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PROMETHEAN
AMBITIONS

Alchemy and the

Quest to Perfect

Nature

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Introduction

FROM ALCHEMICAL GOLD TO SYNTHETIC HUMANS

The Problem of the Artificial and the Natural

Many of us feel besieged by the rapidly eroding boundaries between the realms of the artificial and the natural. Not only does nature itself appear to be experiencing an unparalleled threat from environmental degradation and human encroachment on what once was wilderness, but the very concept of nature as an intelligible category seems increasingly remote.¹ After all, we live in the era of "Frankenfoods," cloning, in vitro fertilization, synthetic polymers, Artificial Intelligence, and computer generated "Artificial Life." Pope John Paul II, driven by fears that the impact of biomedical research on human nature will soon deprive life of its dignity, warns of the "Promethean ambitions" implicit as he sees it in much contemporary science.² But the artistic world too offers challenges to the category of the natural—consider the emergence of transgenic art, which claims to have produced a bioluminescent rabbit by means of DNA extracted from jellyfish.³ All of these technological marvels impinge on areas that, in the not-too-distant past, seemed to belong to a domain beyond the power of humankind. We are worried, and perhaps rightly so.

Part of our fear stems from the feeling that humans are being increasingly outclassed by machines. Not only has our biological champion, Garry Kasparov, been defeated at the hand of the robotic chess master Deep Blue—we are now beginning to observe the animated products of Computer Graphics Imaging substitute for living actors in film and television. The farcical events surrounding Andrew Niccol's virtual actress in the recent film *Simone*

1. For some material on the loss of "nature's" viability as a category, see George Robertson et al., *Futurenatural: Nature, Science, Culture* (London: Routledge, 1996).

2. Pope John Paul II, "Address of John Paul II to the Members of the Pontifical Council for Health Pastoral Care, Thursday, 2 May 2002," *L'Osservatore Romano* (weekly English ed.), May 22, 2002, 9. Despite John Paul II's use of the expression "Promethean ambitions," my own employment of the term stems directly from the myth of Prometheus as the creator of man rather than from the pope's enunciation.

3. For Eduardo Kac and the bioluminescent rabbit, see his Web site at <http://www.ekac.org/>.

stem from genuine apprehensions about the replacement of real humans by animated screen images.⁴ Even fashion models are beginning to feel threatened by their virtual counterparts—the *New York Times* has reported that modeling agencies have begun using cyberspace personalities such as “Webbie Tookay” in their clothing advertisements. The founder of a famous model-management company expounds his semijocular wish that “all models were virtual,” in view of their “hassle-free” personalities and their ability to keep looking good over the long haul. The virtual model, a two-dimensional creature of unthinking electrons impelled by human artifice, could end up replacing her (or his) natural exemplar.⁵

But is the phenomenon of “art” (or as we now say, technology) impinging on nature really a new thing, and is our attendant anxiety a novel sentiment? Clearly the answer must be no, since Leon R. Kass, chairman of the President’s Council on Bioethics, recently raised a minor sensation by assuring Nathaniel Hawthorne’s 1843 story, “The Birth-Mark,” to his fellow committee members as required reading for their deliberations on human cloning.⁶ A closer connection with the theme of the present book cannot be imagined. The principal character of Hawthorne’s story is a chemist named Aylmer, who is obsessed with the desire to remove a hand-shaped birthmark from the cheek of his wife Georgiana, a faultless beauty in every respect other than this blemish. With Georgiana’s consent, Aylmer concocts an elixir that succeeds in eliminating the birthmark, but with one unfortunate side effect—it also kills Georgiana. Hawthorne ends the story with an explicit moral:

had Aylmer reached a profounder wisdom, he need not thus have flung away the happiness, which would have woven his mortal life of the self-same texture with the celestial. The momentary circumstance was too strong for him; he failed to look beyond the shadowy scope of Time, and living once for all in Eternity, to find the perfect Future in the present.⁷

Kass and his committee members broadcast a related message in *Human Cloning and Human Dignity: The Report of the President’s Council on Bioethics*—we

4. Dave Kehr, “A Star Is Born,” *New York Times*, November 18, 2001, sec. 2, 1, 26.

5. Ruth La Ferla, “Perfect Model: Gorgeous, No Complaints, Made of Pixels,” *New York Times*, May 6, 2001, sec. 9, 1, 8.

6. The incident occurred on January 17, 2002, and generated heated responses from a number of quarters. For two more considered examples, see Andrew Ferguson, “Kass Warfare,” *Weekly Standard*, February 4, 2002, 13, and William Safire, “The Crimson Birthmark,” *New York Times*, January 21, 2002, sec. A, p. 15.

7. Nathaniel Hawthorne, “The Birth-Mark,” in *The Centenary Edition of the Works of Nathaniel Hawthorne*, ed. William Charvat et al. (Columbus: Ohio State University Press, 1974), 56.

should ban human cloning in all areas of research, whether intended for producing children or for biomedical purposes. Otherwise we run the risk of tampering too eagerly with nature, and may, like Aylmer, succeed in destroying the very humanity that we desire to improve.⁸

Whatever the reader may think of Kass and his report, one must sympathize with the council’s desire to find some grounding in tradition for the profound ethical dilemmas that surround our increasing power over nature. There is every reason to seek moral guidance in the classics of literature. But there are dangers as well as benefits to such an approach. The key problem, illustrated clearly by the council’s published discussion, stems from the treatment of literature in a historical vacuum. By looking at “The Birth-Mark” as an atemporal index of human repulsion to the hubris inherent in “the pursuit of perfection,” one commits the fallacy of reification.⁹ With all due respect to the council, our reaction to Aylmer is not a “natural” or “necessary” one born of universal, diachronic human emotion without the aid of prior tutelage. Nor did Hawthorne merely draw on his own sense of moral outrage to “invent” the subject about which he wrote so skillfully.¹⁰ Indeed, the council’s discussion failed to notice that Hawthorne himself, in composing “The Birth-Mark,” drew upon a much older tradition of debating the hubris implicit in human beings’ godlike power over the natural world. That tradition forms the subject of *Promethean Ambitions*.

8. Leon R. Kass, *The Report of the President’s Council on Bioethics* (New York: Public Affairs, 2002), 231–241. To be more precise, Kass proposes a permanent ban on cloning for reproductive purposes and a temporary ban of four years (a “moratorium”) on cloning for medical research.

9. I read Kass’s comments and the responses of William E. May and Stephen L. Carter on pp. 27–28 of the transcript in this light. There the discussion focuses on the reader’s tendency to “recoil” at Aylmer’s “repelling” and “repulsive” motives, as it does in much of the remainder of the transcript. At the end of the discussion (p. 36), Kass himself summarizes the goals of his discussion in these terms: “The question is, is that a worthy aspiration or is there something that necessarily gives rise to shuddering as a result of our efforts to do that?” See <http://www.bioethics.gov/transcripts/jan02/jan17full.html#2>.

10. Hawthorne’s sources in the literature of alchemy and natural magic have received some study, but the topic deserves more thorough treatment than literary scholars have devoted to it. Perhaps the most important finding to date has been the discovery by Alfred S. Reid of multiple parallels between Aylmer and the seventeenth-century chymist and natural philosopher, Sir Kenelm Digby. That these associations are not entirely coincidental is assured by the fact that Digby is mentioned in *The Scarlet Letter* as a correspondent of the medical man Roger Chillingworth. See Alfred S. Reid, “Hawthorne’s Humanism: ‘The Birthmark’ and Sir Kenelm Digby,” *American Literature* 38(1966), 337–351. Some other helpful studies are Randall A. Clack, *The Marriage of Heaven and Earth* (Westport: Greenwood Press, 2000); John Gatta Jr., “Aylmer’s Alchemy in ‘The Birthmark,’” *Philological Quarterly* 57(1978), 399–413; David M. Van Leer, “Aylmer’s Library: Transcendental Alchemy in Hawthorne’s ‘The Birthmark,’” *ESQ* 22(1976), 211–220; and Raymona E. Hull, “Hawthorne and the Magic Elixir of Life: The Failure of a Gothic Theme,” *ESQ* 18(1972), 97–107.

Even the most casual reader of Hawthorne cannot fail to see that the "chemist" Aylmer is really an alchemist.¹¹ After presenting a number of traditional "natural magic" demonstrations to Georgiana, such as the magic lantern, camera obscura, and artificial rebirth or "palingenesis" of a plant, Aylmer launches into an enthusiastic discussion of alchemy, describing "the universal solvent, by which the Golden Principle might be elicited from all things vile and base," and the Elixir Vitae that could indefinitely prolong life. As though these well-worn themes were not enough to identify Aylmer's alchemical lineage, Hawthorne later has Georgiana rummage through her husband's library, finding tomes by Albertus Magnus, Cornelius Agrippa, Paracelsus, and Roger Bacon, all famous medieval and early modern writers on alchemy and the occult sciences.¹² All of this is obvious to the reader. What is not immediately evident, however, is that the very language in which Hawthorne clothes his discussion of the powers of art versus nature is itself drawn from a centuries-old debate about the legitimacy of alchemy and its claim to refashion nature in the image of man. If we are going to view current debates on the limits of science in the context of literary traditions, it is imperative that we fully understand the history of the alchemical debate upon which Hawthorne and similar authors drew.

In Hawthorne's words, the alchemists "imagined themselves to have acquired from the investigation of nature a power over nature." Like them, Aylmer had "faith in man's ultimate control over nature." But the omniscient narrator of "The Birth-Mark" points out that in reality, nature "permits us indeed to mar, but seldom to mend, and, like a jealous patentee, on no account to make." Throughout the present book we will meet these three categories time and time again—perverting nature, perfecting nature, and creating nature anew. These were traditional distinctions employed countless times by alchemists and their detractors in order to defend or defeat the

11. One of the council's members, William F. May, points out that Aylmer had alchemical books in his library, but this is as close as the council comes to situating Hawthorne's tale in a historical context:

Hawthorne carefully locates his story within the central project of modern Western civilization. He gives us a peak [sic] into Aylmer's library. It includes the work of the alchemists who stood in advance of their centuries and who imagined themselves to have acquired from the investigation of nature a power above nature but his library also includes "early volumes of transactions of the Royal Society in which the members knowing little of the limits of natural possibility were continually recording wonders or proposing methods whereby wonders could be wrought." (from p. 24 of <http://www.bioethics.gov/transcripts/jan02/jan17full.html#2>)

12. Hawthorne, "Birth-Mark," 44–46, 48. For the tradition that Roger Bacon created a talking head out of brass, see George Molland, "Roger Bacon as a Magician," *Traditio* 30 (1974), 445–460.

art. When Aylmer finally announces to Georgiana that he must "change your entire physical system" in order to eliminate her birthmark, he verges on the third category, a transmutation in all respects as complete as the alchemical conversion of base metal into gold. Even the preliminary demonstration that Aylmer gives of his elixir, rejuvenating a dying geranium by pouring the liquid on its roots, finds its sources in alchemy. The first famous scientist of the American colonies, "Eirenaeus Philalethes" or George Starkey, used the rejuvenation of a withered peach tree by the alchemical elixir as a means of broadcasting his own transmutational prowess.¹³

It is no accident that Hawthorne chose alchemy to illustrate the conflict of art and nature, or that the same cast of alchemists and magicians—including Agrippa, Paracelsus, and Albert—appears in the early education of Mary Shelley's character, Victor Frankenstein. In Shelley's novel it is again the traditional upholders of the occult sciences—and particularly alchemy—who profess the wisdom that Frankenstein updates by more modern means to produce his monster.¹⁴ But as with Hawthorne, Shelley was not creating this fantasy or its attendant philosophical dilemmas out of whole cloth. This book will show that medievals and early moderns alike were already deeply concerned with such issues as artificial human life and the identity of synthetic products with their natural counterparts, topics of profound interest both to alchemists and to their opponents. Not only did such topics raise the general religious problem that man seemed to be usurping the creative powers of his own maker; they also evoked a host of more specific objections. Consider some of the following historical examples.

Let us imagine that humans could produce a laboratory mouse by artificial means, assembling the proper ingredients and subjecting them to heat and moisture in a controlled environment, a feat that most medievals and early moderns believed to be within the realm of possibility. Would this mouse then be the same as its sexually generated counterpart? Not if one consults the twelfth-century Arabic philosopher Averroes, who explicitly raises this puzzle. Even if the two mice look and act exactly the same, the artificial mouse will not be genuine. Averroes explicitly applied the same argument to the gold produced by alchemists. No matter how closely the artificial product matched the properties of its natural exemplar, the two

13. William R. Newman, *Gebominal Fire: The Lives of George Starkey, an American Alchemist in the Scientific Revolution* (Chicago: University of Chicago Press, 2003; first published, 1994), 2.

14. Mary Shelley, *Frankenstein, or the Modern Prometheus*, in *The Novels and Selected Works of Mary Shelley*, ed. Nora Crook and Betty T. Bennett (London: William Pickering, 1996), 1:25–27, 33–34. See also Crosbie Smith, "Frankenstein and Natural Magic," in *Frankenstein, Creation, and Monstrosity*, ed. Stephen Bann (London: Reaktion Books, 1994), 39–59.

would be separated by an unbridgeable gulf.¹⁵ Who has not heard this sort of argument employed by modern proponents of vitamin C from rose hips and other natural food products? Even if they have the same molecular structure, the natural and the artificial are assumed to be different. And lest we prejudice the discussion, it must be admitted that vitamin C from natural sources may well contain impurities that do make it differ from the pure, synthesized variety. Even if we could not perceive these differences with our most powerful tests, they might still be present. Does this mean, then, that the synthetic version of the chemical is fake? And if that is so, does it follow that a sheep cloned from mammary cells like the famous Dolly is a fake sheep? Averroes and his followers would have responded with a resounding yes.

The stakes, of course, were raised when premodern thinkers turned from spontaneously generated mice to the artificial production of human life. Here one encountered a host of concerns beyond the mere identity of the artificial and natural product, though that remained a problem too, of course. Let us imagine that a human being could be made by placing the proper progenerative fluids in a flask and subjecting the apparatus to an incubating heat. In the era of *in vitro* fertilization, this is not a huge stretch of the imagination, even if modern biologists have not yet replaced the human womb as an instrument of gestation. But many premodern thinkers were also capable of believing this eventuality, if their Aristotelian biology was only given a modest bit of fine-tuning. The homunculus, or miniature human created in an alchemical flask, was a topic of discussion already among the medieval Arabs. Could one use this form of generation to alter the sexuality of the child? Why not make a being of extraordinary intelligence, with powers denied to the offspring of normal sexual generation? Was it permissible to use the bodily fluids of the homunculus as a means of curing dangerous diseases? Have we not heard all of these questions discussed recently in the controversy surrounding the artificial selection of gender, the prenatal modification of biological traits, and the use of fetal tissue for medical purposes?

As in the contemporary incarnation of these questions, the medievals and early moderns felt that they were coming perilously close to playing god and transgressing the boundaries imposed on man and nature by a wise Creator. Like many a contemporary critic of cloning, premodern opponents

of artificial life feared the implication that the laboratory worker could create a soul on demand. The famous Catalan physician of the late thirteenth century, Arnald of Villanova, was said to have smashed his gestating homunculus before it could acquire a rational soul, driven by the fear that this would be a mortal sin. Others worried over a different implication of the homunculus. Like Leon Kass and the members of his presidential council—fearing the “manufacture” of human beings and the consequent dehumanization that this might imply—early modern theologians already worried that humanity would soon be relegated to the status of a soulless artisanal product.¹⁶ Over a century after Arnald, his story was still told, with the added concern that the making of such a test tube baby would diminish the role of the human mother, demoting her to the status of a hollow flask. Others, however, were not beset by such worries. Some sixteenth-century followers of the outrageous medical and chymical writer Paracelsus had no problem with the gender-altering connotations of the homunculus.¹⁷ By segregating the male and female generative fluids, they believed that they could separate out the sexual characteristics of their artificial beings and produce a “pure” male and a “pure” female. The ruminations on this experiment are strangely reminiscent of the infatuation that ectogenesis and artificial parthenogenesis hold for modern advocates of biotechnology as a tool of attaining sexual equality, from J. B. S. Haldane in the 1920s to contemporary exponents of radical lesbian feminism.¹⁸ Babies produced in bottles, their sex and other characteristics predetermined in the laboratory, form a desideratum extending well into the Middle Ages.

There is another area as well where the contemporary infringement of technology on nature had prescient underpinnings in the world of premodern Europe. We are accustomed to thinking of the current rivalry between science and the combined arts and humanities as following on the heels of the Second Industrial Revolution in the nineteenth century. As industry and wealth have come to rely ever more on the fruits of applied science and high technology, the place of the arts and humanities has suffered a concomitant erosion. Yet already in the sixteenth century, many artists strongly believed that alchemy had imposed on their discipline and that the

16. Kass, *Report of the President's Council*, 116–120.

17. For a justification of the archaic term “chymistry” as a means of avoiding anachronism, see William R. Newman and Lawrence M. Principe, “Alchemy vs. Chemistry: The Etymological Origins of a Historiographic Mistake,” *Early Science and Medicine* 3(1998), 32–65.

18. For Haldane, see Susan Merrill Squier, *Babies in Bottles: Twentieth-Century Visions of Reproductive Technology* (New Brunswick: Rutgers University Press, 1994), 69–73. To document the long-standing lesbian interest in parthenogenesis, one need only search the internet for the paired terms “parthenogenesis” and “lesbian.”

15. Averroes, *Aristotelis de generatione animalium, Aristotelis opera cum Averrois commentariis* (Venice: Juntae, 1562–1574; reprint, Frankfurt: Minerva, 1962), 6:44v. For a fuller treatment of Averroes' position, see chapter 2 of the present book.

claims of the aurific art should be combated. Artists of such varied stripe as Leonardo da Vinci and the French potter Bernard Palissy attacked alchemy as an irreligious fraud that claimed for itself the creative powers of God. It was the painters, sculptors, and ceramicists who really held the key to imitating nature, not the bragging simulators of gold, silver, and precious stones. Alchemists and visual artists were in an immediate sense rivals in the business of re-creating nature, even if the former claimed to replicate a natural product while the latter were engaged in its representation.¹⁹ Here already we witness a restricted instance of the now commonplace rivalry between art and science, based on their differing attitude toward nature. Yet in the Renaissance, the debate was not between two such radically distinct fields of human culture, but between two "arts," one of which claimed to replicate and one to simulate the features of natural world.

In order to appreciate how such apparently diverse fields as alchemy and painting could once have been competitors, we will have to place ourselves firmly in the minds of our premodern ancestors. Our forebears firmly labored any productive activity carried out with forethought an "art."²⁰ In order to approach the issues that we have touched upon more deeply, it will therefore be necessary to consider evidence from the fine arts, as well as artisanal and technical fields. The central thesis of this book, that alchemy provided a uniquely powerful focus for discussing the boundary between art and nature—a question that resonates even today—can be understood only if the reader is willing to engage with the presuppositions of premodern philosophers, theologians, alchemists, and artists about the structure and nature of the world around them. Although our main target is the period from around 1200 to 1700, it will be necessary, as always, to survey the material left by Greek and Roman antiquity if we are to see how the various arts were thought to interact with nature. The first chapter of *Promethean Ambitions* therefore considers the relationship of the various arts to nature in the ancient world. The fine arts, technology, and finally alchemy will all come under our purview so that we get a sense of the different ways in which Western man has traditionally envisioned the

competition of art with nature and the struggle for supremacy among the arts themselves.

The book then goes on to treat a variety of issues growing out of the relationship between the study of alchemy and the topic of art and nature. In the second chapter I present a brief overview of alchemy with an emphasis on what can be called the art-nature debate, a topic that reached its apogee in the treatises by alchemists and their opponents from the thirteenth through the seventeenth century. The Scholastic theologians and philosophers of the Middle Ages appropriated alchemy as a point of reference for determining the power of human art in general. Whether one believed its claims or not, alchemy served as a convenient benchmark for determining the limits to the power that divinity had placed in the hands of those perennial frustrators of human salvation—the race of demons. Since the powers of demons stood or fell with those of the alchemist, the legitimacy of alchemical claims acquired an importance that it would otherwise probably not have had. A disputation literature therefore emerged on the subject, which branched out into other discussions that were still vibrant in the early modern period. In the third chapter, I examine one of those early modern branches in detail by considering the peculiar relationship between alchemists, painters, and practitioners of the plastic arts during the Renaissance. As we will see, alchemy and the fine arts revisited the classical discussion of competition with nature in the sixteenth century, and the two fields engaged in a head-to-head polemic. Although this was an argument between siblings rather than strangers, we need no reminder that such close and personal encounters are often the most unpleasant to both parties. The fourth chapter examines the most controversial of all alchemical claims—namely the tradition associated with the itinerant preacher, lay physician, and alchemist Paracelsus von Hohenheim, which claimed that he could create a homunculus. As I will show, however, Paracelsus was himself a latecomer to the discussion of artificial life, which had been fermenting for many centuries. The topic of ectogenesis along with its various attractions and moral dilemmas had already been conceived by the early Middle Ages, but its full partrition required the strange mixture of naturalizing intellect and impetuous imagination that stamped the sixteenth century. Finally, in the fifth chapter I discuss the art-nature debate in the history of experimental science, focusing in particular on Francis Bacon and his followers. The alchemical art-nature debate had a direct input into Bacon's ideas on the relationship of man to nature and continued to exercise a surprising degree of influence on his famous apologist Robert Boyle. The newly empirical tendencies of the seventeenth century owe a strong and surprising debt to

19. I use the verb "replicate" in reference to the exact reproduction of a natural product—in other words, the re-creation of a natural thing by man. The verb "simulate," on the other hand, refers to the making of a copy, an ersatz "simulation" rather than a product identical to its exemplar. Although this corresponds to the commonsense usage of these terms, the meanings that I attach to them will be more fixed than common parlance dictates. See Webster's *Third New International Dictionary* (Springfield, MA: G. & C. Merriam, 1966), s.v. "replicate," "simulate."

20. On this point, see the famous article of Paul Oskar Kristeller, "The Modern System of the Arts: A Study in the History of Aesthetics," *Journal of the History of Ideas* 12 (1951), 496–527.

the alchemical literature and to the debate surrounding the natural status of its products. A close analysis of this neglected debate will show that several of the reigning beliefs prevalent in the historiography of science are open to serious and sustained objection.

These themes, all flowing from the traditional debate on art and nature as seen through the lens of alchemy, provide a rich tapestry of arguments and attitudes prefiguring modern views of science, technology, and their limits. As the example of Leon Kass and Hawthorne's "Birth-Mark" shows, current attitudes toward an area as distinct from alchemy as contemporary bioengineering cannot be approached without an understanding of the artificial-natural dichotomy over the *longue durée*. My hope is that *Promethean Ambitions* will open the topic to historical discussion and reveal the wealth of divergent interpretation that characterized its premodern configuration. If the picture that emerges is not a simple one, it will ideally serve to help us reflect on the centuries of argument—colored now with abhorrence, now with approval—that underlie our own fluid perception of the shifting boundaries between the artificial and the natural.

Chapter One

IMITATING, CHALLENGING, AND PERFECTING NATURE

The Arts and Alchemy in European Antiquity

Trickery and the Visual Arts

Our present-day perception that science and technology are rapidly pacing nature had surprising antecedents in the ancient world. The contest between man and nature is a theme as old as Western civilization, possibly as ancient as civilization itself. Greek and Latin literature is with admortory stories of the results of human endeavors to imitate handiwork of the gods, ranging from the disastrous flight of Icarus to transformation of the weaver Arachne into a spider.¹ But the desire to taste or better nature in antiquity was not limited to fabulous recollections of a mythological past. Unlike the common modern view that the true nature comes from science, the Greeks first cast the contest as one between nature and the fine arts. The sculptor Myron (fifth century B.C.E.) was already renowned in antiquity for his bronze cow, so realistic that he supposedly stoned it for its recalcitrant failure to follow their flock; even bulls found it attractive. Some thirty extant Greek epigrams of the date describe the marvelous cow, most of them mocking, and some bawdy. In one epigram, Myron is accused of lying when he said that he made the cow, since it must surely have hardened into bronze naturally. Another accuses him of being a second Prometheus, since like the titan, he has made a living being. Yet another brags (in the voice of the itself) that a calf will moo upon seeing it, a bull will try to mount it, and a herdsman will attempt to lead it into his herd. Finally, the cow provides the pretext for an epigram describing the contest between art and nature. To one who only views the cow, it will seem that art has stolen nature

1. Reijer Hooykaas, *Religion and the Rise of Modern Science* (Edinburgh: Scottish Academic Press, 1972), 56. See also Ernst Kris and Otto Kurz, *Legend, Myth, and Magic in the Image of the Artist* (New Haven: Yale University Press, 1979), 84–90, and Hooykaas, *Fact, Faith, and Fiction in the Development of Science* (Dordrecht: Kluwer, 1999).

power; but to the onlooker who actually touches the animal, "nature remains nature."²

A century after Myron, the famous painter Apelles was incensed when he learned that the judges of an art contest had been bribed. Deciding to "challenge nature itself," he subjected a painting that included horses to the judgment of other quadrupeds rather than to that of the corrupt judges. The horses, upon being shown the paintings of Apelles' competitor, kept their taciturn mien. Only when confronted with the mastery of Apelles' own art did they neigh, signifying their failure to distinguish mimicry from model. An additional example of this sort appears in the rivalry between two other fourth-century painters, Zeuxis and Parrhasius. When the former depicted a bunch of grapes with such accuracy that birds tried to eat them, he could not restrain his braggadocio. Parrhasius, in the meantime, presented a painting covered with a linen curtain. When the overweening Zeuxis asked him to reveal the painting beneath, it turned out that the curtain itself was a painted *trompe l'oeil*, and Zeuxis had to admit his defeat.³

These stories reveal an attitude to the illusionistic power of art that is both reverential and ambivalent. On the one hand, they display an awe at the artist's mimetic skill, while on the other they are clearly meant to mock the victim of the deception. Greek art delighted in the ambiguous tension established between these two poles. The skill that could rival the gods in re-creating nature was also the trickery that fooled the eye.⁴ The same attitude is evident when we turn from the fine arts to what would, in modern terms, be considered technology. Aristotle's *De anima* (1 406b15-22), also a product of the fourth century, contains a brief reference to the ancient craftsman Daedalus. Aristotle reports that Daedalus made a self-moving

2. F. Duebner, *Epigrammatum anthologia palatina* (Paris: Ambrosius Firmin Didot, 1864), chap. 9, epigrams 716, 724, 730, 738. As Deborah Tam Steiner has recently pointed out, Myron's work was apparently not just naturalism for the sake of naturalism. His audience delighted in the "riddling union between the breathing body and the unmistakable fact of the inanimate bronze or stone." See Steiner, *Images in Mind: Statues in Archaic and Classical Greek Literature and Thought* (Princeton: Princeton University Press, 2001), 28 n. 70. See also Kenneth Gross, *The Dream of the Moving Statue* (Ithaca: Cornell University Press, 1992), 139-146, for an interesting discussion of Myron and the tradition of ancient *ekphrasis*, the premodern genre of writing about objects d'art.

3. J. J. Pollitt, *The Art of Greece, 1400-31 BC* (Englewood Cliffs: Prentice-Hall, 1965), 61-65, 154-155, 167. A number of such anecdotes are recounted in Kris and Kurz, *Legend, Myth, and Magic*, 62-67.

4. For the nuanced complexity of this issue, which can only be hinted at here, see Richard T. Neer, "The Lion's Eye: Imitation and Uncertainty in Attic Red-Figure," *Representations* 51 (1995), 118-153. See also Jean-Pierre Vernant, "From the 'Presentification' of the Invisible to the Imitation of Appearance," in Vernant, *Mortals and Immortals: Collected Essays*, ed. Froma I. Zeitlin (Princeton: Princeton University Press, 1991), 151-163, and Steiner, *Images in Mind*, 50. On the theme of art as trickery, see also Kris and Kurz, *Legend, Myth, and Magic*, 61-90.

statue of Aphrodite that owed its motive capacity to quicksilver hidden within. The idea that Daedalus had made robots or automata was widespread in Classical Athens and reflects the same blend of admiration for human handiwork and mocking irony toward the deluded that we have seen in the stories of Myron's cow.⁵ Aeschylus and Euripides both employed Daedalean automata as comic items in their satyr plays, and the latter assures one of his more timorous characters that the self-moving statue only "seems" (*dokei*) to see and to move: it is not a real living being.⁶ Euripides leaves the possibility open that Daedalus's robots are in fact just statues, but statues that fool the eye of the unwary in the same way that Zeuxis fooled a bird and Parrhasius fooled Zeuxis.

The figure of Daedalus shows that the classical ambivalence toward the power of art was not limited to "art" in our sense, but included the *artes* or *technai* in general. Daedalus was not only a fabricator of statues and automata, but the designer of King Minos's labyrinth and a maker of marvelous armor. He was renowned for having designed reservoirs, fortresses, heated grottoes, and even an artificial cow within which Pasiphae, the queen of Crete, could receive the amorous attentions of an especially attractive bull. That the result of this Daedalean intervention was a monster of the Minotaur's stature reveals once again the bipolar power of *technē*.⁷ The activities with which Daedalus was associated display the breadth and complexity contained within the once synonymous Greek and Latin terms *technē* and *ars*, which have parted company in modern English to form the roots for our "technology" on the one hand and "art" on the other. Although it would be wrong to say that the mythical Daedalus was representative of Greek artists in general, ancient divisions of the disciplines did include all manual pursuits under the general rubric of "arts." Aristotle, for example, viewed painting and sculpture as *technai* along with agriculture, building, medicine, and a host of other pursuits. Poetry too was an art, of course, for it led to a product rather than being an ongoing process of discovery (like philosophy).⁸ To Aristotle, then, an art was simply a "reasoned state of capacity to

5. A related theme in Middle Eastern and Greek antiquity is what Christopher Farabee has called the "talismanic statue." See his *Talismans and Trojan Horrors* (New York: Oxford University Press, 1992), 18-35.

6. Sarah P. Morris, *Daedalus and the Origins of Greek Art* (Princeton: Princeton University Press, 1992), 217-223. See also Deborah Steiner, *Images in Mind: Statues in Archaic and Classical Greek Literature and Thought* (Princeton: Princeton University Press, 2001), chap. 1.

7. Diodorus Siculus, *The Library of History*, ed. and tr. C. H. Oldfather (Cambridge, MA: Harvard University Press, 1939), bk. 4, 76-79, pp. 56-68.

8. James A. Weisheipl, "The Nature, Scope, and Classification of the Sciences," in *Science in the Middle Ages*, ed. David C. Lindberg (Chicago: University of Chicago Press, 1978), 461-482.

make" (*Nicomachean Ethics* 1140a8), the ability to produce in a methodical and clever way.

The Meanings of *Mimēsis*

But it was widely held in antiquity that the arts had another common feature besides their concern with production. While painting and sculpture were thought to have the mimicry of nature as their primary goal, it was believed that the arts in general were acquired by imitating various aspects of the natural world. The atomist Democritus (fifth century B.C.E.) already claimed that men had learned the art of weaving from spiders and that of singing from birds.⁹ Aristotle himself, if we are to follow the authority of the fragmentary *Protrepticus*, thought that the carpenter's plumb bob, the straightedge, and a primitive form of compass were discovered by mimicking the behavior of water and of the sun's rays.¹⁰ Talos, the nephew of Daedalus, was said by the historian Diodorus Siculus to have invented the saw when he chanced upon the jawbone of a snake one day and idly used it to cut through a small piece of wood. Imitating this natural object in iron, he crafted the most basic tool of carpentry.¹¹ Vitruvius (first century B.C.E.), the most famous architect of antiquity, maintains that house building was first devised by men who were imitating the nests of swallows.¹² According to him, even machines owe their invention to the mimicry of nature. Their windlasses, capstans, axles, and drums all partake of circular motion (*cyclotē cinesis*), in imitation of the celestial spheres.¹³ A similar, if more elaborate story of invention is told by the Greek poet Oppian, in his second-century hexameter poem about fishing, the *Halieutica*. In explaining how the art of sailing was discovered, Oppian makes extended use of the chambered nautilus. According to Oppian, the nautilus normally travels through the sea by turning over on its back, so that its shell resembles the hull of a ship. The animal then raises two of its feet like masts, and spreads the membrane between them like a sail. Finally it rows with two more feet,

becoming a sort of zoological trireme, easily copied by the first human sailors.¹⁴ Even more sublime stories of discovery are found in the writer Seneca (4 B.C.E.–65 C.E.), recounting the doctrines of the Stoic Posidonius. Seneca tells us that bread was discovered when a philosopher decided to imitate the workings of the teeth, throat, and stomach. Seeing that the teeth crushed grain, which was then lubricated with saliva, transferred to the stomach by the throat, and cooked slowly by the process of digestion, this enterprising intellect invented the mill, the process of making dough, and the baking of bread. Seneca himself rejects this historical theory, not because it is absurd, but because it demeans the philosopher by relegating him to the status of technician.¹⁵

We could relate many other accounts of invention, but it is more relevant to consider the assumptions behind them. Underlying such stories is the notion that human ingenuity operates by producing simulacra of nature. The saw mimics the form of a jawbone, and the process of baking bread imitates the steps involved in eating and digesting grain. Despite the many benefits conferred upon mankind by such products of artifice, however, no one meant to argue that a saw was a jawbone, that lifting machines really approximated the motion of the heavenly spheres, or that bread making was identical to the assimilation of food. Such copies of natural products and processes might be able to perform multiple tasks, but they could not fulfill nature's purpose with the simple perfection of a natural product. As Aristotle put it (*Politics* I 1252b1–5), "nature makes nothing as the cutlers make the Delphic knife, in a niggardly way, but one thing for one purpose; for so each tool will be turned out in the finest perfection, if it serves not many uses but one."¹⁶ In this way, again, the products of the craftsman were like those of the painter or sculptor—the saw of Daedalus's nephew was like Myron's cow in that it was a semblance only, incapable of capturing the essence of the exemplar that it copied.

The most explicit denunciation of artistic *mimēsis* that antiquity produced may well be the blistering attack on poetry and painting found in book 10 of Plato's *Republic* (596B–598C). There Plato famously contrasts the carpenter to the painter. Both work by imitation—the carpenter by mimicking the ideal form of a bed, the painter by copying the artifact that the carpenter has made. Since the painter is "imitating an imitation," his art

9. Democritus, fragment B 154, in Hermann Diels, *Die Fragmente der Vorsokratiker* (Berlin: Weidmannsche Verlagsbuchhandlung, 1952), 2:173.

10. Ingegnar Düring, *Der "Protreptikos" des Aristoteles*, in *Quellen der Philosophie* 9, ed. Rudolph Berlinger (Frankfurt: Vittorio Klostermann, 1969), 52–53 (Greek and German). For more on the attitude of the *Protrepticus* to art and nature, see A. J. Close, "Commonplace Theories of Art and Nature in Classical Antiquity and in the Renaissance," *Journal of the History of Ideas* 30(1969), 467–486.

11. Diodorus Siculus, *Library*, bk. 4, 76, p. 59.

12. Vitruvius, *De architectura*, ed. and tr. Frank Granger (Cambridge, Mass: Harvard University Press, 1983), bk. 2, chap. 1, vol. 1, p. 79.

13. Vitruvius, *De architectura*, bk. 10, chap. 1, vol. 2, pp. 274–279.

14. Oppian, *Halioetica*, bk. 1, lines 338–350. This story accounts for the miniature ships fashioned out of chambered nautilus and lovingly preserved in some Renaissance *Kunstkammern*.

15. Seneca, *Letters from a Stoic*, tr. Robin Campbell (Baltimore: Penguin, 1969), epistle 90, pp. 169–170.

16. Aristotle, *Politics*, tr. H. Rackham (Cambridge, MA: Harvard University Press, 1932), 5–7.

is inferior to that of the carpenter, and both are inferior to nature. Whether Plato is entirely sincere in his attack on painting is a matter of debate, but the language that he uses is remarkable, and resonates with the examples that we have already introduced.¹⁷ The artist, as imitator, is "a creator of the illusion" (*ho tou eidōlou poiētēs*—601C 9) that leads us away from reality. He produces his deceptions in the same way that water refracts light and makes an object appear bent when submerged. He is like a conjuror who feigns life with his tricks (*mēchanai*) and makes his "marionette shows" (*thauumatopoiia*) seem real by means of ruses that appear to be nothing short of magic (*goeteia*—602D 1–4).¹⁸ As in the ancient descriptions of Daedalus that we have already encountered, Plato views the artist as being something like a stage magician. His artifice tricks us into accepting his depiction of nature as the real thing.¹⁹

Plato's distrust of the mimetic arts reflects a widespread ambivalence toward imitation in antiquity. This mistrust is rooted in the idea that the painter or sculptor, by producing a replica of something natural, is engaging in a sort of counterfeiting. The same attitude existed with regard to the *technai* more broadly. Although they might be clever simulacra of nature, they could not themselves be natural. A clear formulation of this distinction between the products of nature and the products of artifice appears in Aristotle's *Physics*, where (at II 1 192b9–19) the Stagirite distinguishes natural products from artificial ones on the basis of the fact that the natural have an innate principle of movement (or change) [*ekbonta en beautois arēnē kinēōōs*], whereas the artificial have no inherent trend toward change [*oudēmian bornēn ebei metabolēs emphyton*].²⁰ For this reason, Aristotle says (II 1 193b, 8–9), "men propagate men, but bedsteads do not propagate bedsteads." The artificial product is static, having received no intrinsic principle of development.²¹

17. For the view that Plato was merely using painting as a convenient example rather than genuinely rejecting it, see Eva C. Keuls, *Plato and Greek Painting* (Leiden: Brill, 1978). See also Hans Blumenberg, "Nachahmung der Natur," *Studium generale* 10 (1957), 266–283. A brief recounting of some other sources dealing with this issue may be found in Steiner, *Images in Mind*, 76 n. 201.

18. Plato, *the Republic*, tr. Richard W. Sterling and William C. Scott (New York: W. W. Norton, 1985).

19. Jean-Pierre Vernant, "The Birth of Images," in Vernant, *Mortals and Immortals*, 164–185.

20. Aristotle, *The Physics*, tr. Philip H. Wicksteed and Francis M. Cornford (London: Heinemann, 1929), 106–115.

21. See Heikki Mäkelä, *An Aristotelian Response to Renaissance Humanism* (Helsinki: Societas Historica Finlandiae, 1992), 107–130, for some of the ways in which the Aristotelian art-nature dichotomy could be taken.

Perfective versus Imitative Art

Aristotle's seemingly stark distinction between the artificial and the natural was more permeable, however, than might appear at first glance. A few pages after introducing the distinction between art and nature, Aristotle adds (at *Physics* II 8 199a 15–17) that art can function in two different ways—"the arts either, on the basis of Nature, carry things further (*epitelei*) than Nature can, or they imitate (*mimetai*) Nature."²² This dichotomy allowed the possibility of having two distinct types of art, one that perfects natural processes and brings them to a state of completion not found in nature itself and another that merely imitates nature without fundamentally altering it.²³ Already in Aristotle's time, Hippocratic medicine had come to epitomize the former type of art, since the physician did not generally lead the human body to an unnatural state, but merely brought it to its natural condition of health by eliminating impediments. In the medical works of Galen (second century C.E.), this idea would be epitomized by the maxim that art acts as the servant of nature.²⁴ Such an art was "perfective," in the sense that it brought nature to an end that would not be realized otherwise.

We must carefully distinguish between Aristotle's concept of a perfective art and the idea, already present at the time of the Stagirite, that the fine arts can "perfect" nature by making a product as beautiful or as affective as its natural model. The most famous example of such perfecting of nature by the visual arts is surely the story of Zeuxis, commissioned to paint a likeness of Helen of Troy by the inhabitants of Croton. Realizing that no ordinary woman would do, Zeuxis convinced the Crotonian authorities to give him five beautiful virgins as models. He selected the best features of each, and thus prepared a composite woman more beautiful than any found in nature. As Cicero put it in his recounting of the story, "he did not believe that it was possible to find in one body all the things he looked for in beauty, since

22. Aristotle, *Physics*, p. 173.

23. Aristotle himself did not mean to present a strict disjunction between two types of art that are necessarily different (as reflected in the Greek, where the perfective art is introduced by *te* and the mimetic by *de*), since some arts operate by both mimicking nature and perfecting it. This fact is reflected in other translations of *Physics* II 8 199a15–17. The translation in Ross's series renders the passage as follows: "generally art partly completes what nature cannot bring to a finish, and partly imitates her." Aristotle, *Physics*, tr. R. P. Hardie and R. K. Gaye, in *The Works of Aristotle*, ed. W. D. Ross (Oxford: Oxford University Press, 1966).

24. Galen, *De constitutione artis medicae ad Patrophilum*, in *Opera omnia*, ed. C. G. Kühn (Leipzig: Knobloch, 1821–1833), 1:303; and *Art medica*, in *Opera omnia*, 1:378. I owe these references to a kind communication from Heinrich von Staden. On the probable derivation of Aristotle's idea from Greek medicine, see Augustin Mansion, *Introduction à la physique aristotélicienne* (Louvain: Éditions de l'Institut Supérieur, 1945), 197–198, 257.

nature has not refined to perfection any single object in all its parts.²⁵ This story of perfecting nature by bringing together a representation of disparate features and thus excelling over the natural object in beauty or some other trait has an astonishingly long history in Western art, being one of the dominant motifs even in the sixteenth century. As Erwin Panofsky showed in his famous *Idea*, it was possible for Renaissance artists to combine this notion with the Neoplatonic belief that immaterial forms exist apart from matter, which in turn receives its qualitative characteristics from them.²⁶ According to Plotinus and his followers, the immaterial, transcendent world of forms was immeasurably superior to the material universe. The artist, when he formed matter into a particular shape or image, was performing a task parallel to that of the demiurge, when he shaped the material world into its present configuration. The idea in the artist's mind, moreover, found its origin in the world of forms, and its imposition on matter could be seen as a process of perfecting, or at least improving, the latter. The Zeuxian goal of attaining a beauty or perfection not realized in unaided nature could then appear as an attempt to attain the formal perfection of the archetypal world. In short, by shifting the emphasis from matter and its alterations to the forms that lay behind it, one could argue that the idea in the mind of the artist had an existence superior to its material embodiment, and that a painting or sculpture was the material reflection of that semidivine form or idea. This belief, however, was quite alien to Aristotle's conception, which insisted on the distinction between real material change and superficial *mimēsis*. From an Aristotelian perspective, it is one thing to improve upon nature, and quite another to improve nature itself.²⁷

In addition, an Aristotelian perfective art could also be mimetic, in the sense that it could imitate natural processes used in order to lead nature to greater perfection. This point is emphasized with particular clarity in the fourth book of Aristotle's *Meteorology*, a work that is now widely considered

genuine.²⁸ At one point (IV 3 381b3–9) Aristotle justifies his use of terms taken from cooking, an artificial activity, to describe processes in nature. He claims that "art imitates nature," using this fact to justify the imposition of technical terms such as "boiling" and "roasting" onto natural phenomena.²⁹ Since artisans have learned their operations by imitating nature, it is unproblematic to use their technical language in describing the natural processes that they have copied. If one takes this to mean that these human artisanal processes are identical to their analogues in the natural world, it opens an avenue by which the imitation of nature—from which the processes are learned—could lead to the very perfecting about which Aristotle speaks at *Physics* II 8 199a15–17. Since this type of imitation would utilize natural processes, one could legitimately argue that it leads to a natural product and that it is in fact perfective.

The purely imitative type of art, on the other hand, which merely mimics nature without perfecting it, had already received Plato's dismissive treatment, as we saw above. Painting and sculpture were among the paradigmatic mimetic arts, and they had nothing to do with perfecting nature in the Aristotelian sense. Indeed, when Galen contrasted nature's work to that of man, he used precisely the example of the great sculptors as a foil—"For Praxiteles and Phidias and all the other statuary used merely to decorate their material on the outside, in so far as they were able to touch it; but its inner parts they left unembellished, unwrought, unaffected by art or forethought, since they were unable to penetrate therein and to reach and handle all portions of the material. It is not so, however, with Nature." The great sculptors, for all their skill, "could not turn wax into ivory or gold, nor yet gold into wax."³⁰ Galen even went so far in another work as to deny that man could make true, homogeneous mixtures.³¹ Despite external appearances, the artistry of man could not in truth compete with that of nature. But since the medical art was the "servant" or "agent" of nature according to the well-worn Galenic formula *ars ministra naturae*, it differed from sculpture

25. Cicero, *De inventione*, II, 1, 1, reproduced in Pollitt, *Art of Greece*, 156.

26. Erwin Panofsky, *Idea* (New York: Harper and Row, 1968), 15, 49, 58, 157, 165, *et passim* (for the Crotonian maidens). The influence of Neoplatonism forms the core of Panofsky's brilliant book; it must be admitted that his failure to give equal billing to the Aristotelian theory of *mimēsis* is a serious weakness. David Summers arrives at a viewpoint not unlike mine in his important book *The Judgment of Sense* (Cambridge: Cambridge University Press, 1987), 1–2, which underscores Panofsky's tendency to downplay or ignore Aristotelian themes in favor of Platonic ones.

27. I make the useful distinction between "improving" absolutely and "improving upon" from the *Oxford English Dictionary*: "[*improve*] *absol.* To make improvements. To improve on or upon: to make or produce something better or more perfect than." *The Compact Edition of the Oxford English Dictionary* (Oxford: Oxford University Press, 1971), 1393, s.v. "improve," no. 8. According to this distinction, "to improve nature" means "to make nature itself better." To "improve upon nature" means to make something better than nature, to outdo nature.

28. H. D. P. Lee, introduction to his translation of Aristotle, *Meteorologia* (Cambridge, MA: Harvard University Press, 1952), xiii–xxi; David Furley, "The Mechanics of Meteorologia IV. A Prolegomenon to Biology," in *Zweifelhafte im Corpus Aristotelicum*, ed. Paul Moraux and Jürgen Wiesner (Berlin: de Gruyter, 1983), 73–93; Pierre Louis, *Aristote: Météorologiques* (Paris: Les Belles Lettres, 1982), xii–xv. But see Hans Strohm, "Beobachtungen zum vierten Buch der Aristotelischen Meteorologie," in *Zweifelhafte*, 94–115. Strohm considers *Meteorology* IV to be a "Bearbeitung." A fairly recent *status quaestionis* may be found in Carmela Baffioni, *Il IV libro dei "Meteorologica" di Aristotele* (Naples: C.N.R., 1981), 34–44.

29. Aristotle, *Meteorology* IV 381b3–9.

30. Galen, *On the Natural Faculties*, tr. Arthur John Brock (London: Heinemann, 1947), 129.

31. Galen, *Mixture*, in P. N. Singer, tr., *Galen: Selected Works* (Oxford: Oxford University Press, 1997), 227.

in leading nature to change the internal constitution of the matter on which it worked. An attitude not wholly unlike Galen's view of sculpture may be found in ancient descriptions of perfumery and textile dyeing. Pliny the Elder, in his *Natural History*, claims that human luxury has conquered nature in the matter of perfumes and is challenging it in the realm of dyes.³² Yet there is nothing in Pliny's text to suggest that he meant anything more than the sort of contest between art and nature that Myron and Zeuxis had already entered into with their deception of animals. Nature is beaten only to the degree that the ersatz product fools the beholder or suits his purposes more than the natural one.

Conquering Nature with Mechanics

There is another sense, however, in which the idea of conquering nature added a very significant elaboration to the Aristotelian distinction between perfective and purely mimetic arts in antiquity. The writers on mechanical subjects effectively made "conquest of nature" a third category of its own. Unlike the notion of a competition with nature that we find in ancient writings on the visual arts, the mechanical writers transferred the contest from the world of the aesthetic to the realm of physics.³³ When Pliny spoke of "conquering" nature, he meant one of two things—the making of a product whose artificiality could not be detected by the human senses, or a product that was even more pleasing than the natural. In either case, the competition with nature was restricted to the ability of an artificial product to appeal to the sense organs of man. The ancient writers on mechanics, to the contrary, saw themselves as making natural objects behave in a fashion that was fundamentally unnatural. They were superinducing a new set of qualities on matter that made it act in ways that were strikingly at odds with its own inherent tendencies. The changes that they imposed were not to be measured merely in terms of human *aisthēsis*, but in regard to the nature of things in themselves.

The earliest example of this attitude may be seen in the *Mechanical Problems* attributed to Aristotle, but probably composed a short time after his death. The *Mechanical Problems* begins with the claim (847a1 ff.) that marvelous phenomena can be produced either when we do not know the cause of a thing or when art is induced to act "against nature" (*para physin*).

32. Pliny the Elder, *Historia naturalis*, bk. 21, XXII, 45–46. See Robert Halleux, *Les alchimistes grecs* (Paris: Belles Lettres, 1981), 1:76, where a number of Plinian references to art and nature are assembled.

33. On the relationship between practical mechanics and the other arts, the reader may consult the important chapter on the mechanical arts in Summers, *Judgment of Sense*, 235–265.

Quoting the Greek poet Antiphon, pseudo-Aristotle says, "Mastered by Nature, we overcome (*kratoumen*) by Art." As an example of this conquest of nature by art, the author then passes to the main topic of the work, "those cases in which the less prevails over the greater." What pseudo-Aristotle has in mind when he speaks of acting against nature, or conquering nature, can be understood only in terms of the genuine Stagirite's teachings on the material composition of things. Aristotle had made it a foundational principle of his system that all substances beneath the sphere of the moon are composed of the four elements fire, air, water, and earth. Each of the four elements had its natural place—fire formed a sphere directly beneath the moon, and air found its natural place immediately below that of fire. Earth, the heaviest element, naturally congregated at the center of the universe, which corresponded to the central point of our globe, and water formed a sort of sphere around the earth. Since each element tended to go to its own natural place, it followed that an art that specialized in making the elements go elsewhere, as in the case of machines that easily raised heavy bodies, operated "against nature."³⁴

At the same time, it must be stressed that the *Mechanical Problems* makes no use of the four Aristotelian qualities hot, cold, wet, and dry. Aristotle argued that these "primary qualities" existed within the four elements and provided the means by which they could be transformed into one another. Fire was dry and hot, air hot and wet, water wet and cold, and earth cold and dry. If fire should lose its dryness and become wet, it would be transmuted into air; if it were to lose both its dryness and its heat, it would become its own opposite, namely water. The operation of the elements and the four qualities occupies many of Aristotle's physical works, such as *De generatione et corruptione*, *De caelo*, and the *Physics* itself. And yet the principles of mechanics, as the author of the *Mechanical Problems* no doubt realized, do not rely on these innate elemental qualities. Here lies a point of basic and paramount importance to our understanding of ancient mechanics. The law of the lever applies regardless of the material constitution of the lever, being determined solely by the distance from the motive agent to the fulcrum and the distance from the fulcrum to the body to be lifted. This mathematical treatment of bodies had no concern for their elemental constitution, nor with the four qualities

34. A nuanced consideration of this subject may be found in Gianni Micheli, *Le origini del concetto di macchina* (Florence: Olschki, 1995), 24–35. Micheli's erudite treatment considers the concept of working "against nature" (*para physin*) only in terms of lifting heavy bodies, however. The historically significant fact that Greek mechanics as a science did not deal with the material natures of bodies but only with the properties that could be expressed geometrically does not form a significant part of his discussion.

underlying them. In this sense too mechanics was seen to work "against nature," for it did not depend on the physical natures of bodies—seen from an Aristotelian perspective—for its success. To the contrary, mechanics imposed a new set of properties on the four Aristotelian qualities, making them operate in a way that was quite contrary to their natural inclinations.³⁵ Mechanics, like carpentry and painting, was not a perfective art, since it did not work with the elemental qualities to bring them to their internally determined goal. At the same time, however, mechanics operated in a way that was frankly contrary to the natural operations of the four qualities, whereas painting and carpentry produced change that was merely irrelevant and superficial to them. Nonetheless, all three disciplines were alike in that they were limited to the production of *artificialia*. Like Aristotle's bed used in the *Physics* to illustrate the distinction between art and nature, an iron lever could not breed new levers any more than a painted horse could assuage its hunger by eating its painted hay.

There is more, however, to the *Mechanical Problems*' claims than a mere reference to the violent imposition of new properties onto matter. The very term *mēchanomai*, the verbal form of the Greek word for machine, was often used in a negative sense, to mean the act of deceitful contrivance.³⁶ Pseudo-Aristotle's focus on apparent marvels produced by hidden causes and by those that act against nature links him to the Daedalean tradition of wonderful yet deceptive machines, such as self-moving statues and simula-cra of animals. To the man on the street these might seem to be alive, but in fact they are not, as the genuine Aristotle stressed in his description of Daedalean automata in the *De anima*. Yet the *Mechanical Problems* has added a new twist to its analysis of marvelous machines. Unlike most previous works, the *Mechanical Problems* explicitly views the forceful conquest of nature as a desirable goal. The making of machines is no longer a mere mimicry of nature, but an actual triumph over it. This claim would bear significant fruit among the later writers in mechanics.

The mathematical writer Pappus of Alexandria (fourth century C.E.) reveals that the tradition inaugurated by the *Mechanical Problems* was still in force half a millennium later. Pappus assures us that mechanics teaches

35. This is what Renaissance writers like Niccolò Leonico Tomeo meant when they argued that mechanics was contranatural and governed by mathematics because "weights and measures are abstracted from the natural material in which they are found." See W. R. Laird, "The Scope of Renaissance Mechanics," *Osiris*, 2d ser., 2 (1986), 43–68, especially p. 49. For Leonico Tomeo, who is not to be confused with the famous Renaissance physician Nicolaus Leoniceus, see Charles Lohr, *Latin Aristotle Commentaries: II Renaissance Jambos* (Florence: Olschki, 1988), 452–454.

36. For some Homeric examples of this use of *mēchanomai* and *mēchanē*, see Micheli, *Le Origini*, 10 n. 6.

us how to force bodies into motions opposed to their normal ones in a way that is "against nature" (*para physin*). In a fashion that seems to prefigure the medieval use of the term "mechanical arts" to mean any sort of handicraft operation, Pappus then relates that mechanics includes the disciplines of metal working, house building, carpentry, and painting, along with the construction of machines proper. Echoing the Platonic tradition of viewing mimetic arts as "illusionist," Pappus adds that some mechanicians are called wonder workers (*thaumasiourgoi*) because they make automata, trying to imitate the movement of animated beings by means of ropes fashioned from gut and grass.³⁷ The same focus on producing marvels by "conquering nature" is found in the work of the sixth-century monastic writer Cassiodorus Senator. In a letter to Boethius, Cassiodorus defines mechanics (*mechanisma*) as the one discipline that tries to conquer (*superare*) nature by imitating it with contrary materials (*ex contrariis*). He adds that it was mechanics that allowed Daedalus to fly, made "the iron Cupid in the temple of Diana hang without support," and continually makes mute things sing, insensate beings live, and immobile ones move. The mechanic is almost a comrade of nature, playing with marvels and simulating nature so beautifully that his machine is not doubted to be the real thing rather than a counterfeit.³⁸

With Cassiodorus, we have returned to the marvelous machines of Daedalus, including not only the famous wings that allowed him to escape from King Minos, but the self-moving statues or automata that had already been credited to him in the time of Plato. Both Pappus and Cassiodorus seem to view the imitation of life as the crowning achievement of the mechanical tradition, the ultimate example of art conquering nature. And yet both authors are also clearly aware that this semblance of life is only an illusion: to Pappus, the mechanicians are *thaumasiourgoi*, while Cassiodorus

37. Pappus of Alexandria, *La collection mathématique*, tr. Paul Ver Eecke (Paris: Desclée, de Brouwer, 1933), 2810–811. It is true that Pappus also says that mechanics teaches the motion of bodies according to nature (*kata physin*) as well as against nature (*para physin*), but a few lines later he reiterates that machines themselves, as opposed to the "rational mechanics" of the mathematicians, work *para physin*. See pp. 809 and 811 of Ver Eecke's translation.

38. Cassiodorus, letter to Boethius (507 C.E.), quoted from Peter Sternagel, *Die Arter Mechanice im Mittelalter: Begriffs- und Bedeutungs-geschichte bis zum Ende der 13. Jahrhunderts*, Münchener Historische Studien, Abteilung Mittelalterliche Geschichte, Band II (Kallmünz über Regensburg: Michael Lassleben, 1966), p. 14: "mechanisma solum est quod illam (sc. naturam) ex contrariis appetit imitari et, si fas est dicere, in quibusdam etiam nititur velle superare. Haec enim fecisse dinoscitur Daedalus volare; haec enim ferreum Cupidinem in Dianae templo sine aliqua illigione pendere; haec hodie facit muta cantare, insensata vivere, immobilia moveri. Mechanicus, si fas est dicere, paene socius est naturae, occulta reseras, manifesta convertens, miraculis ludens, ita pulchre simulans, ut quod compositum non ambigitur, veritas aestimetur." An English translation of this interesting letter may be found in S. J. B. Barnish, *The 'Variar' of Magnus Cassiodorus Senator* (Liverpool: Liverpool University Press, 1992), 20–23.

says that they are so successful at simulating (*simulans*) nature that their work is considered genuine by the unwary. Underlying these comments is a clear realization of the fact that mechanics is not a perfective art in the Aristotelian sense, since it does not alter or develop the innate elemental qualities of matter, but imposes a new set of properties upon the underlying material ones. Wood and iron remain wood and iron even after they have been fashioned into the form of a lifelike automaton. This is what the medieval writers, such as Roger Bacon, meant when they called machines "purely artificial," contrasting them to other types of products that worked by means of natural powers.³⁹ Like Aristotle's bed, machines are purely artificial objects and do not share in genuine self-movement such as that which would allow them to propagate their own species. It is this imposition of a new, feigned appearance that allows automata to be classed in the same category of mimetic arts within which the ancient writers customarily placed painting and sculpture. In all three cases, the artifact retains its original material composition and does not "become" the object that it represents, despite appearances. The grapes of Zeuxis and the cow of Myron may have fooled the unwary, like the statues of Daedalus, but ultimately they left the duped bird or bull unhappy. Nature may have been bested, but it had not been replicated.

Ancient Alchemy and the Relationship between Art and Nature

Into the complex of ideas about mimicry and trickery, perfecting and competing with nature, that characterized the Greek and Roman mind, a new subject inserted itself in late antiquity. This discipline, alchemy, was originally as ambiguous and ill-defined as the groping ideas about art and nature upon which it sought to capitalize. And yet alchemy eventually provided a focus to the discussion of art and nature that had no parallel in antiquity either in terms of sustained interest or interplay of theory and practice. Its end result would be a reassessment of the relationship between the artificial and the natural worlds that would feed the fires of the scientific revolution and provide a host of issues that confront humanity even today with a relentless urgency. Alchemy, unlike painting, sculpture, or the making of lifelike automata, was an art that sought to reproduce natural products in all their qualities, not merely to make a superficial simulation. Like medicine,

39. Roger Bacon, *Epistola de secretis operibus artis et naturae*, in Mangeret, 1:619. Roger contrasts machines, which work by means of art alone (*per figuratiorem viam artis*), to operations such as the making of Greek fire and the marvelous prolongation of life, which work by means of art acting on nature.

alchemy was a "perfective art," and yet it differed from medicine in that its goal was the creation of a physical object rather than the acquisition of a physical state (health). Although the attempts of the alchemists to replicate nature initially focused on the making of precious metals and gems, they eventually branched out to include the duplication of human life itself. These efforts proved necessarily abortive, of course, but they provide us with an unusually transparent porthole into the mind of premodern man. The image that confronts us beneath the antiseptic glass of history may not be entirely attractive, but it is perhaps more mirror than window.

The origins of alchemy are ambiguous by any standard.⁴⁰ Yet one thing is fairly clear. Western alchemy, or its vaguely defined progenitor in the technical literature of Greco-Roman Egypt, was closely related to the very mimetic arts that have formed the object of our discussion. Indeed, the best way to view alchemy in its formative stage—let us call it proto-alchemy—is as a branch of the decorative arts. But in its development, an extraordinary thing happened. The alchemists began to view the products of their workshops as no different from the natural exemplars upon which they based their designs. Imagine a parallel situation occurring in the field of representational art as a whole—every artist would become a Pygmalion, claiming not only to paint his subject, but literally to make it live. This, in a sense, is precisely what happened to the decorative workshop tradition that gradually transformed itself into the discipline of alchemy in late antique Greco-Roman Egypt.

The influential historian of late antique religion, A. J. Festugière, argued that ancient Western alchemy fell into several stages of development. The earliest, "alchemy as simple technology," stretched from Egyptian antiquity to the period around 200 B.C.E. The royal and sacerdotal workshops of the Egyptians were expert in the working of metals, precious stones, glass, and dyes. Fourteen centuries before the Christian era, the pharaoh Turankhamen was interred with an extraordinary cache of artifacts and jewelry. His spectacular pectoral ornament (fig. 1.1) combined gold and silver with the semiprecious gemstones chalcidony, cornelian, calcite, lapis lazuli, turquoise, and obsidian, along with cleverly colored glass apparently meant to give the appearance of precious stones. Within the tomb were also various

40. I speak here of Western alchemy only. The discipline certainly existed in the Greek world by the beginning of the Christian era, as it did in China. Nonetheless, the two civilizations may well have come upon this field independently of one another, and the hazy antecedents of Greek alchemy appear to lie in the Middle East rather than the Far. For a discussion of this point, see Robert Halleux, *Les textes alchimiques* (Turnhout: Brepols, 1979), 60–64. Halleux intelligently synthesizes and critiques the treatments of Joseph Needham.

and Stockholm papyri for the modern libraries where they are kept. Despite the rather late date at which the papyri were copied or composed, they contain a technology that probably represents the earliest stage in the history of alchemy.

The Leiden and Stockholm papyri describe a varied range of technological processes, all focusing on the imitation of natural products. Numerous recipes for making artificial gold and silver are given, of course, but in addition the papyri concern themselves with the making of textile dyes and the manufacture of imitation precious stones. Surprisingly, the papyri even recount a variety of assaying tests for distinguishing the natural product from its ersatz facsimile.⁴³ What is most striking about the papyri is their attitude to the act of mimicry itself. Although the terms for gold making (*poitēis chryson*) and silver making (*poitēis argyrou*) appear there, it is by no means clear that the recipes are intended to produce genuine gold and silver as opposed to similitudes of the noble metals. In fact, the evidence in many instances suggests the contrary. One recipe explicitly announces the goal of making copper "look like" (*phainesthai*) gold and even assures the reader that this product will be detected neither by the fire of the assayer nor by the touchstone. The compiler adds that this "simulation" (*phantasia*) will work best in the case of a ring.⁴⁴ Another recipe uses the same expression for making rock crystal "appear to be" (*phainesthai*) the semiprecious stone chalcedony, while yet another speaks of making a dye for wool that will "appear authentic" (*dokein alēthinon*).⁴⁵ In one case of gold making, the recipe is actually called "Fraud of Gold" (*chryson dolos*), though it is in a sense less fraudulent than others, since the final product would at least contain some genuine gold. The recipe works by "doubling" the gold, that is, by alloying genuine gold with iron, thus increasing its weight.⁴⁶ Another similar recipe in the Leiden papyrus begins with the phrase "Gold is counterfeited" (*Doloutai chrysos*), and then gives the recipe for the fraud.⁴⁷ It is likely that these and similar recipes were composed to satisfy the ancient market for paste or costume jewelry, of which many examples have survived, from colored glass cut to look like nicolos and emeralds, to red faience made to imitate natural jasper (plates 2–3).

Despite this clear evidence that the compilers of the Leiden and Stockholm papyri viewed their own handicraft as ersatz rather than genuine,

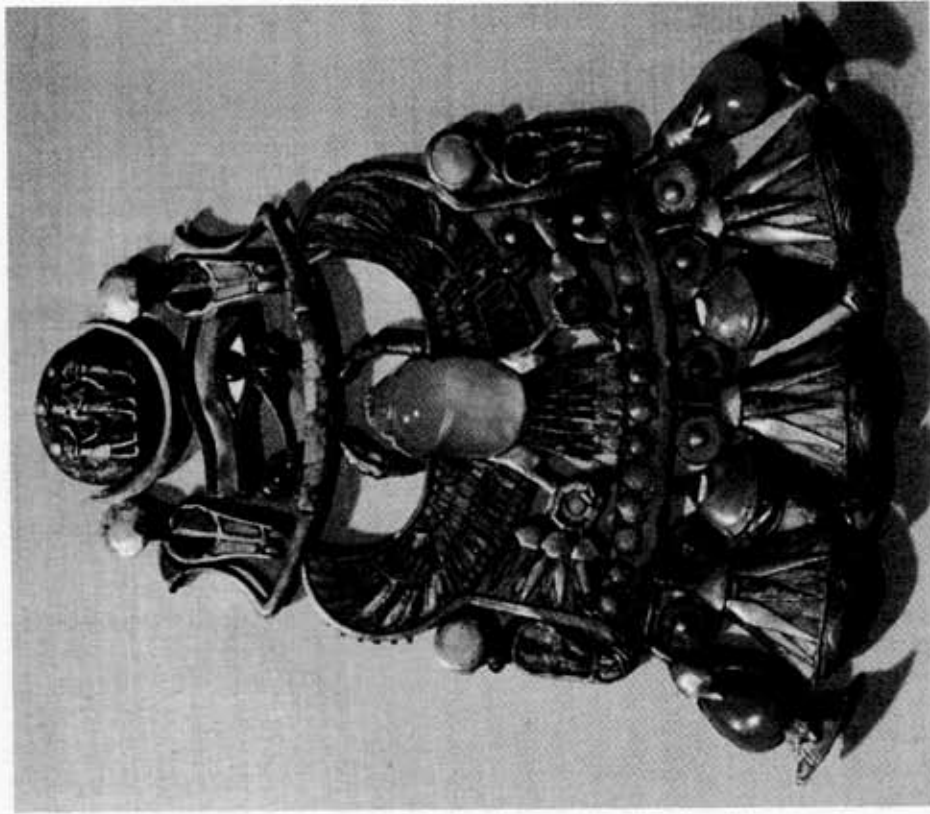


FIGURE 1.1. Pectoral ornament from the tomb of Tutankhamen (14th c. B.C.E.), combining inlays of precious and semiprecious stones with colored glass.

buttons (plate 1) made of "rosy" gold, an alloy of the precious metal and iron salts, which the Egyptian jewelers probably subjected to heat treatment in order to produce a reddish surface not found in nature.⁴¹ There is in fact nothing to make us think that this spectacular artisanal technology viewed itself as really replicating natural products as opposed to imitating them and providing aesthetic improvements.⁴² The most compelling evidence for the attitude behind this ancient proto-alchemy lies in two papyri composed in Egypt around the fourth century C.E., usually called the Leiden

43. Robert Halleux, *Les alchimistes grecs* (Paris: Belles Lettres, 1981), 52.

44. Halleux, *Alchimistes grecs*, 94. Halleux collects a number of such instances on p. 29 of his edition.

45. Halleux, *Alchimistes grecs*, 116 and 146.

47. Halleux, *Alchimistes grecs*, 104.

46. Halleux, *Alchimistes grecs*, 88 and 170.

48. Halleux, *Alchimistes grecs*, 116.

41. Jack Ogden, *Jewellery of the Ancient World* (New York: Rizzoli, 1982), 82, 18.

42. A. J. Festugière, *La révolution d'Hermès Trismégiste* (Paris: J. Gabalda, 1944), 1:219–223.

there are several instances where the recipes announce their affinity to the natural product. A recipe in the Stockholm papyrus for "making emeralds" states that the product will be "like the natural" stone (*homoion tē phýsei*).⁴⁸ The next recipe describes a process for making pearls that are even "better than the natural" (*hyper ton phýsikōn*).⁴⁹ Finally, a recipe for silver in the Leiden papyrus describes a mixture of brass and arsenic that will "in truth be better than silver" (*pros aletheian kreísson aīemōn*).⁵⁰ These assurances seem to reflect the same attitude displayed by Pliny in his *Natural History*, when he announced that perfumes and dyes made by man had "conquered" their natural exemplars.⁵¹ The idea is not that the natural and the artificial are identical, but that the artificial is at least as good as the natural for the purposes of humans, and perhaps even better. Similar claims of equiparity are made today for products ranging from margarine to imitation fur—this is a far cry from asserting that such products are identical to their exemplars in the natural world. And yet, around the time that the Leiden and Stockholm papyri were being copied, other alchemists were making precisely the claim that they could not just simulate, but replicate, natural products.

According to Festugière's chronology, the outlook of ancient alchemy began to change in the period between about 200 B.C.E. and 100 C.E., when the purely technical recipes of the Egyptians came to be blended with a concern about the "sympathies" and "antipathies" between different substances. The technical basis of this new alchemy remained largely as before, but the recipes were now subject to explanation in terms of a popularizing natural philosophy. Here one begins to see the claim that alchemy can really alter substances at a level beneath that of superficial change. Although the founding of this genre of alchemy is traditionally associated with the shadowy Bolos of Mendes, a figure from Egypt who seems to have called himself "the Democritean," no uncontested work by Bolos has survived. A fragmentary *Physika kai mystika* attributed in the Greek alchemical corpus to "Democritus" seems actually to have been composed or reworked in the second century of our era, although it may be based on a lost original by Bolos.⁵²

49. Halleux, *Alchimistes grecs*, 116.

50. Halleux, *Alchimistes grecs*, 103.

51. Pliny the Elder, *Historia naturalis*, bk. 21, XXII, 45–46.

52. Festugière, *La révélation*, I:224–238. The classic, if controversial, treatment of Bolos remains that of Max Wellmann, "Die φυσικά des Bolos Demokritos und der Magier Anaxilaos aus Larissa," *Abhandlungen der Preussischen Akademie der Wissenschaften, Teil I, Phil.-Hist. Klasse* 7 (1928), 1–80. For recent discussion and criticism of Wellmann, see Marthew W. Dickie, "The Learned Magician and the Collection and Transmission of Magical Lore," in David R. Jordan, Hugo Montgomery, and Einar Thomassen, *The World of Ancient Magic: Papers from the First International Samson Etirem Seminar at the Norwegian Institute at Athens, 4–8 May 1997* (Bergen: Norwegian Institute at Athens, 1999), 163–193.

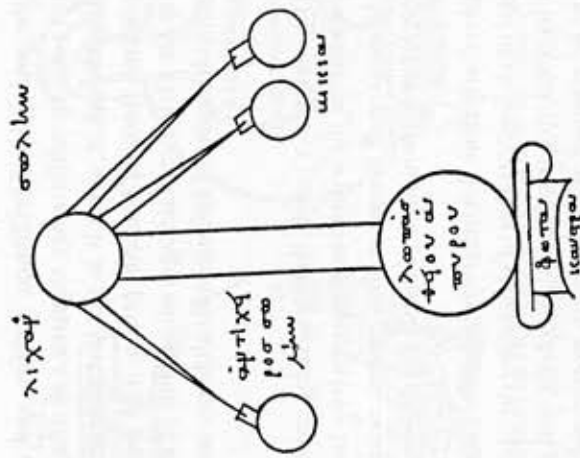


FIGURE 1.2. Three-beaked still (*triphloos*) from the Greek alchemical manuscript *Martianus graecus*, 299, fol. 194v.

The full fruition of this grafting of Greek philosophical ideas onto the chemical technology of ancient Egypt did not occur, however, until somewhat later. We encounter it clearly in the writings of the mysterious and prolific alchemist Zosimos, evidently a native of Panopolis in upper Egypt, who flourished around 300 C.E.⁵³ Zosimos was conversant with the revelations attributed to Hermes Trismegistus in the Greek *corpus hermeticum* and in various types of Gnostic literature. With Zosimos, we see religious motifs drawn from such sources and combined with the philosophical notions of pseudo-Democritus and of late Stoic philosophy in general, all used to explicate the technological basis already provided by texts like the Leiden and Stockholm papyri. No longer content with the goal of simulating natural products, Zosimos views alchemy as providing the means by which nature itself can pass from an imperfect state to a regenerate one. This idea can be observed nowhere better than in the descriptions of distillation and sublimation apparatus given by Zosimos. Indeed, the work of Zosimos gives the first description of a fully workable device for distillation in antiquity (fig. 1.2). He views evaporative processes as the conversion of a body into semimaterial spirit (*pneuma*) or as the release of such spirit from a body in which it has been trapped. In accordance with Stoic theories of matter,

53. Michèle Mertens, *Les alchimistes grecs: Zosime de Panopolis* (Paris: Belles Lettres, 1995), 4xvii.

this pneuma is the principle of brilliance, activity, and color, indeed, of life itself.⁵⁴ Hence a still or sublimatory acquires a profound soteriological importance for the alchemist, since it is the instrument that allows him to liberate the pneuma from its material prison. The beginning of Zosimos's strange text *On Virtue*, containing a succession of dreams and their interpretations, provides a sort of definition for alchemy seen in these pneumatological terms:

The placing of the waters [in a vessel], their movement, growth, disembodiment and reincorporation, the separation of pneuma from body, the binding of pneuma with body, not of foreign or alien natures; rather nature itself, simple and alone, holds the hard shells of metals and the juices of plants.⁵⁵

One thing emerges clearly from this otherwise obscure passage. While Zosimos views the goal of alchemy as that of separating the pneuma of material substances from its restrictive matrix, this is not the end of the story. The pneuma is also to be rejoined with the body, presumably after the body has been purified. Elsewhere in his writings, Zosimos explains that this is a physical death followed by a reanimation of the body undergoing treatment.⁵⁶ Alchemy, by providing the material key to this operation, reveals the method by which nature itself is not merely mimicked but transformed.

At times Zosimos even expresses his goal of radically transforming nature in graphic and violent terms. In *On Virtue*, Zosimos describes a dream in which he sees a flask filled with boiling water. Writhing and moaning within the vessel is an "innumerable crowd" of men, being boiled alive. They too must undergo a transmutation into pneuma, which requires that they undergo this "punishment" (*kolasis*). Upon awakening from his dream, Zosimos decides that this is an alchemical allegory and concludes with some general remarks on the method of the art. Here he passes from a discussion of individual reagents, anthropomorphized as men undergoing punishment, to the torture of nature as a whole. He argues that in order for the alchemist to succeed, Nature (*physis*) must be "forced to the investigation" (*ekthlibomenē pros tēn zētēsin*), whereupon she, suffering (*talaina*), will take on successive forms until her punishment renders her spiritual.⁵⁷ As Michèle Mertens points out in her excellent commentary to the text, the personified Nature is pushed into a state of "confusion," which makes her want to change

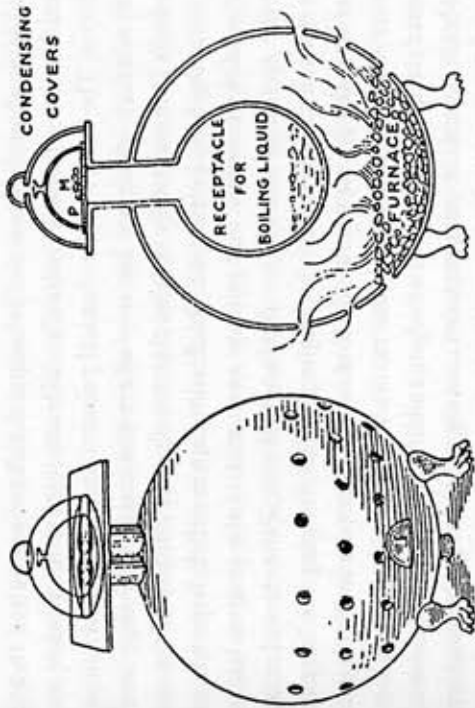


FIGURE 1.3. Modern reconstruction of a *kērotakis* or sublimatory as conceived by E. Sherwood Taylor, and based on *Marcianus graecus* 299, fols. 112r and 195v.

her state. The alchemist then induces her to assume various intermediate states until she is on the verge of death: only by this means can she become pneumatic, and thus useful for the alchemical work.⁵⁸

The result of these operations upon the pneuma, according to Zosimos, will be the acquisition of metals that have undergone a genuine transmutation, not the superficial coloring and alloying of the Leiden and Stockholm papyri. Zosimos refers not only to distillation apparatus in this pneumatic capacity, but to a singular instrument called the *kērotakis*, or "painter's palette"⁵⁹ (fig. 1.3). The name *kērotakis* seems to derive from the plates upon which encaustic painters would melt the wax cakes impregnated with pigment that served them in lieu of paint. Yet Zosimos's *kērotakis* was something quite different from a metal plate sitting on a source of heat. It seems to have been a complex vessel within which a material such as sulfur or arsenic sulfide could be sublimed. Above the vapors of the sublimed material a plate or leaf of metal was fixed in place, and the sublimed substance—seen of course as pneuma by Zosimos—would penetrate gradually into the body of the metal. Using this apparatus with the technology supplied by the papyri, one could produce radical changes in the colors and properties of the metals, which Zosimos interpreted as the requisite integration of pneuma and body.

54. A. J. Festugière, *Hermétisme et mystique païenne* (Paris: Aubier-Montaigne, 1967), 238–240.

55. Mertens, *Zosimos*, 4:34. I have in general followed Mertens's translation, with slight modifications. See her valuable notes to this obscure passage on 214–215.

56. Mertens, *Zosimos*, 4:215.

57. Mertens, *Zosimos*, 4:40–41.

58. Mertens, *Zosimos*, 4:224–225.

59. Mertens, *Zosimos*, 4:cxix–cxi.

In the work of Zosimos and subsequent alchemists, we see an attitude toward human art that is radically different from that of other ancient traditions. The dream of the classical painters and sculptors was a perfect visual mimicry of nature, but one where the imposed change was only skin-deep. One can safely say that this was also the attitude of the artisans who composed the Leiden and Stockholm papyri—their hope was to fool the eye of the beholder and perhaps even that of the assayer, but not to alter the nature of matter in a fundamental way. Painters and sculptors seem typically to have used the language of “challenging” or “surpassing” nature by making a representation that could either pass for the original or be more beautiful than any natural exemplar, a type of language shared by ancient descriptions of perfume making and by the writers of the Leiden and Stockholm papyri. Ancient engineers, on the other hand, characteristically spoke of “conquering” nature directly by means of machines, but again they did not dream of changing one substance into another by means of their levers, pulleys, windlasses, and gears. The rather unusual example of Vitruvius, who accentuated the similitude between machines and nature by arguing that manmade mechanisms mimicked the heavenly spheres, was a rare case in the history of mechanics.⁶⁰

In its claim to alter the fundamental nature of matter, the alchemy of Zosimos and his contemporaries bore some resemblance to the “theurgy” of late antique philosophical magic, which originated in the same geographical area at a slightly earlier period. One of the theurgist’s goals was the animation of inert matter, in the form of statues that were supposedly brought to life by means of a ritual (*telestikē*). According to the famous *Asclepius* of Hermes Trismegistus, the magician would gather various materials having a sympathy toward one another and to a particular divinity. The goal was to attract such a supramundane being so that it would enter the statue and make it utter oracles or perform other marvelous feats. Like ancient alchemy, theurgy claimed to alter matter in a fundamental way, by imparting a principle of activity. But the *raison d’être* of such magic was not the replication of a natural product. To the contrary, the end of the theurgist was communication with the formal beings inhabiting the intelligible realms beyond the material world. From such a perspective, the alchemical goal of reduplicating natural products could only seem a base diversion from the

true path.⁶¹ In this respect, the alchemy of Zosimos betrayed its roots in the workshop traditions of Egyptian decorative art, an umbilical cord that was never entirely severed.

Yet despite the close relationship between the proto-alchemy of the Leiden and Stockholm papyri and the visual *mimēsis* of ancient illusionist art, the alchemy of Zosimos and his descendants entered an area that was more akin to ancient medicine than to the other *technai*. Physicians, like alchemists, spoke of “perfecting” the form within natural things. But the Galenic tradition put strict limits on what man could accomplish in this area, claiming that humans were incapable of following nature in the making of homogeneous mixtures. This would certainly have made the replication of metals an impossibility, since they, along with many other natural products, were ranked among the homogeneous substances by Aristotle (*Meteorology* IV 10 388a10–20) and his countless followers. Already in late antiquity, then, alchemy occupied a privileged rank among its believers in its claim to alter the deep structure of matter in a way that was purely natural. It was this claim that would form the focus of debate in subsequent centuries as a disputational literature gradually grew up with the aurific art at its center. Here was a discipline that claimed not only to imitate nature by deceiving the senses, but to replicate it in every detail. To opponents of alchemy, this claim seemed to make the alchemist a second deity, since he was creating new gold, precious stones, or minerals where none had been before. The charge of “playing God,” commonly leveled against the pioneers of genetic engineering today, was already raised against those medievals who would change the order of the natural world.

61. E. R. Dodds, *The Greeks and the Irrational* (Berkeley: University of California Press, 1951), 283–311; Sarah Iles Johnson, *Hekate Sotera: A Study of Hekate's Roles in the Chaldean Oracles and Related Literature* (Atlanta: Scholars Press, 1990), 76–110; and Brian P. Copenhaver, trans., *Hermetica: The Greek "Corpus Hermeticum" in a New English Translation*, with notes and introduction by Copenhaver (Cambridge: Cambridge University Press, 1992), 80–81, 90–91. See also Kris and Kurz, *Legend, Myth, and Magic*, 79–80.

60. Micheli, *Le origini*, 96–97. It would be interesting to see if this neglect of Vitruvius's view of machines holds for later architectural sources as well. Micheli restricts himself to a discussion of treatises on mechanics.

medieval and early moderns alike with a focal point for considering the limits—both moral and ontological—of natural science and technology.

By the early Christian period, as the works of Zosimos reveal, alchemical writers were claiming not merely to imitate natural products but to replicate them. The ambiguous status of the precious stones and metals fabricated by the methods of the Leiden and Stockholm papyri had ceded to a full-blown claim that the alchemist could convert base metals into genuine gold and silver. By a complex process of transmission, the Greek texts and their attendant recipes then made their way into Syriac and Arabic, where they developed into a massive corpus that remains little studied by modern scholarship. In turn, a significant number of alchemical texts were translated from Arabic into Latin in the twelfth and thirteenth centuries, making it possible for the High Middle Ages to develop their own characteristic approach to the subject. As we will see, the Scholastic writers of the High and Late Middle Ages were keenly aware of the unique character of the alchemical claim to replicate natural products. Indeed, this assertion led to a full-blown debate on the status of artificial and natural products that began in the Middle Ages and continued into the seventeenth century, with repercussions lasting even today. Nor was this debate restricted to the ethereal realms of the Scholastic disputation—it permeated the alchemical texts themselves, and even found its way into the popular imagination by its incorporation into vernacular poetry. The present chapter provides an introduction to this rich and complex topic, but since it has barely been touched by scholarship, we can hardly hope to plumb its depths.

The debate around the legitimacy of alchemy provided a focal point for the consideration of human art in general. Was art always limited to the imperfect mimicry of nature, or could human beings genuinely re-create natural products? Did the assertions of the alchemists infringe on the power of God himself, turning man into a creator on the same level as the divinity? If man had such lofty powers, what did this tell us about the supernatural beings between man and God, the angels and demons of the medieval pantheon? Did these beings share the divine ability to create new substances? Was it by means of their help—especially that of the demons—that alchemists performed their marvelous feats? If so, did this mean that witches too could alter and transform material bodies for their own malefic purposes? And if the alchemists could make precious metals, where did their powers end—could humans even turn to the replication of life itself? If so, could man perhaps improve on the life that his own Creator had formed? In the same way that he coaxed base metals to become a gold even better than the gold of nature, could he make a human being that was better than

Chapter Two

ALCHEMY AND THE ART-NATURE DEBATE

Introduction

Competition with nature had become a broad and diverse theme between the time of Myron, at the origins of naturalistic Greek art, and the early Christian era. The topic of equaling nature by fooling the eye or of outdoing nature's power by producing an object more aesthetically appealing than any in the natural world found ample representation in areas ranging from the making of perfumes to the Zeuxian melding of bodily features to produce a "perfect" female. The ancient mechanicians had their own take on this subject. From pseudo-Aristotle in the third century B.C.E. to Pappus of Alexandria some six centuries later, engineers had been stressing that they could "conquer" the natural world by means of their machines. Even though they could not change the natural tendencies of the elements, the mechanicians could produce unheard-of effects by means of simple machines such as pulleys, levers, and gears. Magic, medicine, and agriculture for their part could claim to lead natural things to a greater state of perfection by im-planting the powers of the heavens in material bodies, by leading the human body from sickness to health, or by careful planting and cultivation of seeds. Alchemy too claimed to have the power of perfecting nature, and yet the alchemists carried this claim into a dimension quite different from that of the other arts. Unlike these other fields, alchemy—at least from the beginning of the Christian era onward—made its central quest the genuine conversion of commonplace materials into entirely distinct substances of much greater value. The twin themes of imitating and perfecting nature, which Aristotle had treated as potentially distinct fields of technical endeavor in his *Physics*, melded together in the alchemical treatises to form one coherent field of enterprise. The unique and forceful character of the alchemists' claims to emulate—and not merely imitate—the products of the natural world did not go unnoticed. This chapter will show how alchemy gradually became the center of a widespread and vigorous discussion about the abilities of man and art in the face of nature. Like no other topic, alchemy provided

the natural? These questions and many others flowed from the alchemical debate like the shimmering ripples rising from a highway as it recedes into the distance, strangely distorting the otherwise mundane scene with their influence. In this and following chapters, we will consider mainly those questions that had ramifications not only for alchemy but for the other arts as well, since the goal of this book is to reveal the influence of the art-nature debate on European culture as a whole.¹

Art versus Nature in Islam: The Problem of Transmutation of Species and the Substantial Form

A few words must be said first about the alchemical art-nature debate in Arabic sources, where it received its initial formulation. It may surprise some to learn that the brilliant polymath Yāqūb ibn Ishāq al-Kindī, active at the dawn of Islamic science, had already written a refutation of alchemy in the ninth century. Al-Kindī was an outspoken advocate of astrology, and even wrote a philosophical justification of talismanic magic, but his antipathy to alchemy is well attested even if no copy of his antialchemical text is known to modern scholarship and its arguments have been passed down through second-hand reports.² Al-Kindī's attack, which according to later reports included the claim that it is impossible for humans to reproduce the actions of nature, was in turn rebutted in the following century by the physician, philosopher, and alchemist Abū Bakr Muhammad ibn Zakarīyā al-Rāzī, but his reply to al-Kindī is likewise lost.³ The well-known scientific writer al-Fārābī (d. 950) also wrote a proalchemical treatise, *The Necessity of the Art of Alchemy*. He argued that the metals all belong to a single Aristotelian

genus, and are distinguished from one another only by their accidents: hence they should be able to undergo mutual transmutation.⁴ The same technical language was employed in what proved to be the most influential attack on alchemy ever made, in the *Kitāb al-Sijfī* (Book of the Remedy) written by the Persian philosopher and physician Ibn Sīnā (d. 1037), whom we will refer to henceforth as Avicenna.

Avicenna's attack on alchemy forms a small part of an impressive treatment of geology and mineralogy. This section of the *Kitāb al-Sijfī* would be translated into Latin by Alfred of Sareshal at the beginning of the thirteenth century as the *Liber de congelatione et conglutinatione lapidum* (Book on the Congalment and Concretion of Stones). Avicenna frames two very powerful arguments against alchemy there, which the Latins would refer to by the title *Scient artifices* (Let the artificers know), the words that began his pronouncement against alchemy. While neither of his arguments explicitly refers to God, they contain overtones that would be developed in a religious fashion by later writers. After admitting that artificers can fabricate clever simulations of natural products, Avicenna denies that alchemists can ever make genuinely natural products, for the following reasons:

Art is weaker than nature and does not overtake it, however much it labors. Therefore let the artificers of alchemy know that the species of metals cannot be transmuted (*Quare scient artifices alkimie species metallorum transmutari non posse*). But they can make similar things, and tint a red [metal] with yellow so that it seems gold, and tint a white one with the color that they want until it is very similar to gold or copper. They can also cleanse the impurities of lead, although it will always be lead. Even though it may seem silver, alien qualities will dominate in it, so that men err in this just as those who accept [artificial] salt and sal ammoniac err. I do not believe that it is possible to take away the specific difference by some technique because it is not due to such [accidents] that one complexion is converted into another, since these sensible things are not those by which species are transmuted; rather they are accidents and properties. For the differences of the metals are not known, and since the difference is not known, how will it be possible to know whether it is removed or not, or how it could be removed?⁵

4. Eilhard Wiedemann, "Zur Alchemie bei den Arabern," *Journal für praktische Chemie*, n.s., 76(1907), 65–123; see 115–123. For further references, see Ullmann, *Natur- und Geisteswissenschaften*, 250. The language of genus and species in the context of metals owes a debt to the lapidary of pseudo-Aristotle, for which see Ullmann, *Natur- und Geisteswissenschaften*, 105–110.

5. William R. Newman, *The 'Summa perfectionis' of Pseudo-Geber* (Leiden: Brill, 1991), 49–50. For the Arabic text and a translation thereof, see Avicenna, *Avicenna de congelatione et conglutinatione lapidum*, ed. and tr. E. J. Holmyard and D. C. Mandeville (Paris: Paul Geuthner, 1927), 85–86, 41–42.

1. For other studies pertaining to this subject, see Chiara Crisciani, "La 'quaestio de alchimia' fra Duecento e Trecento," *Medioevo* 2(1976), 119–165; William R. Newman, "Technology and Alchemical Debate in the Late Middle Ages," *Isis* 80(1989), 423–445; Michela Pereira, "L'elixir alchemico fra artificium e natura," in *Artificialia: La dimensione artificiale della natura umana*, ed. Massimo Negrotti (Bologna: CLUEB, c. 1995), 255–267; Barbara Obrist, "Art et nature dans l'alchimie médiévale," *Revue d'histoire des sciences* 49(1996), 215–286; and Crisciani, *Il papa e l'alchimia. Felice V. Gaugliedino Fabri e l'elixir* (Rome: Viella, 2002). John Hedley Brooke and Geoffrey Cantor, *Reconstructing Nature: The Engagement of Science and Religion* (Oxford: Oxford University Press, 1998), also touches on this theme, though the major thrust of the work concerns natural theology. Reijer Hooykaas considers the art-nature debate at length in his 1976 Gifford Lectures, published only recently as *Fact, Fable, and Fiction in the Development of Science* (Dordrecht: Kluwer, 1999). Although Hooykaas's treatment of the subject may be read with some degree of profit, great weaknesses arise in his recounting of the debate surrounding alchemy. To give but one telling example, the central figure in the debate, the Persian philosopher and physician Avicenna (d. 1037), finds no mention in Hooykaas's account.

2. Yāqūb ibn Ishāq al-Kindī, *De radiis*, ed. M.-T. d'Alverny and E. Hudry, *Archives d'histoire doctrinale et littéraire du moyen âge* 41(1974), 139–269.

3. Manfred Ullmann, *Die Natur- und Geisteswissenschaften im Islam* (Leiden: Brill, 1972), 250.

The first of these sentences contains the universal proposition that art is inferior to nature and therefore cannot make a product that genuinely measures up to its natural exemplar. This idea, which al-Kindī had already expressed in his own attack on alchemy, is probably based on the ancient belief that all arts are learned by imitating nature. Avicenna has simply stated an implicit consequence, that the copy cannot equal its model.⁶ In a parallel attack on astrology, however, Avicenna also condemns alchemy, but in more explicitly religious terms, distinguishing what God has made by natural powers from what man can accomplish by artificial means.⁷

The second proposition in *De congelatione*, that the species of the metals cannot be transmuted, employs the Aristotelian opposition of species (*natura*) and genus (*genus*), as al-Fārābī did. Unlike al-Fārābī, however, Avicenna believes that the mere fact of belonging to a single genus (metallic substance) does not mean that the individual species (the different metals) can be transmuted among themselves. He argues further in the text that man's senses allow him only to perceive the accidents that superficially distinguish the metals, such as taste, color, and weight. The genuine species-determining characteristics of the metals are unknown to man and lurk beneath the level of sense data. Since we cannot even perceive the real specific differences between the metals, how can we hope to transmute them?

The basis of Avicenna's argument against specific transmutation is probably to be found in his overall theory of generation and mixture. In general terms, Avicenna adhered to Aristotle's theory of mixture (*De generatione et corruptione* 328a10–12), which distinguished genuine mixture (*mixis*) from mere juxtaposition of tiny particles (*synthesis*). A genuine mixture was homogeneous in the strict sense—every part of the mixture was identical to the whole. According to Avicenna and a multitude of other commentators on Aristotle, the passage from mere juxtaposition to mixture required the imposition of a new form—the “form of the mixture” (*forma mixti*)—on the four elements fire, air, water, and earth. To most medieval followers of Aristotle, the four elements themselves were composed of the four qualities hot, cold, wet, and dry acting on an undifferentiated prime matter (*materia prima*). Since the “form of the mixture” in turn produced a single,

6. The notion that art is unequal to nature was already a commonplace in antiquity. Examples abound in Cicero's *De natura deorum*, at I, 92 and II, 35, 57, *et passim*. For other examples of this ancient belief, see A. J. Close, “Commonplace Theories of Art and Nature in Classical Antiquity and in the Renaissance,” *Journal of the History of Ideas* 30(1969), 467–486.

7. A. F. Mehren, “Vues d'Avicenne sur l'astrologie et sur le rapport de la responsabilité humaine avec le destin,” in D. Eduardo Saavedra, ed., *Homenaje a D. Francisco Codera* (Zaragoza: Mariano Escart, 1904), 235–250; see 238–239. See also Ullmann, *Natur- und Geisteswissenschaftlichen*, 252.

new substance out of the elements, it was called the “substantial form” (*forma substantialis*).⁸ Avicenna was also an early proponent of the belief in a *dator formarum* (giver of forms), according to which this new substance-changing form did not emerge out of matter, but was imposed from without by the celestial intelligences, the rulers of the planets, which acted as proxies of the divine will. In the case of mixture again, Avicenna believed that the “primary qualities” of the four elements, hot, cold, wet, and dry, did not themselves combine to form a new mixed body, but merely set up the pre-condition that allowed the imposition of a new substantial form by the *dator formarum*. The primary qualities remained somehow in the mixture, but as mere accidents of the immaterial entity that united the elements into a new substance—the substantial form—and this accidental status was true a fortiori for the “secondary qualities” of the metals, such as taste, color, and weight.⁹

To understand Avicenna's position, it is helpful to consider further the substantial form's role in relation to the mixing of the four elements. What is it that makes a human a human, instead of a mere heap of elements—a hot, moist, steaming pile of earth? Avicenna's answer, like that of many peripatetics, was that a substantial form is required, which converts the four elements into an individual belonging to a recognizable species. Thus the substantial form imparted a new identity to the mixture, making it an identifiable “substance” that belonged to a particular species. Because of its role in making individuals belong to distinct species, the term “specific form” (*forma specifica*) was also often employed for the substantial form.¹⁰ In all of this, the perceptible accidents of a natural object—such as the color, density, or melting point of a metal—played no part in determining its essence. The substantial forms of all things lurking beneath the phenomena—insofar as

8. This is not the place to deal with the subtleties of Avicenna's theory of *formae refractae* or *formae remissae*, which allowed a continued existence of the elements in a mixture, but with their qualities in a diminished state and under the umbrella of the substantial form. For some details of this theory, see Anneliese Maier, *An der Grenze von Scholastik und Naturwissenschaft*, 2d ed. (Roma: Edizioni di Storia e Letteratura, 1952), 22–25.

9. For the use of the terms “primary qualities” and “secondary qualities” among the Scholastics, see Maier, *An der Grenze*, 9–12. For the theory of the *dator formarum*, see Avicenna, *Avicenna latinus: liber quartus naturalium, de actionibus et passionibus*, ed. Simone Van Riet (Leiden: E. J. Brill, 1989), 79, and *Avicenna latinus: liber tertius naturalium, de generatione et corruptione* (Leiden: E. J. Brill, 1987), 139.

10. In many instances, “substantial form” and “specific form” can be used interchangeably. This identification was facilitated by the fact that the substantial form imposes “secondary substance” on matter, by making the object in question belong to a species. Hence “substantial” in the sense of secondary substance means “specific.” According to most Scholastics, the human soul, which imposes “humanity,” is the substantial form of the body. For a good introduction to the Aristotelian concept of “substance,” see W. D. Ross, *Aristotle* (London: Methuen, 1923), 23–24, 165–167.

they were causes underlying the sensible world—were to Avicenna unknowable. They were no more accessible to human sense than the so-called occult qualities of the Scholastics, such as magnetic force or the mysterious ability of poisons to infect an entire body in a trifling dose.¹¹ It was reserved to God and the celestial intelligences to have real access to the substantial forms that underlay the phenomena surrounding us. As the great fourteenth-century Muslim historian Ibn Khaldūn would say, when commenting on Avicenna's view, "His assumption is based on the fact that (specific) differences cannot be influenced by artificial means. They are created by the Creator and Determiner of things, God Almighty. Their real character is utterly unknown and cannot be perceived."¹²

The philosophical and theological presuppositions underlying Avicenna's *Scientia artifices* received further elaboration from the pen of Ibn Khaldūn. Although Ibn Khaldūn dismisses Avicenna's argument about specific differences, he seems to follow the philosopher in stressing the great ignorance of man compared to God. The historian asserts that man cannot possibly know the various points through which gold passes in its underground development, any more than he can perceive the stages in the gestation of a human fetus. "All this is known only to the all-comprehensive knowledge (of God). Human science is unable to achieve it." As in Avicenna's argument, human ignorance implies human impotence, and therefore man cannot make gold. But Ibn Khaldūn is much more explicit than Avicenna in laying out the theological background to the claim that art is weaker than nature, and in doing so, he introduces an important additional element:

In general, (alchemy) as they understand it, has to do with universal creations which are outside the (sphere of) effectiveness of the crafts. Wood and animals cannot be developed from their (respective matters) in a day or a month, if such is not the (ordinary) course of their creation. In the same way, gold cannot be developed from its matter in a day or a month. Its customary course (of development) can be changed only with the help of something beyond the world of nature and the activity of the crafts.¹³

Ibn Khaldūn's point is that gold takes over a thousand years to develop within the ground, according to the historian, while alchemists claim to

produce it in a matter of weeks. If they are telling the truth, their methods are more effective than those of nature itself, which Ibn Khaldūn rejects as impossible. "Nature always takes the shortest way in what it does," he says, and in accordance with the principle that art is weaker than nature, it follows that the alchemists cannot abbreviate nature's methods. As a result, alchemy can succeed only by a method that is neither natural nor artificial: in short, it must resort to the supernatural. Ibn Khaldūn goes on to say, therefore, that the products of alchemical success can be viewed only as "miracles or acts of divine grace, or as sorcery."¹⁴

Nor was Ibn Khaldūn the only author to develop the theological implications of Avicenna's position. We need only consider the hugely popular *Secret of Secrets*, attributed falsely to Aristotle, a "mirror of princes" that gradually acquired sections on alchemy, astrology, physiognomy, and other arts that could be put into the service of a ruler. One version of the Arabic text expands on the Avicennian condemnation of alchemy, saying that the true substance of minerals is inaccessible to the alchemist, for man "cannot make himself equal to the Creator—may His name be sublime—in the creation of substances." The writer of this comment then adds Avicenna's notion that man can only know the accidents of metals, and can therefore only make superficial imitations of the precious metals. This addition to the *Secret of Secrets* is also found in Hebrew, whence it was translated into Latin and printed in the Renaissance, giving us some sense of its distribution.¹⁵ Interestingly, this condemnation of alchemy as an infringement on God's power was not adopted by the major theologians of the High Middle Ages, as we will see. And yet it made its way into the literature for and against alchemy that was translated into Latin, where it would lie dormant like one of the "volunteers" in a garden, waiting for the proper circumstances of soil and climate to burst forth in full blossom.

Before passing to the Latin West, we must consider yet another anti-chemical attack stemming from the Arabs. The great Aristotelian commentator of the twelfth century, Averroes, although a vehement opponent of Avicenna in many areas, shared the Persian philosopher's distrust of alchemy. In his commentary to the first book of Aristotle's *De generatione*

14. Ibn Khaldūn, *The Muqaddimah*, 280.

15. Mario Grignaschi, "Remarques sur la formation et l'interprétation du *Sirr al-Asrār*," in W. F. Ryan and Charles B. Schmitt, eds., *Pseudo-Aristotle: The 'Secret of Secrets'* (London: Warburg Institute, 1982), 3–33; see 31–32; Amitai I. Spitzer, "The Hebrew Translations of the *Sod Ha-Sodot* and Its Place in the Transmission of the *Sirr Al-Asrār*," in Ryan and Schmitt, *Secret of Secrets*, 34–54; *Opera hactenus inedita Rogeri Baconi*, ed. Robert Steele (Oxford: Oxford University Press, 1920), 5:173; "Sciendum tamen quod scire producere argentum et aurum, verum est impossibile: quoniam non est possibile equipari Deo Altissimo in operibus suis propriis."

11. Maier, *An der Grenze*, 14–15, 23–26. For Avicenna's assertion of the unknowability of forms, see his *De virtutibus cordis*, in *Avicennae arabum canon medicinae* (Venice: Junctae, 1608), 2:340–341.

12. Ibn Khaldūn, *The Muqaddimah*, tr. Franz Rosenthal (London: Routledge and Kegan Paul, 1958), 3:272–273. The parentheses here and in the following passages from Ibn Khaldūn were supplied by Rosenthal in his translation.

13. Ibn Khaldūn, *The Muqaddimah*, 276–279.

animalium, Averroes introduces the aurific art in the context of spontaneous generation. He argues first that "imperfect" life forms, such as insects and mice, can arise either from the copulation of male and female parents or from putrid matter. In the latter case, the spontaneously generated animal cannot itself generate other animals sexually. Indeed, sexually and spontaneously generated animals must be essentially different, since they have different causes. Developing this principle further, Averroes says that it is impossible for a single specific form to have two diverse materials upon which it can act and produce beings of the same species.

At this point, alchemy enters the picture: "And just as one and the same thing cannot be made both by art and nature, as the alchemists have imagined, since the causes of art and nature are different, so also the causes of natural entities cannot be different and yet agree in species and form."¹⁶ Alchemists commit the same error as those who think the mice generated spontaneously from filth to be the same in species as mice that come from parents. The art of simulating natural products by means of alchemy shares this fallacy with the "art" of "making" animals by artificially induced spontaneous generation. Since the causes employed by art and by nature are different, the products must also be diverse. Taking a very hard-line position on the division between the artificial and the natural, Averroes reiterates that the alchemists have erred: "And likewise, if something artificial is given, quite similar to [something] natural, the similitude can be so great that it will be thought to be the same in species. And if the art of alchemy has any reality, this is what can be done in it."¹⁷ Since artificial things and natural things arise from different principles, it is impossible a priori for them to be identical. Nonetheless, the artificial and the natural may appear to be the same, though this is but the product of illusion.

Like Avicenna, Averroes believed that alchemical gold could never be genuine, however much it might share the sensible properties of its natural exemplar. Lest we fall into the easy habit of accepting a conclusion pleasing to the modern ear without examining its principles, let us consider

16. Averroes, *Aristotelis de generatione animalium*, in *Aristotelis opera cum Averrois commentariis* (Venice: Juntae, 1562-1574; reprint, Frankfurt: Minerva, 1962), 6:44v: "Et sicut non potest dari unum & idem factum ab arte, & natura, ut imaginati sunt Archymistae: cum causae artis, & naturae sint diversae: sic etiam causae entium naturalium non possunt esse diversae, & convenire in specie, & forma."

17. Averroes, *Aristotelis de generatione animalium*, 6:44v: "Similiter etiam, si datur aliquid artificiale valde simile naturali, tanta potest esse similitudo, quod existimabitur ipsum esse idem specie, & si ars Archymistae habet esse, hoc est, quod potest fieri in ea." Another important locus for Averroes' rejection of alchemy may be found in his *Destructio destructionum philosophiae Algazelis*. See the section "in physicis disputatio prima," in the *Opera cum Averrois commentariis*, 9:127r.

the wider ramifications of this view. Averroes, like his Persian forerunner, did not mean to limit this restriction on human technology to the replication of gold. His principle that the artificial and the natural must be essentially different applied not only to the products of chemistry, but to all items of human manufacture. Like those who insist on having their vitamin C from rose hips and believe that there is a fundamental difference between natural and synthetic indigo, Averroes and Avicenna had adopted the unbending axiom that man and nature cannot produce the same effects. The problematic nature of this claim would become ever more apparent in the following centuries as the proponents of alchemy forced their detractors to consider the empirical consequences of their overconfident assertion.

Alchemy and Thirteenth-Century Theology

The reintroduction of alchemy to the Western world has often been dated at 1144, when Robert of Ketton translated a famous Arabic text into Latin.¹⁸ Although this date may put too fine a point on things, it is clear that a multitude of Arabic alchemical works were being translated into Latin by the late 1100s, and that over the course of the next century, the field was gradually appropriated by Scholastic authors. A vast literature came into being during this period, in which original Latin alchemical texts were produced under various pseudonyms. Although alchemy was not an official subject of the medieval university, the style of these texts reveals that many of their authors had an academic background, and a large number of the texts open with a characteristically Scholastic debate on the veracity of the alchemical art. This debate not only carries on the tradition of Arabic alchemical texts, but reflects a new type of emphasis on Avicenna's *Scientificae artifices* that is peculiar to the Latin schoolmen.

The famous translator Gerard of Cremona had prepared a Latin version of Aristotle's *Meteorology* in the twelfth century, but had only included the first three books. The resulting lacuna was filled by Henricus Aristippus in 1156, when he translated the fourth book from Greek. In 1200, however, Alfred of Sareshal of England translated Avicenna's *De congelatione* from Arabic into Latin and attached it to a manuscript version of the combined books of the *Meteorology* prepared by Gerard and Henry. Since a number of

18. Halleux, *Les textes alchimiques* (Brepols: Turnhout, 1979), 70-72; Julius Ruska, "Zwei Bücher De Compositione Alchemiae und ihre Vorreden," *Archiv für Geschichte der Mathematik, der Naturwissenschaften und der Technik* 11 (1928), 28-37; Lee Stavenhagen, "The Original Text of the Latin *Morivnus*," *Amis* 17 (1970), 1-12.

the manuscripts bear only the ascription to Aristotle, it appeared to many Scholastic authors that the Avicennian *De congelatione* was really by the Stagirate.¹⁹ In a world where Aristotle was referred to customarily as "the prince of the philosophers," or simply as "the philosopher," the integration of the *De congelatione* as a stowaway within the *Meteorology* added immense prestige to the Avicennian text. In practical terms, this rebaptizing meant that alchemy was an important and legitimate subject of discussion for commentators of Aristotle's *Meteorology*. At the same time, the Latin translation of the *De congelatione* did not reveal the full force of Avicenna's attack on alchemy, but terminated by suggesting that the artificial transmutation of metals might be possible if they were first reduced into their "prime matter," the undifferentiated material substrate of all things according to Aristotelian physics.²⁰ Hence the *Sciant artifices* came to be fair game for Scholastic disputation both within and beyond the confines of alchemical texts themselves.²¹

We can observe the influence of Avicenna's *Sciant artifices* already in one of the earliest known treatments of alchemy by a university doctor, the commentary on Peter Lombard's *Sentences* written by the famous teacher of Thomas Aquinas, Albertus Magnus, probably in the second half of the 1240s.²² The *Sentences*, composed by Peter in the mid twelfth century, comprise a four-volume collection of theological questions and answers, largely compiled from Saint Augustine, but reprising many other sources as well. Albert, like many writers in the thirteenth century and later, wrote an extensive commentary on the *Sentences*, expressing his views on a multitude of topics. As we will see, Albert is an early representative of what can only be called a Scholastic tradition of using alchemy to determine the powers of demons. Here we must avoid the easy and modern habit of grouping such topics as magic and alchemy under a single, seemingly unproblematic rubric, such as "the occult sciences" or "the occult." Albert definitely does not equate the two fields of alchemy and magic, and it is precisely their

19. Halleux, *Les textes alchimiques*, 72, for full citation of sources.

20. Newman, *Summa perfectionis*, 51: "Hec compositio in aliam mutari non poterit compositionem nisi forte in primum reducatur materiam, et sic in aliud quam prius erat permutebitur."

21. William R. Newman, "Technology and Alchemical Debate in the Late Middle Ages," *Isis* 80(1989), 423-445.

22. Fridericus Stegmüller, *Repertorium commentariorum in sententias petri lombardi* (Würzburg: Ferdinand Schöningh, 1947), 1:25. For alchemy in Albert's *Sentences*-commentary, see Udo Reinhold Jeck, "Materia, forma substantialis, transmutatio: Frühe Bemerkungen Alberts des Großen zur Naturphilosophie und Alchemie," *Documenti e studi sulla tradizione filosofica medievale* 5(1994), 205-240.

distinctness that allows him to draw meaningful comparisons between the two. For him, the claim of alchemy to transmute species represents the ultimate assertion of human power in the natural world. Alchemy is the benchmark against which other arts—even the arts possessed by demons—must be measured. This view became a commonplace among Scholastic authors that would last well into the seventeenth century.

In order to understand Albert's points, we must first consider the passage from Peter Lombard that he is analyzing. Albert's comments on alchemy form part of a gloss on book 2, distinction 7 of the *Sentences*. In this section of the *Sentences*, Peter had presented the position that "the magic arts work by means of the power and knowledge of the devil, which power and knowledge is granted to him by God." What Peter has in mind is several passages from Exodus 7 and 8, where the magicians of Pharaoh are said to have made various animals, including serpents and frogs. While the Bible grants them this, Peter points out that the magicians had no power against the gnats that provided the third plague against the Egyptians at Exodus 8:18. To him, this indicates that the power of magic is an illusion and that the marvelous deeds of the magi are really permitted to them only insofar as God wills it. Otherwise, the demons would themselves be creators (*creatores*) like God Himself, a possibility that Peter resolutely denies. Introducing Saint Augustine's concept of "seminal reasons," the *logoi spermatikoi* of the ancient Stoics, Peter suggests that demons merely collect the otherwise separated and hidden "seeds" of things in order to produce their marvels.

In his commentary to this passage, Albert considers a number of ramifications of Peter's view, but the section that interests us asks "whether demons can induce substantial forms in transmuted bodies." In typically Scholastic fashion, Albert first replies with a list of negative responses, the *responsiones quod non*. Beginning with earlier Christian commentary on Exodus 7, Albert proceeds to a discussion of the serpents that Pharaoh's magicians reportedly made from wooden staffs in their famous contest with Moses and Aaron. This passage from Exodus served as one of the paradigmatic witnesses of demonic power, since it was assumed, of course, that the Egyptian magicians could work their sorcery only with demonic help.²³ Since Albert is here presenting arguments against the claim that demons can induce a substantial form in matter, he argues first that the magicians' snakes were really

23. See Valerie I. J. Flint, *The Rise of Magic in Early Medieval Europe* (Princeton: Princeton University Press, 1991), especially 18-19, 29, 45, et passim for the influence of Exodus 7 on medieval discussions of magic.

just illusory, not transmuted substances. Among the arguments in favor of this view, Albert presents the following:

Likewise, art does not transmute a substantial form into [another substantial] form, because Aristotle says in *Meteorology IV* that "the artificers of alchemy should know that species cannot be transmuted"; therefore, demons cannot [transmute them], because they work only by means of art.²⁴

It is very interesting to see that at this stage in his career, Albert still accepted that the *Sciant artifices*, which he here quotes verbatim, is a genuine statement of the Stagirite's. In his impressive study of mineralogy and alchemy, the *Liber mineralium*, written a few years later, Albert would explicitly reject this Aristotelian pedigree and return the text to Avicenna.²⁵ There can be little doubt that Albert's attribution of the *Sciant artifices* to Aristotle encouraged his otherwise unlikely incorporation of it into a theological treatment of demons. What is remarkable about Albert's use of the *Sciant* is that he has omitted all reference to the metals, making Avicenna's dictum apply not only to them but to species in general.²⁶ The *Sciant* thereby acquired a universalist character that it otherwise lacked: it became a general statement about the limitations of art in the world of nature. And since demons were also thought to work by means of art, the *Sciant artifices* restricted their power just as it put limits on the power of man.

After presenting a number of other arguments against the ability of demons to make genuine transmutations of species, Albert then passes to the other side of the issue. Following the typical method of Scholasticism, he now produces a list of arguments in favor of demons' having actual power over physical substances. First, Albert recapitulates the Augustinian notion that all things on earth are generated from "seminal reasons" or hidden seeds that God imposed on matter during the Creation. When sorcerers perform their incantations, the demons respond by running off to collect these seeds in various parts of the world: "they suddenly (*subito*) bring together the seeds by which this is done, and thus, with God's permission, they lead forth new

24. Albertus Magnus, *Beati Alberti Magni, Ratisbonensis episcopi, ordinis praedicatorum, commentarii in II. et III. lib. sententiarum*, ed. Pierre Jammy (Lyon: Claudius Prost et al., 1651), 1586: "5. Item, Ars non transmutat a forma substantiali in formam, quia dicit Arist. In 4. Metheo. Sciant artifices alchimiae species transmutari non posse: ergo nec daemones, quia ipsi non operantur nisi per modum artis."

25. Albertus Magnus, *Book of Minerals*, tr. Dorothy Wyckoff (Oxford: Clarendon Press, 1967), 170, 177.

26. The Arabic text of the *De congelatione* printed in *Avicennae de congelatione et conglutinatione lapidum*, ed. and tr. E. J. Holmyard and D. C. Mandeville (Paris: Paul Geuthner, 1927), 41, 85, does not use the term for "metals," either, opening up the possibility that Albert had a manuscript of the *De congelatione* lacking the Latin word "metallorum."

species of things from them." In this fashion, the ability of demons to perform marvels is preserved, without allowing them any supernatural power over the material world. All that they can do is join natural agents with natural patients, although their superior knowledge and speed allow them to do this more effectively than man. At this point, Albert reintroduces alchemy, now as a support for the power of demons. He begins by referring to a passage from Job (41:33), where the power of Leviathan is said to exceed that of other beings on earth:

Likewise, Job 41: there is no power on earth which can be compared to him. Therefore it seems that if the power of art worked in the transmutations of bodies, as in alchemy, that demons would be able to do this much more powerfully.²⁷

Albert's introduction of alchemy at this point makes an appeal to the chrysoepoetic art that is entirely distinct from his earlier reference to the *Sciant artifices*. In the earlier passage, Albert used the *Sciant* in his negative arguments to show that demons worked by illusion only, since art cannot genuinely transmute species. Now, to the contrary, he takes it as a given that alchemy can indeed transmute species and works outward from that point. If man can actually transmute species, it follows that demons, who are much more powerful than man, can also do so. The implicit assumption behind this use of alchemy is absolutely clear. In terms of its claims, alchemy is the summum bonum of the human arts. As the apex of human artistry, alchemy serves as the high-water mark against which demonic power must be measured. This use of alchemy as the symbol of man's ability to alter the natural world would have far-reaching consequences. Although Albert may or may not have been the first to use alchemy in this fashion in the tradition of the commentaries on the *Sentences*, his is an early example of a tradition that would continue to bud and ramify well into the seventeenth century.

After finishing with his list of reasons against and for the ability of demons to induce a substantial form in matter, Albert tries to resolve the issue to the best of his ability. In his solution to the question, he modestly admits that only God and the angels can know for a certainty whether demons have this power. Nonetheless, Albert asserts that the doctrines of churchly authority allow one to suppose that demons cannot induce a permanent substantial form into matter except in the case of beings that arise easily from putrefaction. In order to clarify his analysis, he argues that four types

27. Albertus Magnus, *Commentarii in II. et III. lib. sententiarum*, 1586: "4. Item Job 41. Non est potestas super terram quae possit ei comparari: ergo videretur, quod si potestas artis operetur super corporum transmutationes, ut alchimia, quod daemones hoc multo magis facere praevaleant."

of transmutation are possible: first, a transmutation where the ingredients of a mixture retain their identity and operation, while also working in unison to produce a new effect, as in the medicinal operation of the drug theriac; second, one where a body is dissolved into its components, as when fire resolves a body; third, the type of transmutation effected by alchemy; and fourth, the case where nature itself converts one substance into another, as when frogs and toads appear spontaneously, and without parents. Does Albert's inclusion of alchemy in this list mean that he believes in the power of the chrysopeutic art? His response is surprisingly thorough:

The third [type of transmutation] occurs through the stripping off of properties, and the imposition of others through liquefaction, cibation, sublimation, and distillation, which the alchemists effect: and in this fashion by means of a quite well-known operation, bread, ink, and the like come into existence. I impute that [alchemists] do not give substantial forms, as Avicenna says in his alchemy, the sign of which is that one does not find the properties comprising the species in the things produced thus. For this reason, alchemical gold does not benefit the heart, and an alchemical sapphire does not cool off sexual ardor, or cure an affection of the windpipe [*arteriaca*]; nor does an alchemical carbuncle dispel a vaporous poison. And the test [*experimentum*] of all these things lies in the fact that alchemical gold is consumed more in the fire than the other, and also precious stones produced by alchemy; and likewise they do not last as long as the natural ones of that species. This is because they do not have the specific form [*species*], and so nature has denied them the virtues that are given with the specific form for the conservation of the same.²⁸

In this extraordinary passage, Albert reveals a surprisingly negative attitude toward alchemy, given that his later *Liber mineralium* would provide a

28. Here I rely on the critical edition of this passage given by Jeck, "Materia," 226 (corresponding to Albertus Magnus, *Commentarii in II. et III. lib. sententiarum*, 15:86–87): "Tertia est per exspoliationem proprietatum et dationem aliarum et per liquefactionem et cibationem et sublimationem et distillationem, quibus operantur alchimici. Et hoc modo operatione satis nota fit panis et incaustum et huiusmodi. Et puto, quod non dant formas substantiales, sicut etiam dicit Avicenna in *Alchimia* sua. Cuius signum est, quod in talibus operatis non inveniuntur proprietates continentis speciem. Curat aurum alchimum non laetificat cor, et saphirus alchimum non refrigerat ardorem neque curat arteriacam, et carbunculus alchimum non fugat venenum vaporabile in aere. Et omnium talium experimentum est in hoc, quod aurum alchimum consumitur plus in igne quam aliud, et similiter lapides alchimici. Et iterum non durant ita diu sicut naturalia illius speciei. Et hoc ideo est, quia non habent species. Et ideo negavit eis natura virtutes quae dantur cum speciebus ad conservationem specierum." The so-called "alchemy" of Avicenna refers to the pseudonymous *Epistola ad Harsen*, another text translated from Arabic. See Robert Halleux, "Albert le grand et l'alchimie," *Revue des sciences philosophiques et théologiques* 66(1982), 57–80.

mechanism by which alchemists could indeed produce precious metals.²⁹ In his *Sentence*-commentary, Albert evidently accepts the Avicennian position that alchemists cannot work real transmutation, but can only strip off transient accidents and replace them with equally superficial ones. It is for this reason that alchemical gold lacks the medical effect of strengthening the heart that medieval physicians granted to natural gold, and the artificial carbuncle and sapphire lack the marvelous powers ascribed to their natural counterparts.³⁰ But the real proof of their falsity lies in the inability of alchemical gold and precious stones to resist the dissolutive power of fire. Interestingly, this point emerges again in the *Liber mineralium*, where Albert says that he has tested alchemical gold and found it to decompose after six or seven firings.³¹ In the later text he ascribes this to the shortcoming of alchemical practitioners, however, while in the *Sentence*-commentary he apparently views it as a weakness of the art itself.

As we can see, then, Albertus Magnus was an early representative of a tradition that interjected alchemy into the discussion of demonic power. The reasons for this strange introduction are two. First, the *Scientiarum artifices* could be taken—and was taken by Albert—as a statement about the limits of art in general, not just alchemy. On the assumption that art cannot transmute species, it followed that demons could not really perform the wonders that were ascribed to them, at least not by art. Second, if one denied or ignored the *Scientiarum artifices*, then alchemy became the paragon of human artifice, since it actually claimed to replicate natural products rather than restricting itself to mere counterfeiting or representing. On this basis, alchemy became the benchmark against which all arts should be measured, including those of demons. If man could transmute species, then so could demons, and more so. Albert's own position, as we saw above, is that alchemy cannot transmute species, at least not by the method of stripping off accidents and imposing new ones. Near the end of the question, however, he hints that there may be another way by which alchemy can really transmute metals by aiding nature—"art of itself cannot induce a form, as was said before, but it can help nature."³² He may have in mind the same idea that he would describe later in the *Liber mineralium*—that proper alchemists act toward metals as doctors do

29. Albertus Magnus, *Book of Minerals*, 177–179. See also Halleux, "Albert le grand et l'alchimie," 74–75.

30. For more on Albert's views regarding the powers of these precious stones, see Albertus Magnus, *Book of Minerals*, 77–78, 115–116.

31. Albertus Magnus, *Book of Minerals*, 179.

32. Albertus Magnus, *Commentarii in II. et III. lib. sententiarum*, 15:87: "Ad aliud dicendum, quod bene potest esse, quod ars de se non potest inducere formam, ut prius dictum est: sed potest inuare naturam, & ita facit daemones."

toward their patients. The alchemist first cleans and purifies the old metal, just as a doctor employs emetics and diaphoretics to purge his patient. Then he strengthens the elemental and celestial powers in the metal's substance. As a result, the purged metal receives a new and better specific form from the virtues of the celestial bodies. The alchemist, then, has not really transmuted any species: he has only removed one specific form and prepared the way for another to be received.³³

Whatever Albert's final position on alchemy may have been, he exercised a serious influence on later commentators of the *Sentences*. His student Thomas Aquinas, who began lecturing on the *Sentences* in 1252, takes much the same position as Albert in his own commentary on book 2, distinction 7. Thomas begins his question by asking "whether demons can induce a true corporeal effect in corporeal matter." Like Albert, he then proceeds to give a list of negative answers. A number of these are astrological, and have no concern for us. Alchemy soon appears, however, in the fifth *responsio quod non*:

Moreover, demons do not work except by the method of art. But art cannot give a substantial form, whence it is said in the chapter *on minerals*: "the artificers of alchemy should know that species cannot be transmuted." Therefore, neither can demons induce substantial forms.³⁴

Having introduced the *Scientia artifices* in exactly the same form as Albert, assuming it to be a pronouncement on the limits of art in general, Thomas then passes immediately to the strongest piece of contrary evidence—that on the authority of Exodus 7, Pharaoh's magicians really did convert their staffs into snakes. Thomas's solution to the problem is as follows. Demons cannot act on matter by means of their minds alone, as God can. Despite the belief of Avicenna that matter automatically "obeys" separated substances like demons and angels, a view that the Persian philosopher expressed in his commentary on Aristotle's *De anima*, demons can act on matter only by means of art. They are limited to the application of agents to patients, just as man is. Hence if a demon wishes to heat up a portion of matter, he cannot do it by means of his own power, but must subject the matter to fire. Now since Thomas takes the position that the demons must act by means of art, the

33. Albertus Magnus, *Book of Minerals*, 178–179.

34. Thomas Aquinas, *Sacri Thomae Aquinatis commentum in secundum librum sententiarum, Distinctio 7, Quaestio 3, Articular 2*, in *Sacri Thomae Aquinatis opera omnia* (Parma: Petrus Fiaccadorus, 1856), 6:450. "Praeterea, daemones non operantur nisi per modum artis. Sed ars non potest dare formam substantialem; unde dicitur in cap. de numeris: sciunt auctores alchimiae, species transformari non posse. Ergo nec daemones formas substantiales inducere possunt." The phrase "de numeris" must obviously be read as "de mineris."

issue of alchemy—the art of transmuting species par excellence—acquires considerable significance for him. He therefore considers it in the following fashion:

Art by its own power cannot confer a substantial form, but it can do this by means of a natural agent, as is clear in the following—that the form of fire is produced in logs through art. There are some substantial forms, however, that art cannot induce by any means, since it cannot find the proper active and passive subjects. Even in these art can produce a similitude, as when alchemists produce something similar to gold as to exterior accidents. But it is still not true gold, since the substantial form of gold is not [induced] by the heat of fire—which alchemists use—but by the heat of the sun in a determinate place where the mineral power flourishes. Hence such [alchemical] gold does not operate according to the specific form [of real gold], and the same is true for the other things that they [i.e., alchemists] make.³⁵

Thomas's rejection of alchemy is similar to that of Albert except that the former introduces the concept of the *virtus laei*—the power of a specific place. His idea is that metals can be generated only by natural heat operating in the subterranean chambers where ores and metals come into being. It is a priori impossible for man to make metals artificially, since he cannot erect his laboratories in the hidden subterranean depths where the "mineralizing power" operates with the aid of solar heat. Like Albert, however, Thomas is using alchemy to determine the limits of demonic power. Since man cannot induce just any substantial form on matter, it follows that demons are subject to a similar limitation. Alchemy once again serves as the touchstone by which all arts, including those of Lucifer and his minions, are measured.

The tradition of using alchemy as a benchmark for the arts is also found in the early *Sentences*-commentary of Saint Bonaventure, who composed his work between 1250 and 1253 (probably somewhat earlier than Thomas); he also takes the subject up in his treatment of book 2, distinction 7.³⁶ Like

35. Thomas Aquinas, *Commentum in secundum librum sententiarum*, 6:451: "Ad quantum dicendum, quod ars virtute sua non potest formam substantialem conferre, quod tamen potest virtute naturalis agentis, sicut patet in hoc quod per artem inducitur forma ignis in lignis. Sed quaedam formae substantiales sunt quas nullo modo ars inducere potest, quia propria activa et passiva invenire non potest, sed in his potest aliquid simile facere; sicut alchimistae faciunt aliquid simile auro quantum ad accidentia exteriora; sed tamen non faciunt verum aurum: quia forma substantialis auri non est per calorem ignis quo ununtur alchimistae, sed per calorem solis in loco determinato, ubi viget virtus mineralis et ideo tale aurum non habet operationem consequentem speciem, et similiter in aliis quae eorum operatione fiunt."

36. *Bibliotheca sanctorum* (Rome: Istituto Giovanni XXIII, 1963), 3:242, for the date of Bonaventure's *Sentences*-commentary.

Albert and Thomas, Bonaventure asks "whether demons can induce true forms of things in matter." His concern, again, is with the serpents and other animals seemingly produced by the magicians of Pharaoh. His third affirmative reason introduces alchemy into the discussion: "Likewise, the power of demons is greater than that of man through artifice; but men make the species of diverse metals by means of the art of alchemy: therefore demons can do this much more powerfully."³⁷ Although Bonaventure does not spend much more time on alchemy in his commentary, it is clear that he, unlike Albert and Thomas, finds its claims to be unproblematic. His acceptance is based on the fact that he distinguishes more thoroughly than the other two writers between purely artificial actions and those where art and nature cooperate. In purely artificial things, Bonaventure insists, the agent imparts nothing to the patient, but either removes matter or changes its position, as appears in the case of a carving. Thus an agent cannot produce natural forms by its own power, unless the agent is pure act, as is God. Hence demons act only as *ministri* to nature, assistants rather than principal agents. Otherwise they would create things that differ from themselves in name and species, and the demons "would produce just as the Creator does, and thus they would be Creators."³⁸ Bonaventure thus introduces three types of fabrication—the absolute creation of a thing by God, where the created thing differs in name and species from its Creator, the perfective art by which nature is led to a new goal, and purely artificial activities such as carving that do not induce a new substantial form into matter. Alchemists cannot be Creators, but they can administer agents to patients in the same way as demons: they do not act in a purely artificial fashion, but employ their art to lead nature to an end that it would otherwise fail to attain. Once again employing the seminal reasons of Augustine, Bonaventure says that alchemists and demons do not produce their marvels by means of their own power, but by that of the "seeds" that they assemble and coax into their full maturity.³⁹

It is clear then that the theologians of the thirteenth century initiated a tradition of discussing alchemy in the context of demonic power—not because alchemy was a form of magic, but because it represented the apex

37. Bonaventure, *Commentaria in quatuor libros sententiarum magistri, in Petri Lombardi Doctoris seraphici S. Bonaventurae opera omnia* (Quaracchi: Collegii S. Bonaventurae, 1885), 2:201.

38. Bonaventure, *Commentaria in quatuor libros sententiarum*, 2:202.

39. Bonaventure, *Commentaria in quatuor libros sententiarum*, 2:202: "1. 2. 3. Unde tres rationes primae verum concludunt, quoniam non probant, quod faciant virtute sua, sed virtute seminum adductorum."

of the arts in its relationship to nature. To the writers whom we have considered, "magic" (*magia*) automatically meant the work of demons, which did not apply to alchemy as such, although demons, like men, could certainly devote themselves to the transmutation of metals. The *Sententiae*-commentators found alchemy useful precisely because it was not in itself demonic, but an art known to man—it could therefore be used as a yardstick to assess the things that demons could or could not do. This use of alchemy would live on in the *Sententiae*-commentaries of later writers, such as Richard of Middleton and Robert Kilwardby, who add little that we have not already discussed.⁴⁰ At the same time, however, the treatment of alchemy by theological writers spread out into different genres of literary production.

In the last two decades of the thirteenth century, for example, Giles of Rome (Aegidius Romanus) wrote a collection of quodlibetal questions that contain the query "whether man can make gold by art? And if so, whether it be permitted to sell such gold?" Although Giles gives no indication of his impetus for writing this Scholastic *questio*, it is closely related to Thomas Aquinas's commentary to book 2, distinction 7 of the *Sententiae*. Like Thomas and the other *Sententiae*-commentators, Giles considers the passage from Exodus 7, where the magicians of Pharaoh make serpents, to be related to the issue of alchemy—"What can [act] on a nobler form can act on a less noble one. But a sensitive soul can be induced by art, since the magi of Pharaoh made living serpents, while the sensitive form is nobler than the form of gold." By this logic, therefore, the induction of a sensitive form implies that art can also impose a nonsensitive one, such as that of a metal. In opposition to this argument, Giles first cites the *Sciant artifices* and then begins disassembling the simple scale of nobility that buttresses the proalchemical position. He begins by asserting that natural things proceed from determinate principles, and the more perfect the natural object is, the more it requires a specific material of origin. Hence a horse can be generated only in the menstrual blood of its mother, but bees, which are less perfect, can be organized directly from the rotting body of a bull, and wasps can come from a putrescent horse. Then, like Thomas, Giles adds the principle of the *virtus loci*—the power of a particular place. Even some less perfect things, which are generated by putrefaction, can come into being only in a certain place. Thus wine, although it lacks the sensitive soul of bees and

40. Ricardus de Mediavilla, *Clarissimi theologi magistri Ricardi de media villa seraphici ord. Min. convent. Super quatuor libros sententiarum* (Brixia: De consensu superiorum, 1591; reprint, Frankfurt: Minerva, 1963), 2:99–100; Robert Kilwardby, *Quaestiones in librum secundum sententiarum*, ed. Gerhard Leibold (Munich: Verlag der Bayerischen Akademie der Wissenschaften, 1992), 133.

wasps, can ferment only within the skin of the grape. The same may be said for metals. Even though they are less perfect than animals produced by corruption, they still require a determinate place of production, namely the belly of the earth. The conclusion, then, is the same one that Thomas had already drawn—the alchemists are doomed to failure because they try to make their metals on the surface of the earth.⁴¹

Interestingly, Giles does consider the arguments of alchemists themselves that they can make such products as glass and electrum and should therefore have the power to make gold. His reply is that glass has the same relation to the metals as a spontaneously generated animal to one produced from parents. In each pair, the former do not require a determinate place of generation, while the latter do. As for electrum, that is merely a mixture of gold and silver and is not germane to a discussion of transmutation. Returning to the argument about Pharaoh's serpents, Giles responds that a sensitive form may be more noble than that of a metal, but that this has no bearing on the question, since he has already shown in his wine example that even less noble things sometimes require a specific place of generation. In the *quaestio* of Giles, then, we see a clear offshoot of the concerns expressed in the *Sentence*-commentaries, as witnessed by the references to the pharaonic production of serpents by magic. But the issue of alchemy has gone on in Giles's work to live a life of its own, though still in a theological context. We have clear evidence here of the seminal influence of the *Sentence*-commentaries in transmitting the *quaestio de alchimia* to subsequent generations.

Alchemy and Witchcraft: The Influence of the *Canon episcopi*

The hackneyed modern view that automatically equates alchemy with witchcraft, necromancy, and a porpourri of other practices and theories loosely labeled "the occult" has little historical validity before the nineteenth century.⁴² Nonetheless, we have already witnessed an association between alchemy and demonology in the early *Sentence*-commentators, if

only as a means of determining the limits of satanic power by comparing the arts of the demons to the art of species transmutation par excellence. Indeed, the linkage between alchemy and witchcraft received enough support from other sources that it even appears on the first folio of the most famous witch-hunting manual of all time, the *Malleus maleficarum* published by the two Dominican inquisitors Heinrich Kramer and Jakob Sprenger in 1487. This extraordinary fact has gone virtually unnoticed by historians, and yet it demonstrates—as nothing else could—the reality that alchemy and witchcraft were linked in the minds of the most influential proponents of the Great Witch Hunt of early modern Europe. We will return to the *Malleus maleficarum* shortly, but first we must direct our gaze in another direction. In order to understand why the witch hunters turned to alchemy, it is necessary to look beyond the *Sentence*-commentaries, though they were active here too, and to consider the influential fate of another document. I refer to the *Canon episcopi*, a little specimen of ecclesiastical law written in the early Middle Ages, probably by the chronicler, canonist, and musical writer Regino of Prüm.

The *Canon episcopi*, composed around the beginning of the tenth century, and later incorporated into the famous encyclopedia of canon law, the twelfth-century *Decretum* of Gratian, expresses a rather skeptical view toward magic that was common in the early Middle Ages. The *Canon* directs itself to two main areas—the claim that certain heretical women worship the pagan goddess Diana or Herodias in huge groups to which they have been transported over great distances in a single night on the backs of beasts, and that the same women or others can be transformed into animals. Taking the view that these are not real phenomena but illusions induced by Satan, the *Canon episcopi* explicitly rejects the idea that anyone—even Satan himself—can really change his shape or species as heretical and even worse than the ignorance of the heathen.⁴³ How does this concern alchemy? The short answer is that the *Canon episcopi* itself had nothing at all to do with the aurific art, at least not originally. Written some three centuries before the transmission of alchemy from the Islamic world to Europe, the *Canon episcopi* betrays no awareness of the discipline. But we should note the language in which the *Canon episcopi* forbids belief in the shape-changing

41. Aegidius Romanus, *B. Aegidii Coloniensis Romani . . . quaestiones*, ed. Petrus Damasus de Coninck (Louvain: Hieronymus Nempaeus, 1646; reprint, Frankfurt: Minerva, 1966), *Quaestio* 3, *Membrum* 3, *Quaestio* 3, *Quaestio* 8, pp. 147–149.

42. Lawrence M. Principe and William R. Newman, "Some Problems with the Historiography of Alchemy," in William R. Newman and Anthony Grafton, eds., *Secrets of Nature: Astrology and Alchemy in Early Modern Europe* (Cambridge, MA: MIT Press, 2001), 385–431. See also Newman and Grafton, "Introduction: The Problematic Status of Astrology and Alchemy in Premodern Europe," in Newman and Grafton, *Secrets of Nature*, 1–37.

43. Edward Peters, *The Magician, the Witch, and the Law* (Philadelphia: University of Pennsylvania Press, 1978), 72–73. For the Latin text of the *Canon episcopi*, see Emil Friedberg, ed., *Corpus iuris canonici* (Graz: Akademische Druck, 1955), vol. 1, cols. 1030–1031. An English translation of the *Canon episcopi* taken from Henry Charles Lea may be found in Alan C. Kors and Edward Peters, *Witchcraft in Europe 1100–1700: A Documentary History* (Philadelphia: University of Pennsylvania Press, 2001), 61–63.

power of witches: "Whoever therefore believes any created thing to be able to be made or to be changed into better or worse or transmuted into another shape (*speciem*) or likeness, except by the Creator, who made all things, and by whom all are made, is without doubt an infidel and worse than a pagan."⁴⁴

Significantly, the *Canon episcopi* employs the Latin term *species* for the "shape" or "appearance" that the witch supposedly assumes. There is no reason to think that in the ninth or tenth century, before the existence of high medieval Scholasticism, the philosophical sense of the term *species*, an Aristotelian category intermediate between an individual and a genus, is meant. But later commentators, trained in the Aristotelianism of the medieval universities, would indeed see an interdiction on the transmutation of species in the *Canon episcopi*. This association would be aided and abetted by the *Sciant artifices* of Avicenna, which, as we have seen, expressly denied the alchemists' ability to transmute one species of metal into another. Perhaps already thinking in these terms, a well-known commentator on Gratian's *Decretum*, in which the *Canon episcopi* was embedded, explicitly directed it toward alchemy in the mid to late thirteenth century. I refer to the Dominican chronicler Martinus Polonus (d. 1278), whose alphabetically arranged *Margarita decreti* was an influential synopsis of the *Decretum*.⁴⁵ The *Margarita*, which exists today in over one hundred manuscripts, has an entry for alchemy beginning with the following thesis: "alchemy seems to be a false [*reprobata*] art, because he who believes one species to be able to be transferred into another, or into a similar one, except by the Creator Himself, is an infidel and worse than a pagan."⁴⁶ Clearly Martinus has taken the *species* of the *Canon episcopi* to refer not just to the shapes of animals that deluded witches think they can assume, but to the different species of metals, as in Avicenna's *Sciant artifices*.

Martinus's approach would be echoed in many a subsequent writer on ecclesiastical law. The canon lawyer Oldrado da Ponte, an important figure during the Avignon papacy of John XXII, began a long tradition of

defending alchemy against the charge of claiming to transmute species.⁴⁷ Among Oldrado's *consilia*, or legal cases, one finds a rebuttal of the claim that alchemy violates the *Canon episcopi*. Responding in a rather technical fashion, Oldrado replies that alchemists do not *transmute* species, but merely produce one species of metal from another species of metal. Similar cases occur in nature, he says, when silk is made from a worm, and when glass is produced from burnt-up plants. Oldrado is probably thinking of a *species* as a sort of eternal form that inheres in matter: hence one species can be removed from a given parcel of matter and another imposed without "transmuting" the species themselves.⁴⁸ Oldrado's interesting evasion of the *Canon episcopi* may well have originated in alchemical texts themselves, as we will soon see when we examine the alchemists' rebuttals of their adversaries. Although his defense would have a huge impact on subsequent canon lawyers, however, it exercised little effect on the writers of witchcraft manuals, who were for the most part happy to condemn alchemy along with demonolatry.

A compelling example of this condemnation may be seen in the *Fortalium fidei* (1459) of the Franciscan author Alfonso de Spina, a converted Jew who went on to become regent of the theological faculty at the University of Salamanca and confessor of King John II of Castile. In a section of his *Fortalium* that deals with the different types of demons, Alfonso considers the issues raised by the *Canon episcopi*, whether witches can undergo spatial transport at tremendous speed and whether they can change their shape. Alfonso carefully denies both these claims, and then passes to a clarification of what the devil actually can do. He can, in fact, make one thing look superficially like another, and he can accelerate processes so that what normally takes a month to occur will happen in an instant. At this point, Alfonso raises the concerns of the *Sentence-commentators* in their treatment of Exodus 7, at the same time introducing alchemy:

The cause is that he [the devil] knows how to apply actives to passives, as appears in those things that the magicians of Pharaoh did. But that the

47. Francesco Migliorino, "Alchimia lecta e illecta nel Trecento," *Quaderni medievali* 11 (1981), 6-41. Migliorino tentatively dates Oldrado's *consilium* on alchemy to a period before 1310, for Oldrado was in Avignon between 1310-1335, at which time Pope John XXII issued a decretal condemning alchemy, the *Spondent quas non exhibent*. See Migliorino, "Alchimia," 15. On Oldrado and alchemy, see also Chiara Valsecchi, *Oldrado da Pontecorvo: i consilia* (Milan: Giuffrè, 2000), 675-676, and Lynn Thorndike, *A History of Magic and Experimental Science* (New York: Columbia University Press, 1934), 3:48-51.

48. *Species* is a common term in Latin for the Greek *eidos* and *morphè*, both of which can mean "form" in a hylomorphic sense. For Oldrado da Ponte's text on the legality of alchemy, see Johannes Chrysippus Fanianus, *De iure artis alchemiae*, in Manget, 1:210-216; see 211-212. For more on Oldrado's defense of alchemy, see Newman, "Technology and Alchemical Debate," 440-441.

44. "Quisquis ergo credit fieri posse, aliquam creaturam aut in melius aut in deterius immutari, aut transformari in aliam speciem vel in aliam similitudinem, nisi ab ipso creatore, qui omnia fecit, et per quem omnia facta sunt, proculdubio infidelis est, et pagano deterior." Friedberg, *Corpus*, 1: col. 1031.

45. Jean-Pierre Baud, *Le procès de l'alchimie: introduction à la légalité scientifique* (Strasbourg: Cercid Publications, 1983), 25.

46. "Alchimia. Quod alchimia videtur esse ars reprobata: quia qui credit unam speciem posse transferri in aliam vel similem nisi ab ipso creatore, infidelis est, & pagano deterior. 26. qu. 5. episcopi. Circa finem." *Decretum gratiani emendatum et annotationibus illustratum cum glossis Gregorii XIII. Pont. Max. iussu editum* (Paris, 1601), appendix, 4. For a brief discussion of Martinus Polonus and the *Margarita*, see *Biographisch-Bibliographisches Kirchenlexikon* (Herzberg: Verlag Traugott Bautz, 1993), 5:923-926.

devil may cause one man to be converted to a serpent, bird, or plant—this is impossible for him. Therefore, many perverse Christian alchemists are deceived, having pacts with demons, [and] believing that they transmute iron into gold through their art.⁴⁹

Here we see an open elision between the *Canon episcopi*'s denial of diabolical transmutation into various animate creatures and the alchemists' transmutation of base metal into gold. Alfonso clearly thinks that alchemical transmutation is an illusion imposed on alchemists who have, perhaps unwittingly, sold their souls to Satan. In the subsequent text, Alfonso passes into an explicit consideration of the witches' belief that they travel to meet with Diana, further paraphrasing the *Canon episcopi*.

Alfonso de Spina was not the only demonologist to employ the *Canon episcopi* in this fashion. The *Questio lazariorum* of the Observant Franciscan Samuel de Cassinis, published in 1505, contains a more philosophically nuanced treatment of alchemy, beginning also with the *Canon episcopi*'s concern about the magical transport of witches. Samuel is an inveterate opponent of the belief in magical flight, which is how he interprets the witches' travel as described in the *Canon episcopi*. For humans to be carried through the air by demons would violate or exceed the ordained power of nature. In order to demonstrate this, he launches into an elaborate discussion of causality, which need not concern us in its details. What is significant, however, is his distinction between artificial and natural activity. Since magical flight does not occur in nature, Samuel argues, it cannot be induced by the devil either, on the implicit principle that art is weaker than nature. In setting up this distinction, Samuel relies on the artificial mouse of Averroes, which we have already discussed. As Samuel puts it, a demon applying activates to passives must first have some "impressed form of art" in his reasoning faculty, which then guides his actions. In other words, there must be an idea in the demon's mind that he then brings to actuality by joining the proper agencies to their passive recipients. But the very presence of this "form of art," even when the demon uses purely natural agencies, is enough to ensure that his product will not measure up to its model in nature. Here the mouse enters: "For it is not to be imagined that a mouse produced by putrefaction does not have some diversity from that which is generated by coitus,

49. "Et causa est, quia scit applicare activa passivis, sicut patet in his, quae fecerunt magi Pharaonis. Quod tamen diabolus facit, quod unus homo convertatur in serpentem vel avem vel plantam, hoc est sibi impossibile; et ideo in hoc multi perversi christiani alchimistae sunt decepti, habentes pacta cum demonibus, cogitantes quod per eorum artem ferrum convertent in aurum." Joseph Hansen, *Quellen und Untersuchungen zur Geschichte des Hexenwahnens und der Hexenverfolgung im Mittelalter* (Hildesheim: Olms, 1963; photoreproduction of Bonn, 1901), 148. For biographical information on Alfonso, see 145–146.

although it be of the same species. The diversity will be at least something accidental [yet] inseparable."⁵⁰ The same thing, Samuel assures us, is true for alchemy. The "form of art impressed in [the demon's] intellect" is a similitude of the combined agent and patient that nature itself uses, but the presence alone of that artificial form is enough to result in a deficient product.

From which it is inferred that even if the alchemical art could be a true art, and produce some natural composite by means of acceleration, it will never be of the same perfection and goodness as that which is produced by a natural agent and patient applied purely naturally.

Samuel de Cassinis and Alfonso de Spina both use alchemy as a means of reinforcing the skepticism of the *Canon episcopi* by illustrating the weakness of art relative to nature. Both men see the failure of alchemy as a direct support for the *Canon episcopi*'s view that witches cannot travel at incredible speeds or change their shapes. A radically different approach to alchemy would emerge with the notorious *Malleus maleficarum*, though that text too was responding to the *Canon episcopi*. Undoubtedly the most influential witch-hunting guide of all time, the *Malleus* went through at least twenty-six Latin printings from 1487 through 1669, being written, according to one unabashed modern fan, *sub specie aeternitatis*.⁵¹ Given the unflinching gaze and single-minded dedication with which the two authors meet the evil eye of their malefic adversaries, it is perhaps surprising that the text has a rather unfocused beginning. For it is an indisputable yet hardly noticed fact that the *Malleus maleficarum* begins with a denunciation of alchemy as well as witchcraft (fig. 2.1). In response to the obligatory question of whether it is heretical to deny the power of witches, the text first launches into a series of negative replies, which it will of course eventually rebut. One of these denials of the reality and efficacy of witchcraft, found on the very first folio, contains the following thesis, tacitly borrowed from Thomas Aquinas's commentary on Peter Lombard's *Sentences*:

Demons do not work except by art. But art cannot give a true form. Whence it is said in the chapter on minerals that the authors of alchemy should know that species cannot be transmuted. Therefore demons, also working by means

50. "Non est enim imaginandum, quin mus productus ex putrefactione habeat aliquid diversitatis ab eo, qui est generatus per coitum, quamvis sit eiusdem speciei, quae diversitas erit saltem aliquid accidentale inseparabile, sed non quartum!" Hansen, *Quellen*, 266. The parentheses and exclamation point after the unintelligible "quartum" are Hansen's. For information on de Cassinis, see Charles H. Lohr, *Latin Aristotelian Commentaries: II Renaissance Authors* (Florence: Olschki, 1988), 83.

51. Montague Summers, tr., *Malleus maleficarum* (London: Pushkin Press, 1948; reprint, 1951), xvi.

is what the two authors mean when they say, at the end of the first *quaestio*, "because we do not say that one can bring about *maleficium* by means of art without the aid of another agent, it follows that with such aid they can induce the true qualities of disease or of another effect."⁵⁵ In other words, as long as one can argue that the effects of witchcraft are not *purely* artificial, but rather products of art working on "another agent" supplied by nature, then the effects of witchcraft—and possibly even those of alchemy—can be genuine. This conclusion, of course, is strikingly different from what Thomas himself intended, for in his *Sentence*-commentary he upheld the view that alchemy was an unequivocal failure and a useful example of the limitations placed by God on human and demonic power. Although Thomas certainly admitted that demons could produce marvelous effects by uniting hidden agencies to their properly receptive subjects, he wished to stress that this process had limits, as exemplified by the failure of alchemy. But Kramer and Sprenger have taken Thomas's limitation on demonic power to apply only to purely artificial agents, by applying natural agents to natural patients, both demons and alchemists can act on matter.

In the hands of the two Dominican inquisitors, alchemy became yet another tool for dismantling the limitations placed on demonic power by skeptical writers of the Middle Ages. Hence Kramer and Sprenger, intent on aggrandizing the power of witches, undermine the Thomistic argument that limited the alchemists' ability to impress forms on matter. By loosening the bonds of Avicenna's *Sciant artifices*, the witch hunters liberated their own diabolical quarry from the inability to impose new forms and thereby wreak havoc on an unsuspecting world. As the beneficiaries of such gargantuan power, the witches clearly had to be destroyed, resulting in a call to action that is known all too well from the dismal history of the Great Witch Hunt. Although the role of alchemy in this persecution was at most minor, it is testimony to the image of the aurific art as an exemplar of man's artisanal power in the natural world that Avicenna's debunking of alchemy is itself appropriated and in turn deflected in the *Malleus maleficarum*.

55. Kramer and Sprenger, *Malleus maleficarum*, ed. Schnyder, 13: "Demonones operantur per artem circa effectus maleficiales et ideo absque amminiculo alterius agentis nullam formam substantialem vel accidentalem inducere possunt et quia non dicimus quod maleficia inferat partem absque amminiculo alterius agentis. Ideo etiam cum tali amminiculo potest veras qualitates egritudinis aut alterius passionis inducere." The troubling phrase "non dicimus quod maleficia inferat partem absque amminiculo alterius agentis" is clearly ungrammatical as it stands in the 1487 editio princeps (ed. Schnyder, 13). I have consulted the 1574 Venice edition, *Malleus maleficarum in tres divisiones partes* (Venice: Antonium Bertanum, 1574), 14, which alters "inferat" to "inferant," but leaves the problematic "partem" now acting as the object of "maleficia inferant." It is more sensible, in my view, to suppose that "partem" is a misprint or misreading of "p [per] artem."

Arguments for the Legitimacy of Transmutation in Alchemical Texts

We have now seen how Scholastic authors—influenced by Avicenna and bent on establishing a benchmark for the arts—found in alchemy a means of determining the powers of demons. We have also observed that this association between alchemy and demons entered into the literature on witchcraft, partly as a result of misinterpreting the skeptical *Canon episcopi*. But what did the alchemists themselves have to say about the limits of their art? Did they remain mere passive spectators as the thundering debates of theologians and inquisitors raged around their ears? A truly exhaustive treatment of the alchemical issue in Scholasticism would require that we examine the forty or more medieval commentaries on Aristotle's *Meteorology* that are found in manuscript, not to mention the multitudes of alchemical treatises that begin with rebuttals of Avicenna's *Sciant artifices*.⁵⁶ Since our goal is not an exhaustive treatment of the *quaestio de alchimia* as such, however, but an examination of alchemy's contribution to the art-nature debate, we will have to resort to sampling a few of the most significant alchemical texts. As we will see, the more philosophically inclined among the medieval alchemists eagerly assumed the role of responding to Avicenna's attack on alchemy. In doing so, they provided a comprehensive defense of their art, but one that carefully maintained a position for alchemy as the apex of human endeavors in the realm of artisanship. The first work that we will consider is the *Book of Hermes*, which exists in a number of manuscripts from the late thirteenth or early fourteenth century. This little treatise may well be a translation from Arabic, although no corresponding text in that language has yet been discovered.⁵⁷ The *Book of Hermes*, at any rate, contains an extraordinary defense of alchemy in a language that cannot fail to remind one of Francis Bacon's famous claim in the early seventeenth century that artificial and natural products differ not "in form or essence, but only in the efficient."⁵⁸ Indeed, as I argue in the final chapter, the empirical approach to the artificial-natural divide taken by the *Book of Hermes* and other works of medieval alchemy prefigured the attitude of Bacon and his seventeenth-century followers Robert Boyle and John Locke.

Like the *Sentence*-commentaries that we have examined, the *Book of Hermes* divides its arguments into *pro* and *contra*. It begins with the

56. For medieval commentaries on the *Meteorology*, see Charles Lohr, "Medieval Latin Aristotle Commentaries," *Traditio* 23 (1967), 313–414; 24 (1968), 149–245; 26 (1970), 135–216; 27 (1971), 251–351; 28 (1972), 280–396; 29 (1973), 93–197; 30 (1974), 119–144.

57. Newman, *Summa perfectionis*, 9–15. The text is partially edited on 52–56.

58. Francis Bacon, *De augmentis scientiarum*, in Bacon, *Works*, 4:294.