Science in Context (2021), **34**, 297–311
doi:10.1017/S0269889722000163

CAMBRIDGE UNIVERSITY PRESS

RESEARCH ARTICLE

Dyeing off: On the deaths of dyestuffs as scientific objects

Mat Paskins

Independent Scholar
Email: M.Paskins@lse.ac.uk

Abstract

Between the 1870s and the 1920s, the dye industry was at the center of claims about the productivity of organic chemistry. Dyestuffs were widely represented as the most complex molecules to find commercial application, and positioned at the center of nationalist projects to establish chemical industry, especially in Britain and the United States. By the later twentieth century, the complex of scientific hopes which surrounded dyestuffs had largely disappeared. In Hans-Jörg Rheinberger's terms, they had changed from "epistemic things" to, at best, "technical objects," and lost their future-bearing status as the lynchpin of organic chemistry. Although developments in dyeing continue, dyestuffs have vacated the scientifically and culturally dynamic position that they once occupied; any restoration of this status would require a radical change in economic and material conditions. This paper considers the senses in which this change of status should be considered as the death of dyestuffs as a scientific object.

Keywords: Dyestuffs; technical objects; chemical industry; William Perkins; IG Farben

Introduction

For the eighty-five years or so between 1860 and 1945, synthetic dyestuffs were objects of strategic significance and scientific promise, playing an important role in the development of national chemical industries in Europe and the United Sates, and providing an institutional and conceptual foundation for other fields of chemical and pharmaceutical research (Steen 2014; Travis 1993). After World War Two, significant innovation in dyestuff production continued with the development of synthetic fabrics and the synthetic dyes necessary to color them, but synthetic dyestuffs were no longer positioned as lynchpins of other sorts of chemical activities, never mind as key to national defense (Morris and Travis 1992). By the turn of the millennium, in his best-selling book *Mauve,* the popular historian Simon Garfield was presenting the fate of research into novel dyestuffs in explicitly elegiac terms. Garfield wrote:

> If you discover a new chemical that solves a basic health problem, then the pharmaceutical industry will cover all its costs and potentially make a huge profit. That used to be the case in the dyes business—the invention of a new dye would command a premium that would reward the cost of invention and bringing it to market. Sadly, that's no longer the case. (Garfield 2000, 193)

The change in the status of synthetic dyestuffs which Garfield describes is a shift from being an object worth investing in as a potential new pharmaceutical, to being something in which funders and corporations do not consider such investment worthwhile. This change has been accompanied by a more general loss of status for synthetic dyestuffs, as well as a shift in the locations where they are produced, away from Europe and the United States to South and East Asia (Galambos,

Hikino, Zamagni 2007). Synthetic dyestuffs are still produced and consumed in vast quantities, but they no longer enjoy a privileged position within chemical science and industry. The first question addressed by this paper is therefore what became of the constellation of promises and possibilities associated with synthetic dyestuffs after their heyday during the late nineteenth and early twentieth centuries.

The second question this paper explores pertains to how the shift in the status of synthetic dyestuffs compares with the "deaths" or endings of other scientific activities, objects, and institutions—as historians have understood them. It may seem odd to speak of the "death" of synthetic dyestuffs: they are, after all, still produced and consumed in vast quantities every year, and no one claims that synthetic dyestuffs are gone. At first glance, synthetic dyestuffs' quotidian ubiquity makes them unlike other scientific objects whose deaths historians have studied, such as the philosopher's stone, the ether, phlogiston, or the Mendelian gene (Navarro 2018; Chang 2009, 2010; Rampling 2018; Radick 2018). All of these objects were once understood as legitimate objects of scientific enquiry, and all have been relinquished by present-day practitioners who claim to descend from the research communities that used to study them. However much the hopes associated with synthetic dyestuffs have waned, no one claims that they have ceased to exist, let alone that they never existed at all.

From another angle, however, the disappearance of promises made on behalf of synthetic dyestuffs does recall the deaths of those other objects. Studies of the demise of scientific objects are also explorations of unfinished business, of enduring legacies, and of their afterlives. In this spirit, Jaume Navarro and Massimiliano Badino introduce the collection *Ether and Modernity* with a number of teasing questions: "When did the ether disappear? Did it actually ever exist? Is it not back among some contemporary physicists? Are you trying to chase a ghost or resuscitate a zombie?" (Badino and Navarro 2018, 1). Synthetic dyestuffs have never been treated as if they were non-existent, but I will argue here that they share with other dead scientific objects a sense of possibility which has waned, and that the sense that they are now defunct as promising objects helps to shape accounts of the periodization of innovation.

If synthetic dyestuffs can be considered in some way to be dead, what is their mode of death? In the introduction to her edited collection on biographies of scientific objects, Lorraine Daston describes the process by which such objects come into being. Drawing on Hans-Jörg Rheinberger's distinction between scientific and quotidian objects, Daston writes that "in contrast to quotidian objects, scientific objects broaden and deepen: they become ever more widely connected to other phenomena, and at the same time yield ever more layers of hidden structure" (Daston 2000, 13). Such objects can be "banished totally from the realm of the real, as in the case of unicorns, phlogiston, and the ether," but "more often, they slip back into the wan reality of quotidian objects, which exist but do not thicken and quicken with inquiry" (ibid.). In this paper I want to argue that the trajectory from scientific object to quotidian thing maps onto the change of status undergone by synthetic dyestuffs since the mid-twentieth century. But in the case of synthetic dyestuffs, it is a mistake to equate quotidian reality with "wan reality": in becoming more routinized, and less of a focus of novel research activity, synthetic dyestuffs have experienced ambivalent afterlives comparable to those of other dead scientific objects.

Thinking about the history of synthetic dyestuffs after the period that marked their heyday recalls, in some respects, the distinction which David Edgerton draws between histories of innovation and histories of use in his book *The Shock of the Old* (Edgerton 2006). Edgerton has sometimes been interpreted as calling for attention to older technologies, shifting historians' priorities away from a focus on novelties and innovation (Werrett 2019, 3). In Edgerton's terms, however, this paper is still a history of innovation rather than of use. What I am arguing is that the late moment of synthetic dyestuffs' innovation, where future paths are not obvious and where their legacies are actively curated and contested, casts light on the significant roles which scientific objects can continue to play after an initial period of attention and transformative possibility.

There was no single moment when dyestuffs ceased to function as objects of epistemic and connective potentiality. Rather, this process has been drawn out, occurring in different ways across the array of dyestuffs' various uses. For some purposes, dyestuffs have continued to play an important and largely unchanged role, for example in laboratory staining or the routine production of colorants for the textile industries. What has been stripped away is the patina of possibility which they once possessed, the sense that they functioned as lynchpins connecting research and production in organic chemistry and other scientific practices during the second half of the nineteenth century and for much of the twentieth. The following sections consider four "deaths" which dyestuffs have suffered: (1) no longer acting as objects of innovation; (2) no longer providing models and materials for other scientific fields; (3) ceasing to serve as strategic objects of national policy; and (4) their reconstruction as objects of heritage and without a meaningful future in their own right. Throughout the paper, I draw comparisons between synthetic dyestuffs and other dead scientific objects, and in the concluding remarks, I discuss the four deaths of synthetic dyestuffs to draw out some more general lessons about the death of scientific objects.

The first death: Synthetic dyestuffs as innovative objects

According to a well-established standard historical narrative, the first versions of which were significantly shaped by dyestuff chemists and industrialists themselves, William H. Perkins' discovery and commercialization of mauve was followed rapidly by a host of other synthetic dyestuffs, commencing with the development of Fuchsine, and continuing into the direct cotton dyestuffs, the sulfur dyestuffs. Industrial leadership passed during the 1860s from Britain and France to Germany (Fox 1987; Travis 1993; Murmann 2003). Contributions from chemical theory, especially August Kekulé's hypothesis about the structure of benzene, and Peter Griess' discovery of the diazo reaction, contributed to a further flurry of research activity and the development of novel categories of dyestuff, notably the azo dyes. Amidst a host of innovations resulting from the struggle for survival of German companies came the emergence of the industrial research laboratory and the systematic search for further dyestuff molecules, attempts to integrate the production of raw materials such as sulfuric acid, and ventures into diversification into fields such as pharmaceuticals and photochemistry (Murmann 2003, 90).

So intensive were the activities of German companies that in 1908 the industrialist Carl Duisberg, who had been director of research at Bayer, predicted that all possible dyestuffs had already been discovered as a result of the activities of German industry (Murmann 2003, 257). Duisberg was wrong, and a small number of significant dyes were developed in tandem with innovations in textiles during the twentieth century. Realizing their dependence on German industry during World War One, the British and Americans established national dyestuffs industries, which provided the first step towards a more general organic chemical industry in both countries and laid the ground for some significant dyestuff developments during the twentieth century.

In this view of the history of dyestuffs, a central part of their status during this period is the connections they generated between activities and materials that had formerly been distinct. Thus, for example, the sociologist Andrew Pickering argues that with Perkin's commercialization of mauve "a new kind of entity appeared on the social landscape, a site of synthetic dye production, connected not to traditional producers of animal and vegetable raw materials, but to tar distillers. The social world was thus changed and rearranged in Perkin's industrialization of his achievement" (Pickering 2005, 366). According to Pickering, this rearrangement also encompassed research laboratories, factories, and legal regimes of intellectual property. Pickering focuses on the sites of dyestuff production, rather than on dyestuffs as objects. Nevertheless, his view makes it clear that the introduction of synthetics led to dyestuffs, joining together previously unconnected activities. I will consider some of these connections in more detail in the following sections of this paper, after reviewing some of the objections to this view.

https://doi.org/10.1017/S0269889722000163 Published online by Cambridge University Press

During the second half of the twentieth century, significant dyestuff innovations continued with the development of synthetic fabrics and the need to produce dyes which could color these synthetics effectively (Baptista 2012). These new dyes, while very significant, were generally not associated with larger claims about the potential applications of dyestuff chemistry or with large scale industrial transformation. The coda to this narrative, which has sometimes been framed explicitly in terms of a rise and fall, is that—starting in the 1970s—amidst significant overcapacity, tightening environmental regulation, and economic recession, American and (from the 2000s) European industry increasingly divested from dyestuffs, moving their production first to Eurasia and subsequently to China and India (Morris and Travis 1992; Baptista 2012). The four biggest US dye makers left the industry between 1977 and 1982. The British company ICI spun off its dyes division in 1994; the major Swiss firms Ciba-Geigy and Novartis merged in 1996 and stopped producing dyes, focusing instead on pharmaceuticals. Instead of playing a transformative and connective role, since the turn of the millennium dyestuffs have been considered chiefly as "commodity chemicals," their production largely routinized and deprived of the open-ended sense of possibility that had characterized their heyday. Almost all the dyestuffs that remain in use were invented during the nineteenth century, and since the 1990s even the expectation of chemically novel dyestuffs has dried up. In the words of one recent manual for practitioners, "R&D focuses on product formulation and application. The development of new molecular entities has practically come to a halt" (Pollak 2010, 115).

In their former centers of production, dyestuffs are considered in terms of the ways in which they have shaped priorities and cultures of industrial research, rather than as active objects of inquiry. The chemical engineer and economist Fred Aftalion, for instance, detects major national differences between Germany and Switzerland, which had a longstanding prestigious tradition of dyestuff chemistry, and the United States, which did not. According to Aftalion, these national differences were significant in the shift towards the production of fine chemicals: American industry had been accustomed to aiming for size, but fine chemical production, by contrast, involved "production programs that were likely to undergo rapid changes to fit client requirements. In this type of industry, complete product ranges must be available in small volumes, and final development often required much patience. The Swiss, as well as the Germans, perfectly understood these constraints because of a long tradition" of small-scale and rapid change (Aftalion 2001, 265). Dyestuffs are, thus, to be valued mainly in terms of the legacy which they have left behind.

The recent historiography of dyestuffs has done a good deal to qualify, if not to overthrow, this narrative, as it pertains to the early history of synthetic dyestuffs. Historians have shown that the introduction of synthetics was not a single world-changing event, but rather that natural dyestuffs already represented a significant network of experimental practice and material exchange: synthetics were able to flourish primarily because of this pre-existing infrastructure (Nieto-Galan 2001). As Ernst Homburg observes, the effect of relying on a historical narrative constructed by historical actors has been to "underestimate the role of chemistry in industry before about 1870 and to overestimate its role after that date" (Homburg 2018, 568). Often as part of an attempt to claim national priority for their own achievements, dyestuffs promoters constructed a "linear model," according to which chemical theory played the most central role in the successes of German industry. Ursula Klein argues that the connection between industry and academic science associated with the era of synthetic dyestuffs was not a complete novelty, with academic chemists having been involved in industry since the eighteenth century. What changed, in her view, was that the new industries after the 1850s demonstrated much greater "material productivity and technicality" and were characterized by "implementation of quantitative chemical theory and chemical formulae into chemical practice" (Klein 2005, 228).

This work has three effects on the consideration of dyestuffs as generative scientific objects. The first is to expand the temporal scope within which dyestuffs (artificial and natural) need to be understood as objects of inquiry, and to emphasize continuities between the two types of material. The second is to see the connections between industrial and academic sites that were enabled

through dyestuffs as somewhat more fragile and provisional, operating with reciprocal involvement from academic and industrial research. Finally, the third effect is to emphasize that historical understandings have played an active role in shaping accounts of dyestuffs' potentialities in other domains.

There is no reason to assume, a priori, that dyestuff chemistry now based primarily in South and East Asia should not be as generative and connective as were its European and American predecessors. Quite a number of proposals for novel methods for dyestuff application have been mooted in recent years, many emanating from European and American companies. They include the use of natural dyes, synthetics produced by more efficient systems, the use of engineered microbes, and digital textile printing (Bomgardner 2018). These potential innovations have received renewed attention whenever there is a significant disruption to dyestuff supply chains, such as occurred during the summer of 2018, when the Chinese government abruptly shut down most of the country's producers of intermediates used in dye production, especially in Jiangsu province, following what one trade publication termed "a series of environmental transgressions and serious industrial accidents" (Mowbray 2018).

The fact that these novelties have not managed to take hold is attributed by industry observers chiefly to the extremely competitive character of the contemporary textiles industry. As a report in *the Chemical and Engineering News* put it, "The industry's sheer scale makes it hard to have an impact: Textiles are a $3 trillion-per-year business that employs nearly 60 million workers worldwide. . . . Price competition is fierce, and profits are shrinking thanks to volatile raw materials costs and rising wages" (Bomgardner 2018). The result is that the same promises have reverberated for many years, bubbling up whenever it looks like conditions might change only to be submerged again. Long Lin, a color chemist at the University of Leeds, remarks of the development of a "waterless" dyeing process that it is "actually a new application of a technology that has been around for over 20 years, and it has still not been accepted by the textile industry" (Heida 2014). Given the fact that many of the dyes still in use are nineteenth century technologies, twenty years does not seem a very long time to wait for the introduction of these new techniques. Lin's point is rather that they have repeatedly been touted as the "next big thing," without acknowledgment of previous claims to the same effect. Even these speculative novelties, moreover, do not take the form of novel dyestuff molecules, much less the resumption of close connection between dyestuffs and other fields of scientific research and chemical production.

This section has described the rise and fall of synthetic dyestuffs as innovative objects, worthy of significant investment and driving institutional change. The death that has been described here is the sense that new colorant molecules, and novel dyeing processes, are no longer being produced or applied in significant quantities or at a significant scale. If the synthetic dye industries have a future that differs from their present, this future is frozen, involving repeated claims about techniques or processes that are not currently economically viable. The account which I have given of this death does not say very much about synthetic dyestuffs as scientific objects, but the period of time between the mid-nineteenth and mid-twentieth centuries, during which synthetic dyestuff research and production flourished, was also the time when dyestuffs were widely considered as scientific objects of considerable strategic significance. The following two sections of this paper will discuss two aspects of synthetic dyestuffs' status as scientific objects: how they came to be presented as strategically significant, and how they were seen as a lynchpin for other fields of scientific enquiry.

The second death: Strategic dyestuffs

In Britain and the US during the 1910s and 20s, dyestuffs became positioned as strategic objects, associated with security and the establishment of national chemical industries. Promoters of dyestuffs presented their flexible material and epistemic properties, as well as the commercial possibilities which they represented, as offering significant opportunities. Dyestuffs were perceived as

https://doi.org/10.1017/S0269889722000163 Published online by Cambridge University Press

strategic objects for two reasons: first because those nations' chemical industries were almost completely dependent on imports from Germany, and second because of the potential they appeared to present for innovation in the chemical industries, since the intermediate chemicals used for dye productions could also be used for the production of pharmaceuticals and explosives.

These arguments recall Christine Macleod and Greg Radick's discussion of "productivity claims"—the appeal to the "body of theoretical principles" guiding certain "useful techniques and technologies" put forward by scientists in order to legitimize their work in domains formerly dominated by "practical" workers (Macleod and Radick 2013). The claims made on behalf of dyestuffs played this role in seeking to validate chemical research, but went even further by positioning these chemical substances as boundary objects between civil and military domains. Precisely because of their strength, these arguments were contingent and provisional. By the mid-1920s dyestuffs had started to lose the very special status that had been accorded to them. I will give some examples from Britain and the United States about how productivity claims made on behalf of synthetic dyestuffs were used to position these chemicals in the dual economic and scientific strategic role that they enjoyed during this period, and then talk about what became of these claims after their initial establishment.

Arguments about the weakness of the British chemical industry in comparison with Germany had been aired during the celebration of the half centenary of mauve in 1906 (Travis and Baeck 2007). Before the war, observes William Reader, the official historian of ICI, British dyestuff makers were overshadowed by the textile industries, whose representatives "wanted their dyestuffs as cheaply as they could get them, which under conditions of free trade meant that they would usually buy German, not British, and there would be no hope of tariff protection for British dyes as long as the textile industry was held paramount" (Reader 1970, 260). This subservient position also led to a predominantly narrow view of the chemical industry in Britain, with little support for the research expenditures and diversification from dyestuffs into other areas of chemical production that had been so successful in Germany.

Historians have offered a number of different explanations for the reason that the war galvanized the government to action, ranging from an opportunistic desire to capture new industries, to response to a self-evident national crisis, to an attempt to gain greater control over the production of intermediate products crucial for manufacturing explosives (Morris and Perkin 1992; Fox 1989; Reader 1970). The most remarkable aspect of these arguments was the strong connections drawn between dyestuffs manufacture, national security, and the prospect of establishing a national organic chemical industry. The minutes of the Committee of Chemical Supply convened by the Board of Trade at the beginning of the war indicate the ways in which academic chemists used what they claimed were the special properties of dyestuffs, as objects of inquiry as well as of commerce, to advance their productivity claims. As William Henry Perkin Jr, son of the discoverer of mauve and a professor of chemistry at Oxford University, told the committee in August 1914:

> There is an enormous difference between the inorganic industry ... and the organic industry. In the organic industry there is an enormous mass of detail, and the research work in the organic industry is practically academic work: it has very little to do with research work in the Works themselves. Therefore, the class of man who has to go into the dyeing industry and do research work in the dye works is merely an academical chemist, and that sort of man is a man whom it is very difficult to find, even from the Universities. (Board of Trade 1914, 23)

For Perkin, the detailed and comparatively small scale at which dyestuffs could be researched differentiated them as objects of inquiry from other fields of chemistry. He argued that their special status would directly enable the cultivation of a "higher class" of research worker, as well as maintaining the production of complex chemical substances during peacetime.

The impact of these and related arguments was that, after an initial improvisatory and apparently successful response to the loss of German imports by British dyestuff makers, the

https://doi.org/10.1017/S0269889722000163 Published online by Cambridge University Press

government took over one of the main dyestuffs producers, Read Holliday, focusing on the production of explosives. Holliday's rival, Levinstein's, almost doubled in size during the war by refusing to move out of dyestuffs—but Herbert Levinstein, the company's canny and autocratic owner, was aware that it would not be able to continue at the same size in peacetime conditions. With the conclusion of the war, the government took over Levinstein's as well, with its largest direct stake in a private company to date. The new company was called the British Dyestuffs Corporation (BDC) and it launched with ambitious claims about the research that would be conducted under its auspices, as well as boasting about the hiring of a number of chemists who had previously worked in academia. Legislation was passed in order to protect this infant company, which was another novelty. These moves were resisted by dyestuff users, but Levinstein, who had remained at BDC as one of its directors, remarked that "few people question the necessity of maintaining the Dyestuffs Industry. The country in general holds the objects desired as essential to security" (Levinstein 1924, 253).

From its inception, BDC was troubled, with fractious relationships between its board and its technical staff. One commentator remarked that, for the dyestuffs industry, "the position could not have been worse, had there been no Government subsidy," as there had been no recognition of the need for technically qualified management "able to sympathise with and so hold intelligent communication with its staff" (Armstrong 1923, 928). In 1925, the company's replacement chief executive, Albert Stanley, the first Baron Ashfield, remarked that "the first and most considerable writing off is from the valuation on the Corporation's works, which were erected six years ago on far too large a scale and at far too great a cost" (Stanley 1925, 14). The error of overextension had not, Ashfield thought, been confined to BDC; instead, "throughout the world, dyemaking works, partly no doubt because their plant and machinery have been found useful for war purposes, exist on a scale greatly in excess of requirements" (Stanley 1925, 14). With the conglomeration of German dyestuff companies into IG Farben in 1925, and the evident need to diversify beyond dyestuffs, BDC merged with the Nobel Corporation and a number of other British chemical companies to form Imperial Chemical Industries in 1926. Dyestuffs formed one division within ICI, and by the outbreak of World War Two in 1939 was presented as a thriving and mature chemical industry.

Let us now turn to discuss aspects of the situation in the US. I will focus on the experiences of the DuPont corporation. Though these do not give the whole picture of the establishment of the US synthetic organic chemical industry, they do clearly exemplify the role of productivity claims about dyestuffs in building up chemical industry during the second and third decades of the twentieth century (for a more general account, see Steen 2014). At DuPont, the decision to move into dyestuffs was considered politically necessary because of US dependence on imports from Germany of diphenylamine and toluene, which were used as a stabilizer for smokeless powder and for manufacturing TNT, respectively. The corporation tried to reproduce the successes and range of products which were available from German industry. As in Britain, these efforts were fraught with difficulty, and resulted in tensions between company executives and technical researchers. As the authors of a study of DuPont's corporate research strategy remark, "Research played a critical role in this venture, and in many respects Du Pont's research program 'grew up' with the dyestuffs business" (Hounshell and Smith 1988, 77).

But dyestuffs presented tremendous and unanticipated problems for the company. Relying on "incorrect and imprecise data," DuPont spent $3 million on building and then rebuilding a dye plant, and "chemists complained that plants often went up before the laboratory work was completed" (Ndiaye 2007, 28). DuPont chemists struggled to identify competitors' dyes, and struggled to standardize the dyes they produced, with the result that their products were regarded as inferior. The venture continued to struggle despite attempts to broker an agreement with the British firm Levinstein's and, later, to hire German dyestuff chemists. But despite the recession in the early 1920s, DuPont had money to spare, and the dyestuffs venture was later understood as its first successful move into the production of organic chemicals. In both countries, then,

https://doi.org/10.1017/S0269889722000163 Published online by Cambridge University Press

dyestuffs enjoyed a fairly brief flurry of highly specific attention, followed by subsumption into broader projects of organic chemical production. In the process, their pursuit became less speculative, less invested with very high hopes, and more routine.

After World War Two, the strategic significance ascribed to dyestuffs in both Britain and the US receded, but it did so fairly gradually, and through a process of unpicking of the strands of the arguments, legal measures, and institutions that had elevated dyestuffs to the status of strategic objects. In 1946, the Association of British Chemical Manufacturers and the Colour Users Association responded to a report in *The Times* newspaper that IG Farben, whose fate was being debated by the victorious allies, would be allowed to produce dyestuffs sufficient for the domestic German market. The Association warned that "the strength and military potential of the powerful German chemical industry without which she would not have been able to wage the last two wars effectively were largely derived from her dyestuffs industry" (Foreign Office 1946). Allowing IG Farben to continue with any dyestuffs capacity at all would allow the maintenance of "a large cadre of industrial scientists and technicians trained and practised in all the complex processes of chemical manufacture and capable of developing and producing any materials essential to a war economy" (Foreign Office 1946). In internal correspondence, a representative of the Ministry of supply described these claims as "of course, fantastic" (Foreign Office 1946). The productivity claims about dyestuffs' direct connections to national security, which had proved so influential during the previous war, now looked like the pleading of a special interest group.

While the argument about dyestuffs' dual-purpose role had become more marginal by the 1940s, their protection through legislation and tariffs took much longer to unravel. Tariff protection for dyestuffs remained in force in Britain until the 1960s, and in the US, tariffs were finally removed only in the early 1980s (Baptista 2012). By then, the last vestiges of the productivity claims which had been so influential earlier in the century had dissipated: dyestuffs had died as strategic objects, and it no longer made sense to make strong productivity claims on their behalf.

The third death: Diversified dyestuffs

I now turn to another kind of connection associated with dyestuff chemistry: its capacity to furnish concepts, materials, and skills which could be adapted to other areas of research. In the previous section, I argued that claims about synthetic dyestuffs were used to position these chemicals as playing a significant economic and scientific strategic role. I now want to turn to the ways in which dyestuff chemistry contributed directly to conceptual developments in other scientific fields.

Tony Travis, for example, has written a pair of articles outlining the ways in which the Jewish-Silesian doctor and researcher Paul Ehrlich drew upon his acquaintance with, and knowledge of, the products of the dyestuffs industry and the techniques and methods of dyestuffs chemistry (Travis 1989; 2008). As Travis puts it, Ehrlich's "entire career was based on using synthetic, or aniline, dyestuffs and their analogues for biological and biomedical studies" (Travis 2008, 79). Ehrlich's use of dyes had three main strands. First, he developed the use of synthetic dyes as stains for biological samples—with the result that dyes acquired a role in the biology laboratory, enhancing the visibility of cells and tissues through the microscope. Second, Ehrlich used dyestuff chemistry as a source of concepts about the structure of protoplasm and the mode of action of pharmaceuticals. He drew on Otto Witt's theory that dyestuff molecules were formed of two separate parts—one for color-rendering and the other for color-fixing. He also developed models of protoplasmic structure and immunological action on the basis of his investigations of dyestuffs. Third, Ehrlich relied on dyestuff companies to provide new materials whose biological action he could test.

What became of these connections later on, and did dyestuffs continue to play an active role in the research programs to which they contributed so much? In his authoritative history of the

https://doi.org/10.1017/S0269889722000163 Published online by Cambridge University Press

sulfonamide antibacterial drugs, the first of which was developed in 1932 at IG Farben in the form of a red dye called Prontosil, John Lesch offers a detailed answer to this question. Ehrlich's conception of the close analogy between dyestuffs and pharmaceutical action provided a hopeful horizon for the possibility that effective antibacterial treatments would be developed on the basis of dyestuffs. In some locations, this led to very sustained attempts to seek a dyestuff-based chemotherapeutic agent. What sustained this hope, Lesch argues, was the industrialization of research at IG Farben. The systematic character of the research process, the previous experience of researchers in dyestuffs, and the existence of previous drugs devised from chemical substances developed for dyestuffs all contributed to the sense that this was an enterprise likely to bear fruit. Immunologists in other locations were, by contrast, less optimistic about the prospects of dyestuff-based chemotherapeutic research (Lesch 2007, 40-5).

The IG Farben team's research techniques "involved methods of synthesis and concepts of specificity and variability taken over from dyestuffs chemistry" (Lesch 2007, 65). So great was their immersion in the concerns and methods of dyestuff chemistry that one of their number subsequently characterized their activities as being informed by "the myth and fascination of color" (Lesch 2007, 84). As Lesch summarizes, "Color in this context meant the azo bond, and the genealogy of Prontosil indeed placed it among azo dyes with medicinal effect, such as chrysoidine, phenazopyridine, and neotropine" (Lesch 2007, 91). The research group privileged the dye molecule as a whole, as part of a continuous series with other therapeutically effective dyes.

Prontosil and related compounds were subsequently tested at the Pasteur Institute in France. The group had prepared compounds based on Prontosil, all of which were dyes, as they saw "little reason to depart from a research path that was accessible, clearly marked, and rich in possibilities" (Lesch 2007, 125). Subsequent development of this class of drugs thus worked on variants of the intermediate rather than the complete dyestuff molecule, favoring colorless forms. To some later observers, the notion that the IG Farben team had not been aware of the active part of the Prontosil molecule appeared dubious: in a historical account from the 1950s, the British bacteriologist Ronald Hare alleged that the team must have known that the whole Prontosil molecule was not required for antibacterial action, but that they had promoted it on the basis that it could be patented, whereas the active intermediate could not (Hare 1955). Lesch rejects this suggestion, primarily on the basis of the recollections of the IG Farben and Pasteur Institute teams and their research reports, which indicate no inclination to send "fragments" of dyestuffs for testing (Lesch 2007, 82-91).

Although Prontosil and the subsequent development of sulfonamides could be understood as the apotheosis of Ehrlich's dyestuffs-based research program, these investigations also led to the death of dyestuffs as an ideal molecular form, as researchers started to employ intermediates rather than the larger dyestuff molecule. In one of her discussions of the role of objects in scientific practice, Karin Knorr Cetina remarks that "one could say that objects of knowledge structure desire and provide for the continuation and unfolding of object-oriented practice" (Knorr Cetina 2008, 93). Dyestuffs ceased to function as objects of desire in this sense.

In histories which take a longer-term view, dyestuffs have been considered a somewhat primitive starting point in the development of pharmaceutical research. Alfred Chandler notes, for example, that at ICI pharmaceutical research started within the Dyestuffs Division in 1936, but that by the 1950s, pharmaceuticals had "receive[d] their independence" from dyestuffs (Chandler 2005, 253). This way of putting things suggests that dyestuffs were a starting point that went on to become an impediment to dynamic pharmaceutical research, a sense which is borne out by contemporary statements from ICI chemists about the relations between the two divisions. In a lecture delivered in 1954, the British chemist W.H. Sexton presented the transition from dyestuffs into chemotherapy as a natural outgrowth, to which British industry had come late but in which it was now playing an active part. He noted that ICI's dyestuffs division had, in 1936, selected a team of six organic chemists for chemotherapeutic research, and while this team had grown enormously, and a laboratory dedicated to biology had been established, there was

https://doi.org/10.1017/S0269889722000163 Published online by Cambridge University Press

"still an extremely close relationship within ICI between the research work on dyestuffs and pharmaceuticals," adding that . . . "Imperial Chemical (Pharmaceuticals) depends upon the Dye-stuffs Division of ICI for the manufacture of drugs in bulk" (Sexton 1955, 436).

Notably, however, the remainder of the article talked about the involvement of dyestuffs knowledge and approaches only in the context of the company's research into spin-offs from the sulfanilamide drugs, and also emphasized the importance of "introducing" those chemists who were moving from dyestuffs to pharmaceuticals "to current biochemical thinking and to certain aspects of pharmacology," especially the theory of metabolite antagonism (ibid., 437). Moreover, much of the article dealt with ICI's concerns with penicillin and the production of cytotoxic agents, where synthetic chemistry—and knowledge derived from dyestuffs—were of much less significance. In this context, the central connective role ascribed to dyestuffs died off—dyestuffs went from being conceived as a source of skill, materials, and conceptual models to being remembered as a more primitive predecessor of mature pharmaceutical research.

Some researchers have continued to propose novel uses for dyestuffs in medicine, especially through the development of "photodynamic" therapies, which employ molecules sensitive to certain wavelengths of light that can be activated in order to kill pre-cancerous cells. Even proponents of dyestuff-based pharmaceutical research couch their claims about the continued viability of dyestuffs in a language of revival or return rather than of direct continuities of practice or an ongoing exploration of objects. Thus Mark Wainwright, editor of the journal *Pigments and Dyes*, describes how in the wake of antibiotic resistance, dyestuff-based drugs are again being tested as a workable alternative. Pharmaceutical researchers, writes Wainwright,

> have looked outside traditional drug types for an answer, for example to the now ubiquitous MRSA, and this has included the use of dyes. The original gram stain dye, crystal violet, has been employed to combat MRSA in hospitals in Japan. A phenazine dye, clofazimine, useful in the treatment of leprosy, has also been proposed for treatment of common drug-resistant hospital infection. (Wainwright 2003, 588)

As the existing pathways of drug development have led to antibiotic resistance, it may be worthwhile to return to older ones, or to techniques that are not currently considered as effective or as well established as drugs in widespread use. This line of argument presents drugs derived from dyestuffs as candidates for revival, paths not taken in the existing pharmacological present. It restores a sense of their potentiality precisely because they have not been as well-explored as other types of drugs.

The sense that molecules produced in the course of dyestuff research may allow for new avenues of research into pharmaceuticals has some similarities with discussions of the revival of other dead scientific objects, though there are significant differences as well. In his discussions of eighteenth-century experiments that employ phlogiston and frigorific rays, for example, Chang argues that discarded concepts might bear further exploration, and even practical application (Chang 2009). Similarly, historical and philosophical discussions of the ether in physics have examined the possibility that ether theories may make a comeback of some kind (Badino and Navarro 2018). The difference between these arguments about scientific concepts and the claims about revisiting dyestuff-based pharmaceuticals is of course that claims about dyestuffs do not chiefly turn on the revival of now-discarded *concepts,* but rather a return to currently unfashionable *materials*. For researchers like Ehrlich, dyestuff chemistry was conceptually generative as well as a source of useful materials. Even in discussions of returning to investigation of dyestuff-type molecules, there is no suggestion of a further development of the distinctive concepts of dyestuff chemistry.

The preceding three sections have described the rise and fall of synthetic dyestuffs as objects of innovation, of strategic significance and of conceptual generation for other fields. Taken together, these three deaths produce a powerful sense that synthetic dyestuffs are primarily of historical

concern, at least as far as the possibility that they could change or develop goes. The next section discusses the ways in which histories of synthetic dyestuffs are put to use by practitioners, historians, curators, and lawyers.

The fourth death: Dyestuffs as heritage and history

The year 2006 saw the 150th anniversary of Perkins' discovery of mauve. As in 1956 and 1906, the anniversary was commemorated with meetings and events. In contrast with those previous occasions, however, there was little involvement from the chemical industry, and the date did not serve as an occasion for reflection on the state of dyestuffs chemistry and production. Tony Travis, who contributed to some of the historical events of 2006, reflected afterwards that the loss of interest was due to the fact

> that the dye industry founded by Perkin, the world's first high-tech science-based industry, has so little presence in Europe and North America. Environmental problems arising from the manufacture of colorants and the shift of the textile industry to Asia have caused the great dye firms to reinvent themselves as agrochemical and pharmaceutical corporations, casting off long heritages that sometimes go back to the 1860s. (Travis and Baeck 2007, 43)

In these locations, dyestuffs had been converted to objects that are better forgotten. The waning of dyestuff commemoration has coincided with moves such as DuPont's decision in 1999 to abandon the last vestiges of the advertising slogan that had served it since the 1930s, "Better products for better living . . . through chemistry," in favor of a more general, and less specifically chemical claim to purvey "the miracles of science" (Callahan 1999). As part of their PR efforts, American and European chemical companies sought to distance themselves from their twentieth-century activities—dyestuffs were now dead within the corporate traditions and no longer part of the future of chemical companies. In Travis' view, it therefore fell to historians and heritage professionals to continue to study the material and cultural legacies of dyestuff production, which had been abandoned by their former corporate custodians.

As part of the celebrations, the material heritage of dyestuffs was subjected to chemical investigation, with Peter Morris analyzing the historic samples of Mauve in the collections of the Science Museum in London to ascertain whether claims for their provenance, as the original mauve produced by Perkin, could be verified (Morris 2006; Sousa et al. 2008). A recent exhibition at the Deutsches Textilmuseum in Krefeld allowed viewers to see a collection of dresses alongside "about 250 historic bottles still containing the original dyestuffs," arising from the chemical research project "Welt-bunt," which sought to identify and analyze 10,600 bottles of historical importance. This collection had been gathered by the School for Dyeing and Finishing in Krefeld, which eventually became the Faculty of Chemistry at the Hochschule Niederrhein, where it had long been neglected.

According to its analysts and conservators, the collection is a potentially potent record of now lost material practice. They claim that "due to the progressive development in technical chemistry, it is no longer possible to produce some of the dyes in a comparable manner. Especially the early synthetic dyes cannot be reproduced according to their original recipes anymore" (Holly, Herm and Schram 2019). Among the reasons for this loss of knowledge, the researchers list the fact that some raw materials are no longer available, and that safety regulations would prevent the exact reproduction of historical procedures. In addition, the collection does not fit into any of the established types of materials to be conserved; as objects, these historic dyes drive new thinking and practice among conservators, particularly through the identification of agents causing degradation in the dyes (Holly, Herm, Schram 2019).

https://doi.org/10.1017/S0269889722000163 Published online by Cambridge University Press

The sense that historical studies of synthetic dyestuffs involves knowledge which is now difficult to replicate bears comparison with historians' attempts to reconstruct older historical recipes, including the procedures described in manuals of alchemy. In reconstructions of alchemical experiments, there is no sense that identical materials can be used by the present-day researcher; instead, these reconstructions cast light on the possible meanings and techniques described in alchemical texts (Rampling 2020). In the case of alchemical objects, imperfect reconstruction of past techniques is historically suggestive, a potential source of historical evidence to be employed alongside other sources. With collections of synthetic dyestuffs, by contrast, specific historical questions about provenance (the veracity of claims about the Perkins Mauve in the Science Museum's collections) are paramount.

Synthetic dyestuffs' treatment as objects of heritage has impacted the kinds of history that are written about them. David Edgerton has argued that historians of the twentieth century habitually exclude chemistry and chemical industry from their accounts, because of a consensus about which technologies are most worthy of attention, a focus on technological innovation at the expense of use, and a wish to historicize current cutting-edge sciences and technologies above all else (Edgerton 2008). To the extent that they are considered to be closed off from further innovation, objects like dyestuffs do not fit with this agenda. Within Science and Technology Studies, chemistry has received considerably less attention over the past forty years than physics or the life sciences. The spate of recent work by geographers and environmental sociologists under the rubric of the "chemical turn," meanwhile, has focused much more on the health and environmental impacts of chemical production than on accounts of dyestuffs as dynamic objects of inquiry (Agard-Jones 2013; Shapiro and Kirksey 2017). If dyestuffs live on in these kinds of accounts, it is chiefly in the form of their environmentally damaging impacts.

Accounts of synthetic dyestuffs as dead objects, whose primary interest is in the time when they appeared most promising, are also written into linear accounts of innovation. The business historian Alfred Chandler says of the chemical industry of the early twenty-first century generally that it "is no longer a truly high-tech industry because chemical science no longer generates basic new learning to stimulate commercialization of fundamentally new products" (Chandler 2005, 18). As argued above, it is indeed the case that investment in novel molecules for dyeing has largely ceased, and in the past half century there have been fewer direct connections between dye chemistry and other fields of research. But Chandler's uncharitable assessment of the current status of chemical science disregards active research in fields such as catalysis supramolecular chemistry, biochemistry and the like; his account of innovation is based on the notion that only some industries are generative of novelties. The productive and research revolution wrought by chemical industry gives way, for Chandler, to those associated with consumer electronics, information technologies and biotechnologies (Chandler 2005, 283-313). Chandler's sequence of cutting-edge innovative industries is extremely linear and simplistic, and distorts the distinctive histories of each one of the fields about which he writes. Nevertheless, in the present context it is remarkable that aspects of Chandler's influential account of innovation are premised on treating synthetic dyestuffs as dead objects.

Some practitioners in the field of synthetic biology have appealed to the history of chemical synthesis as anticipating their own enterprise, and providing a model for forms of scientific research that connect directly with technological production. As Brian Yeh and Wendell Lim discuss, these practitioners posit that just as "fundamental theories of chemical structure developed concurrently with the explosion of synthesis" in synthetic chemistry, nowadays "the convergence of analytical and synthetic approaches seems to be replaying itself in modern biology" (Yeh and Lim 2007, 522-3; Roosth 2017; Bensaude-Vincent 2009). These appeals, though, do not address the complex political-industrial-scientific-environmental-aesthetic histories of chemical objects like dyestuffs, but rather the productivity claims that dyestuffs promoters made during the nineteenth and twentieth century in order to legitimize their enterprise.

Studies of the heritage of dyestuffs have not been confined to museums, and their historical impact is of more than academic concern. As Travis remarks in another paper, during the 1990s there was as much interest in the history of the industry and its wastes "among environmental litigators, particularly in the United States, as there was in the history of the dye industry among historians of chemistry" (Travis 2002, 21). Toxicological studies had been identifying dyestuff pollution since the 1860s, and its health effects had been a major topic of public concern in the US from the 1950s. The issue rose to particular prominence in Britain during the 1990s through the passage of the Environment Act in 1995, which raised questions about "the need to ascertain fully when damage occurred and became known, and what polluters knew about, and expected, from their waste disposal practices. It also drew attention to historical issues concerning detection and identification, measurements of concentration, especially of trace amounts, and resistance to breakdown of toxic substances" (Travis 2002, 25). Chemical manufacturers had previously endeavored to weaken environmental protections; alongside the displacements of the geography of dyestuff production, the question of historical liability became increasingly significant.

Across a wide range of historical approaches, then, dyestuffs have been configured as dead, lost or decomposing objects. Their activity consists primarily in their environmental afterlives. These commemorations do not tell the whole story, because they do not engage with the current production and use of dyestuffs—and they risk universalizing Western European and Northern European experiences. Nevertheless, they are culturally potent in deciding which aspects of the technical and scientific past have continuities with the present, and which have been left behind.

Conclusion

This paper has traced what happened to the very high claims that were made on behalf of synthetic dyestuffs between the mid-nineteenth and the mid-twentieth centuries. I have shown that during this period synthetic dyestuffs were positioned as highly innovative objects whose production led to significant institutional changes, as strategic objects, on both economic and scientific grounds, and as conceptually and materially generative objects for other fields of scientific enquiry. In all three respects, synthetic dyestuffs have ceased to play these roles, and the meanings ascribed to synthetic dyestuffs in the present portray them as quotidian objects and commodity chemicals, on the one hand, and as a topic of primarily historical interest, on the other.

The arguments presented here have implications for thinking about the history of synthetic dyestuffs, and of dead scientific objects more generally. As a study of synthetic dyestuffs, I have drawn attention to the peculiar temporality of the claims made about this group of chemicals and the processes involved in deploying them, and to the sense that the present state of their use is frozen. Moreover, the ways in which synthetic dyestuffs are mobilized in accounts of the origins of research-driven industrial modernity serves to situate them in a past historical moment, providing—in the works of some commentators—a template for subsequent high-technology innovations, rather than presenting them as objects which possess an ongoing history of development and investigation in their own right.

Placed alongside other dead scientific objects, synthetic dyestuffs have some commonalities and some significant differences. I have compared synthetic dyestuffs to such dead objects as phlogiston, the objects of alchemy, and the ether. The point of such comparisons is not to suggest that synthetic dyestuffs ceased to be considered as legitimate objects of enquiry, as those objects did, but rather that there is a similar sense of unfinished business, of recalcitrance and persistence, in the meanings associated with synthetic dyestuffs and with those other objects. Above all, I hope that the views given here can suggest that there is nothing "wan" or "mere" about a once-scientific object becoming quotidian. The case of synthetic dyestuffs suggests that this change in status can result in the generation of different kinds of activity and meaning, as in the curation and litigation

https://doi.org/10.1017/S0269889722000163 Published online by Cambridge University Press

of the legacies of synthetic dyestuff production, or the proposals for returning to dyestuff-based pharmaceutical research. In other words, the shift to the quotidian is in this sense a beginning as well as an end.

References

Aftalion, Fred. 2001. *A History of the International Chemical Industry: From the Early Days to 2000*. Philadelphia, Pa.: Chemical Heritage Press.

Agard-Jones, Vanessa. 2013. "Bodies in the System.." *Small Axe* **17** (3): 182–192.

Armstrong, Henry E. 1923. "Legislative and Government Interference with Industry and the Common Weal." *Chemistry and Industry* **42** (5): 91–95.

Badino, Massimiliano and Jaume Navarro. 2018. "Introduction. Ether – The Multiple Lives of a Resilient Concept." In *Ether and Modernity: The Recalcitrance of an Epistemic Object in the Early Twentieth Century*. Edited by Jaume Navarro, 1–13. Oxford: Oxford University Press, 2018.

Baptista, Robert. 2012. "The Faded Rainbow: The Rise and Fall of the Western Dye Industry 1856-2000." https://mediakron.bc.edu/fashiondecor/decor-detail-french-empire/contents/review-folder/review-for-test-2/decor-review-folder/aniline-dye, accessed 24/06/2022.

Bensaude-Vincent, Bernadette. 2009. "Synthetic Biology As a Replica of Synthetic Chemistry? Uses and Misuses of History." *Biological Theory* **4** (4): 314–318.

Board of Trade. 1914 "Minutes Of The First Meeting Of The Advisory Committee On Chemical Products, August 28, 1914." In UK National Archives, BT 11/13.

Bomgardner, Melody. 2018. "These New Textile Dyeing Methods Could Make Fashion More Sustainable." *Chemical and Engineering News*. https://cen.acs.org/business/consumer-products/new-textile-dyeing-methods-make/96/i29, accessed 20/10/2019.

Callahan, Sean. 1999. "Dupont Replaces 1935 Tagline to Reflect Corporate Change." *AdAge*, 1 June, online at https://adage.com/article/btob/dupont-replaces-1935-tagline-reflect-corporate-change/247761, accessed 9/01/2020.

Chandler, Alfred. 2005. *Shaping the Industrial Century: The Remarkable Story of the Evolution of the Modern Chemical and Pharmaceutical Industries*. Cambridge, Mass.; London: Harvard University Press.

Chang, Hasok. 2009. "We Have Never Been Whiggish (About Phlogiston)." *Centaurus* **51** (4): 239–264.

Chang, Hasok. 2010. "The Hidden History Of Phlogiston." *HYLE–International Journal for Philosophy of Chemistry* **16** (2): 47–79.

Daston, Lorraine. 2000. *Biographies of Scientific Objects*. Chicago: University of Chicago Press.

Edgerton, David. 2006. *The Shock of the Old: Technology and Global History Since 1900*. London: Profile Books.

Edgerton, David. 2008. "Not Counting Chemistry: How We Misread the History of Twentieth Century Science and Technology." https://www.sciencehistory.org/distillations/not-counting-chemistry-how-we-misread-the-history-of-20th-century-science-and, accessed 08/01/2020.

Foreign Office. 1946. "Chemical Industry: Pharmaceuticals and Dyestuffs." In UK National archives, FO 942/453.

Garfield, Simon. 2000. *Mauve: How One Man Invented a Color that Changed the World*. New York: W.W. Norton Company.

Golambos, Louis, Hikino, Takashi and Zamagni, Vera eds. 2007. *The Global Chemical Industry in the Age of the Petrochemical Revolution*. Cambridge: Cambridge University Press.

Hare, Ronald. 1955. *Pomp and Pestilence: Infectious Disease, Its Origins and Conquest*. New York: Philosophical Library Inc.

Heida, Lydia. 2014. "Can Waterless Dyeing Clean Up the Clothing Industry." https://www.greenbiz.com/blog/2014/07/21/waterless-dyeing-processes-clean-clothing-industry, accessed 20/10/2019.

Holly, Marc, Christoph Herm, and Jürgen Schram. 2019. "Colourful World—Conserving the Dye Collection of the Hochschule Niederrhein."Poster presented at the 8th Interim Meeting of the ICOM-CC working group Art Technological Source Research, September 2019, online at https://www.researchgate.net/publication/336364895_Colorful_World_-_Conserving_the_Dye_Collection_of_the_Hochschule_Niederrhein, accessed 9/01/2020.

Homburg, Ernst. 2018. "Chemistry and Industry: A Tale of Two Moving Targets." *Isis* **109**(3): 565–576.

Hounshell, David A., John Kenly Smith Jr. 1988. *Science and Corporate Strategy: Du Pont R and D, 1902-1980*. Cambridge: Cambridge University Press.

Klein, Ursula. 2005. "Technoscience Avant la Lettre." *Perspectives on Science* **13**(2): 226–266.

Knorr Cetina, Karin. 2008. "Objectual Practice." In *Knowledge as Social Order: Rethinking the Sociology of Barry Barnes*. Edited by Mazzoti, Massimo, 83–98. Farnham: Ashgate.

Lesch, John E. 2007. *The First Miracle Drugs: How the Sulfa Drugs Transformed Medicine*. Oxford: Oxford University Press.

Levinstein, Herbert. 1924. "Some Thoughts on the British Dyestuff Industry." *The Journal of Chemical Industry* Oct 17: 1029–1033.

MacLeod, Christine and Radick, Gregory. 2013. "Claiming Ownership in the Technosciences: Patents, Priority and Productivity." *Studies in History and Philosophy of Science Part A* **44**(2): 188–201.

https://doi.org/10.1017/S0269889722000163 Published online by Cambridge University Press

Morris, Peter and Anthony S. Travis. 1992. "A History of the International Dyestuff Industry." *American Dyestuff Reporter* **81**: 59–59.
Morris, Peter JT. 2006. "Does the Science Museum, London, have Perkin's Original Mauve Dye? A Critical Reassessment of a Chemical Icon." *History and Technology* **22**(2): 119–130.
Mowbray, John. 2018. "China Shutdowns Squeeze Textile Dyeing Industry." *Ecotextile News*. https://www.ecotextile.com/2018061823554/dyes-chemicals-news/china-shutdowns-squeeze-textile-dyeing-industry.html. Last accessed 24/06/2022.
Murmann, Johann Peter. 2003. *Knowledge and Competitive Advantage: The Coevolution of Firms, Technology, and National Institutions*. Cambridge: Cambridge University Press.
Navarro, Jaume ed. 2018. *Ether and Modernity: The Recalcitrance of an Epistemic Object in the Early Twentieth Century*. Oxford: Oxford University Press.
Ndaiye, Pap. 2007, *Nylon and Bombs: DuPont and the March of Modern America*. Baltimore: Johns Hopkins University Press.
Nieto-Galan, Agustí. 2001. *Colouring Textiles: A History of Natural Dyestuffs in Industrial Europe*. Dordecht: Springer.
Pickering, Andrew. 2005. "Decentering Sociology: Synthetic Dyes and Social Theory." *Perspectives on Science* **13**.3: 352–405.
Pollak, Peter. 2010. *Fine Chemicals: The Industry and the Business*. London: Wiley-Blackwell.
Radick, Greg. 2018. "There Was No Such Thing as the Mendelian Gene and this is a Talk About It." Talk at "How Scientific Objects End" Workshop, University of Cambridge 3-4 December 2018.
Rampling, Jennifer. 2018. "Envisioning 'Perfected' Matter: The Philosophers' Stone as Epistemic Object." Talk at "How Scientific Objects End" Workshop, University of Cambridge 3-4 December 2018.
Rampling, Jennifer. 2020. *The Experimental Fire—Inventing English Alchemy, 1300-1800*. Princeton: Princeton University Press.
Reader, William J. 1970. *Imperial Chemical Industries: A History [in 2 vols]. Vol.1, The Forerunners, 1870-1926*. Oxford: Oxford University Press.
Roosth, Sophia. 2017. *Synthetic: How Life got Made*. Chicago: University of Chicago Press.
Sexton, Wilfred A. 1955. "Chemotherapeutic Research in the Laboratories of Imperial Chemical (Pharmaceuticals) Limited at Manchester." *Proceedings of the Royal Society of London. Series A, Mathematical and Physical Sciences* **229**(1179): 425–438.
Shapiro, Nicholas and Eben Kirksey. 2017. "Chemo-ethnography: An Introduction." *Cultural Anthropology* **32**(4): 481–493.
Sousa, Micaela M., Maria J. Melo, A. Jorje Parola, Peter J. T. Morris, Henry S. Rzepa and J. Sergio Seixas de Melo. 2008. "A Study in Mauve: Unveiling Perkin's Dye in Historic Samples." *Chemistry* **14**(28): 8507–8513.
Stanley, Albert. 1925. "Chairman's Speech at an Extraordinary General Meeting of the Shareholders of the British Dyestuffs Corporation Limited, held at the Milton Hall, Manchester on Wednesday 25th November 25th." Reproduced in *Papers Relative to the Liquidation of the Government Interests in the British Dyestuffs Corporation Ltd*. London: His Majesty's Stationary Office: 10-20.
Steen, Kathryn. 2014. *The American Synthetic Organic Chemicals Industry: War and Politics 1910-1930*. Chapel Hill: University of North Carolina Press.
Travis, Anthony S. 1993. *The Rainbow Makers. The Origins of the Synthetic Dyestuffs Industry in Western Europe*. Bethlehem/Pa: Lehigh University Press.
Travis, Anthony S. 1989. "Science as Receptor of Technology: Paul Ehrlich and the Synthetic Dyestuffs Industry." *Science in Context* **3**(2): 383–408.
Travis, Anthony S. 2002. "Contaminated Earth and Water: a Legacy of the Synthetic Dyestuffs Industry." *Ambix* **49**(1): 21–50.
Travis, Anthony S. 2008. "Models for Biological Research: The Theory and Practice of Paul Ehrlich." *History and Philosophy of the Life Sciences* **30**: 79–97.
Travis, Anthony S. and Baeck, Leo. 2007. "Mauve and its Anniversaries." *Bulletin for the History of Chemistry* **32**(1): 35–44.
Yeh, Brian J. and Lim, Wendell A. 2007. "Synthetic Biology: Lessons from the History of Synthetic Organic Chemistry." *Nature Chemical Biology* **3**(9): 521–25.
Wainwright, Mark. 2003. "The Use of Dyes in Modern Biomedicine." *Biotechnic & Histochemistry* **78**(3-4): 147–155.
Werrett, Simon. 2019. *Thrifty Science: Making the Most of Materials in the History of Experiment*. Chicago: Chicago University Press.

Mat Paskins is an historian of science. He is interested in the relations between narrative and material practice in the sciences, especially in chemistry and natural history, and how their entanglements produce different ways of narrating possible futures. Between 2015 and 2017 he was employed at Aberystwyth University on the AHRC-funded Unsettling Scientific Stories website, during which time he compiled a database of scientific visions of scientific and technological futures from across the twentieth century. He has previously overseen an oral history project on wild food foraging during World War Two (together with the Tree Council), and has taught at UCL, Imperial College London and Dickinson College.

Cite this article: Paskins, Mat. 2021. "Dyeing off: On the deaths of dyestuffs as scientific objects," *Science in Context* **34**: 297–311. doi:10.1017/S0269889722000163