Thermodynamic Anaximander

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Admit as given that the commonly perceived supremacy of (natural-) scientific thought, which justifies its hegemony, is worthy of deconstruction.[1] The article at hand demonstrates a conceptual link between Anaximander's ἄπειρον and the notion of *equilibrium* in classical thermodynamics. This towards undermining the perceived singularity of scientific thought, taken to be born out of ahistoricity and underpinning its strongest claims to hegemony. Inheriting the dichotomy of τὸ ἕν contra τὰ πόλλα from Thales, Anaximander's genius consisted of associating it with the opposition between *indefinite* and *definite*. This readily suggests the further connection, as justified below, to the venerable κάοϛ–κόσμοϛ dichotomy, which is taken to be the primary concern of classical thermodynamics. To show this plausible and thus instructive, parallel expositions of classical thermodynamics' qualitative concepts and the doctrine of Anaximander are presented below.[2]

The construction of classical thermodynamics[3] begins with the notion of equilibrium, *e.g.* the state of a ball lying still at the bottom of a bowl. If pushed in any direction and then released, the ball rapidly returns to its original state of rest, after some back–and–forth movement. In such a state, the bowl–ball system is said to be in equilibrium, suggesting a definition:

[1] For the present argument, this normative claim may be justified by whichever rationale preferred. This article was, however, specifically written with the uncoupling of natural and moral philosophy, which the author wishes to oppose, by a single destructive steplet. A argued justification of this is nevertheless beyond the scope of the current text.

[2] A remark on method must here be made: the present argument methodically adopts a bracketing of any claim about the particular scientific methods' value. The two systems of thought considered are thus in comparison taken on equal footing. The alternative route, often traveled, is to assume the truth of uncontroversial scientific claims which, however apt for the modern mind, allows us to go no further than claiming that either Anaximander prefigured modern science or that it has proved him correct. As neither case allows for criticizing naive claims of scientific thought's supremacy, because it assumes that very supremacy, this route must be taken as unsatisfactory. The method of bracketing is thus taken as an acceptable alternative, allowing scientific thought to be examined in context.

[3] Here *classical* specifically refers to the discipline as developed in the 19^{th} century, primarily by Clausius, Rankine and Kelvin, following Carnot. Because of its immense influence, remaining in daily use, and relative ease of understanding, the work at hand primarily concerns itself with this classical formulation, although brief mention will be made of thermodynamics' statistical foundation. The interested reader is referred to Newton Lewis *et al.* (1961), on which the following exposition is founded.

Def. An *equilibrium* of a given system is such a state as to which the system spontaneously returns after a temporary change of external conditions.[4]

As a to thermodynamics more prototypical example, let a glass of hot water be poured into a cooler bath. Intuitively understood, the immediate unequal distribution of warm water spontaneously equalizes, as the bath rapidly re-attains a uniform temperature, somewhat higher than before. Thus steps forward the conceptual link between

$$\text{equilibrium} \sim \text{homogeneity} \quad \text{and} \quad \text{inequilibrium} \sim \text{heterogeneity}.$$

Considering the initially ordered motion outward of the hot water, as it spreads throughout the bath, a further link also becomes apparent:

$$\text{equilibrium} \sim \text{unordered motion} \quad \text{and} \quad \text{inequilibrium} \sim \text{ordered motion},$$

as a sustained ordered motion spontaneously arising from the equilibrium state of uniform temperature is contrary to definition. The reader ought to convince themselves that useful work (*i.e.* the physical quantity measured in joules) is ordered motion, and therefore being in inequilibrium, as the capacity for ordered motion, is also the capacity for performing useful work.[5] Hence the technical (and thus scientific) motivation of classical thermodynamics, developed by engineers of the industrial revolution. To borrow from Heidegger's *Die Frage nach der Technik*, it is in inequilibrium that a system can be made available as a *Bestand* (en. *standing-reserve*).

A final conceptual link is now ready to be made, moving towards the vocabulary of ancient philosophy:

$$\text{equilibrium} \sim \text{κάος} \quad \text{and} \quad \text{inequilibrium} \sim \text{κόσμος}.$$

Note! that unordered motion ($\sim$ equilibrium $\sim$ κάος) does not give rise to persistent properties. Again considering the water bath, a universal tendency suggests itself, by physicists conceived of as the eschatological *2nd Law of Thermodynamics* which may, choosing from many equivalents, be stated as follows:

2nd Law of Thermodynamics. Every system left to itself will spontaneously change towards a state of equilibrium.

[4] The received notions of *physical systems* and their *states*, together with connecting concepts, will here be taken as unproblematic, as the task at hand is not to evaluate the strength of classical thermodynamics' theoretical foundation, but to study the doctrine as received. It ought nevertheless be stated that *equilibrium* is predicated of a state with respect to a set of experimental measurements (both kind and accuracy), being a state where *measured* properties no longer change; eventual difficulties of this conception will be left undiscussed.

[5] If this seems unintuitive, consider the following argument by contradiction: if the bath in equilibrium could perform useful work, then it may spontaneously separate into distinct regions of hot and cold water, *e.g.* by powering a machine similar to an air-conditioning unit. But if the given state is such that the system spontaneously moves out of it, it cannot by definition have been an equilibrium. This completes the argument.

The above exposition demonstrates that the 2nd law is recognized in ancient doctrine as the universal tendency of κόσμοϛ to degenerate in κάοϛ.[6] Anaximander was, as will be demonstrated, no stranger to this notion, whether or not he had these terms available for use. Having inherited, as all Presocratics did, the monistic intuition of his teacher, Anaximander continued Thales' interest for the origin of plurality. Simplicus testifies:[7]

> (*Simp. Phys. 24.13*) Ἀναξίμανδρος [...] ἀρχήν τε καὶ στοιχεῖον εἴρηκε τῶν ὄντων τὸ ἄπειρον, πρῶτος τοῦτος τοὔνομα κομίσας τῆς ἀρχῆς. λέγει δ᾽αὐτὴν μήτε ὕδωρ μήτε ἄλλο τι τῶν καλουμένων εἶναι στοιχείων, ἀλλ᾽ἑτέραν τινὰ φύσιν ἄπειρον, ἐξ ἧς ἅπαντας γίγνεσθαι τοὺς οὐραυοὺς καὶ τοὺς ἐν αὐτοῖς κόσμους· ἐξ ὧν δὲ ἡ γένεσίϛ ἐστι τοῖϛ οὖσι, καὶ τὴν φθορὰν εις ταυτὰ γίγνεθαι κατὰ τὸ χρεών· διδὸναι γὰρ αὐτὰ τὶσιν και δὶκην τῆϛ ἀδικίαϛ κάτα τὴν τοὺ χρόνου τάξιν, ποιητικωτέροις ὀνόμασιν αὐτὰ λέγων.
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> Anaximander named ἡ ἀρχή and element of existing things *the boundless* [τὸ ἄπειρον], being the first to introduce this name for ἡ ἀρχή. He says that it is neither water nor any other of the so-called elements, but a different substance which is boundless, from which there come into being all the heavens and the worlds within them. Things perish into those things out of which they have their being, as is due; for they make just recompense to one another for their injustice [ἀδικία] according to the ordinance [or perhaps *assessment*] of time — so he puts it in somewhat poetical terms.[8]

The ἀδικία is here of primary interest. Although traditionally interpreted as referring to the separation of substances from τὸ ἄπειρον, Guthrie (1962, *pp.* 78–83) convincingly argues that it instead refers to the mutation of the elements into each other, *i.e.* the battle between the four *inter se* contrary elemental properties, as postulated by Greek physics. Simplicus himself appears to concur:

> δῆλον δὲ ὅτι τὴν εἰϛ ἄλληλα μεταβολήν τῶν τεσσάρων στοιχείων [Ἀναξίμανδρος] θεασάμενος οὐκ ἠξίωσεν ἕν τι τούτων ὑποκείμενον ποιῆσαι, ἀλλά τι ἄλλο παρὰ ταῦτα. οὗτος δὲ οὐκ ἀλλοιουμένου τοῦ στοιχείου τὴν γένεσιν ποιεῖ, αλλ᾽ἀποκρινομένωον τῶν ἐναντίων διὰ τῆς ἀϊδίου κινήσεως.

[6] This degeneration, according to thermodynamic doctrine, occurs by irreversible processes, *i.e.* processes which require externally performed work to reverse. Thus *irreversible* here reads: spontaneously irreversible. The famed notion of *entropy* is a quantitative measure of this irreversibility (*i.e.* how irreversible a given process is), related to the amount of energy required in restoring the system to its original state.

[7] Anaximander consistently presupposed the existence of substances endowed with independent existence, whose origins are to be explained. The theoretical danger of this would only be exposed by Parmenides, however already grasped by Heraclitus, who avoided it by asserting that πάντα ρει, *i.e.* that such substances do not exist. (*cf.* Nietzsche 1962, *p.* 98*ff.*)

[8] Translation taken from Guthrie (1962), *p.* 76.

> It is clear that when [Anaximander] observed how the four elements change into each other, he did not think it reasonable to conceive of one of these as underlying the rest, but posited something else. Moreover he does not account for γένεσις by a qualitative alteration of the element, but by a separation of the opposites caused by the eternal motion.

The difficulty of positing, as Thales did, one of the elements as ἀρχή is apparent. For if one element were to commit the greatest ἀδικία, *i.e.* alone make up all that is, then whence is the balanced (read: just) interplay of the elements which is the physical world, according to the Greek physicists? To overcome this theoretical threat, Anaximander took the leap of appealing to the imperceptible, as has been found necessary by investigators of the physical ever since. In crossing this world-historical chasm, he was carried by an observation-intuition, of the kind so often leaned on by the Presocratics: that "wherever definite qualities are perceivable, we can prophecy, upon the basis of enormously extensive experience, the passing away of those qualities." (Nietzsche 1962, *p.* 47) And thus he was lead to understand that for ἡ ἀρχή to be truly fundamental (and thus necessarily eternal) positive qualities cannot be predicated of it and that it can only be understood apophatically. Hence τὸ ἄπειρον as a terms suggests itself, primarily understood in the sense of undefined, *i.e.* lacking internal πέρατα.[9]

It is from this principal indefinite that the elements proceed to *separate out*, forming the perceptible world, whether causally or in time. Avoiding a digressionary exposition of Anaximander's physics, it is sufficient to restate that in the retraction of unity from multiplicity, he identifies τὸ ἄπειρον with τὸ ἕν as ἀρχή and the substances, conceived of as endowed with *definite* properties, with τὰ πόλλα. This is, of course, what has already been seen in the discussion of thermodynamics. Namely that, from the homogeneous κάοϛ of equilibrium, incapable of useful work, heterogeneity proceeds, *i.e.* localized properties (read: substances). Is this not ἡ γένεσις by separation? Thus is justified regarding the notion of equilibrium as giving a monistic foundation to classical thermodynamics, just as τὸ ἄπειρον as ἀρχή to Anaximander.[10] The main conceptual link (Q.E.D.) now apparent, it only remains to note secondary, though instructive, similarities in doctrines of the κόσμοϛ' beginning and end.

First note that ἀποκρίσις, signifying the elements' process of separating out of τὸ ἄπειρον, was in common use by Greek doctors for the separation of an egg from the womb, endowing Anaximander's cosmology with a quasi-organic force self-organizing, (*prima facie*) avoiding the logical need of a *Primum Movens*.[11]

[9] Note! This textbook view is not uncritizised. For an opposing view, *cf. e.g.* Gottschalk (1965) who asserts that τὸ ἄπειρον exclusively refers to spatial infinity. Nevertheless, the received view is the one that allows Anaximander to tackle the issue of plurality in Thales' doctrine, which is here taken to be his main concern.

[10] This is consonant with the larger scientific project, whose generalization and abstraction is precisely a propensity for monism. While most obvious in the universal laws of physics (*cf.* the profound monism of Quantum Field Theory, worthy of expounding elsewhere), this propensity is common to all arts called scientific, ever since Thales first measured the pyramid by proportion.

[11] This ought not to surprise, given Thales' prototypical hylozoism, wherein lies the famed

(Guthrie 1962, *p.* 94) This is the question of how κόσμος arises out of κάος[12], to which thermodynamics provides a similar answer: The equilibrium, though theoretically monistic, is not a monolith, instead predicated of a system's components in aggregate. Again considering the water bath, in which each H^2O-molecule moves ceaselessly: when in inequilibrium, there is an average tendency to this motion, *e.g.* when the warm water disperses; in equilibrium, however, the motion is random, *i.e.* though in principle predictable, on average lacking a preferred direction. There is thus nothing principally stopping the spontaneous emergence of order from equilibrium — *e.g.* the spontaneous formation of distinct hot and cold regions in the bath, by the chance separation of molecules with high kinetic energy from those with low — except for immense improbability.[13] Thus a *Primum Movens* is again avoided, by self-organizing inherent to the system.

Secondly, note the eschatology implicit in Simplicus' description:

> ἐξ ὧν δὲ ἡ γένεσίς ἐστι τοῖς οὖσι, καὶ τὴν φθορὰν εις ταυτὰ γίγνεθαι κατὰ τὸ χρεὼν.
>
> Things perish into those things out of which they have their being, as is due.

Immediately following the permanence of ἡ ἀρχή and the observed corruption of substances, this implies an end-time when the κόσμος again perishes into τὸ ἄπειρον, from which it once separated out. In fact, Aëtius writes:

> (*Aëtius A14*) Ἀναξίμανδρος δ' ὁ Μιλήσιός φησι τῶν ὄντων τὴν ἀρχὴν εἶναι τὸ ἄπειρον· ἐκ γὰρ τούτου πάντα γίνεσθαι καὶ εἰς τοῦτο πάντα φθείρεσθαι· διὸ καὶ γεννᾶσθαι ἀπείρους κόσμους, καὶ πάλιν φθείρεσθαι εἰς τὸ ἐξ οὗ γίγνονται.
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> Anaximander of Miletius says that the first principle of existing things is the Boundless [τὸ ἄπειρον]; for from this all come into being and into it all perish. Wherefore innumerable worlds are brought to birth and again dissolved into that out of which they came.[14]

Note the similarities with the notion of *the heat death of the universe*, as follows from the 2nd Law of Thermodynamics. That is, given enough time every system will degenerate arbitrarily close to equilibrium; the observable universe taken as

demythologization of the Milesians: the substitution of internal development for external compulsion in a self-contained cosmology.

[12] Or: how an ἀρχή is compatible with plurality (cf. Nietzche 1962, *pp.* 47*f.*)

[13] The 2nd law can hence be restated in the from given to it by *statistical* thermodynamics: "Every system left to itself will, on the average, change toward a state of maximum probability", also giving a new definition of equilibrium. (Newton Lewis, *et al.* 1961. *p.* 92; *state* in place of *condition*.)

[14] Translation taken from Guthrie (1962), *p.* 100. An discussion of the ἄπεροι κόσμοι (*innumerable worlds*) can be found in ibid. *pp.* 106–15. For the present argument, it is sufficient to acknowledge that classical thermodynamics concerns itself only with this one present world.

a whole not excepted. Then only the homogeneity of χάος in equilibrium will remain, already identified with τὸ ἄπειρον.

When handling doctrines this far separated, theoretically and in time, it is surely futile to expect correspondence in details of either doctrine or methods. What remains to demonstrate are conceptual links, *i.e.* the insights tending to reappear throughout the history of thought, though diversely clad and towards varying ends. The existence of such a conceptual link, and nothing more, is what this article demonstrates, between Anaximander's τὸ ἄπειρον and the notion of *equilibrium* in classical thermodynamics, towards the purpose of undermining the commonly perceived singularity of scientific thought and thus its strongest claims to hegemony.

References

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