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BY LORD ADRIAN

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FRANCIS BACON,
THE ADVOCATE OF SCIENCE

LORD ADRIAN, Master of Trinity College, Cambridge

THIS YEAR is the 400th anniversary of the birth of Francis Bacon, the great writer and great lawyer and great herald of the scientific age. He was one of the leading figures at the end of Queen Elizabeth's reign and in that of James I. As Attorney-General and afterwards as Lord Chancellor he had to be responsible for some of the celebrated trials of those days and has been blamed for the way he conducted them. His career as a lawyer came to a sad end when he was deprived of his office for accepting bribes, but he has always been recognized, then and since, as one of the great philosophers of science.

This afternoon I shall deal only with that side of his career.

At the South end of the Wren Library at Trinity College there is a large stained glass window put up in the middle of the eighteenth century. The central figure is the youthful King George III, still the sovereign lord of his American Colonies. He sits enthroned on a dais with Britannia in attendance and cherubs above. In the foreground on the left, a lady in flowing draperies, representing Fame, presents Isaac Newton to the King, and on the right below the dais there is the seated figure in Jacobean dress which is the standard representation of Francis Bacon, Baron Verulam and Viscount St. Albans. We are proud of the window for it reminds us that Trinity educated the two most important men in the development of science in the seventeenth and eighteenth centuries.

Francis Bacon was born in 1561, and in 1573 he came up to Cambridge as a fellow commoner at Trinity, the large and relatively wealthy college founded by Henry VIII. He was then only 12 years old, young for University studies even in those days. Bacon must

have been the kind of very clever boy who is not greatly impressed by his teachers or his companions, but he was at Trinity at an impressionable age and so I want to set the stage for Bacon as a scientist by a prologue about Bacon as an undergraduate at Trinity.

You will realize that it is not to be taken very seriously. In fact we know very little about his time at Cambridge, and it is only too easy to try to account for parts of a great man's character by selecting the particular circumstances of his upbringing which might be related to it. Bacon's character does not fit very well with any standard classification, and the state of Trinity when he was a boy there may have had very little to do with his later career, his ambitions and his writings and his actions. However he was at Trinity and a college usually leaves a mark of some kind. He came of a considerable family but he was not like Essex, an aristocrat with his head in the air, and I think we can be sure that a precocious boy between 12 and 15 would have day dreams of great achievement and that they would be coloured by his surroundings. At the very least his years at Trinity convinced him that science needed new methods and that the lectures on Aristotle which were the main courses of instruction were a waste of time, but I think Trinity may have had a more general influence on his career: his years there may have helped to form Bacon's ideas not only on science but on religion and politics and on the relation of justice to the needs of government.

Trinity was founded at the end of Henry VIII's reign and could not expect to be undisturbed by the rapid changes of religious policy which followed. Queen Mary built us a new chapel but after her death there was a period when the Puritan party was in the ascendant. They gave up surplices and broke the chapel windows and when Beaumont, the Master, died in 1567, he left the request that he was to be buried with 'no vain jangling of bells nor any other popish ceremonies'. But Queen Elizabeth did not want the Presbyterians in power and appointed Whitgift to succeed Beaumont. He was Bacon's Master, and he was a man of strong character who believed in order and discipline and the Anglican Church holding on the middle course between Rome and Geneva. Bacon's mother, Anne, also a formidable character, was a severe Puritan with an anxious eye on her son's

religious views, but Whitgift took stern measures to suppress both Puritan and Roman Catholic tendencies in Cambridge, and he secured the position by reorganizing the whole machinery of the University with a new set of statutes which gave all the power to the heads of the Colleges and inflicted heavy penalties for disobedience.

Now at that time the Master acted as tutor to some of the students. Robert Devereux, the 2nd Earl of Essex, who came up six years after Bacon and died on the scaffold, was housed for a time in the Master's Lodge, but Bacon, who became Lord Chancellor, and Edward Coke who became Lord Chief Justice, were also pupils of Whitgift, though they did not live with him. Macaulay described Whitgift, afterwards Archbishop of Canterbury, as 'a narrow-minded, mean and tyrannical priest who gained power by servility and adulation and employed it in persecuting both those who agreed with Calvin about Church Government and those who differed from him concerning the doctrine of Reprobation,' and he speaks of him as exercising much petty tyranny within his own College. Whitgift was certainly a strict Master. The year before Francis Bacon came up, Whitgift, as Vice-Chancellor, issued a decree to the University that 'if any scholar shall go into any river, pool or other water in the County of Cambridge to swim or wash he shall for the first offence be sharply or severely whipped publicly in the Common Hall of the College in which he dwells'. On the other hand his own College and the whole University prospered under his discipline and in 1577, when he preached his farewell sermon before a large congregation 'there were scarce any drie eyes to be found amongst the whole number'. At all events that is what his biographer says.

There is one passage in Whitgift's later career which shows his outlook. After Elizabeth made him Archbishop of Canterbury he had to draw up a set of Articles for the Church of England. The Lambeth Articles which he proposed were strongly, in these days one might say savagely Calvinistic. Here are four of them:

1) God from all eternity hath predestined certain men unto life: certain men he hath reprobated.

3) There is predetermined a certain number of the Predestinate which

can neither be augmented nor diminished.

4) Those who are not predestinate to salvation shall be necessarily damned for their sins.

9) It is not in the will or power of everyone to be saved.

Queen Elizabeth took a more comfortable view of the future and made him withdraw the Articles, but presumably they reflect the views of Francis Bacon's tutor when he was at Trinity.

Bacon was clever, observant and ambitious. Possibly his chief ambition was to be a great leader of a new age in science, and if he had secured a well paid post he might not have needed to become the politic lawyer who prosecuted his patron and friend Essex and brought him to the block and showed James I how he could dispose of Raleigh without a new trial. Bacon was not narrow-minded, mean and tyrannical but there is a suggestion of Whitgift about that side of Bacon's career, about the means he used in pursuit of power and advancement in office and his cold-blooded acceptance of the duty to support the government without regard to private obligations.

But when Bacon could turn from action to contemplation he showed how much he had revolted against what he had been taught at Cambridge. His religious views have no trace of Whitgift's Calvinistic Articles with most of mankind irretrievably damned to eternal punishment. The French Encyclopaedists hailed Bacon as an atheist at heart, but, as Professor Broad says, he seems to have been a sincere, if unenthusiastic Christian of that sensible school which regards the Church of England as a branch of the Civil Service. And he was soon in open revolt against the secular teaching at Cambridge. Macaulay says that 'after three years there he departed carrying with him a profound contempt for the course of study pursued there, a fixed conviction that the system of Academic Education in England was radically vicious, a just scorn for the trifles on which the followers of Aristotle had wasted their powers and no great reverence for Aristotle himself.' In fact Cambridge had evidently done him a lot of good.

Bacon had four years in France to reflect on what he had learnt and then the sudden death of his father made it necessary for him to

earn his living as a lawyer. He went to France in the train of Sir Amyas Poulet, our Ambassador. In 1572, the year before Bacon came to Trinity, the Catholic party in Paris had slaughtered many of the Huguenots in the Massacre of St. Bartholomew, but some of the leaders escaped. The fighting ended, officially at least, with the Treaty of Bergerac in 1577, when Bacon was in France. He had toured the country and must have seen some of the results of religious enthusiasm and weak central government. What he learnt then may have helped to shape his career as a statesman, but then and afterwards at the bar and in the service of the Crown he was always finding time to cultivate his great talents as a writer and to build up his great new plan for the advancement of science.

The plan was for nothing less than a complete reconstruction of human knowledge: in the preface to *The Great Instauration* he records his conviction 'that the state of knowledge is not prospering nor greatly advancing; and that a way must be opened for the human understanding entirely different from any hitherto known, and other helps provided, in order that the mind may exercise over the nature of things the authority which properly belongs to it.' And the way was by systematic induction from observed fact and particularly from experiments 'skilfully and artificially devised for the express purpose of determining the point in question'.

It has often been pointed out that natural science had started a new advance before Bacon wrote about it and that great discoveries had already come from the use of the experimental methods which are the foundation of his system. Attacks on Aristotle's supremacy became increasingly common in the sixteenth century. Copernicus, Tycho Brahé and Kepler were making a new system of astronomy, and the Italian anatomists were already beginning to trust their own observations even though they seemed to conflict with the doctrines of Galen. Whewell in his book on the Philosophy of the Inductive Sciences summed it up in these words:

> The revolution in the methods of science was going on, though the public at large was not aware of it, but Bacon's lofty eloquence, talents, rank, position, gravity and caution stirred the hopes of all classes — and when it was found that the revolution really had occurred, it was natural

that he should be hailed as its author. However, if we must select some one philosopher as the Hero of the revolution in scientific method Francis Bacon must occupy the place of honour.

Macaulay went further by saying that the part which Bacon played in this great change was the part, not of Robespierre but of Bonaparte.

Yet Bacon's part was not so much that of a successful general who won victories, as of a preacher who inspired a crusade. What he did for science is not greatly exaggerated in the passage in Cowley's *Ode to the Royal Society,* which is so often quoted.

> Bacon, like Moses, led us forth at last.
> The barren wilderness he past;
> Did on the very border stand
> Of the blest and promised land
> And from the mountain top of his exalted wit
> Saw it himself and shew'd us it.

His writings did a great deal to convince the seventeenth century that there was a promised land worth reaching and that natural knowledge would remain a barren wilderness as long as it depended on the philosophy of Aristotle and the middle ages.

He believed that he had discovered the true and only way to advance, though here he went astray in claiming so much for his particular method. In fact no one has kept strictly to the path he laid down: but the new land has been explored none the less and it was Bacon who showed what might be gained by reaching it.

Naturally he was on more secure ground as a critic of the existing state of affairs than as a guide to the future. The Schoolmen had built up an elaborate system of the Universe based on Aristotelian logic and ingenious disputations about first principles. Bacon was not the only critic of arguments about the natural world unchecked by the appeal to experience, but it was his criticism which had the greatest impact on his contemporaries. He set out to persuade the learned world that mankind could go further than the Greeks and the Schoolmen if only it would turn back to hard facts instead of wasting its

time trying to formulate the rules for correct thinking, and he did persuade them, even if he may have been preaching to the half-converted.

But his plan for the future, *The Great Instauration*, was never finished. It was to be in six volumes which were to explain and justify his new method. It set out to expound his infallible mechanism for the production of new arts and sciences and this is sketched in the *Novum Organum*. But, as Broad has said, the machinery is incomplete and the engineer, instead of drawing plans for completing it, has to spend his time in collecting raw materials and in planning eloquent prospectuses. What he did find time to write is a constant surprise both because of its excellence and its defects. In much of it he is the herald of a new outlook on the natural world but his detailed treatment of heat and motion looks back to the Middle Ages.

This seems to be marking down *The Great Instauration* as a failure, but, of course, it is far from that. Bacon wrote and published a great deal concerning it, and he never wrote anything that is not worth reading. There is his masterly analysis of wishful thinking in scientific work, the way in which we can deceive ourselves because our intellect is 'no dry light' but is swayed by the emotions and the will. We are too easily guided by conventional beliefs; we think in terms of key words and slogans, the Idols of the Market Place; we think that Nature must fit our notions of order and simplicity and ignore evidence that it does not — the Idols of the Tribe; we direct our work to support our own personal bias, the Idols of the Cave; and we allow ourselves to build up false systems of natural philosophy by using inadequate data, the Idols of the Theatre.

I should imagine that most scientists will realize how often their colleagues and even they themselves have gone wrong by following one or other of Bacon's Idols. But the cure he prescribed for wishful thinking was far too radical. It was that the scientist's work should proceed with a minimum of thinking of any sort. He must record all the facts, measure and weigh and catalogue everything in every condition, and the conclusions will follow when all the data are tabulated. Our first classifications may be erroneous but the right method of recording and tabulating will soon appear.

The record was to show the effects of experimental as well as natural conditions. He says

> For as in ordinary life every person's disposition, the concealed feelings of the mind and passions, are most drawn out when they are most disturbed, so the secrets of nature betray themselves most readily when tormented by art than when left to their own course.

The experiments which Bacon proposed or made himself were intelligently planned, although seldom successful, but the Tables which he drew up to direct the scientist were supposed to do away with the need for this kind of planning. He says

> Our method is of such a nature that there is not much left to acuteness and strength of genius, but all degrees of genius and intellect are brought to the same level.

He expected too much of it. There were to be Tables of Absence, of Presence, of Degrees and Classification of Instances as Solitary, Migrating, Ostensive or Clandestine, and they have not helped scientific discovery to become a mechanical process. The advance still demands both the routine measurement and testing and an acute selection of what to measure and test, guided by an intelligent guess at the most favourable route to follow. In fact the detailed directions he laid down had very little effect on the progress of science.

It has been argued that Bacon did not really suppose that the advance could be made without intelligent people to guide it, for in some of his later writings they seem to be the most important element in the plan. So, in *The New Atlantis,* unfinished and published after his death, the work going on in the great research institute of his dreams, 'Solomon's House', is to be directed by an Academy of thirty-six pre-eminent scientists, though they were to be assisted by a large number of collectors of information, measurers and weighers, who need only work to the rules. In his earlier writing he may not have meant that the work could direct itself: he seems to mean that, but a busy Lord Chancellor in financial difficulties can be excused if his pronouncements out of court have been written hastily.

In any case Bacon's plan, as he described it, was looking too far

ahead. It was to cover the whole world of natural phenomena and there was then so little to build on that it was a hopeless task to begin by tabulating all the data and expecting the laws of nature to emerge from the table. For three centuries scientists have gone about their business by keeping to a small range of phenomena and thinking very hard about the particular tests they should apply. They still have to advance by moving from one working hypothesis to another, but in spite of it in the present century we seem to be coming a good deal nearer to Bacon's dream of a mechanical method of discovery.

Many of us must have visited laboratories where every known sample of some natural product has been collected to be put through a standard range of tests by white-coated technicians, or where every variation of a basic molecular pattern is synthesized to see whether it will make a better tranquillizer or insecticide. Solomon's House still needs the Academicians at the top and there is still a great deal to be left to acuteness and strength of genius, but some of us are beginning to wonder whether scientific research in future will not become more and more like the mechanical process that Bacon foresaw. Even now there are electronic tabulating and calculating machines to take over much of the drudgery and even much of the detailed planning of research. They are machines which work by immensely rapid and encyclopaedic tabulation and comparison, without flashes of genius. They can solve problems quite beyond human capacity and the enthusiasts assure us that machines will be built to find out what problems need to be solved. Electronic machinery promises to 'bring all degrees of genius and intellect to the same level'. All that will be left for us will be to enjoy their products.

In any case Bacon's plan looked too far ahead: it has taken scientists 400 years to come anywhere near it. But his writings about it contain much more than the analysis of human failings and the method that will guard us against them. He broke new ground in insisting that there must be graduated and successive induction, that each branch of science must be built as a pyramid with successive floors of observation and experience as its foundation. He contrasts 'Anticipation of Nature' — jumping to the sweeping and usually false conclusion from inadequate data — with 'Interpretation of Nature'

by taking one step at a time. Scientists even in those days may not have needed to be told to follow the method which came naturally to them, but the nature of the method, the gradual progress by induction from facts obtained by observation and experiment, that was what Bacon expounded and it is one reason why *The Great Instauration* is still a landmark in the philosophy and history of science.

Incidentally I think it is an interesting fact, at all events worth tabulating, that the history of scientific discovery has owed so little to the philosophers who have set out to analyse its methods. The general rule seems to be that the scientist makes his chief contributions to knowledge when he is young and active, as Newton said, 'in the prime of his age for invention', and is so engrossed in the search that he has no time to reflect on the principles which guide him. When he is older and less vigorous or more administrative, he may wonder what it all came to and how and why he did it and it is then that Bacon's writings will make their chief appeal.

But Bacon's writing on science had another and greater appeal to his own time, though it concerns an aspect which is now taken for granted. Macaulay and many who have followed him make this by far the most important feature of Bacon's system. He insisted on the great practical value of scientific knowledge. The insight which the scientist obtains into nature can and should be employed in commanding nature for the service of man. Macaulay says that Bacon used means different from those of other philosophers because he wished to arrive at an end altogether different from theirs. The end was 'fruit' rather than 'light', utility and progress in improving the condition of the human race, the good of mankind in the sense in which the mass of mankind has always understood the word 'good'. 'To make men perfect was no part of Bacon's plan. His humble aim was to make imperfect man comfortable.'

The utility of scientific progress was not, of course, an entirely new idea but it had never been insisted on so forcibly. To quote Macaulay again,

> Plato held that the office of geometry was to discipline the mind, not to minister to the base wants of the body. Archimedes was half ashamed of those inventions which were the wonder of hostile armies. Bacon valued

geometry chiefly, if not solely, on account of those uses which to Plato appeared so base. And it is remarkable that the longer he lived, the stronger that feeling became.

Bacon was well aware that the search for fruits and the search for light must go on together, 'ascending to axioms as well as descending to works'. 'What is most useful in practice is most correct in theory' and 'The improvement of man's mind and the improvement of his lot are one and the same thing'. 'To be ignorant of causes is to be frustrate in action'. He does, however, say this (*Novum Organum*),

> Another powerful and great cause of the little advancement of the sciences, which is this, it is impossible to advance properly in the course when the goal is not properly fixed. But the real and legitimate goal of the sciences is the endowment of human life with new inventions and riches.

But later on he qualifies this:

> Yet (to speak the truth) in the same manner as we are very thankful for light which enables us to enter on our way, to practise arts, to read, to distinguish each other, and yet sight is more excellent and beautiful than the various uses of light; so is the contemplation of things as they are, free from superstition or imposture, error or confusion, much more dignified in itself than all the advantages to be derived from discoveries.

In fact he seems to want it both ways, but I think it must be agreed that Bacon did value 'fruit' at least as much as, and sometimes more than, 'light'.

When it comes to an immediate task in science or anything else we are never in much doubt about why we want to do it, but the distant and the final target to which our activities are, or should be, directed are seldom very clearly in our minds. The scientist who has to explain his work to students and colleagues is bound to put the emphasis on the increased understanding it has brought, but if he is interviewed by the press he will always be asked what benefits mankind can expect from it, and if he examines his conscience he may feel that the immediate stimulus to his work is rarely more exalted than the human urge to solve a problem, whether it is the crossword puzzle in *The Times* or the cause of cancer.

Macaulay approved the search for fruit rather than for light, but

fashions change and the Victorians after Macaulay developed very high standards of respectability. The notion that scientific work should be valued for its material benefits, Bacon's vision of a better world, went out of fashion as those benefits began to accumulate, as the age of steam and public health and electricity began to distort the accustomed pattern of life. For Huxley the scientist's creed must be to seek out the truth; if his search brought useful results, so much the better, but he need not go out of his way to look for them. That, or something near it, is still the orthodox view. It is a comfort to the scientists who work in fields remote from practical application, and it must be admitted that some of the practical applications have brought little comfort to humanity. Does this mean that Bacon's *Great Instauration* had an unworthy aim in that it was a plan to dominate the natural world and not to make men more perfect in understanding?

Macaulay says that Common Sense, without cant or illusions, was the secret of Bacon's influence and I think Bacon's common sense is greatly to be praised for insisting that increased control over the natural world was attainable as well as worth attaining. It is to be praised when he insists that the scientist follows a respectable calling: 'that it is an inveterate conceit which is both vainglorious and prejudicial, namely that the dignity of the human mind is lowered by long and frequent intercourse with experiments and particulars which are the objects of sense and confined to matter'. It is not cant to put truth above comfort, but most of us would like both if we could get them and Bacon's plan aimed at both, for he held them to be inseparable. It is not an illusion to believe that there must be research directed solely to increased understanding, but Bacon said that Science must ascend to axioms as it descends to works. Perhaps he did value the new powers and inventions, the works more than the axioms, yet there is at least one considerable branch of science which would find it difficult to blame him for taking that view. That is the science of Medicine.

Bacon has some hard things to say about the medicine of his time. He took no interest in Harvey's experiments on the heart and his own *History of Life and Death* adds little to knowledge, but medical

science has grown up in the last 100 years and its chief aim is to bring health. Many of us who work in that field have no immediate concern with disease and spend our time in trying to gain a better understanding of the living organism. For the 'pure' biologist that target is enough, but for the medical scientist it is a step towards the prevention of disease and the well-being of the human race, the fruit quite as much as the light. We must learn all we can about the structure and life cycle of bacteria and viruses: those that are most favourable subjects for investigation may be completely harmless to man, but we want the information because it may show how to deal with some that are harmful. In fact for one who works in any branch of medical science the ultimate aim is not so much to enlarge knowledge as to relieve suffering. We can have no quarrel at all with Bacon's desire for the fruits of science as well as for the light.

The leading men and women of the Elizabethan age had failings which make their virtues stand out more clearly. We admire them all the more because they were human. Those of the Jacobean age are less attractive. James I and his court kept the kingdom at peace when Europe was working up for warfare on a grand scale, but this did not call for heroic virtues. Bacon and Coke, the two great lawyers of the time, can be admired for their ability, but much of their biographies must be taken up with half-hearted attempts to excuse some of the things they did. Perhaps later generations will judge them more kindly, but nowadays it is difficult to make a hero of either. Bacon was not a bully and when he took bribes he did not allow them to sway his judgment. His public disgrace was all the more humiliating because he had so often extolled the path of virtue, yet had not thought his conduct unworthy of his position.

I have not seen a psychoanalytic interpretation of Bacon's character but it does not need one to suggest that his upbringing may have given him a distaste for enthusiasms of any kind except for learning and made him see the advantages of strong government conducted without much regard for the feelings of the governed. Yet his writings show his sincere concern for the welfare of mankind as well as his understanding of human failings. His great plan for science tried to eliminate the effects of faulty thinking in our progress in dis-

covery, but it was aimed at discoveries about human nature as well as about that of the world we live in. He wrote so well that any paper about Bacon is bound to be full of quotations and I shall end with another. This one is about Moral Progress. It comes from the seventh book of *De Augmentis* and it shows Bacon's passion for tabulating all the factors and avoiding all the preconceived ideas. In fact it is a good illustration of his method and aims:

> Philosophers ought carefully and actively to have inquired of the strength and energy of custom, exercise, habit, education, imitation, emulation, company, friendship, praise, reproof, exhortation, fame, laws, books, studies and the like. For these are the things that rule in morals; these the agents by which the mind is affected and disposed; and the ingredients of which are compounded the medicines to preserve or recover the health of the mind as far as it can be done by human remedies.

There is the outlook of the dispassionate scientist, and it might well stand today on the title page of a modern textbook on social science or a report on juvenile delinquency.