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The Hive and the Pendulum: Universal Metrology and Baroque Science

Nicholas Dew (McGill University)

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Abstract:

Early modern scholars and statesmen were acutely aware of the need for improved standards of measurement, albeit for differing reasons. The variety of man-made units across territories and histories was, by the time of Pascal (Lafuma 60), already a sceptical commonplace, and was understood in terms of the mutability of human institutions. The late seventeenth century saw many scholars advance possible solutions to the problem. The most well-known of these was the use of a seconds pendulum as a standard for length, a project which was actively pursued by the French Académie des sciences in the 1670s and 1680s. This paper aims to explore the various universal metrological schemes within the context of the period's conceptions of measurement, in which political, theological, and humanistic concerns were combined, as well as certain themes in seventeenth-century thought (universal language schemes; mathesis universalis) which may (or may not) be thought of as "baroque".

"Quelle vérité que ces montagnes bornent" (Montaigne, *Essais*, II.12, "Apologie de Raymond Sebond")

"Vérité au-deça des Pyrénées, erreur au-delà" (Pascal, *Pensées*, Lafuma 60)

The Hive: universal measurement in baroque theory

Towards the end of May 1680, London was hit by a hailstorm. Even in the "little ice age" of the seventeenth century, this was uncommon for the time of year. The curious *virtuosi* rushed into the streets to measure the dimensions of the hailstones. One of these virtuosi was John Locke, who sent news of this strange event to his French friend, Nicolas Toinard: "Last Tuesday hailstones of enormous size fell all over the city here. I myself measured one lump of ice ... which had a circumference of 420 *grys*…"[1] Toinard read the letter to the group of Locke's friends in Paris, a group which included François Bernier, Jean Picard, Eusèbe Renaudot, Henri Justel, and Melchisédech Thévenot, among others. The French *curieux* marvelled at Locke's news--after all, a hailstorm in late May was a strange fact--but were more concerned about interpreting the measurement. The hailstones, Locke said, had a circumference of 420 *grys*--which sounded rather large--but none of the French knew what this strange English unit, the *gry*, was. Toinard had asked his friends who knew some English (like Thévenot and Auzout), but none of them were familiar with the term. Toinard therefore begged Locke to explain the mystery.[2]

Locke replied, apologetically. The *gry*, as he thought he had already explained to Toinard, was a unit of his own invention. A few years earlier, while on his travels around France, he had devised his own measurement system, which was designed to be both rational (being partly decimal) and universal (being based on a naturally-occurring constant). The *gry* was one thousandth of the "philosophical foot". The philosophical foot was to be divided into ten inches, each inch into ten lines, and each line into ten grys.[3] The philosophical foot--also known as the "universal foot"--was one third of the philosophical (or universal) yard. The philosophical yard was the length of a pendulum beating seconds, which was at this time a popular candidate for a universal standard of measurement, not least because it was conveniently close to most existing yard lengths. The *gry* was, then, roughly about a third of one of our millimetres, so Locke's hailstones with their circumference of 420 *grys* were about 4 1/2 centimetres in diameter.

Locke's news may have been about meteorology, but what matters for my purposes is the *metrology*. This minor episode of miscommunication between Locke and the French savants encapsulates, in many ways, the metrological problem that faced the scientific community of the late seventeenth century. Two things are important. The first is the fact that Locke has developed his rational, universal measurement system--in this, I would argue, he is representative of the ambitions of the savant community at large. The second is the very *untranslatability* of his reported data ("420 grys"), which can be taken to represent the acute problems inherent in the communication of measurements in this period. Locke's system was still only a private one, although he hoped it would one day be adopted. This only underlines for us that measurements could only be communicated if a *shared* system existed--but in order to establish such a system, special objects, techniques, and individuals had to travel from place to place. The chaotic diversity of weights and measures in *ancien régime* Europe was, of course, a familiar problem.[4] For instance, in the very same exchange of letters, Locke had also asked Toinard if he could translate some measurement terms from Montpellier--because a friend there had sent him a recipe for baking bread, and he wanted to know what the precise measures in the recipe were (the terms were: "Une *truquette* d'eau", "une *piche* d'eau", and "une *hemine* de farine".) These culinary measures from Lower-Languedoc were unknown in Paris (even to the abbé Picard), so Toinard had promised to send for accurate information from the spot ("sur les lieux"), adding that all *he* knew was "that their pound is four ounces less than ours" [presumably the Parisian].[5]

Both of these instances, the Montpellier bread-making recipe and the hailstones of London, remind us of how problems of metrology were usually also problems of *geography*. To put this another way: The first thing to do, when faced with a measurement-translation problem in the seventeenth century, was to write to friends in other places; if that failed, to ask for specimens of the units to be sent by post; and then, if that also failed, or to be sure of greater precision, the only thing left to do was to travel. (First letters circulate, then brass rulers, and then people.) Measurement systems were defined by their territorial extent--standards usually being named after the city which legally defined them. So *universal* measurement schemes were, literally, *utopian*. In reply to Locke's wish that "that people might some day agree upon the philosophic foot" (175), Toinard agreed heartily with the principle, but was sceptical about its practicality, adding, only half jokingly, that it would perhaps only be possible to institute Locke's system in America--specifically in the colony of Carolina, for which Locke had helped draft the constitution--since there, things could be "cut from a fresh cloth".[6] Toinard adds, tantalisingly, that he has heard a rumour that "a country" is considering adopting the universal yard, but he doesn't dare say which one (in a letter that has to travel from France to England). Meanwhile, with such schemes still pending general adoption, savants like Locke travelled around, continually noting the various values of the coins, weights and measures they found as they toured from one town to the next. Locke, when he was in Paris in 1677, had paid the English-born instrument maker, Butterfield, to make him a brass rule, upon which were inscribed the units of London, Paris, Leyden, Copenhagen, and Rome, along with the philosophical foot for comparison. This he used to take measurements when visiting the Roman ruins in Nîmes, and the Châteaux of the Loire.[7]

Like universal language schemes, projects for a universal system of measurement were widespread at this time, and were usually discussed in the rhetoric of the "Republic of Letters". For example, Locke, when introducing his scheme in his *Essay concerning Human Understanding*, says a decimal system would be of "general convenience" in the "Commonwealth of Letters".[8] At the same time, seventeenth-century savants all knew that measurement standards were tied to local political authority, so that a truly universal system might only see the light under a "universal monarchy". This difference can be understood in terms of the distinction between a universal system conceived as a convention voluntarily adopted by a "scientific community", and one imposed upon a really existing complex economy.[9] Even if it still seemed unlikely, to late seventeenth-century writers, to be something that any European state might actually impose (despite Toinard's rumour), a philosophical measurement system could at least serve as a convenient convention among scholars, and it could also allow for past and present metrics to be passed on to posterity. There remained, nonetheless, a tension between the value of a standard that was merely convenient, and what we might call the *aura* attached to those measurement-standards that were thought to have the moral authority of either Nature or (for these baroque thinkers) of the Ancients. Humanists had long been troubled by their ignorance of the true values for the Roman foot or Hebrew cubit, and it was not uncommon to associate the most ancient values with Divine (and therefore also Natural) authority. It should not be surprising that the English divine Richard Cumberland--best known as a theorist of natural law--wrote a treatise on the values of the ancient Hebrew measures, which was printed by the Royal Society's printer in the year before the appearance of Newton's *Principia*. Cumberland, in his dedicatory letter to Samuel Pepys (the Royal Society's president), cast his metrological researches as both eirenic and commercial, calling it "the peaceable Doctrine of Measures and Weights".[10]

Two decades earlier, John Wilkins, another prominent English divine, and also closely linked to the Royal Society, had already made explicit the connection between reforming language and reforming metrology, in his *Essay towards a real character, and philosophical language*, probably the best-known language-reform scheme to emerge from the English mid-century savant community. In part 2 of the Essay, Wilkins discussed the problem of a universal or natural standard (he identifies the two), noting that it was considered one of the "desiderata" of Philosophy by the learned.[11] Ancient measures were once based on natural things, such as the width of a grain of barley, or the various anthropometric measures (inch, palm, span, cubit, foot, pace, etc), but none of these were suitably invariant. Wilkins notes that the current candidates for a length standard include a division of a meridian arc, which had been suggested by Gabriel Mouton, a Lyon cleric, and was later of course to be revived in the French Revolutionary metric system,[12] as well as a proposal to derive it from "the *Quick-silver experiment*" (i.e. a column of mercury in a Torricellian apparatus). The first Wilkins thought too difficult to achieve with any certainty, and the second obviously too subject to variations in the "gravity and thickness of the *Atmosphere*, together with the various tempers of the Air in several places and seasons". He therefore proposed the length of a seconds pendulum as a length standard (citing Wren, Brouncker, and Huygens) and goes on, just as Locke did, to divide the resulting unit in decimal fashion, complete with derived units of capacity and weight.[13]

Not surprisingly, savants in France were engaged in similar researches. One of Locke's friends, the collector and academy-host Melchisédech Thévenot[14], was working on the same issue in the early 1670s, and proposed a rather striking solution. In a "Discourse on the Art of Navigation", published as an appendix to a collection of travel accounts which was itself an appendix to his larger travel collection, Thévenot discussed the problem of transmitting measurement standards across time and space. The passage is worth quoting in full:

> … in using one of those creations that we say animals make by instinct, we could, it seems to me, reasonably suppose that this instinct, being based in an eternal cause, must always be the same, and exempt from the varieties which distinguish everything that comes from men. Among other examples, I found that the cells

> made by bees of the same species, measured at the time that the bees build them, are equal among themselves, and having since measured those near to Paris, Leiden, and Florence, I found no difference; and if one follows the lines according to which the bottoms or bases of these cells are arranged, one will find that the same number of cells always comes to the same measurement. Thus, if all of the measures that are currently used in the world were to be reduced to that of the bees, posterity would by this means by able to know them all: and this measure, which I here propose, would be all the more universal (*générale*), since there are bees in every part of the world, from the Poles to the equator. And even thought I build it on wax, nothing stops me from believing that this could last as long as the world, and that it is more apt for this design than the [*diaspre*] of the tomb, upon which Gravius marked the English foot, and easier to understand and to put into practice than the measure based on the oscillations (vibrations) of a pendulum done together with astronomical observations, as has been proposed in France and in Poland. But, before being able to establish it, it would be necessary to compare the works (*ouvrages*) of bees in distant places, those from the Cape of Good Hope and from Egypt, for example, with those from Muscovy and from Mexico, etc. And if they are found to be equal everywhere, this measure could be made common to all nations, and by this means we could transmit the knowledge of the measurement systems of our age to posterity -- which is what we are seeking to do.[15]

It is interesting that Thévenot places such emphases on the fact that honeybees made their cells by "instinct", and that, since animal instinct could reasonably be supposed to come from an unchanging (and divine) "eternal cause", honey-bees must be exempt from the mutability which plagued all human endeavour. This was something, he goes to add, that Aldrovandi and Mouffet, and all those other "*personnages de grande lecture*, who believed themselves to have got to the bottom of bee-research simply by collecting everything that the Ancients and Moderns had written about them", had failed to notice.[16] Bees have managed, through God-given animal instinct alone, to construct their cells according to the optimum shape, something that only the most able geometers might have calculated.

> Thus, one might apply to these workers the verses that the Poet applied to himself, and say, *In tenui labor, at tenuis non gloria* ["Slight is the field of toil, but not slight the glory", Virgil, *Georgics*, IV.6]. Or indeed allow that a Persian Poet exclaims, with the license common to the poets of his country, that if Archimedes had examined such a surprising structure (*ouvrage*), he would have "bitten the fingers of admiration with the teeth of envy".[17]

Alongside this nod to the Oriental erudition for which he was known at the time, Thévenot here made what was, for his readers, the obvious allusion to the fourth book of Virgil's *Georgics*, reminding readers of the long tradition of using the bee hive as a metaphor for human polities.[18]

Although published in 1681, Thévenot had been working on his apian metrology much earlier. From his country home at Issy (outside Paris), he had been able to support the work of both Swammerdam and Steno, both of whom studied insects in their time with him. Thévenot had announced his measurement idea to the scientific community in a letter to Henry Oldenburg ten years earlier (in 1671).[19] We also know that Thévenot had built a glass hive with which to observe bee behaviour. Thévenot's friend, the Gassendist philosopher and traveller, François Bernier, in a satirical edict mocking the Sorbonne's motions against the new science (written with the help of Molière and Boileau), mentions Thévenot using a glass hive, and casts him as a spy working maliciously against the Republic of Bees, out of disregard for the teachings of Aristotle.[20]

Bees were a common rhetorical resource for natural philosophers in the mid-century, and interpreting them was, thanks to Virgil, always tied up with emblematic and political significance. The idea of using a glass hive to observe bee life was something that Thévenot could have learned either from the elder Pliny's *Natural history*, or from his contemporaries in the culture of curiosity. In the Hartlib circle, around 1650, there was discussion of a glass hive made by the Gloucestershire parson William Mewe, which inspired Hartlib to pursue apian researches over several years, inspiring others (including Wilkins and Wren) to design glass hives and to write about the "republic of bees", pointing economic lessons for the English interregnum Commonwealth.[21] Earlier still, apian research had, famously, been a part of the Lyncean academy's natural historical work in [Florence and] Rome in the 1620s, not least because the bee was the emblem of the Barberini family, under whose patronage the Lynceans worked.[22] For Thévenot, though, who seems to have been the only scholar to suggest that honeycomb cells were sufficiently regular to become the basis of a length standard, the connection between social order and measurement could not have been more clear. If bees had long been endowed by humans with the power to suggest solutions to the problem of social order, Thévenot was now endowing them with the power to provide solutions to the problem of knowledge.[23]

The Pendulum: establishing a metrological network in practice

Thévenot was (as far as I know) the only person to propose the honeycomb as a fundamental length standard. The length of a pendulum beating seconds, however, was more widely accepted as a *potential* candidate, and had been discussed in these terms by Mersenne, by Huygens, and (as we have seen) by the English. Even while it was being advanced as a candidate, though, there were always concerns about possible problems with the seconds pendulum. Back in 1620, Bacon (in the *New Organon*) had already speculated that weight might vary with altitude[24], and in the 1660s there was a common concern that the pendulum's motion would vary with differing climates, atmospheric conditions, and with latitude. (Boyle and Brouncker in 1661 had proposed that someone take a pendulum clock up the Pico Tenerife, presumably to test the effects of varying air pressure on a pendulum). Christiaan Huygens, who had done more work on pendulums than most, argued in the 1660s for the seconds pendulum as a length standard, but was also concerned about possible latitude variations in weight (since he thought that the earth's rotation would produce a centrifugal force in the atmospheric vortex, which would cause bodies to lose weight when close to the equator).[25]

The seconds pendulum therefore was both the leading candidate for a length standard, and at the same time theoretical objections were being raised, even before any experimental data from diverse locations had been gathered. What made the data available was the mapping expeditions organized by the French Académie des Sciences and centred on the Paris Observatoire. From its very foundation (1666) the Académie Royale was planning expeditions to advance astronomy, geodesy, and cartography. The interest of the savants in using new techniques to radically improve their fundamental constants (like the size of the earth, and the distance from the earth to the sun), was cannily married to the interests of the king and his ministers (with projects like the remapping of France, the establishment of the Paris meridian, and the project to map the whole world from the Paris Observatoire). To these ends, the Paris academy organized a series of expeditions around France--but also further afield--from around 1670 onwards. Since it was already well established as a seemingly good candidate for a universal measure, the measurement of a seconds pendulum was added as a kind of secondary task to the to-do lists of the travelling academicians (whose missions were generally designed for astronomic/cartographic projects). The abbé Jean Picard, in his *Mesure de la Terre* (1671, pp. 3-5), effectively announced the Académie's commitment to the seconds pendulum as a length standard, and also gave one of the best accounts of how the actual measurement needed to be done.

[*Note to readers: Normally, at this point in the story, I cut to the coast of French Guyana, where Jean Richer was sent to make astronomical observations in 1672, and where he returned a length for the seconds pendulum which was slightly shorter [about 2.83 mm] than that for Paris.*[26] *But in what follows, I focus on two other pendulum experiments, just before and a few years after Richer's voyage to Cayenne, partly because they cast light on the Richer story, but also because they cast light on the importance of circulating skills and objects for the metrological enterprise of this period. The two cases I want to deal with are the abbé Picard's voyage to Uraniborg in 1671, and the mission by which the French sent the young Ole Roemer to London, in 1679*.]

Locating Uraniborg

Picard's mission to Uraniborg in 1671 was the first of the Académie des sciences's overseas expeditions.[27] Initially, the Académie had hoped to send a mission to Madagascar; the target was then revised downward to a mission to Egypt; this too proved too ambitious and the Académie had to settle for the cheaper alternative: the Baltic. The aim was for Picard to use modern instruments and techniques (telescopes fitted with micrometers, and the concerted observation of Jupiter's satellites) to find the difference in longitude between Paris and Uraniborg (since the available figures differed), so that the observations of Tycho Brahe (made there almost a century earlier) could be reduced to the Paris meridian. The Uraniborg mission was an exercise in translation, in several senses at once. Locating Uraniborg precisely in relation to Paris would allow the French to translate Tycho's figures onto a Parisian standard. At the same time, the French were interested in appropriating the project to produce a new edition of Tycho's papers (to improve the error-prone text of Kepler's Rudolphine Tables), so that the publication of a new Tycho at the Imprimerie royale would effect a symbolic translation of the prestige of Uraniborg to Paris.

Picard left Paris in July 1671, with a battery of instruments and a young trainee named Etienne Villiard. They visited Leiden en route, where Picard was able to converse with Blaeu about geodesy, and to purchase a piece of luminous Icelandic spar. He was also able to measure the original of the Rhenish Foot, and found that its proportion to the Paris foot was 696:720, rather than 695:720, as had previously been thought.[28] [1.034:1 instead of 1.036:1] After visiting the virtuosi in Hamburg en route, they arrived in Copenhagen, where they were received by the local savants. The French were surprised to learn that the island of Hven, on which Uraniborg of course was built, was no longer a Danish possession, but was under Swedish control (it had been since 1660). Such details of Baltic diplomacy had not reached Paris. The operations on Hven were organized from the Copenhagen Observatory, where Picard's host was Erasmus Bartholin, professor of mathematics and medicine there. Bartholin introduced Picard to a young and gifted student of his, Ole Rømer, and the four of them (Picard, Villiard, Bartholin and Rømer) went to Uraniborg together. Bartholin was already working on the new edition of Tycho, and his cooperation was essential both for the Hven mission and for the publication project. For his part, Picard seemed concerned to make sure that news of his visit did not reach England--it seems because he feared the Royal Society would be keen to get hold of Bartholin's Tycho papers and produce their own edition.[29] The astronomical work went on into November (when the two senior scholars decided to avoid spending winter on Hven, and headed back to the relative warmth of the Copenhagen Observatory, leaving Villiard and Rømer on the island).

The measurement of the seconds pendulum was carried out on Hven, and Picard records in his account of the mission that it was witnessed by both Bartholin, and also a M. Spole, professor of mathematics from the University of Lund. In a letter to Colbert, Picard reported that the agreement of both these witnesses (and the concurrence of both a Dane and a Swede to boot) made the observations all the more "authentic". He also noted, for Colbert's benefit, that the Baltic savants acknowledged that France had now become "the mother of the arts and sciences", and that this was due to Colbert.[30] The result, Picard was happy to report, was that the seconds pendulum was found to have exactly the same length in Uraniborg as in Paris -- namely 36 inches 8 ½ lines, Paris measure. [36.71 Paris inches]

Rømer (and Locke) in London

Picard was so impressed with the work of the young Ole Rømer that he brought him back to Paris with him. Roemer spent the next ten years based in Paris (1672-82) where he engaged in a variety of projects, most notably discovering the finite velocity of light, but also building spectacular instruments for the Dauphin. At the very time of Picard's return (in 1672), another expedition was just setting off--Cassini's trainee Jean Richer was leaving La Rochelle on a slave ship bound for Senegal and then for Cayenne, where he was to conduct astronomical observations, and also measure the pendulum. From Cayenne, which was just under 5 degrees North, Richer was to report that the pendulum needed shortening --by a line and a quarter [= 2.81mm]. This was such a small difference that most of Richer's superiors back in Paris suspected that he had made a mistake.

Before leaving for Denmark, Picard had asked the Royal Society of London to conduct a pendulum measurement. The English reported a figure of 36 inches and 4 tenths of an English foot, which--according to the conventional methods of conversion--seemed to give 36 inches, 11 and 13/20 lines in Paris measures. This seemed considerably longer than the Paris length (now replicated at Uraniborg), which made Picard suspect either an error on the part of the English, or an error in the conversion from English to French units (or both). For this reason he stepped up his requests for an accurate copy of the English foot standard to be made and sent to Paris. In 1679, an opportunity arose to settle the doubts over the question, by sending Ole Rømer to London. Rømer's task was to carry out the pendulum measurement--effectively to show the English how it had to be done--and to verify the exact value of the London foot.[31]

Roemer made the journey from Paris to London with Locke, who had met him in France and was now on his way back to England. They arrived in London in late April 1679. Roemer and Locke spent a few weeks enjoying London together--Roemer seems to have fallen for a pretty girl who ran a hardware shop [pulchra mercatrix], and so bought rather a lot of pliers, knives, and so on (Locke, 2: 26, 52). In late May, finally getting down to his task, Roemer went to Greenwich, where under Flamsteed's eye he began the pendulum work. Flamsteed reported that they found the length to be the same as in Paris, although he noted that Roemer had left him a pendulum ball, so that he could repeat the experiment himself later on.[32] By this time, the pendulum experiment was coming under scrutiny, and the attention to both the material apparatus and to technique is reflected by both the fact that Roemer left a bob with Flamsteed, and also in the fact that Hooke and Denis Papin (Boyle's assistant) visited Roemer and examined his instruments: the brass ball for the pendulum bob, his sliding steel ruler, and even the pendulum cord, made of silkgrass (*pite*), an exotic hemp.[33]

By June 1679, Roemer was back in Paris, supposedly having brought the Royal Society into line with the measurements that the Académie had found in both Uraniborg and Paris. Nonetheless some doubts still remained.[34] In the following months, brass rulers and pendulum balls continued to be sent between Paris and London. In the next couple of years, Picard and La Hire went on mapping missions to the South West of France (to Bayonne and Sète), which provided new evidence of the non-variation of the pendulum. The French then sent another mission to the tropics, which produced an even more unsettling result, although it still failed to convince the Academicians for several years.[35]

Conclusion

The project to establish a universal standard of measurement was conceived in terms of early-enlightenment ideals of natural authority (transcending all human institutions, across space and time, so as to transmit present measures to distant posterity). But in practice, of course, the metrological enterprises of the baroque era, just as those of today, relied upon the circulation of an ensemble of particular objects, people, and skills around privileged scientific sites.[36] Across the 1670s, Picard's project to establish the invariance of the seconds pendulum *seemed* to have worked, since only one 'outlying' measurement had been found--Richer's in Cayenne--and *that* could be discounted or accounted for in various ways. Nonetheless, the attempts to replicate the pendulum measurement had been troubled by the fact that this apparently simply experiment was actually difficult to do. The success of the measurement depended on knowing the correct procedure (such as making sure you set the pendulum to very small vibrations), but also on the accuracy of the timekeeping (which required a large and accurate clock as well as daily solar observations), *and* on material details like the proper kind of thread for the cord, the correct dimensions for the bob, or a properly-shaped metal clip from which to hang the thread. The Académie-sponsored scheme to replicate the Paris pendulum measurements were in fact only made possible by the *circulation* of both appropriately skilled people (Picard, and Roemer, who had been trained by Roemer in the experiment), and these special materials.[37]

The use of the term *baroque* as a category of historical analysis has a history almost as chequered as that of the word itself (see Appendix below).[38] I take our use of the term to be *heuristic*: its purpose is to create an estrangement effect, to make a period we think we know (the "Scientific Revolution") seem unfamiliar. At first glance, the metrological schemes of the baroque can strike us as suitably "non-classical", with their reference to both a Biblical or Ancient past (Noah's Ark, Solomon's Temple, the Egyptian pyramids, the Roman foot), and the explicit connections with contemporary political thought (as in Jean Bodin's point that authority over weights and measures was one of the "marks of sovereignty"[39]). Likewise, the importance of circulating special objects and skilled people might seem to be distinct to the period at first glance (since it implies an earlier stage in the establishment of a standard). And yet in both respects, i.e. both in theory and in practice, baroque metrology constantly reminds us not only of later metrological projects (from the French Revolution to the Victorian age)[40], on the one hand, but also of sociologists' accounts of what happens in contemporary science. It may be that what makes baroque metrology "baroque" is not a difference in kind from later periods, but simply the *degree* to which natural-philosophical ideas about the order of nature, and politico-theological notions of the kinship of power and measurement, are made *explicit*.

Appendix: preliminary notes on the Baroque

- Just as with the term "Enlightenment", the meaning of "Baroque" moves, between Baroque-as-period and Baroque-as-style (of thought). Maravall uses it as a period label for the seventeenth century. Yet the term originally was a style concept. When the term is used for a period, it carries an implication that a range of cultural phenomena from the same period can be understood through the same interpretive lens, an approach which can easily lead to circular analyses, or into the fallacy of the Zeitgeist.[41]
- Our primary sense of "Baroque" (as both period and style) emerged between the late 19th and mid-20th century, and has come to mean slightly different things in each field, but anchored in more or less the same period (c. 1600-c.1720), with strong associations with counter-reformation Rome, Spain, and Latin America; and with the literature of 17th-century Germany.
- But whether period or style, "baroque" is used as a *relative* term. Baroque is defined in opposition to the periods/styles between which it is sandwiched: the (Italian) Renaissance (the baroque is, for Victorians a "degenerated Renaissance" [*OED*, citing the 1877 Baedeker guide to Central Italy and Rome]) and the (French) Classical (even if the transition is placed in different points: in French literature, this threshold is at 1660; in music, at 1750 or later).
- The period labels have replaced, but grew out of, the older sense, which was the only

sense of the term in the 18th century (and indeed seems to have remained the predominant sense of the term in French until the mid-20th century): for eighteenth-century writers, "baroque" meant bizarre, grotesque, outlandish, disordered, imbalanced, impure, kitsch, illogical, inappropriate, garish, crazy, and *in bad taste*. It was opposed to the natural, the harmonious, and proportional. (Not surprisingly, the baroque can even therefore appear as proto-Romantic.)[42]

- It might be that we can resurrect the Victorian sense of the Baroque as a "degenerate Renaissance" (if we can strip this of its dubious echoes of anti-Catholicism, or nineteenth-century racial thought): it then becomes a label for reminding us that in many ways the "early enlightenment" was closer to the "late renaissance" than it was to the "classicism" of the 18th century. Here the potential use of the term (for us) is clearest for me: it may be familiar practice now to remind oneself that Newton's natural philosophy is not (yet) the "classical physics" of his later commentators, but to label it "baroque physics" seems to achieve this estrangement more effectively than most of other labels that we have to hand. "Baroque science", then, could serve as a useful reminder of our need, still, to further historicize the science of the seventeenth century.
- Another separate question would be whether we want to hold on to the idea of a baroque *Denkstil* in science--while breaking any a priori links to other branches of art and culture from the same period. There might well be a baroque style of scientific thought, more or less independent of baroque architecture, sculpture, or drama. Baroque might helpfully label the "thought-style" shared by a particular group of actors, in a particular historical setting (the scientific community of the middle third of the 17th century, say), with distinct values, norms and connections to religious or political concepts. But does the label have any value other than convenience?

NOTES

[1] John Locke, *The Correspondence*, ed. E. S. de Beer, 8 vols. (Oxford: Clarendon Press, 1976-1989), vol. 2, 175-6: Locke to Toinard, 20 May 1680 (Old Style); the passage continues: "… it was rounded in shape and slightly flattened on both sides, so that it was not perfectly spherical. I hear that others were measured by various people and found to have twice as great a circumference; but the middling specimen that I handled myself sufficiently astonished me, and I should be glad to know from your philosophers up to what weight solid bodies of such bulk can be suspended in the air. I doubt whether the Cartesians can have any contrivances to help in this matter, and whether the Occult Qualities of the Peripatetics may not break down under such a load". I am quoting de Beer's translation. Locke's original Latin was: "Die Martis præterito, grando immensæ magnitudinis per urbem hic cecidit. Ego globum unum glaciei (nam ita revera erant) commensuravi cujus circuitus erat 420 grys, forma erat rotunda et ex utroque latere aliquantum depressa adeoque non perfectè globosa. Alios ab aliis mensuratos audio quorum circuitus erat duplo major. Sed mediocris ille, quem ipse tractavi me satis attonitum reddidit, et a philosophis vestris libens scire velim quibus librata ponderibus tantæ molis solida corpora in ære suspendantur. Hic dubito ne Cartesianis desint machinæ, et Peripateticorum sub tanto onere succumbant Occultæ qualitates." Locke at this point usually wrote to Toinard in French, and he apologises for writing in Latin, saying "I am not well versed either in it or in French; but I thought that your refined ears would be less offended by solecisms in a foreign tongue" (176). On Toinard (1628-1706), Locke's main French correspondent at this time, see the note in Locke, vol. 1, 579-82.

[2] Locke, *Correspondence*, vol. 2, 183 (Toinard to Locke, 27 May [6 June OS] 1680).

[3] Locke, vol. 2, 194 (Locke to Toinard, 10 June 1680 OS): "When I used grys in giving the measurement of our hailstones I did so in the belief that I had once told you, when enjoying your delightful company, that this is the name I have given to 1/1000 of the universal foot, so that 420 grys signifies 4 pouces 2 lines or 420/1000 of that foot; but the globule that I handled myself was a very small one". For Locke's invented universal system (which incidentally happens to be decimal), see Locke to Boyle, 16 June 1679 (vol. 2, 38-39 and nn.), de Beer's long note on metrology at vol 2, 14-16. See also *Locke's travels in France, 1675-1679, as related in his journals, correspondence and other papers*, ed. John Lough (Cambridge: Cambridge University Press, 1953), p. 161 (7 August 1677) and 185 (29 Jan 1678). In October 1677, Locke had a brass rule made by Mr Butterfield (the English instrument maker in Paris) which allowed him to measure the feet of Leiden, Paris, Denmark, England, and the Roman "palma" in terms of grys. In his travel journal Locke frequently measured buildings and expressed the measurements in his "universal" system. For contemporary projects for decimal metric systems, see George Sarton, "The first explanation of decimal fractions and measures (1585), together with a history of the decimal idea and a facsimile (no. XVII) of Stevin's Disme", *Isis*, 23 (1935), 153-244, esp. 188-194.

[4] See, for a general account, Witold Kula, *Measures and Men*, trans. R. Szreter (Princeton: Princeton University Press, 1985); for a reference guide, Ronald E. Zupko, *French weights and measures before the Revolution* (Bloomington: Indiana University Press, 1978). See also the discussion in Ken Alder, "A Revolution to measure: the political economy of the metric system in France", in M. Norton Wise, ed., *The Values of Precision* (Princeton: Princeton University Press, 1995), 39-71, and the comments by Norton Wise in *The Values of Precision*, 3-13 ("Introduction"), 92-99 ("Precision: agent of unity and product of agreement. Part 1: Traveling"). I have not yet been able to consult Harald Witthöft, "Mass und Gewicht in Mittelalter und früher Neuzeit: Das Problem der Kommunikation", in *Kommunikation und Alltag in Spätmittelalter und früher Neuzeit* (Wien: Verlag der Österreichischen Akademie der Wissenschaften, 1992), 97-126.

[5] Locke, vol. 2, letters cited, 175, 182-83.

[6] Ibid. (182) ("Il est tres a souhaiter que lon convient dune mezure et dun poids, mails il n'y a pas lieu d'esperer cela que dans la Caroline, ou lon taille en plein drap"); [insert original for "a country" passage here, ibid].

[7] See *Locke's travels in France, 1675-1679* (cited above, note 3).

[8] Locke, *Essay concerning Human Understanding* (London, 1690; bk IV, ch 10, paragraph 10, note a); earlier, unveiling the system to Boyle, Locke (Locke, *Correspondence*, vol. 2. p. 39) says "which measure, whatever it be for other purposes, I thought the fittest for philosophical communications".

[9] In the French Revolution, of course, the problems of imposing a new metric system on a real and complex economy were confronted; see Alder, "A revolution to measure"; see also John L. Heilbron, "The measure of enlightenment", in Tore Frängsmyr, John L. Heilbron, and Robin E. Rider, eds., *The Quantifying Spirit in the eighteenth century* (Berkeley: University of California Press, 1990), 207-42, and Heilbron, *Weighing imponderables and other quantitative science around 1800*, "Historical Studies in the Physical and Biological Sciences: Supplement to vol. 24, part 1" (Berkeley: University of California Press, 1993), 243-77.

[10] Richard Cumberland, *An essay towards the recovery of the Jewish measures & weights, comprehending their monies, by help of ancient standards, compared with ours of England* (London: Printed by Richard Chiswell, printer to the Royal Society, 1686), [reprinted 1699], here at sig. A 6 r-v. On Cumberland, see Jon Parkin, *Science, religion, and politics in Restoration England: Richard Cumberland's* De legibus naturae (Woodbridge and Rochester, NY: Royal Historical Society / Boydell Press, 1999). For other examples of Biblical research and natural philosophy in the period, see Jim Bennett and Scott Mandelbrote, *The Garden, the Ark, the Tower, the Temple: Biblical Metaphors of Knowledge in Early Modern Europe* (Oxford: Museum of the History of Science / Bodleian Library, 1998); see also Zur Shalev, "Measurer of all things: John Greaves (1602-1652), the Great Pyramid, and early modern metrology," *Journal of the History of Ideas* 63 (2002): 555-575.

[11] John Wilkins, *An Essay towards a real character, and philosophical language* (London: Printed for Sa. Gellibrand, and for John Martyn printer to the Royal Society, 1668), 191-92 ("… it were most desirable to find out some *natural Standard*, or *universal Measure*, which hath been esteemed by Learned men as one of the *desiderata* in Philosophy"). I have not yet been able to consult Rhodri Lewis, *Language, Mind and Nature: Artificial Languages in England from Bacon to Locke* (Cambridge: CUP, 2007).

[12] Gabriel Mouton, "Nova mensurarum geometricarum Idea: Et nova methodus eas, & quascumque alias mensuras communicandi, & conservandi in posterùm absque alteratione", in Mouton, *Observationes diametrorum solis et lunæ apparentium, meridianarúmque aliquot altitudinum Solis & paucarum fixarum* ... (Lyon: ex Typographiâ Matthæi Liberal, 1670), 427-448.

[13] Wilkins, *Essay*, 191-2. This contains a reasonably detailed account of how to do the measurement, with the important exception of how to establish a reference for seconds of mean solar time.

[14] On Thévenot generally, see my "Reading travels in the culture of curiosity: Thévenot's collection of voyages," *Journal of Early Modern History* 10 (2006): 39-59.

[15] M. Thévenot, "Discours sur l'Art de la Navigation", in his *Recueil de voyages de Mr. Thevenot* (Paris: Estienne Michallet, 1681), sep. pag., 24-25 (part of a section on "Fixer la valeur de ces lieuës ou mesures, en sorte que les autres Nations & la posterité les puissent entendre", 21-7): "en se servant de quelqu'un de ces ouvrages que nous disons que les bestes font par instinct; nous pouvons ce me semble supposer avec raison que cet instinct leur venant d'une cause eternelle, il doit estre toûjours le mesme & exempt de toutes ces varietez qui distinguent tout ce qui vient des hommes. Entr'autres exemples je trouvay que les cellules des abeilles de mesme espece, mesurées dans le temps que les abeilles les bâtissent, sont égales entre elles, & ayant depuis mesuré celles des environs de Paris, de la Ville de Leyden, de Florence, je n'y trouvay aucune difference; & que si l'on suit les rangs selon lesquels les fonds ou bases de ces cellules sont disposées, l'on trouvera qu'un mesme nombre de cellules donne toûjours la mesme mesure. Ainsi rapportant toutes les mesures dont on se sert maintenant dans le monde, à celle des cellules des abeilles, la posterité pourra par ce moyen les connoistre toutes: Et cette mesure que je propose icy sera d'autant plus generale, qu'il y a des abeilles dans tous les endroits de la terre, aussi-bien aux lieux qui approchent des Poles, qu'en ceux qui sont plus avancez vers la ligne: Et quoy-que je l'établisse sur de la cire, rien ne m'empéche de croire qu'elle ne puisse durer autant que le monde, & qu'elle ne soit plus propre à ce dessein que le diaspre du tombeau sur lequel Gravius a marqué le pied Anglois, & plus aisée à entendre & à pratiquer que celle qui se peut tirer des vibrations du pendule, jointes à une observation celeste, comme on l'a voulu faire en France & en Pologne. Mais auparavant que de l'établir, je voudrois avoir pû comparer les ouvrages des abeilles de lieux éloignez, du Cap de Bonne Esperance & d'Egypte; par exemple, avec celles de la Mosovie & du Mexique, &c. Et si elles trouvent par tout égales, cette mesure se pourra rendre commune à toutes les nations, & par son moyen l'on pourra transmettre la connoissance des mesures de nostre siecle, à la posterité, qui est ce que l'on cherche".

[16] Thévenot, "Discours", 25-6: "que la main de Dieu ne se voit point mieux ailleurs que dans ces ouvrages qui sont faits par instinct, que la structure des cellules des abeilles"; … "[Aldrovandi, Mouffet et] ces autres personnages de grande lecture, qui ont crû avoir traitté à fonds l'histoire des abeilles, à cause qu'ils ont ramassé tout ce que les anciens & les modernes en ont écrit" (26). Thévenot notes that of the three figures that tessellate, (the square, triangle and hexagon), the hexagon contains the most space.

[17] Thévenot, "Discours", 27: "Ainsi l'on peut appliquer à ces ouvrieres les vers que le Poëte s'appliquoit à luy-mesme, & dire à leur honneur, In tenui labor, at tenuis non gloria. Ou bien souffrir qu'un Poëte Persan s'écrie avec une licence ordinaire aux Poëtes de son païs, Que si Archimede avoit examiné un ouvrage si surprenant, il se seroit mordu les doigts d'admiration avec les dents de l'envie".

[18] Virgil, *Georgics*, bk 4; Pliny, *Natural history*, bk 11, 11-70; on contemporary use of the bee tradition, see the special issue of *Studies in Eighteenth-Century Culture*, 18 (1988), with essays by Carol Blum, Jeffrey Merrick, Ann Fairfax Withington, and Roseanne Runte; also Peter Burke, "Fables of the bees: a case-study in views of nature and society", in *Nature and Society in Historical Context*, edited by Mikuláš Teich, Roy Porter and Bo Gustafsson (Cambridge: Cambridge University Press, 1997), 112-123; and Danielle Allen, "Burning the Fable of the Bees: the incendiary authority of nature", in Lorraine Daston and Fernando Vidal, eds., *The Moral Authority of Nature* (Chicago: University of Chicago Press, 2004), 74-99; shortly after our period, of course, there would come Bernard Mandeville's *Grumbling Hive* (1705) and *Fable of the Bees, or private vices, public benefits* (1714).

[19] Thévenot to Oldenburg, 28 Oct. 1671, in Oldenburg, *Correspondence*, eds. Hall and Hall, vol. 8, 310-11. Here Thévenot uses language which is almost identical with the text of his published version, cited above.

[20] [François Bernier, with Molière and Boileau], *Requeste des Maistres ès Arts, Professeurs et Regens de l'Université de Paris, présentée à la cour souveraine de Parnasse: Ensemble l'Arrest intervenu sur la dite Requeste: Contre tous ceux qui prétendent faire, enseigner ou croire de nouvelles descouvertes qui ne soient pas dans Aristote* ("Delphes, par la Société des Imprimeurs ordinaires de la cour de Parnasse" [Paris], 1671); edition by Sylvia Murr in *Corpus: revue de philosophie*, 20/21 (1992), 231-39, at 235: "Que Monsieur Thevenot sera reputé pour espion et peturbateur de la Republique des Abeilles, s'il ne rompt au plûtôt ces maisons de verre, où il les tient malicieusement enfermées, ne se fiant pas à ce qu'en a dit Aristote"; this is repeated in Condorcet, "Liste alphabétique des membres de l'ancienne Académie", in *Œuvres de Condorcet*, ed. A. Condorcet O'Connor and M. F. Arago, 12 vols. (Paris: Firmin Didot, 1847; reprinted Stuttgart: Frommann, 1968), vol. 2, 91 ("[Thévenot] observait les abeilles dans des ruches de verre, ne se fiant pas, dit la requête burlesque de Bernier, à ce qu'en avait dit Aristote").

[21] Hartlib had published a design for a glass hive in his *Reformed Common-Wealth of Bees* (London, 1655), 52; see Adrian Johns, *The Nature of the Book: print and knowledge in the making* (Chicago: University of Chicago Press, 1998), 266-71; see also Jim Bennett and Scott Mandelbrote, *The Garden, the Ark, the Tower, the Temple: Biblical Metaphors of Knowledge in Early Modern Europe* (Oxford: Museum of the History of Science / Bodleian Library, 1998), 162-3, who say that a glass hive was mentioned in Pliny (I have not yet traced this reference in Pliny).

[22] David Freedberg, *The Eye of the Lynx: Galileo, his friends, and the beginnings of modern natural history* (Chicago: University of Chicago Press, 2002), 151-194, and "Iconography between the History of Art and the History of Science: Art, Science, and the Case of the Urban Bee," in Caroline A. Jones and Peter Galison, eds., *Picturing Science, Producing Art* (New York: Routledge, 1998), 272-94; also Paula Findlen, *Possessing Nature: museums, collecting and scientific culture in early modern Italy* (Berkeley and Los Angeles: University of California Press, 1994), 214-6, 378-80.

[23] Later, in the mid-eighteenth century, the regular geometry of honeycomb cells was studied by Réaumur, Bazin, and (although without the suggestion of a length standard). See Ludwik Fleck, *Genesis and development of a scientific fact*, trans. Fred Bradley and Thaddeus J. Trenn, eds. Thaddeus J. Treun and Robert K. Merton (Chicago: University of Chicago Press, 1979), 32-33; and Emma Spary, "The Nature of Enlightenment", in William Clark, Jan Golinski, and Simon Schaffer, eds., *The Sciences in Enlightened Europe* (Chicago: University of Chicago Press, 1999).

[24] Bacon, *The New Organon*, ed. Lisa Jardine, trans. Michael Silverthorne (Cambridge: Cambridge University Press, 2000), Bk. 2, aphorism 36, pp. 163-4.

[25] I am here following the discussion in Léopold Defossez, *Les savants du XVIIe siècle et la mesure du temps* (Lausanne: Edition [sic] du Journal Suisse d'Horlogerie et de Bijouterie, 1946), 153-67; see also Pierre Costabel, "Picard et l'étalon universel de longueur fondé sur le pendule", in Guy Picolet, ed., *Jean*

Picard et les débuts de l'astronomie de précision au XVIIe siècle (Paris: CNRS, 1987), 315-28. Costabel says Huygens is concerned about latitude effects as early as 1666.

[26] See John W. Olmsted, "The scientific expedition of Jean Richer to Cayenne (1672-1673)," Isis 34 (1942): 117-128; and my "*Vers la ligne*: circulating measurements around the French Atlantic", in James Delbourgo and Nicholas Dew, eds., *Science and Empire in the Atlantic World* (New York: Routledge, 2008), 53-72.

[27] For an account of this mission, see Kurt Møller Pedersen, 'Une mission astronomique de Jean Picard: le voyage d'Uraniborg', in Guy Picolet, ed., *Jean Picard et les débuts de l'astronomie de précision au XVIIe siècle* (Paris: CNRS, 1987), 175-203.

[28] Picard, *Voyage d'Uranibourg, ou Observations astronomiques faites en Dannemarck par Monsieur Picard de l'Académie Royale des Sciences* [Paris: Imprimerie royale,] "1680", 29 pp., first published in the Académie's *Recueil d'Observations…* (Paris, 1693), fascicle 3a; reprinted in *MARS 1666-99*, vol. 7 (part 1), 193-232.

[29] Bib. Obs. B.4.11bis, bundle "Picard", letter 7 (Picard to Cassini, 13 Feb. 1672): "les Anglois ont fait leur possible pour auoir les originaux, mais enfin nous sommes maitres".

[30] Guy Picolet, "Une lettre inédite de l'abbé Picard à Colbert (13 octobre 1671)", *XVIIe siècle*, 31: 4 (1979), 389-95 (from BN ms Clairambault 886, f. 155r-56v).

[31] These twin aims are made clear in ARS RPV, t. 7, f. 240v (8 April 1679).

[32] John Flamsteed, *The correspondence of John Flamsteed, the first Astronomer Royal*, ed. Eric G. Forbes, Lesley Murdin and Frances H. Willmoth, 3 vols. (Bristol: Institute of Physics, 1995-2002), vol. 1, 690-92 (Flamsteed to R. Towneley, 3 and 22 May 1679). Flamsteed reports (692, 22 May) "wee tried here the length of a pendulum that vibrates seconds and found it 39 1/8 Inches English Measure, or of the Paris 36 71/100 hee has left a ball of the same weight with his with mee wherewith I intend to repeate the Experiment at my first leasure". 36.71 inches is an approximation of the value that the ARS was now using as its usual value for Paris (usually expressed as 36 inches, 8 1/2 lines, i.e. 36 and 43/60 inches).

[33] Robert Hooke, *Diary*, ed. Henry W. Robinson and Walter Adams (London: Taylor & Francis, 1935), 412 (20 May 1679): "At Mr Romers with Pappin, saw his pendulum of Brasse ball, Silkgrasse string, steel measure sliding, spring beam compasses, Scale, Measure of foot in steel compasses."

[34] See e.g. Locke, 2: 35 (Justel to Locke, 11/21 June 1679), and 91-92 (Roemer to Locke, 5/15 Sept 1679). Justel wonders whether the English have changed their mind; Roemer seems now to think that there is a measurable difference between London and Paris in the length of the pendulum.

[35] I discuss this voyage (that of Varin, Deshayes, and de Glos, to Gorée off Senegal), briefly in my "Vers la ligne", and more fully in a forthcoming paper.

[36] On metrology as a metaphor for all scientific communication, see Bruno Latour, *Science in Action: how to follow scientists and engineers through society* (Cambridge, Mass.: Harvard University Press, 1987), 247-57; see also Latour, "Circulating reference: sampling the soil in the Amazon forest," in *Pandora's Hope: essays on the reality of science studies* (Cambridge, Mass.: Harvard University Press, 1999), 24-80. On the establishment of modern standards, see Joseph O'Connell, "Metrology: the creation of universality by the circulation of particulars," *Social Studies of Science* 23 (1993): 129-173; and Alexandre Mallard, "Compare, standardize and settle agreement: on some usual metrological problems", *Social Studies of Science* 28 (1998): 571-601. See also the studies in Wise, *Values of Precision*; and in Marie-Noëlle Bourguet, Christian Licoppe and H. Otto Sibum, eds., *Instruments, travel and science: itineraries of precision from the seventeenth to the twentieth century* (London: Routledge, 2002); and Simon Schaffer, "Modernity and metrology", in Luca Guzzetti, ed., *Science and power: the historical foundations of research policies in Europe* (Luxembourg: European Communities, 2000), 71-91 (summarizing several other of his articles on metrology).

[37] On replication and craft skill, see (among others) H. M. Collins, *Changing order: replication and induction in scientific practice*, 2nd edn. (Chicago: University of Chicago Press, 1992).

[38] I found the following useful: Timothy Hampton, "Introduction: Baroques", *Yale French Studies*, 80 (1991), 1-12; John Beverley, "Going Baroque? [review essay]", *Boundary*, 2, Vol. 15/3 (1988), 27-39. José Antonio Maravall, *Culture of the baroque: analysis of a historical structure*, trans. Terry Cochran (Minneapolis: University of Minnesota Press, 1986 [1975]).

[39] Jean Bodin, *Six Livres de la République* (1576), bk 1, ch 10; in Bodin, *On Sovereignty*, ed. Julian H. Franklin (Cambridge: CUP, 1992), 80-81.

[40] See Alder, "A revolution to measure", and Schaffer, "Metrology, metrication, and Victorian values", in Bernard Lightman, ed., *Victorian science in context* (Chicago: University of Chicago Press, 1997), 438-74.

[41] This is of course a very familiar problem in the history of ideas; see, for just one early example, the criticisms made by Stephen Toulmin in his review of Rudolph W. Meyer, *Leibnitz and the Seventeenth-Century Revolution* (Chicago, 1952 [1948]): *British Journal for the Philosophy of Science*, 4 (1953), 256-258.

[42] On kitsch and German baroque science, see William Clark, "The scientific revolution in the German nations", in Roy Porter and Mikuláš Teich, eds., *The Scientific Revolution in national context* (Cambridge: Cambridge University Press, 1992) 90-114 (at 97-98); for links to Romanticism see Beverley, "Going baroque", and Anthony J. Cascardi, "The genealogy of the sublime in the aesthetics of the Spanish baroque", in *Reason and its others: Italy, Spain, and the New World*, eds. David Castillo and Massimo Lollini (Nashville, Tenn.: Vanderbilt University Press, 2006), 221-239.