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World-ecology "among the ooze": *Our Mutual Friend* and the Chemistry of Sewage, Soils, and Circulation

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> And have our agriculturists for a moment considered of what the home-made sewage manure consists? . . . it must be remembered that we import as well as produce, fruits of the earth, and that our imports of food alone amount annually to 75,000,000*l*. – in other words, our own home-made guano contains the fertilising elements not only of our own soil, but that of all countries of the earth which pour out their cornucopias into our island . . . and the whole of which is now allowed to run to waste.
>
> ("The Restoration of Our Soil, II." *Once a Week*, 14 Mar. 1863, p. 318)

Agricultural writers of the mid-nineteenth century, such as this anonymous contributor to *Once a Week*, frequently saw "all countries of the earth" as fertile natures to sustain Britain's population. The article addresses mid-Victorian concerns over soil exhaustion, describing a global, yet wasteful, circulation of nutrients. Chemical analysis here isolates the same "fertilising elements" in the "fruits of the earth" and in "home-made sewage." But the article also figures sewage as "guano," a term more commonly associated with bird excrement, imported to Britain from Peru throughout the mid-nineteenth century for use as manure (Kingsley 126-9). Sewage – supposedly a local resource and source of "home-made" soil fertility – becomes entangled instead within global networks of nutrient extraction. Nutrients are here directed by British capitalism, with fertile elements flowing into Britain from across and beyond the empire, then "allowed to run to waste" rather than be re-used as fertilizer. A vocal opponent of this wasteful trade in nutrients was the German chemist Justus Liebig; writing in *The Times* in 1859, he claimed that the global trade in food and fertilizer threatened future soil fertility ("Liebig"). In Charles Dickens's *Our Mutual Friend*, serialized between 1864 and 1865 at the height of Victorian concerns over soil exhaustion, these issues shape an investigation of food production, consumption and waste with global parameters. My article reads this novel alongside Liebig's work to examine how Dickens's London – "The World's Metropolis" (*OMF* 132) – frames an investigation into the co-development of chemistry, capitalism and agriculture during the period.

Dickens was well versed in Victorian science (Buckland). Several scholars have noted his familiarity with chemistry (Wilkinson; Metz 65-70; Parham 4-5), but it has escaped attention, until now, that he was a particular admirer of Liebig's work: "I wish I could be there to meet Baron Liebig," he wrote in 1851 to his friend, Sheridan Muspratt, who had gained a PhD in chemistry under Liebig – "one of the greatest men in Europe, and in whom I am (as who is not?) most strongly interested" ("Letter"). Liebig was visiting Liverpool, and Dickens's regard is unsurprising considering that Liebig's science, as William Brock notes, focussed on questions of "food production, nutrition and public health" (Brock ix). Dickens's own advocacy for similar causes is well known (Parham), and as editor of *Household Words* and *All the Year Round* he published over twenty-five articles referring to Liebig's science between 1850 and 1865. Contributions such as "The Farmer of Tiptree Hall" (1852), "Dirty Cleanliness" (1858), "A Way to Clean Rivers" (1858), "The Poor Man and His Beer" (1859), and "Artificial Fertility" (1865) also attest to a wider knowledge of agricultural concerns; important too is the work of agriculturist, and early chemical-fertilizer manufacturer, John Bennet Lawes – a commissioner on the *Royal Commission on the Sewage of Towns* at the end of the 1850s, as *Household Words* reported.

The questions of sustainable soil use that my article engages relate to a long history of critical readings of waste in *Our Mutual Friend* (Sucksmith; Metz; Toker). More recently, scholars have turned from the novel's prominent dust mounds to its river and sewage (Allen; Shannon; Kluwick). This shift parallels a burgeoning interest in soils within the environmental humanities, stimulated in part by Bruno Latour (1999) and since developed by Maria Puig de la Bellacasa (2014) and Anna Tsing (2015), among others. Despite this, however, the dominant understanding of nineteenth-century soils remains Jonathan Bate's assertion that, as rural populations moved from country to city, local connections to soils were lost (Bate 16). Yet this conceals a parallel reality, where British capitalism networked the world's soil fertility through increasingly globalized agricultures, making peoples, animals, plants and soils – precisely because of their topographical removal – ever more entangled. To frame this investigation, I borrow from Jason Moore's concept of world-ecology, identifying capitalism as "a way of organizing nature" (Moore 2). I centre this discussion "among the ooze" of the novel (*OMF* 164), in and around *Our Mutual Friend*'s various soils, in order to unravel the imbrication of matter, chemistry and commerce within the narrative.

My article is split into six sections. The first two detail the circulatory chemical worldview of the period, evidenced first in Lawes's writing, and then shown to act across the opening chapters of *Our Mutual Friend*. I then examine Liebig's fears of soil exhaustion, focussing on how chemical circulation is compromised, in his work, by anxieties over energy degradation. Sections four and five show how *Our Mutual Friend*'s courtship plots function as investigations of nutrient circulation, before my final section draws out the tensions and contradictions inherent in the novel's solutions to soil fertility. Following this structure, I make three arguments about *Our Mutual Friend*. First, Dickens engages with chemistry in its relations to agriculture to craft a chemical poetics delicately attuned to nutrient circulation in the mid-nineteenth century. Second, this analysis is complicated by thermodynamic anxieties over energy degradation, which call into question understandings of nutrient cycles as closed systems. Third, while *Our Mutual Friend* uncovers links between nutrient extraction and inequality as inherent to capitalist agricultures, the solutions the novel proposes to soil exhaustion preserve unequal and productivist economics. In order to make these arguments, I first outline the dominant Victorian conception of chemical circulation, evidenced in Lawes's writing on sewage.

Sewage and Providential Chemistry

In the mid-nineteenth century, chemistry and Providence were mutually supporting in envisioning a circulatory chemical system of growth and decay (Hamlin). In his 1855 paper "On the Sewage of London", J.B. Lawes examined wheat growth across the previous decade at his Rothamsted farm in Hertfordshire. His aim was to isolate the nutrients important for plant growth that sewage might provide, and he understood his results in terms of a providential circulation of chemical elements in various molecular combinations:

> The term *manure* includes a great variety of substances, from the disgusting mass of corruption, . . . to the purest and most delicate crystallised salts. It is not one of the least of the many beautiful arrangements which we see around us whereby the Almighty has endowed the same particles of matter with the property of entering into a variety of forms . . . In this ever changing circle, nothing is without its value, nothing is lost. (263; emphasis in original)

Lawes's providential chemical cycle is a closed system. Ordained by "the Almighty," this "ever changing circle" of molecular transformation becomes a "beautiful arrangement" when isolated through scientific inquiry. Chemical analysis here becomes the methodology required to uncover the workings of nature, understood to be in harmonious balance at the molecular level, with matter "entering into a variety" of chemical combinations underpinning a providential natural economy, of which sewage is a crucial part.

If sewage flowing out to sea in the Thames severed a link in this natural economy, the prospect of harnessing it successfully for agriculture promised financial opportunity. As particles of matter "enter into a variety of forms," Lawes wrote, they have an "absolute value when considered in a scientific point of view" as well as a "proper money equivalent" as "articles of commerce" (263). Forming part of a providential closed system, Lawes viewed manures as inexhaustible sources of fertility with the potential to generate correspondingly limitless commercial wealth. Conflating scientific and financial understandings of value and loss, this molecular understanding of a providential nature becomes entangled with capitalist economics. With grass fertilized by sewage manure "peculiarly adapted for the production of milk" – one of "few articles with which the inhabitants of the metropolis are so inadequately supplied" – the providential circulation of chemical elements through soils, plants, animals and people creates financial wealth by restoring healthy populations (277). The manure trade is here brought under the legitimizing hand of Providence, the social and ecological co-created as "capital and power . . . develop through the web of life" (Moore 26). The logic of capital circulation and flow thus penetrates to the molecular, with providential chemistry underwriting, while simultaneously being directed by, capitalist economics.

Commercial opportunity saw Lawes enter the chemical-fertilizer industry in the 1840s. By mixing "bones dissolved in sulphuric acid" with other organic materials, he manufactured his patented "Super Phosphate of Lime" at a factory in London's Deptford, arriving independently at a process that Liebig also suggested in 1840 (Brock 121-29; Russell 92-97). This commercial success, allied with his revolutionary Rothamsted field trials, led to Lawes being appointed a commissioner on the *Royal Commission on the Sewage of Towns* (1857-1865). His early work with the Commission was reported in *Household Words* at the height of the Great Stink in July 1858 ("Clean Rivers" 81), with Dickens publishing a second article in the same month

advancing the providential chemical worldview to which Lawes adhered: "The physical circle whose laws we are compelled to obey, . . . is a never-ending round of absorption, digestion, assimilation, and rejection; of birth, growth, increase, life, death, decomposition, and dispersion; and then life and growth again" ("Dirty Cleanliness" 122). In articulating this vision of circulatory chemical combination, the article reported that London's sewerage system failed to adhere to the "wisdom of Providence" (122). "A]llowed to flow into the river," sewage was "a loss to the community" at once financial, agricultural and, potentially, terminal for the health of the nation (122). If it was not possible "to get rid of [sewage] usefully" as manure, the article argued, "the whole machinery of agricultural and horticultural production must stop," resulting in "utter sterility" and "famine" (122). These issues of sustainable sewage disposal, agricultural production, and food consumption find expression through a chemical discourse strikingly similar to Lawes's in *Our Mutual Friend*.

Our Mutual Friend's Chemical Poetics

The novel begins with Gaffer and Lizzie Hexam "float[ing] on the Thames" (1). Jesse Oak Taylor rightly notes that *Our Mutual Friend* offers little direct description of the excrement that filled the river (Taylor 60), but here "the filthy water" leaves Gaffer with "wet and dirty arms" (3) in a clear allusion to sewage (Allen 86). Father and daughter make their "living" by removing anything of value from the water (3). The excremental foundations of this economic relationship are suggested in Gaffer's clothing, seemingly "made out of the mud" (2), with the pair "allied to the bottom of the river . . . by reason of the slime and ooze" in which humans and boat are covered (1). Material connections between bodies and sewage are affirmed as Gaffer tells Lizzie that "the very river" is "meat and drink" to her (3). His words slip between the literal and metaphoric, drawing on the idea of Thames sewage as wasted manure in linking the river's excremental filth with its potential fertility. As Ursula Kluwick argues, "the Thames emerges as extraordinarily fertile" (189), but the Hexams are sustained within a nutrient cycle that shifts in scale as Gaffer discovers a body, later (wrongly) identified as John Harmon's. Formerly a colonial "farmer" in South Africa (15), Harmon's past suggests globalized agricultures linked to London via the "tiers of shipping" lining the river in which his supposed corpse is found (1). In taking coins from this body's pockets, Gaffer draws sustenance from a river where productivity is enmeshed within geographies stretching far beyond the parameters of Southwark and London Bridges, "between" which the novel's opening chapter is nominally set (1). The Hexams are thus sustained upon waste inherent to globalizing agro-economics, trade believed to make Thames sewage, as Liebig was reported as stating in *Household Words*, "the most valuable manure in the world" ("Tom Tiddler's" 331).

Our Mutual Friend's second chapter turns from the river to a high-society dinner. The Veneering family's butler is here introduced as "a gloomy Analytical Chemist; always seeming to say, after 'Chablis sir?' – 'You wouldn't if you knew what it's made of'" (10). Michael Cotsell correctly draws attention to the role of Victorian chemists in detecting adulterated food (26-7), but the novel's chemical analysis is meant to extend far beyond food adulteration, as Lady Tippins's experimental chemistry suggests:

> Lady Tippins has made a series of experiments on her digestive functions, so extremely complicated and daring, that if they could be published with their results it might benefit the whole human race. Having taken in provisions

> from all parts of the world, this hardy old cruiser has last touched at the North Pole. (11)

Dickens here applies chemical investigation to both food and excrement, as did Lawes. His chemical poetics extend beyond Lawes's science, however, by beginning to isolate the locations where fertility originates and – once consumed by Tippins – to where it might disperse. Tippins is sustained upon globalized agricultures as she digests food and drink "from all parts of the world," linking her consumption to the excremental river of the first chapter. In the midst of her "experiments," she introduces a discussion of Harmon's origins as a "small proprietor, farmer, grower" (15). The analytical method with which she is associated here "fix[es] him with a local habitation" in "the country where they make the Cape wine" (13). Chemistry thus analyzes both wine and sewage as related links in a global nutrient cycle itself shaped by capitalist economics, bringing agricultural produce to London only to see fertility disperse in the Thames.

The "Analytical Chemist" remains ever-present as Tippins enjoys "the fruits of the earth" (411) and consequently suffers from a "chronic state of inflammation" (618; see also 121, 209, 250-53, 619). He serves quantities of "claret" (14), "madeira" (15), "curacao" (118), and "champagne" (120, 626), names that etch economic links between London dinners and agricultures in Europe, the Caribbean and Africa. His name is later shortened to "the Analytical" (114), a contraction that Nancy Metz writes "illustrates metaphorically the process he is called upon to perform" (65); as he serves agricultural produce imported from across the British empire, the chemical method he represents traces links within these networks that begin to invoke what Moore terms "modernity's projects and processes . . . as environment-making processes" (12). Wine is drunk as Cape wine production is discussed, linking dinner in a London borough and agriculture in Southern Africa such that consumption in the former drives environmental change in the latter.

Within London, Dickens's chemical poetics draw *Our Mutual Friend*'s famous "Dust" into the novel's agricultural investigations (13). While the presence of excrement in the dust mounds has been hotly contested (Sucksmith; Allen 86-7; Cotsell 30-3; Kluwick 191), of greater interest here are the broader links between this dust and agriculture. Cotsell notes that "vegetable-dust" (*OMF* 13) was used as manure (Cotsell 33); to this can be added the novel's "bone-dust" (13), sold to manufacturers of artificial fertilizer, such as Lawes, who required bone matter for his factory in Deptford, as my next section details. For Leona Toker, describing and processing the contents of the dust mounds is to "analyse" their contents in order to bring them into economic circulation (51); links to agricultural chemistry become apparent as Silas Wegg reads to Mr. Boffin from Merryweather's *Lives and Anecdotes of Misers* (1850). Wegg details how "one of Mr Dancer's richest escretories was found to be a dungheap in the cowhouse; a sum but little short of two thousand five hundred pounds was contained in this rich piece of manure" (482). "[B]ank notes and gold" are also found, but the most valuable source of wealth is clearly the "rich piece of manure" itself (482). This fertile matter realizes financial value only when released from the miser's grip, the circulation of nutrients becoming entangled, as it was for Lawes, within imbricated natural and financial economics.

One of *Our Mutual Friend*'s principal characters, Eugene Wrayburn, introduces a discussion of "Energy" that complicates this analysis of nutrient circulation, however (20). Dickens's capitalisation offers what John Parham terms a "deliberate allusion" to thermodynamics (8). Allen MacDuffie goes further, uncovering how Eugene's words conflate scientific and economic definitions of waste and work as he flounders "within

a system of conservation and expenditure" (122-5). Yet it remains to be noted that, while Eugene travels by coach through London to Limehouse, his thermodynamic discourse immediately precedes the novel's one direct reference to sewage:

> The wheels rolled on . . . by the Docks; down by Ratcliffe, and by Rotherhithe; down by where accumulated scum of humanity seemed to be washed from higher grounds, like so much moral sewage, and to be pausing until its own weight forced it over the bank and sunk it in the river. (20-1)

The sewage that flows through this passage becomes "moral" in its associations with energy physics. Fertile sewage matter disperses in the Thames, and this is simultaneously a "moral" loss in its associations with the poor of Ratcliffe, Rotherhithe and Limehouse. With links between sewage and chemistry already established, this population should be thought of within a "residuum" discourse. Sarah Alexander shows how this term developed newly thermodynamic applications from the mid-1860s, when "residuum" shifted from referring to a waste "deposit or sediment" to suggesting that "England's underclass" might be as "irredeemable" as the chemical residue left by combustion (99). The thermodynamic suggestion of sewage as wasted energy is here applied to the proximate poor, identifying this population in terms of lost economic productivity. The simultaneous implication is that, as sewage disperses in the Thames, fertile nutrients might not deplete from chemical circulation temporarily but disappear from human use entirely.

Liebig's Thermodynamic Anxieties

Liebig's writing on soil exhaustion provides a route into understanding the significance of this shift. The introduction of "Energy" in *Our Mutual Friend* draws on William Thomson's findings, published in 1852, that the usable – or "potential" – energy available in systems always reduces over time ("Universal" 306). Although Thomson didn't use the term entropy (it would not be coined until 1867), he described what would come to be the second law of thermodynamics (Gold 8). As Libb Thims shows, this began to have a profound effect on chemistry from the 1870s, with thermodynamics revolutionizing how chemical reactions were understood in terms of energy and entropy (78-86). Critical work on nineteenth-century chemistry has, thus far, emphasized Liebig's foundational role in propagating the providential view of chemical circulation in texts such as his 1840 *Organic Chemistry* (Hamlin). I do not dispute this, but also believe that certainty in the closed chemical system was, for Liebig himself, undercut by nascent awareness of thermodynamic energy transfer.

The seeds of this awareness are evident in Liebig's *Animal Chemistry* (1842). In "On the Dynamical Theory of Heat," published in July 1852, Thomson highlighted statements in Liebig's work that "virtually imply the convertibility of heat into mechanical effect" ("Dynamical" 10). Liebig's wording is as follows: "When we kindle a fire under a steam-engine, and employ the power obtained to produce heat by friction, it is impossible that the heat thus obtained can ever be greater than that which was required to heat the boiler" (*Animal Chemistry* 33). By 1859, in a new chapter written for the fourth edition of his *Familiar Letters on Chemistry*, Liebig was drawing on the pioneering work of physicist Robert Mayer to offer a clear expression of the first law of thermodynamics: any "apparent annihilation" of energy was really "only a conversion into some other form," he explained (*Familiar Letters* 172). Matter is understood here in terms of energy transformation and, while Liebig's writing does not necessarily imply entropic decay, his words move in the direction of thermodynamics,

with Thomson of course referring to his writing only three months before publishing his own revolutionary theory of energy degradation.

With matter understood in terms of energy transfer, Liebig's certainty in closed chemical cycles seems to have been undermined by the suggestion of irreversible energy degradation through the system. This is suggested in a letter he wrote in 1859, on the subject of sewage, to the English agriculturist John Mechi. Published in *The Times*, Liebig bemoaned "indifference to the future" within the British agricultural community, arguing that sewerage infrastructure was leading to an "irretrievable" waste of nutrients:

> [Farmers] think that they may continue to take from the field as long as there is anything left, and that it will be time enough to provide for this necessity [of soil restoration] when it knocks at their doors. They do not, of course, know how large their stock [of nutrients] on hand is nor are they aware that . . . what they have wasted is irretrievable. ("Liebig")

Soil degradation moves in this passage from a transitory state of depletion to a terminal condition of exhaustion. MacDuffie is right to point out that Victorian theories of nutrient cycling often "miss[ed] the irreversible dynamics of a new kind of energy economy" (126), but Liebig here moves beyond the dominant discourse of chemical circulation in his fear of "irretrievable" soil exhaustion. This thermodynamic anxiety manifests as soil temporalities diverge. The harmony and balance of chemical circulation, where farmers always have "time enough" to restore their land, is disrupted because soil change occurs not only via short-term molecular transformations. As energy flows through soils but is not replaced in the form of manure, change occurs also in terms of longer-term energy depletion, with every harvest "take[n] from the field" removing potential energy from the soil. For Liebig, if existing practices continued, "complete exhaustion" was inevitable across Europe's soils within fifty years ("Liebig").

While this "irretrievable" exhaustion suggests that Liebig held some thermodynamic awareness, his solution stepped abruptly away from a full avowal of entropic energy degradation. Arguing that sewage-manuring could circulate "elements . . . collected without loss, and every year returned to the fields," he brought the old certainties of providential chemistry to bear on his thermodynamic anxieties. These fields "would then retain the power to furnish every year to the cities the same quantity of corn and meat," he wrote ("Liebig"). Liebig's closed system is a thermodynamic impossibility, but sewage appears as a route to reconciling the diverging ontologies of chemistry and thermodynamics. In his letter to *The Times*, nutrient cycles are neither entirely circular (chemistry) or linear (thermodynamics), but a mixture of the two; while failure to adhere to providential circulation leads to entropic soil degradation, uniting elemental fertility with soils indefinitely prevents thermodynamic exhaustion. There is a suggestion of Barri Gold's "thermodynamic optimism" here (10-11), with Liebig viewing local sewage-manuring as capable of resisting the universal drive to entropic degradation. At the same time, although Liebig's knowledge of energy physics is clearly uncertain, his thermodynamic anxieties seem to suggest something of chemistry's coming thermodynamic revolution.

Mechi published another letter on sewage manure from Liebig in 1863. Though chemical analyses suggested that sewage held quantities of ammonia and potash, they showed it to be deficient in phosphorous. Liebig argued that this was because animal bones, rich in this chemical element, could not find their way into the sewers

("Utilisation" 656). *Our Mutual Friend*'s "bone dust" (13), then, can be understood as valuable because of its phosphate content: it was "bone dust," as John Russell details (91-6), that Lawes began experimenting with on turnips in the late 1830s, and although Lawes would later replace bones with mineral phosphates in his "Super Phosphate of Lime," Liebig argued that combining this phosphatic fertilizer with sewage would make an "efficient and valuable" manure ("Utilisation" 656). Other agriculturists went further, stating that lime could be used to separate fertile sewage matter from water, as an article published by Dickens in 1858 reported:

> London drainage on each side of the Thames could then be planned . . . [with sewage] to be carried directly into great reservoirs then precipitated with lime and got rid of: partly by the flow of the clear and practically harmless liquid into the stream of the Thames, partly by distribution of the deodorised mud for agricultural use. ("Clean Rivers" 81)

Liebig was sceptical about the possibilities of precipitating sewage from water, (as was Lawes), but his 1863 paper similarly suggested that sewage might be rendered more valuable in molecular combination with lime-based fertilizer. Such chemical unions often evoked a sense of providential marriage, as in the 1858 *Punch* poem, "Mechi the Mourner." While an imagined Mechi laments "phosphates . . . going to the sea," he dreams of "Ammonia / . . . to a proper acid wed," hoping that his "fallow fields" might provide a "bridal bed" (qtd in Kingsley 136). As I now show, this discourse of chemical marriage, and the wider agricultural tensions between chemistry and thermodynamics, find expression in *Our Mutual Friend* through the "union" of Lizzie Hexam and Eugene Wrayburn (*OMF* 812).

Precipitating Eugene Wrayburn

In the thirteenth chapter of the novel, Eugene, Mortimer Lightwood and a Police Inspector embark on what is described as an "elaborate . . . lime fiction" (162). They are attempting to apprehend Gaffer Hexam at his home in Limehouse because he is believed to be guilty of John Harmon's murder. The policeman suggests Eugene and Mortimer adopt disguises as "two lime merchants" to avoid arousing suspicion (160). Their disguise is suitable because "the lime trade" fuels the Limehouse economy, with "lime barges," "lime-burners" and "shipper[s] of lime" all noted through the chapter (160-1). Though this lime draws on the imagery of disguise and illumination suggested by "lime lights" (162), there is also a rich agricultural imaginary yet to be drawn out here. Limehouse lies near Deptford, where Lawes's "Super Phosphate of Lime" was manufactured, and Dickens invokes "the principle which matrimonially unites contrasts" as Lizzie and Eugene meet "among the ooze," stimulating a courtship that develops around a chemical discourse of precipitation centring on the excremental Thames (34, 164).

Eugene has long been seen to "fade away" through the novel, to wear down, and this depletion can be thought of as a dissolution of energy entangled with the flow of river (122). This is evident as Eugene and Mortimer drink sherry in a pub on the Limehouse riverbank, a "locality" afflicted by excess sewage:

> Lightwood helped him to some more of that stuff, but it had been cooling, and didn't answer now.
>
> "Pooh," said Eugene, spitting it out among the ashes. "Tastes like the wash of the river."

> "Are you so familiar with the flavour of the wash of the river?"
> "I seem to be to-night. I feel as if I had been half-drowned and swallowing a gallon of it."
> "Influence of locality," suggested Lightwood. (164)

Energy degradation is described above in the transfer of heat from sherry to its surroundings. In Eugene's earlier "Energy" (20) passage, entropic depletion is linked to sewage via metaphor, whereas here Dickens uses the homonym "Pooh;" Eugene's involuntary disgust at the cooling drink indicates, as Mortimer's subsequent question confirms, the excremental "wash of the river." As heat is lost from the sherry, potential fertility flows in the Thames, dissipations of energy meeting in the "half-drowned" Eugene. In highlighting the thermodynamic similarities between the dissolution of Eugene's energies and the wasting of potential fertility in the river, boundaries between Thames water and human body begin to dissolve.

In contrast to Eugene, Lizzie is "firm" and "fixed" in her character (67). This "fixed" nature suggests an ability to "fix" Eugene chemically, depriving him of "volatility and fluidity" in their union as a chemical compound (*OED*, "fix" *v*. 4a). A resident of Limehouse, Lizzie "concentrate[s]" (235) Eugene's attention when they are "brought into contact" (237), chemical stimulus evident in an earlier "intensification" of his character (166). Their bodies begin to merge as Eugene notes how "that lonely girl with the dark hair runs in my head" (162); Lizzie herself senses changes in Eugene "to be inseparable from some touch of their opposites in her own breast" (236). Precipitation culminates on the riverbank where the Thames flows through Oxfordshire's "pastoral and blooming" farmland (522). Scholars have noted that the river links rural and urban in Dickens's work (Allen 114), and these "deep green fields of corn, so prospering" (689), embody agricultural productivity (in metropolitan sewage) soon to be accessed in Lizzie and Eugene's chemical union. Eugene's antagonist, Bradley Headstone, is jealous of this potential union, and his sudden attack, "mashing [Eugene's] life," seeks to dissolve distinctions between body and river completely (698). Eugene's blood forms "dark red streaks" in the water, but as bodily matter disperses in the Thames, Lizzie extracts his unconscious form from the river (700). Bodily dissolution continues in the days that follow, Eugene's brow moving "like a shape made in water" as his consciousness rises like "a drowning man, to sink again" in death (736, 740). Lizzie's rescue and continued "touch" here denote chemical contact that restores Eugene amidst this dissolution (740). As she utters the words "my dear husband" (753), a marriage "blessed" by "Providence" secures the chemical bond between precipitate and matter suspended in solution (742).

As Bradley Headstone is drawn into this courtship plot, the novel develops Goethean chemical metaphors. Goethe's *Elective Affinities* (1809) applies a discourse of chemical attraction and displacement to sexual unions (McKinnon 112-6; Thims 395-410), and a similar poetics direct the interactions of Lizzie, Eugene and Bradley. Lizzie's rejection of Bradley's marriage proposal is prefigured as she "detect[s] something that repel[s] her in [his] momentary touch" (229); while Bradley remains "under the influence of some tremendous attraction" (397), he fails to "form the connexion" with Lizzie because the chemical bond between her and Eugene is stronger (231). This is because Lizzie and Eugene, as Jenny Wren identifies, are not of the same "sort" (347). Bradley may be closer to Lizzie in social standing, but the class differential Jenny highlights provides the basis for chemical marriage. As Andrew McKinnon writes of *Elective Affinities*, "those substances that have a 'very remarkable' affinity for one another may interact not because they are the same, but despite being different"

(114). With elemental difference the basis for precipitation, Dickens's courtship plot develops the Goethean chemical tradition by bringing Eugene as dissolving matter "into contact" (237) with Lizzie as suitable precipitate.

Our Mutual Friend's flows of energy deepen this examination of nutrient circulation. Living "among the ooze" (164) in Limehouse and sustained upon the fringes of the capitalist economy, Lizzie has been seen to "evoke the spectre . . . of the prostitute" (Allen 100). Implicated within the novel's thermodynamic residuum discourse, descriptions of Lizzie as "a dark combination of traitor and pickpocket" (294), a "horrid female waterman" (816) and a form of "corruption" (339), unsettle her status as a symbol or "purity" (695). She is, in a sense, reminiscent of Lawes's manures, ranging from the "mass of corruption" to the "purest . . . salts" ("Sewage" 263), and there is a parallel between the fertility Lawes finds in the "disgusting mass" and Lizzie's release from the threat of "moral sewage." While Lizzie describes how she is unable to "make [a lady] of such materials as myself," marriage to Eugene forms a productive compound that enriches both in linked moral, financial and biological senses (348). Lizzie's "purity" is secured in marriage, akin to pure water flowing from precipitated Thames sewage. Eugene simultaneously accesses an internal "mine of purpose and energy," signalling both individual productivity and stores of potential fertility precipitated from Thames water (754).

In this merging of chemical and thermodynamic discourses, the novel echoes Liebig by invoking the local application of sewage as a means to restore degraded soils. Bradley's attack leaves Eugene "exhausted" (738), yet marriage to Lizzie restores him to "energy" (754) and new life amidst "blooming" and "prospering" farmland (522, 689). Bradley is similarly "exhausted" (639) and depleted of "resources" (395), but instead drowns with Rogue Riderhood "under the ooze and scum" of the upper Thames (802), in the midst of countryside figured as a "white and yellow desert" (801). Signalled by their death in Thames mud, Headstone and Riderhood embody an entropic rupture of nutrient circulation, whereas Lizzie and Eugene's chemical union, "blessed" by "Providence," secures a regional nutrient cycle between country and city. Yet, as Eugene lies recovering, "the river outside the windows flow[s] on to the vast ocean," suggesting the global extension of nutrient cycles (736). These are examined in *Our Mutual Friend* through the courtship of Bella Wilfer and John Harmon.

Proving Bella Wilfer

Scholars have long seen similarities between the novel's courtship plots, with both John and Eugene escaping death in the Thames and being reborn through marriage. When viewed chemically, however, John and Bella's courtship invokes a different method of "proving" (373, 379, 772). Rather than forming a marital compound via precipitation, this chemical discourse aims to analyze Bella's "quality" and "content" before marriage (*OED*, "proof" *v.* 1a). John realizes that a loveless marriage to Bella – though securing his inheritance and satisfying her "mercenary" desire to be rich (208) – would "degrade" each of them "in the other's mind" (372). When Mr Boffin learns of John's true identity as heir to the dust business, he forms a plan to expose Bella to the corrupting influences of wealth, metaphorically applying "the furnace of proof" to "prove" her innate goodness (461). Known throughout as "The Golden Dustman," Boffin's immense wealth stems from his expertise and experience in "sort[ing] a lot of dust" (577) – isolating, among other things, the agricultural fertility held in "vegetable" and "bone dust." This shift in chemistry's processes, from precipitating chemical combination to isolating elemental constitution, mirrors the ways John's and Bella's courtship focuses the novel's analysis on nutrient cycles as they extend beyond Britain.

Their marriage attempts a systemic extension of Lizzie and Eugene's precipitation, suggesting that the novel's wastes, in sewage and dust, might be harnessed in the form of agricultural fertility, imported to Britain from across the world.

Long before she marries John, Bella enjoys dinner "overlooking the river" in Greenwich (318). Understood by scholars as reflecting "the naval and mercantile pre-eminence of the British nation" (Allen 89) and "a place of benevolence and connection between strangers" (Shannon 110), Greenwich here offers an analysis of global nutrient circulation. While Bella eats and drinks "wine," she watches the "ships and steamboats" that will extract this produce from other continents sail past her window. As these vessels make "their way to the sea with the tide," she dreams of journeying with John "to look after their vines" in South Africa, of marrying "a merchant . . . so enormously rich that everything . . . upon the river . . . belonged to him," and of voyaging "to fetch a cargo of sweet-smelling woods" from "among the coral reefs and cocoa-nuts" (318-9). Paul Young argues that Dickens's fiction describes modern capitalism's "chaotic, uneven, yet powerful imbrication of the local and the global" (713), and Bella's reverie here blurs topographic and temporal scales as it entangles global natures, capitalist agricultures, and a London dinner. This imbrication extends to "the beggar-boys below the window," who "put their heads in the mud" in a futile search for sustenance (319). Immersing themselves in Thames sewage, these children come into contact with nutrients imported to Britain but made inaccessible in nutrient cycles enmeshed with capitalist economics. The lower-Thames thus offers an image of the world's soil fertility channelled through London by a British capitalism extracting, and wasting, nutrients from across the empire and beyond.

As a former colonial farmer, John's associations with the river offer another perspective on this nutrient economy. When he is immersed in the lower Thames, John is "driv[en] fast with the tide" amidst the global fertility that the river's "tidal mud" contains (369-70). This image is prefigured early in the novel, as news of his apparent murder spreads:

> Thus, like the tides on which it had been borne to the knowledge of men, the Harmon murder . . . went up and down, and ebbed and flowed, now in the town, now in the country, now among palaces, now among hovels, now among lords and ladies and gentlefolks, now among labourers and hammerers and ballast-heavers, until at last . . . it got out to sea and drifted away. (31)

Appearing in the same chapter as the novel's description of "moral sewage," this passage functions by tracing sewage's dispersal once "sunk . . . in the river" (21). Lizzie and Eugene's marriage may evoke sewage harnessed as manure, but here it flows in "town" and "country" to no productive effect before dispersing "out to sea." As each independent clause suggests, while sewage may be the accumulated produce of all, its waste disproportionately affects certain populations. Shannon is right to note that Dickens's tidal river complicates links between rural and urban (114), but here it also disturbs distinctions between global and regional nutrient circulation. Describing the local impact of global forces, these tides tie both Harmon and sewage to geographies beyond London. Local flows of nutrients, and their effects on local populations, are entangled with agricultures far beyond British shores.

Bella and John's marriage suggests a systemic harnessing of this nutrient fertility for agriculture. This is embodied in the birth of their "inexhaustible baby" (755, 756, 766, 774), conceived as Bella's "proving" nears completion. John tests for his

wife's former mercenary characteristics once more, offering her a carriage so as not "to soil" her shoes, but Bella refuses, preferring contact with soils – as her "weeding and trowelling and other small gardening" indicates (681-2). These small-scale associations with soils extend globally as Bella conveys news of her pregnancy to John via a description of an approaching child, born "by a ship upon the ocean" (688, 755). Maintaining imagery introduced during the global Greenwich dinner, reproductive fertility here simultaneously signals agricultural fertility. Bella's proving mirrors the sifting of "vegetable" and "bone dust" for use as manure; together with John's immersion in global sewage, they unite the novel's agricultural wastes in a fertile marriage. In averting the "degrading" union John earlier fears, this is in effect a "scaling up" (Tsing 38) of Eugene and Lizzie's solution to agricultural productivity, where chemical combination averts entropic soil degradation. The novel's dust and sewage thus meet in Bella and John's marriage, suggesting fertility that merges Liebig's hopes for sewage manure – enhanced with "Super Phosphate of Lime" and offering "perpetual fertility" – with the globalizing forces of capitalist agricultural chemistry ("Liebig"). In an extension of "the Analytical" focus supplied by the Veneering butler, the shortening and capitalisation of the baby's name to "The Inexhaustible" emphasizes this in a formulation underlining the systemic harnessing of the world's so-called inexhaustible nutrients to sustain British agricultural production (774, 777, 807-8).

World-ecology in "The World's Metropolis"

While suggesting inexhaustible fertility harnessed in John and Bella's union, "the inexhaustible baby" is of course more accurately "Inexhaustible" in her consumption and production. She produces an awful lot of noise and, presumably, excrement. Baby Johnny – the other child to whom Mr and Mrs Boffin are devoted – offers the novel's counterpoint to the "inexhaustible" capitalist logic of globalized agriculture. Bella journeys from her Greenwich dinner to Johnny's bedside, where he dies as "all the rest of his family" have done before (198). The poor become the victims of economics that channel nutrient fertility from across the world only to distribute it unevenly, inequality emphasized by the fate of Johnny's grandmother, Betty. She looks to escape London to find work in a "market-" or "hop-garden" (384), but these "market-gardens . . . will soon die under [the railways]" (218), and her death in Lizzie's arms makes it clear that small-scale agricultures will not survive for long alongside their intensive capitalist counterparts.

Mr Podsnap, whose fortune is in "Marine Insurance," looks to "Providence" to explain such "people . . . lately died in the streets of starvation" (128, 140). While he is "sustained upon commerce with other countries" (128), the poor live off "fragments of orange-chests and mouldy litter," the waste inherent to the global capitalist agricultures he facilitates (730). Dickens's metaphor of degraded human life as "rejected cabbage-leaf . . . and damaged orange countenance" draws further links between capitalism's wasteful channelling of soil fertility and the poverty that afflicts certain populations in London (729). Yet the novel, in its presentation of a systemic solution to this poverty, perpetuates inequalities inherent to extractive agricultures. Anna Tsing's work is pertinent here, identifying how "seemingly scalable" capitalist modes of agriculture reshape ecologies (37-43). In scaling from regional precipitation to the systemic harnessing of nutrients from across the globe, *Our Mutual Friend* does not eliminate inequalities and unsustainable extractions but exports them elsewhere; Thames sewage, although harnessed as manure, remains the digested "fruits of the earth" (*OMF* 411; "Restoration" 318). Just as Podsnap's unerring capitalisation of London as "The World's Metropolis" seeks to collapse global and regional into a single formulation,

the nutrient cycle the novel instantiates is tied to, and indeed predicated upon, the existing capitalist world-ecology for its productivity (132).

The entrenchment of this world-ecology is evident as John and Bella inherit the dust business at the end of the novel. They spend their newfound fortune on, among other things, "tropical birds and beautiful flowers" (767); wealth here circulates globally, glinting in "sunlight" after "a long, long rust in the dark" (778). This financial circulation corresponds exactly with the instantiation of the nutrient cycle. John and Bella take possession of their fortune "on the very day when the last waggon-load of the last Mound was driven out at the gates of Boffin's bower" (779). Capitalist logic once more penetrates to the molecular as it organizes nature, nutrient and financial wealth brought into the "sunlight" as crops and capital growing together. Capitalism and nature are thus "dialectically joined" (Moore 8), embodied in Bella and John's return to Greenwich on their wedding day to eat "whitebait" described as "specimens of all the fishes that swim in the sea" (668). Their marriage – or rather the systemic harnessing of nutrient fertility it evokes – enmeshes soils, plants and animals "into a web of life whose connections are much denser, more geographically expansive, and more intimate than ever before" (Moore 12). The novel, detailing what might first seem to be an urban population isolated from agricultural production, presents instead a world-ecology where modern capitalism associates lives across the world in and around soils and their exploitation.

Like their non-human counterparts, human lives are of course entangled in this capitalist web of agricultural production as well. As John and Bella enjoy their wedding dinner, "the boys down below" continue "put[ting] their heads in the mud" in search of sustenance (670). No less pervasive within the narrative is the unquestioned burden placed on women to restore, renew and reproduce life through marriage. Silvia Federici's analysis of capitalism's "primitive accumulation" uncovers how the "sexual division of labour subjugat[es] . . . women's reproductive function to the reproduction of the work-force" (12); *Our Mutual Friend* here reinforces dominant conceptions of male-female relations, with heteronormative marriage and male economic employment as moral restoration within capitalist economics. The twin threats of Lizzie's potential "corruption" and Bella's "mercenary" character are isolated and removed by a masculinist discourse of chemical science. Chemistry's implicit subjugation of these women, and their transgressive qualities, is closely related to the subjugation of fertile natures for agriculture. It would take a further article to fully disentangle these relations in *Our Mutual Friend*, but it bears commenting that the novel's chemical courtship plots evoke conceptions of "nature" and of "wife" that, to borrow Val Plumwood's words, create a "subordinate other encompassing and representing the sphere of materiality, subsistence and the feminine" (3). Where Plumwood's work links the domination of women and nature, it highlights too how "the labour of colonised non-western, non-white people" also "gets subsumed . . . into nature" (4). *Our Mutual Friend* is notable for the absence of these people, silenced in a world-ecology that exploits natures, and the lives playing out within them, for agricultural production.

In line with recent scholarship, this can be viewed as Dickens upholding "forms of primitive accumulation, exploitation, and violence . . . central to the way the Victorians penetrated and networked the world" (Young 705). At the same time, might the analogy the novel draws between female reproduction and soil fertility suggest limits to this world-ecology? While capitalism reshapes natures, Anna Tsing argues, certain biological processes remain beyond its control. Although humans are enmeshed within the novel's capitalist world-ecology, Tsing's work emphasizes that "capitalists cannot produce human life, the prerequisite of labour;" even capitalist agricultures, she

suggests, "depend on life processes outside of their control, such as photosynthesis and animal digestion" (63). Tracing *Our Mutual Friend*'s productionist analogy from the human body to soils suggests similarly emergent processes directing interactions integral to farming. While "The Golden Dustman" offers another formulation to collapse capitalism and nature by merging financial and nutrient wealth, Mr Boffin is also described as "one broad piece of sunshine" (775) and "the worm of the hour" (306, 476, 497, 582). The agricultural resonances of these metaphors, suggesting biological processes releasing energies and nutrients necessary for plants to grow, introduce interactions to the novel's web of life that capitalism may only take advantage of, rather than direct. Money and fertile elements circulate together in *Our Mutual Friend*, but they do so in "sunlight" (778), opening a possible tension between how capitalism makes humans, soils, plants and animals productive as appropriated fertility, while emergent forms of biological growth and (re)production resist capitalist logic by refusing straightforward reductions of value and use.

Conclusion

Providential and ecological understandings of soils are clearly at odds in *Our Mutual Friend.* The novel exposes how chemical agricultures and capitalist trade together make nutrients accessible to some as fine food but inaccessible to others as putrefying mud. At the same time, with narrative structure and content both dependent to varying degrees upon globalized agriculture, the novel elides much of the violence and exploitation implicit within this global system of food production. Dickens's chemical poetics are here clearly shaped by Liebig, who was both feted and ridiculed in the British press, and in Dickens's own publications, for his repeated warnings over soil exhaustion. An 1865 article in *All The Year Round* termed him "the angry foreign chemist," and there is perhaps a suggestion of Liebig in the Veneering butler, the novel's "gloomy analytical chemist" ("Artificial Fertility" 157). *Our Mutual Friend*'s marriage plots grapple with the same uneasy knowledge of degrading soils, applying the novel's "Analytical" focus at those intersections of chemistry and thermodynamics that Liebig's work seems to suggest. Dickens here provides a space in which soil tempos are imbricated, where the temporalities of soil change inherent to matter and energy, but also to market gardens, Oxfordshire farms and African plantations, are placed in dialogue. The novel thus entangles humans, animals, plants and soils across geographic and temporal scales, suggesting ecological complexity even as the narrative operates alongside the techno-scientific drive to reduce natures to a providential and resource-driven economics.

Liebig's science embodies similar tensions. His undoubted commitment to "the concept of recycling" and suggestion that Britain could produce all the food it required by using sewage as manure occlude the details of a similar argument he presented in *The Times* (Brock 272; "Utilisation" 657). He wrote that previous experience ought to have taught the farmer:

> in what a condition of perpetual fertility he might have preserved his fields if the elements of the guano which he has transported in the shape of meat and products of his fields into cities were recovered and brought in a form which would admit of their being restored to his fields every year. ("Liebig")

Liebig's "perpetual fertility," another so-called inexhaustible nutrient cycle, becomes founded once more upon global nutrient extraction. Lesley Kingsley's work on the nineteenth-century guano trade demonstrates how the extraction and exhaustion of bird

dung from Peruvian islands partly stimulated interest in sewage as manure (Kingsley 126, 138). In my article's epigraph, and in Liebig's writing above, "guano" shifts from referring to a resource imported from abroad to "home-made sewage" ("Restoration" 318). As the signifier "guano" shifts referents, the co-development of chemical science and capitalist economics, shaping and being shaped by nutrient circulation, occludes unsuitable nutrient extraction across the globe. Where chemistry isolates soil fertility for capitalist production, the circulatory logic of nineteenth-century chemical economics finds its thermodynamic corollary in the exhausted and degraded soils of twentieth- and twenty-first-century agricultures. With Maria Puig de la Bellacasa's work showing how "the tension between production and sustainability at the heart of soil science involves a clash of temporalities" (699), Liebig's uneasy attempts to reconcile conflicting soil tempos offers a pertinent example of how certain responses, formulated from within the sciences alone, may not be appropriate to crises that are social, environmental and historical in their formation and bearing.

Considered together, then, Dickens and Liebig betray a crisis that is "attritional," "gradual" and "out of sight" (Nixon 2). These terms, used by Rob Nixon to describe "slow violence," are pertinent here, for they encapsulate not only the crises and effects of soil exhaustion, but also how the resolutions Liebig's chemistry and Dickens's novel supply to agricultural production elide the continuing exploitation of peoples, animals, plants and soils in disparate locations across the globe. The violent, uneven and extractive economics of globalized agriculture conceptualize diverse soils and ecologies in terms of fertility, isolating while homogenizing disparate local sites as potential production. Globalized agriculture thus presents a chemical model for food production, developed in certain laboratories and fields in Western Europe in the mid-nineteenth century, and translated to various soils across the world through the twin forces of colonialism and capitalism. Conflating the closed systems of chemistry and the open systems of thermodynamics, this productivist logic exists at the point where providential and ecological understandings of matter and energy become confused. The question remains, does capitalism inhabit every corner of the web of life, as Moore's world-ecology argues, or may emergent natural process resist the ceaseless logic of capital, as Tsing would have it. Where both these scholars find the entangled roots of capital and nature in sixteenth-century agricultures, the nineteenth-century intersections of fiction and science also warrant consideration if we are to disentangle the productivist logic continuing to structure Western culture's treatment of soils.

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