

SECTION 1

THOUGHT EXPERIMENTS
IN THE HISTORY OF
SCIENCE AND PHILOSOPHY

THOUGHT EXPERIMENTATION IN PRESOCRATIC PHILOSOPHY

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I. THOUGHT EXPERIMENTS

IN intellectual regards, *homo sapiens* is an amphibian who can live and function in two very different realms—the domain of actual fact which we can investigate in observational inquiry, and the domain of imaginative projection which we can explore in thought through reasoning. This second ability becomes crucially important for the first as well, when once one presses beyond the level of a mere *description* of the real to concern ourselves also with its *explanation*. In the history of Western thought this transition was first made, as far as we can tell, by the Greek nature-philosophers of Presocratic times. It is they who invented thought-experimentation as a cognitive procedure and—as will be seen—practiced it with great dedication and versatility.

A “thought experiment” is an attempt to draw instruction from a process of hypothetical reasoning that proceeds by eliciting the consequences of an hypothesis which, for aught that one actually knows to the contrary, may well be false. It consists in reasoning from a supposition that is not accepted as true—perhaps is even known to be false—but is assumed provisionally in the interests of making a point or resolving a conclusion.¹

In natural science, thought experiments are common. Think, for example, of Einstein’s pondering the question of what the world would look like if one were to travel along a ray of light. Think too of the physicists’ assumption of a frictionlessly rolling body or the economists’ assumption of a perfectly efficient market in the interests of establishing the laws of descent or the principles of exchange, respectively. Indeed thought experiments are far more common in science than one may think. For Ernest Mach made the sound point that any sensibly designed *real* experiment should be preceded by a *thought* experiment that anticipates at any rate the *possibility* of its outcome.² The conclusion of *such* a thought experiment will clearly be hypothetical: “If the experiment turns out X-wise, we shall be in a position to conclude....” There is good reason to see thought

experimentation as an indispensably useful accompaniment to actual experimentation.³

To us moderns, brought up on imaginative childrens' nursery rhymes ("If wishes were horses, then beggars would ride") and on obvious adult fictions, this sort of belief-suspensive thinking seems altogether natural. It takes a logician to appreciate how complex and sophisticated thought experimentation actually is. What it involves is *not* simply the drawing of an appropriate conclusion from a given fact; rather, it exploits the higher-level consideration that a particular thesis (be it fact or mere supposition) carries a certain conclusion in its wake.

It is thus interesting to note that the use of thought experimentation in philosophy is as old as the subject itself. For—as this brief discussion will endeavor to substantiate—it was already a prominent instrumentality in the thought of the Presocratic nature-philosophers of ancient Greece who launched the philosophical enterprise on its way. The present discussion is, accordingly, a small contribution towards that yet undeveloped discipline, the history of modes of argumentation and reasoning.

II. THALES OF MILETUS

Thought experimentation is *explanatory* in character when it inheres in a line of reasoning of the form: "*X* is hard to account for, but if we assume that *P*, which we certainly don't know but which is not inherently implausible, then we obtain a perfectly good explanation of *X*." This projection of a conjectural reason in the interests of explanatory understanding represents a perfectly sensible use of thought experimentation, and actually affords its very oldest use in the philosophical domain. For this sort of explanatory use of thought experimentation was already used by Thales of Miletus (b. ca. 620 B.C.), the first of these Presocratic nature philosophers. As we learn from Aristotle and his followers:

[Thales held that the flooding of the Nile occurs because] "the Elesian winds, blowing straight on to Egypt, raise up the mass of the Nile's water through cutting off its outflow by the swelling of the sea coming against it." (Aetius IV, 1, 1; Kirk & Raven, p. 77.)⁴

[Thales taught] "that the earth floats on the water, and that it stays in place though floating like a log or some other such thing..." (Aristotle, *De Caelo*, B13, 294a28; Kirk & Raven, p. 87.)

[Thales and Hippon] declared it [the *psyche*] to be made of water, apparently being persuaded by considering seeds, which are all moist. (Aristotle, *De Anima*, A 2, 405 b1; Kirk & Raven, p. 90.)

This sort of use of thought experimentation in the context of explanatory conjectures answers to the following pattern:

METHOD NO. 1 (Explanatory Conjectures)

— It is to be shown that *P* is the case (where it has not yet been established whether *P* or not-*P*).

- Assume—as “thought experiment”—that *P* is the case (which is not inherently implausible).
- Explain *Q* on the basis of this assumption, where *Q* is something patently true which we could not readily explain otherwise.
- Hence maintain that *P*.

The reasoning attributed to Thales throughout the preceding examples illustrates exactly this pattern of thought. Take the case of the position of the earth as a body that remains fixed on its place under the canopy of the heavens:

- To show: the earth floats on water (like a log).
- Assume this to be so, that is, suppose that the earth floats (like a log) on a large body of water.
- Note that this supposition will naturally explain the earth's remaining in its place in nature (and does so at least as well as any available alternative).
- Therefore: we are justified in claiming that the earth floats on water (like a log).

Again, consider the case of the *psyche*, the principle of life, regarded as that which enables living things to be living, and which all living things thus have to have in common. Here we have:

- To show: that the *psyche* is made of water.
- Assume this to be so, that is, suppose that the *psyche* is made of water.
- Note that this supposition that the *psyche* is made of water naturally explains why all seeds both have moistness in them and need water to develop.
- Therefore: we are justified in claiming that the *psyche* is made of water.

The Etesian winds case can also clearly be accommodated by the same overall pattern.

This positive and productive use of thought experiments for explanatory purposes in contexts of what ultimately came to be known as “hypothetico-deductive” reasoning represents their oldest and no doubt most familiar employment.

IV. ANAXIMANDER OF MILETUS

One of the most common uses of explanatory thought experiments proceeds by way of *analogy*. For example, in discussing why Thales' younger contemporary Anaximander of Miletus (b. ca. 610 B.C.), maintained that the earth is at the world's center, Aristotle credits him with reasoning: “[T]hus if the earth now stays in place through the operation of a force, it too comes together at the center by being carried there because of the vortex” (*De Caelo*, B 13, 295a7; Kirk & Raven, p. 127). Here we clearly have the reasoning: “In vortices, objects tend to the center; let us suppose the

world to be vortex-like; clearly this would explain that a large solid object like the earth would come to be positioned at the center." The thesis being supported by means of the analogy at issue is clearly being argued by the same method of explanatory thought-experimentation that we have been considering in the context of Thales.

However, in Anaximander we also find another, negatively demonstrative use of thought experimentation that is quite different from such explanatory employment. Thus consider the following justification for Anaximander's contention that "the earth stays aloft, held up by nothing, but remaining in place on account of its similar distance from all things" (Hippolytus, *Refutatio haeresium*, 1, 6, 3. Kirk & Raven, p. 134):

"It stays still because of its equilibrium. For it behooves that which is established at the center, and is equally related to the extremes, not to be borne one whit more either up or down or to the sides." (Aristotle, *De Caelo* B13, 295b10; Kirk & Raven p. 134.)

The reasoning thus takes the line that if the earth were not at the center, then it would eventually succumb to a tendency to move it further in one direction or another, and so would not have a stably fixed and firm position at all. This use of thought experimentation exhibits the following sort of structure:

METHOD No. 2 (Negatively Demonstrative Reasoning)

- To be shown that P (where we do not yet know whether P or not- P).
- Assume—as "thought experiment"—that not- P .
- Deduce Q on the basis of this assumption, where Q is some patently false thesis.
- Hence maintain that P .

This negatively demonstrative employment of thought experiments may be characterized as their *refutatory* use. It is based on the well-known principle of indirect or "apagogical" reasoning that concludes negatively where a correlative positivity entails a false consequence. This reasoning is aptly characterized in Baumgarten's *Logica* as "*demonstratio falsitatis alicuius propositionis ex sequentibus ex illa falsis*" (sect. 691).

This sort of recourse to thought experimentation also recurs in the following remarks of Aristotle's regarding Anaximander:

Belief in the *apeiron* ("the unlimited") would result for those who consider the matter... [*inter alia*] because only so would generation and destruction not fail, if there were an infinite source from which coming-to-be is derived. (*Physics*, Bk. Gamma, 4; 203b15; Kirk & Raven, p. 112.)

The derivation of a patently false conclusion (the termination by this time of all natural process) from an assumption of the initial premiss—that the source of natural process is something finite—is taken to establish the falsity of that premiss.

Again, Aristotle attributes to Anaximander the following reasoning for holding that the composition of the *apeiron* is something different from the four elements:

They [the four elements] are in opposition to one another—air is cold, water moist, [earth dry,] and fire hot—and therefore if any one of them were itself the infinite *apeiron*, the others would already have been destroyed. (*Physics*, Bk. Gamma, 5; 204b22; Kirk & Raven, p. 112.)

Clearly what we have here is once more the derivation of a patently false conclusion ("There is only one 'element' in nature; the rest have vanished long ago") from an assumption of the initial premiss—that one of the elements is itself to be identified with the inexhaustible *apeiron*. Here, exactly as in the preceding case, Aristotle attributes to Anaximander a line of reasoning which derives a patently false conclusion from the hypothetical assumption of the thesis whose falsity is to be established, and thus proceeds by way of a thought experiment.

Another example is present in the following passage:

Further he [Anaximander] says that in the beginning man was born from creatures of a different kind; because other creatures are soon self-supporting, but man alone needs prolonged nursing. For this reason he would not have survived if this [present one] had been his original form. (Pseudo-Plutarch, *Stromata*, 2; Kirk & Raven, p. 141.)

Here the negatively probative use of thought experimentation is once more clearly at work. Our sources indicate that this refutatory use of thought experiments was a favorite method of Anaximander's.

IV. THE PYTHAGOREANS

In the school of Pythagoras of Samos (b. ca. 570 B.C.), the negatively probative mode of hypothetical reasoning came to be transmuted into a formal mathematical method of proof—the mode of demonstration that has come to be known as *reductio ad absurdum* argumentation. It is based on the following line of reasoning:

METHOD NO. 3 (*Reductio ad Absurdum*)

- To be demonstrated that *P*.
- Assume—as "thought experiment"—that not-*P*.
- Deduce an outright contradiction from this assumption (this is generally effected by deducing *P* itself).
- Hence establish *P*.

The notorious proof of the incommensurability of the diagonal of a square with its sides—the great Pythagorean secret for whose betrayal Hippasus of Metapontium was, according to tradition, expelled from the Pythagorean school (and perhaps even drowned at sea)—was accomplished by just this device. It remains to this day the standard way of establishing the irrationality of the square root of two—one assumes the working hypothesis and

derives a contradiction. *Reductio* clearly represents a further development in the use of thought experiments—the transmutation of the negativity-productive mode of thought experimentation into a formal method of mathematical proof.

V. XENOPHANES OF COLOPHON

Xenophanes of Colophon (b. ca. 570 B.C.) also resorted to the explanatory use of thought experiments:

Xenophanes thinks that a mixing of the earth with the sea is going on, and that in time the earth is dissolved by the liquid. [Earlier there was a reverse phase of solidification of the sea.] He says that he has proofs of the following kind: shells are found inland, and in the mountains and in the quarries of Syracuse he says that an impression of a fish and of seaweed can be found, while an impression of a bayleaf was found in Pharos in the depth of the rock, and in Malta flat shapes of all marine objects. These, he says, were produced when everything was long ago covered with mud, and the impression was dried in the mud. (Hippolytus, *Ref.* I, 14, 5; Kirk & Raven, p. 177).

This passage clearly shows that Xenophanes sought to substantiate his doctrine of alternative phases of solidification and dissolution through the use of thought experiments by way of explanatory conjectures.

However, Xenophanes also introduced an important innovation. He inaugurated a style of *sceptical* use of thought experimentation. The salient thesis of Xenophanes affords the classical instance of this sort of reasoning:

But if cattle and horses or lions had hands, or could draw with their hands and do the works that men can do, then horses would draw the forms of the gods like horses, and cattle like cattle, and they would make their bodies such as they each had themselves. (Kirk & Raven, p. 169, fragment 15; Clement, *Stromata*, v, 109, 3.)

This style of reasoning may be depicted as follows:

METHOD NO. 4 (Sceptical Thought Experimentation)

- Things being as they are, we incline to accept that *P* must be true.
- But suppose—by way of a “thought experiment”—that our situation were appropriately different (as *mutatis mutandis* it well might be).
- Then we would not accept *P* at all, but rather *P'*, which is incompatible with *P*.
- Hence we aren't really warranted in our categorical acceptance of *P* (seeing that, after all, this is merely a contingent aspect of our particular, potentially variable situation).

What we have here is a resort to thought experimentation as an instrumentality of thought that is powerfully sceptical in its impetus.

Consider, for example, the following argument presented by Xenophanes:

If god had not made yellow honey, men would consider figs far sweeter. (Kirk & Raven, p. 180, fragment 38.)

The reasoning of this last passage answers to the pattern:

1. Things being as they are, honey is "the sweetest thing in the world"—the very epitome of sweetness.
2. But suppose that honey didn't exist.
3. Then figs would be the sweetest thing we know of, so that *they* would be the epitome of sweetness.
4. Hence we should not maintain that honey is actually the epitome of sweetness; it merely happens to be the sweetest thing we happen to know of.

This argumentation clearly instantiates the procedure of Method No. 4. Xenophanes repeatedly employed this general technique to support his deeply sceptical position to the effect that:

No man knows, or ever will know, the truth about the gods and about everything I speak of: for even if one chanced to say the complete truth, yet one knows it not. Seeming is wrought over all things. (Frag. 34; Kirk & Raven p. 179.)

The very formulation of the position reflects the use of the thought experiment: "Suppose even that we asserted the full truth on some topic. The fact still remains that we would not be able to identify it as such." In this way, Xenophanes relied on thought experiments to establish the relativity of human knowledge, a device that was later to prove a major armament in the arsenal of the sceptics.

VI. HERACLITUS OF EPHEBUS

Of all the Presocratics, however, it was Heraclitus of Ephesus (b. ca. 540) to whom thought experimentation came the most naturally. In his thought, the projection of "strange" suppositions is a prominent precept of method:

If one does not expect the unexpected, one will not make discoveries [of the truth], for it resists discovery and is paradoxical. (Frag. 18/7; Burnet, p. 133; Kirk & Raven, p. 195.)⁵

Sometimes, Heraclitus' epigrams have the lucid pungency of proverbial wisdom:

[Offered the choice,] donkeys would choose straw rather than gold. (Frag. 9/51; Burnet p. 137.)

A nice thought experiment this—who, after all, ever did, or would, offer gold to a donkey!? Here, then, we have a Xenophanes-reminiscent argument for a Xenophanes-reminiscent relativism.

Frequently, however, we find Heraclitus proceeding to earn his nickname of "the obscure." The following thought experiment is an example:

If all things were turned to smoke, the nostrils would distinguish them. (Frag. 7/37; Burnet, p. 136).

It is not all that clear just what we are to make of this. But one construction is that we here again have a sceptical line of thought akin to the delibera-

tions of Xenophanes: "Were all things smoky, the information we could obtain about them would be limited to what we can learn by smelling. Reality thus eludes the senses—and accordingly our knowledge as well. For our information about things is limited to their sensory aspect alone, and sense experience provides only information geared strictly and solely to the correlatively sensory aspect of things."

Heraclitus was also given to thought experimentation of the following analogical format:

METHOD NO. 5 (Analogical Thought Experimentation)

- Suppose someone did *X*.
- Then (one would say that) he is *F* (mad, bad, or the like).
- But doing *Y* is just like doing *X* in *F*-relevant regards.
- Therefore (one should also say that) someone who does *Y* is *F*.

This analogy-exploiting, critical use of thought experimentation is clearly something very different from its explanatory use as exemplified in Thales.

Examples of this are as follows:

They vainly purify themselves by defiling themselves with blood, just as if one who had stepped into the mud were to wash with mud. Anyone who saw him doing this would deem him mad. (Frag. 5/129 & 130; Burnet, p. 145; Kirk & Raven, p. 211.)

For if it were not to Dionysius that they make the procession and sing the phallic hymn, the deed would be most shameless.... (Frag. 15/127; Burnet, p. 141; Kirk & Raven, p. 211.)

And they pray to these statues as though one were to talk to houses, not realizing the true nature of gods or demi-gods. (Frag. 5/126; Burnet, p. 141; Kirk & Raven, p. 211.)

All of these passages exemplify the analogical use of thought experimentation described in the preceding paradigm.

Thought experimentation of this sort is evidently a useful tool for a thinker who maintains the Heraclitean thesis that:

To God all things are fair and good and right, though men hold some things wrong and some right. (Frag. 102/61; Burnet, p. 137.)

And so Heraclitus repeatedly uses thought experiments to expose what he saw as deficiencies in contemporary religious practice, continuing the critique of early Greek religiosity launched by Xenophanes.

Heraclitus also employed thought experiments to argue that if reality differed in a certain respect, things could not be as they are in other, correlative respects:

If the sun did not exist, it would (always) be night (despite all the other stars). (Frag. 99/31; Burnet, p. 135.)

Or again:

The learning of many things teaches not understanding, else would it have taught Hesiod and Pythagoras, and again Xenophanes and Hekataios. (Frag. 401/16; Burnet, p. 134.)

These thought experiments answer to the patterns of Method 2 above.

We learn from Aristotle's *Eudemian Ethics* (H1, 1235a25) that:

Homer [*Iliad*, XVIII, 107] was wrong in saying "Would that strife might perish from among gods and men" for there would be no musical scale unless high and low existed, nor living creatures without male and female, which are opposites [and all things would be destroyed]. (Frag. 22/43; Burnet, p. 136; Kirk & Raven, p. 196).

Here again we have a straightforward instance of Method 2, a refutatory (negatively probative) use of hypothetical reasoning. This method too was apparently a favorite of Heraclitus!

Another, quite new style of characteristically Heraclitean thought argumentation is also prominent in his thought:

METHOD NO. 6 (Value Dominance Argumentation)

- Assume—by way of a "thought experiment"—that *X* did not exist.
- Establish that then we could not even form the conception of *Y*, seeing that *X* and *Y* are correlative concepts (hot/cold, cause/effect, etc.).
- Conclude that therefore *Y*'s place in the overall scheme of things cannot be less important or valuable than *X*'s.

Heraclitus uses this sort of reasoning repeatedly to argue for the mutual dependence of opposites:

Men would not have known the name of justice if these things [that people deem unjust] were not. (Frag. 23/60, Burnet, p. 137).

And again:

It is not good for men to get all they wish to get. It is sickness that makes health pleasant; evil, good; hunger, satiety; weariness, rest. (Frag. 111/104; Burnet, p. 140.)

Presumably, in these cases the point is not that there would be no *instances* of healthiness or justice in a realm where *instances* of the opposite (sickness and importance) could not be found. The point, rather, is that there just is not work for the contrast-conception at issue to do in such a realm, a circumstance that would render its introduction pointless.

This style of argumentation is evidently tailor-made for a thinker who sought to maintain that the mutual interdependence of opposites establishes the co-equal importance of the conceptions at issue:

Men do not know how what is at variance agrees with itself. It is an attunement of opposite tensions, like that of the bow and the lyre. (Frag. 51/45; Burnet, p. 136.)

Here, thought experimentation can be used to show that in removing the tension, we destroy also the very object that is at issue.

As these considerations indicate, Heraclitus was a devoted practitioner of thought experimentation, given to extracting far-reaching conclusions from fact-contravening hypotheses. The circumstance that we learn useful lessons about what is by assuming what is not is clearly congenial to a thinker who maintains that "Nature loves to hide" (Frag. 123/10; Burnet, p. 133). Heraclitus was deeply persuaded that it is ultimately by mind (which can contemplate what is not) rather than by vision (which can only contemplate what is) that the deepest truths are to be learned. This "Heraclitean" view of the matter has much to be said for it, and anyone who shares it is bound to think highly of thought experimentation as a cognitive instrument of substantial value.

VII. CODA

In concluding, let me reemphasize that thought experimentation is an important and flexible intellectual resource that has many varieties and allows very different sorts of employment. Our survey has shown the extent to which this cognitive resource was pioneeringly employed by the nature-philosophers of Presocratic Greece as a salient methodological device for developing their ideas. Though their interest was in reality, their deliberations about it placed extensive reliance on the use of problematic hypotheses in thought experimentation. Interestingly enough, "fiction" first made its way into Greek thought not in the setting of *belles lettres*, but in that of natural philosophy. For the Presocratics, conjecture was not a creative activity pursued for its own speculative interest, but an instrumentality for the investigation of the real.

Someone might perhaps be tempted to think that the success which the Greek nature-philosophers had with *thought* experimentation exerted a dampening influence on their development of *real* experimentation. But this would be both unjust and inappropriate. For if the perspective attributed to Mach at the outset of this discussion is anything like correct, the development of thought experimentation is in fact an essential *preliminary* to the development of real experimentation as such.

The history of different styles of argumentation and reasoning has yet to be written. When it is, the Presocratics are clearly destined to obtain a good deal of credit. For the *methods of thought* they pioneered have been no less important and influential than then *substantive theories* they introduced.

NOTES

1. Sometimes thought experimentation is taken to call for a supposition that is known or believed to be false. But this is in fact only one, particularly strong form of thought experiment. When the detective reasons, "Now suppose that the butler

did it...," at some early stage of the investigation, his reasoning is clearly not unraveled as a thought experiment if it eventually turns out that he indeed did so.

2. "Ueber Gedankenexperimente" in *Erkenntnis und Irrtum* (Leipzig, 1906), pp. 183-200 [see p. 187].

3. For an interesting discussion of scientific thought experiments see T. S. Kuhn, "A Function for Thought Experiments in Science," in Ian Hacking (ed.), *Scientific Revolutions* (Oxford, 1981), pp. 6-27.

4. In general, the texts are drawn from G. S. Kirk and J. E. Raven, *The Presocratic Philosophers* (Cambridge, 1957). For the exception to this rule see footnote 5.

5. The fragments of Heraclitus are here numbered in the order: Diels/Bywater. I have generally adopted Bywater's translation as improved by John Burnet, *Early Greek Philosophy* (London, 1892; 4th ed. 1930). But see also G. S. Kirk, *Heraclitus: The Cosmic Fragments* (Cambridge, 1954).