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.

The most outstanding feature of his personality was, I suppose, the intense sincerity of his search for truth. Like all single-minded investigators of Nature, he was continually overwhelmed at the thought of the comparative smallness of his achievement. In the light of all that is known as to the transparent honesty and unaffected simplicity of his character, his oft-quoted comparison of himself to "a boy playing on the seashore, whilst the great ocean of truth lay all undiscovered before me," must be regarded as a perfectly sincere statement of how his great triumphs appeared to him. This modest simplicity, combining with an over-sensitive and profoundly moral nature, produced two outstanding results in his scientific life. In the first place, he suffered fools far too gladly, and spent more than enough time and energy explaining his scientific position to critics who had neither the knowledge nor the capacity to understand. In the second place, he was over-sensitive to criticism, and perhaps over-ready to discover insincerity, unfairness, or intellectual dishonesty in his opponents. He had such an abhorrence of these qualities that the bare suspicion of them infuriated him, so that at times he showed neither chivalry nor common courtesy in controversy.

There has been much discussion as to what must be deemed to be the outstanding qualities of Newton's intellect and genius. First and foremost must of course be placed his stupendous mental grasp and breadth, his capacity for seeing all aspects of a question and so making unerringly the right choice between alternatives which would have seemed equally probable to a less powerful mind. With his accustomed modesty, which seems to have amounted almost to ignorance that his talents were in any way exceptional, he declared that "if he had done the world any service, it was due to nothing but industry and patient thought." So it may have seemed to him, but obviously his genius must have been something more than an infinite capacity for taking pains; this could neither explain the gigantic amount of his scientific output nor the terrific speed with which his results appeared. We must surely add, in extreme measure, the much rarer capacity for not taking pains, or wasting time, over lines of thought that lead nowhere, the capacity of choosing the right course by a clear vision emanating from sound knowledge. In this quality, which is often described by the superficial terms of 'sagacity' or 'ingenuity,' he was supreme: this is the aspect of him which is commemorated on his statue in

Trinity Chapel: "Newton. qui genus humanum ingenio superavit."

Apart from this, his amazing success must, I think, be attributed largely to the 'all-roundness' of his mental equipment. This exhibited no *lacunae*, his mind working with equal ease and certainty over the whole range from mathematical abstractions to mechanical details. Biot puts it only slightly differently when he says, "Comme géomètre et comme expérimentateur Newton est sans égal; par la réunion de ces deux genres de génies à leur plus haut degré, il est sans exemple."

There are parts of his works which one cannot read, even now, without being struck, often as by a blinding flash, with the intense modernity of his thought. The artist attributes modern feeling to, say, Bach or Michelangelo, because their complete mastery of their arts led them to perceive, at least in outline, almost everything which these arts were capable of expressing; in a sense music and sculpture do not so much advance beyond Bach and Michelangelo as oscillate round them. With obvious limitations the same is true of Newton. So clearly and so completely had his mind grasped the essential outlines of the physical universe that, time after time, we find his unerring thought travelling much the same path and encountering much the same difficulties as the scientific investigator of to-day.

A striking example appears in the first few pages of the "Principia," where Newton discusses the difficulty of distinguishing between relative and absolute motion, conjecturing that possibly "in the remote regions of the fixed stars, or perhaps beyond them, there may be some body absolutely at rest," but that "absolute rest cannot be determined from the positions of bodies in our regions." Since Newton wrote this the fixed frame of reference of the luminiferous ether has come and gone, and what might have been considered antiquated thought a few years ago could well be transposed bodily into a treatise on Relativity to-day. Similarly, Newton's theory of 'fits of easy reflexion and transmission,' which seemed foolishness until recently, is now seen to be closely allied in principle to Einstein's 'probability-coefficients' for the interchange of energy between atoms and radiation, while his support of a corpuscular theory of light has acquired a new significance from the modern theory of light quanta. As a final example we find him writing to Bentley (Dec. 10, 1692): "It seems to me that, if the matter of our sun and planets and all the matter of the universe were evenly scattered . . . throughout infinite space,

it would never convene into one mass ; but some of it would convene into one mass and some into another, so as to make an infinite number of great masses, scattered great distances from one to another throughout all that infinite space. And thus might the sun and fixed stars be formed, supposing the matter were of a lucid nature." I

doubt if modern cosmogony can give a much better account of the genesis of the stars.

So, although two centuries have elapsed since Newton died, we may expect to hear this morning not only of work accomplished more than two centuries ago, but also of scientific methods and lines of thought that seem entirely alive to us to-day.

Newton's Work in Astronomy.¹

By Sir FRANK DYSON, K.B.E., F.R.S.

WRITING in the year 1738, Voltaire narrates that Madame Conduitt, Newton's niece, had related to him that in the year 1666, Newton, seeing an apple fall in the garden of Woolsthorpe, meditated profoundly on the cause which draws all bodies in a line which, if produced, would pass through the centre of the earth. Voltaire then tries to reconstruct the line of thought which led Newton to the law of universal gravitation. Would it act if the apple were a mile high or ten miles high ? If so, might it not act so far away as the moon, and this power, whatever it is, be the same as that which keeps the moon in its orbit round the earth, the planets moving round the sun, and its satellites round Jupiter ?

Vague ideas were current as to the forces which kept the planets in their orbits. Descartes put forward a theory of vortices in a fluid medium diffused through space. This gave a possible sort of mechanism suggested by water or air whirling on the earth, but the details could not be fitted to agree with the known facts of astronomy. Kepler had suggested an attraction between the planets varying as the inverse square of the distance and had afterwards substituted the inverse distance. Others before Newton may have suggested the inverse square, but were unable to carry the idea further. Newton was able to bring the hypothesis to the stage at which it could be tested by its agreement with phenomena. Assuming that the force by which the earth attracted outside bodies varied inversely as the square of the distance and at the earth's surface caused a body to fall 16 feet in one second, he calculated that, as the moon is sixty times as distant from the centre of the earth, the attractive force of the earth at that distance would pull the moon inwards towards the earth 16 feet in one minute. He then calculated the actual force necessary to keep the moon moving round the earth in 27 days 7 hours at a distance of sixty times the radius of the earth. It is said,

but without much evidence, that Newton used the erroneous value of 60 miles for 1° of latitude of the earth's surface employed by mariners to calculate the earth's radius, and was unacquainted with the more accurate measures of Norwood in 1636, which made 1° of latitude 70 miles. He thus obtained a value one-seventh part too small, and in view of this discrepancy for a time turned his thoughts to other things. He may have returned to the subject a few years later when he became acquainted with the results of Picart's triangulation from Paris to Amiens made in 1669-1670.

Though we do not know the precise date when Newton had satisfied himself of the truth of the law of gravitation, in 1684 it was complete, and he could not only demonstrate to Halley that under a law of the inverse square planets would describe ellipses round the sun, but could also promise to send to the Royal Society the mathematical principles of natural philosophy in which the doctrine of universal gravitation is set forth in order and its manifold consequences deduced.

In Book III. of the "Principia" Newton begins with the astronomical evidence. The four satellites of Jupiter describe equal areas about Jupiter in equal times ; and the squares of their periodic times are proportional to the cubes of their distances from Jupiter's centre. The same is true of the satellites of Saturn. The same holds for the motion of the planets round the sun. The moon, too, if the small disturbances caused by the sun are neglected, describes equal areas in equal times about the earth's centre. It follows from the mathematical demonstration in Book I. that the forces which keep Jupiter's satellites in their orbit tend to Jupiter's centre and are inversely as the square of the distances of the satellites from that centre. The same applies to Saturn and its satellites. The movements of the planets round the sun are known to obey these laws of Kepler's with very great accuracy. Consequently this law of the inverse square holds with equal accuracy. The moon, however, does not move accurately in an ellipse,

¹ Address delivered on Mar. 19 at Grantham in connexion with the commemoration of the two-hundredth anniversary of the death of Sir Isaac Newton.