SCIENTIFIC METHOD IN GALILEO AND BACON

I

Galileo (1564–1642) and Bacon (1561–1626) were contemporaries, although Galileo outlived Bacon by sixteen years. It is interesting to note that both were also contemporaries with Shakespeare (1564–1616). It is highly improbable, however, as has sometimes been claimed, that Bacon had anything to do with the writing of Shakespeare's plays. Both Galileo and Bacon strongly opposed the authority of Aristotle in Science. Bacon was especially concerned to combat Aristotle's syllogistic and his rules of inductive enquiry; for Galileo, Aristotelian physics was the main enemy. They were certainly aware of each other's work. On a number of occasions Bacon mentions that of Galileo, especially his astronomical discoveries by means of the telescope, which he acclaims, although he shows himself critical of the latter's theory of tides. On the other hand, Galileo criticises Bacon's theory of tides, but does not explicitly name him.

Bacon published his *Novum Organum* in 1620. He had, however, been working on it from 1608 to 1620. Galileo had by then published a number of works, among which were the astronomical discoveries he had made with the telescope. Some parts of the *Great World Systems*, which was not published until 1626, had already been circulated in unpublished form, and it is possible that Bacon may have seen them. A letter written to Bacon in 1619 from his friend Toby Matthew, then in Brussels, tells him that Richard White, from whom Galileo had heard of Bacon's theory of tides, was returning to England from Florence bringing back copies of Galileo's published and unpublished works.

As is the case with most great men, opinions about Bacon and Galileo have varied considerably over the years. From the 19th century onwards, Bacon's reputation has progressively declined, and it is only in recent years that there has been a revival of interest in his work. On the other hand, Galileo's intellectual stature has constantly increased, and at the fourth centenary of his birth, his reputation stands higher than ever, despite the recent attempt by Koestler in his book *The Sleepwalkers* to devalue Galileo in favour of Kepler.

Both Bacon and Galileo found themselves involved in a judicial process at the close of their lives. One was arraigned before the House of Lords for the taking of bribes, the other before the Inquisition for heresy. The former was a statesman and a lawyer, who was finally disgraced for conniving in the practices of a corrupt government, and who in his spare moments wrote what he could about science and its methods. The latter was a highly original man of science, persecuted by the Church for holding the Copernican view. Throughout his life his work in astronomy and physics was his major preoccupation. Bacon was much more conformist than Galileo in his scientific and religious views. He accepted, for examle, Tycho Brahe's terrocentric system. This was probably due to its being closer to common sense than the helio-centric system of Copernicus. His deficiency in mathematics may also have played a part here. Nevertheless, just because he was not a specialist in any branch of science, he was able to view science in a much more general perspective than could Galileo.

II

The main aim of this paper will be to examine the respective contributions of Galileo and Bacon to scientific method, a field to which they both contributed, Galileo by his own work in astronomy and physics, and Bacon by attempting to analyse and explain the methods and practice of the working scientist. We shall ask (*a*) how far do the methods used by Bacon and Galileo resemble each other, (*b*) in what respects do they differ, and (*c*) on which of these methods did science finally come to model itself ? To answer these questions we shall have to examine more closely their respective approaches to science, and make some comparison between them.

The life of Galileo need not be described in this article; we merely need to note here that Galileo started his scientific career at Pisa at the age of 25, 31 years before the publication of Bacon's *Novum Organum.* Galileo was one of the great advocates of the experimental method. But unlike Bacon, who only recommended us to observe and experiment, Galileo combined experimentation with the need for making accurate measurements. Thus not only did he observe and experiment, but he also measured and counted. In his three most important works, *The Assayer*, the *Great World Systems* and the *Two New Sciences*, Galileo shows how he was thus able to obtain knowledge of the precise mathematical laws regulating phenomena.

The essentials of Galileo's approach to a problem in science would seem to be as follows. By means of intuition we isolate in a specific phenomenon certain elements, usually of a spatio-temporal character, which we then translate into a quantitative form. We next endeavour to discover some mathematical law or formula which will correlate these elements in a systematic manner. Deductions made from this law must always be true of similar instances of the phenomenon, and this can be verified by experiment. By thus introducing what in effect are ideal mathematical laws to correlate the quantitative features of observed events, Galileo was led to experiments which he could not have thought of otherwise.

A corollary of Galileo's view that the laws of nature require to be stated in a mathematical form, was his belief that nature was a simple orderly system, basically mathematical in character. It was mathematics, and especially geometry, which gave us the key to the understanding of the physical universe. From this characteristic of nature there follows the rigorous necessity of to deal with sugar, silk and wool must discount the boxes, bales and other packings, so the mathematical scientist, when he wants to recognise in the concrete the effects he has proved in the abstract must deduct the material hindrances, and if he is able to do so, I assure you that things are in no less agreement than the arithmetical computation "[2].

Two things emerge from Galileo's argument : (1) that nature is fundamentally mathematical, which is why demonstrations made in the abstract apply also in the concrete; (2) that we can obtain an insight into these mathematical relations as a result of refining our sensory experiences by a process of abstraction. If we are to understand Galileo here, we need to note, as Mach points out, that " he was already in possession of instinctive experiences prior to his resorting to experiment. Freely falling bodies are followed with more difficulty by the eye the longer and further they have fallen; their impact on the hand receiving them is in like measure sharper; the sound of their striking harder. The velocity accordingly increases with the time elapsed and the space traversed ". In order that these instinctive experiences may be used for scientific purposes they require to be formulated in mathematical terms. This, Mach goes on, " is effected by isolating and emphasising what is deemed of importance, by neglecting what is subsidiary, by *abstracting*, by idealising ".[3] By this use of mathematical abstraction Galileo was enabled to investigate a phenomenon by specially arranged experiments in which irrelevant conditions were excluded, so that it could be studied in its quantitative relations with other phenomena. For example, when letting balls run down an inclined plane, he was able to vary the degree of inclination of the plane. In this way he verified that there is a constant relationship between the distance fallen through and the time taken.

This method of abstraction and idealisation is, of course, not entirely new. In some ways it was an adaptation of the postulational method of Euclid and Archimedes, but applied rather to the problem of falling bodies. Examples of this process of idealisation may be seen in medieval science, in the ideal balance with weightless arms, the expression of motion in geometrical terms, the use of epicycles and the other devices of Ptolemaic astronomy. A similar process can be observed in Galileo's search for the mathematical laws underlying such phenomena as the acceleration of heavy bodies, the swing of a pendulum, the trajectory of a cannon-ball and the motions of the planets. In his study of such phenomena, Galileo replaced them by ideally simplified bodies, their motion being described in terms of a series of spatial and temporal measurements.[4]

Eddington has rather humorously described this process of idealisation. He tells us that when we read about an elephant whose mass is two tons sliding down a greasy hillside, for the physicist the elephant fades out of the picture and a mass of two tons takes its place. When we go on and read that the slope of the hill is 60°, the hillside too fades away for him and an angle of 60° takes its place. Similarly, the softly yielding turf is replaced by a coefficient of friction. Thus, Eddington concludes, from the point of view of exact science, " the thing that really did descend the hill can only be described as a bundle of pointer readings ".[5]

Galileo's belief that the behaviour of things was entirely the product of their mathematical structure led to his further belief that we can draw valied conclusions from a few experiments, which reach far beyond the immediate situation in which they were performed. He asserts, and this may seem strange to the modern reader, that knowledge of a single fact acquired through knowledge of its causes (i.e. the law or formula of which it is a particular case), enables us to ascertain other facts without the need for further experiment. He illustrates this by means of an example taken from his study of projectiles. Once we know that the path is a parabola, we can demonstrate by pure mathematics without recourse to experiment that the maximum range is 45°. To quote

Galileo's own words, " precisely as in the present case, where by argument alone the Author proves with certainty that the maximum range occurs when the elevation is 45°. He thus demonstrates what perhaps has never been observed in experience, namely, that of other shots those which exceed a full shot of 45° by equal amounts have equal ranges ".[6] From this it will be seen that Galileo undoubtedly believed that we can make genuine physical discoveries by theoretical scientific analyses. Experiment would only seem to be necessary in the case of phenomena into whose rational basis we have no insight, or where we want to convince people who are unconvinced by our rational demonstrations.

IV

Closely allied to this process of the abstraction and simplification of phenomena, is Galileo's use of what might be called ideal or thought experiments. This brings us to a rather peculiar fact about Galileo. Although he is generally recognised as being one of the founders of the experimental method, many of the experiments referred to by Galileo seem only to have been performed mentally or merely stated by him as possibilities. Thus he often brings in mental experiments, or experiments are only described without being performed. Verification by experiment appears at times to be only of secondary importance. Even when he does experiment, he may say, " I made an experiment about it but natural reason had very firmly convinced me in advance that the phenomenon was bound to take place as it actually did ".[7] In the *Great World Systems*, for example, Salviati criticises Simplicius for repeating the statements of others that the stone will not come down at the foot of the mast, without observing if this is really the case. But when Salviati is asked whether he has himself verified that the stone will come down at the foot of the mast, he replies that this is unnecessary, as he can reason out what will happen well enough.[8] It was not, however, until 1640 that this fact was experimentally verified by Gassendi.[9]

In order to discover a law of nature, Galileo did not seem to have started as Bacon might by first performing a large number of experiments, and then allowing the law inherent in the experimental results to crystallise out, as it were. He rather used experiment to verify a relation that he had deduced mathematically from more or less self-evident suppositions. For example, starting from the fact that the phenomenon of fall is accelerated, Galileo proceeds to define in mathematical terms the general features of this change of motion, and then attempts to verify this resultant law experimentally.[10] Galileo conceived the function of experiment to be a specific one; not the discovery of new hypotheses, but the elimination of false hypotheses and the verification of the true one. If the hypothesis was verified he took it as a necessary fact, if not he tried again until he found one which could be verified. Galileo seems to have thought that science advanced through a series of alternatives, each decided by an appeal to a crucial experiment. The whole purpose of this experimental procedure, then, is to show conclusively by the elimination of all alternatives that a given theory is true.

We must be careful, however, not to over-estimate the part played by formal demonstration or thought experiments in Galileo's work. The tendency to do this is increased by the fact that Galileo's writings are couched in the classical style of formal argument and proof. He also rarely gives details of the experimental procedures he employs. The reader can therefore easily get the impression that he did not bother to test experimentally many of his deductions. Against this must be offset the fact that from an early date Galileo was an assiduous experimenter, constructing his own apparatus and obtaining accurate results. He may therefore probably have tested personally many of the experimental facts he writes about.

Galileo's position as far as method was concerned may have been similar to that of Archimedes, who at one time was thought to have made his discoveries in mechanics purely by mathematical demonstrations. However, when at the beginning of this century Archimedes' work on *Method* was discovered, this showed that he had actually employed experimental procedures for the solution of mechanical problems. The axiomatic presentation of his results was largely a concession to the conventions of the period which looked with disdain on physical manipulations. Could anything like this have been true of Galileo ? Was the formal manner in which he presented his data merely a *facon de parler*, and not the way he actually made his discoveries ?[11]

Summing up the contribution of Galileo to scientific method, it is worth noting that (1) he introduced the hypothetico-deductive method into science; (2) reason and imagination play for him an important part in the elaboration of hypotheses, which are grounded in certain self-evident intuitions about physical nature; (3) since it is assumed that the structure of nature is a mathematical one, starting from these intuitions reason can arrive at the laws of nature, which have an a priori character but whose truth may be checked by experiment; (4) experiment is, as it were, the touchstone by which we select relevant from irrelevant hypotheses and is used for testing rather than discovering hypotheses; (5) mental experiments play a part at least equal in importance to actual experiments. In all this, as we shall see, Galileo's method differs radically from that of Bacon, which tends to relegate the part played by hypothesis and conjecture to the background, substituting for the process of individual discovery a quasi-mechanical method.

V

If we wish to place Francis Bacon, Lord Verulum, in his historical perspective, a few words about his life and times are necessary. His father had been Lord Keeper of the Great Seal under Queen Elizabeth I. At the age of 12 he went to Trinity College, Cambridge. When he left at the age of 15, he proceeded to study law at Gray's Inn and thereafter also spent some time in France. At 24 he became a Member of Parliament, and a year later published his first philosophical essay. This was followed by a long series of works among which were the *Novum Organum* and the *Advancement of Learning*. He played an important part in public life during the reigns of Queen Elizabeth and James I. Unfortunately, his public career was brought to an abrupt end when he was found guilty of accepting bribes in the course of his duties as Lord Chancellor of England. Nevertheless, in spite of the burden of his official duties, Bacon found time to continue with his writings on science, in which he (*a*) advocated a new method of scientific enquiry and (*b*) preached the need for improving the material condition of man.

Opinion as to the value of Bacon's work has been sharply divided. To quote two 19th century British scientists who held opposing views about him. Sir David Brewster, for example, said, "If Bacon had never lived, those who study nature would have found in the writings and works of Galileo, not only the much vaunted principles of the inductive philosophy, but also their practical application to the highest achievements of invention and discovery".[12] On the other hand, there is the mathematician John Playfair's evaluation, "More substitutes might be found for Galileo than for Bacon....but the history of human knowledge points out nobody of whom it can be said that, placed in the situation of Bacon, he would have done what Bacon did; no man whose prophetic genius would have enabled him to delineate a system of science which had not yet begun to exist!"[13]

Both these judgements are certainly exaggerated. Without Galileo and Bacon science might have taken longer to advance, but advance it certainly would have done. As far as Bacon is concerned, there is no doubt that his doctrines influenced the Royal Society's programme of research during its early years. And for many years on the Continent, especially in France, his reputation stood very high. However, in the last century both his work and personal life were subjected to severe criticism, among contemporaries. Bacon was impressed by the effects produced on the culture of his day by a few inventions, particularly printing, gunpowder and the magnet. " For these ", he says, " have changed the whole face and state of things throughout the world; the first in literature, the second in warfare, the third in navigation; whence have followed innumerable changes; insomuch that no empire, no sect, no star seems to have exerted greater power and influence in human affairs than these mechanical inventions ".[18] Bacon emphasised the need for organised co-operative research in science, as opposed to the individual research which had been the rule up till then. His description of the duties of the workers in Solomon's House, the scientific utopia described by him in his *New Atlantis*, where the scientific investigations are carried out by a group of research workers graded hierarchically in accordance with the tasks they perform, certainly anticipates modern team-work in science. Bacon also did not restrict the use of the scientific method to natural science; he wished to apply it to a variety of disciplines, which included law, politics and even theology.

In the 17th century in England and later in France, the Baconian method became synonymous with the study of nature by observation and experiment. It should be noted, however, that Bacon used the word experiment in a wider sense than we use it today. He used it to cover every purposive interference with nature. Thus not only did it cover strictly scientific procedures, but also the arts and crafts associated with industry and agriculture. The foundation of the Royal Society owed a great deal to the influence of Bacon's writings, and its early members were certainly stimulated by some of his ideas. In common with him, they avoided hasty generalisation, they rejected authority, and they emphasised the need for collecting natural histories, i.e. for making a complete inventory of the data relevant to any specific subject-matter. However, they had a much better understanding of mathematics, and they also employed experiment to better advantage. As might be expected from their mathematical interests, the method they subsequently came to use in their enquiries was largely that of Galileo. Although curiously enough it become identified with that of Bacon, both within and outside the Royal Society.

As we have seen in Galileo's method,[19] intuition and imagination play a key role in the formulation of the law under which the empirically determined series of measurements are subsumed. On such a view, scientific discovery is akin to artistic creation, and different scientists have given very different accounts of how they actually made their discoveries. For example, in reading how Kepler came to discover that the orbit of Mars was an ellipse, we get the impression that the solution came to him in something like a moment of mystical illumination.

Bacon's approach is a very different one. He is looking for a method which will make it possible for all men to make discoveries in the same way as the great innovators of science have done. He believes that when the faculties of men are provided with an adequate intellectual instrument, it will become as easy for the weakest of human intelligences to obtain real knowledge as the acutest minds, just as it is for the most unskilled hand to trace true circle with a compass. In this way the differnces in intelligence among human beings will become levelled out. The discovery of laws in nature would then be transferred from the work of individual intuition and imagination to a definite conscious procedure in which every step would be clearly stated. This procedure, he believes, might to some extent be mechanised. As he puts it, " the mind itself be from the outset not left to take its own course, but guided at every step, and the business be done as if by machinery ".[20]

The logical development of such an approach would be a machine capable of discovering the laws governing natural phenomena. Though we are still a very long way off from such a device, nevertheless in the ordering of scientific data by means of statistical procedures, etc., we have introduced powerful auxilliary aids for facilitating the process of scientific discovery. Further, today computing machines are being programmed to take over a good number of repetitive tasks in idustry and commerce, and this process will no doubt be accelerated. We have also our programme to enable computers to play chess and even, it is claimed, to compose music and write poetry of a sort. If this is really the case, mechanisation would seem to be making inroads into what at one time was taken to be the porper province of thought and imagination. If an inductive machine could be developed it might, Crowther believes, take over the business of discovery and research. In this way, he goes on, we may be able to convert " the discovery of new facts and theories from a process of individual inspiration and craftsmanship into one of mass-production of discoveries by machines, along industrial lines ".[21] What Crowther does overlook is, that even if this Wellsian nightmare became true, it still might be more economical to employ teams of human scientists co-operating together in the manner outlined by Bacon.

The divergence between the Baconian and the Galilean methods, as we have already noted, shows itself in present day controversies in the philosophy of science as to whether science makes use of the inductive or hypothetico-deductive method in its investigations. Though Bacon was critical of the use of hypothesis in science, we must not forget that so was Newton. His remark that " hypotheses have no place in experimental philosophy " is well known. It has, of course, been frequently argued that Newton nevertheless did use and was indeed the chief exponent of the hypothetico-deductive method. Even if this was the case, it is unlikely that Newton arrived at his hypotheses purely intuitively, as Galileo might have done. Unlike Galileo, he did not regard the laws of nature as *a priori*. His knowledge of them was largely obtained from the experiments he actually performed. As he himself says, " I began the foregoing experiments to investigate the resistances of fluids, before I was acquainted with the theory laid down in the propositions immediately preceding ".[22] Of course this does not mean that Bacon or Newton did not make use of some kind of hypothesis in their work. They both believed in the importance of experiment, and we cannot have experiment without some sore of guidance as regards the direction it is to proceed.

Further, it is argued that Bacon's statement that his method would equalise men's ability to attain truth is plainly false, and will remain so as long as individual differences exist. Whewell, for example, believed that an art of discovery was not possible, and that we can give no rules for the pursuit of truth which should be uniformly applicable. It is just here, it is argued, that rules and methods are of no avail and where the individual insight of the experimenter is all-important. It is he who dicides which rules and methods to employ. Nevertheless, Bacon did recognise that, other things being equal, the growth of science depended on superior minds. In his Solomon's House, which formed the model for the Royal Society, he allows a place for a few men of high distinction to carry out the co-ordination of effort occasioned by the scientific division of labour.

Another major difference between Bacon and Galileo is the stress Bacon puts on intellectual co-operation or team-work in science. Although Bacon's suggestions as to the need for the division of labour in scientific research and the specialisation it involves, may have seemed somewhat odd in the early 17th century yet there is little doubt that in recent years systematically planned research has proved to be extremely rewarding. New discoveries of vital importance have been made as a result of scientific team-work. Science has also been applied to industry. Good examples of this are to be found in the chemical and electronic industries, in which the individual discoveries of the chemist and physicist have been put to an important industrial use. In these fields Bacon's dream that science will become harnessed to industry for the improvement of the condition of man has some chance of coming true.

VII

Some account should be given of the actual method Bacon suggests we should use in our approach to nature. As a preliminary he develops his doctrine of *idols* or false ideas which stand in the way of our attaining true knowledge. He finds four types of such ideas : (1) those that have their origin in human nature itself, i.e., in the limitations of perception and intelligence; (2) mistaken ideas arising from our personal character and education; (3) the way words may trick us by their ambiguity, emotional content, etc.; and (4) how ideas derived from different philosophies (*weltanschuung*) may bias our thinking. In all this there is some resemblance to the Cartesian method of doubt. It is only by laying aside " received opinions and notions " and making, as it were, a new start that we will be able to make a proper use of his new instrument.

Bacon's method[23] proceeds by listing the experimental observations relevant to a specific enquiry into three tables : (1) a table containing all the known instances in which the simple phenomenon whose cause we are trying to discover is present, for example, the phenomenon of heat; (2) a table containing instances corresponding to those in (1), except that the phenomenon is absent; and (3) a table containing instances in which the phenomenon is present in varying degrees.[24] Now in order to find the cause of heat we have to discover another phenomenon which always occurs with it, is always absent when it is absent and always increases or decreases with it. This we do by examining all the possible alternatives listed in these tables, excluding all except the one which proves adequate. This is the cause we are in search of. If we could carry out this process of exclusion thoroughly, we would arrive at the cause of heat, which Bacon hazards a guess is a form of motion.

As it is usually not possible to carry out a complete survey of all the instances of any phenomenon, this renders Bacon's process of exclusion inconclusive. Further, the elements in Bacon's tables are never clearly defined in quantitative terms. They merely enable us to establish certain vague correspondences between phenomena. Although they may show that certain natural phenomena are functions of others, they do not reveal the precise form these functions take on, as these correspondences are not expressed in terms of some mathematical law, but merely in vague qualitative terms. Bacon also believed that his method could give certain conclusions. In this he was undoubtedly mistaken, as the results of inductive reasoning can never be more than probable.

A basic assumption underlying Bacon's method is that nature consisted of a small number of natural kinds out of which its rich complexity was constructed. He compared this with an alphabet, and suggested that the only way we can learn to understand nature is by learning its alphabet. Galileo had asserted that the book of nature is written in the mathematical language, the letters of which are triangles, circles and other geometrical figures. Bacon seems to have approached this queation from a rather different direction, that of codes and ciphers. He had developed fairly early in his career a biliteral cipher by means of which all the letters of the alphabet could be resolved into permutations of the two letters *a* and *b*. He clearly saw that any one difference can be made a ground of a code of signals; he thus used what in effect is a binary code. It is interesting to note that modern information theory, which is based on a similar code, has been applied to genetics to explain how the biological organism can be built up from a few simple elements in the D.N.A. molecule.

Bacon tells us that since particular concrete things are infinite and transitory, we need to search for the abstract natures which determine what properties a concrete thing will have, and which are few and permanent. " That these natures are like the alphabet or simple letters, whereof the variety of things consisteth; or as the colours mingled in the painter's shell, wherewith he is able to make infinite variety of faces and shapes ".[25]

Curiously enough, Galileo outlines a somewhat similar view. If we take, he says, the alphabet itself, we may gather out of it a most perfect system. " For there is no doubt but that he who knows how to couple and correctly dispose this and that vowel with the right consonants may gather thence the infallible answers to all doubts and deduce from them the principles of all sciences and arts. In the same manner the painter, from many simple colours laid individually upon his palette proceeds, by mixing a little of this and a little of that with a little of the third, to represent life-like men, planets, buildings, birds, fishes ".[26] It will be seen that this passage and the one quoted above from Bacon have a remarkable similarity. There is, of course, the possibility that the ideas expressed in both cases were fairly commonly held at that period. But in view of the somewhat satirical context in which Galileo's remarks occur, there is some possibility that he may have had Bacon in mind here.

To sum up, Galileo and Bacon wished to break away from the old Aristotelian modes of thought, and to put science on a new basis in which the part played by observation and experiment was to be emphasised at the expense of an appeal to authority and syllogistic reasoning. The method of Galileo, as we have seen, comes to much the same thing as the hypothetico-deductive method employed in physical science. It differs from Bacon's view, since he believes that the function of experiment is simply to test theories rather than to help to discover them. He also believes that once such an hypothesis has been verified, it must hold with certainty. In this he is at one with Bacon who also believes that his method of exclusions can give certainty. On the other hand, Galileo did not seem to pay much attention to co-operative scientific activity; science for him was largely an individual affair. Since Bacon looked largely for qualitative correspondences his method was, within its limits, probably of greater applicability to such fields of enquiry as biology and sociology than to the physical sciences. Indeed, J. S. Mill, who adapted Bacon's methods believed that they could form a basis for the social sciences.

As we have seen Bacon, unlike Galileo, was essentially interested in making clear the methods used by the scientist, and finding out what was or was not essential to them. He also believed that his own method could revolutionise the process of scientific discovery by formalising it. However, the fact that Bacon was largely unsuccessful in his enterprise must not make us overlook that this is a field still worthy of some investigation. The division of labour in science has already gone some way in making the process of scientific discovery a product of group rather than individual activity. We cannot rule out that at some future date certain of these procedures may be taken over by mechanical devices, or by some combination of man-machine.

Dijksterhuis has pointed out that we can only ignore Bacon's work at our peril, and that even if we enlarge on his defects his inspiring influence is not destroyed by this. As he puts it, " The Athenians when obliged to support Sparta in war, instead of soldiers sent the lame poet Tyrtaeus. His fighting value was nil, but with his war-songs he inspired the Spartans so greatly that they were victorious. Bacon was—to speak in his own style—the Tyrtaeus of seventeenth century science. Without personally enriching it with concrete discoveries, he inspired numerous others to further it ".[27]

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NOTES

1. *Two Great Systems.* Third Day.
2. *Two Great Systems.* Second Day.
3. Ernst Mach, *The Science of Mechanics* (English Translation), p. 161.
4. Thus in dynamics a moving body is conceived as a quantity of matter concetrated at its centre of gravity – traversing a given space at a given time.
5. Eddington, *The Nature of the Physical World,* pp. 251–2.
6. *Two New Sciences.* Third Day.
7. Letter to Ingoli.
8. *Great World System.* Second Day.
9. Cf. Dijksterhuis, *Mechanization of the World Picture*, p. 353.
10. For example, in Galileo's derivation of his law of squares he found it confirmed during repeated experiments with a groove in an inclined plane along which a ball rolled down. In this particular case the experimental verification consists of a series of measurements, showing the concomitant variations in space travelled and time passed.
11. Dijksterhuis, *ibid.* p. 340, argues against such a view. He refers to some rough notes of Galileo in which he attempted to derive his law of squares. In this, he tells us, Galileo "has to resort to the most tortuous logical devices in order to deduce from an untenable premise a correct result ... And finally, when certain statements in his letters are taken into account as well, it proves the complete baselessness of the belief tenaciously maintained by supporters of the Galileo-myth, namely that he discovered the law of squares by performing with a falling body a number of measurements of distance and time, and noting in these values the constant ratio between the distance and the square of the time".
12. Sir David Brewster, *Martyrs of Science*, p. 93.
13. Quoted from *Francis Bacon*, by J. G. Crowther, p. v.
14. Harvey, the discoverer of the circulation of the blood, who was also Bacon's physician, is reputed to have said that Bacon wrote about science as a Lord Chancellor. In his *Francis Bacon* (p. 11), J. G. Crowther considers this to be a merit. He wrote, he says, as "an experienced and responsible statesman, and not as a clever specialist skilful in solving particular technical problems". We have today many skilled scientists but few statesmen who can administer science as an integral part of modern life.
15. Jevons, for example. referred to Bacon's notion of scientific method as a form of scientific bookkeeping. In recent times Bacon's method of induction has been severely criticised by Popper, who comes out in favour of the hypothetico-deductive method.

16. Two recent books emphasising this aspect of Bacon's work are : *Francis Bacon : Philosopher of Industrial Science*, by Benjamin Farrington, 1951; *Francis Bacon : The First Statesman of Science*, by J. G. Crowther, 1960.
17. *Lord Bacon*, p. 169.
18. *Novum Organum*, p. 129.
19. Cf. Crowther, *Ibid.*, pp. 5–8, on the difference between Bacon's and Galileo's methods.
20. *Novum Organum*. Preface.
21. *Ibid*, p. 9.
22. *Principia Mathematica*. Book 2, Sec. 7. Scholium. Exp. 4.
23. In his method Bacon emphasises what was later called by J. S. Mill the principles of agreement, difference and concomitant variations as instruments of empirical analysis. Although these methods were being used by the scientists of his day, among whom Galileo must be counted, and had for that matter been implicitly used at all times by ordinary men, it was Bacon who first clearly formulated them. What he did was to show the important part played by analogies of different sorts in the inferences of science and daily life.
24. Galileo in *Two Great Systems*, Second Day, puts forward the method of concomitant variations as follows. " Thus I say that if it is true that one effect can only have one basic cause, and if between the cause and the effect there is a fixed and constant connection, then whenever a fixed and constant variation is seen, there must be a fixed and constant variation in the cause. "
25 *Valerius Terminus*, Cap. 13.
26. *Great World Systems*. Second Day.
27. *Ibid.*, p. 402.