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Anatomical Mercury: Changing Understandings of Quicksilver, Blood, and the Lymphatic System, 1650–1800

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Abstract. The use of mercury as an injection mass in anatomical experiments and preparations was common throughout Europe in the long eighteenth century, and refined mercury-injected preparations as well as plates of anatomical mercury remain today. The use and meaning of mercury in related disciplines such as medicine and chemistry in the same period have been studied, but our knowledge of anatomical mercury is sparse and tends to focus on technicalities. This article argues that mercury had a distinct meaning in anatomy, which was initially influenced by alchemical and classical understandings of mercury. Moreover, it demonstrates that the choice of mercury as an anatomical injection mass was deliberate and informed by an intricate cultural understanding of its materiality, and that its use in anatomical preparations and its perception as an anatomical material evolved with the understanding of the circulatory and lymphatic systems. By using the material culture of anatomical mercury as a starting point, I seek to provide a new, object-driven interpretation of complex and strongly interrelated historiographical categories such as mechanism, vitalism, chemistry, anatomy, and physiology, which are difficult to understand through a historiography that focuses exclusively on ideas. ***Keywords:*** mercury; anatomy; lymphatic system; blood; materiality; preparations; physiology; vitalism; mechanism.

ANATOMICAL collections from the long eighteenth century all over Europe contain refined wet and dry preparations of human and animal anatomy injected with quicksilver, suggesting that

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mercury was an important material for contemporary anatomists. The meanings and uses of mercury in related disciplines such as medicine and chemistry in this period have been described to some extent in recent publications, yet the significance of mercury for anatomy has remained largely unclear, save for a few case studies.[1] This is curious, as historians of science now generally agree that academic fields were very fluid in the long eighteenth century, and in early chemistry categories that were later made distinct, like the science of matter and the science of life, were blended.[2] If we want to understand the use and meanings of a boundary material in strongly interconnected fields, we cannot ignore its widespread application in one of those fields.

This article argues that quicksilver had a distinct meaning in anatomy, that the choice of mercury as an anatomical injection mass was no coincidence, and that its use in anatomical preparations evolved with the understanding of the circulatory and lymphatic systems. As recent work on the circulation and different uses of substances shows, studying these materials in context gives new insights into mixed artisanal and learned practices, and the formation of observational and experimental sciences.[3] Cunningham and Klestinec have shown that the interrelation of manual and speculative practices in early modern anatomy and physiology was integrally constitutive of these strongly intertwined disciplines, yet the role of materials as physical and philosophical entities in them has thus far remained underexposed.[4]

1. For (al)chemical mercury, see, e.g., Lawrence M. Principe, *The Secrets of Alchemy* (Chicago: University of Chicago Press, 2012); and John Powers, *Inventing Chemistry. Herman Boerhaave and the Reform of the Chemical Arts* (Chicago: University of Chicago Press, 2012). For the medicinal use of mercury, see Richard M. Swiderski, *Quicksilver : A History of the Use, Lore and Effects of Mercury* (Jefferson, North Carolina: McFarland, 2008); and Kenneth Dewhurst, *The Quicksilver Doctor. The Life and Times of Thomas Dover Physician and Adventurer* (Bristol: John Wright & Sons Ltd., 1957). For case studies of anatomical mercury, see M. H. Kaufman and J. J. K. Best, "Monro Secundus and Eighteenth Century Lymphangiography," *Proceedings of the Royal College of Physicians of Edinburgh,* 1996, *26*, 75–90, and M. M. A. Hendriksen, "Quicksilver Anatomy: Exploring the Lymphatic System with Mercury," in *Elegant Anatomy. The Eighteenth-Century Leiden Anatomical Collections in Context* (Leiden: Brill Publishers, 2014), Chapter 3.

2. Bruce Moran, "Introduction," *Isis,* 2011, *102*, 300–4, 303–4.

3. Ursula Klein and Emma C. Spary, "Introduction: Why Materials?," in *Materials and Expertise in Early Modern Europe. Between Market and Laboratory*, ed. Ursula Klein and E. C. Spary (Chicago and London: University of California Press, 2010), 1–23.

4. Andrew Cunningham, "The Pen and the Sword: Recovering the Disciplinary Identity of Physiology and Anatomy before 1800. Part One. Old Physiology: The Pen," *Stud. Hist. Phil. Biol. Biomed. Sci.,* 2002, *33*, 631–65; Andrew Cunningham, "The Pen and the Sword: Recovering the Disciplinary Identity of Physiology and Anatomy before 1800. Part Two. Old Anatomy: The Sword," *Stud. Hist. Phil. Biol. Biomed. Sci.,* 2003, *34*, 51–76; Cynthia

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Although some publications on the historical development of anatomical preparation techniques are available, these tend to focus either on very specific preparations, or primarily on the work of a specific anatomist. Other pieces concentrate on technical processes and achievements without much reference to either the anatomical questions that led to their development, or to the broader cultural and epistemic changes that influenced them.[5] In short, this piece seeks to remedy the lack of a diachronic study of the use of mercury injections in the long eighteenth century. Using the remaining material culture of anatomical mercury—the preparations and plates of mercury-injected anatomy—as a starting point will provide us with a completely new understanding of the developing epistemology of the lymphatic system in the long eighteenth century. Instead of the existing conception of eighteenth-century lymphatic research as intermittent and a purely anatomical matter, it turns out to have been an ongoing international effort, developing in close relation to chemistry and the changing understanding of materials. This article shows that complex categories such as mechanism, vitalism, alchemy, chemistry, anatomy, and physiology can sometimes be interpreted more clearly through objects and their materiality than solely through case studies that are isolated in either time or location, or through a history of ideas.

DISCOVERING ANATOMICAL MERCURY: 1650–1800

This withered preparation of mercury-injected lymphatic vessels from the abdomen by Leiden University anatomy professor Antony Nuck (1650–92) may look a little murky, but is in fact a revolutionary object (Figure 1). To understand why it is so revolutionary, we have to go back to the first known use of mercury as an anatomical material,

Klestinec, *Theaters of Anatomy. Students, Teachers, and Traditions of Dissection in Renaissance Venice* (Baltimore, Maryland: John Hopkins University Press, 2011).

5. For example, D. H. Tompsett, *Anatomical Techniques* (Edinburgh & London: Longman Group Limited, 1970); F. J. Cole, "The History of Anatomical Injections," in *Studies in the History and Method of Science*, ed. Charles Singer (Oxford: Clarendon Press, 1921), 285–344. M. H. Kaufman, "Monro Secundus," 90, Rüdiger Schultka and Luminita Göbbel, "Präparationstechniken Und Präparate Im 18. Und Frühen 19. Jahrhundert, Dargestellt an Beispielen Aus Den Anatomischen Sammlungen Zu Halle (Saale)," *Anatomie. Sektionen Einer Medizinischen Wissenschaft Im 18. Jahrhundert*, ed. Jürgen Helm and Karin Stukenbrock (Stuttgart: Franz Steiner Verlag, 2003), 49–82, 74–80.

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Fig. 1. LUMC Ak0006. Mercury-injected lymph vessels. Probably from the collection of Antony Nuck (1650–92). This preparation on a slate of glass was originally mounted on a dark wooden board. In the 1990s, it was removed from the board and put in a jar because of health and safety regulations. © Anatomisch Museum LUMC 2012. Photographer: Arno Massee.

which suggests a strong association between mercury and lymphatic fluid, red sulfur, and blood. The first mention of mercury as an anatomical material appears to be by the Italian anatomist Marcello

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Malpighi (1628–94), who used mercury injections to study the finest branches of the blood vessels in the lungs in 1661.[6]

Although Malpighi did not elaborate on his choice of mercury as an injection material, it implicitly becomes clear that he chose it because of its particular visual and alchemical qualities. He had been experimenting with injections of air and colored fluids to gain a better understanding of the structure and functioning of the lungs, yet there were a number of issues Malpighi had not been able to resolve yet, like the question of whether the vessels in the lungs reconnect at some point after having branched out (mutual anastomosis), or that they end in the substance of the lungs. His initial injection experiments had not answered this question, as they mostly ended up in the interstitia (the tissue and space around the air sacs of the lungs). Apparently hoping that mercury would give different results, Malpighi resorted to injecting this.

Although mercury clearly ran into the smallest bifurcations, when a little pressure was applied, the whole of the injected mass collected in the interstitia again. Yet in a way the mercury injections were a success—the material and symbolic qualities of mercury made it a superior injection mass to air and ink. Describing ways to make the fine ramifications of the pulmonary artery in the lungs visible, which he qualified as "standing out like the branches of a tree," Malpighi advised that "If you want a more beautiful picture [than blowing air into the vessels gives], introduce mercury and these branches will stand out silvery, even to the smallest."[7] So the material qualities of mercury—its silvery shimmer and its weight and density—meant it gave a more beautiful and clearer picture of the injected anatomical structure. Moreover, it made the injected vessels look like the branches of a tree, which inevitably brings to mind contemporary mercurialist alchemical treatises in which mercury-based, tree-like structures play a central role.

As Principe points out, many illustrations and descriptions of naturalistic trees can be found in alchemical literature well into the seventeenth century. To the mercurialists—who believed Philosophical

6. Marcello Malpighi and Luigi Belloni. *De Pulmonibus, ristampa, trad. ital. e introd. a cura di Luigi Belloni* (Messina: Società Italiana di Istochimica, 1958).

7. James Young and Marcello Malpighi, "Malpighi's '*De Pulmonibus*,'" *Proc. R. Soc. Med.*, 1929, *23*, 1–11, 4.

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Mercury was somehow to be produced from quicksilver and gold—the tree signified the vegetation of the "seed of gold." The "body" of gold from which the tree grew was often depicted as a dead human body, making the symbolic echo of the mercury tree branches in injected lung tissue even more striking.[8] A close reading of the remainder of Malpighi's text also strongly suggests he chose mercury not just for its visual qualities, but because of its alchemical material qualities as well.[9] As Pamela H. Smith has shown, early modern artisans understood the flow of blood and the flow of metal in similar ways.[10] This appears to apply to Malpighi too, as two paragraphs after describing the disappointing results he obtained with his mercury injections, he wrote:

> I need not persuade you by many words that, in Nature, there are bodies which were not originally endowed with fluidity but have their smallest parts ready for connection and union, so that, only with greatest force can they be separated, and, when separated, they endeavour to bring about mutual union. Again, these bodies, by admixture with another interposed body, become fluid. We see this in **metals** and other things fused by fire.[11]

Although mercury is not mentioned explicitly here, Malpighi's contemporaries, and particularly his learned audience, will have thought not just about metals becoming fluid in fire, but also of how metals will stay fluid when heated and dissolved in quicksilver. The interrelation between anatomical and alchemical substances is found across

8. Lawrence M. Principe, "Apparatus and Reproducibility in Alchemy," *Instruments and Experimentation in the History of Chemistry*, ed. Frederic L. Holmes and Trevor Levere (Cambridge, Massachusetts: MIT Press, 2000), 65–70, 55–74.

9. As Lawrence M. Principe, "Alchemy Restored," *Isis,* 2011, *102*, 305–12, 306, points out, the search for metallic transmutation or chrysopoeia is now often referred to as "alchemy," but in the late seventeenth century was ordinarily viewed as synonymous with or as a subset of chemistry. In the early eighteenth century, chrysopoeia was increasingly referred to as "alchemy" and banned fairly quickly from respectable chemistry during that period. I here use the terms alchemy and chemistry and their derivatives according to these early eighteenth-century actor's categories: alchemy refers to chrysopoeia or metallic transmutation, chemistry to the emerging discipline that increasingly denied and ridiculed the possibility of chrysopoeia. Also see William R. Newman and Lawrence M. Principe, "Alchemy vs Chemistry: The Etymological Origins of a Historiographic Mistake," *Early Sci. Med.,* 1998, *3*, 32–65.

10. Pamela H. Smith, "Vermillion, Mercury, Blood and Lizards: Matter and Meaning in Metalworking," in *Materials and Expertise in Early Modern Europe: Between Market and Laboratory*, ed. Ursula Klein and Emma C. Spary (Chicago: University of Chicago Press, 2010), 44–48, 29–49.

11. James Young, "Malpighi's '*De Pulmonibus*.'" Hyphen mine.

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Malpighi's anatomical and medical works, since for him nature's téchne was uniform across the animal, mineral, and metal worlds.[12] Moreover, Malpighi described the blood in terms that could equally be understood as a description of the qualities of mercury:

> Nor is there a doubt that there are parts in the blood mass which are inclined to easy union, and may attain so much solidity that they rival a stone in hardness. The evidence of this is in the red part of the blood, which, separated from the serum and dried so that it bears the nature of a stone, can be rubbed down into small pieces of definite form. (…) **From the serous, or white part, the fluidity of the red part arises**.[13]

When mercury is heated over fire in contact with air, it dissolves in what appears to be a bright red powder (mercury oxide) and a transparent fluid. When heated again, the red powder and the transparent fluid will resolve into mercury again—like the fluidity of blood, the fluidity of the red part of mercury arises from the white or transparent part. Although this process is actually caused by a reaction of the heated mercury with oxygen, to seventeenth-century eyes, it must have looked as if mercury, like blood, consisted of a solid red part and a fluid watery-white part. Indeed, a couple of lines later, Malpighi stresses that the serum, or the white of the blood, is the same as the "lymph of Bartholin."[14] He argues that after the blood that has coursed through the body returns to the heart, it is roughly mixed with the lymphatic fluid in the right ventricle. It is then sent into the lungs, which, with their fine vessels, are able to mix the blood more thoroughly.[15] Summarizing, Malpighi understood the lymphatic fluid to consist of the serous, white, fluid part of the blood, and the lymphatic system as an extension of the circulatory system in which only

12. Domenico Bertoloni Meli, *Mechanism, Experiment, Disease. Marcello Malpighi and Seventeenth-Century Anatomy* (Baltimore: John Hopkins University Press, 2011), 230–32.

13. Ibid., 5. Hyphen mine.

14. The Dane Thomas Bartholin (1616–80) was the first to publish a description of the lymphatic system and fluid in the human body in 1652.

15. Ibid. Around the same time, Kohlhans presented his novel idea of the lymphatic fluid as an "animal alkahest" or at least an analog of the Helmontian universal solvent in animal bodies. See Ana Maria Alfonso-Goldfarb, Márcia Helena Mendes Ferraz, and Piyo M. Rattansi, "Lost Royal Society Documents on 'alkahest' (universal Solvent) Rediscovered," *Notes Rec. R. Soc.*, 2010, *64*, 435–56, 440. Whether Kohlhans drew any analogies with mercury as the universal solvent of metals requires further research.

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this serous substance could penetrate, and not the hard red parts of the blood.

This analogy of chyle and blood with mercury processes is remarkable, as the traditional analogy was with wine. This held that the liver changed white chyle into red blood, like the skins of grapes turn white wine into red.[16] Yet the wine analogy was problematic, as it is impossible to make red wine white again, whereas blood, like mercury, could be distilled into a colorless serum and a solid red mass. Throughout the seventeenth century, a vivid discourse on the nature of the color of blood therefore emerged in Europe. The Dutch anatomist Reinier de Graaf, for example, in 1668 concluded that a washed-out liver injected with milk actually turned white, which led him to argue that the redness of blood is not caused by the liver.[17] The apparently alchemical process that led to the redness of the blood must have raised associations with the process of rubedo, the rubification or reddening of the white matter of the Philosopher's Stone at the final stage in the opus alchymicum.[18] Moreover, the association with the Philosopher's Stone speaks from Malpighi's description of the dried red part of the blood as bearing "the nature of a stone": some believed the Philosopher's Stone to be a fine red powder, and blood—human or animal—was often cited in early modern recipes as the only substance that could soften or cut hard gemstones.[19]

His findings also led Malpighi to conclude that the function of the lungs was not simply to cool the body, as was the classic Aristotelian understanding. In the lungs, he argued, the mixing of the lymphatic fluid and the solid red parts took place, thus ensuring the fluidity of the blood, as well as the renewal of the blood mass, and they functioned as a storehouse for blood.[20] When injections with air and colored water failed to give him a satisfactory idea of the structure and function of the vessels in the lungs, he chose mercury as an alternative injection material because of both its visual and alchemical qualities,

16. Domenico Bertoloni Meli, "The Color of Blood: Between Sensory Experience and Epistemic Significance," in *Histories of Scientific Observation*, ed. Lorraine Daston and Elizabeth Lunbeck (Chicago and London: The University of Chicago Press, 2011), 117–34, 120–21.

17. Reinier de Graaf, *Korte Beschryving Van "T Gebruyk Der Spuyt in D" Ontleedt-Konst. Met Een Inleiding Door Dr. H.L. Houtzager* (Delft: Reinier de Graaf Stichting, 1989), 665–66.

18. Lyndy Abraham, *A Dictionary of Alchemical Imagery* (Cambridge: Cambridge University Press, 1998), xv. Principe, *The Secrets of Alchemy*, 174–75.

19. Pamela H. Smith, "Vermillion, Mercury, Blood," 43.

20. Principe, *The Secrets of Alchemy*, 6.

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particularly the implicit idea that mercury consisted of similar red and white parts as blood, which could be modified through applying heat.[21] Because of mercury's similarity to the serous matter in the blood, which Malpighi took to be the lymphatic fluid, and because of mercury's visual and penetrating qualities, it was the most suitable injection mass to visualize the finest branches of the blood and lymphatic vessels in the lungs. This shows that the selection of mercury as an anatomical injection mass was not a coincidental but a meaningful choice; the visual, material, medical, and alchemical qualities of quicksilver made it the best choice for injection of the lymphatic vessels.

It may now seem strange that Malpighi did not explicitly mention the alchemical qualities of mercury that inspired him to use it as an injection mass, but it is important to remember that the seventeenth century was alchemy's great age—alchemical theory was a pervasive force in the intelligent explanation of the world.[22] In this context, it could be said to be relational knowledge, as described by Collins: it is not tacit or implicit because of deliberate secrecy, it is just so embedded, so obvious to the members of the epistemic culture of which it is part, that there is no need for them to make it explicit.[23] Therefore, it does make sense Malpighi felt no need to refer to the relevant alchemical properties of mercury as an anatomical injection mass: his contemporaries understood this as it was also their own frame of reference, and as the above analysis of Malpighi's text shows, he did refer to the—generally alchemically understood—qualities of metals to explain his understanding of the blood and the lymphatic fluid.[24]

As for the tangible results of his injections, Malpighi probably did not have the technical means to create lasting mercury-injected

21. This emphasis on the alchemical qualities of mercury is also striking because Robert G. Frank has argued that Malpighi's account of respiration was wholly mechanical, as opposed to the accounts of the Oxford group, which embraced other causes, such as fermentation as well. See Robert G. Frank Jr., *Harvey and the Oxford Physiologists. A Study of Scientific Ideas* (Berkeley, California: University of California Press, 1980), 228–29. More recently, Bertoloni Meli has described these chemical processes as fully "mechanical" in the sense that they are material, uniform explanations for bodily processes, explicitly aimed at diminishing the importance of the action of the soul. Domenico Bertoloni Meli, *Mechanism, Experiment, Disease*, 12–16.

22. Lyndy Abraham, *A Dictionary*, xv; Principe, *The Secrets of Alchemy*, 82.

23. Harry Collins, *Tacit and Explicit Knowledge* (Chicago: University of Chicago Press, 2010), Chapters 4–6.

24. Obviously, it would helpful to know more about Malpighi's interests and training in alchemy and whether he subscribed to transmutation, mercurial, or otherwise. This is a topic that warrants further investigation.

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preparations, so his experiments did not result in commercially or academically valuable anatomical objects that could be circulated among anatomists to study.[25] Yet the use of mercury in anatomy would continue for at least another two hundred years, because of a Dutch invention. The technique of injecting anatomical structures with mercury only became a lasting one because of a finding at the University of Leiden in the second half of the seventeenth century. Here, anatomists exploring the structure and functioning of the human body started searching for methods to solidify the results of their injection experiments. Like Malpighi, by injecting colored fluids into vessels, arteries, and veins, they mapped anatomical structures and tried to fathom physiological processes.

Reinier de Graaf, for example, became controversially famous for his experiments on the function of the lacteal glands and the pancreas in dogs, which he thought could be extrapolated to humans.[26] He improved the syringe, and even wrote a short treatise on its use in anatomy: *Korte beschryving van't gebruyk der spuyt* (1668). In it, he presented his own version of the syringe: a copper tube with a piston, onto the front of which tubes of different shapes could be screwed. With this instrument, the anatomist could inject liquids of different colors into the veins and arteries of dead bodies and living animals to demonstrate to students which arteries supplied which intestines, and how blood flowed through the arterial system. De Graaf also saw great opportunities for anatomists to discover thus far "hidden things," which would be of benefit to everyone and would make the anatomist himself "immortal."[27]

Yet the essential development was the discovery of hardening injection fluids, which allowed the researchers to preserve the injected organs and other tissue as anatomical preparations. The first mention of this occurs in 1666, when Jan Swammerdam (1637–80) developed solidifying fluid wax masses and succeeded in creating lasting injected

25. Malpighi probably did create some lasting preparations, as Lazarro Spallanzani, *Viaggi alle Due Sicilie e in alcune parti dell' Appennino* (Pavia: Stamperia di B. Comini, 1792–97), vol. 5, 1795, 37, mentions that they were lost in an earthquake in Bologna in 1783. However, it is unclear, and unlikely, that these were injected preparations. Also see Rüdiger Schultka, "Präparationstechniken Und Präparate," 72–73.

26. Evan R. Ragland, "Experimenting with Chymical Bodies: Reinier De Graaf's Investigations of the Pancreas." *Early Sci. Med.*, 2008, *13*, 615–64.

27. Reinier de Graaf, *Korte Beschryving*, 14.

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preparations, which could be preserved either dried or in fluid.[28] Antony Nuck, a contemporary of de Graaf and Swammerdam, was probably the first who managed to successfully use their innovations to create mercury-injected anatomical preparations. Nuck graduated from Leiden University in 1677 with a dissertation on diabetes, and subsequently practiced medicine and anatomy for a decade in The Hague. In 1687, he was appointed professor of anatomy at Leiden University, a post he would hold until his early death in 1692.

Nuck was famous for his numerous dried preparations of lymph glands, arteries, veins, eye, and saliva ducts. He injected the lymph glands with a mixture of mercury, lead, and tin, and the arteries and veins with colored wax.[29] The fact that the injection masses sometimes seemed to pass from the circulatory to the lymphatic vessels and vice versa led Nuck to belief that they were interconnected systems; the lymphatic system an extension of the circulatory system.[30] Injecting techniques and the resulting preparations were an admired novelty, as they greatly enhanced the seemingly unmediated visibility of anatomical structures, whereas many anatomists doubted the reliability of microscopic observations.[31] This also shows from the fact that the famous Leiden medical professor Boerhaave mentioned in his lectures how impressed he was as a student by the sight of mercury-injected lymph vessels mounted on wooden boards at Nuck's house.[32] Nuck himself praised mercury for its penetrating qualities in a 1685 work on the tear and salivary ducts:

> Mercury opens the small canals of the glands so widely that secretion can occur abundantly. Once mercury has made itself part of the blood, divided into an innumerable quantity of small round particles, it easily

28. Boerhaave mentioned 1667, but Swammerdam himself stated that he demonstrated his method of the solidifying injection mass to Van Horne, Slade, Thévenot, and Steno in Leiden. See F. J. Cole, "Anatomical Injections," 301.

29. By the time Nuck graduated, Malpighi's 1661 *De Pulmonibus* had been circulated throughout Europe as an appendix to a work by Bartholin. See Robert G. Frank Jr., *Harvey*, 155, on the English reception of *De Pulmonibus*. Another edition appeared with a Leiden publisher in 1672.

30. Jürgen Helm and Karin Stukenbrock, eds., *Anatomie*, 72.

31. Edward G. Ruestow, *The Microscope in the Dutch Republic. The Shaping of Discovery* (Cambridge: Cambridge University Press, 1996), 85–91. Also see Jutta Schickore, *The Microscope and the Eye: A History of Reflections, 1740–1870* (Chicago: The University of Chicago Press, 2007), Chapter 4, on microscopical fallacies.

32. Herman Boerhaave, *Praelectiones Academicae in Proprias Institutiones Rei Medicae. Edidit, Et Notas Addidit Albertus Haller*, 6 vols. (Amsterdam: J. Wetstenium, 1747), I: 576.

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> adapts itself to every shape of the pores and shatters the sharp deposits of salts where they have settled. When they have been brought into motion, most of the obstructions are abolished, and when these are removed all the disease-generating substances are washed away through the salivary ducts.[33]

Because of these penetrating and cleansing qualities, mercury was very suitable as both the main ingredient of an injection mass and as a medicine in clearing out all kinds of obstructions.[34] The specific mention of deposits of salts in the body that are shattered by mercury is interesting too, as in iatrochemistry, disease was often explained as an overabundance of either acidity or alkalinity, which could be balanced by using a medicine of the opposed character. In such acid–alkali systems, mercury was seen as an acid metal and hence would shatter an overabundance of salts.[35] This may seem inconsistent with Nuck's supposed mechanism, but iatrochemistry had a strong base in late seventeenth-century Leiden in the person of professor Franciscus de le Boë Sylvius (1614–72), one of Nuck's teachers. Moreover, combining descriptions of chemical operations in iatrochemical terms (acids and alkalis) and mechanistic explanations was not unheard of amongst Nuck's peers—like mechanism and vitalism were porous categories and not mutually exclusive, so were iatrochemistry and mechanism.[36]

33. Antony Nuck, *De Ductu Salivali Novo, Saliva, Ductibus Oculorum Aquosis Et Humore Oculi Aqueo* (Leiden: Pieter van der Aa, 1685), 37, translation from A. M. Luyendijk-Elshout, "Antony Nuck (1650–1692) the "Mercator" of the Body Fluids. A Review of His Anatomical and Experimental Studies," *Circa Tiliam. Studia Historiae Medicinae Gerrit Arie Lindeboom Septuagenario Oblata*, ed. C. van der Meer, J. V. Meininger, and J. Schouten (Leiden: E.J. Brill, 1974), 150–64, 159–60.

34. Mercury as a penetrating substance was a common occurrence in alchemical literature, especially in the seventeenth century. Also see Lawrence M. Principe, *The Aspiring Adept. Robert Boyle and His Alchemical Quest. Including Boyle's "Lost" Dialogue on the Transmutation of Metals* (Princeton, New Jersey: Princeton University Press, 1998), Chapter 5.

35. Bruce T. Moran, *Distilling Knowledge. Alchemy, Chemistry, and the Scientific Revolution* (Cambridge, Massachusetts: Harvard University Press, 2005), 116–17; Richard S. Westfall, *The Construction of Modern Science: Mechanisms and Mechanics* (Cambridge: Cambridge University Press, 1971), 67.

36. Nicolas Lémery (1645–1715) and other French chemists did this too. See Bruce T. Moran, *Distilling Knowledge*, 122, and Bernard Joly, "Could a Practicing Chemical Philosopher be a Cartesian?," in *Cartesian Empiricisms*, ed. Mihnea Dobre and Tammy Nyden (Dordrecht: Springer, 2013), 125–49. For more on the heterogeneity of physiological and medical–philosophical categories in late seventeenth-century Leiden, see Harm Beukers, "Mechanistische principes bij Franciscus dele Boë, Sylvius," *Tijdschrift voor de Geschiedenis van de Geneeskunde, Natuurwetenschappen, Wiskunde en Techniek,* 1980, *3*, 28–36.

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On top of the curing qualities of mercury, there were other, more allegorical, meanings inextricably attached to it: as mentioned previously, it was traditionally associated with resurrection, as quicksilver separates into numerous tiny, perfectly round balls but merges back into a perfectly smooth mass when these balls are captured together in a vessel or container.[37] Nuck referred to mercury on various occasions as "Noster Mercurius," which, written with capitals, does not refer to common mercury, but to philosophical Mercury, the union between sulfur and argent vive or first mercury.[38] Moreover, he used a rather elaborate analogy in his 1691 *Adenographia* to explain his work on the lymphatic system. He compared himself to a *Mercator* or seafaring merchant, sailing unexplored rivers of bodily fluids in order to discover unknown lands and treasures.[39] This seems to be a reference to mercury too—both to the injection mass he used for these explorations as to the Roman god Mercury, protector of commerce and travelers.

From this, it appears that Nuck's motivations to use mercury as an injection mass were polyvalent and not all purely practical. His work is full of references to the multiple meanings of mercury—alchemical, mythological, medical. It is therefore too easy to dismiss Nuck's anatomy and his use of anatomical mercury as mechanistic, especially as mechanism and vitalism are complicated categories, tinged with ahistorical ideal types. Strict Cartesian mechanism leaves no room for imperceptible or undefined forces like the soul or some other kind of life-giving power in the explanation of natural phenomena.[40] Yet as Reill has argued, mechanism, or the mechanical philosophy of nature, is at best a vague concept.[41] Like other anatomists in this era, Nuck understood "mechanical" as "machine-like" rather than "based on the laws of mechanics," and, as Bertoloni Meli argues, mechanical anatomists and philosophers often sought to exclude the soul as a

37. Lyndy Abraham, *A Dictionary*, 125. Betty Jo Teeter Dobbs, *Alchemical Death and Resurrection: The Significance of Alchemy in the Age of Newton* (Washington, DC: Smithsonian Institution Libraries, 1990), 21–22.

38. Lyndy Abraham, *A Dictionary*, 124; Lawrence M. Principe, *The Aspiring Adept,* 10.

39. Antony Nuck, *Adenographia,* 4.

40. See, e.g., Peter Dear, "A Mechanical Microcosm: Bodily Passions, Good Manners, and Cartesian Mechanism," in *Science Incarnate: Historical Embodiments of Natural Knowledge*, ed. Christopher Lawrence and Steven Shapin (Chicago: The University of Chicago Press, 1998), 51–82, 53.

41. Peter Hanns Reill, *Vitalizing Nature in the Enlightenment* (Berkeley, California: University of California Press, 2005), 34.

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cause of bodily activity, and instead concentrated on matter. However, this matter was often described alchemically, as having active, living properties.[42]

Ascribing active properties to alchemical and bodily matter thus suggests a certain vitalism; an understanding of life as generated and sustained through some form of nonmechanical force or power specific to and located in matter.[43] Although this theory is usually associated with the presence of a sensitive and inorganic soul and Romanticism, this is a narrow and somewhat anachronistic understanding of vitalism. Perceptions of nature and even alchemical substances—particularly mercury—as somehow living or at least life-generating entities, possessing independent powers of animation and self-direction, as well as vital energies of self-generation, can be found much earlier, like with van Helmont (1580–1644).[44] The widespread signification of mercury in alchemy as *argentum vivum* (living silver) confirms its early modern status as a vitalist material.[45]

Nuck's quicksilver preparations, intended to show the lymphatic system as it is laid out in the living body suggest that he understood mercury in a vitalist, nonmechanic way on the anatomical level. Like many of his Leiden contemporaries, Nuck was not a strict Cartesian—principles from Cartesianism, Newtonianism, and the works of Leibniz and Wolff alike were combined, tried, and tested in virtually all early eighteenth-century Leiden University departments.[46]

42. Domenico Bertoloni Meli, *Mechanism, Experiment, Disease*, 13–14, 61–62, 74.

43. K. M. Chang, "Alchemy as Studies of Life and Matter: Reconsidering the Place of Vitalism in Early Modern Chemistry," *Isis*, 2011, *102*, 322–29, stresses the undeniable role vitalism played in alchemy, and in the work of "mechanistic" philosophers and physicians.

44. Catherine Packham, *Eighteenth-Century Vitalism: Bodies, Culture, Politics* (New York: Palgrave Macmillan, 2012), 1, 9; William R. Newman, "Vitalism in Van Helmont," *Gehennical Fire: The Lives of George Starkey, an American Alchemist in the Scientific Revolution* (Chicago: University of Chicago Press, 2003), 148–51. On the life-generating powers of mercury, also see Pamela H. Smith, "Vermillion, Mercury, Blood," 47–48; Lawrence M. Principe, "Reflections on Newton's Alchemy in the Light of the New Historiography," in *Newton and Newtonianism: New Studies,* ed. J. E. Force and S. Hutton (Dordrecht: Springer, 2004), 214–15, argues that according to Van Helmont certain types of changes in materials operate not by a mechanistic means, but that it remains to be demonstrated how truly "vitalistic" these actually are.

45. Principe, *The Secrets of Alchemy*, 69.

46. Willem Otterspeer, *Groepsportret Met Dame II. De Vesting van de Macht. De Leidse Universiteit, 1673–1775* (Amsterdam: Uitgeverij Bert Bakker, 2002), 25–36. Henri Krop, "Medicine and Philosophy in Leiden around 1700: Continuity or Rupture?," in *The Early Enlightenment in the Dutch Republic, 1650–1750*, ed. Wiep van Bunge (Leiden: Brill, 2003), 173–98; Wiep van Bunge, "Dutch Cartesian Empiricism and the Advent of Newtonianism," in *Cartesian Empiricisms*, ed. Mihnea Dobre and Tammy Nyden (Dordrecht: Springer, 2013), 89–104.

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Although his understanding of the human body and the effect of the metal mercury upon it were largely mechanistic, Nuck's description of quicksilver as a medicine and injection mass shows that he was also influenced by the alchemical idea of mercury as an active, reviving entity. This is a strong indication that there was no distinct demarcation between mechanist and vitalist ideas in Nuck's work.

That the choice for mercury was motivated by considerations other than the purely practical becomes even clearer when the downsides to the uses of mercury as an injection mass are taken into consideration, some of which must have been immediately clear to Nuck and his contemporaries. Mercury's weight means that if a column of it builds up inside a vessel, it could easily rupture it if only even slightly too much of the mass was injected—a problem Malpighi already encountered. Even if an injection was initially successful, it would remain very delicate, especially as long as the mercury mass had not dried, and handling it could cause the preparation to fall apart anyway—in Nuck's remaining mercury preparation, we can also see that some of the quicksilver has escaped. As noted before, injecting lymph glands with mercury was therefore something that not only required the right equipment, a sharp eye, and a lot of patience, but also hard won tacit bodily knowledge, a practical skill impossible to describe in text. Nuck knew that early decay or artificial edema helped in making the lymph glands easier to find. In order to fill the capillary lymphatic vessels, he would look for a very small vessel and insert a tiny iron tube through which he inserted the mercury, mixed with tin or lead to ensure it would harden.[47]

Only two of Nuck's mercury preparations of lymphatic glands, demonstrations of both his state-of-the-art anatomical knowledge and refined manual skills, remain now. Worn by the centuries that have passed and taken from their dark wooden boards and put into jars for health and safety reasons, they are mere shadows of the preparations that evoked the admiration of Boerhaave and his contemporaries. As we will see, Nuck's work inspired colleagues and students all over Europe for more than a century and a half, resulting in an impressive array of anatomical preparations of the lymphatic system injected with mercury mixtures.

47. Rüdiger Schultka, "Präparationstechniken Und Präparate," 72–73.

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Many of these were the result of serious research and objects of study, although there was a commercial aspect too. In 1695, for example, the Dutch physician Steven Blankaart (1650–1704) extended a section on "The new method of embalming" to a new Latin edition of his *Reformed Anatomy*. In it, he briefly mentions the possibility of injecting vessels with a mercury amalgam, but he seems unimpressed with the use of the technique for clarifying anatomical structures, stating that this was mainly done "for financial gain."[48] This remark suggests—and Dániel Margócsy's work confirms—that at least to some late seventeenth-century anatomists, mercury-injected anatomical preparations were primarily commodities, not aimed at acquiring and exchanging anatomical knowledge.[49] Yet in *The Anatomy of the Brain*, also from 1695, Humphrey Ridley (?–1708), an physician from Nottingham who studied in Oxford, Cambridge, and Leiden, notes that an injection with mercury "...by its permanent nature and color, contributes mightily towards bringing to view the most minute ramifications of vessels, and secretest recesses of Nature." Ridley preferred mercury to wax, the latter being too coarse for the finest vessels.[50]

However, these accolades for mercury as an anatomical material and its potential to create commercially valuable preparations did not mean anatomical mercury was a constant success. To the contrary, during the first decades of the eighteenth century, it appears hardly any mercury-injected anatomical preparations were created.

RETHINKING MERCURY, BLOOD, AND THE LYMPHATIC SYSTEM: 1700–50

Between roughly 1700 and 1750, it appears few or no anatomical preparations injected with mercury or a mercury amalgam were created, either in the Netherlands or Britain. Not only are there hardly any mercury-injected anatomical preparations from this period now, contemporary collection catalogs also suggest a distinct gap in the production and acquisition of these preparations. How is this possible, as anatomical mercury was praised for its visual and material qualities,

48. Stephan Blankaart, *Anatomia Reformata, Sive Concinna Corporis Humani Dissectio, Ad Neotericorum Mentem Adornata* (Leiden: Boutestein & Luchtmans, 1695), 758, §XXX.

49. Dániel Margócsy, "Advertising Cadavers in the Republic of Letters: Anatomical Publications in the Early Modern Netherlands," *Br. J. Hist. Sci.*, 2008, *42*, 187–210.

50. Humphrey Ridley, *The Anatomy of the Brain* (London: Sam. Smith and Benj. Walford, 1695), 4.

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and mercury preparations apparently sought after commodities by the late seventeenth century? One thing is certain: this temporary disappearance had nothing to do with the availability of mercury. Although not extremely cheap, mercury was affordable for miners, university professors, apothecaries and mirror, felt, and instruments makers, who used it for mining gold and silver, chemical experiments, medication, the production of mirrors, glass, hats, and thermometers, respectively. In fact, the supply of mercury in Europe was better than ever around 1705, as the previous monopoly of the Amsterdam trading company Deutz, which sold mercury from the quicksilver mines in Idria in the Habsburg Empire, was challenged by the English import of mercury from China.[51]

To understand why anatomical mercury all but disappeared in the first decades of the eighteenth century, we have to look not at economic factors, but at the state of the art of anatomy, particularly at Leiden University, after Nuck's sudden death in 1692. Nuck had planned to map the entire lymphatic system in the human body using mercury injections when he died suddenly—according to a contemporary biographer after opening a "malicious blister" while dissecting a body.[52] Nuck's successors had other research interests: Johannes Jacob Rau, for example, was primarily interested in osteology, and paid little attention to other aspects of anatomy and physiology.[53] In part, this will have had to do with emerging critiques of injection techniques in general and of mercury as an injection mass in particular—its tendency to burst through structures and create unnatural connections was well known by now and even echoed by Boerhaave, who otherwise admired Nuck's mercury-injected preparations.[54] However, injection techniques and mercury injections were used

51. Marieke M. A. Hendriksen, "Mercury: Back to the Source," *The Medicine Chest* (blog), May 19, 2013, https://themedicinechest.wordpress.com/2013/05/19/mercury-back-to-the-source/ (accessed September 29, 2014).

52. The simplistic view of Newtonian mechanics has been challenged before by a.o. Anita Guerrini, *Obesity and Depression in the Enlightenment. The Life and Times of George Cheyne,* ed. Robert Markley, Oklahoma Project for Discourse and Theory, Series for Science and Culture (Norman: University of Oklahoma, 2000), and Theodore Brown, *The Mechanical Philosophy and the "Animal Oeconomy"* (New York: Arno Press, 1981), but not in the context of Dutch Enlightenment medicine.

53. J. Dankmeijer, "Is Boerhaave's Fame Deserved?," in *Boerhaave and His Time: Papers Read at the International Symposium in Commemoration of the Tercentenary of Boerhaave's Birth, Leiden, 15–16 November 1968*, ed. G. A. Lindeboom (Leiden: Brill, 1970), 17–30, 24.

54. Bertoloni Meli, *Mechanism, Experiment, Disease*, 303.

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more or less continuously in anatomical research well into the nineteenth century. Hence, these developments do not sufficiently or satisfactory explain the sudden and temporary disappearance of anatomical mercury preparations.

The key to this lapse lies in the changing understanding of both the human body and of mercury, changes that occurred in a period of renewed international fame for the Leiden University faculty of Medicine. This era dawned in the first decades of the eighteenth century with the appointments of Herman Boerhaave and his former student Bernhard Siegfried Albinus.[55] Both of these men showed little interest in anatomical mercury, even though Albinus created a detailed atlas of the human body and a famous collection of anatomical preparations.[56]

When Nuck died, there was no universally accepted understanding of the lymphatic system. Some natural philosophers believed it to be an independent absorbent system, others—such as Malpighi and Nuck—understood it as nothing more than the extremely small offshoots of blood vessels, where only the serous fluid of the blood could penetrate. Nor was it clear whether there was such a thing as an integrated lymphatic system throughout the human body and if so, how big it was and exactly what it looked like, nor whether chyle and lymphatic fluid were the same substance. Nuck's Leiden successors understood the lymphatic vessels as an extension of the circulatory system, and lymphatic fluid a part of the blood, which could be said to be a mechanistic idea, as no vital force was required to filter the lymphatic fluid from the blood. However, their understanding of mercury, in contrast, was primarily vitalist, an apparent contradiction that challenges the traditional Anglo-Saxon tendency to interpret Dutch Enlightenment medicine in the tradition of Newtonian and Cartesian mechanical philosophy and physiology.

Herman Boerhaave maintained Nuck's view that the lymphatic system arises from the arterial system, as it fitted well into his physiological

55. Herman Boerhaave, 1668–1738, was appointed as a lector in medicine in 1701, as a professor of botany and medicine in 1709, and as a professor of chemistry in 1718. Bernard Siegfried Albinus, 1692–1770, succeeded his father Bernhard Albinus (1653–1721), who was the professor of anatomy at Leiden University. Bernhard Siegfried was appointed as a lector of anatomy and surgery in 1721, as a professor of anatomy and surgery in 1724, and as a professor of medicine in 1745.

56. For Albinus's work, see, e.g., H. Punt, "Bernard Siegfried Albinus (1697–1770). On 'Human Nature', Anatomical and Physiological Ideas in Eighteenth Century Leiden," 1983, and M. M. A. Hendriksen, "Une recherche commune de 'l'homo perfectus'? La perfection dans la relation de travail de Bernard Siegfried Albinus (1697–1770) et Jan Wandelaar (1692–1759)," *Alliage*, 2010, *1*, 22–34.

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understanding of the structure of tissues. Boerhaave argued that the entire body was built from small units, the "vasa minima," and fed by the blood, which provided structural elements from digested food to these vessels.[57] This view explains why Boerhaave felt little need to do further research on the lymphatic system—it could be nothing else than an extension of the circulatory system. Moreover, his physiology was largely a subject of the pen, a theoretical, philosophical discipline.[58] As professor of botany, medicine, and chemistry, Boerhaave left dissections, anatomical experiments, and the creation of lasting preparations mostly to his fellow professor in anatomy. Although Boerhaave did not create any anatomical preparations himself, mercury-injected or otherwise, he did have ideas about mercury, and these influenced the anatomical and physiological work of his former student and young colleague, Albinus. As we have seen, Malpighi explicitly compared blood and metals in terms of their reaction to heat, and described mercury injections into the vessels of the lungs in terms that evoked alchemical imagery; Nuck's description of mercury also hinted at alchemical ideas. Boerhaave, in contrast, like many of his contemporaries, tried to distance himself from transmutational alchemy.[59] Yet this distancing also implies he was still familiar with the traditional alchemical knowledge of metals and materials. Moreover, Boerhaave's physiology was not as strictly mechanistic as much historiography wants us to believe: he was sensitive to the same variable influences on health and disease emphasized by his vitalist associates.[60]

Boerhaave experimented with metals, especially mercury, to test this traditional alchemical knowledge. He initially believed quicksilver to be a fixing principle of metallic bodies, without which all metals would be loosely floating particles. It was through studying elements like mercury that he could glimpse the perfection of the Creator. After all, the symbols for mercury and gold suggested that gold was a purified form of mercury—the purest metal actually

57. Herman Boerhaave, *Institutiones medicae in usus annuæ exercitationis domesticos* (Leiden: Johannes van der Linden, 1721), §246–50, 462, 467.

58. For the distinction between anatomy and physiology in the eighteenth century, see Andrew Cunningham, "The Pen and the Sword. Part One. Part Two."

59. Lawrence M. Principe, "Alchemy Restored," 305–6. Herman Boerhaave, *Hermanni Boerhaave Sermo academicus de chemia suos errores expurgante, quem habuit, quum chemiae professionem in Academiâ Lugduno-Batavâ auspicaretur* (Leiden: Petrus van der Aa, 1718).

60. Elizabeth A. Williams, *A Cultural History of Medical Vitalism in Enlightenment Montpellier* (London: Ashgate, 2003), 227.

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possible.[61] After performing a variety of experiments on mercury over decades, Boerhaave published the results. In these *Experiments*, he described how he subjected mercury to at least fifteen different experiments, to test the Philosophers' claims that mercury is the seed of all metals.[62] One of the experiments led him to state that "the Serpent that has bitten itself dies. It arises again more glorious from death."[63] Notwithstanding the resurrection metaphor, in the end, Boerhaave came to the following conclusion: "The Nature of Mercury is constant, simple, and cannot be separated into dissimilar Parts by Distillation; not into fixe'd and volatile; not into pure and impure; not into feces and defecated; not into different Elements."[64] Also, he stated that "it does not appear through these experiments that mercury and fire may form metals. Therefore fire … is not demonstrated to be the Sulphur of the Philosophers, fixing mercury into metal."[65] This understanding of mercury as a constant and simple substance showed no similarities whatsoever to Boerhaave's idea of blood and lymphatic fluid. These, like all other bodily fluids and tissues, originated from milk according to Boerhaave, as every animal "is nourished, and lives on its own proper milk; and from this alone prepares all the other parts, both the solid and the fluid."[66] The lymphatic fluid, which Boerhaave called "the serum of the blood," was blood minus the red part, and the constituent of the entire body:

> This serum contains all the matter which circulate thro' the vessels of the body, except the red part, and therefore holds whatever afterwards arrives at any vessel, whether great or small; that is, contains the

61. Rina Knoeff, *Herman Boerhaave (1668–1738): Calvinist Chemist and Physician* (Amsterdam: Edita, 2002), 151.

62. Herman Boerhaave, *Some experiments concerning mercury. By J. H. Boerhaave, professor of physick at Leyden. Translated from the Latin, communicated by the author to the Royal Society* (London: J. Roberts, 1734), 12–13: *"Most of these Philosophers say, that Quicksilver is the common Matter of all Metals: That this being changed by the Power of the vital Seed, gives a Metal which is defined or determined according to the peculiar Property of the seminal Efficacy: That every Metal, when the Quicksilver and this Metallific Power (which they call Sulphur) are maturely and, as it were, thoroughly boil's and concocted, is brought to a perfect Species of each such Metal. And fro hence, That every Metal is again resolved into these two Principles Mercury and Sulphur."*

63. Ibid., 39–40.

64. Ibid., 41.

65. John Powers, *Inventing Chemistry,* 235, Herman Boerhaave, *Some Experiments,* 162.

66. Herman Boerhaave, *A new method of chemistry: including the history, theory, and practice of the art: translated from the original Latin of Dr. Boerhaave's Elementa chemiæ, as published by himself. To which are added, notes; and an appendix, … With sculptures. By Peter Shaw, M.D.* (London, 1741), vol. II, 186.

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> nutrimental matter for supplying all the parts requiring growth, or repair; and consequently, the matter of the whole body, both solid and fluid.[67]

Boerhaave's ideas on the nature of mercury, blood, and lymphatic fluid also explain why he was cautious when it came to advising quicksilver as a cure. Unlike many of his contemporaries, Boerhaave did not believe quicksilver to have any active, resurrective medicinal powers. He had a purely mechanical understanding of the working of quicksilver in the body: because of its weight, it could breach obstructions, but as it was poisonous too, he repeatedly warned against using it in all but the most hopeless cases.[68] Although Boerhaave did not pay any attention to mercury as an anatomical material, his ideas about its materiality, combined with his understanding of blood and the lymphatic system did influence the work of Albinus.

The view of the lymphatic system as an extension of the circulatory system also clearly emanates from the work of Albinus, who devoted much of his career to the production of a monumental atlas of the human body, the *Tabulae Sceleti Et Musculorum Corporis Humani*. As the title implies, it contains tables of the bones and muscles of the human body. Sketches kept in Leiden University Library's special collections suggest Albinus also intended to publish tables of the nervous system, but probably his draftsman Jan Wandelaar died before the project was finished.[69] In addition to the *Tabulae*, Albinus published a plate of the chyle ducts with the azygos vein, the intercostal arteries, and surrounding parts, from which it appears he understood the chyle ducts and lymphatic system as an integrated whole.[70] From his lectures and published work, it becomes clear why he paid no detailed attention to the rest of the lymphatic system (Figure 2).

Albinus tried to find microscopic proof for the existence of Boerhaave's *vasa minima*, but did not succeed. What he did find was an amorphous gelatinous mass, which penetrated all bodily structures.

67. Ibid., 219.

68. Herman Boerhaave and Cornelis Jacobsz. Lóve, *De geneeskundigen onderwyzingen van de groote Herman Boerhaave, …/vertaald, en vermeerdert met aanteekeningen, inleyding, en naukeurigen registers door Cornelis Lóve* (Amsterdam: Johannes Gysius, 1745), 415–37, 45.

69. Tim Huisman and A. M. Luyendijk-Elshout, *De Volmaakte Mens: De Anatomische Atlas Van Albinus En Wandelaar* (Leiden: Museum Boerhaave, 1991).

70. B. S. Albinus, *Tabulae vasis chyliferi cum vena azyga arteriis intercostalibus aliisque vicinis partibus* (Leiden: I. & H. Verbeek, 1757).

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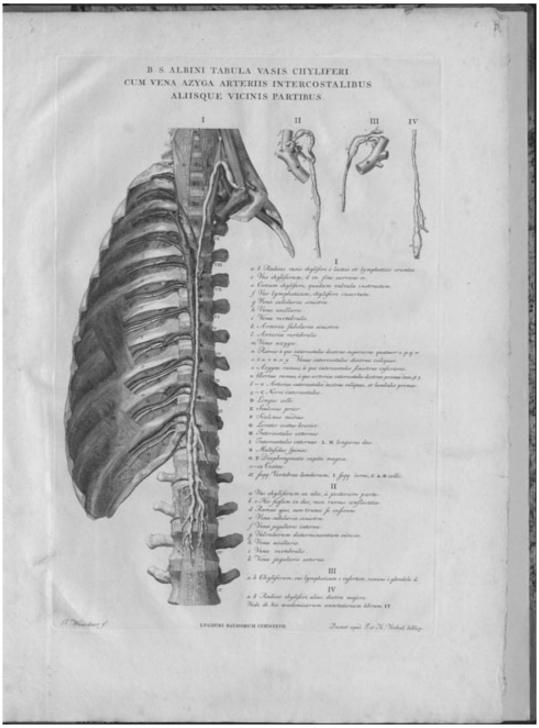

Fig. 2. Albinus, B. S. Tabulae vasis chyliferi cum vena azyga arteriis intercostalibus aliisque vicinis partibus. Leiden: I. & H. Verbeek, 1757.

This led him to argue that this mass was an active matter, which arose from nutrition, powered by the mechanic metabolism and a life force that Albinus called *vis vitalis* or *enormoun*. This force to him was the difference between living and dead matter, and Albinus believed that it might have substance in the form of fluid in the nerves and the cerebrum.[71] It could be argued that Albinus incorporated Boerhaave's understanding of the human body into a more vitalist one. Hence, most of his anatomical research focused on the formation of the bones, the nerves, and the sensory organs, which he thought played a central role in transporting the *vis vitalis*. Unlike for Boerhaave, physiology and anatomy were integrated disciplines for Albinus—his

71. H. Punt, "Bernard Siegfried Albinus" (1983), Chapter 5.

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anatomical experiments fed his physiological ideas and vice versa.[72] The reason that anatomical mercury played only a minor role in the material sediments of his research—his atlas and preparations—had to do with the fact that the lymphatic system in his idea of the body did not play a central role. Albinus, who saw Nuck's preparations in the Leiden collections, as well as some preparations with quicksilver injections made by Bidloo, used mercury in at least one preparation, of the glands of the penis, but he made no mercury-injected preparations of the lymphatic system, as the focus of his collection of preparations was on the nerves and the sensory organs, which he believed held the key to understanding the *vis vitalis*.[73]

Hence, the rare use of mercury injections by Albinus was a result of Boerhaave's demotion of the status of mercury and the fact that Albinus did not find those vasa minima for which mercury injections could have been well suited, but rather used microscopes to describe a uniform gelatinous mass, for which mercury injections would have been useless. For Albinus, practical considerations arising from his changing understanding of the nature and importance of the lymphatic and nervous systems were quite important. The almost complete absence of anatomical mercury preparations in the first decades of the eighteenth century can thus at least partly be explained from the enormous influence of Boerhaave's ideas on the teaching and practice of anatomy and physiology and the understanding of quicksilver in Europe.[74] Yet notwithstanding Boerhaave's influence, as Albinus's critical adaptation and reshaping of his model shows, he also taught his students to constantly

72. Andrew Cunningham, "The Pen and the Sword," has argued that physiology and anatomy were strictly separate disciplines in the eighteenth century. Steinke has countered this argument by describing Von Haller's work as experimental physiology. Hubert Steinke, *Irritating Experiments. Haller's Concept and the European Controversy on Irritability and Sensibility, 1750–90*, The Wellcome Series in the History of Medicine (Amsterdam, New York: Rodopi, 2005). Although I agree with Cunningham that physiology was primarily a philosophical discipline and anatomy a practical discipline, Albinus's and Von Haller's work convincingly shows that the two were often mutually dependent.

73. For the Bidloo preparations, see H. J. Witkam, "Catalogues Anatomy Hall Leiden University" (Leiden: Leiden University, 1980). A preparation of a penis injected with mercury is mentioned in lecture notes by student W. Box; see Punt, H. "Bernard Siegfried Albinus" (1983), 190, footnote 161. For Albinus's collection: M. M. A. Hendriksen, *Elegant Anatomy*, Chapter 4.

74. For Boerhaave's influence, see, e.g., Robert G. W. Anderson, "Boerhaave to Black: The Evolution of Chemistry Teaching," *Ambix*, 2006, *53*, 237–54; G. A. Lindeboom, *Herman Boerhaave. The Man and His Work* (Rotterdam: Erasmus Publishing, 2007); and John Powers, *Inventing Chemistry. Herman Boerhaave and the Reform of the Chemical Arts* (Chicago: University of Chicago Press, 2012).

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question their knowledge. This led to the development of new schools of thought and practice, in the case of the lymphatic system and anatomical mercury most notably in England and Scotland.

A NEW ERA FOR ANATOMICAL MERCURY: 1750–1800

Reill has argued that the Edinburgh medical school, founded in 1726 and modeled on Boerhaave's Leiden medical faculty, developed an independent approach from the 1740s onwards, and physicians such as Alexander Monro *secundus* replaced what was left of iatromechanism in the Leiden approach—which was, as we have seen, not so strictly mechanistic to begin with—with vitalism.[75] Although both Boerhaave and Albinus also adopted a form of vitalism in the course of their careers, by the 1750s, the influence of Leiden medical teaching was withering in Europe, and the star of the Edinburgh medical professors was rising. Moreover, Albinus's vitalism focused strongly on the nervous system; as previously described, his understanding of the circulatory and lymphatic system remained primarily mechanistic. It is very well possible that Alexander Monro *secundus*' renewed use of anatomical mercury to research the lymphatic system was at least partly inspired by Nuck's mercury-injected preparations of the lymphatic system in Leiden University's anatomical collections, implying pedagogical continuity from Leiden to Edinburgh rather than the independent approach Reill describes.

Monro *secundus* (1733–1817) gained a degree in medicine from Edinburgh in 1755, but he was already made professor of anatomy a year before graduating, as his father, anatomy professor Alexander Monro *primus*, had so many students that his classes grew too large. In his 1754 inaugural address, "A description of the seminal vessels," Monro *secundus* referred to Albrecht von Haller's work. Haller, a former Swiss student of Albinus, had managed to inject the epididymis or spermatic artery with mercury.[76] As Cunningham writes, Monro in his thesis briefly mentions that he believes the lymphatic vessels to be an absorbent system that runs throughout the body. A spillage from an epididymis that burst when it was injected with mercury did not only show up

75. Peter Hanns Reill, *Vitalizing Nature*, 212; Elizabeth A. Williams, *A Cultural History*, 227.

76. Alexander Monro, *A Description of the Seminal Vessels* (Edinburgh: G. Hamilton and J. Balfour, 1754). For the sake of readability, from now on "Monro" will refer to Monro *secundus*.

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in the surrounding cellular membranes, but also in lymphatic vessels, which Monro argued proved that the lymphatic vessels originated from those membranes and that they absorbed fluids from them.[77]

After graduating in Edinburgh, Monro briefly studied with William Hunter (1718–83) in London. As lecture notes by his students show, Hunter had studied the epididymis in animals with mercury injections, and had argued that the lymphatic system was absorbent as early as 1752.[78] He suspected that Monro had heard about his findings from Edinburgh students who took some classes in London. Maybe this was the reason that Monro did not stay in London for long. He soon traveled to Berlin, where he worked with anatomist Johann Friedrich Meckel the elder (1724–74). After his stay in Berlin, he went to Leiden University in 1757, where he met, amongst others, Albinus, and must have seen the anatomical collections, including Nuck's mercury-injected preparations.[79] Together with Meckel, Monro brought anatomical mercury and research on the lymphatic system back into the limelight. Monro published two "observations" on the lymphatic system in 1758, printed in Berlin, and reprinted in 1760 and 1770.[80] In *De Venis Lymphaticis Valvulosis*, he claimed to have discovered the absorbent nature of the lymphatic system before William Hunter. This led to a very public priority dispute between Monro and Hunter, from which Hunter withdrew once he realized the absorbent nature of the lymphatic system had first been suggested by Francis Glisson in the mid-seventeenth century.[81]

77. Andrew Cunningham, *The Anatomist Anatomis'd. An Experimental Discipline in Enlightenment Europe* (London: Ashgate, 2010), 289.

78. Ibid.

79. That Monro was interested in Albinus's work also appears from the fact that he apparently purchased notes of Albinus lectures on physiology. See http://www.otago.ac.nz/library/exhibitions/monro/cabinet6/inside2.html (accessed September 29, 2014). It is not surprising Monro decided to visit Leiden; his father had studied there and maintained contacts. See, e.g., Anita Guerrini, "Alexander Monro Primus and the Moral Theatre of Anatomy," *The Eighteenth Century*, 2006, *47,* 1–18.

80. Alexander Monro, *De Venis Lymphaticis Valvulosis* (Berolini: 1757).

81. C. T. Ambrose, "The Priority Dispute over the Function of the Lymphatic System and Glisson's Ghost (the 18th-Century Hunter-Monro Feud)," *Cellular Immunology,* 2007, *245,* 7–15. It was actually Francois Glisson (1597–1677) who discovered the absorbent nature of the lymphatic system first, but his mid-seventeenth-century publication on the topic did not resurface until Monro II and William Hunter had independently reached the same conclusion. Some sources state that a certain Friedrich Hoffman, personal physician to the King of Prussia in the early eighteenth century, gave a description of the lymphatic system as absorbent before Monro and Hunter, but there is no evidence of a publication of that kind.

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J. F. Meckel, by the time Monro visited him in Berlin, had repeated Nuck's *Adenographia*, tracing the lymph vessels with mercury injections. It is likely that he was inspired to do so when he studied with former Leiden University student Albrecht von Haller, who had become professor of medicine, anatomy, botany, and surgery at the University of Göttingen. Meckel had studied the lymphatic nodes closely, and came to the conclusion that the lymphatic system was in fact an entirely independent entity from the circulatory system, with a flow of its own.[82] Although the work of Haller and Hunter had started the renewed use of anatomical mercury and new research on the lymphatic system, the publications by Monro and Meckel were actually the first printed works that challenged Nuck's views on the lymphatic system as an extension of the circulatory system, and marked the start of renewed, international interest in anatomical mercury and the lymphatic system.

In 1760, their work on the lymphatic system was combined in one publication printed in Leiden.[83] It is unclear whether Albinus or other Leiden professors played a role in this, or how they responded to it.[84] However, Albinus had suffered from problems with his eyesight since the mid-1740s, preventing him from giving anatomical demonstrations or making preparations, and by 1760, he seems to have regretted a long-running conflict he had with his former student Haller about the irritability of the nerves.[85] Moreover, as has been argued before, Albinus's physiological understanding of the human body had become increasingly vitalist. It is therefore possible that he stimulated a Leiden publication of the work of Monro and Meckel as a way to contribute to renewed research of the lymphatic system using anatomical mercury. But whether Leiden professors actively supported it

82. Johann Friedrich Meckel, "Dissertatio epistolaris de vasis lymphaticis glandvlisqve conglobatis" (Berolini: 1757), A. M. Luyendijk-Elshout, "Antony Nuck," 163.

83. Alexander Monro and Johann Friedrich Meckel, *Opuscula Anatomica De Vasis Lymphaticis*, 2 vols. (Leiden: Lipsius, 1760).

84. It is clear from correspondence from the 1780s that Monro must have kept in touch with Petrus Camper (1722–89) after they met in Leiden in 1757, although they disagreed on many things. However, it is unclear whether Camper had anything to do with the 1760 Leiden reprint of Monro's work on the lymphatic system. See Leiden University Library Special Collections MS BPL 247: 107, Letter from Petrus Camper (1722–89) to Alexander Monro (1733–1817), dated January 17, 1787, and Amsterdam University Library Special Collections MS OTM: hs. X 99: a–b, Monro Secundus, Alexander, Two Letters to Petrus Camper, Edinburgh 1783–88.

85. H. Punt, "Bernard Siegfried Albinus," 11, 13. Also see Hubert Steinke, *Irritating Experiments*.

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or not, anatomical mercury and the lymphatic system were back on the anatomical research agenda once again.

The renewed interest in anatomical mercury and the lymphatic system led to the production of new preparations and publications. Meckel apparently made some successful mercury-injected preparations of the lymphatic system, although these no longer exist today.[86] According to contemporary catalogs, Monro managed to create two full body preparations in which the lymphatic system had been injected with mercury, one of which is still in the collections of the Anatomical Museum of the University of Edinburgh today. An eighteenth-century life-size engraving of this preparation shows that it must have been even more impressive at the time, and recent radiographs still clearly show mercury-filled lymphatic vessels in the legs.[87] Even though the preparations and publications by Monro and Meckel persuaded many of their contemporaries that the lymphatic system might very well be an absorbent system, its exact function and structure remained largely unclear, so there still was a need for further research.[88]

Therefore, the Parisian Academy of Sciences in 1784 offered a prize for the best work demonstrating the structure and function of the lymphatic vessels. The Italian Paolo Mascagni (1752–1815) had returned to the injecting techniques originally developed in the second half of the seventeenth century to study the lymphatic system and improved them in the 1770s and early 1780s, for example, replacing the usual metal tubes used for injecting mercury by glass tubes, allowing for more control and thus more refined results.[89] He sent in two substantial illustrated reports, which arrived after the deadline, but as the Parisians were deeply impressed with his work, they offered him a prize anyway.[90] As Mascagni probably feared his work would be plagiarized, he published a brief version of the work he had sent to the

86. Rüdiger Schultka, "Präparationstechniken," 69, footnote 109.

87. M. H. Kaufman, "Monro secundus."

88. William Hunter, together with his assistants Hewson and Cruikshank, also continued researching the lymphatic system with anatomical mercury until his death in 1783. However, the resulting publications by Hewson (1774) and Cruikshank (1786) lacked the quality to become reference books. Also see A. J. Miller and A. Palmer, "The Three Williams—Hunter, Hewson, and Cruikshank: Their Unique Contribution to Our Understanding of the Lymphatics," *Lymphology*, 1995, *28*, 31–34.

89. Rüdiger Schultka, "Präparationstechniken," 73.

90. http://sdrc.lib.uiowa.edu/exhibits/imaging/mascagni/about.htm (accessed September 29, 2014).

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academy in the same year, followed by a magnificent atlas of the lymphatic system that appeared in 1787, and that would remain the authoritative guide on the subject for over a century.[91] In the preface, Mascagni notes that he was inspired by Nuck's mercury injections to trace the lymph vessels.[92]

In addition to these printed works, Mascagni also produced a great number of both wet and dry mercury-injected preparations. Because these were used intensively for medical teaching until the early twentieth century, only a few dried preparations of limbs remain. The mercury injections in the remaining preparations are now hard to discern in photographs of the aged preparations, but radiographic images from the 1930s clearly show the intricate webs of mercury.[93] Although he made numerous impressive mercury-injected preparations himself, in his written work on the lymphatic system, Mascagni referred admiringly to the work of both Nuck and a contemporary who never made it into the historiography of lymphatic research because he did not publish on the topic: Eduard Sandifort (1742–1814), professor of anatomy at Leiden University from 1771.[94]

Sandifort had a completely different understanding of the function of the lymphatic system and the nature of the lymphatic fluid and the blood than his Leiden predecessors Nuck and Albinus, yet he was a great admirer of their refined preparations.[95] Inspired by their research and the contemporary interest in anatomical mercury and the lymphatic system, Sandifort created a small but impressive collection of wax- and mercury-injected preparations himself.[96] These preparations clearly referred to his illustrious predecessors: he chose mercury injections in the style of Nuck, which by the 1770s had a dual function (Figure 3). As we have seen, research on the lymphatic system and its role in health and disease was far from completed, making mercury-

91. Paolo Mascagni, *Prodrome D'un Ouvrage Sur Le Système Des Vaisseaux Lymphatiques* (Sienne: Vincent Pazzini Carli & fils, 1784); Paolo Mascagni, *Vasorum Lymphaticorum Corporis Humani Historia Et Ichnographia* (Senis, 1787).

92. Paolo Mascagni, *Vasorum Lymphaticorum,* 36.

93. Leonetto Comparini, "I preparati anatomici di Paolo Mascagni," in *La scienzia illuminata: Paolo Mascagni nel suo tempo (1755–1815)*, ed. Francesca Vannozzi (Siena: Nuove Immagine Editrice, 1996), 165–77.

94. Paolo Mascagni, *Prodrome D'un Ouvrage,* 132.

95. For Sandifort's understanding of the physiology of the lymphatic system, see Eduard Sandifort, *Handleiding tot de genezing der inwendige ziekten* (Leiden: E. Sanifort, 1788), 128–38.

96. For a detailed discussion, see M. M. A. Hendriksen, *Elegant Anatomy*.

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Fig. 3. LUMC Al0007. Heart injected with red wax and mercury. Probably from the collection of Eduard Sandifort (1742–1814). © Anatomisch Museum LUMC 2012. Photographer: Arno Massee.

injected preparations of the lymph glands of great interest once again. Yet Sandifort had another motivation: by creating these preparations, he placed himself firmly within the tradition that he himself called "elegant anatomy." Creating mercury-injected preparations Nuck-style

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was the ideal manner in which to continue the traditions of the Leiden anatomical collections for Sandifort.[97]

The use of a notoriously difficult preparation technique, and an injection material that was no longer associated with transmutational theories and practices, guaranteed Sandifort that he was putting himself on a par with illustrious predecessors, while simultaneously working on a contemporary research topic. However, the focus in Leiden at the time was not so much on research of the lymphatic system, but on pathology. The board of the university and the medical professors hoped this would restore the attractiveness of Leiden as a place to study medicine. The mercury-injected preparations therefore remained a small private project for Sandifort on which he never published, and they were not recognized as examples of excellent anatomical craftsmanship until they became part of the university's collection in the nineteenth century.[98] The lack of mercury-injected preparations in anatomical collections in certain periods thus may seem indicative of a lack of investigation of the lymphatic system, yet an analysis of preparations in combination with texts shows research and changing conceptions of the lymphatic system and mercury were more or less continuous. The material culture of anatomical mercury is indispensable for understanding changing perceptions of mercury and the lymphatic system and enables us to gain a better understanding of complex actor's categories, but both the presence and absence of objects should be read carefully and in context.[99]

After 1800, anatomical mercury quickly lost its appeal as an injection mass. Its penetrating qualities turned out to be a disadvantage in many cases: although it had been clear since the early eighteenth century that mercury broke through the barriers between the lymph glands and other structures, leading to incorrect conclusions about their interconnections, the full integration of the microscope in medicine stressed the extent of this problem. Moreover, preparations were

97. A. M. Luyendijk-Elshout, "The Elegant Anatomist: The Italian Medical Connections of Eduard Sandifort (1742–1814)," in *Italian Scientists in the Low Countries in the XVIIth and XVIIIth Centuries*, ed. C. S. Maffioli and L. C. Palm (Amsterdam: Rodopi, 1989), 305–20, 312.

98. Gerard Sandifort, *Museum Anatomicum Academiae Lugduno-Batavae Descriptum*, vol. III (Leiden, 1827).

99. Glenn Adamson, "The Case of the Missing Footstool: Reading the Absent Object," in *History and Material Culture. A Student's Guide to Approaching Alternative Sources*, ed. Karen Harvey (London: Routledge, 2009), 192–207.

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vulnerable as even small temperature changes damaged them.[100] Yet being able to inject lymphatic vessels with mercury long remained a proof of skill. Mercury injections were not for beginners: in his 1860 preparation handbook, Hyrtl remarks that it is "no job for students," who "except in class have never seen lymph vessels, let alone that they wish profoundly to try and inject them." According to Hyrtl, there were few anatomists who occupied themselves with this "specialism."[101]

CONCLUSION

This article has shown that when the remaining material culture of anatomical mercury is taken as a framework, a much larger and more integrated history of the use of quicksilver as anatomical research and preservation material emerges. Moreover, it demonstrates that complex and interconnected categories such as vitalism and mechanism, or anatomy and physiology, are easier to understand in terms of the materiality of the objects that resulted from them than purely through the history of ideas. This historiography transcends and connects existing case studies and technical accounts, and gives us insight in the mixed artisanal and learned practice of eighteenth-century lymphatic anatomy and physiology in the development of which anatomical mercury played such a crucial role. The continuous admiration for the preparations and publications that resulted from the use of anatomical mercury show the importance of and appreciation for the artisanal skills of learned men in the long eighteenth century, as well as the circulation of anatomical knowledge through objects and words throughout Europe.

As we have seen, the initial choice for mercury as an anatomical injection mass in the late seventeenth century was no coincidence; quicksilver had a wide variety of practical qualities and symbolical meanings that made it the ideal material to explore the structure of largely unknown lymphatic system—a practice that informed and reinforced the physiological understanding of the lymphatic system as an extension of the circulatory system. The apparently contradictory use of a material so rich with meaning, a material still largely

100. F. Knox, *The Anatomist's Instructor, and Museum Companion Being Practical Directions for the Formation and Subsequent Management of Anatomical Museums* (Edinburgh: Adam and Charles Black, 1836), 122; F. J. Cole, "Anatomical Injections," 341–42.

101. Joseph Hyrtl, *Handboek Der Praktische Ontleedkunst : Als Leiddraad Bij De Anatomische Oefeningen En Tot Het Vervaardigen Van Præparaten* (Schiedam, 1860), 655.

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understood in alchemical, transmutational and even vitalist terms within a primarily mechanical understanding of the human body shows that distinctions between mechanism and vitalism in the late seventeenth and early eighteenth century although existent, were not very strict or mutually exclusive. Although mercury-injected anatomical preparations were valued by many by the late seventeenth century, either as potential commodities or as implements in research and teaching, a changing understanding of blood, mercury, and the lymphatic system meant a temporary lapse in the use of mercury in anatomical and physiological research, although it never disappeared entirely.

In the long run, the use of anatomical mercury in the long eighteenth century changed the lymphatic system from mercurial entity—elusive and largely mysterious—to a solid part of human anatomy. Initially chosen as an injection mass not only because of its material but also its symbolical qualities, anatomical mercury became and remained the material of choice for research of the lymphatic system. The intensity with which it was used was directly related to the understanding of the materiality and nature of both the lymphatic system and mercury itself. After initial explorations in the second half of the seventeenth century which led to a dominantly mechanistic understanding of the lymphatic system as an extension of the circulatory system, anatomical mercury was used marginally in glandular research for a couple of decades. Meanwhile, the understanding of mercury changed gradually from possibly having organic properties to a lifeless, inorganic material. Accidental spillages from the glands into the cellular tissue and the ensuing absorption of mercury into the lymphatic vessels led to a new understanding of the lymphatic system as absorbent, a renewed interest in anatomical mercury as a research tool, and fresh attempts to fathom the exact function and structure of the lymphatic system.

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