Seneca's Scientific Fictions: Models as Fictions in the *Natural Questions*

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ABSTRACT

Seneca's Naturales Quaestiones *explains the causes and functional mechanisms of natural phenomena, from common sights like rainbows to exotically out-of-reach ones like comets. The vividness with which he brings them all within the reader's grasp is certainly a literary feat as much as a scientific one, but the rhetorical power of his explanations does not cost them their epistemological validity. Analyses drawn from current philosophy of science reveal elements of fictionality omnipresent in scientific models and experiments, suggesting an approach to Seneca's 'scientific fictions' not as failed analogies but as a sophisticated expansion of the tradition of analogical scientific explanation.*

Keywords: Seneca (the Younger); *Naturales Quaestiones* / *Natural Questions*; ancient science; Roman science; rhetoric; fictionality; scientific models; fictions in science

I INTRODUCTION[1]

Early in Seneca's *Natural Questions*, the reader is confronted with a dismaying image: a roomful of diners, crazed by their self-perpetuating search for luxury and novelty, carefully observe the asphyxiation of a mullet in a glass vessel.[2] The dying fish becomes a spectacle of transient beauty, as it turns first one colour and then another until its eventual demise:

> quo peruenere deliciae! iam pro putrido his est piscis occisus. 'hodie eductus est.' 'nescio de re magna tibi credere. <ipsi oportet mihi credam >.[3] huc adferatur, coram me animam agat.' … illa audiebamus: 'nihil est melius saxatili mullo,' at nunc audimus: 'nihil est moriente formosius. da mihi in manus uitreum in quo exultet <et> trepidet.' ubi multum diuque laudatus est, ex illo perlucido uiuario extrahitur. tunc, ut quisque peritior est, monstrat: 'uide quomodo exarserit rubor omni acrior minio! uide quas per latera uenas agat! ecce sanguineum putes uentrem! quam lucidum quiddam caeruleumque sub ipso tempore effulsit! iam porrigitur et pallet et in unum colorem componitur.'

[1] For their many strengthening suggestions, sincere thanks to Daryn Lehoux, audiences at Cornell University and the University of Colorado at Boulder, and the anonymous readers of the *Journal*. Any errors that remain are my own.

[2] On the moralizing aspects of this passage see Williams 2012: 76–9; for a brief note on the ichthyological plausibility of the scene, see Alexander 1955: 192–3. I follow the revised ordering of the books suggested by Hine (3, 4a, 4b, 5, 6, 7, 1, 2) according to which this passage appears in the original first book of the work; the rationale behind the order is described at Seneca 1996: xxii–xxv; Seneca 2010: 1–2; Williams 2012: 12–14. However, in this and what follows, the argument does not crucially hinge on the ordering of the books.

[3] The text is problematic here; some MSS have *credas*, others *credere*. Hine prints 'ipse oportet †me credas†' in his edition, suggesting the emendation above (combining readings of Madvig and Erasmus) as an attractive possible solution at Hine 1996: 53–4. In any case the importance of autopsy is stressed.

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> How far their voluptuousness has come! Now for them a dead fish is as good as rotten. 'It was caught today.' 'I'm not sure I trust you on this important question; I had better trust myself. Have it brought here, let it give up the ghost in front of me.' … We used to hear, 'nothing is better than a rock mullet,' but now we hear, 'nothing is lovelier than a dying one. Hand me a glass container where it can flop around and quiver.' When it has been long and thoroughly praised, it is extracted from that transparent enclosure. Then each demonstrates the extent of his experience: 'See how redness is kindled on it, brighter than any cinnabar! See the veins it brings out along its sides! Look, you would think its stomach was bloody! How bright and blue it glowed at its very temples! Now it is stretching out and going pale and settles into one colour.' (3.18.3–4)[4]

To be sure, the moral dimensions of Seneca's complaint about the scene, which have been much discussed elsewhere, are central to its interpretation within the work as a whole.[5] These 'degenerate diners', in Williams's memorable phrase,[6] are no longer happy merely to consume this fish (itself a symbol of luxury) but now insist on the further spectacle of seeing it die in front of them; their appetites are indeed to be condemned.[7] The spectacle is itself somehow destructive to its witnesses, as Williams observes: 'in their perverse fixation on the details of death by controlled suffocation they themselves are seemingly constricted in their own narrow confinement.'[8]

However, there is at the same time an epistemological problem here, and it is on this that I will focus. The diners' insistence on witnessing the mullet's death for themselves turns them into parodic empiricists.[9] They demand autopsy to settle the jejune question of the fish's freshness: '"It was caught today." "I'm not sure I trust you on this important question. I had better trust myself."' The fish is trapped in a transparent enclosure (*perlucido uiuario*): it is perfectly visible, so that the diners can see every shade of its transitioning colours. They see everything without distortion or obstruction, but at the same time they see nothing of value.

Contrast this vignette to a later act of viewing described near the end of the work (in what I take to be the penultimate book), where a distorted view paradoxically yields greater truths:

> litterae quamuis minutae et obscurae per uitream pilam aqua plenam maiores clarioresque cernuntur; poma formosiora quam sunt uidentur, si innatant uitro; sidera ampliora per nubem aspicienti uidentur, quia acies nostra in umido labitur, nec adprehendere quod uult fideliter potest.
>
> Letters, as small and indistinct as you like, are perceived as larger and clearer through a glass ball full of water. Fruits appear lovelier than they are, if they are swimming in glass; the stars appear fuller to one who looks at them through cloud, since our sight diffracts in moisture, and cannot faithfully apprehend what it is after. (1.6.5)

The water-filled glass sphere magnifies crabbed writing to make its meaning clear; artificially magnified fruit possesses greater beauty than its natural state allows; even the

[4] Translations are my own.
[5] Lehoux 2012: 100–2; Williams 2012: 75–80.
[6] Williams 2012: 75.
[7] For the association of the mullet with luxury see Pliny, *NH* 9.67. A complete bibliography of death as spectacle in ancient Rome is not my purpose here, but references of particular relevance include Barton 1993, where this incident is referred to at p. 60; Kyle 1998: ch. 6; Williams 2012: 77: 'So at 3.17–18, those who delight in the shifting hues of the dying mullet act unnaturally from the Senecan viewpoint, not just in their luxury appetites of both eye and stomach but also in their perverse interest in death as play or theater.'
[8] Williams 2012: 79.
[9] For background on contemporary medical empiricism see von Staden 1994. For a thorough consideration of the rôle played by experiment in earlier Greek medicine see Edelstein 1967; von Staden 1975.

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stars become, curiously, more visible when seen through cloud. Mediated, distorted viewing can serve as a route to genuine understanding, as long as the viewer understands the distortion through which he is viewing, and Seneca stands by to teach him how to do so.

Seneca has set himself this task throughout the *Natural Questions*: to enable his reader to truly understand a whole spectrum of natural phenomena, even those which are difficult or impossible to observe directly. In contemporary scholarship, the toolbox Seneca gives his reader to perform this task has traditionally been equipped with a single instrument: analogy, in which one thing is compared to another with similar attributes. A common example is the assimilation of the human body to the earth or the cosmos as a whole in its principles of ordering, its inclusion of veins beneath the surface, its liability to decay, and so forth.[10]

The *locus classicus* for analogy as a tool of ancient philosophy and science is Lloyd's *Polarity and Analogy*, which thoroughly analyses the use of analogy in archaic Greek literature, the pre-Socratic philosophers, the Hippocratic corpus, and Plato and Aristotle. So successful was Lloyd's explanation that it still forms the core of recent extended analyses of Seneca's scientific reasoning by Armisen-Marchetti and Williams.[11] Lloyd's original definition of analogy is quite broad, but many subsequent approaches concentrate particularly on analogy as a way of moving from visible things to hidden ones.[12] The aim of moving *ex apertis in obscura* of course has particular relevance for a work that so often takes flight to the unreachable parts of the cosmos.[13] Both Armisen-Marchetti and Williams emphasize that not only did Seneca draw on a long-established tradition of reasoning by analogy, he also did not invent many of the specific analogies he refers to. Armisen-Marchetti provides a useful catalogue of Seneca's analogies, including the language he uses to link one component to another (*quemadmodum uelut*, *sicut*, etc.) and their antecedents when these are known.[14]

Analogy is, of course, very often the right tool for the job, and very often it is the tool Seneca employs. However, I will suggest that Seneca's accounts of the complexities of seeing can point the way towards a more thorough understanding of how his 'scientific' and rhetorical goals intertwine. The dying mullet, though it can be seen plain as day in its *perlucidum uiuarium*, turns out not to be a source of the most valuable kind of knowledge; instead the reader must take the long way around, developing the analytical skills needed to extract true knowledge from objects that are harder to observe. Analysis of Seneca's epistemological structures can likewise benefit from taking the long way around: recent developments in the philosophy of science have greatly enriched our

[10] Seneca uses this analogy often (3.15.1, 3.15.4, 3.16.2, 6.3.1, etc.), and he is far from unique in using it: for example, see Lloyd 1966: 232–72; Taub 2003; Kullmann 2010: 70ff.; Williams 2012: 62, 174, 241–2.

[11] Armisen-Marchetti 1989; 2001; Williams 2005; 2007; 2012.

[12] In Lloyd's original definition, analogy encompasses 'any mode of reasoning in which one object or complex of objects is likened or assimilated to another', though he does specify that in general one of the two similar objects is less well-known than the other (Lloyd 1966: 175). Armisen-Marchetti, following Blanché, differentiates three types of analogy: the equality of relationships, particularly mathematical ones (a:b::c:d) referred to by Euclid as *analogia* (e.g. 5.21); a resemblance of form or substance where quantitative relationships are indefinable; and a 'subjective' analogy which should not properly be considered a logical construction at all (Blanché 1973: 177–85; Armisen-Marchetti 1989: 284). These three types of analogy are closely mirrored in a series of examples Armisen-Marchetti elsewhere draws from Aristotle (Armisen-Marchetti 2001: 162–3). In the *Nicomachean Ethics*, Aristotle uses the word *analogia* strictly to define geometrical proportion (1131b10–1134a28.). In the *Poetics* he proposes the possibility that analogy might also apply between qualities, e.g. old age is to life as evening is to day (1457b16–23). In the *Rhetoric*, something comparable to the 'subjective' analogy appears in the case of a metaphorical transfer of meaning between distant objects, which may be carried out by a poet as well as by a philosopher (1412a11–13: δεῖ δὲ μεταφέρειν, καθάπερ εἴρηται πρότερον, ἀπὸ οἰκείων καὶ μὴ φανερῶν, οἷον καὶ ἐν φιλοσοφίᾳ τὸ ὅμοιον καὶ ἐν πολὺ διέχουσι θεωρεῖν εὐστόχου …).

[13] Armisen-Marchetti 2001: 159; Williams 2012: 232–79. Cf. *De otio* 5.5.

[14] Armisen-Marchetti 1989: 287–95. For the originality of Seneca's images generally, see ibid.: 223–40.

understanding of scientific models, and in particular the productive use of fictions as scientific models. I will argue that Seneca self-consciously uses the same kinds of approximations as are now acknowledged to inhere in scientific models to create his 'scientific fictions': detailed, compulsively visualizable descriptions whose vividness evokes belief.

While my intention is not at all to detract from prior work on Seneca's use of analogy, expanding the set of explanatory models we apply to his work beyond analogy can help explain the Senecan passages that do not fit that mould very well.[15] Such unco-operative explanations are typically written off as 'merely' heuristic, pleasant interludes that make up in rhetorical value what they lack in scientific validity. It remains tempting to look exclusively for analogy, and to grade those analogies on the strictness of the isomorphism between known and unknown. For this highly recognizable pattern has a long history of usage in ancient philosophical literature: from the pre-Socratics, to Plato's apprehension of the Forms from their worldly analogues, to Aristotle (who uses the word itself), to Stoic ideas of resemblance by similitude and by analogy. Armisen-Marchetti argues, indeed, that there is 'pas de science ni même d'ébauche de science sans imagination analogique'.[16]

Seneca certainly draws on all these traditions, most of them by name. However, he is not just working in the philosophical domain, and the time he spends on such 'poetic' or 'heuristic' constructs is not just scene-setting, but an epistemological move in its own right. The *Natural Questions* is a work of great complexity and sophistication, epistemological as well as rhetorical, and it does not seem unreasonable to suppose that Seneca might be working with a richer concept of what scientific models can be and do than analogy alone allows for. Lehoux has recently argued that the *Natural Questions* relies, at least in part, on a legalistic mode of argumentation rather than what we would now refer to as a strictly 'scientific' mode.[17] From this perspective, the question of how Seneca makes the reader see what he sees becomes just as important as the logical links between steps of the progress from visible to invisible.

Contrary to the idea that the 'true, scientific, or logical' analogy and the 'merely poetic' analogy are two separate domains, the 'fictions' Seneca creates are best understood as epistemological tools in their own right. Recent work on the rôle of representation in science opens up the possibility of considering fictions as constitutive of scientific knowledge, rather than antagonistic to it.[18] As Knuuttila puts it, 'for as long as philosophy of science operated predominantly on the basis of propositions (derived from theories and models) and their fit with the data (via the procedure of testing), the question of representation did not arise'.[19] Now, by contrast, philosophers of science routinely acknowledge that scientific models involve images and other non-propositional content, and that the models themselves function although (perhaps, indeed, because) they do not perfectly match up with the qualities of the systems they describe.[20] What

[15] Some places where analogy is observed to break down are collected at Armisen-Marchetti 1989: 285; Williams 2012: 232–3.

[16] Armisen-Marchetti 2001: 162.

[17] 'Seneca gives us abundant clues in the *Naturales quaestiones* that he frequently has not just a rhetorical model, but in particular a judicial model, in mind' (Lehoux 2012: 82). In particular Lehoux cites Seneca's use of jurisprudential language and figures, his references to witnesses and evidence, and the way the arguments of each book are structured.

[18] On models as representations, see Hacking 1983; Knuuttila 2005; Hughes 1997; Humphreys 2012. Harré 1970 was an early voice in the differentiation of 'sentential' from 'iconic' models; Knuuttila 2005: 1266–9. On material models, see Norton Wise 2006; Chadarevian and Hopwood 2004. On mathematical models in antiquity, see Goldstein 2008.

[19] Knuuttila 2005: 1263.

[20] On aspects of the relationship between model and 'target' that are particularly relevant here, see Boon and Knuuttila 2011: 68ff.; Knuuttila 2005: 1260; Elgin 2009: 85; Bokulich 2009: 105–6; Morrison 2009: 111–12.

changed was not so much the practice of science itself as the way it is described; the science that has already been done admits of such revisions in its description just as much as the science that has yet to be done. Hence it should not be seen as anachronistic to shift from a view informed by twentieth-century views of scientific models as propositional constructions, to one that responds to more recent developments in philosophy of science by assigning greater primacy to other elements. This line of thought allows us to keep Seneca's arguments and his 'fictions' bound together in a coherent persuasive enterprise.

II MODELS AND MICROWORLDS

What do I mean when I say Seneca makes use of scientific models? A few examples will clarify the basic types. In structural models, there is a morphological resemblance between the 'source' and the 'target'. For example, Seneca uses a ball to model the earth, arguing that mountains are high compared to us, but not on a cosmic scale:

> quod nisi esset, non diceremus totum orbem terrarum pilam esse. pilae proprietas est cum aequalitate quadam rotunditas. aequalitatem autem hanc accipe quam uides in lusoria pila: non multum illi commissurae et rimae corii nocent quominus par sibi ab omni parte dicatur. quomodo in hac pila nihil illa interualla officiunt ad speciem rotundi, sic ne in uniuerso quidem orbe terrarum editi montes, quorum magnitudo totius mundi collatione consumitur.
>
> If this were not true, we would not say that the whole earth is a ball. The defining quality of a ball is roundness with a certain degree of uniformity. But think of the uniformity that you see in a sports ball: its seams and the cracks of its leather do not keep it from being called equal in every direction. Just as in this ball those irregularities do not obstruct its appearance of roundness, neither do towering mountains for the earth as a whole; their size is reduced to nothing in comparison to the whole world. (4b.11.2–3)

Note that the irregularities of the ball's surface are part and parcel of this model; this is not a case of the infamous 'spherical cow'.[21]

A second type of model asserts that the source functions in the same way as the target. A whirlwind's behaviour, for example, is modelled on that of an eddy in a stream:

> euenire in fluminibus solet ut, quamdiu sine impedimento feruntur, simplex et rectum illis iter sit, ubi incucurrerunt in aliquod saxum ad latus ripae prominens, retorqueantur et in orbem aquas sine exitu flectant, ita ut circumlata in se sorbeantur et uerticem efficiant. sic uentus, quamdiu nihil obstitit, uires suas effundit; ubi aliquo promuntorio repercussus est aut locorum coeuntium <angustiis> in canalem deuexum tenuemque coniectus, saepius in se uolutatur, similemque illis quas diximus conuerti aquis facit uerticem.
>
> It usually happens in rivers that, as long as they are carried along without impediment, their path is simple and straight; when they run into some rock jutting into the side of the bank, they are twisted back and turn their waters without an outlet, so that having been carried back on themselves, they are swallowed down and create a whirlpool. Likewise the wind, as long as nothing gets in its way, pours out its strength; when it is repelled by some promontory or crowded into a sloping and slender channel because of the narrowness of spaces running together, it is often turned back against itself, and makes a whirlpool similar to those which we have said are churned up by water. (5.13.1–2)

[21] This mainstay of physics humour is used as a tool to discuss representation, similarity, and categorization at Boroditsky 2001: 657.

Here the resemblance is not just a matter of the two effects looking the same; they have the same cause, and the same forces govern their motion, which is not an assertion being made about the earth and the ball.

A third type of model, used sparingly by Seneca, involves quantitative comparisons, as when the periodicity of a spring's ebb and flow is compared to the regular intension and remission of a periodic fever:

> quemadmodum quartana ad horam uenit, quemadmodum ad tempus podagra respondet, quemadmodum purgatio, si nihil obstitit, statum diem seruat, quemadmodum praesto est ad mensem suum partus, sic aquae interualla habent quibus se retrahant et quibus reddant. quaedam autem interualla minora sunt et ideo notabilia, quaedam maiora nec minus certa.
>
> Just as a quartan fever arrives punctually, just as gout appears on schedule, just as menstruation keeps its appointed day if nothing prevents it, just as birth attends its proper month, so waters have intervals in which they draw back and those in which they return. But some intervals are lesser, and notable on that account; others are longer but not less definite. (3.16.2)

Seneca's quantitative matches are usually rough like this; they are quite unlike the mathematical models used in modern laboratory science, and even unlike the more precise quantitative models used by other ancient authors like Hero of Alexandria. But they are models all the same, and it will be my purpose in what follows to examine how they work as tools of persuasion even despite their roughness.[22]

Armisen-Marchetti likewise proposes three ways an analogy can work: 'Quant à la similitude même sur laquelle repose le raisonnement par analogie, elle peut être, selon les cas, une similitude de nature … de structure … ou de fonction.'[23] She correlates these three types of similarity with explanations from Seneca: lightning is analogous in nature to fire; the earth is structurally analogous to a ball; the wind is functionally analogous to a river. Such analogies fit neatly into a syllogistic construction that allows conclusions to be extracted: in the fire-lightning analogy, for example, the premises 'fire and lightning are analogous, and fire is produced by friction or shock' yield the conclusion 'therefore lightning is produced by friction or shock'.[24]

What, then, is the relationship of what I am calling a 'model' to what has conventionally been called an 'analogy'? The comparison of the earth to a ball is quite a useful illustration of the difference, because Seneca does not just compare the two sphere-like shapes, he extracts a surprising feature of the ball — its irregularity, which is not a structural analogue for the earth in the same way that their approximate spherical shape is. The irregularities of the ball do not denote actual irregularities on the earth. If you look very closely at the ball you have chosen to represent the earth, you will see peaks and valleys that have nothing to do with those on the earth itself. So the ball is really quite a bad *structural analogy* for the earth, but it is a perfectly good *fictional representation* of it.[25] An analogy might thus best be seen as a special case of a model that actually only 'works' when all characteristics of source and target match up. This is often very useful, but it takes away the ability to make use of the differences and roughness that models more broadly considered employ, which a focus on their 'fictionality' by contrast allows.[26]

[22] Inwood (2005: 168–9) observes that by keeping these quantitative comparisons 'surprisingly abstract', Seneca is able to explain many phenomena at once.
[23] Armisen-Marchetti 2001: 160.
[24] Armisen-Marchetti 2001: 165.
[25] For a distinction between factual and fictional representations which is particularly relevant here, see Elgin 2009: 78.
[26] For example, models that admit of fictionality give us access to non-existent sources, as Elgin exemplifies by a picture of a unicorn; less exotic examples include ball-and-stick models of molecules, Bohr's model of the atom, and so forth (Elgin 2009: 78).

Indeed, Armisen-Marchetti argues that from a logician's standpoint analogy does not really qualify as a form of reasoning.[27] Analogy is flawed because of the imprecision involved with finding resemblances between one thing and another, and using those as a scaffolding upon which to reach conclusions. The logical rigor of an analogy depends, in this view, upon making the relationships between its components as explicit as possible. The best-case scenario is the kind of analogy we find in 5.6.1, in which air and wind are said to differ in the same way as a lake and a river do.[28] Even in this maximally rigorous case, however, analogy must be relegated 'au niveau de la conjecture et de l'invention'[29] rather than considered a genuine method of reasoning. The 'subjective' analogy is presented as a particularly degenerate case. Armisen-Marchetti, again referring to Blanché, defines 'l'analogie subjective — affective, mystique, ou poétique — qui laisse de côté la logique et ne relève plus que de l'intuition et de l'imagination'.[30] Armisen-Marchetti's response to this problem is to differentiate between 'heuristic' and 'demonstrative' analogies.[31] The heuristic analogy can in this view be a source of hypotheses, and can assist in extracting their implications, but it is never legitimized as a scientific tool. Even the demonstrative analogy is only allowed to reach the level of verisimilitude, not truth.[32]

She denies Senecan analogy the status of genuine reasoning not only on the grounds that Aristotle had previously rejected it as such, but also using an appeal to contemporary scientific epistemology: 'le philosophe antique et les épistemologues modernes se rejoignent dans une même défiance à l'égard du raisonnement par analogie.'[33] These constraints emerge from a particular, once-prevalent view of the relationship between analogy and hypothesis in modern science, in which the use of analogy is reserved for the construction of hypotheses, which are later demonstrated through experimental methods. However, more recent work in the philosophy of science suggests a much closer ontological and epistemological connection between models and experiments than Armisen-Marchetti allows, and the link is precisely their fictionality. Elgin observes that 'like an experiment, a work of fiction selects and isolates, manipulating circumstances so that particular properties, patterns, and connections, as well as disparities and irregularities, are brought to the fore'.[34] Boon and Knuuttila note that models, like experiments, involve the construction of a 'self-contained artificial' system that makes theoretical conjectures 'conceivable, articulated, and workable'.[35]

Rouse likewise focuses on the creation of such an artificial system: his 'laboratory fictions' depend on the conceptual construction of 'microworlds', defined as 'systems of objects constructed under known circumstances and isolated from other influences so that they can be manipulated and kept track of'.[36] This in turn allows the investigator to work within a simplified conceptual environment rather than confronting a phenomenon in all its complexity. Rouse later argued for the primacy of such experimental 'systematically intraconnected "microworlds"' in scientific discovery.[37] This conceptual structure derives its explanatory power from its robust internal connections

[27] Armisen-Marchetti 1989: 284; Williams 2012: 149–68 compares the apparent logical validity of a broader range of Senecan argumentative strategies.
[28] Armisen-Marchetti 1989: 300 describes this type of analogy as 'sous la forme d'une égalité de rapports dans laquelle les quatre termes sont explicités'.
[29] Armisen-Marchetti 1989: 284.
[30] Armisen-Marchetti 1989: 284.
[31] Armisen-Marchetti 2001: 168.
[32] Armisen-Marchetti 1989: 303.
[33] Armisen-Marchetti 1989: 302.
[34] Elgin 2009: 82.
[35] Boon and Knuuttila 2011.
[36] Rouse 1987: 101.
[37] Rouse 2009: 45.

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rather than its strict resemblance to the world it is supposed to model: that is to say, the microworld is good fiction. That it is also acknowledged to contribute to good science represents a profound change from the view of scientific activity Armisen-Marchetti appears to have in mind, in which theory (expressed through some set of symbolic propositions) is central and the experiment is only for justification.[38]

In shifting 'from justification to conceptual articulation and domain-constitution', Rouse invokes a rôle for experimentation which speaks as well to Seneca's use of references to 'experiments', even though these lie far outside the domain of what is now known as 'laboratory science'.[39] In constructing his own 'microworlds' within the text, Seneca uses references to his own experience, direct address to the reader, and detailed description of the phenomena to be observed to heighten the reader's connection to the 'experimental' events being described.[40]

These techniques are too common in the *Natural Questions* to list every case,[41] but the three are respectively exemplified by the following passages:

> primum ego tibi uinearum diligens fossor adfirmo nullam pluuiam esse tam magnam quae terram ultra decem in altitudinem pedes madefaciat.
>
> First I, a diligent digger of vines, affirm that no rain is so great as to dampen the earth beyond a depth of ten feet. (3.7.1)

> uidemus, cum fistula aliquo loco rupta est, aquam per tenue foramen elidi, quae sparsa contra solem oblique positum faciem arcus repraesentat. idem uidebis accidere si quando uolueris obseruare fullonem: cum os aqua impleuit et uestimenta tendiculis diducta leuiter aspergit, apparet uarios edi colores in illo aere asperso, quales fulgere in arcu solent.
>
> We see, when a pipe is broken somewhere, that water is squeezed out through the narrow opening; when sprayed opposite the sun, it displays a sideways rainbow. You will see the same thing happen, if you ever care to observe a fuller: when he fills his mouth with water and lightly sprinkles the clothes spread out on the stretcher, it appears that various colours are produced in that water-sprayed air, just as typically shine in a rainbow. (1.3.2)

> cum in piscinam lapis missus est, uidemus in multos orbes aquam discedere et fieri primum angustissimum orbem, deinde laxiorem ac deinde alios maiores, donec euanescat impetus et in planitiem immotarum aquarum soluatur. tale quiddam cogitemus fieri etiam in aere: cum spissior factus est sentire plagam potest; lux solis aut lunae uel cuiuslibet sideris incurrens recedere illum in circulos cogit.
>
> When a stone is cast into a pool, we see the water recede in many circles; at first the tightest circle appears, then a looser one and then other, larger ones, until the force dies out and is resolved into the surface of still waters. Let us imagine that something similar happens in air as well. When it is thickened it is susceptible to blows; the light of the sun or moon or any star, striking it, compels it to recede in circles. (1.2.2)

These examples begin to clarify the remarkable things Seneca does with the established technique of analogy. In the third passage, for example, it is clear that in one sense

[38] For consideration of the rôle played by justification in the laboratory sciences, see for example Hacking 1983; 1992.
[39] Rouse 2009: 45.
[40] Note that I am not claiming here that Seneca carried out all (or any) of the 'experiments' he describes, nor even that what I here term 'experiments' qualify as such in any strict sense, e.g. that defined in von Staden 1975: 180.
[41] Additional cases include 1.7.1, 1.12.1, 2.9.4–2, 2.16.1, 2.27–8, 3.20.3, 4b.9.1, 6.19.1, and many others besides.

Seneca is using an argument from analogy; his wording makes this obvious ('tale quiddam cogitemus fieri etiam'). In another sense, however, he is applying quite a different persuasive technique: he simulates a viewing experience shared with the reader (*uidemus*, *cogitemus*), turning the text itself into a kind of virtual experimental space, realized by his vividly detailed description. He is not satisfied to assert that water currents and air currents sparked by a point impact have the same shape. Instead he sets the water flowing before our eyes, lets the ripple subside, and shifts the quieted substrate to air as smoothly as the ripple died down: now it is the impact of a ray of light that strikes the substrate, and the 'halo' of a star that ripples outward.

Seneca creates opportunities for the reader to become involved in this kind of experimental theatre throughout the text. Sometimes the experiments take place in the far-off territory of Williams's 'cosmic vision'; sometimes they are earthbound and material. For example, explaining why some subterranean waters are naturally hot, Seneca appeals to a familiar man-made apparatus which becomes an impromptu laboratory:

> facere solemus dracones et miliaria et complures formas in quibus tenui aere fistulas struimus per decliue circumdatas, ut saepe eundem ignem ambiens aqua per tantum fluat spatii quantum efficiendo calori sat est. frigida itaque intrat, effluit calida.
>
> We are accustomed to make 'serpents' and tall chutes and a great many shapes in which we form narrow bronze pipes, spiralling downward, so that water going around the same heat-source many times flows through only as much space as is needed for creating heat. And so it goes in cold, and flows out hot. (3.24.2)

Seneca highlights the ubiquity of his 'experimental' devices — persuasion depends not on emphasizing the exotically high technology of laboratory equipment, but on reinforcing the sense that the reader experiences this phenomenon every day — and he can see it happen right in front of him in the text.

Williams refers to Seneca's 'domesticating use of analogy', by which he explains something unfamiliar through something familiar, something horrifying and sublime through something from a lower register.[42] In this view, 'domestication' serves to highlight the Stoic unity of the different parts of the world, much as Empedocles had done before to draw attention to his own brand of cosmic unity.[43] This must surely be true. But here I want to focus not so much on the extra-textual philosophical purposes Seneca might have had in mind as on the remarkable effect he achieves within the text itself: he *makes the experiment happen* before the reader's eyes. He does this repeatedly: for example, in his explanation for why certain types of water can float heavy objects on the surface, the reader is once again directed to imagine himself performing the experiment:

> quamcumque uis rem expende et contra aquam statue, dummodo utriusque par sit modus: si aqua grauior est, leuiorem rem quam ipsa est fert et tanto supra se extollet quanto erit leuior; [grauiora descendent] at si aquae et eius rei quam contra pensabis par pondus erit, nec pessum ibit nec extabit, sed exaequabitur aquae et natabit quidem, sed paene mersa ac nulla eminens parte.
>
> Weigh out anything you wish and weigh water against it, making sure there is an equal volume of each. If the water is denser, it lifts the thing that is less dense than it is, and raises that thing

[42] Williams 2012: 220.
[43] On Lucretius' slightly different approach to analogy as 'a cognitive principle integrated into a rational system', see Conte 1994: 152.

> above it by an amount proportional to how much lighter it is; [denser things descend]; but if the weight of the water is equal to that of the thing which you are going to weigh against it, it will neither sink down nor project above, but will be made equal with the water and indeed will float, but barely submerged and with no part protruding. (3.25.5)

The first task is to find a sample weight, so we search our mind for what we will use — ah, it can be anything, so that is easy enough to imagine! Now that this step is complete, we take care to mentally prepare just the same volume of water for the other side of the scale, and see in our mind's eye how the immersion experiment plays out. Indeed, Seneca concisely walks us through several iterations of the trial, with heavier and lighter objects; if we read carefully we imagine the shifts in the relative densities of the water and the floating objects, we see them projecting above the surface or sinking deeper into it, until finally the variation of parameters ends with the perfect density match.

These passages exemplify the two principal techniques Seneca uses to create his own kind of fictional 'microworld': detail (selective yet poignant, making the microworld manageable for the imagination, but vivid enough to create a coherent vision for the reader), and the direct engagement of the reader in imagining the events of the 'experiment'. Armisen-Marchetti seems to hint at a comparable strategy when she invokes the 'scientific image' as a way of bridging the gap between scientific analogy and literary imagery: 'il existe entre images scientifiques des équivalences, notion qui n'a pas de sens pour les images purement littéraires.'[44] The 'scientific image' might be a promising justification for Seneca's extensive use of carefully crafted descriptions of scenarios designed to explain the natural world despite the epistemological problems analogy seems to present. However, the concept is not further developed there.

III FICTION AND RHETORIC: A PRAGMATIC APPROACH

Seneca's descriptive strategies seem to be rehabilitated somewhat by approaches that seek to move the discourse to another domain with different standards of proof. Williams, for example, credits Seneca's analogical arguments with the capacity to 'showcase a stringently rational approach to physical explanation' in a context where 'strengths and weaknesses in specific points of argument matter less than this overall impression of assurance and control'.[45] Williams is absolutely correct that the *Natural Questions* should be read as a rhetorically sophisticated work written in a particular time and place, for a particular audience. Once again, however, a focus on analogy means we end up making some kind of apology for Seneca, as his analogies' fictive elements are seen as being at loggerheads with their scientific utility.

Lehoux, reviewing the text's courtroom rhetoric, suggests rather that 'in offering his argument as though it were before judges, he is consciously pushing the best case he can muster, rather than seeking to pave the world with finished doctrine'.[46] This does not mean Seneca is not trying to convince, however: he is guiding the reader through a tangled mass of conflicting evidence and explanations, by helping him to figure out his own way and make his own decision.[47] Lehoux here invokes a comparison with modern scientific heuristics, in which 'what we might call the truth-value of theories emerges in an engagement with multiple arguments and competing evidence'.[48] Scientific discovery requires the dynamic construction and manipulation of imagined models, which must be

[44] Armisen-Marchetti 1989: 302.
[45] Williams 2012: 303. Williams is here referring to *NQ* 2.12–30, 2.54–8.
[46] Lehoux 2012: 82.
[47] On Seneca's acknowledgement that he cannot compel agreement, see Lehoux 2012: 103.
[48] Lehoux 2012: 105.

left behind when they have served their purpose or destroyed when they are found wanting. The orator's exploitation of his audience's malleable imagination, aiming to make them see the parts of the truth he wants them to see, has much in common with the work of scientific model construction, and exploring their common ground can make better sense of Seneca's rhetorically sophisticated explanations of natural phenomena. What if we look more deeply into how Seneca's rhetoric works to create the scientific fictions in the *Natural Questions*, taking Quintilian and Cicero as more reliable guides than Aristotle and Euclid?

Emphasizing the power of the scientific fiction to 'make believe' reinstates an important figure much missed from accounts that place deductive reasoning on propositions at the core of scientific thought: the reader. The so-called 'semantic' or 'structuralist' conception of models (to which analogy in Lloyd's sense belongs) is dyadic: it relies on a structural isomorphism between model and target.[49] The 'pragmatic' approach, on the other hand, acknowledges the model's creator as an agent with principles of his own. The model's user is taken into account as well: he is not just a machine for gauging the quality of matches between a model and its real-world analogues, but rather brings intentionality of his own, and is subject to persuasion by means which depend on his background. Suárez suggests that the interpretive challenges the user represents can be handled by shifting focus from isomorphism, denotation, or whatever other grounds the representation is supposed to rely on.[50] Instead, the user's presence becomes an invitation to focus on *why* a model can make a competent user draw the inferences necessary to think of a particular target, and why scientific representation can sustain such 'surrogate reasoning'.[51]

The 'pragmatic' approach allows a more flexible view of models as 'epistemic artifacts through which we gain knowledge in diverse ways' rather than attempts at representation which succeed as explanatory tools only to the extent that they create a perfect isomorphism with the system they represent.[52] As 'epistemic artifacts' with attributes whose level of detail is quite flexible, models enable the exploration, articulation, and even refutation of hypotheses and theories, all of which aid in scientific discovery. By accepting a wider range of 'epistemic artifacts', by taking the model's reception by a reader into account, we can account for the full range of models Seneca invokes. Rather than tracking the similarities between an object in the world and some linguistic entity charged with the unenviable task of representing that object perfectly, the pragmatic approach examines the relationships between some system in the world, a hypothesized model with all the generalizations it entails, and the principles and circumstances of its creators and interpreters.

Finding a balance between explanatory generality and the specific details of a scene vividly set before an audience's imagination is the challenge at the core of creating persuasive fiction. Payne contrasts the fictionality of the general and the particular: the difference between New Comedy's stable of dramatic 'types' who are taken to embody some universal subsets of human qualities, and Hellenistic poetry that creates a richly fictional world by setting those types aside in favour of 'fictional particulars'. Payne goes on to describe the creation of fictional spaces within which universalizing stories like those of New Comedy take place, and of spaces within which particularizing stories take place. These 'fictional particulars', such as are seen in Callimachus' *Hecale* or the urban *Idylls* of Theocritus, are often positioned in real-world locations 'to offer an imitation of everyday life without the full-scale dramatic plots and character types of

[49] The semantic conception is explained in Giere 2004; Suárez 2004; Knuuttila 2005.
[50] Suárez 2004. Suárez restricts representation thus: 'A represents B only if (i) the representational force of A points towards B, and (ii) A allows competent and informed agents to draw specific inferences regarding B' (773).
[51] Suárez 2004: 769; Knuuttila 2005: 1264.
[52] Knuuttila 2005: 1260; see also Boon and Knuuttila 2011: 69–72.

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New Comedy'.[53] The use of familiar reference points to efficiently create a scaled-down yet vividly particular fictional environment: what is this but another kind of 'microworld'?

The persuasive power of such fictions was of great interest to rhetoricians in the ancient world: it is at the heart of the technique of *enargeia* ('vividness, clarity') which Quintilian says 'seems not so much to narrate as to show, and our feelings will be moved just as if we were actually present during the events'.[54] *Enargeia* inherently involves an audience; as Leach observes, '*enargeia* differs from pictorial verisimilitude in the complexity of the receptive act it demands from the spectator'.[55] Lehoux observes in Seneca a closely related rhetorical technique, argument from *similitudo*: 'argument by comparison where the comparator is deliberately and suggestively rich'.[56] *Similitudo*, like *enargeia*, depends for its credibility on the creation of an absorbing imaginary world. Whichever label we choose to give the rhetorical strategy Seneca employs in crafting his scientific fictions, the cognitive response of the audience is key: this is, again, 'pragmatic' rather than 'semantic' territory. The next two sections will explore the primary strategies Seneca uses to create his rich comparative fictions: detailed description and immediacy.

IV FICTIONALITY: EXTENDED DESCRIPTION

Lehoux makes the important claim that the virtual vision the text allows the reader does crucial epistemological work: in rhetorical texts' theoretical discussions of how arguments from *similitudo* work as well as the *similitudines* we find deployed in practice, 'comparisons are convincing because they are visual'.[57] *Enargeia* is largely a matter of sight; hence Quintilian's invocation of its power to make absent things seem present to the eye.[58] Ideally, the reader or listener comes to imagine that he is in the presence of the things being described, a witness to past events. This is precisely the focused vividness of the 'microworld', a constrained sequence of natural events unfolding as though before the reader's eyes: a rainbow in a haze of water droplets, ripples flowing in a pool, the expanding halo of a star. Seneca makes us see these things — and, as in the rhetorical works from which he draws his techniques, seeing is believing.

To be sure, the importance of vision is not lost on analogy-based approaches to Seneca: since analogy proceeds from the visible to the invisible, at some point vision must become an interior cognitive event. So Williams finds a structure in the *Natural Questions* in which

> a roughly chronological sequence from the Pre-Socratics onward is matched by a movement first to analogical inference and then toward more abstract speculation, the mind's eye increasingly our sole guide as Seneca penetrates further into nature's secrets.[59]

Vision, whether carried out by the eye or the mind's eye, is thoroughly discussed by Williams and Armisen-Marchetti, with particular attention to the disruptions of vision caused by optical illusions. Their primary concern, however, is with the *fact* of vision, with the match between the seen and the unseen. This leaves aside the question of *how* Seneca makes his reader see, how he effects the convincing comparisons Lehoux alludes to. How does he manage to lead his reader to the increasingly high levels of abstraction Williams observes, using images which are themselves compellingly concrete?

[53] Payne 2007: 13.
[54] Quintilian, *Institutiones Oratoriae* 6.2.31–2.
[55] Leach 1988: 7.
[56] Lehoux 2012: 89.
[57] Lehoux 2012: 89.
[58] Quintilian, *Institutiones Oratoriae* 6.2.29.
[59] Williams 2012: 237.

Some examples of the vivid descriptions which permeate the *Natural Questions* have already been seen: the dying mullet; a ball with a rough, cracked surface; wind whirling against obstacles; a water-heater's helix of metal piping. Seneca's scientific explanations are never abstracted into general principles, they are always situated concretely (if sometimes speculatively) in the world. It is the rôle of the 'scientific fiction' to create a space, rich with visual detail, in which the reader can be completely absorbed in the contemplation of a highly specific natural phenomenon. Our mind's eye is focused exactly on the wriggling fish, the mist as it sprays from a punctured pipe or the fuller's mouth; we 'zoom in' to peer more closely at the irregular surface of a ball that once looked smooth; we trace the path of the water as it spirals around its heating-pipe.

This combination of detail and focus is precisely what orators exploit for *enargeia*: they rivet the attention of the audience on a single, highly-detailed scene. The detail makes it vivid, while the focus makes it comprehensible: too big a field of vision must lose detail or lose its audience, as we can only cope with so much information at a time. This, indeed, is why perfect analogy is unattainable: since analogy relies on the matching of attributes, a 'complete' analogical model would be an inexpressibly detailed proposition, a map as large as the territory. Hence it will be useful to determine a more flexible approach to model-making which openly admits of approximation; how this is done will become clearer later, but already the links between Seneca's focused descriptions and Payne's 'fictional particulars' become apparent.

Seneca adds familiarity to particularity when he draws comparative detail from that most intimately familiar natural system, the human body. Again and again he compares the earth to the human body; here he addresses the proposition that the sea is a unified, organic entity, constantly renewing itself from its own veins:

> Quaedam ex istis sunt quibus adsentire possumus, sed hoc amplius censeo: placet natura regi terram, et quidem ad nostrorum corporum exemplar, in quibus et uenae sunt et arteriae, illae sanguinis hae spiritus receptacula. in terra quoque sunt alia itinera per quae aqua, alia per quae spiritus currit; adeoque ad similitudinem illa humanorum corporum natura formauit ut maiores quoque nostri aquarum appellauerint uenas.
>
> Some elements from these are things we can agree to, but I propose this in addition: I believe that the earth is regulated by nature, and indeed according to the model of our bodies, in which there are veins and arteries — the former reservoirs of blood, the latter of breath. In the earth too there are some routes through which water runs, others through which breath does; nature has indeed created them so much in the likeness of human bodies that our ancestors named them 'veins' of water. (3.15.1)

Seneca goes on from here to an exquisitely detailed description of the features of this resemblance. The human body is well-stocked with a variety of fluids, some necessary and some that do harm when they are corrupted or thickened: the head is swimming with brains, mucus, saliva and tears; the bones have marrow and something less well-identified that lubricates the joints, and so forth. The earth is likewise suffused with different kinds of fluids, including those that harden into metals and bitumen, so becoming available to us. Like the body's liquids these are subject to decay because of violence, old age, cold, or heat, as a result of which 'suppuration concentrates a liquid, which sometimes lasts a long while and sometimes a short one' ('suppuratio contraxit umorem, qui modo diuturnus est, modo breuis') (3.15.4). Severing a vein in the human body lets blood flow until it is gone, or until the cut heals or something else stops it, 'like the blood in our bodies … so the stream or flood in the earth is poured out when its veins are released and laid open' ('ut in corporibus nostris sanguis … ita in terra solutis ac patefactis uenis riuus aut flumen effunditur') (3.15.5).

Seneca enhances the comparison by introducing an element of quantitative dependence:

> interest quanta aperta sit uena, quae modo consumpta aqua deficit, modo excaecatur aliquo impedimento, modo coit uelut in cicatricem comprimitque quam perfecerat uiam; modo illa uis terrae, quam esse mutabilem diximus, desinit posse alimenta in umorem conuertere.
>
> It matters how large the opened vein is — sometimes it fails when the water is gone, sometimes it is stopped up by some impediment, sometimes it comes together as in a scar and compresses the path which it had made, sometimes the earth's power, which we have said is changeable, ceases to allow nourishment to be converted into liquid. (3.15.6)

Certainly analogy is at work here: no one could deny that Seneca is drawing comparisons between the structure and function of elements of the body and elements of the earth in order to enable his reader to understand something he cannot see directly. But the way he does it is so complex as to deserve further attention. He begins with the combative legalistic language Lehoux observes, seeking to convince the reader of his claims by creating a richly detailed dual landscape of bodily and terrestrial forms. The lines between these two landscapes are deliberately blurred: the structure and function of bodily organs are shown from an alien perspective as remote caves through which liquids may or may not travel, while the earth is seen to share in our body's fluid vulnerability and so evokes a kind of pathos.[60]

The rhetorical technique of *similitudo* is defined in the *Rhetorica ad Herennium* as achieving a kind of metaphorical transfer of meaning between two different objects, according to four modes: 'opposition, negation, detailed comparison, and abridgement' (4.59). The other three modes will become relevant shortly, but for now let us focus on detailed comparison (*conlatio*), as this is the approach that the author links directly to the work of 'putting before the eyes' that is so central to *enargeia*.[61] *Conlatio* achieves vividness through contrast, exemplified by a gorgeously dressed and physically imposing lute-player who goes on to shock his admiring audience with a croaking voice and unpleasant gestures. The contrast highlights the truth once it is revealed; this is precisely what 'puts the thing in everyone's view' ('sub aspectus omnium rem subiecit') (4.60), and at the same time depends on the relationship between a set of contrasting elements. The model Seneca creates by juxtaposing the human body and the earth's 'body' likewise derives its vividness not just from the matching details, but also from the awareness it sparks in the reader of the vast difference between the two components.

Contemplation of this difference drives an emotional response, both because of the pathos involved in contemplating our own vulnerability and because of the massive shift in scale that becomes part of what Williams refers to as the 'Senecan sublime'.[62] This emotional element is often vital to the deployment of *enargeia* in a rhetorical context: that is to say, it does not detract from the audience's concentrated vision but rather adds to its vividness. The orator first has to summon up before his own eyes an image of what he plans to describe: for an accusation of murder, this should include the sudden intrusion of the murderer, the victim's cries, the fatal strike, and the bloody expiration of the victim. The orator generates *enargeia* from the feelings this act of imagination

[60] Compare Holmes 2010: 121–4, 138–46 on the tragic vulnerability of the body's 'cavity'. Seneca's emphasis here on the importance of the size of the opening takes on a particular pathos when considered retrospectively alongside Tacitus' account of Seneca's own suicide (*Annales* 15.62–4), which was agonizingly protracted because his veins were contracted with age and frailty.

[61] '*Similitudo* will be applied for the sake of putting the matter before the eyes; this will be articulated through detailed comparison as follows …' ('ante oculos ponendi negotii causa sumetur similitudo; dicetur per conlationem sic …') (*Rhetorica ad Herennium* 4.60).

[62] Williams 2012: 197–231.

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stirs up in him, which are supposed to be identical to what he would feel if actually witnessing the events.[63]

Seneca enlivens his descriptions of natural systems by suffusing even inanimate things with human emotion. For example, when he turns to explain earthquakes through the action of subterranean 'breath', he motivates that breath by suggesting that it has a will, desires, and emotions of its own (6.18.1–3). When it 'is not stirred up and keeps to itself in an empty space, it lies dormant and harmless and is not dangerous to its environment' ('hic quamdiu non impellitur et in uacanti spatio latet, iacet innoxius nec circumiectis molestus est'). When some external force first 'agitates (*sollicitat*)' it into a constricted area, if possible 'it just yields and wanders away' ('cedit tantum et uagatur'). However, when it finds itself trapped it grows fierce and angry; Seneca here cites Virgil's description of the winds kept imprisoned by Aeolus (though keeping the wind here solitary).[64] Now the personification kicks into high gear as the wind struggles fiercely against the walls that hold it: 'then, when it has completely surveyed the whole space where it is held, and cannot escape' ('deinde cum circa perlustrauit omne quo tenebatur, nec potuit euadere'), it 'frees itself through the untamed power of its nature, at least when it has been roused and is claiming justice for itself' ('indomita naturae potentia liberat se, utique cum concitatus sibi ius suum uindicat'). Seneca uses the same evocation of emotion that serves *enargeia* in the courtroom to make vivid the violence of the winds unseen beneath the earth, and so to convince his reader that something as insubstantial as breath could shake and crack the very ground.

The author of the *Rhetorica ad Herennium* suggests that the ability to create apt and convincing *similitudines* comes from mastering a world's worth of fodder for comparisons:

> sed inuentio similium facilis erit, si quis sibi omnes res, animantes et inanimas, mutas et eloquentes, feras et mansuetas, terrestris, caelestis, maritimas, artificio, casu, natura conparatas, usitatas atque inusitatas, frequenter ponere ante oculos poterit et ex his aliquam venari similitudinem, quae aut ornare aut docere aut apertiorem rem facere aut ponere ante oculos possit.
>
> The creation of similar things will be easy if one is able to put all things in crowds before his eyes: animate and inanimate, mute and eloquent, wild and tame, terrestrial, celestial, marine, those made by art, by chance, and by nature, the familiar and unfamiliar — and from among these hunt down some *similitudo* with the capacity to ornament or teach, or to make the subject clearer or put it before the eyes. (4.61.12–19)

In a similar vein, Payne describes how the Cyclops in *Idyll* 11, upon despairing of Galatea's affections, consoles himself by thinking of all the lovely things he could offer her (cattle, milk and cheese, baby animals to play with, good music, a pleasant cave): 'he passes all these before his mind as he sits upon the shore, and, in doing so, he turns the real world he inhabits into an imaginary object, a secondary object of desire that can take the Nymph's place.'[65] Seneca performs a comparable feat in the *Natural Questions*: he brings together before the reader's eyes a sequence of 'microworlds', a string of vivid vignettes that add up to a whole world of amazing natural phenomena.

V FICTIONALITY: IMMEDIACY

Now that we have seen how Seneca engages rhetorically poignant and precise detail for his scientific world-building, let us return to another tactic crucial for the creation of his

[63] Quintilian, *Institutiones Oratoriae* 6.2.31–2.
[64] *Aeneid* 1.55–6.
[65] Payne 2007: 79.

'microworlds': the deictic expressions that implicate the reader in the work of model-making. The connection between this class of expressions and fictional power has previously been observed by Payne, who emphasizes the power of what he classifies as 'deictic expressions' to implicate an audience in a dramatic narrative. For example, in the *Ion*,

> Ion points to what the audience can see — the stage building and the slopes behind the theatre — as a way to get it to imagine what it cannot see: nests on the cliffs of Parnassus, an eagle, a swan with purple feet.[66]

The invisible becomes visible through the use of deictic expressions that indicate, call out to, and even command the audience. In addressing the audience directly, instructing them what to see and how to see it, the narrator opens up a connection to the audience so close that they are imaginatively embroiled in the narrative. As in the rhetorical feat of 'placing before the eyes', they are enabled to 'see' things that are not in fact there to be seen, so vividly that their absence is forgotten. The use of deictic expressions Payne finds in the *Ion* is hardly limited to drama, and does not even require a literal performative context.[67] Payne observes that deictic expressions are often linked, in such chronologically and generically divergent works as *On the Sublime* and Pindar's *Pythian* 4, to the very kind of 'imaginary journey' or 'vicarious transport' Williams alludes to.[68]

Payne's argument that 'direct speech is central to the production of fictional presence in ancient literary theory' thus appears to apply to a field of texts so broad that it might not be surprising to find an inquiry into nature written by a rhetorically accomplished author among them.[69] Seneca creates this sense of fictional immediacy, reaches out to include the reader in scenes of exploration and discovery, through references to his own experience and to common experience, and through vocatives and imperatives addressed directly to the reader.

Seneca invokes his own (notionally) lived experience as a source of reliable information, as when he adduces his hands-on experience of digging his vineyards as evidence that rain only seeps into the soil up to a certain depth (3.7.1). The unspoken corollary here is of course that if the reader were to try this himself he would see the same results; the first-person singular here does not indicate exceptional experience but a norm, creating an implicit connection between Seneca's experience and the reader's own.

More often he uses the first person plural to make the generalization more explicit: 'and the mirrors we know, when they are carried far away from us, do not return the image, since our vision does not have the reach to get all the way back to us' ('apud nos quoque specula, cum procul a nobis abducta sunt, faciem non reddunt, quia acies nostra non habet usque ad nos recursum') (1.13.2). He also makes frequent use of hortatory expressions that encourage the reader to think or look along with Seneca in a certain way. When describing how the air's tension may be discerned from things heard and seen, he invites the reader along: 'let us move on to smaller things' ('ad minora ueniamus') like trumpets and water-organs; 'let us consider the things that achieve great force in secret' ('consideremus quae ingentem uim per occultum agunt') (2.6.5), like small seeds that grow in the cracks between stones and eventually grow big enough to break them.[70]

[66] Payne 2007: 51.
[67] Payne 2007: 50–3.
[68] Payne 2007: 55–8.
[69] Payne 2007: 11.
[70] Seneca is of course not unique in using first-person plural verbs in this way; as Lehoux points out, Lucretius uses them much more often, and particularly for verbs of perceiving (Lehoux 2013: 136–9).

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Seneca draws the reader in still more deeply when he fully fleshes out the fictive experimental context. Consider his detailed account of the rainbow-like array of colours in the fuller's spray of water droplets (1.3.2). The detail of the description is crucial for creating a world absorbing enough that the reader can be drawn into it, but the act of drawing in is empowered by the use of the first and second persons. 'We' see something — this is common experience, so the fictional world extends to include the reader. 'You' will see a phenomenon for yourself, if you put yourself in a certain observational position by seeking out a fuller to observe. Then Seneca neatly obviates the necessity to actually go out and make this observation, by creating a vivid fictional version of it that you, his reader, can observe right here in the text.

He implicates the reader in another such observational experience when he recommends a way of indirectly observing a solar eclipse:

> Quotiens defectionem solis uolumus deprehendere, ponimus pelues quas aut oleo aut pice implemus, quia pinguis umor minus facile turbatur et ideo quas recipit imagines seruat. apparere autem imagines non possunt nisi in liquido et inmoto. tunc solemus notare quemadmodum soli luna se opponat …
>
> Whenever we want to capture an eclipse of the sun, we place bowls which we fill with either oil or pitch, since a thick liquid is less easily disturbed and therefore preserves the images it receives, but images cannot appear except in something liquid and still. Then we are accustomed to note how the moon positions itself before the sun … (1.12.1)

Not only do 'we' observe these phenomena, but we do so regularly (*solemus*); Seneca suggests an experimental habit that allows the procedure to be repeated whenever we want ('quotiens … uolumus'). Nor is this experiment unique in its familiar repetition; *solemus* likewise signals the familiarity of the water-heating coils, among other experimental scenes.

Familiarity has a persuasive, image-building power of its own. Quintilian's advice for achieving *enargeia*, for example, hints that 'minds most easily admit what they recognize'.[71] Augustine observes that the mind naturally fills in any details left out of a description from its own past experience: if Alexandria is mentioned but not described in detail, his mind might supplement the gaps using prior knowledge of Carthage.[72] Payne asserts that drama and poetry can both achieve fictional power by setting their 'fictional particulars' in real spaces known to the audience. This aids the descriptive economy of the 'microworld': Seneca gives us the outline of the model, and we fill in the gaps from our own experience to make the image seem real.

To Seneca's accounts of what 'we' habitually do, and exhortations for 'us' to visualize or do something, may be added deictic expressions directed at the reader. While the use of the first person plural opens up a kind of collaborative activity space, the second person merges the reader in Seneca's fictional space rather differently. The reader may simply be enjoined to learn from the text:

> placet nobis terram esse mutabilem: haec quoque quicquid efflauit, quia non libero aere excipitur, crassescit protinus et in umorem conuertitur. habes primam aquarum sub terra nascentium causam. Adicias etiam licet quod fiunt omnia ex omnibus, ex aqua aer, ex aere aqua, ignis ex aere, ex igne aer.

[71] 'facillime enim recipient animi quod agnoscunt' (Quintilian, *Institutiones Oratoriae* 8.3.71). On this point, see Webb 2009: 109–11.

[72] 'apud me ipsum inuenio phantasiam Carthaginis' (Augustine, *De trinitate* 8.6.9). Compare Cicero, *Orator* 8–9 on the creative process behind Pheidias' statue of Zeus: he modelled it not on any specific person, but on the basis of an internal image of beauty which lay in his mind ('ipsius in mente insidebat species pulchritudinis eximia quaedam'), and in contemplating this image he shaped the statue; on this passage see also Platt 2011: 227–8.

> We agree that earth is mutable; and these things too: whatever it breathes out, because it is not received into free space, immediately condenses and is converted into moisture. So you have the first account of waters being born beneath the earth. You may also add that all things come from all things: air from water, water from air, fire from air, air from fire. (3.9.3–10.1)

Here the reader is asked to trade in propositions: 'you have' knowledge from the text; you can add new explanatory material to it — a common enough technique.[73] It is rather different for Seneca to prepare you not just to read a text, but to read the world:

> intentionem aeris ostendent tibi inflata nec ad ictum cedentia; ostendent pondera per magnum spatium ablata gestante uento; ostendent uoces, quae remissae claraeque sunt prout aer se concitauit.
>
> Things that are inflated and do not yield to a blow will show you the tension of air; weights carried over a great distance under wind power will show it to you; voices will show it to you, which are faded or clear depending on how the air is stirred up. (2.6.3)

The textual education the reader receives from Seneca will turn him into someone to whom the secrets of nature are revealed in the world. When you have been properly educated, you will not just see an inflated object, rather you will see through it to the invisible tension that inflates it; when you hear voices, you will also hear the traces of the path they took to you through air of varying tension.

Because encouraging the reader to picture himself involved in observations and experiments invokes a rich supply of pre-existing imaginative detail, the 'scientific fiction' permits explanations of phenomena that would otherwise be difficult to describe. For example, when Seneca argues that the rainbow is caused when the sun is mirrored in a cloud's damp concavity, he concedes that there are rigorous mathematical arguments out there, but that these are not what he chooses to provide his reader:

> rationes quae non persuadent sed cogunt a geometris adferuntur, nec dubium cuiquam relinquitur quin arcus imago solis sit male expressi ob uitium figuramque speculi. nos interim temptemus alias probationes quae de plano legi possint.
>
> Accounts that do not persuade but indeed compel are adduced from geometers, and no doubt remains for anyone but that the rainbow is an image of the sun, badly imitated because of the flaw and form of the mirror. Meanwhile, let us test some other proofs which can be read extrajudicially. (1.4.1)

The term *de plano* is a legal term signifying a broadly accessible proof. Hine explains the term as contrasting the high tribunal of magistrates with the level ground where most people stand, and suggests that Seneca 'seems to have thought that Roman readers could not cope with the geometry'.[74] For a more accessible argument, Seneca asks the reader to imagine himself reflected in a mirror made from a segment of a sphere. He credits Artemidorus of Parium for the image:

> 'si speculum' inquit 'concauum feceris quod sit sectae pilae pars, si extra medium constiteris, quicumque iuxta te steterint inuersi tibi uidebuntur et propiores a te quam a speculo …'

[73] Contrast, for example, the directive in 6.14.1: 'hear what it is they say' ('quid sit quod ab his dicatur, audi'), and the invocation of the reader at 6.23.1: 'if a crowd of witnesses is going to achieve anything for you, Callisthenes (a man none hold in contempt) also approves' ('si quid apud te profectura testium turba est, hanc etiam Callisthenes probat, non contemptus uir'). The *Natural Questions* contains many such formulations, and they do not particularly distinguish this text from others.

[74] Seneca 2010: 240, n. 40.

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> He says, 'If you make a concave mirror which is part of a section of a sphere, then if you stand outside the centre, whoever stands next to you will appear inverted to you and nearer to you than to the mirror …' (1.4.3)

The immediate accessibility of this image and its persuasive power come precisely from its strong linkage to everyday experience. The imagination is not given a simple task here. The catoptrical argument (if the surviving texts are any indication) would likely have involved the reflection of a simple shape like a polygon in the concave mirror. Seneca, on the other hand (possibly ventriloquizing Artemidorus, but at any rate this is the argument he chose to include), asks the reader to visualize two human figures, a much more complicated activity. Familiarity, however, makes this an easier task, as the reader is able to leverage his own past experience of looking at himself in a mirror. Indeed, in reading this passage 'you' are constantly being positioned as the central subject: you make the mirror, you stand beyond its focal point, and the relative positions of your reflection and that of the companion you engage to stand beside you are easy-to-imagine proxies for the distorted reflection that creates the rainbow.

Seneca's recommendations to observe and compare are not binding; his claims do not depend on the reader's actually going out to perform this experiment for himself. Lehoux observes something similar at 2.28.1, as Seneca ostensibly invites the reader to perform the experiment of trying to create noise by clapping with the back of his hands, so demonstrating that the sound of the thunderclap depends on the concave shape of a cloud:

> *aversus inter se manus collide*, 'go and try it', he effectively says to the reader. The challenge is an interesting one, insofar as it implicates the reader directly in the argument, even if Seneca does not really expect us to put the book down and put backhanded clapping to the test. (Indeed, should we actually try it, his argument is weakened: it does make quite a bit of sound.)[75]

The argumentative power of the *Natural Questions* does emerge largely from this kind of direct engagement of the reader imagining himself viewing or participating in the observational and experimental opportunities Seneca conjures up. The power of the 'scientific fiction' is indeed such that it seems to obviate the reader's going out and performing the experiment in the world, because the vivid descriptions in the text have already 'virtually' walked us through it. The disturbing corollary is, as Lehoux observes, that the vivid fiction might (like any other fiction) turn out to be a falsehood seductively masquerading as truth. The hand-clapping falsehood is an example of the worst-case scenario on a spectrum of falsehoods, ranging from demonstrably false claims, to unfalsifiable conjectures, to models that are mostly true but make some compromises. All these varieties of falsehood are alarming to the reader in search of strict analogies, but Seneca makes frequent use of them nonetheless. In fact, falsehood is part and parcel of model-making, which opens up the interesting question of how it is possible to go on anyway in the face of this knowledge.

VI MODELS, APPROXIMATIONS, AND LIES

Scientific models are in many respects best regarded as a type of fiction: they abstract, idealize, and exemplify, and they may indeed include literal impossibilities. Yet far from robbing them of their explanatory power, these 'fictional' aspects of models are precisely what make them scientifically useful. Those of us more accustomed to thinking of honey and wormwood as discrete entities might ask how 'scientific fictions' can be said to

[75] Lehoux 2012: 84.

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explain anything.[76] Bokulich points out that every scientific model involves some idealization, and hence is in a very real sense counterfactual. All models have to explain, then, by demonstrating a match in the 'pattern of counterfactual dependence' between the model and the thing it is modelling.[77] Woodward calls this the 'what-if-things-had-been-different question'.[78] What if the earth's peaks and valleys exactly matched up with the subtle irregularities on the surface of the ball? What if the backs of our hands were as fleshy as the palms, so that the noise they make when slapped together was dampened? What if the periodicity of a fever was a better quantitative match to the ebb of a spring? Seneca does not require apologies for this kind of model's failure to match up exactly with the outside world: no model really succeeds.

Cartwright was among the first to develop a robust scheme for thinking about how scientific models might be used as epistemological tools even in full acknowledgement of their failure to match up perfectly with reality. What we call laws of physics, she argues, are in fact lies, as they do not accurately describe situations in the real world; such description requires supplementation by concrete models, approximations, and provisos.[79] Cartwright later distinguished laws from models by observing that whereas laws are so abstracted from the concrete systems they allegedly govern that they do not really approximate them, models are in fact constructed from properties of the system manifest in its behaviour.[80] Models are selective (and in that sense they are fictions), but they are built from pieces of the real world in a way that laws are not. As Morrison describes it, in the course of this building process one 'mentally rearranges' features of the real system to create an idealized model.[81]

Barberousse and Ludwig observe that all models are representations of an observational or experimental situation, though they may be 'literally false' in the sense of representing something which does not actually exist (for example, a model of a gas as a cloud of billiard-ball like particles).[82] The important factor that determines the worth of a model is, in this view, not its degree of literal truth or falsity but its 'usable content'. Models do representational work using structures and processes that do not actually exist in the world, which may indeed be impossible: thus, models are fictions. Like other fictions, a scientific fiction is evaluated on its ability to 'make its interpreters imagine a certain intentional content, or to make believe that some proposition is true'.[83]

We have seen how Seneca directly engages the reader in imaginative activity, and provides richly detailed mental images, to foster the act of 'make-believe' a maximally effective scientific fiction requires. What place, if any, can be found in this system for the approximations, concessions, and even counterfactuals the authors above suggest are intrinsic to scientific models? These are, after all, the cases where strict analogy seems to fail most spectacularly as a heuristic or explanatory tool.

The definition of *similitudo* in the *Rhetorica ad Herennium*, as a multifaceted method for turning disparate things into vivid mental images, indicates a flexibility that matches the varieties of scientific fiction quite well.[84] From detailed comparison (*conlatio*), to abbreviation (*brevitas*), to negation (*negatio*), to opposition (*contrarium*): suddenly we

[76] We would not be the first to ask; see for example Hempel 1965; Salmon 1984, which reject fictions as explanatory mechanisms from the standpoint that scientific explanations are necessarily deductive arguments.
[77] Bokulich 2009: 105.
[78] Woodward 2003.
[79] Cartwright 1983.
[80] Cartwright 1989: 211.
[81] Morrison 2009: 127.
[82] Barberousse and Ludwig 2009: 57.
[83] Barberousse and Ludwig 2009: 58.
[84] *Rhetorica ad Herennium* 4.59.

are equipped with a host of possible relationships between 'source' and 'target', none of which really relies on analogical matching. Even *conlatio* derives its persuasive power from mismatches between two systems at least as much as from similarities. Likewise, Quintilian observes that 'similitude is joined with ambiguity' ('iungitur amphiboliae similitudo').[85] While analogy seems to suffer from ambiguity, similitude flourishes in that territory, making a virtue of the mind's ability to slide between the two domains.

Seneca is concerned throughout the *Natural Questions* with the unpredictable imperfections and irregularities that serve as obstacles to straightforward transformations of images from one domain to another. Sometimes these imperfections afflict transformations from model 'source' to 'target': for example, the earth is an irregular ball-like shape, and for that matter so is a ball. Seneca's observation that the distortions produced by viewing through water can clarify vision even as they warp it likewise invokes the complicated epistemological virtues of the imperfect match. His imaginary opponent then speaks up:

> 'Quoniam' inquit 'uitri fecisti mentionem, ex hoc ipso argumentum contra te sumam. uirgula solet fieri uitrea, striata uel pluribus angulis in modum clauae torosa; haec si in transuersum solem accipit, colorem talem qualis in arcu uideri solet reddit, ut scias non imaginem hic solis esse sed coloris mutationem ex repercussu.'
>
> He says, 'Since you have made mention of glass, I shall raise an argument against you based on this very thing. Glass rods are often made, striated or many-angled and knotty like a club. If one of these absorbs sunlight obliquely, it returns colour such as is usually seen in the rainbow, so that you know that there is no image of the sun here, but a change of colour owing to the reflection.' (1.7.1)

Seneca's rebuttal addresses the imperfections of the improvised experimental apparatus. The problem, he says, is just that the rod is not smoothly formed, so it cannot give off the image of the sun (though it tries (*conatur*)); 'if it were properly crafted, it would return the same number of suns as it had knots' ('si apta fabricata foret, totidem redderet soles quot habuisset in se toros') (1.7.3).

Nor is it only objects external to us whose imperfections stand in the way of trouble-free insight into the workings of the world; our own vision is similarly complicated, even above and beyond our susceptibility to optical illusions. Seneca's references to troubles with vision are too numerous to list here, but we can draw out some highlights. Some natural phenomena simply occur on a scale that is inaccessible to the naked eye, as he posits may be the case for the movement of earthquake-causing breaths through channels in the earth: their passages may be too fine for us to see (6.24.1). Our eyes have other weaknesses as well: for example, we cannot see things very far away (1.13.2), or objects that are too bright (1.17.2).

Even the things we see, we have trouble processing when the truth is less straightforward than what meets the eye:

> 'Iam uero nimis oculis permittit, nec ultra illos scit producere animum, qui non credit esse in abdito terrae sinus maris uasti.'
>
> 'Now surely he entrusts too much to his eyes, and does not know how to conduct his mind beyond them, who does not believe that the basin of a vast sea is in the hidden part of the earth.' (6.7.5)[86]

[85] Quintilian, *Institutiones oratoriae* 6.3.62.

[86] Hine notes the difficulty of ascertaining whether these are Seneca's words or his imagined interlocutor's at Seneca 2010: 203, n. 12.

The reference here to the progress from visible to hidden that analogy is supposed to help make possible is unmistakable, but Seneca complicates their relationship here. Orthodox analogy begins with careful attention to the facts accessible to the senses, but Seneca suggests there might be such a thing as too much attention to the visible, which endangers the transition to what Williams calls the 'cosmic viewpoint'. Seneca elsewhere suggests that divine cosmic truths 'both fill and flee our eyes' ('oculos nostros et implent et effugiunt') (7.30.4), so that visibility itself becomes a hazard to understanding. We can get closer to the truth through the contemplative methods Williams outlines, but at that point we are engaging in a model-making process rather different from analogy: increasingly detailed observation of the visible breaks down for a host of possible reasons, preventing the creation of more detailed isomorphic models of the invisible.

Some models are notionally determinate, but require conjecture because only time will reveal the truth. For example, the growth of an individual human being is governed by forces which are completely determinate, but invisibly encoded:

> ut in semine omnis futuri hominis ratio comprensa est, et legem barbae canorumque nondum natus infans habet (totius enim corporis et sequentis auctus in paruo occultoque lineamenta sunt), sic origo mundi non minus solem et lunam et uices siderum et animalium ortus quam quibus mutarentur terrena continuit.
>
> As the whole nature of a man-to-be is contained within the seed, and the infant has the principle of his beard and white hairs even while not yet born (for the delineations of the whole body and the growth to come are there, small and secret), so the origin of the world preserves the sun and moon and turnings of the stars, and the origins of animals, no less than those into which earthly things are changed. (3.29.3)

As above, so below: the growth of the human, orderly but mysterious, is analogically linked to the great cycle of earthly cataclysm and rebirth, which is quantitatively predetermined by laws inaccessible to us.

But the cataclysm itself highlights another, quite different need to approximate. While the overall trajectory of the cycle might be reassuringly predictable, the individual destructive processes involved are more chaotic, like the cataclysmic flood which will spread like disease in the human body:

> quemadmodum in morbum transeunt sana et ulceri uicina consentiunt, ut quaeque proxima terris fluentibus fuerint, ipsa soluentur stillabuntque, deinde decurrent, et hiante pluribus locis saxo per fretum salient et inter se maria component.
>
> Just as healthy things shift into disease, and the surrounding tissue conspires with an ulcer, so will everything close to the lands that are flooding; they themselves will be dissolved and trickle away, then flood away, and when the rock gapes in many places they will leap through the strait and connect the seas together. (3.29.7)

Here the emphasis is not on a steady, regular process like the growth of a human being, but on a breakdown made all the more terrifying by its swift and unpredictable spread. The troubling incalculability of the factors that might make one thing or another crumble first is given a more palpable edge of fear through comparison to a chaotic process of bodily decay. Holmes provides a wonderfully eloquent account of the comparable unease expressed in the Hippocratic corpus at the possibility of a tiny, imperceptible internal tear that eventually ulcerates and spreads into serious illness.[87]

[87] Holmes 2010: 138–42.

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In the face of these frightening complexities, it is no wonder that Seneca seeks refuge in the comprehensible approximations of models, fictional though they may be. Taken as a whole, the world is too complex and chaotic to be modelled without making some sacrifices. Even if the information to construct a strict analogical model were available, the analogy itself would be as complex as the system it was meant to model, so presenting its own set of epistemic problems. As counterintuitive as it is at first glance, the 'scientific fiction', the model that works to persuade despite its approximations and alterations of the world it models, turns out to be a more useful epistemological tool.

Morrison argues that the abstraction, idealization, and downright physical impossibility scientific models entail do not present an insurmountable logical problem of deriving true conclusions from false premises, but rather an epistemic problem of deriving information about concrete cases from fictionalized representations.[88] This is how an unrealistic representation can produce reliable knowledge: the focus shifts from how precise the match is between named attributes of an object in the world and its analogical model, to how the model — flawed and fictional though we know it is — can nevertheless convey knowledge about the world. Seneca uses a complex suite of techniques to make his scientific fictions vivid, persuasive, and deeply true, and he uses them in full awareness and acknowledgement of the fiction he is building.

VII CONCLUSION

The *Natural Questions* is a sophisticated and multifaceted text, and it flouts some of our expectations of what a 'scientific' text can or should be. Armisen-Marchetti describes the surprising experience of seeing that Seneca uses comparison and metaphor in diverse and non-linear ways, of coming to realize that a single direction of inquiry will not suffice.[89] Seneca himself hints at this when he acknowledges that 'in other matters our investigation is rambling, when we have nothing we can hold by the hand, and our conjecture must be dispatched broadly' ('in aliis rebus uaga inquisitio est, ubi non habemus quod manu tenere possimus, et late coniectura mittenda est') (1.3.14). The words *inquisitio* and *coniectura*, associated respectively with legal investigations and augury, hint at the variety of types of knowledge Seneca envisions bringing to bear on coming to understand the natural world.

Indeed, Seneca ranges, frequently and voluntarily, into territory that is not well-suited to strict analogy. In this regard it seems incorrect to ascribe to him, as Armisen-Marchetti does, a

> comportement qui consiste à s'inscrire dans une tradition déjà établie pour lui emprunter ce qu'elle a de fructueux, mais cela, sans servilité et en toute lucidité … Sénèque ne fait que manipuler un outil qu'il a trouvé tout prêt, à portée de sa main.[90]

This does not give him enough credit for the bold epistemological venture of the *Natural Questions*: Seneca is not reinventing analogy, but rather hybridizing the epistemological tools he inherits with the audience-focused techniques of rhetoric to create a uniquely effective way of telling challenging truths about nature. This is what I want to suggest about Seneca's use of analogy: not that he does not use it, but that he uses the tools of rhetorical persuasion to enrich his model-making repertoire far beyond lining up matching sets of attributes. Moreover, he does so consciously, with the intention of

[88] Morrison 2009: 111.
[89] Armisen-Marchetti 1989: 283.
[90] Armisen-Marchetti 2001: 171.

creating genuine epistemological tools, not just making decorations for an analogical core that somehow serves the entirety of his real scientific purpose.

Seneca hints that he will not be making orthodox use of the well-established technique of analogy when he suggests that 'our acuteness, once trained on invisible things, will be no worse in visible ones' ('in occultis exercitata subtilitas non erit in aperta deterior') (3.pr.18), a playful inversion of the traditional formula that analogy moves from visible to hidden things. This is not, of course, to be taken as a declaration of open war on analogy; rather, I think, it is a teasing nod to the complications of attempting to apply analogy universally. In Hine's ordering of the books, this would indeed be something of a thought-provoking programmatic statement of the rich rhetorical and epistemological adventure the reader is about to undertake.

Acknowledging that the fictionality of scientific models is no barrier to their ability to provide useful and convincing explanations of natural phenomena allows us to fill in some of the blanks left in analogy-focused accounts that still want to suggest that the text conveys genuine scientific knowledge.[91] The approaches outlined here shift the focus of study from the relationship between two objects in the world, or an object in the world and a verbal proposition about it, to include the creator and user of the model, showing how fiction can yield not just persuasive trickery, but genuine insight.

Let us return, finally, to the unfortunate mullet with which we began. The glass enclosure where it is left to expire seems to afford the perfect observational opportunity: it offers a perfectly simple, undistorted view, and keeps the object of the experiment handily at arm's length. Yet its observers learn nothing. Certainly that particular set of spectators is infected with moral failings that make them less than ideal observers. At the same time, though, there is something wrong with the act of observation itself as they perform it: it is *too* simple, as somehow the enviably undistorted view yields only the superficial information that the fish turned various colours and then died shortly before being eaten. More meaningful knowledge and appreciation of the world is somehow gained from a glass that distorts, refocusing our vision to show us a less-obvious truth: the bowl of water that makes writing more legible, reveals the beautiful structural details of a piece of fruit or the form of a faraway star.

For Seneca there is more to the visible than meets the eye: analogy-centred analyses of his arguments, in focusing on the journey from visible to invisible, lose sight of Seneca's repeated emphasis on the subjectivity of seeing. I have tried to show here how an approach that acknowledges his creation of a series of fictional worlds into which the reader is meant to be absorbed, to have his mind's eye guided in a certain way, can restore more of this magnificent work to scientific respectability. Here we may reflect on Cartwright's dictum that 'the truth doesn't explain much'[92]: confronting complexity and approximation head-on leads us first to fiction, and through properly-crafted scientific fiction to a more genuine truth.

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[91] For example, Armisen-Marchetti 1989: 307: 'Et de fait les questions qu'elles posent ne relèvent plus de la seule stylistique: ici, les questions qu'ils posent ne sont pas un procédé d'expression, mais un mode de raisonnement dont l'étude nous introduit au coeur de la méthode scientifique antique. Moyen d'établissement des hypothèses, source de l'imagination scientifique, l'analogie est aussi, dans les domaines où la science antique ne possède pas de moyens d'investigation satisfaisants ou n'en possède pas du tout, le procédé qui permet d'ordonner la complexité du réel.'; Williams 2012: 237: 'the Senecan inferential process at work in these examples … is itself a unifying mechanism, promoting similarity and continuity between separate orders. Yet the Senecan process is not limited to intuitive leaps of an Empedoclean kind as characterized by Conte; rather, it constitutes "a logical procedure" in the Lucretian manner, a "structured form of thought" that, by this stage in *Natural Questions* 6, truly knows.'

[92] Cartwright 1983: ch. 2.

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