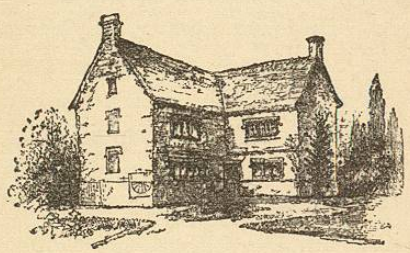
what similar to those which occupied his attention in maturer years. His mother wished him to be a farmer, and for a time he followed that business. But a discerning uncle discovered his talent and had him sent to Cambridge. At Cambridge his unparalleled genius for mathematical reasoning and investigation soon displayed itself, and when he graduated he was at once made a fellow, and almost immediately became mathematical professor. But as a teacher Newton can scarcely be said to have been a success. His power of mathematical reasoning was so



WOOLSTHORPE MANOR
(Showing a solar dial made by Newton when a boy.)

exalted that what seemed easy and simple to him was in reality difficult and abstruse. His lectures, therefore, were for the most part unattended. When he published his "*Principia*" he presented complimentary copies of it to heads of colleges and other learned men; but, as one of the most distinguished of these said, there were not half a dozen persons in Europe who could read and understand the book. While he was pursuing his more difficult investigations his devotion to his work was so intense that he became exceedingly pre-occupied and absent-minded. He would forget to eat, forget to sleep, forget even to dress himself. His mind was always wholly en-

grossed with the problems he was working at. All through life he was neglectful of sleep and food, and as to physical exercise it is said that he took none whatever. For many years his income was only sufficient barely to support him. But when he was fifty-three, through the influence of Lord Halifax, he was made Warden of the Mint. This appointment enabled him to give up his college duties, remove to London, and live in a manner befitting his station and his reputation. In 1703 he was elected President of the Royal Society, and every year thereafter, until his death almost a quarter of a century later, he was re-elected to that honorable office. In 1705 he was knighted. With the exception, perhaps, of his memory, he retained his faculties unimpaired until the very last. Even in the year of his death he could read manuscript without spectacles. He died March 20, 1727, at the age of 85, and was buried in Westminster Abbey. Dukes and earls were proud to be his pallbearers. He had never married.

says, none of them possessed a "convincing proof" of it. Hooke, however, maintained that he had one by him, but refused to produce it until the world, by trying, should find out how difficult it was, and would therefore appreciate the ability of its discoverer.

In August, Halley set out for Cambridge, to consult Newton, who had no knowledge that these discussions were going on. Without mentioning anything of his deliberations with Wren and Hooke, he asked what path a body would describe under the action of a central force varying as the inverse square of the distance from the center. Newton at once calmly replied, "An ellipse." Halley was greatly struck with the quiet confidence of this answer, and asked him how he knew this. Newton replied that the problem had occurred to him about fifteen or twenty years before, and he had solved it. The greatest minds in the world were puzzling over this complex problem, and to Newton it had occurred, and he had solved it, and never knew that he had done a great thing. It came quite naturally to him, and when asked to produce his paper on the subject, so little had he thought of it that he could not find it.

Halley, however, seems to have convinced him of the importance of this work, and accordingly he promised to forward to the Royal Society a treatise, "*De Motu*" ["*On Motion*"], which should contain this and other demonstrations of great interest.—E. J. C. MORTON.

NEWTON'S "PRINCIPIA"

Newton seems to have been strangely averse to publishing his work. Perhaps he remembered his contentions with Linus. Certainly he could ill afford the expense. The Royal Society had, too, liberally assisted less important publications, and was now in want of funds. It should never be forgotten by students of science that we owe to the disinterested generosity of Halley* the publication of the "*Principia.*" The minutes of the council of the Royal Society for the 2nd of June, 1686, contain the resolutions, "That Mr. Newton's book be printed," and "That Mr. Halley undertake the business of looking after it, and printing it at his own charge, which he engaged to do." The whole work was given to the world, complete, about midsummer, in 1687.

Unlike most great works of science, the "*Principia*" was the result of one continuous, unbroken effort of thought, and possesses thereby a oneness and perfection which is as striking as its wonderful originality.

When we consider that the accomplishment of any one of the six steps of its grand inductive ascent would have been enough to place its author in the sacred ranks with Hipparchus and Ptolemy, with Copernicus and Kepler and Galileo, we must feel, with Dr. Whewell, that all six steps made at once formed "not a leap, but a flight." And when we consider the state of knowledge in which Newton found the world, and the dim, uncertain twilight in which men groped after the ends of truth before the "*Principia*" was published, and then see the masterly grasp with which he there seized all the facts, and laid the foundations of all physical science so firmly and so well that for two centuries they have never been touched

* Fourteen years Newton's junior, his warmly attached friend, afterwards Astronomer Royal.

by others, but they have been marred, we must know that Pope's epigram is hardly an exaggeration—

> "Nature and nature's laws lay hid in night;
> God said, 'Let Newton be,' and all was light."
> E. J. C. Morton.

NEWTON'S DISCOVERY OF THE CAUSE OF TIDES

Many great discoveries now [after the discovery of the law of gravitation] crowded in upon Newton. He first of all gave the explanation of the tides that ebb and flow around our shores. Even in the earliest times the tides had been shown to be related to the moon. It was noticed that the tides were specially high during full moon or during new moon, and this circumstance obviously pointed to the existence of some connection between the moon and these movements of the water, though as to what that connection was, no one had any accurate conception until Newton announced the law of gravitation. Newton then made it plain that the rise and fall of the water was simply a consequence of the attractive power which the moon exerted upon the ocean lying upon the globe. He showed also that to a certain extent the sun produces tides, and he was able to explain how it was that when the sun and the moon both conspire, the joint result was to produce especially high tides, which we call "spring tides;" whereas if the solar tide was low, while the lunar tide was high, then we had the phenomenon of "neap tides."—Sir Robert S. Ball, LL. D., F. R. S., *in "Great Astronomers."*

SOME OF THE THINGS IN NEWTON'S "PRINCIPIA"

But perhaps the most signal of Newton's applications

of the law of gravitation, was connected with certain irregularities in the movements of the moon. In its orbit round the earth, our satellite is, of course, mainly guided by the great attraction of our globe. If there were no other body in the universe, then the center of the moon must necessarily perform an ellipse, and the center of the earth would lie in the focus of that ellipse. Nature, however, does not allow the movements to possess the simplicity which this arrangement would imply, for the sun is present as a source of disturbance. The sun attracts the moon, and the sun attracts the earth; but in different degrees, and the consequence is that the moon's movement with regard to the earth is seriously affected by the influence of the sun. It is not allowed to move exactly in an ellipse, nor is the earth exactly in the focus. How great was Newton's achievement in the solution of this problem will be appreciated if we realize that he not only had to determine from the law of gravitation the nature of the disturbance of the moon, but he had actually to construct the mathematical tools by which alone such calculations could be effected.

The resources of Newton's genius seemed, however, to prove equal to almost any demand that could be made upon it. He saw that each planet must disturb the other, and in that way he was able to render a satisfactory account of certain phenomena which had perplexed all preceding investigators. That mysterious movement by which the pole of the earth sways about among the stars had long been an unsolved enigma; but Newton showed that the moon grasped with its attraction the protuberant mass at the equatorial regions of the earth, and thus tilted the earth's axis in a way that accounted for the phenomena which had been known but had never been explained for two thousand years. All these discoveries were brought together in that immortal work, Newton's "*Principia.*"—SIR ROBERT S. BALL, LL. D., F. R. S.

THE GREATNESS OF NEWTON'S FAME

Though Newton lived long enough to receive the honor that his astonishing discoveries so justly merited, and though for many years of his life his renown was much greater than that of any of his contemporaries, yet it is not too much to say that, in the years which have since elapsed, Newton's fame has been ever steadily advancing, so that it never stood higher than it does at this moment.

We hardly know whether to admire more the sublime discoveries at which he arrived, or the extraordinary character of the intellectual processes by which those discoveries were reached. Viewed from either standpoint, Newton's "*Principia*" is incomparably the greatest work on science that has even yet been produced.—SIR ROBERT S. BALL, LL. D., F. R. S.

READERS' AND STUDENTS' NOTES

1. There are many popular accounts of Newton available. "Newton" forms the subject of a chapter in Sarah K. Bolton's "*Famous Men of Science,*" already mentioned.

2. In Morton's "*Heroes of Science—Astronomers,*" already mentioned, there are three chapters devoted to an account of Newton and the explanation of his discoveries and writings. The "Law of Gravitation" is taken up and explained and a popular account is given of Newton's great work, the "*Principia.*"

3. The student who follows closely Miss Buckley's account of Newton (chapter XVIII) in her "*Short History of Natural Science*" (New York: D. Appleton & Co.) will have a very fair idea of Newton's place in the history of astronomical and mathematical science.

4. One of the best accounts of Newton available to ordinary readers—a recent account and one written by one who is himself an authority in astronomy of the highest rank—is to be found in the work entitled "*Great Astronomers,*" by Sir Robert S. Ball, D. Sc., LL. D., F. R. S., Professor of Astronomy in the University of Cambridge. The work constitutes in fact a biographical history of astronomy. It contains sketches of the lives and works of all the great astronomers of the world from Ptolemy and Copernicus down to Leverrier and Adams, including Galileo, Herschel, and many others. It is handsomely illustrated. (London: Isbister & Co.).

5. The standard "life" of Newton is Sir David Brewster's.

SIR ISAAC NEWTON

SELECTED STUDIES AND REMINISCENCES

NEWTON'S FIRST INTRODUCTION TO ASTRONOMY

For some time Newton was extremely idle, and made no progress in his studies; but one day, having fought and beaten a bully much bigger than himself, he seems to have been stirred up by the incident to greater exertion in other directions, and soon rose to the top of the school. Still, like most great men of science, he was not remarkably clever as a boy, and the only indication of scientific ability was, as in the case of Galileo, his love of constructing working models of machines, in particular water-clocks. In order easily to set these, he observed the position of the sun by means of the shadows cast by pegs fixed into a wall, and in the course of a few years he managed so to correct the marks he made on the wall to denote the position of the shadow at the hours, as to make a sun-dial of considerable accuracy. This seems to have been his first introduction to astronomy.—E. J. C. MORTON, B. A., *in "Heroes of Science—Astronomers."*

NEWTON'S PREDILECTION FOR MATHEMATICS

Before Newton left Woolsthorpe his uncle had given him a copy of Sanderson's "*Logic,*" and when in the be-

ginning of his college career he attended lectures on this subject, he found that he knew more of it than his teacher. This was recognized by his tutor, and he was admitted instead to lectures on Kepler's "*Optics.*" This book was soon mastered by Newton at home, and he began to turn his attention to other subjects. He had bought a book on astrology at Stourbridge fair, but finding it impossible to understand it without a knowledge of geometry, of which even at this time he appears to have known but little, he purchased a Euclid; but the earlier propositions seemed to be so self-evident, that he laid it aside "as a trifling book." He now took up Descarte's "*Geometry,*" and this he seems to have found difficult; but after repeated attempts to overcome the various points that puzzled him, he finally mastered them all without the aid of a tutor. The different ways in which he regarded these two works illustrate the bent of his mind, afterwards shown in his own mathematical researches. He always preferred, and even seems to have found easier, the direct synthetic method of the old geometry to the algebraical or analytical method introduced by Descartes, and since developed into the most powerful instrument of scientific reasoning.

The mastery of Descarte's "*Geometry*" seems, however, to have brought out his great mathematical powers; for in the years 1664 and 1665 much of his work on infinite series and the quadrature of curves was done. So severely did he work at these subjects that an illness was brought on, which was further intensified by sitting up at night to watch a comet that appeared in 1664. From this illness we are told that "he learned to go to bed betimes."—E. J. C. MORTON.

NEWTON AND THE LAW OF GRAVITY

It is now [in 1665, after he had taken his degree at college] that Newton's great scientific career began. In this year he, for the first time, committed to writing his ideas on the mathematical method of fluxions, which formed the germ of the differential calculus. And in this year also the first idea of the law of gravitation occurred to him. For, according to the account given by his niece, Catharine Barton, to Voltaire, having been driven away from Cambridge by the plague, he was sitting in the garden at Woolsthorpe, thinking of the laws of motion, when he saw an apple fall from a tree. The apple being at rest on the tree, it could fall only because some force acted upon it towards the center of the earth. This force, which gives bodies their property of weight, was called "gravity," even at that time; and it seems to have struck Newton that this force of gravity acted upon the apple up in the tree as well as upon the ground; that it acts upon bodies on the summits of the highest hills as in the depths of the deepest valleys; and then the great thought struck him—Might not this very same force extend outwards from the earth's surface as far as the moon, and be the cause which bends her path out of the natural straight course in which she would freely move, into her curved orbit surrounding the earth.

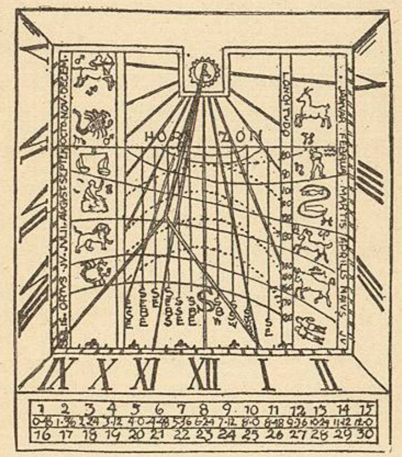
We have seen, that ever since the discovery of the laws of motion [by Galileo], men had known that some force must act upon the moon at every point towards the interior of her orbit; and it had been suggested that it might act towards the center of the earth; but no one

had ever conceived that the familiar force of gravity, that gives the bodies we have to do with their familiar property of weight, was the very force that held the moon in her course.

No sooner did this idea occur to him, than Newton set to work to find the law in which it acted.—E. J. C. Morton.

NEWTON'S UNCONSCIOUS MATHEMATICAL POWER

The problem of finding what the law of attraction must be to cause a body to describe an ellipse with the



SIR ISAAC NEWTON'S SUN DIAL

center of a force in the focus, was one which was clearly proposed and considered before Newton published its solution. In the beginning of 1684, Halley, Wren, and Hooke were discussing it in London. They all seem to have thought the inverse square was the law, but, Halley