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S.I. : USE & ABUSE OF MATHS

Vital anti-mathematicism and the ontology of the emerging life sciences: from Mandeville to Diderot

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Abstract Intellectual history still quite commonly distinguishes between the episode we know as the Scientific Revolution, and its successor era, the Enlightenment, in terms of the calculatory and quantifying zeal of the former—the age of mechanics—and the rather scientifically lackadaisical mood of the latter, more concerned with freedom, public space and aesthetics. It is possible to challenge this distinction in a variety of ways, but the approach I examine here, in which the focus on an emerging scientific field or cluster of disciplines—the 'life sciences', particularly natural history, medicine, and physiology (for 'biology' does not make an appearance at least under this name or definition until the late 1790s)—is, not Romantically anti-scientific, but *resolutely anti-mathematical*. Diderot bluntly states, in his *Thoughts on the interpretation of nature* (1753), that "We are on the verge of a great revolution in the sciences. Given the taste people seem to have for morals, *belles-lettres*, the history of nature and experimental physics, I dare say that before a hundred years, there will not be more than three great geometricians remaining in Europe. The science will stop short where the Bernoullis, the Eulers, the Maupertuis, the Clairauts, the Fontaines and the D'Alemberts will have left it.... We will not go beyond." Similarly, Buffon in the first discourse of his *Histoire naturelle* (1749) speaks of the "over-reliance on mathematical sciences," given that mathematical truths are merely "definitional" and "demonstrative," and thereby "abstract, intellectual and arbitrary." Earlier in the *Thoughts*, Diderot judges "the *thing* of the mathematician" to have "as little existence in nature as that of the gambler." Significantly, this attitude—taken by great scientists who also translated Newton (Buffon) or wrote careful papers on probability theory (Diderot), as well as by others such as Mandeville—participates in the effort to conceptualize what we

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might call a new ontology for the emerging life sciences, very different from both the 'iatromechanism' and the 'animism' of earlier generations, which either failed to account for specifically living, goal-directed features of organisms, or accounted for them in supernaturalistic terms by appealing to an 'anima' as explanatory principle. Anti-mathematicism here is then a key component of a naturalistic, open-ended project to give a successful reductionist model of explanation in 'natural history' (one is tempted to say 'biology'), a model which is no more vitalist than it is materialist—but which is fairly far removed from early modern mechanism.

Keywords Anti-mathematicism · Materialism · Vitalism · Medicine

Le règne des mathématiques n'est plus. Le goût a changé. C'est celui de l'histoire naturelle et des lettres qui domine.

Diderot to Voltaire, 19 February 1758

1 Introduction

Intellectual history still quite commonly distinguishes between the episode we know as the Scientific Revolution, and its successor era, the Enlightenment, in terms of the calculatory and quantifying zeal of the former—the age of mechanics—and the rather scientifically lackadaisical mood of the latter, more concerned with freedom, public space and aesthetics. Thus the eminent specialist of early modern medicine, Mirko Grmek, describes the eighteenth century, as regards life sciences and technology, as "a kind of bridge thrown from the seventeenth to the nineteenth century…. The eighteenth century is far less original than the seventeenth. The Enlightenment develops the research programs invented by the Scientific Revolution" (Grmek 1980, pp. 323–324). More socio-politically driven studies of the Enlightenment portray it in terms equally far removed from the present study, as possessed of a *rage de calcul*, a calculating frenzy associated with figures such as Condorcet: a will to map out society and the natural world, that is, to quantify and control them, as it develops the weights and measures of the metric system (Mayr 1986, pp. 66, 42–54, 124).[1] Conversely, some prominent historians of Enlightenment medicine wish to emphasize that constellations such as Enlightenment vitalism are far removed from the "merely mechanical" Scientific Revolution, with its overtones of alienation from Nature (Williams 2003).

The present discussion of eighteenth-century 'anti-mathematicism' in the context of programmatic and methodological discussions in the life sciences does not operate according to such distinctions. Rather, it seeks to turn our attention towards, not a school of thought or an individual figure, but a trend that emerges in the shift of focus towards the life sciences, i.e., in the various efforts to conceptualize an emerging

[1] Mayr seems to be recycling an old intuition of Foucault's, according to which the eighteenth century was essentially concerned with discipline, automatization and social control, in an obsessive extension of a *mathesis universalis*, with La Mettrie's 'man-machines' serving as an image of infinitely reproducible automata under the orders of Frederick the Great (Foucault 1975, p. 138). Minsoo Kang endorses Foucault's view in his otherwise superlative study of automata across the centuries, which I learned a great deal from (Kang 2011, p. 133f.). For an overview of the theme of automatization in the Enlightenment, see Schaffer (1999).

scientific field or cluster of disciplines—the 'life sciences', particularly natural history, medicine, and physiology (for 'biology' does not make an appearance at least under this name or definition until the late 1790s, even if recent scholarship is pushing back this recorded usage by a few decades[2]). A comparable analysis was suggested, with an earlier historical case study, by Claire Salomon-Bayet. Studying the anatomical reports at the Académie des Sciences in the first decades of its existence, after its foundation in 1666, she showed that despite the Académie being set up on Cartesian, mechanistic bases, as it focused on cases drawn from the 'biomedical' world (anatomy, embryology, vital chemistry and so on) it quickly contradicted this research program (Salomon-Bayet 1978). In my case, I specifically examine anti-mathematicism as a defining feature of some central, programmatic Enlightenment statements of the status of the life sciences, and will suggest that it appears in different versions, some stronger, some weaker. I will broadly characterize these different types of anti-mathematicism as either more *skeptical* or more *ontologically* based.

What interests me in this attitude—taken by great scientists who also translated Newton (Buffon) or wrote careful papers on probability theory (Diderot), as well as by others such as Mandeville—is that it participates in the effort to conceptualize what I shall call a new ontology for the (newly emerging) life sciences, very different from both the 'iatromechanism' and the 'animism' of earlier generations, which respectively failed to account for specifically living, goal-directed features of organisms, or accounted for them in supernaturalistic terms by appealing to an 'anima' as explanatory principle.[3] Anti-mathematicism is also not Romantically anti-scientific.[4] I suggest it was part of a more naturalistic, open-ended project to give a successful reductionist model of explanation in 'natural history' (one is tempted to say 'biology'), in the sense of an explanation which takes a higher-level phenomenon, say, voluntary action, or the association of ideas, and explains it in terms of lower-level processes, whether these be physiological (as in La Mettrie) or psychologically deterministic (as in Diderot). Such models attend to the specificities of vital processes without being thereby 'vitalistic', and they often, but not always, are associated with more or less overt materialist implications in the texts discussed here, while also seeking to create a distance from early modern mechanism.

Programmatic ideas for how to conceptualise the life sciences—their scope, their method, and their boundaries—in the mid- to late-eighteenth century often appealed to Newtonian insights. From the celebrated physiologist Albrecht von Haller to the

[2] McLaughlin (2002); see in addition Bognon-Küss and Wolfe (Eds.), forthcoming. I have made the preliminary case elsewhere for why a considerable part of the (broad) domain of 'natural history' as used by authors such as Diderot and Buffon corresponds to what we would call 'biology': not just a 'geological'-type history of Life but also a comprehensive, comparative study (Wolfe 2009).

[3] On iatromechanism see Grmek (1972); on Stahlian animism see Duchesneau (2000). The idea of a 'neither-nor' position will also be familiar to those who have studied eighteenth-century medical vitalism, which is not the topic of the present article, although I touch on authors like Bordeu and Venel who belong to that story.

[4] Of course there were traditions of 'Romantic science' (as discussed in Cunningham and Jardine (Eds.), 1990; Poggi and Bossi (Eds.). 1994), but the strands of anti-mathematicism I describe here were not attempts at erecting 'parallel' or 'rival' scientific programs; in addition, an author like Diderot is a committed determinist, quite willing to allow for natural 'modelling' of human behavior, including in the sense of social regularities.

group of physicians known as the Montpellier vitalists, this kind of approach sought to capitalize on the power of the Newtonian analogy—i.e., the claim that postulating an unknown in order to deduce regularities from it, as Newton did with gravity, can also be a fruitful approach in the study of specifically vital properties, postulating a 'vital principle' or 'vital force'—without any metaphysical or experimental claim to be doing a 'different kind of science'. But some other approaches, which also had a strong affinity to vitalism, albeit in the form of a 'vital materialism' (Reill 2005; Wolfe, 2017), were more opposed to physico-mathematical encroachment onto the territory of the life sciences, while nevertheless not being 'anti-science'.

2 Anti-mathematics and quantification

One form of anti-mathematicism in life science was the physician Bernard Mandeville's skeptical attitude, in his *Treatise of Hypochondriack and Hysterical Diseases* (1711, revised 1730) towards quantitative, numerical approaches in medicine, itself reminiscent of Thomas Sydenham's hostility to mechanism-friendly anatomical experimentation. Where Mandeville stated that "Our shallow Understandings will never penetrate into the Structure of Parts of that amazing as well as mysterious Composition, the Mass of Blood" (p. 168), Sydenham, in a 1668 manuscript entitled *Anatomia*, which may well have been written with Locke (indeed, current scholarship tends to attribute its authorship primarily to Locke), is explicitly hostile to the value or success of quantitative experiments and intervention in medicine: "it is …beyond controversy that nature perform all her operations in the body by parts so minute and insensible that I think noe body will ever hope or pretend even by the assistance of glasses or any other invention to come to a sight of them."[5] In his *Treatise*, which is in dialogue form, Mandeville addresses the issue in a more diverse fashion, including by bringing in an analysis of social trends in medicine, such as mathematization. The upshot is a rather skeptical discussion of a newer version of the phenomenon, Newtonianism in medicine (Mandeville 1730, pp. 175, 201). The character Philopirio, who various hints identify as Mandeville,[6] specifies that it is in the realm of *practice* that he cannot see the usefulness of mathematics. The other character, Misomedon notes that it may be a matter of time:

> But the Scheme of bringing Mathematicks into the Art of Medicine is not of many Years standing yet. The *Newtonian* Philosophy, which I believe has in a great measure been the Occasion of the Attempt, was not made publick before the latter End of the last Century: And considering the vast Extent the Art of Physick is of, both as to Diseases incident to human Bodies, and the Medicines that are made use of, great length of time must be required before an entire

[5] Sydenham/Locke, *Anatomia* (1668), Locke ms., National Archives PRO 30/24/72/2 ff. 36v–37r., transcribed in Dewhurst (1963), pp. 85–93, here, p. 85. The manuscript is attributed variously to each or both authors, different parts being in the handwriting of one or the other.

[6] Philopirio clearly seems to be a kind of avatar of Mandeville—a foreign-trained physician with radical materialist leanings when he waxes theoretical or metaphysical (stated first in the Preface (Mandeville 1730, p. xiii) and more explicitly with reference to the 'Low Countries' (3)). Later in the book (p. 126) Philopirio notes he studied in Leyden (like Mandeville, who had defended a thesis on animal automatism at Leyden in 1689), and adds (p. 132) that he defended a thesis "Chylosi vitiata" in 1691.

> System can be form'd, that shall be applicable to all Cases, and by the Help of which; Men shall be able to explain all *Phenomena* that may occur, and solve all the Difficulties and Objections that may be made (Mandeville 1730, p. 181).

Obviously, in the mechanical approach to the structure of the body, we need mathematics, Philopirio grants: "All Fluids likewise are subject to the laws of Hydrostaticks" (p. 179). But if we do not know the exact nature of the elements of these entities, calculations are pointless (p. 183). What physicians want to know and they lack is (a) the *causes* of diseases and (b) the properties ("virtues") of each remedy in the *materia medica* (*ibid*.). An exact mathematico-mechanical model in which the dose of the remedy is proportionate to the quantity of blood in the individual is false, since temperaments or individual natures as encountered by the physician do not obey such laws (p. 187). Mandeville had already expressed some irony with regards to this quantitative confidence earlier, recalling his skepticism towards the promise of a kind of transparency in knowledge (like Sydenham's): "I know it is a *received opinion* now-a-days, that a Man of Sense who understands Anatomy, and something of Mechanick Rules, ought to penetrate into the Manner of every Operation that is performed in a Human Body, it being but a mere Machine" (p. 115).

The latter opinion was a core claim of the Scottish iatromechanist (and medical Newtonian) William Cockburn, some decades earlier: "The doses of medicaments necessary to elicit a certain effect are proportional to the quantity of the blood" in the individual:

> for if a particular dose were required to alter the thickness of, say, one pound of blood to a particular degree, then twice the dose would be necessary in order to alter two pounds to the same degree, thrice to three, etc. And generally, if the quantity of blood *b* requires dose d, then the quantity of blood *mb* requires the dose *md*. (Cockburn and Southwell 1704, pp. 2119–2220)

Perhaps the most radical statement of this pro-mathematical view in its Scottish 'medical Newtonian' version was that of the Edinburgh physician Archibald Pitcairne. In his 1692 Inaugural Lecture at Leyden, entitled "An Oration Proving the Profession of Physic Free from the Tyranny of any Sect of Philosophers," Pitcairne emphasized the priority of mathematics over philosophy for physicians (Pitcairne 1715, p. 8), and in his *Elementa Medicinae* of 1717 wrote that "All Diseases of the Fluids consist either in a Change of their Qualities, or a Change of the Velocities of their Motions"; hence "The cure of every Disease, whether in the Vessels or Fluids, or both, is to be effected only by mechanical Laws."[7]

Such views concerning, not just the pertinence of mathematics in medicine but its absolute applicability, continued to be held in the Enlightenment by figures such as George Cheyne, focusing notably on a quantitative approach to fevers and to diet, although with a more heuristic usage of mathematics than in earlier 'static medicine'

[7] *Elementa Medicinae* (1717), translated as *The Philosophical and Mathematical Elements of Physick* (1718), §§ LXXVII and LXXXVIII, in Pitcairne (1718), pp. 353, 354. That Pitcairne's arguments in favour of mathematics, contra philosophy may have a political subtext (promoting the 'certainty' of mathematics against the danger of dissent, enthusiasm and theological ferment, as discussed in Schaffer 1989) lies beyond the scope of the present paper.

(*medicina statica*). The latter program, associated notably with Sanctorius (who was William Harvey's professor at Padua) sought to measure bodily ingesta and excreta, including blood, sweat, urine and tears, and formulate ratios of these measures in order to further enhance the medical goal of preserving health (Dacome 2012). Thus, for instance, Pitcairne summarized Sanctorius as presenting proportions such as "the Excretions made in a given Time have commonly this Proportion, that if the Excretion by Stool be as 4, That by Urine is as 16, and That thro' the Pores of the Skin as 40, or more" (cit. in Stigler 1992, p. 110).[8]

It is worth stressing the literally quantitative character of the claims of the Scottish iatromathematicians, because such claims are often erroneously assimilated to the earlier, enormously influential proofs for the circulation of the blood in William Harvey. The latter proofs are often treated as quantitative—one author wrote rather anachronistically that "Harvey was the first biologist to use quantitative proofs",[9] but this is a real misunderstanding. In Chapters X and XI of *De Motu Cordis* Harvey used the language of "experimental evidence" ("the first proposition (of circulation) has been proved…by reference to experimental evidence…," Harvey 1628/1976, Chapter X, p. 85) but overwhelmingly cashed this out in qualitative terms, and the 'paradigmatic' ligature experiment in Chapter XI is full of appeals to our ability to "feel" changes in the blood, as is also the case in the later *De Generatione Animalium*, where primarily *qualitative* observations predominate, and are presented as experiments by him (e.g. chapter XVII, in Harvey 1651/1981, p. 99).[10]

As Peter Distelzweig has observed, Harvey's proofs, however much they may appeal rhetorically to simple arithmetic, and granting that they do deal with the quantity of blood produced in the body, are not at the service of a larger mathematical articulation of significant relations among quantifiable aspects of nature; nor are these proofs taken, the way they might be in, say, Galileo, as the basis of a quantitative "method."[11] Exactly what should count as quantification, quantitative proofs, quantitative explanations, etc., is not immediately apparent: "not giving specific quantities …is not the same as being content with rough values because they are adequate to prove the point."[12] Some prominent figures who were seen as champions of mechanical medicine (and

[8] The prominent iatromechanical physician Giorgio Baglivi insisted in the early 1700s that static medicine be considered a legitimate part of the medicine of solids, and recommended to this end the reading of both Harvey and Sanctorius (Dacome 2012, p. 385), a connection reiterated in the scholarly literature, e.g. "Harvey was to some extent applying the mental habits of the dietetic physician" (Bylebyl 1977, p. 383). Similar considerations were involved, not in the study of digestion but of circulation (before and after Harvey), for instance with regard to how much blood it was suitable to eliminate in bloodletting.

[9] Kilgour, cit. in Massey (1995), p. 20. See also Pagel (1976), pp. 3–5.

[10] See Salter and Wolfe (2009) for more discussion of this point. Massey (1995) critically evaluates various charges against Harvey's experiments for not being 'quantitative enough' (pp. 43–45), in a way which complements my 'qualitative' point here (and what is termed "embodied empiricism" in Salter and Wolfe (2009)). The same point can be made by focusing on the term (and the notion) of a *law* (thinking of e.g. Galilean laws, like the law of falling bodies): Harvey doesn't speak about his account of circulation as a law, while the Scottish Newtonians in the 1690s and thereafter explicitly use the language of laws.

[11] See Massey (1995), Distelzweig (2016) for detailed discussion of Harvey's method as quantitative or not, mathematical or not, mechanistic or not. Thanks to Peter Distelzweig for helpful discussion of these matters.

[12] Jevons, cit. in Massey (1995), p. 41; see also Porter (2000).

by later philosophers of science, as formulators of beautiful quantitative proofs) such as Harvey, actually seem to attend more to qualitative differences, e.g. between blood being newly generated and blood in a circular circuit (correlated, e.g. with the food we ingest), especially if compared to more zealous quantifiers such as the 'medical Newtonians', particularly Pitcairne. Similarly, the different forms of anti-mathematicism I discuss here have no strict (at least other than contextual and situated[13]) definition of quantification. But what did the skeptical responses amount to, other than being sarcastic about claims that the body was a "mere Machine"?

3 Skeptical anti-mathematicism

Objections very similar to Mandeville's but now emanating from a vitalist context were made by Jean Charles Marguerite Guillaume de Grimaud, a late figure of Montpellier vitalism whose medical thesis on irritability was published only under his initials ('D.G.') in 1776. Grimaud explicitly targeted Keill and others on their claims to quantify muscular action, specifically contractility, combining mathematical criticisms with appeals to empirical evidence, ranging from the bizarre feats of muscular strength in the animal world to King Augustus II of Poland's ability to bend horseshoes with two fingers, and the better-known case of the polyp (Grimaud 1776, pp. 33, 35). Some like Keill or Boerhaave ended up under-estimating muscular capacity; others like Borelli, due to their belief that the internal structure of muscular tissue was rhomboids, ended up overshooting the figure by 60 times (p. 37).

Again like Mandeville, the prominent Montpellier vitalist Théophile de Bordeu was suspicious with regard to quantification, but in his case took the example of sphygmology, i.e. the medicine of the pulse, and discussed attempts to measure the pulse using a watch or a metronome; for Bordeu, in this influenced by Japanese and Chinese medicine via Jesuit translations, a pulse was either fast or slow, soft or hard, etc.[14] Bordeu also has combined criticisms of chemists, mathematicians *and* mechanists that seem to imply a stronger ontological commitment to the nature of Life as something specific with regard to physico-mechanical Nature: the mechanist, but also the "most sublime mathematician" cannot grasp the depths of nature; just as the chemist cannot literally *make* blood, the physician "cannot make a machine like the heart, the brain or the stomach" (p. 831). Bordeu opposes this sense of life to the most sublime ideas of mathematicians, physicists, and other sorts of natural philosophers (the term itself was not used in French).[15] These criticisms are similar in kind to earlier medical crit-

[13] Cf. Roux's "historically situated and empirical definition of mathematics": "what should be called 'mathematics' is the activities of those who called themselves or were called by others 'mathematicians"' (Roux 2010, p. 325).

[14] Bordeu, *Recherches sur le pouls par rapport aux crises* (1754), in Bordeu (1818), vol. I, pp. 257–258 (All translations are mine unless otherwise indicated); see also Terada (2006). Bordeu's discussion of the history of medical theories of the pulse is actually more complicated than this, as he criticizes both Galenic and more ancient (e.g. Chinese) theories for their vagueness, and proposes what we might call more "functional" descriptions, referring to the activity of other organ systems such as the arteries, but also to rhythm and pace.

[15] Bordeu, *Recherches sur les maladies chroniques* (1775), § XVI, in Bordeu (1818), vol. II, pp. 831–832. However, there is no monolithic anti-mathematical position in the Montpellier vitalist context. The Stahlian

icisms of the (medical) pertinence of weighing a patient's urine, and more generally to criticisms of the 'anthropometric' tradition of *medicina statica* that were made e.g. in reaction to Sanctorius' program to quantify all bodily intakes and outtakes.

In his *Treatise*, Mandeville had given the example of water: the difference between cold water, which we drink with pleasure and is necessary to our survival, and hot water, which makes us vomit, is not a difference that can be measured in its mass (Mandeville 1730, pp. 192–194). Vomiting, purgatives and emetics had obviously posed a challenge to both dogmatic mechanists ('triturationists' with regard to digestion) and strict iatrochemists, since the processes involved could not be properly accounted for by reductive explanations of either kind; this led authors such as Leibniz, a few decades earlier, to devise hybrid, mechanico-chemical explanations for such phenomena (Smith 2011, Chapter 1). If he was not (quite) a mechanist, how does Mandeville account for the physiological processes which apparently underly our corporeal and mental life? In *chemical* terms, appealing to "ferment" concepts in medicine (p. 17), naming "Concoction" as "that which is the basis of the whole Oeconomy" (p. 84). In the iatrochemical tradition of authors such as Thomas Willis, fermentation was a fundamental explanatory tenet, enabling the physician to account for a variety of phenomena, from digestion to fevers to disease overall, in terms of different chemical mixtures and their degrees of 'fermentation'. Of course there is no absolute historical or conceptual opposition between Newtonianism and chemistry: Herman Boerhaave, the author of the *Elementa Chemiae* (1732), would certainly not have approved of opposing them. But thinkers such as Mandeville and Diderot did so, the first on practical, falsifiable grounds, and the second for reasons involving matter theory and broader ontological commitments. And this difference between two anti-mathematical positions fits with the broader diversity of pro-mathematical projects for transferring, say, Newtonian methodology to the social sciences, without any particular foundationalist ontological claims.[16]

Again, Mandeville was skeptical but allowed that medicine might be mathematized *in time*. Albrecht von Haller—no opponent of geometrization (he stated in the famous first sentence of his influential textbook in physiology, the 1757 *Elementa physiologiæ*,

Footnote 15 continued
Boissier de Sauvages, a professor in Montpellier during the study years of figures such as Bordeu and Venel, was explicitly dismissive of anti-mathematical trends, bluntly asserting that "I attribute the errors committed in Medicine to a lack of knowledge of Mathematics," describing mathematics as the "foundation of physics and philosophy," and warning against those who seek to "banish it from medical schools" (de Sauvages 1772, vol. I, p. 77). Sauvages acknowledges that some parts of mathematics, like "astronomy and trigonometry," are not useful to medicine, but contrasts these with fluid dynamics (for understanding blood vessels), acoustics and optics (for understanding hearing and vision) (pp. 77–78). Similarly, Robert Whytt, a member of the same medical tradition (animism) in the Scottish context, also privileges the soul as an explanatory term *while at the same time conducting extensive quantitative experiments in life science*, notably repeating the 'hydrostatic' experiments of Stephen Hales, and using quantitative arguments to address cases like the treatment of gallstones (Whytt 1755).

[16] Thanks to Sebastián Molina for this point. One could add that the distinction between ontologically founded and strictly skeptical forms of anti-mathematicism matches the diversity of iatromathematical projects, some which genuinely seek to reduce bodily organs to mathematical entities (an 'ontological' reduction, then), others which view mathematization as a kind of heuristics.

that "the fibre is to the physiologist what the line is to the geometrician"[17])—stakes out a kind of middle ground, first granting mathematics a place: "I shall not insist on the usefulness of mathematics in the *animal economy*. It is evident in the functions of the eye, but is not with regard to the movements of the vital organs," but conceding that it has not yet arrived at a satisfactory level of development: "Up until now, the calculators have arrived at such opposed results that they have put off modern physiologists from any use of geometry" (von Haller 1777, XXIII, p. 428b).

It is not just a matter of being pro- or anti-mathematical; further sub-categories are needed here, because Mandeville, Haller, and others all concur on a 'relative place' for mathematics in life science (potentially a great place, in Haller), yet they differ from each other. We should distinguish between stronger and weaker skeptical attitudes towards mathematics in life science (medicine and physiology in particular), represented here by Mandeville and Haller respectively: Mandeville's stronger skepticism, with its Molière-like demystification of the pretentions of the learned physicians, is quite different from Haller's weaker skepticism, which amounts to the confidence that medicine and physiology may achieve mathematical rigor (and quantification) in time. And somewhere in between—less skeptical of medical confidence in general than Mandeville but also less confident of a gradual, cumulative improvement of mathematical tools in medicine than Haller—lies the position succinctly put in a 1695 polemic against Pitcairne as "It is not the Use, but the Abuse of [Mathematics] I complain of."[18] Now, more mathematically oriented readers might ask at this point, but which mathematics is at issue? which branch of mathematics, at which stage of historical evolution? But my analysis is concerned with *anti*-mathematical arguments, which I classify according to different forms, indeed 'strengths' of anti-mathematical attitudes. And these arguments seem to use 'mathematics', the idea of quantification, abstraction, formalization and such more or less as overlapping terms, running them into one another if not treating them as synonyms per se.

Consider the criticism made by a noted mathematician, D'Alembert, of the application of calculations to "the art of healing," in a rather visible place, the "Discours Préliminaire" of the *Encyclopédie*. D'Alembert warns that we should take mathematical hypotheses in medicine with quite a grain of salt:

> Yet we must admit that *the Geometricians sometimes abuse this application of Algebra to Physics*. Lacking experiments on which to found their calculations, they really allow themselves the most convenient (*commodes*) hypotheses they can, which often are quite far from what really exists in Nature. *People have sought to reduce even the art of healing to calculation*; and the human body, this very complex machine, has been treated by our algebraic Physicians as if it were the simplest (and easiest to decompose) machine.[19]

Similarly, the deliberately ambiguous comment in the article "Méchanicien (Médecine)," also in the *Encyclopédie*, combines an empirical observation ("Of all the

[17] *Fibra enim physiologo id est, quod linea geometræ* (von Haller 1757, I, p. 2).

[18] Edward Eizat, *Apollo Mathematicus: or the Art of Curing Diseases by the Mathematicks*, 1695, cit. Stigler (1992), p. 114.

[19] *Enc*. I, p. vi, emphasis mine (thanks to Iulia Mihai for calling my attention to this passage).

physical sciences to which we have attempted to apply Geometry, it appears that there is none in which it penetrates less than Medicine") with a more slippery distinction between an illegitimate 'geometrization' of medicine and a legitimate 'geometrical inspiration' in the same science ("With the support of Geometry, physicians will undoubtedly be better physicists, that is, the *esprit géométrique* they take from Geometry, will be of greater use to them than Geometry") (Anon 1765, p. 221).

All these objections to iatromechanics in its particularly mathematical form are fundamentally *empirical*. With the exception of some of the vitalist authors, who we will encounter again below, the objections do not rest on an ontology of Life or, differently put, they do not *ontologize* the features of either mathematical entities (negatively) or organic, biomedical entities (positively). At most, Mandeville seems to be skeptical of quantification inasmuch as it purports to deliver universal explanations; he stresses particulars, such as particular temperaments.

4 Ontological anti-mathematicism

In contrast to all of the above, Diderot offered a much sharper, and perhaps more 'categorical' form of Mandeville's objection. Where Mandeville was skeptical about mechanical methods but allowed for their content to be gradually filled in by successful experiments (like Haller), and D'Alembert was concerned about applicability, Diderot hinted at a profound *ontological* divide between the two kinds of sciences, in this passage from his *Pensées sur l'interprétation de la nature* (1753–1754):

> We are on the verge of a great revolution in the sciences. Given the taste people seem to have for morals, *belles-lettres*, the history of nature and experimental physics, I dare say that before a hundred years, there will not be more than three great geometricians remaining in Europe. The science will stop short where the Bernoullis, the Eulers, the Maupertuis, the Clairauts, the Fontaines and the D'Alemberts will have left it. …We will not go beyond.[20]

Diderot uses 'geometricians', as he often does, as a generic term for mathematicians. (E.g., in a text that occurs in different versions in several of his writings, in which Diderot describes an absent-minded "geometrician" lost in thought and behaving in an automatic, indeed deterministic fashion, the geometrician is clearly D'Alembert.[21] It is also obvious that his objections elsewhere, centring on abstraction, have little to do with the specifics of geometry understood as a technique of spatial visualization.) His crucial claim, whether or not it was historically validated, is that mathematics will just drop off or stay where it is, whereas the 'life sciences' will take off (the "history of nature" or "natural history" was a term designating the cluster of activities we might today call biology: Hoquet 2010; Wolfe 2009, 2014).[22] Diderot meant this both as a

[20] Diderot, *Pensées sur l'interprétation de la nature* § IV, in Diderot (1975), IX, pp. 30–31. I discuss this at greater length in Wolfe (2014), with regard to Diderot's labelling of an epigenetic materialism as a kind of 'modern Spinozism'.

[21] *Éléments de physiologie*, ch. VI, "Volonté," in Diderot (1975), XVII, p. 485.

[22] It is indeed the case that the program of natural history had something to do with a rejection of Cartesianism, definitely with an anti-mathematical attitude. Similarly, it is possible, or even probable, that a

fact about scientific activity and as an ontological claim, that the processes and entities life scientists seek to understand are not to be understood in mathematical terms, as he explained in the same text:

> One of the truths that has recently been announced with great courage and force, which a good physicist should not lose sight of, and which will have the most beneficial consequences, is that the realm of the mathematicians is an intellectual one, what we take to be rigorous truths absolutely loses this advantage when it is brought down to our earth. It was concluded that experimental philosophy had to rectify the calculations of the geometricians – a consequence even the geometricians granted. But what's the point of correcting geometric calculations by experience? Isn't it more direct to rely on the latter's results? This shows that mathematics, especially of the transcendent sort, leads to nothing particular without experience; it is *a kind of general metaphysics which strips bodies of their individual properties*…(§ II, emphasis mine).

The issue is not just an 'externalist' one of which sciences rise and which sciences fall, as seen from a kind of sociological standpoint, but also that of a metaphysics which fails to do justice to the properties of (individual) bodies.

A major influence on Diderot's ideas here was the work of the great naturalist Buffon, whose *Histoire naturelle* had begun to appear in (1749), thus just a few years before Diderot's *Interprétation*. There, Buffon had spoken of an "overreliance (*abus*) on mathematical sciences," given that mathematical truths are merely "definitional truths": "exact and demonstrative" but also "abstract, intellectual and arbitrary."[23] Buffon was a mathematician and translator of Newton (*Méthode des fluxions*, 1740), just as Diderot published works on probability theory and attempted an analysis of Newton in his *Mémoires sur différents sujets de mathématiques*.[24] Here, however, Buffon is less of a Newtonian, for he is seeking to define and delimit the realms of "natural history and particular physics" (*physique particulière*), *as non-mathematical*. In natural history, Buffon declared, "the topics are too complicated for calculations and measures to be advantageously applied."[25] Indeed, Diderot's bold claim about a "revolution in the sciences" follows shortly after a passage referring to Buffon's criticism of abstraction.[26] Buffon's critique of mathematical truth opposes it to *physical*

Footnote 22 continued
different intellectual strand, more Baconian, more Lockean, leads through natural history to 'biology'. Yet Bacon would not have approved of the anti-mathematical impulse in Diderot and Buffon (see Bacon, *De Augmentis Scientarum*, III, 6, in Bacon 1857, p. 578; Vartanian 1992, p. 130).

23 Buffon, "De la manière d'étudier l'Histoire Naturelle," in Buffon (1749), I, "Premier discours," p. 54.

24 On Diderot's mathematical ability (his capacity to follow differential calculus but not the work of Euler or D'Alembert, and his work in probability theory), see Dhombres (1985).

25 Buffon, "De la manière," in Buffon (1749), I, p. 62; Hoquet (2005), p. 175; Hoquet (2010), p. 38 (which emphasizes the difference between a mathematical project and a 'physical' project in Buffon, where the latter is a kind of natural history, but conceived of as a quasi-physics).

26 Eric Schliesser has pointed out that this resembles Hume, *Treatise* I.iv.1; the question of Diderot's debt to Hume is not easy to make out, although for a convincing textual confrontation between Hume's *Dialogues* and Diderot's *Letter on the Blind* that reveals surprising resonances and perhaps chains of influence, see Paganini (ms. 2015).

truth, a distinction specific to him (mathematical truths are abstract and definitional; physical truths are "non-arbitrary," "do not depend on us," and "are based on facts"[27]) but which is comparable to Diderot's remarks in the *Pensées sur l'interprétation de la nature* and the *Principes philosophiques sur la matière et le mouvement* (where he asserts "I, who am a physicist and a chemist, who take bodies in nature and not in my mind," Diderot 1975, XVII, p. 34), as I discuss in Sect. 4. Buffon's work is not always easy to classify, and it is peppered with conceptual personifications such as the *moule intérieur*, about which no scholarly consensus has emerged over the past few generations of excellent Buffonian work. But it seems safe to say that he valued many kinds of mathematics while being suspicious at least of their *current applicability* to the sciences of living nature. As I will discuss in closing, Diderot 'ontologized' and generalized this kind of suspicion.

Nicolas Fréret, the Secretary of the Académie des Inscriptions et Belles-Lettres in Paris, close to the *encyclopédistes*, and overall a fascinating figure at the intersection of historical erudition and underground intellectual activity, often described as one of the major atheist writers of the first half of the eighteenth century in France, made a very similar criticism of the dangers of mathematical abstraction, with an additional reference to atomism as the original version of the problem, for its mistaken belief that one could treat the size, shape or motion of atoms as separate properties. In his influential clandestine work, the *Lettre de Thrasybule à Leucippe* (written in the 1720s-1730s, in circulation from 1745 onwards, although only formally published in 1768), he wrote that

> In mathematics, for instance, geometricians, whose object [of study] is the magnitude or quantity of bodies, have grown accustomed to examine the following: points, i.e. extensions without length, width or depth; lines, i.e. extensions with length alone; surfaces, which possess length and width but no depth; and lastly, solids, i.e. bodies which possess these three dimensions. They are the first to grant that no body does or can exist, in the way they imagine their points, lines and surfaces; that these mathematical bodies only exist in our mind, whereas all natural bodies are genuinely extended in all directions.[28]

These criticisms are very close to Diderot's comment, also in the *Pensées* (shortly before the passage quoted above), in which he judges "the *thing* of the mathematician" to have "as little existence in nature as that of the gambler."[29] Of course, this was not intended as a derogatory comment, as Diderot was discussing the mathematics of games, but he does emphasize that the existence of mathematical entities, like that of the entities in games, is purely conventional.

[27] Buffon (1749), I, pp. 54–55.

[28] Fréret (1745/1986), ch. VII, pp. 339–340, 370–371. Fréret continues with a less frontal critique of arguments for the divisibility of matter. In his 1751 report on the Abbé du Resnel's *mémoire* on the utility of mathematics versus that of belles-lettres, Fréret enumerates many positive traits of mathematics both internally and for its concrete accomplishments, but notes (Fréret 1751, p. 24) that the "esprit de calcul" can indeed be extended beyond its legitimate realms of applicability, with results that then turn negative.

[29] Diderot, *Pensées sur l'interprétation de la nature*, § III, in Diderot (1975), IX, p. 30.

In addition to these critiques of mathematical abstraction, which as we can see, were part of a certain kind of radical intellectual subculture of the time, Diderot makes two major points in the passage on 'revolution in the sciences' cited above. The first is a claim about the revolutionary dimension of the life sciences in contrast to the 'static' situation of the mathematical sciences. This claim is both a 'sociological' observation and prediction concerning the objects of scientific interest, and a more normative assertion that a certain kind of entity—living beings—will require a certain kind of science, with methods and implicitly an ontology different from those of previously existing sciences such as geometry and mechanics (Wolfe 2011). The second claim hints at a critique of mathematical abstraction. Importantly, both have a twofold dimension, in that they are *both empirical claims and amount to an ontological commitment to a materialist metaphysics of Life*.[30]

5 Chemical anti-mathematicism

Diderot reiterates his critique of mathematical abstraction a number of years later, in a short piece of natural philosophy he composed in 1770, the *Principes philosophiques sur la matière et le mouvement* (*Philosophical Principles on Matter and Motion*). There, his criticism of mathematical abstraction has a more explicitly chemical reference:

> You can practice geometry and metaphysics as much as you like; but I, who am a physicist and a chemist, who take bodies in nature and not in my mind, I see them as existing, various, bearing properties and actions, as agitated in the universe as they are in the laboratory where if a spark is in the proximity of three combined molecules of saltpeter, carbon and sulfur, a necessary explosion will ensue (Diderot 1975, XVII, p. 34).

In Diderot's lecture notes from Guillaume-François Rouelle's chemistry course in the 1750s at the Jardin du Roi (which he attended for three years), he also criticized the abstractions of "physics" and insisted that "it is from chemistry that it learns or will learn the real causes" of natural phenomena.[31] Diderot's position relies on a chemical conception of matter as possessing active properties, over and against Newton, and

[30] In addition, neither of these claims are particularly skeptical in the senses I discussed earlier. In the first workshop in which we presented our ideas on anti-mathematicism (Warwick University 2013) Eric Schliesser set out a very suggestive distinction between *global* and *containment* strategies in eighteenth-century anti-mathematicism, where "global" refers to arguments that challenge and undermine the *epistemic* authority and solidity of mathematical applications as such, while "containment" refers to arguments restricting the application of mathematical tools to specific domains (astronomy, optics). This distinction resembles my distinction between ontological and skeptical forms of anti-mathematicism, but notice that Schliesser's "global" strategies are presented in epistemic terms, neatly contrasting with my ontological emphasis. His "containment" strategies seem to fit rather well within the spectrum of more or less skeptical challenges to mathematics that I describe, perhaps closer to the weaker form of skepticism.

[31] Diderot (1975), IX, p. 209. His lecture notes were first published in 1887, and are now available in the standard edition of his works: *Cours de chimie de Mr Rouelle* (1756), in Diderot (1975), IX. See discussion in Pépin (2012).

drawing on Rouelle's (Stahlian) chemistry of mixts. What does this more or less anti-Newtonian attitude mean, and what is the Rouellian chemical background?

It is too strong to label Diderot's chemico-materialism (and its inspiration, the vital chemistry of Rouelle and Gabriel-François Venel) as "anti-Newtonian" (Guédon 1979), or in more inflated terms to present him as "the supreme anti-Newtonian of the High Enlightenment" (Israel 2006, p. 222).[32] Rather than the more common ideological opposition to Newton as the patron saint of a Boyle Lectures-type natural theology,[33] the tension here focuses on the ontology of action at a distance without promoting against it a form of Cartesian physics.[34] Diderot's attitude towards the particular case of mathematics associated with Newton and Newtonianism is not easy to make out clearly, but one can summarize his overall relation to the issue as follows: he has an *ontological* opposition to the mathematical treatment of life, whilst he thinks that probability theory does not do violence to the nature of organisms the way that, say, iatromechanism did. The more empirical and the more ontological strands of anti-mathematicism are also present in Diderot's integration of chemistry, as I discuss now.

Rouelle's project of tables of affinities, which is central in post-Stahlian chemistry, including that of Venel (Pépin 2012; Restrepo 2013), was ontologically opposite to the idea of a system of Newtonian attraction. Rouelle promoted a chemistry of *affinities* (itself explicitly connected to the older idea of *sympathies*) over and against Newtonian gravitation:

> The ancient chemists noticed that certain bodies placed at a certain distance attracted one another. They named the cause producing this effect …*sympathy*, a term which modern chemists have replaced with *affinity* or *relation*, which does not follow the universal law of gravity …but that of the homogeneity of surfaces.[35]

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32 Indeed, more recent examination suggests it is an overstatement to call Rouelle an "anti-Newtonian" as well (Franckowiak 2003). And the opposition between a chemically 'rich' conception of matter and a more 'crude' mechanistic picture is … specific to a given program: one could also cite chemists of the period for whom Newtonian attraction was a liberation from strict mechanism.

33 Diderot did understand Newtonianism as an ideological construct associated with natural theology earlier on, most dramatically, in the figure of the blind mathematician Saunderson in his 1749 *Letter on the Blind*).

34 Diderot's (not especially aggressive) criticisms of the ontology of action at a distance occur in an "Observation" at the end of the *Interprétation de la nature* and later in the 1761 *Réflexions sur une difficulté proposée contre la manière dont les newtoniens expliquent la cohésion des corps* (in Diderot 1975, IX; a text printed anonymously in the *Journal de Trévoux* in April 1761, in which he also presents attraction as a "general property of matter": Diderot 1975, IX, p. 341). The most significant author at the heart of this Diderot-Newton relation would be John Toland, since his matter theory is an influence on Diderot's and he was perhaps the strongest materialist critic of Newtonianism, but the comparison indicates a stronger anti-Newtonianism in Toland. For more on Toland and Newton see Schliesser (ms.).

35 Rouelle, *Cours de chimie, 1754–1758*, ms., cit. in Franckowiak (2003), p. 244; see also Guédon (1979), p. 191. Interestingly, the language of sympathies and affinities was also used in this period to describe properties of organic interdependence which earlier mechanistic medicine had failed to account for (thus further illustrating the relation between this 'vital chemistry' and medical vitalism): see e.g. Ménuret de Chambaud (1765), p. 318b; Grimaud (1776), p. 43 (although de Sauvages 1772 is critical of the term 'sympathies', e.g., p. 65, he ends up using it positively later on in this work). The same language is found in Diderot's *Éléments de physiologie* (in Diderot 1975, vol. XVII, p. 499). Hoquet notes the presence of the concept of sympathy in Buffon, now as a term explaining properties of the nervous system, in the chapter of the *Histoire naturelle* dealing with … puberty (Hoquet 2005, p. 218).

Maupertuis had also challenged Newtonian attraction as an insufficient explanation in natural philosophy in his *Système de la nature ou Essai sur les corps organisés*,[36] which obviously should not be taken to mean that Maupertuis was a blanket anti-mathematicist; on the contrary, from his use of probability theory in studying cases of polydactyly in Berlin to his expedition to Lapland, he was a major proponent of the use of *some kinds of mathematics* in the life sciences, *in some contexts*. Here the specific challenge was how to account for processes of generation (or 'development' as we would say), and even "the simplest chemical operations."[37] Maupertuis explicitly stated that Newtonian attraction does not sufficiently account for organic phenomena, and differently put, that the laws of movement are not sufficient to explain the reproduction of living beings. In the earlier *Vénus physique* he had formulated the hypothesis that natural organisms were formed by attraction alone; now, in the context of an epigenetic theory, he acknowledges that the force of attraction alone cannot sufficiently account for the production of *specifically organized bodies*: "A blind, uniform attraction distributed throughout the parts of matter would not explain how these parts arrange themselves to form even the simplest organized body. …Why shouldn't they unite at random?"[38] But aside from these ways of positioning projects in the emerging life sciences within Newtonian frameworks or at a distance from them, what specifically appealed to Diderot (who entered into a separate polemic with Maupertuis concerning the relation between metaphysics and theory of generation) in Rouelle's anti-attractionist chemistry of affinities is that it supported a commitment to the unbroken continuity of matter.

In his commentaries on Rouelle, Diderot connected this vision of affinities and sympathies with his idea of a universally sensing matter. If we recall Diderot's attitude in the two earlier quotations (from the *Pensées sur l'inteprétation de la nature* and the *Principes philosophiques sur la matière et le mouvement*), we can see that the combination of the first claim I distinguished (the autonomy of the biological with respect to mechanical and mathematical explanations) and the second claim (an appeal to irreducible chemical properties) are at work here too. Now, Diderot's anti-mathematicism is tightly bound to his overall materialist ontology of active matter (or vital matter, since all of matter is potentially alive in his view, which tends to present sensitivity in particular as the higher-level property which is inherent in all matter[39]), but even though he draws on the vital chemistry of Rouelle et al., his arguments are not exclusively of chemical provenance. Robert Schofield spoke rather mockingly of Diderot's

[36] This text first appeared in Latin in 1751 under the title *Dissertatio inauguralis metaphysica de universali naturae systemate*, signed with the pseudonym Dr Baumann; it was translated by Maupertuis in 1754 as *Essai sur la formation des corps organisés* and later was included in his 1756 *Œuvres* under the title *Système de la nature*.

[37] Maupertuis, *Système*, § III, in Maupertuis (1756/1965), p. 141.

[38] *Système*, § XIV, in Maupertuis (1756/1965), pp. 146–147.

[39] In the *Rêve de D'Alembert* Diderot wonders whether sensitivity is a "general property of matter" or rather a property of organized matter alone (Diderot 1975, vol. XVII, p. 105). Fifteen years earlier, he already described life as a "physical property of matter" in the *Encyclopédie* article "Animal," influenced by Buffon (Diderot et al. 1751, p. 474a); in the later, unfinished *Éléments de physiologie* (1770s), he names sensitivity, life and motion as properties of matter, but goes on to discuss cases of organic matter ("flesh") in particular (Diderot 1975, vol. XVII, p. 333).

vision of matter as "resembl[ing] at worst a neo-Platonic living macrocosm and at best a Leibnizian pre-established harmony of self-sufficient monads" (Schofield 1978, p. 187). Leaving aside the judgmental tone, Schofield noticed something important: the Leibnizian dimension in Diderot. Diderot definitely takes over the Leibnizian *petites perceptions* in his philosophy of mind, often emphasizing the variety of subpersonal processes at work (in perception, in instinct, in consciousness, in the will) although his theory is also a paramount case of what has been called the 'materialization of the monad', as when he described the monad as "the real atom of nature, the real element of things."[40] As Roselyne Rey put it, "what was a principle of change in substance has become a property of living matter" (Rey 1997, p. 122). This was exactly the reading of Leibniz denounced by his supporters like Samuel Formey, in his (1747) *Recherches sur les éléments de la matière*. Yet, to turn back to chemistry, Diderot's non-mechanistic, non-passive concept of matter is not just derived from Leibniz in accordance with an internal logic of dominant figures in the history of philosophy; it also borrows freely from more marginal sources, such as the ideas of Van Helmont, as Diderot discusses in the article "Théosophes."[41] And these 'chimiatric' ideas bring us back to the specifically chemical motivation of Diderot's anti-mathematicism, both inasmuch as it allows for a richer matter theory, and because of the 'transformative', 'manipulative' dimension of chemistry—which is per se more empirical, focusing on activity.

When Diderot writes in "Théosophes" that he wishes he could return to the "sublime" intuitions of a Paracelsus or Van Helmont, without giving in to their extravagance or manic enthusiasm (Diderot 1765, p. 253b), he is emphasizing a chemical determination of matter: "The *theosophists* all were chymists, they called themselves *philosophers by fire.* Now, there is no science which offers the mind more associative conjectures, more subtle analogies, than chymistry" (p. 254a). However, the idea of "philosophers by fire" also refers to his enduring interest in chemistry as 'the great worker', the crucial part of Nature, a conception again quite far removed from mathematization—at least as understood in the period. In his 1750 "Prospectus" for the *Encyclopédie*, Diderot wrote that "chemistry is the imitator and rival of Nature: her object is almost as vast as that of Nature itself. She either *decomposes*, *revitalizes* or *transforms* the entities [in Nature]."[42] Diderot may be echoing Shaftesbury here, given his early work translating this author: Shaftesbury had written that "'Tis no wonder if in this Age the Philosophy of the Alchymists prevails so much […]. We have a strange Fancy to be Creators, a violent Desire at least to know the Knack or secret by which Nature does all" (Shaftesbury 1711/1978, vol. II, p. 189). Lissa Roberts notices this 'fabricative' and 'manipulative' aspect of Diderot's engagement with chemistry in her astute article on the 'sensuous chemist', stressing that for Diderot, the artisan

[40] Diderot, entry "Leibnizianisme" *Enc*. IX, 1765, p. 374a; he also identifies monads with "entelechies" (p. 374b), an identification which is very close to Maupertuis's letter on monads (letter VIII), in which monads are presented as the prime elements of matter (as they will be in Charles Bonnet and Jean-Claude de La Métherie as well). For more on Diderot as a Leibnizian, albeit somewhat loosely argued, see Belaval (1976).

[41] See Diderot (1765) and Fabre (1961).

[42] Diderot's *Prospectus* of the *Encyclopédie*, in Diderot (1975), vol. III, p. 410.

rather than the mathematician is the type of natural philosopher who can apprehend and indeed comprehend the heterogeneity of Nature, here in a relation of manipulation (Roberts 1995, p. 504). This in turn coheres with the specifically chemical insistence on qualitative rather than quantitative analysis in this period and in this specific intellectual milieu: thus Roberts speaks of how Rouelle "engaged the senses in a search for qualitative distinctions," contrasting with Lavoisier's later, more objectified, quantitative types of measurement.[43] Indeed, despite his ontological commitment to a specificity of the life sciences over and against mathematics, Diderot also expressed pragmatic or utilitarian views towards both mathematics *and* life science: "in a few centuries, it will be utility (*l'utile*) which will serve as a constraint for experimental physics [*sc.* life science, CW], as it now serves as a constraint on geometry" (*Interprétation*, § VI, in Diderot 1975, IX, 33). This is neither a belief in the future success of mechanism (filling in place-holders, as Haller might have had it), nor a categorical rejection of this possibility.

The search for qualitative distinctions, indeed for a qualitatively rich matter theory (and materialism) is, however, not just a matter of practice and manipulation. What an analysis like Roberts' leaves out is the twin novelty I've sought to call attention to here: that these ideas belong to a projects which seek to create a conceptual matrix for the emerging life sciences, and that this 'vital(ist)' suspicion towards mathematics favors an ontology of Life, not just in Diderot but in chemists like Venel. In his article "Chymie" in the *Encyclopédie*, Venel linked chemistry and life science, in contradistinction to the 'imperialist' tendencies of physics (understood as an extension of older mechanism). If Diderot was an anti-mathematical, materialist metaphysician of Life, Venel was a professional chemist but one who understood his task (much like biologists will in the next generations, and as Buffon intimates) as articulating an *autonomous* science which can study the laws of living organization.[44]

Venel and Bordeu, in their respective articles in the *Encyclopédie*, both insisted that the mistake of the mechanists (primarily in medicine) was to underestimate the power of Nature, in what amounted to an attack on *mathesis*. Venel's criticism of any kind of physicalization or mathematization of physics targeted what was to become, with Lagrange in the decades immediately following the publication of Venel's in the 1765 'set' of volumes of the *Encyclopédie*, a formalization that made Newtonian physics (and the chemistry it understood as a subset) a fully rational discipline, abstracting (as Buffon and Diderot had also stressed in the 1750s) "from all particular physical properties of bodies" and their motions (Restrepo 2013, p. 188). For Venel et al., one can calculate the force of attraction between two particles but not the force of "mixture" of particles. The energy present in chemical processes was not explicable, Venel held, in mechanistic terms, and Bordeu asserted much the same thing about the

[43] Roberts (1995), p. 517. For a different perspective which presents eighteenth-century chemistry as possessing many types of quantification, see Lundgren (1990).

[44] Venel (1753), p. 410. François Pépin notes that Diderot takes over these points regarding the autonomy of chemistry in his historical introduction to Rouelle's chemistry lectures, which he wrote after attending the lectures between 1754 and 1757 (Pépin 2011, p. 134).

energy in *vital* processes.[45] Both of their criticisms can also be understood as resisting the reduction of secondary to primary qualities. From Diderot's general criticisms of mathematical abstraction in the *Pensées sur l'interprétation de la nature* to the more specifically chemically oriented criticisms that he shares with chemists such as Venel, what I called an ontological commitment was consistently present. Indeed, when comparing the purely abstract character of mathematical entities to the world of games, Diderot playfully retorted to those mathematicians who ridiculed "metaphysics" for its lack of reality, that they are far more metaphysical in that sense, in contrast to an experimentally nourished, naturalistic metaphysics of living matter.[46]

6 Conclusion

I have tried to distinguish between an *ontological* hostility and a more *skeptical* suspicion towards mathematics. Both have an 'empirical' component, or a 'claimed empirical' component: as Diderot wrote to Voltaire with a socially diagnostic tone not unlike that of Mandeville, "The rule of mathematics is over. Tastes have changed. The predominant [trend] now is natural history and letters."[47] The ontological form of anti-mathematicism that I have described was particularly linked to programmatic attempts to sketch out the contours of an emerging life science (a.k.a. 'biology'), not merely in operational terms but with ontological foundations. It includes and builds on the critique of mathematical abstraction we associate with authors such as Buffon. In contrast, the skeptical form of anti-mathematicism made no foundational pronouncements on the difference between 'geometry' and the emerging other sciences (be it chemistry, medicine, "natural history," or proto-biology). As we saw in Mandeville but also in Haller (the same is true of D'Alembert), this attitude acknowledged that physicians could have had a legitimate suspicion in the past towards calculation and geometry, but they believed the difficulties with quantification will be resolved, completed in the future. Recall Haller's "Up until now, the calculators have arrived at such opposed results that they have put off modern physiologists from any use of geometry." The same is true of the other intermediate position, according to which mathematics of a particular sort might be seen as inapplicable to medicine or 'biology' (or yielding false or misleading results), while another sort of mathematics (like probabilities) was viewed favorably (including by Buffon and Diderot).

A contemporary observer might find the identification of mathematization and quantification puzzling, as there are plenty of mathematical analyses which do not treat their objects quantitatively, but in the historical context I have focused on, this near-identification seems to be predominant. Further, there seems be an ambiguity in the narrative I have presented: even if one grants the novelty of the new life sciences project with its ontological foundations and specific matter theory, isn't it exaggerated and/or misleading to present it as hostile to quantification? Indeed, Buffon and

[45] Bordeu, *Recherches anatomiques sur la position des glandes et leur action* (1751), in de Bordeu (1818), I, pp. 178–180.

[46] Diderot, *Pensées sur l'interprétation de la nature*, § III, in Diderot (1975), IX, p. 30.

[47] Diderot to Voltaire, 19 February 1758, in Diderot (1997), p. 73.

others were very *empirically* oriented and even (as can be seen in Diderot's *Eléments de physiologie*) *experimentally* oriented. Should the distinction then be between a deductive model, appealing to the *esprit géométrique* and in that sense 'natively' mathematical, and a non-deductive model, proper to these new life sciences?[48] This matches the known territory of the history and philosophy of Enlightenment life science, including the classic studies from the 1960s (e.g. Roger 1963/1993). But I have been emphasizing a different aspect of the story, namely, that there is something like a *spectrum* of anti-mathematical attitudes in the period, from the mildly skeptical to the strongly (ontologically) foundational; and authors such as Haller are actually geometry-friendly, if not in a strictly deductive fashion. In addition, I have suggested that ontological anti-mathematicism was characteristic of a particular variant of *materialism*, which we might term 'vital anti-mathematical materialism'. Both the history of philosophical materialism and that of Enlightenment biology (or the emergence of modern biology, depending on how Whiggish one wishes to be) might profit from including the existence of a materialist anti-mathematicism as part and parcel of an ontology for the emerging life sciences.

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48 I thank an anonymous reviewer for making me clarify these two points (what mathematization might entail and to what extent it should be opposed to the new life science projects, and how). For the complexity of earlier forms of mathematization, see Roux (2010).

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