ANCIENT THEORIES OF WIND, AND THE PHYSICAL
PRINCIPLES ON WHICH THEY ARE BASED, FROM
THE EARLIEST TIMES TO THEOPHRASTUS

A dissertation submitted for consideration for the
degree of Doctor of Philosophy in the University of
Cambridge; being a revision of a dissertation for-
merly submitted in September 1956, but not approved.

By

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September 1969.
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PREFACE

This dissertation is the product of research begun in October 1962, and is a revision of a dissertation submitted in September 1966, which was not approved. The present version has been almost completely rewritten, and considerably enlarged, in the light of the criticisms made of the former one.

I must express my warmest thanks to my supervisors, Professors W.K.C. Guthrie and F.H. Sandbach; to Dr G.E.R. Lloyd for advice on certain points; to Dr N.J.E.A. Branson for information and advice over matters relating to modern science; to Professor R.M. Cook and Mr E.B. Shefton for archaeological information; to Miss V.E. Heard for assistance with the bibliography; and, last but not least, to the various University authorities who have in different ways allowed me the unconscionable time I have taken to complete this dissertation.

J.J. Hall

30. ix. 1969

This dissertation is the result of my own individual work and no part of it has been carried out in collaboration with anyone else.

J.J. Hall
INTRODUCTION

The ancient philosophers' meteorology has long been, as indeed it often was to the philosophers themselves, a Cinderella of a subject. No ancient account of the physical world, and no modern history of ancient physics, could, if comprehensive, ignore it altogether; but most have preferred to pass it briefly by. There were few, if any, important philosophers (except for the very earliest) to whom meteorology was a major interest; and the great developments in ancient philosophy and science never arose from, and scarcely even affected, their meteorological theories. And yet the subject merits less neglect than it receives: it was a major interest of the earliest philosophers, especially Anaximander, so that the study of it should illuminate the origins of philosophy; and I believe that it will also throw some light on the later history of ancient science in general (see chapter 9).

In the present dissertation I have studied a single aspect of ancient meteorology: that is, theories of the nature

1. Here, as elsewhere, I use 'meteorology' in the modern sense.
and causes of wind. In chapters 3-8 I have discussed in order the ancient thinkers, from Anaximander to Theophrastus, of whose ideas on wind some information is preserved, describing each thinker's wind theory and relating it to the physical theories on which it depends: that is, both to that thinker's most general physical theories, about the nature of matter or the universe as a whole, and to his more particular theories, about (for example) the region in which wind occurs (the atmosphere) and the processes which immediately produce it (such as evaporation). I have thus, in these chapters, arranged my material philosopher by philosopher, a method which differs from the arrangement by topics used in the three previous detailed discussions of the subject: my treatment should therefore make it easier than it has been previously to see the relation between the ancients' wind theories, and the physical ideas on which they depend.

What I say of the most general theories of the thinkers I discuss, such as their theories of matter, is mostly not original; but in discussing their wind theories, and other theories directly relating thereto, such as theories of

1. Ideler, 'Meteorologia veterum Graecorum et Romanorum' (1832), Gilbert 'Die meteorologischen Theorien des griechischen Altertums' (1907), and Boeker's Pauly article 'Winde' (1958).
evaporation, I have made my own search for relevant evidence and, as far as possible, an independent assessment of it. I have not the space to describe in detail, either here or in the notes to particular chapters, exactly which evidence and interpretations I have taken from other modern authorities, which are (as I believe) my own, and which are a combination of the two; but I have indicated in each section of the dissertation what modern authorities I have consulted, reference to which will show how much I have taken from them.

I must, however, mention here certain authorities of which I have made an especially great use. Of the three works on meteorology already mentioned, I have used extensively Gilbert's and Boeker's; but Gilbert, while making a thorough collection of material, left a good deal to do towards interpreting it; and Boeker's interpretations are sometimes highly speculative. I have often obtained more help from works not primarily concerned with meteorology. On the pre-Socratics I have, of course, used very extensively

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1. In particular, I have examined certain physical works of no immediate relevance to meteorology, such as the biological works of Aristotle and Theophrastus; this has yielded some evidence at least indirectly relevant to ancient wind theories, which I do not think has been cited before in this connexion.
Diels-Kranz, 'Die Fragmente der Vorsokratiker', and have used as my basic authorities for the interpretation of their general physical systems Guthrie's 'History of Greek philosophy' and Kirk and Raven, 'The Presocratic philosophers'; I have also used extensively Kahn's 'Anaximander', in discussing Anaximander and the origins of meteorology.

I cannot single out any modern authority as the source of my description of Aristotle's general system, though much of what I say is certainly not original. In discussing his meteorology, I have made the greatest use of Lee's edition of the Meteorologica, and also of Webster's translation and Strohm's 'Untersuchungen zur Entwicklungs geschichte der aristotelischen Meteorologie'. On Theophrastus, the works I have found most useful are Steinmetz, 'Die Physik des Theophrastos', and Strohm, 'Zur Meteorologie des Theophrast'.

The chapters on individual philosophers are preceded by two chapters, on the pre-philosophical background to ancient wind theories and on certain features common to several, or all, of the wind theories of the pre-Socratics (or which might be thought to be so). In the first chapter, the sections on the atmosphere and on wind are partly derived from the modern authorities there quoted; but my discussion of ideas about the atmosphere in authors later than Homer, and the section concerning ideas on exhalation, are, I believe, largely
original to myself, as are the main sections (i.e. §§ 2, 3 and 4) of chapter 2.

In my last chapter I discuss and try to evaluate the methods used by ancient meteorologists, and the light which this throws on the general development of science in antiquity. Parts of this are inevitably speculative; but I believe that there are sufficient indications of the methods the ancients used, to make the discussion worth while. One modern work which I have found especially helpful here is Lloyd's 'Polarity and analogy'.

I would stress that I am concerned only with the nature and cause of wind as a meteorological phenomenon: except insofar as they will throw light on this, I am not concerned with wind's effects (e.g. in causing earthquakes), nor with ancient ideas on related subjects, such as πνεύμα in biology. Accordingly, I have not discussed (except in passing) those ancient thinkers on whose wind theories (if any) no information survives, such as the Pythagoreans and most of the Hippocratic writers, because there is no way of telling how

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1. For a fuller list of the modern works I have most often consulted, see the Classified Bibliography (p. 487).
2. I do discuss a few treatises which express views on the nature of wind in the atmosphere; v.p.198ff.
their ideas on related subjects may have influenced their ideas on wind.¹ For the same reason, I deal rather briefly with Diogenes of Apollonia (p.193f), because our information about his wind theory (and the use he made of ἔμπνευσις in other non-biological fields) is so slight.²

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1. It is very unlikely that Pythagorean ideas on Πνεῦμα influenced anyone's wind theory: all the surviving pre-Socratic wind theories were held by philosophers of the Ionian tradition. I have quoted certain ideas from the Hippocratic treatises which illuminate other thinkers' wind theories; but I have not found (despite an extensive search) enough evidence of this type to merit a separate discussion.

2. I have also largely ignored Empedocles, as it seems to me improbable that he genuinely held the wind theory Olympiodorus attributes to him (DK 31A64; v.p.338n). (I do not mean the attribution is not worth discussing; but reasons of space and time compel me to restrict my subject.)
1) Modern works. Those most often cited I refer to by the author's name alone, or by an abbreviation, as explained in the following list; other important works I refer to, at the place where I first mention them, by the name of the author, plus a short form of the title or a description (e.g. 'edition of ') and the date of publication; I thereafter cite them by author and date only. Other works I refer to by author and date only (e.g. 'Lloyd (1968)'). Details of these works, and of all the other modern works I cite, are given in the general bibliography, p.467.

2) Ancient works. I normally use the abbreviations of book-titles used by LSJ. Some exceptional abbreviations and methods of reference are explained in the following list; a few others which I have used should be self-evident.

Note that I normally use the abbreviations of book-titles in the following list without giving the name of the author.

Alexander

Alexander, 'In Aristotelis Meteorologicoorum libros commentaria'.

Arab.

The Arabic fragment of Theophrastus' meteorology (v. bibliography, p. 465 ).
<table>
<thead>
<tr>
<th>Author</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>R. Boeker and others</td>
<td>'Winde'. (Article in Pauly-Wissowa, 'Real-Encyclopädie', 2.Reihe, Bd VIII.2 2211-2387. A part of the article not by Boeker I cite as (e.g.) 'Schmidt in Boeker'.)</td>
</tr>
<tr>
<td>J. Burnet</td>
<td>'Early Greek philosophy'.</td>
</tr>
<tr>
<td>F. H. Sandbach</td>
<td>(Refers only to statements made privately.)</td>
</tr>
<tr>
<td>O. Gilbert</td>
<td>'Die meteorologischen Theorien des griechischen Altertums'.</td>
</tr>
<tr>
<td>W. K. C. Guthrie</td>
<td>'A history of Greek philosophy'.</td>
</tr>
<tr>
<td>G. S. Kirk &amp; J. E. Raven</td>
<td>'The Presocratic philosophers'.</td>
</tr>
<tr>
<td>C. H. Kahn</td>
<td>'Anaximander and the origins of Greek cosmology'.</td>
</tr>
<tr>
<td>'Oeuvres complètes d'Hippocrate', ed. É. Littré.</td>
<td>(I cite passages of the Hippocratic Corpus by volume, page and line of this edition, e.g. 'L.VI 102.6'.)</td>
</tr>
<tr>
<td>H. G. Liddell, R. Scott and H. S. Jones</td>
<td>'A Greek-English lexicon'.</td>
</tr>
<tr>
<td>H. D. P. Lee's edition of Aristotle's 'Meteorologica'.</td>
<td></td>
</tr>
<tr>
<td>G. E. R. Lloyd</td>
<td>'Polarity and analogy'.</td>
</tr>
<tr>
<td>Mete.</td>
<td>Aristotle, 'Meteorologica', books I-III.</td>
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<tr>
<td>Mete. IV</td>
<td>&quot;</td>
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<tr>
<td>Olympiodorus</td>
<td>Olympiodorus, 'In Aristotelis Meteora commentaria'.</td>
</tr>
<tr>
<td>PN</td>
<td>Aristotle, 'Parva naturalia'.</td>
</tr>
<tr>
<td>Philoponus</td>
<td>J. Philoponus, 'In Aristotelis Meteorologicorum librum primum commentarium'.</td>
</tr>
<tr>
<td>Probl.</td>
<td>[Aristotle], 'Problems'.</td>
</tr>
<tr>
<td>SVF</td>
<td>'Stoicorum veterum fragmenta', ed. H. von Arnim.</td>
</tr>
<tr>
<td>Steinmetz</td>
<td>P. Steinmetz, 'Die Physik des Theophrastos von Eresos'.</td>
</tr>
<tr>
<td>Sutton</td>
<td>O.G. Sutton, 'Understanding weather'.</td>
</tr>
<tr>
<td>Syr.</td>
<td>The Syriac fragment of Theophrastus' meteorology (v. bibliography, p. 465).</td>
</tr>
<tr>
<td>Vent.</td>
<td>Theophrastus, 'De ventis'.</td>
</tr>
<tr>
<td>WKCG</td>
<td>W.K.C. Guthrie. (Refers only to statements made privately.)</td>
</tr>
</tbody>
</table>

References such as '13A5', '21B30', 'Anaxagoras Bl9', etc., refer to passages in DK.

The ancient commentaries on Aristotle are cited by page and line of the Berlin Academy 'Commentaria in Aristotelem Graeca'.

For further details of modern works listed above, and
a list of other ancient works cited by reference to a particular edition, v. bibliography, p.461.
CHAPTER 1

THE PRE-PHILOSOPHICAL BACKGROUND

Thought about wind, as about other things, did not begin with the first philosophers; Anaximander and his successors were "not the roots but the lowest surviving branches of a far mightier tree"¹. We cannot understand their thought unless we look beyond them, at the ideas of their predecessors and contemporaries who were not philosophers. I shall accordingly begin by examining certain pre-philosophical ideas that were to influence the philosophers' wind theories: in particular, ideas concerning the atmosphere, wind itself, and exhalation².

1) The atmosphere

The development in Greek popular thought of a concept of the atmosphere, of a material filling the space over the earth's surface, is best illustrated by examining

2. The main general surveys of these and similar subjects which I have used are Mugler 'Les origines de la science grecque chez Homère' (1963) and Kopp 'Das physikalische Weltbild der frühen griechischen Dichtung' (1939).

UNIVERSITY LIBRARY CAMBRIDGE
relevant occurrences of ἀήρ, ἀθόρ and πνοή.

A. Homer, Hesiod and the Homeric Hymns

In Homer, δήρ means 'mist', though frequently not a normal mist, but something produced by a god to render invisible one or two objects or persons; and in such cases it must often resemble our 'air' by being itself invisible: "we can see right through both the 'air' and the hero" (EGP 68). But in these passages, as elsewhere,

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1. On δήρ in Homer see Louis 'Le sens du mot δήρ ...' (Rev. de Phil. 1948 63ff); on δήρ and αθόρ, Kahn 137-46; Snell 'Lexikon d. frühgr. Epos (1955-') s.vv. Also Kopp (1939) 316-21; Gilbert 17-37.

I have myself examined Homer's usage, using Gehring 'Index Homericus' (1891-5).

2. By 'Homer' I mean the author or authors of the Iliad and Odyssey, without presupposing any view of how they were composed. I do, however, assume that all of both poems, and of Hesiod's Works and Days and Theogony (and probably also the Hesiodic Catalogues and Scutum, on whose date see West, ed. of Theogony (1966) 49) are so early as to be free of philosophic influence. This may not be wholly justified (Page (1959) 315-24 regards one passage of our Iliad as composed in the 4th century B.C.); but, as I discuss passages from many different parts of these poems, I do not think it could be plausibly denied that the majority must be pre-philosophical.

3. E.g., at η 135ff, it is unlikely that the Phaeacians see a column of mist (concealing Odysseus) coming towards them.
it lacks our 'air's' essential features of permanence and universality: Homeric ᾱρ is local and temporary only.

There is, however, one exceptional passage: Σ 280ff, Hera and Sleep come to Mt. Ida; and Sleep stops before Zeus can see him, (Σ 287f)

εἰς ἐλάτην ἀναβὰς περιμῆκετον, ἦ τοτ' ἐν Ἁδη
μακροτάτη πεφυγὶα ὅτι ἡρὸς ἀλθέρ' ἴκανεν,
(and there Sleep sits, disguised as a bird). Whatever its nature, must not this ᾱρ cover the earth always and everywhere, up to a certain altitude - how otherwise can it indicate height? Or, if the ᾱρ and ἀλθήρ are mentioned not primarily to indicate height, but because ἀλθήρ is clearer than ᾱρ, so that Sleep has a better view¹, even so, can this ᾱρ be local or temporary? Whence this sudden swirl of mist upon Mt. Ida, which we have never heard of before and never encounter again?² Mt. Ida is not permanently covered in mist.

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1. As Kahn 145 maintains, though WKCG considers this to 'distort the Greek'.
2. The ᾱρ of Σ 282 is clearly different, being confined to Sleep and Hera.
(cf. Hera's remarks at Ε 330ff); and I refuse to believe that Mt. Ida is covered with atmospheric air, but not the rest of the world.

Now, if ἀήρ here covers the earth always and everywhere, it is 'air', not 'mist': for 'mist' does not permanently cover the earth's surface. The poet may have been unconscious that he was using ἀήρ in a new sense; yet, had he been asked, he must have admitted it is so: ἀήρ has become a permanent, universal phenomenon, and must thereby have ceased to be opaque and to conceal things: it has become what we call 'air'.

Note also Γ 7, where the cranes bring strife to the pygmies ἡρως, 'flying through the air' seems more appropriate than the alternatives, 'early in the morning' or 'im Wolkendunkel' (Gilbert 18n4). Here, however, all three are possible; or, if ἀήρ ἡρως is connected etymologically with ἁειρω, it may mean 'high up', with no connotation of 'in the air' (as a material).²

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2. For such a thought cf. Hesiod Op.777 ἡροπότης, also Sc.316. On ἡρως in Homer v. Leaf (1900-02) on A 497; Γ 7 (where he prefers my second meaning, though admitting the first is possible).
\( \alpha \theta \eta \rho \) in Homer is normally 'sky', and in some places must be\(^1\), and in most very likely is, confined to a region far above the earth. Note, however, o 292f: Athene, to speed Telemachus' ship, sends a breeze \( \lambda \beta \rho \nu \ \delta \pi \alpha \gamma \iota \zeta \o \nu \tau a \ \delta t \ ' \alpha \theta \epsilon \rho \circ s \ \) "rushing violently through the \( \alpha \theta \eta \rho \)": her sending it through (not from) the \( \alpha \theta \eta \rho \) suggests that the \( \alpha \theta \eta \rho \) extends down to, or close to, the sea's surface\(^2\). If so, then, \( \alpha \theta \eta \rho \) here corresponds to our idea of 'air'.

There are also three passages in Homer (out of 23 occurrences) where \( \pi \nu o \iota \iota \) remotely suggests the idea of air. M 207, \( \beta \) 148: a bird \( \pi \epsilon \tau e \tau o \ \pi \nu o \iota \iota \varsigma \ \delta \nu \epsilon \mu \nu o \) sim. Often, a wind obviously affects a bird's flight (so FHS) - but its mention is only an incidental detail, not necessary to the action. \( \delta \) 838f: an \( \epsilon \dot \iota \omega \nu \lambda o \circ n \), after delivering a dream-message, \( \lambda \iota \sigma \eta \ \varepsilon \varsigma \ \pi \nu o \iota \iota \varsigma \ \delta \nu \epsilon \mu \nu o \) 'withdrew into the breaths of the wind'.

These passages suggest, I think, that there are normally \( \pi \nu o \iota \iota \) present in the space over the earth; which foreshadows the use of \( \pi \nu \epsilon \circ \mu a \) to mean 'air'.

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1. v. N 837, \( \zeta \) 288, 0 686, \( \Sigma \) 207, 214, T 379: \( \alpha \theta \eta \rho \) is something reached by an especially loud sound, tall tree, etc.

2. So, apparently, Gilbert 20n2.
In Hesiod\textsuperscript{4} and the Homeric Hymns\textsuperscript{2}, the idea of air occurs once: H.Cer.\textsuperscript{3} 379ff, Hermes and Persephone come from Hades; seas, rivers, valleys and mountains did not stand in their way, ἄλλ' τπὲρ αὐτὰν βαθὺν ἥρα τέμνον λόντες (383). As I can see no reason why the seas etc. should all have been swathed in mist, I deduce that ἄηρ is 'air'.\textsuperscript{4} In Hesiod, ἄηρ is normal mist or cloud at Op.549 (cf. pp.45f, 50), 'mist' in which deities conceal themselves at Op.125, 223, 255, Th.9. ἡροειδὴς used of πόντος\textsuperscript{5} and νεφέλη (Hesiod Th.757), and ἡρόεσις used of Tartarus\textsuperscript{6}, ζόϕος\textsuperscript{7}

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1. Cf. Paulson (1890) and the word-index in Merkelbach and West (1967).
   I list on p.462ff the editions whose numeration I have used for different authors' fragments.


4. I disregard H.32.5 ἄηρ as being obscure and of very uncertain date (Allen etc. (1936) cix, 431ff).


7. Hesiod Th.653, 658, 729; fr.280.23; H.Cer.80, 337, 402, 446, 464, 482.
and Maia's cave\(^1\), must mean 'misty', 'dark'; and at Hesiod Th.294 σταθμῷ ἐν ἁρδευτὶ πέρην κλυτοῦ 'Ὠκεανότῳ the connection with Ocean suggests 'misty'. Id. Fr.26.20 ἁρδευτι appears to mean 'early'.

αλθήρ is 'sky' at Hesiod Op.18 and fr.343.9 (Zeus αλθῆρι ναίων), at Th.697 (φλὸς αλθῆρα ὀίαν ἵκανεν\(^2\)), and H.Cer.70 (the sun 'looks down from the αλθήρ'); at H.Ap.434 (a breeze λάμβρος ἐπαγίζων εἰς αλθῆρος propels a ship) the breeze coming from (not through) αλθήρ suggests that αλθήρ does not reach sea-level (cf. p. 5). At H.Cer.67, 457 and H.33.13 αλθήρ might or might not reach the earth\(^3\). Passages where Αλθήρ is a deity\(^4\) and the fragmentary fr.150.35 are here unhelpful\(^5\).

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1. H.Merc.172, 234, 359 (for the meaning cf.6, 229).
2. Accepting Naber's conjecture.
3. I ignore H.8.7, which seems very late (Allen etc. (1936) 385).
5. πυντή is never as near meaning 'air' in Hesiod or the Hymns as in the 3 Homeric lines mentioned p.5 (except possibly H.31.13f - but that may be very late, Allen etc. (1936) cix, 431ff).

I have glanced through the other Homerica in Evelyn-White's (1936) ed., but have noticed no other instances of αήρ, αλθήρ, πυντή or derivatives.
There are, then, up to seven lines in Homer, Hesiod and the Homeric Hymns\(^1\) (out of over 30,000) which imply, or suggest, that \(\delta\eta\rho\), \(\alpha\theta\eta\rho\) or \(\pi\nuo\iota\iota\) fill all, or much, of the space over the earth\(^2\). In these passages, \(\delta\eta\rho\) etc. cannot just be synonyms for empty space,\(^3\) as is clear both from the original meaning of these words - of \(\delta\eta\rho\) as mist, of \(\alpha\theta\eta\rho\) as the bright sky, of \(\pi\nuo\iota\iota\) as a blast of wind or breath - and from some of the passages themselves\(^4\).

In these poems, then, the idea of air, though not often mentioned, was beginning to emerge. That this should have happened so early is not surprising; for the existence of air is obvious to anyone who thinks about it:

1. \(\Sigma\ 288\), \(\Gamma\ 7\), \(\omicron\ 293\), \(\Mu\ 207\), \(\ Beta\ 148\), \(\omicron\ 839\), H.Cer.383.
2. They may have been taken to mean this, even if the poets did not intend it.
   By comparison, the Aeneid speaks of 'air' several times oftener in c.9,000 lines: 'aer' means 'air' 7 times (all except 1.411, 6.887), 'aerius' 'airy' at least 4 times (3.680, 5.520, 9.679, 12.810) (cf. Wetmore (1930)), and Lewis and Short (1879) cite 15 other passages where 'aurae' means, at least roughly, 'air'.
3. As (e.g.) Cornford ('Principium sapientiae' (1952) 194n) supposes \(\delta\eta\rho\) sometimes is.
4. E.g. at \(\Sigma\ 288\) \(\delta\eta\rho\) and \(\alpha\theta\eta\rho\) are distinguished, so must each have their own distinct properties, and cannot just be synonyms for nothingness; at H.Cer.383, where \(\delta\eta\rho\), air, is cut, it must be a material; \(\pi\nuo\iota\iota\) \(\delta\nu\epsilon\mu\omicron\nu\) obviously is not a synonym for empty space.
we feel it - that is, we feel some body - as we breathe, and whenever we fan ourselves. It is unlikely that any man ever consciously thought that the space immediately around him was occupied by no body at all, except where he could see one; rather, primitive men will never have thought about it one way or the other. Whenever anyone tried to think about it, the discovery of air would be made. Indeed, I suggest that the existence of air may have seemed so obvious to its first discoverer that he failed to realise he had discovered something new, and was using ῥη (or some such word) in a new sense; and, if so, he may well have forthwith forgotten his idea, until he chanced to return to the same train of thought; on other occasions, he may have spoken of related things, like breath and wind, without the idea of 'air' entering his mind.

Indeed, this might apply to a whole society, and surely did in early Greece: everyone was vaguely aware of air's existence - might occasionally speak of it, and recognise it when others did so, and yet at other times forget or ignore it, or use a term for the space over the earth which simply means 'space', with no implication as to whether matter fills it. Such a term, at least in its origin, was χῶς (assuming it is from the root of
χάσκω), used of the space over the earth probably in Hesiod (at least, I think, at Th. 700), and certainly later. Similarly, Aristotle says (Ph. IV 213a22ff) that οἱ ἄνθρωποι regard what is really full of air as κενόν, οὐκέμενον ... τὸ δὲ ἄλλο εἶναι σῶμα (sc. αἰσθητόν); obviously, men in general will not have pondered the problem and consciously adopted this view; Aristotle is speaking merely of a subconscious assumption. As we have seen, it was not the only one; the space over the earth might also be regarded as full of matter. In the earliest period, both concepts are rare; generally, the space over the earth's surface was not spoken of at all, which confirms that the earliest Greeks had not thought about it.

1. For a list of the later passages, and discussions, v. Cornford (1952) 194f; KR 26ff; West (1966) 192f (with Solmsen's review (1968) 325); Gigon 'Ursprung d.gr.philosophie' (1945/68) 28-31; Hoelscher (1953) 397-400; Stokes (1963) 17-23. (I would only claim that the root meaning of χάσκω must connote simply 'space'; I cannot here discuss whether it meant that to Hesiod etc.).

2. i.e. they think that all there is is perceptible body, and hence assume that a place where there is no perceptible body is void (though in fact it is full of air); cf. Ross (1936) ad loc., also GC 318b21ff. (With Ph. 213a22ff, cf. de An. 419b34, PA 656b15, quoted by EGP 109n.)
The first glimmerings of the idea of air may in fact be far older than Homer. Wilson (1949) 117 quotes from an Egyptian text of 2,000-1,500 B.C., this sentence:
"I (the Creator) made the four winds that every man might breathe thereof like his fellow in his time". Assuming the translation correct, this shows definite traces of the idea of air: for it implies that in breathing we take into our bodies some stuff - the stuff of wind - which is always available everywhere, i.e. which fills the space above the earth's surface - the essential characteristic of atmospheric air.

B. The concept of 'air' gains currency: the atmosphere in non-philosophical literature, c.600-400 B.C.2

In this period ἀήρ and derivatives are rare in poetry other than comedy (v. p. 435f): evidently ἀήρ was regarded as a prosaic word, unsuited to serious poetry.

In poets mainly active before 450 B.C., ἀήρ evidently means 'mist' at Pindar fr.52f.137f ἀέρος ἔχρυψαν κόμ[α]τ; 3 'dark' is meant at Theognis 1036 Τάρταρος ἰερόςις and (according to the scholiast and

1. Note that I found this by chance and know nothing about it.
2. I know no full discussion of this; for some remarks v. Gilbert 34-37, Kahn 146f. I have used the word-indexes etc. listed on p. 435f.
Steph. Byzant.) at Aeschylus Supp. 75 δερίας ἀπὸ γᾶς (i.e. Egypt). Other occurrences are doubtful: Simonides fr. 80 ἡπίη Τεράντα: either 'misty' or 'high in the air' seems possible. Aeschylus Supp. 871 ἐβρελαίς εἰν αὖραις, δερίας. Hartung: the conjecture is uncertain (v. Tucker (1889), Rose (1957-8) ad loc.). Id. fr. 198 (Aristophanes Ra. 1291) κυνέν δεροφοῖτος might refer to 'air' or 'mist', depending on what the κυνές are (Rogers (1902) and Mette (1963) 111 say vultures, Van Leeuwen (1896) 'furiae').

Finally, on a vase-painting of 440-430 B.C. there is a female figure marked 'Sappho', holding a book on which appear, inter alia, the words ἐπεα πτερὸντα and ἡπίων ἐπ᾽ ἔων ἁρχομαι (=PMG Adespota 938d). 'Airy' ἐπεα seems likelier than 'misty' or 'early'. If, therefore, these words are really Sappho's (as Edmonds (1922) lff argues), this looks like another early reference to 'air'; but they may be no earlier than the

1. Cf. Tucker (1889) ad loc. It is not clear why Egypt is so called.

2. Presumably much the same as ἐπεα πτερὸντα (so FHS. For an alternative explanation v. Onians (1951) 67).
vase-painting.

Probably, therefore, ἀήρ and its epithets still normally meant 'mist', 'misty' down to c.450 B.C. In later writers they usually have no discernible connotation of 'mist' or 'darkness', and presumably refer to air. So at Sophocles El.87 δῶς φάστων καὶ ὑπὸ ὶοὺρ' ἀήρ. Euripides Hel.1478, fr.1047, birds fly through ἀήρ; Supp.1155f, words are 'borne away on the ἀήρ'; Or.7, Tantalus apparently 'hangs in the air', ἀήρι τοτάται; I.T.1134, ἀήρι seems to be a wind; Tr.546 ἀήριον ... κρότον ποδῶν (of a dance); fr.27.4 ἀέριων ... πατέσματα ('creatures of the air', as opposed to sea and land). FMG Adespota 1006 ἀεροβατάν μέγαν οἶχον ἀνέμον.

However, 'dark' must be meant at Euripides Ph.1534 ἀερίου οὐχότον and FMG 925(e).9 (a papyrus of 280-240

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1. Also, ἀέριων might mean 'raised up', 'flying', with no thought of 'like air' (as a material), cf. p.4 (? cf. Homer Σ 505 χηρύξων ... ἀεροφόνων ... 'lifting up the voice', cf. Leaf (1900-02) ad loc., Louis (1948) 65.)

2. "Non esse 'tenebras' ex v.91 intelligitur" (Ellendt (1872)s.v.).

3. If the text is right: v. Platnauer (1938) ad loc.
Doubtful passages are Ion Chius (PMG 745.1) δοῦν δεροφίταν (of the Morning Star); Telestes (PMG 805(c).2) δαίμονος δερόβεν πνεύμα ms., δερόν Bergk (presumably 'airy'; but where has δερόν this meaning? Cf. LSJ); and PMG Adespota 1023.15-7 (restoration doubtful) φέρει δ' ἄμεριον φάος / ὀιδή κύματος δερίου πταμένα ... "brings the light of day, flying through the δέριον wave".

In Old Comedy, ἄηρ and derivatives seem never to refer to mist. Aristophanes' usage is interesting on the relation of ἄηρ to αἷπηρ. In Av., ἄηρ is 13 times the region between sky and earth, where the birds live and build their city; but at 689 the birds are αἷπηριοι, at 1394 αἷπηροφόροι; at 1277 Nephelococcygia is an αἷπηριος πόλις. 1183 αἷηρ seems the same as 1173 ἄηρ; cf. 1400 with 1392.

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1. At Aristophanes Nu.337, Av.1389 ἄηριος might mean 'misty', but no positive evidence suggests it. (On Ra.1291, quoting Aeschylus, v.p. 12).

2. Everywhere except 694, which does not mention the birds.

3. But possess other divine qualities, which birds would not normally be said to have; so they may not be normally αἷπηριοι.

4. N.b. also 349, 776 αἷπηριον νέφος, where αἷηρ's connotation of brightness (cf. p. 439f, 442) is evidently forgotten. At 776 the phrase virtually means 'the atmosphere'. (With the phrase, cf. Nu.570: αἷηρ is father of the clouds).
Cf. Nu.: at 375 thunder is due to the clouds, at 380 to an άληθέ ρος δί νος, at 393 to δή ρ. At Th.43 (praying that άληθέ ρος be windless and the sea calm), άληθέ ρος clearly touches the sea. In all these places δή ρ and άληθέ ρος are synonyms1: which is used, rather depends on metre: δή ρ etc. occur predominantly in iambics, άληθέ ρος etc. in other metres (p. 436), or, if in iambics, in parodies of serious poetry; or the word is put in the mouth of Euripides, whose pet word (p. 435) and principal divinity (according to Aristophanes2) it was3.

There are also about 13 passages in other authors where άληθέ ρος evidently reaches down to the earth, and so is, or includes, 'air'4:

1. However, at Nu.264f they are distinct sophistic divinities, and ib.285 οίμων άληθέ ρος apparently means the sun, which is not usually said to be in δή ρ (though cf. Ion Chius (quoted p. 14) and p. 142f).
2. v. Rogers (1904) and (1902), on Th.14, Ra.892.
3. Av.1183, Ra.100, 311, 892, Th.14, 272, 1099 come in these categories; Av.1277 is the only possible exception.
   On άληθέ ρος at Th.1050, 1068 (= Euripides frr.122, 114), v. p. 141.
4. Cf. Empedocles' use of άληθέ ρος to mean 'air' (v., e.g., HGP II 145).
Pindar 0.7,67, of Rhodes rising from the sea, φαεννον ες αλθερα ... πεμφθειαν ; Aeschylus Th.155
(describing an army) δοριτινακτος αλθηρ ... ἐπιμαίνεται , "the air rages with shaken spears"; Supp.607f (of hands raised in voting) χεροι δεξιωνύμοις / ἔφρυξεν αλθηρ  ; cf. Fr.103. Sophocles Ant.420f (a whirlwind raises a storm of dust) ἐν ὦ ἐμεστόθη μέγας / αλθηρ .
Euripides Cyc.410, the Cyclops belches, φάρυγος αλθερ' ἐξειλες βαρύν ; ib.629 σιγώμεν ἐγκάψαντες αλθερα γνάθους ; Med.829f, the Athenians αει δια λαμπροτάτου βαλνοντες ... αλθερος ; cf. Hipp.447f, φοιτή δ' ἄν' αλθερ', ἐστι δ' ἐν θαλασσῇ / κλύδωνι Κύπρις ; ? Ph.674f γαϊαν, ἄ νιν εθηλιοσι δείξεν αλθερος πνοαίς (of the warriors who sprang from the dragon's teeth). Also Tr.325 πάλλε πόδα. αλθεριον ἄναγε χορόν (of a dance); Andr.830 (Hermione to her headgear) ἔρρ' αλθεριον πλοχάμων ἐμῶν ἀπο, λεπτότητον φάρος ; Hel.1362f ὅμβου ... εἴλισσομένα κύκλος ἕνοις αλθερία , of the whirling of a bull-roarer. 2

1. Ζεὺς ἐστιν αλθήρ. Ζεὺς δὲ ἥτιν, Ζεὺς δ' οὐρανός, Ζεὺς τοι τὰ πάντα χωτὶ τῶν', ὑπέρτερον. αλθήρ is the whole space between οὐρανός and earth.
2. I have omitted Aeschylus Fr.157 and Euripides Ba.1099f, where αλθήρ evidently extends down onto a mountain, but need not reach sea-level (cf. p. 440n ).
Finally, the usage of ἀηρ in 5th century prose writers (including all the Hippocratics).

1) Herodotus. Powell (1938) lists 8 occurrences of ἀηρ; all seem to refer to 'air'.

2) Thucydides. Essen (1887) gives no instance of ἀηρ.

3) The Hippocratic Corpus. I have supplemented the word-index in Heiberg (1927) (containing 11 out of 70 treatises) from my own notes.

Aer. contains 10 instances of ἀηρ: five refer to mist, five to air; Vict.IV §89 (L.VI 644.21) ἱππος is evidently 'mist'; all the other 68-69 instances of ἀηρ I have found refer to air. (No doubt the

1. So Heiberg (I include the title).
2. §6 (L.II 24.14); §8 (p.34.15); §15 (p.60.20); §19 (p.70.14). (Also §5 (p.22.25) – a corrupt passage, but p.24.14 shows the meaning of ἱππος.)
3. Title; §6 (L.II 26.1); §8 (p.34.14); §15 (p.62.5); §19 (p.72.9).
4. As follows: From Heiberg: Lex 1; Praec.1. Found by looking all through the work indicated: Flat. 28 (Heiberg's index is incomplete); Morb.Sacr.16-17. Noticed incidentally (I have looked all through the §§ indicated); Vict. (§§34, 38, 89) 3; Morb.I (§11) 1; Nat. Puer. (§§12, 25, 30) 6; Morb.IV (§57) 1; Carn. (§§2, 16, 17) 4; Cord. (§§2-3) 4; Hebd. (the Greek text in L.IX p.433f) 2; Aph.VII (§51) 1. (In some places in Flat. 8-14 where ἀηρ, within the body, is purely theoretical, 'mist' could be meant; but as, wherever in Flat. its meaning is clear, ἀηρ is 'air', it is presumably 'air' everywhere. I have not counted the obscure ἱππος in Vict.I §10 (L.VI 486.1.)
Hippocratics had little occasion to mention mist. 1
Thus, after c.450 B.C., ἀήρ is usually 'air'; in only eight out of more than 120 occurrences listed on pp. 13-15, 17 has ἀήρ or a derivative any definite connotation of 'mist' or 'darkness'. αἴθήρ, too, sometimes touches the earth, and so is air (p. 15f), or else is a synonym for ἀήρ (p. 14f). By the end of the 5th century the idea of 'air' was clearly perfectly familiar 2.

For c.600-450 B.C. the evidence suggests that ἀήρ generally had a connotation of 'mist' (p.11-13); αἴθήρ, however, must touch the earth in 4 places 3 out of c.40 (pp. 15f, 435), as against one probable in Homer out of 25 (pp. 5, 435). Also, πνεοί approaches the idea of 'air' at Aeschylus Pr.88f ὁ ὄιος αἴθήρ καὶ ταχύπτεροι πνεοί, ποταμῶν τε πηγαὶ κτλ..

1. αἴθήρ occurs once in Herodotus (VII 8), never in Thucydides; I know three instances in the Hippocratics (VICT.IV 889 (L.VI 650.18), Carn. 82 (L.VIII 584.13) and a poetic version of the Oath (Heiberg (1927) 6.3). None is relevant to the idea of air.

2. This being proved by the usage of ἀήρ and αἴθήρ, it is unnecessary to discuss here the contemporary usage of πνεῦμα and πνοή.

3. 3 in Aeschylus, 1 in Pindar.
implying that πνεύμα fill all the space above the earth (cf. ανθρώποι) or at least occur in many parts of it (cf. rivers), and at Bacchylides V 28f, (a bird flies)
σῶν ζεφύρων πνεύματιν (on which idea cf. p. 5).
Anything resembling our idea of 'air' was clearly rare
in poets of this period, though not unknown; whether it
was commoner than in early epic there is insufficient
evidence to show.

1. On winds in the early poets in general e., Hopp (1938)
254-264 (with whom I largely agree), and Hopp (1963)
49-60, Gilbert 511, 539-43. I have made my own study,
largely with the aid of the word-indexes cited on pp. 34 ff.
3. He desires and/or begets a horse, as well as becoming
the shape of one; unlike, say, less approaching Europa
in the form of a bull.
4. There is some evidence that, in archaic art, wind-gods
were sometimes represented with a human form above,
but a snake's tail (or tails) (cf. Pausanias VII 19.4,
von Hase (1915) 76ff); but this belief cannot have
been important - the only hint of it in literature
seems to be Hesiod's derivation of some winds from
Typhon (v. p. 21): οὐκ ἐπέφυγεν ξύπνοις ἐκ ἄτλας ἔντωνν.
Although there is evidence for the worship of winds on Linear B tablets (which apparently mention their priestess), winds do not seem to have been often worshipped, or clearly-envisaged deities, in early classical times. In Homer, winds are only once prayed to, at Ψ 194ff; and only there (where they are feasting in Zephyrus' house, and each wishes Iris to sit beside him) are they clearly thought of as gods in human form. At Π 149f and Ψ 223f a wind is father of horses (by a ἀρπυτε or by mares), and so presumably has a horse's nature; nowhere else is there any indication of the shape of a wind-god.

1. On winds in the early poets in general v. Kopp (1939) 254-284 (with whom I largely agree), also Mugler (1963) 49-60, Gilbert 511, 539-43. I have made my own study, largely with the aid of the word-indexes cited on pp. 435f.


3. He desires and/or begets a horse, as well as assuming the shape of one; unlike, say, Zeus approaching Europa in the form of a bull.

4. There is some evidence that, in archaic art, wind-gods were sometimes represented with a human form above, but a snake's tail (or tails) (v. Pausanias V 19.1; von Massow (1916) 76f); but this belief cannot have been important - the only hint of it in literature seems to be Hesiod's derivation of some winds from Typhoeus (v.p. 21).
In Hesiod's mythology winds are equally unimportant. Boreas, Notus and Zephyrus are barely mentioned at Th. 378-382 as the offspring (with the stars) of Eos and Astraeus — this in a passage full of dim and obscure deities (Creius, Pallas, Astraeus etc.), some of them perhaps invented to make up the genealogy. At 869ff other winds are said to be ἐκ Τυφώςεος: their baleful character is described in purely naturalistic terms.

Sometimes, indeed, winds in Homer behave, or are treated, in ways strictly applicable only to living creatures, and so are presumably thought of as gods, although the shape or nature of a god is not otherwise evoked: Ε 524 εὐδροι μένος Βορέας; Π 765f, Eurus and Notus ἐνιαίνετον; Μ 281 (Zeus) κοιμήσας ἄνέμους; Ω 26 (Hera) πεπεσοῦσα θυέλλας; ε 384, Athene (ἄνέμους) ἐκέλευος ...

eὐνηθήναι. Also, ὀρνυτι, 'arouse', is frequently used

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1. I assume that the Catalogues are post-Hesiodic, cf. p. 2n.
3. The ἀρνυτα, equivalent to θυέλλα at least at ν 77 (cf. 66; cf. also α 241, ξ 371 with δ 727) is equally unimportant in early mythology, being certainly divine or alive only at Π 150 (cited p. 20; cf. T 400) and at Hesiod Th. 265-9 (where the Ἀρνυτα are given an apparently factitious genealogy). (On the Harpies v. Steuding 'Windgötter' (1924-37) 512; Leaf (1900-02) on Π 150; Kopp (1939) 269; West (1966) on Th. 265-9).
of a god causing wind. But here the 'personification' of the winds is very slight; indeed, some of these expressions may have been conscious metaphors.

Elsewhere there is no indication of whether the winds are divine; and in some passages they clearly are not gods, or at least not gods having human or animal shape: e.g. γ 289, Zeus λιγέων ἄνέμων ἐπ' ἀυτιμένα χεῖς (on a fleet); ε 317 μισγομένων ἄνέμων ... θείλα; κ 19f, where the winds are confined in a bag which clearly is simply inflated (and so solid-looking; cf. p. 91f). If the winds were man-like gods, then a phrase like ἄνέμου πνοιή should denote the god's exhaled breath; but in several such places this idea has clearly been forgotten, if it was ever there at all, as at δ 838f, Μ 207 and β 148 (quoted p. 5 f); cf. ζ 20, Athene comes to Nausicaa's bedside ἄνέμου δς πνοιῆ ; also passages where a god, horse or Harpy travels ἀμα πνοιής ἄνέμοιο 4 or ἀμα πνοιής (Π 149) or ἀμα πνοιή Ζεφύροι ... ἦν περ ἐλαφρατάτην φάσ' ἐμεναι(Τ 415f). In such places, the important features are the πνοιαί, invisible bodies moving in the

1. Μ 253, Ε 254, Φ 334f, ε 109, λ 400, 407, μ 313f, etc.
2. As assumed by Mugler (1963) 50f.
3. Cf. Η.Merc.146f, Hermes διὰ κλῆθρον ἔσμεν αὖρη...ἐναλήγκτο
4. ο 342, α 98, ε 46, Hesiod Th.268.
space over the earth. The genitives (ἀνέμου etc.) are surely intended merely to characterize the πνοιαί, not to indicate their origin. At 5 567f Ζεφύρωστο ... ἂντας Ἀκεανὸς ἄνίσών this must be so, since the origin of the ἂντα is clearly Ocean.

In Homer and Hesiod only Ψ 194ff, and perhaps Ο 26 and Op.645,¹ suggest that a wind can choose whether or not to blow; often elsewhere a god arouses or stops the winds, but never a wind-god: e.g. ε 292ff, η 272, ι 400, ο 110 (Poseidon); Μ 253, 281, γ 289, ι 67, μ 313f (Zeus); β 420f, ε 109, 383ff (Athena); etc.² Ἄνδες οὐρος ³ is presumably no more an independent deity than the more familiar Ἄνδες οὐρος (ι 111, 358 etc.) - rain is never regarded as a god. Even minor deities, Aeolus, Circe and Calypso, can control winds.⁴ The winds therefore usually lack the gods' proper power of independent decision and action, as well as lacking the gods' proper shape. Homer will not consciously have denied that winds are alive: a

¹ "Primitive man simply does not know an inanimate world" (Frankfurt (1929) 16).
² Ἄποκρόμος, Τιθωνις, Μιδας, Θιναρας etc.
³ Ἅρης 2.10f, 20.9, 37, 17.5, 31.3, 1.18ff, 1.33, 16, 1.42, 16; Ἀκηννία 1158, 1275; Αἰασσέας fr. 102.
⁴ Ἁρης 20ff, μ 149f, ε 268.

1. εἰ γὰρ ἄνεμοι γε κακῶς ἀπέξωσιν ἂνται.
4. x 20ff, μ 149f, ε 268.
Homeric Greek would have made no clear distinction between the animate and inanimate; but clearly he did not, as a rule, consciously attribute to wind the properties of a divine or animate being, except perhaps in a very limited degree.

In later poetry, even in the 7th–6th centuries, the winds are anthropomorphised more often. The Hesiodic Catalogues told of the Boreads' pursuit of the Harpies (fr.150ff), and Theognis (715f) and perhaps Ibycus (PMG 292) refer to the story. Alcaeus speaks of Eros as child of Zephyrus and Iris (fr.23; cf. Page (1955)271); and Tyrtaeus (fr.9.4) mentions Boreas in a list of men and man-like figures, suggesting that the wind, too, has a human form. Cf. also Alcaeus fr.Z2.1, τῶν ἄνεμων στάσιν. However, many 6th century passages give no indication that winds are gods; and at [Hesiod] fr.204.126 and Alcaeus

1. "Primitive man simply does not know an inanimate world" (Frankfort (1949)14).
2. The Cyclopes, Tithonus, Midas, Cinyras etc.
3. Meaning perhaps "the strife of the winds" (Page (1955)196).
4. v. [Hesiod] fr.75.6, 204.126; Sappho fr.2.10ff, 20.9, 37, 47, 90.22; Alcaeus fr.B6Α.13, B6Β.1, L1.5 and 11, Q1.13, 0 1; Ibycus, PMG 286.9; Solon fr.1.18ff, 1.45, 11; Archilochus fr.43; Theognis 1168, 1273; Anacreon fr.102. (I admit that some of these passages are very fragmentary, and that the winds might appear as gods were the context complete: so especially Sappho fr.20.9, 90.22; Alcaeus fr.B6Α.13 and B6Β.1.)
fr. Q1.2f, as so often in Homer, wind is caused to blow by a god other than a wind-god.

I cannot here discuss 5th century literature, in which mentions of wind-worship and of the winds as gods (especially the story of Boreas, Oreithyia and their children) become still commoner: it is not important, because the attitudes to wind of poets and of philosophers must by now have become fairly clearly distinct.

In this century appear the first suggestions, in literature or art, that wind is breath from a wind-god's lips. The power of breath from Boreas' lips was evidently stressed in Aeschylus' Oreithyia (fr. 492); but here Boreas was inevitably anthropomorphised - Aeschylus need not have thought of wind as from a god's lips in other contexts. Also, Euripides Med. 838-40 (τάν κύριν κλήκουσιν ... καταλαμβάνει μετρίας ἀνέμων ἡπυνόσους αὔρας) appears to

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1. For example, at least five dramas concerned Boreas, Oreithyia and/or their children: Aeschylus' Phineus and Oreithyia, and Sophocles' Tympanistai and 2 plays called Phineus (v. Mette (1959) and Pearson (1917). For discussions of wind-worship in antiquity v. (e.g.) Steuding (1924-37) 513-5; Farnell (1896-1909) V 415-7, 448-9; Hampe (1967). (Hampe (especially p. 13f) argues that wind-worship was widespread and of great antiquity. I would not deny this; but I would say that the cult cannot have been important, and that the earliest Greek authors tended to forget it when they spoke about winds.)
suggest that Aphrodite breathes forth wind - but there is here no wind-god, and some doubt about the text (v. Page (1938) ad loc.). In art the first such representation, and apparently the only one of the century, seems to be a 'cabiric' vase-painting, dated to the later 5th century,\(^1\) showing Odysseus on a sea-voyage and a bearded human head marked ἘΡΘΕΙΑΙ\(^2\) blowing upon him. Wind-gods often appear on vase-paintings before this, but are shown as winged human figures,\(^2\) not blowing. All, or nearly all, are pictures of Boreas and Oreithyia or Zephyrus and Hyacinthus or Chloris, in which it would be grotesque to portray the god blowing; but, as the literary evidence has shown, this is a reflection of the limited contexts in which wind-gods were thought of as having human or animal form. Thus the vase paintings confirm that the notion of wind as from a wind-god's lips

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1. v. Wolters-Bruns (1940) p.109 (M.16) and p.125. (The vase-painting is illustrated by Gardner (1895) pl.26).

2. A few early representations may show a wind-god wholly or partly in animal form (v. H.Steinmetz 'Windgötter' (1910) 33, and p.20n supra.)

3. The Greeks need not consciously have denied that wind has a human or animal form; I mean simply that no idea of such a form entered their minds.
is not an archaic myth, but the fancy of later artists and poets.¹

The early Greeks, then, seldom thought in terms of wind-gods having human or animal form: much more often they spoke, and presumably thought, of no feature of wind save obvious observable ones (cf. p. 20-23). Fairly often, winds are spoken of as alive to some extent - as being 'aroused', quarrelling, sleeping, being persuaded, etc. (pp. 21f, 24) - although nothing evokes the image of a wind-god with human or animal shape: evidently wind was sometimes thought of as alive and self-moving,² but yet with no physical form save what we can observe, i.e. an invisible but palpable body moving in the space over the earth.³ Now such an attitude to wind strongly resembles the view which the Milesians, as hylozoists, had towards their ἄρχαι; for the latter, too, are alive and self-moving, but have the physical form only of a type of

¹. This paragraph is mostly derived from H. Steinmetz (1910), especially pp. 33-36. (I am grateful for further information to Mr. B. B. Shefton.)

². Its swiftness was proverbial, cf. passages cited on p. 22, also Tyrtaeus fr. 9.4, Theognis 715f and the Homeric epithets ἀλλόπος and ποδήνεμος.

³. The Greeks need not consciously have denied that wind has a human or animal form; I mean simply that no idea of such a form entered their minds.
The earliest philosophers would not have regarded the view of wind just described as having anything mythological about it, whereas they would have rejected any idea of an overtly anthropomorphic god causing wind. I suggest that the view of wind I have postulated was one source whence the Milesians took their hylozoism: this would explain, along with the familiar connection of breath with life, why Anaximenes made ἀὴρ/νεῦμα his ἄρχή; and—to return to wind—it would help to explain why some philosophic writers seem to have regarded wind as self-moving.²

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1. No doubt the Milesians consciously denied any human or animal form to their ἄρχαι.

3) Exhalation

A. The origin of 'breath' in early literature.

Many words which Homer uses of the winds are also used by him of living creatures' breath - πνοή, πνέω, ἄπνη - or else seem related to words used of breath - ἄημι, ἀήτης, ἀείλα (cf. ἄνφη?), ἀνεμος itself (cf. 'anima'), even θείλα (cf. θεμός, the breath soul). Wind resembles breath in that both are invisible bodies moving in the space over the earth; but, as shown above, it is unlike it in not issuing from any creatures' lips or nostrils.

Now in this it resembles certain other sorts of 'breath'. For example, ἄνφη may be a person's breath, the breath of winds, or the blast of a bellows. But it may also be a smell: μ 369, νλός ἢδος ἄνφη, cf. Σ 174; and fire, too, has an ἄνφη, as at π 290, τ 9,

2. On θεμός v. Onians (1951) 44ff. On the etymologies here mentioned v. Boisacq (1950) and Frisk (1954-) s.vv.: they express doubt about the relation of ἄημι etc. to ἄνφη, but seem confident of the others.
4. I 609f, K 89f εἰς ὁ χ' ἄνφη ἐν στήθεσιν μένη; cf. Ψ 765.
5. ι 400, 407 ἄνεμων ... ἄνφην; cf. Γ 289.
6. Σ 470f φύσαι ... ἄνφην ἐξανείσαι.
20 πυρὸς ... ἀνυμὴ (i.e. smoke, cf. π 288, τ 7, 18); 
1 389f βλεφαρ’ ἄμφι καὶ όφρας εἴσεν ἀνυμὴ γῆληνς καιμομένης (that which singed, εἴσεν, is presumably flame\(^1\)).

Similarly with πνοή and πνέω. πνοή is the breath of living creatures at \( \psi \) 380, \( \gamma \) 439 and presumably \( \phi \) 355 (see below); twice it is an air-current produced mechanically (\( \eta \) 590, \( \psi \) 367); in its other 18 occurrences it is wind. πνέω and compounds are used of living creatures' breath\(^2\), and of wind\(^3\); but they are also used of smell, ὁ 445f ἀμβροσίην ... ἢδη μάλα πνεοῦσαν, 406 (φῶκαι) πικρὸν ἀποπνεοῦσαι ἀλὸς ... ὀμήν.\(^4\) πνέω, πνοή etc. are not used in the Iliad or Odyssey of fire, except at \( \phi \) 355 πνοή ... Ἰφιλιστώο, which is both flame and the god's breath; but such a usage is found later: Η.Μερκ.110, Hermes lights the first fire ὀμπυντο ὀδ Θερμὸς ἀνυμή; Aeschylus

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1. So too at \( \phi \) 366f ἀνυμὴ Ἰφιλιστώο; but this is presumably also the god's breath.

2. \( \Delta \) 524, \( \eta \) 385, 654, \( \rho \) 447, \( \omega \) 442, \( \sigma \) 131, etc.

3. ὡ 360f, 567, \( \eta \) 119, etc.

4. Presumably it was not only the seals' breath that stank. For πνέω of smell in later poetry v. Aeschylus A.1309, fr.486.5; Sophocles fr.565; and perhaps Archilochus fr.80.7. For πνεύμα of smell v. Euripides Hipp.1391, Med.1075, Tr.758.
Pr.361 κεραυνός ἐκπνέων φλογά ¹.

The case is perhaps less clear with θέσσα, θυμός and their congeners, because it involves a series of words with different meanings, but apparently related etymologically.² however, if (as both Boisacq (1950) and Frisk (1954–) assume) θύω (or θυίω) 'rage' and θύω 'burn in sacrifice' were in origin the same word, then it is clear that words from this root were used in all the contexts mentioned above with regard to άντμή and πνέω: θυμός is the breath-soul, apparently regarded as a vapour from blood (v. Onians (1951) 47ff); θυόδος, θυής, and τεθυμένος all mean 'fragrant'; while other words combine the idea of fragrance with that of burning, as θύων (a sort of wood) in ε 59-61 (τηλέος ο' δομή κέδρου τ' εὐχέατοτο θύον τ' ἀνά γήσον δοῦσει δασιμένων ), and θύω when used of a fire sacrifice.³ θέσσα refers to wind, as does λαίλατι

1. Cf. Aeschylus A.820 (quoted p.36n); Pindar O.8.36; Sophocles Ant.1146; Euripides Tr.814f (if πνεύμα is there the right reading); fr.1059.1-2.
(I do not here discuss how πνέω and derivatives are used of emotions, or knowledge, or other things we would call abstractions, because I am concerned with the physical origins of πνεύμα or πνεύμα, and in these cases we cannot be certain what the origin was thought to be. On these uses v. Onians (1951) 46ff.)

2. On Homer's use of these words in relation to the later ἄνθυμας cf. Gilbert 45On.

The notion of 'boil', 'seethe', suggested by LSJ's renderings s.v. θύω (B), seems the natural link between the derivatives of this root, suggesting both violent movement (and so 'raging', 'rushing') and the discharge of steam (which resembles smoke, and so suggests burning and smell).

Thus three roots, those of αὐτή, πνέω and θύω, are each used in early Greek literature in connexion with breath, wind, smell and fire: clearly, these four ideas were to the earliest Greeks closely related. This group of ideas must underlie the philosophers' concept of 'exhalation': for Aristotle's words for this, ἄμυς and ἀναθύμιασις, are derived from two of these three roots, ἄμυς from αὐτή, and ἀναθύμιασις, via θύμια, from the root θυ-. On this development see p. 37ff; the survival of the old group of ideas down to Aristotle's time is clearly shown by πνέω and its derivatives, which,

2. On these etymologies v. Boisacq (1950) and Frisk (1954-) s.vv.; on the third v. also Gilbert 450n, Onians (1951) 44-8.
regularly used of breath and wind, were also used on occasion of fire, smell, and water evaporating. On fire, cf. Theophrastus HP V 9.6, the best sort of fire-stick μαλακτε̑ντα ... καὶ πλεῖστον ἀναπνεῖ, "flares up most quickly and freely" (Hort (1916)); Probl. XXIV 3 (936a21ff), flame scorches wood because ἡ μὲν φλὸς λεπτομερὲς, καὶ τὸ ἀπ' αὐτῆς πνεῦμα; also Aristotle's theory that flame is burning πνεῦμα, or burning καπνὸς or πνεῦμα. On smell, note Theophrastus CP VI 5.5 (ὀσμαῖ) ἐξ τῶν ἐκπνέουσαν χαμάτων ... θάνατηφόροι; HP IX 7.1-2, as one approaches a certain place εὐθὺς ὅσμῃ προσβάλλεται, οὐ μὴν πορρωτέρω γε ἡ ἀποστολὴ γίνεται; Od. 13, certain perfumes ἀφίασι πόρρω τὰς ἀποστολὰς (and so are perceptible at a distance); ib. 47, compound perfumes containing rose at first smell only of it, but later the rose-scent is lost: λεπτὴ γάρ οὕσα ἡ ἀναπνοή ... προτερεῖ τε τῶν λοιπῶν καὶ

1. I quote instances of πνέω, πνοή and compounds, in preference to πνεῦμα or πνευματός, because πνεῦμα was more often used in special senses, as a philosophers' technical term.

2. v. p. 252n. This is connected with Aristotle's special theory of dry exhalation=smoke=wind; but, in view of the evidence quoted above, the connection of πνεῦμα with fire is more likely a source of the theory than a result of it.
For examples of πνέω and derivatives used of water evaporating, v. [Hippocrates] de Arte 12 (L.VI 24.14f) φθάτων θερμῶν ἀποπνεύοµαι; Nat.Puer. 24 (L.VII 520.17) ὅταν ἀποπνέῃ ἐν τῷ γῆ ἀπ' αὐτοῦ (i.e. water); 2 Nul.II 133 (L.VIII 284.10f), arrange a vapour-bath ὡς παραπνεύσονθαι μηδέν, 'so that no vapour escapes'; Aristotle PA 671a20 διαπνέοντος τοῦ ὕγρου διὰ μανῶν τῶν σαρκῶν, cf. 32f εὐδιάπνουν ... τὸ ὕγρον; GA 744a16f, the region about the brain is at first moist, ἀποπνέοντος δὲ καὶ πεπτομένου σωματοῦτα; Theophrastus CP I 1.3 διαπνεύεται καὶ ἐξατμίζεται; V 18.1 διαπνεούσης ... τῆς θερμότητος καὶ ὕγρωτης; HP V 5.6 ἀναξηρανθῇ καὶ διαπνευσθῇ ... ᾄ ... ὕγρωτης.

Smell and fire would naturally come to be connected with breath and wind: smell, like wind and usually breath, is a moving invisible body (one moving from the scented object to the nose). A fire creates a draught, and emits smoke (which resembles the visible 'vapour' we exhale on

1. Cf §3 10...τῆς ὁσμῆς ἐν ἄναπνοῇ, with Hort's (1916) note. The connotation of πνέω is similar where διαπνέω, ἄναπνοη etc. are used of a perfume's losing its scent: v. Od. 39, 41, 42, 43, 55, 56.

2. What leaves the water here does blow as wind; cf. p.207f.
a cold day). Even flame resembles breath, wind and smoke in having properties we would call 'gaseous' - it is highly mobile, has no fixed shape or size, and can naturally rise upwards.

It was surely the common possession of such 'gaseous' properties that caused the early Greeks to connect these different ideas. Now breath, odours, smoke and flame share a further feature: each is normally derived from something which we would call 'solid' or 'liquid': breath comes from the body of the breathing animal (or perhaps, to the Homeric Greeks, from its blood); odours usually from some scented solid or liquid; smoke and flame from a solid or liquid fuel. This provides the link with the philosophers' concept of vapour: an invisible, gaseous body derived from a liquid, water (or, in Aristotle, from a solid, earth); and it must also be somehow connected with their theories of wind, for the pre-Aristotelians apparently all derived wind from water, cloud or a similar body (p.59ff), and Aristotle derived it from his dry

1. Cf. Onians (1951) 47.
2. Cloud, being opaque and the source of rain, snow and hail, is clearly akin to a solid or liquid.
exhalation from earth (p. 263).

The ancients, however, cannot simply have transferred to wind, and to water as its source, their usual expressions for breath, smell and fire. When πνέω and πνεῦμα are used of wind, the expressions used nearly all have the form ὠνεος πνεύ or πνεῦμα πνεύ; phrases like ὤωρ πνεύ or ὤνατος πνοή, corresponding to those used of smell, evaporation etc., though very occasionally used of wind, are always quite exceptional. Moreover, neither ἀτμίς nor ἀναθυμίας nor any related term was used, other

1. E.G. Homer's κνήσης ἀντιμή, πυρὸς ἀντιμή; v. pp. 29ff, 33ff.
2. [Hippocrates] Vict.III 68 (L.VI 602.21f) (τὰ ψύχεα τὰ πρώτα καὶ τὰ ἐς τὴν ἔσπέρν, ὡσα ποταμῶν η νύμνα η χένες ἀπονέουσιν) must refer to cold breezes, cf. the author's account of wind, quoted p.60; many ancient authors mention cold breezes blowing from rivers in the early morning (p. 341). Cf. Euripides fr.1059.2 ποταμῶν ...πνοαί. [Hippocrates] Nat.Puer. 8524-25 compares the formation of wind with the behaviour of water in a wine skin, of which he says ἀπονεοῦσαι τὸ ὄωρ (L.VII 524.1), "the water will breathe forth...", this being evidently analogous to wind blowing from water; but he does not use such expressions of wind itself. (Other expressions are occasionally used of both wind and fire etc.; compare δ 567f μήτας ἐκεινος ἀνέγαρ and Probl.XXV 2 (938a3-5) ποταμόλ ... πνεῦμα αἰφάλοι with Aeschylus A.820 ὁποδὸς προτέμεται ... πλοῦτον πνοᾶς, also 2 471, H.Merc. 114. Theophrastus CP VI 5.5 (δοµατ) ἐκπνεοῦσαι resembles expressions like ἀνεος πνεύ; in ἩΡ ΙΧ 7.2 ἀπονοή is first 'scent', then 'wind', being employed in similar expressions in the two places.
than exceptionally, of 'vapour' in meteorology (or of
wind) before Aristotle's day (p.37ff ). Before discussing
this question further, I must first consider certain other
evidence.

B. Terms used for exhalation in the 6th to 4th centuries.
i. θυμιάω, ἀμιλς and related terms.1

Although they were not used in meteorology, the pre-
Aristotelian usage of these terms throws some light on
Aristotle's use of ἀμιλς and ἀναθυμίαςς.

ἀναθυμίαςς , Aristotle's regular word for 'exhalation',
and ἀναθυμίάω , seem to have been first used by him2; but
θυμιάω (and other derivatives) occurs earlier, being found
first in Sappho. It means either 'burn so as to produce
smoke' (LSJ)3, or 'produce vapour over' a thing, 'pass

1. I have used the word indices listed at pp. 17, 435f
(but not Heiberg (1927)), and also Ast's (1835-6) and
Saupe's (1869) indices to Plato and Xenophon.

2. In the one apparent previous occurrence, DK 22B12, they
are probably not Heraclitus' words. (So Wilamowitz (1927)
276; EGP 151n; Kirk 'Heraclitus' (1954) 274, 368; contra,
Diels (1909) xvf, Woltjer (1901) 140-2; but neither ade-
quately explains why these words never recur before
Aristotle.)

3. E.g. Pindar fr.122.3f τὰς ... λιβάνου ἔανθα δάχρη
θυμιάτε. Cf. Herodotus 3.107 (bis), 112; 6.97; 8.99;
Hermippus fr.8; Amphis fr.27. For the passive v.
Herodotus 4.75; hemp-seed thrown onto hot stones
θυμιάται ... καὶ ἄμιλδα παρέχεσται. In the Hippocratics
cf. (e.g.), in Mul., L.VIII 186.18f, 398.16-19, 400.2,
402.3-6; Superf.32 (L.VIII 500.12).
vapour through' it.¹ It is normally used of the artificial production of vapour, e.g. of incense-burning, or, in the Hippocrates² (in every instance I have examined) of a kind of treatment, 'fumigation'. A possible exception is Plato Ti.66D: no-one has ever perceived a smell from any of the four elements; smells come from ἑβρεχομένων ἑσπομένων ἑτηκομένων ἑθυμωμένων ... τινων. Taylor (1928) ad loc. thinks the participles refer generally to changes between air and water, which (Plato next says) are what causes smells. But more likely, they simply refer to processes known to produce smells³, and the point about elemental changes is

¹ E.g. Sappho fr.2.3f βάμωι δὲ τεθυμιασε-νοι [αι]βανότω (so Page (1955) 34, 36. δεμπεμισε- the papyrus, δὲ ἐπιθυμιασε- Diehl (cf. Page l.c.)). Cf. also Hipponax fr.80 (doubtfully authentic); Euripides fr.773.14. In the Hippocrates, cf. (e.g.) Nat.Mul.3 (L.VII 316.4) θυμίησαι τοίσιν ἄρμασι (sc. τὰς όστέρας), "fumigate the womb with aromatic stuffs"; Mul.I 78 (L.VIII 196.17) θυμίησθω, "let her be fumigated" (cf. L.VIII 242.8, 250.15).

² I have noticed θυμίαω and related words often in Nat. Mul., Mul.I, II, III, Superf.; twice in Morb.II (L.VII 80.15, 94.14), once in Aph. (L.IV 554.4). I have examined only a sample. (Besides θυμίαω, ὑκοθυμίαω, θυμίησις and ὑποθυμίησις all occur (e.g. L.VII 314.21, 372.9, 370.13).

³ This is obviously true of rotting and (say) incense-burning, if not of τηκομένων; for βρεχομένων cf. Theophrastus Od.44.
introduced by the next sentence; for ἑξομενῶν and σηπομένων (at least) do not naturally refer to elemental changes in general. If so, θυμιωμένων may refer to processes like incense-burning, as it does elsewhere. I know no other pre-Aristotelian passage where θυμιάω may refer to natural exhalations.¹

The early usage of θυμιάω does, however, suggest one line of investigation relevant to meteorology. In Aristotle's exhalation theory (v.p. 233f) ἀτμίς is water-vapour (sometimes visible 'vapour', v.p. 420n ), while dry exhalation is related to smoke. One basis of this must be the familiar contrast between smoke and visible 'vapour': similar bodies - whitish clouds rising from a source, and disappearing - but derived from opposed sources, water and fire. Did the pre-Aristotelians make this distinction, e.g. by using different expressions for water-vapour and smoke? θυμιάω used for incense-burning clearly refers to smoke, not 'vapour', and often this seems true in the Hippocratics, e.g. L.VIII 186.18f ἵπτης φῆλα ἐπὶ πῦρ ἐπιθεὶς θυμίην ; Ib.402.3ff

¹. I ignore Aristophanes fr.635, which is obscure and unhelpful.
In all these, from 374.4 on water is often mentioned, and elsewhere it is usually not clear how vapour for fumigations is produced (at least, without more knowledge of the ingredients than I have), I tentatively conclude that normally θυμιάω was used of the production of vapour by burning, not by boiling; and that therefore the pre-Aristotelians, in their use of θυμιάω, did distinguish...
smoke from vapour.  

άτμις and άτμός everywhere denote gaseous bodies, always or nearly always derived from a solid or liquid. Up to c.400 B.C. they had the same range of meanings as Homer's ἀντὶς, except that they were not used of wind or a mechanically produced air-current; most often, they denote vapour derived from (or connected with) fire:

Aeschylus Eu.137-9 (invoking the Erinys against Orestes): συς ὁ ἄλματηρὸν πνεῦμ' ἐπουρίσασα τῷ, | ἀτμῷ κατισχναίνουσα, νησίδος πυρί, | ἔπου. "Follow him, breathing upon him a bloody breath, weakening him with ἀτμῶς, with fire from the womb".

Sophocles fr.370 λάμπει ὁ ἄγνευς βαμφός ἀτμίζων πυρὶ | σμύρνης σταλαγμοῦς, βαρβάρους εὐσμίας. "Apollo's altar is bright with fire, steaming with the ooziness of myrrh", with barbaric fragrance".

1. However, καπνός, normally 'smoke', is sometimes from water, v.p. 253; cf. also Mete.IV 387a30f, ὑμιλαῖος is κοινή ἐκφρασις ἔποιος καὶ ὄγρος.

Compare Euripides fr.781.1-2, and 52f; Herodotus 4.75 (quoted p. 37n ); also Hesiod Th.862, describing a thunderbolt: ΠΟΛΛΗ δὲ ΠΕΛΟΡΗ ΚΑΙΕΤΟ ΓΑΣ | ἄμη (or αὐμη ?) θεσπεσίη. The earth "was scorched by the terrible vapour" (of flame, cf.859; tr. Evelyn-White (1936)). The correct reading, whether αὐμη or ἄμη, was evidently some form intermediate between the epic ἄμη and the later ἄμης, ἄμος.

At Eu.137-9 ἄμος is connected with breath. At Sophocles fr.370 ἄμης evidently causes smell; cf. Aeschylus A.1311, Cassandra smells blood: ὡσπερ ἐκ τάφου πρέπει. Cf. also Pherecrates fr.108.14f, cooked foods ἔσιστον <ἀπ->ἀμίξοντα.

In texts that may be later than 400 B.C., however, ἄμης is almost always derived from moisture:

1. ἄμη vulgo, αὐμη West (1966); cf. his commentary and ap.crit. ad loc.
2. Cf. in a later author, Nicostratus fr.15 ἄνω 'βάδιζε ... ἄμης τις εἰς τὰς βίνις (from food); probably also Philoxenus, PMG 836(b)15 - but that is too corrupt for the meaning to be certain.

I ignore Aeschylus fr.456: even if ἄμος is rightly read there (which Mette denies), its meaning seems impossible to determine.
Xenophon An. 4.5.15 refers to natural evaporation from water: "snow ετετήκει διὰ χρήμα τινὰ ἢ πλησίον ἢν ἀτυλιζονοσ ἐν νάπη... a spring... emitting vapour..."

Plato Ti. 36E-37A: certain χυμοί in the body cause disease in the soul: έντιδς ... εἰλλόμενοι τὴν ἀφ' αὐτῶν ἀτυλίδα τῇ τῆς ψυχῆς φορᾷ εὐμιλεύοντες ἀνακερασθώσι "being confined within, they combine their vapour with the soul's motion and are mixed with it".

[Hippocrates] Flat. 8 (L. VI 102.17-20): ἀπὸ τῶν ἐσωμένων ὑδάτων ἀτυλίς ἑπανιῶν, ἢν ἔχῃ στερέωσα πρὸς ὧ τι χρῆ προσπίπτειν, παχύνεται καὶ πυκνοῦται, καὶ σταγόνες ἀποπληθοῦσιν ἀπὸ τῶν σωμάτων, οἶς ἐν ὧ ἀτυλίς προσπίπτη. (Cf. Id. 102.6).

Id. Morb. I 25 (L. VI 190.18f), the cause of sweat: the finest part of the body's φλέγμα is melted and separated off, τὸ δὲ ὧ ἀπὸ θερμασίης λεπτονύμενον ἀτυλίς γίνεται, καὶ οὖν τῷ πνεύματι μισούμενον ἑξῆ χωρεῖ. "The part that is rarefied by heat becomes vapour; it mixes with the air and leaves the body".

Id. Morb. IV 47 (L. VII 574.17ff): when the body cannot breathe, and so cool "τὰ ἐν τῇ κοιλίῃ", ἔξατμιή ἑξῆ τοῦ ὑγροῦ πάν τὸ χωτικὸν καὶ οὕτω θενήσει δ' ἀνθρωπος. "All the vital part of the moisture evaporates..." (cf. ib. 574.21-22; 849 (p. 580.4-16) has ἔξατμιάω four times,
ατμίῶ twice, ἔξατμίξω once: on the evaporation with heat of the body's moisture, and of water. Cf. also §45 (p.570.3), part of the ἱκμάς in the body διατιθεί ἔξω).

Cf. Mul.II (L.VIII 236, 1f), quoted p.40.

I know no passages possibly later than 400 B.C., where ἀτμίς etc. may be not from moisture, except for Nicostratus and Philoxenus as cited on p.42n, and these two:

[Hippocrates] Mul.II (L.VII 362.20f), one must construct a device ἕφ δ ἔξομένη 1 εἰσεισεν ἀτμίδς δς τας μήτρας, "on which the woman can sit so that vapour can enter the womb". (I am not certain whether the vapour is produced by boiling or burning - cf. ib.21ff; the verb is ἔποθεμιήν).

Id. Gland.7 (L.VIII 562.1ff) ἀνακέμπετι τὸ σῶμα ἀτμίδς εἰς τὴν κεφαλὴν παντοίους ἄνω, οἵς αὖδες ἡ κεφαλὴ δπίσω ἄφισον. Whether this is vapour from moisture is obscure.2

Only in Mul.II (L.VIII 360.20f) is the vapour likely to be from fire. Hence it is clear that the

1. ἔξομένη FHS ; —μεν η Littré.

2. On exhalation within the body v. further pp.254f, 258, 447.
restriction of the meaning to 'water-vapour' had begun before Aristotle.¹

ii. Other ways of speaking of exhalation.

In the above passages θυμιάω, ἀμύς etc. are connected with meteorology only at Xenophon An.4.5.15. For, primitive references to evaporation in meteorological contexts employ no word meaning 'evaporation' or 'vapour'; instead, it is said that water is drawn up from sea or earth, or that mist rises from it. Genesis 2.6: "a mist went up from the earth";² I Kings 18.44 "a little cloud... is rising out of the sea" (RSV); Amos 5.8 (the Lord) "calls for the waters of the sea, and pours them out upon the surface of the earth" (RSV); cf. Job 36.27; Psalm 135.7. Homer A 359 (Thetis) καρπαλίμως ... ἀνέδω πολυής ἀλός ἢτ' ὀμίχλη; Hesiod Op.549ff

¹. ἀμύς and derivatives invariably refer to vapour from moisture in Mete., though not always elsewhere in Aristotle, cf. Mete.IV 388b31f (quoted p. 254 ), Sens. 444b31f.

DK's index mentions no instance of a form of ἀμύς or θυμιάω in a fr., except Democritus fr.25, which is not verbatim, and conjectures in Empedocles fr.4.3 and Antipho fr.32.

². RSV, cf. AV; but RSV has note on "mist": "or 'flood'". (Cf. Solmsen 'Aristotle's system of the physical world' (1960)407n.)
"A fruitful mist is spread over the works of prosperous men; which, drawing itself up (or 'drawing water') from the ever-flowing rivers, is raised high above the earth.... and sometimes falls in rain" etc.

From the 5th or early 4th centuries, cf. Herodotus 2.25: ὁ ἡλιος ... ἐλκετ ... ἐπ' ἐωντὸν τὸ ὕδωρ ; variations of which recur four times in this §.

[Hippocrates] Ἀερ. 8 (L.II 32.19f): ὁ ἡλιος ἀνάγει καὶ ἀναπλάξει τοῦ ὕδατος τὸ τε λεκτότατον καὶ κοινότατον; this long account of rain has no word for 'vapour'. Ib.15 (p.60.20): ἥρ τε πολὺς κατέχει τὴν χώρην ἀπὸ τῶν δόρων "Much mist, derived from the waters, prevails over the country".

Vict.II 37-38 (L.VI 530.6-534.16): winds blow from snow and ice, and from moist and cold places; this probably means that wind is due to exhalation (the general pre-Aristotelian view, v.p. 59ff ), but the §§ have no word meaning 'vapour'. Cf. ib. 530.26f: in the north the sun does not ἀποξηραίνων τὸν ἥρα ἐκπέφει τὴν ἱμάδα.

Nat.puer.25 (L.VII 522.10f) τοῦ ἡλίου ... ἐλκοντος ἀπ' αὕτης [the earth] πρὸς ἐωντὸν τῆς ἱμάδος.
A different way of referring to a type of evaporation in meteorology was to speak of 'wind blowing from water', as in the passages from Nat. Puer. §§24–25 quoted on pp. 34
36n and 207f.

Similar expressions, employing no word meaning 'vapour', also occur in non-meteorological contexts: v. Nat. puer. 12 (L.VII 486.22f); Vict. II 58 (L.VI 570.18-20);
Mul. I 1 (L.VIII 12.12f); etc.

Thus in meteorological contexts before Aristotle, references to evaporation virtually never use ἀτυμίς, θυμία, 
ἀναθυμίασσι or any related term. In doxographical accounts of pre-Socratic meteorology, these terms (though not the ideas they express) are certainly anachronistic; the pre-Socratics themselves will have used expressions of the type just quoted, speaking of 'moisture drawn up', etc. Probably only two verbatim fragments refer to exhalation, Xenophanes B30 and Heraclitus B36 (quoted pp. 59 , 144 ): neither uses any word meaning 'vapour'.

It is easy to explain why θυμία, ἁτυμίς etc. were for so long not used in meteorology. θυμία always, or almost always, denoted the artificial production of vapour; and before c.400 B.C. ἁτυμίς etc. were almost invariably derived from fire (i.e. presumably were smoke or flame), or else
caused smell (cf. p. 41f): smoke and flame nearly always come from a definite, fairly small source, and so usually (and certainly in the 3 relevant passages, cf. p. 41f) does smell; breath, too, which is somehow involved at Aeschylus Eu.138, comes from a limited source, the breathing animal. In 4th century authors and the Hippocrates, Δρυς etc. is generally water-vapour, and sometimes cannot be perceptible (e.g. at L.VII 574.17ff, v. p. 43); but it still generally comes from a small source (e.g. the human body, or water artificially boiled; even at Xenophon An.4.5.15 the source is clearly small). Vapour occurring naturally on a large scale, such as is important in meteorology, is seldom visible (cf. [Aristotle] Mu.394a10ff), and comes from no small source, but from wherever on the earth there is moisture. Its presence in the air must have been mainly an inference, from the occurrence of moisture there as dew, rain etc.; hence it was naturally called not Δρυς but 'moisture drawn up' etc.

C. The origin of exhalation theories of wind.

There are, then, two groups of ideas underlying Aristotle's concept of exhalation, which originated in the pre-philosophical period: the concept of breath, smell
and fire (evidently a concept of moving, gaseous bodies derived from a localised source); and the typically meteorological concept of moisture drawn up from a wide area of the earth. In the period between Homer and Aristotle wind was connected with the second of these concepts (cf. Xenophanes B30, Vict.II 37-38 and Nat.puer. 24-25, cited on pp. 46f ). Nat.puer., indeed, by its use of υνέωμα and ἀπονέω, is also linked with my first concept (cf.p. 32-4 ); but the way in which υνέω is used with respect to wind is distinct from the way in which it is used of other sorts of evaporation (p. 36 ). It is also true that, in the early epics, the same or related expressions (ἄνεμη, υνέω etc.) are used both of wind and of breath, smell and fire; but presumably the feature wind was supposed to share with the other three was that all are moving, gaseous bodies, rather than that all are from a definite source; for wind has no obvious source; and my discussion of the primitive Greek concept of wind (p.20ff ), and also the Greeks' preference for expressions like ἄνεμος υνεὶ rather than ὅδωρ υνεἰ, strongly suggests that the early Greeks had no generally-held belief in sources of wind.

Sometimes, however, even in Homer and Hesiod, a wind does seem to have a source, and that not a divinity but a feature of the natural world: ὁ 567f, in Elysium αἰὲν
sometimes it turns to rain towards evening, and sometimes to wind when Thracian Boreas huddles the thick clouds" (tr. Evelyn-White (1936)); 1 Φ 334f, a storm (of Zephyrus and Notus) is sent εξ ἀλόθεν; ο 360f οὗροι ... ἄλωσες . Note also B 145f, Eurus and Notus ἐπαίδεσα πατρὸς Διός εἴκ νεφελᾶς; perhaps A 275-8 νέφος ... ὑπὸ Ζεφύρου ίωῆς ... ἀγετ ... λαίλαπα; also ε 478, τ 440, Hesiod Op.625, Th.869 ἄνέμων μένος ὕγρον ἄντων (which, except for Th.869, evidently refer to all winds). 2 Note also Solon fr.1.18-22:

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1. ὅστις (i.e. ἄφρ) (550) must be subject of ἐστι (otherwise it is nominativus pendens), so presumably is subject of ἄσητοι also: I take it that the ἄφρ blows, i.e. emits wind, adding extra force to the wind (Boreas, 553) already blowing. (Kopp (1939) 291 renders ἄσητοι 'jagt er', presumably meaning it is blown rapidly - which surely requires ἄσητοι; alternatively, ἄσητοι might be impersonal. The usage is anyway unique: LSJ quotes no passage, and I can find none in Homer or Hesiod, where ἄσητοι is either impersonal, or used in the active of wind blowing with any subject other than 'wind'. On the passage v. further Gilbert 441f; Solmsen (1960) 407f; Kahn 145f; Stokes (1963) 10; Plass (1963) 83-89.)

2. These Homeric passages are collected by Mugler (1963) 55-9, 63f.
Wind seems here to originate in the depths of the sea, and rises to the earth's surface, and then to the sky.

Note that no passage uses expressions like 'Ὀξεανοῦ ἄφων or 'Ὀξεανὸς πνεῖ, comparable to πυρὸς ἄφων, ἀμβροσίην πνεύοσαν etc., used of fire and smell (p. 29f) (except Hesiod Op. 552, if we there understand ἀδὴρ ἄησο); thus in Homer, as later, the expressions which link wind to its source, water, differ from those which link the ἄφων or νοοῖ of fire or smell to their sources (cf. p. 36).

These passages mostly concern particular winds, not winds in general.¹ In Greece, where the sea is never far away, many winds obviously blow off or over the sea;² and many ancient writers describe breezes blowing from rivers

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¹ ε 478, τ 440, Hesiod Op. 625 and possibly Solon fr. 1 are exceptions.
² Similarly, in Elysium, at the limits of the earth (δ 563), winds must blow from Oceanus.
At the onset of violent winds the sky often clouds over.¹ Also, winds often move the clouds, as Homer describes:² the earliest Greeks may sometimes have confused cause and effect, as children do, and supposed that clouds cause wind.³ Such simple observations and deductions must have been made by the earliest Greeks, and are referred to in the passages just quoted. Although some of them connect all winds with moisture or the sea (p. 51 & n.), there can have been no consistently-held belief in such a connexion; for the passages just quoted are only a few of those in early epic that concern wind; and other passages speak of wind as derived from quite different parts of the natural world.

Thus certain winds originate at particular places on land (Mount Ida, or Thrace)⁴ - but this was hardly a
suitable basis for a theory explaining 'wind' in general. At 0 171, T 358 and ε 296 Boreas is αἰθρηγενής or αἰθρηγενέτης, 'born from clear skies'. Later writers speak of Boreas as αἰθρηκός, 'causing clear skies';¹ I suggest that, as with wind and cloud, the earlier Greeks inverted cause and effect, and supposed clear skies to cause the wind.² Compare Ἡ.Αρ.434, wind blows ἐξ αἰθρήκος

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1. Mete.364b6ff, Vent.6-7, Probl.947b4ff, cf.939b19f. (Some think αἰθρηγενής may mean 'causing clear skies', cf. Snell (1955-) s.v.)

2. So Ameis - Hentze - Cauer (1940) on ε 296. I confess that at 0 171, T 358 and ε 296 the sky is not clear; but the epithet may have become purely conventional. Mugler (1963) 57 (cf. Leaf (1900-02) on 0 171) thinks αἰθρηγενής means that Boreas originates in a region of pure, always sunny αἰθήρ that is above the ἀήρ, and into which the Thracian mountains extend. But this seems an improbably elaborate speculation for Homer. Also, αἰθήρ, whence αἰθρηγενής is immediately derived, means 'a condition of clarity', not 'sky' as a region; and anyway Homer does not normally regard the highest mountains as extending into such a region of αἰθήρ. (The only good evidence for such a view is Χ 43-5: there is no wind, rain or snow on Olympus, ἀλλὰ μαλία ἀἰθήρ πέταται ἀνέφελος, λευκὴ δ' ἐπιδέσμους αἴγιλη. This is contradicted by passages where there is snow on Olympus (A 420, Σ 186, 616; cf. Hesiod Th.62, 953; H.Μερκ.505), or cloud (Π 364f, v 103f; cf. Ἡ.Αρ.98, Pindar fr.52f.92f). I know no evidence that other mountain-tops are thought to extend into a region of αἰθήρ (unless one counts Σ 288 - but that concerns a tree, and is anyway unique, cf.Π. 58), or to be permanently above the clouds etc.: and they often have snow or cloud upon them (Γ 10, E 522f, Ν 754, Σ 227, Π 298, P 594, Y 385; τ 338. N.b. also μ 73-76: Scylla's rock reaches the οὐρανός, but its peak is always cloud-covered).
I suggest, then, that this was another simple deduction based on commonplace observation, comparable to that which connected wind and cloud. Why did the connexion of wind with cloud and water lead to a widespread philosophic theory, while the connection of wind and clear skies led to none?¹ I suggest that the reason was a feeling

1. On the significance of these passages, and some of those concerning cloud, for the origins of naturalistic explanations of wind, cf. Kopp (1939) 255-282 passim. (He also cites Λ 297 θπεραξί... δέλλη, and passages where πίκω and compounds are used of the onset of wind (e.g. ε 295, Hesiod Op. 547); but in these any indication of an origin of the wind is much less strong.) He also (p.268) discusses Ν 795f, where thunder causes wind; but that seems connected with later theories of thunder, not wind, cf. p.379f.

2. The notion of Βορέας αλέρησεν can hardly have led to the idea that the sun causes wind (as Mugler (1963)58 suggests): the point of αλέρης is its clearness, not its heat (cf. Π 646, Μ 75). The idealised Olympus of ζ 43-45 will not have been thought of as conspicuously hot: Elysium, described in similar terms at δ 566-8, clearly is not). Similarly, Homeric αλέρης is not hot (p. 439f); and Boreas was notoriously cold (Ο 171, Τ 358, ξ 475; Hesiod Op. 505ff, 547; [Hippocrates] Aer. 4(L.I1 18.18f); Mete.364a19ff, b21f).

(I would not, however, deny Mugler's view ((1963) 55-7; cf. Kopp (1939) 279, on Ε 864f) that other Homeric passages may have suggested that heat causes wind: (i) passages connecting wind with fires on the earth (Α 155ff, Π 736ff, Υ 490-2, Φ 334ff, Υ 214-6; in all these wind is said to spread or increase fire; but other observers might have inverted cause and effect, cf. p. 52 ); (ii) Ε 865 καύματος δι' ανέμου δυσσέως δραμένου "a stormy wind arising after hot weather" (so Leaf (1900-02)). This might have suggested to Anaximander that heat causes wind, even if to Homer it was purely a matter of chronological sequence - though the connection seems, at best, remote.
(perhaps subconscious) that an ἀντίκή, πνοή or θύελλα that was wind, like other sorts of ἀντίκη, πνοή etc., ought to be derived from a solid or liquid (cf. p. 55). As I showed on pp. 35-7, the connexion (there described) between wind, breath, smell, fire and philosophic exhalation theories did not lead directly to the exhalation theory of wind, but must be somehow related to it. I now suggest that the connection was this: when the ancients had to decide between two theories, both supported by common observation, that wind is from cloud or water, and that it is from clear skies, their subconscious assumption that a πνοή, ἀντίκη etc. ought to have a solid or liquid source determined their choice of the former.¹

1. Such a choice might also have been encouraged by the idea, argued by Furtwaengler (1905) 450ff, and Hampe (1967) 10f, that winds were connected with earth, and were 'chthonic' deities; but this cannot have been important, because early philosophers connected wind with water, not earth.
CHAPTER 2

PRE-SOCRATIC WIND THEORIES: PRELIMINARY

Our testimonies on the pre-Socratics' wind theories are so scanty that they cannot be properly interpreted on their own; before discussing them individually, I must first, in this chapter, establish certain general conclusions about early wind theories, by comparing them with each other, with fuller accounts of similar, later theories, and with related theories about other things; in particular, I shall try to determine whether any pre-Socratic defined wind as air in motion, or understood the expansion of compressed air; and will discuss their theories that wind is derived from water or some related body, and that it is due to rarefaction, and also their ideas on the nature of cloud.

1) Wind defined as air in motion.

The post-Aristotelians seem unanimously (if with minor variations) to have defined wind as 'air in motion'¹; and

¹ For a list of passages v.Ideler (1832) 55n, to which add [Plato] Def.411C; Mete. IV 387a29f; Procl. 882b16; 932b30; 933a37; 940b7; 944a26 (ητοί τοῦ ἀέρος ή τοῦ ἀναχάεντος ύγρου χίνησις); SVF II 697; Cicero ND II 101; [Aristotle] Mu. 394b8f; Hero Spir. 6.6f Schmidt.
though Aristotle himself rejected this (p. 263), Top. 127a4f, 146b29 shows that in his day χίνης δέρος was already a common definition. Earlier instances are [Hippocrates] Flat. 3 (L.VI 94.4) ἄνεμος ... ἐκ τῶν ἀετῶν ᾲρος βεῦμα καὶ χεῦμα and Plato Cratylos 410B, ἄηρ is so called ὅτι πνεῦμα ἐξ αὐτοῦ γίγνεται ἐν πλήθει δέρος (DK 47A22) suggests wind is air in motion.¹

Many reports of pre-Socratic wind theories mention ἄηρ²; but none gives the simple definition 'wind is ἄηρ in motion'. Alexander 53.28 and Olympiodorus 98.1f, commenting on Mete. 349a16ff (which mentions this definition), refer to [Hippocrates] Flat., which suggests they did not know the definition in any pre-Socratic (if they did, why quote a doctor?); but Aristotle here cannot be thinking solely of [Hippocrates]; for part of the theory mentioned is that air condenses to cloud and rain, of which

¹. Cf. also Leucippus 67A24(3) (ἄηρ) πνευματοῦμενος ... κατὰ τὴν χίνησιν; but this may well be Epicurean, cf. HGP II 406n2.

². Anaximander 12A11(7), A24, 64A9; Anaximenes 13A5, A7(7), A19; Anaxagoras 59A1(9), A42(11); Diogenes 64A9; Democritus 68A93a; Metrodorus 70A18.
[Hippocrates] says nothing. Wind is ἄηρ in motion', then, was an established definition by c.350 B.C., but is not reliably attested before c.400. (The pre-Socratics were, in any case, uninterested in definitions.) It was, however, probably implicit in later pre-Socratic wind theories: Plato, Archytas and the author of Flat. were but minor meteorologists, and would hardly have formulated this definition, if previous meteorologists had not somehow suggested to them that wind and air are connected.

1. Flat.8 (L.VI 102.16) says that, in the body, τὸ ... πνεῦμα συνιστάμενον ὑόπρ χεῖται. But this is hardly a likely basis for Aristotle's remark on νέφος καὶ ὕόπρ.


3. Achilles Isag.33 p.68 Haass, Ideler (1832) 55n and Gilbert 512 claim that Anaximander defined wind as air in motion, quoting DK 12A24 ἀνεμον ἐλγαι ὑςὶν ἄηρος τῶν λεπτοτάτων ζεν αὕτῇ καὶ γυροτάτων ὑπὸ τοῦ ἣλιοῦ χινομὲνων ἢ τηκομὲνων. But, even if this is accurate (12A11(7) has nothing like ὑςὶν ἄηρος), it does not quite support the claim; for only part of the ἄηρ flows to produce wind (cf. p.114ff), and ἄηρ here is probably 'mist' rather than 'air' (p.62).
2) Wind and water: a general feature of early wind theories.¹

Four or five accounts, or partial accounts, of pre-Aristotelian wind theories survive verbatim:

1) Xenophanes fr. 30

πηγὴ  ὁ ἐστὶ θάλασσ(α) ὕδατος, πηγὴ  ὁ ἀνέμοιο.
οὔτε γὰρ ἐν νέφεσιν <γίνοιτο κε ἐς ἀνέμοιο
ἐκπνεῖοντος> ἐσώθεν ἄνευ πόντου μεγάλοιο
οὔτε ὅσαλ ποταμῶν οὔτ' ἀλ<θέρος> ὁμβριον ὕδωρ,
ἀλλὰ μέγας πόντος γενέτωρ νεφέων ἀνέμων τε
καὶ ποταμῶν.

(So DK. See further p. 135f.)

2) [Hippocrates] Nat. puer. 25 (L.VII 522.12ff) τὰ ...

πνεύματα ... ἐστι πάντα ἄφ' ὕδατος· τούτοις δὲ πέρι πάρα
[i.e. πάρεστι] συμβάλλεσθαι, ὅτι οὕτως ἔχει, ἀπὸ
γὰρ τῶν ποταμῶν πάντων πνεύματα χωρεῖ ἐκάστοτε καὶ τῶν
νεφέων, τὰ δὲ νέφεα ἐστὶν ὕδωρ ἐννεκές ἐν ἡρέ(κf.
p.522.17f; p.524.10-12; §24 p.520.17. For translation
v.p. 207)

¹ On the pre-Aristotelians in general v. Gilbert 511-22.
3) [Hippocrates] Vict. II 38 (L.VI 530.12-16) φύσιν
... ἔχει τὰ πνεύματα πάντα ὑγραίνειν καὶ ψύχειν τὰ τε
σώματα τῶν ἵππων καὶ τὰ φυόμενα ... διὰ τάδε· ἀνάγκη τὰ
πνεύματα ταῦτα πνεῖν ἀπὸ χιόνος καὶ κοινωτάλλου καὶ
πάγων ισχυρῶν καὶ ποταμῶν καὶ λιμνῶν καὶ γῆς ὑγρανθείσης
καὶ ψυχθείσης. (For translation etc. v.p. 203.)

4) With 3) cf. Herodotus II 27 κάρτα ἀπὸ θερμῶν
κυρέων οὗ οὐκ ἔστι οὐδὲν ἀποκενέειν, αὖρῃ δὲ ἀπὸ
ψυχροῦ τινος φιλέει πνέειν. "It is unlikely that a breeze
should blow from very hot places – they tend to blow from
something cold". (However, Herodotus may be referring only
to breezes from rivers (he is talking about the Nile), cf.
p. 341.)

5) A doubtful passage is Anaxagoras fr.19, which in DK
includes the words: τὸ ... περικεχόμενον ¹ ὅφει ὑφὶ νέφει
ἀνέμον ἐπολήσειν ἢ ἑξέχεεν οὐμπρόν , "the water that is
poured round the cloud produces wind or pours forth rain."
Unfortunately, it is doubtful whether this is really from
Anaxagoras. ²

1. Solmsen (1963) 251 would read περικεχόμενον.
2. v.p. 456-8 . (I think the words more probably genuine.)
In four of these five passages wind originates in water, or something connected with water; and the cold of the fourth (from Herodotus) connects it with the ice etc. of Vict., and should connect it with water.¹

This common feature is shared by most of the testimonia on the pre-Socratics. Two derived winds from water or a watery vapour: Heraclitus (22A1(10): both his exhalations are connected with water, p. 140f), and Metrodorus (70A18). Anaximenes derived winds from dense air, which must be or resemble cloud or water (p. 57); Democritus held that winds occur "cum exiguum locum multa corpora impleverint" (Seneca NQ V 2, DK 68A93a), i.e. when in some place the matter is dense; dense matter in the atmosphere must be cloud, as the ancients' general opinion on cloud shows (p. 100f).²

On Anaximander, 12A27 derives wind from water-vapour;

¹ Cold and wet were often associated (water usually feels cold): in Anaximander, the middle of the cosmos, when first formed, is both cold (12A10) and wet (12A27); Anaximenes associated cold with density (13B1) and thought water dense (13A5 etc.); Empedocles, v.fr.21.5; Anaxagoras, v.fr.15, cf.frr.4, 12; etc.

² Seneca NQ V 3, criticising V 2, considers it implies cloud.
but 64A9, a parallel passage, says the vapour first becomes δήρον and that this causes wind; 12A11(7), A24 say wind is due to the finest (or finest and wettest) parts of δήρον. Here, atmospheric air might be meant; but no other pre-Aristotelian wind-theory clearly derived wind from air in its normal state; also, 12A11(7) and 24 look like a primitive version of the rarefaction theory of wind (v.pp. 55ff, 116), other versions of which almost all involve the rarefaction of something denser than atmospheric air - moisture, cloud or moist air (v.pp. 57; 82f). It is most unlikely that Anaximander, who probably had no clear concept of atmospheric air (v.p. 107-9), used it in explaining wind, when almost all later thinkers with similar wind-theories, though knowing of atmospheric air, here used some denser body.

Anaxagoras 59A1(9) and A42(11): wind occurs λεπτομενων του δήρου. This might refer to atmospheric air:

1. Though wind must still be ultimately from water.

2. 12A24 (quoted p. 58n) was perhaps originally an explanation of wind and rain (cf. p. 114), i.e. wind and rain have the same origin, obviously cloud. If 12A24's 'wettest parts' really did help to cause wind, then wind requires moisture, as in other pre-Socratics.
but B19 (if genuine; cf. p. 60), and the analogy of related theories, make it likely that ἀνέδεικτο here means mist or cloud (v. p. 67). (It could mean this in Anaxagoras' day, cf. p. 18f.) On Diogenes, v. 12.27, 54.9 and A17: wind is derived, ultimately at least, from water. Only the doubtfully authentic Empedocles 31.64 (v. p. 338n) says nothing of water etc.

Thus all, or nearly all, pre-Aristotelian wind theories are similar, in that wind is derived from cloud or water, or from dense or moist air, or from wet or cold places. (This influenced Aristotle's wind theory (p. 266), and Theophrastus' still more (p. 372), besides still later thinkers.)

I have already discussed the origins of this theory (p. 48-55): to the considerations there mentioned (especially p. 51f) may be added others: for example, winds usually feel cold, which suggests derivation from a cold place or material (p. 61n); and the long duration of some winds is easier to explain if winds come from

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1. This has not, I think, been noticed previously. (HGP II 425 slightly misses what seems to me the point.)
something denser than atmospheric air (cf. p. 264) - this helps to explain how the wind theory described above remained current even after air's existence had become well-known. A further factor was doubtless simple conservatism: few ancient thinkers were interested enough in meteorology to invent new theories (cf. p. 405f).
3) Wind and rarefaction

I shall here discuss eight passages which seem to contain variations of one wind-theory:

1) Anaximenes 13A7(7) ἄνεμους ... γεννάοσθαι ὅταν ἀνεκπευκνωμένος ὁ ἀέρ ἀραίωθες φέρηται "winds occur when air that has been thoroughly condensed is rarefied and moved."¹

2) Anaxagoras 59A1(9) ἄνεμους γίγνεσθαι λεπτυνομένου τοῦ δέρος ὑπὸ τοῦ ἥλιου (cf. A42(11), on which see p. 168ff).

3) Vent. 41 πάντα [sc. πνεύματα] μετὰ τοῦ ἥλιου διαχέοντος τῷ ὕγρῳ ἐν τῇ ὑγρεύσει ἐλαίας τὴν ἀρχήν. (Cf. p. 340 .)

4) Probl. XXVI 35 (944a31ff) ἀπάντα τῷ πνεύματι τοῦ ἥλιου διαχεύοντος τῷ ὕγρῳ γίνεται ... πρότερον γὰρ συνεστηκός, ὅταν ἦ τῷ θερμῷ ὀξύωμις πλησιάζῃ, ἔδαπτε.²

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¹ I agree with Boeker 2226f that the text need not be altered.

² "... For when moisture has previously collected and the sun's heat draws near, it ignites it." For 'ignition' in causing wind cf. DK 70A18 ἐκκαυσών, (v.p. 195f ), 59A42(11) ἐκκαυσμένων (which seems equivalent to λεπτυνομένου ; cf. 59A90, on evaporation, quoted p. 164 .

As will appear, this parallels the equivalence of διαχέοντος and ἔστησε in Probl., as do other passages where ἐκκαυσῶ is used of moisture drying up or of evaporation, cf. p. 331n , also DK 60A4(2)). However, Forster (1927) reads ἐκκαυσώ for ἔδαπτε in Probl. XXVI 35, perhaps rightly (cf. p. 359ff ).
5) Ib. 54 (946a39ff), easterly winds blow early in the morning σοτ το τον ἄέρα καθυγρον ςοντα  ὁν τη νυκτι διαχρίνοσοι καλ κινέοσοι ... υπ τον ἡλιου.

6) Ib. 33 (944a10ff), why does the west wind blow προς την ὕελην ... πωi δε ου? Is the cause the sun's rising and setting? ὅταν γαρ ὕγρον ὑντα τον ἄέρα διαδερμαινων πετη2 καλ διαχρινη, εις πνευμα διαχρινει· ἐδα ν δε η πνευματωδης δ ἄηρ, ἐτι μαλλον ἐκπνευματοται υπ τον ἡλιου. ("... If the air is windy, it is turned still more to wind by the sun." Cf. p. 80 ) Ib.a15ff: when the sun is rising, it is far from the west; ὅταν δε περι το ουνειν ἡο, τοτε διαχερμαινον ἐστι το πνευμα τελεως. ἀπο δε μεσον ἡμερας καλ προς την ὕελην συμμετροτατα ἔχει προς το διαδερμαναι καλ διαχριναι. Cf. also ib.19ff.

7) Diogenes Laertius VII 152 (SVF II 698): to the Stoics, wind is due to τον ἡλιον εξατμιζοντα τα νεφη.

8) Hero Spir. p.12.15-18 S. τα πνευματα ... εκ σφοδρας ἀναθυμιασεως γινεται, τον ἄέρος εξωθομενου καλ λεπτυνομενου

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2. On this v. p.362f.
Several features are common to nearly all these passages. First, in all save passage 1 the efficient cause of wind is the sun (or ἀναθωμίας, which is also a source of heat). Second, in all save passages 2 (perhaps) and 8 wind is produced not from ordinary air, but from moisture or moist air (as in passages 3, 4, 5 and 6), or what must resemble such. Thus in Anaximenes cloud and water are produced by ὕπ π ρ condensing (DK13A5, A7(3)); so presumably ὕπ π ρ ἐκπευκυκνομένος in passage 1 resembles cloud or water. As to passage 7, cloud was generally regarded as intermediate between air and water (p. 100f ). In passage 2 (Anaxagoras) also, the analogy of other pre-Socratic wind theories (v. p. 59ff ), combined with that of the other passages here quoted, makes it likely that ὕπ π ρ resembles mist or cloud, rather than what we call 'air'.

1. At ib.p.12.4-15 ἀναθωμίας causes dew by providing heat to produce water-vapour, so presumably it functions here (at least partly) as a source of heat. (I cannot here discuss the features unparalleled in the other passages, ἕξωθομένου etc.)

2. Which, as I shall show, are parallel.
Now the passages also share a third feature: the process expressed by the verbs ἄραιωσθαι, λεπτύνεσθαι, διαχρίνεσθαι, (ἐξ-)ατμίζεσθαι and διαχείσθαι seems in every case the same: cloud etc. is changed from something more like water to something less like it, and more like dry air: although the meaning of these verbs differs considerably, they all mean this in the present context, as I shall next show.

A. ἄραιωσθαι (v. passage 1, p. 55)

Anaximenes regarded all other materials as formed by ἄραίωσις or πύξωσις of ἄηρ: comparison of the relevant testimonia shows that, in passage 1, ἄραίωσις of ἄηρ ἐκπευκνωμένος must be a change away from something like water (cf. p. 57) towards air in its 'normal', primary state.

Basically, a thing is πυχνός when there is much of it in a small space, leaving small intervals, or none, between its parts or units. Thus, a mass of units crowded together are πυχνά (e.g. βέλεα, φλέβες, νεῦρα) 2; something

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2. v. Homer A 576, Δ 281; [Hippocrates] Genit.2 (L.VII 472.7); Aristotle Mete. 348b25; PA 678a1; Theophrastus CP II 9.1.
impenetrable is πυκνός, as having no gaps through which anything might pass (e.g. a thicket impenetrable to sun, wind or rain, \(^1\) or plants which retain moisture because ὧ ... ἡλίως οὐχ ... ἐξάγει οὐδὲ τὴν πυκνότητα \(^2\)); elsewhere, a thing is πυκνή ... ὅτι συνεχής (Theophrastus Ign.33). More generally, anything dense, of close texture, is πυκνός (e.g. a cloak, bedding\(^3\), or a hard or wood-like plant\(^4\)).

It follows that, when applied to changes between different materials, πύκνωσις, becoming πυκνός, means that matter becomes packed into a comparatively small space; and its opposite, ἀπαλάωσις or μάνωσις, that matter is spread out over a large space. Cf. Aristotle Ph.IV 214a32ff ἐνδέχεται ... πυκνοῦσθαι μή εἰς τὸ κενὸν ἀλλὰ οἴδὰ τὸ τὰ ἐνόντα ἑκπυρηνιζεῖν.\(^5\)

Now, when water boils, the vapour produced obviously occupies a much larger volume than the water whence it has

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1. τ 440-3, cf. ε 471, 476-81 etc.
2. Theophrastus CP III 11.2; hence, what is μανός is penetrable, cf. I 12.7 ἀδιδοδος ... καὶ μανός.
3. Homer ε 521f, I 621 etc.
4. Theophrastus CP I 7.2, III 6.6, etc.
formed; i.e., this change is μάνωσις, and (consequently) its opposite is πύκνωσις; thus water (and cloud, as intermediate between the two) is more πυκνός than dry air: this will apply in every ancient physicist, whatever his theory of matter.¹

B. λεπτόνεσθαι (v. passages 2 and 8, p. 65-7).

λεπτός means 'fine', i.e. 'thin' or 'small', being often used of a plurality of small objects², and occasionally of a mass composed of small parts.³ By extension, a continuous material, e.g. air or water, can be λεπτός, as having (I suppose) the properties of a fine body

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¹ Cf. Plato Tim.49C; Aristotle Ph.IV 216b22ff, 217a11ff; Mete.348b6ff, 369a12ff, 370a2, 372b15ff, 30f, 377b16 with 19f; Theophrastus Vent.2 πυκνότατος καὶ συνεφόστατος δὲ ἄρπ; 7 (air or wind) πυκνώθες; τὸ στίνος γίνεται. Cf. CP I 137; Probl.II 20 (868a24), XXVI 8 (941a3ff) 56 (946b35f). (This is the normal view, though ancient writers are sometimes inconsistent, e.g. at Mete.370b8, Probl.XXXV 22 (940a14), where πνεῦμα or ἀέρ is πυκνότερον, but nothing indicates that it is like water).

² E.g. Homer Ḫ 280 δέσματα, Aristotle GA 720b13 πόρους, 782a23ff τρίχες, Theophrastus HP III 10.5 σπερμάτα.

or mass of particles\(^1\) (e.g. lightness\(^2\), being moved or flowing easily\(^3\), passing readily through other objects\(^4\)).

Now such properties are possessed by air compared with water, and by water compared with solid bodies, i.e. changes between such materials are instances of λέπτυνσις or πάχυνσις, as well as of ἄραξινς or πώξινς. Hence, Aristotle used πυκνός and λεπτός as opposites in speaking of theories like Anaximenes\(^5\); λεπτός and παχύς often seem equivalent to μακρός and πυκνός when used of air or πνεῦμα or changes between air and water\(^6\); and vapour or air is λεπτός compared with water or cloud\(^7\). Aristotle states

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1. Such bodies may be regarded as composed of particles, cf. Aristotle Cael. 303b27 λεπτόν ... τὸ μικρομερές (of elements), Mete. 370b6-8 λεπτομερέστερον (of πνεῦμα); Theophrastus Ign. 49 λεπτόν connected with μικρομερές (he has been talking of air and liquids). Cf. also Aristotle Cael. 304a14, de An. 405a22-4, GC 330a1ff, Metaph. A 989a1.

2. λεπτός and κοῦφος connected: e.g. Theophrastus Ign. 33; CP II 4.4; II 18.3; [Hippocrates] Aer. 8 (L.II 32.19ff).


4. Aristotle Resp. 478a18f; Theophrastus CP V 14.1; Ign. 25.


6. Mete. 370b5ff; Probl. XXVI 8 (941a3) πυκνομένου seems equivalent to 8 παχύτερου. Theophrastus Sens. 35, Ign. 48.

7. [Hippocrates] Aer. 8 (L.II 36.1ff), 19 (L.II 72.9f); Morb. IV 49 (L.VII 580.10-13); Aristotle Cael. 305b13ff; Mete. 365b28ff (πνεῦμα is λεπτότατον of all things, cf. de An. 405a22f, on Diogenes); PA 658a6-10; Resp. 478a18-20; Mete. IV 383b26ff, 30; 384a10; cf. Theophrastus CP V 10.3; V 14.2, 5; fr. 171.5.
that λέπτυνσις involves expansion\(^1\), which ἄραιωσις also
does (p. 69) - a natural (though not necessary)
assumption, since a solid mass commonly occupies more space
when broken into particles (e.g. a pile of sawdust compared
with the wood whence it has been sawn).\(^2\)

λεπτός and μάνυς, used of bodies like air, are also
equivalent in reports of Anaxagoras: v. Theophrastus in
DK 59A70 (τὸ μὲν μανῦν καὶ λεπτὸν θερμὸν, τὸ δὲ πυχνὸν
καὶ παχῦ ψυχρόν, of αἰθήρ and ᾠρ) and A92(30) ὄζειν ...
μᾶλλον τὸν λεπτὸν ἀέρα, θερμαίνόμενον μὲν γὰρ καὶ
μανοῦμενον ὄζειν ... οὐχ αὐσθάνεσθαι τὰ μὲν μεγάλα
[sc. ξύλα] τῆς λεπτῆς ἀέρος, τὰ δὲ μικρὰ τῆς πυχνῆς.

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1. Gæl.303b23ff, 304a29f, 305b13. Cf. Theophrastus fr.159
(πάχος of water whose volume is reduced). On Hero v.
p. 83.

2. This equivalence of πυχνὸς and παχῦς, λεπτός and μανῦς
applies only to materials like air or water (continuous
masses with no definite shape or structure), not to
other bodies (e.g., small units packed together are both
πυχνὰ and λεπτὰ (as Aristotle PA 652b32); a thin hair
is λεπτός but not thereby μανῦς; and so on.
Exceptionally, even a body like air or water is both
πυχνὸς and λεπτός, e.g. Theophrastus Ign.33f, flame is
λεπτή ... ὅτι κοῦφος, πυχνὴ δὲ ὁτὶ συνεχής ; CP III 6.8
μανή καὶ κουφή soil contrasted with λεπτόγειος
(λεπτόγειος perhaps refers to soil's poverty, cf. LSJ);
Probl.XXIII 8 (932b11f), fresh water is πυχνὸν ὅτι
λειτομέρειαν (the fine parts are thought to fit closely
together, the opposite view to that mentioned on p. 72;
 cf. Probl.XI 58 (905b4f), τὸ υγρὸν is λειτότερον than earth
and has ποροῦ ... πυχνοῖ, probably narrow pores, cf. LSJ
s.v. πυχνὸς i.2).
In Anaxagoras' cosmogony, the dense, moist and cold (evidently solids and liquids) collect in the centre of the cosmos, while what is rare, dry, hot, and therefore λεπτόν, (i.e. fire) goes out to form the sky (cf. p. 159). B16 speaks of cloud apparently changing via water and earth to stone; clearly, as in Anaximenes (13A5, A7(3)), these are changes from a rarer to a denser body. Therefore, the λέπτυνσις of cloud or air is an (apparent) change to something more like ordinary air or fire.

Compare Hero Spir. p. 10.19-28 S., when things are burned τὰ μὲν λεπτότερα ... εἰς τὸν άνωτάτω χωρεῖ τόπον, ἐνθάπερ καὶ τὸ πῦρ. τὰ δὲ ... παχυμερέστερα εἰς τὸν ἄερα· τὰ δὲ ἐτί τοῦτων παχύτερα ... τοῖς γεώδεσι συνάπτει. μεταβάλλει δὲ καὶ τὸ ὄξωρ εἰς ἄερα ... οἱ γάρ ... ἄμοι (from cauldrons) are αἱ τοῦ ἄγροῦ λεπτύνσεις εἰς ἄερα χωροῦσαι. (The same happens to air: p. 10.19-28 is explaining, by analogy, how fire λεπτύνει τὸν ... ἄερα.) Clearly, any λεπτύνσις is part of the change from earth, through water and air, to fire.

1. Note that in B16 at least part of the change is due to cold.
C. \( \delta \iota \alpha \chi \rho \iota \nu \iota \sigma \omicron \sigma \theta \omicron \) (v. passages 5 and 6 on p. 66)

This word's basic meaning is 'separate', cf. (e.g.) Homer B 475, Μ 98, 102 (the separating of two flocks, or opposed combatants). Hence, in physics, it is used of the separating of a mass into its component parts, e.g. in describing Empedocles' and Anaxagoras' physical theories: there is no real change, but only mixing, and the separation, \( \delta \iota \chi \rho \iota \sigma \omicron \varsigma \), of components formerly mixed. ¹

But Aristotle also uses \( \delta \iota \chi \rho \iota \nu \omega \) when speaking in terms of theories which admit the reality of change, in describing the changes of uniform bodies. Here \( \delta \iota \chi \rho \iota \nu \nu \) cannot denote the mutual separation of different materials, but must mean that the parts of the uniform body are separated from each other — are divided and made smaller², and moved apart (so that the body becomes finer (i.e. less viscous), and less dense). Thus at Metaph.A 988b32ff, speaking of the monists' theories, Aristotle says that τα μὲν ... συγχρίσει, τα δὲ διαχρίσει ἐξ ἄλληλων γίγνεται, and that that material would seem "most elemental" ἐξ οὗ

1. v. Aristotle Metaph.A 984a9-16, 985a24-8; GC 333b12-15; Theophrastus fr.46; etc.
2. Aristotle could speak of an elemental body as \( \mu \iota \chi \rho \omicron \omicron \omicron \omicron \epsilon \varsigma \), cf. p. 71n.
Such would be the finest... from which things first come to be by συγκρίσις. Such would be the finest of bodies, and that with the smallest parts" (i.e. fire). Thus what is μάλιστα διαχρισθέντων is λεπτότατον; other bodies are formed by joining these fine parts. Similarly, at Ph.VIII 260b7ff, speaking of the view that πάντων τῶν παθημάτων ἄρχῃ πάντως καὶ μάνως, he says that πάντως... καὶ μάνως are συγκρίσις καὶ διάχρισις (260b11, cf.265b30-32).

Aristotle uses διαχρίσις similarly in Mete., speaking of his own theory. At 340a9ff he mentions τὴν ὄρεξιν τῶν ὄρχων that occurs ὅταν ἐξ ὑδάτος ἀπε γένηται διαχρισθέντος ἢ πῦρ ἐξ ἄραρος; i.e., these changes involve an increase in volume: διαχρισθέντος must mean that the bits of water are separated from each other and moved apart, causing this increase. διαχρίσις presumably means the same when used of evaporation: 340b3 ἢ... ἀτμίς ὑδάτος διάχρισις ἐστὶν; cf. 344b22ff, 354b30.

1. Cf. Plato Ti.49C, Theophrastus Sens.54 (διαχρίσιν contrasted with πυκνοῦν).

2. Alexander 10.6 and 72.10 paraphrases διαχρίσιν in 340a10, 354b30 by διαχρίσιν καὶ λεπτόντα; so, too, at 44.10-12 (on 346b22), which concerns the forming of exhalation, and in two places which concern other phenomena: 13.20f (on 340b13f), 36.31(on 345a8).
Outside Mete., cf. Plato Ti.49C, water τηχύμενον καὶ
dιακρινόμενον becomes πνεῦμα καὶ δέρα; [Hippocrates] Morb.
IV 52 (L.VII 590.7ff); Probl.II 22 (868a37f); SVF II 707.¹

If διακρίνω meant the separation of any element out
of another, it could equally well be used of the formation
of water from cloud or air; but such a usage is virtually
unknown²: the term for the latter change is συνιστάονται ³
or some other σω-compound.⁴ Therefore, δια- in these
contexts implies that bits of matter are moved apart, and
the material rarefied⁵, and σω- implies that they are
moved together.

1. For some probably parallel, or related, instances of
διακρίνω, v.Aristotle GA 735b15f; GC 317a27-9; Probl.XI
14 (900a36).

2. I have found only Arrian fr.3, p.247.3ff Wachsmuth,
tὸ νεφός ξυνέλθον ... εἰς θεόν διακρίνεται.

3. v.Mete.340a25, 29, 34, b30; 344b24; 346b29; 347a27, b13;
349a3, 18, b23, 31; etc., etc. Cf. [Hippocrates] Flat.
8 (L.VI 102.16); Aristotle Somn.Vig.457b31ff, 8a5;
Mete.IV 380a24; 382b28f; Theophrastus Sud.1; Probl.
XXVI 8 (941a2ff); etc.

4. E.g. συγκρίνειν (Mete.341a4; 347a17, 19; 350a13; etc.);
συστρέφεσθαι ([Hippocrates] Aer.3 (L.II 36.2)).

5. διαχείν is used in the same way as διακρίνειν (p. 77f ),
as also δυσλίθεην (e.g. Mete.344b23, 355a31, 367a24; Probl.
II 36 (870a22f), 40 (870b10); cf. also Cael.303b17-19).
(Exceptional is[Hippocrates] Morb.Sacr.13 (L.VI 384.13ff)
νότος ... ἄρχεται ... ἡρα συνεστήκοτα ... διαχείν
... καὶ ... δυσλίθεην, meaning it becomes wet: the author
reverses the normal view of moist and clear air's
relative density.)
D. ἀμίλειν, ἐκατμίλειν (v. passages 3 and 7, p. 65f)

ἀμίλειν (passage 3) normally means 'emit vapour' or 'be vaporous'; but this makes no sense when applied, as there, to the sun: ἀμίλειν there, like ἐκατμίλειν (passage 7; cf. Mete.347b27, 355a18) must mean 'turn to vapour': ¹ to Theophrastus (p. 327) and the Stoics ² this means nearly, if not exactly, 'turn to air'.

E. ὁμαχεῖν (v. passages 3 and 4, p. 65).

In Peripatetic meteorological contexts ὁμαχεῖν usually means 'pour apart', i.e. 'disperse', without any qualitative change; ³ but this is unlikely here, wind being a movement


2. Like Anaximenes, they believed that the elements change into each other by condensation and rarefaction, earth being progressively rarefied to water, air and fire, and so on (SVF II 413, 581, 436, 406; Cicero ND II 84); this suggests that evaporation is water changing to air, which is confirmed by statements that air is evaporated from water or the earth (perhaps meaning water on the earth): SVF I 102, 535; II 527, 563, 579, 1146; Cicero ND II 26-7.

3. Cf. Mete.370b5 (πνεύμα) ὁποράθην ὁμαχεῖσθαι; Vent.3, a wind is ὁμαχεῖσθαι over a wide area and so less strong: Vent.26, in open places ἄνευ ὁμαχεῖσθαι (while in hollows it is massed together).
of air, not moisture (p. 55ff). On the analogy of ὀικοκτίω and ὄλω, ὀικέω is clearly applicable to changes like that from water to air, and it is occasionally so used.¹ Probably, therefore, ὀικέω in these two passages implies a change occurs, as in my other passages, away from water and towards air.

In all my eight passages, save that on Anaximenes (on which v.p. 123ff) the cause of the change is heat (p. 67); and this accords with these authors' normal view of the change from water to air, or of λέπτυνσι etc. in general.² This view, however, like others, is not invariable; many ancient theories³ reflect the obvious fact

1. v.DK 13A7(3), A8, on Anaximenes; Probl.XXIV 10 (937a5); SVF II 413 (p.136.23); ? Heraclitus B31 <γη> ὄλωσα ὀικέσαται κτλ.

2. On Anaxagoras, v.p. 72f; on the Hippocratics, Flat.8 (L.VI 102.6ff) and Morb.IV 49 (L.VII 580.10-13); on Aristotle, v.pp. 213f and 258f (heat causing evaporation, cf. also GA 735b15f; on cold causing condensation, v.pp. 234-6, 258, also Mete.IV 382b28-30 al.); on Theophrastus, v.pp. 101f, 340, also CP I 13.7, II 19.3, V 14.5, Sud.1. In Probl., v.II 20 (868a20), 36 (870a22), XXIV 10 (937a3f), XXVI 8 (941a2ff), 19 (942a30-3), 27 (943a19f). For the Stoics v.SVF II 593, 702, Cicero ND II 26f; for Hero, Spir.p.10.9ff, 24ff; p.16.10-12; p.178.9f 3. (Heat and cold are thus regular causes of rarefaction and condensation; they need not be the only ones.)

3. E.g.Mete.IV 382b30ff, etc.; GA 735b14-16, 739b23ff; Resp. 480al; Theophrastus CP I 22.2. (This need not be inconsistent with heat rarefying and evaporating water, cf. Mete.IV 383a16f.)
that heat frequently thickens solids and liquids, instead of rarefying them, (e.g. eggs, mud); and they sometimes say similar things of water and air. But that heat causes λέπτυνοις of water and air was clearly a normal view, and, judging from the passages I have collected, much commoner than the other.

Thus in all eight passages quoted on p. 65-7, the process which produces wind is the change, or part of it, from water into air (or an analogous change from air into a finer material); and therefore they can all be said to contain variations of one wind-theory (cf. p. 65), despite the differences in their authors' more general physical

1. But not water itself, as Aristotle Sens.441a20ff, GA 735b4 says; cf. p. 364.

2. Several passages say παχύς air is, or may be, hotter than λεπτός air (v. Aristotle GA 788a19f, Theophrastus Vent. 21, Ign.48, CP V 14.7 (cf. V 14.1-2), Probl.XXV 6 (938a37ff)); Probl.XI 32 (903a4) says heat παχύνυ ηδέρα τὸν υόρα. (Most, at least, of these passages are reflecting the familiar fact that humid air often feels hotter than dry, clear air.) Probl.XI 33 (903a13ff) suggests that ὂργανον by day is παχύς because filled with φως (or πῦρ); Aristotle GA 735b8-10 says παχύνυσαί... τὸ εἴς θύμος καὶ πνεύματος... when hot (e.g. foam, semen). (For similarly exceptional passages v. Theophrastus Ign.11, CP VI 17.5, fr. 171.5) I cannot here discuss how, if at all, these ideas were reconciled with the view that heat causes λέπτυνοις etc.: Aristotle and Theophrastus (at least) were generally ready to modify theories, or adopt new ones, when, as here, observation required (pp. 316ff 375ff).
At least two of the authors quoted on p. 65-7 regarded wind as a special kind of matter: Anaximenes thought it the first stage in the condensation of ἀήρ (DK 13A5 and, conjecturally, A7(3)\(^1\)); and the author of Probl. XXVI 33 evidently held a similar view (cf. p. 66). He says that the sun ὑγρὸν ὑντα τὸν ἄερα ... ἐς πνεῦμα διαχρίνει; and that, as the sun goes on acting on the πνεῦμα, it becomes διαχερασμένον ... τέλεως, upon which (the context makes clear) wind ceases: clearly, wind is a special type of air, intermediate in density between moist air and (presumably) ordinary dry air. The πνευματόδης ἀήρ which the sun "turns still more to wind" I take to be air more or less in this special state already.\(^2\) (In my

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1. Cf. DK's Addenda. (This view seems inconsistent with A7(7) (passage 1 on p. 65 supra); the parallels, just discussed, with other wind-theories lead me to agree with Boekeer 2226f that A7(7) must be right. For an explanation of the inconsistency v. p. 123.)

2. Cf. Probl. XXVI 8 (941a2ff) χειμών γίνεται συνισταμένου καὶ πυκνομένου τοῦ ἁέρος. ὅταν μὲν οὖν χρατή θηλίος, διαχρίσει καὶ αλθείαζει αὐτόν ... (and there is no storm). This will be parallel to XXVI 33 if we suppose that a storm is produced by rarefying dense air (and ends when the air is rarefied completely), and that the sun, rarefying the air, may prevent the condensation forming which might cause a storm. (Cf. also Probl. XXVI 57 (947a7ff. Cf. the interpolated Vent. 60), though the parallel with XXVI 33 is less close.)
other six passages there is nothing to show whether wind is a special sort of material.

How important is 'rarefaction' in these passages? Many ancient writers spoke of wind as derived from exhalation or water or cloud, giving no further explanation of the processes involved (p. 59ff): conceivably, therefore, 'rarefaction' is merely meant to explain how wind's material is formed, and accounts for nothing else about wind's origin.

I believe, however, that rarefaction has more significance than this. When water boils, we see visible 'vapour' moving away from it - in suitable conditions, more or less horizontally; if the vapour must pass through a narrow opening, the motion is violent. Now Vitruvius uses this analogy to explain wind: I 6.2, wind is produced "cum fervor offendit umorem"; this is illustrated by means of aeolipiles (vessels with a narrow opening in which water is boiled, causing a strong blast through the opening). The use of a special instrument may be Vitruvius' own

1. Aeolipiles can be used for blowing fires; but there is no evidence that they were so used in antiquity. (The principle is occasionally used in pneumatic devices.) (v. Hildburgh (1951) 27-31.)
contribution; but the analogy itself is surely far older; for it employs very familiar facts, and makes much more plausible the common derivation of wind from water: the conversion of water to air or vapour not only provides wind's material but also causes its motion; also, we only see vapour moving as and just after it forms, before it merges into the atmosphere, which explains why wind was thought a special material, not yet become ordinary air.

Indeed, we can go further. Seneca NQ V 4.3: "... multa ex omni parte terrarum et assidua ferri corpuscula. quae cum coacervata sunt, deinde extenuari sole coeperunt, quia omne quod in angusto dilatatur spatium maius desiderat, ventus existit." As in my original eight passages, the sun causes the process; and the 'corpuscula' which are borne up and 'coacervata' should resemble cloud, which is (sometimes described as) made of exhalation, and is dense (v.p. 100f ); cf. V 5.1 "quae dense steterant ... extenuata nituntur in ampliorem locum". The Stoics regarded air as formed from water by rarefaction (p. 77n ), so a similar

1. The beginning of V 5.1 seems to refer back to V 4.3, so heat must still be cause of the rarefaction (pace Boeker 2232). On rarefaction and wind v. also NQ V 6, 9.4 (and 12.2, where alone what is rarefied is not called dense; but that concerns only a special wind, the ἔκνεφίας ).
process is presumably meant here. What appears new is the clear indication that rarefaction involves expansion, and that the motion of expansion is the wind. (This is particularly neat, because it explains most simply the movement, which is wind's essential feature, and which the earlier rarefaction theory leaves somewhat obscure.)

Was this Seneca's original idea? The πυκνωσίς and ἀπαλωσίς of matter, as defined on p. 59, implies contraction and expansion. It is uncertain whether Anaximenes and Anaxagoras recognised this; but Aristotle, his successors and Hero certainly did. Moreover, the Peripatetics were familiar with the idea that expansion and contraction might cause seemingly unrelated movements: at Aristotle Resp.479b32ff the throbbing of φύστα and the heart's beating are caused by moisture expanding with heat

1. v. Ph.IV 217a27ff, Cael.305b12ff, GC 321a9ff, Mete.340a9ff, Resp.479b32ff, GA 755a17-19 on changes between air and water; Ph.IV 213b15-18, 214a32ff, 216b22ff, Cael.296a17ff, 299b8, 303b23ff, 304a29f on μάγωσις and πυκνωσίς in general. (V. also GA 753b25, MA 701b13ff.)

2. Probl.XXIV 10 (937a3ff), expansion as moisture becomes πυκνός cf. II 22 (868a37f); on cold causing contraction of water, v. Theophrastus fr.159 (and 161). Cf. also CP I 8.3. (Before Aristotle, v. [Hippocrates] Vict.II 57 (L.VI 570.12-14) (heat expanding moisture).)

3. Spir. p.178.9f and 15 S.
(and, at least with φύματα, its conversion into πνεύμα); at ἹΑ 701b13ff contraction and expansion due to cold and heat are the ultimate causes of animals' movement; cf. also 703a19ff.

The Peripatetics, therefore, could easily have concluded that wind is due to the expansion of water or cloud turning to air. Although no text says this, it seems likely that the idea was, at least, at the back of the minds of Theophrastus at Vent.41, and the authors of Probl.XXVI 33, 35, 54.

By Charles' Law, the volume of a mass of gas at constant pressure is directly proportional to its temperature (p.184). Removing any reference to pressure (of which the ancients had no clear concept), and translating into qualitative terms (since they seldom made exact measurements), this becomes a statement that the volume of a gas varies with heat and cold. The cause of wind is that air flows from a region of higher to one of lower pressure; the pressure differences are produced by the sun's unequal heating of the earth (p.184).

Again translating pressure into volume, this amounts to saying that winds are due to the sun's heat making parts of the air expand; which is roughly what is said by Seneca
and, less clearly, (I suggest) other authors. This, therefore, is as near to the true cause of wind as the ancients could get, granted their ignorance of pressure, starting from what they knew of the rarefying effect of heat.¹

This theory, however, as given by the ancients, involves several difficulties. Heated air expands in the direction in which there is least pressure, i.e. (in the atmosphere) upwards; consequently, pressure high over a hot region tends to be high, but (as heated air rises) that at the surface is low; so that wind at the surface is often towards a hot region (Sutton 35f). Thus the ancient rarefaction-theory should really produce an upward motion; and it does not explain why winds often blow from cold to hot regions, e.g. from the north². (This problem arises in all theories where heat causes wind 'a tergo'). A frequent escape was to suppose (as in one form of the rarefaction-theory, p. 80 ) that excessive heat prevents

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¹. The merits of the rarefaction theory have long been realised, cf. comments on Anaxagoras' theory (p. 65 ) in Riva (1733) xii; Ideler (1832) 55n; but I know no full discussion other than mine.

². Cf. e.g., Mete.361a5ff, Probl.XXVI 35 (944a36ff), Vent.2: north and south winds are commonest.
wind (cf. pp. 287ff, 329ff)\textsuperscript{1}; but this is impossible in the better form of the rarefaction-theory, where expansion causes wind.

I shall here discuss generally what the ancients knew of this phenomenon.

Later authors describe it clearly. Thus Hero explains that air consists of particles with void spaces between them (\textit{De aer.} 8. 17ff.), when air is compressed (\textit{σωκόλοι ... τὸ δὲ τινὸς ἀεροσφάλειας ...} particles are forced into these spaces (\textit{De aer.} 9. 5). The air is now under tension, and if the compressing force is released, its tension makes it return to its normal state, as happens with scrapings of horn and dry sponge (\textit{De aer.} 5. 5 ἀνανεώσεως ἔλαιον τῆς ἀεροσφάλειας τῇ τῶν ιδιῶν τοιούτων αὐτῶν ἀνακατακαθήμενα). This Hero illustrates by the experiment of blowing through a tube into an air-tight metal sphere; the air is obviously compressed inside the sphere, as is shown by the way the sphere is raised.

\textsuperscript{1} I know no general discussion of the ancients' knowledge.

1. Anaxagoras probably had a different solution, p. 171ff.
There are certain reports of the pre-Socratics which it is tempting to interpret as meaning that air is compressed and consequently expands, so causing wind (v. pp. 124, 126, 173). To test the plausibility of this, I shall here discuss generally what the ancients knew of this phenomenon.

Late authors describe it clearly. Thus Hero explains that air consists of particles with void spaces between them (Spir. p. 6.11ff. S.); when air is compressed (πιείονται ... ἐκ βίας τινὸς προσελθοῦσας) particles are forced into these spaces (Ib. p. 8.3-5). The air is now under tension, and if the compressing force is relaxed, its tension makes it return to its normal state, as happens with scrapings of horn and dry sponges (Ib. p. 8.6-9 ἀνέσεως ὡς γενομένης πάλιν εἰς τὴν αὐτὴν τάξιν ἀποκαθισταται τῇ τῶν ομάτων εὐτονίᾳ κτλ). This Hero illustrates by the experiment of blowing through a tube into an air-tight metal sphere; the air is obviously compressed inside the sphere,

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4) The ancients' knowledge of compressed air.¹

I know no general discussion of the ancients' knowledge of air-pressure save the brief one in Ideler (1832) 22-5. (On the modern theory v. p. 182ff.)
and when the tube is afterwards opened air can be heard rushing out through it (Ib. p. 16.26-20.20).

The expansion of compressed air was also known to Ctesibius, who employed it to work a catapult, described by Philo Belopolica p. 77.9-78.38 in terms that recall Hero. Ctesibius realised that air is ἵσχυρὸν ... καὶ ἐστονον καὶ ἑκάνητον, and that when confined in a strong container it can πλησιν ἐπιδέχεσθαι καὶ πάλιν διάστασιν ταχείαν εἰς τὸ ἵσον πληροῦμενον μέγεθος τοῦ ἄγγελου, "undergo compression, and again a swift expansion to the equal filled size of the container" (?'to a bulk equal to the full size of the container') (Ib. 77.17-24, cf. Hero Spir. p. 8.6-9); this he illustrated by trying to hammer a closely-fitting piston down a cylinder: the piston would yield a little, but once the air in the cylinder was compressed would not yield to the strongest blow; if not kept in by force, it would leap violently out of the cylinder (Philo op. cit. 78.1-8). The compressed air has a desire for τὴν κατὰ φύσιν ὑπάρχουσαν αὐτῷ κατάστασιν (Ib. 78.27-30, cf. Hero op. cit. 246.2).

The source of Hero's proem and Ctesibius' invention of
the catapult date from c.270 B.C. at the earliest. Had any earlier thinker developed the same ideas?

Air's compression, and subsequent expansion, are most evident when air is compressed in a vessel of fixed dimensions, kept there for a time, and then released. If the vessel can expand (like an empty wine-skin), or if the compressed air is at once released through another opening (as in playing a wind-instrument), then a student might suppose the volume of a given mass of air to be constant, and that every accession of air in the vessel is exactly balanced by expansion of the skin, or departure of air through the other opening. The ancients knew vessels of these latter kinds long before Ctesibius, but may have been unconscious of the fact of compression. In Ctesibius' cylinder and certain instruments in Hero (I 10; II 2; 15) the compression is obvious; but such instruments are not

1. i.e. assuming, what I find doubtful, that Hero's proem accurately represents Strato (cf. Diels (1893) 101-27, Gottschalk (1965) 127ff; also Wehrli (1950) 19ff, 56ff. For contrary or sceptical views v. Schmekel (1938) 110-119; Drachmann (1948) 90ff. On Ctesibius' date v. Tittel. (1914) 64-7; Drachmann (1948) 1-3 and (1951-3) 1-10.
recorded before Ctesibius.\(^1\)

Most earlier evidence concerns expansible bodies, like wine-skins. I know only one passage on ἀσκολ as modern-sounding as the pneumatists' accounts of compressed air: \(\text{Probl. XXV I (937b31ff)}\): why do the limbs suffer pain if enclosed in inflated skins? πότερον οἰδά τὴν πίεσιν τοῦ ἄερος; for as the air does not yield to outside pressure on the skin, so it presses on things enclosed within. ἢ διότι βία κατέχεται καὶ πεπίληται; ἐξω οὖν πάντη ὅμων κατὰ φύσιν προσαπερείδεται πρὸς τὸ ἐντὸς ἀπειλημμένον οῶμα. This second explanation clearly mentions the air's compression, and consequent tendency to

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1. Pliny \textit{NH VII} 125, Vitruvius \textit{IX} 8.2 say Ctesibius discovered pneumatics; ib.2-3 suggests he discovered the principle of cylinder and piston. In Hero's instruments air is compressed in a vessel half full of water by blowing or pumping; another aperture is opened, and the air drives the water out up through it. There are no such instruments in Philo's earlier \textit{Pneumatics} (Drachmann (1948) describes many of his instruments; I have looked through the French or Latin versions (v.bibliography, p. 464 ) of the rest) - presumably they were unknown in his day (on which v. Drachmann (1948) 41). The experiment of Hero \textit{Spir. p.16.26ff} (v.p.87f) might have been performed at any period, but, having no practical use, would hardly be performed by men not already interested in compression; I have seen it nowhere save inHero.
expand (essential features of a modern account of compressed air). In the first, however, though the air exerts and resists pressure, these features are absent; nor are they clearly mentioned by earlier authors.

The ancients knew from an early period that inflated skins do not yield to pressure and that the air within rushes out if it can, as Homer x 19-47 shows: the bag in which the winds were confined did not yield to pressure (whence the sailors thought it held gold and silver, 45 - so Mugler), and when it was opened all the winds rushed out.

In early times it was not realised that these phenomena are due to the compression of the air in the skin. The skin's non-compressibility was explained simply by saying that the body within did not yield to pressure; cf. the first explanation of Probl. XXV 1, and, probably, the proof that there is no void by Anaxagoras and others, στρεβλούντες τοῦς ἄσχοδες καὶ δεικνύντες ὅς ἱσχυρὸς ὁ ἄρη (DK 59A68). This would be gravely weakened as a disproof of void, were it realised that the air must be compressed. (Anaxagoras probably denied the possibility of such

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Similarly, the rush of air from the skin was explained without reference to compression, simply by saying that there is wind in the skin, which rushes out if it can, as at Homer η 47 ἄσχων μὲν λύσαν, ἀνέμοι ὡς πάντες ὀροοῦσαν. Mete.349a33ff uses a similar expression: does wind (ἀνέμος) flow as from a container, until the container is exhausted, ὅλον ἐξ ἄσχων ἀφιέμενον, "like when it is emitted from wine-skins"?

With these passages compare accounts of thunder etc. which regard them as due to the emission of wind trapped in clouds, and evidently depend on an analogy with ἄσχωι or similar phenomena. Earliest written is Aristophanes Nu.404-7:

1. So Alexander 54.27-30; Ideler (1834-6) I 448; Bonitz (1870) s.v. ἄσχως; Webster (1931). Lee "wine...from wine-skins", surely wrongly. (Inflated skins were well known; their unsinkability was proverbial at least by Zeno of Citium's day (DK 29A18). Other refs.: v.p.90ff, also Aristophanes Pl.1129 and Scholia; Xenophon An.111 5.9-12; [Hippocrates] art. 47 (L.IV 210.9), 77 (L.IV 308.), Hochl.25 (L.IV 368.14); Metrodorus of Chios ap. Flutarch Fac.11n.928B; for 3 in Aristotle v. Cherniss (1957) 80n; v. also Frobl. XXV 13 (939a33ff.)
When a dry wind is raised high and shut up in them (the clouds), it blows them up like a bladder from within, and then by necessity it breaks them and is borne out violently because of its density, burning itself by its violent rush. (This is then compared to the bursting of a γαστήρ cooked without a slit in it). Nothing is clearly said of air's expansion distending and breaking the cloud; rather, there is wind in the cloud, which rushes from it (presumably) simply because wind's nature is to rush.

Compare Lucretius VI 124ff, thunder occurs

"cum subito validi venti collecta procella nubibus intorsit sese conclusaque ibidem turbine versanti magis ac magis undique nubem cogit uti fiat spisso cava corpore circum, post ubi comminuit vis eius et impetus acer, tum perterricrepol sonitu dat scissa fragorem, nec mirum, cum plena animae vesicula parva saepe ita dat parvum sonitum displosa repente". ¹

¹. I quote this, despite its date, as an exceptionally detailed example of this sort of theory. (Similar theories occur still later, e.g. Seneca NQ II 27, 54; [Aristotle] Mu.395a11ff.)
Again, we hear throughout of wind, not air; and expansion is unmentioned. Wind revolves within the cloud, first confining it to a dense 'skin' round the whirlwind, then bursting it (it is not clear by what means); this is compared to the bursting of an inflated bladder.

The bladder-analogy is mentioned by Aristophanes and Lucretius, as also by Theophrastus (Syr.352abff) and Seneca (NQ II 27.3, 28.2), and presumably underlies other thunder-theories, which do not mention it, but are otherwise similar. ¹ Cf. DK 12A23, according to Anaximander thunder occurs εκ τοῦ πνεύματος ... ὀταν γὰρ περιληφθὲν νέφοι παχεί βλασφεμον ἐκπεσὴ τῇ λεπτομερείᾳ καὶ κονφότητι, τοθ' ἴ σήξει causes the thunder, and so on. ² Here too wind bursts violently from a cloud, but expansion is not

1. Cf. Gigon (1945/68) 97. Boeker 2225f (cf.2292) thinks the analogy is with noises in human digestive organs, less plausibly: his only direct evidence is from Olympiodorus. (The earlier ancient use of words like κούλα, κολάωμα does not prove his view, since they have no necessary digestive connotation. Aristophanes Nu.392 mentions such an analogy, but only in connection with clouds colliding (cf.384, 388). Also, ῥήγνυμι and congeners, used in the thunder-theories, are not commonly used in connexion with digestive organs - I admit καταρρήγνυμι is sometimes so used, cf. LSJ s.v., II.4.)

mentioned; the πνεῦμα bursts the cloud by its fineness and lightness.  

Probably, the bladder-analogy originally suggested this explanation of thunder: it offers a means for the sudden production of noise, and sometimes of violently projected matter (cf. Aristophanes Nu.410f), from a body previously at rest; I cannot see what else can have suggested this theory. If so, the early accounts of thunder etc. here quoted reveal the explanation of the bursting of bladders and the like current in the 6th and 5th centuries.

Also relevant are certain earthquake-theories. Archelaus 60A16a: winds are borne into hollows in the earth, and when the spaces there are full "et in quantum aer potuit densatus est, is qui supervenit spiritus priorem premit", and this, seeking a way out, shakes the earth. Here wind seems to be forcibly compressed; but the compressed air then moves the earth because it is moved from behind, not by its own expansion.

Compare Mete. II 8. Earthquakes are due to wind within

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1. Which, presumably, makes it mobile and so able to shift other things, cf. Mete.365b29ff.
the earth (366a4 al.); the more wind, the greater the earthquake (e.g. 367a30f). 366b10ff: dry exhalation (i.e. wind) is forcibly compressed within the earth (ἐναπολαμβάνεσθαι ἐν στενοτέροις τόποις καὶ ἀποβιώζεσθαι εἰς ἑλάττω τόπον), by water filling the earth's hollows; then (ib.12ff) ὅταν ἀρέσται χρατεῖν διὰ τὸ πολὺ εἰς διὼγον πιληθῆναι τόπον, ἵσχυρῶς κινεῖ βέων ὁ ἄνεμος καὶ τροπίκτων (sc. and there is an earthquake). Here the wind apparently does exert a force because it is compressed; but Aristotle says nothing of the wind expanding.¹ 367a3 nearly does so: part of the earth swelled up (ἀνύρθω) during an earthquake, until the wind burst out of the earth - but this is not the same as saying the wind expands.

[Hippocrates] Flat. also contains expressions worth comparing with those already quoted. Note especially §10 (L.VI 104.19f) ὅταν αἱ περὶ τὴν κεφαλὴν φλέβες γεμίσθωσιν ἄμρος ... ἡ κεφαλὴ βαρύνεται τῶν φυσέων ἐγκειμένων (v.further p. 201f .)

Thus phenomena which were later regarded as due to

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¹. This passage does employ a biological analogy; with ἄνεμος and τρόμος (b 15ff); v. p. 273.
compressed air expanding, were originally explained simply by saying that wind is confined in (say) a wine-skin, from which it rushes if it can. The confinement is the essential feature: nothing is clearly said of compression or expansion, though some expressions may hint at it. Thus Aristophanes Nu.406 διὰ τὴν πυκνότητα, DK 60A16a 'densatus', Mete.366b14 πυκνότητα, Lucretius VI 124 'collecta' all at least suggest that the air or wind occupies an unusually small space; Aristophanes Nu.405 φυσικά, Mete.367a3 ἀνάφως, Lucretius VI 126f 'magis et magis' etc., all suggest that the air or wind causes the body enclosing it to expand, though without saying that the air or wind expands itself; while most of my quotations 1 indicate that wind or air presses against the enclosing body. On the other hand, all (except Probl.XXV 1 2) differ from the later explanation in speaking of wind (e.g. ἄνεμος, πνεῦμα, φύσις), not air, exerting this pressure. In every passage except Mete.349a33ff and possibly 366b10ff, 'wind' is mentioned (and sometimes is said to move) before it has

1. The exceptions are Homer, Anaximander, and Anaxagoras and Mete.349a33ff.

2. And Anaxagoras, where there is nothing about air escaping or pressing on the skin.
set in motion or escaped from the enclosing body; evidently, in the early writers' view, wind must be already moving about within the enclosing body, in order to exert pressure on it.\(^1\) If so, then passages which speak of it as (e.g.) made dense need imply no realisation that air exerts a force because it is compressed; for wind exerts a force in any case, and obviously anything concentrated thereby possesses its properties in a stronger degree.

Before the third century B.C., then, the ancients had not fully grasped that still air, if compressed, must press upon and try to expand into its surroundings. We have seen what explanations they did give for phenomena later regarded as due to this cause, and with these we can compare the other passages, which may possibly refer to compressed air expanding (cf. p. 87).

I have here only discussed passages which suggest that air is forcibly compressed, as by being blown into a wine-skin,\(^2\) disregarding other ideas which the ancients

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1. Flat.14 (L.VI 112.16ff) may be an exception, but is very unclear.

2. In Aristophanes Nu.404ff the \(\gamma\alpha\omicron\omicron\nu\omicron\omicron\-\)analogy suggests that heat ultimately causes the process; but I include it, as the lines quoted say nothing of heat.
never connected with this, though they are relevant to the modern concept of air-pressure: heat making air expand, matter flowing into a void, the air's weight, the concept of air as composed of perpetually moving atoms. I have also usually ignored the general theories of matter (if any) held by the authors I discuss. As we have seen, the same idea, of wind pressing on or escaping its enclosure, recurs in thinkers whose theories of matter differed widely. No doubt their concepts of wind consequently differed also, in some degree;¹ but yet they all meant by ἀνεμος or πνεῦμα the same familiar empirical phenomena, and insofar as different thinkers spoke and thought in terms of such familiar phenomena, it is legitimate to compare theories, as I have done here, and point out their common features, without considering the more general theories which each thinker adopted (cf. p. 389 ).

5) **Clouds**

On pp.59-86 above I describe theories which relate wind to water and similar bodies, including cloud; I shall here complete this by briefly describing the ancients' concept of cloud: here, again, numerous ancient thinkers adopted similar ideas, in spite of differences in their more general physical theories.

Typically, cloud is intermediate between air and water, i.e. ἄηρ that has undergone some πάξνωσις (but not enough to become water) (cf. pp. 67 , 69f ). Alternatively, it is produced from vapour—usually by πάξνωσις or something similar, at least in later thinkers. (Some

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2. Anaximenes 13A5 ἄηρ ... πάξνωσιν ... ἄνεμον, εἵτα νέφος, ἂτι δὲ μᾶλλον ὑώρ ... , cf. A7(3), (7), A17, Anaxagoras 59A85; Metrodorus 70A4; Plato Ti.49C (cf.66E); Aristotle Mete.372b16ff and 23, also 30ff (cf.346b32f, 373b19ff, Top.146b29). Cf. also Epicurus Ep.II 99, Cicero ND II 101, Seneca NQ II 30.4; Plutarch Prim.Fr. 948E, 951B, Fac.Lun.938A-B.
4. Mete.369a12ff, 372b (ut supra); [Aristotle] Mu.394a19, 26f; Anonymus II (p.126.20f Maass); cf. Seneca NQ II 30.3-4, V 12.1. Before Aristotle, v. [Hippocrates] Aer. 8 (L.II 34.19f), water raised into the air ὀχόταν ... ἄηρος ὑκαὶ συντραγῇ εἰς τὸ αὐτὸ turns to rain, presumably via cloud; Democritus 68A99 (Aetius IV 1, 4) νάφη ... ἐκ τῶν ἄτμων πιλοῦθαι - but the two parallels to this (p. 178n ) have nothing like πιλοῦθαι.
reports of the pre-Aristotelians say nothing of πύκνωσις etc.\(^1\); nor would they naturally have mentioned it here, when their usual expression for 'vapour' was (e.g.) 'water drawn up' (p. 45ff\(^2\)). It matters little whether air or vapour be said to cause cloud, since the two were so often identified.\(^3\) Many writers make clear that a cloud is not quite water, though it is almost so.\(^4\)

The cause of air's or vapour's conversion to cloud and rain is usually cold\(^5\), or compression (e.g. by wind\(^6\);

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1. v. Xenophanes B30 (but A1(19), A46 may imply πύκνωσις); on Democritus v.p. 100n4; Metrodorus 70A16 (but cf. p. 100n2); [Hippocrates] Aer. 15 (L.II 60.20), quoted p. 46 (but v.p. 100n4).

2. This presumably explains the exceptional [Hippocrates] Nat. puer. 25 (L.VII 522.15), cloud is ζωωρ συνεχες ἐν ἡγμ.

3. Cf. pp. 193n, 195f, 236ff, 327. In Anaximenes and Anaxagoras air's formation from water must be equivalent to evaporation (pp. 12ff, 154f).

4. Cf. p. 100nn. Also Mete. 360b36f, 373b20, implying water only forms in clouds as rain starts to fall; Vent.5, Stoics ap.Diogenes Laertius VII 153; Seneca NQ II 26.1-2, cf.I 6.6; Arrian fr.3 (Stobaeus I p. 247.3ff W); Plutarch Prim. Fr. 950D-E.

5. Cf. passages cited at p. 78n. (For the pre-Aristotelians, heat regularly causes evaporation (p. 453-5), so cold presumably causes condensation.

6. [Hippocrates] Aer. 8 (L.II 34.19ff); Antipho B29 (on hail); Theophrastus Vent.5 and ap. Olympiod. 80.31ff; Epicurus Ep.II 99; Lucretius VI 459ff.
Theophrastus used both causes (Olympiodorus 80.31ff).

Such is the view of cloud relevant to the wind theories mentioned on p. 100. Many thinkers, however, simultaneously held other theories, whose implied views of cloud are to us plainly incompatible with it: clouds act like bladders, having wind trapped within them which bursts forth to cause thunder etc. (p. 92ff); the rubbing together of clouds, or cloud and air or wind, is compared to that of fire-sticks or flints, and produces lightning by friction or percussion; clouds as they condense, and so contract, squeeze out dry exhalation trapped within them, as fruit-stones are shot out from between fingers squeezed together (Mete.369a12ff). These theories all attribute to cloud properties actually possessed only by solid bodies. I cannot here discuss how, if at all, the ancients thought these theories reconcilable with the view of cloud described above. The reason for them is, plainly, the extreme difficulty the ancients must have had in finding likely explanations for phenomena like lighting in terms of any facts known to them.

1. E.g. Lucretius VI 160ff; Seneca NQ II 22-3. Cf. Democritus 68A93.
In the following chapters I discuss the ancient meteorologists individually, describing each thinker's wind theory and relating it to his general system: in particular, to his theory of matter, of the nature of and changes undergone by the materials involved in meteorology; and to his view of the structure of the universe (especially, his view of the space between sky and earth, in which the winds blow).

Only one undisputed pre-Socratic fragment directly concerns wind (Xenophanes B30); Aristotle, as interpreted by Alexander (citing Theophrastus), provides some information on Anaximander and Diogenes, but about no-one else. For the rest we depend on brief notices in the doxographers, especially Aetius and Hippolytus.

1. DK 12A27, 64A9; cf. Alexander 73.16-22.
2. Mete.349a16ff, 360a17ff also refer to earlier wind theories, but are too vague to be helpful. (Aristotle's silence does, however, mean that the doxographic tradition cannot have been distorted by his misinterpretation.)
The doxographers, of course, are often unreliable; but in these circumstances the only possible approach is to presume they are usually right, and to see how plausible a picture they present. Our knowledge of other parts of the pre-Socratics' systems, and the comparative evidence collected in Chapters 1 and 2, provide a standard by which to assess and interpret their accounts of individual wind theories.

1) Anaximander

A. His theory of matter.

According to Anaximander, the world is formed from τὸ ἀπειρόν when opposite materials, the hot and the cold, are somehow formed from it (12A10, cf. A9)²; but how they are formed is disputed (v.p. 115f); and only 1281 says anything of how materials inter-act and change into each other in the world we know: ἐὰν δὲ ἡ γένεσις ἐστὶ τοῖς

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1. On the pre-Socratics' general systems I have mainly used HGP, KR and sometimes EGP; on Anaximander also Kahn, and sometimes Seligman 'The apeiron of Anaximander' (1962) and Vlastos 'Equality and justice in the early Greek cosmologies' (1947).

2. Anaximander probably used more concrete expressions, e.g. τὸ πρ or φλὸς and ἡμρ (cf., e.g., Lloyd (1964a) 95-9 and PA 44n; KR 133).
It is agreed that mutual injustice and recompense must refer to inter-action between equals:¹ for example, winter's cold and night's darkness are unjust encroachments on heat and light, which are avenged by summer and by day; and vice versa. Presumably Anaximander thought that such inter-action involves the transformation of (say) cold material into hot (e.g. water into fire); but ὀιόδοναι - τἀξιν does not directly speak of such transformation, and, though the preceding sentence mentions γένεσις and φθορά, it is disputed whether it genuinely refers to interchanges between materials in the natural world.² That Anaximander believed (as a general proposition) that natural materials change into each other is thus only a presumption, though there is no reason to doubt he did.

The ambiguity and brevity of our sources suggests that Anaximander said very little of how different

1. And not, as 12A9 (quoting 12B1) implies, to changes between ordinary materials and the Boundless; cf. EGP 53f; Vlastos (1947) 170-3; KR 11Bf; Kahn 183f; Seligman (1962) 72-6; HGP I 80.

2. Kahn 183, HGP I 81 say it is; EGP 53f, Vlastos (1947) 170-3, Seligman (1962) 72-6 and KR 117f, 121 deny it.
materials are formed from the Boundless and from each other: for the doxographers describe other thinkers' theories on such subjects, while here they are practically silent. That different materials are derived from each other (e.g. vapour from water, flame from wood) is obvious: an early thinker might take such changes for granted, never thinking much about how they happen. This, I suspect, Anaximander did; the description of a means by which such changes occur (i.e. condensation and rarefaction) was left to Anaximenes.

B. The structure of the universe.

The earth, shaped like a column-drum, is at rest at the centre of the cosmos (cf. Kahn 53-56); the heavenly bodies are rings of fire surrounded by δύο with holes through which the fire is visible (12A11(4), A18); these rings are many times the size of the earth (cf. Kahn 58-63). But what fills the space between the rings and the earth?

2. E.g. 13A5, A7(3); 22A1(9), A5.
3. As seems assumed by Kahn 237; cf. Farrington (1953) 39. (On Anaximander v. further p. 115ff.)
Later thinkers regarded the space above the earth as full of ἄηρ; and our sources on Anaximander speak of ἄηρ in four sorts of context; but in all of them, either the evidence is probably unauthentic, or ἄηρ almost certainly means 'mist'.

I. The ἄηρ surrounding the rings of fire evidently prevents our seeing the complete rings, and so is 'mist', though presumably of the 'Homeric' type which both is itself transparent and makes transparent what it surrounds (p.2; EGP 68). 12A10: in cosmogony, a sphere of flame περιφεύνατ τῇ περὶ τὴν γῆν ἁέρι; the sphere breaks, and the heavenly bodies are formed: presumably this ἄηρ then surrounds the rings of fire, i.e. it is mist; it seems the same as the cold mentioned shortly before in 12A10 (Kahn 87).

II. ἄηρ and wind. 12A11(7): wind occurs τῶν λεπτοτάτων ἀτμῶν τός ἁέρος ᾑποκρινομένων καὶ ὅταν ἁέρος ἐδοθεῖσθαι κινομένων (cf, 12A24, 64A9). Prima facie, 'air' or 'mist' might be meant; but comparison with other ancient wind-theories shows that 'mist' is almost certainly right.1

1. v.pp. 59-64, especially 61f; similar conclusions in Gilbert 512f, Kahn 101.
III, IV. Probably unauthentic is the earthquake-theory of 12A28 (v. Boeker 2225 and works there cited; Kahn 103f)¹, and in 12A23, "Quare et sereno tonat?" etc.²

Thus to Anaximander υηρ was normally 'mist', as in the earliest poets (pp.2, 6ff)³. He must have been vaguely aware of air as a body filling the whole space over the earth (since earlier poets mention it, p.8); but he evidently made no use of it in his physical system. The υηρ which he was interested in was a local phenomenon, found only around the rings of fire in the sky, in places where wind was blowing, and (presumably) in places where

¹. Even if genuine, the 'aer violentus' mentioned is clearly 'wind', not 'air' in general.

². Cf. Kahn 65. (Face Bicknell (1968) 181-4, I prefer Aetius' account of Anaximander's lightning theory to Seneca's (both in 12A23): both the manner of Seneca's account (the imaginary dialogue) and its matter (the explanation of rare subsidiary phenomena) are characteristic of him (cf. NQ II 28-30, 55) and quite unlike normal doxographies. Seneca is unreliable on the early pre-Socratics, cf. DK 13A21 (Anaximenes' earthquake theory), where Mete. 365b6ff shows that Aetius III 15.3 is right and Seneca NQ VI 10 wrong (pace Kranz (1938) 109f.).) (Even if all 12A23 is Anaximander's, it need not refer to air: the 'crassus aer' that causes thunder on a clear day may be local and temporary only.)

³. However, the 'finest vapours' of υηρ which form wind obviously neither are visible themselves nor conceal anything. This is a development of the word's meaning, since in earlier poetry υηρ is connected with wind only at Hesiod Op. 548ff (v.p. 45f, 50).
there was visible cloud or mist.¹

C. Heat and cold, and evaporation.

The primacy of heat and cold in cosmogony (p. 104) suggests that they were the most important opposites in Anaximander's system. To him they will not have been, as they are to us, merely physical causes of phenomena, but living powers, whose behaviour may be spoken of in terms we confine to men (cf.12A1)²; but they nevertheless produce effects which heat and cold really produce: and so, the sun's heat draws up moisture, or ἀηρ³, from the water on the earth⁴, which causes astronomical and meteorological phenomena, and even the formation of animals (12A11(6), A30).

Pre-philosophical writers mention mist and moisture rising from water (p. 165); but apparently no-one before

1. Kahn 147f is surely wrong to say that Anaximander's meteorology requires that the whole space above the earth be filled with atmospheric air.
3. Anaximander probably used expressions like this for 'evaporation', v.p. 45ff; cf.64A9 ἀερα γενεσθαι.
4. v.pp. 449, 452 (which show there is no good evidence for evaporation other than from water in Anaximander).
Anaximander said that the sun makes them rise.¹ That it does so is a simple deduction from the drying up of lakes, rivers etc. in summer, and the emission of visible 'vapour' from artificially heated water. (Natural visible 'vapour' (from lakes, rivers etc.) normally occurs in cold conditions²; but Anaximander rightly discounted this observation.)

The moisture drawn up from the earth evidently causes cloud, which may then turn to rain (12A11(7) says rain is due to ἄτμις, and rain obviously falls from cloud), or to wind: 12A27 and 64A9 say wind is due to water-vapour, and wind is immediately derived from cloud or something like it (p. 107). Vapour also 'increases the heavens' and causes the τροπαί of sun and moon (12A27, 64A9; cf. p. 113).

That water-vapour condenses to rain is an easy deduction: visible 'vapour' resembles cloud, whence rain

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¹ For possible instances in Homer v. Mugler (1963) 61-4, 118f. Several passages speak of fire or the sun boiling or drying liquid (Φ 361ff, Χ 358ff, Ζ 98, cf. Hesiod Th.693ff), but only Χ 149f speaks of vapour rising from a hot liquid, and this concerns an exceptional type of evaporation.

² Since it consists of minute water-drops, formed by the condensation of true, invisible vapour (cf. Barton (1933) 121).
falls, and we often see artificially produced vapour condensing on cold surfaces.¹ This cycle was known, before Anaximander, to Hesiod (pp. 45f, 50; Kahn 145f, 151). To Anaximander it was presumably a cycle of the type implied by 12B1: the drawing up of vapour is an unjust encroachment by heat, its falling as rain is cold water's revenge.

Kahn (151-3, 183f) and Guthrie (HGP I 80) maintain that this is only part of a larger cycle: the water-vapour turns to fire, and fire back into cloud and rain; hence there is a regular process of interchange between the major cosmic bodies, corresponding to the interchange between the elements of later philosophy. But this is against the evidence. Our sources say that wind and rain are formed from vapour from the earth, not from fire descending from heaven; no common phenomenon can be easily interpreted as wind, or the heavenly bodies' fire, turning into any other substance, nor is Anaximander said to have spoken of one; and he had no motive for postulating such a phenomenon, if he had no general theory of how different

¹ Such condensation is later cited by Theophrastus (Syr. 352b32-4 and ap.Olympiod.80.31ff) and Vitruvius VIII 2.3-4; cf. Epicurus Ep.ii 108 (on dew).
materials change into each other (p. 105f). Indeed, Aristotle implies that the vapour that causes wind and the τροπαί, and increases the heavens, does not return to the earth: 12A27, τὸ μὲν διατίμισαν πνεῦμα καὶ τροπὰς ἥλιου καὶ σελήνης ... ποιεῖν, τὸ δὲ λειφθὲν θάλατταν εἶναι: οὐδὲ καὶ ἐλάττω γίνεσθαι ἐξηραινομένην οὐονταί καὶ τέλος ἐσσεθαί ποτε πᾶσαν ἐξηράν. "What is evaporated causes winds and the turnings of sun and moon, and what is left is the sea; and therefore the sea is drying up and becoming less" etc.¹: if the vapour which causes winds etc. returned to the earth as rain, this would not happen. Aristotle recognised that on Anaximander's theory some water-vapour turns to rain: for Mete.355a25ff (following 64A9) criticises the theory that moisture nourishes the sun, and the Anaximandorean theory just mentioned, on the grounds that all water-vapour falls again as rain, δὲ οὕτε τρεφομένων τῶν ἄνωθεν, οὕτε τοῦ μὲν μένοντος ἄρος ἢ δὴ μετὰ τῆς γένεσιν, τοῦ δὲ γενομένου καὶ φθειρομένου πάλιν εἰς ύδωρ. "Thus neither are the heavenly bodies nourished, nor does some of the air that forms remain air,

¹. Note that the process is a continuing one, not confined to cosmogony.
while the rest becomes air and then turns back into water." 

τρεφομένων - ἄνωθεν clearly refers to the 'sun's nourishment' theory, the rest to Anaximander's; it confirms that, in Anaximander's view, while some water-vapour condenses to rain, part never does. The injustice involved in its formation will never be avenged in the present state of the cosmos, but only by the onset of a 'great winter', when earth's desiccation will be reversed (so Kahn 140), or by the re-absorption of our world into the Boundless. ¹

In the mean time, the vapour either remains in the sky as δήρ (cf. Mete. 355a29 μένοντος δέρος), or nourishes the heavenly bodies; it causes the τροποί of sun and moon (i.e. the solstices and the moon's equivalent motion²), either because winds blow sun and moon about³, or because sun and moon move about in search of nourishment.⁴

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1. On re-absorption into the Boundless v. EGP 53; Vlastos (1957) 170-3; Seligman (1962) 72ff; HGP I 100f; Kahn 185f; KR 122f.

2. This, the normal meaning, is perfectly satisfactory, cf. Lee 125n, 135n, Kahn 66f. The doubts of Boeker 2219ff, HGP I 97 seem unjustified.


4. Cf. Alexander in 12A27, with the comments of Kahn 66f, HGP I 97. (On 12A27 and 64A9 in general v. Stokes (1963) 6-8.)
D. Wind

12A11(7) (quoted p. 107): "winds occur when the finest vapours of ἄηρ are separated off (ἀποξωμένων), and, when they are collected, are moved."

12A24 (quoted p. 58n): "wind is a flow of ἄηρ, the finest and wettest parts of it being moved or melted by the sun."

12A11(7) might be interpreted in two ways:

1) ἄηρ is a mixture of vapours of varying densities, of which the finest are separated off and constitute wind. In this case, what remains must become progressively less fine, perhaps eventually becoming rain: rain's formation would then be complementary to that of wind, as may have been stated by the original version of 12A24: the 'wettest parts' of ἄηρ seem inappropriate to wind, and presumably in fact cause rain, mention of which has dropped out of the text.  

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1. Cf. Gilbert 511-5; Kahn 63, 100-2; HGP I 105f.
2. This paragraph follows Gilbert 512f, 515; Gigon (1945/68) 98; Kahn 63, 100f; HGP I 105. Kahn (cf. Gigon) thinks 12A24 τηξωμένων refers to the liquefaction of cloud in becoming rain (cf. [Hippocrates] Morb.sacr.13 (L.VI 384.14), Probl.XXVI 42 (945a15), where compounds of τηξω, used of ἄηρ or ἄγραν, refer to increase of moisture. But elsewhere τηξω is used of water becoming air, e.g. Plato Ti.49C, [Hippocrates] Flat.8 (L.VI 102.13)).
2) Alternatively, ἄηρ may be a uniform body, parts of which become fine and are separated off. The unseparated residue will not now become denser, and the ἄηρ may go on becoming fine and turning to wind until no more is left. (In this case, the turning of τὰ ἄγαρότατα to rain would be an alternative process, not a complementary one.)

ἀποχρίνειν in 12A11(7) is probably Anaximander's own word\(^1\), since it is used in other testimonia, of the formation from the Boundless of our world (i.e. of opposites, or τὸ γόνιμον of them, or ὅραμαν and ξόμοιον\(^2\): A9, A10), and of the formation of stars from the fire in the cosmos (A11(4)): presumably it was Anaximander's regular term for the derivation or formation of one material or object out of another. Probably, however, he did not mean by it any clearly defined process. In A11(4) it seems merely the separation of a part from the main mass of a material, with no change occurring; and the same doubt as in A11(7) arises in A9 and A10, whether Anaximander meant by ἀποχρίνειν the separating of ingredients from a mixture, or the formation of something new from a uniform

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1. So, e.g., Seligman (1962) 44f.
This rather confirms that Anaximander had no clear idea of how different materials are formed from each other (cf. p. 105f), and leaves it impossible to decide between the two interpretations of 12A11(7); Anaximander himself need not have been clear about the matter.

The 'separation of the finest vapours' from cloud (caused, as 12A24 suggests, by the sun) looks like a primitive, Anaximandean version of the later 'rarefaction theory' of wind. That theory seems based on an analogy with the evaporation or boiling of water (p. 81f), and the same analogy was presumably used by Anaximander (he

1. A developed theory, resembling Empedocles' or Anaxagoras', that the Boundless or other materials were mixtures, would be an anachronism for Anaximander, implying a knowledge of Parmenides' denial of change (Kahn 236); but Anaximander might have spoken of the formation of one thing from another in terms implying separation from a mixture, without realising that logically this would mean that no change had occurred. (On the Boundless as a mixture cf. HGP I 86f; Kahn 40f; Seligman (1962) 40ff; KR 130ff; Vlastos (1947) 170-3.)

Kahn 156 suggests that 12A10 τὸ γόμωμον (of heat and cold) ἀποχριθήναι (from the Boundless) uses a biological analogy, since ἀποχρίνεσθαι "is the normal term for the ... ejection of seed"; but this analogy can hardly apply to wind-formation, where what is separated undergoes no further change before becoming wind.

3. v.p. ἐν (cf. p. 182); Gigon (1944/45) 84.
knew the sun causes evaporation, p. 109f. ).

12A23 (quoted p. 94 ) confirms that wind is λεπτός and cloud παχύς. The derivation of wind from cloud is, therefore, a process of λέπτυνσις; evaporation should also involve λέπτυνσις, judging from the analogy of later theories (p. 70ff ). This foreshadows Anaximenes' theory that all forms of matter are derived from ἄφρ by condensation and rarefaction; but Anaximander clearly did not develop such a theory himself.

In 12A23 wind bursts out of a cloud because of its fineness and lightness: evidently wind's fineness makes it mobile, and so able to move other things. Presumably Anaximander, like Anaximenes and others (p. 80 ), regarded wind as a special sort of matter: it is the finest ἄφρ, which either must always be in motion (as Lucretius thought that wind revolves within the cloud before it bursts out to cause thunder, p. 93 ), or, perhaps more likely, is like an active living creature, moving whenever

1. The analogy fits either interpretation of 12A11(7). In the end, the sea will dry up completely (p. 112 ), which fits my second interpretation (p. 115 ); but the sea is what is left behind as evaporation occurs (being, presumably, denser and heavier than what evaporates, as in Anaxagoras (59A90, cf.A42(4)) and [Hippocrates] Aer.8 (L.II 32.20ff)), which better fits my first interpretation (p. 114 ).


3. v.p. 95n (cf.p. 265 ); Gigon (1945/68) 98.
it is able and striving to break out of its trap in the cloud.¹

1. On such a concept of wind cf. p. 27f.
   (Boeker 2224f interprets 12A11(7) as meaning that by 
   ἀπόκρισις opposites are separated from each other and 
   react together, and that this somehow produces motion: 
   2224.65ff, "Winde entstehen, wenn infolge eines 
   immerwährenden Ausscheidungsprozesses - ἔκχρισις - 
   Ballungen (Anaxim. bei Hippol.I 6,7=12A11...)... 
   eines ἀντικειμένον neben einem anderen zur ἀντιπαρίστασις 
   führen und damit eine Ausgleichstendenz gegeben ist." 
   By ἀντιπαρίστασις he seems to imply a conflict between 
   opposites, cf. 2224.39ff; but there is no evidence 
   whatever for deriving wind from a conflict between 
   opposites thus separated from each other; opposites help 
   to cause wind in that sun and ἄρη have opposite properties, 
   but nothing suggests they were actively involved in any 
   other way).
2. Anaximenes.

A. His general theories.

Anaximenes' ἀρχή was ἄηρ ἄειρος (13A1, A5, A6, A7(1) al.). This is not mist, but air in our sense, cf. 13A7(2) ὅταν μὲν δυσαλώτατος ᾧ, ὑψεῖ ἀόηλον, ῥηλοῦσθαι ὅς τῷ ψυχρῷ καὶ τῷ θερμῷ καὶ τῷ νυστερῷ καὶ τῷ κινομένῳ; i.e. when ἄηρ is 'most even' we cannot see it, but we know it is there because we feel it to be hot or cold or humid or in motion.¹ This ἄηρ, which we feel but cannot see, and which is connected with breath and wind (13B2, cf. p. 130ff), must be, not mist, but atmospheric air.² It surrounds the cosmos (13B2), and the heavenly bodies ride upon it.

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1. Cf. KR 146. To translate ῥηλοῦσθαι 'made visible', as others do, is inconsistent with what follows, which implies that air's eternal motion causes its changes.

2. Also, it is less dense than both cloud and wind (13A5, A7(7)); Anaximenes would hardly regard (invisible) wind as intermediate in density between cloud and visible mist, therefore his ἄηρ is 'air' (cf. Gilbert 474n). (That Anaximenes' ἄηρ is air is accepted by Gilbert 474, HGP I 123-6; EGP 74 and KR 146 accept it with reservations. Stokes (1963) 23ff says it is mist, rejecting 13A7(2) as self-contradictory (he says it means that ἄηρ is made visible by motion, and that it is always in motion; i.e., it can never be ὑψεῖ ἀόηλον). But, ῥηλοῦσθαι here does not mean 'made visible'. Hippolytus, the author of 13A7, is a good source for Anaximenes (KR 6), and should not be rejected without good reason. Also, 13B2 and Anaximenes' wind theory, even if (as Stokes says) not proving that ἄηρ = air, are highly suggestive.)
All this suggests that it covers the whole surface of the earth.

That air exists was not a wholly new idea (p.8-11); but Anaximenes was the first man to make it explicit and to put it to use. 13A7(2) tells us how he knew air existed. Among his reasons for making it the ἄρχη were presumably that air, as breath, is essential to life², and (I suggest) the popular concept of wind as a living but shapeless body (v.p.28); also, air resembles Anaximander's ἄξωμον, being boundless and characterless (cf.KR 147) - this was perhaps the decisive reason, since it alone was new.

Air turns into other things by πῦκνωσις or μάνωσις (13A5, A7(3)), by being massed together and made solid and impenetrable, or spread apart and made less solid (p. 58ff ). This explains naturally how different things are formed from one uniform body (cf.HGP I 119ff), and is supported

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1. This seems a more probable view for Anaximenes than Aetius' statement (II 14.3) that the stars are fixed τῶν χρυσαλλοειδέων (DK 13A14. Cf.EGP 77n, KR 155f, Lloyd PA 317f; contra, HGP I 135-7). (ἐντοιοὶ δὲ κτλ. in Aetius II 14.3 surely means "But some say (sc. that Anaximenes said) that" etc., cf. 21A40.)

by much empirical evidence, notably that steam, and smoke and flame, have a much larger volume than the boiling water or burning fuel whence they are derived.¹

5. Evaporation.

In Anaximenes' system, unlike Anaximander's, evaporation plays a negligible part. Only 13A6 and A7(5) mention it, saying that the heavenly bodies are derived from the earth. In A7(5), moisture, ἰχμάζ, rises from the earth, is rarefied to fire and forms the stars; but in A6 'the sun is earth', which ignites because of its swift motion. The mention of rarefaction in A7(5) sounds characteristic of Anaximenes. But A7(5) and A14 mention earthy bodies carried round with the stars, i.e. there are earthy bodies in the sky; and it seems prima facie improbable that the sun, with its unvarying shape and movements, is simply burning vapour (though Xenophanes believed this, 21A40): later Ionians usually regarded the sun as at least partly solid.² Possibly

¹. On the empirical evidence concerning Anaximenes' theory (which does not all support it), v.IHP I 124-6.

². Heraclitus regarded it as vapour burning in a σκόνθη (22A7(9)), Anaxagoras thought it a fiery stone (59A72 etc.), Diogenes said it was like pumice (64A13, cf.A12).
Anaximenes (like Heraclitus) believed that the heavenly bodies consist partly of solid matter and partly of burning vapour.

With this doubtful exception\(^1\), we hear nothing about exhalations in Anaximenes, not even in his meteorology (we have his views on wind, cloud, precipitation, lightning and rainbows, cf. A7(7)-(8) etc.). This omission was a consequence of his general physical theory: all \(\Delta \rho\) may take on any form; may be rarefied to fire, or condensed to earth and stones (13A5, A7(3) etc.). This leaves no place for Anaximander's limited cycle sea - vapour - cloud - rain - sea (v.p. 109ff). No doubt water is rarefied to air, and air condenses to clouds and rain; but there is no reason why the changes previous to these should have been from air to water or water to air - the air may well have been formed from condensing fire, the water from earth. Therefore Anaximenes said only that rain and wind are formed from \(\Delta \rho\), and said nothing of the \(\Delta \rho\)'s origin (13A5, A7(3) A7(7), A17).

1. Earthy material drawn up unchanged from the earth (which is consistent with A6), would hardly be an exhalation.
C. Wind. 1

Wind is the first stage in the condensation of air, with cloud the next (13A5) 2; but 13A7(7) (quoted p. 65) says: "winds are produced when highly condensed air is rarefied and moves". 4 This looks inconsistent with 13A5, making wind a product of rarefaction, not condensation: but I take Anaximenes' view to be that, when listed in a theoretical order of density, wind comes between ordinary air and cloud; but that in practice it is normally produced by the rarefaction of cloud, not by the opposite process. He was probably influenced by the analogy of boiling water (cf.p. 81f), and must have known that boiling water emits a mass of rapidly moving steam, but that there is no comparable moving body when water forms by condensation in the air. 5

13A7(7) is one version of a frequent ancient wind-theory (p. 65ff; Anaximander's theory is another instance

2. 13A7(3) is usually emended to agree with it (DK 11 I p. 488.11f).
3. The χυ- of ξυπερυπωμένους I take to be intensive: the air is at first still more condensed than when it is wind.
4. I ignore 13A19: the 'Galenic' work whence it comes seems a late forgery (v.Keheim (1916) 75-8).
5. Cf., in A7(3), εξ ἐρον ... νέφος ἀποτελεῖσθαι.
of it, p. 116); but this version differs from the rest
in not making heat cause the rarefaction. What did
Anaximenes regard as the cause? According to Boeker 2226f,
Anaximenes' theory is the same as the modern one; he says
of 13A7(7): "Heisst das physikalisch: Luft weht sich
entspannend immer von Stellen höherer Dichte nach Stellen
niederer Dichte"; i.e., δῆρ ἔκπεπυκνωμένος is 'air at high
pressure' in the modern sense, which must at once expand
if it has less dense air round it (p. 182-4).

This, however, is unlikely. πεπυκνωμένος does not
naturally have the meaning required. I have examined every
instance of πυκνός and related words in Mete.I-III: none
suggests that this property makes a gaseous body expand
automatically, as compressed air does. Water and earth
are, to Anaximenes, highly πυκνός bodies, but they do not
so expand\(^1\).

Moreover, though two of Anaximenes' theories reveal
some knowledge of what we call air-pressure, his knowledge

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1. Hero (Pneum.p.16.23; 76.5, 11, 13 etc.) and Philo Byz.
(v.p. 88 \(\)) generally used πιλέω of 'compressed' air -
cf. occurrences in 13A6, A7(3); but the latter do not
concern bodies which automatically expand.
was clearly very limited. First, he believed that earth and stars do not fall because they ride upon air. Cf. Aristotle Cael.294b13ff: Anaximenes, Anaxagoras and Democritus say that the earth ἐπικοματὶς εἰς τὸν ἄερα , comparing this with τὸ ἐν ταῖς κλεψυδραῖς ὄσω (ib.20)¹; thus οἶδα ... τὴν στενοχωρίαν οὐκ ἔχων τὴν πάροδον ὁ ἄηρ μένει (ib.26f). This implies that the earth extends (presumably) to the edge of the universe, and that consequently the air below cannot get past the earth and rise above it. But this cannot apply to the stars; and both Aristotle (ib.14ff) and others (13A6, A7(4), Aetius III 15.8 in A20) say that the earth rests on air because of its flatness - which, as Aristotle remarks, is irrelevant to the theory as he describes it. Probably, therefore, Anaximenes did not use the clepsydra analogy, but simply believed that flat bodies float on air as wood floats on water; he held that the sun is 'flat like a leaf'², and we know that a flat leaf falls very slowly.³ (No passage says

¹. It is not clear how the analogy is applied: v. Guthrie (1939) 226n.
². 13A15, cf. Aetius II 14.3 in A14 (on which v.p. 120n ).
³. KR 153, Lloyd PA 317f, Gladigow (1967) 15-17 adopt this interpretation; contra HGP I 138.
that the air supporting the earth is πυχνός, though Aristotle says it is άθρόος). The only assumption implied by this theory is that air is a body which resists pressures put on it, as solids and liquids do.

More complicated is 13A15: ἢπδε πεπνυμένου ἁέρος καὶ ἀντιτύπου ἕξωθούμενα τὰ ἄστρα τὰς τροπὰς ποιεῖσθαι , "the stars make their turnings because they are pushed back by dense, resistant air". This clearly represents an earlier version of the theory of Anaxagoras discussed on p. 172ff:¹ it must be explaining, primarily, the solstices and the moon's equivalent motion.² Here the air apparently exerts pressure, instead of just resisting pressure - though I doubt Anaximenes need have been clear about this distinction - and evidently does so more effectively because it is dense; naturally, since anything concentrated thereby possesses its properties in a stronger degree.³ However, for reasons explained on p. 173f, this theory is unlikely to be based

1. Anaxagoras tends to follow Anaximenes in the details of cosmology, cf. HGP II 304ff.
2. Though this has been doubted: v. Zeller (1920) 328n; Heath (1913) 33n; Kiessling (1914) 849f.
3. It is curious that the air here presumably exerts pressure on the thin edge of the (flat) sun, although air only supports earth etc. because they are flat.
on any observation of compressed air expanding; or, if it is, Anaximenes cannot have understood it. Therefore, Anaximenes' wind theory cannot have been identical with the modern one, and probably has nothing to do with the automatic expansion of compressed air.

We must, then, seek another explanation why 13A7(7) does not mention heat. As is well known, 13B1 explains that heat and cold are products of the rarefaction and condensation of air, i.e. they are not primary qualities. Examination of the testimonia suggests the possibility that Anaximenes may, in consequence, have deliberately avoided speaking of them as causes of other phenomena (contrast Anaximander, pp. 109f, 116); for the only places where they appear to be so mentioned are as follows:

13A7(3), concluding the account of Anaximenes' theory of matter: Ὅστε τὰ κυριώτατα τῆς γενέσεως ἐνάντια εἶναι, ἑρμόν τε καὶ ψυχρόν. This can hardly be right (cf. Lloyd (1964a) 95), since it contradicts what precedes: 13A7(2) (cf. A5) says that air's eternal motion causes all change - unless τὰ κυριώτατα τῆς γενέσεως means not 'the chief causes of generation' but 'the chief of created things'.

1. Cf. LSJ s.v. γένεσις IV.
13A7(8) σεισμον ... [γεννᾶσθαι] τῆς γῆς ἐπὶ πλεῖον
ἀλλοιωμένης ἐπὶ θερμασίας καὶ ψύξεως. The mention of
heat and cold here may well be inaccurate: other sources,
including Aristotle, speak of flood and drought, not heating
and cooling, as causes of earthquakes.¹

13A14 (Aetius II 19.1,2) Πλάτων τὰς ἐπισημασίας τὰς
tεθερμάνας καὶ τὰς χειμερινὰς κατὰ τὰς τῶν ἀστρών ἐπιτολὰς
tε καὶ ὀυσμᾶς γίνεσθαι. 'Ἀναξιμένης δὲ διὰ μὲν ταῦτα
μηδὲν τούτων, διὰ δὲ τὸν ἥλιον μόνον "... But Anaximenes
says that none of these (i.e. ἐπισημασίαι) occur because
of these (i.e. stars rising and setting), but only because
of the sun." This might mean² that the sun causes changes
of season³; but I doubt Anaximenes need have been talking
about more than signs of the seasons.⁴ (Aratus, quoted in

Most ancient authors would indeed assume that heat and
cold cause drought and flood; but the best source does
not attribute this to Anaximenes.

2. As, e.g., Kahn 105 and apparently Pfeiffer (1916) 22
suppose.

3. Cf. πῶς γίνεται χειμῶν κτλ. in the title of [Plutarch]
II 19.

4. ἐπισημασίαι apparently might mean either signs or changes
of the seasons (cf. LSJ s.v., Rehm (1940) 175ff,
Pfeiffer (1916) 84ff). (Those authorities show that the
word ἐπισημασία was probably not used as early as
Anaximenes: if he used any word from the root of σηματον,
he surely must have meant signs of seasonal changes, not
the changes themselves.)
Aetius II 19.3, is certainly talking about signs of the seasons, not their causes.)

The sun's rays also cause rainbows by burning clouds (13A18), and the moon's light may be kindled from the sun's fire (O'Brien (1968) 118-24); but the rainbow is an unimportant phenomenon, and the second theory admittedly speculative.

I suggest, then, on this evidence, that Anaximenes in his physical system made considerably less use than Anaximander of heat and cold, presumably because he thought them only secondary qualities; this may explain why heat is not mentioned in his wind theory.

The ultimate cause of all change is the eternal motion (v.p. 127 ) of air which is divine (13A10), and so alive. But Anaximenes clearly did not believe that the immediate cause of all changes is the self-motion of the matter concerned (which is a form of air, and so alive); for some testimonia mention external physical causes. Thus earthquakes are due to flood or drought, and rainbows to the sun (cf. supra); and Anaximenes must have known (after Anaximander had pointed it out, v.p. 108f ) that heat frequently appears to cause evaporation. He must therefore have accepted that pieces of matter act on each other. Possibly he thought that rare or dense matter tends to
impart its rarity or density to other things; thus cloud
might be rarefied to wind by the sun's fire imparting its
rarity to the cloud (the heat being incidental, and not,
as others thought, the cause of the process). On this
hypothesis, Anaximenes' wind theory would be almost the
same as Anaximander's and other versions of the rarefaction
theory (pp. 65ff, 114–7). An alternative cause of wind,
especially of wind from cold regions, (or conceivably the
only cause) might be the spontaneous rarefaction of air
which is regarded as alive.

D. ἀὴρ and πνεῦμα.

In 13B2 these words seem to be ascribed to Anaximenes:
οἶον ἡ ἐκ ψυχῆς ἡ ἡμέτέρα ἀὴρ ὁβα ὑσιγκρατεὶ ἡμᾶς, καὶ
ὁξον τὸν κόσμον πνεῦμα καὶ ἀὴρ περιέχει. These cannot be
Anaximenes' exact words, and it is disputed how accurately

1. Similarly, he may have held a view of the solstices and
Etisians similar to that which (I suggest) Anaxagoras
held (p. 174f), except that heat and cold are only
incidental, and not the causes. (On this hypothesis,
the sun may cause seasonal changes etc. (v.p. 178f)
without heat causing them.)

2. Cf. p. 132. Gilbert 516 considers air's perpetual motion
the cause of wind (though he accepts Diels' καὶ ἀεικεῖς for
ἀραῳεῖς in 13A7(7)). Any explanation of this theory
must be speculative; but the two I have proposed are, I
think, the only ones suggested either by Anaximenes'
general theories or by similar wind theories in other
thinkers.
they represent his thought \(^1\); but at least Aetius' comment λέγεται ὅτι συνωνύμως ἄθρ καὶ πνεῦμα implies that these two are Anaximenes' words. \(^2\) I assume, what there seems no good reason to doubt, that the 'fragment' represents his thought with reasonable accuracy.

The 'fragment' contains two ideas not recorded before Anaximenes, and which would naturally have first occurred to him, as the effective discoverer of air:

1) The \(ψυχή\) is ἄθρ. Anaximenes' view of the soul is clearly based on primitive ideas of a 'breath-soul' \(^3\); 1352 is the earliest passage where ἄθρ is connected with the soul or with breath - it obviously would not be connected with either so long as it meant 'mist'.

2) The idea of πνεῦμα surrounding the cosmos must derive from the Homeric concept of πνοή, usually 'wind', but whose meaning sometimes approaches that of 'air' (pp. \(^5\), 30). 1352 therefore connects wind with ἄθρ

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1. KR 158-62; HGP I 131f; Lloyd PA 235f.

2. πνεῦμα seems to occur before this at Sappho fr. 90 col. iii 22 ζεφυρῷ πνευμά[; but this is a lemma in a commentary whose lemmata are apparently unreliable (v. Lobel (1951) 16).

3. HGP I 128; on the 'breath-soul' cf. Onians (1951) 44-61; Guthrie (1950) 137ff.
in the sense of 'air' - another new idea, though foreshadowed by Hesiod and Anaximander, who connect δήρ, i.e. 'mist' or 'cloud', with wind (pp.50, 107f). Anaximenes' usage in turn foreshadows the later definition of wind as 'air in motion'.

Assuming πνεύμα in 13B2 has a connotation of 'wind', this suggests two conclusions concerning Anaximenes' wind theory. The apparent connection of wind with soul suggests that wind is somehow alive\(^1\); and πνεύμα surrounding the cosmos - which apparently was mentioned to prove air is the δραχη\(^2\) - suggests that wind is important in the cosmos, which accords with my suggestion (p.27f) that the primitive concept of wind as an invisible, self-moving, living body influenced Anaximenes' choice of air as δραχη.

These conclusions, however, are unsupported by other evidence. Elsewhere, wind is a special variety of matter, not necessarily alive and not especially important (p.123ff). (Presumably air's qualitative changes, and the movement of

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1. This conclusion is uncertain, as it assumes 13B2 is putting forward a microcosm/macrocospm analogy, and I agree with Longrigg (1964) that it need not be.
living creatures' breath, are aspects of air's eternal motion more important than wind.) The conclusions just deduced from 13B2, therefore, seem to be ideas Anaximenes did not develop far in working out the details of his system.

The analogy of wind and breath, however, may have influenced Anaximenes' wind theory. Breath is most like wind when exhaled through pursed lips; and 13B1 says that such breath is compressed and so cold (as wind feels cold); clearly, such breath is slightly condensed air, which Anaximenes said was wind (13A5). Presumably this feature of breath was one factor that led Anaximenes to this wind theory. (But, exhaled breath is no longer important to us, and so winds need have no special importance in Anaximenes' universe.)

1. This analogy need not affect the idea that wind is derived from still denser air: exhaled breath comes from the interior of our bodies, which is plainly dense and wet. (It is also hot; but that would remain a problem however we interpret Anaximenes' wind-theory.)

2. On cold days, when we exhale visible 'vapour', that must be still more condensed air, i.e. cloud.
3) Xenophanes

A. General

Xenophanes held no general theory of matter: Aristotle's denial that anyone made earth the ὅρχη (Metaph. A 989a5), and the doxographers' disagreements, make it incredible that frr. 27, 29 and 33 are part of a developed physical theory.) Xenophanes did, however, know that air exists: B28,

γαίης μὲν τὸ δὲ πεῖρας ἄνω παρὰ ποσοὶν δραται

ἡρὶ προσπλάξον, τὸ κάτω ὅ' ἐς ἀπειρον ἱκνεῖται.

(ἡρὶ Diels, vulgo; καὶ βεί mss.; αἰθηρί Karsten) "This upper limit of the earth we see at our feet, in contact with the ὅρ (?); but the lower part goes down without limit." If the ὅρ/ἀθερ touches the earth, it is air.

However, air plays no part in Xenophanes' meteorology: his position was the same as I inferred to be Anaximander's

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1. Cf. the different testimonies in 21A1(19), A29, A32, A33(3) and A36. (For some remarks v. HGP I 383-7; KR 176f).

2. Perhaps rightly, cf. A47 and Empedocles B39. (ἀθερ could mean 'air' at this period, cf. p. 147f.)

3. So EGP 120, KR 175, DK's tr., Kahn 146n. Homer M 285, λ 583 seem to support this.
Fr. 30 (quoted p. 59) shows that the sea (or, as we would say, water-vapour) is the source of cloud, wind and rain; and, if Diels' supplement is correct, that winds blow from within clouds. Based on this fr. (quoting the first five words) is A46: ἀπὸ τῆς τοῦ ἡλίου θερμότητος ὡς ἀρκτικὴς αἰτίας τὰν τοῖς μεταφέρεις συμβαίνειν. ἀνελκυμένου γὰρ ἐκ τῆς θαλάττης τοῦ ὄγρου τὸ γλυκὸ διὰ τὴν λεπτομέρειαν διαφυγόμενον νέφοι τε συνιστάναι διαχρόνευον καὶ καταστάζειν ὀμβρούς ὑπὸ πτιθομέως καὶ διατέλειαν τὰ πνεύματα. (The last three words appear to mean 'evaporates the winds'; but in the context they must describe how wind is produced. Perhaps, therefore, πνεύματα is an internal accusative, 'evaporates in wind', 'in a windy way'; or, if this is not possible, the text must be wrong.)

A46 purports to give details not in B30. Some of them (notably συνιστάναιν, ὑπὸ πτιθομέως of condensation) were...

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1. Cf. HGP I 390-4, also Gilbert 445-7 etc.
2. HGP I 391n compares Mete. 353b8 τὸ ... διαπύκναν πνεύματα ... ποιεῖν.
common ideas', perhaps added by the doxographer to modernise Xenophanes' vocabulary; but others, especially the sentence about the sun (because it is a separate statement), and the idea that both sweet and salt water evaporate, but only the sweet condenses to rain (because it is an unusual idea; v.p. 147-9) were probably derived from further statements by Xenophanes.

The importance of the sun is confirmed by A42, on the sun's importance in the world in general, and by A1(19) της ἄφ' ἥλιον ἀπιέσες ἀναφερομένης (where the sun must be agent, not source: no-one could say vapour is carried up from the sun to form clouds).

Xenophanes also believed that the sun and heavenly bodies are formed from burning clouds, or ἐκ πυριδίων μὲν τῶν συναθροιζομένων ἐκ τῆς ὕγρας ἀναθυμιάσως, συναθροιζόντων δὲ τὸν ἥλιον. (These seem to be two versions of the same theory; so Kahn 17.) The sun and stars are

1. Cf. p. 75 and DK 13A6, A7(3).
2. 21A32 fin., A38, A40.
3. 21A40 (ascribed directly to Theophrastus, so should be the most reliable, but cf. also A32, A33(3)).
extinguished and reformed every day (A33(3), A38, A41).

This involves Xenophanes in an inconsistency: for, if water-vapour is drawn up by the sun, and the sun is formed each day from water-vapour, then what can draw up the water-vapour which forms the sun? It is, however, possible to comprehend these theories in the light of what was probably the main object of Xenophanes' physics: the denial of the traditional gods. Meteorological and other phenomena are not due to the action of Zeus or any other god, but to the action of the sun on water; and the sun which causes them is not divine or immortal, but transitory, and formed from the same water on which it acts.

This theological purpose apart, Xenophanes' meteorological theories are unimportant, being largely simplifications of Anaximander's and Anaximenes' theories; their value is that they provide confirmatory evidence, partly preserved in the original words, of the sort of theories the latter thinkers will have held.

1. Thus Anaximander had held that the sun causes evaporation (and hence meteorological phenomena) (p. 109f ); compare also the statements on wind in 21B30 and A46 with 12A11(7), A24, 13A7(7); 21A45 with 12A23 (on lightning etc.); on rainbows v. HGP I 392f. (However, Xenophanes also explained phenomena not known to have been discussed previously: v. 21A39, A44.)

2. Pointed out by EGP 122; Gilbert 447.
4) **Heraclitus.**

A. The atmosphere.  

No fragment uses any word like δήρ, αἰθήρ or πνεῦμα, except fr. 76, saying that δήρ is the death of fire or water, and water or fire the death of αἰθήρ; and this is probably not verbatim.  

B31 also deals with elemental changes, but mentions only fire, water and earth (cf. B36, where soul is equivalent to fire, p. 145n). More significant, the doxography in A1(9) mentions only fire, water and earth (though those at A5 include air, cf. Clement in B31): a doxographer familiar with the four element theory might easily interpolate a mention of air, but would not leave air out, if Heraclitus ever mentioned it.

But Heraclitus' system was not without an atmosphere. 22A16(129-30) says that we draw in the divine λόγος (i.e. fire, cf. HGP I 432) 'ὅτε ἀναπνοῆς', and that our mind τῷ

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1. On Heraclitus I have made considerable use of Kirk 'Heraclitus' (1954) and Marcovich 'Heraclitus' (1967).


implies that there is fire around us. A1(10) and A12\textsuperscript{1} (cf.31A62) say that the sun is brighter than the moon because it passes through a purer region, the moon through a murkier one, nearer the earth; this is meaningless unless these regions are filled with matter. A1(9) states that there are bright and dark exhalations, and continues τὸ ὑδὲ περιέχον ὅποιόν έστιν οὐ ὄηλοι: εἶναι μέντοι ἐν αὐτῷ ὁχάφας, in which the bright exhalations are collected and burned, thus producing the stars; the theory just quoted then follows. This suggests that τὸ περιέχον is in fact filled with exhalation - presumably the moon's ὁχάφη burns dark and bright exhalations mixed (cf.Kirk (1954) 272). If so, then the exhalations, being derived from the earth, should also fill the space up to the moon.

B. Exhalations.\textsuperscript{2}

\begin{quote}
DK 22A1(9)-(11): γίνεσθαι ... ἀναθυμιάσεις ἀπὸ τῆς γῆς
\end{quote}

1. A1 again does not use ἄηρ, though A12 does.

2. For discussions (from which I differ widely) v. Gilbert 447-58; Kirk (1954) 270-6. (I found, after writing this §, that some of my arguments already occur in Solmsen (1960) 409f).
Many have held that this theory was an important source for Aristotle's exhalation-theory; but in fact the only resemblance is the idea that there are two exhalations, one fiery, the other wet. The differences are great: Aristotle's exhalations are 'dry' and 'wet' (v.p. 229), not 'bright' and 'dark'; and in him the fiery exhalation is from the element earth (p. 233), while in Heraclitus it is from water. (The fiery exhalation is bright: 22A1(9), (11)). The dark exhalation 'increases moisture' (Ib. (9), cf. (11))³; it is not clear whether this exhalation is formed wholly or partly from the element  

2. v. 22A1(9), the 'way down' begins with fire, the 'way up' ends with exhalation from the sea; and they clearly correspond. 22A12, sun (and moon) are derived from the sea, or from wet exhalation. 22B36, B12 and Aetius in A15 all derive soul from water or moisture; and soul is closely connected with fire, cf. B36 with B31 (B117, B118 and Aristotle and Macrobius in A15 also suggest a connection between soul and fire; cf. Kirk (1954) 340f, HGP I 432f, Marcovich (1967) 361). Against this could be set only 22A11, the stars are nourished ευ της δισ γης αναθεμάτως; and the stars' nourishment might be said to be δισ γης , whether it comes from sea or land (HGP I 484n).  
3. Thus there is, strictly, no dry exhalation in Heraclitus: one exhalation is from water, and the other, if not from water, anyhow increases moisture.
earth, or whether all exhalation is from water, and ἀπὸ τε γῆς καὶ θαλάττης means 'from water on land (lakes, rivers etc.) and from the sea'. I suspect the latter: Heraclitus certainly thought earth changes into water (B31, B36 etc.); but it seems strange that it should change into a moist vapour, without becoming water first. If so, Heraclitus did not anticipate Aristotle in postulating different exhalations from the elements earth and water.

The burning of exhalation in the σχάφαι produces the heavenly bodies, especially the sun (p. 139); bright exhalation consequently causes day (22A1(11)). The prevalence of dark exhalation causes night and winter (22A1(11)).

DK 22A1(10) adds that γίνεσθαι ... μὴνας καὶ ἀρας ἐτείους καὶ ἐνιαυτοῦς τετοῦς τε καὶ πνεύματα καὶ τὰ τοῦτοις ὄμοια κατὰ τὰς διαφόρους ἀναθυμιάσεις.

1. Which is supported by [Hippocrates] Aer.8 (v.p.147f).
2. Kirk (1954) 271f denies Heraclitus believed this, saying that the sun's absence is sufficient explanation of night (cf. KR 204n). But is it not natural that Heraclitus, with his 'obsession with the opposites' (Kirk (1954) 216; v.frr.57, 67, 126 etc.) should regard day and night, and summer and winter, as due to the interaction of opposite causes? (For similar theories v. DK 31A65, 6402).
The exhalations presumably cause months and years in causing the seasons, since months make up seasons and seasons years (so WKCG.) That exhalation causes wind and rain is normal pre-Socratic doctrine (v.p. 444f). A difficulty is that, if dark exhalation increases moisture (22A1(9)), it should presumably cause rain (so Solmsen (1960) 430); but it seems obvious (though it is unattested) that it is via clouds and rain that fire becomes water on the 'way down' (so Kirk (1954) 333; WKCG, cf. HGP I 463), i.e. rain should be from bright exhalation. Very likely it was: in [Hippocrates] Aer.8 the dark vapour only causes mist, while the bright one evidently causes rain: Heraclitus may have thought the same. Alternatively, the exhalations might change into one another above the earth's surface: fire on the 'way down' would be first bright exhalation, then dark exhalation, then rain.

I can see no reason why Heraclitus should not have held this two exhalation theory; Kirk's arguments ((1954) 273-5) against the dark exhalation are groundless. The silence of

1. Also, at 22A14 an exhalation (presumably the fiery one, Kirk (1954) 275) causes lightning.

2. Cherniss's argument ((1955) 415f) is refuted by Kirk (1954) 276n.
the doxographers other than Diogenes (in 22A1) proves nothing (since no-one else purports to give Heraclitus' view of night, winter, wind and rain, which the dark exhalation was, or may have been, used to explain), nor does Mete.'s silence, since Aristotle's account of earlier meteorology is very incomplete: e.g., he says virtually nothing about earlier wind theories (p. 103), and fails to mention that anyone had explained thunder etc. by the action of wind on cloud.¹ The brief general criticisms of earlier theories at 341b7, 349a14f, 355a5 are not (pace Kirk) suitable places for special digressions on Heraclitus' two exhalations, especially as Heraclitus' remarks on exhalations may have been as brief and uninformative as Diogenes' report (cf. HGP I 483). Kirk ib. 275 further objects that a second exhalation would destroy the predominance given to sea-exhalation by 22A1(9). But that may refer to both exhalations (since both may be from water, p. 140f); or, it may ignore dark exhalation as unimportant. Nor does Aristotle de An. 405a25 (22A15) ην αναθυμίασιν prove that Heraclitus had but one (cf. Kirk ib.): Aristotle

¹. As had Anaximander (12A23), Anaximenes (13A17), Heraclitus (22A14), Diogenes of Apollonia (64A16), Metrodorus (70A15).
sometimes uses ἀναθωμίας, isolated and unqualified, to refer to either of his own two exhalations (v.p. 249f); presumably he could do the same for Heraclitus.

Moreover, Kirk does not adequately explain why this theory, if not Heraclitus' own, was attributed to him; it can hardly be, as he supposes (ib.273), by a confusion of a Heraclitean single exhalation theory with Aristotle's theory of two; for the theory is quite unlike Aristotle's (p.140) and all post-Aristotelian theories. Nor would Diogenes' doxography, which admits ignorance on several points (Kirk ib.271), have invented so strange a theory, or transferred it to Heraclitus from another philosopher.¹

Probably Heraclitus had no noun meaning 'vapour'², but used a periphrasis, like other early authors (p.45ff).³ Once, at B36 ἐκ ὑδάτος ... ψυχή, we surely have the principal text which later writers paraphrased by speaking of ἀναθωμίας (saying soul is one; 22A15, B12. Cf. Kirk

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1. Since the doxographers nowhere else mention such a theory.
3. [Hippocrates] Aer.8, whose exhalation theory resembles Heraclitus' (v.p. 147f), has no noun for vapour.
Burning is a process by which other things are changed into fire; bright exhalation is equivalent to fire, or at least is a stage in its formation (p. 140). Therefore, the turning of other things to water and then of water to bright exhalation and fire is a process of ignition: it is the exchange of other things for fire (B90), πῦρ ἀπτύμενον (B30). It thus has a vital part in Heraclitus' general theory of change, which explains why exhalation was more important to him than to other pre-Socratics (p. 444-52).

The space furthest from the earth, through which the sun passes, is filled with (presumably) pure bright exhalation/fire (p. 139); but closer to the earth darkness, cold and wet are too frequent for this to be credible. To

1. Kirk (1954) 275, 340f implicitly denies Aristotle de An. 405a25 (in A15) is derived from B36; but it probably is: B36 ψυχή obviously is fire (Kirk ib. 340f, HGP I 433), i.e. is Heraclitus' ἥφαιστη; but B36 does not say this, but only that ψυχή comes from water. Therefore Aristotle calls ψυχή both 'exhalation' and Heraclitus' ἥφαιστη.

2. Plato Ti. 49C γιγνόμενον ὀξὺμα ... ἔνυχαυθέντα ... ἀπὸ πῦρ, cf. 57A; Aristotle Cael. 307a24ff, GC 327b11ff.

3. Marcovich (1967) 289 (on B31) has a slightly similar view.

4. It is bright, not dark, exhalation that is important, cf. p. 140-3.
explain these things, I take it, Heraclitus postulated the dark exhalation. The impure region near the earth presumably contains the two exhalations mixed; we draw in this mixture as we breathe, and become ψεφοτ from the fire/Logos in it (v.p. 138f ).

Heraclitus thus made more use than Anaximander or Xenophanes of the atmosphere (i.e. the body filling the space over the earth), perhaps owing to Anaximenes' influence. To judge by the testimonia, his direct contribution to meteorology was negligible; in making water-vapour cause wind and rain he was simply copying Anaximander and Xenophanes. His fondness for exhalation is shown by his apparently making vapour cause lightning directly, while wind's action on cloud only causes thunder (A14); but this still resembles Anaximander's theory. His only importance is that he may have suggested long afterwards, to Aristotle, the idea of a meteorology based on two exhalations, one

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1. Marcovich (1967) 332 rejects the dark exhalation, but regards variations in the brightness etc. of the atmosphere as due to "the varying quantity of the only sea-exhalation, say from 10% of fire in the winter-time up to 90% in the lightning" (p.334). This leaves it obscure what the non-fiery part is. I think Marcovich is roughly right, but that what is not fiery is dark exhalation.
fiery and one moist; and even here the connexion would be remote (p. 140).

It would probably be idle to ask of Heraclitus, what is the efficient cause of meteorological phenomena. DK 66.2, attributed to 'Heraclitisers', suggests that the sun causes evaporation¹; but all other passages on Heraclitus' exhalations (i.e. those mentioned on p. 139f., and 22A14) mention no cause, nor do most of the passages on Heraclitus' general view of change.² Heraclitus evidently did not think in terms of physical causes: if everything is changing all the time, then it is superfluous to look for the cause of any particular change.³

C. Heraclitus' and other early dual-exhalation theories.⁴

The only close parallel I know to Heraclitus' theory is [Hippocrates] Aer. 8 (L. II 34. 13ff); (water) ἐκεῖ ὅπως ἀρπασθῇ...

1. ἐκ ... τῆς θαλάσσης τῶν ἡλιῶν ἀναθηματίσθαι , either 'the sun draws up vapour' (so LSJ, Forster (1927)), or 'the sun is evaporated (is formed from vapour) from the sea' (cf. HGP I 434) - in the latter case the sun may or may not cause the evaporation.
2. So B31, B36, B90, B76, A1(9); contr. Aetius in A5.
3. Unless one says that the Logos is the cause (so WKCG).
καὶ μετεωρισθῆ περιφερόμενον καὶ καταμεμιμένον ἐς τὸν ἥρα, τὸ μὲν ἔθολερδν αὐτοῦ καὶ νυκτοειδὲς ἐκχρίνεται καὶ ἕξισται ¹ καὶ γίνεται ἡρ καὶ δμίκλη, τὸ δὲ λαμπρότατον καὶ κοινφότατον αὐτοῦ λείπεται... (He goes on: while it is scattered, it is carried about in the air; but when massed together, it falls as rain).

Anaximander and Xenophanes probably held similar theories: they distinguished fine vapours from (presumably) coarse, thick ones (12A11(7), A24; 21A46), and at least three pre-Socratics connected brightness with λεπτότης and/or darkness with παχύτης, two of them in meteorological contexts.² Xenophanes and [Hippocrates] also agree in holding that rain is derived from fine or bright vapour - a surprising idea (considering the widespread connexion of water with density and hence with darkness), which also fits the requirements of Heraclitus' system (p. 142 ). (It might also be relevant that Anaximander 12A24 appears to connect the finest and wettest parts of ἄηρ, cf.p. 114 .)

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¹ I assume ἕξισται, like ἐκχρίνεται, means roughly 'is separated from'.

² v. Anaximander 12A23, Anaximenes 13A18, and Anaxagoras, for whom 59B4, B12, B15 taken with A70 connect bright/dark with λεπτός/παχύς.
Evidently this theory was widespread in the 6th-5th centuries, but later forgotten. We can only speculate about its origin. Possibly, the bright vapour was thought to cause those phenomena (including wind and rain) that can occur in bright conditions, and sometimes also to feed the heavenly bodies' fire, while the dark vapour causes mist and darkness. This might explain the disappearance of the theory, when men ceased to regard darkness as a special material.
CHAPTER 4

THE LATER PRE-SOCRATICS: PARMENIDES TO METRODORUS

1) Parmenides.

Parmenides, though totally uninterested in meteorology, is nevertheless important in its history, because his denial of the void caused his successors to be more aware of the atmosphere.

The earliest Greek authors do mention the atmosphere, but only very rarely; and I have argued (p. 8-10) that men in early times were but vaguely aware of air's existence, sometimes being conscious of it, and sometimes forgetting. Anaximenes was the first man to have thought much about it: he clearly realised that invisible air exists, and seems to have mentioned evidence - our perception of temperature, etc. - which proves this (p. 119f). But this was evidence men must always have been half aware of, and Anaximenes probably laid little stress on it (since only one source mentions it). The idea about air which he stressed was its transformation into other materials, and that he could not prove; so that

he left his successors with little more reason to pay attention to the atmosphere than they had had before he wrote. Hence, air is unimportant in Xenophanes and Heraclitus (though noticeably more important in Heraclitus than it had been before Anaximenes) (pp. 134f, 145f).

I must also mention the pre-Parmenidean Pythagoreans, who are supposed to have identified πνεῦμα with τὸ κενὸν (cf. HGP I 276-30). The evidence for this is Aristotle Ph. 213b23f, κενὸν ... ἐπεισεῖναι ... τῷ ὀδράνῳ ἐκ τοῦ ἄξερον πνεῦματος ὡς ἀναπνέοντι καὶ τὸ κενὸν , with Simplicius' comment (in Ph.651.26) τὸ κενὸν ἐπεισεῖναι τῷ κόσμῳ οἷον ἀναπνέοντι ... αὐτῷ ὅπερ πνεῦμα. (cf. Stobaeus in Di 56A30, Aetius II 9.1). This is difficult to evaluate. The dating seems doubtful; Simplicius clearly regards 'breathing' as merely an analogy, and in Aristotle and

1. It is said that after Parmenides breath and void could not have been identified (cf. HGP I 279). But, if the Pythagoreans' doctrines were preserved orally until the late 5th century (KR 220, cf. HGP I 180), the post-Parmenidean Pythagoreans are equally unlikely to have preserved unmodified a theory which they could see to be unsound, because it made this identification. Also, would a pre-Parmenidean have used the phrase τὸ κενὸν? - Parmenides never does. (Baldry (1932) 30n regards the void in Ph.213b23f as a late addition to the theory.)

2. Ross (1936) ad loc. renders "to inbreathe the void as well" sc. as the ... πνεῦμα'. Cf. Raven (1948) 48f.
Stobaeus breath and void may be separate things.\(^1\) The Pythagoreans surely can never consciously have regarded breath as being literally empty space; but they may have spoken sometimes of the cosmos drawing in breath, and at other times of its drawing in space (e.g. χάος), without considering how the two were related (cf. p. 8-10); and they may have regarded πνεῦμα as somehow less real than the cosmos that inhales it.\(^2\)

Before Parmenides, then, most men had only vague ideas about the space around us, sometimes realising it is full of invisible material, and sometimes forgetting this. But Parmenides marks a turning point: what-is, he asserted, cannot be divided or scattered (B4, B8.22); it must be continuous (B8.25); τὰν ... ἐμπλεόν ἐστιν ἔντος (B8.24) -

1. Aetius is still less clear. (HGP I 280 cites also Alcaean A5 ἄκοψεν ... φησὶ τοῖς ὁσίοις, ἀπότι χενὸν ἐν αὐτοῖς ἐνυπάρχει· τοῦτο γὰρ ἦκεῖν ... τὸν ἀέρα δ᾽ ἀντηχεῖν. But, what produces echoes is a hollow place, with solid bodies all round it; the χενόν here must be a hollow within the ear, empty of the normal materials of the body. (Aristotle, when he mentions the view (referred to Alcaean by DK 24A6, Beare (1906) 94) that τὸ χενόν causes hearing, seems to mean a hollow place within the ear (v. de An. 420a18f, also 419b33, PA 656b15f)). Alcaean may have been well aware that fully substantial ἄρο fills this space.

2. Cf. Aristotle GC 318b27ff, air popularly regarded as less real than other matter.
for what-is, he implies, could only be separated from itself by what-is-not, and what-is-not cannot exist. To his immediate successors, this logic seemed unassailable: they must either admit the world to be a delusion, or give an account of it from which what-is-not is excluded: which, meant, to them, that the world must be absolutely full of matter. Here, then, an end must be put to any vague idea that the space around us is 'empty'. That it is actually full of air was no new idea; but never had it been so strongly impressed on anyone as it was on Empedocles and Anaxagoras as they struggled to work out physical systems that would not violate the canon of Parmenides. The evidence they adduced to prove air's existence, too, - the inflated skin and the clepsydra (DK 59A68) - was not new: it served merely to remind men of something they had always been half aware of.

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1. On inflated skins v.p. 91; the clepsydra was known in the 6th century, cf. Last (1924) 171 and authorities there cited.

2. The inflated skin and clepsydra (unlike Anaximenes' reference to air's heat, etc.) would refute any idea that air was discontinuous, or less real than other matter (since no water enters the clepsydra until air is let out, and a fully inflated skin does not yield at all to pressure).
From this time on all philosophers were fully aware of air's existence: Empedocles frequently mentions air as one of his four elements, and in other contexts it is important in Anaxagoras (p. 159ff); and, although the atomists rejected Parmenides' denial of the void, the existence of air was by now well-known and they evidently spoke of it often. The atmosphere had become a vital part of every physical system.

This clear establishment of air's existence was important for many branches of physics, including meteorology. Two facts should be noted about it: it was not the discovery of a new idea, but the establishment of an old one; and the cause of this establishment was not, as we might expect, any new observation or experiment, but the logic of Parmenides, in which observation played no part at all.

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1. B17.18, B71.2, B98.2, B109.2; evidently B6, B21.4, B115.9ff.
2. e.g. B38, B78, B100, B149; cf. A65, A72, A89 etc.
3. e.g. 68A135 8850, 52, 54, 74, 80, 81; A77, A78, B30.
2) **Anaxagoras.**

A. Anaxagoras' theory of matter.

I cannot here discuss Anaxagoras' system in detail, but will adopt in the main the similar interpretations of KR 375ff and HGP II 279ff: I assume that "ν παντὶ παντὸς μοῖρα ἓνεστι" (B11) means that in every piece of matter, however small, there is a portion of all the things that Aristotle calls 'homoeomerous', i.e. bone, hair, flesh, gold etc.; and that what appears to be a piece of matter of a particular kind, say bone, is a piece of matter containing more portions of bone than of anything else. There is no real coming-to-be or perishing, only mixing and separation (B17); i.e., there is no real change; only the proportions vary in which the μοῖρα of different kinds of matter are mixed.

I assume that by μοῖρα Anaxagoras meant an infinitesimal, or purely notional, bit of pure matter (e.g. pure bone, or pure gold); and I suspect that by σπέρμα

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1. It seems a gratuitous complication to suppose that each μοῖρα contains a portion of everything – i.e. Anaxagoras could not even imagine a bit of pure matter.
he meant the same as μοῖρα.¹

I also disagree with HGP and KR concerning the opposites. HGP II 285f states that "the hot, the cold, the wet, the bright, the black, etc., were substances having these characteristics... on the same footing as flesh and bone"; cf. KR 380. This implies that there exist μοῖραι of the hot, the cold, the wet, etc., in addition to the μοῖραι of fire and water and the other substances that naturally possess these qualities (cf. HGP II 291). This may be so; but it is not always thus that Anaxagoras speaks of the opposites. B12 and B15 state that, in cosmogony, the dense, the cold, the moist and the dark are separated from the rare, the hot, the dry and the bright; by these four pairs is clearly meant all the matter of the cosmos. It can hardly be meant that there were then more portions of density, cold etc. at the centre of the cosmos than of

¹ Since everything contains σχήματα of everything, B4 init. (Lloyd PA 246n argues that σχήματα and μοῖραι must differ because B4 mentions 'seeds having forms, colours etc.', not 'seeds of' them; but why need these expressions differ in meaning? KR 378 say that 'seeds' are necessary because the infinite regress involved in Anaxagoras' theory of matter 'must be ... halted', if the visible world is to be built up; but infinitesimal μοῖραι could as easily combine to form a large finite body as to form minute finite 'seeds'.)
anything else, so that the centre of the cosmos would appear to be a mass of density, cold etc.; for could anyone ever imagine these things as appearing to exist apart from the substances - water, earth etc. - of which they are normally qualities? Rather, it must be meant that all the materials that are normally dense, cold etc. collect at the centre of the cosmos; 'the dense' or 'the cold' does not consist of 'portions' other than the 'portions' of materials which naturally have these properties, like stone and water; rather, the 'portions' of these materials are themselves dense, cold etc., and hence can be summarised as 'the things that are dense and cold and dark and moist'. In B4, too, where πάντα χρήματα seem to be defined as the same eight opposites καὶ γῆς πολλῆς ἐνεσθος καὶ σπερμάτων ἀπείρων πλῆθος, Anaxagoras can hardly have meant by these eight opposites simply 'portions' of these qualities, leaving everything else in the universe except them and earth to be expressed as σπερμάτων ἀπείρων πλῆθος; rather, he must include in τοῦ τε ὀιεροῦ καὶ τοῦ ἐγροῦ κτλ. the substances of which
Anaxagoras may well have believed that there are 'portions' of what we would call qualities, as well as of substances (e.g. there may be 'portions' whose only quality is heat, as well as 'portions' of fire, which both are hot and have fire's other properties): if a body becomes hot without undergoing any other change, this can only be explained, on Anaxagorean principles, by supposing that 'portions' whose only quality is heat are added to it; and several testimonia speak of qualities and substances together, as though to Anaxagoras they had the same nature. But, when a substance permanently possesses some quality, it is implausible and unnecessary to assume that it only does so because it has 'portions' of that quality mixed with it: is Anaxagoras likely to have thought that fire is of itself not hot at all, and only feels so because its 'portions' have 'portions' of heat mixed with them?

1. The opposites listed presumably denote all the material of the universe, as in B12, B15, γῆς κτλ. being genitive absolute, added to show that bodies not usually regarded as characterised by one of the eight opposites are in fact included (cf. HGP II 295).

2. v. HGP II 285f.
B. The structure of the universe.\(^1\)

\(\delta \eta \rho\) is cold and dense, \(\alpha \theta \eta \rho\) hot and rare (A70); and probably they are respectively moist and dark, and dry and bright, since B4, B12, B15 connect the latter pairs of opposites with the former ones, and B15 connects the rare, hot and dry with \(\alpha \theta \eta \rho\).\(^2\) Before the cosmos was formed, πάντα \(\delta \eta \rho\) τε καὶ \(\alpha \theta \eta \rho\) χαρέλχεν (B1); evidently this was a mixture of \(\delta \eta \rho\) and \(\alpha \theta \eta \rho\), in which all the opposites cancelled each other out (cf. B4, HGP II 295): neither heat nor cold was discernible, nor light nor darkness, and so on.

In cosmogony, the eight opposites just mentioned are separated off from each other (B12); dense, moist, cold and dark substances are concentrated at the centre of the cosmos, while their opposites go out εις τὸ πρόσω τοῦ \(\alpha \theta \epsilon \rho \circ\) (B15, cf. A42(2)). Presumably distinct masses of \(\delta \eta \rho\) and \(\alpha \theta \eta \rho\) first become visible (cf. B2), the \(\delta \eta \rho\) being

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2. Anaxagoras identified \(\alpha \theta \eta \rho\) and fire: v.59A43, A73, A84; Ἰνετ.359b21ff. Cf. 59A70, A82, A71 \(\alpha \theta \epsilon \rho \alpha \nu \pi \rho \iota \iota \nu \circ\), A109 'aetherium calorem'.

What is Anaxagoras' ἄηρ? Its darkness suggests it is mist (cf. HGP II 295n); but it cannot be solely the local, temporary phenomenon we call 'mist' (though that was probably a form of ἄηρ, cf. p. 165). It is of comparable importance to the ἀλθήρ of the sky, not only in cosmogony (B1, B2) but in the present world, cf. 212 νῦν περιχωρεῖ ... ὅ ἄηρ καὶ ὅ ἀλθήρ (and the heavenly bodies); in several testimonia it must be atmospheric air, e.g. A68, A69 on ἄηρ and the clepsydra; A74 (quoted p. 161); A85, cloud rises into cold ἄηρ (high above the earth); A92(30), ἄηρ causes smell. ἄηρ clearly fills the space immediately over the earth, with ἀλθήρ above it.

By day the sun heats the air around us: if mixing and separation are the only forms of change, it can only

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1. That this is how the cosmos is organised is clear from B15, A42(2), A1(8), cf. A84, A82 on ἀλθήρ (and ἄηρ).

2. If ἄηρ is air, then either its darkness, humidity etc. are only relative, ἄηρ being dark relative to ἀλθήρ though appearing light to us, and so on (cf. Plato Phd. 109Bff; Bargrave-Weaver (1959) 85ff) or, it is naturally dark, humid etc., but appears light through admixture of other matter (the Stoics' view, cf. SVF II 429, 430 etc.; Seneca NQ II 10.1).
do this by emitting hot, bright matter (perhaps αἰθήρ) which is by day mixed with the air (and perhaps expels cold, dark matter from it); by night this hot matter must in turn be expelled or submerged, possibly by ἀηρ's natural cold and darkness.

By day the sun impedes hearing, A74: τῆς ἁμαρας σίζειν καὶ ψοφεῖν τὸν ἁέρα θερμαινόμενον ἀπὸ τοῦ Ἥλιου; evidently its heat slightly boils the air, making it hiss and causing in it κίνησιν τρομώδη καὶ παλμοδες ἔχουσαν (revealed by motes in a sunbeam). A similar process (on a larger scale) causes thunder and lightning (A84, and Mete.369b12ff): αἰθήρ is drawn down from above (perhaps not from the sun), imprisoned within a cloud, and then separated from it: the flash of the αἰθήρ is then the lightning, the hiss as it is extinguished by the cloud is thunder. (These theories confirm the connexion of ἀηρ and cloud with water, on the analogy of whose boiling they are evidently based.)

Anaxagoras knew that temperature falls with height (A85), as must always have been obvious in mountainous country; he explained the fact (says Aristotle) οἶδα τὸ

1. Pindar 0.13.88 αἰθέρος ψυχρᾶς suggests knowledge of this temperature-fall.
lower air twice, both descending and ascending- Aristotle's own view was similar (p. 224).

The heavenly bodies are fiery stones carried round by the ἄλθηρ (A12, A42(6), A71). But the moon's light is not its own (B18, A42(8), A76, A77), i.e. it is not itself fiery, or not very fiery: presumably it is near the border of ἄηρ and ἄλθηρ, and the invisible bodies that are carried round with the sun and moon (A42(6)) are wholly in the ἄηρ. (On the upper limit of the ἄηρ see further p. 172ff.)

Anaxagoras, like Anaximenes, believed that the earth rests on air (v.p. 125). It seems likely that, being interested in clepsydrae, Anaxagoras was the first to support this theory with the clepsydra analogy; as is slightly confirmed by 59A42(3), the earth is at rest ὄλα τῷ μέγεθος καὶ ὄλα τῷ μῆ εἶναι κενὸν καὶ ὄλα τῷ τῶν

the size of the earth seems irrelevant, unless because it means that the air has no room to get past (cf. Aristotle Cael. 294b25).

This, however, raises a difficulty, videlicet that some heavenly bodies are evidently carried round in the ἄηρ (p. 152), i.e. some ἄηρ revolves with the sky, as B12 also tells us¹. The heavenly bodies, and therefore the ἄηρ and ἀλθηρ with them, pass below the earth as they revolve², i.e. ἄηρ is constantly passing from above to below the earth and back again, contrary to my conclusion in the last paragraph. Indeed, even if we assume that the edge of the earth reaches the ἀλθηρ², and that no ἄηρ revolves, it would still seem inexplicable why ἄηρ should not displace ἀλθηρ, which is finer and rarer (p. 159),

1. τὴν περιχωρήσιν ... ἴν νῦν περιχωρέει τά τε άστρα καλ ὁ ἢλιος καὶ ἡ σέληνη καλ ὁ ἄηρ καὶ ὁ ἀλθηρ οἱ ἀποχρινομένοι.
2. Cf. A42(8), also A80 τὸν ... ἢλιον ὑπὸ τὴν γῆν φερόμενον.
3. A71 (τὸν ... ἀλθηρα ... τῇ ... εὐτονίᾳ τῆς περιβληθεὶς ἀναφέροντα πέτρους, to form the stars) may support this (cf. Boeker 2236.32ff); but other scholars (as EGP 269, 346; KR 392; Heath (1913) 81; cf. Lanza (1966) 128f, 238f) maintain that the stones that form the stars are thrown off the earth by centrifugal force, citing B16 (stones) ἔχωρεον μᾶλλον τοῦ υδάτος (though the meaning of this is uncertain); while A12 implies that the stones that form the heavenly bodies have never been part of the earth: (the stars) τὸ πρῶτον ἔχρατηθε μὴ πεσείν ἐνεῦρο τῶν ψυχρῶν καὶ βαρέων ἀποχρινομένων τοῦ παντὸς. The balance of the evidence is clearly that the earth's edge does not reach the ἀλθηρ.
and rise above the earth. The most plausible explanation would seem to be that δῆρα below the earth is kept in place by the revolution of the cosmos, which drives heavier matter, including δῆρα, into the centre; this would ensure that the δῆρα is kept close beneath the earth, and cannot escape to rise past it.\(^1\) The assumption that the δῆρα below the earth cannot move past the earth's edge seems to be paralleled in Anaxagoras’ wind-theory, with respect to δῆρα above the earth (p. 171\(^1\)).

C. Exhalation.

αἰθήρ is hot and rare, and δῆρα cold and dense; and from δῆρα cloud is formed, from cloud water, from water earth and from earth stones (p. 159f): presumably these are progressively denser bodies, as in Anaximenes (13A5, A7(3)). This being so, evaporation must be the separation out of water of fine, air-like bodies, as 59A90 probably states: τοῦ ... λιμνάζοντος ὑγροῦ περικαίνοντος ὧπο τῆς ἡλιακῆς περιφορᾶς καὶ τοῦ λεπτοτάτου \(^2\) ἐξατμισθέντος ...
The sun causes evaporation (A90, A1(8)): presumably not matter from it is mixed with the water and initiates the separating-off.

Anaxagoras' meteorology, however, made little use of evaporation. 59A86a, indeed, says that ol ἀνεμοὶ κατὰ ... Ἀναξαγόρας ἐκ τῆς γῆς γίνονται; since B19 (if genuine) says that 'the water round a cloud' causes wind, this may imply that vapour causes cloud and rain also. But it cannot have been important, as no other report concerning these phenomena mentions exhalation (v.A1(9), A42(11), A85, B16, B19); either 59A86a is mistaken, or Anaxagoras referred to vapour in this context only incidentally.

Why Anaxagoras thus ignored vapour is easily explained. ἐν παντὶ παντὸς μοῖρα ἐνεστὶ (B11 etc.) implies that everything can be derived from everything, if not directly then via the proper sequence of changes (e.g. fire - air - cloud - water - earth), as Simplicius says (A45) and B16 confirms. If, so, then cloud or water in the air can as easily be derived from fire (via air) as from water; indeed, they evidently were derived from fire and air originally (p. 159f ). Thus, while evaporation does occur, the occurrence of cloud, rain etc. in no way depends on it. Hence it has no importance in Anaxagoras' meteorology - his position is the same as Anaximenes' (p. 121f ), a
thinker Anaxagoras often followed.

D. Wind.\(^1\)

59\(a1\)(9) and \(A42\)(11) say that \(\alpha\nu\epsilon\mu\omicron\omicron\nu\gamma\nu\epsilon\sigma\theta\alpha\iota\) λεπτυνομένου τοῦ ἀέρος ὑπὸ τοῦ ἥλιου: the analogy of related wind theories suggests that ἀέρ is primarily mist or cloud, something denser than ordinary air.\(^2\) λεπτυνομένου τοῦ ἀέρος means that mist or cloud turns (or rather, appears to turn) into something more like ordinary air (or that air turns to something more like fire) (v.pp. 79; 164); λεπτός here presumably means 'light', 'divisible', 'mobile'.\(^3\)

In Anaxagoras' cosmogony different lots of matter are characterised as τὸ πυκνόν and τὸ ὀρεινόν (v.p. 156), which (given his theory of matter) implies that these are permanent qualities of different types of material: λεπτός

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2. v.pp. 59ff , 67; B19, if genuine, confirms this (v.pp. 60 , 456-8).

3. Cf.p. 70f. It cannot mean 'composed of small parts', since all matter is infinitely divisible (HGP II 289). (If larger bodies are formed from 'seeds' of finite magnitude (as KR 377ff, HGP II 298ff suppose), then a λεπτός body might be one composed of small seeds; but v.p. 155f.)
and παχύς, being associated with πυχνός and μανός (A70), must be similarly permanent qualities: a λεπτός body consists predominantly of μοίραι which are light, mobile etc.

There is no real change, only mixture and separation. Therefore, ἄηρ must (appear to) become fine by having fine matter mixed with it, or coarse, dense matter separated from it, or both. The sun works on the ἄηρ by sending down hot, rare, fine matter into it (p. 160f): clearly, it makes the ἄηρ fine because this matter becomes mixed with the ἄηρ, and perhaps expels dense matter from the ἄηρ. (The ἄηρ may also appear to expand (cf. p.71f), because of the quantity of matter from outside that is mixed with it.  

Anaxagoras' wind theory is an instance of the rarefaction theory, which is based on the analogy of water boiling (pp. 65ff, 81f ). Wind-production is therefore another aspect of the process described on p. 151 : the sun 'boils' cloud or mist, gradually turning it (or rather, appearing to turn it) into a finer material, which

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1. Real expansion would be a change other than mixture or separation, so Anaxagoras evidently denied it can occur (cf. DK 68A46a).
is then emitted as wind (just as boiling water turns into and gives off steam; cf. p. 81f). (The vibratory motion that the sun is always producing in the air (v. p. 161 ) corresponds to the random motion in boiling water that has not yet become steam).

59A42(11) adds to my quotation on p. 166 some words not in A1(9): καὶ τῶν ἐκκαλομένων πρὸς τὸν πόλον ἐκκαλωμένων καὶ δύσοφερομένων ἐκκαλωμένων "... and the ignited parts withdraw towards the πόλος and are borne back from it." The ἐκκαλομένα are presumably identical with the ἀήρ λεπτοθυμενος; but what happens to them? Does πόλον mean 'the vault of heaven' or 'the north pole'? Boeker 2235f interprets as follows: the 'dry and light and hot and bright' ascend to the περιέχον ἄπαν, the region of άθηρ; but "wird nur die bis zur höchsten Verdünnung...Ätherisierite Luft in die Umlaufbewegung des περιέχον ἄπαν aufgenommen, während die 'dickere' Luft zurückgeworfen wird". This rejected air (Boeker evidently

2. So Boeker 2235-7; also EGP 271, HGF II 312n, though they do not try to interpret it.
thinks) forms the winds.

To Anaxagoras hot, gaseous bodies tend to rise; and sufficiently light and hot matter even reaches the αλοηρ, at least in cosmogony (v.p. 159). But there is no evidence (unless A42(11) be such) that these bodies ever reach the αλοηρ, if they are not light enough to stay there; Boeker says that they do in Aristotle, citing Mete. 340b14 (which seems quite irrelevant) and 341a28ff—which speaks of fire borne forcibly downwards from its own region, but does not suggest that such fire is heavier than what remains, as Boeker's theory requires. For Anaxagoras, Boeker compares his theory of meteors with his wind-theory (2236.32-63), regarding meteorites, like the heavenly bodies, as solid lumps detached from the edge of the earth by the αλοηρ (cf.p. 163n) but (pace Boeker) this cannot be how the matter that causes wind is carried up to the αλοηρ; nor is there any evidence for a connexion between the meteorite and wind theories: their juxtaposition in 59A42(10)-(11) (cf. Boeker 2236.43ff) is simply the

1. ἄηρ presumably can enter the αλοηρ, since αλοηρ enters the ἄηρ (p. 160f); but that αλοηρ does not seem to be borne up again in a mass.
normal doxographical order of subjects.\textsuperscript{1} \textit{Mete.} 344b33 ὑπὸ πνεύματος ἀφθολς (cited by Boeker 2236.53) has nothing to do with Anaxagoras, who held that the meteorite at Aegospotami had fallen from the sun (59a1(10), A11). πόλον in \textit{A}42(11) must mean περίεξον ἀπαν if it is Anaxagoras' word (cf. passages cited by Boeker 2236.4ff): but Hippolytus may be using it in his own sense (cf. 59a1(9) πόλον, clearly the celestial north pole (so \textit{WMG}).\textsuperscript{2}

There are, further, positive difficulties in Boeker's view: (i) ἄηρ as well as ἀλήρ is involved in the περικόμωσις (59b12); is it likely that air passes up through the revolving air to the ἀλήρ, and back again, without becoming involved in the revolving air's motion, and that

\begin{itemize}
  \item 1. Shooting stars etc. come between astronomical and atmospheric phenomena (cf. Aetius III 1-3). In any case, \textit{A}42(10), on shooting stars, need have nothing to do with meteorites. Shooting stars are like sparks (\textit{A}42(10), A1(9), A82), derived from ἄηρ (A1(9), or (more likely, since it is fiery) ἀλήρ (A82). Nothing is said of stones, and I know no reason why Anaxagoras should have connected shooting stars with the stone at Aegospotami.
  
  \item 2. \textit{A}42(10) πόλον is 'sky'; but this does not decide the meaning in ib.(11); Hippolytus is not developing an argument, but throwing out odd scraps of information: many of his sentences have little connection with those before and after them.
\end{itemize}
it then causes wind on the earth? (ii) ἅποχροϊντων: part of the air, ignited by the sun, 'withdraws' - does not this more naturally mean that the air moves away from the sun, i.e. towards the poles, than that it moves towards the sun, i.e. towards the αἰθηρ? (iii) ἀποφερομένων or <ἀντ>ἀποφερομένων, Boeker 'zurückgeworfen': is it natural to think of winds as descending from above? (In Aristotle the winds receive their motion from that of the heavens; but it is a motion round the earth, not a descent (p. 269-71).)

Boeker's theory thus seems implausible, and I therefore prefer the other, on which πόλον is the north pole. The rarefaction theory of wind suggests that all winds should blow from hotter regions to colder, in which case north winds are impossible (p. 85f). Anaxagoras, I suggest, met this difficulty by supposing that air, rarefied by the sun, moves north until it reaches the edge of the earth; and then, being unable to go further, it is

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1. This difficulty would vanish could πόλος include the revolving ἀηρ. But would the word naturally mean this? (In A42(10) it is probably αἰθηρ only, cf. A82 and p. 170r.)

2. That ἀηρ cannot go further is suggested by the solstice theory, where the sun pushes air together in the north (see below). This would be parallel to the behaviour of air under the earth, cf. p. 164.
by some means 'borne back again', thus producing a northerly wind.

It is true that, on this theory, $A42(11)$ is muddled, the first part concerning winds in general, the second north winds only; but $A1(9)$ omits the second part of $A42(11)$, and so on Boeker's view is incomplete as a general theory: so pay your money and take your choice.

But how is the wind 'borne back' to the south? The only clue seems to be Anaxagoras' theory of solstices$^1$:

$59A72$, solstices occur ἀνταλώσει τοῦ πρὸς ταῖς ἄρκτοις ἀέρος, δόν αὐτῶς συνωθῶν εἴ τῆς πυκνώσεως ἡχυροποιεῖ, "because the sun is repelled by the air in the north, which the sun itself pushes together and makes dense and so strong." Cf.$A42(9)$: the sun and moon τροπὰς ... ποιεῖσθαι ... ἀπωθουμένους ὅπω τοῦ ἀέρος. σελήνην δὲ πολλὰκις τρέπεσθαι διὰ τὸ μὴ σύνασθαι κρατεῖν τοῦ ψυχροῦ.$^2$

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1. On this v. Gilbert 686; HGP II 308; Lanza (1965) 60f.

2. A difficulty is that the sun is in the αὐθήρ, not the ἄηρ (p. 152): perhaps it is near the lower edge of the αὐθήρ, so that the ἄηρ's movements can affect it. (The boundary of αὐθήρ and ἄηρ need not be permanently fixed.)
The sun or moon might push the air together in the north in various ways: for example, they might turn the δφρ beneath them to wind, which blows northwards; or, the heavenly bodies' heat and the air's cold may mutually repel each other (cf.p. 174), in which case air will withdraw before the heat when the heat is strong. Either process (they need not be mutually exclusive) would fit both A42(11) and the solstice theory.

Air naturally becomes stronger when pushed together, since everything is stronger when concentrated. But what sort of strength does it possess?

We naturally think of "compressed air", and might suppose that air in the north, compressed by the sun, acquires an automatic tendency to expand and so pushes the sun southwards. But this is unlikely for Anaxagoras. No ancient writer before the third century B.C. clearly describes compressed air expanding (p.87-99, cf.pp. 201, 202); and I know none, of any period, who speaks of free air being compressed and expanding: the air is always confined in a container (p. 96f). Moreover, as the sun cannot act on the air by night, compressed air in the

1. Anaxagoras probably denied that matter can be compressed (cf.p. 157n).
north should expand then: if Anaxagoras based his theory on some instance of compressed air expanding\(^1\), he had quite misunderstood it.\(^2\)

It seems more in accord with normal pre-Socratic ideas that heat or cold should cause solstices, as A42(9) implies. The sun and moon are pushed back southwards by air's density (A72) and cold (A42(9)): presumably sun and moon, as they heat the air beneath them, drive away the cold, dense material in the air and concentrate it over the polar regions. (Wind seems to be derived from such dense, moist air, cf. p. 166.) Perhaps, then, Anaxagoras, like Anaximander, believed in a conflict of opposites, and supposed that the stronger of two opposites repels the weaker and causes it to 'withdraw'\(^3\): hence the sun and moon at first repel the air; but when the air is thereby concentrated sufficiently, it becomes stronger than moon or sun, and so drives it back again.\(^4\) Alternatively, one

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1. Or of a compressed solid expanding (e.g. horn scrapings or a dry sponge; cf. Hero Spir. p. 8.7-10 S.)
2. Also, \(\pi\nu\chi\nu\varsigma\) does not imply automatic expansivity (p. 124; cf. A72 \(\pi\nu\chi\nu\varsigma\)\).
3. An idea mentioned by Plato Phd.103D (cf. Ti.62B).
4. Cf. the theory of \(\alpha\nu\tau\iota\pi\epsilon\rho\iota\sigma\tau\alpha\varsigma\varsigma\) (v. p. 280ff).
might suppose Anaxagoras to have thought that the sun always tends to rarefy dense air and turn it to wind, and that at midsummer, because the air in the north is then as dense as it can become, and cannot move further north (p. 171), it is compelled, as the sun rarefies it, to move southwards, carrying the sun with it. Whatever the exact process, the dense air in the north must move south at or after the solstice, so that the sun can push it north again next year; which process must surely produce a north wind on the earth (the Etesian winds, as Boeker 2239-41 says). This corresponds with my interpretation of A42(11) (p. 171f): air, worked on by the sun, moves northwards and then is somehow carried south again, thus producing a north wind.

A similar theory of solstices, and so, perhaps, of the Etesians was held by Anaximenes (v.p. 126), and possibly by Anaximander and Diogenes (if they thought the solstices due to wind, v.p. 113); a similar theory of the Etesians was held by Metrodorus (v.p. 196f). Vent.2 (on which v.p. 350) also recalls this theory. (All these

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1. The air's density would then be merely an indirect cause, explaining the strength of the southward movement.
are cited by Boeker l.c., except Anaximander). The wind-theory I attribute to Anaxagoras thus has several parallels in other thinkers closer than Aristotle's theory is to Boeker's view of Anaxagoras (v.p. 171) - the only possible parallel I know of.

Although affirming the reality of void, the atomists could not, after Parmenides, Empedocles and Anaxagoras, ignore the atmosphere (p. 154). Its atoms, like others, must have weight, which presumably might take effect in either of two ways: either the atoms all the time press downward on the earth, but cannot get further because any that did so would at once be squeezed out again; or, the effect of their being in motion is to push against the void, so that the air is produced.

1. V. also Boeker 2332-5. (However, I doubt he is right to connect this theory with the idea that the north and south winds are the only winds, since that implies this is the only way in which winds are produced, for which view there is no good evidence. (59A42(11) alone might suggest it, cf. p. 172). The theory that north and south are the only winds is surely accounted for by their prevalence in Greece (v. Boeker 2334-23ff); the connection of east with south, and west with north, winds, which seems associated with this theory (Hete. 364a18ff) already occurs in Homer (Gilbert 539-41).

2. Boeker 2235-29ff speaks of a similar theory held by Diocles or the hippocratics, evidently referring to Diocles ap. Olympiaed. 30.6-10; but that does not explain Diocles' wind theory.
3) Democritus.

A. Theories of matter, the atmosphere and evaporation.

To the atomists, the universe consists of atoms and void; the atoms are perpetually in motion\(^1\), and it seems agreed that this motion is random.\(^2\) When collected in a cosmos, however, all the atoms (in effect) have weight, and tend to collect at the centre; but the smaller ones are squeezed out upwards by the larger.\(^3\)

Although affirming the reality of void, the atomists could not, after Parmenides, Empedocles and Anaxagoras, ignore the atmosphere (p. 154). Its atoms, like others, must have weight, which presumably might take effect in either of two ways: either the atoms all the time press down on the earth, but cannot get further because any that did so would at once be squeezed out again; or, the effect of the atoms' weight and the upward motion of atoms that have been 'squeezed out' balance each other, so that in effect the motion of atoms in the atmosphere is random.

1. 67A16, A17, A18.
2. EGP 345; Bailey (1928) 83f, 132f; KR 417; HGP II 400-4.
3. EGP 341-5; Bailey (1928) 128-32, 144-6; KR 414-6; HGP II 401-3, 410f.
In practice, the motion seems regarded as random (pp. 179f., 187f.); indeed, atomic motions in a cosmos must always be partly random, or the atoms could never become entangled to form compound bodies.¹

Democritus² probably taught that the Nile floods are due to the sun melting snow in the north at the summer solstice: from the vapour thus produced clouds are formed, which are blown south to Africa by the Etesian winds and cause rain there, which in turn causes the Nile to flood. Democritus therefore probably believed that the sun causes water-vapour to form, and that clouds and rain are formed from this vapour.

All this recalls the theory of Aristotle and Theophrastus, that Etesian winds are caused by exhalation, which is formed by the midsummer sun melting frozen water in the north (Mete.361b35ff; Vent.11-12); which raises the

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1. Cf. passages quoted by HGP II 404f.
2. v. Aetius IV 1.4 (68A99), Diodorus I 39.1-3 and the Anonymus Florentinus (a doxographical fragment mentioned by Diels (1879) 227f; for. eds. v. bibliography, p. 463). (The scholiast on Apollonius Rhodius IV 269f (68A99) attributes to Democritus a different theory, that the floods are caused by an influx of water from the southern sea; but this seems less likely, simply because the majority is against it. Cf. Rehm (1936) 584f.)
possibility that, in Democritus too, the vapour causes the Etesians. However, no source says this; nor does the theory of the Nile floods attributed to Democritus imply any particular view of the cause of the Etesians.  

B. Wind.

Democritus developed a new, atomist, version of the common view that winds blow from clouds (cf. p. 59ff):

68A93a, "cum exiguum locum multa corpora impleverint, necesse est alia aliis incidant et impellant ac repellantur implicenturque et comprimantur, ex quibus nascitur ventus, cum illa quae colluctabantur, incubuere et diu fluctuata ac dubia inclinavere se." ("...when the atoms that were struggling together, after long hesitation and motion to and fro, turn themselves and push in one direction"). This is compared with the struggles that occur when a crowd is confined in a narrow space.

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1. As suggested by Rehm (1907) 715.

2. However, Aristotle is unlikely to have invented his theory of the Etesians' cause, since it ill accords with his general wind theory (v. pp. 266, 303ff). Also, DK 68A89 and Lucretius V 614ff show that Democritus did not hold the theory of the solstices and Etesians that I have argued was held by Anaxagoras; so he may have held Aristotle's Etesian theory.

The atoms' behaviour, as described in the first part of my quotation, closely resembles other accounts of how atoms interact, e.g. 68A37 στασιάζειν ... καὶ φέρεσθαι ἐν τῷ κενῷ ... φερομένας οὖ ἐμπίπτειν καὶ περιπλάκεσθαι; cf. 67A14 (DK II 75.25ff); also 68A43, A47 etc. It is less usual that, as a result of this behaviour, all the atoms should move en masse in one direction; but even this is partly paralleled in the atomists' cosmogony: 67A1 (31) φέρεσθαι ... πολλὰ σώματα ... εἰς μέγα κενὸν, ἀπερ ἀθροισθέντα οἶνην ἀπεργάζεσθαι μιᾶν, καθ' ἣν προσκρούοντα καὶ παντοδαπῶς κυκλούμενα διακρίνεσθαι χωρὶς τὰ ὁμοία πρὸς τὰ ὁμοία; cf. A10, 68B164, B167. This resembles the wind-theory in that a number of atoms, moving at random, and unaffected by any external force, somehow begin to move together en masse (in the οἶνη, when forming a cosmos). There is also a remoter resemblance in the idea that similar atoms collect together: for here also a movement which is not random in the mass seems due to no cause except random atomic collisions.

1. A principle mentioned also at 68A99a, A165. (Like the wind theory, it is supported by familiar analogies, B164.)
Thus the wind-theory of 68A93a accords with the general principles of Democritus' system.¹ Boeker 2227-9, indeed, denies this, asserting that "der Gedanke einer Translation des Schwerpunktes eines Körpers, veranlasst aus einer Summe von Relativbewegungen seiner Teile" is inconsistent with Aetius I 23.5 and I 12.6 (DK 68A47); but I cannot see why the idea that the motion of individual atoms is the result of collisions is inconsistent with the idea that the total effect of a number of such collisions in a mass of matter is to cause that mass to move as a body in one direction.

Boeker goes on to suggest that the efficient cause of wind is the ἄνω φερόμενα θερμά (particles which rise from water and cause flat bodies to float on it) of 68A62. But this is pure speculation: if wind must have some external efficient cause, then the likeliest cause is the sun, which causes wind in other pre-Socratics (v.p.¹⁹⁷), and may be an important cause of events in Democritus' system.

¹. 68A68 (asserting that Democritus used chance ἐν τῷ κοσμωτολογίᾳ but not ἐν τοῖς μερικωτέροις; cf. A69) might be thought to undermine my analogy between cosmogony and wind-formation. But cosmogony is not really due to a different type of cause from other events, cf. HGP II 474-9, especially 478f.
But no such assumption is necessary: 69A93a provides, on its own, a satisfactory explanation of wind.  

Democritus' wind theory is worth some further discussion, for, as Sambursky (1956) 112 says, the atomic theory of Democritus "reminds us of the atoms of the ideal gas in the modern kinetic theory of gases, which are kept in perpetual motion characterized by constant collisions."  

According to the kinetic theory, a mass of gas consists of a very large number of very small particles (atoms, or molecules); these are in constant, rapid, random motion and continually collide with one another and with any body in contact with the gas. The gas thereby exerts a pressure on such a body; which pressure can be altered greater than the atmosphere's, e.g. because the gas is.

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1. Ambrosia is τὰς ἀμύλαις αὐτὸς ὁ Ἑλικος τρέφεται (68A25): this suggests that the sun is divine, which in atomist terms would presumably mean it is an important cause of events in the cosmos. (Cf. Xenophanes 21A42, Plato R.509B, Mete.339a19-24.) This, however, is speculative.

2. The sun may cause wind indirectly, since the dense atoms of 68A93a evidently form a cloud (p. 61), and clouds are due to vapour drawn up by the sun (p. 178).  

3. That collisions between atoms were important in Democritus' theory is shown by reports that the atoms' motion is due to a 'blow' (68A47).  

4. The information in this and the following paragraphs is taken from: Barton (1955) 94f, 185-214; Sutton 34-36; and conversation with Dr N.J.B.A. Branson, Fellow of Trinity College.
either by changing the number of collisions which the molecules of gas make on that body in a given time (e.g. by compressing the gas, so increasing the density of its molecules), or by changing the average velocity of the molecules making the collisions, or both. (The average velocity of the molecules is changed by heating or cooling the gas, for "the temperature of a body is measured by the average kinetic energy of its molecules" (Barton (1935) 204)).

Any mass of gas, then, exerts a pressure on its surroundings. Hence, it must expand, unless the bodies around it are exerting an identical or a greater pressure on it. Imagine a mass of gas in a cylinder enclosed by a piston. If the pressure of the gas is the same as the pressure of the atmosphere on the outside of the piston, the piston is at rest. If the pressure of the gas becomes greater than the atmosphere's, e.g. because the gas is heated (so that the velocity of its molecules is increased), then the gas expands and drives the piston up the cylinder, until its pressure falls again to that of the atmosphere (because it becomes less dense, so that its molecules' collisions with the piston are less frequent); similarly, if the atmosphere's pressure becomes the greater, it pushes the piston down the cylinder, until the density, and so
the pressure, of the gas inside becomes enough to stop it. (This behaviour of the gas is described by the Laws of Boyle: that the volume of a given mass of gas is inversely proportional to its pressure, provided that the temperature remains unaltered (so that if gas is compressed, its pressure rises, and vice versa); and of Charles: that the volume of a given mass of gas is directly proportional to its temperature, provided that the pressure remains constant; as is illustrated by the heated gas driving the piston up the cylinder).

The behaviour of the gas is the same if cylinder and piston are eliminated: if, in a continuous mass of gas, one part is at a higher pressure than the rest, then it expands and gas flows from the region of higher to that of lower pressure. This happens in the atmosphere, where pressure differences are produced by the unequal heating of the earth's surface by the sun; this is the cause of winds.¹

To modern scientists the value of this theory is that from its few and simple assumptions, mentioned above, there

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¹ Though the effect of the earth's rotation diverts the wind from blowing directly from the area of high to that of low pressure.
can be deduced the various empirically-established laws that govern the behaviour of gases (the laws of Boyle and Charles, and some others) — and that not just qualitatively, as I have described it, but quantitatively also. The ancient atomists made very similar assumptions; but their empirical knowledge was much less. Did they make any of the deductions from their assumptions that modern scientists have made (and, if so, did they use them in explaining wind)?

There was clearly no ancient counterpart to the quantitative aspects of the modern theory; nor are the atomists' ideas on heat of much help here. Unlike the moderns, they believed that heat is produced by a particular type of atom, sometimes said to be spherical, sometimes sharp.¹ They added, indeed, of spherical atoms, that they are especially mobile, and able to move other atoms (DK 67A28 κινεῖν τὰ λοιπὰ κινούμενα καὶ αὐτὰ, cf. Aristotle Cael.307a17); but this mobility presumably meant, not velocity², but an ability to be set in motion easily: a

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1. Spherical: DK 67A15, 68A101, A106 etc.; Aristotle GC 326a4. Sharp: DK 67A14, 68A135(65). (The atoms are not in themselves hot, but only produce what we call heat and fire, cf.68A49, B9.)

2. The fastest bodies are long and slender, e.g. arrows, triremes.
ball is set rolling more readily than bodies of other shapes. The basis of this theory is presumably that very hot bodies either are more liable to move than cold ones (e.g. molten metal compared with solid) or are always in motion (e.g. flame, steam, boiling water); in these latter instances, at least, the motion caused by the spherical atoms was presumably thought to continue for as long as the body remained hot. This would represent a near approach to the modern theory of heat; but it is only an inference; and there is no evidence that the atomists ever used this theory to explain the expansion of heated bodies\(^1\) (cf. p. 183).

We are left, then, with the parts of the kinetic theory that do not concern heat. First, what relevant data did the atomists have? They knew air exists (p. 154), but not that it always exerts a pressure.\(^2\) They therefore could not know Boyle's Law; and they probably were not clearly aware that compressed air expands if it can

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1. They must have noticed instances of this, e.g. that steam occupies a larger volume than the water whence it is derived.

2. They did not have the barometer, which proved this to 17th century scientists.
It was, however, already a familiar idea that matter would at once flow into a void, or to prevent one forming. This followed necessarily from Anaxagoras' and Empedocles' denial of the void, and was used by them to explain breathing, implicitly by Empedocles, perhaps more explicitly by Anaxagoras. Democritus, too, accepted that matter must flow to fill an extensive void, at least within a cosmos: 68A165 (on magnetism) εἰς τὸ κενὸν πάντα φέρεσθαι, etc. The atomists, then, had no empirical evidence that air is always exerting a pressure; but the atomic theory implies that it does (cf. p. 18); and several passages indicate that the atomists realised this. DK68A62, flat heavy bodies float because they are supported by heat-particles rising from the water; but (says Aristotle) this effect would occur even more in the air, as Democritus himself objects; but his solution is feeble: φησὶ γὰρ

1. B100 (e.g. 6f). The same principle evidently operates in clepsydrae.

2. 59A115; cf. Diogenes 64A31. (Both passages concern fishes' breathing; and the mechanism of human breathing could still be misunderstood, as by Plato Ti.79C-E. The principle of horror vacui as applied to breathing was, therefore, still largely speculative.)

3. ?Cf. 68A97 γῆν ... ἐλκοσαν (sc.ζυφόρ) εἰς τοὺς κενούς τόπους.
\( \text{the cove, was not only an upward motion}, \) but might operate in other directions; presumably the air's atoms (or some atoms in it) beat upon a body from all sides (so that their net effect is nil and the body is not supported); that is, they exert a pressure on it. Cf. 68A106: the atmosphere squeezes our bodies and forces out the atoms of soul (\( \tau \delta \varepsilon \rho \varepsilon i \chi o n \) ςυνθλίβον; \( \varepsilon \kappa \) \( \tau \) δο επε ιρε χοντος εκθλίψεως; etc. Cf. 67A28). This 'squeezing' is not said to be due to random collisions of air-atoms with our bodies, but that seems the likeliest explanation. (Alternatively, the atoms might press upon our bodies because of their weight (cf. p. 177) - but, to a modern scientist, the air's weight is merely another way of regarding its pressure.)

A later writer, Lucretius, more clearly describes air-pressure produced by random atomic motions. IV 929ff explains the languor of our bodies:

(932)"externa corpus de parte necessum est,
aeriis quoniam vicinum tangitur auris,
tundier atque eius crebro pulsarier ictu".

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1. Plato Cra.412B says just that \( \sigma \omega d\) means \( \tau \alpha \chi e \alpha \delta \) \( \delta \rho \mu \gamma \).
"Because our body is in contact with the breezes of the air, it must be struck and beaten on the outside by its frequent blows". (Cf. I 581ff, II 1140ff.) VI 998ff. explains magnetism: a stream of atoms from the magnet pushes away the air between it and the iron, producing a near vacuum there - an untenable idea, for how can the atoms expel the air save by filling the space themselves? The atoms of the iron then flow in a body into the vacuum; (1017) "hoc fit idem cunctas in partis, unde vacefit cumque locus, sive e transverso sive superne corpora continuo in vacuum vicina feruntur."

This idea, unlike the preceding one, is sound, as is the additional cause mentioned in 1026ff.

"qui post est cumque locatus aer a tergo quasi provehat atque propellat. semper enim circumpositus res verberat aer". "whatever air is behind the iron (i.e. on the side away from the magnet) as it were pushes and drives it on (sc. into the vacuum). For air always strikes upon what it surrounds." Though inapplicable to magnetism, 1026ff would serve well as an explanation of (say) suction. (Democritus, too, knew that matter tends to flow into a void (p. 157); but we are not told how he explained this.)
Densely-packed atoms, it says, cause wind: thus wind is derived from dense air, which, in the modern theory, is air at high pressure, and therefore flows into regions where air's density and pressure is less; which is the modern wind-theory. But Democritus apparently did not consider how dense air acts on the air around it, but spoke only of its atoms acting on each other; though he might have realised, when he put forward his crowd analogy, that a dense crowd (if leaderless) does not normally begin to move all in one direction; but, if a vacant space is available, the crowd will certainly spread into it - this would be equivalent to compressed air expanding. Here, as elsewhere, Democritus almost discovered the truth, but did not quite, and produced a theory which (if DK 68A93a is accurate) cannot in fact work (as Boeker 2228 points out).

Also worth quoting here, though not atomist, is

1. We have no Epicurean account of wind, except possibly Epicurus Ep.II 106, which may be part of an account of some other phenomenon (v. Bailey (1926) ad loc.).

2. The physical theory assumed may be Strato's (Gottschalk (1965) 120, 160f).

3. Unless its temperature is low.
Probl. XXV 22 (940a3ff): why does air constantly ebb and flow in lofty rooms? Perhaps because the air is πολύκενος; hence, when it begins to flow into the room, the air inside is compressed (συγχωρεῖ ... καὶ συστέλλεται — presumably, the void spaces get filled up). As a result the air outside becomes πολυκενώτερος ... καὶ ἔφεραν πολλὴν ἵσχει. The air in the room, being near, now flows into this space ὅπειρα τὸ κρέμασθαι καὶ τὴν τοῦ κενοῦ φύσιν μὴ δύνασθαι ἀντιστηρίζειν, "because it is in suspense (whatever that means) and the void can offer no resistance." This makes the room πολύκενος, and so air flows back into it; and so on.

From the point of view of the kinetic theory, the chief weakness of this is that it does not state (though it may be imagined) that the parts of the air are in constant random motion\(^1\), without which assumption there is no reason why air should flow into the void. Probl. XXV 22 is therefore further from the kinetic theory than several atomist passages. It is noteworthy that it speaks of flow

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1. Hero (if he accurately represents Strato's theory) suggests that in Strato air-particles are not in constant motion: he compares them to horn-scrapings and sand-grains, Spir. p. 6.23-6, p. 3.7f S.
into void: this was the one form of flow due to pressure-differences of which the ancients were thoroughly conscious. Only a few ancient authors, however, used flow into a void to explain wind; presumably because it was difficult to imagine large void spaces forming in the atmosphere. (This is easier to imagine on a small scale, as in Probl.XXV 22.)

The above discussion shows that, starting from the same assumptions as modern scientists, the ancients achieved some remarkable anticipations of their views, but often narrowly failed to work out the most plausible (and actually true) theory, as in DK 68A93a and Probl.XXV 22. These theories reveal the limits of what could be achieved - and the achievement is remarkable - without the use of precise experimental data.

1. Apart from expansion due to heat.
4) Diogenes of Apollonia.  

Diogenes derived wind from air, or vapour, evaporated from the moisture on the earth by the sun (12A27, 64A9, A17).  

These were widespread pre-Socratic ideas (v. pp. 59ff, 453-5); whether his complete wind theory included other details we cannot tell.

What is noteworthy is that Diogenes adopted these ideas when his general system might have suggested other theories. He cites the regularity of the winds to prove that intelligent ἀφίλο controls the cosmos (B5, B4, B5); this suggests that wind should be due to air's self-motion, which may indeed, be the immediate cause of wind. But it is not a sufficient cause, if the sun must first produce the vapour which is wind's material. I have argued that Anaximenes generally did not speak of heat as a physical cause (p. 127ff): in Diogenes, though his view of the ἀρχή was the same (implying that heat is not a primary quality4), heat clearly...
was important: not only does the sun cause evaporation, but hot air is πάντων τῶν ζώων και ψυχή (B5).\textsuperscript{1} This hot air is compared to that παρὰ τῷ ἁλῷ (ibid.), which suggests that the latter has a controlling function in the cosmos. It was a widespread belief that the sun controls the cosmos, or at least that heat causes various events in it\textsuperscript{2}; but it seems more appropriate to Diogenes' general theory to regard events as caused by air in its typical state, i.e. atmospheric air.

The same applies to the idea that wind's material is formed by evaporation. If all materials can change into each other, then wind's material (presumably air, p. 193) should be as easily formed from fire condensing as by evaporation from water; and in Anaximenes and Anaxagoras, of whose systems the same is true, vapour is not said to cause meteorological events (pp. 121f, 155f). That Diogenes refuses to follow them shows how widespread the view must have been, that wind is derived from vapour.

\textsuperscript{1} On animals' natural heat v. also A24, A28, A29, B6 fin.
\textsuperscript{2} v.pp. 181f, also 109, 116, 160f, 155f, 195.
5) Metrodorus of Chios\(^1\).

**DK 70A18:** διατόθες ἀναθυμιάσεως διὰ τὴν ἥλιαν ἐκχαυσὶν γίνεσθαι ὑφήν πνευμάτων θείων \(^2\). τοῦ δὲ ἑτησίας πνεῖν τοῦ πρὸς τὰς ἀρκτοὺς παχυθέντος ἀέρος ὁποχωροῦντι τῷ ἥλιῳ κατὰ τὴν θερινὴν τροπὴν ἐπισυμμέρεοντος, "the impulse of the (...) winds is from (?) wet exhalation, because the sun burns it. The Etesians blow because the air in the north has been made dense; as the sun withdraws (sc. southwards) at the summer solstice, this air flows upon it." Whatever the right reading, the context in Aetius suggests that the first sentence should explain winds in general, or all winds other than northerly ones (which are explained in the second sentence - the Etesians are not the only north winds, but may be mentioned here as especially important). \(^3\)

I assume, then, that to Metrodorus the normal cause of winds is the sun 'burning' water-vapour. That the Etesians are due to air suggests that air and vapour are virtually the same, which 70A4 and A16 confirm, saying respectively

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1. On his wind theory v. Gilbert 517.

2. ἄρμαν Diels (but most winds are cold), λόγων Kern (v.DK); I know no parallel in other wind theories to either conjecture.

3. If this is right, one might read πνευμάτων νοτίων (cf. the idea that the north and south winds are the only ones, v.p. 178n. However, the latter idea seems to have been that east winds are really south winds and west winds really north winds; and the sun could as easily cause west winds as east winds.)
that clouds are formed from πυκνούμενος ἀήρ and from ὕδατω γήαφορα. Metrodorus, being an atomist\(^1\), cannot have thought air-atoms and water-atoms identical; but presumably vapour derived from water contains many atoms of both types, and so could be regarded as 'air'.

Parallel passages in other authors (quoted p. 65 ) suggest that ἔκκαυσις should here be equivalent to λέπτυνσις, the conversion of water or air to something more like air or fire. 70A4 supports this (ὑδωρ ... ἀραιούμενον ἔξάπτεσθαι, so re-igniting the sun); but this view of the sun's extinction by night and re-ignition seems inconsistent with 70A9, the stars ἄνδ τοῦ Ἕλλου προσλάμπεσθαι \(^2\), and the notion of rarefaction does not occur in other passages, which relate the sun to cloud or air (70A14, A15, A20). It is therefore uncertain whether we should assume it in A18.

The second half of A18 recalls Anaxagoras' theory described on p. 171ff. Air is condensed in the north, presumably by the sun's action (on how this occurs v.p. 173 ). When the sun 'withdraws', i.e. moves south, after the summer solstice, the force by which it compressed the air must

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1. v.70A2, A3, A6, B1 context. 
2. 70A4, however, has a different account of the stars.
cease to act, and the air flows southwards upon the sun.\(^1\)
(Why this happens is not stated.)

Metrodorus was clearly not an original thinker about wind: all the elements of his account were borrowed from his predecessors.\(^2\) Its importance lies in indicating how widespread the theories he borrowed were.

1. There is no suggestion here that the condensed air causes the solstice, as in Anaxagoras (p. 172).

2. On wind derived from water-vapour v.p. 58ff; on the sun's action on vapour or ἄνηρ causing wind v.pp. 114, 116 (on Anaximander), 165 (on Anaxagoras).

3. I do not discuss ἐνδή (1.12 454), because I can derive from it no information about the cause of wind.
CHAPTER 5

THE HIPPOCRATICS

The Hippocratic writers\(^1\) were not interested in meteorology as such; they discuss wind and related topics only for their relevance to other subjects, and what they say generally does not, or may not, constitute a full account of them. Its value is that the relevant treatises were written before (or at least are uninfluenced by) Aristotle's work on meteorology\(^2\). Almost all our information about pre-Socratic meteorology comes from later testimonia, and may have been distorted by later ideas and terminology: the Hippocratic treatises enable us to check the testimonia, by providing specimens of the meteorological terms and theories which pre-Aristotelians actually used; I have often quoted them for this purpose in the preceding chapters.

There are, however, three passages on wind which merit a special discussion: De flatibus 3, De victu II 38 and De natura pueri 24–25.\(^3\)

3. I do not discuss Heb.d.3 (L.IX 454), because I can derive from it no information about the cause of wind.
1) De flatibus

Flat. 3 (L.VI 94.4) defines άνεμος as ήρος βεῦμα καὶ χεῦμα - probably the earliest surviving occurrence of this definition (p.57). At first sight, it differs from the normal pre-Socratic view, that wind is derived from cloud or water (v.p.59ff); but this need not be so in fact. Many later writers held both that wind is air in motion and that it is, or is derived from, exhalation;¹ and Flat. states that πνεῦμα can be derived from a liquid and condense to one (§§ (L.VI 102.15f) τὸ αἷμα ... τήκεται ... χλιαινόμενον καὶ γίνεται ἐξ αὐτοῦ πνεῦμα ... 15f τὸ γὰρ πνεῦμα συνιστάμενον ὑδόρ χεῖται ²). The author may therefore have believed that the material of wind was ultimately derived from water.

The definition of wind just quoted gives no clue to what sets the air flowing; but the author's following words, ὅταν οὖν πολὺς ἀὴρ ἵσχυτιν ρεῦμα ποιήσῃ (which refer to wind)

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1. e.g. Theophrastus (p. 327); [Aristotle] Mu.394b7ff; Seneca NQ V 1 & 4-5, etc.; Pliny NH II 114.

2. This πνεῦμα is within the body, i.e. is 'breath' or 'air', not 'wind'. (πνεῦμα and ἀὴρ are often synonymous in Flat., cf. especially L.VI 108.1 & 5, 20 & 21; 112.14 & 17.)
perhaps suggest that the air moves itself. 1 Cf. §9 (L.VI 94.2f)

άηρ is μέγιστος ἐν τοῖς πάσι τῶν πάντων

συνάστης; §4 (p.96.1) αὐτό τρομάζει; §10 (p.106.1)

αὐτόματος ὁ αὐτὸς ἀληθῶς ἐς τὰς φλέβας. 2 In the importance

he assigns to air, and in regarding it as self-moving, Flat.

was following Anaximenes and Diogenes; but it is doubtful

whether either of them regarded wind as due to air's self-

motion (pp.129f, 132f, 193f). Flat. therefore provides

some confirmation that such a view of wind did exist.

Flat.'s text does not suggest any cause of wind except

air's self-motion; but at least some air-movements are due

to other causes. One cause is heat: §6 (L.VI 102.6-8)

ῶσπερ ... ἄπτ ἃν ἕρηταιν ἀκμαὶς ἀνέρχεται ... ἐξουσίαν

toῦ ὑδατος, ὥσπερ κἀ̃ τοῦ σώματος θερμαινομένου διαίσθηε

diὰ τοῦ στόματος ὁ αὖρ; §9 (L.VI 104.13f) ἀφαιρεύομενον ...

ἠτὸ τῆς θερμαῖνης τοῦ ψυχήματος ἀνέρχεται τὸ πνεῦμα

toῦ σώματος; §14 (L.VI 114.8-10) τὸ αἷμα ... διαθερμανθὲν

1. They may, however, mean just that much air, when set in

motion by an external force, produces a strong flow

because of its quantity.

2. Norb.Sacr. similarly suggests that air moves itself:

§4 (L.VI 368.4f) ὁ γὰρ ὁλον τὸ πνεῦμα στῆναι (said

of breath, also called ἀὴρ in the preceding sentence);

§7 (p.374.11ff) ὅταν ὁ αὐτὸς ἀποκλεισθῇ ἐν τοῖς μέλεσι ...

dίσων ... διὰ τοῦ αἷματος ἄνω καὶ κάτω ὁμοιοῦ διάκοιντι;

§16 (p.390.12f) τὴν ... φρόνησιν ὁ ἀὴρ παρέχεται κτλ.
that heat causes various sorts of motion, including wind, was a common pre-Socratic theory\(^1\); Diogenes, presumably Flat.'s immediate source, accepted heat's importance (p. 193f.), so it is natural that Flat. does the same. In Flat., the heat, besides causing motion, causes rarefaction, the dividing up of a liquid, the formation of vapour: this would fit the rarefaction theory of wind (v.p.65ff). A possible alternative cause of wind is therefore heat.

The treatise seems to contain also a third suggestion, that air moves when there is a lot of it in a confined space: §10 (L.VI 104.19f) ὀταν ἀλ περὶ τὴν κεφαλὴν φλέβες γεμισθῶσιν ἥρος ... ἡ κεφαλὴ βαρύνεται τῶν φυσέων ἐγκεκιμένων. Cf. §14 (p.112.16ff) ἐπειδὰν ... ἐς τὰς ... φλέβας πολὺς ἀπὸ βρίση, βρίσας ὃς ἡμείν, καλύπτει τὸ ἀίμα ὀιείειναι. τῇ μὲν οὖν ἐνέστηκε, τῇ ὁ δὲ νυσθῆς ὀιείερχεται, τῇ ὁ δὲ θάσσον. As a result πᾶν ... τὸ σῶμα ... τετίνακται τὰ μέγερα τοῦ σώματος ὑπηρετέοντα τῷ ταράχῳ ... τοῦ αἷματος ... οὕτως ὃ ἀπὸ ταραχθεὶς ἀνετάραξε τὸ ἀίμα.

"When much air weighs upon the ... veins, and remains

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in place, weighing upon them, the blood is hindered from passing through them; and so in one place it stops (?: so Jones (1925)), in another it moves sluggishly, and in another more quickly." As a result "all the body ... is shaken, its parts following the confusion of the blood... Thus the air's confusion causes confusion of the blood. The details are obscure; but the enclosure of 'much air' in the veins¹ does seem somehow to initiate a confused movement of body, blood and air.²

The last two passages cannot be directly relevant to ordinary winds, because the air is enclosed. 810 (L.VI 104.19f) recalls the theories discussed on p.90ff (v.p.96-8); the second passage rather resembles Democritus' theory that wind occurs 'cum in angusto inani multa sunt corpuscula': as in Flat., this produces (initially, at least) a confused motion (v.p.179): it is interesting to find a similar theory in a non-atomist author.³

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1. The air must be within the veins, since it is mixed with the blood (L.VI 112.14f).

2. Another cause of air's motion seems to be a tendency to ascend (v.687 (L.VI 100.4), 14 (p.114.1f), 78 (p.102.4ff; partly quoted above); but this could not directly cause wind.

3. Remotely similar to Flat.14 is Vict.III 71 (L.VI 610.2ff): when men overeat, they at first sleep pleasantly, ἀλὴθεῖς ἡ δένων ὃς ἐξ ἀκτησθησθαι ἐπὶ τὸ σῶμα τὴν πλησιμονὴν, ἀπόκρισιν ... ἀριστοίοιοι, ἀλλὰ τῆς ὅπεναντομένη τῇ ῥοπῇ παράσοι τὴν πυχήν ... here, too, fulness causes a confused movement.
2) *De victu*

Vict. II 38 (L. VI 550.12ff; quoted p.60) "All winds naturally moisten and cool both animals' bodies and plants, for this reason: these winds (i.e., evidently, all winds) must blow from snow and ice and severely frozen places and rivers and lakes and land that has been moistened and cooled." This is a typical example of the pre-Aristotelians' normal wind theory (v.p.59ff), differing from the rest only in affirming that the sources of wind are cold. The material of the πνεύματα, though derived from water and ice, is presumably air or something like it: for the winds are compared with πνεῦμα = breath exhaled (L.VI 550.18ff); and the same passage refers to as τὸ πνεῦμα ὁ ἀνανέωμεν the air outside us which we breathe in (II 37 (p.528.17), 38 (p.534.13f)).

An interesting idea is that winds as they blow require moisture as τροφή: II 38 (p.534.8-11), πνεύματα that blow over land οἵ̣ ἔχοντα ... τροφήν ὄχθεν ἐκαγάγηται ... ἐκ τῶν ἔτης ἔλχοντα τὸ ὑγρόν ... "having nowhere else whence to draw nourishment for themselves, draw moisture from animals..." This accords with the general principle (I 3 (p.472.17f)) that τὸ μὲν ... πῦρ δύναται πάντα διὰ παντὸς κυνῆσαι, τὸ δὲ ὕδωρ πάντα διὰ παντὸς θερέψαι. Apart from living creatures, the author elsewhere speaks of
moisture nourishing fire and heat\(^1\), and, curiously, of its nourishing still air (II 37 (p. 528.17f) dry air ἐλκεῖ ... τὸ ὕγραιν ἐς τροφὴν ἑαυτῷ ). "Nourishment" presumably implies that a thing's matter is replenished, thus enabling it to fulfil its functions (cf. p. 206 ).

I 3 (p. 472.17f; just quoted) states that fire can move all things; cf. I 3 (p. 472.22f), also I 10 (p. 486.7ff), the hottest and strongest fire is πυχὴ, νῦν ... κίνησις κτλ. and πάντα ... κυβερνᾷ.\(^2\) Note especially passages where heat draws moisture from the body\(^3\) (since the account of wind in II 38 implies the drawing of moisture from the earth), or where moisture and heat help to cause flatulence (II 52 (p. 554.12f): dark, sweet wines φυσίων ὕγρασίν ἐμποιεόντες \(^4\); Ib. 21ff γλεῦκος φυσὶ ... ὅτι θερμαίνει ... )

All this suggests that heat causes wind's motion. But the implication of II 38 is against this: the north wind

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1. I 3 (p. 472.20f), 35 (p. 514.1f); II 47 (p. 543.1f) and 62 (p. 576.21ff), both on heat within the body.

2. See also I 9 (p. 482.14f), and I 35 (p. 514.1f, p. 516.7ff, p. 518.20ff, p. 520.17f) where fire in the soul causes its movement. (However, p. 512.21ff, 514.4ff suggest that ὑδατος τὸ ἑξηρότατον could move itself.)

3. e.g. II 57 (p. 570.8-10), 58 (p. 570.18-20); perhaps also II 62 (p. 578.3-5).

4. Wine is hot: II 52 (p. 554.7).
the south wind blows from similar places (II 38 (p.532.4ff), but διὰ ... τῶν ἔφοδων τοῦ ἥλιου καὶ ἐπὶ τὴν μεσημβρίνην πνέων, ἐκπετάται τὸ υγρὸν ὑπὸ τοῦ ἥλιου ... διὸ ἀνάγκη θερμὸν αὕτων καὶ ἐπὶ ἐνθάδε παραγίνεσθαι (Ib.8ff). The natural inference is that the sun, and so presumably, fire and heat, have no part in originating wind, but may affect its temperature etc. as it blows.

The author may have denied this, and have said that wind's motion is due to a small amount of heat, not sufficient to make wind feel hot. Alternatively, he may have thought wind due to some different cause of motion, such as later passages of Vict. mention, e.g. attraction into a place that has been 'evacuated'¹, or (perhaps) movement resulting from an excess of matter filling a place²; though neither of these were normally regarded as causing wind.³

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1. II 60 (p.574.16f) the body χενοουμένου ... τοῦ ὑπάρχοντος ὕγρος, πνεύματος ἐκπατοῦ πληρεύμενον ψύχεται (Cf.II 62 (p.578.3-5) though there heat is also involved.) I am not clear whether this means flow into a literal void, or something different.


The fact is that the author was interested only in wind's effects, not in its nature or cause: very likely, he meant nothing in particular by speaking of wind's τροφή, and intended no implication about wind's cause when he said it blows from regions the sun does not reach. If challenged, he would surely have said that heat caused the motion of wind, as of everything else; but the question did not interest him.

1. i.e. he thought just that moisture is τροφή for all things, therefore whatever absorbs it absorbs τροφή, without considering how the τροφή affects the thing. (Similarly, a modern meteorologist can call dry air 'thirsty' (Shaw (1933) 90.)
§24-5 explain why the earth's interior is hot in winter and cold in summer: in winter the earth πυκνοτέρη ... έστιν ... καὶ οὐξ ἔχει διαπυκνήθη ὑδαμίνην, "is denser, and nothing blows through it" (L.VII 513.26f); when rain falls on the earth, ὅταν ἀποπνέῃ ἐν τῇ γῇ ἀπ' αὐτοῦ, οὐ δείκται πρόσω, ἢτε πυκνής θαυμάσια τῆς γῆς' ἀλλ' ἐπὶ ὅπισω ἐς τὸ υπώρ ἔρχεται, "when wind blows from it (the rainwater) within the earth, it does not go far through it because the earth is dense; but the blast goes back into the water" (ib.520.17-19, cf.20-22). In summer, on the other hand, the earth is ἀραὶή; and it has water within itself (ib.522.9-12). "All winds come to us from water; and it is possible to infer that this is so: for winds always blow from all rivers and clouds (and a cloud is a continuous volume of water in the air)" (ib.12-15, quoted p.59). Consequently, within the earth, χωρεόντος ... τοῦ ὕδατος αἰεὶ ἀποπνέει αὐτόθεν ἐτερον ἐς ἐτερον πνεῦμα: τὸ δὲ ἀποπνέουν διὰ τῆς γῆς ἔρχεται κοινής καὶ ἀραϊῆς θαυμάσια καὶ ψυχος τῇ γῇ ποιέει ..., "as the water flows, more and more wind is constantly blowing from it; the wind that blows from it passes through

the earth, which is light and rare, and produces cold there" (ib. 17-19).

πνεῦμα is clearly 'wind' rather than 'air', as is shown by 'πνεῦματα' in 522.12ff (it is natural to speak of 'winds', but not of 'airs'), and by the fact that the πνεῦμα moves through the earth to cool it. The production of πνεῦμα on a minor scale is compared with these processes, in 522.20ff: a skin is partly filled with water¹, punctured, hung up and then lifted: πνεῦμα διαϰωρήσει διὰ τοῦ τετρημένου (524.3); if the skin is completely filled with water, no πνεῦμα passes through the puncture, ἀλλ' ὑδωρ, οὗ γὰρ ἔχει εὕρυχωρίνῃ ἥ ἀπονεῦσεται τὸ ὑδωρ, "for there is no open space in which the water can give off πνεῦμα".² Thus the formation of wind is directly comparable to the small-scale production of vapour (and its subsequent movement). Hence, what is said elsewhere of πνεῦμα on a small scale should apply to wind also.

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1. The water has εὕρυχωρίνην, p. 524.2.

2. 522.20ff. The skin is evidently hung up with the puncture at the top. Raising the skin bends it, so reducing the volume within and forcing the adjacent matter out through the hole: if the skin is full, this is water, if not, it is air. (Cf. Senn (1923) 245ff.) [Hippocrates] errs in supposing that the πνεῦμα forms within the skin; it is there, as a separate body, all the time.
§12 speaks of the 'breathing' of the human embryo, comparing it with πνεῦμα from other things, especially green wood and leaves that are heated or burned. Of the latter he states, as in §25, that moisture is a source of πνεῦμα:

p.486.22f ὁκόταν ὑδατερμανθῇ τὸ ὄψραν τὸ ἐν τῷ ἄνθρῳ ἔνεδν, πνεῦμα γενόμενον χωρέει ἔξω. (Cf.488.5f.) But usually in this § heat causes πνεῦμα: 488.7ff πάντα ...

ὁκόταν θερμαίνεται, πνεῦμα ἀφίησι, καὶ ἕτερον ψυχρὸν κατά τὸ τοῦτο ἄντισπερ, ἄφ' οὔ τρέφεται ... ἡ γονὴ θερμαίνομένη ἐν τῇ μήτρῃ πνεῦμα ἄσχει καὶ ἀφίησιν ἄμα δὲ καὶ ἀπὸ τῆς μητρὸς πνεούσης πνοήν ἄσχει ... "everything that is heated emits breath, and thereupon draws to itself other, cold breath, from which it is nourished". (Cf.486.3-10). The second sentence distinguishes breath due to the embryo's heat from breath that it derives from the mother:

1. With this cf.p.436.11f, 18-22, p.535.7ff; but Nat.puer. contains no indication that this drawing in of cold breath occurs when wind forms, unless πνοὴ 'going back into the water' (p.520.17-19, quoted p. 207 ) was regarded as a drawing in of breath by the water - in any case, that only applies to certain 'winds'.

The author also states that πνεῦμα, emitted from wood, ἐλίσσεται κερὶ τῷ πυρίν, 'revolves about the crack' (p.486.17): I am unsure what is meant; it seems unlikely to apply to wind.
presumably the former is not derived from outside the embryo, but forms within it, i.e. heat causes \( \pi e \nu \upsilon \mu \alpha \) to form. Perhaps, therefore, the formation of \( \pi e \nu \upsilon \mu \alpha \) = wind is also due to heat.

Possibly also relevant to wind is §23, p.516.21ff, which suggests that \( \pi e \nu \upsilon \mu \alpha \) is formed from \( l \chi \mu \alpha \zeta \) (cf.§22, p.514.15ff); compare the formation of wind from water in §25.

In §22 p.516.16f the sun draws watery material to itself; in Morb.IV, too, which Littré regards as a continuation of Nat.puer., heat causes evaporation (cf. passages cited on p.43). As presumably the formation of wind from water resembles (if it is not identical with) the formation of vapour, these passages are further evidence that heat causes wind. §§24-25 themselves, however, say nothing about heat causing wind; heat is not involved in the 'experiment' with the skins which illustrates the process of wind-formation; and §25 (p.522.10f) speaks of the sun drawing \( l \chi \mu \alpha \zeta \) to itself, without suggesting that its doing so causes wind. There is, therefore, here as in Vict., some doubt whether the author in fact thought heat causes wind.
4) Conclusions.

I said on p. 198 that the Hippocratics are mainly important in meteorology as providing accurately-preserved specimens of pre-Aristotelian theories; thus Flat. provides the definition 'wind is air in motion' (cf. p. 57f.), and Vict. and Nat. puer. specimens of the common theory that wind is derived from water. My discussion shows that they probably held further ideas on wind: the authors of Vict. and Nat. puer. probably thought wind caused by heat - another idea attributed to the pre-Socratics, cf. pp. 195, 197 - and the author of Flat. seems to think wind is caused by air's being alive and moving itself: a theory which (as I have argued) certain pre-Socratics should have held, though the available evidence fails to prove it. Thus these ideas all fit in with the known or probable views of the pre-Socratics. The Hippocratics also mention unexpected ideas about wind - e.g. that it is nourished - but these seem unimportant. All this is what we might expect, since (as said on p. 198) the Hippocratics had little interest in meteorology as such.
CHAPTER 6

ARISTOTLE I: PHYSICAL PRINCIPLES

UNDERLYING ARISTOTLE'S METEOROLOGY

1) The controlling forces of the sublunary region.

The heavens are a system of concentric spheres, revolving for ever, composed of the 'fifth element' and filling the space from the moon upwards (Cael. I 2, etc.); below them is the changeable sublunary region, filled with fire, air, water and earth (Mete. I 2 al.) in that order from above (e.g. Cael. 287a51ff, 312b3ff). The fire and air roughly correspond to our 'atmosphere'.

All events in the sublunary region are ultimately due to the movements of the heavenly spheres. 1 Mete.339a19-24: δ ... περὶ τὴν γῆν ὅλος κόσμος ... ἐστὶ ... συνεχὴς ... ταῖς ἄνω φοραῖς, ἵστατε πᾶσαν αὐτὸν τὴν δύναμιν κυβερνᾶσθαι ἑκείθεν, ὡσεὶ γὰρ ἡ τῆς κινήσεως ἅρχη πᾶσιν, ἑκείνην αἰτίαν νομιστέον πρῶτην. Cf. GC: the heavens' motions cause γένεσις and φθορά (336a15ff), the actual cause being the sun's motion along the ecliptic (ib.25-b2); the sun's motions cause the cycle of the seasons, which in turn cause other

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events (338a17-b5). 1

One would naturally suppose that the sun causes all these changes by its heat; and Aristotle certainly regarded heat and cold as the principal efficient causes of sublunary events. 2 They are the active pair (ποιητικά) of the four primary opposites (GC 329b23ff), which are the source of other opposites (ib.32ff), and whose combinations produce the four elements (ib.11 3); the same four opposites cause the main biological events (PA 648b2ff). Heat and cold cause, or help to cause, animals' generation 3, nourishment, growth and motion 4; and heat is essential to life. 5 In Mete.IV, heat and cold are the principal efficient causes of change in inanimate bodies 6; and, in meteorology, heat

1. Cf. also Cael.II 3; Ph.VIII 6-9; also Ph.II 194b13, metaphor.A 1071a15-17. (Similar views were held previously, cf. p.181ff, 194.)


3. GA 736b33-5, 762a18-22; especially, 777b25ff: sun and noon contribute to all τὰς γενέσεις καὶ τελευσεις. αἱ γὰρ θερμότητες καὶ ψύξεις μέχρι συμμετρίας τινὸς ποιοῦσι τὰς γενέσεις, μετὰ δὲ τὰτα τὰς φθοράς.

4. PA 652b7ff, 653a31; GA 740b30ff, cf. 743a4ff; de An. 416a12ff; MA 703b14f.

5. Ph 465a18ff, 469b7ff, 474b12; PA 652b7ff.

6. Cf. 378b12 et passim. (Following Lee vii, xiiiiff, and Gottschalk (1961), I regard the book as in outline by Aristotle, though probably including later alterations and additions).
(usually derived from the sun) causes the exhalations which cause almost all meteorological phenomena (v.p. 246), while cold produces precipitation from the wet exhalation.

1. v. mete. 341b6f; 347a5f; 349b3; 354b26ff; 355a15, b19; 356b22, b27ff; 359b34f; 361a7ff (all mentioning sun only). 346b24ff mentions the sun and 'other heat from above'. 360b31f mentions 'heat from above' (but not the sun), and also heat from within the earth. 350a5ff, 16; 362a5ff; 364a11ff; 365b25ff mention heat from the sun and heat from within the earth. Heat causes evaporation in other treatises also, v.p. 258.

2. Mete. 346b26ff, 347a9, 15ff, b12ff, etc.
2) **The generation of heat.**

It follows from what I say in §1 that the heavenly spheres must *exercise* their control of sublunary events by inducing heat and cold there; but how they do so raises a problem, for the fifth element, which composes them, has been 'removed by nature from among the opposites' (ἐξελέσθαι ἐκ τῶν ἐναντίων) (Cael.270a13ff), and so can be neither hot nor cold (cf. Cael.II 7, Mete.341a16, 31ff).

The solution to this problem Aristotle gives only in Mete., and in Cael.II 7, a chapter more closely related to Mete. than to the rest of Cael.¹

The heavenly spheres produce two effects in the sublunary region. First, the region of fire, and the upper part of the air below, are carried round with the heavens' revolution²; air below the level of the highest mountains does not revolve², but the revolving air affects it in causing winds' motion (Ib.351a22ff).

Second, and far more important, the heavenly spheres produce heat: as they revolve, the heavenly bodies ignite by

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1. As Strohm (1935/6) 5-7 points out.
3. Mete.341a1ff, 344a9ff; cf. IA 699b23f.
their motion (as we would say, by friction\(^1\)) the matter immediately below them: Cael.289a19f ἡ ... θερμότης ἀπ' αὐτῶν (the heavenly bodies) καὶ τὸ φῶς γίνεται παρεκτριβομένου τοῦ ἀέρος ὕπο τῆς ἑκείνων φοράς; cf. Ib.30ff; Hete.340b1ff, 341a17ff.

This raises several difficulties. First, why do only the heavenly bodies themselves emit heat and light\(^2\), when the whole sphere in which each body is situated is composed of the same material (Cael.289a11ff), and is (presumably) equally in contact with, and so rubs against, the air? Second only the sphere nearest the earth (i.e. the moon's\(^3\)) can touch the air, whereas Aristotle states that the sun causes most heat by this method.\(^4\)

A third difficulty is that Aristotle speaks of ἀέρ being heated by motion, not πῦρ, whereas πῦρ occupies the highest place among the sublunary elements (p. 212). This, however, is explicable.\(^5\). To Aristotle, πῦρ has two senses:

1. I am not certain whether the ancients realised that rubbing is an essential part of the process.
3. Hete.340b8, 341a22ff, 345b1ff.
5. Lee 24 gives (briefly) a similar solution.
'elemental fire', a kind of hot (or heat-producing) matter, and 'fire' in the everyday sense: a process, in which fuel turns to smoke and ashes, giving out heat and light.\(^1\) Cf. Mete. 340b21ff, around earth and water there are ἄηρ τὲ καὶ ὅ ὁιδὰ συνήθειαν καλοῦμεν πῦρ, οὐχ ἔστι ὃ ἐπὶ πῦρ ἐπερβολὴ γὰρ θερμῶν καὶ οἷον ζέσις ἔστι τὸ πῦρ. That is, the proper sense of πῦρ is my second one, a process, 'a sort of boiling'; the fire of the highest sublunary region is 'elemental fire': a hot, dry material, which may be 'on fire' in the proper sense, or may not (v. infr.): consequently, ἄηρ can include it as well as the hot, wet matter below, which is ἄηρ in the strict sense.\(^2\) (Cf. 340b24-6 τοῦ λεγομένου ἐφ' ἡμῶν ἄερος τὸ μὲν περὶ τὴν γῆν οἷον ὄγρον καὶ θερμόν εἶναι ... τὸ ὁ ὑπὲρ τοῦτο θερμοῦ ἡδῆ καὶ ἔρην\(^3\)). This stuff is called 'fire' because it is highly inflammable (Ib. 341b16ff), and easily ignited by motion.\(^4\) It is identical with the hot,
dry exhalation. 

Aristotle's theory of the heavenly bodies' heat contains also another difficulty: how is frictional heating consistent with his general theory of change? Aristotle's element theory assumes that changes occur between two opposites, e.g. heat and cold, in a substrate (fn. I 6-7, especially 190b29ff; GC 329a24-b5), and that hot, cold, wet and dry are primary opposites, irreducible to any other pair (GC II 2, especially 330a24-29). Things totally unlike - e.g. a line and whiteness - cannot act on each other except by accident (ib.323b25ff); ἀνάγκη ... τὸ ποιοῦν καὶ τὸ πάσχον τῷ γένει μὲν ὁμοιον εἶναι καὶ ταῦτα, τῷ ὀ' εἶδει ἀνόμοιον καὶ ἐναντιον ... (ib.31ff). οἶο εὐλογον ... τὸ τῇ πῦρ θερμαίνειν καὶ τῷ ψυχρὸν ψύχειν, καὶ ὅλως τῷ ποιητικὸν ὁμοιον ἑαυτῷ τὸ πάσχον: τὸ τῇ γὰρ ποιοῦν καὶ τὸ πάσχον ἐναντία ἐστί, καὶ ἡ γένεσις ἐλς τοῦ ἐναντιον (324a9ff).

1. Ib.6-16: the smoky (Ib.10 καπνώδη) exhalation ἐπικολάξειν διὰ τὸ θερμὸν ... διὰ ταῦτα ... κρῶτον ... ὑπὸ τὴν ἐγκύκλιον φορὰν ἑστιν τὸ θερμὸν καὶ ἕρων, δ' ἐλέγομεν πῦρ (ἀνάψυκτον γὰρ τὸ κοινὸν ἐπὶ πᾶσης τῆς καπνώδους διαχρίσεως ...). Obviously the καπνώδης διάχρισις is the same as the smoky exhalation; cf. Ib.35, 35, 342a18, 28 etc., where this material is called ἀναδυμίαςις.
Thus what acts on a thing should itself possess the quality it imparts\(^1\); this cannot be so when the heavenly spheres produce heat, for they cannot be hot.

Aristotle does indeed recognise that the principle just quoted is not universally applicable; e.g., GC 324a26- b4 states that τὸ πρῶτον κινοῦν or κοινοῦν, e.g. ἡ λατρίκη, (as opposed to τὸ ἔσχατον καὶ ἀπτόμενον) need not have τὴν αὐτὴν ὀργêν as what it works on; evidently it need not possess the quality it imparts. Other passages mention different exceptions\(^2\); none of them seems particularly adapted to explaining frictional heating\(^3\), but their existence does mean that Aristotle's theory of the heavenly bodies' heat cannot be said to contradict his element theory. Nevertheless, the former theory is one for which the element theory makes no provision - this illustrates the limited scope of the element theory.

In Cael. Aristotle supports his theory of the heavenly bodies' heat only by citing examples of heating due to

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1. Cf. also GC 320b19ff; Ph.II 198a26f, VIII 257b6ff; Metaph. Z 7-9, I 1049b24-9; de An. 417a14ff, 429b31ff.
2. v. Ph.VIII 257b12, Metaph. Z 1032b1, 21ff, 1034a22ff, b16ff; also, GC 320b18-21 (where I would adopt Joachim's (1922) reading and interpretation).
3. Except perhaps Metaph. Z 1034b16ff: only an actually-existing substance can generate another substance, but this does not apply to qualities. But that contradicts GC 324a9ff, quoted p. 218.
friction or percussion (Cael.289a21f πέφυκε γὰρ ἡ κίνησις ἐκπυροῦν καὶ ἡμῖλα καὶ κλίπους καὶ σιδηροῦ. He then describes the (imaginary) melting of a lead missile in flight); but in Mete. there seem to be hints about now the process works\(^1\): 340b11ff φερομένου ... τῶν πρῶτων στοιχείων κόλαχ ... τὸ προσεχές ἀεὶ τῶν κατω κόσμων ... τῇ κινήσει διαχρίνυμεν ἐκπυροῦται. Cf. 341a17f ἄραμεν ... τῇ κίνησιν ὅτι οὐναὶ διαχρίνειν τῶν ἀέρα καὶ ἐκπυροῦν, also 341a26ff. Frictional heating, then, is due to the διάχρισις, the 'separating' or 'dissolving', of the heated matter. διαχρίνειν here cannot mean simply 'disperse', since that would not cause the matter to change its character; and it is unlikely to mean 'separate into constituent elements', since, so far as we are told, there is but one element, fire, in the highest sublunary region.\(^2\)

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1. I know no passage in other works that explains friction etc. though some do mention it (v.HA 516b10f, PA 655a17, GA 717b25, Metaph.2 1052b25f).

2. As elemental fire is dry exhalation (p.217f), and the two exhalations are said never to be separated (Mete.359b32f), it is conceivable that this region contains a little wet exhalation mixed with the dry, which is separated from the dry when the dry ignites. But if Aristotle believed this, he would surely somewhere mention that both are present in the highest sublunary region. (Mete.340b31f οὐκ ἐνεστὶν ἄηρ μόνον ἀλλὰ μᾶλλον οἷον πῦρ might be quoted to support such a view. But the last three words suggest that the meaning is "there is there not just ordinary air but rather something special, resembling fire" - referring to the quality of a uniform body, not to a mixture.)
Probably, therefore, διακρίνειν here means 'rarefy', as frequently in Mete. (p.75): the bits of elemental fire are separated from each other, so that the fire is made fine and rarefied.¹

Aristotle believed that the change of water to air or air to fire involves rarefaction (p.74f), and that such rarefaction (at least of water to air) is caused by heat (p.78n). Evidently he also accepted the converse: friction rarefies matter, and thereby makes it hot.² (This need not imply that temperature changes can be reduced to changes in density, which would contradict the view that heat is a primary quality²; only that the two are so closely


2. Cf. Mete.367a 9-11, 371a15f ἀὴρ εἰς μικρὰ χερματισθεὶς, or πνεῦμα becoming λεπτότερον, ignites (cf. Strohm (1932/6) 65n11b); 367b5f συνιούσα ὑ' ὑγρότητα ἡ ἀτμισθότης ἀπόρροια ποιεῖ τὸ ψύχος. Also Anaximenes 1551 (e.g. ἡ πνοή ... γίγνεται θερμὸν ὑπὸ μανότητος); probably Democritus 68A135(65) (τὸν ... δὲν ... θερμαλνὲιν τὸ σῶμα κενότητας ἐμποτοῦντα, κτλ. ; Seneca Nq II 57.2 ("sera ... motus extenuat ... extenuatio incendit").

3. Ph.VIII 260b7ff (saying all other πάθη can be reduced to differences in density) cannot be Aristotle's real view, cf. Wicksteed and Cornford (1934) ad loc., Ph.VIII 265b30ff.
connected, that to cause one must involve causing the other. 1)

1. Just as, for example, a draught makes a fire blaze up, and a bright fire makes its own draught. In fact, however, while heat expands a gas, expansion cools it (Barton (1953) 257f) - but this is an apparent paradox, and difficult to observe: no wonder the ancients missed it.
5) The transmission of heat; characteristics of the atmosphere.\(^1\)

At Mete.341a29-31 Aristotle, after describing the generation of heat by friction, continues: διά τε ταύτην ὁμ τὴν αὐτὶν ἀφικνεῖται πρὸς τὸν τόπον ἡ θερμότης, καὶ διὰ τὸ τὸ περιέχου πῦρ τὸν ἄξον διαρραίνεσθαι τὴ κινήσει πολλάκις καὶ φέρεσθαι βία κάτω (..."because the fire that surrounds the air is often scattered by the motion and forcibly borne downwards"). Thus a secondary means by which heat reaches earth is the actual descent of elemental fire. The primary means is, apparently, said to be friction; but friction cannot explain heat's transmission through the lower air, which is not in constant motion: presumably heat passes through the lower air simply because, as GC describes, the potentially hot must become hot when τὸ θερμαντικὸν is (i.e. an actually hot body) is present\(^2\) (524b8ff, cf.a9ff); fire heats a distant body by heating the air between, which heats the other body (527a3ff). In this way heat is transmitted without movement of matter; presumably this is part of the process which is contrasted with the 'scattering' of heat in Mete.341a29-31.

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2. Bodies must be in contact to act on each other, cf. 322b22f, Ph.III 202a8f, VIII 251b1-3.
In addition to heat from the region of fire, heat from within the earth also affects the atmosphere, since it helps to cause exhalations (v.p. 214n).

Aristotle knew, what is obvious in mountainous country, that temperature falls with height (Mete. 340a25ff); he says this is because the cold part of the atmosphere "is not near enough either to the stars ... or to the rays reflected from the earth". The reflected rays cease διὰ τὸ σχίζεσθαι εἰς ἀνατίς; "because they are split and lost in the wideness of space" (reflected from a spherical earth, they must be separated from each other as they move away from it, cf. Philoponus 27.51-53).² Hence, the lower atmosphere is heated twice, by the ray descending and ascending (cf. Alexander 11.27 ὑπολή παράδοφ), the upper air once only.³

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1. Cf. also 346b23f, 354b31, Somn.Vig.457b31ff, PA 553a4ff, mentioning or implying the coldness of the upper air. For this idea in earlier authors v.p. 16ff.

2. If a ray consists of hot matter descending to the earth, then it clearly can be reflected, i.e. can rebound; but a ray should normally be a flow of heat without movement of matter (cf.p. 223, on heat-transmission): Aristotle never explains, and I find it hard to imagine, how such a ray can be reflected. Indeed, Aristotle says very little in de An. and Sens. about the reflection of light and sound: probably he just accepted reflection as an obvious empirical fact, and never tried to work out how it happens.

3. Aristotle is right in supposing that temperature falls with height because of heat from the sun received by and re-emitted from the earth; he is wrong about the details. V. Sutton 19.
The lower air is misty and dense, compared with that above: Mete. 575b10ff, ἀνυφός air makes things look larger, e.g. τὰ ἐν ταῖς ἀκλύσιν, οἶνον καὶ ἥλιος καὶ ἀστρα ἀνίσχοντα καὶ ἰόντα μᾶλλον ἥ μεσοπρανοῦντα (cf. on this Alexander 149.17f, rising and setting stars οἶδα ... τοῦ περιγείου ἄερος ὀρατά, δέ ἀκλυσίν καὶ παχύτερος τοῦ ἐν ὑψει). Cf. Mete. 342b5ff (cf. Alexander 24.17f), light οἶδα ... ἀνυφότερον διαφαινόμενον tends to look red, e.g. (9f) rising and setting stars ἐκ τῆς ἀσίμα - this last proviso seems to introduce a further complication.

This density should imply that the lower air is more like water than the upper (p. 59ff). It is presumably connected with Aristotle's theory that clouds (plus, presumably, dependent phenomena, e.g. rain, lightning) occur only below the highest mountain-tops, in the part of the air that does not revolve (v.p. 215; Mete. 340b32-1a5); winds, too, obviously cannot occur, in their ordinary form,

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1. This idea presumably originates simply in the appearance of the atmosphere in Greece (cf. Guthrie (1950) 208). (Also, clouds generally do not appear to occur very high above the earth.) It is one derivative of the contrast between ἄφω and ἀλων as different parts of the space above the earth, which first occurs at Ε 288.
in the revolving air.¹

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¹ This, in its context, is the only possible meaning of ἱστημένος ἀνάμεσα τά πνεύματα τῶν ἐν ψηλών ὀροί, cf. Strohm (1935/6) 65-7; Philoponus 33.3ff; Olympiodorus 171.17ff. (However, other authors with similar theories (v. Capelle (1916)) presumably meant that there is total calm above the highest mountains; and the preceding statement that winds rise in marshy districts seems inconsistent with the rest of Mete. Perhaps 340b36-1a1 is an interpolation.)
4) Air as an element and the atmosphere

Air is characterised by the primary opposites hot and wet (GC II 3, 330a30ff); this chapter of GC suggests no variation or limitation to air's heat and wetness, except 331a3ff, saying air belongs to moisture rather than heat. One element changes into another when one or both of its qualities changes into its opposite; hence air changes readily into fire (hot and dry) or water (cold and wet), but less easily into earth (cold and dry), since this involves change of both air's qualities (GC II 4).

This is theoretically very neat, but at best an over-simplification, as 330b21ff admits: οὐχ ἐστὶ δὲ τὸ πῦρ καὶ δ ὄλας καὶ ἐκαστὸν τῶν εἰρημένων ἀπλοῦν, ἀλλὰ μιχτόν. τὰ δ' ἀπλὰ τοιαῦτα μὲν ἔστιν, οὐ μὲντοι ταῦτα, οἶον εἴ τι τῷ πυρὶ ὀμοίουν, πυροειδές, οὐ πῦρ ... τὸ δὲ πῦρ ἐστὶν ὑπερβολὴ θερμότητος κτλ. "Fire, air and each of the aforementioned bodies (i.e. fire, air, earth and water in the everyday sense) are not simple bodies, but mixed; the

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1. In the strict sense, excluding elemental fire.
2. Cf. Strohm (1935/6) 6, 11f on the 'fictive' character of GC's elements.
3. A passage that interrupts the argument, and is perhaps a later addition.
4. i.e. are not πρᾶτη ὄλη characterised by two primary opposites only.
simple bodies are like them (i.e. are like fire etc. in the everyday sense), but are not the same; for example, an element resembling fire is fire-like, but is not fire... but fire is an excess of heat ..." This interpretation is proved by Mete.340b21ff (quoted p. 217): both passages mean that πῦρ's true sense is its everyday one, 'a process of combustion', and not the philosophers' sense 'elemental fire'; GC makes a similar distinction with regard to the other elements. To say that the names used for the elements do not properly apply to them (which implies that they have no names of their own), comes near to admitting that we never perceive elements in a pure state: what actually exists around us is mixtures of them. Ib.33f confirms that 'pure' air does not exist, saying of the elements: ἄξρα μὲν καὶ εἰλικρινέστατα πῦρ καὶ γῆ, μέσα δὲ καὶ μεμιγμένα μᾶλλον ὑδωρ καὶ ἄηρ .

The atmosphere must be a mixture, if Aristotle is to σώζειν τὰ φανόμενα ; for the atmosphere is obviously not a uniform hot, wet body. In the terms of his analysis in

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1. Which is virtually that of Joachim. (1922) ad loc.
2. GC II 8, concluding (335a22f) that ἄπαντα τὰ σώματα ἐξ ἄκατων συνέστηκε τῶν ἄκατων , also suggests that 'pure' elements do not occur.
GC, Aristotle would presumably say that the atmosphere is a mixture of all four elements; because, once air's neat and wetness is tempered by cold and dryness, then there is present some hot and wet, some hot and dry, some cold and wet and some cold and dry. 1 But it would sound absurd to say that an atmospheric event was due to an admixture of earth in the air. Hence, in Mete., Aristotle adopts a different mixture theory: air is a compound of two exhalations, one cold and wet, the other hot and dry: ὃστε καθάπερ ἐκ σύμβολων συνίστατο ἐν δ ἀηρ υγρὸς καὶ θερμὸς (360a21ff, cf. 340b24ff). 2 The mixture is presumably of the sort described in GC I 10: something different from its ingredients, which no longer exist ἐνεργεῖα (GC 327b23ff, 328a6ff). 3 (The exhalations never occur separately, Mete. 369a14.)

1. That all four elements are present when the four opposites are is implied by GC 335a7-9: ἐκεῖ ... ἐνυπάρχει ... θάτερα ἀκρα τῶν ἐναντίων ("of the pairs of opposites, one set of extremes is present"); ἀνάγκη καὶ θάτερα ἐνυπάρχειν, ὡστ' ἐν ἄπαντι τῷ συνθέτῳ πάντα τὰ ἀκλά ἐνέσται.
Cf. Joachim (1922) ad loc.

2. ἐκ σύμβολων: the two exhalations are two halves which naturally fit together to make a whole, air (cf. LSJ s.v. σύμβολον I 1): thus air is really a unity, although formed from two other bodies. (The usage here differs from GC 331a24, b4, 332a32, where elements which share a common quality ἐχει σύμβολα πρὸς ἀλληλα.)

3. Olympiodorus 38.17-19 says the exhalations are ὁ θατὸς χρᾶειν συνημμέναι (ὁς γὰρ ἐν πάλιν διόστατο), ἀλλὰ θατὸ παράδεσθειν. But the ingredients of an Aristotelian mixture can be separated, GC 327b23-9. (They exist in the mixture ὑναμένετε, as do the exhalations when mixed, Mete. 369a14.)
Thus all four opposites are present in air, and variations of temperature and humidity can be explained by assuming variations in the mixture. The statement that ἄηρ is wet and not presumably now means that, in air, these two are generally stronger than their opposites.

This theory cannot be held to contradict GC's element theory, if GC's pure elements have no actual existence; the only valid criticism of GC would be that its elements have become wholly otiose: all that matters is its account of the opposites\(^1\) (which Mete. does follow, v.p. 236ff).

However, this distinction between the theoretical pure elements, and the actually existing mixtures called 'air', 'fire' etc., may have been less clear in Aristotle's mind than in the account just given. The main passage in GC which makes the distinction (330b21ff) may be a later addition\(^2\);

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1. As PA 646a12ff admits: bodies are formed \(\varepsilon \times t\omicron v\) καλουμένων ὑπὸ τιμων στοιχείων ... ἕπι δὲ βέλτιον ῥοσ \(\varepsilon \times t\omicron v\) ὀυμάμεων λέγειν ... (i.e. hot, cold, wet and dry). Mete. IV, too, begins by analysing the primary opposites, only mentioning in passing that the elements are formed from them.

2. v.p. 227 (I assume it is an addition by Aristotle himself, since other passages of GC quoted on p. 228 are consistent with 330b21ff, though they do not go so far.)
and at the beginning of Mete. (339a11-340b21) Aristotle summarises his element theory without giving any hint of it. The distinction is first implied only at 340b22ff, where Aristotle distinguishes 'elemental fire' from fire in the normal sense (v.p. 217 ), and states that the (lower) air derives its qualities from the exhalations (340b24f). Only 360a21ff clearly states that air is a mixture of the exhalations; and Mete. nowhere makes the distinction I have described in general terms. Perhaps, therefore, Aristotle was conscious of the distinction only fitfully and partially; in many passages he may assume that the air, water etc. he mentions are the same as the elements described in GC.

One aspect of Mete.'s 'mixture theory' of air has clearly been brought into it from GC's 'pure element' theory, and fits the new theory rather badly: the idea that air is wet and hot (Mete.340b24, 360a26). Aristotle has to say this in GC, because one element must be hot and wet, and this is, doubtless, least inappropriate to air.¹ But in practice the atmosphere is frequently cold or dry, as

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¹. Earlier philosophers mostly held either that air has no fixed thermal properties (Anaximenes 15A7(2), Diogenes 64b5 (DK II p.61.17f), cf. [Hippocrates] Flat.3 (L.VI 94.11-13)), or that it is cold (Anaxagoras 59A70). However, [Hippocrates] Carn.2 (L.VIII 584.15f ) says ἄφρ is hot and wet.
Aristotle admits\(^1\); outside Mete., his theory that the function of breathing is to cool our bodies (Resp.472a33ff, etc.), and that air's cold cools small animals without their breathing\(^2\), implies that air is not normally hot.\(^3\) Mete.'s statement that ἄηπ is hot and wet is, therefore, a relic of the superseded theory of GC, which Aristotle himself frequently ignores.\(^4\)

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1. Thus, the upper air is always cold (p. 224 ), and Aristotle often speaks of cold or drought in (evidently) the lower atmosphere (e.g. Mete.1 10-11; 360b1ff; 367a25ff; GA 738a19ff; 782b33ff).

2. Ib. 474b25ff, 475b6ff.


4. However, he has other theories where air's heat or moisture is important (e.g. Sens.443a6f, b5, his theory of smell. V. also p. 256 ).
5) The nature of the exhalations.\(^1\)

Hete. 341b6-10 θερμαίνομένης ... τῆς γῆς ὑπὸ τοῦ ἑλίου τὴν ἀναπνείαν ἀναγχαίον γίγνεσθαι ... διπλῆν, τὴν μὲν ἀτμιώδωστέραν τὴν δὲ πνευματώδεστέραν, τὴν μὲν τοῦ ἐν τῇ γῇ καὶ ἐκ τῇ γῇ ὕγρου ἀτμιόδα, τὴν δ' αὐτῆς τῆς γῆς οὕσης ξηρᾶς καπνώδη. Αἰμὶς is wet (Ib. 340b27f, 360a22 etc.), probably cold (see below), and ὑπνάμει οἶον ὕδωρ (340b29); dry exhalation - formed, 341b10 makes clear, from the earth as a material\(^2\) - is hot, dry and ὑπνάμει οἶον πῦρ (340b28-30, 360a25). Neither exhalation occurs without the other (359b32ff, cf. 358a21ff, 362a10), at least in the lower atmosphere (Aristotle never suggests there is water-vapour in the sphere of fire, cf. p. 220 ); the proportion in which they are mixed varies (v.p. 237f ). The dry exhalation is identical with the elemental fire of the highest sublunary region (p. 217f ); the air of the lower atmosphere is a mixture of both exhalations (v.p. 229 ). (Presumably all existing air and fire has at some time been formed from water or earth: in the course of infinite time, all matter must undergo every possible change). Heat causes the

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1. For a general discussion v. Gilbert 460-70.
2. Cf. Sens. 443a29: smoky exhalation condenses to γῆς τοῦ εἰδός (i.e. soot - Ross (1955) ad loc.). Cf. p. 253f.
exhalations to form (p. 273f.), by rarefying the water or earth (cf. 340b3 ἡ ... ἀττικὸς ὄδατος διάκρισις ἑστιν ; v.p.75. Aristotle nowhere speaks of dry exhalation being formed by rarefaction of earth⁴; but its formation seems parallel to that of water-vapour - at Sens.445a28f both condense (συνίσταται), to water or earth).

Water is cold and wet (p. 227 ); when it turns to ἀττικός, its moisture evidently remains unaltered, while its coldness is partially replaced by heat. It is evidently cold at 358a51, 55; 360a23f; 367a34, 55; but at 340b27 the received text calls it θερμόν (but two MSS. ψυχρόν²), GC 350b4 implies ἀττικός is hot, and Hete.347a24f says it is θερμότερον ὄδατος (ἐχεῖ γάρ τὸ ἀνάγον ἐτι πῦρ ). Other passages show that ἀττικός automatically condenses if separated from dry exhalation (see below). All this suggests that it is of its own nature cold rather than hot, but must condense to water unless it has some heat in it³. (Cf.

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1. Alexander 44.10-21 (on 346b22) speaks of both exhalations being formed by rarefaction.

2. Accepted by Ross (1949) 109n and others, I think rightly - ἀττικός should have the same qualities as water, with which it is at once compared. But θερμόν would not refute my view of the thermal properties of ἀττικός, nor the similar view of Ross ib. GC 350b4 I doubt is relevant, cf. p. 259n .

3. On the thermal properties of ἀττικός v. Gilbert 490-4, 497f; Olympiodorus 172.3ff. (My conclusion is not original).
When dry exhalation forms, earth's dryness remains unchanged, but its cold is replaced completely by heat:¹ this exhalation is always hot (340b28, 341b11, 360a25 etc.), and in several places heat's effects in the atmosphere are ascribed to it² (and not, as usual³, to the sun). Thus, its presence in the air prevents condensation, 344b22ff: διαχρίνεσθαι ... τὸ διατιμίζον τὴν ἁπτὴν τοῦ πλήθους τῆς θερμῆς ἀναθυμιάσεως, ὥστε μὴ συνίστασθαι ἄρσις ἐλς ὕδωρ; cf. 372b30ff, 367b4ff. Because of its heat, the dry exhalation tends to rise above the wet (341b11); the latter,  

1. Dry exhalation does not form unless both dry and moist are present (362a8-10) - it is not clear if this also applies to the formation of ἄφαίς.  
2. On this cf. Strohm (1935/6) 76f.  
3. Cf. 340a29f (the sun's heat prevents clouds forming); 373a28, 377b31-8a7, cf. 374a12 (it dissolves the formations of dense air which cause certain optical phenomena); 347a4, 359b35ff, 361a7ff (its absence causes condensation). Also, it is the usual cause of exhalation (p. 213f).
being thus isolated, condenses to cloud or rain: again, the dry exhalation is a source of heat; its presence prevents condensation and cooling, which occur on its departure.

What Aristotle never explains is how dry exhalation, once formed, returns to the earth, which it must, if the supply of earth is not to be exhausted (v.p. 285f).

These two exhalations, one naturally hot, the other cold, are mixed to form ἀηρ (p. 229). Go 334b8ff says that, when heat and cold are mixed, the result being ὡς μὲν θερμὸν ψυχρόν, ὡς δὲ ψυχρὸν θερμὸν οίδα τὸ μιγνύμενα φθείρειν τὰς ὑπεροχὰς ἄλληλων, τότε ὅθεν ἡ ὀλη ἔσται

1. 369a15ff: clouds are wetter and colder towards their upper limit, ἢ ... ἐκλείπει τὸ θερμὸν διαχρινόμενον ἐτὸν ἀνω τόπον; ib. 24ff ἢ μὲν οὖν ἐκχρινομένη θερμότης ἐτὸν ἀνω διασπελταὶ τόπον· ὅση δ' ἐμπεριλαμβάνεται τῆς ἔρας ἀναχνισάσεως ἐν τῇ μεταβολῇ ψυχομένου τοῦ ἄερος (is ejected downwards and causes thunders etc.); obviously the θερμότης which ascends is the same stuff as the ἀναχνισάσεις (so Alexander 127.32f). Cf. parallels at 560b33ff (where Alexander 95.25-7 seems to confirm that τὸ θερμὸν which is carried up is dry exhalation) and 346b24-31 (where Olympiodorus 84.4f and probably Philoponus 122.15-19 do so). In 346b24ff the upper air's cold is another cause of condensation, cf. 528, some θερμότης is quenched οἶδα τὸ μετεφρίζεσθαι πορρώτερον ἐτὸς τὸ ὑπὲρ τῆς γῆς ἄερα; cf. 554b31. (Theophrastus syr. 552a21ff clearly describes the ascent of dry exhalation over wet, though a lacuna conceals the effect of this.) (Outside natel. the upper air's cold is the sole cause of condensation: Somn.Vig. 457b26ff, Pa 652b5ff.)

2. Its heat may also affect the formation of exhalations (347a25-b11, Ñ. and S. winds' temperature affects exhalations forming; 358a25-b1, their temperature depends on exhalations. Cf. p. 238)
"οτε δεικτων των εναντίων διάκερτον δεντελεχεία ἀπλῶς,
ἀλλὰ μεταξύ· κατὰ δὲ τὸ συνάμει μᾶλλον εἶναι θερμὸν ἢ
ψυχρὸν ἢ τοῦντιον, κατὰ τούτων τὸν λόγον διλασίως
θερμὸν συνάμει ἢ ψυχρὸν, ἢ τριπλασίως κτλ... "For a hot
ting, cold, and, for a cold thing, not; because the
ingredients of the mixture destroy each other's excesses.
Then it will not be the matter that exists, nor both of the
two opposites existing actually and completely, but an
intermediate; but according as it is cold rather than hot,
or hot rather than cold, it will be potentially¹ twice as
hot as it is cold, or three times" etc. (Cf. ιβ.328a28ff,
general account of mixture of opposites).² Presumably, the
heat and cold (and dryness and moisture) of the exhalations
work on each other as here described; air is not perfectly
hot, nor perfectly cold, but something between; the
exhalation present in the greater quantity makes it hot rather

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1. "συνάμει both hot and cold, in the sense that the heat
and cold, which it actually possesses, are present in ... a reduced degree" (Joachim (1922) 241).

2. This might seem to contradict the principle that τὰ...
ἐναντία οὐ πέρυκε συνδέσοσαι (GC 550a51, cf., e.g.,
 metavarph.1015a25ff); but presumably this means that only
one of a pair of opposites can be actually present in
a thing; GC 554b8ff says only that each of the pair is
potentially present. (On intermediates between
opposites v. also metavarph.I 1057a18-534.)
than cold, or cold rather than hot (cf. Mete.358a23ff, 367b4ff); droughts and rainy seasons are explained similarly (344b18ff, 360b2ff).

A large quantity of one substance mixed with a small quantity of another ὅποιεὶ μέξιν, ἀλλ' σκέψιν τοῦ κρατοῦντος· μεταβάλλει γὰρ θάτερον εἰς τὸ κρατοῦν (GC 328a24ff, cf. 334b23). Consequently, when water-vapour has been separated from dry exhalation, or most of it, it prevails over the heat remaining in it and condenses to water (cf. p. 235f).

When the sun heats the air, it must be helping the hot ingredient of air to prevail over the cold. If heating air involves drying it - a natural assumption - this means that the hot-dry ingredient of air, i.e. dry exhalation, is being increased. If the heat now evaporates water, one might say that the dry exhalation is causing evaporation: thus ἀτύλιζε rises, and is mixed with the dry exhalation that produced it. This perhaps explains 347a24f ἀτύλιζε ... ἔχει ... τὸ ἀνάγον ἐτὶ πῦρ, which implies evaporation is caused by a special hot material, contrary to my view that the sun's heat reaches the earth without movement of matter (p. 223). Cf. 346b26f, where θερμότητος ... ἀναγόσης is dry exhalation, p. 236n).
It is often said that Aristotle's exhalations are "the intermediate stages, the one between earth and fire, the other between water and air". Some passages in Mete support this view, at least of ἀτμίς - notably 346b32f ἐστὶ ο' ἢ μὲν ἐξ ὑδάτως ᾠναθυμλασίς ἀτμίς, ἢ ο' ἐξ ἄερος ἐλς ὑδώρ νέφος. Cloud is evidently an intermediate stage as air changes to water, so presumably ἀτμίς is an intermediate stage in the opposite change. But this is an over-simplification. The exhalations do not exist in isolation, but λέγεται κατὰ τὴν ἥπεροχήν (359b32ff).

Presumably, water-vapour exists actually wherever there is more of it than of dry exhalation; such vapour tends to condense, and so must in a sense be halfway between water and air. But there is some ἀτμίς present in all air, at least potentially, mixed with dry exhalation, from which it


2. Alexander 12.6f and Philoponus 28.36ff state that ἀτμίς is intermediate between air and water in commenting on Mete.340a33ff ὁ περὶ τὴν γῆν οὐ μόνον ἄφρ ἐστὶν ἀλλ' ὅλον ἀτμίς, which they say is Aristotle's view; but I think that Aristotle puts forward the two alternatives of 340a32ff simply as a starting point for his argument, without precisely adopting either: his own view is not that the lower air is really vapour, but that the upper air is really fire (340b30ff).
can be separated (v. pp. 229, 235f). As for dry exhalation, there is no common natural phenomenon which could plausibly be regarded as intermediate between earth and fire or air (or, if Aristotle thought there was, he does not say what it is); and Mete. 372b20ff (cf. 344b20ff, p. 235) implies that air containing much dry exhalation is clear air—it will not tend to condense to earth. Dry exhalation is identical with elemental fire (p. 217f) here it can be no intermediate stage between earth and fire; in fact, no such intermediate stage plays any part in Aristotle's meteorology. (Smoke, identical with or closely related to dry exhalation, is presumably intermediate between earth and fire or air, but plays no part in meteorology; v.p. 252-5). Thus, to call the exhalations 'intermediate stages' is not an accurate definition of them.

Another inaccurate idea is that ἄτμος is identical with air. Aristotle often speaks of ἀέρ, or ἄερ and ἄτμος, condensing to water or cloud (or vice versa)\(^1\); but this does not prove their identity. Air is a mixture of both exhalations; there is some dry exhalation even in clouds and rain (358a21ff). Air condenses when water-vapour predominates; but other air, having more dry exhalation, will not

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1. v. 340a10, 24; 346b31; 347a3f; 349b22, 23f; 364b27; 359a27; 372b16, 30ff; 375b15, 21; 377b25, 27; 346b32.
condense. (Aristotle does, however, connect ἀηρ and ἀτμος, often speaking of ἀηρ condensing to water, but hardly ever using ἀηρ as equivalent to dry exhalation, e.g. by saying that wind is ἀηρ in motion (though 567a20, 567b31 and 368a15ff seem to imply this), or that ἀηρ ignites (though it does so at 567a11, 371a17). Conversely, Aristotle often uses πνεῦμα as equivalent to dry exhalation (e.g. 565b26ff, 366a1, 4), but never as equivalent to water-vapour (e.g. by saying that it becomes water), except possibly at 370a7).
6) **Dry exhalation and the sea's salt.**

In note 35a5ff dry exhalation appears to have several extraordinary properties. Aristotle asserts that his double exhalation must cause the sea's salt (35b24ff). Then, at 35a6ff, he says that in living bodies τὸ ἄπειστότατον, i.e. τὸ περίπττωμα τῆς ὑγρᾶς τροφῆς (urine and sweat) is ἀλμυρόν; similarly, when things are burned, ash is left ὅποιο μὴ κρατήσῃ τὸ θερμὸν (a12); ash corresponds to the περίπττωμα. He continues (ib.16ff), ὅποιον καὶ ἐν τῷ ὕλῳ ἐκ τινων φυσικῶν καὶ γενετομένων κατὰ φύσιν ἀεὶ ἀεί νοεῖν, ὡσπερ ἐκ πνευματικῶν τὸ λειτομένον τοιαύτην εἶναι γῆν, καὶ ὅλῃ καὶ τῇ ἐν τῇ ἐνεργῇ ἀναθεμάτισιν πᾶσαν, "... so too, we must suppose, in the world as a whole, what is left over from things that grow and come to be by nature, just as from things that have been burned, is earth of this kind (i.e. like ash)." What follows is puzzling. Alexander 84.3f paraphrases καὶ ὅλῃ - πᾶσαν; καὶ ὅλῃ καὶ τῇ ἐν τῇ ἐνεργῇ ἀναθεμάτισιν πᾶσαν εἶναι τοιαύτην, presumably "and the

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1. For the saltiness of περίπττωμα cf. 35b4ff, also PA 676a34, GA 776a28–30; for περίπττωμα as ἄπειστόν cf. GA 738a34f, 745b19f etc. (though this does not always apply: ib.762b7f, 776a25ff).

2. For the saltiness of ash cf. Mete.35a31ff.

3. Since πεψθς is due to heat: hence the unburnt, where heat does not prevail, resembles the περίπττωμα. (For this analogy between burning and life cf. PN 466b28ff, 469b20ff, etc.).
exhalation that forms on dry land is all of this kind." This implies that dry exhalation is the salty residue, which (as 353a20ff shows) is carried down in rain and causes sea's saltiness.  

But this raises several difficulties. It seems to me a forced interpretation, to understand καὶ ὅ - πᾶσαν as: καὶ ὅ καὶ τὴν ἐν τῇ ἔκτροφῇ (sc. γῆς γενομένην) ἀναθυμιάσει πᾶσαν (sc. γῆς εἶναι τοιαύτην); and what Aristotle says here of the sea's salt contradicts what he elsewhere says of dry exhalation. First, Alexander's interpretation implies that all dry exhalation is formed ἐκ τῶν φυομένων καὶ γενομένων κατὰ φύσιν, i.e. largely from living things: but everywhere else it is formed simply from earth, or earth and moisture, and is caused directly by heat (p. 213f), and not, as here, as a by-product of other changes. Secondly, dry exhalation cannot be equivalent to ash. 358a12, quoted above, implicitly contrasts ash with some product of burning over which heat does prevail: presumably this is elemental fire, or smoke and flame. Dry exhalation is

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1. So Alexander 84.3ff, Olympiodorus p. 157, Lee ad loc.  
2. 340b25 ἀναθυμιάσεις γῆς; 341b10 ἀντὼς τῆς γῆς τῆς.  
3. Since both exhalations occur together: v. 359b34-360a10, 365b21ff, etc.  
4. Since burning is a process by which other matter becomes elemental fire (p. 145).
elemental fire (p. 217f.) and smoke, and, when ignited is flame (p. 252?); therefore, it cannot be ash. Thirdly, 358b4, 359a5ff show that the sea's salt is heavy and παχύς; dry exhalation is naturally light (p. 235) and fine (365b35ff).

Other passages of Mete. show that the exhalations are involved in causing the salt¹, but none says exhalation and salt are identical²; in view of what I have just said, it seems more likely that the sea's salt is a by-product or special variety of dry exhalation, but not identical with it — perhaps the dry exhalation is fully concocted matter, and salt a περιττωμα left over as it forms. (This will involve assuming a corruption in our text, probably a lacuna, in which case Aristotle's exact theory is irrecoverable.³)

Mete. 358a3ff shows that dry exhalation can be related to πέψις, a vital concept in Mete. IV and the biological

1. 357b24ff, 358a21ff, 29ff.
2. Thus at 358a24 the salt is ταύτης τῆς ὑπάρχουσας, at 358b4 τοιούτων, at ib. 5f τῆς τοιαύτης γῆς.
3. Thurot (1870) 254 and Webster (1931) ad loc. propose in 358a19f ἐν τῇ ἐνεργῇ ἀναθυμιάσει, explaining the clause as meaning that dry exhalation contains earthy material resembling ash. But can their proposed text really convey this meaning?

On this passage v. also Gilbert 420ff, Strohm (1935/6) 73ff.
works; but it is unimportant for understanding the rest of Mete.: for, if my interpretation is right, the passage is explaining only a by-product of dry exhalation, of no importance elsewhere; while if Alexander is right, it is so inconsistent with what is said elsewhere that it would be rash to draw conclusions from it to apply in other places.

causing wind) (1b. 11 8), and thunder etc. (1b. 11 9-11 1); only in the causing of optical phenomena are exhalations unimportant. Though few of these ideas are wholly unprecedented, no predecessor had made exhalation as important as this (cf. p. 444-6).

The dry, fiery exhalation from the element earth was one of the few important innovations in the history of ancient meteorology. Probably, no previous thinker believed in an exhalation from this element (v. p. 448-53). Aristotle's element theory, plus obvious empirical facts, compelled him to regard atmospheric air as a mixture (p. 256f). That it is a mixture of exhalations was a more recent and is a more interesting of the best

1. Selmon (1960) 406-12 regards the two-exhalation theory as largely original to Aristotle.

2. Except for Farmanides' γῆς ἀρχής (284a37); but that is presumably an exhalation from dense matter in general (γῆ being one of his two ἄρχα;) rather than from earth as opposed to water.
7) Origin of the dry exhalation theory

Aristotle's exhalation theory is the basis of almost all his meteorology, the wet exhalation producing cloud and precipitation (Mete.I 9-12), the dry one shooting-stars etc. (Ib.I 4-8), the sea's saltiness (probably indirectly, cf. supra), winds (Ib.II 4-6), earthquakes (indirectly, by causing wind) (Ib.II 8), and thunder etc. (Ib.II 9-III 1); only in the causing of optical phenomena are exhalations unimportant. Though few of these ideas are wholly unprecedented, no predecessor had made exhalation as important as this (cf.p. 444-6).

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1. Solmsen (1960) 406-12 regards the two-exhalation theory as largely original to Aristotle.

2. Except for Parmenides' γῆς ἀπὸνομένην (28A37); but that is presumably an exhalation from dense matter in general (γῆ being one of his two ἀρχαί ) rather than from earth as opposed to water.
presumably suggested by the importance of vapour in pre-
Socratic meteorology (cf. p. 444f.), and also, I think, by
another aspect of Aristotle's element theory. If change is
equally easy between any pair of elements that share a
common quality (GC 531a13-b4; Mete. 339a36f.), then earth
changes to fire (both being dry) as easily as water to air
(both being wet); therefore, if the latter change is
continually occurring, and important in meteorology, then
the former must be so equally. It is true that the two-
exhalation theory does not quite carry out this scheme:
although dry exhalation has the qualities of fire, dryness
and heat, the wet one by nature has those of water, wetness
and cold (v. p. 234), not those of air; and air is formed
from the two exhalations together, not from the wet alone.
These, I suggest, are modifications made to fit the simple
scheme to obvious facts about the atmosphere (e.g. if much
dry exhalation rises from earth to the sphere of fire it
must be an important ingredient of the lower atmosphere as
it passes through; and if both ingredients of the lower
atmosphere were naturally hot, cold and condensation in it
would be inexplicable).  

Another reason behind this theory is presumably the familiar contrast between visible 'water-vapour' and smoke: similar bodies - whitish clouds rising from a source, and disappearing - but derived from opposed sources, water and fire. Aristotle perhaps inferred that smoke, like visible 'water-vapour', must have its invisible counterpart in meteorology. A further reason for the dry exhalation may have been a feeling that wind and rain should have different causes. Aristotle calls dry exhalation πνευματωδέστεραν at the first full statement of the exhalation theory (341b9, 11), and at 359b34ff assumes it causes wind without any real argument - presumably the desire to explain wind was a pre-supposition (perhaps subconscious) behind the theory.  

1. Gilbert 449f, cf. 532, says that the dry exhalation is a misunderstanding of the re-emission from the earth of heat received from the sun (on which v. Sutton 31f). But can Aristotle have known this occurs? The fall of temperature with height might suggest it - but Aristotle explained that by reflection, p. 224. (FHS said that one often feels heat coming off the earth, especially off rocks (e.g. it feels hot, if one sits by a rock after the sun has gone in). But Aristotle's dry exhalation does not come from rocks.)

2. A reason for connecting wind with the smoky, fiery exhalation was that fire is associated with draughts (p. 222n): cf. hete.371a30ff, and p.252n, on the view that flame is burning πνεύμα.
Additional note: the meaning of ἀναθυμίαςις.

In Μετέ. ἀναθυμίαςις can mean dry exhalation, or wet exhalation, or both. In meteorological passages of Μετέ. I-III it clearly has the first of these meanings 36 times\(^1\), 9 times with an attributive epithet\(^2\), the rest without. (Of the latter, n.b. especially 340b26, 27, 29: ἀναθυμίαςις, without an epithet, is dry exhalation the first time the word is used\(^3\). Elsewhere, Aristotle usually explains at the beginning of each section which exhalation causes the phenomena under discussion (341b6ff, 344a9ff, 346b20ff, 359b27-360a13, 365b21ff, 369a12ff), from which the meaning of isolated later occurrences of ἀναθυμίαςις can be inferred). The word means wet exhalation five times, 3 with a descriptive epithet or phrase (342a19, 346b32, 361a11), 2 without (347b3, 11). 14 times it refers to both exhalations.\(^4\)

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1. The passages in Fobes’ Index not otherwise mentioned in this note nor on p. 251f.

2. As ξηρά, θερμή, καπνώδης, πνευματώδης.

3. This is the only passage in Μετέ. I-III where ἀναθυμίαςις, unqualified, is contrasted with ἄνυμι as ‘dry’ and ‘wet’ exhalations. (This contrast recurs at Sens. 443a26).

4. 341b7, 357b24, 358a22, 359b28, 360a8, 11, 15, b1, 16, 18, 26, 365b22, 366b8, 369a12.
(ἀναθυμίαςις in the singular, unqualified, can refer to both exhalations: 360a15 τὴν ἀναθυμίασιν διαφέρειν, 360a34-b1 ὅτα ... τὸ συνεχῶς ... γίγνεσθαι τὴν ἀναθυμίασιν, ἀεὶ νέφη τε καὶ πνεῦματα γίγνεται κτλ.)¹

Thus, while ἀναθυμίαςις is normally dry exhalation, it can also mean the wet exhalation (cf. also p. 258), or both: all three must be borne in mind when considering isolated occurrences of the word in other works and authors.

¹ I here ignore 4 passages where the reference of the word seems unclear: 342a22, 344b1, 368b34, 369a2.
8) The exhalations outside meteorology.

A. Dry exhalation

Aristotle, I think, never mentions the theory that air is a mixture of the two exhalations outside Mete.; and he refers to dry exhalation only very seldom, in the following contexts:

i. Minerals.

Mete. 378a15-b6 suggests that the two exhalations, within the earth, cause the properties of different minerals.¹ The suggestion seems to be a product of the fit of enthusiasm for exhalations in which Aristotle wrote Mete.; for the early Peripatetic writings only twice elsewhere refer to it (Mete.IV 384b30ff, Theophrastus Lap.50), and then briefly, although both works say much of the types of material mentioned in Mete.378a15ff: clearly, when they were written, Aristotle and/or his successors, though unwilling to dismiss the exhalations altogether, did not regard them

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¹ This is a variation of the theory that certain solid materials (mainly metals) consist chiefly of water, while others are mainly earth; cf. Plato Ti.58d-59c; Mete.IV 10; Theophrastus Lap.1.
as a satisfactory basis for a general theory of minerals.

ii. Fires on the earth.

Flame is burning smoke (GC 331b25, Mete.IV 388a2, Long.465b25, Theophrastus Ign.3); dry exhalation is smoke, or is smoky.¹ Naturally, therefore, flame is burning ἀναθεματικός (Mete.342a4ff², cf. 369a35-5; Juv.469b31, Theophrastus Ign.50); by extension, exhalation is involved in all fires³ (Ib.7, 65 – the latter mentions moisture as an alternative).

This accords with the theory that inflammable exhalation/elemental fire fills, and burns in, the highest sublunary region (p. 217ff); but to say that flame is burning smoke in no way implies the rest of the dry exhalation theory.⁴ At GC 331b19ff Aristotle relates this

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1. Mete.341b10, 15, 359b31f, 360a10, 25, b3, 361a19, 378a19; Sens. 438b24f, 443a21ff; PA 649a22; Theophrastus Ign.30, cf. 39.

2. Which means that a just-extinguished lamp re-lights if placed beneath a flame, Alexander 22.1ff.

3. Presumably always dry exhalation, though the word has an epithet only at Ign.7; at Mete.342a4, 369a35-5 the (meteorological) context shows dry exhalation is meant.

4. Elsewhere, flame is burning πνεῦμα, or burning καλυός or πνεῦμα: Mete.341b22, 366a1ff, 371a33ff, IV 388a2. Contrast 355a9.
view of flame to his element theory without mentioning dry exhalation: fire is formed from air and earth when air's moisture and earth's cold are destroyed, as observation confirms: μάλιστα μὲν γὰρ πῦρ ἡ φλόξ, αὕτη ὅ' ἐστὶ καπνὸς καὶ ομένος, ὃ ὅκαπνὸς ἐξ ἀέρος καὶ γῆς. Here, πῦρ/φλόξ is the element, and καπνὸς a stage in its formation; whereas in Mete. the smoke would be the element, and fire, burning, a process which it undergoes (cf. p. 216f). The GC passage is probably a step on Aristotle's way to the dry exhalation theory.

I know no previous author who speaks of flame as burning smoke, but very likely some did do so; for several spoke of fires as caused or maintained by moisture or water-vapour¹, and καπνὸς is sometimes said to be from water.²

iii. Smell.

Sens.443a21f, δοκεῖ ἐνικεὶ ὡς καπνώδης ἀναθυμίας

1. Most often, this is said of the heavenly bodies, v. p. 446; v. also Mete.354b33ff, [Hippocrates] Vict.I 3 (L.VI 472.20f), II 47 (p. 548.1f).

2. Homer Χ 149f (and perhaps μ 202, 219; but this smoke may be directly from fire, cf. μ 68) (passages from Hugler (1963) 62f); Plato Ti.66E; DK 59A98. Cf. the early usage of ἄτμις etc., pp. 41ff.
This exhalation condenses to γῆς τι ἐλόσ, as ἄτμις condenses to water (ib.28f): it is evidently intermediate between air and earth, which links the passage with GC 331b25, quoted supra (as against Mete., where dry exhalation is finer and lighter than air, pp. 235 , 244 ): Aristotle is thinking of smoke as we know it, rather than of Mete.'s hypothetical invisible, dry exhalation.

At Sens.445a30ff Aristotle rejects this exhalation theory of smell; but at 438b24, 445a26 he apparently accepts some form of it; v. also Theophrastus Od.13, 44 (speaking of an ἄνανθυμίαςις from the object smelled), Mete.IV 388b31f (λιθανωτοι ... καὶ τὰ τοιαῦτα παραπλησίως τοῖς ἔσολοις ἄτμιςι ).

iv. Hair.

GA 782b18ff suggests that hair is straight or curly ὅπειρα τὴν ἐν τοῖς θριξὶ καθάρτι ἄνανθυμίαςις. ἄν μὲν γὰρ ἡ καπνώδης,
The above are all the passages outside Mete. where Aristotle mentions dry exhalation: they are most remarkably few. Twice, it enables Aristotle to bring familiar ideas into a systematic form: the relation of smoke, flame and elemental fire, and earlier ideas on smell - dry exhalation provided an obvious explanation for these, since both clearly involve an exhalation (a gaseous body moving from a solid or liquid), which often clearly is not from water. The other theories, on minerals and hair, are merely suggestions, about which Aristotle himself was probably doubtful.

Outside Mete., in fact, Aristotle keeps the two

1. GA 784b8-17 ρέοντος δύναμις differs from dry exhalation, being earthy and wet.
exhalation theory at the back of his mind, occasionally citing it, in discussing particular problems, but preferring to ignore it. One might almost suppose that he wrote Mete. in a fit of enthusiasm, the two exhalation theory having just occurred to him; and that, on second thoughts, he began to have doubts about the whole thing.

Besides the above, a few passages recall dry exhalation without actually mentioning it. Thus Sens.441b1ff says that ἀλέως are γῆς τι εἴδος and that water becomes bitter by passing through τέφρα (cf.GA 761b9ff). More important is GA's theory of a hot πνεῦμα involved in generation, present in semen or the embryo, etc.¹ Usually, the πνεῦμα may be thought of as hot merely because ἀήρ, as an element, was supposed to be so²; but at 735b33ff he says that semen, when emitted, is στιφρόν καλ λευκόν ... πνεῦμα πολὺ ἔχουν θερμόν, ἔξελθον ὁ ὅταν ἀποπνεύσῃ τὸ θερμὸν καλ ὁ ἀήρ ψυχή, ἀγρόν γίνεται καὶ μέλαν , adding at 736a1 τὸ ... πνεῦμα ἐστι θερμὸς ἀήρ ; this suggests that πνεῦμα is a special, hot, variety of ἀήρ, which looks like a recurrence of Mete.'s theory that dry exhalation/πνεῦμα is the hot

¹ GA 735b33f, 736a1, b30-7a1, 742a14f, 762a20.
² Cf. 742a14f, πνεῦμα is hot and wet. 735b30 implies ἀήρ is usually, if not always, hot.
ingredient in air. Analysis, however, shows that GA's theory is inconsistent with Mete.: for 736b33ff explains that the heat that causes generation is not fire, but ψυχή and a φύσις in it resembling the material of the stars; hence the sun's, and animals', heat causes generation, while fire does not.¹ This implies that the sun itself is hot, which Mete. denies; and Mete. makes no such distinction between the heat of dry exhalation/ψυχή and that of fire (v.pp. 215ff, 252f). Nevertheless, Mete.'s and GA's theories of ψυχή surely influenced each other: indeed, the view that ψυχή is hot presumably originated in biology; for breath feels hot, while wind does not.

B. Water-vapour.

Although in Mete. much less important than dry exhalation (being the main cause only of cloud and precipitation), water-vapour is much the more important elsewhere²: it is involved, for example, in Mete.IV, in the explanation of rotting (379a22ff), drying (382b20f),

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1. On this cf. Strohm (1935/6) 18f.
2. Outside Mete. it is usually referred to by some phrase like συνεξατυλίζοντος τοῦ όγροῦ.
πῆξίς and πάχυνσις (583a15ff), and oil's turning white (383b29); in PA in the congealing of blood (650b13ff, 651a8ff) and the formation of bone (653a35); in GA, in the formation of nails, horns, hoofs, beaks and eggshells (718b18f, 743a13ff, 752a35)¹, in the growth of larvae, in the expansion of bodies due to yeast (755a17-19), and in hair (V 3-4). It is also important in digestion: as food is digested, vapour rises from it, which subsequently condenses to a liquid² in another part of the body; unlike other water-vapour, this is usually called ἀναθωματισίς (or, ἀναθωματοφαί is used).³

These passages give little new information on water-vapour's nature; but they confirm that heat makes the vapour form and/or rise⁴, and that cold causes condensation.⁵

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1. Since moisture must be removed by evaporation before these bodies can form.
2. Cf. PN 444a13 δέματα, 456b5 blood (ἐξαματοῦτα), 458a2f φλέγμα, κατάρροι; etc. PN 457b31ff, PA 652b36ff compare this process with the formation of rain.
3. PN 444a12, 456b4, 19f, 34, 457a25, 29, b14, 458a2, 6, 9, 462b6, 480a10. PA 652b36, 672b18.
4. Mete.IV 383a16, PA 653a6, 23, 35, GA 718b18ff, 755a17ff, 772a14ff, 783a34ff, PN 456b22, 457a28f, b20, 31ff, 479b32.
5. PA 653a1, 6f; PN 444a12.
In several passages, where evaporation is associated with cooling, Aristotle states that the vapour leaves the body concerned together with the heat:¹ in origin, this theory was presumably an attempt to reconcile the principle that heat causes evaporation with the accurate observation that bodies often cool as their moisture evaporates.² It is mentioned in Mete.I-III (v. 359a31f, on salt manufacture), but not in meteorological contexts (perhaps because in them, Aristotle is interested only in the vapour, not in the water whence it forms).³

In Mete., πνεῦμα is used only of dry exhalation, except at 370a7 (v.p. 241 ); but elsewhere Aristotle uses πνευματόω, 'turn to πνεῦμα ', of water evaporating:⁴ this

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1. E.g. PA 651a8f τοῦ ... θερμοῦ ὑπὸ τοῦ ψυχροῦ ἐκθελομένου συνεξατμίζει τὸ ὕγρον ; cf. GA 743a13, 783a16f, 54ff, b7f, Mete.IV 379a22ff, 383a14ff.

2. On the real cause of this v.Barton (1933) 195.

3. Mete. leaves it doubtful whether ἀῦμα is naturally hot or cold (p. 234 ). In other works one might suppose it hot, since heat causes it (p. 258 ): at PN 456b21, 457b16, 458a1 the digestive vapour is referred to as, or included in, τὸ θερμόν. But I doubt these passages are a safe guide to the properties of ἀῦμα in Mete., where hot dry exhalation always accompanies it.

is further evidence that Aristotle outside Mete. more or less forgot dry exhalation and its connexion with wind.¹

C. θυμίασις (Mete.IV 387a23-8a9).

387a25f defines άτμις as ή έπο θερμός καυστικός εἰς ἀέρα καὶ πνεῦμα ἔχρισις εἰς ὕγρον διαντική : θυμίασις differs from άτμις, ὅτι οὕτω διαίνει οὕτω πνεῦμα ² γίγνεται (ib.28f); it is ή έπο θερμός καυστικός κοινή ἔχρισις έπρος καὶ ὕγρον ἄθροώς (ib.30f); καπνός is a variety of it (ib.52f); the different bodies observed to emit θυμίασις are recounted in some detail (387a32-b13, 8a2-9). θυμίασις resembles dry exhalation in being distinct from άτμις, and connected with dryness and smoke, but differs in being formed from dry and wet³, and in not causing wind⁴, which is due to άτμις.

Düring (1966) 50f maintains that Mete.IV is earlier than Mete.I-III, saying that, were it later, its discussion of θυμίασις would mention Mete.'s two-exhalation theory

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¹ Though not quite completely, cf. FN 445a26 πνευματόδους ... άναθυμίασις.
² i.e. wind, cf. ib.29f.
³ However, dry exhalation is always accompanied by the wet: cf. 362a10f, ὅταν ἔχῃ τὸ ἔρημον δρόσητα, τούτε θερμαίνομενον θυμίαται, referring to dry exhalation. However, dry exhalation is always accompanied by the wet: cf. 362a10f, ὅταν ἔχῃ τὸ ἔρημον δρόσητα, τούτε θερμαίνομενον θυμίαται, referring to dry exhalation.
⁴ Note, however, 388a2 ἄνφοδες πνεῦμα ἃ καπνὸς καόμενος, where πνεῦμα and καπνὸς seem nearly the same.
(ib. 386n). If so, Mete. IV is important evidence for the development of the latter theory: we can infer that the dry exhalation theory was developed from Mete. IV's \( \thetaυμίασις \), a largely empirical theory about varieties of smoke; and that, at this stage, Aristotle still held the traditional view that wind is derived from water-vapour.

But Durig's dating is uncertain; and the author of our passage of Mete. IV need not have been ignorant of the two-exhalation theory. He is primarily interested in what he had observed on \( \thetaυμίασις \); and the theoretical basis adopted in Mete. IV is that of the four primary opposites and elements, not the two exhalations. It would therefore be distracting and unprofitable for the author to undertake the delicate task of reconciling \( \thetaυμίασις \) with the rather different theory of dry exhalation; he may well have preferred to ignore the latter theory.

2. In this chapter I give Bosker references to Mete. (385a20-37886) without naming his work.
1) The material of wind.  

The two exhalations cause nearly all meteorological phenomena (p. 245); Aristotle, in writing Mete., clearly just assumed a priori that this is so: for he repeatedly begins his own account of a group of phenomena with a statement of his exhalation theory or part of it (e.g. 359b27f \( \text{περὶ} \) δὲ πνευμάτων λέγωμεν, λαβόντες ἀρχὴν τῆν ἐνδημένην ἕμιν ἑνὶ πρῶτον. ἢστι γὰρ ὁ ἐν ἑνὶ τῆς ἀναθυμιάσεως, κτλ. )\(^2\). Only twice, at 359b34ff and 365b28ff, does he attempt to show why an exhalation, rather than anything else, should cause the phenomenon concerned, and even there these arguments follow statements of the exhalation theory, which strongly suggests that Aristotle had in fact prejudged the issue. At 359b34ff, moreover, which concerns wind, the argument is exceedingly feeble, possibly

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2. In this chapter I give Bekker references to Mete. (338a20-378b6) without naming the work.
3. Cf. 341b6ff, 344a8ff, 346b20ff, 357b23ff, 365b21ff, 369a12ff.
proving that heat causes exhalations, but simply asserting that dry exhalation causes wind.

Neither exhalation occurs without the other; one or other is said to be present κατὰ τὴν ὑπεροχήν, i.e. when it is in greater quantity than the other (359b32ff). When wet exhalation predominates, the mixture tends to condense to cloud and rain (p. 234–5). Cloud can be spoken of as produced by exhalation condensing (369a12ff), or air (346b32f, cf. Top. 146b29), or both (372b16f); it is an intermediate stage between air or exhalation, and water. \(^1\) Cloud contains both exhalations, but is denser the less dry exhalation there is (358a21ff, 369a12–19). Cold usually causes the condensation (cf. pp. 235f, 258); air's stillness may be another cause (340b32ff).

Wind occurs when dry exhalation predominates (360a34ff). Aristotle defined wind as πλήθος τί τῆς ξηρᾶς ἐκ γῆς ἀναθυμιάσεως κινούμενον περὶ τὴν γῆν (361a30f), rejecting the already current definition 'air in motion' (360a20f, 27f; cf. p. 57). For this rejection Aristotle had a plausible reason. \(^2\) Some movements of air, he says, cannot be winds — e.g., air moved ὑπὸ τινὸς μεγάλης πτώσεως — just as some

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1. v. 346b32f, 372b16ff, 23f, 50ff.
flows of water are not rivers; a wind, like a river, must have a source (πηγή) (360a27ff). Cf. 353b21ff (on rivers) ὤν νοεῖν οὐκ ὅπερ ἐξ ἀγγείου ταμιευμένων τὴν ἀρχὴν εἶναι πηγήν, ἀλλ' ἐίς ἢν ἐὰν γενόμενον καὶ συρρέον ἀπάντῃ πρῶτην, "by 'source' we must not understand the origin from which things (i.e. already-existing things, cf. 350b22-7) are served out, as from a vessel, but the point at which things that are continuously forming and flowing together first meet". Earth and clouds cannot contain sufficient permanently-existing water to supply the rivers; water must be continuously being formed from vapour, and collecting to form rivers' sources (349b16-27, 350b22-36). Similarly, I take it, there cannot be enough air already existing to supply the winds; winds must be due to exhalation continuously being formed, and then collecting.¹

This does not imply that wind is not an air-movement, since the exhalations form air - only that, as 360a28ff says, wind is not every movement of air: a reasonable conclusion. What Aristotle does not prove is his view that

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¹ Cf. 361b1ff, quoted p. 295. The argument was especially plausible when applied to wind, because a given amount of water produces a much larger volume of vapour (cf. p.82f), i.e. water (or earth, presumably) would provide much more wind than the same volume of air. (Aristotle's predecessors may have argued similarly, p.63f.)
wind is dry exhalation rather than wet. His reason was, I suspect, the connexion of fire with a draught\(^1\), and the obvious mobility of wind, which suggests it should be due to the finest (and so most mobile\(^2\)) of bodies, i.e. fire (p. 221): both considerations suggest that the fiery, dry exhalation causes wind.

In practice, however, Aristotle fails to adhere to this view.\(^3\)

If wind's material is dry exhalation, winds should occur when there is more dry exhalation than wet; cloud and rain occur when wet exhalation predominates (p. 253). Thus winds should be associated with droughts, and should not coincide with cloud and rain. Sometimes Aristotle seems to believe this: v. 344b18ff, 366b7-9, and especially 360b2ff: ὅπως ... τὸ ἐνίοτε μὲν τὴν ἀτμιδόθη (sc. ἀναθυμλασίαν) γίγνεσθαι πολλαπλασίαν ὅτε δὲ τὴν ξηρᾶν καὶ καπνώδη, ὅτε μὲν ἐπομβρα τὰ ἐτη γίγνεται καὶ ὕγρα, ὅτε δὲ ἀνεμώδη καὶ αἰχμοῖ. Alternatively, he goes on, there may be drought in

1. pp. 222n, 248n. (For the connection of wind, fire and mobility cf. 366a2f.)

2. Cf. 365b28ff, arguing that the body which is κινητικῶτατον and τάχιστα φερόμενον is τὸ λεπτῶτατον.

one district and rain everywhere else, or vice versa. Also, wind usually blows after rain has fallen, and ceases when rain falls (360b27ff), because after rain has fallen ἡ γῆ ξηραίνομένη ... ἀναθυμᾶται (360b31f), which vapour is the material of wind. Here Aristotle begins to drift away from his own principles: when the earth is wet with rain, the exhalation should surely be largely wet.

This divergence is more marked in what follows, 361a4ff, which says that the prevalence of north and south winds is due to the same cause. For the sun does not pass over the northerly and southerly regions of the world, so that clouds and rain are most frequent there; ὅπου δὲ πλεῖστον ὕδωρ ἢ γῆ δέχεται, ἐνταῦθα πλεῖστην ἀναγκαῖον γίγνεσθαι τὴν ἀναθυμίασιν παραπλησίως οἷον ἐκ χλωρῶν εἴλων καπνῶν, ἢ ὁ ἀναθυμίασις αὕτη ἀνεμός ἐστιν . It seems most unlikely that, in these circumstances, there can be more dry exhalation than wet.¹

¹. Aristotle surely borrowed this theory from some predecessor who held that all winds are due to water-vapour (possibly Democritus, cf. p.178f. On 361a4ff v. further p. 303 ).
Still more inconsistent, to all appearance, is 367a33ff: winds feel cold διὰ τὸ κινεῖν τὸν ἀέρα πλήρη πολλῆς ὀντα
καὶ ψυχρὰς ἄτμιδος (cf.358a35). Here Aristotle seems to abandon his definition of wind completely; though he might perhaps have argued that, just as, when a wind carries clouds with it, we do not regard the clouds as part of the wind, so too the ἄτμις which the wind moves is not part of it. 367a33ff goes on to compare wind with breath blown through pursed lips, which feels cold (he says), except immediately in front of the lips, for the same reason as wind. This implies that dry exhalation differs from ἄτμις in being at the origin of the wind, and what is initially set in motion. Dry exhalation naturally rises above ἄτμις (p.235f), and the source of winds' motion is from above (see below).

Perhaps, therefore, its ascent explains why it is first set in motion as wind; and perhaps wind blows after rain has fallen because then large quantities of both exhalations form, so that then there are large amounts of dry exhalation to rise above the wet and be set in motion. If this was Aristotle's theory, it was much more consistent than I have suggested; but he has certainly failed to make his meaning clear.

Obvious empirical facts compelled Aristotle to explain how wind can be cold, and how winds can blow in wet conditions; his difficulty in doing so without inconsistency
illustrates the weakness of his wind theory; though there is an equal absurdity in the normal pre-Aristotelian theory that wind is derived from moisture, which suggests that wind cannot occur in dry conditions.

The fire and air above the highest mountain-tops is carried round by the motion of the heavens (p. 215); a rising mass of dry exhalation meets the revolving air, and is carried round in its revolution; other dry exhalation, below the first, then becomes involved in this movement, and so a horizontal motion is gradually transmitted down to the earth's surface, and wind is produced there; thus the ἡ ἄνευκατακάρδης of wind is; from above, ἄνευκατάκαρδης (364a32).

To this, Alexander 93.26ff brings two objections: first, the theory implies that wind's motion is not ἐκ τοῦ ἐνθεούμενου. On Aristotle's principles, this seems a valid objection, not so much to the wind theory itself, as to the perpetual revolution of the fire and upper air, on which it depends, for dry exhalation's naturally rising into the superheated fire.

1. This interpretation resembles that of Gilbert 529ff and (apparently) Düring (1966) 39ff, as he (ib.) and Boekez (2256.7ff) point out, Aristotle's theory must partly be due to observation of clouds moving before we feel the wind, cf. 361a26f (where I would adopt Webster's (1931) reading).

2. Perhaps taken from Theophrastus, whose alternative theory Alexander here approves.
2) The cause of wind's motion.

Dry exhalation's natural motion is upwards; it moves horizontally as wind because πᾶς ὁ κόχλῳ ἀήρ συνέπεται τῇ φορῇ ... τῶν πορρωτέρων (361a24f, 34), ... "follows the motion of the further (presumably the heavenly) bodies."

The fire and air above the highest mountain-tops is carried round by the motion of the heavens (p. 215); a rising mass of dry exhalation meets the revolving air, and is carried round in its revolution; other dry exhalation, below the first, then becomes involved in this movement, and so a horizontal motion is gradually transmitted down to the earth's surface, and wind is produced there; thus the ἄρχη τῆς χινῆσεως of wind is from above, ἀνωθεν (361a32).¹

To this, Alexander 93.26ff brings two objections²: first, the theory implies that wind's motion is not κατὰ φύσιν. On Aristotle's principles, this seems a valid objection, not so much to the wind theory itself, as to the perpetual revolution of the fire and upper air, on which it depends; for

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2. Perhaps taken from Theophrastus, whose alternative theory Alexander here approves.
this is open to the objection with which Cael. 296a27ff disproves the earth's revolution: that revolution is not earth's natural motion, and that it cannot have an enforced revolution, because no enforced motion is eternal. How Aristotle would have answered this, I do not know; Theophrastus, whose theory of wind's motion depends on the elements' natural motions, was perhaps trying to avoid the difficulty so far as wind is concerned (v.p. 332ff).

Alexander's second objection is that, on Aristotle's theory, all winds ought to be in the same direction, i.e. from east to west. Ammonius and Olympiodorus (Olymp. 175. 14-29; 177.35ff)¹ try to meet this by saying that the wind-material does not follow the upper air's revolution, but encounters it and is carried downwards from it - it apparently bounces off the revolving air, and may then go in any direction (Olympiodorus 178.3f, ἀποκάλλεται ἐκ τὸ κάτω καὶ τὸ λοιπὸν πελαγημένως κινεῖται). But this seems inconsistent with 361a24 συννέπεται τῇ φορῇ, and with dry exhalation's naturally rising into the region of fire, which has just been mentioned (360b34f; cf. p. 235f).

I conclude that the interpretation of 361a24f given on p. 269 is correct, and that Aristotle had simply failed

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1. Whose interpretation is adopted by Boeker 2238.63ff.
to think out its consequences; just as he apparently failed
to realise that the sun's sphere is not in contact with the
sublunary region, and so cannot cause heat there by friction
(p. 216).

1. Some passages suggest that the sun causes wind's motion,
though this is uncertain. Usually the sun helps to
cause wind merely by causing exhalation, the wind's
material (cf. 359b34ff, 361a4ff, b14ff, 35ff, 362a16ff),
and this may be so (cf. Olympiodorus 198.16ff, Lee 195n)
at 364b13ff (winds veer in the direction of the sun's
movement because ἄρχη ... κινεῖται τῶν πνευμάτων ὡς
ὁ ἥλιος), despite Alexander's comment (112.31) οὕτως
γὰρ ... αὐτὸς τῆς τῶν ἀνέμων κινήσεως. 368b21 says,
evidently of winds, ὅταν ἄρχην λάβωσιν ἀπὸ τῆς τοῦ ἥλιου φορᾶς, which Webster (1951) and Lee evidently
take as meaning that the sun moves previously formed
exhalation; but the passage is obscure and probably
corrupt (cf. their notes), and certainty is impossible.
3) Other causes of the motion of πνεῦμα.

The heavens' motion does not explain all the movements of πνεῦμα in Mete. In causing lightning etc. πνεῦμα is moved by being trapped in a cloud, which contracts and so shoots it out like fruit-stones shot from between the fingers\(^1\); the motion of πνεῦμα within the earth, which causes earthquakes (II 8), is another movement which the heavens' motion cannot cause.\(^2\)

In the case of some earthquakes, the wind is caused or increased by dry exhalation being compressed within the earth (v.p.95ff): but Aristotle does not suggest that this applies to all earthquakes. Indeed, he nowhere mentions a general cause of πνεῦμα's motion within the earth; which suggests the possibility that the πνεῦμα moves itself;\(^3\)

\(368a9 \quad \delta \rho μι \ το \ τυ \ πνεῦματος\) might refer to such self-motion (v.p.293f \(\)). This would be contrary to Aristotle's principle that a true self-mover is impossible\(^4\); but it is worth comparing what he says of πνεῦμα in the biological

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1. II 9-III 1, especially 369a22ff; also 342a9ff.
2. Cf. 368b17ff, distinguishing the cause of earthquakes and wind. (On Aristotle's earthquake theory v. Gilbert 305ff, Strohm (1935/6) 55ff.)
4. Ph.VII 241b34ff, VIII 255b31-6a3. Even living creatures seem not truly self-moving, ib. 253a7ff, 259b1ff.
works, especially as his account of earthquakes uses a biological analogy. ¹

This analogy is with οφυμός, τρόμος, τέτανοι and οπασμοί. At 366b20-22, μετά τὴν οφυμον ... τρόμος appears to be due to 'reciprocal replacement' (cf.p. 280 )²; otherwise the cause of οφυμός etc. is said to be πνεῦμα, but not further explained.

The biological works say little of these phenomena. Ga 781a24f τὸ πνεῦμα τὸ σύμφωνον ποιεῖται ἐνίοις ... τὴν οφύμον adds nothing to Mete.; but Resp.480a2f says ἐν ... τῇ καραίᾳ ἀ τοῦ ἀεὶ προσείόντος ἐκ τῆς τροφῆς γυροῦ διὰ τῆς θερμότητος διχώσις ποιεῖ σφυμόν, κτλ. (cf.479b37f πνευματομένου τοῦ γυροῦ ὑπὸ τοῦ θερμοῦ ; 480a14f οφύμον ... ἀ τοῦ γυροῦ θερμαίνομένου πνευμάτωσις³ here the πνεῦμα is clearly not self-moving.

There are, however, other passages where πνεῦμα causes animals' motion. Insomn.461a24f: certain χάθη (melancholy, fever, intoxication) πνευματική ὁντα πολλὴν ποιεῖ χίνησιν καὶ ταραχὴν. Probably this πνεῦμα is connected with the

¹. 366b15-30, 368a6-8, b23-25.
². ἀντιμεθοποιοῦ τοῦ πνευματος ἐξελθεν εἰσεω.
³. Cf. also 480a9f, where ἀναθυμήσις seems to cause οφυμός. At Ma 701b27ff τρόμοι are due to 'heat, cold or something similar' - nothing is said of πνεῦμα.
exhalation caused by the heat of digestion\(^1\), i.e. heat forms the \(\text{πνεῦμα}\), and moves it by making it rise.

\(\text{FA 659b14ff}\), non-breathing animals perceive and move τῷ συμφύτῳ πνεῦματι; cf. Somn. Vig. 456a16f, ἔσχάν ... ποιεῖ ἢ τοῦ πνεῦματος κάθεξις; GA 737b36f. This seems explained by ΜΑ 703a4-27 (cf. especially 703a9f): σύμφυτον πνεῦμα initiates animals’ motion by expanding and contracting, and by its lightness and weight relative to the other elements (703a20-24). But this πνεῦμα is merely an ὄργανον (703a20), the first σῶμα to move (cf.703a6ff); the first cause of the movement is τὸ ὀρέκτων, that which causes desire (700b23f).\(^2\)

The same must apply where σύμφυτον πνεῦμα causes generation, e.g. GA 736b33ff πάντων ... ἐν τῷ σπέρματι ἐνυπάρχει, ὅπερ ποιεῖ γόνιμα εἶναι τὰ σπέρματα ... τοῦτο δὲ ... τὸ ἐμπεριλαμβανόμενον ... πνεῦμα ... (Cf.741b37 and (on spontaneous generation) 762a18ff, b16f.) Generation is clearly initiated by the parent; the πνεῦμα is merely the instrument which conveys the parent’s form to the

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1. Cf. Somn. Vig. 457a12 πνεῦμα and in general Somn. Vig. §3 and Insomn. 461a13.

2. Cf. de An. 453b12-20. (For a fuller account, which I follow, v. Peck (1942) 576-8; v. also Jaeger (1913) 47ff.)
material of the embryo. 1 (Similarly, spontaneous generation seems to be initiated by the heat of the atmosphere, not by πνεῦμα, cf. 762b13-17.)

Thus πνεῦμα in Aristotle's biology is not truly self-moving. It is the point of transition between the immaterial (e.g. desire) and the (material) body's movement (cf. Peck 11.c), an idea doubtless connected with Mete.'s statement that πνεῦμα is the most mobile material (365b29ff); but it does not initiate its own motion. There is therefore no support for the idea that πνεῦμα is self-moving in Mete.II 8.

Dry exhalation, as it leaves the body whence it forms, must be in motion; and, as exhalation within the earth cannot rise, Aristotle perhaps thought that this motion develops into wind, which causes earthquakes. 2 This could not apply in the atmosphere (where exhalation can rise); nor could the compressing of exhalation in hollow places (cf.p. 272).

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2. So, In Resp. the formation of πνεῦμα causes the movement of σφυγμὸς (p. 273).
4) Aristotle's wind theory compared with his predecessors'.

Aristotle himself dismisses the earlier theories with brevity and contempt, saying (349a12-16) that ὁ δὲν παρειλήφαμεν λεγόμενον δὲ μὴ κἀν δ' τυχῶν εἶπεν. . From one point of view, this scorn was not unreasonable: all previous wind theories seem to have been variations on one view, whose origins are traceable in Homer: that winds are derived from water, cloud, or dense air (pp. 49ff, 59ff).

Aristotle's dry exhalation theory is a new departure: hence his contempt of the old view (which roughly corresponds to the one previous theory he mentions: 349a16-19, "some ... say that wind is ... a moving current of ... air, while cloud and water are the same air condensed; they thus assume that water and wind are of the same nature... " (tr. Lee; cf. 360a16ff): this connection of wind with water is the characteristic feature of the old theory.)

However, Aristotle's theory is hardly an improvement on the old one. His criticism of the idea that wind is air in motion (p. 263f) is not valid against the old theory, which derives wind from something denser than air; and his two principal innovations, that dry exhalation is winds' material and that the heavens' revolution causes their

1. On 349a20ff v.p. 298.
motion, are both, as we have seen, manifestly impossible.

Aristotle's theories of opposites, elements and exhalations assume a simple view of how opposites interact, changes occur between opposites in a substrate, if a pair of opposites, whichever is present in greater strength imparts itself to the substrate; or, the opposites interact to produce in the substrate an intermediate state between their extremes (pp. 351ff, 387ff, 347ff).

Experience, however, reveals some phenomena, e.g., hail in summer, which seem not to fit this simple scheme. This compelled Aristotle to assume alternative ways in which opposites interact, as the passages I next discuss show. See also note on the fourth opposition, pp. 371a1-3.

Note. 360b2ff states that some years are rainy and wet while others are dry and windy (p. 355). 360b5-26 adds that, while usually the drought or rain extends over a wide area (360b12ff), sometimes only a small area is dry while all around is wet, or vice versa (37ff). The context suggests that wind should always accompany the drought; but 368b13ff denies this, saying wind is never confined to a small area (because, Alexander 125.7ff suggests, the exhalation, as it flows together into a small area, is already wind). At all events, the passage casts an
5) Special theories about exhalation and wind.

Aristotle’s theories of opposites, elements and exhalations assume a simple view of how opposites interact: changes occur between opposites in a substrate; of a pair of opposites, whichever is present in greater strength imparts itself to the substrate; or, the opposites interact to produce in the substrate an intermediate state between their extremes (pp. 218f, 227ff, 234ff).

Experience, however, reveals some phenomena, e.g. hail in summer, which seem not to fit this simple scheme. This compelled Aristotle to assume alternative ways in which opposites interact, as the passages I next discuss show.

A. Mete.360b5-26 and 361a1-3.

Mete.360b2ff states that some years are rainy and wet while others are dry and windy (p. 265). 360b5-26 adds that, while usually the drought or rain extends over a wide area (360b12ff), sometimes only a small area is dry while all around is wet, or vice versa (37ff). The context suggests that wind should always accompany the drought; but 368b13ff denies this, saying wind is never confined to a small area (because, Alexander 125.7ff suggests, the exhalation, as it flows together into a small area, is already wind). At all events, the passage casts an
interesting light on the behaviour of the exhalations. The cause of these local droughts etc. is (360b18ff) τὸ ἐξατέραν μεταπίπτειν εἰς τὴν τῆς ἐκομένης χώρας ἀναθυμίαςν, οἶνον ἡ μὲν ἐπὶ κατὰ τὴν οικείαν δεῖ χώραν, ἢ ὁ θυρὸν πρὸς τὴν γεντνίωσαν, ἢ καὶ εἰς τῶν πόρων τινὰ τόπων ἀπειώθη ὑπὸ πνευμάτων· ὅτε δὲ αὐτὴ μὲν ἔμεινεν, ἢ δ’ ἐναντία ταῦταν ἐποίησεν. "Each exhalation goes over to that of the neighbouring district; for example, the dry exhalation flows within its own district while the wet flows to the neighbouring one or even is driven to some more distant place by the winds. On other occasions the wet exhalation stays where it is, and its opposite does the same (i.e. as the wet one did on the former occasions)." Evidently the exhalations are, as usual, formed together, but then get separated, one staying where it is and the other moving elsewhere. The only clue to how the separation occurs is in b22ff: συμβαίνει τούτῳ πολλάκις, ὡσπερ ἐπὶ τοῦ σώματος, ἐὰν ἡ ἀνω κοιλία ἐπὶ ἡ, τὴν κατὰ ἐναντίως διακείσθαι, καὶ ταύτης ἐπὶ σύγχρος ὁσπερ ὁγρᾶν ἐναι τὴν ἀνω καὶ ψυχρὰν, ὁστὶ καὶ περὶ τὸς τόπων ἀντιπεριστασθαι καὶ μεταβάλλειν τὸς ἀναθυμίαςες. I have found no passage in the biological works which explains what is here said of the
upper and lower ξοιλία; the only helpful clue is the word ἀντιπεριστάσθαι.

'ἀντιπεριστάσις' has two main meanings: 'reciprocal replacement', a process by which one body displaces another, that body displaces a third, and so on, the final body in the series moving into the space the first has left; and 'surrounding and compressing': in this process, a material possessing a quality - or perhaps the quality itself - is surrounded and compressed (usually by the opposite quality, or a body possessing it), thereby becoming more intense; e.g., hail forms in hot weather ἀντιπεριστάσμενον εἶσον τὸ ψυχρὸν ὁδὸ τὴν κύκλῳ θερμότητα, 348b6f, cf. 16f.

1. This might mean either two parts of an animals' digestive organs (so Lee, Webster (1937); cf. PA 650a13, 675b17ff), or Thorax and abdomen (cf. LSJ s.v. ξοιλία I.1; so in Aristotle presumably at Somn.Vig.456a5, where τὸ περί τὴν χαρδίαν μέρος lies between head and ξάρῳ ξοιλία); or, ἄνω ξοιλία is thorax plus stomach (so Ideler (1854-6) I 555, Tricot (1955) 120n). None of these possibilities helps to explain the passage.

2. v. Ph.IV 215a15, VIII 267a16, 18; Resp.472b16; Hete.IV 382a12, 14.

3. For accounts of the theory, which I mostly follow, v. Lee 82n; Steinmetz 124-6. In Aristotle's genuine works it occurs only at Hete.347b6 (compression of heat causing evaporation), 348b2 (earth's interior hot in winter and cold in summer), 348b6, 16, 349a8, 361a1 (on rain or hail); Somn. 457b2, 458a27 (compression of hot matter in the body causes sleep; this might be relevant to the ξοιλία analogy in 360b22ff, but I cannot see how); Hete.IV 382b10 (cold causing burning). Sometimes ἀντιπεριστάσις is mentioned without the word being used: v. PA 655a12ff (on the cause of sleep), Resp.479b19ff, 480a13f (palpitations due to compression of heat by cold within the body). Cf. Hete.378a20 (wet exhalation squeezed together and frozen ὁδὸ ξηρότητα).
Cf. 361a1-3: ὅταν εἶς ταῦτα συνωθῶσι τὰ νέφη καὶ ἀντιπερίστατῃ εἶς αὐτὰ ἢ ψύξις, ὅπωρ γίγνεται καὶ καταψύχει τὴν ἔφην ἀνασυμίασιν. Hence rain stops wind. This differs from 348b6f etc. in that the compression of cold is not due directly to heat. (Presumably dry exhalation is cooled not just within the cloud, but elsewhere: the cold, produced in a small area, takes effect over a wider one.)

At 360b25 either meaning of ἀντιπερίστασις seems possible. 360b18ff may well mean that, while wet exhalation is leaving district A for district B, at the same time dry exhalation is leaving B for A. If so, this is something like reciprocal replacement; and that meaning fits with b26 μεταβάλλειν (which presumably refers to change of place).  

On the other hand, ἀντιπερίστασις in this sense elsewhere implies circular movement: bodies move round (περί) each other to take each other’s places, like points on the circumference of a wheel. This can hardly be so at 360b25. The meaning of 'surrounding and compressing' also makes sense, since the result of the process, in the atmosphere, is that in one area the air is very dry or wet, while all around it

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1. Lee, Webster (1931), and Tricot (1955) think 'reciprocal replacement' is meant here.
2. περίστασις can mean 'revolve' (cf. LSJ s.v. B II.1).
has the opposite quality (360b7ff).

\( \delta ντινερίστασις \) is one alternative means by which opposites interact (cf. p. 278), which Aristotle uses in meteorology and elsewhere. In \( \delta ντινερίστασις \) a quality is surrounded, and compressed, and so intensified — naturally, since a thing's properties are always stronger when it is concentrated. Often, this concentration is caused by the opposite quality (which is generally the prevailing one in the existing circumstances, e.g. heat in summer causes hail): thus antagonism between the opposites leads to intensification of the weaker, not, as usual, to its destruction. In 360b5-26, whatever its exact interpretation, there is again an antagonism which does not result in the mutual destruction of opposites (but in their mutual separation: the κουλία-analogy at least shows that the exhalations become separated because of their opposite qualities). A similar antagonism is found in passages where evaporation occurs as a body cools, because heat is squeezed out by cold, and moisture leaves the body with it (v.p.259&n). 1

1. It is not clear exactly how we should envisage these processes. Does (say) the compression of cold always involve the compression of material which contains the cold (as it clearly does in 361a7-3, cf.p. 281), or can the quality alone move, departing from a larger volume of matter and gathering in a smaller one (as might be so in, e.g., 348b6f) ? I cannot discuss this here; Aristotle himself need not have been clear about it.
The principal basis of these theories was presumably simple observation: for example, caves feel cold in summer and hot in winter, and hail falls in hot weather; so Aristotle postulated ἀντιπερίστασις to explain these things. But, to maintain some sort of consistency with the general rule that opposites destroy each other, he presents the exceptions, as well as the rule, as effects of antagonism between the opposites, which can be paralleled in the different results of human antagonisms: men may destroy their enemies; they may drive them out of a place (compare cold squeezing heat and vapour out of a thing); they may surround them, thereby causing them to concentrate (compare ἀντιπερίστασις); or, hostility may cause a community to split into hostile groups (compare the separating of exhalations to cause local droughts and rains).

B. 361a4ff, 364a4ff

These passages may contain another instance of this sort of interaction between opposites. Both explain the prevalence of north winds, as due to there being abundant cloud and rain in the north (cf. p. 266). 361a7ff says: ὁ γὰρ ἔλιος τοῦτος μόνους ὅπερ ἐξέρχεται τοῦς τόπους (i.e. the north and south) ... ὅπως τὰ νέφα συνίσταται ἐν τοῖς πλαγίοις (i.e. on either side of the sun's course),
Here clouds etc. may form merely because water-vapour naturally condenses in the absence of heat (cf. p. 234-6). 364a8ff, however, suggests something more than this: πολλά πλέον ὕδωρ καὶ χιόν
ἀπωθεῖται ἐς τοῦτο τὸ μέρος (i.e. the north) ὀπὸ τὸ ἐκεῖνα (the south) ὑπὸ τὸν ἥλιον εἶναι καὶ τὴν ἐκεῖνον φορὰν.
Here the sun seems actually to push water and snow away from itself: which may be another instance of the antagonism of opposites causing the weaker one to withdraw. Cf.
Theophrastus Vent. 2: the prevailing winds are from north and south ὀπὸ τὸ συνωθεῖσθαι πλεῖστον ἁέρα πρὸς ἀρκτὸν καὶ μεσημβρίαν, πλαγίων ὄντων πρὸς τὴν τοῦ ἥλιου φορὰν ...
ἐξωθεῖται γὰρ ἐνταῦθα τῇ τοῦ ἥλιου ὄνυμαί (ὠρ is naturally cold, according to Vent. 22; though v. p. 335 ).
In both places, however, other explanations are possible, e.g. the 'pushing' may be metaphorical and the rain etc. may form in the way I suggest is intended at 361a4ff.¹

C. Heat and cold preventing winds.

Aristotle's general theory suggests that hot, dry

¹. This must be so at 361a7-9, though not at b10ff, where ὅπως may merely that explanation frequently refers to the north. It appears more accurate to refer to the north only as a place where the prevailing winds come from north and south, and not as a place where the sun is naturally cold, according to Vent. 22; though v. p. 335 .
weather should cause winds (because heat causes exhalation, and hot air has a high proportion of dry exhalation, v. p. 238 ). Accordingly, Aristotle often speaks of the sun causing wind by causing exhalation (cf. p. 271n), and sometimes of droughts being windy (v. p. 265 ). Conversely, cold and wet weather prevents wind; cf. 361a1-3 (quoted p. 281 ) and b24ff γίγνονται αι νηνεῖαι ... διὰ ψυχὸς ἀποσβεννυμένης τῆς ἀναθμίασεως . 362α7 gives a different cause: (the Etesian winds) λωφῶσι διὰ τὸ τὰ κεπηγότα τηχόμενα παύεσθαι διὰ τὴν ψυχρότητα : this depends on the theory that more exhalation, i.e. more wind-material, forms when the earth is wet (v. p. 266 ). A third explanation, given at 366a18ff al., I discuss on p. 292ff .

At 361a1ff and b24ff cold prevents wind by cooling or quenching the dry exhalation — presumably turning it into something else,1 though Aristotle never says what. Indeed,

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1. This must be so at 361a1-3, though not at b24ff, where ἀποσβεννυμένης κτλ. might mean merely that exhalation ceases to be formed: for σβεσις frequently refers to the prevention of a process (cf. Juv.469b20ff (also 474b10ff), σβεσις of fire (and of life) is due to cold depriving it of τροφή), or to the prevention of something from beginning or being formed (cf. 347b9, the north wind σβέννυσιν water-vapour πρὸν συστήνατι τῇ πλῆθος ; 344a18, σβεσις of an ἄρχῃ πυρόδῃς ; cf. 359b6, 371a6f, Ha 522b25ff).
he nowhere adequately explains how dry exhalation returns to the earth (which it must, or the supply of earth will be exhausted): 2 Sens.445a28f says smoky exhalation condenses to earth, but Mete. never mentions this, and earth does not fall like rain from the sky. (Cf. p. 254 ) In Mete., 341a5ff speaks of elemental fire (which is dry exhalation) turning to air, but implies this is balanced by the opposite change; 358a21ff possibly (but improbably: v. p. 242-5 ) refers to dry exhalation being carried down in rain; but there cannot be much of it, or no rain would have formed (p. 235f ). Lastly, 366a7f etc. speak of dry exhalation flowing into the earth; but it there does not cease to be dry exhalation (v.p. 292ff). 1 Aristotle's most plausible solution would be to say that dry exhalation (which always has wet exhalation mixed with it) is turned by cold to wet exhalation and condenses to rain (so Philoponus 99.27-31); but nothing in Mete. supports this.

By whatever means, then, cold destroys the hot, dry

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1. 358b30ff (... oúte déi tā avtā méρh diaméνei, oúte γῆς oúte thaláttēs ... tō mēn γαρ ἀνέρχεται, tō de páλin συγκαταβάλει ) implies (pace Lee) that both earth and sea are carried up as exhalation and then somehow fall again (so Webster (1931)), but does not indicate how the dry exhalation returns to earth.

exhalation and so prevents wind. But it is not alone in doing so: heat can have the same effect. 361b14ff, δ ... ἢλιος ... ἀφενεῖς ... καὶ ὀλύας ὁσας τὰς ἀναθυμιάσεις μαραίνει τῷ πλείονι θερμῷ τὸ ἐν τῇ ἀναθυμιάσει ἐλαττον δὲν, καὶ διαχρίνει. Εἰτὶ δὲ αὐτῇ τῇ ἡ τῆν φθάνει ἐξηαλώνυ πρὶν γενέσθαι ἐκχρισιν ἄθροαν, ὡσπερ εἷς πολὺ πῦρ ἢν ὀλύον ἐμπέσῃ ὑπέξχαμα, φθάνει πολλάκις πρὶν καπνὸν ποιῆσαι καταχαυθῇν. "For when the exhalations are weak and few the sun quenches by its greater heat the lesser heat in the exhalation, and disperses it. Further, it dries up the earth itself before exhalation can collect in any quantity, just as, if a little fuel falls into a large fire, it is often consumed before smoke is produced". (Drying the earth prevents dry exhalation because the exhalations only occur together, Alexander 96.5f, cf. Mete.359b32f). This is an instance of the Peripatetic doctrine that a greater heat

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1. Thus heat stops wind when it is strong (in relation to the exhalation present); cf. 366a14ff; also 361b24ff, where heat evidently stops wind in summer, i.e. when it is hottest; 362a2ff, the Etesians blow when the sun departs a little, and the heat and exhalations are σύμμετροι. Cf. GA 777b27ff for the general view that heat and cold cause generation μέχρι συμμετρίας τινὸς ... μετὰ δὲ τὰ ἀπὸ τὰς φθοράς. )
or fire quenches a less\textsuperscript{1}. At Juv.469b21ff Aristotle says that (while σβέσις is destruction by an opposite) μάρανσις is the destruction of a thing by itself; this happens because of lack of fuel: (b29ff) ταχὸ γάρ ... καταναλίσκει τὴν τροφὴν πολὺ συναθροίζομενον τὸ θερμόν, καὶ φθάνει καταναλίσκον πρὶν ἑπιστῆναι τὴν ἀναθυμίασιν . "Heat is massed together and quickly exhausts the fire's nourishment; it uses it up before more exhalation forms" (i.e. to provide more fuel: fire is burning ἀναθυμίασις, cf. p. 252). Hence, a larger fire or flame quenches a lesser that is placed near or in it (b31-470a5). This suggests that, in Mete. 361b14ff, μάρανσις occurs when the sun interrupts the flow of exhalation by drying the earth\textsuperscript{2}; but in fact both b15ff (ut supra) and b21f distinguish the drying of the earth from μάρανσις. The former process\textsuperscript{3} (to judge by the comparison with burning fuel) is due to earth's moisture being dried

\textsuperscript{1} Gilbert 532; cf. Aristotle GC 323b8f, PN 455b23-5, 466b28ff, 469b31ff, Theophrastus Ign.10-11.

\textsuperscript{2} 361b29-30 (calms in spring and autumn occur τῷ ἡῶ ἐξεληλυθέναι τὴν ἀναθυμίασιν καὶ ἄλλην μὴκω ἐπιρρεῖν ) also sounds like Juv.469b29ff and so could refer to μάρανσις; but it is not called so, and great heat is not appropriate to these seasons.

\textsuperscript{3} b17, cf. 362a2.
so quickly that no vapour has time to form (cf. p. 287); it is not clear how this can happen, cf. infra); when μάρανσις stops wind, it would seem (b14-17), exhalation does form, but is then "withered" by the heat.

But what does this 'withering' mean? There is no process of combustion in the atmosphere; what does dry exhalation become when a greater heat 'withers' it? Aristotle presumably knew empirically that when it is very hot there is no wind (he may have been misled by the illusion that winds usually feel cold); and the principle that a greater heat destroys a less seemed an obvious means of explaining this; but he seems not to enquire how the explanation he has elsewhere given of μάρανσις can apply here. The statement that heat dries the earth before much exhalation can form, also raises a question: what does the earth's moisture (or the fuel that is burned without giving off smoke) become if not some gaseous body? - it cannot simply become nothing. Aristotle relies too simply on appearances - water-vapour is invisible, and in many contexts it is natural simply to say that water has dried, and to ignore what it has become. ¹ But this is

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¹. So sometimes in speaking of rivers etc., as 351a34, 352b35, 353a7ff; cf., e.g., Mete. IV 381a32, 385a25.
not legitimate here, where the exhalations are in point.
In 361b14-19 there is merely an impression of consistency
with what Aristotle says elsewhere, which vanishes when the
passage is analysed (see p.256f for another instance of
this).

D. Mete.II 8: calms and earthquakes.

Mete.II 8 mentions alternative explanations of calms,
in which the calm is due to dry exhalation being confined
within the earth, and so absent from the air - their purpose
is to explain how there is exhalation within the earth to
cause earthquakes.

366a14ff: there is calm because the sun ὅταν μάλιστα
κρατῇ, κατακλείει τὴν ἀναθυμίασιν εἰς τὴν γῆν . (This
resembles 361b14ff, in that the strongest sun causes calm.)
κατακλείει should perhaps be connected with ἀντιπεριστάσις ;
for that is sometimes spoken of as a 'confining' of one
opposite by another 1; and if a quality can be destroyed by
its like, as well as by its opposite, then presumably a
quality can also confine and compress its like. Alternatively,
the strong sun might confine the exhalations by drying and
so closing up 'pores' on the earth's surface, as at Mete.IV
381a32ff (on roasting): ἰδί ... τὰ ἔγγύτερον τοῦ πυρὸς

1. e.g. Probl.936b15f, cf.21; Theophrastus fr.163, Ign.13.
ξηραίνεται θάττον ... συνιόντων οδν τῶν ἐξω πόρων οὐ
dόναται ἐκχρίνεσθαι το ἐνυπάρχον υγρόν, ἀλλ' ἐγχατακλείεται.

However, Hete. never suggests the earth has πόροι.

367b30f: when the heat from the moon fades just before it is eclipsed, ἀνιεμένον ... ὁ κατείχετο δ ἄηρ καὶ ἥρεμει,
πάλιν κινεῖται καὶ γίγνεται πνεῦμα , "when the cause which held it quiet ceases to operate the air is set in motion again and a wind arises" (tr. Lee). This does not fit Aristotle's previous accounts of calm, which say that heat destroys or prevents exhalation, implying more exhalation must form before wind can blow. Inconsistencies are not infrequent in Hete.; but there are other grounds for suspecting this passage to be an interpolation.¹

1. 367b25-32 (γίγνονται γὰρ κτλ.) says nothing of earthquakes, and not only does not explain what precedes, but even contradicts its statement that the fading of heat before an eclipse prevents wind. (See, however, Alexander 121.4-28.) Also, 367b25-32 is almost identical with Probl.XXVI 18 (942a22-8); and the compiler of Probl. is unlikely to have known Hete., or he would have copied more from it, as he did from Vent. (v. p. 326 ). Therefore, the passage was more likely copied from Probl. into Hete., by someone who wished to compare it with 367b19-25 - Hete. has some, but only a few, interpolations, cf. Lee on 362b10-2 and 376b22-8 and p. 226n supra on 340b36-1a1.

¹. Cf. The reflection of the sun's heat (p. 324n ).
². v. Hete. 394a5ff and Py. 330c. Note (ed. of 1886; in 'Appendix dubiarum'), Lasser (1934-6) 1501.
Alternatively, calms are caused by dry exhalation flowing into the earth (where it then causes earthquakes, i.e. it remains dry exhalation). At 366a17ff this seems due to cold: αἰ νόκτες ... τῶν ἁμερῶν νηνεμώτεραι ὅλα τὰ ἀκουσίαν τῇ τοῦ ἥλιου. ὡστε ἐσω γιγνεται πάλιν ἡ ὑπός κτλ.; cf. 367b19–25. Elsewhere it appears not to be, as at 367a26ff, where dry exhalation's departure causes cold; at 365b28, 366a7f, 368b7f cold is not mentioned. This reversal of the exhalation's normal movement is comparable to the ebb tides of the Euripus (366a19–23, cf. 367a28 μεταρροίας) - a natural and plausible idea, but unrelated to any general theory¹; for Aristotle nowhere makes more than incidental comments on tides, and those are inapplicable here.² Indeed, he nowhere explains why dry exhalation, which naturally rises, should ever descend into the earth.

366a6–8 speaks of this descent in different terms: συνεχῆς ... ὅσα ἡ ἁναθυμίας ἀκολουθεῖ ὡς ἐπὶ τὸ κολῷ τῇ ὑμῃ τῆς ἀρχῆς, ὡστε ἐς ἐσω ἀμα ἡ ἐξω ὑμῃ πᾶσα. It is a natural assumption that, if one part of a continuous mass of matter moves in a particular direction, the rest will

¹. cf. the reflection of the sun's heat (p. 224n).
follow; but what is the ὁμὴ τῆς ἀρχῆς? Why does the first part of the mass begin to move as it does?

ὁμὴ and ὁμάω in Aristotle denote 'rush' or 'rapid movement', or the beginning or cause of such movement. In the latter sense, ὁμὴ is sometimes a source of movement inherent in a thing, as at Ph. II 192b18, an artefact has no ὁμὴν ... μεταβολῆς ὑματον; hence, often, ὁμὴ or ὁμάω denotes a natural tendency to behave in a certain way, e.g. an animal ὁμὴ πρὸς τὰς ὀχέλας or πρὸς τὴν θήραν; or, a fever possesses a man or a weight falls κατὰ τὴν δαυτοῦ ὁμὴν. But if ὁμὴ at 366a7 meant such a 'natural tendency', it would have to be a tendency to rise (ἐξω) or descend (ἐσω); which is hardly possible, since we know that dry exhalation's motion is upwards.

More likely, therefore, ὁμὴ here means simply 'motion', or 'beginning of motion', as at HA 582b34f ἢ ... τῶν γυναικῶν ὁμῆ, cf. 587b32-4; GA 750b19f, certain birds προσδέονται τοῦ ἀρρενοῦ πρὸς τὴν ὁμὴν τῆς τοῦ περιττάματος ἐκκρίσεως (i.e. require an external cause of movement). If

1. HA 546a15, 523a17f; cf. HA 542a24, 574a13, 581b12, 552b23f, 573b31ff, En 1102b21, Po. 1449a2-5.


366a7 δρμὴ is simply motion, or the beginning of it, then δρμὴ in 366a8 will simply mean 'move rapidly'¹, and the whole sentence means merely that, where the first bit of the exhalation goes, the rest follows; the δρμὴ does not cause the movement.² Thus 366a6-8, like the rest of Mete. II 8, does not explain why exhalation descends into the earth. It is not unnatural that Aristotle should omit to explain this, since he is discussing earthquakes, not wind, and is concerned only with their immediate cause. Earthquakes are infrequent phenomena; he may reasonably have supposed that exhalation flows into the earth, to cause them, by some rare, accidental combination of forces, which it is unnecessary and impracticable to describe. This perhaps justifies his putting forward in Mete. II 8 a series of explanations of calms which, as we have seen, differ from those given in his main account of winds (p. 284ff.), and have so little connexion with the rest of his meteorology.

1. As also at 366a10, 368b10 (and perhaps b19), which are similar.
2. Nor, probably, is it the cause at 364b5f (certain winds are strongest and most frequent διὰ τὸ ἀγγελτάτῳ ... τὴν δρμὴν αὐτῶν εἶναι), where δρμὴ appears to mean merely 'source', 'origin'. 368a9f (earthquakes die down gradually, partly because ἡ δρμὴ τοῦ πνεύματος ... ὅτι εὔθεις ἄπασαν ἄνηλομαν τὴν ὅλην) presumably means that the movement, δρμὴ, of the first piece of material to move is gradually imparted to the rest. δρμὴ cannot be a tendency to move inherent in the material, or it would surely affect all of it at once; but it might be the initial cause of movement in some other way.
6) **Winds, rivers** and Aristotle's wind-rose.

Winds, like rivers, have sources; a source is "the point at which things that are ... forming and flowing together first meet" (p. 264). This should imply that material from a wide area collects at a single point, and only then constitutes wind; and Aristotle evidently believed this: 361b1ff, winds are formed \( \text{ἐκ πολλῶν ἀναθυμιάσεων συνιονουσῶν κατὰ μικρόν, ὥσπερ οἱ τῶν ποταμῶν ἀρχαί}. \) He states, in proof of this, that winds become stronger as they get further from their sources, i.e. he thinks extra material joins and swells the wind as it blows. \( \sigmaυνιονουσῶν \) implies that exhalation comes **together**, presumably from a wide area to join a wind blowing on a narrow front - another idea obviously suggested by the river analogy.

With this compare 367a31ff (cf.p.267): wind feels cold (although caused by dry exhalation) because it sets cold air in motion; for the same reason, breath blown through the lips feels cold, except close to the lips (b1-4). But breath only feels cold if blown through pursed lips (cf.367b2 ὅσκερ - ἀὔξωμεν); therefore, the analogy implies that winds

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1. Cf. Boeker 2229f; but I know no evidence for the view he imputes to Aristotle, that air causes wind because it is heavy and flows downwards. (361a30, which he cites, must be explained differently, v.p. 269f.)
blow initially over only a narrow front. Aristotle's windrose suggests the same conclusion, speaking as if each wind blows from a single point (τὸ ἀφ' Ἰ Ἀ, etc.; v. Mete. 363a 34-4a2).

Aristotle's winds further resemble rivers in having fixed sources: every major wind blows from a particular region, and must be coming from that region no matter in what part of the ὀλυμμένη it is blowing. Cf. Mete. 362b35f: "our own north wind does not blow right across the region in which we live" (tr. Lee). With us, north winds are most frequent; "yet even in our region they fail and are not strong enough to travel far" (363a4f, tr. Lee): hence in 'the sea south of Libya' the prevailing winds are east and west, not north and south. Aristotle clearly assumes that all north winds have their origin to the north of the ὀλυμμένη. The south wind's origin is similarly

1. Theophrastus Vent. 19 makes this explicit, cf. p. 365ff.

2. Other authors thought differently; e.g., [Hippocrates] Aë. speaks of 'the winds that blow between the winter sunrise and sunset' etc. (§3, L. II 14.21ff; §4, p. 18.18f; §5, p. 22.15f). (Cf. H. Steinmetz (1907) 23-25, 42-49 - though some of his conclusions seem rather dogmatic.)

3. Evidently at the north pole, cf. 363a8 ὁ δὲ τοῦ ἐκτέφου πόλον πνέων ἀνέμος. Cf. also 361b1-8: there is little wind at the north pole; but τὸ κατὰ μικρόν ἀκοπνεύον κτλ. seems to imply that the north wind starts from there, even though it only becomes significant as it moves further off.
fixed, at the Tropic of Cancer (not the south pole or the Tropic of Capricorn) (362a31f, 363a8ff).

Thus winds have fixed, narrow sources, fixed directions (obviously), and, limits to the distance over which they blow. Hence, every wind must be clearly distinct from every other; the winds are "a certain limited number of individualised things, each having its own particular domicile" (Thompson (1918) 54). This is confirmed by Aristotle's wind-rose.¹ To us, the winds do not have fixed sources, and wind may blow from any direction whatever; consequently, we provide names for different directions at equal intervals all round a circle (North, North-North-East, North-East, etc.). But Aristotle's wind-rose is irregular: 363b28ff, two winds (Meses and Thrascias) blow on either side of due North; but there are no corresponding winds at the opposite points of the compass (b33ff), unless from S.30°E. ἐκ ὀλίγον πνεύμων ἄνεμος , called in that region Phoenicia. Thus Aristotle's wind-rose is not just a conventional means of indicating wind-direction, but a statement of what winds actually blow; each wind is an

¹ Other wind-roses imply the same view (v. Seneca NQ V 17.2, 5; Vitruvius I 6.9). For comments on this aspect of ancient wind-roses v. Thompson (1918) and Rehm (1916) 5. (I know no full discussion; but there is much literature on wind-roses which I have not read.)
individual entity, of which there may or may not be one in any given region. Phoenicias blowing only 'for a short distance' also shows that each wind has a fixed origin, presumably at or beyond the edge of the oikoumēnē.

All this shows how closely winds resemble rivers: a wind, like a river, is a distinct entity, with its own name, a fixed narrow source (where material collects from a wide area), and a fixed course (since the wind's direction and distance are both fixed).¹ This explains why Aristotle is so scornful of those who say that, because the air that moves is one and the same, therefore ἕνα ... ἄνεμον εἶναι πάντας τοὺς ἄνέμους, its differentiation by place of origin being apparent only, παρακλησίως λέγοντες ὡσπερ ὅν εἰ τις οἴοιτο καὶ τοὺς ποταμοῖς πάντας ἕνα πόταμον εἶναι (349a20-26). This theory was clearly a protest against the view that winds from different directions are distinct entities, and to us should seem highly reasonable; but the wind-river analogy was so firmly established in Aristotle's mind that he regarded it as nonsense.

1. All this is confirmed by 364b14f, where Aristotle can only describe a wind veering by saying that one wind stops and then its neighbour starts (ἀλ ... περιστροφῆς γίγνονται αὐτῶν κατὰπανομένων ἐν τοῖς ἐξομένοις).
This analogy between winds and rivers has no relation to Aristotle's general wind theory. Exhalation obviously can occur in any part of the world\(^1\); which surely implies that wind can originate in any place, and not just at fixed points round the edge of the olxoubemn\(\). Similarly, winds may both blow on a broad front (cf.365a6ff) and be composed of exhalation that has formed over a wide area:\(^2\) it seems most unlikely that in such cases the material first collects at a narrow 'source' and then spreads out again after it has become wind.

The wind-river analogy, in fact, depends not on philosophical theories, but on primitive and popular ideas about wind. When the early Greeks regarded Boreas, Zephyrus etc. as gods (p.20ff), they clearly were distinct individual entities. Moreover, the actual winds of the Mediterranean seem to suggest that each wind has an individuality of its own, in a way which does not apply in Britain: different winds tend to blow there at regular seasons, and with more

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1. As Mete. implies. Cf. especially 360b26ff: wind blows after rain because more exhalation forms when the earth is wet. Obviously Aristotle is not thinking only of rain on the edges of the olxoubemn\(,\) therefore the exhalation is not confined to those regions.

2. Cf. 363a16ff: the south wind is strong because the region whence it originates is \(\delta\nu\alpha\kappa\varepsilon\pi\tau\alpha\mu\varepsilon\nu\circ\).
or less fixed characteristics; even today, many winds in the Mediterranean are known by special names, while in Britain such names are exceedingly rare. Similarly with winds' origins: we never see them; and the same wind might blow over the whole region with which the early Greeks were familiar. Hence they would naturally assume that winds originate beyond or at the edge of the region which they knew.

Such primitive, popular assumptions provided the basis of Aristotle's wind-rose and the wind-river analogy. Aristotle no longer regarded the winds as divine, and thought they had fixed sources; but, while rejecting the obviously mythological features of the primitive view of wind, he remains strongly influenced by it, even when it is inconsistent with his general wind-theory.

Aristotle's failure to think out the problems his wind theories raise is further illustrated by his wind-rose. In

1. Shaw (1926) 15, 28; Schmidt in Boeker 2212-4; Cary and Warmington (1963) 17.
2. Shaw (1926) 27f and (1933) 53.
3. The Etesian winds blow over the whole eastern Mediterranean (Schmidt in Boeker 2212).
4. Thus, in Homer, Boreas and Zephyrus blow from Thrace (I 5).
5. A natural assumption, if each wind has a fixed direction and originates at the edge of the οἰκουμένη. (Wind-gods would presumably have some freedom of movement.)
describing it he arranges the winds round δ τοῦ δρόξοντος χόκλος (363a27), i.e. he thinks in terms of the horizon visible from one point, and of winds blowing from different quarters of it. He admits that the circle is merely τοῦ μᾶλλον εὖςμως ἔχειν, and represents the section of the earth in which we live (the temperate zone) (363a26ff)\(^1\); but this is drum-shaped (362a25), and he nowhere considers how the circle is to be fitted to the drum.\(^2\) His attitude is illustrated by 364a27ff: opposite winds ἀμα πνείν ... ὅχι σόλον τε (because ἄτερος ... παῦσεται ἀποβιασθεῖς); but winds which are not opposite may blow at once, so that the wind is sometimes favourable for ships sailing at the same time from different directions to the same point. Aristotle is thus not thinking solely of what winds can blow at a single point; but he is still thinking of winds blowing towards one point; and his denial that opposite winds can blow simultaneously seems reasonable only if limited to winds blowing at the same time and place (as may be intended by

1. The southern hemisphere has a separate set of winds (362b30ff).

2. Thus the south wind apparently originates at a fixed point, and on the Tropic of Cancer (p.296ff): as the Tropic is a circle, where can this point be? Or should there not be several south winds, e.g. one for Africa, one for Asia?
Aristotle evidently started by thinking in terms of the winds that can blow at a single point, and never fully succeeded in escaping from this viewpoint, and envisaging clearly how winds might blow over the temperate zone as a whole.

1. In fact, opposite winds frequently blow simultaneously in different places (e.g. on the opposite sides of a depression); Mete.344b36f, 368b6f mentions an instance of this happening (cf. Boeker 2255).
7) **Prevailing winds, and the seasons at which winds blow.**

Much of what Aristotle says on this subject closely accords with his more general theories. The sun's motions cause all sublunary events (p. 212f.), and in particular the exhalation which provides the material of wind (cf. 359b34ff). Hence, the commonest winds are from north and south, because the sun does not pass over those regions, with the result that there is most water there, which causes more dry exhalation to form (361a4ff, cf.p. 266) - this, however, Aristotle later modifies, saying that the south wind blows from the Tropics\(^1\), where there is no water because of the nearness of the sun, and that its strength is due to the great size of the area whence it blows (363a12ff).\(^2\)

The Etesian winds, which blow from the north after the summer solstice, are similarly explained as due to the exhalation which the sun then causes in the north.\(^3\) In the

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1. 362a31f, 363a8ff. Cf. Alexander 93.11ff (but Hayduck (1899) deletes the passage, which is not in his best Ms., cf. his p.vif); Olympiodorus 170.33ff.

2. This is inconsistent with the view that great heat prevents wind (p. 287); also, 363a 16-18 (νότος is μετέξων καὶ πλεῖστον ... τοῦ βορέω) is inconsistent with 364a5ff, which says north winds are commoner (cf. 365a5f - but that may mean only that north winds are **locally** commonest).

3. 361b35ff (on which cf.p. 287n ), 362a18ff (a slightly different account).
same way, but less continuously, the Leuconoti blow from
the south at the opposite season. ¹

Thus far, Aristotle's account accords reasonably well
with his general theories, and (at least so far as concerns
the prevalence of the north winds, and the occurrence of
the Etesians) with the actual weather of Greece. ² Other
statements about winds and seasons, however, have no
relation to his general theory, and presumably depend
entirely on observation or popular beliefs about the winds:
for example, 364a2ff, opposite winds blow at opposite
seasons, e.g. Caecias and Lips at the two equinoxes and
Zephyrus and Eurus at the solstices: nothing in Aristotle's
meteorology explains why east and west winds should blow at
particular seasons (although he knows that in some places
they are the prevailing winds: 363a5ff). Cf. 361b30ff, the
rising and setting of Orion are times of storm ³, because they
occur ἐν μεταβολῇ ὃ ρας ... αἱ ὑε μεταβολαὶ πάντων
tαραχώδεις διὰ τὴν ἀναίστιαν : I know no other occurrence

1. 362a14ff. (It is not clear why they should blow then,
if south winds blow from the tropics, which the sun passes
over throughout the year.)

2. v. Shaw (1926) 24, 27 and (1933) 53; Schmidt in Boeker
2212-4; Boeker 2326ff.

55; Probl.XXVI 13 (941b24ff); Hesiod Op.615f, 619ff;
Virgil A.1.535, 4.52, 7.719; Horace C.I 23.21, III 27.18.
of such a general principle in Aristotle, nor does it seem to have any relation to the rest of his meteorology.

Thus Aristotle's general theories only partially explain what he reports about prevailing and seasonal winds; nor do they explain all he says in Mete.II 6 on the characteristics of the different winds (though they do explain some of it). This incompleteness was inevitable: even modern meteorology has so far failed to provide a complete explanation of the 'general circulation' of the winds over the earth (Sutton 38-46).

1. Cf., however, the belief that disease tends to occur at changes of season: v. Herodotus II 77, with which now and Wells (1912) ad loc. compare [Hippocrates] Aph.III 1 (L.IV 486.4-6).
8) The date of the Meteorologica.

No absolute date can be established for the Mete.: some remarks in it might appear to indicate one, but all are of uncertain significance, or may be later additions.¹ It must, however, be later in the main than Cael. and GC:² for the beginning of Mete. repeatedly refers to those two works³; and in them Aristotle establishes ideas that are important in Mete.: the theory of the fifth element⁴, and the primacy of the opposites hot, cold, wet and dry⁵, which characterise the exhalations in Mete. in the same way as the elements in GC.⁶ There is no meteorological reason for these ideas: clearly Aristotle adopts them in Mete. because he has already established them in the other two works.⁷

1. v. Jaeger (1948) 307n, Lee xxiii-v. (On Mete.'s date v. also Strohm (1935/6); Düring (1968) 247f.)
2. So Jaeger l.c., Strohm (1935/6) 1ff.
3. Mete. I 1-3 (538a20ff, 339a11ff, b16ff).
4. Cf. p. 212 supra; Strohm (1935/6) 3f, 15ff, etc. (This theory underlies Mete. I 3-8.)
5. Cf. GC II 2.
7. The same applies to the natural heat and wetness of air; v. p. 231f. (Isolated passages in Cael. (II 7) and GC (330b21-30), which seem more closely related to Mete. than to their own contexts (v. pp. 215, 227), were presumably subsequent additions to those works, made in the light of Aristotle's later, meteorological ideas.)
Now the element-theory of Go II depends on the doctrine that change occurs between two opposites in a substrate, expounded in Ph. I 6-7, to which GC 329a27 evidently refers; and Cael. probably represents a middle stage in the development of Aristotle's astronomy.\(^1\) Therefore, Mete. cannot be among Aristotle's earliest work, and is later than, at least, a considerable part of Ph., Cael. and GC.

It is also clear that, when Mete. was written, Aristotle was already interested in biology: for it contains detailed biological analogies\(^2\), and Mete.I\(\text{I}\) relates Mete. to the biological works as well as to Ph., Cael. and GC. The presence of this introductory chapter suggests that Mete. was not written until after Aristotle had decided to arrange his physical works to form a complete account of the physical world. Now meteorology clearly was not one of Aristotle's major interests: compared with his work on other subjects, his account of it is both brief\(^3\) and unoriginal (see pp. 398 - 401); it seems natural to suppose that

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1. So, for varying reasons, Jaeger (1948) 299ff; Guthrie (1939) xv-xxxvi; Lloyd (1968) 27.
2. As 358a5ff, 360b2ff, 366b15ff.
3. Mete.I-III fills less than 40 Bekker pages, compared with c.154 for the fundamentals of Aristotle's physics (Ph., Cael., GC) and over 300 for the biological works.
Aristotle began by studying those aspects of nature in which he was most interested (i.e. general physical principles and biology); that he then decided to arrange his work as a systematic account of nature; and that he consequently started to write Mete., its subject being one that a systematic account of nature had to cover. This suggests that Mete. is later than part, at least, of the biological works.

Finally, was Mete. itself written all at one period? Strohm (1935/6) advances a theory of the development of Aristotle's meteorology (based on Jaeger's theory of the development of Aristotle's interests away from metaphysical speculation and towards empirical science) in which he regards those parts of Mete. in which phenomena have a 'transcendent' cause (the heaven's motion) as earlier than those in which the causes are 'immanent'; which seems to imply (though Strohm never says this) that different parts of Mete. were written at different periods of Aristotle's life, as his outlook on the world altered. But I think that this and other changes of emphasis and inconsistencies were necessitated by the subjects discussed in Mete., and need not reflect changes in Aristotle's outlook (e.g., the heavens' motion must be less important in the lower than in the upper atmosphere). It is improbable that Aristotle was very long
over writing Mete.: for this would imply that the two exhalation theory, so important in Mete., was a pre-occupation of Aristotle's over a long period; and if it was, it would surely be mentioned more often in Aristotle's other works (cf. p.251-6).

Probably, then, Mete.I–III can be regarded as a unity. Indeed, Mete.I 1 shows that Aristotle himself regarded his physical writings as a whole as forming a general account of the natural world (so, presumably, he was not aware of any irreconcilable inconsistencies between them). This is not a surprising or original conclusion; but it does justify (what some studies of Aristotle's development might suggest to be impossible) our regarding his physical works as constituting a single system. It is to consider the place of meteorology in that system that I now turn.

1. Thus stock seas, e.g., an essential part in Aristotle's definition of wreth (see Anc. Phys. 251a-25), in his theory of animals' reproduction (the male provides the form: see 722a10, 728a-21 etc.) and in his discussion of animal species (as PA 642a34, 643a1, 11, etc.). On the final cause in biology see (e.g.) Randell (1969) 325ff.

2. The only typically Aristotelian usage of the concept of 'form' which refers to meteorology seems to be at 357b28, 31 (the sea remains the same always but not any.

(Other occurrences of this, either do not refer to meteorology (363a32), or need have no connotation of the peculiarly Aristotelian concept of 'form' (339a25, 339a29, 359b28, 360a18, 373a20).) The only hints of final cause seem to be 353a34–35, where Aristotle mentions and rejects the idea that the heaven exists for the sake of (oιδρων) the earth, and 359b32, where it is explicitly a means (of the rain-cycle), which suggests some sort of purpose but does not say what it is.
9) **The absence from Mete. of formal and final causes.**

Form and purpose are two of the four causes Aristotle distinguishes in Ph.II (194b23ff); they are of vital importance in the biological works; they are not absent from those that discuss the first principles of physics and the theory of the elements (Gae., GC, also Mete.IV; v.infra); and Aristotle repeatedly says that a physical explanation should include all four causes (Ph.II 198a22-4, Metaph.II 1044a32ff). It is therefore remarkable that in Mete.I-II formal and final causes are, in effect, totally absent.  

Now Mete. is concerned with two sorts of objects:

(i) certain materials: the elements, and bodies of comparable simplicity, e.g. cloud, and, especially, the

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1. Thus εἶδος has, e.g., an essential part in Aristotle's definition of ψυχή (de An.412a5-28), in his theory of animals' reproduction (the male provides the form: GA 729a10, b18-21 etc.) and in his discussion of animal species (as PA 642b24, 643a1, 11, etc.). On the final cause in biology see (e.g.) Randall (1960) 225ff.

2. The only typically Aristotelian usage of the concept of 'form' which refers to meteorology seems to be at 357b28, 31 (the sea remains the same εἶδος but not ἀριθμός). (Other occurrences of εἶδος either do not refer to meteorology (363a32), or need have no connotation of the peculiarly Aristotelian concept of 'form' (358b25, 339a29, 359b28, 360a15, 378a20).) The only hints of final cause seem to be 353a34-b5, where Aristotle mentions and rejects the idea that the heaven exists for the sake of (χάριν) the earth, and 354b32 ποῦτ' ἐξελέει τὸ άουλεμα τοιετῶ ἃ φύσις (of the rain-cycle), which suggests some sort of purpose but does not say what it is.
exhalations; these move about and change into each other, but do not form into more complicated bodies.

(ii) certain events: most meteorological phenomena are not simply material objects, but events, i.e. material objects undergoing certain movements or changes (e.g. wind is a mass of dry exhalation moving round the earth, 361a30f). Does Aristotle outside Mete. regard such materials and events as having a form or purpose?

Now Cael. and GC several times speak of the elements or primary opposites, or some of them, as having or being 'form'; for example, GC 329b9f (beginning Aristotle's account of the primary opposites) says that only tangible opposites σώματος εἴδη ... ποιοῦσιν; 323b31ff that τὸ ποιοῦν and τὸ πᾶσχον must be εἴδει ... ἐνάντιον (instancing heat and cold, 324a9f); 324b18-20 implies that τὸ θερμὸν is the formal element in fire; 318b16f says that heat is form and cold privation. One element can be called μᾶλλον ... εἴδος than another (318b32f, 335a14ff, Cael.312a12ff); a body moving to its own place moves ἐξ τὸ αὑτοῦ εἴδος (Cael.310a51ff). Bodies like flesh, bone and wine also have 'form': GC 321b21ff, 328a23.

1. Mete. also concerns subdivisions of these phenomena, e.g. the different winds as distinguished by direction; but it is natural that their form or purpose (if any) should be ignored, if that of the main classes of phenomena is so.
Thus when, in meteorology, simple bodies change into each other and move to a new natural place (when, say, water turns to vapour and rises into the air), then change of form is involved; and it is comprehensible why Mete. does not speak of 'form': Aristotle uses the concept in his theoretical analysis of change; but when he discusses the elements in particular (in GC II 2-7, 329b7-334b30; Cael. III-IV), their form is hardly mentioned, and, when it is, the ideas expressed tend to be ones that Aristotle never developed (as with the ideas just cited from Cael.).

Meteorological phenomena are mostly events (cf. p. 311). Typically, Aristotle's 'forms' are forms of objects (e.g. house) or their qualities (e.g. health), and it is not clear whether an event has a form. Metaph. Z 1041b7f says that the substance is the cause, i.e. the form, which makes the matter to be a definite thing; and the preceding discussion has mentioned not only objects and qualities ('house', 'cultured'), but also events: eclipses and thunder (1041a10-b7); which implies that such events have not form merely, but even substance.¹ Metaph. H 1044b8ff,

¹. Cf. H 1043a19-24, apparently implying that ἡγεμονία has both form and substance.
however, takes a different view, denying that eclipses have substance, and saying that for them ως εἶδος ο λόγος (b12), "their λόγος (formula, definition) corresponds to the form", and that the λόγος is not clear unless it mentions the cause. 1 If what corresponds to the form of an event is simply its definition, then such are not absent from Hete.; though, indeed, many phenomena are not defined.

Next, final causes. On the principle that 'nature does nothing in vain', meteorological events should have a final cause; or, at least some should, if we assume that events which occur always or usually (e.g. rain in winter) must occur for a purpose (cf.Fh.II 198b34-9a5). GC 336b25ff gives as the reason for the continual coming-to-be and passing-away of sublunary things that being is better than not-being, and that continual coming-to-be is their nearest approach to continual being (cf.Metaph.9 1050b27ff). This presumably is the final cause of elemental changes, and fits with GC 324b14-18, 335b6f, which identify final cause with form: the end of things is to be themselves, to exist. It would be difficult to develop this view of the elements'

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1. As an example, he says that an eclipse is στέρησις φωτός, to which the cause should be added ὑπὸ γῆς ἐν μέσῳ γεγομένης (b13-15).
final cause into any detail. (Mete. IV 390a3ff also mentions their final cause, but only to say that it is less clear than that of other things.)

If meteorological events do not strictly speaking have a form (cf. p. 312f), then they cannot have, as final cause, the achievement of that form. Their purpose can only relate either to the materials involved (i.e. the elements and similar bodies, whose final cause I have just discussed), or to something outside the phenomenon altogether. In fact, the only final causes of meteorological phenomena which Aristotle (so far as I know) ever suggests, are of the latter kind: Ph. II 198b18ff, the purpose of rain is its effect on the crops; and Afo.94b33f, thunder occurs as a threat to those in Tartarus. In neither place does Aristotle seem to regard this as the true final cause; and indeed, this sort of final cause, by which a thing exists for the good of something outside itself, is not the sort in which he believed: to him, a natural thing serves only its own good, or the good of its species or the whole of which it is part.¹ Hence, Aristotle evidently doubted whether meteorological and similar events have a final cause at all: Metaph. Z 1041a27ff says that the substance of a thing is its cause,

¹ v., e.g., Allan (1952) 87f.
i.e. essence, which with some things (e.g. a house) is
their purpose, but with others is τι ἐχίνης πρῶτον —
presumably these have no purpose; thunder is mentioned, and
seems to belong to this class (cf. Ross (1949) 173);
similarly, Metaph. H 1044b11f says of eclipses τὸ ... οὗ ἔνεκα ἵσσως σῶ ἔστιν.

All this makes it natural that Mete. should have
nothing in particular to say on formal and final causes.
However, in view of the brief remarks on form and purpose
that are made in Cael.III-IV, GC and Mete.IV, it is
surprising that Mete. says nothing about form or purpose at
all. The explanation presumably lies in the tradition of pre-
Aristotelian meteorology, which is concerned solely with
material and efficient causes. I suggested on p. 307f that
Mete. was written to fill a gap in Aristotle's account of the
physical world: meteorology was a traditional concern of the
physicists, and no account of physics could ignore it;
Aristotle discusses it, without being very interested in it,
or having anything very new to say about it, because his
predecessors had made it an essential part of physics; and
therefore he was prepared to follow their tradition, and
say nothing of final or formal causes.
10) **Material and efficient causes.**

In this field, the relation of Mete. to Aristotle's other works is far more evident. Two works, Cael. and GC, lay down general laws concerning the elements and opposites, which Mete. should then apply in explaining meteorological phenomena; Mete.I 1-3, by its references to the other works (p. 306), recognises this, and much of Mete. in fact does it: thus Mete. expands Cael.'s and GC's brief account of how the heavens' revolution causes heat, and so other events, in the sublunary world (p. 212-21); the rising of the exhalations and fall of rain, snow etc. employs Cael.'s doctrine of the elements' natural places; and the changes between the exhalations and other materials, and interaction between the exhalations themselves, employ GC's theory of changes between the four primary opposites (p. 234-8).

Logically, the biological works and Mete.IV, insofar as they concern material and efficient causes, should also

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2. Much of this might depend purely on common observation; but Cael.'s theory is clearly the basis of Mete.'s doctrines that elemental fire/dry exhalation fills the highest sublunary region (pp. 212, 215, 217f.), and that it rises above water-vapour (p. 235f.).
be applying the general laws of Cael. and GC in their own particular fields; and so they do, at least insofar as not, cold, wet and dry are always of fundamental importance.

In some respects, however, both they and Mete. diverge from Cael. and GC, for example in disregarding the theory of the four elements: in Mete., the elements are largely replaced by the exhalations (p. 228-30); PA 646a12ff (quoted p. 230n) says that it is better to regard the primary opposites, not the elements, as the ultimate constituents of animals, and later (648a19-649b28) discusses the opposites, but not the elements, at length; the biological works in general largely ignore fire, which rarely has a part in a biological material or process, and frequently regard as a source of cold, and not, as it should be, of heat;

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1. In PA, MA, IA, GA, de An., PN I have noticed only the following: various places in Resp.473a4-480b1, where within the body seems essential to life (cf. de An. 416a2-18, PA 652b7ff, 670a25; but the PA passages seem in doubt whether this is literally fire, and similar passages speak only of heat: PN 466b32, 469b7f, 470a19. Also GA 736b33ff denies that the (surely similar) heat essential to generation is fire.) GA 761b17ff, Resp.477a30 say that certain animals belong particularly to fire, out of the four elements; Sens.438b20 says similarly that the sense of smell belongs particularly to fire; and PA 651a20ff, Long.466a23f say that contains or is connected with fire. (I omit passages which draw an analogy between burning and biological events.)

2. PA 667a24ff, 668b33ff; in PN 456a7ff, 470b4, Resp. passim; cf. de An.405b28, PA 642a35ff. (V. also p. 232 supra.)
and Mete. IV is based on a consideration of the primary opposites rather than the elements\(^1\), though it says much of both.

The primary opposites — heat above all — retain their importance, in Mete. and elsewhere. But even here Aristotle cannot simply follow GC's theory, because GC is based almost entirely on a simple theory of how each quality tends to turn its opposite into itself (v.p. 278\(^2\)), and Aristotle's other works discuss many phenomena which this clearly does not suffice to explain: he must, therefore, elaborate or modify GC's theory.

In practice, when he meets this problem, he tends to base his explanations on some empirical observation, which often has no clearly-defined relation either to GC's general theory or to the observations he has used in other places. GC II 2, 329b26ff, says that θερμὸν ... ἐστὶ τὰ συγκρινοῦν τὰ ὄμογενη, and that consequently συμβαίνει ... ἔξαιρεὶν τὰ

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1. Cf. §1, and 379b10ff, 381b23f, 382b27, 28, at the beginning and end of the early sections of the book, which speak of the primary opposites as subjects of the sections.

2. GC II 2 explains how various non-primary qualities must logically be derivatives of one of the primary ones; but he does not explain by what means such effects are produced, except for brief remarks (329b26-30) on the effects of heat and cold, on which see below.
ἀλλότρια, 'it incidentally expels foreign bodies from things'. 1 (Aristotle is here thinking of how heat breaks up mixtures into their constituent materials, as when fresh water is separated from salt by distillation (Mete. 358b16ff), or a metal extracted from its ore or purified by heat (cf. Mete. IV 383a30ff).) This, then, is said to be heat's main effect in Aristotle's most general physical works; but elsewhere it hardly occurs. In Mete. heat's principal effect is to cause the formation of exhalations (i.e. rarefaction, διάχρυσεων, cf. p. 75); and in Mete. IV the 'δύναμις' of heat is πέψις, whose varieties are ripening, boiling and roasting (379b12f, cf. Lee ad loc.). PA 648b10ff - a general discussion of heat - introduces further complications: things may be 'hot' in different ways; e.g., boiling water θερμαίνει more than flame, but only flame causes burning or melting (ib. 26f); boiling water is hotter to the touch than oil, but grows cold and freezes more quickly (30ff); blood feels hotter than water and oil, but solidifies more quickly (32f). GC nowhere suggests that there are different sorts of heat; and most of the instances of heat mentioned in this part of PA have no relation to

1. Cf. Cael. 307a31ff; also Mete. IV 378b21ff, heat and cold are both συγχριτικῶν.
In the biological works as a whole, the most important effect of heat is probably πέψις, but this normally refers not to the processes cited above from Μετε.ΙV, but to zoological ones such as digestion and the formation of semen (e.g. ΠΑ 650a2ff, GA 719b2).

Now, none of these processes is actually inconsistent with the general theory of GC and Cael. The exhalation theory accords fairly closely with GC's theory of the opposites (p.234-8). Some of the other processes, e.g. πέψις, have no such evident connexion with GC; but all of them can be regarded as possible variations of the effect produced when a hot body heats some other body. Nevertheless, in all these places Aristotle has introduced some factor which is foreign to the theory of heat in ΒC; he has supplemented GC's theory, by choosing some effect or effects which he had observed that heat produces - e.g. evaporation, ripening, cooking - and basing a theory of how heat works upon it; and in each field of study he has chosen a different observed effect, one that seemed particularly significant.

1. Nor have they any particular connection with the processes due to heat just cited from GC, Μετε. and Μετε.ΙV.
2. Μετε.ΙV 381b6ff relates digestion to boiling.
3. In Μετε., the frequent mention of διαχρίσειν, συνίστασθαι etc. as effects of heat and cold (cf. pp.75f, 78n) is an element foreign to GC.
to the field of study concerned. (Occasionally, obvious empirical facts induced Aristotle to adopt ideas which are incompatible with GC's general theory: for example, frictional heating (p.215ff), the reflexion of heat (p. 224&n), ἀντιπέρστασις (p. 280ff), μάρανσις (p. 288ff), the idea of cold squeezing out heat and vapour with it (p. 259&n).)

The relation of these various ideas to GC differs widely: for example, frictional heating appears completely inexplicable in the terms of GC's theory (p. 218ff); but ἀντιπέρστασις, though not consistent with GC, seems to be developed from it, in that it depends on the idea of a conflict of opposites (p. 283); and dry exhalation, though inconsistent with GC in detail (p. 252f), and never mentioned there, seems to be in large part deduced from its theory (p. 247) (though in this it is exceptional). The point I would stress is that Aristotle has no developed general theory of heat, which he can apply in the different branches of physics. His general theory tells him only that heat must be important in every field; the way in which it functions he has to work out ad hoc, for each field of study and for particular phenomena. His idea of the way heat functions he usually bases on some empirical observation, adopting a different idea for each different subject; and
he is prepared to adopt ideas inconsistent with GC's general theory (without, so far as we can tell, being led by this to try and work out a new, modified, general theory of heat). A function of heat which is vital to one field of study may be virtually ignored elsewhere: outside Mete. the two exhalation theory is hardly mentioned (p.251-6), while Mete. itself virtually ignores πεψίς. 1

Similarly with ἀηρ, πνεύμα and wind. Obvious facts compelled Aristotle in Mete. to abandon GC's theory that ἀηρ is simply hot and wet, and to adopt a theory which allows it to be cold and dry (p.227ff). In Mete. wind, πνεύμα, consists of dry exhalation, and so is theoretically hot (p.265 al); and in GA, too, πνεύμα seems to be a special hot variety of ἀηρ; but GA's theory, though connected with Mete.'s, is not consistent with it (p. 256f); the actual reason why πνεύμα is called hot in GA must be that it is within the body, which we know is hot. In Resp., on the other hand, the function of breathing is to cool the body, i.e. πνεύμα is cold: breath as we inhale it, we know, is cold. Again we find that Aristotle modifies

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1. Mentioning it only at 357b9, 358a6-10 (on the sea's salt - an exceptional passage, v.p. 242-5), and at 371a5, a τυφών is ολον ἀθεφίλας ἀπεπτος (either because it is uncoloured, while a προσήνηρ is coloured (371a2, 17); or because, unlike an ἀθεφίλας, it is not freed from the cloud whence it forms (370b31f), i.e. its development from the cloud is not complete - so, perhaps, Ideler (1834-6) II 255.
his theory, in different ways in different works, to fit obvious facts about each work's subject.

Aristotle's physical works, then, do not constitute a precise, self-consistent system; Aristotle, as he must have realised, had not the means to construct one: neither the means he himself would have wished, of rigorous deduction from evident premises (since he had no such premises), nor the modern method of precise systematic experiment and observation.1 His most general physical works merely gave him broad outlines which his more detailed physical works follow: for example, that phenomena should be due to the four primary opposites; in studying particular subjects he felt himself free to develop or modify such outline-theories in whatever way seemed most appropriate to that subject.

This applies to Mete., as to other works2: in fact, Mete. adheres rather more closely to Cael. and GC than do (say) the biological works, e.g. in the close connection of the exhalations with GC's theory of the primary opposites.

1. This absence of a rigid system is a general feature of Aristotle's work; see, for example, Peck (1965) vff, xxxif, on animal classification, and more generally Jaeger (1948) 373f.

2. Similar considerations explain the inconsistencies and lack of relation of some parts of Mete. to each other (cf. pp.242-305 passim).
(p. 234-8). This, I suggest, is due partly to the similarity of the subjects of Mete. and Gae.1, partly to the difficulty of observation in meteorology, which left more scope for pure theory, and partly, perhaps, to Mete.'s being deliberately written, not for its own sake, but to fit with Aristotle's other works as part of a complete account of the physical world (cf. p. 307f).

In fact, Theophrastus, when he discusses general issues, tends merely to expound the problems involved, and puts forward his own views (if any) only tentatively; and, while scholars have argued that, at least in some such instances, he was in fact confident of the truth, it yet seems not unlikely that, where he indicates doubt, he really felt it: very likely, he had no definite physical system for research to discover. It therefore seems best to begin with his wind-theories, and only introduce more general ideas when the explanation of these requires it.

I shall use as evidence for Theophrastus the works and fragments in Wimmer's edition, the passages in other

1. The one detailed study, that of Steinmetz, is in various respects unsatisfactory; cf. Gottschalk (1967) 22ff.
2. As Zeller (1879) 632-4, Gerscke (1895) 31 and Steinmetz 116-121 argue (in different ways) of Igo.1-9 or part of it.
3. But I assume Sign. is not by Theophrastus, at least as it stands; cf. Rogenbogen (1940) 1112ff.
CHAPTER 8

THEOPHRASTUS

1) Introductory

I cannot begin this chapter by describing Theophrastus' general physical theories; for his general system has not been adequately studied,¹ nor have I space to study it here. In fact, Theophrastus, when he discusses general issues, tends merely to expound the problems involved, and puts forward his own views (if any) only tentatively; and, while scholars have argued that, at least in some such instances, he was in fact confident of the truth², it yet seems not unlikely that, where he indicates doubt, he really felt it: very likely, he had no definite physical system for research to discover. It therefore seems best to begin with his wind-theories, and only introduce more general ideas when the explanation of these requires it.

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ancient authors which attribute views to Theophrastus by name, and the Arabic and Syriac excerpts from his meteorology ('Arab.' and 'Syr.'). I also discuss certain passages of Probl.XXVI; an early Peripatetic book, heavily influenced by Theophrastus, it sometimes throws further light on his ideas, or shows how a related thinker developed them. I do not discuss the later works, classical and Arabic, which Theophrastus is believed to have influenced: I do not think there is sufficient evidence to enable us to use them with safety as sources for his meteorology.

1. First published by, respectively, Bergstraesser (1918) and Wagner/Steinmetz (1964). (Cf. bibliography, p. 455. I am dependent on the German translations.)
3. Parts of it are almost verbally identical with Vent. (cf. the notes of Forster (1927), Flashar (1962)), and most of it uses ideas resembling Vent.'s. (Cf. Steinmetz 60-68).
4. v., e.g., Strohm (1953), Reitzenstein (1924).
2) Theophrastus' general wind-theory

Theophrastus described his general wind-theory in a book now lost (v. Vent.1); it has therefore to be inferred from Vent. (which mainly concerns particular wind-phenomena), supplemented from Syr., Arab. and remarks in Alexander and Olympiodorus (v. p. 335).

A. The material of wind

Several passages of Vent. state or imply that wind is air in motion, while others derive winds from water-vapour (i.e. from ἀνυμία , 'moisture drawn up' (or just 'moisture'), melting snow, etc.); some mention both (cf. nn. 3 and 4), or derive winds from 'cloudy air', 'moist air', etc. (§§2, 22, 26): air and vapour must be nearly identical. Vent. nowhere clearly mentions Aristotle's dry exhalation, though other sources do (v. p. 335f). We shall see further into the relations of these bodies by considering the efficient cause of wind.

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3. Especially §29; also 2, 1C, 18-20, 22, 23, 26, 46, 47, 49. Cf. 4, 7, 35f, 42.
4. §§11, 12, 15, 23, 24, 25, 40, 41, 48, 49; cf. 47, where the wind blows from clouds.
5. Isolated ἀναθυμίας in Vent. 15, 23 is ambiguous, v. p. 249f. (In 23 the following sentence shows it must be or include water-vapour).
B. The cause of wind's motion: Vent.15-18

Vent.15-22 is the only part of Vent. that concerns winds in general, not particular winds. It begins: εἰ δὲ πάντων τῶν πνευμάτων ἡ αὐτή καὶ ἃπο τῶν αὐτῶν γένεσις τῷ τι παραλαβεῖν, ὁ ἡλίος ἀν ὁ ποιῶν εἶναι τάχα δ' οὐκ ἀληθές καθόλου εἰπεῖν ἄλλῳ ὡς ἢ ἀναθυμίας οὗτος δ' ὡς συνεργῶν. "If all winds have the same origin due to the same agents, by taking something, the sun would be the active cause. But perhaps it is not true to say generally (sc. that the sun is the active cause), but to say that the exhalation is, and the sun as working with it". 'Exhalation' is apparently the main efficient cause of wind, ὁ ποιῶν, not just its material (on this v. pp. 333, 337). He then says that the sun seems both to raise and to stop winds, the cause (when this happens) being that ὅταν μὲν ... ἔλαττον ἡ τὸ ἀνηγμένον ὄγρον, τούτου κατακρατῶν ἐξανήλωσε καὶ κατέπαυσεν ὁ ἡλίος, ὅταν δὲ πλέον, συμπαρώμησε καὶ σφοδροτέραν ἐποίησε τὴν κίνησιν. "When the moisture that is drawn up is less, the sun prevails over it and uses it up, and stops the wind; but when there is more, the sun arouses it and makes its motion stronger". Wind can also be

2. What this means I am uncertain.
stopped by absence of heat: §16, the sun ἐνίοτε ... ἀμα τῇ ὀθόνῃ κατέκαυσαν ἀφελόμενος τὴν ἀπ’ αὐτοῦ κίνησιν ἢν ἐδωκεν. ταύτην δὲ ὁπλὸν ὡς ἔχειν τινὰ ὤει συμμετρίὰν ὡστε μήτ' ἐξαναλίσκεσθαι μήτ’ ἐξ αὐτῆς ὀδυνᾶσθαι κινεῖσθαι πλείω χρόνων . (The sun) "sometimes as it sets stops the wind, taking away the motion which it gave. This (the motion, apparently) clearly must be in proportion (sc. to the sun's heat), so that it is not expended nor is the wind enabled, as a result, to blow for a longer time" (i.e. after sunset). Sometimes at sunset ἔνια ... πνεύμα σφὸδροι κωλῦει μᾶλλον οἷον ὡς κατέχεται τῇ θερμότητι καὶ ὤσπερ ἀναξιράνεται καὶ ἐκχαίεται.

"There is no longer anything to prevent certain winds blowing, for example those which are as it were dried and burnt by heat" (and so they blow at sunset). §17, the sun at rising or setting τὰ πνεύματα ... ὅτα μὲν ... κατέκαυσαν, ὅτα δὲ ὤσπερ ἀφῆκεν. 1 §18, there is least wind at midnight and noon: for at midnight, in the sun's absence, (ὁ δὲρ ) κρατεῖ ... μεσομβρίας δὲ κρατεῖται: κρατῶν δὲ καὶ κρατοῦμενος ἐστήκεν, ἢ δὲ στάσις νηνεμλα.

The idea that heat causes movement is common in Theophrastus 2, as elsewhere, and so is the idea that an

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1. §17 next suggests that the connexion of sun and wind may sometimes (ποτε) be accidental, κατὰ σύμπτωμα (cf. §15, οὕς καθόλου ... τούτ’ ἀληθὲς). But it is not clear what this is meant to apply to.

2. For heat causing motion, or processes involving motion (e.g. generation), ν.(e.g.) CP I 4.4; I 5.5; I 13.4f; I 15.1; I 22.2; III 22.3f; III 23.1; Ign.46f; Sud.27.
effect may be due to several factors in a proper proportion, and that an excess of one prevents the effect. Aristotle had held that heat causes and prevents wind (p. 284ff); but Vent.'s account differs in not saying, as Aristotle unsatisfactorily does (p. 287-9), that heat prevents wind by "μαρανοῖς". Instead, heat prevents wind by 'prevailing' (κρατεῖν) over air, moisture or wind, by expending, drying or burning it (εξαναλίσκειν, ἀναξηραίνειν, ἐξαλέειν). Matter is frequently said ἀναλίσκεσθαι when it is all used up in one way (e.g. is changed into a different material) and so is not available to produce some other effect. The mentions of drying and burning suggest

1. For examples concerning heat and cold, v.CP I 22.2; II 3.8; V 6.3; Ign.27; Sud.27.
2. Theophrastus may have said this elsewhere: Alexander 94.3-8 speaks of "μαρανοῖς" in this connexion, in elaborating the theory ascribed to Theophrastus at 95.35ff: 94.3-8 may well be from Theophrastus also. (Vent.35 has (πνοης) μαρανθείσης, but without reference to heat).
3. Vent.16 (cf. Probl.XXVI 34, 944a27, probably derived from it) appears to speak of εξαναλίσκειν χίνην: I can find no parallel to this, nor do I see what it can mean, except 'using up the moving material' (or 'material which tends to move') — I assume it means this here.
4. E.g., matter is all converted into fat and so cannot become seed, Aristotle PA 651b14f, for comparable effects, in biology, cf. Ib.688b3, 694a8, b20, GA 74.6b27; Theophrastus CP II 10.1; II 11.2 etc.; in relation to fire, cf. Aristotle PN 465b23-5, 466b30ff. (Usually that which ἀναλίσκει a thing uses it up on itself; but not always, cf. Theophrastus Od.19, 41; Lap.56; Aristotle PA 671b14, HA 497a9; Mete.IV 382b26. Therefore, in Vent.15f the sun need not use up the moisture/air to maintain itself, pace Steinmetz 164f).
5. For the drying of moisture preventing wind, cf. Vent.49.
that change of material is involved in Vent.15f: moisture or moist air becomes dry air (or fire), and so cannot produce wind (which evidently requires moisture). Vent.47 states: ὅταν ὁ ἥλιος ἐλέκων μηκέτι κρατή τότε ἀφελέμενος ὁ ἄηρ βεῖ: presumably the sun, turning moist air to dry air¹ (or possibly fire²), draws it towards itself, when (obviously) the air cannot be wind³; when the sun becomes too weak to do this, it 'releases' the air⁴ and wind results.

Vent.15: when there is more moisture, the sun συμπαρώμησε καὶ σφοδροτέραν ἐποίησε τὴν χίνησιν .

This implies that moisture to some extent moves itself (cf. 17 ἀφῆκεν , 47 ἀφελέμενος ὁ ἄηρ βεῖ ); though it cannot always move itself, cf. 16 (the sun) τῇ δύσει ... ἀφελέμενος ... χίνησιν , also 18. συμπαρώμησε (cf. Mete.361b14 οὐσεξορμα ) suggests that the sun 'arouses' or 'encourages' wind, as if it were a living creature⁵, but I doubt it actually means this: ὀρμή and its compounds are used elsewhere of inanimate bodies' motion⁶,

1. ἐκχαλεταί I take to mean that moisture is completely dried up or removed from the air, cf. Ign.39, Aristotle Sens.443a19, also Mete.343a10 and probably IV 384a20, 23.
2. Burning might be regarded as conversion into a material, fire (p.145); but κατέλυ often cannot mean this (e.g. Mete.359b10), so need not here.
3. It is then, I take it, that the sun 'holds' wind, κατέχει τῇ θερμώμη (§16).
4. Either air which had been drawn up now cools and falls again, or it is meant merely that no more air is drawn up.
and there is no clear indication here - and still less in Mete. - that wind is regarded as alive¹.

Vent.15-18 tells us, then, that the sun, if neither too strong nor too weak, increases or causes the motion of wind (i.e. of moist air); and that this motion might occur even without the sun. We still do not know how the motion occurs². Other parts of Vent. in fact contain several explanations of wind's motion; but the one most likely to underlie Vent.15-18 is presumably that mentioned just afterwards, at Vent.22

C. Vent.22: wind the resultant of opposite natural motions³.

οὔτ' αὖτις ὑφ' αὐτοῦ ⁴ μόνον κινοῦμενος ὁ ἀὴρ 
οὔθ' ἢπὸ τοῦ θερμοῦ κρατοῦμενος ταύτην φέρεται 
tὴν φοράν ... εἰ μὲν γὰρ ὑφ' αὐτοῦ διὰ τὸ ψυχρὸς 
εἶναι φύσει καὶ ἀτμισώδης κατὰ δὲν ἐφέρετο, εἰ δ' Ὑπὸ 
tοῦ θερμοῦ ἀνώς· τοῦ γὰρ πυρὸς κατὰ φύσιν αὕτη ἡ φορὰ. 

νῦν ὦ' ἠσπαστὸ δὲ ἀμφοῖν μικτὴ διὰ τὸ μὴ' ἐτερον κρατεῖν.

"Air is not moved with this motion [i.e. as wind] by itself alone, nor because heat prevails over it; for if it were moved

¹. Steinmetz 38 apparently supposes that Vent.15 ὁ ἄλογος ... συμμαρώμεσθε κτλ. means that the sun's rays are a fine material which works by striking on the air, not by heating it; but I can see no reason for this.
³. Cf. Gilbert 529n2; Strohm (1937/8) 260-2; Steinmetz 41-3.
⁴. Scripsimus, for ὑφ' αὐτοῦ.
by itself, it would move downwards, because it is naturally cold and vaporous, and if by heat, it would move up; for this is the natural motion of fire; but as it is, its motion is, as it were, mixed from both, because neither prevails". Thus wind is the resultant motion produced by the opposed tendencies of heat and cold.

This will explain nearly all of Vent.15-18: it explains why too much heat or too little prevents wind; why some heat and moisture are needed to cause it; and (in part) why exhalation is the efficient cause of wind and the sun only συνεργῶν (p.328), since the downward tendency of ἀτμίς is essential to the process. It does not explain how wind can move itself; on this v.p.337.

That a horizontal motion can be the resultant of opposite vertical ones had been suggested by Aristotle, at Mete.342a24ff, explaining the horizontal motion of shooting stars (they naturally rise, as composed of dry exhalation, but are squeezed out downwards by air contracting with cold), and, tentatively, at GA 782b18ff, explaining the curliness of hair (v.p.254f).

Whether such theories would work depends on how exactly they were imagined. The resultant of two exactly equal and opposite forces is no motion at all (cf. Aristotle Ph.VIII

1. It also accords with my interpretation of ἡλευων in Vent.47 (p.331).
262a6ff, cited by Sambursky (1962) 88: simultaneous opposite motions ἴσοις καὶ παθούσιν ἀλλήλας; Cael.271a28ff; MA 699a37); but if the forces are only approximately vertical and opposite, the resultant would be a slight, roughly horizontal, motion (cf. [Aristotle] Mech.854b15-5a26 – perhaps post-Theophrastean). Such passages should have warned Aristotle and Theophrastus of the difficulty of the theories just cited; but in forming the latter they may have been less influenced by the theoretical considerations of Ph., Cael. and Mech. than by commonplace observations of head-on collisions: as the forces involved will seldom in practice be exactly opposite, these should result in some sideways motion.

D. What materials are involved in Vent.22.

The upward and downward tendencies are those of τὸ θερμῶν πῦρ, and of ἄηρ... ψυχρὸς... φύσει καὶ ἀτμιστῶν. That fire and τὸ θερμῶν naturally ascend was an important doctrine of Aristotle's, and is used elsewhere by Theophrastus (Ign.50, 55f; CP V 1.11). Aristotle also stated (Cael.311b8ff, 312b3ff) that ἄηρ has weight in its own place, but he makes no use of this idea.

1. Cael.IV 4-5; cf. Mete.342a16, 369a21 etc.
ψυχρός ... φόβει καὶ ἄμισωδός suggests that ἄηρ (when unheated) is misty, tending to condense to water and so to descend: for ἄμισωδός in Aristotle condenses in heat's absence (p.234-6), and cold causes condensation (p.363).

Vent. mentions only sun (and moon) as sources of heat or fire; but other accounts of Vent.22's theory mention another source: dry exhalation. Alexander 93.35ff says that to Theophrastus wind's motion is horizontal ὅτα μὴ ἄπλως αὐτὸς ἐκ ἐξήρας τε καὶ θερμῆς ἀναθυμιάδεως γίνεσθαι: ἄνω γὰρ ἵν ἐφέρνοντο, which implies dry exhalation does help to cause wind. Cf. Olympiodorus 97.5ff: to Theophrastus ἐν τῇ καπνώδει τάστῃ ἀναθυμιάδει μεμίξθαι τίνα πυρόδως οὐσίαν καὶ γηλίνην, αὐτίνις τὴν ἐναντίαν κίνησιν κινούμεναι καὶ μαχόμεναι λοξὴν ποιοῦνται τὴν κίνησιν (cf. 175.6ff). This must be wrong in deriving wind from dry exhalation only, which contradicts both Vent. and Alexander; but it confirms (like

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1. Cf. Ign.75 ἄηρ φόβει μέλας (but Gercke (1896) ad loc., Steinmetz 355 and others reject this); for ἄηρ's natural cold, cf. Ign.26 ὅ... ἄηρ ἐν ψυχρός σβέννυσι (sc. πῦρ) and perhaps CP IV 12.5 τοῦ ἄερος ἐν ψυχρότης. Against this, pure air is dry and clear (p.360), and Frg.171.6 says that ἄηρ would seem hotter than τὸ ψυχρῶν. Much more often, Theophrastus is concerned with ἄηρ's possible variations in temperature and humidity (CP II 1.5-7, II 3, III 2.6, III 22.4, IV 9.5, etc.). He thus is inconsistent over ἄηρ's properties (like Aristotle, p.322). Presumably Vent.22 calls ἄηρ cold and vaporous because those properties are essential for causing wind by this process. (Cf. Strohm (1937/8) 258n19).

2. Syr.352a30-34 says that the dense vapour (i.e. water-vapour), on its own, would naturally descend; cf.p.336n.
Alexander) that wind is the resultant of opposite vertical motions, and is also evidence that dry exhalation is somehow involved.

It seems unlikely that Alexander, who presumably had Theophrastus' complete work on wind, should be mistaken in his clear implication that dry exhalation had some part in Theophrastus' theory; which leads to the conclusion that, sometimes at least, dry exhalation provided the upward tendency in the theory of opposite vertical motions. (Vent. 22 τὸ θερμων may mean dry exhalation (as sometimes in Mete., p. 236n), or at least include it). Syr. confirms that the opposite tendencies are those of the two exhalations (353b22-25): "Die zur Seite gehende und die abweichende Bewegung aber [von den naturlichen Bewegung nach unten] sind (die Folge) von den zwei Dampfen. Der eine ist schwer, [der andere leicht. Der leichte] aber geht nach oben. Der schwere bewegt sich [abwärts. Weil der leichte die (natürliche) Bewegung des schweren hindert], wird die Bewegung (zur Seite) abweichend." Presumably, the upward tendency may also be due to or aided by the sun, as Vent. implies (p. 335; cf. Strohm (1937/8) 260f and n23). (These two ideas need not have been clearly distinguished: Aristotle seems not clearly to distinguish the ideas of sun and of dry exhalation raising water-vapour, p. 238).

1. Steinmetz 41f reconciles these two ideas by saying that dry exhalation, to Theophrastus, was 'Reflexion der
These passages help to explain Vent.15. If dry exhalation is an alternative source of heat, that explains how there can be wind even without the sun (cf. p. 333). Δναθυμίαςις in Vent.15 (cf. p. 327f) might now mean either wet exhalation alone (which in Vent. appears to be wind's material and an essential part of its cause of motion), or dry exhalation, or both together (cf. p. 249f) (since either might be spoken of as efficient cause of wind, on the theory given by Alexander and Syr. - the latter would seem more likely).

Wärme [i.e. of the sun's heat - he regards the sun's rays as moving material, ib.38] (gegebenenfalls mit erdartigen Partikeln untermischt)" , and that this reflected heat causes the upward tendency. But (though Vent.45 mentions such reflected heat) I can see no reason for identifying it with dry exhalation: Δναθυμίαςις is a very strange word to apply to such reflected heat. (The evidence suggests no great difference between Theophrastus' theory of dry exhalation and Aristotle's, except that in Theophrastus it was less important: mentions of dry exhalation in Ign. and Lap. are paralleled in Aristotle (p.251f), and Syr. (352a21-34, 353b22-5) connects the two exhalations, without suggesting any difference in the quantity of each, nor any greater difference in their natures than there is in Aristotle. However, I agree with Steinmetz that probably dry exhalation's only importance in Theophrastus' wind theory was as a source of heat).
Why is dry exhalation not clearly mentioned in Vent.? Aristotle sometimes maintains that there is wind in some place because there is much rain there, and because the two exhalations occur together (Mete.361a4—21al. (v.p.266), cf. 361b17 (v.p.287ff)). Theophrastus, I suggest, carried this tendency further: the exhalations occur together; only from water does evaporation visibly occur. Therefore, only water-vapour need be mentioned - that dry exhalation occurs with it can be understood, as it must be at Mete. 362a14ff. Theophrastus in Vent., in working out the details of his wind-system, was probably drifting away from his general theory, in trying to reconcile it with observed fact (that water-vapour is the only observable exhalation) and, perhaps, with earlier theories (as Aristotle had done, cf. p.266n); for if Theophrastus' wind theory was as I have argued, then (except concerning the cause of wind's motion) it is virtually indistinguishable from the pre-Aristotelian (v.p. 402, 404).

The theory of Vent.22 was evidently Theophrastus' main wind theory: it forms part of the only section of Vent.

2. Presumably the passages quoted above of Alexander, Olympiodorus and Syr. are derived from the more general work on wind mentioned in Vent.1.
3. It was apparently his original idea - Olympiodorus 102.1ff (DK 31A64) ascribes a similar theory to Empedocles, but probably by an error (cf.Stueve (1900) ad loc., Gilbert 520n2), as he has just ascribed it to Theophrastus (97.5ff), and there is no other evidence Empedocles, or any other pre-Theophrastean, held it.
that concerns winds in general (v.p. 328); it serves to explain most of the rest of that section (and several other passages of Vent. \(^1\)); and three other sources attribute forms of the same theory to Theophrastus. However, the rest of Vent., though mostly consistent with Vent. 22, would be equally consistent with other wind theories; and some passages do mention alternative theories, as I shall next show.

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1. Besides passages already cited, cf. especially, with Vent. 15 ἦλιος ... συνεργῶν, §§10 συνεργοῦσιν, 19 συναίτιφ, 41 συνεργοῦντος.
3) Other theories compatible with Vent.15-18.

A. Rarefaction.

Vent.41: winds occur μετά τοῦ ἡλίου διαχέοντος τὸ υγρὸν ἡ ἀτμίζοντος ... ἡ συνεργοῦντος εἰς τὴν ἀρχήν.

(These alternatives need not be mutually exclusive. The point — contrary to the implication of Vent.15ff — is evidently that the sun is essential for causing wind). συνεργοῦντος is parallel to Vent.15 συνεργῶν , and ἀτμίζοντος may mean merely that the sun causes evaporation¹, thus providing wind's material; but διαχέοντος refers to the 'rarefaction theory' of wind, discussed on p.65ff. Vent.15-18 is compatible with the version of that theory of Probl.XXVI 53 (v.p.80): there, too, the air must be moist; too much sun or too little prevents wind, while the right amount causes or increases it; and the air may be πνευματώδης , 'windy', before the sun affects it², in which case wind presumably occurs without the sun.

B. The vagrancy of water-vapour.

Vent.24: τὸ ἀναξάδεν ὅπω τοῦ ἡλίου μένειν οὔτε πεφυκὸς οὔτε δυνάμενον φέρεται καὶ τούτι πυθήν. τὸ

¹ Cf. Vent.24, 48 (also 11f), CP III 11.2, IV 15.5f, etc.
² With this cf. Theophrastus CP IV 12.5 τοῦ ἀέρος ἢ ψυχρότης ... ἐνυδρός... καὶ μὴ πνευματική.
must be water-vapour, for Vent.23-25, discussing ἀθραῖ from rivers and lakes, stress that these are cold and derived from moisture. As in Vent.15-18, moisture is essential to wind, heat can prevent wind (cf. n.1), and wind's material can move itself. However, unlike §§15-18, §§23-25 rather suggest that heat has no part in causing wind.

But why can the vapour not be at rest? I know only three parallels: Probl.XXVI 2, 94ббф, suggests that νότοι are οὐ συνεχείς , i.e. do not blow steadily, because they are moist, καὶ τὰ ὕγρα πλανητικά κόσιν, ὡσε οὐ μένοντα (so Flashar (1962), for MSS. μένων ) ἐν ταχτῷ τόπῳ συμμεθέστηκαν καὶ τήν τοῦ ἄνερσ χίνησιν ("... (moisture) by not remaining in the same place, changes the air's motion as well.") Presumably, moisture moves from the south wind's source in varying directions, and so makes the wind's direction vary. Cf. Vent.40, the West wind.

1. Vent.23, they are πάντα ψυχρὰ διὰ τὴν ὑγρότητα τοῦ ἄνερσ ; 24, they blow ἀποψυχομένης τῆς ἄμυδρος διὰ τὴν ἀπολειψιν τοῦ θερμοῦ ; etc. (Cf. Probl. XXIII 16 (and Flashar's (1962) note) = XXVI 30; [Aristotle] Ἱκ.39б12; Seneca Ὅμ. V 8.1, 9.1. ἀθραῖ were clearly a special type of wind, specially connected with moisture; cf. Homer ε 469, Herodotus II 19, 227 (cf.p.60), where ἀθραῖ means 'a breeze from a river'.)

2. With no apparent need to postulate dry exhalation - an awkward postulate at Vent.18, 22, which contrast ἄὴρ with the sun or heat, suggesting that hot, dry exhalation is not part of ἄὴρ (which in Mete. it is, p. 229. However, at Mete.372β3 officer ἄὴρ 'prevails over' heat, i.e. they are implicitly contrasted).

3. Heat would be an inappropriate cause of cold breezes.
πλανάται διὰ τὸ ἄφ' (v.i. ἄφ') ὑγροῦ βεβηκέναι, which appears to be explaining why this wind is οὐ συνεχῆς.1

In these two passages moisture 'wanders', but the significance of this is not the same as in Vent.24. A closer parallel is Probl.XXIII 16 (933a36f) = XXVI 30 (943b13f) ἐξαρομεύουν ... τοῦ ὑδάτος ὁ ἄηρ ὁ γυνόμενος φέρεται, ὁ ἑστὶν αὖθι. But none of these four passages explains why the moisture should 'wander'.

C. ἡρατεῖν and wind.

This is one of several ideas which, while compatible with Vent.15-18, are in fact also ambiguous and so do not help to explain it.

In Vent.15 the sun prevents wind, καταχρατῶν water-vapour; in 18 there is no wind when ἄηρ either prevails or is prevailed over by the sun; in 22 ὁ ἄηρ ... ὡς τοῦ θερμοῦ κρατούμενος cannot be wind. In Vent.11 the Etesians blow when the sun ἀφέσσεται λόγῳ τὸν πάγον καὶ ἡρατεῖν; in 40 Zephyrus blows ἀρτὶ τοῦ ἥλιου

1. Vent.40 is mostly repeated at Probl.XXVI 52, 946a20ff, where Forster (1927) and Flashar (1962) explain πλανάται κτλ. differently; but they ignore the preceding sentence of Vent., οὐ συνεχῆς κτλ., which Probl. omits - surely by an error, as it leaves what follows with much less point. However, the context is obscure, and I claim no certainty.
κρατοῦντος καὶ...πάλιν ὅτε οὐκέτι κρατεῖ; in 47 wind blows when the sun μηκέτι κρατῇ. All this merely confirms that wind occurs when the sun has some strength but not too much; for κρατεῖν is an extremely general concept, and is no evidence of how the sun exercises its strength.

To Aristotle and Theophrastus anything—quality, form, material or whatever—'prevails', κρατεῖ, when it produces an effect in another thing, or preserves its own characteristics against that which would deprive it of them. For example, the main ingredient in a mixture is τὸ κρατοῦν (GC 328a24ff); change between elements occurs when one primary quality κρατηθῇ by its opposite (GC 331a26ff); heat or fire κρατεῖ when it burns a fuel (Mete.358a12, Ign.67r), dries up moisture (GA 767a17), causes πέψις (Mete.358a12, IV 380a3, 23; Sud.19), is not extinguished by τοῦ προσπήπτοντος (sc. ἀρρητός; Ign.19), or when a larger fire extinguishes a smaller (Ign.26). In reproduction or nutrition, an animal or plant (or its δροχή) 'prevails' when it imposes the appropriate form on matter; the matter (e.g. a plant's τροφή) 'prevails' when it does not receive this form. Vines κρατεῖ τοῦ ἥλιον, when they continue growing in spite of the sun that would stop them (CP III 16.2); a plant's τροφή κατακρατεῖ when it does not rot (ib.III 22.5); at ib.VI 10.9 ἡ ἀλμυρίς ἑργάζεται.

1. GA 766a15ff, 768a2ff etc.; CP I 9.1, II 8.3, III 11.3 etc.
2. CP I 18.2, IV 4.9 etc.
thus affecting certain plants. ἩΡ IX 17.2, drugs lose their power through habituation, our nature κατακρατοῦσης. Od. 17, in mixing perfumes, ἐπικρατεῖ ... τὸ ἔσχατον ἐμβαλλόμενον.

When an effect is produced by several factors in a proper proportion, the 'prevailing' of one of them may prevent the effect. So ΜΑ 699a37f ἀλ μὲν ἴσαι (sc. ἰσχύες) αὐταῖς ἀπ' ἄλληλον, κρατοῦνται δὲ κατὰ τὴν ὑπεροχήν ("equal forces are unaffected by each other (i.e. cancel each other out); but when one is in excess, it prevails (and causes movement)"). GA 767a17-20, heat prevents generation if λίαν ... κρατοῦν or ἐλλεῖπον: it must have τὸν τοῦ μέσου λόγον towards the thing formed. CP V 8.3 plants suffer if the winds are ψυχρά σφόδρα ἡ θερμά, κρατείται γὰρ ταῖς υπερβολαῖς. οἱ ο' ὅρατοι χειμῶνες ἀφελοῦσι.

The usage of κρατεῖν in meteorology is similarly varied. In Mete., condensation and freezing occur (and ὑφόνες, due to dry exhalation, are prevented) when cold or air κρατεῖ heat or dry exhalation \(^1\); the sun, when it μᾶλιστα κρατῇ, shuts exhalation into the earth (366a16f, v.p. 290f). Wind ἀρέσται κρατεῖν when it has been compressed (366b13; v.p. 96); the sea flows κρατομεῖν ὧπο τῶν πνευμάτων (369a1). (Cf.

\(^1\) 347b26, 371a6ff, 372b30f.
Vent.30, one wind ∆ντικνεῖ καὶ κρατεῖ another 1.  

Vent.22 explains that, on the opposite-vertical-motion theory, wind is prevented if heat or air κρατεῖ. But the sun is also said κρατεῖν when it rarefies air and κρατεῖσθαι when it fails to rarefy it: Probl.XXVI 8, 941a3-5, ὅταν μὲν ... κρατῆι ὁ ἡλιος, διακρῖνει ... αὐτὸν (i.e. ἀέρα), ὅταν δὲ κρατήται, ἐπινεφῆ κοιτεῖ. Hence, if wind is caused by the sun rarefying air to some extent but not too much 2, wind will again be prevented when either heat or air prevails. At Vent.23-25, also, the sun clearly 'prevails' when it prevents αὐρατ.; and if there is thought to be some heat in the vapour that causes them 3, then the 'prevailing' of cold or moisture also prevents wind.

Thus all three wind theories discussed on p.332-42 are compatible with the occurrences of κρατεῖν cited on p.342f - as is, indeed, virtually any theory that fits the rest of Vent. (The Peripatetics' usage of κρατεῖν clearly derives from Aristotle's principle that change is due to qualities displacing (i.e. prevailing over) their opposites (pp. 218, 227, etc.); this is so general a principle that it and the use of

1. Vent.40 perhaps mentions a further variety of prevailing: Zephyrus is not continuous ὄδα τὸ μὴ κρατεῖσθαι τὸ γίνομενον πνεῦμα. But the meaning of this is to me obscure.
2. As at Probl.XXVI 33, and as may be meant in XXVI 8; v.p.80.
3. As is likely, since otherwise it would presumably condense. But v.p. 341.
κρατεῖν can be applied to almost any event.)

D. Other ideas compatible with Vent.15-18.

At §§11f, 48 and perhaps 41 (v.p. 340) the sun apparently causes wind merely by causing evaporation: this fits all the theories discussed on p.332-42, since all require moisture. Simple statements that heat causes wind (§49, lines 4-6 in Wimmer's Teubner ed.), or that winds cease because of the sun (§31), are also compatible with any explanation of §§15-18. These statements are thus as ambiguous as Vent's usage of κρατεῖν.

E. Concluding remarks on Theophrastus' general wind theory.

The three wind theories discussed on p.332-42 need not be mutually exclusive. Possibly, the point of the sun's rarefying air (v.p. 340) is that it thereby brings the air to that state where its heat and cold balance each other, so that it

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1. One passage, Probl.XXV 4 (938a23ff), perhaps explains wind simply in terms of prevailing and not prevailing, without any thought of a more detailed theory: air is at rest ὅταν κρατήῃ κρατῆται (by the sun), μαχόμενος ὃς κινεῖται. This seems to suggest that fighting in itself implies motion, leaving no necessity to look for a further cause. The origin of this problem is evidently Vent.18 (so Flashar (1962)); but nothing there corresponds to μαχόμενος, and the ordinary usage of κρατεῖν does not suggest that the absence of prevailing was generally associated with motion - at Aristotle MA 699a37f the opposite is the case.
moves horizontally, as in Vent.22. In Vent.24, also, if
the vapour has some heat in it, then conceivably it moves
precisely because its heat and cold balance each other — more
likely, however, ἀύρατος, whose cold and moisture are
stressed, are not due to quite the same cause as other winds.

1. On these winds in general v. Gilbert 563f.
2. The ἄνεκλοντις... of wind, usually from moist winds (Vent.
27f; cf. Probl.XXVI 7 (Sudzurfr), Lc (St. Salonfr)) is
parallel to this, but is not said (except perhaps in the
last passage) to involve the causing of air. (On this
phenomenon v. Becker 215ff.)
4) **Wind due to the massing together of air, or to horror vacui**

Besides the theories so far discussed, Vent. contains other ideas on the causes of wind, of which these are two.

A. **The massing together of air.**

Vent. 26: τροπαὶ ('reverse winds', i.e. sea-breezes, so-called because opposite to ἀπόγειαι)¹ occur συναθροισθέντος τοῦ ὕγρου ἀέρος. For the τροπή is like a blowing back (παλιμπνοή) of wind ὡσπερ ἐν τοῖς ἐθρίποις τῶν ὕγρων. ὅταν γὰρ ἀθροισθῇ καὶ πλῆθος λάβῃ, μεταβάλλει πάλιν εἰς τὸ ἐναντίον,

"...such as happens where water ebbs and flows; for when it has been collected and there is a mass of it, it changes again to its opposite". This happens especially ἐν τοῖς κοίλοις, because air is collected in them; in open places the air is dispersed. Theophrastus is evidently thinking of an analogy with water: for example, when water is pushed to one end of a bath, it piles up there and then flows back again (whereas water poured on open ground flows away); the same evidently happens to air; its flowing back constitutes the τροπαὶ.²

Cf. Vent. 29: ἐν τοῖς στενοῖς δὲι πνεῦμα μένειν γὰρ

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¹. On these winds in general v. Gilbert 565f.
². The ἀνάκλασις of wind, usually from mountains (Vent. 27f, 31; Probl. XXVI 1 (940a25ff), 40 (945a1ff)), is parallel to this, but is not said (except perhaps in the last passage) to involve the massing of air. (On this phenomenon v. Boeker 2257f.).
δ' ἀν' οὗ ὀσναται δικ τὸ πλῆθος. Here, however, the massing of air may merely intensify wind that was blowing already ¹: for Theophrastus has just said that the narrowness or openness of the ground causes τὸ σφοδρότερα καὶ ἕμεστερα γίνεσθαι (sc. τὰ πνεύματα).

Vent. 26 calls τροπαί the ἀνταπόδοσις of the ἀνέγειαι ², which expression also occurs in §10: whatever material is blown south by the north winds ἀνταποδίδοται πάλιν ... εἷς τὸδε τοῖς τόποις.

ἡ ἀνταπόδοσις γίνεται καθάπερ παλιρροοῦντος τοῦ ἄρρος, "there is a compensation (between the north and south winds), the air as it were flowing back". Vent. 53 also speaks of ἡ ἀνταπόδοσις καὶ όλον ἣ ἀντίρροια (and instances land- and sea-breezes), in discussing the change of winds into their opposites. It is tempting to assume that ἀνταπόδοσις implies the same mechanism in all three places; but this is doubtful. ἀνταποδίδοναι means 'to give back an equivalent', e.g., in ethics, to make a proper return for an injury or benefit ³: the point is that the return balances what has been received; it need not be (in

1. As it clearly does at Vent. 34: places that are κατ' ἀνέμους ἐπισεκθῆ are consequently πνευματωδότερα, ὥστε συμβαίνει συναρροίζομενον ἐκ τοῦ ὕψος οἷον ἀρχεῖσθαι τὸ πνεύμα καὶ ἐμπίπτειν ἄρρον. (Cf. Mete. 354a6ff, of the sea).
2. συμβαίνει ... ἡ ἀνταπόδοσις ἀνὰ λόγον τοῦ τε πλῆθους καὶ τοῦ μεγέθους ὡς ἄν αἱ ἀνεγείαι πνεύσωσιν. This clearly means that the strength of the ἀνταπόδοσις (obviously the τροπαί) is proportioned to the strength of the land-breezes.
3. Cf. passages from Aristotle EN listed by Bonitz (1870) s.vv. ἀνταπόδοσις, - διδόναι, also Rh. 1367a22, 1379b7.
ethics clearly is not) an automatic consequence of it, as τροπαί are of ἀνταπόδοσις in Vent.26. In Vent., too, the point of ἀνταπόδοσις is that an equivalent is returned, i.e. that the same quantity of air moves one way as previously moved the other; it need not imply any particular mechanism by which the air moves back.

Steinmetz 26f regards wind as due to the massing of air at Vent.2 (on the importance of north and south winds):

"much air being collected on each side (i.e. to north and south of the sun's course) the flow of air (sc. from north and south) is generally both stronger and longer-lasting". But this, surely, is simply saying that where there is much wind-material there will be more wind, which would be so on any wind theory. Nothing suggests (as do §§26, 29) that much material must be collected for wind to blow at all. There is no reason to connect this with Vent.26 etc. rather than with any other theory.

1. ἀνταπόδοσις is an automatic giving-back at Probl. XXVI 4, 940b20 (which concerns τροπαί, like Vent.26) and [Aristotle] Aud.803a30-32 (where it is a string's response to our plucking it) (cf. also Plato Phd71E-72B), but not in any other passage cited by Bonitz l.c., nor at Theophrastus Fr.171.3, Sign.48 (nor, earlier, at (e.g.) Batr.186, Herodotus I 18, Thucydides I 43).

2. Cf. 10 οἶον τάξις, 53 κατὰ λόγον τάξις, 26 ἀνὰ λόγον κτλ. (v.p.349ν2).

3. In Vent.10 the sun helps to cause the wind in both directions, which is inconsistent with Vent.26.
If Vent. 2 is dismissed, then clearly the massing of air was only a minor or secondary cause of wind: winds in narrow places\(^1\), and sea-breezes are minor winds; \(\text{ἀνταμόσωσις}\) in Vent. 10, 53 (if it is relevant) involves more important winds, but could only be a secondary cause, since it requires a preceding wind the other way.

B. Wind and void.

That matter must flow to fill, or prevent the formation of, a void was held by several thinkers before Aristotle (p. 187); and Aristotle himself implies that this must happen at Ph.IV 214a28ff, saying that locomotion does not require the existence of void: \(\text{ἂμα γὰρ ἐνδέχεται (sc. σώματα)}\) \(\text{ὑπεξεῖναι ἄλληλοις}\) (i.e., when a body moves, matter gives way before it, and it gives way before other matter which flows into the place it is leaving). Aristotle seems never, in practice, to speak of the prevention of void causing motion; but at, for example, Resp.480a29f \(\text{ἀλρομένου (sc. τοῦ θώραχος)}\) ... \(\text{ἀναγκαίον εἰσεῖν τὸν ἄξον τὸν θύραθεν}\)\(^2\), it seems most likely that the impossibility of void provides the necessity\(^3\).

1. In my view, at least; v.p. 368
2. Cf. 474a12ff, PA 669a16f.
3. The idea that air automatically flows to fill or prevent a void clearly occurs in Probl.VIII 8, 13, XXXIII 16, XXV 22 (on which v.p. 191f).
This principle was thus well known before Theophrastus, but there is no evidence it was applied to wind. Arab./Syr., however, does just this: if air is collected in one region "und keine leere Stelle findet", it flows "nach einer anderen Gegend, die ihr gegenüberliegt, da die Leere sie zwingt, und zieht mit sich Dunst ... bis keine Stelle mehr übrig bleibt". Similarly, water is sucked up a tube "durch Saugen und den Zwang der Leere ... bis sich nichts Leeres in der Röhre findet". This is perfectly clear; but unfortunately Arab./Syr. probably includes the remains of doxographies, and perhaps later additions to Theophrastus' text. We therefore cannot safely attribute this theory to him, unless his other works support it.

Only one passage throws light on whether, as a general principle, Theophrastus admitted void to exist: Metaph.18, saying that it is paradoxical to include τὸ μὴ δὲ μηδὲ γεγονὸς μηδὲ μέλλον... εἰς τὴν τοῦ παντὸς φύσιν.

This is evidently a criticism of the atomic theory, but could refer merely to the atomists' formulation of their theory, and

1. Arab.47-9 (Reitzenstein's version (1924)), cf. the fragmentary Syr.353b11ff. V. Steinmetz 57f.
2. Cf. Bergstraesser (1918) 28-30; Reitzenstein (1924) 43-5; Wagner/Steinmetz (1964) 34f; Gottschalk (1965a) 159f, (1965b) 759f. (The present theory could be atomist, cf. p.187ff). However, the section on wind does not include the lists of alternative explanations which suggest that other parts of Arab./Syr. are doxographical.
not be an actual denial of void's existence.

Vent. 33\(^1\) apparently refers to void causing motion, and perhaps (like Arab. 49) to suction as exemplifying this: there is no wind at the foot of a certain cliff, because the air at the cliff-foot does not give way before the wind. When there is no wind at the foot of a certain cliff, because the air at the cliff-foot does not give way before the wind. When the doors of a room are shut less wind comes through the windows. For, the room being πλήρες ... καὶ μὴ δεξαμενὲς τὸν ἀέρα. When the doors of a room are shut less wind comes through the windows. For, the room being πλήρες ... καὶ μὴ δεξαμενὲς τὸν ἀέρα. πρὸς γὰρ τὸ κενὸν ἡ φορὰ' οἷον καὶ τὸ ἐλκεῖν οὐ καλῶς λέγεται ... "being full and (sc. 'the air in it') not giving way, it does not receive the air from outside. For motion is towards the void. For this reason, the term 'drawing' is not a good one." (i.e., presumably, ἐλκεῖν is a bad term for 'suction', because what is sucked moves of itself into the void above, and is not 'drawn' up\(^2\).) Whatever τὸ κενὸν means, this passage cannot be fully parallel to Arab. l.c., because the 'void' is mentioned only incidentally: in the part of 33 that concerns wind, it is air giving way, not void, that renders wind possible. But motion πρὸς τὸ κενὸν is still somehow related to wind.

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1. On this v. Steinmetz 46f.
2. So, apparently, Wood's translation (1894). However, Wimmer's "trahere quaedam loca ventum non recte dicunt" (in Didot ed., 1866) (cf. Steinmetz 47) is perhaps equally likely: it involves supplying several words not in the Greek, but is supported by Vent. 29 θυρίδες ἐλκουσίν ... πνοὴν.
What, however, is τὸ χενὸν? Apparently it actually exists (i.e. Theophrastus does not say motion occurs 'because there can be no void'); and being contrasted with πληρές in the preceding sentence, which clearly means 'full of air', it presumably means 'empty of air'; this suggests that it is void in the full sense; but there is very little other evidence that Theophrastus ever used this concept.

The likeliest parallel is in Ign.23f, on the 'suffocation' of fires and men: παχύς γαρ ὅν ὁ ἄηρ καὶ ἄχλητος οἶον καταπιέζει καὶ θλίβει καθαπερεὶ τι στερεῶν ἀδ' οὗ ὃναται διαβιδάσσει τὸ πῦρ ("... air presses down (sc. flame) ... like a hard body which fire cannot force its way through"); χενὸν γαρ ὁ ἡ χαρίτερ πρὸς δ' καὶ ἐν ὃ ἡ φορά. οἷα τούτο ὅν καὶ τὸν πνεύμαν ποιεὶ τοῖς ἐργαζόμενοις ὁ ἄηρ ὅτι παχύς τε καὶ ἱμεύμων ("... air causes the suffocation of workmen ..."). Fire, then, "seeks empty space, towards which and in which is its movement": χενὸν is contrasted with στερεῶν and παχύς ... ἄηρ καὶ ἄχλητος.

Nothing is likely to have suggested to Theophrastus that fire burns in an actual vacuum; so χενὸν must be either air with void spaces in it, or, more probably, a space empty of solid bodies, in which air moves freely and so is λεπτός.

1. Pointed out by Steinmetz 129n.
2. Cf. Ign.24 ὅπως λεπτόνηται τῇ κινήσει.
This meaning of κενόν - an open space, in which air is fine and mobile (and so gives way to wind) - also makes sense at Vent.331, though it leaves πληρες with less point2.

These are not the only places where matter tends to move into what is κενόν . CP II 9.12 κενωθέντα ... τὰ ἐριναστὰ μᾶλλον ἐπιστάται καὶ πλεῖω τὸν ὅπον (apparently "the figs, having been entered by the gall-insects and emptied (by the insects, who feed on the juice), draw in more juice more intensively")3. Ib.II 12.5, some plants are μανὸν ... καὶ κενόν ... ὄστε εὐδίοδον εἶναι τῷ κακοποιοῦντι . This makes relevant passages using μανὸς : HP V 3.5 τῆς ἐλάτης τὰ μανὰ καὶ σαρκώδη ἔλκει τὸν ἄρα (? cf. V 9.6); CP IV 14.2, the κόσμος ... τὴν δυρχότητα μάλιστ' ἔλκειν εἰς ἐαυτὸν οίδα τὴν μάνωσιν.

Thus a solid body which is empty of liquid, or not continuously solid (this, I take it, is the meaning of μανὸν ) is liable to be entered by (usually) air or a liquid. These passages are probably not talking about vacuum; more likely, it is bodies not filled with liquid or solid - but, presumably, containing air in their spaces4 - that here exercise attraction

1. If so, we must take ὅδ - λέγεται as Wimmer does (p.353n).
2. But one might say that space containing rarefied air is not πληρες : more air can enter it.
3. So evidently Wimmer (1866) and Schneider (1818) ad loc.
4. Since this is the commoner meaning of 'empty space' within a solid body. Also, most of the bodies concerned seem to be permanently κενόν or μανὸν , and Theophrastus can hardly have denied what for a century had been generally agreed, that a long-lasting continuous vacuum is impossible in our world (pp. 153f, 187, 351).
in some sense.

Thus the passages in Theophrastus where matter tends to enter places or bodies that are 'empty' or 'rare' are most of them unlikely to refer to actual vacuum, and none need do so. They therefore provide very little support for the theory of Arab. 47-9 that wind is due to horror vacui. This is not decisive, since only a small part of Theophrastus' works survive and he is not always consistent; but it seems more probable either that Arab. 47-9 is an account of someone else's theory, or that the 'void' in it is a misrepresentation of τὸ κενόν as it seems to appear in Ign.25 and presumably Vent.33: an open space filled with fine, mobile air, but not actual void.

C. The importance of the two previous theories

Steinmetz 26f, 30ff regards Vent.2, 10 and Arab.46-9, as all presenting the same theory: the sun, pushing air to North and South, upsets the air's equilibrium, to restore which the air flows back. This reflux is ἀνταπόδοσις;

1. Note that Vent.33 and Ign.23, which are most likely to refer to actual vacuum, do not state that τὸ κενόν in itself causes motion; it may be only a condition that makes motion possible.

2. On void in Theophrastus v. also Steinmetz 171, 328, which suggests he may have believed there are void spaces in matter; but, if he did, it is surprising that his surviving works never clearly refer to this idea.
the force which causes it is 'horror vacui'. This Steinmetz evidently regards as Theophrastus' main wind-theory, interpreting other parts of Vent. in its light (Steinmetz 32, 35, 40); and he suggests (ib.27) that it is "eine Vorahnung der Gesetze des hohen Drucks".

Much of this seems to me untenable. The connection of the piling up of air with horror vacui as causes of wind is supported by no evidence, and the analogy with water at Vent. 26 (and 29) tells against it. All the passages in Vent. which are likely to refer to either theory concern only minor or secondary winds (cf. p. 351); passages where heat causes, or helps to cause, wind are far more numerous (p.328ff); and, though some of the vaguer ones are compatible with Steinmetz's theory, they are equally compatible with other theories, which Vent. clearly mentions as general causes of wind (i.e. the opposite -vertical-motion and rarefaction theories), and which are accordingly far more likely to underlie ambiguous passages than the largely hypothetical theory of Steinmetz.

There remains the suggestion that wind caused by horror vacui, or the piling up of air, foreshadows the modern theory of wind as due to differences in atmospheric pressure

1. Steinmetz 45, 47, 52 connects Vent.26, 33, 53 with this same theory.
2. Even if Steinmetz interprets Vent.2 rightly (cf.p.350 supra), it is unique in Vent.
(cf. p. 182ff). Movement into a vacuum, like wind, is due to atmospheric pressure, but is doubtfully relevant to Theophrastus' wind theory (cf. supra). The massing of air is remote from the concept of air-pressure, because Vent. does not speak of it possessing tension or expansivity, or pressing on other bodies, as other ancient authors do. The latter, however, speak only of air exerting pressure when confined within a container; Theophrastus is in one respect nearer the truth, in that he accepts that the density of free air can differ in different places, and uses this in explaining wind.

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1. cf. Amstelius s. v. 850a2ff; 602a1; 606b6, 17, de An. 146b26, Phylac. 2b6, Phren 21, GA III 449-51, 75b2b36; Mot. IV 2.5 passim. Theophrastus C.F. 1 17.1; 1 21.7; 22 3.6, II 4.1.; V. Phis. VII 7.5; Od. 49.; Igu-13f; 80b.15.

2. Cf. Mot. IV 379b18; αἰθαίρω; cf. other examples quoted on p. 87ff.
5) πέψις in meteorology.

πέψις is a process, caused by heat\(^1\), which produces changes in matter, usually to enable it to attain some definite end\(^2\): examples are cooking, digestion, ripening, the formation of semen. Atmospheric processes have no apparent end or purpose, nor do they appear to have the complicated nature of most examples of πέψις (cf. p.362\(^3\)). In consequence, πέψις is hardly mentioned in connection with meteorology (in Mete. only in three passages, and then incidentally, v.p. 322\(^4\)).

In Vent. and Probl.XXVI, however, it has some part in causing wind or other major meteorological phenomena, in Vent.50 (whence Probl.XXVI 3 (94Cb68ff) is derived) and Probl.XXVI 33 (944a13)\(^5\).

Vent.50: the South wind blows after snow and hoar-frost, because πέψως τίνος γενομένης καὶ ἀποκαθάρσεως

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1. E.g. Aristotle PA 650a2ff, 652a5, 668b8, 11, de An. 416b26, PN 466b28ff, 474a25ff, GA 718b19-21, 752b55f, 786a17, Mete.IV 2-3 passim, Theophrastus CP I 17:1, I 21:7, II 3:8, II 8:1, V 6:3, VI 7:8, Od.49, Ign.13f, Sud.19.

2. Cf. Mete.IV 379b18 πέψις ... ἐστὶν τελείωσις, cf. 25ff. (379b18 adds ἁπὸ τοῦ φυσικοῦ καὶ δικεῖον ἠμεμοῦ; but this can hardly apply, at least, to cooking, cf. ib.381a23).

3. Plus, possibly, ib.35 (944a34), where Forster (1927) conjectures ἐκκέπτετε (accepted by Flashar (1962)), I think unnecessarily (v.p.65). In any case, the conjecture is based on the parallel at 944a13, and so can add nothing to it.
Theophrastus adds that after rain, hail etc. with the South wind. Theophrastus adds that after rain, hail etc. with the South wind. 

\[\text{δ\'εναντίος \ ο\ νότος (so that the North wind changes to a South wind.)}\]

\[\text{α\ποκάθαρσις suggests that matter is removed from}\]

\[\text{the air, leaving it pure\(^2\); what is removed is presumably the}\]

\[\text{snow, frost etc.: it is frequently stated or implied that}\]

\[\text{καθαρός \ air is clear, dry or \ λεπτός \(^3\), which implies}\]

\[\text{it is free from cloud or moisture (pp.68, 70ff)\(^4\). With}\]

\[\text{πέψις \ here cf. [Hippocrates] Aer.8 (L.II 34.13ff,}\]

1. Presumably snow and hoar-frost (so Wood).
2. \[\text{α\ποκάθαρσις, \ -αρος, tends to have a connotation of}\]

\[\text{removing something; cf., e.g., Aristotle PA 683a29,}\]

\[\text{HA 568b9, 587b1, Mete.IV 383a34, Probl.IV 30 (880a32).}\]

3. \[\text{v. Theophrastus CP V 12.2 \ καθαρός contrasted with}\]

\[\text{ἐπινεφός, \ θολερός; VI18.3 \ καθαρός ...}\]

\[\text{άερι καλ \ αν\υδρωφ;Ign.24, 48 \ λεπτός implicitly}\]

\[\text{contrasted with \ δμωχσίς, \ θολερώδης, \ θολερός.}\]

\[\text{Cf. CP VI 17.1, 9, on pure \ δυμή \ and \ αποπνοή. (In}\]

\[\text{other authors, v. Diogenes 6A19(44). [Hippocrates]}\]

\[\text{Aer.15 (L.II 62.4f), Morb.Sacr. 13 (L.VI 384.8-10),}\]

\[\text{Plutarch Prim.Fr.951B, Fac.Lun. 939B-C. Elsewhere}\]

\[\text{in Theophrastus air is naturally dark and moist (p.335);}\]

\[\text{but such air is never called pure).}\]

4. \[\text{πέψις \ is also connected with purification at}\]

\[\text{Aristotle GA 744b13, 765b10, 35, Somn.458a10ff,}\]

\[\text{Theophrastus CP VI 3.4, VI 12.5. (It is also associated}\]

\[\text{with drying - but generally this means the evaporation}\]

\[\text{of moisture from a solid body (cf. CP VI 14.3, 10;}\]

\[\text{Lass.6; Aristotle GA 744a16f), not its precipitation).}\]
partly quoted p.147f): the murky part of water—vapour is separated out, τὸ δὲ λαμπρότατον ... λείπεται καὶ γλυκαῖνεται ὑπὸ τοῦ ἥλιου καὶ ῥεῖσέν τε καὶ ἐψύχειν. On this interpretation πέψις is, as it should be, the attainment of an end, in that air, being purified, comes closer to its proper form.

But perhaps πέψις in Vent.50 implies something more than this. Boeker 2234 regards the πέψις as a comparison "des Aufwallens beim Einsetzen des Kochens von Wasser mit dem Aufstieben der Böe eines einsetzenden Gewitters ... (meist mit Staubauftrieb verbunden". But, even granting that commonplace observation of storms might suggest this analogy¹, and discounting its obvious inapplicability to hoar-frost, it still seems unlikely: the mere boiling of water is seldom, if ever, called πέψις;² πέψις usually denotes processes like ripening, digestion or the formation of semen, which (to all appearance) involve no violent movement, such as Boeker's analogy requires³.

1. Which seems doubtful. Modern observation and analysis may do so (cf. Sutton 71), but that is another matter.
2. Mete.IV 530b12ff discusses ἐψησις as a form of πέψις, but mainly concerns food etc. cooked in boiling water, not the water itself.
3. However, I agree with Boeker l.c. that Theophrastus in Vent.50 was perhaps thinking of the sequence of weather at the passage of the 'cold front' of modern meteorology: a sudden veering of the wind and heavy rain, followed by a lifting of the clouds and improved visibility (v. Sutton 86).
The more probable point of \( \text{πέψις} \) in Vent.50, also hinted at by Boeker l.c., seems indicated by: \( \text{μετὰ . . . τὴν πέψιν . . . εἷς τοῦνάττιον ἡ μεταβολὴ.} \) \( \text{πέψις} \) implies a general, complex change in the body concerned; \(^1\) and so, here, there is a complex change in the air, with precipitation forming and wind changing. (The Peripatetics' account of \( \text{πέψις} \) suggests no other reason why it should involve a change of wind - in any case Vent.50 is inconsistent about the change, speaking first of the north wind changing to a south wind, then of 'winds falling': Theophrastus can have had no very precise idea how \( \text{πέψις} \) affects wind).

**Probl.XXVI 33 (944a11f):** when the sun \( \gammaρόν \) ὅντα τῶν ἀέρας διαθερμαίνον πέττῃ καὶ διακρίνῃ, εἷς 
\( \text{πνεύμα} \) διακρίνειν. \( \text{διακρίνει} \) means that moist air is changed to something finer, nearer dry air (p.65ff): \(^2\) this corresponds

\(^1\) E.g., when bread is digested and becomes blood (the \( \text{τελευταία ῥαφῆ} \) of animals, Aristotle PA 650a34), it liquefies, is heated, and changes its colour, taste, smell etc. (This complexity must have been obvious, though seldom directly referred to; for passages connecting \( \text{πέψις} \) with a general, unspecified \( \text{μεταβολὴ}, \) v. Aristotle de An.416a32, PA 650a2ff; Theophrastus CP VI 14.3, VI 15.2. The point of Vent.50 \( \text{εἷς τοῦνάττιον} \) is merely, I suppose, that all changes are between opposites (on this and \( \text{πέψις} \), cf. Aristotle de An. 416a32ff, Mete.IV 379b18f \( \text{ἐξ τῶν} \) \( \text{ἀντικειμένων} \) \( \text{παθητικῶν} \), also, perhaps, Theophrastus CP VI 6.3).)

\(^2\) This is analogous to evaporation and so fits the drying elsewhere associated with \( \text{πέψις} \) (p.360a ).
fairly well with my interpretation of πέψις in Vent. 50, except that here the moisture is removed by being dried, not by precipitation. There can be little idea here of a complex change; perhaps πέψις is introduced simply as being heat's normal effect (cf. Mete. IV 379b10ff).

There remain two problems. First, πέψις should be due to heat (p. 359): it is so in Probl. XXVI 35, but hardly in Vent. 50, since cold, not heat, causes precipitation. Sometimes, indeed, Theophrastus speaks of cold apparently causing πέψις; but usually it does so indirectly, through ἀντιπερίστασις of the heat. Possibly, he thought that this happens in Vent. 50: that cold prevails only where precipitation is forming, and that heat is causing πέψις elsewhere. This is not convincing, since snow and frost (though not hail) occur when the air as a whole is cold; but I can suggest no alternative, unless Theophrastus was writing at random or regarded the πέψις as merely metaphorical.

The second problem is that πέψις normally makes things denser, more compact — the opposite of its effect in

1. v. pp. 78n, 101f.
2. As at CP VI 18.11; Ign. 13f. (Not, however, at CP VI 8.6).
3. E.g. Aristotle GA 747a5f, 765b2f, Mete. 358a10, Mete. IV 380a4-6, Theophrastus CP VI 16.3, Ig. 41f.
the present passages, as I interpret them. This, however, can be explained: \( \text{πέψις} \) generally affects solid or liquid bodies, which heat often makes solider and thicker (as in many cooking processes). Mete.IV 380a4-6 says that \( \text{πέψις} \) makes bodies \( \text{παχύτερα} \) because that is heat's effect\(^1\), i.e. it is not a special feature of \( \text{πέψις} \) as opposed to other heat-induced processes. Other passages admit there are some things—notably water—which \( \text{πέψις} \) does not thicken, e.g. Mete.IV 380b11 ὅσωρ ἑφθαν \( \ldots \) \( \text{λέγεται} \), but \( \text{οὐ παχύνεται} \), i.e. water can in some sense undergo \( \text{ἐψησις} \) (which is \( \text{πέψις} \), 379b12), but does not thereby thicken. Cf. Probl.II 33 (869b34):

\[ τὸ \text{θερμὸν ἐξπεττεῖ καὶ πνευματοῖ τὰ ἐν ἠμῖν δυρᾶ \]  

Thus \( \text{πέψις} \) does not always thicken things: it thickens those bodies which heat obviously does thicken, but when applied to other materials, e.g. water, it has, or may have, heat's normal effect, and makes them rarer and finer: which is what happens in Vent.50 and Probl.XXVI 33.

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1. Steinmetz 37a regards this as interpolated, mainly because it is inconsistent with IV.\text{Met}. But Theophrastus in 33 probably refers to the apparent exception) that heat, which is normal to the bodies under consideration, does not thicken them, but instead makes them thinner.

2. Cf. Aristotle PA 668b9f, Mete.IV 381a6ff, Theophrastus CP VI 7.3 \( \text{πέψις} \ldots \) \( \text{τὰ μὲν} \ldots \) διατιμίζει, \( \text{τὰ δὲ παχύνει} \); Od.3 \( \text{τὰ πεπεμμένα καὶ λεπτὰ} \).
6) Winds through narrows; the sources of wind.

Vent. 19f explains that winds are cold, though due to heat, because (a) heat is only **συναιτίον** (on which v.p. 339), and (b) if a movement due to heat is **κατά μικρὸν** ... **καὶ ὁδὸς στενοῦ τίνος**, then the air set in motion need not be hot, but will remain as it was previously. Hence breath blown through pursed lips is cold; τὸ αὐτὸ δὲ καὶ ἐπὶ τῶν πνευμάτων συμβάλλει· ὁδὸς στενοῦ γὰρ οὖσας τῆς πρώτης κινήσεως κτλ. ; cf. §3, north and south winds are cold near their origin because τὸ ... ὁδὸς στενοῦ καὶ σφοδροτέρως φερόμενον ψυχρότερον. What are these 'narrows'? Steinmetz 39f denies that they are connected with Aristotle's 'sources' of wind (cf. infra), saying that "der Begriff der Windquelle kommt im ganzen Traktat de ventis nicht vor"², and that the river analogy is inconsistent with the **ἀνταπόδοσις** theory (the importance of which in Theophrastus Steinmetz exaggerates, v.p. 356f — Theophrastus may have held other theories inconsistent with it).

1. Steinmetz 27n regards this as interpolated, mainly because it is inconsistent with §19f. But Theophrastus in §3 probably refers to the apparent empirical fact, disregarding §19f's theory (he seldom adheres rigidly to one theory, cf. p. 375-7. Experience hardly fits §19f, which suggests that the breath should often be warm, i.e. whenever the air is).

2. Which is not strictly true, v. Vent. 28, wind compared with ὑδωρ ἢ πό μετὰς πηγῆς ... ἐδου ; also §§30, 37, 39, 50 refer to the **ἀρχή** of wind. Cf. also p. 368n.
Steinmetz's (p.40) own interpretation is that "die als Materie gedachten Sonnenstrahlen...müssen zwischen den Korpuskeln der Luft hindurchdringen" - the 'narrows' are apparently spaces between air-particles made by the sun's rays as they proceed down to the earth\(^1\). This seems very forced. Who calls the passage of a narrow particle through a fluid 'motion through a narrow space'? Also, innumerable heat-particles must produce innumerable 'narrows'; but the text mentions only one. The sun's rays must travel far before causing wind on the earth - their motion then is not their first motion; the 'first motion' must be that of the air, i.e. of the wind: the wind moves at first over only a narrow front.

This Boeker 2230-2 accepts, comparing Vent.29, which says there is always wind in narrow places (v.p. 348f supra), and supposing that all winds (or at least the main north and south winds) were thought to be produced from gaps in imaginary mountain-ranges in the northern (the Rhipaeans) and southern parts of the οἰκουμένη. This goes far beyond the evidence. Undoubtedly the north wind was often

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\(^1\) Theophrastus (sometimes at least) thought of the sun's rays as material, cf. Ign.38 τὴν ... τοῦ ἥλιου θερμότητα ... εἰς ἀγχωθεῖ ... εἰς τοὺς πόρους. But nothing suggests that the sun's rays are particularly thought of as material in Vent.15-22, as Steinmetz 38 thinks is the case in Vent.15 (v.p. 332n).
thought to blow from the Rhipaeans\(^1\); but in no author does it blow from a gap in the Rhipaeans; nor is there any hint of such a gap in other passages that explain the North wind (cf. pp. 266, 303; Vent. 11f). Also, Procl. RXVI 52 (946a17ff) (from Vent. 58, 40, 41, but with a better text) suggests that a wind might blow 'through a narrow' even from a mountainless area: 946a26ff, Zephyrus is ὑμαλός; οὗ γὰρ ἀπ' ὅρεων πνεῖ ... ἀλλὰ βραδίως ἤσσωρ οὐ ἀφλῶνος (Vent. ἀφλῶν τα μὲν γὰρ πρὸς βορέαν καὶ νότον ὤρεινά· πρὸς ἐσπέραν δὲ οὔτε ὦρος οὔτε γῆ ἔστιν, ἀλλὰ τὸ 'Ἀτλαντικὸν πέλαγος ... "for it does not blow from mountains...,

but easily, as though through a valley (or 'pipe'). For the regions to the north and south are mountainous; but to the west there is neither mountain nor land, but the Atlantic Ocean..." (i.e., presumably, the west wind, at its origin, has a smooth and unimpeded course, while the north and south winds, impeded by mountains, are gusty and irregular – thus mountains affect wind's nature, but are not necessary for its production. Note that the smooth path through which the wind flows is 'as it were' something narrow, a valley or pipe).

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1. v. [Hippocrates] Aer.19 (I.II 70.7f), Damastes fr.1. Also, Boreas has been thought to mean etymologically 'mountain wind' (v.Boisacq (1950), Frisk (1954-) s.v.), and 'Rhipaean' suggests the rushing of wind (Cary and Warmington (1963) 237).
Nowhere, pace Boeker, do the 'narrors' appear to cause wind¹, nor (to judge by Vent.41) need they be definite physical features of the ground (cf. Wood (1894) 31n). Most probably they are the imaginary narrow, fixed sources of winds, resembling those of rivers, in which Aristotle believed (p.295ff); for Vent.19f resembles Mete.367a31ff, which seems connected with the latter theory (p.295f); and Theophrastus certainly believed the main winds to originate in fixed regions², and to be distinct entities³. He also explicitly compared winds with rivers in explaining how the configuration of the ground affects them⁴.

1. Except possibly in Vent.29, which concerns only minor winds (cf. p.348f). Vent.19 refers to Theophrastus' general wind theory (pp.339, 365), which has nothing to do with narrows.

2. Vent.2: each wind has τόπος ίδιος. Vent.3: Notus is warmer with us than further south because it has travelled further (cf. p.365). Vent.4, winds are rainy or not according to distance (πρὸς τὴν ἀπόστασιν); hence, the south wind brings rain to the north, but clear weather in the south (§§6-7). Vent.5, to dwellers in the north Boreas is strong as it starts to blow, Notus as it ceases, because Boreas ἐπικείμενος ... ἐπικείμενος, while Notus μακρὰν ἀφέωςτικα. Vent.30: some places are windless, despite being ἐγκυμονοὶ ... τοῖς ἀρχαῖς of wind. Vent.41 confirms that north, south and also west winds originate in distinct regions (cf. p.367).

3. Cf. Vent.52, the veering or backing of wind is change ἐν τοῖς ἐφασμένοις (cf. p.298); Vent.30, 48, 53f, winds 'blow against', 'hinder', 'prevail over', 'fight with' each other, etc.; also Vent.39, the properties of Caecias.

4. Vent.28, 29; also, implicitly 34 (quoted p.349n).
Theophrastus, however, here as elsewhere, does not confine himself to one theory: Vent. 26 compares some winds with εὐριποῖοι, i.e. with a marine phenomenon (v. p. 348); Vent. 4, 6, where wind is κυματῶδες or ἀχυμον (I take it, gusty or not gusty), suggests a similar analogy. Theophrastus evidently recognised that the wind-river analogy can at best explain only certain characteristics of wind.

1. Pace Steinmetz 40, it is not an important one.
7) Wind due to the air's weight\(^1\).

Probl.XXVI 36 (944b4ff): is wind, like water, borne
\(\text{ἀπὸ πηγῆς τινος} \ldots \text{καὶ τοῦτος οὐ̃χ ἔστιν}
\text{ἀνωτέρω} \text{αὗτο} \text{ἐνεχθήναι, "... and is it unable to be borne}
\text{higher than this?" Water flows more swiftly on a slope than}
in a plain, and similarly air is always in motion in high
places, but not in hollows (b8-12). In the very highest
places, however, there is no (violent) wind\(^2\), and water does
not flow strongly (b12-15, 18-20). Hence, wind evidently
does blow from a source, and so \(εἰς \tauὸ \text{ἀνω} \ldots \)
σκέτα \(ς \text{δύναται διι̃κνείσθαι}(b16f)\).

This suggests that wind, like water, naturally flows
downwards. Cf. Probl.XXVI 5 (940b21ff): the air involved in
land-breezes collects over the sea, because the sea
\(\text{ἐν κολλῇ ἔστιν}. \) \(\delta \) \(\text{δὲ} \text{ ἀὴρ, ὡσπερ} \tauὸ \text{ὕδωρ, δεῖ} \text{δεῖ}
\text{εἰς τὸ κολλότατον , "... always flows into the deepest}
hollow". This natural descent presumably causes the land-
breeze (though obviously not the following sea-breeze).

This was presumably a development of Aristotle's and
Theophrastus' wind-river analogy; but neither that theory
(since it does not explain wind's cause of motion), nor any
other in Mete., Vent. or Probl. implies that wind is caused

\(\text{1. For slight remarks on this theory v. Boeker 2229f;}
\text{Strohm (1937/8) 258n, 266 and (1953) 289.}
\text{2. On this v.p. 226n, Capelle (1916).} \)
by air flowing naturally downwards\(^1\). Vent. 22 states, indeed, that air naturally descends\(^2\), and other thinkers had regarded air as in some sense heavy\(^3\); but they did not regard its weight as causing wind\(^4\) - Vent. 22 denies that the air's descent can cause wind on its own\(^5\).

Probl. XXVI 5 and 36 in fact contain an obvious difficulty, which may explain why their theory was not more widespread. Consider the analogy with water: if a hollow is full of water, and more water is poured in, the new water will presumably only sink to the bottom of the hollow if it is specifically heavier than the old; therefore, as the earth's whole surface is covered by air (as any post-Aristotelian must have known, cf. p. 154), air will only flow to the lowest part of that

\(^1\) Pace Boeker 2229f, the notion that wind is ρόσις ἀέρος does not imply this: a 'flow' may be upwards as well as downwards: at Mete. 361a33 δεσμεύσαι τὸ ἄνηλόν (i.e. dry exhalation) refers to wind's motion; cf. 365b28, sometimes wind within the earth ἐξω βελ πᾶν, i.e. flows upwards into the atmosphere.

Mete's theory that wind's motion originates from above does not imply it is a natural descent (v.p. 269-71); nor, probably, does Vent. 36, saying that certain upper air phenomena (e.g. shooting stars) are signs of wind; for 35 has just spoken of the sea giving warning of wind.

\(^2\) But Theophrastus Ign. 55 denies that air, like water, collects in a τόπος ἔγχυσις.

\(^3\) On Aristotle v.p. 334. In Anaxagoras ἀέρ collects at the centre of the cosmos (p. 159); on the atomists v.p. 177. V. also Plato Ti. 60C.

\(^4\) Water's downward flow is obviously due to its weight, cf. Mete. 356b18f.

\(^5\) Probl. XXVI 33 (944b19ff) also implies that air's weight does not cause wind.
surface if it is specifically heavier than the air there already. Yet Probl. mentions no air save that which is flowing downwards.

A later ancient writer, Seneca, shows some sign of understanding this: Nq V 8.1-2, water–vapour forms in places surrounded by mountains, fills and overflows them: "illa collectio (of vapour)...onerata quaeirit quo defluat". Vapour is evidently heavier than ordinary air, and so flows down below the air, after over-filling its hollow. V 14.2-3; there are hollows inside the earth, and lakes in them; hence "necesse est...aera onerari oneratumque incumbere et ventum propulsu suo concitare", "it must be that the air is burdened (sc. with vapour from the lakes), and that being burdened it exerts a pressure (presumably on the air next it) and rouses wind by its force". Heavier air evidently moves as wind by pressing against and displacing lighter air.

All this is of importance, because one way of looking at atmospheric pressure is to regard it as the air's weight, so that Probl., and Seneca still more, were groping at an idea that would lead to the true explanation of wind. For comparison, I quote an early modern writer, Hadley (1735) 59: the sun causes the trade winds by heating and rarefying the air at the equator; "by which means the air there becoming specifically lighter than the rest round about, the cooler air will by its
greater density and gravity remove it out of its place to succeed into it itself, and make it rise upwards".

1. I have nowhere discussed Arab. 50ff., explaining whirlwinds c.t.c., because I have not dealt with earlier theories of these, which connect them with thunder and lightning.
2. This is consistent with the derivation of wind from both exhalations, if, as in Aristotle (p. 329 above) both are constituents of air.
3. Alexander 54.3-8 explains why winds produced by the process described at 53.35ff. (v.p. 315 supra) blow from north and south towards us, and not away. This addition (presumably Theophrasteaean) is important if the direction of winds is to be adequately explained.
8) The character of Theophrastus' wind theories.

Theophrastus' most general theory was evidently based on Aristotle's, in that dry exhalation was important in it (p. 335ff); but Theophrastus tried to remove Aristotle's obvious errors. He restored the χίνης ἄρος definition of wind (p. 327, cf. p. 263-5); his theory of wind's motion makes possible other than easterly winds (p. 332ff, cf. p. 269ff); his theory of how heat causes and prevents wind avoids the difficulties of Aristotle's theory (p. 328ff, cf. p. 287ff). The importance he accorded to water-vapour perhaps seemed another correction of Aristotle's perverseness: for this corresponds with the general pre-Aristotelian view (p. 59ff), and Aristotle admits that water-vapour may determine the occurrence and character of winds (p. 265ff): this therefore may have seemed to Theophrastus an established fact.

Theophrastus' account of wind was thus more conventional than Aristotle's, and more in accord with common-sense. It

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1. I have nowhere discussed Arab. 50ff, explaining whirlwinds etc., because I have not dealt with earlier theories of these, which connect them with thunder and lightning.

2. This is consistent with the derivation of wind from both exhalations, if, as in Aristotle (p. 229f) both are constituents of air.

3. Alexander 94. 3-8 explains why winds produced by the process described at 93. 35ff (v. p. 335 supra) blow from north and south towards us, and not away. This addition (presumably Theophrastean) is important if the direction of winds is to be adequately explained.
differs also in its greater attention to detail (i.e. to particular types of wind, etc.), and in regarding particular sorts of wind (e.g. ἀφρατος (p. 340-2), and sea-breezes (p. 348ff)) as due to special, largely unique, causes.

It seems strange that wind should be explained by several alternative causes; but there is really no reason why similar effects should not be produced by distinct causes, when the circumstances differ, as in these instances. Theophrastus, however, also describes what appear to be alternative causes for winds in general (i.e. without explaining in what circumstances each cause operates); and he tends to use vague expressions about wind's causes (especially the effects of heat), which are compatible with any of his more precise explanations (p. 328-46); evidently he was confident that heat helps to cause wind, but not of how it does so.

All this illustrates a further characteristic of his thought. He is always aware of the difficulty and complication of physical problems. He will not commit himself to a definite general theory of a subject like wind, or of the first principles of physics (cf. p. 325): he evidently felt that

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1. Modern scientists hold that rain is produced from clouds by two distinct processes, Sutton 74-6.
his predecessors had all failed to solve these problems with
certainty, and that to find certain solutions was impossible.
In considering less general questions he likes to explain how
alternative causes\(^1\), or several factors in combination\(^2\), may
produce one effect, or different conditions produce variations
in things one would suppose similar\(^3\). Because he no longer
hoped to find a convincing general explanation of a topic like
wind, to which the phenomena must be fitted, he had no motive
for disregarding their actual complication: he naturally
accepted all the varying explanations which the circumstances
of individual phenomena suggested, and preferred to regard
phenomena as caused by several independent factors, which
made their complications easier to explain\(^4\).

As we have seen (p. 316ff.), Aristotle, in working out the
details of his physical system, develops his most general
physical theories in different ways in different works, and
sometimes modifies or ignores them, according to the require-
ments of each subject; in the same way, he modifies his

1. So Vent. 24, 26 (cf. supra); Lap. 2\(1\), 9; Ign. 35\(1\) (two
   reasons why walking in the sun is cooler than sitting),
   65 (heat requires ῥηρότης or ἀναθυμίασις); etc.
2. Sun and vapour 'work together' to produce wind(Vent. 15,
   etc.). Sun, earth and air all provide τροφή for
   plants, and, with the plants' δύναμις, contribute
   to its generation (v. CP I 17.1; I 21.2\(1\); II 1.4; III 2.1;
   III 12.2; III 16.4; etc.). Wetness, ἀρνοὶ and heat
   combine to produce rotting (ib. IV 14.3).
3. E.g. CP IV 9.4, 6, IV 11.6ff, the differences produced in
   things by variations in soil, air etc.
4. On these aspects of Theophrastus' thought v. further
general meteorological theories in working out their details (p. 323n). Theophrastus carries this a stage further. Being aware of the inadequacy of any possible general theory, he tries to avoid committing himself to one; and he is still readier than Aristotle to adopt a new theory when a subject requires it, regardless of its relation to what he has said elsewhere.

Strohm (1937/8) 254ff; Steinmetz 33, 327 et passim (v. index s.v. 'Pluralismus der Ursachen'); Regenbogen (1950) 154ff passim; Eichholz (1965) 5-7.
CHAPTER 9

CONCLUSIONS

In this chapter I discuss by what methods the ancient meteorologists worked out their theories, what their scientific value was, why they never pursued this study further, and what light this throws on the origins and development of ancient philosophy and science in general.

1) The origins of meteorology.

A. The early poets.

In the typical pre-Aristotelian wind theory, wind is derived from water, cloud, or some similar body (p. 59ff). Homer, Hesiod and Solon anticipate this theory in passages which derive or connect wind — but usually some particular wind, not winds in general — with the sea, cloud, moisture etc. These passages are not the reflection of a carefully thought out theory of wind, but usually just descriptions, or simple interpretations, of obvious facts about wind in certain conditions, which happen to have come into the poets' minds at these particular points (cf. p.49ff).

Homer makes similar remarks about snow and thunder:

ταρφειαλ νιφάδες Διός ἐκποτεονται ψυχραλ, ὑπὸ διπῆς αἰθρηγενέος Βορέαο. ¹

In 795f, certain warriors

ἴσαν ἄργαλέων ἀνέμων ἀτάλαντοι δέλλῃ,

ὁ δὲ θ' ὑπὸ βροντῆς πατρὸς Διὸς εἶσι πέδονόε.

The poet, again, is simply describing familiar atmospheric occurrences²; but T 357f suggests that Boreas causes the snowfall, and N 795f at least connects wind and thunder. Both—or, at least, the commonplace observations behind both—seem, like the passages on wind just mentioned, to be among the sources of philosophic theories.³

Indeed, the Greeks had begun to develop detailed meteorological theories even before Anaximander. Hesiod Op. 548–52 (quoted pp. 46, 50), connecting mist with evaporation, rain and wind, is obviously more than the description of a familiar phenomenon: no-one could see all these things happening as successive parts of one event;

1. Cf. Ν 156ff, O 170f. (On these and similar passages cf. Kopp (1939) 295 and Mugler (1963) 57, 65f, 71.)

2. Both passages are from similes, so presumably are describing familiar things.

3. On thunderstorms see below; for wind causing precipitation v. p. 101.
Hesiod must be generalising from various observations of mist, of visible 'vapour' rising from rivers, and of rain and wind, and conjecturing that mist and vapour provide – as he apparently thinks – rain's and wind's origin (cf. p. 50n); and he thereby comes very close to the philosophers' meteorological theories.

Cf. Th. 706f, describing Zeus' thunderbolts;

σὸν δ’ ἄνεμοι ἑνοεὶς τε κοινὴν τ' ἐσφαράγιζον
βροντῆν τε στεροπήν τε καὶ ἀθαλόσεντα κεραυνών.

Whatever the exact meaning of ἐσφαράγιζον, it implies that the winds somehow cause earthquake, thunder etc.¹, which brings Hesiod close to many philosophic thunder and earthquake theories (cf. p. 92ff).² We may say, in fact, of his meteorology what Cornford said of his cosmology, that "the process of rationalization had been at work for some considerable time before Thales was born".³

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1. On ἐσφαράγιζον v. West (1966) 354f. (On the evidence he quotes, the word's root meaning seems likely to be 'cause by blowing', rather than 'swell', 'inflate', as he suggests).

2. Th. 845f also connects thunder and wind. (For remarks on both passages cf. Kopp (1939) 313.) For a comparable physical speculation in Homer v. τ 205-7.

B. Anaximander.

Anaximander believed that wind and rain are derived from clouds, which are formed from water-vapour, and that thunder and lightning are caused by wind. All these ideas are foreshadowed in Homer and Hesiod: he presumably obtained them by systematising, and drawing general conclusions from, casual observations and elementary theories such as I have just quoted from those poets. But he combines them with ideas that appear to be new: the most important is that the sun's heat causes evaporation and wind.

Heat and cold were important in Anaximander's general system (p. 109). To some extent earlier poets had anticipated this; for Anaximander probably used concrete expressions, such as φλόξ and δήμα, rather than θερμόν and ψυχρόν (p. 104n), and at least these two terms have connotations of light.

1. pp. 61f, 94f, 109ff, 444f, 449, 452.
2. pp. 109f, 116f.
3. As Cornford (1952) 196f, 201 assumes, connecting Anaximander's heat with the poets' sky. There is, however, no evidence that early poets regarded οὐρανός or άλθημα as hot or fiery (v.p. 439f; Kahn 137ff). (There are heavenly bodies in the οὐρανός; but this does not prove it fiery, any more than the sun's rising from Ocean (Π 421ff, τ 433f) proves Ocean fiery. άλθημα, however, is bright, which confirms light's importance, cf. infra.)
and darkness\(^1\), which are important in early poetry:\(^2\) Day and Night are important in Hesiod's Theogony\(^3\), light is frequently connected with life and darkness with death, and so on.\(^4\) The sun's important property is its light\(^5\): the poets rarely mention its heat (but v. Hesiod Op.414f), or its producing effects due to heat: drying a dead body (Ψ 190f), clothes (ζ 98) or a piece of ground (η 124); arousing thirst (χ 160); softening wax (μ 176); killing stranded fish (χ 388); or causing putrefaction (H.Ap.371, 374).\(^6\) Even Hesiod's graphic description of summer's heat and winter's cold\(^7\) does not suggest that heat or cold causes

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2. Cf. Gigon (1945/55) 34, 77f al. (who maintains Anaximander's initial opposites were light and night). On light and darkness v. also Kann 159-62.
3. 123-4, 211ff, 744ff.
4. Lloyd Fa 42f.
5. Its function is φαένεται (γ 2, μ 383, 385, H.XXI 8, Hesiod Op.528, Th.372); it is φαέθων (Δ 735, ε 479, λ 16, τ 441, χ 388, Hesiod Th.760) or φαεσφβρωτος (χ 138, 191, Hesiod Th.958); it sees all things (Γ 277, λ 109, μ 323 etc.). When the sun sets, or vanishes, darkness follows (Δ 475, Β 413, Θ 485f, Λ 194, 209, Π 455, Β 388, γ 329, etc.); to live is 'to see φῶς ἡελίωτο();' (passages cited by Mugler (1963) 130f); bright objects shine like the sun (Ξ 185, Χ 134f, δ 45, η 84, τ 254); etc., etc. (Of. also Mugler (1963) 120f.)
(say) meteorological phenomena, or growth and decay. Very seldom does any early poet suggest, even remotely, that the sun or heat causes evaporation or wind (v. pp. 54, 109f).

Anaximander's originality lies, not in his regarding bodies like ἦλιος, φῶς and ἁίρ as important, but in regarding them as major causes, producing effects where their influence is not immediately obvious, such as meteorological phenomena and the formation of animals (cf. p. 109). Earlier Greeks, when they looked for the remoter causes of events, ascribed them to the action of a god: Anaximander's dissatisfaction with mythological explanations compelled him to seek new causes; and he chose hot and cold bodies as his principal causes, since such were already familiar as causes of minor events, and as marked features of the world as a whole. Hence arose one original feature of his meteorology.

1. For further passages, on heat or fire melting metals, boiling water etc. v. Mugler (1963) 118-20: none suggests heat is of great importance in meteorology or the cosmos as a whole. On the general unimportance of heat and cold in pre-philosophical texts v. Lloyd PA 43-6. (The connexion, there mentioned, of heat and cold with life, death and the emotions, can hardly have been of great importance, in view of the limited evidence cited from early poetry there, and by Onians (1951) 46f, 95n.)

2. On Anaximander's choice of heat and cold cf. EuP 8f. (On why Greek philosophers spoke of pairs of opposites v. Lloyd PA 26ff; on hot, cold, wet and dry in Anaximander in general v. Lloyd (1964a) 94ff.)
Two other meteorological ideas of his that do not occur in the poets are that wind is an emission of 'finest vapours' from cloud, and that wind causes thunder by bursting from cloud.¹ Both ideas seem based on analogies, drawn between wind and the boiling and evaporation of water, and between thunder and the escaping of wind from an inflated bladder (pp.94f, 116f). Another analogy, with artificially boiled water, probably influenced the ideas that the sun causes evaporation, and that water condenses to rain (p.110f).

Commonplace observation of the atmosphere probably suggested certain meteorological theories (pp. 378–81 ), possibly including the idea that heat causes atmospheric events; for the atmosphere's temperature, and wind, cloud etc. in it, both vary with the time of day or year, which suggests they are causally connected. But observation of the atmosphere alone was not sufficient to suggest adequate explanations of what happens in it: it was necessary to apply to the atmosphere further ideas, obtained from elsewhere. The earliest Greeks did this, when they explained events as caused by a man-like god. But the pre-Socratics were dissatisfied with such mythological images, and usually preferred to use ideas suggested by other natural phenomena,

¹ pp.114ff, 94f.
or artificial processes like cooking.

In principle, this was an innovation: "Homer does not ... use comparisons to provide ... explanations of natural phenomena (for this ... he never undertakes to give)."¹ He and Hesiod do, however, use the same imagery as Anaximander - boiling water, or inflated skins - in describing rare phenomena, or the effects of divine intervention. Aeolus' bag is an inflated skin (p.91); boiling water and the like is mentioned at Χ 149f, of the Scamander's hot spring:

ἀδφὶ δὲ καπνὸς

γίγνεται ἐξ αὐτῆς ὡς ἐὶ πυρὸς αἰθωμένῳ.

Cf. δ 361ff, Hephaestus attacks the Xanthus

ἀναὶ δὲ ἐπινε ἔκακε βέβηρα

ὡς δὲ λέβης ζῇ ἐνδόν, κτλ. ²

Anaximander's innovation was not the imagery, but the use to which he put it: to explain (as well as describe) normal events. ³

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¹ Lloyd PA 190.
² Cf. also Hesiod Th.695, 647.
³ The poets also foreshadow philosophic analogies in another way. "Our use of any general term depends on the recognition of a similarity between the instances to which it is applied" (Lloyd PA 172): the poets, by applying a general term to things not obviously similar, might suggest an analogy to a philosopher. Thus their using πνεῦμα and ἀναμετρον of breath, wind, fire and smell perhaps suggested a macrocosm/microcosm analogy to Anaximenes (v. p.130ff), and subconsciously influenced the philosophers' exhalation and wind theories (p.54f).
Similar analogies probably underlie most of Anaximander's detailed theories: he compared the earth to a column-drum (12A11(3), A25), and described the heavenly bodies by analogies with wheels (12A21, A22), lightning, and τρηστήρος αἰλός probably the 'funnel' of a tornado. The initial formation of the heavenly bodies he explained by an analogy with an egg, the bark of a tree, or both, and that of animals and men by an analogy with supposed instances of spontaneous generation, and perhaps with the embryology of dogfish.

These analogies evidently provided Anaximander's normal method of describing and explaining natural phenomena, when direct observation was inadequate; indeed, it was almost the only method available. Direct observation was often impossible (as with cosmogony), or insufficient to suggest an adequate explanation (as with lightning); he had to apply to the

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1. What I say of philosophers' methods in this chapter is not meant to apply to the ways in which they discovered their δρχάλ.


3. 12A30; cf. KR 142, HGP I 104, Lloyd PA 323n.
phenomena ideas derived from elsewhere, and could seldom get them purely by abstract thought; inevitably, he took his ideas from things familiar in the world around him; that is, he reasoned by analogy from them to what he was explaining.¹

Occasionally he could use other methods. It was easy to invent measurements without using analogies: his figures for the heavenly bodies' distances and the earth's dimensions are not due to any apparent analogy or observation.² He also explained why the earth is at rest without an analogy, saying simply (in effect) that there is no reason for it to move (12A26, cf. A11(3)); but this, explaining why something does not happen, is hardly comparable to explanations of how a thing does happen, or of what it is; besides, this explanation did not seem plausible to his closest successors, who preferred an analogical one (pp. 125, 162f).

To Anaximander's successors analogy was less important. They mostly had developed theories of how different materials change into each other (cf. p. 105f), which might suggest explanations of phenomena without the assistance of analogies, or at least determine what sort of explanations that thinker

2. 12A10, A11(5), A21, A22. For views on this v. HGP I 95f and authors cited, also Kahn 94-6, Dicks (1966) 36.
gave. But Anaximander's general theory probably provided only the vague idea that events should be due to a conflict of opposites, especially heat and cold; and this was not enough on its own to suggest detailed explanations - indeed, had he tried to develop in detail 1251's notion of δίχανα and τισούς, it would have led him back to the mythological type of explanation from which he wished to escape.

2) The development of meteorological theories.

A. Introductory.

All ancient theories of weather-phenomena were expressed, at least in part, in terms of familiar empirical facts, whose occurrence, or apparent occurrence, no physicist could deny: these include atmospheric phenomena, such as wind, cloud, air itself, evaporation, and processes used as analogies, e.g. water boiling, the emission of wind from inflated skins, etc. Insofar as meteorological theories are expressed in such terms, we may conclude that thinkers whose general theories of matter differed widely, nevertheless held identical meteorological theories (cf. pp. 99f).

But a meteorological theory frequently included other elements, derived from the general physical theories of the thinker concerned - for example, it might mention atoms - and insofar as it was expressed in such terms, it must be peculiar to that one thinker, or group of thinkers. Now a thinker may explain (say) wind in new terms, derived from a new general physical theory, without having thought about wind at all. Thus, if several thinkers explain wind by an analogy with boiling water, and one has a general theory which causes him to describe water boiling in different terms from the others, then he will presumably use those terms in explaining wind; but yet he need have no new idea
about wind as such. His only idea about wind may be the same as the other thinkers', viz. that its occurrence is analogous to water boiling. For example, Heraclitus explained wind in terms of his exhalation theory, which was clearly influenced by his general theory of change; but his only idea about wind, i.e. that it is caused by a watery vapour, was shared by many other thinkers. ¹ Similarly, Anaxagoras' general theory must have led him to interpret λέπτυνσις in a peculiar way; but he uses it in his wind theory in the same way as other authors. ²

In what follows I ignore ideas like these; I am concerned only with the development of ideas about wind.

The familiar empirical facts, such as I mention above, which ancient meteorologists used in their theories, were almost all already familiar before Anaximander's day. The only new facts established by the philosophers which are important in general wind theories are, I think:

(i) that heat causes evaporation (v.p.109f); and

(ii) that air exists (v.p.150-4).

1. pp.140-2, 145.
2. pp.65ff, 166f.
Both 'discoveries' were based on long familiar evidence, and are mentioned, or hinted at, in pre-philosophical authors; the philosophers' part was merely to render them generally familiar; which happened, in both cases, because the relevant evidence was impressed on the minds of philosophers by non-physical considerations: Anaximander came to appreciate that heat causes evaporation, and other events, through his desire to find non-mythological explanations of phenomena (p. 383), and the clear realisation of air's existence by Parmenides' successors was a consequence of Parmenides' logical disproof that void exists (p. 152f).  

B. The pre-Aristotelians.

When so little addition was made to the established empirical facts to which their theories might refer, it becomes less surprising that virtually all the pre-Aristotelians agreed, following Anaximander, that wind is

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1. Two similar facts established by the philosophers, and occasionally used in wind theories, are that matter must flow to fill or prevent a void (another consequence of Parmenides' denial of void; v.pp. 187, 191f, 351ff), and that rarefaction implies expansion (p. 82ff). Both facts again depend on long familiar empirical evidence.
derived from water, cloud, or a similar body (p.59ff).^1 It was also widely held^2 that the efficient cause of wind is heat or the sun. These ideas can be expressed entirely in terms of familiar empirical facts; we have general wind theories attributed to Xenophanes, Heraclitus, Metrodorus, [Hippocrates] Vict. and Nat. puer., and perhaps Herodotus,^3 which employ, so far as I can see, no significant ideas about wind apart from these.^4

Anaximander, Anaximenes and Anaxagoras held that wind is due to the rarefaction of cloud etc.^5 This, too, is based

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1. It is remarkable, but not inexplicable (v.p.63f), that this was so little modified when air's existence became clearly appreciated. (This appreciation led, before Aristotle's day, to the standard definition 'wind is air in motion' (p.56-8), but post-Aristotelians - and so presumably their predecessors - found this compatible with the derivation of wind from water etc. (p. 199 ). Apart from [Hippocrates] Flat., of whose ideas on wind we have only the definition ήρος βεύμα (p. 199 ), the one thinker who, on the surviving evidence, may just possibly have derived wind from what we would regard as atmospheric air (and not from dense air, water, etc.) was Anaxagoras (pp.62f, 67, 166).)

2. By Anaximander (p.114-6), Xenophanes (p.135f), Anaxagoras (p.166-8), Metrodorus (p. 195f ) and perhaps [Hippocrates] Vict. (p.204-6 ) and Nat. puer. (p. 209f ).

3. v.pp.135-7; 141f and 146; 195f; 203-6; 207-10; 60.

4. On minor ideas on wind held by some of these thinkers v. pp. 393 , 407 .

5. pp.65ff, 116f.
on undeniable empirical facts, i.e. evaporation and water boiling\(^1\); but Anaximenes' general theory that change is due to condensation and rarefaction perhaps led him to express it in a more accurate way than Anaximander (v.p. 406\(n\)).

Two other important ideas about wind depend on the general physical theories of the thinkers who held them:

(i) that wind moves itself because it is alive was held possibly by Anaximenes and Diogenes and probably by [Hippocrates] Flat.\(^2\); this depends on their view that air is divine and alive, and is the \(\alpha\rho\chi\eta\);

(ii) Democritus' view that wind results from the movements of densely packed atoms was derived from his general atomic theory (p.179ff).

Another important idea, probably held by Anaximenes, Anaxagoras and Metrodorus\(^3\), is that the Etesians are due to air being massed together in the north and then flowing southwards, sometimes thereby causing the summer solstice. I shall not speculate how this idea arose; but it seems connected, at least in Anaxagoras, with the idea that \(\alpha\nu\rho\varphi\) is confined to the centre of the cosmos\(^4\): an idea such as this,

\(^1\) pp.68, 81f, 116.
\(^2\) pp.129f, 193f, 199f.
\(^3\) pp.126f, 171ff, 195-7.
\(^4\) pp.164, 171.
about the structure of the cosmos, was a further factor which might influence meteorological theories.

It thus appears that pre-Aristotelian wind theories mainly depend on commonplace observations and analogies with generally familiar phenomena. Only in a minority do general, or other, physical theories peculiar to one thinker or school play an essential part. Much the same is true in other fields. The evaporation of water with heat, and the condensation of visible 'vapour' to water-drops, were too familiar to leave much scope for variation in theories of rain: different ideas could be held on whether water-vapour is identical with air, or on the cause of condensation; but the different ideas were evidently expressed, or expressible, in terms of familiar empirical facts; there is no record of rain theories that must have been peculiar to one thinker. ¹

With thunder and lightning, although there was nothing obviously familiar in the process producing them, the pre-Aristotelian theories nearly all involve the trapping of something (probably always wind or fire) in a cloud, or at

¹ v.pp.100f, 444-55 and passages there cited. (Aristotle's theory of cloud and rain, too, mostly accords with previous theories, v.pp.100f, 263 (also p. 234-5 - the ideas there mentioned are partly peculiar to Aristotle, but partly paralleled in Anaxagoras' hail theory, cf.DK 59A85 and p.161f supra).
least some inter-action of wind and cloud\(^1\) - ideas which seem ultimately derived from analogies such as that with wind escaping from an inflated bladder, or a heated paunch bursting (p.92ff). These thunder theories were elaborated in various ways, but the elaborations all seem to involve analogies with familiar phenomena (e.g. friction\(^2\), the sea's phosphorescence\(^3\), the hiss of fire quenched by water\(^4\)). Some of these theories partly depend on general theories peculiar to one thinker\(^5\); but the greater part of all of them might have been accepted by any physicist.

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1. Cf. Anaximander (DK 12A23), Anaximenes (13A17), Heraclitus (22A14), Anaxagoras and Empedocles (Mete.369b12-370a10), Archelaus (his view was the same as Anaxagoras', 60A16), Leucippus (67A25), Democritus (68A93), Metrodorus (70A15), Aristophanes Nu.404-7. Apparent exceptions are Xenophanes (21A45) and Clidemus (62.1).

2. Democritus 68A93.


5. E.g. Empedocles' and Anaxagoras' idea that the sun's rays or ζηληπ are trapped in clouds (cf.Mete.l.c.): this clearly derives from their denial of the reality of change, which implies that fire cannot form in the clouds, but must be introduced from elsewhere. Also, Democritus 69A93 mentions atoms (τὰ γεννητικὰ τοῦ πυρὸς); but the passage is obscure, and I am not clear how important a part the atomic theory plays.
C. Aristotle.

In many respects, in meteorology as in other fields, Aristotle's thought marks a new departure. He had new terms, ἀτμίς and ἀναθυμίας (cf. p. 36ff); he went much further into detail than his predecessors; he had the entirely original theory that the cause of wind's motion is the revolution of the heavens (p. 269ff); above all, he had his new theory of two exhalations, of which one is dry and derived from earth (p. 233ff al.): this enabled him to abandon the common derivation of wind from cloud or water (so that he can explain how wind and rain alternate), and made possible a new definition of wind (instead of the standard 'wind is air in motion') (p. 56f).

Now the dry exhalation theory is remarkable for this, that no substantial observation can be cited to support it. Certain simple observations and analogies may have suggested that wind is caused by a hot, fiery body, distinct from water-vapour; and these considerations, plus the contrast

1. This must be so, because Aristotle clearly wrote far more than they (except possibly Democritus).
2. v.p. 265f. (On the older view this would seem a difficulty.)
3. v.pp. 248, 256f, 265.
between smoke and visible 'vapour' (p. 248), may have helped to suggest the theory of dry exhalation. But the main basis of this theory seems to be the requirements of Aristotle's element theory\(^1\); and that theory is another which is independent of any direct observation. Certain observations must in the last analysis underlie it, determining, in particular, the choice of the four primary opposites and elements; but it is remote from any observation, and formally depends on Aristotle's detailed logical analysis of concepts like \(\delta\rho\chi\eta\) (cf. Ph. I) and \(\gamma\epsilon\nu\epsilon\sigma\iota\varsigma\) (cf. GC), being directly based on his analysis of change as occurring between two opposites in a substrate (cf. p. 307). There is much more logical analysis and deduction, and much less observation, underlying this theory and (consequently) the exhalation theory, than there is in the analogies of (say) Anaximander (p. 384ff.), where the conclusion is reached by a direct analogy with one commonly observed phenomenon.\(^2\)

Aristotle had several other theories relevant to meteorology whose formulation must largely have depended on

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1. v. pp. 228f, 246f.

2. Pre-Socratic theories of matter are, of course, not dependent on such direct analogies; but they do not give rise to meteorological theories comparable to that of dry exhalation (cf. p. 401).
abstract, a priori, considerations. Thus he would never have proposed the theory that the heavens produce heat by friction had he not concluded a priori that they cannot be hot (p. 215ff); and his theories that the sky's revolution causes wind's motion, and that dry exhalation rises above the wet, must have occurred to him largely as a result of his concern, in Cael., with 'natural motions': Cael. is another work which contains far more logical analysis and deduction than it does observation. A priori deduction was a sine qua non for these theories, even though they also depend on observations (of friction, of the sky revolving, and of smoke rising), in a way that dry exhalation does not. This greater dependence on abstract reasoning is the main distinction between Aristotle's meteorology and his predecessors.

Sometimes Aristotle's general theories sufficed, on their own, to suggest explanations of particular meteorological phenomena: for example, he explains various occurrences of wind merely by postulating differences in the amounts of the exhalations present (e.g. Mete.360a34ff). But frequently he had to combine his more general theories with further analogies or observations. Thus in his lightning theory

1. pp.269ff, 235f.
(Met. 969a12ff) the dry exhalation's natural ascent depends on a more general theory (p.398); but the enclosure of matter in cloud was traditional (p.394f), and Aristotle has to add the analogies of fruit-stones shot from between the fingers and the 'laugh of Hephaestus' to provide an adequate theory. The theory of ἀντιπερίστασις owes to Ph.1 and 60 the idea of a conflict of opposites, but depends also on observations of (e.g.) hail in summer (p.280-5). At other times Aristotle virtually ignores his more general theories (except perhaps in just mentioning primary opposites or an exhalation): for example, in the ideas that heat and cold prevent wind by μάρανος and ζώος, that heat is reflected, and that dry exhalation flows into the earth like an ebbing tide. None of these theories can be satisfactorily analysed in terms of Aristotle's general theories: he relies on analogies with familiar phenomena, as his predecessors so often did, and deduction from first principles is of little or no importance. Other parts of his discussion of wind are purely descriptive; but these seem to be, at least in large part, a collection of traditional beliefs

It follows from all this that the principal innovations in Aristotle's wind theory are due to deductions from his most general theories, of the elements, primary opposites and natural motions - it is this that chiefly distinguishes Aristotle's methods in meteorology from his predecessors’. Now considering Aristotle's physical system as a whole, I think it might be said that his innovations mostly lie in four areas: in the collection of facts (as in HA), in his discussions of final and formal causes (cf. pp. 310ff.), and in his logical analysis of and deductions from fundamental concepts and principles like ἔνεστις, ἄρχη and natural motion. Facts about the atmosphere Aristotle assembled largely by collecting popular beliefs (cf. supra) - he was probably too little interested (p. 307) to undertake the greater labour of systematic atmospheric observations; and

1. Thus several features of his wind rose seem primitive (p. 289ff.); the connexion of storms and Orion was traditional (p. 304), as was the connection of westerly with northerly, and easterly with southerly winds (p. 176n). That Caecias turns back on itself was proverbial (Mete. 364b12ff); Homer, before Aristotle, seems to connect north winds with fair weather (p. 53), and says that the north wind brings snow (Ὁ 171f, Τ 557f; cf. Mete. 364b21f).

2. Some of the analogies mentioned on p. 399 are in fact original (as is, in some respects, Aristotle's way of using analogies: v. Lloyd PA 362ff, especially 577f). But this represents a less important aspect of his meteorology.
I have previously shown how his ideas on formal and final causes were inapplicable to meteorology (p. 310ff). There remains the analysis of first principles; and from that, as I say, come his main innovations.

Of course the pre-Socratics had sometimes applied to meteorology their first principles of physics - in particular, the atomists' deductions about atomic movements, by which Democritus explained wind (p.179ff), are not less ingenious than Aristotle's meteorological deductions from his first principles.¹ The difference is that Aristotle's deductions had brought him to conclusions - e.g. dry exhalation's existence, the effect of the heavens' motion in causing wind - which one might expect simple observations to confirm: he surely might have realised (as Theophrastus evidently did) that they do not. Aristotle's methods thus differ in the greater reliance he puts on unchecked deduction from first principles; and meteorology is a field where logical deduction, unchecked by observation, can accomplish little. Thus his methods (and hence his conclusions), although partly new, are no real improvement on his predecessors'.

¹. That these atomist theories, unlike Aristotle's, resemble modern ones (p.182ff), is largely fortuitous since neither atomists nor Aristotle had an adequate basis for their general theories, from a modern point of view.
D. Theophrastus.

Theophrastus differs from his predecessors in paying greater attention to the details of wind phenomena, and in his caution: his awareness of the complexity of phenomena and reluctance to commit himself to a precise theory (p.374ff ). He evidently realised that some of the theories Aristotle had based on deduction from first principles were contrary to common observation and common sense, and consequently abandoned some of them (p. 374 ), and minimised the importance of dry exhalation (p.335-8 ). He accepted that wind is air in motion, and derived from or connected with water-vapour, thus reverting to pre-Aristotelian theories; but he also proposed some new ones: for example, the 'opposite-vertical-motion' theory of wind (p.332ff ), evidently based partly on Aristotle's theory of natural motions; and the idea that water-vapour cannot be at rest (p.340-2 ), whose origin I cannot conjecture. Other new theories he based on analogies of wind with watermovements (pp. 348 , 369 ); his use of πέψις (p.359ff ) is the application to meteorology of a principle established in other fields - a thought-process resembling the use of
analogy. These theories, though new, are thus obtained by old methods. His knowledge of the details of wind phenomena, like Aristotle's, seems derived to a considerable extent, if not entirely, from popular belief, and not his own observation of the atmosphere. Theophrastus' work thus does not constitute any marked advance in the study of meteorology (except in the negative sense that he was more aware than his predecessors of the inadequacy of his, and their, methods). Indeed, his general meteorological

1. I here pass over Theophrastus' use of expressions like χρωτέλν, διαλίσκειν etc., which, as he would evidently have admitted, do not in themselves adequately explain wind (pp. 328-32, 342ff, 375-7); but will mention one other feature of his wind theories, which differs from those previously discussed in being derived, not from empirical observation or another physical theory, but from an attitude of mind. I mean the idea of proportion and balance: wind is caused by the sun and water-vapour if they are in the right proportions (cf. pp. 328ff, 342ff); winds are followed by equivalent winds in the opposite direction (p. 349f). Symmetry, balance, proportion were important in Greek philosophy from Anaximander (fr. 1) onwards, and are used in Aristotle's wind theory (v.Mete. 362a4, 11ff), if not in earlier ones. In Theophrastus they are more important, because he liked to regard phenomena as due to the inter-action of two or more causes (p. 376); but this use of symmetry is a consideration of a kind that no doubt influenced many ancient wind theories, although I have not remarked on other examples.

2. Cf. Vent. 2, 13, where he explains reported (cf. φαιν., λέγουσι) phenomena whose truth he doubts, and 37, 49-51, which explain phenomena described in weather-proverbs.
theories look like a deliberate attempt simply at reconciling earlier theories: by accepting that vapour and air are the same (p. 327 ) he forestalls any dispute whether wind and rain are derived from one or the other; he combined the two theories that wind is from water and that it is from dry exhalation (p.335-8 ); and he accepted both alternative views, that cold and that compression cause condensation of air/vapour to water (p.101f). 1

E. Conclusions.

The foregoing discussion shows that three of the main sources of the ancients' theories were: commonplace observations of the phenomenon concerned; direct analogies with supposedly similar phenomena; and the consideration of physical theories about other things - usually, general theories of matter or the nature of the universe. 2 The

1. We cannot be certain how Theophrastus explained thunder etc.: the remarks in Ign.1 and frg.16 are too brief, and the series of alternative theories in Syr./Arab. may be partly doxographical (cf.p. 352 ), i.e. we cannot tell which theories Theophrastus accepted.

2. Of course, these other theories may themselves be based on analogies. What I say of these three origins of meteorological theories applies mainly to theories of wind (etc.) in general: particular wind phenomena could then often be explained merely by assuming variations in the factors which produce winds in general (as in Aristotle, cf.p. 398 ).
influence of general theories is of primary importance only in Aristotle and possibly Democritus. Such general theories are usually not enough to suggest meteorological theories on their own; but they help to do so in combination with analogies with familiar phenomena.

Second, there is a marked conservatism in ancient meteorological theories. The derivation of wind from water, and of thunder and lightning from wind or fire trapped in cloud, or wind and cloud somehow interacting, are ideas which recur again and again, though there appears to be no compelling reason for accepting them, instead of inventing other theories. This conservatism contrasts with the radical differences in the more general theories, about (e.g.) the nature of matter, which were adopted by the thinkers I have discussed. The reason is surely that new and improved general theories were to a large extent suggested by the logical analysis of concepts like ἄλημα, τὸ ἀπέρμον or γένεσις: this is made very clear by the influence of Eleatic theories on the later pre-Socratics, and by Aristotle's system. But primitive men know pretty well, from ordinary experience, what wind and rain are, and thought about these concepts, on its own, can do little to advance our understanding of them. Reflection on common observation occasionally established relevant facts which were not obvious
to common observation alone (p. 390f.), or led to improved formulations of a single basic theory.¹ But too much reliance on logical analysis was in meteorology obviously misleading, as Aristotle's example shows: so that the method by which the ancients improved their general theories was in meteorology of little use.

1. Hence Seneca's version of the 'rarefaction theory' of wind is better than earlier ones (p. 82f.), and Anaximander's (to judge by the doxographers' wording) looks noticeably the most primitive (cf. DK 12A11(7) (quoted p. 107) with quotations on p. 65ff). Aristotle's adoption of a special term for 'vapour' (p. 396) was a similar improvement.
3) Biological and vitalistic imagery in ancient wind theories.

Very few wind theories use imagery which implies that wind is alive. [Hippocrates] Flat. (a second-rate thinker) is the only early author to whom definite evidence attributes the idea that air, being alive, causes wind by its self-motion (p. 393). [Hippocrates] Vict. speaks of wind's τροφή: but it is doubtful whether this has any particular significance (pp. 203f, 206). Similarly, Mete., Vent. and Probl. contain only scraps of definitely biological imagery applied to wind, such as Probl. ΑΧ 4 μαχόμενος, ΑΧ VI 12 (941b18f) ἄνεμους ἠγείρεν, νότους ἐγείρει. \(^1\) Theories involving analogies with inanimate objects (e.g. water boiling, air bursting from an inflated bladder\(^2\)) were far more widespread: it seems clear that the earlier Greek thinkers, insofar as they distinguished animate and inanimate things, tended to be more influenced by biological ideas than their

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1. Both passages are exceptional among Peripatetic accounts of wind: on Probl. ΑΧ 4 v.p. 346n; ΑΧ VI 12 (941b9f) employs the concept of ἐπισήμασις (on which v.p. 128f), which nowhere recurs in Mete., Vent. or Probl. ΑΧ VI. (I can see no definitely vitalist connotation in Mete. 364a29 ἀποβλασθεῖς (cf. 351a6, 365b4, which are clearly not biological), 364b4 ἐπιπλήκτουσι (cf. non-biological examples of the word in LSJ) - two passages where Boeker 2241f sees the remains of mythological ideas on wind.)

2. v.pp. 65ff, 92ff.
generally regarded winds as inanimate.¹

This, however, is not to say that vitalistic and biological ideas did not influence their wind theories. Aristotle and Theophrastus frequently apply to wind ideas elsewhere applied to both living and to inanimate bodies, e.g. πέψις (cf. p. 359ff), δρμή (pp. 292ff, 331), ἀντικεριστασις (p. 279ff), μάρανος (p. 342ff), ἀναθυμίασις (p. 251ff).² Some of these ideas are biological in origin (e.g. πέψις, δρμή, κρατεῖν), some are not (e.g. μάρανος, ἀναθυμίασις): they therefore merely show that Aristotle and Theophrastus believed (like modern biochemists) that the same physical processes operate in both living and inanimate bodies. Their use of primarily biological concepts like πέψις shows that their wind theories were influenced by biological ideas; but all these concepts are used of other inanimate bodies besides wind: their wind theories do not seem to be more influenced by biological ideas than their

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1. Late authors sometimes apply explicit and detailed biological imagery to wind (cf. Semeca Νο V 4.2, 5.1-2; Fliny NH II 116 "generabilis rerum naturae spiritus"); but this they cannot have derived from the pre-Socratics or early Peripatetics.


3. Cf. also the analogy between earthquakes and throbblings in the body: the latter are explained in Resp. as due to the formation of πνεῦμα from moisture with heat, which is not a process confined to living beings (cf. p. 273).
theories of other things. The originally biological ideas in their wind theories are simply one aspect of the biological influence which affects their whole physical system, inextricably mingled with ideas of non-biological origin. Much the same is true of the crowd analogy in Democritus' wind theory (p.179): it is just one aspect of a biological influence that affects his physical system as a whole.¹

(The early philosophers likely to have made a special use of vitalist ideas in their wind theories are Anaximenes and Diogenes, with their hylozoist view of air; but unfortunately lack of evidence makes this impossible to assess.²)

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1. v. Lloyd PA 247ff, 270f on Democritus, 258ff on Aristotle.
4) **Evaluation of the ancients' methods in meteorology.**

To explain with certainty a meteorological phenomenon it is necessary to discover both the nature of the phenomenon and the conditions under which it occurs, and the general physical laws which explain why it occurs under those conditions. The former can only be discovered by observing or performing experiments on the atmosphere. The latter may be discovered by experiments or observations in which the atmosphere has no part; but such experiments cannot, on their own, prove anything about the atmosphere, unless it is also shown that the conditions of the experiment actually occur there; otherwise they can only suggest possible hypotheses, that certain conditions might occur in the atmosphere to produce the observed phenomena.

Much of this the ancients appreciated. Their theories of (say) wind obviously involve some knowledge of what wind is, obtained by at least casually observing the atmosphere, and usually explain the phenomena by some reference to generally applicable physical principles: they refer to general physical theories, such as the atomic theory, or employ analogies, which involve the implicit assumption of generally applicable principles (as well as assumptions about conditions in the atmosphere which cannot be observed): for example, if thunder is regarded as due to wind bursting out of a cloud, in the same way that
wind bursts out of a punctured inflated bladder, this involves assuming (a) a general rule that, given the right conditions, wind always or usually bursts out of a bladder or other enclosure, and (b) that the appropriate conditions occur in a thundercloud, although we cannot observe them—both assumptions are necessary to make the theory plausible.

This method, so much used by the ancients, of inferring explanations of atmospheric phenomena by analogies with facts observed elsewhere has also given rise to important modern theories: for example, that thunder and lightning are electrical phenomena; for, when this was first suggested, it had only been noticed that a flash and crackle can be produced electrically; confirmation of this theory—Franklin's derivation of electricity from a thunder-cloud via the string of a kite—was first provided nearly half a century later.

1. Sometimes such rules are stated in general terms, e.g. Vent. 29 φοροθέτον ... δεί ... τὸ διὰ τοῦ στενοῦ καθάπερ ὑδάτος ἔμετρον ; probably more often, ancient writers drew a direct analogy between the atmospheric event and one particular phenomenon (e.g. λειψάνων, thunder occurs τὸν αὐτὸν τρόπον ... τῷ ... ψόφῳ, δὲν καλοῦσιν...τὸν Ἐρασιστοῦ γελᾶν). But there is an implied general rule in every case.

2. V. Hauksbee (1706/7) 2414, Wall (1708/9) 71; Encyclopaedia Britannica (9th ed.) vol. 8 p. 4-5 (s.v. Electricity).

For a more recent instance of such an unconfirmed hypothesis v. Sutton 74f, describing a process which might explain certain problems concerning rain-formation which
In principle, therefore, the ancients' method of analogy was sound, as was the use in their theories of atmospheric observations and their first principles of physics. They erred in two main ways: their observations, of the atmosphere and of facts used as analogies, were too vague,1 and they seldom tried to confirm whether the conditions their theories assumed occur in the atmosphere, and whether the general physical principles they used were true - partly, perhaps, because they failed to appreciate the hypothetical nature of their analogical arguments2, but also because theories as imprecise as theirs are often impossible to confirm or refute (cf. p.418ff).

The ancients' methods sufficed to provide a theory of rain which, though vague and drastically over-simplified, is not untrue.3 But even common observation could have shown the inaccuracy of most of their thunder and lightning theories (p.102); and indeed Theophrastus and Seneca mention

"is easily demonstrated in the laboratory", but yet is only called "a plausible mechanism (my underlining) for the initiation ... of rain".

1. For greater precision they needed to experiment, and observe systematically.


objections that were brought against them. They both put forward plausible counter-arguments; but neither faces the real difficulty, that their theories involve attributing to clouds properties which we never see possessed by any but solid bodies. The only real excuse I can see for the ancients' thunder and lightning theories is that, had they abandoned them, they would have been left with no theory at all; and that is even less satisfactory than having only a bad theory.

With regard to wind, too, some ancient theories can be refuted by common observation, e.g. Aristotle's account of the cause of wind's motion (as Theophrastus seems to have realised, cf. pp. 269ff, 374). Other theories contain

1. Syr. 351a17ff (noise should be produced by hard bodies, not by fine, wool-like clouds), and NQ II 27.4-28 (clouds should produce thunder by colliding with mountains, if they do so by colliding with each other). On the two passages v. Wagner/Steinmetz (1964) 56f, Steinmetz 187-9.

2. Other examples could be quoted; but note that some ancient theories - e.g. that of solstices and Etesians discussed at p. 171ff - though obviously not exactly in accord with observed facts (e.g. the Etesians are not as regular as the sun's motion), were yet, from their proponents' point of view, plausible simplifications, which might reasonably be thought the basic cause of the phenomenon in question, though complicated by other factors - modern meteorologists also make such simplifications (e.g. Sutton 15ff, 34ff).
implausibilities which might have been discovered just by thinking about them, e.g. the assumption that the main winds are individual entities with sources at the edge of the oikoumēnē (p.299ff). Also, the ancients might occasionally have devised new, correct theories merely by reflection on known facts, e.g. that wind is due to air flowing to prevent a vacuum forming as hot air rises; for they knew that hot gaseous bodies rise and that matter flows to prevent a vacuum - the ancients might have discovered more than they did by their method of reflection upon common observation.

Much more often, however, to confirm or refute the ancients' theories required a new approach. It was impossible to check by common observation whether wind can really be derived from water; whether water and air change into each other; whether heat causes wind and if so how, or whether there is some other cause; and so on. Equally, it was impossible to check by common observation traditional beliefs about (for example) particular winds (e.g. whether Caecias really draws the clouds to himself). ¹

¹ Since the traditional beliefs depend on common observation, i.e. on men noticing the winds every day, without particularly thinking about it, and then generalising from a retrospective impression of what (say) a particular wind had been like on different occasions.
Easiest to check would be traditional beliefs of this kind: this requires only regular observation and recording of easily visible atmospheric events. Some systematic observations evidently were made, for different purposes, though not enough to increase significantly the ancients' knowledge of the atmosphere: the ancient παραπήγματα, produced from the 5th century on, contained both astronomical and meteorological predictions for particular days; and the latter can hardly be pure guess-work: they must be derived from regular weather-observations, made for at least one year.

It needs no special observations to show that both stellar movements and the weather recur approximately every year; and careful observation showed that apparently random stellar phenomena (e.g. eclipses, planetary movements) in fact occur quite regularly. It would be natural to infer from this that the weather, if observed long and carefully enough, would also prove to have a perfectly regular cycle.

1. V., e.g., DH 68814, the frr. of Democritus' παραπήγμα; [Geminus] Calendarium; Ptolemy Phaseis II; Rehm (1949) 1295-1366. (The παραπήγματα are too precise to be dependent on popular weather-predictions, cf. ib.1339, speaking of "eine...notwendig ungenaue Zeitbestimmung" in early times. Ib.1342 considers Democritus' weather-predictions the result of observation).
Eudoxus held that there was one of four years (Pliny NH II 130). This assumption must underlie the παραπήγματα. But in fact there is no such cycle; any attempt to discover one must end in frustration, and would yield predictions no more certain or precise than ancient accounts of the causes of meteorological phenomena.¹

Another sort of observation more systematic than commonplace ones (as defined on p. 414n) is the description of particular instances of a phenomenon. There are several examples in Mete.², but all concern rare phenomena, such as comets³, earthquakes⁴, and parhelia⁵, never wind alone. The only example used to prove anything about wind is 544b31ff, citing three occasions when (Aristotle says) a comet coincided with a strong wind, in order to prove that wind and comets are both due to dry exhalation. This is remarkable,

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1. Other noteworthy, if less precise, records of the weather of single years occur in the 'constitutions' of [Hippocrates] Epid. I 1, 4, 7 (L.II 598.1ff, 614.8ff, 638.6ff) and III 2 (L.III 66.14ff); but these could be based merely on what the author could remember about the weather at the year's end.

2. At least two, at 543b11ff, 30f, but probably not the majority, are Aristotle's own observations. (On this cf. Düring (1966) 385 and (1968) 247.)

3. v.543b1ff, 11ff, 18ff, 30f, 544b31ff.

4. v.367a1ff, 368b6ff.

5. v.372a14-16.
but not scientific enough. There is in fact no connection between comets and wind: 1 Aristotle's examination of records of comets must have been biased - as is likely to happen in such a case - by the desire to prove his theory. 2

To improve general theories of the cause of wind required in the first instance experimental investigation, to establish the relevant general physical laws (cf. p. 410), and make possible the construction of instruments, such as thermometer and barometer, to measure the relevant variables in the atmosphere (on this see below). 3 In the preceding chapters there are, I think, only three clear instances of ancient thinkers trying to discover new facts by experiment.

1. Information from M.J.B.A. Branson.

2. Properly to check this theory would require systematic observation of comets, and probably a statistical analysis of the results. Herelby to cite a few prominent instances, as Aristotle does, is useless for such a purpose. Aristotle is not to blame for what he does - he is most unlikely to have had systematic records of previous comets and the associated weather, and (comets being rare) it would take many years to make such records. But the result is clearly unfortunate.

3. In 'experimental investigation' I do not include (i) the description of already familiar instruments, such as clepsydra and cupping-glass, nor (ii) experiments which merely demonstrate what was already known (e.g. those at [Hippocrates] Horb. IV 57 (L.VII 612.5ff) and Hero Spir. p.4.17ff 2., which in principle are simply repeating the ordinary functioning of the clepsydra).
ancient pneumatists evidently attained by experiment. Aristotle's view that air has weight in its own place (cf. p. 34) was presumably arrived at by weighing an inflated skin (as mentioned at Cael. 711b4), and Aristotle's view that air has weight in its better understanding of compressed air's expansion (p. 87f), and ancient pneumatists evidently attained by experiment a better understanding of compressed air's expansion (p. 87f).

1. I suppose this was a deliberately performed experiment, as it does not seem likely to have happened accidentally.

2. It is not clear whether the discovery was made by experiment for its own sake, or in the course of constructing air catapults and the like (v. ibid).

3. V. Ross (1936) 26f. (Note that the accuracy of Aristotle's experiment is disputed, cf. Ross l.c. and Lloyd (1964) 67n.)

4. E.g. that heat causes rarefaction and expansion, that matter flows to fill a void, etc.

5. V. Ross (1936) 26f. (Note that the accuracy of Aristotle's experiment is disputed, cf. Ross l.c. and Lloyd (1964) 67n.)

6. V. Ross (1936) 26f. (Note that the accuracy of Aristotle's experiment is disputed, cf. Ross l.c. and Lloyd (1964) 67n.)

7. V. Ross (1936) 26f. (Note that the accuracy of Aristotle's experiment is disputed, cf. Ross l.c. and Lloyd (1964) 67n.)

8. V. Ross (1936) 26f. (Note that the accuracy of Aristotle's experiment is disputed, cf. Ross l.c. and Lloyd (1964) 67n.)

9. V. Ross (1936) 26f. (Note that the accuracy of Aristotle's experiment is disputed, cf. Ross l.c. and Lloyd (1964) 67n.)

10. V. Ross (1936) 26f. (Note that the accuracy of Aristotle's experiment is disputed, cf. Ross l.c. and Lloyd (1964) 67n.)

11. V. Ross (1936) 26f. (Note that the accuracy of Aristotle's experiment is disputed, cf. Ross l.c. and Lloyd (1964) 67n.)

12. V. Ross (1936) 26f. (Note that the accuracy of Aristotle's experiment is disputed, cf. Ross l.c. and Lloyd (1964) 67n.)
there is a dry exhalation. These, however, are not questions which any obvious experiment will answer. That air as a whole cannot change into water the ancients might have inferred from the obvious fact that under no known conditions does more than a small part of the atmosphere condense to water. In fact they did not infer it; and there is no immediately obvious experiment which will prove the fact more clearly than this observation. Similarly with dry exhalation: if I assume that it can never be separated from wet exhalation, then I cannot hope to isolate it; and if I have no way of measuring the proportion of dry to wet exhalation in the air, I cannot hope to establish by experiment the properties of (say) air containing 75% of dry exhalation. So long as the ancients thought in purely qualitative terms, then many theories required no experiment to prove them, and many others could not be proved or refuted even with experiments.

Similar difficulties would prevent attempts to confirm that the conditions assumed in ancient wind theories actually occur in the atmosphere. Although the upper atmosphere and the supposed 'sources' of the main winds (v.p.295ff) were not accessible, the source, and course, of a local breeze was. But, the simplest forms of ancient wind theories were refuted by common observation (e.g. if
wind is due to heat rarefying air, then winds should blow only from hotter to colder regions; which is not so); one must suppose there are complications involved, as Theophrastus (especially) did (p. 375f ). Thus he maintains that heat and moisture in combination cause wind. But he never defines any verifiable interrelation of the two as producing wind, nor could he have (having no means of measuring them); which means that his theory cannot be proved or refuted: for, if any one combination of heat and humidity proves not to cause wind, it remains possible that some other combination does; and if a variety of conditions of heat and humidity are compatible with wind, then it is impossible to be sure that they are the causes. Theophrastus' theory cannot be proved unless it can be made more precise.

1. Physiological sensation, at least of heat, was known to be unreliable, cf. Aristotle Pa 643b15ff. (Occasionally ancient authors mention more objective criteria in estimating temperature, e.g. the formation of visible 'vapour' is cited (wrongly, cf. p.110) as evidence of heat (Hete.347b5, cf. ὅσιον; more clearly, Philoponus 125.29ff); elsewhere, objective evidence is cited of a country's hot or cold climate (v. Plutarch Alex.52.5, Herodotus II 22, Seneca NQ IVa.2.18). But the latter evidence cannot indicate short-term temperature-changes, which are most likely to be important in explaining wind; and frequently no objective evidence was available.)
Precision involves measurement, which in meteorology needs instruments: the two essential instruments, which eventually led to a better understanding of the atmosphere's properties, were the thermometer and the barometer.¹ There seems to be no technical reason why the ancients should not have constructed both. As to the thermometer, the ancients knew that there are many possible degrees of heat and cold, i.e. temperatures.² To make a thermometer requires a body possessing an observable property which

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¹ v. Shaw (1926) 115, 147f.
² v. p.236f for Aristotle's explanation of this. (The fact that many regarded heat and cold as primary qualities did not make thermometers impossible (pace Barnett (1956) 270). (Aristotle GC 329b13ff regards weight as a quality (cf. Sambursky (1962) 32f), but cannot have denied weights are measurable). A temperature-scale would simply be a set of numbers arbitrarily attached to different degrees of heat, and would not imply that heat is basically a quantity. (Galen 'De simplicium medicamentorum temperamentis ...' III 13 (Kuehn XI pp.570-2) does this, speaking of four degrees of hotness and four of coldness, and assigning different drugs to each degree (v. Barnett (1956) 272f and Clagett as there cited) - this is not a temperature-scale, as each drug belongs permanently to the same degree, but it resembles one). The fact that heat and cold were regarded as distinct positive qualities could be dealt with by defining a mean between their extremes - Galen suggested constructing one by mixing equal amounts of ice and boiling water ('De temperamentis' I 9 (Kuehn I p.561); v. Sambursky (1962) 40).
varies continuously with temperature (e.g. the volume of a mass of liquid or gas), and some means of accurately observing these variations, e.g. by compelling the liquid or gas to expand along a graduated tube (in a gas thermometer this tube is closed by a liquid, which is attracted and repelled as the gas contracts and expands).

The ancients knew that the volume of bodies changes with temperature (p.82ff), and could have constructed thermometers working on this principle; indeed, two devices in Philo (Pneum.?) and Hero (Spir.II 8) closely resemble the earliest gas thermometers, though they clearly were not used as such.\(^2\)

The barometer might also have been invented, had anyone pursued far enough experimental investigation of 'horror vacui' or the weight of the air.\(^3\) The ancients knew that if a vessel immersed in a liquid, and filled with it, is raised from the liquid in such a way that its open end

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1. Theophrastus Fr.159 gives figures for the different weights of a \(\kappa\omega\tau\alpha\lambda\) of a certain sort of water in summer and winter, i.e. he had had the idea of measuring how such a property varies with different temperatures. But his figures are absurd. (Cf. Gottschalk (1967) 25.)


remains beneath the surface, it raises part of the liquid with it, and so remains full, unless some air can get in.\textsuperscript{1} They did not know that liquid can be raised in this way only to a limited height, and that if the top of the vessel is raised above this height, a vacuum will be produced there, because atmospheric pressure can only support a certain weight; had they discovered the fact, they could easily have explained it, as many believed that the air is heavy and admitted the possibility of a vacuum.

To make the simplest type of barometer they needed mercury (a water barometer would be impracticable, since it must be over 54 feet high) and a transparent airtight tube over 50 inches long (v. Shaw (1933) 36). Mercury they certainly had in the 4th century B.C. (Aristotle de An. 406b19) and apparently in the late 5th\textsuperscript{2}. Whether they could have made a glass tube long enough I am uncertain - so far as I know, they could have made one with a mould\textsuperscript{3}. (The ancient pneumatists sometimes used both mercury and glass: Hero Spir. mentions mercury only for one instrument

\begin{itemize}
\item\textsuperscript{1} Cf. the raising of water in a clepsydra, also Philo Pneum. p.472.8ff Schmidt.
\item\textsuperscript{2} So Ganschinetz (1914) 55; Berthelot (1888) 84.
\item\textsuperscript{3} Forbes (1957) does not mention glass tubes; but I know no use for them, save in scientific experiments.
\end{itemize}
its great weight was appreciated. He and Philo several times suggest the use of glass or horn vessels, when they want what occurs in a vessel to be seen. 1)

thermometer and barometer were two experimental investigations which they could have performed, but never did. A major reason for this, I think we must suppose, is simply that such questions as the exact effects of different temperatures on air - which were the sort of general physical laws and facts they in fact needed to improve their meteorological theories - did not seem to them of sufficient importance to be worth serious study. 2

1. Or, in another field, the laws of motion, over which the ancients should have found it easy to demonstrate Aristotle's errors, if not to discover the truth (cf. Lloyd (1964) 60-2; Sambursky (1962) 62ff. On Aristotle's failure to study them adequately cf. Lloyd FA 27ff).

2. That this was so is shown by the fact that the ancients did not write general accounts of (e.g.) heat and its effects, or exhalation, what they thought about them has to be inferred, partly from books on more general subjects (e.g. Aristotle 68, a general account of ὕπνος and ἀοἴδη and the four elements), and partly from accounts of specific phenomena like wind and lightning (as they were generally the closest people to these phenomena). 2

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5) Why the ancients failed to experiment.

One reason for this is clear from pp. 418ff: many of their problems were ones that no easily-devised experiment could solve. But the making of thermometer and barometer were two experimental investigations which they could have performed, but never did. A major reason for this, I think we must suppose, is simply that such questions as the exact effects of different temperatures on air¹ - which were the sort of general physical laws and facts they in fact needed to improve their meteorological theories - did not seem to them of sufficient importance to be worth serious study.²

---

1. Or, in another field, the laws of motion, over which the ancients should have found it easy to demonstrate Aristotle's errors, if not to discover the truth (cf. Lloyd (1964b) 60-2; Sambursky (1962) 62ff. On Aristotle's failure to study them adequately cf. Lloyd PA 271f).

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The main pre-occupation of most ancient physicists is with the ultimate nature of the universe: to discover from what material or materials it is ultimately constructed and what force or forces have brought it to its present form. They wished to know, for example, whether void exists; whether all matter consists of atoms; whether hot, cold, wet and dry are primary qualities. These are questions which no simple experiment or observation can answer with certainty. Ancient authors occasionally cite experiments or deliberate observations in discussing them (especially in discussing void); but these yield answers no surer than were obtained by the ancients’ normal methods, such as logical analysis of the concepts involved (cf. p. 405), or the citing of commonplace observations.¹

The ancients studied these questions, difficult and remote from ordinary happenings as they were, because they

¹. Thus clepsydrae and inflated skins do not prove void’s non-existence, as Anaxagoras and Empedocles claimed, but only that air exists (Aristotle Ph.IV 213a25ff). Even the experiments and observations in the Proem. of Hero Spir. does not prove what Hero claims, the theory of void intervals (cf.p.87). He proves that air can be expanded and compressed; but if it is conceivable, as many ancients believed, that matter can change in volume although there is no void (v., e.g., Aristotle Ph.IV 214b1ff) (which Hero’s experiments do nothing to disprove), then Hero clearly fails to prove his point.
seemed important, if they were to understand the universe. Other questions were studied because they concerned things which the ancients had seen or felt occurring: e.g. eclipses, or lightning, or wind. It was an immediately obvious question: how does this happen? These, too, are usually questions which no simple experiment or observation can directly answer, because in the natural world there are so many variable factors involved in every problem. A question answerable by a simple test should be one concerning easily perceptible and measurable physical factors (e.g. temperature, or air-pressure), but from which as many variable factors as possible have been removed: e.g., how much will a given rise in temperature cause a given type of matter to expand? or, how great a pressure is exerted by air compressed to a given extent? These are not obvious questions, immediately suggested by things we see around us; nor do they appear important questions, such as will reveal the ultimate nature of the universe. In particular, it cannot have seemed important to answer such questions precisely; hence the ancients failed to discuss them deeply, or to make accurate measurements in discussing them. It is, I suggest, an important reason for the ancients' failure to develop the experimental method, that questions like these, which could be investigated by simple experiments, did not seem
worth the trouble of investigating.

It is natural that the ancients should have concentrated on other questions, which were either obvious or important; but the effects were unfortunate: because they did not develop the habit of experimenting, they failed even to perform experiments relevant to questions of real interest to them: the invention of the barometer would have illuminated (even if without conclusively answering) the important question of the void, in addition to its vital importance if progress was to be made in meteorology.
6) Reasons for the failure of ancient meteorology.

Meteorology was among the philosophers' earliest interests—wind, cloud, rain and other precipitation, thunder and lightning, and rainbows were all discussed by Anaximander, Anaximenes or both. These were obvious phenomena to ask questions about (cf. p. 427); and the prevalence of mythological explanations of them will have made it especially important to thinkers dissatisfied with myths to find other explanations (v. Cornford (1952) 131). Perhaps, too, the apparent randomness and violence of many meteorological phenomena made them more obvious objects of interest than (say) biological phenomena, which may have seemed individually trivial and collectively more orderly, and so could at first be taken for granted.

Although meteorology always remained an essential part of philosophic accounts of the physical universe, it rapidly ceased to be a major interest. We have seen how conservative the later meteorologists were, and how little they advanced in the real understanding of meteorology (p. 389-406). The methods by which the ancient philosophers improved their theories about other things were often difficult or

1. Dh 12a11(7), 423, 424; 13a5, 47(7-8), 47, 48.
impossible to apply in meteorology, or inappropriate when applied (pp. 400f, 405f); and the methods which they normally used in meteorology could not lead to more than minor improvements (p. 412ff). Moreover they gradually became more conscious of the uncertainty of their theories: early thinkers admitted the uncertainty of human knowledge in general (Lloyd PA 337f), and Aristotle says specifically of meteorology: ἐν οἷς τὰ μὲν ἄποροί μεν, τῶν ὡς ἐφαπτόμεθα τινα τρόπον (Mete.339a2)\(^1\); but this seems not to have prevented them from proposing single explanations for each phenomenon, with apparent confidence in their truth. Theophrastus' uncertainty, however, is clearly reflected in the alternative theories he mentions and the ambiguity of much that he says (p. 375-7); and the meteorology of later authors reveals their lack of confidence in a similar way.\(^2\)

The uncertainty of their theories did not discourage ancient philosophers from propounding theories of subjects

\(^1\) Cf.344a5f, on comets. (He makes similar statements about astronomy, cited by Ideler (1834-6) I 322, McCue (1962) 6-11, Lloyd PA 262.)

\(^2\) By giving lists of alternative explanations: v. Epicurus Ep.ii, Seneca (e.g. NQ V 4-6), Pliny (e.g. NH II 114, 116).
they thought important, such as the fundamentals of physics, or ethics; nor, indeed, in such fields, would most of them admit their theories were uncertain. But meteorology did not seem important. Once philosophic theories of the universe had come to be generally accepted among the educated, one of the original motives for meteorological study (the refutation of myth) will have disappeared. It cannot have seemed important to explain meteorological phenomena in detail; and the first philosophers' theories about them served well as examples of the sort of explanation which (it was now agreed) must be given for them.

All this makes it easy to see why the ancients lost interest in meteorology: they could see they were getting nowhere, and it did not seem to matter.

Meteorology is, in fact, a very complex science: the proper understanding of meteorological phenomena required a much better understanding of facts about the atmosphere, and of the physical laws that control events in it, than the ancients ever possessed. Historically, the modern explanation of winds seems to be based on the description and mapping of the trade winds¹; that is, it required a

¹. See Halley (1686), Hadley (1735); discussed by Shaw (1926) 288ff.
knowledge of the weather in parts of the world quite unknown to the ancients. The ancients could have investigated some of the physical laws that control atmospheric events, but in fact never did, partly (as I have suggested) because this involved the discussion of problems which were neither obvious nor of evident importance, and so never occurred to the ancients as subjects of study; and partly because many of those problems relating to general physical laws which the ancients were most likely to have wished to investigate, were not ones which any simple experiment could solve. The ancient physicists needed, not just to perceive that physical problems can be solved by experiment, but also to pick on those few problems (often apparently trivial, like the measurement of heat) which they could have solved experimentally, and would in fact have led to a better understanding of meteorology.

It was thus a major reason for the ancients' lack of progress in meteorology, that the vital questions they needed to ask were not easy to find, and that they failed to find them. In the history of science, what requires genius as much as anything else is to find the right
questions to ask. The great 16th and 17th century scientists managed to ask the vital questions that led to progress in meteorology; the ancients could have asked and answered many of the same questions, but in fact nobody did. Various reasons might be suggested why no-one did: for example, the effect of slave-owning is a commonly given reason for the ancients' failure to experiment.

What I have tried to show is that it was no special perverseness in the ancients' mind that prevented progress in meteorology: to find the way to progress was genuinely difficult. To say more would require a detailed comparison of conditions in the ancient world with those of the 16th and 17th centuries, which would be beyond the scope of this dissertation.

1. Koestler (1959/64) 265 says of the great 16th–17th century scientists: "first and foremost they were giant question-masters" (cf. ib.260n).

2. Though not, for example, that about the trade winds.
## APPENDICES

### APPENDIX I

Table: Instances of ἀφε, ἀφε, and related words in Greek non-philosophical poetry before c.400 B.C.

| Poet etc. | Index etc. used | Instances of: | Derivatives of ἀφε | ἀφε | ἀφαρχ
|-----------|-----------------|----------------|-------------------|-----|-----
| Illiad & Odyssey | Gehring (1891-9) | 28 | 32 | 25 | 0
| Homer's Hymns | 2 | 11 | 5 | 0
| Other Homerica | (v-p.7m) | 0 | 0 | (1) | 0
| Hesiodic Corpus | (v-p.6an) | 5 | 16 | 5+|1 | (1)
| Sappho | Patutto (1966) | 0 | 0-1 | 1-2 | 0
| Alcmanus | 0 | 0 | 1 | 0
| Steinschura | 0 | 0 | 1 | 0
| Pindar | 0 | 0 | 5 | 1
| Sapphylidas | 0 | 0 | 6 | 0
| Other passages in Page 767 | 0 | 4-5 | 6 | 176m
| Theognis | Patutto (1966) | 0 | 1 | 2 | 0
| Simonides | (Edmonds) | 0 | 1 | 3 | 0
| Ion Chius (elagias) | Edmonds | 0 | 1 | 1 | 0
| Eupides (elagias) | 0 | 0 | 1 | 0
| Anaxilus | Italie (1954) | 0 | 2-3 | 15-16 | 3
| Sophocles | Ellenko (1976) | 1 | 0 | 6 | 1
| Euripides | Allen & Italie (1954) | 4-6 | 3 | 9.92 | 11
| Other tragedy | Nauck (1892) | 0 | 0 | 9 | 0
**APPENDIX 1**

Table: Instances of ἄγρ, ἄθηρ and related words in Greek non-philosophical poetry before c.400 B.C.

<table>
<thead>
<tr>
<th>Poet etc.</th>
<th>Index etc. used</th>
<th>Instances of:</th>
<th>Derivatives of ἄγρ</th>
<th>ἄθηρ</th>
<th>ἄθέρειος</th>
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<tbody>
<tr>
<td>Iliad &amp; Odyssey</td>
<td>Gehring (1891-5)</td>
<td>28</td>
<td>32&lt;sup&gt;1&lt;/sup&gt;</td>
<td>25</td>
<td>0</td>
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<td>2</td>
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<td>5</td>
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<td>0</td>
<td>(1)</td>
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</tr>
<tr>
<td>Hesiodic Corpus</td>
<td>(v.p.6nl)</td>
<td>5&lt;sup&gt;2&lt;/sup&gt;</td>
<td>16&lt;sup&gt;3&lt;/sup&gt;</td>
<td>5&lt;sup&gt;2&lt;/sup&gt;+(1)</td>
<td>(1)</td>
</tr>
<tr>
<td>Sappho</td>
<td>Fatouros (1966)</td>
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<td>0-1&lt;sup&gt;4&lt;/sup&gt;</td>
<td>1-2</td>
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<td>0</td>
<td>9</td>
<td>1</td>
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<tr>
<td>Bacchylides</td>
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<td>0</td>
<td>6</td>
<td>0</td>
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<tr>
<td>Other passages in Page PMG&lt;sup&gt;+&lt;/sup&gt;</td>
<td>&quot;</td>
<td>0</td>
<td>4-6&lt;sup&gt;5&lt;/sup&gt;</td>
<td>2&lt;sup&gt;6&lt;/sup&gt;</td>
<td>1?5&lt;sup&gt;a&lt;/sup&gt;</td>
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<td>Theognis</td>
<td>Fatouros (1966)</td>
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<td>Euripides</td>
<td>Allen &amp; Italie&lt;sup&gt;1&lt;/sup&gt; (1954)</td>
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<td>3</td>
<td>c.92</td>
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<td>Other tragedy</td>
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<td>5</td>
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<td>Derivatives of άηρ</td>
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<td>αλθήρ-λος</td>
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<td>Todd (1932)</td>
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<td>2</td>
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<td>2</td>
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<tr>
<td>Aristophanes</td>
<td>Todd (1932)</td>
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<td>1</td>
<td>4</td>
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<td>Aristophanes</td>
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I have not here attempted to distinguish between an author's genuine and spurious works.

Numbers in ( ) refer to testimonia where άηρ etc. is a deity (cf. p. 7n4); I have not looked in the testimonia for other occurrences of αλθήρ etc., since such occurrences might not preserve the author's own words.

I have omitted proper names beginning δερ- or ηηρ-, e.g. E389 'Ηηριβοτα.

Notes: (1) Inc. all instances of ηήριος (cf. p. 4) but not ηήριοφόνων (cf. p. 13 n).

(1a) Excluding the Hymn to Ares (H.8 in recent eds.).
(2) Reading αλθέρα for ηήρα at Th.697.
(3) Inc. fr.26.20 ηήρια.
(4) v.p. 12f
(5) Ion Chius (lyrics) 1; Telestes de conj. 1; Adespota 4 (or 3, v.p. 12f).
(6) Lamprocles 1; Adespota 1.
(6a) Timotheus, fr.791.24 in PMG.
Notes: (7) I have looked through the relevant parts of his 'Lyra Graeca' II (1924), finding two relevant passages (frr. 51, 122 Diehl) not listed by Fatouros.

(8) I have looked through his 'Elegy and iambus' (1931) (finding nothing relevant in iambic poems).

(9) Inc. one instance of ἀθεροδρόμος.
The properties of \( \alpha \theta \eta \rho \) in non-philosophical literature to c.400 B.C.\(^1\)

In Homer, \( \alpha \theta \eta \rho \) may occasionally reach down to the earth, but elsewhere is confined to a region high above it (p.5), in which case it seems roughly equivalent to \( \omicron \varphi \rho \alpha \nu \omicron \varsigma \), another goal reached by particularly tall trees etc.\(^2\); both are inhabited by the gods\(^5\); and they are coupled together at \( \Theta \ 555/\Pi \ 500, \ O \ 192. \)

Elsewhere, however, \( \omicron \varphi \rho \alpha \nu \omicron \varsigma \) is above \( \alpha \theta \eta \rho \), or the highest part of it: things pass from earth through \( \alpha \theta \eta \rho \) to the \( \omicron \varphi \rho \alpha \nu \omicron \varsigma \), or vice versa.\(^4\) Also, there are heavenly bodies in, or going to or from, the \( \omicron \varphi \rho \alpha \nu \omicron \varsigma \) in 22 out of 113 lines where the word occurs\(^5\), while they are never clearly said to be in \( \alpha \theta \eta \rho \) in 25 occurrences.

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2. E.g. A 517, B 153, 458, \( \Theta \ 509; \ E \ 239; \) etc.
3. \( \alpha \theta \eta \rho \): B 412, A 166, \( \omicron \ 523, \) cf. A 255, \( \omicron \ 610. \)
\( \omicron \varphi \rho \alpha \nu \omicron \varsigma \): E 749f, \( \Theta \ 395f, \ Z \ 108; \ A \ 67 \) etc.
5. E 769, Z 108, \( \omicron \ 423, \ \omicron \ 46, \ \omicron \ 68, \ \omicron \ 555, \ \omicron \ 371, \ \Pi \ 777, \ E \ 485, \ T \ 128, \ 150, \ \omicron \ 518; \ Y \ 2, \ \omicron \ 400, \ I \ 145, \ 527, \ \lambda \ 17, \ 18, \ \mu \ 380, \ 381, \ \nu \ 115, \ 257. \)
αλθήρ is clear and bright, cf. Π 299f and Π 371f (connecting it with the absence of cloud), Π 364f (on which v. Kahn 142n2) and Θ 555f (connecting it with the appearance of numerous stars and a bright moon). One might expect it to be hot and fiery, in view of its apparent derivation from αίθω; but it is never called so, and only two passages may possibly suggest it is: Π 371f πολέμιον ὑπ' αλθέρι, πέπτατο α' αβγή ἡσιλίου δεξια, and Ν 837 ἠχή δ' ἄμφοτέρων ἵκετ' αλθέρα καὶ Διὸς αβγάς. Both passages connect αλθήρ and αβγαί; and at Ν 837, though not Π 371f, they are clearly in the same place. But this does not prove αλθήρ fiery: an αβγή is perceptible some distance from the fire, sun etc. which is its source: at Π 371f, the sun's αβγή is 'spread about', but obviously not the sun itself; and someone sitting ἐν πυρὸς αβγή (ζ 305, ψ 89) sits in the firelight, not in the fire. Also, the light of an αβγή is much more often

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1. For the etymology v. Boisacq (1950), Frisk (1954-) s.v. αλθόμενος occurs in Homer 22 times, being always used of something on fire. However αλθός is used 24 times of ὀῖνος, 11 times of bronze, once of καπνός; αλθών thrice of σόλοπος, thrice of λέβης, once of τρίπους (besides ambiguous passages where it qualifies animals). Thus these 2 words, also apparently related to αλθήρ, are seldom or never used of fire; i.e. their common root had, or could easily come to have, a connotation of brightness without having one of fieriness.

2. The phrase Διὸς αβγάς is unique in Homer; it means presumably something like 'the light of the sky'. (Cf. Kahn 141n.)
important than its heat\textsuperscript{1}, and at \textit{N} 341 it comes from
flashings bronze, not from fire at all. Therefore, \(\varepsilon l\) is bright, but not fiery.\textsuperscript{2}

After Homer, \(\varepsilon l\) continues to be a goal reached by
especially bright lights etc. from the earth:

Hesiod Th.697 de conj.; \textit{Sappho} fr.44.26f; Simonides
fr.122; Pindar I.4.66; \textit{Hes.} fr.41f; fr.227;

? Bacchylides XIII 61; Euripides Tr.1320, \textit{Ba.1973}.

Cf. \textit{Aeschylus} fr.278A;\textsuperscript{3} \textit{Ion} Chius \textit{Elegiacs} 1.6;
Euripides Supp. 987.

Unlike Homer, his successors situate the heavenly bodies
in \(\varepsilon l\):  

1. Light is clearly in point in 8 passages (\textit{B} 456, \textit{N} 244,  
341, \textit{P} 377, \textit{S} 211, 610, \textit{A} 27, 134), in 2 heat is (\textit{Z} 98,  
\textit{m} 175); the rest are unclear.

2. Gilbert 20f further argues that \(\varepsilon l\) is fiery because
the heavenly bodies and lightning occur in it. But Homer
never clearly says they do, nor would it prove the point
if he did (cf. p. 381n). Gilbert ib. also deduces that
\(\varepsilon l\) is fiery from its connection with Olympus, which
is \(\alpha l\gamma l\eta\) (\textit{A} 532, \textit{N} 243, \textit{v} 103, cf. \textit{Z} 45); but Olympus
is also snowy (p.53n), which \(\varepsilon l\) can hardly be; and
flashing bronze has an \(\alpha l\gamma l\eta\) (\textit{B} 458, \textit{T} 362, cf.\textit{η} 34ff),
but is not fiery.

3. \(\chi a t^t ' \textit{Idaion p\`agovl\`ados p\`atiph\`ov b\`awos `e\s`t} `e\n\varepsilon l\`epi.\)
This implies that \(\varepsilon l\) is something high above the
earth into which high mountains like Mt. Ida extend
(cf. \textit{Euripides} Supp.987 \(\varepsilon l\`e\`ptan `e\pi\`tan\), 'a rock
reaching the \(\varepsilon l\)`).
Homer H.Cer.70; Theognis 997; Simonides Fr.51, 64;
Findar 0.1.6; Aeschylus Fr.1092, A.6; Sophocles Ant.415;
Euripides Elegeiacs 2.1, Ion 84, 1079, 1147, 1152,
Elsewhere, however, αλόηρ reaches down to the earth (p.15f);
and sometimes there are birds, clouds, winds etc. in it¹:
Birds²: Aeschylus Fr.125, 280, 594; Bacchylides V 17;
Sophocles OC 1082; Euripides El.397; Aristophanes,
Euripides Ph.165f, Fr.530, cf. Hel.584 with 705, 1219³;
Euripides Ph.674f. Thunder or lightning: Sophocles OC
1456, 1471; ? Euripides Fr.122⁴.
Evidently meteorological phenomena and the heavenly bodies
were thought to occur in the same region; this throws light
on the analogies drawn between them by Anaximander and
Xenophanes (pp. 386 ; 156f).

1. Cf. Homer τ 540, a bird flies ἐς αλόηρα ; also ο 20, 192
ἐν αλόηρι καὶ νεφέλῃ (where αλόηρ is surely clear sky
between clouds, not (as Gilbert 19n supposes) a region
above them, which implies, improbably, that clouds fill
the whole region below).
2. Note that birds fly in ἄφρ in Euripides (p.13) and
Aristophanes (p.14).
3. The εὐόμολον of Helen is made of αλόηρ at 584, of νεφέλη
at 705, 1219. (Also of οὐρανός at 34).
4. This is Aristophanes Th.1050, where v. Rogers (1904).
In this period, as in Homer, αλθήρ was often bright: φαεννός: Pindar 0.7.67, Fr.52c.17, Euripides Fr.919. λαμπρός: Id.Med.550, Or.1087, Ion 1445, Il 29, Fr.443, Hipp.178, cf. Antiope 11; Aristophanes Nu.285. λευκός: Euripides Andr.1228. πολίος: Id.Cr.1576, Fr.1543.

Also, it often has fire in it (heavenly bodies (p. 440f ) and once, apparently, lightning (p. 441 )); but only once is it called fiery: Id.El.991 φλογερὰν αλθέρ'. Occasionally it has different qualities: several passages connect it with cloud (p. 441 ); it is once cold (Pindar C.15.88 ψυχράς), once dewy (ιουρ.5a.555 δροσερόν): fieriness was not yet αλθήρ's regular property.

The contrast of αήρ and αλθήρ found at Θ 236 (p.3) does not recur in this period; where their relation can be discerned, they are generally identical (v. especially p.14f). Consistently with this some writers speak of the sky, the region of the heavenly bodies, as αήρ; ¹ so Ion of Chios (p.14); Diogenes of Apollonia Ε5 αήρ ... παρά τῷ ἥλιῳ; Plato Phd.109D, because we live in a hollow of the earth, we call τὸν αέρα οὐρανόν: [Plato] Def.411C οὐρανὸς σώμα περιέχων πάντα τὰ αἰσθητὰ πλην αὐτοῦ τοῦ ἀνωτάτω ἄερος ; Cf. [Hippocrates] Φλάτ.5 (L.VI 94.13f) ἥλιον τε καὶ σελήνης

¹. Cf. Kahn 103.
Anaximander and Anaximenes similarly connected the heavenly bodies and \(\alpha\eta\rho\) (pp. 107, 125).

I here attempt to list all the occurrences of the sense of 'exhalation' in pre-Socratic physical theories. By 'exhalation', I mean the formation or emission of any gaseous body (as defined on p. 33) from a solid or liquid. I also mention of certain commonplace phenomena, such as breathing and flame, which fall within this definition, unless specially connected with other occurrences of 'exhalation'.

This list is by no means complete in other authors.

I. Meteorological uses

a) Cause of wind: Anaximander (DK12427, 7A11(7); 64A9; cf. Alexander 75.16–22); Xenophanes (214A6, 23C);

b) Heraclitus (224A (10–11)); T. Anaxagoras (59A35a; but v.p. 765); Diogenes (184A7; 6A9; cf. Alexander 75.16–22); Metrodorus (70A16; v.p. 1053).

1. In this section, but not in the later ones, I give some references to authors other than philosophers.
APPENDIX 3

Pre-Socratic theories of exhalation

I here attempt to list all the occurrences of the idea of 'exhalation' in pre-Socratic physical theories. By 'exhalation' I mean the formation or emission of any gaseous body (as defined on p.35) from a solid or liquid. (I omit mentions of certain commonplace phenomena, such as breathing and flame, which fall within this definition, unless specially connected with other occurrences of 'exhalation'. I have been mainly concerned with exhalations in meteorology; but I believe that my list of mentions of 'exhalation' in other contexts should be reasonably complete.)

A. Uses made of exhalation:

I. Meteorological uses¹

a) Cause of wind: Anaximander (DK12A27, A11(7); 64A9; cf. Alexander 73.16-22); Xenophanes (21A46, B30); Heraclitus (22A1 (10-11)); ? Anaxagoras (59A36a; but v.p.165); Diogenes (12A27; 64A9; cf. Alexander 73.16-22); Metrodorus (70A18; v.p.195f). Cf.

¹. In this section, but not in the later ones, I give some references to authors other than philosophers.
b) Cause of cloud or mist: Xenophanes (21A1(19), A46, B30); ?? Anaxagoras (v.p.165); ? Democritus (v.p.176); Metrodorus (70A16; v.p.195f). Presumably also the other thinkers who derived rain from exhalation, v. c). Cf. [Hippocrates] Aer. 8, 15 (v.p.46).

c) Cause of rain: Anaximander (12A11(7); v. also p.112f); Xenophanes (21A46, B30); Heraclitus (22A1(10-11)); ?? Anaxagoras (v.p.165); ? Democritus (v.p.176); Metrodorus (70A4, A16; v.p.195f). Cf. [Hippocrates] lb.8 (v.p.46), and (presumably) Herodotus II 25.

d) Cause of lightning etc.: Heraclitus (22A14).

(Exhalation may be an indirect cause in other authors, since lightning etc. were often thought due to cloud and/or wind.)

e) Water left behind by evaporation is sea: Anaximander (12A27); Anaxagoras (59A1(3), A42(4), A90 (Aetius III 16.2)); Diogenes (12A27, 64A17).

f) Cause of seasons: Heraclitus (22A1(10-11)).

g) The sun causes evaporation; what happens to the vapour not stated (cf. e)): Diogenes (64A18); ? Heracliteans (DK66.2; v.p.147). Cf. [Hippocrates] Vict.II 38
II. Astronomical uses.

a) Sun and stars are nourished by or formed from vapour: Anaximenes (13A6, A7(5)); Xenophanes (21A40, cf. A32, A38); Heraclitus (22A1(9), A11, A12; ? DK66.2); ? Parmenides (28A37); Democritus (68B25); Hecataeus of Abdera (73B9). Cf. Metrodorus (70A4: water quenching and lighting sun; cf. p.196); Antipho (87B26: the sun feeds on moist air).

b) Cause of comets' tails, Milky Way (phenomena caused by reflection): Hippocrates of Chios (DK42.5, 6).

c) Cause of τροπαί of sun and moon (v. p.113):
   Anaximander, Diogenes (12A27, 64A9, cf. Alexander 73.16-22).

d) Cause of day and night: Heraclitus (22A1(10-11)).

III. Biological uses.

a) Animals first formed by the evaporation of moisture:
   Anaximander (12A11(6), ? A30); ? Anaxagoras (59A1(9), A42(12)); ? Archelaus (60A1(17)); ? Democritus (68A139, 68B5.1 (Diodorus I 7.3); also B5.3). 1

1. Only 12A11(6) clearly mentions evaporation - the others resemble that passage, and perhaps imply it.
b) Exhalation is or causes soul: Heraclitus (22A15; B12, B36); Pythagorean School (58B1a(28)).

c) Effect on plants of vapour in the earth: Clidemus (62.5).

d) Exhalation within living beings: Empedocles (34A70 (Aetius V 26.4): evaporation of moisture makes plants drop leaves; A81 (Aetius V 11.1): evaporation of heat in semen causes unlike children); cf. also IIIe.

e) Sensation: Pythagorean School (58B1a(28)-(29): an ἄμμος within the body causes ἄθος. Elsewhere there is a vapour, or something like it, from the object perceived: n.b. Heraclitus (22B7, on καπνός and smell; cf. p. 253f), and the theory of ἀπορροή from all things (cf. VI below).

IV. Other uses.

a) Exhalation and fire: n.b. Anaxagoras (59A98, smoke is from water; cf. p. 253); also passages cited at IIIa above.

b) Miscellaneous: ? Heraclitus (22A1(9) σχεδὸν πάντα ἐπὶ τὴν ἀναθήμασιν ἀνάγυς, cf. A15: this may include other uses than the above); Philolaus (44A18: exhalations from fire and water are τροφαὶ of κόσμος); ? Diogenes (64A33: discharge of ἴμματα and metals).
V. N.b. also passages which speak of air being formed from water or earth: ? Heraclitus (22A5, B76; but v.p. 138);
Farmanides (28A37); Empedocles (31A49 (Aetius II 6.5));
Archelaus (60A4(2), A1(17)); ? Diogenes (64A19(44)\(^1\));
? cf. Leucippus (67A24(3); but v. p. 57a).\(^2\)

VI. N.b. also the theory of \(\delta\nu\rho\rho\omega\alpha\) from all things:
Empedocles (31B39, A86, A88, A89, A90, A92 etc.);
Leucippus (67A29); Democritus (68A155(50 etc.),
A165); Gorgias (82B4).

(This last theory, of 'effluences' that are leaving all bodies all the time, and retain the nature of the bodies they leave, is quite distinct from normal exhalation theories: it may have given a little encouragement to Aristotle's theory of an exhalation from earth (cf. p. 246), but surely not much. I ignore it in what follows.)

B. The nature of these exhalations.
I note against each thinker evidence for the nature of his exhalations (particularly whether his only exhalation

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1. \(\tau\delta\nu\ \alpha\pi\rho\delta\ \tau\eta\zeta\ \gamma\eta\zeta\ \delta\varepsilon\rho\alpha\) - this may be air that has become impure through contact with the earth, rather than air formed from earth.

2. At Anaxagoras 59A45 (DK II 13.20f) the formation of air from water is a conjecture by Simplicius, cf. 1.19\(\varepsilon\nu\gamma\gamma\varepsilon\nu\ \iota\omega\zeta\).
was water-vapour).

Anaximander. Ia: 1 12A27 (DK I p.88.7f) ὑγρὸν ἀπαντα τὸν περὶ τὴν γῆν τόπον (cf. p.88.11ff; 64A9, Alexander 73.1off similar). Ic: 12A11(7) ἀτμίος ... ἐκ γῆς; but Aristotle's evidence (quoted p.112f) indicates water-vapour.2 le and llc: v. on Ia. IIIa: 12A11(6) <ἐξ ὑγρὸν> ἔξατμισομένου; cf. in A30 ἐν ὑγρῇ, 'ex aqua terraque'.

Anaximenes. IIIa: 13A6 ἐκ γῆς, ἀποφαίνεται ... τὸν ἥλιον γῆν; A7(5) ἰκμάδα, i.e. moisture. (V.p.121f.)

Xenophanes. Ia, v, c: 21A45 ἄνεκθυμενον ... τοῦ ὑγροῦ. 530 πηγὴ ... ἑλασσα; πόντος γενέτωρ νεφών κτλ. IIa: 21A40 τῆς ὑγρᾶς ἀναθυμιάσεως, also νεφῶν (cf. A52, A58 - clouds from water-vapour, cf. Icb).

Heraclitus.3 Ia, c, d, f, g, IIa, d, IIIb, IVb, V. v.p.159ff. (IIIe: καπνὸς might be thought derived from water or earth, cf. p.252f.)

Parmenides. IIa, V: 28A37 τῆς μὲν γῆς ἀπόχρισιν εἶναι τὸν ἀέρα διὰ τὴν βιαστέραν αὐτῆς ἔξατμισθέντα

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1. Numbers and letters refer to list A.
2. 12A11(7) γῆς may therefore be a place rather than a material.
πλησιν, τοῦ δὲ πυρὸς ἀναπνοῆν τὸν ἥλιον καὶ τὸν γαλαξίαν κόχλον [For tr. v. KR 284].

Empedocles. IIIa: 31A70 (DK I p.296.21f) τὰ … ἐλλιπτικῶς ἔχοντα τὸ ὕγραν ἐξικαμαξομένου αὐτοῦ … φυλλορροεῖν. A81 θερμασίας ἐξατμισθείσης. V: 31A49 ἐξ οὗ [i.e. ὑδατός] θυμιαθῆναι τὸν ἄερα.

Hippocrates of Chios. IIb: 42.5 (Mete.343a3) τῆς ἐλκομένης ὑγρότητος.

Philolaus. IVb: 44A18 οίττην εἶναι τὴν φθορὰν τοῦ κόσμου, τὸ μὲν ἐξ οὐρανοῦ πυρὸς ὑπόντος, τὸ δὲ ἐξ ὑδατος σεληνιακοῦ, περισσοτέρῳ τοῦ ἄερος ἀποξυθέντος καὶ τοῦτων εἶναι τὰς ἀναθυμιάσεις τροφὰς τοῦ κόσμου.
(This seems to imply exhalations from both fire and water).

Pythagorean School. IIIb, e: 58B1a(28)-(29). The nature of the ἄτμος is not clear, except that it is hot.


Archelaus. IIIa: cf. on Anaxagoras. V: 60A1(17) τηκόμενον … τὸ ὑδωρ ὑπὸ τοῦ θερμοῦ … καθὼ … περιρρεῖ
da γεννᾶν  (A4(2) is rather similar).

Clidemus. IIIc: 52.5 οιερὰν ... ὅθεν καὶ μαρεῖαν 
τὴν γῆν ἀτμιώσῃ γίνεσθαι (οἰερὰν suggests moisture).

Diogenes. Ia, e: v.p. 449, Anaximander Ia. Ig: 64A18 ὑπὸ ἥλιον ἀρπάξεσθαι τὸ ὦδωρ; "sol humorem ad se 
rapit". Iic: v.on la. Ivo: 64A33 ἱκμάς. V: formation 
of air may not be involved, cf. p. 448n.

Leucippus. V: 67A24(5) τὸ ... πλῆθος τῶν 
ἀναθυμισμένων σωμάτων ἔπληττε τὸν ἀέρα καὶ τοῦτον 
ἐξέθηλης. (Nature of this exhalation is obscure, and 
the passage perhaps wrongly referred to Leucippus.)

Democritus. Ib, c: 68A99 τῆς χιόνος ... διαχειμένης 
νέφη ... ἐκ τῶν ἀτμών πιλοῦσθαι (other sources cited at 
p.173n are similar). IIa: 68B25 ἀτμίδας (these need 
not be from water, if the word is Democritus' own; 
p. 446.

Metrodorus. Ia: 70A18 ὑδατώδους ἀναθυμιάσεως.

Ib: 70A16 ὑδατώδους ἀναφορᾶς. Ic: cf. on Ib, as 
rain falls from clouds (so 70A4, though it is not there 
clear that clouds are from exhalation). Ila: 70A4 
ὕδωρ ... ἀραιούμενον ἐξάπτεσθαι might be relevant to 
exhalation.

Hecataeus of Abdera: IIa: 73B9 ἐκ θαλάττης.
Antipho. IIa: ὧν ὅποι ὁ ἀνθρώπος ἔχει ὅποι ὁ ἀνθρώπος ἔχει 

not as exhalation.

Of these 18 thinkers or groups, all except Parmenides, 
the Pythagorean School and Leucippus would seem to 
have believed in an exhalation, or something like one, 
from water or moisture. For Anaximander, Anaximenes, 
Heraclitus, Parmenides, Anaxagoras and Diogenes there is 
prima facie evidence for an exhalation from earth; but most 
of this is doubtfully reliable. It is quite uncertain 
whether Anaximander 12a11(7) and A50, Anaximenes 13a5 or 
Diogenes 64a19(44) is meant to refer to vapour formed from 
earth as a material. In the case of Anaximander 12a11(7), 
a better authority (Aristotle instead of Hippolytus) 
indicates the vapour is from water (p.449); and 
Anaximenes' theory of matter implies that gaseous bodies 
cannot form from earth except via water (cf.13a5, A7(3)). 
It is very doubtful whether Heraclitus believed in exhalation 
from earth as a material (p.139ff); and there is independent 
reason to doubt the reliability of 59a36a, the only evidence 
for such an exhalation in Anaxagoras (p.165). The only 
remaining evidence for exhalation from earth refers to

1. Gilbert 445-7 attributes an earth exhalation to Xenophanes, 
but on no good evidence.

2. v.pp. 449n, 446n; 121f; 448n.
Farmerides' Way of Seeming – not an influential work. Any idea of such an exhalation can have been but of minimal importance to the pre-Socratics.

My quotations on p.449-52 mention some other sorts of exhalation, but they are unimportant here. Empedocles' 'evaporation of heat' (A81) is paralleled by (e.g.) Aristotle Resp.479a17; but this idea seems never employed in meteorology. The passages quoted under Philolaus, Pythagorean School and Leucippus (67A24(5)) are all of very doubtful value; and 28A37 πυρὸς ἀναπνοή, from Farmerides' Way of Seeming, is unlikely to have influenced other thinkers. Clearly the only exhalation important in pre-Socratic thought was one from water.2 (some believed there were two types of this, cf. p.147-9).

C. Causes of exhalations: I list the evidence for this thinker by thinker, as on p.449-52 (omitting passages where nothing is said of the cause).

1. On Philolaus see KR 307-12; on Diogenes Laertius VIII 24ff (=58B1a) see HGP I 201n; on DK 67A24 see HGP II 406n2.
2. The passages from Herodotus and the Hippocrates cited in §A similarly speak only of evaporation from water, cf. quotations on pp.46, 209ff, 207ff.
Anaximander. Ia, e, III: 12A27 ὑπὸ ... τοῦ ἡλίου ἐπραινόμενων, τ.τ.η. ἐξατμίζεσθαι. 64Α9 ὑπὸ τοῦ ἡλίου θερμαίνομενον. (Cf. Alexander 75.16ff.) IIIa: 12A11(6) ὑπὸ τοῦ ἡλίου; A30 "aqua terraque calefactis".


Heraclitus. v.p.147.

Parmenides. V: v. quote, p. 449f. Apparently, air is squeezed out as the earth is compressed.

Empedocles. IIIId: 31A70 (DK I p.295.21f) ἐξεκιμαζομένου ... τῷ θερέτι suggests evaporation is due to heat.

Hippocrates of Chios. IIb: 42.5 (Hete.343a3) τῆς ἐλχομένης δηρότητος ὑπ' αὐτοῦ, i.e. the planet that is a comet; this suggests heat causes evaporation.

Anaxagoras. Ie: 59A1(8) διατιμοθέντων ὑπὸ τοῦ ἡλίου; A90 τοῦ ... γαροῦ περικαῦντος ὑπὸ τῆς ἡλιακῆς περιφορᾶς.

Archelaus. V: quotation on p. 450f shows heat causes formation of air from water; cf. 60A4(2) κατακαιόμενον.

Diogenes. Ia, e, IIIc: v. Anaximander Ia, also 64A17 (DK II 54.21) ἀνάγοντος τοῦ ἡλίου. Ig: quotations on p. 451 mention sun causing evaporation.

Democritus. Ib, c: 68A99 τῆς χιόνος ... ὑπὸ θερμῶν τροπᾶς ἀναλυομένης suggests heat is cause, cf. the parallel
Thus to the pre-Socratics heat was the normal, though not the only, cause of evaporation; it is also the cause in several of the passages cited on p. 45f (though not in the biblical and pre-philosophical passages), and in many of the passages with θυμιάω, ἀμος etc. cited on p. 37-44. However, many passages speak of exhalation without mentioning the cause of it, and we must therefore allow for the possibility of other causes: [Hippocrates] Vict. II 37 mentions one, dryness of the air: L.VI 528.17f τὸ πνεῦμα ὑ ἀναπνέομεν, ἕκετο ἐκ τῶν σωμάτων τὸ υγρόν. 

1. This idea is correct: evaporation from a liquid at a given temperature of vapour in the space above the liquid, cf. Sutton 65, 196; Barton (1933) 195-5. The ancients knew, too, that wind assists evaporation, cf. Vent. 60, Lucretius V 256f. (On why this is so v. Sutton 196f.)
APPENDIX 4

Anaxagoras B19

DK print this fragment, from the ET scholia on Homer, p. 547, as follows: ('Anaxagóraς δὲ φησιν') Ἰριν δὲ καλέομεν τὸ ἐν τῇ σειν νεφέλησιν ἄντιλάμπον τῷ ἡλίῳ. χειμώνος όβν ἐστὶ σύμβολον τὸ γὰρ περιχεόμενον ὑδῷ τῷ νέφει ἄνεμον ἐποιήσεν ὃ ἐξέχεεν ὑμβρον.

Solmsen (1965) 251f argues that only the first sentence is quoted from Anaxagoras. His principal argument is that there is "little ... connection between the first sentence ... and the second ... The presence of water so essential for the χειμών is mentioned only in the second part of the fragment ... It therefore seems better to regard ... χειμώνος - ὑμβρον as continuing the definition of the rainbow which the ET scholia set forth before they quote Anaxagoras: ὅταν ἐξ ἐναντίας νέφος τῷ ἡλίῳ στῇ πεπιλημένον καὶ πληρές ύδατος, αὐτὸ δὲ ἀκτίνες προσπίπτον τῷ νέφει".

This seems unjustified. Fifty-two words separate χειμώνος όβν from πληρές ύδατος (just quoted), to which Solmsen thinks όβν refers. This space seems improbably long; and the connexion of thought is satisfactory in the fragment as DK give it: "the rainbow appears in clouds; and therefore
it is a sign of storm, because the water which is present in the cloud causes storms". It can surely be assumed, especially by an Anaxagorean, that clouds contain water (cf. p. 101 and n2), without actually stating the fact.¹

Solmsen adds the three following arguments:

(i) νεφέλη, not νέφος, is Anaxagoras' word for 'cloud' (cf. B16, B19 init.). But, Anaxagoras might have used both words, as Hete. does (cf. Fobes' index, reprinted in Lee); Hete. uses both words in successive sentences.²

(ii) B16 ἐκ ... τῶν νεφελῶν ὑδωρ ἀποχρίνεται describes rain forming in a different way from B19. But, B16 is primarily explaining how cloud, water, earth and stones were formed in cosmogony; hence Anaxagoras naturally uses ἀποχρίνω, his usual word for 'separation' from the initial mixture (B2, B4, 59, B12). B19 seems purely meteorological, so Anaxagoras might naturally use a different word.

(iii) χειμώνος σύμβολον is "the scholiast's language". But, why should it not be Anaxagoras' also? σύμβολον is a

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1. FHS objected that not all clouds rain: one might as well object that "Προ- ἡλίῳ is nonsense because not all sun-illuminated clouds have rainbows.

2. νέφος is an Ionic form, cf. Herodotus 8.109, [Hippocrates] Aer.8 (L.II 34.22, 24), Nat.puer.25 (L.VII 522.12ff).
'sign' or 'portent' in contemporary authors (e.g. Aeschylus A.8, 315; Pindar 0.12.7; cf. Aeschylus Fr.487); and, though LoS quote no early instance of it governing a genitive of what is portended, this seems a perfectly simple construction, cf. Homer P 548f τέρας...χειμάνως, Aeschylus Fr.454 χείματος τέκμαρ. 1

Moreover, if only Ἄριν - ἥλιος is quoted from Anaxagoras, it seems impossible to understand why it is quoted: it is simply another account of the rainbow, clearly less good than the one already given. But if all DK's B19 is from Anaxagoras, the reason is evident: the scholiast, having described the rainbow, then quotes Anaxagoras to explain why P 548f calls it τέρας...χειμάνως.

Assuming, then, that the scholion is a coherent piece of Greek, it seems to me much more probable that all DK's B19 is from Anaxagoras (and if not, non liquet); though I concede that other scholars, including FMS, agree with Solmsen.

1. Romano (1965) 58f and Lanza (1966) 240f add that B19 contradicts A42(11) (v.p.166ff); but to say that (e.g.) θυγρός ἡπ causes wind is hardly inconsistent with saying that water in a cloud does so. Lanza adds that οὖν occurs nowhere else in Anaxagoras' frr. (which surely proves nothing), and that it is not an Ionic form (but it occurs in [Hippocrates] Aer.22 (L.II 78.9), 23 (L.II 86.5)).
APPENDIX 5

The dating of the Hippocratic treatises

Dr. G.E.R. Lloyd suggested that, if I did not wish to discuss this question at length, I might assume as correct the dating given by Bourgey 'La collection Hippocratique' (1955). I therefore follow Bourgey (p. 41) in regarding the whole Corpus (except Praeceptiones and De decenti habitu, which I do not quote) as pre-Aristotelian — the only dating necessary for my purpose.

This dating is supported by the important meteorological passages (Aer. 8, Vict. II 57-8, Nat. puer. 24-5), which make no use of certain words and concepts characteristic of Aristotle's meteorology (use of ἀναθυμίας, ἀτμίς; the two-exhalation theory). The use of ἄηρ to mean 'mist' confirms the early date of Aer. (v. p. 11-19). In Vict. II 38, L VI 532.5 τοῦ νοτίου πόλου suggests a fairly late date: LoGi cites no instance of this use of πόλος before Aristotle. However, Aristotle seems less likely to have invented this use than some earlier 4th century astronomer, e.g. Eudoxus; Plato Ti. 408 θ'ν διὰ παντὸς πόλον τεταμένον comes near to it. πόλος confrms Jaeger's mid-fourth century dating of De vict. ('Paideia' (1939-) III 56-40), but not Kirk's view.
((1954) 26-9) that it has been influenced by the Peripatetics\(^1\).

1. FHS considered πόλον no argument against a date c. 350 or even 375 B.C.
A. Editions of certain ancient texts used.

Here list only

(1) editions of ancient texts found in unequal places;

(2) editions of texts cited by reference to a

particular edition (e.g. by citing page and line. I exclude

the editions explicitly mentioned in bibliography);

BIBLIOGRAPHIES

A. Editions of certain ancient texts used. p. 452

B. Modern works.

I. General bibliography. (A list of all

the modern works cited in the text.) p. 457

II. Classified bibliography. (A list of the

modern works of which I have made the

greatest use, arranged by subjects.) p. 487

(2) In the following list, 'Diehl'-E. Diehl 'Anthologia

lyrica Graeca' (Bibliotheca Teubneriana. Lipsiae, 1925 and

later ed.); 'Edmonds'-J.M. Edmonds 'The fragments of Attic

comedy' (Leiden, 1957-61).

Achilles. Iasgosa. Ed. E. Mease, in 'Commentariorum in

Aretum reliquiae' (Berolini, 1898), pp. 25-75.


Alcaeus. Fragments. Ed. E. Lobel and D.L. Page, in

A. Editions of certain ancient texts used.

I here list only

(i) editions of ancient texts found in unusual places;

(ii) editions of texts cited by reference to a particular edition (e.g. by citing page and line. I exclude the editions explained on p. xff);

(iii) editions whose numeration of an author's fragments I have used.

Note: (1) In the case of authors included in Diels-Kranz 'Die Fragmente der Vorsokratiker' (5th and later eds., Berlin, 1954 etc.), von Arnim 'Stoicorum veterum fragmenta' (Leipzig, 1905-24), and D.L. Page 'Poetae melici Graeci' (Oxford, 1962), I have used the numeration of fragments in those editions, and do not list the individual authors here.

(2) In the following list, 'Diehl'=E.Diehl 'Anthologia lyric Graeca' (Bibliotheca Teubneriana. Lipsiae, 1925 and later eds.); 'Edmonds'=J.H. Edmonds 'The fragments of Attic comedy' (Leiden, 1957-61).


'Anonymus II. Isagoga.' Ed. E. Haass, in 'Commentariorum in Aratum reliquiae' (Berolini, 1898), pp. 99-133.
——— Elegiac fragments. Diehl.
Hermippus. Fragments. Edmonds.


Arabic version: 'Le livre des appareils pneumatiques et des machines hydrauliques par Philon de Byzance, édité d'après les versions arabes...et traduit en français par le Baron Carra de Vaux.' (Notices et extraits des manuscrits de la Bibliothèque Nationale 38 (1903) 27-235).


1. This survives only in an Arabic translation, and an incomplete Latin translation from the Arabic.
Theophrastus. Works and fragments (Greek). Ed. F.Wimmer (Bibliotheca Teubneriana. Lipsiae, 1854-62; also Didot, Parisiis, 1866).

Arabic fragment. 'Neue meteorologische Fragmente des Theophrast; arabisch und deutsch, herausgegeben von G.Bergstraesser.' (Sitzungsberichte der Heidelberger Akademie der Wissenschaften. Philosophisch-historische Klasse (Ed 9). Jahrgang 1918. Abh.9.)

(German translation, revised, reprinted in E.Keitzenstein 'Theophrast bei Epikur und Lucrez' (Orient und Antike, 2. Heidelberg, 1924)).


1. A fragment of the Syriac text whence the Arabic is immediately derived.

Tyrtaeus. Fragments. Diehl.

Here lie all the modern works cited in the text.

(Editions of ancient texts cited for some point of interpretation, etc., are included, under the name of the editor.)

Note: Ex-Paulys Real-Encyclopädie der classischen Altertumswissenschaft. Neue Bearbeitung. Erg. von R. Wesche (W. Kroll, etc.). (Stuttgart, 1894-).


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B. Modern works.

I. General Bibliography.

I here list all the modern works cited in the text. (Editions of ancient texts cited for some point of interpretation, etc., are included, under the name of the editor.)

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