Looking Back, Crafting Futures

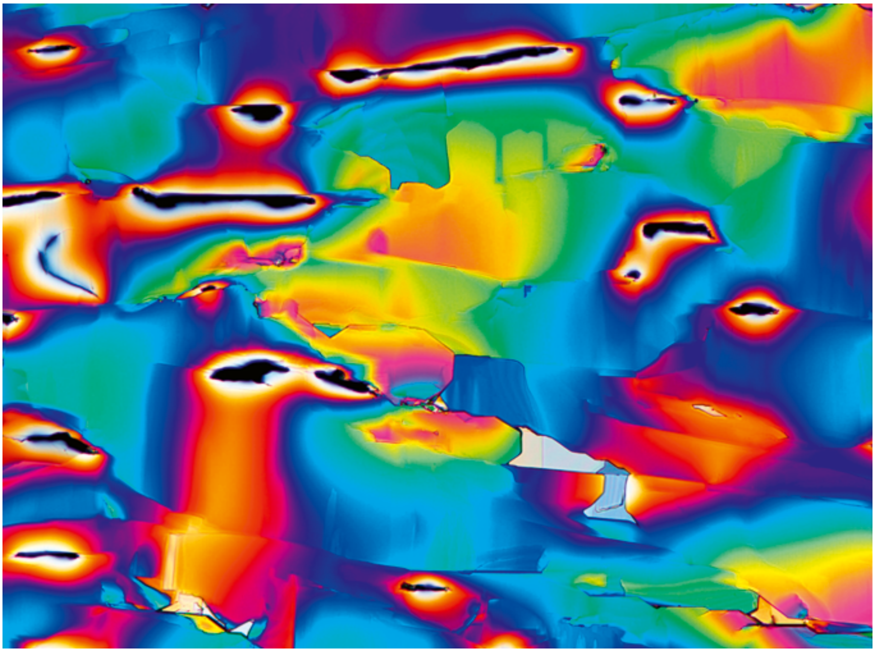

FIGURE P7 Mimesis within mimesis: this image of saccharine crystals depicts a material used to imitate sweetness. At its inception in the late nineteenth century, saccharine was prohibited from sale in some countries. This material remains a metaphor for fakery, as in the 'saccharine smile'. The image itself, artificially coloured, generates a double mimesis, at once iconographical and material

CHAPTER 19

Afterword

Esther Leslie, Samuel Iliffe, Lucas M. Mueller, Pauline Krijgsheld, Ann-Sophie Lehmann, Sophie Pitman, Samir Boumediene, Benjamin Aldes Wurgaft, Leah Anderson and Maximilien Urfer

Following Patrick Joyce and Tony Bennett in their widely-read account of *Material powers* (2010, 21), with *The matter of mimesis* we seek 'to extend thinking beyond the familiar division between what is and is not "material"'. Ongoing debates in anthropology and the sociology of knowledge over 'assemblages', 'actants' and 'quasi-objects' (hybrids of the social and the natural) are currently reshaping scholarly models of materiality in ways that challenge claims about material determinism. The implications of these discussions for other disciplines are still unfolding. Our volume has approached materiality from the vantage point of the replicated object, a fruitful and provocative instance that allows us to construct the complex relations between social and political agency, meaning, making and use for a variety of different cultures and circumstances. At the same time, we as scholars feel a need to be reflexively attentive to our own position, given the major transformations in techniques, media and technologies of replication such as 3D printing, cloning, and digital humanities that are in the process of reshaping not only our labour as scholars, but even its object; not only our source materials, but even our understanding of what counts *as* a source; not only our daily lives, but even our sense of self. Such was historically the case with new media. Benjamin's *The work of art in the age of mechanical reproduction* (1936), for example, famously grapples with the way that theories of artistic creativity based on appeals to subjectivity, genius and autonomy were challenged by the mechanical reproduction of works of art. Benjamin saw the value of a work of art as both reduced by reproduction and rendered subject to political interventions which altered its original meaning. Today, we face similar challenges, albeit posed by very different media, which present viewers with increasing difficulties in differentiating between reality and its many representations, as the essays of both Conte and Kromholz in this volume vividly illustrate. It is not *infidelity* in the act of representation that concerns us (as it did early moderns); rather, it is the ever-growing *accuracy* that new technologies afford that is problematic, for it seems to obliterate even the possibility of authenticity, originality and especially uniqueness. In

 | DOI:10.1163/9789004515413_027

William Gibson's *Neuromancer* (2001), one of the trademarks of high-quality virtual reality is its reproduction of imperfections such as dirt, which approximated the virtual world more faithfully to the real one than cheaper VR. This theme of reality as underpinned by imperfection, with its play on Platonism, is addressed in our volume by Henning's chapter on another new medium of reproduction, the daguerreotype.

Authors of science fiction have long warned of the dangers of going astray in the world of the mind, of blurring the boundary between the material and the ideal. New materials and new media constantly throw up new challenges of precisely this kind. We have ourselves become hybridised with our artefacts. The objects of material mimesis can stand in various kinds of relations to ourselves, relations which are not only historically and culturally specific, but also prospective. Their outcomes and effects are indeterminate. In the film *Elizabeth harvest*, which supplies the epigraph for our book – an updated version of the Bluebeard myth – the eponymous character is a woman who has been cloned multiple times by her scientist husband so that he can murder her again and again. As the capacity to replicate encompasses even the fabric of living bodies, so the purposes to which material mimesis can be put diversify ever more, from lightbulbs to artificial meat, from the Shroud of Turin to nanoparticles, from 'antique' ceramics to geckel.[1] So too do the forms of identity and agency needed to engage with them.

♦ *What follows is an exploratory enterprise*. The matter of mimesis *is a work with multiple dimensions, spanning numerous disciplinary areas, a quality dictated by the broad-ranging implications of its subject matter. Our introduction raised more avenues of enquiry than could possibly be addressed in a single volume, and material mimesis, as an act, embraces a plurality of disciplines. As editors, we decided that inviting a single scholar from our current, carefully honeycombed world of specialisms would not facilitate the kind of broad-ranging perspective we sought to accomplish with this book. Accordingly, we invited a number of specialists working in very diverse fields to provide contributions. We asked them to respond to three questions*:

- What would you describe as the main way in which your work engages with material mimesis?
- What kinds of groups of practitioners and users are involved in your work?
- How do you envisage mimetic material practices changing future material culture and/or society?

♦ *This Afterword is the product of their reflections. It makes clear that not only are different disciplines involved in practices of material mimesis, it is also possible to* express *material mimesis – to write and reason about it – in very different ways. The contributors have adopted very different perspectives upon what material mimesis is, who does it, and how it might develop in the future, as material needs, uses and significance transform or vary over time and place.*

♦ *We begin with* Esther Leslie*, a critical theorist who explores the ways in which matter and materials – chemicals, plastics, liquid crystals, dyestuffs, glass, ice, dairy, to name some examples – shape and are shaped by historical, political processes*:

Esther Leslie: Tender Empiricism

In relation to the various objects I have looked at of late – liquid crystals, milk and butter, clay and porcelain, clouds and fog, the glass of touchscreens – I have been interested in the ways in which a material suggests its own modes of approach, its theoretical unravelling, as suggested by Goethe's 'tender empiricism': All factuality is already theory, he observes. This is how I might first understand material mimesis – to read a liquid crystal is to explore it from the perspectives of liquidity – how it allows for flow – and crystallinity, in what ways it freezes the world, social relations, and in what ways its flips from phase to phase offer new ways of engagement socially and historically. The clouds and fog arrive with a flurry of ideas of fuzziness and obscuring, of naturalised forms and mobility – all of which are transferred into their apprehension in the hi-tech world of cloud computing and fogging networks. Milk is a material of endless extension, distributed in our cultures as milk of kindness, as sexualised fluid, as white supremacist token, as prerequisite of a technological quest for enhanced humanity, and on and on. Milk spills into various histories, and has the capacity to be present in various forms – liquid, solid, powder, emulsion, froth or foam. It can be, has been, poured, pressed, cast, extruded. It is formless, but may take on any form, any shape – the shape of vessels or the shapes pressed into it when in solid form as butter or ice-cream – blocks or coils, or sometimes cartoonic characters or body parts. Milk may be indexical. In that indexicality, I find compressions of significance. My recent work is on how wind and rain built a synthetic chemical industry in Teesside, in the North East of England. Natural capacities forged history and social forms in the conglomerate Imperial Chemical Industries, which gave a boost to synthetics in the UK, a problematic one, yet no less problematic now it is no longer in existence, and it leaves a wrecked environment behind it.

I have worked with artists who seem drawn to my poeticising of materials, finding within them political, social and historical resonance, ways in which they as materials transform worlds or close off possibilities – for example Geraldine Juárez, who works with gorilla glass from smart phones and with ice. Or Philippe Parreno and Agnieszka Kurant, who were drawn to liquid crystals. Or Kerstin Schroedinger and Mareike Bernien, who developed filmwork around the idea of artificial dyes and colour processing in Nazi Germany and the GDR, with reference to my book *Synthetic worlds: Nature, art and the chemical industry*. I have worked most with Melanie Jackson, collaborating on various projects. One goes under the title *The Urpflanze*, and was about Goethe's imaginary plant that contains, coiled up within itself, the potential to generate all possible future plants – Walter Benjamin extends this into a notion of the anticipatory idea of all future forms coiled up in select objects. Science nowadays looks to primordial plant matter for clues on how to proceed. Plant science becomes an art of morphology and mutation, re-presentation and transformation, characteristics it shares with the medium of drawing. Contemporary plant science assumes the ability to create as yet undreamt of botanical objects, using an array of tools and techniques, such as nanoscience, transgenics and biomimicry. Our work on milk, called 'Deeper in the pyramid', allowed the mingling of writing, painting, video-work, sculpture, print forms and exploratory work with actual materials – the powders, liquids and solids of dairy – to empirically explore material meanings and capabilities. This led to a commission to explore butter for an Irish art biennale. Grass-fed cattle making butter becomes a material slide into a panoply of themes around veins, gold, extraction, invention, witches, bogs, the dairy and more in relation to Irish and global history.

Contemporary science spends much energy on advanced materials, engineered substances that improve on nature. Sometimes they draw on nature, plunder its aspects, in order to find ingenious ways to do things that were previously done elsewise or never done before. Biomimetics applies principles from engineering, chemistry and biology to the synthesis of materials, synthetic systems or machines that have functions that mimic biological processes. Biomimetics recognises nature as the progenitor of complex materials and structures, for example, a mosquito-control device inspired by the mechanism of the carnivorous *Utricularia vulgaris* plant, a kinder hypodermic needle based on the mosquito's proboscis, made of several thin needles, lower air-resistant turbine blades with humped edges similar to the humpback whales, thermal clothing modelled after polar bear fur, micro-mist spray technology copied from beetles, hydroelectricity captured in something modelled on the bell shapes of jellyfish, solar-powered signs with pollution filtering mechanisms motivated by marine creatures like salpidae, paddlefish, and peacock worms, bat sonar imitated to fly drones around obstacles in the dark, the wrinkling of a skin to repel dirt or to clean. These activities, such as the last mentioned, sometimes involve nonlinear behaviours that challenge old notions in physics. And space-time is reconceptualised from the perspective of the non-human. Slime moulds for one have been used for urban design, specifically road planning. *Physarum polycephalum*, the 'many-headed slime', is a plasmodial, single-celled organism that expands from a single point, in its quest for food sources. Having located them, its many branches die off, leaving a slimy, single-celled efficient route between the nodes of food sources. There are suggestions, not fully comprehended, that the slime may possess a memory of those lost routes, which could be operationalised one day. The possibilities of mimesis are immense, compelling potentially a re-recognition of nature's remarkableness and a demoting of bourgeois arrogance.

♦ Samuel Iliffe *is a Designer as well as a Material Scientist and Engineer, with an interest in how new materials can be used to solve everyday problems. In his work, there is a seamless relationship between the natural world and scientific practice: the two articulate in the imitation of evolutionary solutions to problems of materality.*

Samuel Iliffe: Against Anthropocentrism

Now

As a design engineer I am interested in using elements of mimesis to broaden our traditionally anthropocentric view of the world. The humble desert ant can trace its way back home after travelling miles across featureless desert, which from a human perspective seems like magic. However, scientists have discovered that these ants can perceive polarised light, and, using it as a compass along with dead reckoning, they can locate their way home. A project I was part of called Aweigh attempted to materialise this perception for humans, using polarised light sensors connected to an LCD display, acting as a form of navigation that didn't rely on GPS.

Mimicry can be used to imbue information into a material, like recreating the texture of wood in plastic to feel more 'natural' to humans, but the effects can be even more profound with animals. Certain smells (or semiochemicals) can carry information to animals that is imperceptible to humans. Queen

Mandibular Pheromone, or QMP, is used by the queen honeybee to attract her worker bees. It is possible to impregnate this semiochemical into materials like plastic and immediately attract honeybees, and this technique is frequently used in beekeeping. In a research project called Aromavert, I created a toolkit which could enable other designers to use these cues, specifically for steering animals away from danger. In one example, I looked at seabirds which are inadvertently caught in fishing nets as bycatch. Using a chemical found in the liver of sharks, these birds can be repelled from the nets almost immediately.

To test the design, I went gillnet fishing with one of the last gillnetters on the Thames. It was a baptism of fire, heading out with the fisherman on his boat, catching fish and learning about their life. He was open to new designs, but fishing is a tough business, where things must work without fail, so I knew that whatever I designed would need to be simple and robust (and not affect the fish catch in any way). The final design was an infuser containing the repelling chemical, attached to the net container that the fisherman used.

Throughout these designs I constantly collaborated with scientists and researchers. My role as a designer is often to look at new potential applications of work done by other scientists. When done without respect for the scientists' work, this will come across as akin to stealing or appropriating, but when done correctly, design not only applies the research to society, it brings that research to a wider audience, and helps people understand its importance.

Future

There are lots of possible shifting events, known in the design world as weak and strong signals, that relate to mimetic material practices and which will shape society.[2] Strong signals like the climate crisis and the connected loss of biodiversity are making it painfully evident that we must change our use of materials.

We will be incorporating more 'biomaterials' that mimic the desirable properties of fossil fuel-based materials like plastic. Much of my work with the design studio Atelier Luma has been uncovering the uses for algae for this purpose. Algae refers to a large group of organisms known for supplying 60–70% of the oxygen to the planet, as well as sequestering carbon dioxide. If algae can be used to mimic other materials, like plastics, they might offer a version that is not only less harmful but positively beneficial to the planet, while still being economically viable.

We might start using mimetic material practices to change the idea of waste, perhaps borrowing from the aesthetics of the antique or vintage item, and moving away from a material being simply for one purpose.

I hope we will use mimesis to improve our understanding and empathy towards each other and our ecosystems. By translating information outside our perception to information we can perceive, we can begin to truly empathise with the world around us.

♦ Lucas Mueller *is a historian interested in environmental crises in the nineteenth and twentieth centuries. He investigates how scientists have represented natural disasters and hazards in laboratory studies, field experiments, and computer simulations to study cause and effect and to control damage. In these practices, mimesis is deeply embedded in the way scientific knowledge-claims are demonstrated and made credible.*

Lucas Mueller: Mimesis, Analysis, and Synthesis in Regulatory Science

Identifying, measuring, and monitoring contaminants have constituted key mimetic practices of late twentieth-century regulatory science. From setting standards for the amount of contaminant allowed in food, to comparing the prevalence of a 'natural' toxin to such standards, regulatory scientists produced these abstractions through the analytical power of animal experiments and physicochemical instruments. Scientists determined and synthesised the molecular structures of toxins, then simulated and reproduced them in an experimental setting as standards, mimetic artefacts by means of which to regulate the nutritional quality and commercial value of food. This standardised and routinised form of science has become central to the governance of health, trade, and environment in the late twentieth century.

The history of aflatoxin as a standard for assessing food quality illuminates the mimetic practices in regulatory science. Aflatoxins are some of the most potent carcinogenic substances known to science, causing lethal liver cancer. In the spring of 1960, veterinarians were investigating mass mortality of poultry on British farms. Initially they identified peanuts from specific feed consignments to be the source of Turkey 'X' disease, but soon discovered aflatoxin, excreted by *Aspergillus* moulds found within the feed, as the final cause of the mortality. The scientists isolated aflatoxin by feeding samples to living ducklings, which acted as 'mimetic detectors', validating the samples' toxic contaminant by reproducing its effects, the avian disease.

By November 1963, the US Food and Drug Administration began to cultivate the mould on a massive scale to produce aflatoxin as a research substance and standard. The FDA's Division of Microbiology cultured the mould, the Division of Food extracted and purified aflatoxin, and the Division of Pharmacology tested it on ducklings.[3] This material was distributed to laboratories around the globe. As such, aflatoxin became a 'natural kind' from which to measure, compare, and contrast the supposedly natural contamination of food. Chemists and nutritionists at the Massachusetts Institute of Technology were among the recipients, obtaining 200 mg of crude extract from the FDA.[4] They purified the substance and determined its molecular structure with a whole array of analytical devices, including mass spectrometer, nuclear magnetic resonance spectroscopy, and day-old White Pekin ducklings. In 1963, they published the structure, a graphical rendering of the essence of that which was once signified by a strange avian disease. In 1967, they synthesised this molecule in the laboratory as a mixture of different atomic arrangements.[5] Researchers succeeded in synthesising aflatoxin in a single form forty years later.[6] Was that the most perfect mimesis of the food-born illness?

This vignette suggests that regulatory science's mimetic practices have depended on context to create nature and artifice. The notion that Turkey 'X' disease was reducible to the natural toxicity of substances like aflatoxin, which have a molecular structure, is not a natural fact but the product of a political economy of industrialised feed and food, and of practices of molecular sciences in the late twentieth century. Scientists relied on utilitarian as well as aesthetic judgements to decide which representation of nature was sufficient to serve as a standard that revealed the really real toxicity.

♦ Pauline Krijgsheld *is a biologist with an interest in how composite biomaterials can inspire innovative design solutions and new concepts of sustainable materials. Just as organisms can exercise mimicry to advantage, she argues, so too humans can put potential natural resources to use by exploiting expert knowledge of material properties in a sustainable and regenerative manner.*

Pauline Krijgsheld: Fungi for the Future

Nature can be seen as an 'effective and giant laboratory where trial and error experiments take place through evolution' (Bar-Cohen 2016). Nature constantly changes, and therefore, species and organisms are continuously evolving new mechanisms to avoid extinction, for example resistance to parasites. This is nicely illustrated by Lewis Carroll in *Alice through the looking-glass* (1871), when the Red Queen tells Alice: 'now, *here*, you see, it takes all the running you can do to keep in the same place'. Her words basically indicate that, in order to be able to keep up (or to survive), you need to change continuously. We can make use of this knowledge that has been gained during evolution, for instance in mimicry, and incorporate it in new strategies or materials.

Müllerian and Batesian mimicry occur in nature from insects to plants. We may all be familiar, through the example of a wasp and an innocent insect like a hoverfly in the garden, with the use of Batesian mimicry by a harmless species that mimics or imitates the warning signals of a predator. When we think of the yellow and black stripes of wasps and bees, we may also recognize how similarity among unpalatable species confers mutual benefit (Müllerian mimicry).

Mimicry occurs at all levels, from microscopic to macroscopic, as can also be seen in nature: for instance, the plant pathogen *Fusarium oxysporum* is a fungus that infects roots using a functional homologue of the plant regulatory peptide RALF (rapid alkanization factor), in order to increase its infectious potential and at the same time suppress host immunity (Masachis *et al.* 2016). We ourselves can mimic, albeit on the larger scale. For instance, by examining the 'water collection properties' of the spines of the cactus *Opuntia microdasys*, we can mimic a mechanism for collecting water from air. In another example, the mechanism of the specialist neuron Lobula Giant Movement Detector (LGMD) in locusts can be mimicked to provide an algorithm that prevents collisions in self-driving cars. We can also learn from natural decomposers, creating new biodegradable materials out of waste products by researching fungal materials.

The use of fungi as material is not a new idea. In 3400 BCE, Iceman Ötzi carried with him an object made from the fungi *Fomes fomentarius* (tinder fungus) and *Fomitopsis betuline* (birch polypore), which he probably used as tinder. For this purpose, he used a part of the fungi that was treated by beating and placed into a 'firelighter kit' together with other plant and stone materials. Many consider fungi or moulds to be disgusting, as in the cases of mouldy food or rotten fruit, or a bathroom with black mildew. However, besides their uses as tinder or foodstuffs (e.g., edible mushrooms), fungi are valuable in many ways. For instance, they play a very important role in nature in degrading organic waste.

Fungi grow by means of hyphae, which form a network, the mycelium. By secreting enzymes, fungi are able to degrade polymers such as cellulose in the waste they colonise. We can use this ability to create materials; we can even create materials from waste products like sawdust, or the remains of tomato plants after the tomatoes have been harvested. These pure mycelium (fungal) or composite (substrate and mycelium together) materials can contribute to a circular economy: the materials are both natural and biodegradable. Currently, we can create a range of mycelium (composite) materials possessing a variety of properties: they can be cork-like, leather-like, or foam-like. But there is still scope for improving and diversifying these properties.

In the project 'Research through design', we worked together with designers and artists to create tailor-made mycelia and new concepts of sustainable materials. Designers used the mycelium to make objects ranging from shoes and clothes (for example, a mycelium dress) to art objects. To get a better understanding of the uses of the materials, we have investigated the production factors influencing the mechanical properties of mycelium-based composites in collaboration with designers from TU-Delft and the Design academy Eindhoven. We found that if we changed the fabrication process, different performances could be produced from mycelium materials. The type of mushroom-forming fungus used, the substrate and the method of processing the material all influenced performance. For instance, the combined application of heat and pressure resulted in a composite material with a density, elastic modulus and flexural strength similar to that of natural materials like wood and cork.

Back in 2014, when we started working with fungal materials on the NWO project 'Mycelium design', we had to convince the public of the safety and usefulness of fungal materials. The first reaction was that fungal materials would not fit in a living room. Nowadays, however, many start-ups have adopted the interesting properties of fungal materials, and art, bricks and packaging material are being designed out of mycelium-based material, as well as vegan leather. I believe in the future we will look back in amazement at the indiscriminate use of non-renewable materials like plastics, which are so difficult to break down, and finally end up as waste in the environment, or piled up in giant landfills, or (in nature) causing harm to humans, animals and plants. I think we have been 'standing still' for too long, and haven't kept up with an environment that has changed.

Our projects will continue to see how far we can investigate and improve fungal materials for a variety of applications, from building a house on the moon to materials that can conduct electricity. Currently, we are seeing start-ups in the production of acoustic panels, dresses, shoes, packaging materials, surfboards, and even caskets from fungal material. In the future we will sit on circular-economy-proof, mycelium-based furniture, or even live in houses made out of fungal hyphae.

♦ *Trained as an art historian,* Ann-Sophie Lehmann *develops a process-based approach to art and visual material culture in her research. She studies how materials, tools, and practices partake in the meaning-making of art; how images and* *texts represent and reflect creative practices; and how knowledge about making engenders material literacy. In her contribution, Lehmann calls for an inclusive and precise terminology to describe materials' multifariousness across disciplinary boundaries.*[7]

Ann-Sophie Lehmann: Speak, Materials!

In its beginnings, the material turn in the humanities and social sciences established itself against the hegemony of language and text as dominating concepts in theoretical discourse. While such concepts had initially helped to expose objectivist and empirical world views as constructions, as texts with particular authors rather than truths, this came at the cost of materials and things, which were driven out of discourse, and rendered irrelevant and invisible. This is the state of affairs that Arjun Appadurai criticised and aimed to change in his seminal edited volume *The social life of things* in 1986, and it still appears to be dominant in 2003, when Karen Barad (2003, 801) writes that 'Language has been granted too much power [...] every "thing" – even materiality – is turned into a matter of language or some other form of cultural representation'.

Things, and the materials from which they are made, have definitely arrived, and need not be positioned against language any more. What is more, because things and materials have become an accepted, even required aspect of scholarship, particularly in the histories of art and science, it now becomes possible to point out a curious blind spot within the critique of language's hegemony: the material turn itself has largely been effective through language. Scholars of material culture did not leave language behind and start to converse with things – like those at the Academy of Lagado, in Jonathan Swift's brilliant parody on the ambition of replacing language entirely with material objects – but materialised their scholarship through and in writing. On the one hand, the continuity of language as primary scholarly medium explains why some theoretical writings of the material turn can remain curiously abstract, despite their promise of direct material engagement. On the other hand, scholars who actually work with things, materials and processes adapted their language to fit their object of study better. This is no easy task. In 'The language of art history', Michael Baxandall (1979) found the field to be in need of a demonstrative language that could precisely describe what there was to see and experience in a work of art. Because of its sequential nature, language, he wrote, was intrinsically inapt for capturing the makeup of things, particularly when it came to their materials and textures. He famously illustrated this point through the description of a green lead pencil. Finding words for its particularities, such as 'the scalloped edge of the green paint at the point where it meets the conical end', he actually demonstrated that the gap between words and materials bears a productive potential, if one only takes care to find and shape one's words in such a way that they resist languages' reductive force. Literally writing things 'up' and not 'down' results from the awareness of language's deficiencies, and can produce words more sensitive to their material environment.

I believe that the next step for the study of the histories of materials is to think about and develop a shared language for materials, in which a refined understanding of languages' comparative structure is paramount. Every artist, conservator, art historian, historian of science, chemist, philosopher and materials scientist knows that one material is not another. Yet the generic terminology used to diversify one of the largest possible container terms our language offers – 'materials' – suggests otherwise. Such a language would capture and relate chemical formulae, explain idiosyncratic behaviour in particular historical and geographical settings using different languages, and it would pay attention to the general and specific role materials play in works of art and science.

Material mimesis lies at the heart of a language sensitive to materials, because language relies so much on comparison, metaphor and likeness. To describe material mimesis – the interrelations of materials through superficial visual or physically and chemically deeply engrained likenesses – a refined vocabulary is paramount. In fact, literary studies introduced mimesis as a theoretical concept to understand how fiction is developed from descriptions of the real world.[8] A sensitive language is needed to describe the bafflement we experience in the face of mimesis, something which Michael Taussig (1993, xviii) pinpointed as its core quality: 'to marvel at its wonder or fume at its duplicity, is to sentiently invoke just that history (of imitation) and register its profound influence on everyday practices of representation'. The hundreds of new materials synthesised and engineered during the Industrial Revolution bear witness to that history, for their names derive in part from the materials they are in themselves, and in part from those they mimic. Take for instance the poetic *Galalith*, which means 'milk stone'. Subsumed under the family name of plastic, it was produced by hardening the milk protein casein with the toxic organic compound formaldehyde. The result had the visual and material properties of ivory and horn. It could be carved, turned on the lathe, and dyed with aniline. H. G. Wells (1922) wrote of such synthetic materials that 'many of the first employments of these gifts of science have been vulgar, tawdry, stupid or horrible. The artist and the adaptor have still hardly begun to work with the

FIGURE 19.1 'Original-Kunsthorn Marke "Galalith"'. Sample card no. IV, showing the different colour variants of Galalith or 'milk stone', a new material synthesised of milk proteins and produced in the early twentieth century to imitate horn and ivory. Mustertafel mit Galalith-Erzeugnissen Nr. 4, Internationale Galalith-Gesellschaft Hoff & Co. Harburg (Hamburg) 1928–1930

endless variety of substances now at their disposal'. From this nameless variety, Galalith assumed identity by being named. Worked into buttons, combs, piano keys and knife handles, and with a surprising durability, it convinced myriads of users of its authentic character, one bridging the division between animal (milk), vegetable (formaldehyde), and mineral (stone) – though the last only in name.

A masterfully comical evocation of mimesis's potential to excite wonder and irritation at one and the same time was, like Baxandall's seminal article, written in 1979. In *The hitchhiker's guide to the galaxy*, Douglas Adams (1995, 92) lets his thirsty hero stumble upon a particularly deceitful specimen of material mimesis in the cafeteria of a spaceship. Here, Arthur Dent finds 'a Nutri-Matic machine which provided him with a plastic cup filled with a liquid that was almost, but not quite, entirely unlike tea'. To let such materials speak, those that are almost, but not quite, entirely unlike others, is the next challenge for the material turn and those who study materials in all their beautiful, mimetic and mimicking complexity.

♦ Sophie Pitman *is a cultural historian of the early modern period with a particular interest in clothing, textiles, sumptuary law, and issues of luxury. She considers how mimesis in fashion operated to overcome the stumbling-block of social distinction in the face of sumptuary legislation in the early modern period:*

Sophie Pitman: Fashion Materials

Many iconic early modern fashions did not rely on the most sumptuous materials, but instead utilised innovative fabrics and techniques that imitated the sensory effects of luxury materials. Through my research, which examines material mimesis using archival, visual, and material sources and through hands-on reconstruction, I explore the ways in which skilled craftspeople imitated visual and material effects in textiles and other materials, which led to new craft specialisations, diversified the market, cleverly skirted legal restrictions, and enabled people across the social spectrum to participate in fashion. I am also interested in recovering how mimetic fashions might have been thought about by the early modern men and women who wore them.

Mimetic materials provided the non-elite with fashionable dress within their budget and in line with sumptuary laws that often restricted the use of fine fabrics, rare dyestuffs, and exaggerated silhouettes. Many of these imitations, like mockado (velvet woven with wool and linen or hemp rather than silk) or copper lace (simulating gold) were made by enterprising immigrants, women, and children who were not part of official guild structures, and so invented desirable novelties that were not yet controlled or taxed. We can often follow their material negotiations by seeing how imitation goods retained visual and physical traces of their inspirations. For example, cast pewter buttons still copy the three-dimensional raised patterns created when silk is wrapped around wooden buttons.

Some guilds restricted their members from working with mimetic materials in order to protect both buyers and sellers (there could be harsh penalties for deliberately deceiving a buyer and thus damaging the guild's reputation). But many successful simulants were adopted by guilds or new corporations, such as the Venetian *supialume* makers who controlled the manufacture of blown glass imitation pearls from 1672 onwards. Most mimetic fashions were not designed to mislead the purchaser, but were presumably worn in the hope that they would give a suggestive impression at a slight distance. Sumptuary laws sometimes explicitly forbade the use of fake materials, suggesting that convincing visual effects might be more problematic than the material 'truth'.

For example, Spanish legislation specifically noted in 1551 that hats could not be adorned with gold decorations, even if the gold was fake.[9]

Simulation materials were eagerly consumed by those wealthy and elite enough to acquire the real thing, so they should not be regarded as inferior substitutes. Mockado fabric and 'artificial pearls' are found in elite accounts, so they must have appreciated these alternatives for silk velvets and natural pearls which were both legally and financially available.[10] Courtly splendour required such a magnificent display of extravagance that members of the elite also needed what Timothy McCall (2018) has termed 'material fictions' such as *oricalco* (brass gold substitute) or paste gems and coloured foils in order to create the effect of shimmering brilliance expected of the elites on a vast scale.

In March 2020, the Refashioning the Renaissance project reconstructed Isabella Cortese's recipe for 'counterfeit pearls that look natural', which involved making clay beads, coating them in Armenian bole and egg white, gilding with silver, and adding lustre with parchment glue.[11] While we were initially skeptical of these materials as we worked up close with burnishers and brushes – how could sheet-silver mimic white pearl? – when we glanced across laboratory benches at one another's pearls, we realised that the imitation worked successfully at a distance. Cortese's imitations even promised to improve on nature: 'when you compare it with a real pearl, this will always seem more beautiful to the eye for being more lustrous and rounder'.[12] The language used regarding these objects suggests that mimetic materials were highly regarded simulations of nature made by skilled human hands, fit for even the most important of occasions. When James I was crowned at Westminster, he wore a mix of real and fake gems in his cloth of estate; the invoice lists topaz, sapphire, emerald and ruby alongside 'Stones lyke topasses [...] lyke saphyres [...] lyke emaraldes [...] and other made stones'.[13]

I believe that 'made' materials could be so successful that many early modern imitations are hiding in plain sight. As scholars turn their attention to the mimetic materials of fashion, we might start to reconsider what we see in historical portraits (does Eleonora di Toledo wear a real or a 'more beautiful' fake pearl in her portrait?) and re-examine objects in museum collections using scientific testing to check that objects are what we assume (are velvets woven with silk or blended fibres cleverly treated to imitate silk's lustre?) By paying attention to mimetic materials and reconstructing imitative processes, we can reveal how early modern fashions were not worn to imitate one's superiors but rather were creative responses to social, economic, legal, and material restrictions. We might also consider how the culture of imitation relates to the later

FIGURE 19.2 Sophie Pitman holding a fake pearl made according to instructions by Isabella Cortese, *I secreti* (Venice: Giacomo Cornetti, 1584) next to a natural pearl
IMAGE COURTESY OF THE REFASHIONING THE RENAISSANCE PROJECT

development of synthetics that further accelerated the fashion world into the fast, dynamic, and environmentally damaging industry we know today.[14]

♦ *Trained as a historian of early modern knowledge*, Samir Boumediene *studies how everyday-life practices such as cooking, healing or gardening are governed and commodified. He's particularly interested in the history of plants and the use of* succedanea, *the substances chosen to substitute for medicinal materials. They raise vital questions about cure, trust, and above all what 'it' is that is to be imitated.*

FIGURE 19.3 Studio of Agnolo Bronzino, *Eleonora di Toledo*, *c.*1562–1572. Oil on panel, 77.8 × 58.7 cm
WALLACE COLLECTION, LONDON. IMAGE: CC-BY-NC-ND 4.0

Samir Boumediene: Differences that Matter: Material Substitution, Value and Innovation

In these comments, I will consider material substitution from research I've been conducting on the history of drugs and on the use of *succedanea*. In this perspective, material substitution involves a major philosophical question: what is difference? If we follow the classical distinction between difference of nature and difference of degree, we could consider material substitution as an illustration of the second case: a *succedaneum* is almost the same thing as what it replaces, but with a small difference of degree. In practice, things are more complex. You can replace a material by another one that is *very similar*, but you can also replace it with a *completely different* one.

In the first case, the key question is to determine the differences that matter and the ones that don't. For instance, *Artemisia absinthium* and *Artemisia vulgaris* can be used indifferently in some situations, because there are enough similarities between them. Such an assumption raises several issues, however. Firstly, if you can ignore some differences, you can also hide them, and this is why, in practice, substitution can facilitate fraud. Secondly, the situations in which differences *don't* matter are not as stable as it might appear: Alain Touwaide (2012) has shown that Ancient practitioners needed to follow rules that defined the people, diseases and contexts in which small changes could be hazardous. But, thirdly, the fact that differences *do* matter also opens other possibilities: if a *succedaneum* can in some cases be less efficient than the original, in other cases it can be better. Substitution allows therapeutic modulation and innovation.

Let's consider, now, the second case: how can one material replace another that is completely different? Here, the key question is to determine the property (or the set of properties) shared by two things. For instance, the malleability or resistance of some plastics make them useful for replacing ceramic, wood or bone. In these cases, the artificial substitute is expressly designed around the property it imitates. Although diametrically opposed to the previous example, this one raises exactly the same issues: the substitute may lead to fraud, it may be either worse or better, and it may pave the way for innovation. A specific question is raised when a product has been designed to have just one property. It can be an advantage if the material it replaces has other properties considered to be dangerous, but it can be a problem if the power of the original material resides in the complexity of its structure that the substitute does not mimic. The core of the debate between synthetic pharmacology and phytotherapy lies here.

Hence, the issue of difference is linked to another issue: value. By positioning heterogeneous items on a unitary scale, value creates at once commensurability of and hierarchical differentiation between them. Here I will limit my comments to mercantile value, where the unitary scale is expressed by prices, and where the production of a commodity is captured in two ways of behaving with it: using and selling. This struggle between 'use-value' and 'exchange-value' was at the core of a notional transformation occurring during the sixteenth century. Until that time, as I have argued with Valentina Pugliano, the notion of the *succedaneum* was neutral: it referred to any kind of substitutive remedy.[15] With the development of the exotic drugs trade, a second, depreciative meaning began to appear: as with the German 'ersatz', *succedaneum* referred to a second-choice option. In the language of mercantile value, this was expressed as a lower price. Accordingly, the use of *succedanea* implied a calculation: for whom was low cost more important than better quality?

The depreciative connotation of *succedanea* has been reinforced by their link with fraud, which precisely consists of substituting a less valuable product for the original without declaring it. This has contributed to the neglect

FIGURE 19.4 A goa stone. Made in India from a paste of clay, crushed shell, amber, musk and resin, this object was a common early modern substitute for the stones found inside the stomachs of certain kinds of animal, known as bezoar stones, which served in medicine to treat numerous complaints and as an antidote to poisons. While contemporaries knew that artificial and natural bezoar stones differed in origin and composition, goa stones remained highly valuable commodities throughout the early modern period, and were stored in ornate containers, as shown here

CREDIT: WELLCOME IMAGES. ATTRIBUTION 4.0 INTERNATIONAL (CC BY 4.0) of substitution as a theme in the history of knowledge. Some seminal works, however, have shown how crucial reproducibility was in early modern science and technology: what processes could be imagined to certify that two things or two phenomena might be considered equivalent? In the secrecy of laboratories and apothecaries' shops, fraud occurred not only when practitioners wanted to decrease their costs, but also when they confronted shortages of an ingredient. At any rate, creating an equivalent product, whether at a lower price or not, was a constructive way to face constraints.

If mimesis can be considered as the production of the self, it also consists in understanding the difference between self and other. Adulterating a product requires knowledge of how to conceal differences – and consequently also of how to see them. In seventeenth-century Livorno, for instance, the apothecary Giacinto Cestoni was considered the best supplier of exotic plants: the papers he left show that he knew exactly how they were adulterated. Following the intuition of historians of art, we could say that the best expert is always the *faussaire* or forger.

Another way to understand the role of substitution in the history of knowledge is to focus not only on the substituted thing, but also on the substituting thing. For instance, if we wanted to replace sugar, all ersatz substances will be considered to be 'quasi-sugar' and substitution will be considered to be emptiness. But if we examine this story from the point of view of the substitut*ing* product (stevia, for instance), substitution will be an addition that leads in this case to a new use of the plant. Many of the remedies employed against particular diseases were originally used as substitutes for others (something today referred to as 'drug repositioning'). A large part of the history of medicaments is to some extent continuous with the history of *succedanea*. Accordingly, the value of products derives not only from their acknowledged properties, but also from their capacity to imitate others, or, contrariwise, from their non-substitutability. In other words, high value belongs either to the product that cannot be replaced (in the history of pharmacy, the specific, i.e., the only substance that is effective for treating a particular disease), or to the product that can replace all the others (the panacea).

In today's world, we find this intertwined history of innovation, science, commerce and technology in debates surrounding forms of renewable energy (is it possible to replace carbon?), but also in the production of soy, an almost universal substitute for meat, forage, plastic, etc.[16] This leads me to a final remark. If the search for alternative solutions can be a motor for innovation, it can also make knowledge disappear. In a world where everything can be replaced by the kind of low-cost solutions William Morris criticised in his time, many practices may be lost.[17] When overused, material substitution tends to lead us to forget that differences matter.

♦ Benjamin Aldes Wurgaft *is a historian, writer, and ethnographer whose recent work concerns copying meat by growing it in laboratories. This seemingly most obvious and ethical of mimetic acts, however, is fraught with complexities deriving from meat's entanglement with consumers' aesthetic expectations and their corporeal self-knowledge*:

Ben Wurgaft: Mimicked Meat

There are many ways to mimic meat, defined for these purposes as animal muscle and fat consumed as food. You can fold sheets of bean curd to imitate duck, chicken, pork, or beef, a method traditionally used to provide vegetarian meat in China. You can turn pea proteins into a kind of slurry, along with other ingredients, and then extrude them at high pressure and temperature to create a "burger" with something approaching the texture and flavor of conventional hamburger. Such tactics try to approximate the sensory qualities of animal muscle and fat while using a very different, plant-based, substrate. But why not mimic meat using animal cells? From 2013 to 2019 I conducted ethnographic research with scientists, engineers, and entrepreneurs who hope to produce 'cultured meat', which begins with animal muscle stem cells carefully cultivated in bioreactors.[18] At the time of writing, cultured meat is not yet a consumer product. Two motivations for creating cultured meat predominate. Many in the 'cultured meat movement' hope that they can replace much of conventional industrial agriculture with cultured meat, undercutting, first, the enormous cruelty to animals that industry entails, and second, the significant environmental footprint of that industry; by some accounts animal agriculture produces 14% of the world's greenhouse gases *per annum*, and is very expensive in terms of land and water used. From the perspective of mimesis, though, cultured meat entails both technical challenges and a certain critical perplexity, the latter because it does something quite unusual: copying a naturally occurring form, animal flesh, not by using a different substrate, but by using the expected natural substrate, artificially grown. You could call cultured meat a 'carnal skeuomorph'.[19] Skeuomorphs (Greek for 'container-shapes') are objects defined by their shape, rather than by a necessary relationship between material and shape. Sometimes they develop because a group of designers and builders continue to produce the same form while working with new materials.

In Classical Greek buildings, the 'dentils', little square protrusions under cornices, are thought to be a remnant of the ends of wooden cross beams used before the Greeks began building with stone. But what might it mean to take the form of meat (a chicken drumstick, say) and then fill it with lab-grown cells, producing meat as a kind of skeuomorph of itself? Such a gesture would imply that the material we call 'meat' has become significantly, and uncannily, plastic. This would utterly change the nature of meat as a material. Cultured meat could utterly sever the organic relationship between material and form. But notably, cultured meat scientists haven't yet (at least to this researcher's knowledge) successfully copied drumsticks, or any other form of meat that is clearly part of the animal body. This is because of one remaining technical hurdle yet to be cleared: the thickness of tissue we can grow in a bioreactor. While teams have successfully grown sheets of cells and then shaped strands of muscle fibers into a loose collection of tissue to produce hamburgers and sausages, a steak, or any other form of meat very reliant on texture, would be much harder. Such forms rely on layers of muscle grown (with some interleaving fat) in precise configurations, much as they occur in the animal body. To grow them would require a bioreactor capable of transporting nutrients to all the cells; mammalian cells, for example, can only thrive within some 200 micrometers of a nutrient supply, which is why sheets of cells are easier than more three-dimensional constructs. But if the future of meat mimesis remains unclear, the present is already uncanny. There are already versions of fast-food meat, such as the McDonald's McRib, which involve bits of meat pressed into new, meat-like shapes: meat's relationship with itself is becoming more skeuomorphic even as I write.

♦ Leah Anderson *is an artist and teacher whose research explores the status of the unique, the multiple, and the copy in the work of art and other cultural practices, with a keen interest in material and immaterial expressions of (con) text.* Maximilien Urfer *is an artist and teacher, with a diverse practice that interrogates the points of articulation and overlap between different media (sound, performance, video, drawing, painting, text …) and their cultural forms, embedded within a space without differentiation between art and life. They have been undertaking short informal studio collaborations since the beginning of 2020. Here, they reflect on whether all forms of mimesis are the same.*

Leah Anderson and Maximilien Urfer: But the Same Things (In Three Chapters)

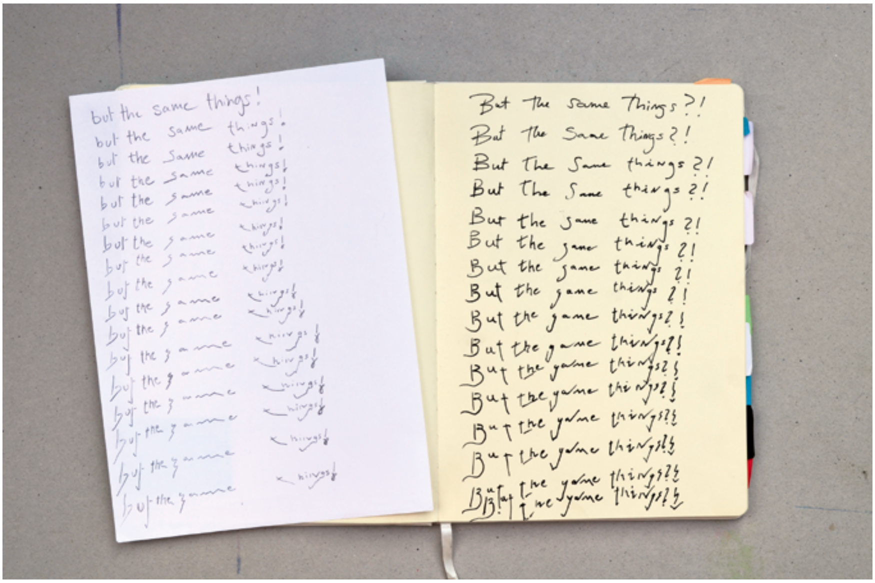

FIGURE 19.5 Maximilian Urfer and Leah Anderson, *But the same things* (2020). Pen and ink on paper

1

It's a weeknight in January, 2020. The two artist comrades are seated opposite each other on the train. They are going to the opening night of the Geneva Art Fair. They joke and laugh about the foibles of language and translation as well as the posturing of people who attend fancy art fair parties.

The irony is not lost on them.

MAXIMILIEN (in exaggerated local French accent): '*Mais les choses pareille!*'

(Between breaths of laughter): 'So how would you translate that literally?'

LEAH (in English): 'Hmm, let me think. I know: But the same things'.

MAXIMILIEN and LEAH: (laughter)

MAXIMILIEN (in English with a slight French accent especially on the 'th' of 'things'): 'But the same things. Yeah! But the Same things!'

MAXIMILIEN and LEAH: (laughter)

LEAH (mimics in English with an exaggerated French accent): 'But the same things! It works pretty well in English too'.

MAXIMILIEN and LEAH: (laughter)

2

It's a hot Wednesday in July, 2020. Maximilien and Leah are at the MODERNA art studio. They are drinking coffee and looking at a new stack of vinyl records. They begin playing different discs and messing around mimicking DJ gestures with the turntable system Maximilien set up. After an hour or two they redirect their attention to the mimesis project. They talk through their different ideas for a while, then Maximilien walks over to his shelf of paper, removes a sheet, and grabs a clipboard and pencil.

MAXIMILIEN: (In French): 'At some point it's like we are always saying to students at the school, isn't it? Stop overthinking and just do something […]'

LEAH (opens her notebook to a fresh page, removes a pen from her desk and responds in English): 'Yeah you're right, let's give it a try'.

MAXIMILIEN (in French): 'What should the sentence be?'

LEAH (in English): '*But the same things*, of course'.

MAXIMILIEN and LEAH: (each writes the sentence on their respective pages of paper. They pass their papers and pen/pencil to the other and try to copy (as best they can) the sentence the other has written. They repeat this copying again and again, until their pages are full. It takes about 45 minutes. They chat, in a mix of French and English, about their observations of the activity unfolding, and the evolution of their project.)

3

It's a Wednesday in July, 2020. MAXIMILIEN and LEAH are in the music room trying out another activity and trying to work with some questions that remain after their mimetic drawing session earlier that month. They each play a two-minute segment on the keyboard and then try to recreate from memory (as best they can) the other's composition. As they listen to the recording playing back their sound experiment, they discuss what the limits between copying, reproduction, and mimesis might be.

LEAH (in French): 'Yeah, maybe that is it! Maybe that's where copying and mimesis are different'.

MAXIMILIEN (in French): 'Yeah. It's about how mimesis allows corruption and deviation in a copy because of how it incorporates the subjective'.

Bibliography

Asao, Toyonobu *et al.*, 'Aflatoxins B and G', *Journal of the American Chemical Society*, 85, No. 11 (1963), 1706–1707.

Auerbach, Erich, *Mimesis. Dargestellte Wirklichkeit in der abendländischen Literatur*, 9th edition, Tübingen and Basel, 1994 [orig. 1946].

Autumn, K., 'Properties, principles, and parameters of the gecko adhesive system', 225–255, in: *Biological adhesives* (A. Smith & J. Callow, eds.), Berlin 2006.

Barad, Karen, 'Posthuman performativity: Toward an understanding of how matter comes to matter', *Signs*, 28 (2003), 801–831.

Baxandall, Michael, 'The language of art history', *New literary history*, 10, No. 3 (1979), 453–465.

Benjamin, Walter, *The work of art in the age of mechanical reproduction* (J.A. Underwood, trans.), London 2008 [orig. 1936].

Bijker, Wiebe E., *Of bicycles, bakelites, and bulbs: Towards a theory of sociotechnical change*, Cambridge, Mass. 1995.

Boumediene, Samir & Valentina Pugliano, 'La route des succédanés. Les remèdes exotiques, l'innovation médicale et le marché des substituts au XVIe siècle', *Revue d'histoire moderne et contemporaine*, 66, No. 3 (2019), 24–54.

Buechi, George *et al.*, 'Total synthesis of racemic Aflatoxin B1', *Journal of the American Chemical Society*, 89, No. 25 (1967), 6745–6753.

Cortese, Isabella, *I secreti*, Venezia 1584.

Du Bois, Christine M., *The story of soy*, London 2018.

Gibson, William, *Neuromancer*, London 2001 [orig. 1984].

Hughes, Thomas P., *Networks of power: Electrification in Western society, 1880–1930*, Baltimore 1985.

Leslie, Esther, *Synthetic worlds: Nature, art, and the chemical industry*, London 2005.

McCall, Timothy, 'Material fictions of luxury in Sforza Milan', 239–276, in: *Luxury and the ethics of greed in early modern Italy* (C. Kovesi, ed.), Turnhout 2018.

Merki, Christoph Maria, 'Sugar versus saccharine: Sweetener policy before World War I', 192–205, in: *The origins and development of food policies in Europe* (J. Burnett and D. J. Oddy, eds.), London & New York 1994.

Minar, Edward H., 'The thinging of the thing: A late Heideggerian approach to skepticism?', *Philosophical topics*, 27, No. 2 (1999), 287–307.

Miodownik, Mark, *Stuff matters: Exploring the marvelous materials that shape our man-made world*, New York 2014.

Morris, William, *L'âge de l'ersatz et autres textes contre la civilisation moderne*, Paris 1996.

Mueller, Lucas M., 'Risk on the negotiation table: malnutrition, toxicity, and postcolonial development', 138–162, in: *Risk on the table: food production, health, and the environment* (A.N.H. Creager & J.-P. Gaudillière, eds.), New York, 2021.

Pitman, Sophie, 'Prodigal years? Negotiating luxury and fashioning identity in a seventeenth-century account book', *Luxury: History, culture, consumption*, 3, Nos. 1–2 (2016), 7–31.

Pitman, Sophie, 'Codes: Redressing London – sumptuary laws and the control of clothing in the early modern city', 65–86, in: *A cultural history of law in the early modern age* (P. Goodrich, ed.), London 2019.

Pitman, Sophie, 'Una corona di ambra falsa: imitating amber using early modern recipes', online: https://refashioningrenaissance.eu/imitating-amber/ [accessed 8 December 2020].

Pitman, Sophie, 'Imitation in early modern clothes and accessories', online: https://refashioningrenaissance.eu/experiments/imitation/ [accessed 8 December 2020].

Spilman, John & William Herrick, 'Bill for repairing the Crown Jewels for the Coronation of King James the First of England', 4 June 1604, in: Historical Manuscripts Commission, *Report on the Laing manuscripts preserved in the University of Edinburgh*, vol. 1, London 1914.

Taussig, Michael, *Mimesis and alterity: A particular history of the senses*, London 1993.

Touwaide, Alain, '*Quid pro quo*: Revisiting the practice of substitution in ancient pharmacy', 19–61, in: *Herbs and healers from the ancient Mediterranean through the medieval West* (A. van Arsdall & T. Graham, eds.), Farnham 2012.

Trost, Barry M. & F. Dean Toste, 'Palladium catalyzed kinetic and dynamic kinetic asymmetric transformations of γ-acyloxybutenolides. Enantioselective total synthesis of (+)-Aflatoxin B1 and B2a', *Journal of the American Chemical Society*, 125, No. 10 (2003), 3090–3100.

Wells, Herbert G., *A short history of the world*, London 1922.

Wunder, Amanda, 'Spanish fashion and sumptuary legislation', 243–272, in: *The right to dress: Sumptuary laws in a global perspective, c.1200–1800* (G. Riello & U. Rublack, eds.), Cambridge 2019.

Wurgaft, Benjamin Aldes, *Meat planet: Artificial flesh and the future of food*, Oakland, Calif. 2019.

Wurgaft, Benjamin Aldes, 'Meat mimesis: Laboratory-grown meat as a study in copying', *Osiris*, 35 (2020), 310–323.

Wurgaft, Benjamin Aldes, 'Designing a new future for flesh: The case of the carnal skeuomorph', *Mold magazine*, 18 February 2020, online: https://thisismold.com/process/manufacture/designing-a-new-future-for-flesh-the-case-for-the-carnal-skeuomorph#.XvuL8_J7mRs, accessed 8 December 2020.

Endnotes

1 Bijker 1995; Hughes 1985; Wurgaft 2019, 2020a; Miodownik 2014. 'Geckel' is the name of a biological adhesive that uses carbon nanotubes to mimic the structure of a gecko's feet (Autumn 2006).

2 Mueller 2021.

3 'Memorandum of conference. Subject: Aflatoxin (peanut mold toxicity)', 21 November 1962, Folder Aflatoxin Studies, 1962, 1963, vol 1; General Subject Files 1938–1974, 1963, 426.6 THRU 428.2.-.31, Box 3511; Records of the Food and Drug Administration, Record Group 88; National Archives at College Park, Md.

4 Asao *et al.* 1963.

5 Buechi *et al.* 1967.

6 Trost & Toste 2003.

7 Minar 1999.

8 Auerbach 1994.

9 Wunder 2019, 258.

10 See examples in Pitman 2016, 2019.

11 For more on this, see Pitman 2020a, 2020b.

12 Cortese 1584, 205.

13 Spilman & Herrick 1914, 94. Thanks to Michael Pearce for this reference.

14 This research is part of the Refashioning the Renaissance project that has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement number 726195).

15 Boumediene & Pugliano 2019.

16 Du Bois 2018.

17 Morris 1996.

18 See Wurgaft 2019.

19 See Wurgaft 2020b.