where the work was supervised, and fulling mills and workshops where the cloth was stretched and pressed. In 1618, an English writer estimated that a clothier who made twenty broadcloths a week provided work for 500 persons, counting wool sorters, carders, spinners, weavers, burlers, fullers, cloth finishers, dyers, and loom and spinning wheel makers. In the West Country, the capital investments were larger and the number of operations directed by the clothier more extensive than in the Yorkshire country of the north.

The transition from craft production to preindustrial capitalism taking place throughout the century was more pronounced in the rural rather than the urban putting-out systems. A clothier in the rural putting-out system was freer than his urban counterpart from municipal taxes and regulations and from restrictions on the quality of his product, the number of his employees, and his methods of production. "The expansive years between 1460 and 1560 are particularly important because the balance of tradition and innovation shifted gradually but decisively. . . . But by 1560 the cleavage between capital and labor . . . was firmly and widely established in many parts of industrial Europe."[31] Rising prices widened the separation between wages and profits with a larger share of community wealth going to the capitalist.

A second industry that employed the poor as wage workers was mining.[32] Large-scale operations were rare, with only a out 100 workers being employed in each of the larger mines. In England, the coal industries at Newcastle-Upon-Tyne and Wear developed rapidly in the late sixteenth century, impelled by the increasing scarcity of timber.

In the British copper and brass industry that developed in the 1560s, large capital investments were necessary for opening and developing the mining shafts, smelting the ore, producing brass wire, and flattening ingots. Since neither the workers nor any single capitalist had the necessary funds, capital was supplied by English and German shareholders—members of the nobility, clergy, state officials, and merchants. Separation of worker and capitalist was thus a prerequisite for the start of this industry.[33] In the iron industry, foundry and forge were owned and products marketed by entrepreneurs. Free and independent miners and metal workers were a decreasing group.

A similar separation was taking place within the crafts, created by decreasing upward mobility for journeypeople. By hard and diligent work or by marrying the master's daughter, a journeyman might succeed.[34] But more and more masters tended to pass their craft to their sons, making the group hereditary. Masters became "small-scale industrial capitalists," and journeypeople became their paid workers, with less chance for independence. The journey[illegible] owned neither [illegible] ier, nor the looms, as did the master weaver.

Within the craft guilds, some masters accumulated money and extended the markets beyond their own towns. Lower craftspersons became more dependent on them. The same phenomenon of market extension and dependence also took place between one craft and another.

Francis Bacon's early interest in writing a "History of Trades" was a manifestation of his desire to discover those secrets of the craft workshops that could be applied to the practical needs and interests of middle-class society. Growth and progress could be achieved from the study of the mechanical arts, "for these . . . are continually thriving and growing."[35]

The concept of scientific progress that Bacon developed as a program sanctioned the gap between journeyman and mastercraftsman. Much has been made of the concept of progress in Western society, through which standards of living for "all mankind" are presumably improved. But did the "public good" really include the cottager, journeyperson, and peasant, or did it function so as to benefit the master craftsman, clothier, and merchant?

The idea of scientific progress has been associated with the rise of technology and "the requirements of early capitalistic economy" by scholars who have argued that the idea of cooperation and the sharing of knowledge for both the construction of theory and the public good stemmed from the intellectual attitudes of sixteenth-century master craftsmen, mechanical engineers, and a few academic scholars and humanists. "The absence of slavery, the existence of machinery, the capitalistic spirit of enterprise and economic rationality seem to be prerequisites without which the ideal of scientific progress cannot unfold."[36]

The sixteenth-century groups that evolved the concept of progress are the same groups that right up until the present have pressed for increased growth and development: entrepreneurs, military engineers, humanist academics, and scientists and technicians. Sixteenth-century master craftsmen and technicians who embraced the idea of progress in written works included: Kaspar Brunner (1547), master of ordnance, locksmith, and clockmaker; Robert Norman (1581), instrument maker; Peter Apian (1532), mechanic, globe and instrument maker, and mathematics professor; Ambroise Paré (1575) master of the guild of barber surgeons and surgeon to the king and military; and Gerard Mercator (1595), instrument maker, map maker, and surveyor. Military engineers included William Bourne (1578), gunner and military engineer, who addressed his treatise to "all generals and captains"; Niccolò Tartaglia (1537), mathematical advisor to gunners and merchants; Simon Stevin (1608), military engineer and bookkeeper; and Bonaiuto Lorini (1597), military technician to the Medicis. Humanists and academics included Abraham Ortelius (1570), classical scholar and mapmaker; François Rabelais (1535), writer; Jean Bodin (1566), political philosopher; and Loys Leroy (1568). Humanist concerns are not only fully compatible with the improvement of the human condition through technological advance, but imply an environment filled with humans at the expense of nature.

What had been merely prefaces and statements advocating a utilitarian concept of progress in these sixteenth-century treatises became a whole program and ideology in the utopian thought of Francis Bacon. In the *New Atlantis*, progress was placed in the hands of a group of scientists and technicians who studied nature altered by "the mechanical arts" and "the hand of man" that her secrets might be utilized to benefit society.

MECHANISM AND THE NEW ATLANTIS. The scientific research institute designed to bring progress to Bensalem, the community of the *New Atlantis*, was called Salomon's House. The patriarchal character of this utopian society was reinforced by designating the scientists as the "Fathers of Salomon's House." In the *New Atlantis*, politics was replaced by scientific administration. No real political process existed in Bensalem. Decisions were made for the good of the whole by the scientists, whose judgment was to be trusted implicitly, for they alone possessed the secrets of nature.

Scientists decided which secrets were to be revealed to the state as a whole and which were to remain the private property of the institute rather than becoming public knowledge: "And this we do also, we have consultations, which of the inventions and experiences which we have discovered shall be published, and which not: and all take an oath of secrecy for the concealing of those which we think fit to keep secret, though some of those we do reveal sometimes to the state, and some not."[87]

The cause of the visit to the governor by a scientist from the distant Salomon's House, which resulted in a conference with the visitors to Bensalem, was shrouded in secrecy. No father of the institute had been seen in "this dozen years. His coming [was] in state, but the cause of his coming [was] secret."

The scientist father was portrayed much like the high priest of the occult arts, the Neoplatonic magus whose interest in control and power over nature had strongly influenced Bacon. He was clothed in all the majesty of a priest, complete with a "robe of fine black cloth with wide sleeves and a cape," an "undergarment . . . of excellent white linen," and a girdle and a clerical scarf, also of linen. His gloves were set with stone, his shoes were of peach-colored velvet, and he wore a Spanish helmet.

The worship to be accorded to the scientist was further enhanced by his vehicle, a "rich chariot" of cedar and gilt carried like a litter between four richly velveted horses and two blue-velveted footmen. The chariot was decorated with gold, sapphires, a golden sun, and a "small cherub of gold with wings outspread" and was followed by fifty richly dressed footmen. In front walked two bareheaded men carrying a pastoral staff and a bishop's crosier.

Bacon's scientist not only looked but behaved like a priest who had the power of absolving all human misery through science. He "had an aspect as if he pitied men"; "he held up his bare hand as he went, as blessing the people, but in silence." The street was lined with people who, it would seem, were happy, orderly, and completely passive: "The street was wonderfully well kept, so that there was never any army [which] had their men stand in better battle array than the people stood. The windows were not crowded, but everyone stood in them as if they had been placed."

Bacon's "man of science" would seem to be a harbinger of many modern research scientists. Critics of science today argue that scientists have become guardians of a body of scientific knowledge, shrouded in the mysteries of highly technical language that can be fully understood only by those who have had a dozen years of training. It is now possible for such scientists to reveal to the public only information they deem relevant. Depending on the scientist's ethics and political viewpoint, such information may or may not serve the public interest.

Salomon's House, long held to be the prototype of a modern research institute, was a forerunner of the mechanistic mode of scientific investigation. The mechanical method that evolved during the seventeenth century operated by breaking down a problem into its component parts, isolating it from its environment, and solving each portion independently. Bacon's research center maintained separate "laboratories" for the study of mining and metals, weather, fresh- and salt-water life, cultivated plants, insects, and so on.

The tasks of research were divided hierarchically among the various scientists, novices, and apprentices. Some abstracted patterns from other experiments, some did preliminary book research, some collected experiments from other arts and sciences; others tried out new experiments, or compiled results or looked for applications. The interpreters of nature raised the discoveries into greater observations, axioms, and aphorisms. This differentiation of labor followed the outlines of Bacon's inductive methodology.

In the laboratories of Salomon's House, one of the goals was to recreate the natural environment artificially through applied technology. Large, deep caves called the Lower Region were used for "the imitation of natural mines and the producing of new artificial metals by compositions and materials."[38] In another region were "a number of artificial wells and fountains, made in imitation of the natural sources and baths." Salt water could be made fresh, for "we have also pools, of which some do strain fresh water out of salt, and others by art do turn fresh water into salt."

Not only was the manipulation of the environment part of Bacon's program for the improvement of mankind, but the manipulation of organic life to create artificial species of plants and animals was specifically outlined. Bacon transformed the natural magician as "servant of nature" into a manipulator of nature and changed art from the aping of nature into techniques for forcing nature into

new forms and controlling reproduction for the sake of production: "We make a number of kinds of serpents, worms, flies, fishes of putrefaction, where of some are advanced (in effect) to be perfect creatures like beasts or birds, and have sexes, and do propagate. Neither do we this by chance, but we know beforehand of what matter and commixture what kind of those creatures will arise."

These examples were taken directly from Della Porta's *Natural Magic* (1558), the second book of which dealt specifically with putrefaction and the generation of the living organisms mentioned by Bacon—worms, serpents, and fishes. The chapter dealing with putrefaction had discussed the generation of canker worms from mud, so that "we may also learn how to procreate new creatures."[39] "Serpents," wrote Della Porta, "may be generated of man's marrow, of the hairs of a menstrous woman, and of a horsetail, or mane," while "certain fishes," such as groundlings, carp, and shellfish, "are generated out of putrefaction." New beasts and birds could be generated through knowledge and carefully controlled coupling.

Della Porta also set down instructions as to how to produce a new organism in a series of trials. Such creatures "must be of equal pitch; they must have the same reproductive cycle, and one must be equally "as lustful as the other." Furthermore "if any creatures want appetite . . . we may make them eager in lust."

The *New Atlantis* had parks and enclosures for beasts and birds where just such experiments were performed: "By art likewise we make them greater or taller than their kind is, and contrariwise dwarf them, and stay their growth; we make them more fruitful and bearing than their kind is, and contrariwise barren and not generative. Also we make them differ in color, shape, activity, many ways."[40]

The scientists of Salomon's House, not only produced new forms of birds and beasts, but they also altered and created new species of herbs and plants: "We have also means to make divers plants rise by mixtures of earths without seeds, and likewise to make divers new plants differing from the vulgar, and to make one tree or plant turn into another."

Rather than respecting the beauty of existing organisms, Bacon's *New Atlantis* advocated the creation of new ones:

> We have also large and various orchards and gardens, wherein we do not so much respect beauty as variety of ground and soil, proper for diverse trees and herbs. . . . And we make (by art) in the same orchards and gardens, trees and flowers to come earlier or later than their seasons, and to come up and bear more speedily than by their natural course they do. We make them by art greater much than their nature, and their fruit greater and sweeter and of differing taste, smell, color, and figure, from their nature.[41]

Della Porta had, again, given numerous examples of changing the colors and tastes of plants: a white vine could be turned into a black one, purple roses and violets could become white, and sweet almonds and pomegranates sour.

That such experimentation on animals and the creation of new species was ultimately directed toward human beings was intimated by Bacon: "We have also parks and enclosures of all sorts of beasts and birds, which we use not only for view or rareness but likewise for dissections and trials, that thereby we may take light [i.e., enlightenment] what may be wrought upon the body of man. . . . We also try all poisons and other medicines upon them as well of chirurgery as physic."[42]

Much of Bacon's strategy in the *New Atlantis* was directed at removing ethical strictures against manipulative magic, of the sort found in Agrippa's *Vanity of Arts and Science* (1530), a polemic probably written for Agrippa's own self-protection, containing important arguments against transforming and altering nature. Just as Agricola had been obliged to refute Agrippa's views on mining in order to liberate that activity from the ethical constrants imposed by ancient writers, so Bacon was obliged to refute the constraints against the manipulation of nature. Agrippa had argued against tampering with nature and maiming living organisms:

> Those exercises appurtenant to agriculture . . . might in some measure deserve commendation, could it have retained itself within moderate bounds and not shown us so many devices to make strange plants, so many portentous graftings and metamorphoses of trees; how to make horses copulate with asses, wolves with dogs, and so to engender many wondrous monsters contrary to nature: and those creatures to whom nature has given leave to range the air, the seas and earth so freely, to captivate and confine in aviaries, cages, warrens, parks, and fish ponds, and to fat them in coops, having first put out their eyes, and maimed their limbs.[43]

Agrippa had further inveighed against the manipulators of nature who had tried to discover "how to prevent storms, make . . . seed fruitful, kill weeds, scare wild beasts, stop the flight of beasts and birds, the swimming of fishes, to charm away all manner of diseases; of all which those wise men before named have written very seriously and very cruelly."

Much of Bacon's program in the *New Atlantis* was meant to sanction just such manipulations, his whole objective being to recover man's right over nature, lost in the Fall. Agrippa had observed that after the Fall nature, once kind and beneficent, had become wild and uncontrollable: "For now the earth produces nothing without our labor and our sweat, but deadly and venomous, . . . nor are the other elements less kind to us: many the seas destroy with raging tempests, and the horrid monsters devour: the air making war against us with thunder, lightning and storms; and with a crowd of pestilential diseases, the heavens conspire our ruin."

In order to control the ravages of wild tempestuous nature, Bacon set as one of the objectives of Salomon's House the artificial control of the weather and its concomitant monsters and pestilences: "We have also great and spacious houses, where we imitate and demonstrate meteors, as snow, hail, rain, some artificial rains of bodies and not of water, thunder, lightnings, also generation of bodies in air, as frogs, flies, and diverse others." Tempests (like that produced by Shakespeare's magician, Prospero), could also be created for study by using "engines for multiplying and enforcing of winds."[44]

The Baconian program, so important to the rise of Western science, contained within it a set of attitudes about nature and the scientist that reinforced the tendencies toward growth and progress inherent in early capitalism. While Bacon himself had no intimation as to where his goals might ultimately lead, nor was he responsible for modern attitudes, he was very sensitive to the trends and directions of his own time and voiced them eloquently. The expansive tendencies of his period have continued, and the possibility of their reversal is highly problematical.

Bacon's mechanistic utopia was fully compatible with the mechanical philosophy of nature that developed during the seventeenth century. Mechanism divided nature into atomic particles, which, like the civil citizens of Bensalem, were passive and inert.

Motion and change were externally caused: in nature, the ultimate source was God, the seventeenth century's divine father, clockmaker, and engineer; in Bensalem, it was the patriarchal scientific administration of Salomon's House. The atomic parts of the mechanistic universe were ordered in a causal nexus such that by contact the motion of one part caused the motion of the next. The linear hierarchy of apprentices, novices, and scientists who passed along the observations, experimental results, and generalizations made the scientific method as mechanical as the operation of the universe itself. Although machine technology was relatively unadvanced in Bensalem, the model of nature and society in this utopia was consistent with the possibilities for increased technological and administrative growth.

In the *New Atlantis* lay the intellectual origins of the modern planned environments initiated by the technocratic movement of the late 1920s and 1930s, which envisioned totally artificial environments created by and for humans. Too often these have been created by the mechanistic style of problem solving, which pays little regard to the whole ecosystem of which people are only one part. The antithesis of holistic thinking, mechanism neglects the environmental consequences of synthetic products and the human consequences of artificial environments. It would seem that the creation of artificial products was one result of the Baconian drive toward control and power over nature in which "The end of our foundation is the knowledge of causes and secret motions of things and the enlarging of the bounds of human empire, to the effecting of all things possible."[45] To this research program, modern genetic engineers have added new goals—the manipulation of genetic material to create human life in artificial wombs, the duplication of living organisms through cloning, and the breeding of new human beings adapted to highly technological environments.

THE BACONIAN PROGRAM. The development of science as a methodology for manipulating nature, and the interest of scientists in the mechanical arts, became a significant program during the latter half of the seventeenth century. Bacon's followers realized even more clearly than Bacon himself the connections between me-

chanics, the trades, middle-class commercial interests, and the domination of nature.

Lewis Roberts lamented the unexploited state of Mother Earth in his *Treasure of Traffike, or a Discourse of Foreign Trade* (1641):

> The earth, though notwithstanding it yieldeth thus naturally the richest and most precious commodities of all others, and is properly the fountain and mother of all the riches and abundance of the world, partly . . . bred within its bowels, and partly nourished upon the surface thereof, yet is it observable, and found true by daily experience in many countries, that the true search and inquisition thereof, in these our days, is by many too much neglected and omitted.[46]

John Dury and Samuel Hartlib, followers of Bacon and organizers of the Invisible College (ca. 1645), forerunner of the Royal Society, connected the study of the crafts and trades to increasing wealth. One of Dury's objectives was to make observations of the inventions and sciences "as may be profitable to the health of the body, to the preservation and increase of wealth by trades and mechanical industries, either by sea or land; either in peace or war."[47]

The avowedly Baconian utopia "The Kingdom of Macaria, (1641), attributed to Hartlib but probably written by Gabriel Plattes, an English writer on husbandry and mining, was dedicated not merely to the "knowledge of causes and secret motions of things," as was the *New Atlantis,* but to the total agricultural, commercial, and medical improvement of society.[48] In Macaria, the king has improved his forests, parks, and lands "to the utmost"—bringing in huge revenues. Owing to the efforts of the council of husbandry, "the whole kingdom is become like to a fruitful garden, the highways are paved, and are as fair as the streets of the city." Any man who held more land than he could develop and improve was admonished and penalized for each year during which he continued to leave it unimproved, until at last "his lands be forfeited and he banished out of the kingdom, as an enemy to the commonwealth." A council of fishing was to establish laws "whereby immense riches are yearly drawn out of the ocean," while the councils of trade by land and sea were to regulate the number of tradespeople and encourage all navigation that "may enrich the kingdom."

The health of the inhabitants was maintained by a "college of experience, where they deliver out yearly such medicines as they find out by experience." As members of the Society of Experimenters, all were required to defend any new ideas before a Great Council, which judged the truth or falsity of the discovery. "If any divine shall publish a new opinion to the common people, he shall be accounted a disturber of the public peace and shall suffer death for it."

Dissent, not only in science but also in religion, would be avoided "by invincible arguments as will abide the grand test of extreme dispute." Rational scientific judgment would thus overcome the passions and individualism of religious sects and promote health, welfare, and commercial growth in Macaria.

The virtuosi of the Royal Society were interested in carrying out Bacon's proposal to survey the history of trades and augment their usefulness. The English divine Thomas Sprat, whose *History of the Royal Society* (1667) defended it against its critics, desired to extract from the "operations of all trades," their "physical receipts or secrets," their "instruments, tools, engines, [and] manual operations." He extolled "our chief and most wealthy merchants and citizens" who had added their "industrious, punctual, and active genius" to the "quiet, sedentary, and reserved temper of men of learning."[49]

Human dominion over nature, an integral element of the Baconian program, was to be achieved through the experimental "disclosure of nature's secrets." Seventeenth-century scientists, reinforcing aggressive attitudes toward nature, spoke out in favor of "mastering" and "managing" the earth. Descartes wrote in his *Discourse on Method* (1636) that through knowing the crafts of the artisans and the forces of bodies we could "render ourselves the masters and possessors of nature."[50] Joseph Glanvill, the English philosopher who defended the Baconian program in his *Plus Ultra* of 1668, asserted that the objective of natural philosophy was to "enlarge knowledge by observation and experiment . . . so that nature being known, it may be mastered, managed, and used in the services of humane life." To achieve this objective, arts and instruments should be developed for "searching out the beginnings and depths of things and discovering the intrigues of remoter nature."[51] The most useful of the arts were chemistry, anatomy, and mathematics; the best in-

struments included the microscope, telescope, thermometer, barometer, and air pump.

The harshness of Bacon's language was captured in Glanvill's descriptions of the methods of studying nature. Bacon had advocated the dissection of nature in order to force it to reveal its secrets. For Glanvill, anatomy, "most useful in human life, . . . tend[ed] mightily to the eviscerating of nature, and disclosure of the springs of its motion." In searching out the secrets of nature, nothing was more helpful than the microscope for "the secrets of nature are not in the greater masses, but in those little threads and springs which are too subtle for the grossness of our unhelped senses."

According to Glanvill, Robert Boyle's experimental philosophy had advanced "the empire of man over inferior creatures" by taking seriously "those things which have been found out by illiterate tradesmen" and by developing the "dexterity of hand proper to artificers." Glanvill advocated chemistry as one of the most useful arts, for "by the violence of [its] artful fires it is made [to] confess those latent parts, which upon less provocation it would not disclose." By chemical techniques, "nature is unwound and resolved into the minute rudiments of its composition."

In his "Experimental Essays" (1661), Boyle distinguished between merely knowing as opposed to dominating nature in thinly veiled sexual metaphor: "I shall here briefly represent to you . . . that there are two very distinct ends that men may propound to themselves in studying natural philosophy. For some men care only to know nature, others desire to command her" and "to bring nature to be serviceable to their particular ends, whether of health, or riches, or sensual delight."[52]

The new image of nature as a female to be controlled and dissected through experiment legitimated the exploitation of natural resources. Although the image of the nurturing earth popular in the Renaissance did not vanish, it was superseded by new controlling imagery. The constraints against penetration associated with the earth-mother image were transformed into sanctions for denudation. After the Scientific Revolution, *Natura* no longer complains that her garments of modesty are being torn by the wrongful thrusts of man. She is portrayed in statues by the French sculptor Louis-Ernest Barrias (1841–1905) coyly removing her own veil and

Figure 17. ***Nature Reveals Herself***, sculpture by Louis-Ernest Barrias (French, 1841-1905). This sculpture suggests the sexuality of nature in revealing her secrets to science. A similar statue by the same sculptor in the Ecole de Medecine, Rue de la Sorbonne, Paris, bears the inscription, "La Nature se devoilant devant la Science" ("Nature Revealing Herself to Science").

exposing herself to science (Fig. 17). From an active teacher and parent, she has become a mindless, submissive body. Not only did this new image function as a sanction, but the new conceptual framework of the Scientific Revolution—mechanism—carried with it norms quite different from the norms of organicism. The new mechanical order (Chapter 8) and its associated values of power and control (Chapter 9) would mandate the death of nature.