



On Experimental Science

Roger Bacon

Roger Bacon was born in 1214. After being educated at Oxford, he went to Paris to study, and in spite of the spirit of scholasticism there prevalent, became learned in the thought of the Arabs and interested more in science than in the theological discussions of the doctors of the Paris university. At the time there was little real scientific spirit in the lands under the power of the Church. The Bible and the church fathers were considered the best authorities not only in spiritual but in scientific matters. Most of the thought of the time was given to the formulation of dogma, and what little attempt there was in scientific subjects set out from preconceived notions rather than from experience and research. It is the great merit of Roger Bacon that he appreciated the method which has become recognized as the correct one proceeding to the investigation of scientific subjects.

After his return to England in 1250 he joined the Franciscan order. In 1257 the general of the order interdicted his lectures because they were thought to be too closely connected with magic and not entirely orthodox, but Clement IV, whom he met in England, befriended him and commanded him to write out what he had investigated. After Clement's death his books were condemned by Jerome de Ascoli, the general of the order at the time and afterwards pope, and Bacon himself was thrown into prison to remain there for fourteen years. He was freed in 1292 and died about two years later.

His great work is the Opus Majus, which is an encyclopedia of the knowledge of the period. There are two ideas in it that have been fruitful. The first is that in order to be a science a subject must be sufficiently understood to be mathematically stated. The second is that experience is all important in scientific investigation.

Bacon describes the making of gunpowder and many other inventions, of the age, besides some that are undoubtedly mythical. He believed in revelation as well as experience and that the former gave really the surest knowledge by the shortest method, and was a partisan of astrology and alchemy. In many such ways he is thoroughly a part of his age, but he had glimpses of the road that was eventually to lead to a clearer insight into the mysteries of the universe.

ON EXPERIMENTAL SCIENCE

Having laid down the main points of the wisdom of the Latins as regards language, mathematics and optics, I wish now to review the principles of wisdom from the point of view of experimental science, because without experiment it is impossible to know anything thoroughly.

There are two ways of acquiring knowledge, one through reason, the other by experiment.

Argument reaches a conclusion and compels us to admit it, but it neither makes us certain nor so annihilates doubt that the mind rests calm in the intuition of truth, unless it finds this certitude by way of experience. Thus many have arguments toward attainable facts, but because they have not experienced them, they overlook them and neither avoid a harmful nor follow a beneficial course. Even if a man that has never seen fire, proves by good reasoning that fire burns, and devours and destroys things, nevertheless the mind of one hearing his arguments would never be convinced, nor would he avoid fire until he puts his hand or some combustible thing into it in order to prove by experiment what the argument taught. But after the fact of combustion is experienced, the mind is satisfied and lies calm in the certainty of truth. Hence argument is not enough, but experience is.

This is evident even in mathematics, where demonstration is the surest. The mind of a man that receives that clearest of demonstrations concerning the equilateral triangle without experiment will never stick to the conclusion nor act upon it till confirmed by experiment by means of the intersection of two circles from either section of which two lines are drawn to the ends of a given line. Then one receives the conclusion without doubt. What Aristotle says of the demonstration by the syllogism being able to give knowledge, can be understood if it is accompanied by experience, but not of the bare demonstration. What he says in the first book of the Metaphysics, that those knowing the reason and cause are wiser than the experienced, he speaks concerning the experienced who know the bare fact only without the cause. But I speak here of the experienced that know the reason and cause through their experience. And such are perfect in their knowledge, as Aristotle wishes to be in the sixth book of the Ethics, whose simple statements are to be believed as if they carried demonstration, as he says in that very place.

Whoever wishes without proof to revel in the truths of things need only know how to neglect experience. This is evident from examples. Authors write many things and the people cling to them through arguments which they make without experiment, that are utterly false. It is commonly believed among all classes that one can break adamant only with the blood of a goat, and philosophers and theologians strengthen this myth. But it is not yet proved by adamant being broken by blood of this kind, as much as it is argued to this conclusion. And yet, even without the blood it can be broken with ease. I have seen this with my eyes; and this must needs be because gems cannot be cut out save by the breaking of the stone. Similarly it is commonly believed that the secretions of the beaver that the doctors use are the testicles of the male, but this is not so, as the beaver has this secretion beneath its breast and even the male as well as the female produces a secretion of this kind. In addition also to this secretion the male has its testicles in the natural place and thus again it is a horrible lie that, since hunters chase the beaver for this secretion, the beaver knowing what they are after, tears out his testicles with his teeth and throws them away. Again it is popularly said that cold water in a vase freezes more quickly than hot; and the argument for this is that contrary is excited by the contrary, like enemies running together. They even impute this to Aristotle in the second book of Meteorology, but he certainly did not say this, but says something like it by which they have been deceived, that if both cold and hot water are poured into a cold place as on ice, the cold freezes quicker (which is true), but if they are placed in two vases, the hot will freeze quicker. It is necessary, then, to prove everything by experience.

Experience is of two kinds. One is through the external senses: such are the experiments that are made upon the heaven through instruments in regard to facts there, and the facts on earth that we prove in various ways to be certain in our own sight. And facts that are not true in places where we are, we know through other wise men that have experienced them. Thus Aristotle with the authority of Alexander, sent 2,000 men throughout various parts of the earth in order to learn at first hand everything on the surface of the world, as Pliny

says in his Natural History. And this experience is human and philosophical just as far as a man is able to make use of the beneficent grace given to him, but such experience is not enough for man, because it does not give full certainty as regards corporeal things because of their complexity and touches the spiritual not at all. Hence man's intellect must be aided in another way, and thus the patriarchs and prophets who first gave science to the world secured inner light and did not rest entirely on the senses. So also many of the faithful since Christ. For grace makes many things clear to the faithful, and there is divine inspiration not alone concerning spiritual but even about corporeal things. In accordance with which Ptolemy says in the Centilogium that there is a double way of coming to the knowledge of things, one through the experiments of science, the other through divine inspiration, which latter is far the better as he says.

Of this inner experience there are seven degrees, one through spiritual illumination in regard to scientific things. The second grade consists of virtue, for evil is ignorance as Aristotle says in the second book of the Ethics. And Algazel says in the logic that the mind is disturbed by faults, just as a rusty mirror in which the images of things cannot be clearly seen, but the mind is prepared by virtue like a well polished mirror in which the images of things show clearly. On account of this, true philosophers have accomplished more in ethics in proportion to the soundness of their virtue, denying to one another that they can discover the cause of things unless they have minds free from faults. Augustine relates this fact concerning Socrates in Book VIII, chapter III, of the City of God: to the same purpose Scripture says, to an evil mind, etc., for it is impossible that the mind should lie calm in the sunlight of truth while it is spotted with evil, but like a parrot or magpie it will repeat words foreign to it which it has learned through long practice. And this is our experience, because a known truth draws men into its light for love of it, but the proof of this love is the sight of the result. And indeed he that is busy against truth must necessarily ignore this, that it is permitted him to know how to fashion many high sounding words and to write sentences not his own, just as the brute that imitates the human voice or an ape that attempts to carry out the works of men, although he does not understand their purpose. Virtue, then, clears the mind so that one can better understand not only ethical, but even scientific things. I have carefully proved this in the case of many pure youths who, on account of their innocent minds, have gone further in knowledge than I dare to say, because they have had correct teaching in religious doctrine, to which class the bearer of this treatise belongs, to whose knowledge of principles but few of the Latins rise. Since he is so young (about twenty years old) and poor besides, not able to have masters nor the length of any one year to learn all the great things he knows, and since he neither has great genius or a wonderful memory, there can be no other cause, save the grace of God, which, on account of the clearness of his mind, has granted to him these things which it has refused to almost all students, for a pure man, he has received pure things from me. Nor have I been able to find in him any kind of a mortal fault, although I have searched diligently, and he has a mind so clear and far seeing that he receives less from instruction than can be supposed. And I have tried to lend my aid to the purpose that these two youths may be useful implements for the Church of God, inasmuch as they have with the Grace of God examined the whole learning of the Latins.

The third degree of spiritual experience is the gift of the Holy Spirit, which Isaiah describes. The fourth lies in the beatitudes which our Lord enumerates in the Gospels. The fifth is the spiritual sensibility. The sixth is in such fruits as the peace of God, which passes all understanding. The seventh lies in states of rapture and in the methods of those also, various ones of whom receive it in various ways, that they may see many things which it is not permitted to speak of to man. And whoever is thoroughly practiced in these experiences or in many of them, is able to assure himself and others, not only concerning spiritual things, but all human knowledge. And indeed, since all speculative thought proceeds

through arguments which either proceed through a proposition by authority or through other propositions of argument, in accordance with this which I am now investigating, there is a science that is necessary to us, which is called experimental. I wish to explain this, not only as useful to philosophy, but to the knowledge of God and the understanding of the whole world: as in a former book I followed language and science to their end, which is the Divine wisdom by which all things are ordered.

And because this experimental science is a study entirely unknown by the common people, I cannot convince them of its utility, unless its virtue and characteristics are shown. This alone enables us to find out surely what can be done through nature, what through the application of art, what through fraud, what is the purport and what is mere dream in chance, conjuration, invocations, imprecations, magical sacrifices and what there is in them; so that all falsity may be lifted and the truths we alone of the art retained. This alone teaches us to examine all the insane ideas of the magicians in order not to confirm but to avoid them, just as logic criticizes the art of sophistry. This science has three great purposes in regard to the other sciences: the first is that one may criticize by experiment the noble conclusions of all the other sciences, for the other sciences know that their principles come from experiment, but the conclusions through arguments drawn from the principles discovered, if they care to have the result of their conclusions precise and complete. It is necessary that they have this through the aid of this noble science. It is true that mathematics reaches conclusions in accordance with universal experience about figures and numbers, which indeed apply to all sciences and to this experience, because no science can be known without mathematics. If we would attain to experiments precise, complete and made certain in accordance with the proper method, it is necessary to undertake an examination of the science itself, which is called experimental on our authority. I find an example in the rainbow and in like phenomena, of which nature are the circles about the sun and stars, also the halo beginning from the side of the sun or of a star which seems to be visible in straight lines and is called by Aristotle in the third book of the Meteorology a perpendicular, but by Seneca a halo, and is also called a circular corona, which have many of the colors of the rainbow. Now the natural philosopher discusses these things, and in regard to perspective has many facts to add which are concerned with the operation of seeing which is pertinent in this place. But neither Aristotle or Avicenna have given us knowledge of these things in their books upon Nature, nor Seneca, who wrote a special book concerning them. But experimental science analyzes such things.

The experimenter considers whether among visible things, he can find colors formed and arranged as given in the rainbow. He finds that there are hexagonal crystals from Ireland or India which are called rainbow-hued in Solinus Concerning the Wonders of the World and he holds these in a ray of sunlight falling through the window, and finds all the colors of the rainbow, arranged as in it in the shaded part next the ray. Moreover, the same experimenter places himself in a somewhat shady place and puts the stone up to his eye when it is almost closed, and beholds the colors of the rainbow clearly arranged, as in the bow. And because many persons making use of these stones think that it is on account of some special property of the stones and because of their hexagonal shape the investigator proceeds further and finds this in a crystal, properly shaped, and in other transparent stones. And not only are these Irish crystals in white, but also black, so that the phenomenon occurs in smoky crystal and also in all stones of similar transparency. Moreover, in stones not shaped hexagonally, provided the surfaces are rough, the same as those of the Irish crystals, not entirely smooth and yet not rougher than those---the surfaces have the same quality as nature has given the Irish crystals, for the difference of roughness makes the difference of color. He watches, also, rowers and in the drops falling from the raised oars he finds the same colors, whenever the rays of the sun penetrate the drops.

The case is the same with water falling from the paddles of a water-wheel. And when the investigator looks in a summer morning at the drops of dew clinging to the grass in the field or plane, he sees the same colors. And, likewise, when it rains, if he stands in a shady place and the sun's rays beyond him shine through the falling drops, then in some rather dark place the same colors appear, and they can often be seen at night about a candle. In the summer time, as soon as he rises from sleep while his eyes are not yet fully opened, if he suddenly looks at a window through which the light of the sun is streaming, he will see the colors. Again, sitting outside of the sunlight, if he holds his head covering beyond his eyes, or, likewise, if he closes his eyes, the same thing happens in the shade at the edges, and it also takes place through a glass vase filled with water, sitting in the sunlight. Similarly, if any one holding water in his mouth suddenly sprinkles the water in jets and stands at the side of them; or if through a lamp of oil hanging in the air the rays shine in the proper way, or the light shines upon the surface of the oil, the colors again appear. Thus, in an infinite number of ways, natural as well as artificial, colors of this kind are to be seen, if only the diligent investigator knows how to find them.

Experimental science is also that which alone, as the mistress of the speculative sciences, can discover magnificent truths in the fields of the other sciences, to which these other sciences can in no way attain. And these truths are not of the nature of former truths, but they may be even outside of them, in the fields of things where there are neither as yet conclusions or principles, and good examples may be given of this, but in everything which follows it is not necessary for the inexperienced to seek a reason in order to understand at the beginning, but rather he will never have a reason before he has tried the experiment. Whence in the first place there should be credulity until experiment follows, in order that the reason may be found. If one who has never seen that a magnet draws iron nor heard from others that it attracts, seeks the reason before experimenting, he will never find it. Indeed, in the first place, he ought to believe those who have experimented or who have it from investigators, nor ought he to doubt the truth of it because he himself is ignorant of it and because he has no reason for it.

The third value of this science is this---it is on account of the prerogatives through which it looks, not only to the other sciences, but by its own power investigates the secrets of nature, and this takes place in two ways---in the knowledge of future and present events, and in those wonderful works by which it surpasses astronomy commonly so-called in the power of its conclusions. For Ptolemy in the introduction of the *Almagest*, says that there is another and surer way than the ordinary astronomy; that is, the experimental method which follows after the course of nature, to which many faithful philosophers, such as Aristotle and a vast crowd of the authors of predictions from the stars, are favorable, as he himself says, and we ourselves know through our own experience, which cannot be denied. This wisdom has been found as a natural remedy for human ignorance or imprudence; for it is difficult to have astronomical implements sufficiently exact and more difficult to have tables absolutely verified, especially when the motion of the planets is involved in them. The use of these tables is difficult, but the use of the instruments more so.

This science has found definitions and ways through which it quickly comes to the answer of a whole question, as far as the nature of a single science can do so, and through which it shows us the outlines of the virtues of the skies and the influence of the sky upon this earth, without the difficulty of astronomy. This part so-called has four principal laws as the secret of the science, and some bear witness that a use of this science, which illustrates its nature, is in the change of a region in order that the customs of the people may be changed. In connection with which Aristotle, the most learned of philosophers, when Alexander asked of him concerning some tribes that he had found, whether he should kill them on account of their barbarity or let them live, responded in the *Book of Secrets* if

you can change their air let them live; if not, kill them. He wished that their air could be altered usefully, so that the complexion of their bodies could be changed, and finally the mind aroused through the complexion should absorb good customs from the liberty of their environment; this is one use of this science.

Oliver J. Thatcher, ed. *The Library of Original Sources*. Vol. V: The Early Medieval World. Milwaukee: University Research Extension, 1901.

© SophiaOmni, 2011. The specific electronic form of this text is copyright. Permission is granted to print out copies for educational purposes and for personal use only. No permission is granted for commercial use.