writings where he asks: "If all places to which we have access are filled with living creatures why should all these immense spaces of the heavens above the clouds be incapable of inhabitants?" Reticent though such a sentence is, it was Newton who finally forced the educated world of men to recognise the meanness of man's domicile. The earth had been the centre of the universe: Newton revealed it as a humble satellite of the sun. It needed but recognition of the fact that our sun is but one of millions of stars and man's outlook was transformed. Are there no other stars in the galactic universe which have satellites? We cannot believe it. Are those satellites devoid of life? It is incredible. Has life always taken the same evolutionary course as that which has led to the creation of man upon this earth? Has such evolution never progressed beyond the stage at which man now finds himself? Each question we are practically forced to answer in the negative; and, when we give such answers, what is man in the great scheme of things? Though Newton has been dead two centuries, it is only in our own day that his countrymen, in the mass, are asking the questions to which his discoveries inevitably led.

On the fine statue by Roubiliac which takes the place of honour in the ante-Chapel of Trinity, there is inscribed the line

Qui genus humanum ingenio superavit,

"who in genius surpassed the whole world." It is the tribute of Lucretius to Epicurus, and a greater than Epicurus merits the praise. Wordsworth saw that statue, an inspiration to many an undergraduate before and since his day; and wrote the lines:

The marble index of a mind for ever
Voyaging through strange seas of Thought, alone.

But through stranger seas than Newton ventured has he set men voyaging alone. What is our destiny, as individuals and as a race? Made of dust and water, specks on a small globe, apparently of no special importance in the vast range of creation, we live for but a tick of the astronomer's clock. Light reaches us to-day which began its journey before humanity had appeared upon this earth. Are we, then, of any importance in God's sight? Have we, as individuals or as a race, any permanence? Are we, after all, such stuff as dreams are made of? I give the old answer: "the things which are seen are temporal, the things which are not seen are eternal." The body returns to dust and water; but the mind, which ranges through space and time with a freedom that partakes of the divine, shall not perish. The spirit of a man who strives for truth and seeks goodness belongs to the realm of the eternal.

Here it is fashioned by labour, by self-discipline, by reverence and love. Elsewhere in its perfection it shall have a richer existence. Does it matter that we are little more than point-instants in space-time? I think not; for eternal values are not measured by rods and clocks, nor are they to be found in the blind forces of Nature. "Not by might nor by power but by my spirit, saith the Lord;" and Newton with his simple piety would have accepted the Hebrew prophet's words. As the spirit of man is transformed by the spirit of the Lord, as righteousness and truth fit him to serve God and think His thoughts, he becomes a Son of God and an inheritor of the Kingdom of Heaven.

Newton's Place in Science.

By F. S. MARVIN.

TWO men in science have attained a world-wide position and stamped their names on periods marked by the triumph of their theories: and only two. Both were Englishmen, and Newton's position is even clearer and less disputed than Darwin's. Descartes left behind him a Cartesian school and a Cartesian philosophy, but he is not remembered as one of the most eminent men of science. Archimedes and Galileo, the two names one might put beside Newton's as men of science, did not produce a striking, conclusive, and all-embracing theory, such as that which made Newton famous and founded a 'Newtonian' synthesis to last without question or modification for two hundred years.

Though Newton's position is thus unique, it must

be studied in connexion with that of others and in its right place in the history of thought. For science being the central thread in the history of mankind, great men of science can less than any other type be isolated and treated as individual phenomena. A Michelangelo, a Shakespeare or a Beethoven, even an Alexander or a Napoleon, may be more legitimately thus isolated and wondered at, but never a man of science; and Newton, like the rest, brought to fruition the labours of others and was himself surrounded by many men close in pursuit of the same truth, dimly perceived, but by him to be clearly articulated and established. This was his special quality as a thinker and a man of science. He was a mathematician, primarily a

geometrical mathematician, and he applied a mathematical mind of the most powerful order to the elucidation of problems which were being approached at that time on lines of somewhat vague and quasi-philosophical speculation.

Newton's relation to Descartes is typical. He studied him eagerly as a young man, and was more

influenced by him and by Wallis's "*Arithmetica Infinitorum*" than by any other writers. But his reaction was always critical. Descartes, besides his "*Géométrie*" published in 1637, elaborated, in his "*Principia*" of 1644, a physical theory of the universe which stimulated strongly the growing tendency of thought to explain all celestial phenomena by the same mechanical laws which, thanks to Galileo's experiments, had been shown to hold good for phenomena on earth. Des-

cartes therefore must rank as a co-founder, but his work was vitiated by 'metaphysical' reasoning—that is, the assumption that certain results must, by the 'nature of things,' be what investigation had never proved them to be, or had actually proved them not to be. Such were Descartes's assumptions of a number of vortices in the centres of which the sun and planets were swept round, the secondary whirlpools in which the planets moved causing variations of density in the major whirlpool of the sun, and hence deflecting them from their natural

circles into ellipses. Newton confronted these imaginary conclusions with the facts observed and the laws deduced from them by Kepler and Galileo, and showed their inconsistency. This appears in the second book of Newton's "*Principia*," published in 1687 but written long before. He was of the lineage of Archimedes and Hipparchus, and not of

Aristotle, and his coincidence with Galileo's work on bodies falling to the earth is the true link in the formation of the first and most powerful of all physical syntheses.

Kepler had established his three laws of planetary motion by 1619, but he had been unable to connect them with the law of falling bodies on the earth. His notion of gravity was the quite vague one of the mutual tendency of similar bodies to unite, and in the introduction to his work on Mars he actually committed him-

self to the mistaken idea that "if the earth and moon were not kept at their respective distances they would fall one on the other, and, supposing them of the same density, the moon would pass through $\frac{5}{4}$ of the distance, the earth through the remaining part."

Then came Galileo's work at Pisa and Padua, of which the full account was published in the "*Dialogues on the Two Sciences of Mechanics and Motion*" in 1638, though the capital conclusions had been reached some years before. It was in

FIG. 3.—Portrait by Vanderbank, 1726, in the meeting-room of the Royal Society, over the president's chair, and given by Mr. C. B. Vignoles in 1841 to the Society.

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bringing together and proving the identity of Kepler's and Galileo's laws that Newton's genius shone forth. To guess that there was a connexion was easy and almost inevitable for any one who brought the two sets of facts together; to show it accurately and irrefutably was Newton's greatest work. It happened sometime between 1665 and 1679, but the solution was not passed on to others until the autumn of 1684. In the August of that year Halley, who, with several others, had been puzzling at the problem, went to Cambridge to consult Newton about it. Hooke, Huyghens, and Wren, as well as himself, were, he said, all working on the theory that the force of the attraction of the sun or earth on an external particle varied inversely as the square of the distance, but they could not from that law deduce the orbits of the planets. Could Newton find out what the orbit of a planet would be, if the attraction were as the inverse square of the distance? Newton replied that it was an ellipse and that he had worked it out in 1679. He promised to recover it from his notes or his memory and sent it in to Halley in November. On receiving it Halley went again to Cambridge and at this second visit set up those relations between himself and Newton which enabled him to extract the "*Principia*" from its reluctant author. Halley's was the persuasion and Halley's the financial guarantee. Under this stimulus the first book of the "*Principia*" was finished by the summer of 1685 and presented to the Royal Society on April 28, 1686. The second book was also completed in the summer of 1686 and deals with hydrostatics and hydrodynamics—motion in a resisting medium—and gives the criticism of the Cartesian theory of vortices to which allusion was made above.

It is interesting to note the similarities in the genesis of Newton's other most famous achievement—the infinitesimal calculus—which he knew as the 'method of fluxions.' Here again many minds were at work, and they were working on an ancient problem to which the Greeks had made a geometrical approach and Descartes had brought much nearer by his approximation of algebra and geometry. Of Newton's contemporaries, several, including especially Fermat, Wallis, and Barrow, had foreshadowed a calculus, by which infinitesimal quantities might be summed and infinitesimal differences in varying quantities measured. Newton's greatness was shown by welding together from the various indications he received from others a sound and practical method which he used for his own purposes so early as 1666, but did not

publish until 1693. In its reception he had not the same good fortune as with the law of gravitation, for there was no Halley to steer his ship into port. On the contrary, thanks to his long delay in publication and to the fact that some of his unprinted papers came into the hands of Leibniz in 1676, there was always a doubt as to the priority and independence of Leibniz' method, which was actually printed in 1684. No one need reopen the question now, though it was disputed long and bitterly in the last years of Newton's life. Of Newton's own originality—in the only sense in which a man can in such a matter be original—there is no question; he invented for himself a 'method of fluxions' with his own notation, and it is also unquestioned that Leibniz' method of notation was the more convenient and gained general acceptance. In fact, England, remaining more Newtonian than Newton, was left in the rear-guard of mathematics for more than a hundred years. We may well believe, however, that two great men came by rather different paths to similar, but not identical, conclusions, on a practical question, small in form but big with consequences, on which the ablest mathematical brains of the seventeenth century had been all converging.

It is not within the scope of this article to deal with the modifications in the Newtonian system as a whole which speculations in our own days have introduced; it must suffice to point out the magnitude of the results Newton achieved, and one or two general qualities in his way of thinking, partly characteristic of his time, partly peculiar to himself. These have much to do, first with the enormous success and dominance of the system for more than two centuries, and then with the reaction.

The seventeenth century was the flowering age of mathematics, as the eighteenth was of chemistry and the nineteenth of biology, and the last four decades of the seventeenth saw more forward steps taken than any other period in history. The fact that these developments of mathematics were in the direction of physics, and had so large an effect in the world of practice, was due to Newton's mechanical bent. He had been as a boy fond of making mechanical models, and it was not until later that he took up mathematics theoretically. Euclid was an interesting novelty to him when he went to Cambridge at the age of eighteen, and by that time he could see the truth of the propositions intuitively and went on to Descartes for further light. The great work of those closing decades of the century was predominantly that of Newton, and it included, beside the two fundamental discoveries which we

this Newton also often plunged, and it is the strongest testimony to the solidarity of his mind that he never allowed such speculations to deflect in the smallest degree the correctness of his reasoning. Being dissatisfied with the attraction of bodies at a distance, as the final explanation of gravity, he assumed in his own mind the existence of a 'spiritus' or active principle which "penetrates to the very centres of the sun and planets without suffering the least diminution of its forces. . . . For,

It is well that these thoughts should be revived and borne in mind, not in any sense as a derogation from the strictly scientific nature of Newton's work, but as pointing three important morals in the general history of thought, as well as the position of Newton in modern science. First, that every thinker is the child of his times and cannot be dissociated from them or understood without them. Newton's philosophy, including therein its science, fits in perfectly with the theology of "Paradise Lost," which was published in 1667, the year after Newton's own *annus mirabilis* of gravitation and calculus. Secondly, that it is quite possible to combine in the same brain the most rigidly positive

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doctrines about certain aspects of phenomena with highly speculative and undefinable theories about others. Newton is the noblest example of the mind which can shut the door of its laboratory, and leave instruments and notes of research intact, while it proceeds in its oratory to speculate about the unknown and write numerous works on divinity and prophecy. Thirdly, that this absolute and undescribable sphere of Newton's thought, while it does not affect the validity of his conclusions so far as they go, made it certain that revision would come in the fullness of time. That revision began

¹ A.J. SNOW, "Matter and Gravity in Newton's Physical Philosophy" (Oxford, 1926).¹

soon after the bi-centenary, not of his death, but of the completion of his capital works. It has not impaired their greatness, but, completing and putting them in their true setting, it has enhanced their glory and shown their author not as an isolated and immutable genius but as a mighty branch of an ever-growing tree.

One strange paradox and error has come with the whirl of time. The name of the most deeply

religious and theological of all great men of science is now often held to describe a purely mechanical, materialistic, and unspiritual hypothesis of the universe. By eliminating the unknown, and attaching the hypothetical forces to matter itself, the system could be turned in this direction. But it is an undeserved and unexpected fate for the author of "The History of the Creation."

Isaac Newton ¹

By J. H. JEANS, Sec. R.S.

WE are met to do homage to the memory of one who was certainly the greatest man of science, and perhaps the greatest intellect, that the human race has seen. We can claim this position for him without arrogance; it is not only accorded him by his own countrymen and co-workers in science, but also by those most capable of forming an unbiassed judgment. Laplace considered that the "Principia" had assured to it for all time "a pre-eminence above all other productions of the human intellect." Lagrange used similar terms, describing it as "the greatest production of the human mind," and confessing himself dazed at such an illustration of what man's intellect could achieve. He added that Newton was not only the greatest genius that had ever existed, but also the most fortunate, for as there is but one universe it can but happen to one man in the world's history to be the interpreter of its laws. Voltaire wrote of him that "if all the geniuses of the universe were assembled, he should lead the band."

As British men of science we may rejoice that this greatest of all men of science was British. We may feel the satisfaction of the French soldier when he thinks of Napoleon, or of the Italian sculptor when he thinks of Michelangelo, the satisfaction of knowing that the greatest man in our own calling was our own countryman. But we may experience also a wider satisfaction. In the words of his monument in Westminster Abbey, "*Sibi gratulentur mortales tale tantumque extitisse humani generis decus*," we may rejoice that there has appeared so great a glory to the human race.

This afternoon we are to make a pilgrimage to the house which is doubly distinguished as being the birthplace both of the man and of his greatest achievements. This morning we are met in the school in which he acquired the rudiments of

knowledge to contemplate the vast extensions that knowledge received at his hands. But before turning to his life's work, let us glance for a moment at his life.

We see him first as a child of delicate health, having indeed been so feeble and undersized at birth that it was scarcely hoped that he could live. At the age of eleven he is sent to school here. He is, on his own admission, far from industrious, and does not in any way distinguish himself at first. But one day, being maltreated by a senior boy, he decides to fight, and wins. This awakens a spirit of emulation; henceforth he applies himself to his studies with a new zest, speedily outstripping his enemy, and in time reaching the top of the school.

We may speculate as to what would have been the effect on the course of his life, and on the history of science, had it not happened that a big boy lost his temper nearly three centuries ago and kicked a small boy, perhaps in this very room. For myself I imagine it would have all been much the same. Whatever he may have done, or not done, in lesson time at school, he spent his leisure time in scientific and mechanical occupations, in making model windmills and water-clocks, or in estimating the force of the wind by the ingenious method of measuring how much farther he could jump with it than against it; he found less pleasure in flying his kite than in experimenting as to the best length of tail and the best point at which to attach the string. When he was taken from school at the age of fourteen to help on the family farm at Woolsthorpe, his mind refused to be tied down to the dull routine of crops and herds, and turned, as though to its natural element, to problems of mathematics and mechanics. When he was driven from Cambridge to Woolsthorpe by the plague, he sat in the garden and "fell into a speculation on the power of gravity"; he "began to think of gravity extending to the orb of the moon," with results which are familiar to all the world.

¹ Opening address delivered on March 19, in the Old School, King's School, Grantham, at the commemoration of the two-hundredth anniversary of the death of Sir Isaac Newton.