Francis Bacon and Scientific Method.

By Dr. C. D. BROAD.

I.

FRANCIS BACON, who died on April 9, 1626, and whose tercentenary is to be celebrated at Cambridge on October 5 of the present year, was born at York Place, Strand, on January 22, 1560/61. His father was Nicholas Bacon, Lord Keeper to Queen Elizabeth, and his mother was Anne Cook, daughter of Sir Antony Cook, who had been tutor to Edward VI. Bacon went to Trinity College, Cambridge, at a very early age; he was only fifteen when he finally went down in 1575. He was sent to France by his father, who died while he was there, leaving Bacon ill provided for. He decided to follow the career of a lawyer, and was admitted to Gray's Inn on November 21, 1576. During Elizabeth's reign Bacon had much legal work to do, and received many promises of preferment, but he was not greatly rewarded either in money or in offices. Under James I. his advancement was rapid. He rose to be Lord Chancellor and Baron Verulam in 1618 and Viscount St. Albans in 1620-21.

This was the culmination of Bacon's career. On May 3, 1621, he pleaded guilty to a charge of corruption; was fined 40,000*l.*; imprisoned in the Tower during the King's pleasure; made incapable of sitting in Parliament or holding any office of State; and banished from the verge of the Court. The King soon freed Bacon and remitted his fine; but the fallen statesman retired to his estate at Gorhambury, and devoted the rest of his life to those literary, scientific, and philosophic labours which had always been his main interest. His most important philosophical and scientific works are the "*De Augmentis*" and the "*Novum Organum*." There are in addition a great many fragments and sketches which throw much additional light on his scientific and methodological theories. Bacon died a martyr to experimental science, and might well be made the patron saint of the cold storage industry. In extremely cold, snowy weather he stopped his coach near Highgate, bought a chicken, and stuffed it with snow, in order to see whether this would preserve the meat. He caught a severe cold, which was aggravated by the damp bed into which he was put at Lord Arundel's mansion, where he had stopped for the night, and he died in his sixty-sixth year.

In order to understand Bacon's dissatisfaction with the science of his time, we must try to imagine a state of affairs in which physics and chemistry were in much the same position as psychology and sociology are now. There were various sects or schools of physicists, following various masters, wrangling with each other, and producing much heat, little light, and less fruit. Existing scientists are divided by Bacon into two classes: (1) the extreme rationalists who rush to wide general principles from a few common-place and badly analysed facts, and then profess to explain everything by means of these principles; and (2) the mere empiricists, who investigate with extreme diligence but no scientific method some small region of phenomena, and then put forward theories of the universe in terms of the small corner of it with which they happen to be best acquainted. Nothing satisfactory can be reached

in either of these ways. The theories of the rationalists are more plausible than those of the empiricists, but they lead to no practical results and give us no control over Nature. The empiricists (*e.g.* the alchemists) have sometimes stumbled by chance on useful practical results. But each of these is isolated from the rest, and Nature cannot be controlled practically until its structure and laws are understood theoretically. So Bacon demands that the sciences shall be built up again from better foundations and by a new method, which shall combine the careful observation and experiment of the empiricists with the generality and systematic connexion of the rationalists. Like other philosophers of his time, Bacon made the mistake of thinking that, because a good method is necessary in order to accomplish anything, it is sufficient in order to accomplish everything. He compares it to a ruler or a compass in drawing; and, like Descartes, he thinks that it will reduce all human intellects to a level.

Now Bacon holds that science has so far failed, partly because the human mind has not had an adequate, trustworthy, and properly selected set of data to work upon, and partly because it has not applied a suitable instrument of interpretation to the data which have been available. He thinks the first defect more serious than the second; for he says that important generalisations could be gained even by the present imperfect logical processes from an adequate natural history, whilst even the most perfect logical instrument would be powerless to elicit truth from the present scanty and unreliable data. In order to remedy this evil, Bacon holds that the first necessity is to prepare the mind for collecting a proper natural history and for interpreting and generalising from this history. The mind of any grown man is a highly distorting mirror, and our first business is to plane and polish it as far as may be. The factors, innate and acquired, which cause bias and error are called by Bacon "*Idols*." Certain of these are common to the human race, *e.g.* the tendency to ascribe to Nature the particular kind of orderliness and simplicity which is pleasing to men. These are called "*Idols of the Tribe*." Others vary from individual to individual; *e.g.* some men tend to dwell on resemblances and neglect differences, whilst others have the opposite bias. These are called "*Idols of the Cave*." Then, again, the suggestions and associations of language are a fruitful source of error; since words and phrases embody theories which are often false and observations which are often mistaken. These are called "*Idols of the Market Place*." Bacon admits that these three kinds of *Idol* can never be completely eliminated. But we can be put on our guard, so that we allow for them and thus render them harmless. Finally, there are false systems of philosophy and science erected by bad logic on flimsy foundations. These are called "*Idols of the Theatre*"; and there is no reason why they should not be completely removed, partly by pointing out their fallacies and their unfruitfulness, and partly by substituting good reasoning and properly attested data.

The human mind has, however, many deficiencies

as well as positive sources of error. When the latter—the Idols—have been removed, it is time to provide aids to supplement the former. The senses have two defects. In the first place, they are sensitive only for a small range of stimuli. Secondly, their deliveries are always infected by subjectivity; they tell us of things, not as they are in Nature, but as they affect a particular organism at a particular time and place. The first kind of defect can be remedied to a large extent by suitable instruments. The second can be remedied by comparison between different senses of the same observer, or the same sense of different observers. Bacon holds that the deliveries of the senses, when properly compared, criticised, and neutralised, are trustworthy, and are the only possible foundation of science.

When the mind has been thus purified and helped, it is time to give it directions for collecting a complete natural history. Bacon recognised that the actual collection of such a natural history would be a work which would take much time, trouble, and expense, and in which many men would have to co-operate. He hoped to secure such co-operation, and to confine himself to giving directions and to completing the logical principles for interpreting and generalising the facts. Unfortunately he received no help either in money or in kind, and so he was forced to collect his data for himself, a task for which he was obviously ill-fitted.

Bacon's scheme for a complete natural history was as follows. It was to consist of an account of the normal course of Nature, of abnormalities spontaneously produced in the course of Nature, and of results deliberately produced by the interference of man. Bacon attached very great importance to deliberate experiment as compared with passive observation. He also attached great weight to the observation of spontaneous abnormalities. They set us free from prejudices, and they suggest means of producing new substances and changes artificially. Bacon explicitly recognised that there is no fundamental distinction between natural and artificial products. In the history of the normal course of Nature we are not to neglect what is commonplace or to omit what is filthy. The method of selection is to be the following. Data are to be chosen, not for their intrinsic interest or for their immediate practical usefulness, but for their capacity to throw light on the structure and laws of Nature. Bacon's views on

practical applications in science are admirably just. On one hand, he regards the practical control of Nature as the ultimate end of science, and ability to produce observable results as the ultimate test of any scientific theory. On the other hand, he fully recognises that Nature can be controlled practically only by being understood theoretically; and he constantly asserts that to aim directly at particular applications is fatal to pure science and short-sighted even from the point of view of practice.

Bacon gives rules for recording and arranging the data of the natural history when they have been collected. The following are the most interesting. All data that can be accurately measured should have their values recorded; where accurate measurement is impossible, upper and lower limits should be assigned. All difficult experiments must be fully and carefully described, so that others can criticise and, if necessary, repeat them. The data must be tabulated and classified from the very first. But we must recognise that at first the natural history will almost certainly contain some alleged facts which are not genuine, and that our first classifications will be partly inappropriate. If, however, the bulk of the data recorded are genuine facts, they will suffice to establish the general laws and structure of Nature; and, in the light of this, the few errors will stand out as anomalies and can be reinvestigated and corrected. Similarly, it will be necessary to return to the natural history again and again as our knowledge of the general laws and structure grows, and to reclassify the data in the light of this increased knowledge. Probably a work like Beilstein's "Dictionary of Organic Chemistry" would be a good example of what Bacon meant by a natural history. Yet of course the classification of compounds within this dictionary depends entirely on chemical theory, whilst Bacon wanted his natural history to be as free from theory as possible. The solution of this apparent contradiction is that the natural history and the theories induced from it act reciprocally and successively on each other. The first and crudest form of the natural history involves the minimum of theory and gives rise to the crudest inductions. The natural history is now corrected and reclassified in terms of these inductions. It thus imbibes an additional dose of theory, and becomes the basis for more accurate inductions which in turn react on itself.

(To be continued.)

Antarctic Weather.

THE recent publication of Dr. Simpson's interesting Halley Lecture of 1923 focusses attention once more on the little-known causes which are responsible for the weather of the Antarctic continent. In his lecture Dr. Simpson dealt particularly with the meteorological conditions as they affected adversely Capt. Scott's journey to and from the South Pole, and justified Scott's own view that the conditions on the last stage of the return journey were such as could not have been foreseen. This impossibility of forecasting weather conditions is of course shared by the Antarctic continent with many other regions of the earth, but there is some reason for believing that the contrasts in weather conditions from year to year and from day to

day are very pronounced, at least in the region of South Victoria Land, to which area these remarks chiefly refer.

A visitor's first sight of the still active volcano forming the summit of the ice-clad Ross Island is indeed prophetic of the contrasts he will later experience; he will be no less surprised to discover that the continent, roughly circular and of radius some 1200 miles, is almost entirely covered with ice and snow, though it could, so far as precipitation is concerned, be classed almost as a desert. The general surface circulation is anticyclonic, the air flowing outward from the continent with an easterly component due to the earth's rotation. Superposed on the normal distribution of wind velocities