

told that an immense space interposed between the planetary orbits and the starry sphere would be useless and vain, being idle and devoid of stars, and that any immensity going beyond our comprehension would be superfluous for holding the fixed stars, I say that it is brash for our feebleness to attempt to judge the reason for God's actions, and to call everything in the universe vain and superfluous which does not serve us. . . .

Nature's Servant and Interpreter

*Novum Organum (The New Organon;
or, True Directions Concerning the Interpretation of Nature),*
by Francis Bacon, translated by James Spedding

Francis Bacon (1561–1626), son of Sir Nicholas Bacon, Lord Keeper of the Great Seal of Queen Elizabeth, was born in London and studied at Cambridge and Gray's Inn. He entered Parliament in 1584, and under James I rose to Attorney General, Lord Keeper, and Lord Chancellor, becoming Baron Verulam in 1618 and Viscount St. Albans in 1621—when he pleaded guilty of accepting bribes and was barred from holding office. During his remaining years he pursued the scientific studies that had been central for much of his life. Among his many publications were *Essays* (1597–1625); *De Sapientia Veterum* (On the Wisdom of the Ancients, 1609); and *New Atlantis* (1627), a scientific utopia dedicated to “the knowledge of causes, and . . . the effecting of all things possible.” Most important was his unfinished *Instauratio Magna* (Great Instauration, or Great Renewal), of which two parts were completed: *The Advancement of Learning*, published in English in 1605 and in an expanded Latin edition in 1623; and the *Novum Organum* (New Organon; “Organon” was the name of Aristotle's logical writings) of 1620, from which our excerpts are taken in the translation by James Spedding from Bacon's Works (1857–74), as reprinted in his *Selected Writings*, ed. Hugh G. Dick (1955).

Bacon was not a major scientist—the only experiment he is remembered for, his stuffing of a chicken with snow to test the properties of refrigeration, led to his death from pneumonia—nor was he in the vanguard of scientific thought of his time. William Harvey “dismissed Bacon as one who ‘writes philosophy like a Lord Chancellor,’ and Bacon in one of his less fortunate pronouncements,” Gillispie remarks in *The Edge of Objectivity*, “denied the circulation of the blood,” as well as Gilbert's magnetism and Copernicus's heliocentric cosmos. Yet no other thinker played so important a role in propagating the new science as an activity fundamentally distinct in method from the old philosophy that it sought to eliminate: “We must begin anew from the very foundations . . .” Bacon's repudiation of philosophic authority, not only of the Scholastics' Aristotle but also of the humanists' Plato, in the name of experience takes a sometimes stridently reductive form as he endeavors (despite tributes to the “honor” of the Greeks) to eradicate any influence they might have. In his judgment, as expressed in *Book I* of *The Advancement of Learning*, “the overmuch credit that hath been given unto authors in sciences, in making them dictators, that their words should stand, and not counsels to give advice,” has been the principal hindrance to the growth of learning, abetted by “too great a reverence, and a kind of adoration, of the mind and understanding of man; by means whereof men have withdrawn themselves too

to begin with doubts, he shall end in certainties.” He distinguishes in *Novum Organum* four kinds of “Idols,” or “empty dogmas,” that impede understanding—the Idols of the Tribe, founded in human nature itself; of the Cave, or the individual person; of the Marketplace, the “intercourse and association of men with each other”; and of the Theater, “dogmas of philosophy” and other systems. To establish “progressive stages of certainty,” Bacon proposes that the true—though untried—way of discovery is to rise in “a gradual and unbroken ascent” by a posteriori reasoning, or induction, from the particulars of sensory perception, verified by careful experiment, to general axioms securely founded upon them.

Bacon has not unjustly been faulted for his mechanistic epistemology—“In Baconian science the bird-watcher comes into his own,” Gillispie writes, “while genius, ever theorizing in far places, is suspect”—and for an instrumental view of science directed toward “progress as it has been understood everywhere in the West since the seventeenth century, progress through technology and the domination of nature.” “In an age when nature and the problem of understanding it were being gradually detached from the realm of spirit and from theological presuppositions,” Leonard Nathanson observes in *The Strategy of Truth* (1967), “it became increasingly difficult to maintain the traditional view that nature, while rationally coherent, was not mechanically uniform and determined.” But if Bacon, by categorically distinguishing experimental knowledge of nature from unexamined religious belief, contributed to a sharpened dichotomy between faith and reason, in other important respects he helped break down the antinomies of philosophy. Thus, despite high position at court, he looked for knowledge—more like Socrates among the artisans of Athens than Plato in the Academy—among those involved in practical pursuits of industry, trade, agriculture, and seafaring. And by viewing the history of arts as a part of natural history, “he departed radically,” Paolo Rossi writes in *Francis Bacon: From Magic to Science* (1957; English trans. 1968), “from the traditional opposition of art and nature where the former is only a vain attempt to imitate the latter. . . . For Bacon natural and artificial objects possessed the same kind of form and essence. Art was man added to nature.”

Most importantly, his promotion of scientific inquiry as a business “done as if by machinery” is offset by conviction that “the subtlety of nature is greater many times over than the subtlety of the senses and understanding.” Far from simply advocating domination of nature, he knew that “Nature to be commanded must be obeyed”; and far from exalting either the empirical ant or the rational spider one over the other, he favors the middle course of the bee, which transforms whatever it gathers. To portray this passionate interpreter of nature and prophet of science, who would inspire the Enlightenment in Europe for a century and a half after his death, as a mere technocrat of induction would be to forget what Basil Willey emphasizes in *The Seventeenth Century Background* (1935): “Bacon was the seer, almost the poet, of the scientific movement in England.” Indeed, if matter—as Bacon, who admired Heraclitus (Chapter 9 above), wrote in his essay “Of Vicissitude of Things”—“is in a perpetual flux, and never at a stay,” certain knowledge of it is perhaps not attainable even by the most rigorous method.

FROM THE Preface

Those who have taken upon them to lay down the law of nature as a thing already searched out and understood, whether they have spoken in simple assurance or professional affectation, have therein done philosophy and the sciences great injury. For as they have been successful in inducing belief, so they have been effective in quenching and

tred of the ancient sophists, or from uncertainty and fluctuation of mind, or even from a kind of fullness of learning, that they fell upon this opinion—have certainly advanced reasons for it that are not to be despised; but yet they have neither started from true principles nor rested in the just conclusion, zeal and affectation having carried them much too far. The more ancient of the Greeks (whose writings are lost) took up with better judgment a position between these two extremes—between the presumption of pronouncing on everything and the despair of comprehending anything; and though frequently and bitterly complaining of the difficulty of inquiry and the obscurity of things, and like impatient horses champing the bit, they did not the less follow up their object and engage with nature; thinking (it seems) that this very question—viz., whether or no anything can be known—was to be settled not by arguing, but by trying. And yet they too, trusting entirely to the force of their understanding, applied no rule, but made everything turn upon hard thinking and perpetual working and exercise of the mind.

Now my method, though hard to practice, is easy to explain; and it is this. I propose to establish progressive stages of certainty. The evidence of the sense, helped and guarded by a certain process of correction, I retain. But the mental operation which follows the act of sense I for the most part reject; and instead of it, I open and lay out a new and certain path for the mind to proceed in, starting directly from the simple sensuous perception. The necessity of this was felt no doubt by those who attributed so much importance to logic; showing thereby that they were in search of helps for the understanding, and had no confidence in the native and spontaneous process of the mind. But this remedy comes too late to do any good, when the mind is already, through the daily intercourse and conversation of life, occupied with unsound doctrines and beset on all sides by vain imaginations. And therefore that art of logic, coming (as I said) too late to the rescue, and no way able to set matters straight again, has had the effect of fixing errors rather than disclosing truth. There remains but one course for the recovery of a sound and healthy condition—namely, that the entire work of the understanding be commenced afresh, and the mind itself be from the very outset not left to take its own course, but guided at every step; and the business be done as if by machinery. . . .

FROM *Aphorisms Concerning the Interpretation
of Nature and the Kingdom of Man*

I Man, being the servant and interpreter of nature, can do and understand so much and so much only as he has observed in fact or in thought of the course of nature: beyond this he neither knows anything nor can do anything.

III Human knowledge and human power meet in one; for where the cause is not known the effect cannot be produced. Nature to be commanded must be obeyed; and that which in contemplation is as the cause is in operation as the rule.

IV Towards the effecting of works, all that man can do is to put together or put asunder natural bodies. The rest is done by nature working within.

x The subtlety of nature is greater many times over than the subtlety of the senses and understanding; so that all those specious meditations, speculations, and glosses in which men indulge are quite from the purpose, only there is no one by to observe it.

XIII The syllogism is not applied to the first principles of sciences, and is applied in vain to intermediate axioms; being no match for the subtlety of nature. It commands assent therefore to the proposition, but does not take hold of the thing.

XVIII The discoveries which have hitherto been made in the sciences are such as lie close to vulgar notions, scarcely beneath the surface. In order to penetrate into the inner and further recesses of nature, it is necessary that both notions and axioms be derived from things by a more sure and guarded way; and that a method of intellectual operation be introduced altogether better and more certain.

XIX There are and can be only two ways of searching into and discovering truth. The one flies from the senses and particulars to the most general axioms, and from these principles, the truth of which it takes for settled and immovable, proceeds to judgment and to the discovery of middle axioms. And this way is now in fashion. The other derives axiom from the senses and particulars, rising by a gradual and unbroken ascent, so that it arrives at the most general axioms last of all. This is the true way, but as yet untried.

XXII Both ways set out from the senses and particulars, and rest in the highest generalities; but the difference between them is infinite. For the one just glances at experiment and particulars in passing, the other dwells duly and orderly among them. The one, again, begins at once by establishing certain abstract and useless generalities, the other rises by gradual steps to that which is prior and better known in the order of nature.

XXIII There is a great difference between the Idols of the human mind and the Ideas of the divine. That is to say, between certain empty dogmas, and the true signatures and marks set upon the works of creation as they are found in nature.

XXVI The conclusions of human reason as ordinarily applied in matter of nature, I call for the sake of distinction *Anticipations of Nature* (as a thing rash or premature). That reason which is elicited from facts by a just and methodical process, I call *Interpretation of Nature*.

XXXI It is idle to expect any great advancement in science from the superinducing and engrafting of new things upon old. We must begin anew from the very foundations, unless we would revolve forever in a circle with mean and contemptible progress.

XXXVIII The idols and false notions which are now in possession of the human understanding, and have taken deep root therein, not only so beset men's minds that truth can hardly find entrance, but even after entrance obtained, they will again in the very instauration of the sciences meet and trouble us, unless men being forewarned of the danger fortify themselves as far as may be against their assaults.

XXXIX There are four classes of idols which beset men's minds. To these for distinction's sake I have assigned names—calling the first class *Idols of the Tribe*; the second, *Idols of the Cave*; the third, *Idols of the Marketplace*; the fourth, *Idols of the Theater*.

XL The formation of ideas and axioms by true induction is no doubt the proper rem-

XL I The Idols of the Tribe have their foundation in human nature itself, and in the tribe or race of men. For it is a false assertion that the sense of man is the measure of things. On the contrary, all perceptions, as well of the sense as of the mind, are according to the measure of the individual and not according to the measure of the universe. And the human understanding is like a false mirror, which, receiving rays irregularly, distorts and discolors the nature of things by mingling its own nature with it.

XLII The idols of the Cave are the idols of the individual man. For everyone (besides the errors common to human nature in general) has a cave or den of his own, which refracts and discolors the light of nature; owing either to his own proper and peculiar nature; or to his education and conversation with others; or to the reading of books, and the authority of those whom he esteems and admires; or to the differences of impressions, accordingly as they take place in a mind preoccupied and predisposed or in a mind indifferent and settled; or the like. So that the spirit of man (according as it is meted out to different individuals) is in fact a thing variable and full of perturbation, and governed as it were by chance. Whence it was well observed by Heraclitus that men look for sciences in their own lesser worlds, and not in the greater or common world.

XLIII There are also idols formed by the intercourse and association of men with each other, which I call Idols of the Marketplace, on account of the commerce and consort of men there. For it is by discourse that men associate; and words are imposed according to the apprehension of the vulgar. And therefore the ill and unfit choice of words wonderfully obstructs the understanding. Nor do the definitions or explanations wherewith in some things learned men are wont to guard and defend themselves, by any means set the matter right. But words plainly force and overrule the understanding, and throw all into confusion, and lead men away into numberless empty controversies and idle fantasies.

XLIV Lastly, there are idols which have immigrated into men's minds from the various dogmas of philosophies, and also from wrong laws of demonstration. These I call Idols of the Theater; because in my judgment all the received systems are but so many stage-plays, representing worlds of their own creation after an unreal and scenic fashion. Nor is it only of the systems now in vogue, or only of the ancient sects and philosophies, that I speak: for many more plays of the same kind may yet be composed and in like artificial manner set forth; seeing that errors the most widely different have nevertheless causes for the most part alike. Neither again do I mean this only of entire systems, but also of many principles and axioms in science, which by tradition, credulity, and negligence have come to be received. . . .

XLV The human understanding is unquiet; it cannot stop or rest, and still presses onward, but in vain. Therefore it is that we cannot conceive of any end or limit to the world; but always as of necessity it occurs to us that there is something beyond. Neither again can it be conceived how eternity has flowed down to the present day: for that distinction which is commonly received of infinity in time past and in time to come can by no means hold; for it would thence follow that one infinity is greater than another, and that infinity is wasting away and tending to become finite. The like subtlety arises touching the infinite divisibility of lines, from the same inability of thought to stop. But

ing unable to rest still seeks something prior in the order of nature. And then it is that in struggling towards that which is further off it falls back upon that which is more nigh at hand—namely, on final causes; which have relation clearly to the nature of man rather than to the nature of the universe, and from this source have strangely defiled philosophy. But he is no less an unskilled and shallow philosopher who seeks causes of that which is most general, than he who in things subordinate and subaltern omits to do so.

L But by far the greatest hindrance and aberration of the human understanding proceeds from the dullness, incompetency, and deceptions of the senses; in that things which strike the sense outweigh things which do not immediately strike it, though they be more important. Hence it is that speculation commonly ceases where sight ceases, insomuch that of things invisible there is little or no observation. Hence all the working of the spirits enclosed in tangible bodies lies hid and unobserved of men. So also all the more subtle changes of form in the parts of coarser substances (which they commonly call alteration, though it is in truth local motion through exceedingly small spaces) is in like manner unobserved. And yet unless these two things just mentioned be searched out and brought to light, nothing great can be achieved in nature, as far as the production of works is concerned. So again the essential nature of our common air, and of all bodies less dense than air (which are very many), is almost unknown. For the sense by itself is a thing infirm and erring; neither can instruments for enlarging or sharpening the senses do much: but all the truer kind of interpretation of nature is effected by instances and experiments fit and apposite; wherein the sense decides touching the experiment only, and the experiment touching the point in nature and the thing itself.

LI The human understanding is of its own nature prone to abstractions and gives a substance and reality to things which are fleeting. But to resolve nature into abstractions is less to our purpose than to dissect her into parts; as did the school of Democritus, which went further into nature than the rest. Matter rather than forms should be the object of our attention, its configurations and changes of configuration, and simple action, and law of action or motion; for forms are figments of the human mind, unless you will call those laws of actions forms.

LIX But the *Idols of the Market-place* are the most troublesome of all: idols which have crept into the understanding through the alliances of words and names. For men believe that their reason governs words; but it is also true that words react on the understanding; and this it is that has rendered philosophy and the sciences sophistical and inactive. Now words, being commonly framed and applied according to the capacity of the vulgar, follow those lines of division which are most obvious to the vulgar understanding. And whenever an understanding of greater acuteness or a more diligent observation would alter those lines to suit the true divisions of nature, words stand in the way and resist the change. Whence it comes to pass that the high and formal discussions of learned men end oftentimes in disputes about words and names; with which (according to the use and wisdom of the mathematicians) it would be more prudent to begin, and so by means of definitions reduce them to order. Yet even definitions cannot cure this evil in dealing with natural and material things; since the definitions themselves consist of words. and

LXII Idols of the Theater, or of Systems, are many, and there can be and perhaps will be yet many more. For were it not that now for many ages men's minds have been busied with religion and theology; and were it not that civil governments, especially monarchies, have been averse to such novelties, even in matters speculative; so that men labor therein to the peril and harming of their fortunes—not only unrewarded, but exposed also to contempt and envy: doubtless there would have arisen many other philosophical sects like to those which in great variety flourished once among the Greeks. For as on the phenomena of the heavens many hypotheses may be constructed, so likewise (and more also) many various dogmas may be set up and established on the phenomena of philosophy. And in the plays of this philosophical theater you may observe the same thing which is found in the theater of the poets, that stories invented for the stage are more compact and elegant, and more as one would wish them to be, than true stories out of history.

In general however there is taken for the material of philosophy either a great deal out of a few things, or a very little out of many things; so that on both sides philosophy is based on too narrow a foundation of experiment and natural history, and decides on the authority of too few cases. For the rational school of philosophers snatches from experience a variety of common instances, neither duly ascertained nor diligently examined and weighed, and leaves all the rest to meditation and agitation of wit.

There is also another class of philosophers, who having bestowed much diligent and careful labor on a few experiments, have thence made bold to educe and construct systems; wresting all other facts in a strange fashion to conformity therewith.

And there is yet a third class, consisting of those who out of faith and veneration mix their philosophy with theology and traditions; among whom the vanity of some has gone so far aside as to seek the origin of science among spirits and genii. So that this parent stock of errors—this false philosophy—is of three kinds; the Sophistical, the Empirical, and the Superstitious.

LXX But the best demonstration by far is experience, if it go not beyond the actual experiment. For if it be transferred to other cases which are deemed similar, unless such transfer be made by a just and orderly process, it is a fallacious thing. But the manner of making experiments which men now use is blind and stupid. And therefore, wandering and straying as they do with no settled course, and taking counsel only from things as they fall out, they fetch a wide circuit and meet with many matters, but make little progress; and sometimes are full of hope, sometimes are distracted; and always find that there is something beyond to be sought. For it generally happens that men make their trials carelessly, and as it were in play; slightly varying experiments already known, and, if the thing does not answer, growing weary and abandoning the attempt. And even if they apply themselves to experiments more seriously and earnestly and laboriously, still they spend their labor in working out some one experiment, as Gilbert with the magnet, and the chemists with gold—a course of proceeding not less unskillful in the design than small in the attempt. For no one successfully investigates the nature of a thing in the thing itself; the inquiry must be enlarged, so as to become more general . . .

xcv Those who have handled sciences have been either men of experiment or men of

philosophy: for it neither relies solely or chiefly on the powers of the mind, nor does it take the matter which it gathers from natural history and mechanical experiments and lay it up in the memory whole, as it finds it; but lays it up in the understanding altered and digested. Therefore from a closer and purer league between these two faculties, the experimental and the rational (such as has never yet been made) much may be hoped.

xcvi We have as yet no natural philosophy that is pure; all is tainted and corrupted: in Aristotle's school by logic; in Plato's by natural theology; in the second school of Platonists, such as Proclus and others, by mathematics, which ought only to give definiteness to natural philosophy, not to generate or give it birth. From a natural philosophy pure and unmixed, better things are to be expected.

Fruits Never Yet Forbidden

*Micrographia: or Some Physiological Descriptions of Minute Bodies
Made by Magnifying Glasses, by Robert Hooke*

Robert Hooke (1635–1703) attended Westminster School and Oxford, and in 1662 became Curator of Experiments for the Royal Society, founded in 1660. In 1665 he was appointed professor of geometry at Gresham College, and in 1667 City Surveyor. He was known for a wide range of inventions and improvements of scientific instruments, and for contributions to mechanics, physics, physiology, biology, chemistry, optics, and meteorology. As Margaret 'Espinasse writes in Robert Hooke (1956), he “came very near the early ideal of a scientist whose field is the whole of knowledge.” Galileo had been among the claimants to inventing the microscope (in 1610), but Hooke, along with his Dutch contemporary Antony van Leeuwenhoek (1632–1723), pioneered the use of this instrument, by which “we now behold almost as great a variety of creatures as we were able before to reckon up in the whole universe itself.” He published his principal results (including study of plant cells), along with superb illustrations, in the *Micrographia* of 1665.

The preface from which the following selections are taken is a noteworthy statement of essentially Baconian principles of scientific method (to which the Royal Society was dedicated) by a practicing scientist. Like Bacon, Hooke stresses the need, in investigating nature, to rectify the misleading operations of sense, memory, and reason, especially by adding “artificial organs [such as the microscope] to the natural”; also like Bacon, he urges science to “return to the plainness and soundness of observations on material and obvious things” after “wandering far away into incredible notions.” He shows both the modesty of the experimental scientist who knows that “infallible deductions” and “certainty of axioms . . . are above my weak abilities” and supreme confidence that by following proper method there is nothing that human wit or industry cannot compass. “As at first, mankind fell by tasting of the forbidden tree of knowledge, so we, their posterity, may be in part restored by the same way, not only by beholding and contemplating, but by tasting too those fruits of natural knowledge, that were never yet forbidden.”