

THE ARTIFICIAL AND THE NATURAL





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THE ARTIFICIAL AND THE NATURAL

An Evolving Polarity

edited by Bernadette Bensaude-Vincent and William R. Newman

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INTRODUCTION: THE ARTIFICIAL AND THE NATURAL:

STATE OF THE PROBLEM

Bernadette Bensaude-Vincent and William R. Newman

With each passing day the traditional boundary between the natural and the artificial becomes less distinct. Consider a few examples from the realm of biology. Bioengineering has proposed strawberries with genes taken from fish, “genetic artists” boast of having made a phosphorescent rabbit by implanting DNA from jellyfish, and in Mexico, genetically modified “Frankencorn” has possibly made its way into the wild, hybridizing with varieties of maize hitherto untouched by humans. Are such living entities rendered “artificial” by the human intervention that modified their genetic makeup? If so, does it not follow that hybrids produced by old-fashioned cross-breeding are human-made as well, and that every tomato or pear that we eat is an “artificial” product? Perhaps the reader will recoil at this suggestion, since it would imply that virtually every fruit, vegetable, meat, or drink that serves for our nutrition is factitious. So let us imagine for the moment that the products of hybridization and contemporary biotechnology are “natural.” In that case, further problems arise. If we do not label the products of bioengineering as artificial, then what right does any human-made product have to the term? Why should a polymer or dyestuff made by tinkering with coal-tar molecules be any more artificial than a rabbit whose DNA has been altered so that it glows in the presence of a certain wavelength of light? If we turn to the realm of cold, hard silicon, similar questions emerge. Computer science has bridged the chasm between man and machine, giving us “Deep Blue,” the IBM product that defeated Garry Kasparov at chess. Unsatisfied with this conquest, the computational laboratories of MIT are building robots that simulate human emotion, while researchers at Carnegie Mellon are devising ways humans may one day give up their biological bodies, allowing computers to become the recipients of their consciousness, digitized and uploaded into a suitable machine-readable matrix.¹ Assuming the eventual feasibility of this science fiction scenario, where then would the line be drawn between an artificial and a natural human being? The triumph of Ian Wilmut

and his team in engineering a sheep cloned from a mammary cell just a decade or so ago now seems a mere memory—a distant prelude to the polyvalent symphony of human intervention that is sure to follow.

The recent products and future dreams of biotechnology and artificial intelligence present striking challenges to the commonsense distinction between the natural and the artificial. But in reality this dichotomy has always been confounded by human activities in the form of even the most primitive machines and technologies. All materials, whether natural or artificial, are first extracted from nature and then processed according to human purposes. Cotton, wool, or wine—items that we usually consider natural—are in fact the result of a long manufacturing process including many sophisticated chemical and mechanical operations. At the same time, artifacts are never really unnatural. As physical and chemical systems they belong to nature and generate a number of effects independent of the intentions of their designers. And of course our artifacts have such a profound effect on ecosystems that their mass production increasingly raises important environmental issues.

If we turn from individual “natural products” to nature in the wild, it is clear that we will fail to find the absolutely natural here either. Over centuries and millennia of agricultural and industrial activities nature has been deeply reconfigured by humans. “Native forest” in the sense of woodland absolutely untouched by humans exists nowhere but in the human imagination. No part of the earth has been completely unaffected by the effects of human technologies. This is by no means a recent discovery resulting from an increasing concern with environmental issues. As early as the eighteenth century, when the first artificial soda was synthesized and when gardens with sheep grazing in meadows became fashionable—supplanting the *jardins à la française*—Jean-Jacques Rousseau clearly realized that the state of nature was an intellectual construction, an indispensable fiction for ascertaining the foundations of the political order.² Given these and other considerations, we should reasonably conclude that there is no such thing as a great divide between nature and art. More precisely, instead of opting for an absolute distinction of quality between the artificial and the natural, one should accept only a gradual distinction of degree.

But the omnipresence of this divide in our culture and its persistence in contemporary debates cannot be overlooked. As Roald Hoffman pointed out in *The Same and Not the Same*, the “rational” arguments used by modern chemists in order to fight the popular prejudice against chemicals are largely useless, because they ignore the cultural aspects of

the issue.³ The concept of nature functions and has always been used as a cultural value, a social norm, and a moral authority. Debates over art and nature generally conceal the broad questions that undergird and drive them: is *technē* a continuation of nature's activity (tools being viewed as something like the prolongation of a person's hand), a rebellion against nature, or a challenge to nature? The nature of technology and its legitimacy, the situation of humans as technicians among other animals, and the status of artisans in society are among the broad issues at stake. Because of the importance of such philosophical implications and cultural roots in all the debates over the impact of technologies, we cannot simply dismiss the distinction between art and nature as a "popular prejudice" or as an "irrational nostalgia for the past." Rather we have to disentangle the cultural roots of current debates about new technologies.

How then can we expect to reflect on our current situation without having taken a census of the past? The present book originated out of precisely this perceived need, for the editors were struck by the absence of any combined attempt by specialists of different periods and various disciplines to consider discussions of art (in the broad sense) and nature in their respective fields of expertise. It is not too much to suggest that the resulting book is the first collective effort to devote itself specifically to the issue of the artificial and the natural over the *longue durée*, incorporating the perspectives of historians of science, art, and philosophy.

CHANGING BOUNDARIES

The task is difficult, since discussions about art and its power form a deep and perennial issue with roots in the civilization of classical antiquity. Given the paucity of research that scholars have devoted to this subject, we could hardly hope to engage the topic on a comprehensive scale. Rather than aiming at a grand history of the art-nature dichotomy in the Western world, we have therefore assembled a collection of disciplinary and chronological core samples in an effort to understand them in their specific contexts. For various periods, we try to bring the concepts of nature and art into confrontation with the scientific and technological practices of their times and with contemporaneous philosophical and religious debates. Even the few selective samples that we have brought to light reveal surprising patterns. Perhaps the most striking result that emerges from the following chapters is the fact that while the opposition between art and nature is itself a major leitmotif throughout

the history of the West, the forms that this dichotomy takes are themselves far from stable or constant over the centuries. On the contrary, the divide is continuously challenged and reassessed. The pseudo-Aristotle of the *Mechanical Problems*, for example, was amazed by the power of circular wheels set in tandem to drive mechanical devices. In recognition of the circle's ability to make heavy things move against their natural tendencies, pseudo-Aristotle remarked that mechanics works "against nature" (*para physin*). Centuries later, the spell of machines had grown so much in power that Descartes and his followers would reject this now-hoary dictum, claiming that machines were not only not contrary to nature, but that nature itself was mechanical. If one could only extend his field of vision to the suitably small, he would see nothing but mechanical operations underlying our sensible universe. On the other hand, the historian can find many instances where the power of a given artificial product to challenge nature diminishes over time instead of becoming more compelling. The superficial patinas and colorations applied to metals by late antique alchemists were thought in some cases to yield products that were "superior to the natural." In the Middle Ages, however, such products came to be routinely disparaged by alchemists themselves as "sophistical," fraudulent, and artificial. Clearly the bar had been raised in the challenge between artifice and nature, partly as a result of technological progress in the art of alchemy.

The shifting boundaries between the artificial and the natural are revealed in another way as well that will appear throughout this book. We refer to the absence of any clear and unambiguous terminology for distinguishing artificial and natural products in the English language (or any language that we know of). This may seem a surprising claim, given the rich vocabulary at our disposal for distinguishing the genuine and natural from the inauthentic and artificial. But we have already pointed to some borderline cases where living creatures have been modified to the point that many would call them unnatural and even artificial. Indeed, living things such as plants, seeds, genetic materials, and transgenic animals are considered patentable in a number of countries, and fall under the same legal strictures as "inventions" on the assumption that they result from human art or intervention.⁴ But are they artificial in the sense that an imitation leather belt or a plastic woodgrain desk bears that attribute? Surely not, one may say, since a bioluminescent rabbit is a new creation, not an imitation of anything else. The rabbit, moreover, has not been created out of whole cloth, but is merely a normal rabbit

whose nature has been tweaked by science. At what point, then, does the natural object cease to be natural, and become artificial?

A SPECTRUM OF RELATIONS

The distinction between the artificial and the natural has traditionally been addressed by considering the limiting cases supplied by examples of pure artisanship and unaided nature. A most influential instance of this approach can be seen in book 2, chapter 1 of Aristotle's *Physics*. The Stagirite argues there that a bed cannot be natural, since if a planted bed could grow and bloom, it would not sprout beds, but trees. The shape and structure of the bed are merely human impositions on the unchanged matter that remains a natural product. The *physis*—or “nature”—of the wood itself remains unaffected by the artificial form imposed on it by the carpenter. But in a later passage—often ignored by modern commentators—in the same book of the *Physics* (chapter 8) Aristotle undermines this clear distinction, pointing out that there are two sorts of arts—those that imitate nature and those that lead it to a greater state of perfection. The physician's art can be taken as an example of the second sort, since it brings the diseased body to health without changing the essential nature of the body itself. Well and good, one may say, but where does this perfecting process stop? To return to the example of alchemy, the scholastic practitioners of that discipline were often wont to say that they did not make artificial precious metals but genuine natural ones, since they merely perfected the base metals, achieving what nature could have done beneath the earth if there had been enough time and sufficiently pure materials. Pushing this line still further, they argued that their art could make metals and minerals better than those available in nature, and that such products could sometimes serve in turn as macrobiotic medicines for humans. Not only could the natural human lifetime be greatly extended by the ingestion of such products, some alchemists argued; it was possible even to refashion humans themselves by a process of artificial incubation in a flask. The result of this process, the homunculus, would have remarkable powers unshared by other human beings, such as the gift of preternatural intelligence. All of this discussion was couched in the language of the traditional debate between the artificial and the natural, and the alchemists almost invariably saw themselves as perfecting nature in the Aristotelian sense.

Despite the extravagant character of the homunculus discussion, one can see how it underscores the problems of the approach taken by

Aristotle in the famous example of the bed. The limiting cases of the purely natural tree and the utterly artificial bed allow for no intermediate gray area, and are inadequate in trying to determine whether something like a homunculus, or for that matter a transgenic rabbit, is a real human or a real rabbit. Or to use a less exotic example, it would be difficult to employ Aristotle's criteria in determining whether a product of grafting, such as the tree created when an apricot scion is inserted on a plum tree, remains a natural plum tree. Could one deny that the physis of the tree has been changed by human intervention, given that it now produces apricots rather than plums? How far can the nature of a thing be pushed before that thing ceases to belong to its original species in the natural world? The more general question is far from trivial, and points to the inherently relativistic character of the categories "natural" and "artificial."

The problem is only intensified for the Aristotelians by the position that the Stagirite takes in other works beyond the *Physics*. Book 4 of Aristotle's *Meteorology*, a work whose authenticity has been questioned by philologists (though not in the premodern era), argues that the "artificial" boiling and roasting carried out in a kitchen are analogous, and perhaps identical, to processes that occur naturally within the earth. After all, these arts and others originated from human attempts to mimic nature, as Aristotle points out. But this opens up an entirely distinct avenue for asserting the naturalness of human products. If we take the emphasis off of the product itself, and focus on its mode of production, then we can say that something as seemingly unnatural as glass is actually a product of nature. After all, by one interpretation of *Meteorology* 4 the heat employed in fusing sand and alkali together into a hard, clear substance is the same as the heat that melts stone in volcanoes. Since we use nature's own agencies in making glass, the product is itself natural by this line of reasoning. Hence one tradition in medieval scholasticism argues that manufactured glass is a "stone," and just as natural as any stone found in the world at large.⁵

Such ambiguities are hardly the exclusive province of our ancestors. We moderns often discuss the differences between the artificial and the natural without explicitly considering the kinds of action that art is said to exert on nature. Verbs matter here insofar as the substantives *nature* and *art* are defined by their mutual relation. Does art mimic nature? Represent nature? Simulate nature? Complete nature? Improve on nature? Counterfeit nature? Violate nature? In addition to the difficulties engendered by ignoring these verbal distinctions, a group of concepts

and terms clustering around the troublesome idea of imitation provides particular problems. When we say that something is an artificial imitation of a natural product, do we mean that the former is necessarily different from the latter in some respect other than the mere fact that it is human-made? Let us consider the nineteenth-century examples of celluloid and ivory, which clearly bore the same relationship to one another as fake fur and real fur—one was viewed as the genuine thing, the other as a poor substitute, a sort of counterfeit. But what about the artificial vitamin C manufactured by pharmaceutical supply houses and the natural vitamin C extracted from rose hips? The ascorbic acid that makes each of these substances capable of being called “vitamin C” is the same in both cases. We cannot simply say that one is fake and the other real.

For this reason, chemists speak of “synthesizing” natural products—that is, reproducing the very molecules that nature employs—when they want to express a relation of identity between the natural and the manufactured product. But even chemists acknowledge that while they can produce pure substances by synthetic processes, they cannot introduce all of the impurities that are typically found in a natural product. As Roald Hoffmann has pointed out, the vitamin C from rose hips will contain a host of other molecules in varying proportions that the chemist does not try to reproduce. Although the impurity of natural substances is not a problem for someone making ascorbic acid, it does present huge difficulties for those trying to reproduce natural odors and tastes. Anyone who has tasted synthetic strawberry or watermelon flavoring can vouch for the reality of the artificial-natural dichotomy, even if the main active ingredients of the manufactured flavoring are identical to the preponderant molecules in the natural substance.

In a certain sense, then, even the products of synthetic organic chemistry can be viewed as ersatz—they often replace (*ersetzen*) a natural substance, but are not always equivalent to it in every respect. Similar problems arise in the laboratory manufacture of precious stones, natural pigments, and medical products. The synthetic product is often too pure to do the job of the natural one and hence the former is artificial in at least two senses—first, by the brute fact that it is a product of human intervention, and second, because it is chemically or physically different from its natural exemplar. Still, one has to admit that a synthetic pure substance bears a closer relationship to its natural model than does an outright counterfeit, like margarine, polystyrene pearls, or simulated leather. The latter are mere substitutes for a natural product that work by deluding the senses. Just as we may be fooled by a *trompe l’oeil*

painting when looking at it from a distance, but recognize its illusory character on approaching, so taste, touch, or smell immediately reveals the fraudulent character of imitation butter, pearls, or hide (at least in their incarnations as of 2007).

CONFLICTING PERSPECTIVES

As we have now seen, the terms *natural* and *artificial* mean quite different things, depending on the context and point of view in which they occur. Indeed, one can reach quite opposite conclusions when starting from different standpoints. A thing's "naturalness" or "artificiality" has one meaning when we are talking about its origin (extracted from nature versus human-made) and quite another when we are discussing its inherent qualities. For instance, metals are "natural" since they are extracted from nature whereas plastics are "artificial" since they have to be synthesized. But in the language of ordinary life and commerce, plastics are often more "natural" than metals because they are more flexible and soft, and less conductive of heat and electricity, making them more like biological tissue. Similar conflicts occur when we are talking of the end product itself or of its mode of manufacture. Let us first consider product rather than process—in this case, an important distinction hinges on whether the producer has consciously imitated a natural product or rather altered a naturally occurring thing in some way that yields a result not found in nature. Assuming that the product is in some sense an imitation, however, the measure of its artificiality is radically conditioned by the extent of variation between the product and its exemplar—fake leather is not artificial in the same sense as synthetic strawberry flavoring, even though both may be obviously different from their natural models. In the second case, where process is the determining factor, the range of artificiality is itself a historically conditioned artifact of the manufacturing techniques present in a given time. To give but one example of this fact, the Italian painter of the fifteenth century Cennino Cennini labeled such pigments as vermilion produced by subliming mercury with sulfur and minium made by calcining lead as "artificial." Few of us today (with the possible exception of those who specialize in the manufacture and use of "historical pigments") would think of these chemicals in such terms, any more than we call metallic silver or copper "artificial" merely because they have been reduced from a sulfide ore at some point in their existence in order for us to arrive at a more useful product. As the man-

ufacturing process for a particular yield becomes more commonplace, the distinction between the artificial and the natural loses its force.

CONCEPTUAL AND MATERIAL PRACTICES

Needless to say, the full range of nuance in the antithetical terms *artificial* and *natural* cannot be addressed in a single introduction. Rather than dwelling on generalities, the subsequent chapters invite the reader to consider the interplay between the conceptual dichotomy “art-nature” and specific practices such as medicine, painting, collecting, building machines, or performing chemical syntheses. To what extent can the materials worked on and the actions of the technician transforming the raw materials shape and reshape our concepts of nature, or of life itself? Or to invert the question, how much have the cultural patterns of representation of nature and art influenced specific technological changes? Fierce debates over the artificial and the natural have been raised by very diverse practices over the course of time, including medicine, alchemy and metallurgy, mechanics and the making of automata, agriculture and gardening (grafting), breeding (hybridization and selection), painting and sculpture, chemical synthesis, materials technologies, cybernetics and artificial intelligence, genetics, and even patenting (since the distinction between art and nature, invention and discovery, is the basis of most patent legislations).

This book cannot cover such a wide range of fields. We have been forced to leave out many interesting subjects, such as the eighteenth-century enthusiasm for artificial flowers or Darwin’s comparison between natural selection and breeders’ selection.⁶ However, in order to give a sense of the diversity of practices that formed the core of the debates over time, we have not limited the discussion to the artificial-natural divide in the sciences alone. Until very recent times, the term *art* referred both to the field now called “fine arts”—mainly painting, the plastic arts, and literature—and to what is now called “technology.” One major advantage of the historical perspective developed in this book is to go beyond the recent divide between “the two cultures” and to restore *art* to something like its full set of traditional meanings. Without an understanding of the original domain of *art*, one cannot appreciate the development of the art-nature dichotomy. Classical civilization already had problems with the issue of trompe l’oeil technique in visual art and persuasive rhetoric in poetry, both of which were thought by

Plato and various others to be morally questionable. Over the course of time, similar arguments have arisen in fields as diverse as alchemy and bioengineering. We therefore invite the reader to consider the similarities and differences that emerge from these discussions in their respective disciplines as they develop over the period of emerging Greek civilization up to the present.

OVERVIEW OF THE BOOK

Our book begins with Heinrich von Staden's magisterial contribution "Physis and Technē in Greek Medicine" (chapter 2). Von Staden opens his chapter with the observation that physis—nature—had multiple meanings and uses in the Greece of the Hippocratic writers, beginning in the fifth century BCE. Not only was there nature at large, but also the natures of individual beings, the natures of their parts, and the natures of the poisons and remedies that acted on those parts. In contrast to these multiple natures was the technē—the art of medicine—which employed the *dynamis* or powers of drugs, regimens, and of the body itself, to combat disease. At times, Von Staden points out, the adversarial relationship between the medical art and disease expanded into a surprisingly general account of the relationship between art and nature as a whole. Hence, in a seemingly Baconian fashion, the Hippocratic work *On the Technē* speaks of art as violating nature by means of "forcible constraints." Using the metaphor of judicial torture, the Hippocratic author recommends that drugs be employed to make the patient evacuate humors that will reveal the inner state of his body—hence nature is forced to inform on itself in the same way that a slave would be forced to reveal incriminating information. Although this strikingly agonistic opposition between art and nature was not developed further by Greek physicians, Von Staden presents additional material to show that the possibly artifactual character of dissection and vivisection led to a reluctance on the part of the ancients to develop anatomy to its fullest potential. Finally, he considers the remarkable work of the Hellenistic physician Erasistratus, who not only rejected the Greek taboo on vivisection, but who explicitly viewed the body in mechanical terms. In a way that will bring to mind the millennia-later discoveries of Harvey and Descartes, Erasistratus seems to have borrowed the image of the recently invented double-action pump from the engineer Ctesibius and used it to explain the workings of the human heart.

Chapter 3, Francis Wolff’s “The Three Pleasures of Mimesis According to Aristotle’s *Poetics*,” carries the discussion of *technē* and *physis* beyond the realm of medicine and natural philosophy into the arena of aesthetics. As Wolff points out, early modern writers on the fine arts tended to employ arguments taken from Platonic and Aristotelian discussion of the arts as a whole (including all branches of technology) when writing about painting, sculpture, and poetry. In doing so, however, they often failed to note that Aristotle himself had carefully separated off the fine arts and created a separate category for them in his *Poetics*. There Aristotle designates poetry, drama, and the visual arts as *technai mimētikai*—mimetic arts, because their *raison d’être* lies in the realm of mimicry. Wolff argues, nonetheless, that Aristotle saw the *technai mimētikai* as being analogous to the other arts in an important respect. Most of us are familiar with Aristotle’s theory of four causes, developed in book 2, chapter 3 of his *Physics* and elsewhere. In the famous example of a statue, for example, Aristotle argues that the material cause is the bronze out of which the effigy is made, the efficient cause is the sculptor or his hands, the formal cause is the idea of the statue in his mind, and the final cause is the purpose for which the statue is made. Wolff argues that a parallel system of causation implicitly operates in Aristotle’s discussion of the mimetic arts. By this line of reasoning, the material cause is the medium that the artist employs—shapes and colors in painting, words for literature, rhythm and melody for music, and so forth. The formal cause is the idea in the artist’s mind of the thing represented, the efficient cause is the agency of representation, for example the narrator or the actors in epic poetry and drama, and the final cause for all the *technai mimētikai* is pleasure—the pleasure of mimicking and of observing mimicry. Wolff thereby provides an important new element to our understanding of the concept of “art” in antiquity.

The book’s fourth chapter, “Art and Nature in Ancient Mechanics,” by Mark J. Schiefsky, provides a nuanced and original reading of the complex relationship between art and nature in the writings of ancient mechanical engineers. Beginning with the foundational *Mechanical Problems* of pseudo-Aristotle, Schiefsky shows that this text cannot be used to support the mistaken idea that Aristotelian science ruled out knowledge of nature arrived at by employing “artificial” techniques and interventionist processes (this widespread view has elsewhere been referred to as the “noninterventionist fallacy”).⁷ Schiefsky is particularly concerned with discrediting the oft-cited position of the historian Fritz

Krafft that Greek mechanicians viewed their discipline as “tricking” or subverting nature itself, with the implication that this made mechanics an invalid way of learning about nature. Indeed, Schiefsky points out that Aristotle himself often draws elaborate analogies between art and nature, and at times even seems to blur the distinction between the two. In support of his position, Schiefsky offers an important and controversial new reading of *Physics* II 8 199a15–17, where Aristotle distinguishes between arts that mimic nature and those that complete nature or bring it to a state that it could not otherwise attain. In Schiefsky’s novel reading, mechanics itself could be viewed as an art that completes nature, thus throwing further doubt on the thesis of Krafft and others that the ancient mechanists viewed their discipline as a field necessarily occupying an antithetical relationship to nature and its products. Schiefsky further argues that mechanics operated in a way similar to an Aristotelian subordinate or “middle” science in the Stagirite’s view, occupying much the same relationship to physics as did harmonics, astronomy, and optics. Schiefsky’s sustained and detailed defense of this fresh viewpoint is bound to open up new questions for scholars of ancient, medieval, and early modern mechanics, with ramifications leading up to Galileo and Descartes.

William R. Newman’s contribution, “Art, Nature, Alchemy, and Demons: The Case of the *Malleus maleficarum* and Its Medieval Sources” (chapter 5), carries the Aristotelian analysis of art and nature into a highly unexpected venue, namely, the use that scholastic theologians and inquisitors made of alchemy in determining the power of demons and witches in the Middle Ages and early modern period. From the time of Albertus Magnus in the mid-thirteenth century, scholastic authors used alchemy as a test case within their highly Aristotelian thought world for determining the limits of human and demonic power. Demons were typically thought to be restricted to the use of technology—they could not create by mere will alone as God was said to do, but had to join active natural substances to passive ones in order to achieve their ends. Alchemy, on the other hand, was the one art that offered par excellence to transmute species by imposing new substantial forms on matter. If humans could really convert one metal into another by transmuting its species, then demons should be able to do the same. And if such radical changes wrought by humans were admitted as a general principle, then demons and their servants, the witches, should be able to alter matter by imposing new forms that would also make it possible for them to work horrific effects on their enemies, resulting in dis-

ease, deformation, and even death. Evidence of the widespread use of alchemy as a technological benchmark receives significant support from the fact that Heinrich Kramer and Jakob Sprenger employed the aurific art in precisely that fashion in the most influential witch-hunting manual of all time—the *Malleus maleficarum* of 1487, a work that would become symbolic of the great witch hunt that followed over the course of the next two centuries.

Dennis Des Chene's chapter, "Forms of Art in Jesuit Aristotelianism (with a Coda on Descartes)" (chapter 6), deals mainly with the changing fortunes of the art-nature relationship in Jesuit commentaries and textbooks of the sixteenth and seventeenth centuries. As Des Chene points out, Jesuit authors tended to argue that human art was secondary in that it could only imitate nature, superficial in that it could only employ local motion and outward figure, and subordinate in that its artificial products lack the innate activity of natural ones. Nonetheless, certain arts, such as the making of automata, the art of magic, and alchemy, seemed to challenge this devaluation. Of these three arts, the Jesuits managed to make short work of automata and magic, reducing them to either fraud or manipulation of outward figure. That left alchemy, which the Coimbrans—relying on the same scholastic tradition outlined in chapter 5—admit as an area where art can possibly challenge or exceed the products of nature. Nonetheless, it remained for Descartes to restrict nature to the same status as art by reducing matter to extension and eliminating the powers and virtues that characterized natural substances for the Aristotelian. The result of this elision appears most fully in Descartes's *Dioptrique*, where the philosopher prescribes a cyborglike combination of man and machine in the form of a water tube implanted in the eye to improve vision. Despite the novelty of Descartes's idea, one cannot help but be reminded of Erasistratus's fusion of mechanics and medicine as described by Von Staden. The combination of a mechanistic matter theory in both authors, along with a physiology that blurs the distinction between art and nature, suggests that these ideas have an innate contextuality rather than acquiring their juxtaposition merely from coincidence.

The explicit contest between art and nature that we see in Des Chene's Jesuit commentators—where art is generally the loser—appears in a very different light in the paintings of Giuseppe Arcimboldo, as analyzed by Thomas DaCosta Kaufmann in chapter 7, "The Artificial and the Natural: Arcimboldo and the Origins of Still Life." Arcimboldo's style is typically viewed as the height of artifice and chimerical fantasy

in painting, as we find it described by his admirer Gregorio Comanini. Despite the fame of Arcimboldo's playful "composed heads," compositions made up of sea life, combustibles, and so forth, Kaufmann argues convincingly that we should also situate the Milanese painter at the origins of the early modern still life. Arcimboldo compiled careful studies of individual animals before integrating them into his illusionistic compositions, displaying a keen desire to imitate nature by means of his art. The skill with which he carried out such nature studies reveals itself in a particular type of painting in which he excelled, where the upright painting shows a head, but when inverted, it reveals a still life. Kaufmann dwells on one recently discovered Arcimboldo painting of this sort—a head that shows a fruit basket when inverted. Here as elsewhere in Arcimboldo's art, the painter was seen by his contemporaries as being engaged in a contest with a personified Nature. Whereas she could only make humans from human members, Arcimboldo was able to weave plants and their parts together to compose his humans—hence he had not only challenged Nature but surpassed her. Art's use of figure and surface derided by Jesuit authors now became the very means of outdoing Nature in the game of producing very different compositions from the same pictorial elements.

The sources used by Anthony Grafton for his "Renaissance Histories of Art and Nature" (chapter 8) display many of the characteristics found in Kaufmann's. Grafton's chapter focuses on the many Renaissance discussions of human invention and its relationship to nature that preceded the technological optimism of Francis Bacon and Tommaso Campanella. Locating this positive view of technē's progress partly in the princely tradition of *Kunst- und Wunderkammern*, Grafton sees a similarity between Samuel Quiccheberg's 1565 "theater" of "artificial and miraculous things" and the inventories of human artifice described by Campanella and Bacon. But the interaction of art and nature was not always seen as one of linear progress, as Grafton also points out. The jurisconsultant Guido Pancirolli and his commentator Heinrich Salmuth both stressed that the ancients had possessed arts now lost, though perhaps made up for by the "modern" inventions of Greek fire and the compass. The same emphasis on art's ability to evolve, and in so doing to surpass nature, is also seen in another of Grafton's cases, the famous humanist and writer on the visual arts, Leon Battista Alberti. As in Kaufmann's treatment of Arcimboldo and Comanini, Grafton stresses the claim of Alberti that art can even exceed the creative powers of nature, in this case by creating the composite likeness of a perfect female. A

similar expression of art's power entered into Alberti's discussion of engineering feats like the building of the Florentine duomo, and this rhetoric made its way, via the unlikely source of Heinrich Cornelius Agrippa's *De occulta philosophia*, into the revived discipline of Renaissance magic. Agrippa and his heirs, such as the Jesuit writer Gaspar Schott, emphasized that their "mathematical magic" could surpass and even overpower nature by means of marvelous machines. As Grafton concludes, then, such early modern genres as the Kunst- und Wunderkammer literature, the histories of the arts, and the extensive writings on learned magic all emphasized a growing fascination with the topos of art progressing beyond nature.

Horst Bredekamp's contribution, "Leibniz's Theater of Nature and Art and the Idea of a Universal Picture Atlas" (chapter 9), picks up chronologically where Grafton's leaves off. Beginning with a discussion of the current vogue of recreated Kunst- und Wunderkammern, Bredekamp points to the interesting contrast between the highly visual character of these protomuseums and the abstract character of our increasingly digital world. As Bredekamp makes clear, this interesting antithesis finds a prototype in the work of the brilliant codiscoverer of the calculus, Gottfried Wilhelm Leibniz, who was also an enthusiast of *Kunstkamern*. In a way that will be surprising to those who know Leibniz only as a mathematician or philosopher, Bredekamp manages to link his interest in the visual organization of knowledge to the great Renaissance pictorial mnemotechnics of writers such as Campanella, Johann Valentin Andreae, and above all Jan Amos Comenius. Perhaps it should come as no surprise that Leibniz the librarian and maven of universal languages would also have an interest in imagistically organized knowledge, and yet the degree of his enthusiasm for this subject is indeed impressive. For a quarter of a century he promoted a scheme for an *Atlas universalis*, a pictorial compendium of knowledge that would inculcate the arts and sciences into the tender brains of young students. Bredekamp concludes by suggesting that Leibniz's emphasis on the visual as a means of learning coupled with his love of mathematical abstraction may contain clues to our own bipolar culture, with its seemingly antithetical love of the image and the algorithm.

The case of Spinoza presented by Alan Gabbey—in chapter 10, "Spinoza on the Natural and the Artificial"—is of special interest for our topic because the Dutch philosopher refused any "artificialization" of nature. This was rather exceptional in a period when the mechanical explanations that prevailed in natural philosophy led to descriptions of

nature as a machine and God as its supreme engineer or as a clockmaker. Moreover, Spinoza's metaphysics, as Gabbey emphasizes, denied any possible distinction between nature and human art. All objects whether human-made or extracted from nature should be the products of necessity. Even the artists' intentions derive from a natural necessity rather than from free will. Gabbey argues, however, that Spinoza used a dual language for art. As an artisan, a lens grinder, he could not realistically consider lenses as a simple product of nature's necessity. As a political thinker he insisted on the artificial nature of states and governments. How could he sustain the contradiction? Here is a splendid illustration of the interplay between practices and concepts. As a metaphysician, aiming at understanding the eternal truth, Spinoza blurred the distinction between art and nature. But as a practitioner of one art concerned with human welfare, Spinoza assumed a difference between nature and art. These conflicting views suggest that whatever the rational arguments against the dichotomy between art and nature, it remains implicit in all human actions and indispensable for understanding them.

Creating artificial life is an old interest dating back to antiquity and currently pursued in many laboratories. It does not mean that this project is the expression of one and the same long-standing project. Rather, as Jessica Riskin shows in chapter 11, "Eighteenth-Century Wetware," various attempts to create lifelike artificial creatures mirror the changing views of life and matter, or of humans, animals, and machines. In the long story of artificial life, Riskin singularizes the second half of the eighteenth century as a crucial moment when artisans and engineers designed automata for testing the mechanistic understanding of life shaped by materialist philosophers. The spectacular automata built by Jacques Vaucanson or by the Jacquet-Droz family were much more than clock mechanisms performing rigid motions. Their attempts went so far as to simulate the soft and wet texture of living matter. They performed not only locomotion, writing, or music playing but also inner physiological processes such as digestion and defecation. According to Riskin, it would be unrealistic to consider the theatrical performances of such automata as counterfeits intended to fool the spectators, even though they provided—and can still provide when they work in museums—the kind of pleasure that Aristotle conferred on the mimetic arts. These machines, Riskin argues, were experimental models used in the same manner as modern simulations. They worked in two ways: they illustrated the mechanization of life since they were animal-like machines and at the same time they animated the machinery. Finally,

Riskin emphasizes the similarity between late eighteenth-century automata and late twentieth-century artificial life developed as simulations of life.

Nineteenth-century attempts at reproducing the products of life are the subject of John Hedley Brooke's chapter, "Overtaking Nature? The Changing Scope of Organic Chemistry in the Nineteenth Century" (chapter 12). Brooke revisits a landmark episode often presented as a triumphal step in art matching nature. Friedrich Wöhler's production of urea in 1828 was the first *in vitro* synthesis of a substance up to then exclusively produced by living organisms. Nineteenth-century chemistry textbooks assumed that this synthesis proved that chemists had the power to reproduce organic compounds artificially and that their art destroyed the metaphysical belief in the existence of a vital force. In fact Wöhler's synthesis could not—and did not—challenge vitalism or the theological view of nature. First, it was not a complete synthesis since it started from organic products such as horn. Second, the replication of a natural product did not imitate nature's process. Reconsidering this famous synthesis in the long perspective of the debates over art and nature as well as in the context of nineteenth-century culture, Brooke develops an alternative view of its impact. Far from securing the triumph of materialism, the Faustian ambitions of the synthetic chemists prompted objections that favored further distinctions between products and processes and between various types of syntheses. Moreover, Brooke emphasizes the contrast between the triumphalist rhetoric of the champions of organic synthesis and its dramatic effect on the discipline of chemistry, whose theoretical framework was consequently split between inorganic and organic chemistry. Despite the vaunting verbiage used by the promoters of organic syntheses, these syntheses in reality challenged the identity and consistence of chemistry as a field.

The contrast between the chemical optimism raised by nineteenth-century attempts at synthesis and the cultural perception of chemical synthesis toward the end of the twentieth century is striking. The antithesis between "chemical" and "natural" did not work to the benefit of chemistry. To what extent do the deep changes that affect the cultural image of chemistry result from changes in the aims and practices of chemical synthesis? In chapter 13, "Reconfiguring Nature through Syntheses: From Plastics to Biomimetics," Bernadette Bensaude-Vincent addresses this question through a review of three different strategies of synthesis: polymerization, combinatorial chemistry, and biomimetic syntheses. She argues that synthetic polymers favored a view of nature as a

rigid set of limited resources opposed to the plasticity and profusion of synthetic artifacts. By contrast, the more recent strategy of making drugs through combinatorial chemistry favored the view of nature as a huge library of resources gathered through random processes of combination. Mimicking nature in this case means mimicking the stupid and blind process of natural selection. Art thus loses one of its major distinctive features, intentionality. An alternative view of nature as an unrivaled engineer underlies the attempts at making artificial materials with characteristics analogous to the variety of properties offered by natural materials such as muscle, blood, or spider silk. Hence we arrive at the conclusion that the notions of nature and art are mutually constructed. Nature and art are continuously and mutually redefined in coordination with the intellectual and materials strategies used for designing artifacts.

Thus the dance that Roald Hoffmann imagines at the end of our book—in chapter 14, “Concluding Comments”—goes on over the centuries. Art and nature are two inseparable partners whose movements continuously shape and reshape the map of those cultures that have inherited the ancient yet modern distinction between technē and physis.

NOTES

1. For the obtaining of antifreeze protein from winter flounder, see http://www.actahort.org/books/484/484_99.htm. For Eduardo Kac and the bioluminescent rabbit, see <http://www.ekac.org/>. For the argument that transgenic maize has made its way into the wild in Mexico, see David Quist and Ignacio H. Chapela, “Transgenic DNA Introgressed into Traditional Maize Landraces in Oaxaca, Mexico,” *Nature* 414 (2001): 541–543. For robotics and artificial intelligence, see Rodney A. Brooks, *Flesh and Machines: How Robots Will Change Us* (New York: Pantheon Books, 2002), and Hans Moravec, *Mind Children: the Future of Robot and Human Intelligence* (Cambridge, MA: Harvard University Press, 1988).

2. Monique Mosser and Georges Teyssot, *Histoire des jardins de la Renaissance à nos jours* (Paris: Flammarion, 1991); Jean-Jacques Rousseau, *Discours sur l'origine de l'inégalité parmi les hommes* (Paris, 1755). Bernadette Bensaude-Vincent, “L’alchimie du jardinage,” in Georges Farhat, ed., *André Lenôtre. Fragments d'un paysage culturel* (Paris: Musée de l’Ile du France, 2006) 152–161.

3. Roald Hoffman, *The Same and Not the Same* (New York: Columbia University Press, 1995), 87–125.

4. Jean-Pierre Clavier, *Les catégories de la propriété intellectuelle à l'épreuve des créations génétiques* (Paris: Lharmattan, 1998); J. Rifkin, *Le siècle Biotech: Le commerce des gènes* (Paris: La découverte, 1998); American College of Medical Genetics 1999, *Position Statement on Gene Patents and Accessibility to Gene Testing*; Maurice Cassier and Jean-Pierre Gaudillière, “Recherche, médecine et marché: la génétique du cancer du sein,

Sciences sociales et Santé 18 (2000): 29–51; UNESCO, Division of Human Sciences, “Ethics, Intellectual Property and Genomics, International Symposium, Paris, January 30–February 1, 2001.

5. William R. Newman, *Promethean Ambitions: Alchemy and the Quest to Perfect Nature* (Chicago: University of Chicago Press, 2004), 247, 266.

6. Christine Velut, *La rose et l’orchidée: Les usages sociaux et symboliques des fleurs à Paris au XVIIIe siècle* (Paris: Larousse, 1993), 111–134.

7. For the expression “noninterventionist fallacy,” see Newman, *Promethean Ambitions*, chapter 5.

