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PREFACE

The "World's Great Scientists" presented in this volume comprise sixteen of the greatest names that the world of science has known. The history of their lives and achievements would, if written in full, be a history of the development of modern scientific knowledge.

The history of the lives and achievements of these great men as here set forth, is of course, a history for popular reading. The aim has been to interest as well as to instruct, and to both interest and instruct in accordance with those conditions of limited space and absence from all technicalities, which prior publication in a popular daily newspaper necessarily imposes.

At the same time it is believed that the reader who makes himself master of what is contained in this book will become well grounded in most of the essential elements of that wonderful story of scientific development which the lives of these men enacted.

J. E. B.

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN
DIRECCIÓN GENERAL DE BIBLIOTECAS

CONTENTS

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN ®
DIRECCIÓN GENERAL DE BIBLIOTECAS

LIST OF ILLUSTRATIONS

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN
DIRECCIÓN GENERAL DE BIBLIOTECAS

Galileo Galilei

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN
DIRECCIÓN GENERAL DE BIBLIOTECAS
BIBLIOTECA

I. GALILEO GALILEI

1564-1642

BIOGRAPHICAL STUDY

BY JOHN EBENEZER BRYANT, M. A.

From the very beginning of his civilization man took an interest in the motions of the heavenly bodies, but for ages his knowledge of their motions was incorrect. It was all based on the assumption that the earth was a fixed central point round which the sun, the moon, the planets, and the stars, revolved in their several courses. This assumption corresponded with the notion which people got of the matter from their ordinary observation. But, what was of greater moment, it corresponded also with the supposed teachings of the scriptures. In the middle ages the church was omnipotent, and whatever it wished the people to believe it took care they did believe. Disbelief, indeed, frequently resulted in death. The doctrine that the earth was the center of the universe, and that sun, moon, and stars revolved around it, the church declared was taught in the scriptures, and therefore it was one that the people were required to believe. Unfortunately, it was also one that was

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THE WORLD'S GREAT SCIENTISTS

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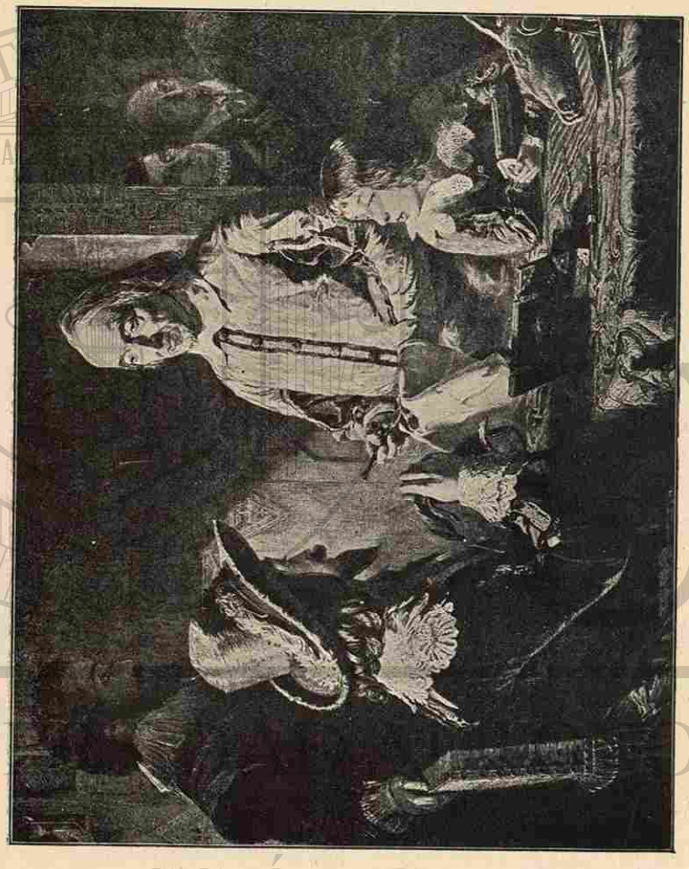

HARVEY DEMONSTRATING THE CIRCULATION OF THE BLOOD TO CHARLES I

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EDITED BY

SEYMOUR EATON

THE WORLD'S GREAT SCIENTISTS

GALILEO	HARVEY	NEWTON
FRANKLIN	HERSCHEL	DALTON
CUVIER	HUMBOLDT	DAVY
AUDUBON	FARADAY	LYELL
AGASSIZ	DARWIN	TYNDALL
	HUXLEY	

NEW YORK
THE DOUBLEDAY & McCLURE CO.
1901

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DIRECCIÓN GENERAL DE BIBLIOTECAS

I. GALILEO GALILEI

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DIRECCIÓN GENERAL DE BIBLIOTECAS

out obtaining the doctor's degree, which alone would permit him to practice.

Galileo was thus barred from entering upon the profession which he had chosen as a means of livelihood, but the seeming adversity was in reality a piece of good fortune. It determined his lot in life. He went home and at once began to pursue with ardor those studies with which afterward his great fame was to be associated. Galileo's genius for physical investigation was the greatest that up to his era, so far as is known, was ever given to man; and even since his era we have to come down as late as Faraday before we can find his peer. When a young student in the university he had, by watching the oscillations of the great lamp in the cathedral, which a verger had left swinging to and fro, discovered the physical fact of the isochronism of the pendulum, the fact upon which the principle of all modern clock-making is based. Though he did not invent the modern clock, he at once turned his knowledge of the fact he had discovered to practical use in the profession he was then preparing for by devising an instrument for determining the rate of the pulse-beat. By the time he was twenty-four he had earned for himself a widespread reputation as a bold and original investigator of mechanical and other physical laws. At twenty-six he was appointed professor of mathematics in the University of Pisa, the university that six years before he was too poor to obtain his degree from. Three years later he was promoted to a similar position in the University of Padua. Galileo was not merely a bold thinker and a clever, original investigator. He was also an able and convincing lecturer and demonstrator. His facility of illustration, his wit and his humor in the presentation of his themes, as well as his

clinching logic, made him the most popular teacher of his age. People flocked to hear him who were not professional students. Sometimes, because of crowds, he had to resort to large halls. Sometimes, too, he had to resort to the open air. He was besides equally skilled and renowned as a writer. His scholarship and literary skill and grace, together with his fame as an investigator, made his correspondence sought for by all the learned men in science in Europe.

LEANING TOWER OF PISA.

Galileo's popularity was mainly with his students and the multitude. His students, indeed, loved him utterly, and some of them in their turn became almost as great and fa-

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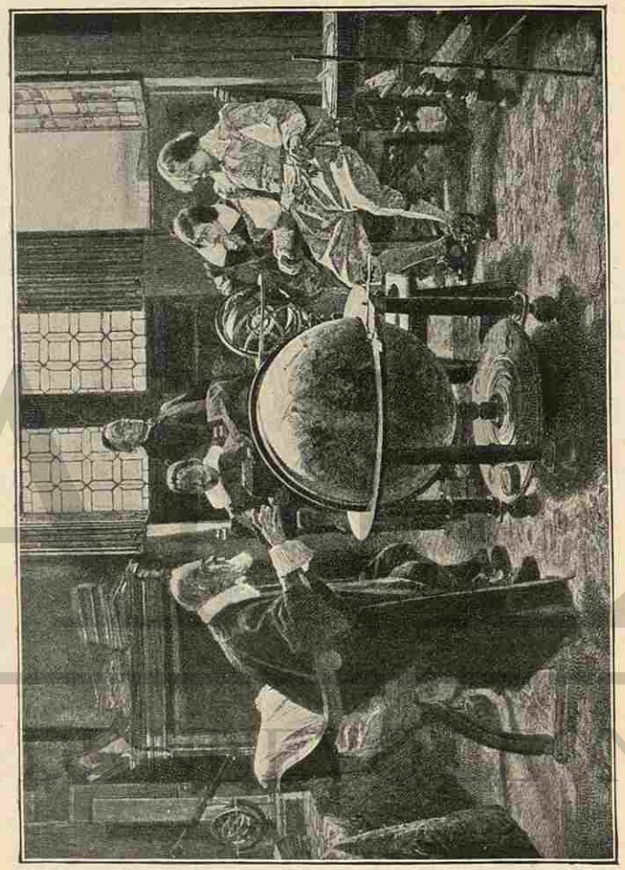
mous as he was. But with his fellow-professors in the universities, and with all those who thought that science was like a dead language—a domain that might be cultivated but could not be extended—his bold investigations and his original discoveries were far from being acceptable. At Pisa he had propounded the doctrine that all bodies, whether heavy or light, fall with equal velocity; and had demonstrated the doctrine by going up to the top of the famous leaning tower there and letting fall a 100-pound weight and a one-pound weight at the same moment and showing that they reached the ground below at the same moment. But, notwithstanding this demonstration, his fellow-professors would have none of the doctrine. It was contrary to Aristotle's dictum, and to them this was ample proof of its falsity. At Pisa, too, Galileo had become convinced of the truth of the Copernican theory of the construction of the solar system. He had, however, said little about it there, for he had not then been able to add anything to its demonstration. But at Padua he was able by his wonderful invention of the telescope to adduce fact after fact in clinching proof of the Copernican doctrine. He showed that the moon was not a plane reflector, as it was generally supposed to be, but an orb with a rough surface of mountain and valley, precisely like our earth. He showed, too, that the sun was not a simple globe of light, but that it had immense dark spots upon its face, and that these spots had motion, or, in other words, that the sun itself had motion about an axis. He showed, too, that Venus has phases, just as the moon has, a fact which Copernicus had been able to predict, but which he had not been able to demonstrate because he had only his own natural vision to make observations with. Finally Galileo



MILTON VISITING THE AGED GALILEO

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discovered that Jupiter has moons—four moons—and was able to prove that these moons revolve around their primary planet just as our moon revolves around our earth. All these facts in confirmation of the Copernican theory Galileo not only demonstrated for himself, but was able by means of the excellent telescopes he made to place within the easy demonstration of others.

But the Copernican theory by this time had come under the ban of the church, and the teachings of Galileo, notwithstanding the physical demonstrations on which they were based, were deemed heretical. Galileo, however, went to Rome about it, and he was so well received there, and his arguments were so favorably listened to, that he thought he had converted the authorities to his views. In this he was sadly deluded. He was a good churchman and a sincere Christian, and he lived a blameless life. Besides, he was noted for his great kindness of heart and his abounding charity. The sympathy of every one, therefore, was with him; but as against what was thought to be fatal error sympathy had no weight. Before he left Rome he was peremptorily forbidden to teach his doctrine further. In 1623, when Urban VIII. came to the pontifical throne —a man of learning, and of interest in education and science—Galileo again went to Rome on the matter. Again he was kindly received, and again he thought he had succeeded in his heart's desire. He went home rejoicing, for he loved his church and was sincerely anxious to do nothing contrary to her will. He at once set to work at his famous book, the "*Dialogues on the Ptolemaic and Copernican Systems.*" No sooner, however, was his great work published than he was summoned to Rome to answer for it. He arrived February, 1633. He was then in his

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DIRECCIÓN GENERAL DE BIBLIOTECAS

seventieth year. He was feeble from illness, and broken in mind from worry and anxiety. His trial began almost at once. He was put in the chambers of the inquisition and examined again and again. It is true that he was dealt with in a kindly spirit, but yet with all the rigor that the rules of the inquisition prescribed. He had really no defense. None, indeed, was possible. He had taught and written what he knew to be true, but that which he had taught and written the accusing court declared to be false. It was, therefore, submission and recantation for him, or else torture and death at the stake. His spirit broke. He had always believed in the religious authority of the church; he now acknowledged its authority over his mind and reason. The ignominious recantation and abjuration was drawn up for him, and he solemnly swore to it and signed it—June 22, 1633. He lived nine years more, but no longer free. He was practically a prisoner of the inquisition. In those last sad years, however, he discovered and enunciated the laws of motion which Newton afterward demonstrated so conclusively.

GALILEO GALILEI

SELECTED STUDIES AND REMINISCENCES

THE DRAMATIC CONTRASTS OF GALILEO'S CAREER

The history of the life and labors of Galileo is pregnant with a peculiar interest to the general reader, as well as to the philosopher. His brilliant discoveries, the man of science regards as his peculiar property; the means by which they were made, and the development of his intellectual character, belong to the logician and to the philosopher; but the triumphs and the reverses of his eventful life must be claimed for our common nature, as subjects of deep interest, and serious meditation.

The lengthened career which Providence assigned to Galileo was filled up throughout its rugged outline with events of even dramatic interest. But though it was emblazoned with achievements of transcendent magnitude, yet his noblest discoveries were the derision of his contemporaries, and were even denounced as crimes which merited the vengeance of Heaven. Though he was the idol of his friends, and the favored companion of princes, yet he became the victim of a cruel persecution, and spent some of his latest hours within the walls of a prison; and though the Almighty granted him, as it were, a new sight,

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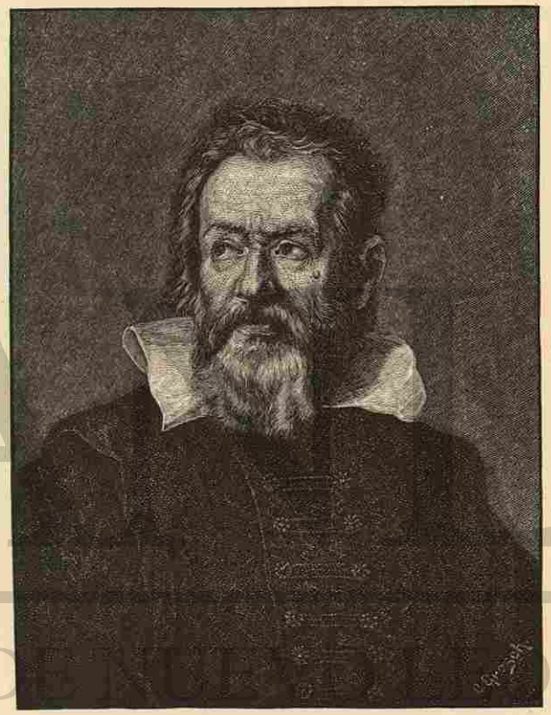
set forth as true in the writings of the great philosopher Aristotle, whose teachings in all speculative and physical matters were for centuries accepted by the learned of the world as unquestionable. The doctrine therefore had both indisputable intellectual authority and the definite announcements of the church arrayed in its favor, as well as what was supposed to be plain common sense. To doubt it would enter the head of scarcely any one. To hold a different doctrine would be the part only of courageous independent thinkers, of whom in those days there were very few. To teach a different doctrine would be the part only of those who were not afraid to contemplate martyrdom.

The honor of propounding and demonstrating the true theory of the motions of the heavenly bodies—namely, that the sun is the center of a system around which the several planets revolve, that the earth is one of these planets, that the moon likewise is a planet, but also a satellite of the earth, and that the apparent motions of the sun, moon, and stars around the earth are in reality optical illusions caused by the motion of the earth on its own axis—this honor belongs to Copernicus, a learned and observant monk of Prussia. Copernicus was born in 1473, and it was not until he was seventy years old (1543), and on his deathbed, that he published his great work on "The Revolutions of the Heavenly Bodies"—the work that has made his name immortal. Copernicus was a quiet, studious man, very little given to discussion or self-assertion, and the importance of his teachings and demonstrations was scarcely guessed during his lifetime, nor, indeed, until some years after his death. But it was not very long before the "Copernican system," as it was called, began to



GALILEO GALILEI.
Painting by Susterman, Florence.

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secure the adherence of bold observers and thinkers, and also to come under the condemnation of that organization for the defense of the faith of the church whose deeds now seem to us to be so cruel—the inquisition. In 1600, for teaching doctrines which were only corollaries from the demonstrations of Copernicus, Giordano Bruno was, after six years of imprisonment, burned at the stake. In 1633, for teaching similar doctrines, Galileo, then an old and feeble man of seventy, was saved from a like awful fate only by a recantation, made, there is but little doubt, through fear of painful torture.

Galileo Galilei, known to fame by his Christian name, Galileo, was born in Pisa, Italy, February 15, 1564. He was thus a contemporary of the English Shakespeare, who was born in the same year. But he lived much longer than Shakespeare, and was in his old age visited by the English Milton. He was the eldest son of a Florentine noble; but his father, though a man of scholarship and refined tastes, was, unfortunately, of impoverished fortune, and was therefore unable to provide for him an education suited to his station and talents. It was at first determined that he should be a cloth merchant. But young Galileo's surpassing ability, his skill in drawing and coloring, his cleverness in devising and making mechanical contrivances, his skill also in music, in which art, indeed, he showed great genius, soon convinced his father that he must be given at least a professional education. He was therefore sent away from Florence, where his father then lived, to the University of Pisa to pursue a course in medicine there. But, though he pursued his studies in medicine for four years, his father was unable to pay the necessary graduation expenses, and so he had to leave the university with-

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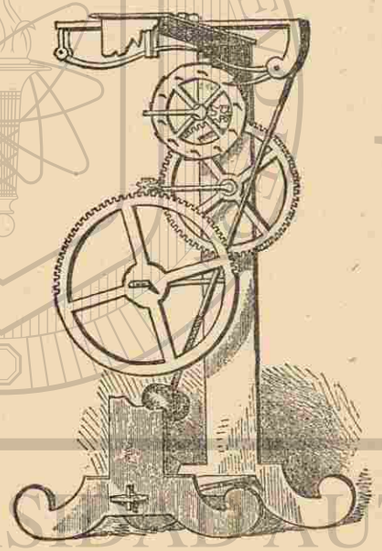
to descry unknown worlds in the obscurity of space, yet the eyes which were allowed to witness such wonders, were themselves doomed to be closed in darkness.

Such were the lights and shadows in which history delineates

"The starry Galileo with his woes."

But, however powerful be their contrasts, they are not unusual in their proportions. The balance which has been



GALILEO'S PENDULUM.

struck between his days of good and evil, is that which regulates the lot of man, whether we study it in the arbitrary sway of the autocrat, in the peaceful inquiries of the philosopher, or in the humbler toils of ordinary life.—SIR DAVID BREWSTER, *in "The Martyrs of Science."*

GALILEO'S EARLY YEARS AND EDUCATION

The early years of Galileo were, like those of almost all great experimental philosophers, spent in the construction of instruments and pieces of machinery, which were calculated chiefly to amuse himself and his school-fellows. This employment of his hands, however, did not interfere with the improvement of his mind; and though, from the straitened circumstances of his father, he was educated under considerable disadvantages, yet he acquired the elements of classical literature, and was initiated into all the learning of the times. Music, drawing, and painting were the occupations of his leisure hours; and such was his proficiency in these accomplishments, that he was reckoned a skillful performer on several musical instruments, especially the lute, while his knowledge of pictures was held in great esteem by some of the best artists of his day.—SIR DAVID BREWSTER.

GALILEO, THE MOON, AND THE ARISTOTELIANS

The first celestial object to which Galileo applied his telescope was the moon, which, to use his own words, appeared as near as if it had been distant only two semidiameters of the earth. He then directed it to the planets and the fixed stars, which he frequently observed with "incredible delight."

The observations which he made upon the moon possessed a high degree of interest. The general resemblance of its surface to that of our own globe naturally fixed his attention; and he was soon able to trace, in almost every part of the lunar disc, ranges of mountains, deep hollows,

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entered into an alliance against the philosophical tyrant, who threatened them with the penalties of knowledge. —SIR DAVID BREWSTER.

GALILEO'S CELEBRATED "DIALOGUES"

Having overcome all these difficulties [namely, of publication], Galileo's work appeared in 1632, under the title of "*The System of the World of Galileo Galilei, etc.* in which, in four dialogues concerning the two principal systems of the world—the Ptolemaic and the Copernican—he discusses, indeterminately and firmly, the arguments proposed on both sides." . . . . . The dialogue is conducted by three persons—Salviati, Sagredo, and Simplicio. Salviati, who is the true philosopher in the dialogue, was the real name of a nobleman and friend of Galileo. Sagredo, the name of another noble friend of Galileo, performs a secondary part under Salviati. He proposes doubts, suggests difficulties, and enlivens the gravity of the dialogue with his wit and pleasantry. Simplicio is a resolute follower of Ptolemy and Aristotle, and, with a proper degree of candor and modesty, he brings forward all the common arguments in favor of the Ptolemaic system. Between the wit of Sagredo, and the powerful philosophy of Salviati, the peripatetic sage is baffled in every discussion; and there can be no doubt that Galileo aimed a more fatal blow at the Ptolemaic system by this mode of discussing it, than if he had endeavored to overturn it by direct argument.—SIR DAVID BREWSTER.

THE GREAT TRIAL

Worn out with age and infirmities, and exhausted with

the fatigues of his journey, Galileo arrived at Rome on the 14th of February, 1633. . . . . During the whole of the trial which had now commenced, Galileo was treated with the most marked indulgence. Abhorring, as we must do, the principles and practice of this odious tribunal, and reprobating its interference with the cautious deductions of science, we must yet admit that, on this occasion, its deliberations were not dictated by passion, nor its power directed by vengeance. Though placed at their judgment seat as a heretic, Galileo stood there with the recognized attributes of a sage; and though an offender against the laws of which they were the guardians, yet the highest respect was yielded to his genius, and the kindest commiseration to his infirmities.

In the beginning of April, when his examination in person was to commence, it became necessary that he should be removed to the Holy Office; but instead of committing him, as was the practice, to solitary confinement, he was provided with apartments in the house of the fiscal of the Inquisition. His table was provided by the Tuscan Ambassador, and his servant was allowed to attend him at his pleasure, and to sleep in an adjoining apartment. Even this nominal confinement, however, Galileo's high spirit was unable to brook.

. . . . . .

Having duly weighed the confessions and excuses of their prisoner, and considered the general merits of the case, the Inquisition came to an agreement upon the sentence which they were to pronounce, and appointed the 22nd of June as the day on which it was to be delivered. . . . On the 22nd of June Galileo was clothed

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in a penitential dress, and conducted to the Convent of Minerva, where the Inquisition was assembled to give judgment. A long and elaborate sentence was pronounced, detailing the former proceedings of the Inquisition, and specifying the offenses which Galileo had committed in teaching heretical doctrines, in violating his former pledges, and in obtaining by improper means a license for the printing of his Dialogues. After an invocation of the name of our Saviour, and of the Holy Virgin, Galileo is declared to have brought himself under strong suspicions of heresy, and to have incurred all the censures and penalties enjoined against such delinquencies; but from all these consequences he is to be held absolved, provided that, with a sincere heart and faith unfeigned, he abjures and curses the heresies he has cherished, as well as every other heresy against the Catholic Church. In order that his offense might not go altogether unpunished, that he might be more cautious in future, and be a warning to others to abstain from similar offenses, it was also decreed that his Dialogues should be prohibited by public edict, and that he himself should be condemned to the prison of the Inquisition during its pleasure.—SIR DAVID BREWSTER.

THE ABJURATION

The ceremony of Galileo's abjuration was one of exciting interest, and of awful formality. Clothed in the sackcloth of a repentant criminal, the venerable sage fell upon his knees before the assembled cardinals; and laying his hands upon the Holy Evangelists, he invoked the Divine aid in abjuring and detesting, and vowing never again to teach the doctrine of the earth's motion, and of the

sun's stability. He pledged himself that he would never more, either in words or in writing, propagate such heresies; and he swore that he would fulfil and observe the penances which had been inflicted upon him. At the conclusion of this ceremony, in which he recited his abjuration, word for word, and then signed it, he was conveyed, in conformity with his sentence, to the prison of the Inquisition.—SIR DAVID BREWSTER.

GALILEO'S BLINDNESS

Every relaxation of Galileo's misery excited the malice of his enemies; secret denunciations of his influence were poured into Rome, and kept him in constant fear. Then his favorite daughter died. Yet he roused himself out of even this misfortune, and wrote his work on the laws of motion. At last his final misery overtook him. He was attacked by a disease of one eye, which slowly darkened, and then the other began to fail, and at last he was quite blind. "This heaven, this earth," he wrote, "this universe, which with wonderful observations I had enlarged a hundred, a thousand times beyond the belief of bygone ages, henceforth for me is shrunk into the narrow space which I myself fill in it. So it pleases God; it shall therefore please me also."—E. J. C. MORTON, B. A., *in "Heroes of Science—Astronomers."*

GALILEO'S GREATNESS

The scientific character of Galileo, and his method of investigating truth, demand our warmest admiration. The number and ingenuity of his inventions, the brilliant discoveries which he made in the heavens, and the depth and

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beauty of his researches respecting the laws of motion, have gained him the admiration of every succeeding age, and have placed him next to Newton and Kepler in the lists of original and inventive genius. To this high rank, he was doubtless elevated by the inductive processes which he followed in all his inquiries. Under the same guidance of observation and experiment, he advanced to general laws; and if Bacon had never lived, the student of nature would have found, in the writings and labors of Galileo, not only the boasted principles of the inductive philosophy, but also their practical application to the highest efforts of invention and discovery.—SIR DAVID BREWSTER.

READERS' AND STUDENTS' NOTES

1. Accounts of Galileo are given in almost every handbook of the history of science and in almost every handbook of scientific biography, for Galileo is a great name in science, and the story of his life is fascinating. A very readable account of him is given in Sarah K. Bolton's "*Famous Men of Science*" (New York: T. Y. Crowell & Co., $1.50), a work that also gives accounts of Newton, Cuvier, Herschel, Humboldt, Davy, Audubon, Lyell, Agassiz, and Darwin, on our list, besides several other "famous men of science." The work is illustrated with numerous portraits.

2. The student who wishes to know something more about Galileo than his biography will find in "*Heroes of Science—Astronomy*" (London: The S. P. C. K. New York: E. & J. B. Young & Co.) by E. J. C. Morton, B. A., not only his biography, but also a readable account of his discoveries and scientific work generally. This work is essentially a history of astronomy, written for the general reader. Besides an account of the life and work of Galileo, it contains accounts of the lives and works of

Copernicus, Tycho Brahë, Kepler, Newton, Lagrange, Laplace, and Herschel.

3. One of the most distinguished students of the nineteenth century was Sir David Brewster. One of his works was "*The Martyrs of Science*," or "*The Lives of Galileo, Tycho Brahë, and Kepler*." Students who wish a somewhat longer and more minute account of Galileo than those which the foregoing works give, but one that is perfectly readable, even by those who do not understand mathematics, will find the sketch of Galileo in this book eminently instructive and entertaining. The book is all the more valuable because of its similar accounts of the lives and works of Tycho Brahë and Kepler.

4. One of the most useful works that a young student can possibly have is Arabella B. Buckley's work, entitled "*A Short History of Natural Science and of the Progress of Discovery from the Time of the Greeks to the Present Time*." (New York: D. Appleton & Company, $2.00.) It is prepared especially for the use of the general reader, and is quite intelligible not only to those who do not understand mathematics, but also to those whose education in any branch of science is only elementary. Its great merit is that it is not only thoroughly sound and scientific, but also exceedingly readable and interesting. The student will find it helpful to him in his study not only of Galileo, but also of almost every other of the "World's Great Scientists" on our list.

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DIRECCIÓN GENERAL DE BIBLIOTECAS

and other inequalities, which reverberated from their summits and margins the rays of the rising sun, while the intervening hollows were still buried in darkness. The dark and luminous spaces he regarded as indicating seas and continents, which reflected, in different degrees, the light of the sun, and he ascribed the phosphorescence, as it has been improperly called, or the secondary light, which is seen on the dark limb of the moon in her first and last quarters, to the reflection of the sun's light from the earth.

These discoveries were ill received by the followers of Aristotle. According to their preconceived opinions, the moon was perfectly spherical and absolutely smooth; and to cover it with mountains, and to scoop it out into valleys, was an act of impiety which defaced the regular forms which Nature herself had imprinted. It was in vain that Galileo appealed to the evidence of observation, and to the actual surface of our own globe.—SIR DAVID BREWSTER.

GALILEO PROVES THAT THE EARTH IS NOT THE CENTER OF THE UNIVERSE

The importance of this great discovery [of the moons of Jupiter] was instantly felt by the enemies, as well as by the friends, of the Copernican system. The planets had hitherto been distinguished from the fixed stars only by their relative change of place, but the telescope proved them to be bodies so near to our own globe as to exhibit well-defined discs, while the fixed stars retained, even when magnified, the minuteness of remote and lucid points. The system of Jupiter, illuminated by four moons, performing their revolutions in different and regular periods, exhibited to the proud reason of man the comparative insignificance of the globe he inhabits, and proclaimed in impressive language that that globe was not the center of the universe.—SIR DAVID BREWSTER.

GALILEO, KEPLER, AND THE PROFESSOR OF PHILOSOPHY OF PADUA

The reception which these discoveries [of the moons of Jupiter, etc.] met with from Kepler is highly interesting, and characteristic of the genius of that great man. He was one day sitting idle, and thinking of Galileo, when his friend Wachenfels stopped his carriage at his door, to communicate to him the intelligence. "Such a fit of wonder," he says, writing to Galileo, "seized me at a report which seemed to be so very absurd, and I was thrown into such agitation at seeing an old dispute between us decided in this way, that between his joy, my coloring, and the laughter of both, confounded as we were by such a novelty, we were hardly capable, he of speaking, or I of listening."

In a very different spirit did the Aristotelians receive the "Sidereal Messenger" of Galileo. The principal professor of philosophy at Padua resisted Galileo's repeated and urgent entreaties to look at the moon and planets through his telescope; and he even labored to convince the Grand Duke that the satellites of Jupiter could not possibly exist. Sizzi, an astronomer of Florence, maintained that as there were only *seven* apertures in the head—*two* eyes, *two* ears, *two* nostrils, and *one* mouth—and as there were only *seven* metals, and *seven* days in the week, so there could be only *seven* planets. He seems, however, to have admitted the visibility of the four satellites through

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the telescope; but he argues, that as they are invisible to the naked eye, they can exercise no influence on the earth; and being useless, they do not therefore exist.—SIR DAVID BREWSTER.

GALILEO'S FIRST VISIT TO ROME

Galileo had long contemplated a visit to the metropolis of Italy, and he accordingly carried his intention into effect in the early part of the year 1611 [when he was forty-seven years old]. Here he was received with that distinction which was due to his great talents and his extended reputation. Princes, cardinals, and prelates hastened to do him honor; and even those who discredited his discoveries, and dreaded their results, vied with the true friends of science in their anxiety to see the intellectual wonder of the age.

In order to show the new celestial phenomena to his friends in Rome, Galileo took with him his best telescope; and as he had discovered the spots on the sun's surface in October or November, 1610, or even earlier, he had the gratification of exhibiting them to his admiring disciples. He accordingly erected his telescope in the Quirinal garden belonging to Cardinal Bandini; and in April, 1611, he showed the spots to his friends in many of their most interesting variations. From their change of position on the sun's disc, Galileo had inferred that the sun revolved about an axis. He found that the spots must be in contact with the surface of the sun—that their figures were irregular—that they had different degrees of darkness—that one spot would often divide itself into three or four—that three or four spots would frequently unite themselves into

one—and that all the spots revolved regularly with the sun, which appeared to complete its revolution in about twenty-eight days.—SIR DAVID BREWSTER.

GALILEO'S IMPETUOUS ARDOR

The ardor of Galileo's mind, the keenness of his temper, his clear perception of truth, and his inextinguishable love of it, combined to exasperate and prolong the hostility of his enemies. When argument failed to enlighten their judgment, and reason to dispel their prejudice, he wielded against them the powerful weapons of ridicule and sarcasm; and in this unrelenting warfare, he seems to have forgotten that Providence had withheld from his enemies the intellectual gifts which he had so liberally received. He who is allowed to take the start of his species, and to penetrate the veil which conceals from common minds the mysteries of nature, must not expect that the world will be patiently dragged at the chariot-wheels of his philosophy. Mind has its inertia as well as matter; and its progress to truth can only be insured by the gradual and patient removal of the difficulties which embarrass it.

The boldness—may we not say the recklessness—with which Galileo insisted upon making proselytes of his enemies, served but to alienate them from the truth. Errors thus assailed speedily entrench themselves in general feeling, and become embalmed in the virulence of the passions. The various classes of his opponents marshalled themselves for their mutual defense. The Aristotelian professors, the temporizing Jesuits, the political churchmen, and that timid but respectable body who at all times dread innovation, whether it be in legislation or in science,

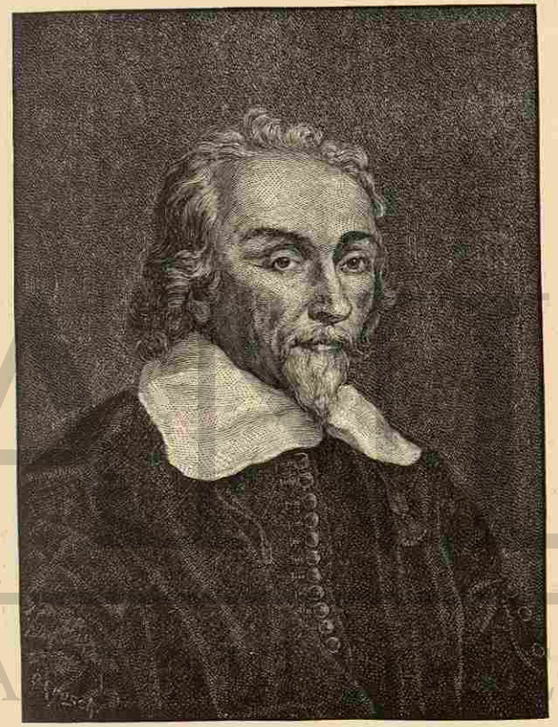
UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN
DIRECCIÓN GENERAL DE BIBLIOTECAS

William Harvey

UANL
UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN ®
DIRECCIÓN GENERAL DE BIBLIOTECAS

it be, was not even guessed at three centuries ago. We can scarcely realize, indeed, the ignorance of the world in regard to the functions of the various organs of the human body when Harvey began his investigations. For fifteen centuries, ever since the time of Galen (A. D. 130-200), the knowledge of the world in regard to such matters had been at a standstill. It was still believed and taught, as Aristotle and his followers had believed and taught eighteen centuries before, that the liver was the chief engine for the distribution of the blood throughout the animal system, and that that organ sent its fluid matter to the right ventricle of the heart, whence by a sort of suction it was conveyed to the lungs and throughout the body generally by means of the veins. The arteries were supposed to convey to the lungs and to the body generally from the left ventricle of the heart another sort of fluid, subtle and aerial in its character, which was called the "vital spirit," although Galen showed that the fluid which passed from the left side of the heart contained blood as well as vital spirit. But no "periodic circulation" of the blood fluid throughout the body was ever dreamed of, and the utmost amount of circulation that was supposed to take place was a vague sort of "diffusion." The heart was not recognized as an important organ in the blood system at all, but the veins and arteries were supposed to "suck" the blood from the heart and so convey it to various parts of the body. Such were the beliefs which even learned men of science held of the motion of the heart, and of the conveyance of the blood throughout the body, when Harvey first began to study the question.

William Harvey was born in Kent, England, April 1,



WILLIAM HARVEY.

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN ®
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1578, and was the son of a prosperous yeoman. Having been given a good preliminary education at the grammar school at Canterbury, he was sent to Caius college, Cambridge, where at the age of nineteen he received his B. A. degree. Then, having chosen medicine as a profession, he went to Padua, Italy, to study under the learned Fabricius there. Fabricius had discovered in the veins of the human body those little valves whose use we now know to be the prevention of the blood from flowing backward in its return passage to the heart. Fabricius, however, had not discovered the true use of the valves, and the explanation of their use that he put forward did not seem to his young student Harvey to be satisfactory. It was, indeed, Harvey's endeavor to obtain a satisfactory explanation of these valves that suggested to him the larger question of the explanation of the entire motion of the blood, and so led to his own immortal discovery. When, in 1602, Harvey returned to England with his doctor's degree, and settled in London, he brought no little reputation with him, and it was not long before he had gained an excellent practice. Among his patients was Sir Francis Bacon. Later on he was made physician extraordinary to King James, and afterward he was physician in ordinary to King Charles. In 1607 he had become a fellow of the Royal College of Physicians, and two years later physician to St. Bartholomew's hospital. In 1615 he had been made Lumleian lecturer. These were important appointments for so young a practitioner, but Harvey's professional career was continuous in its honors and successes to the end. In the year 1616, a year that may be remembered from the fact that it was the year of Shakespeare's death, he first began to

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN
DIRECCIÓN GENERAL DE BIBLIOTECAS

bring publicly forward in his lectures his views of the movements of the heart and blood. But it was not until twelve years later, in 1628, twenty-eight years after he first began to study the question, that he gave his conclusions to the world in printed form. But when he finally did so he had demonstrated his case so clearly there was no gainsaying it. His theory was at once acknowledged, by all those who took the trouble to examine it, as established beyond doubt. Harvey indeed had left no room for doubt. He had proved his views, not by a citation of authorities, as the wont then was, but by an examination of nature herself. To use his own words, the motion of the heart was asserted to be what he actually saw it to be in living animals. He had taken all branches of the animal kingdom into consideration in his investigation, and dogs, pigs, serpents, frogs, fishes, slugs, oysters, lobsters, insects, the transparent shrimp, and the chick in the shell, had contributed to his proof. In short, so far as an anatomical and physiological theory could be established by actual demonstrations without the use of the microscope (the microsccpe was not then invented), so far had Harvey in 1628 established that theory of the circulation of the blood which is now believed throughout the world.

Harvey's demonstration of his theory was scarcely less complete in its detail than it was in its general principle. He proved that it is the heart that by its muscular contractions squeezes the blood into the arteries, both general and pulmonary, and gives it the necessary impetus for its regular circulation by means of the arteries outward and the veins back again throughout the whole body. He proved that there is no passage between the two sides of the heart (although before his time it had always been be-

lieved that there was such a passage), but that one side of the heart is concerned with the reception of the dark blood from the body by the general veins and conveying it to the lungs by means of the pulmonary artery, and that the other side of the heart is concerned with the reception of the bright blood from the lungs by the pulmonary vein and conveying it to all parts of the body by means of the general arteries. He proved, too, that the blood in the arteries and in the veins is the same blood in different stages of its circulation (although it had formerly been believed that the blood in the arteries had been mixed with the subtle fluid called vital spirit), only that the bright blood in the arteries is blood mixed with air obtained in the lungs, while the dark blood in the veins is blood mixed with substance obtained in its passage through the tissues after it had left the arteries. He also proved that the circulation of the blood throughout the system is regular and periodic, corresponding with the beating of the heart and the throbbing of the pulse. Finally he proved that the liver, which for ages had been considered a principal engine in the diffusion of blood throughout the body, was not a factor in the circulatory system at all, the whole force for the periodic movements of the blood through both arteries and veins being obtained from the rhythmical muscular contractions or squeezings of the two sides of the heart. The only part in the whole circulatory system as now understood which he did not explain was the passage of the blood in its progress from the arteries to the veins, through the tissues, by means of the capillaries. He had no knowledge of those minute microscopic ducts that unite the visible and traceable arteries with the visible and traceable

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN ®
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II. WILLIAM HARVEY

1578-1657

BIOGRAPHICAL STUDY

BY WELLINGTON PROUT, M. A.

Seldom does the world think of its debts to the great men of science whose discoveries and inventions have done so much to promote its happiness. Its debt to Harvey, the discoverer of the true motions of the heart and of the circulation of the blood in the living body, it probably remembers as infrequently as any. It is now nearly three centuries since Harvey began to ponder upon the question the solution of which gave birth to the science of modern medicine. This is perhaps a reason why he is so infrequently thought of. Matters that then seemed dark and mysterious, even to the most learned and skillful, are now the common knowledge not alone of childhood but of uninstructed ignorance. It would be difficult indeed to find in any civilized community of our time any one who does not know that the action of the heart in a living body causes the blood to flow in regular periodic pulsations throughout the body. And yet this knowledge, rudimentary and elementary though

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DIRECCIÓN GENERAL DE BIBLIOTECAS

veins, and convey the blood from one system into the other, for he had no microscope by which he could possibly discover them, but he demonstrated clearly enough that such a conveyance must take place. It was not until four years after Harvey's death that Malpighi with the microscope, then newly invented, demonstrated the existence of the minute capillary vessels by which the conveyance is effected.

Harvey's great work, the "*Dissertation on the Movement of the Blood in Animals,*" was not published until 1628, when he was in his 50th year. He had taken sixteen years in which to study and establish his theory after he first conceived it before he taught it in his lectures; and he had taken twelve other years in which to complete his demonstration of it by means of further examinations of living animals before he made it known to the world in a treatise. Though for a number of years there was no opposition to this theory, yet in course of time opposition did come, and come so bitterly that he was loath to give to the world other results established by his acute powers of observation and reasoning. It was only because admiring friends and followers took the matter into their own hands, and published his other demonstrations almost against his will, that we have evidence other than the dissertation of 1628 of Harvey's genius and ability as an original scientific investigator. But the subjects in which, after the discovery of the circulation of the blood, Harvey was specially interested (for example, the growth of the chick in the egg was one of them) were such as could be properly investigated only with the aid of the microscope, and, as we have seen, the microscope was unknown in Harvey's time. But, notwithstanding his lack of the microscope, Harvey

observed enough, and demonstrated enough, to win the reputation of being the greatest physiological investigator of his age, and his reputation as a skillful practical physician and surgeon was equally notable. He acquired an ample fortune, and as his wife died before him and he had no children, he found his chief pleasure in his later years in making substantial benefactions to the College of Physicians. Of this institution for many years he had been the most illustrious member, and as a crowning honor of his life he was chosen its president. One of his benefactions was to the effect that an annual oration was to be given before the fellows of the college to exhort them "to study and search out the secrets of nature by way of experiment, and for the honor of the profession to continue mutual love and affection among themselves," and this oration has been given annually until this day. A generous provision, a noble object, a wise and notable compliance. Harvey died June 3, 1657, in the eightieth year of his age.

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN ®
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custom, I interposed by observing "How free you yourself are from the fault you indicate all know who are acquainted with you; and this is the reason wherefore the learned world, who are aware of your unwearied industry in the study of philosophy, are eagerly looking for your farther experiments."

"And would you be the man,"* said Harvey, smiling, "who should recommend me to quit the peaceful haven where I now pass my life and launch again upon the faithless sea? You know full well what a storm my former lucubrations raised. Much better is it oftentimes to grow wise at home and in private, than by publishing what you have amassed with infinite labour, to stir up tempests that may rob you of peace and quiet for the rest of your days."—*From the "Epistle," written by Dr. George Ent, prefixed to Harvey's "Treatise on the Generation [or Development] of Animals," published in* 1651.

HARVEY COMPARED AND CONTRASTED WITH HUNTER

William Harvey may perhaps be compared more fitly with John Hunter† than with any single scientific man

* The conversation here recorded took place at Christmas, 1650, when Harvey was in his 73rd year. The defeat and ruin of the royalist party had given him a somewhat gloomy view of life. Though he had made many observations and some important discoveries, he was averse to further bringing himself before the world. Nevertheless during this interview Dr. Ent persuaded him to consent to the publication of his "*Treatise on the Generation of Animals*," almost his last literary effort. "I gladly charge myself with the whole business of correcting the press," said the faithful Ent.

† John Hunter (1728-1793) physiologist and surgeon, and one of the great founders of the modern science of comparative anat-

who either preceded or followed him. Harvey laid the foundation of modern medicine by his discovery of the circulation of the blood. Hunter laid the foundation of modern pathology not by any single and striking discovery, but by a long course of careful observation. Harvey, like Hunter, was a careful and competent observer; both were skilled anatomists, both were ardent pathologists, both were comparative anatomists of a high order. By singular ill fortune we have lost the records of many years of careful work done by each of these great men. Harvey's work was destroyed or scattered by the violence of the times in which he lived, and we can only be grateful that so much is spared to us; Hunter's work was lost irrevocably by the crime of his trusted assistant and brother-in-law. Harvey, like Hunter, was choleric, but his nature was the more lovable, though each had the power, innate in every great teacher, of attaching to himself and enrolling in his work all sorts of unlikely people. The collecting or acquisitive spirit was equally developed both in Hunter and Harvey, but the desire for knowledge was less insatiable in Harvey.

The influence of breeding and education is nowhere more marked than in these two great men, otherwise so nearly allied. Harvey's knowledge is always well within the grasp of his intellect. He can formulate it, often in exquisite language, and it is so familiar to him that he can afford to use similes and images which show him to be a man of wide general education. He thinks clearly so that his unerring conclusions are drawn in a startlingly

omy—to be distinguished from his brother, William Hunter (1718-1783), a physiologist and physician, and the first great teacher of anatomy in England.

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DIRECCIÓN GENERAL DE BIBLIOTECAS

easy manner. Yet he was often hampered by the theories of the ancient philosophical schools of medicine. Hunter's knowledge was gigantic, but it was uncontrolled. His thoughts are obscure, and so ill-expressed that it is often difficult to discover what he would say. His conclusions too, are sometimes incorrect and are frequently labored, yet the advance in knowledge in the hundred years and more which separated him from Harvey afforded him many additional data.

Harvey's acquaintance with the literature of medicine enabled him to cite apposite examples, and must evidently have been of the greatest service to him in elucidating his problems. Hunter too often traversed paths which were already well-trodden, for his defective education prevented him from knowing the works of his predecessors. The atmosphere of courts and of the refined and learned society in which Harvey spent most of his life, has given a polish to his writings and a gentleness to his character which were wholly wanting to John Hunter, upon whom the *res angustae domi* *—absent in Harvey's case—had impressed a certain ruggedness of character; but in both there was a native strength and robustness of constitution which render them not dissimilar.—D'Arcy Power, F. S. A., F. R. C. S., *in "William Harvey," in "Masters of Medicine" Series.*

READERS' AND STUDENTS' NOTES

1. Perhaps the biographical account of Harvey most available to the ordinary reader is that in the series of monographs, entitled

* "Narrow circumstances of his life."

"Masters of Medicine," edited by Ernest Hart, D. C. L., editor of the *"British Medical Journal,"* published by Longmans, Green & Co., New York, at $1.25 each. The work in the series on *"William Harvey"* is written by D'Arcy Power, F. S. A., surgeon to the Victoria Hospital, Chelsea, London.

2. A brief but very excellent account of Harvey's discovery of "the circulation of the blood" is given in Arabella B. Buckley's *"Short History of Natural Science"* (New York: D. Appleton & Co.).

3. Harvey's great work is principally known by its English title: *"On the Motion of the Heart and Blood in Animals."* It was written in Latin. An edition of the standard translation of this work is edited by Alex. Bowie, M. D., C. M., and published by George Bell & Sons, London. Dr. Bowie prefixes to the work a short but interesting biographical account of Harvey.

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WILLIAM HARVEY

SELECTED STUDIES AND REMINISCENCES

HARVEY'S GLORIOUS LEGACY TO RATIONAL PHYSIOLOGY

That there is one blood stream, common to both arteries and veins; that the blood, poured into the right auricle, passes into the right ventricle; that it is from there forced by the contraction of the ventricular walls along the pulmonary artery through the lungs and pulmonary veins to the left auricle; that it then passes into the left ventricle to be distributed through the aorta to every part of the animal body; and that the heart is the great propeller of this perpetual motion, as in a circle;—this is the great truth of the motion of the heart and blood, commonly called the circulation, and must forever remain the glorious legacy of William Harvey to rational physiology and medicine in every land.—ALEXANDER BOWIE, M. D., C. M., *Editor of Harvey's "Motion of the Heart and Blood in Animals."*

HARVEY'S DEMONSTRATION COMPLETED BY MALPIGHI

In one point only was the demonstration of the circulation incomplete. Harvey could not discover the capillary channels by which the blood passes from the arteries to the veins. This gap in the circulation was supplied several

years later by the great anatomist, Malpighi, who in 1661 saw in the lungs of a frog, by the newly invented microscope, how the blood passes from the one set of vessels to the other. Harvey saw all that could be seen by the unaided eye in his observations on living animals; Malpighi, four years after Harvey's death, by another observation on a living animal, completed the splendid chain of evidence.—DR. P. H. PYE-SMITH, *in "Encyclopaedia Britannica."*

A GLIMPSE OF HARVEY'S CHARACTER, MIND, AND VIEWS

Harassed with anxious and in the end not much availing cares, about Christmas last, I sought to rid my spirit of the cloud that oppressed it, by a visit to that great man, the chief honour and ornament to our college,* Dr. William Harvey, then dwelling not far from the city. I found him, Democritus like, busy with the study of natural things, his countenance cheerful, his mind serene, embracing all within its sphere. I forthwith saluted him and asked if all were well with him? "How can it be," said he, "whilst the Commonwealth is full of distractions, and I myself am still in the open sea? And truly," he continued, "did I not find solace in my studies, and a balm for my spirit in the memory of my observations of former years, I should feel little desire for longer life. But so it has been, that this life of obscurity, this vacation from

* The College of Physicians, London. The "Epistle" of which this abstract forms a part was addressed:—"To the Learned and Illustrious, the President and Fellows of the College of Physicians, London." It was written in 1650, not long after the execution of Charles I, who had been a friend to Harvey, and a patron of his studies. The writer was Dr. (afterwards Sir) George Ent, a faithful disciple of Harvey.

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public business which causes tedium and disgust to so many, has proved a sovereign remedy to me."

I, answering said, "I can readily account for this. While most men are learned through others' wits, and, under cover of a different diction and a new arrangement, vaunt themselves on things that belong to the ancients, thou ever interrogatest Nature herself concerning her mysteries. And this line of study, as it is less likely to lead into error, so is it also more fertile in enjoyment, inasmuch as each particular point examined often leads to others which had not before been surmised. You, yourself, I well remember, informed me once that you had never dissected any animal—and many and many a one you have examined—but that you discovered something unexpected, something of which you were formerly uninformed."

"It is true," said he; "the examination of the bodies of animals has always been my delight, and I have thought that we might thence not only obtain an insight into the lighter mysteries of Nature, but there perceive a kind of image or reflex of the omnipotent Creator himself. And though much has been made out by the learned men of former times, I have still thought that much more remained behind, hidden by the dusky night of nature, uninterrogated: so that I have often wondered and even laughed at those who have fancied that everything had been so consummately and absolutely investigated by an Aristotle or a Galen, or some other mighty name, that nothing could by any possibility be added to their knowledge. Nature however is the best and most faithful interpreter of her own secrets; and what she presents, either more briefly or more obscurely in one department, that

she explains more fully and clearly in another. No one, indeed, has ever rightly ascertained the use or function of a part who has not examined its structure, situation, connection by means of vessels and other accidents, in various animals, and carefully weighed and considered all he has seen. The ancients, our authorities in science, even as their knowledge of geography was limited by the boundaries of Greece, so neither did their knowledge of animals, vegetables, and other natural objects, extend beyond the confines of their country. But to us the whole earth lies open, and the zeal of our travellers has made us familiar not only with other countries, and the manners and customs of their inhabitants, but also with the animals, vegetables and minerals that are met with in each. And truly there is no nation so barbarous which has not discovered something for the general good, whether led to it by accident, or compelled by necessity, which had been overlooked by more civilized communities. But shall we imagine that nothing can accrue to the wide domains of science from such advantages, or that all knowledge was exhausted by the first ages of the world? If we do, the blame very certainly attaches to our indolence, no wise to nature.

"To this there is another evil added. Many persons wholly without experience, from the presumed veri-similitude of a previous opinion, are often led by and by to speak of it boldly, as a matter that is certainly known; whence it comes, that not only are they themselves deceived, but that they likewise lead other incautious persons into error."

Discoursing in this manner and touching upon many topics besides with wonderful fluency and facility, as is his

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Sir Isaac Newton

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which may be stated thus: All planets revolve about the sun in elliptical orbits with the sun as one focus. But though these laws of Kepler's were wonderful conclusions to arrive at, yet even they afforded no key to the constitution of the solar system and of the universe. The laws were unrelated to each other. They were unrelated to any dominant principle of astronomical truth by which they might be explained. They were also unrelated to any known fact or principle of nature outside of astronomical phenomena. In short, though they were remarkable and curious, they explained nothing, and were themselves in need of explanation.

Now, what did Newton do? He discovered one simple law, so simple that it can be stated in twenty words, which, when properly understood and applied, explains all the facts that Kepler had established, and every other fact relating to the motions of the heavenly bodies that any other observer had ever established, or that any other observer has succeeded in establishing since Kepler's time. For it must be remembered that Kepler's so-called "laws" were in reality "facts," though they were facts that were based on an infinity of particular observations. But Newton's law is an elementary principle that pervades all nature, and is as applicable to explain the motion of a stone thrown from a boy's hand, or the motion of a ball projected from the mouth of a cannon, as the motion of a planet or a comet that whirls around the sun. His law, somewhat wordily expressed, is this: Every particle of matter in the universe is attracted by every other particle of matter in the universe with a force that is proportional to the mass of the attracting particle and also proportional to the inverse square of the distance between the particles. For

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DIRECCIÓN GENERAL DE BIBLIOTECAS

example, a certain particle of matter, say a cannon ball, is pulled to the earth with a force that we call its weight. If the earth had twice as much matter in it as it really has, but still remained of the same size, the weight of the ball would be twice what it now is. Also, if the cannon ball could be removed to a distance from the center of the earth twice its present distance, its weight would be only one-fourth of its present weight. And so on. Newton took this law, and he proved that the earth and all the other planets must revolve around the sun, and the moon around Jupiter, in exactly the same way as Kepler had demonstrated from Tycho Brahë's tables that they do revolve—that is, in elliptical orbits, with the sun or other attracting body in one focus, etc., etc.

It must not be supposed, when Newton had discovered his law, and had divined that it was going to be a sufficient explanation of the problem he wished to solve, that his task was an easy one. The inspiration of the idea came to him one day in his twenty-fourth year, when, sitting in his orchard pondering upon the matter, he saw an apple fall. The very force that drew the apple toward the earth might also, he thought, draw the moon toward the earth. And if the moon toward the earth, why not the earth toward the moon? Why not, too, the earth toward the sun? And what was the measure of that force? How did it operate? What effects would it produce? Would the motions of the planets be circular? or elliptical? or of some other figure? What would the shape of the earth be? What effect would the force have upon the waters of the earth? Would it account for the tides? These and many other such were the questions he asked himself. But even when he had thus got on the right track for the

solution of the problem, it took him months and years before he was satisfied that the explanation he had got was the true explanation. And it must not be supposed that Newton was a laborious mechanical calculator like Kepler. Newton invented whole systems of mathematical labor-saving processes to facilitate his calculations. No man that has ever lived could have proved what Newton proved with only the means he had to use when first he began his proof. But Newton's genius in the work he undertook was omnipotent. He not only invented new processes of calculation but he invented new means of observation. The refracting telescope which Galileo had designed he found to be cumbrous, difficult to make, and inefficient. He at once invented the reflecting telescope, the model upon which most astronomical telescopes since his day* have been made. Moreover, he took the problem and he reversed it. He proved not only that the law of gravitation as he stated it is sufficient to account for all the known motions of the heavenly bodies, but also that the motions of the heavenly bodies known can be accounted for only by a law of gravitation identical with that which he assumed.

One difficulty that Newton had in establishing his theory was the incorrectness of the supposed facts that he had to rely upon in working it out. For example, one supposed fact that he had to make use of in his calculations was the size of the earth, or, what is almost the same thing, the length of a geographical degree. At that time it was supposed that the length of a degree on the earth's surface was sixty miles. But, when Newton

* Or at least until comparatively recent years.

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used this length as a fact in his calculations, he was unable to reconcile the known motion of the moon around the earth with what his solutions based on his law of gravity showed that the motion should be. He therefore modestly laid his theory aside and was almost persuaded that after all he was wrong in it. Ten years later, however, he discovered that the length of the geographical degree was not sixty miles, but nearly seventy miles. He now resumed the problem, and on working it out had the satisfaction of being able to show that the motion which his theory demanded that the moon should have, exactly corresponded with the motion which the moon actually does have.

Newton was the most self-effacing philosopher known in the history of science. If it had not been for the persistent watchfulness of those who knew his genius, it is probable that many of his discoveries and solutions would never have become known to the world except by accident. Some of his greatest discoveries became known only because his friends took it upon themselves to make them known. His "*Principia*," the work that embodies his theory of gravitation, and his solutions of the motions of the heavenly bodies, was not published till 1687, although it had been practically ready for publication for some years before that date. Even then it was published only through the kindness and painstaking interest of Halley, afterwards Astronomer Royal. As it was, Halley had great difficulty (because of the controversy Newton feared it would provoke) in persuading him to publish the very part the world would be most interested in, the part that explained the motions of the solar system. But a more remarkable instance of Newton's modesty even than this is recorded. In the working out of the problem relating to the motions of the moon, Newton had obtained a result which did not agree with a fact established by astronomical observation. This discrepancy remained for many years the only thing known to science that the law of gravitation did not account for. And yet, so scrupulous is science, because of this small discrepancy, the universality of the law was to some extent doubted. Even new statements of it were proposed. But in the beginning of the present century, a distinguished French mathematician discovered that by working out the problem with greater completeness in some details that had previously been neglected, theory and fact might be reconciled. The point of importance is this: A few years ago, among some unpublished papers of Newton's, there was found, worked out by Newton himself, the problem in its full completeness. Newton had thus caused the discrepancy to disappear, and yet had not said a word about it to anyone.

Newton's character was as noble and lovable as his genius and career were distinguished. The details of his life, too, are very interesting, but few of them can be recounted here. He was born at Woolsthorpe, in Lincolnshire, and was the only son of a father who died before his birth. As an infant he was weak and puny, and his life was many times despaired of, but he grew up to have a fair measure of health and strength, and he lived to a good old age. In his childhood he was remarkable principally for his devotion to all sorts of ingenious boyish contrivances, such as windmills, water clocks, sundials, aerial lanterns, and the like. As a youth he became studious and deeply absorbed in physical problems some-

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DIRECCIÓN GENERAL DE BIBLIOTECAS

III. SIR ISAAC NEWTON

1642-1727

BIOGRAPHICAL STUDY

BY JOHN EBENEZER BRYANT, M. A.

Galileo's was the greatest genius that in the realm of physical science up to his era the world had ever known. But on the very day that Galileo died—December 25, 1642—a greater genius even than Galileo's was given to the world—a genius that in the realm of mathematics, and of mathematics applied to science, was the greatest ever possessed by man. And even this is an insufficient statement. for it implies comparison. But Newton's genius in the field he especially cultivated was incomparable. Neither an equal nor an approximating second can be named with it. In the power of abstract mathematical investigation, and especially in the power of investigating the mathematical laws which dominate the physical world, Newton is not simply peerless. His reputation is like a sun. When it is seen no other luminary is visible.

To understand something of what Newton did for the world of science it will be best to take up his greatest achievement—namely, his discovery of the law of gravita-

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DIRECCIÓN GENERAL DE BIBLIOTECAS

tion, and his application of it to the explanation of the motions of the solar system. To do this it will first be necessary to glance at what previous investigators had discovered or achieved. Copernicus (1473-1545) had controverted the old theory of the constitution of the universe (namely, that the earth is the center of the universe, and that sun, moon, and stars all revolve about the earth) and had stated the true theory, now called in his honor the "Copernican theory" (namely, that the earth is a planet; that the planets revolve about the sun; that the moon is a secondary planet and revolves about the earth; that the sun, with its planets primary and secondary, constitute one system called the "solar system;" and that this system is only a very small portion of the universe). Galileo (1564-1642) had by means of his invention of the telescope, and his fine powers of physical demonstration, established innumerable proofs of the truth of this theory. Tycho Brahë (1546-1601), a Danish noble, one of the most painstaking and accurate astronomical observers that the world has ever known, had accumulated an enormous mass of recorded observations that embodied exact particulars as to the revolutions of the planets—their paths, their periods, their positions at certain times in their periods, their distances from the sun, etc.—but these particulars he was unable either to systematize or to show to be affected by fixed general laws. Finally Kepler (1571-1630), an assistant of Tycho Brahë's, a most indefatigable calculator and investigator, had taken the observations of his master, and, by wonderful ingenuity continued through many years of laborious industry, had discovered that the motions of the planets seemed to obey three laws (now known as the "three laws of Kepler"), the first of

SIR ISAAC NEWTON.

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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.

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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.

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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 phe-

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DIRECCIÓN GENERAL DE BIBLIOTECAS

nomena 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.

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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.

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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.

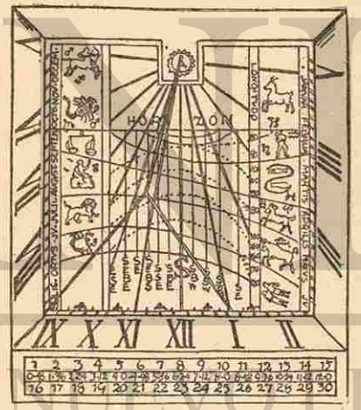
We have seen, that ever since the discovery of the laws of motion [by Galileo], men had known that some force must act upon the moon at every point towards the interior of her orbit; and it had been suggested that it might act towards the center of the earth; but no one

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

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Benjamin Franklin

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delphia and subsequently an alderman. In 1752 he was elected by his fellow-citizens a member of the General Assembly. In 1753 he was made Postmaster-General of the colonies. In 1757 he was sent by the Assembly to England as agent of the colony to look after the interests of the colonists as against the Penns, the so-called "proprietaries" of the colony. He remained in England in this employment for five years.

In 1764 Franklin went to England again in a similar capacity and this time he remained eleven years, during which period he represented not only Pennsylvania but Massachusetts, New Jersey, and Georgia. If any influence in the world could have sufficed to restrain the king and government of Great Britain from alienating the affections and loyalty of their colonies in America Franklin would have been able to exert that influence. But even he failed, and not only failed but at last was treated ignominiously. In 1775 he returned to Philadelphia, and at once was in the very thick of all those movements which led to the declaration of independence and the war against Great Britain. He was a member of the Congress of 1775 and served in no less than ten committees in it. He was a member of the Congress of 1776, and was one of the committee of five appointed to draw up the Declaration of Independence, and was one of the signers of that declaration. He was also president of the convention that was formed to organize a republican government for the province of Pennsylvania. In September, 1776, he was chosen one of three commissioners to go to France to represent in that country the newly formed American republic, and, if possible, to secure its recognition by the government of France. In

1778 (March 20) he had the satisfaction of being formally received by the king of France and of being a chief participant in the ceremony by which the United States of America was first recognized by France as an independent nation. Remaining on at his post, he was, in February, 1779, made sole commissioner or envoy plenipotentiary of the republic at the court of France. During the period of this representation he succeeded in borrowing for the republic from the French nation, for the purpose of carrying on the war of the revolution and organizing and sustaining the new government, no less a sum than 26,000,000 francs. No man in America or out of it could have done this but Franklin. In 1781 he was appointed joint commissioner to settle terms of peace with England, and on November 30, 1782, he, with Adams, Jay, and Laurens, affixed his name to the document by which peace was assured, and his country acknowledged by Great Britain to be free and independent. And though now 76 years old and longing for rest he was not yet permitted to return to his home. He had to remain on for three years longer. And when, at last, in 1785, he did return home he found that his country was still desirous of his services. For three years he was president of the newly constituted commonwealth of Pennsylvania, at each election being chosen unanimously. And, greatest honor of all, he was a member of the convention of 1787, the convention that finally determined the constitution of the republic; and not only so, but it was he who, more than any one else, by his wisdom, by his prescience, and by his faculty of conciliation, was able to devise, and to get accepted in that convention, the clauses which settled the points of contention that were so terribly in dis-

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pute—points which if not settled would have broken up the republic at its very beginning. This was when he was in his 82d year. But, still working and planning for the republic, he lived three years longer yet. When he died —April 17, 1790—he had entered upon his 85th year and his time of life was full. Yet the republic mourned for him as if he still had been in the prime of youth.

But no summary of details such as the above can give an adequate idea of either the interest or the importance of Franklin's life. It was a life that, for all he was so practical, was full of romance and light and color and agreeable charm. Wherever he was, with whatever class it was his business to associate, he made hosts of friends, and won general favor no less by his pleasing manner than by the pleasing interestingness of his conversation. But it was his thorough good sense that most impressed itself upon those with whom he had to deal. His neighbors and fellow-citizens soon saw that when he recommended a scheme that scheme was both deserving and certain of success. They knew at once that it would have for its object the benefit of the people. They knew, too, that under his practical direction it would soon accomplish all that it was intended to accomplish. They had proof of this not only in the way he managed his own affairs but also in the way he managed those of the public. For example, when he took over the postoffice of Philadelphia it was full of irregularities, but he soon corrected all these. Again, when he took over as Postmaster-General the management of the postal system of all the colonies, there was no surplus revenue for the home government, and the service was irregular and incomplete. Franklin traveled all over the main postal

routes, visited all the main postoffices, and soon, not only had a service that was satisfactory to the colonists, and that gave him a good salary besides, but had one that furnished a good revenue to the home government as well.

Franklin was an ideal citizen. While he loved his own business, and took every pains to make money out of it, he never failed to serve the people publicly when asked to do so, or to serve them privately of his own motion if he saw that his service so rendered would be productive of benefit. As is well known, it was he who organized the first police and fire protection for his adopted city. It was he, too, who established, or at least was most instrumental in establishing, those splendid institutions the University of Pennsylvania, the Pennsylvania Hospital, and the Public Library of Philadelphia. It was he also who founded the American Philosophical Society. At one time, when the general commanding the British forces in America (General Braddock) wanted a great number of wagons for transport, and when there seemed no way of getting them except by confiscation, it was the patriotic Franklin who took upon himself the whole trouble of getting them, even going so far as personally guaranteeing the payment for them, and doing all this without the hope of one penny of commission, interest or reward. Similarly, before he set out for Paris, when the war of the revolution was going on, he lent to congress every pound he could raise for the purpose of helping to carry on the war. And while in Paris he defrayed his own expenses, with little certainty of ever getting his disbursements back again. Nor was he less an ideal citizen in the attitude he took in regard to the sacredness of public service. He asked for no public office, either representative or executive. His

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elections and his appointments were all made not upon his own suggestion. And though he valued his public offices highly, and on the other hand did not neglect his own interests while he held them, yet he valued his own self-respect too highly to seek them of his own accord; and in all his dealings with the public interest it was in every case his country first and himself second.

It is, however, with Franklin as a man of science that we are most concerned here. And yet Franklin the scientist is but the same as Franklin the statesman, the journalist, or the man-of-letters. His whole life was a constant effort to increase his knowledge and improve his powers, and a constant endeavor to apply his knowledge and his powers in some practical way to the benefit of his fellows. This is the explanation of his career as a scientist. He became interested in electricity as a matter of curiosity, as hundreds of other persons in the world at that time had become interested in it. But he saw that little practical use was being made of such knowledge of it as had already been obtained. He saw, too, that the common explanation of electricity—namely, that it was created when the electrical body was rubbed—was not in accordance with common sense. So in his simple, homely way he endeavored to examine the phenomena of electricity and see if they could not be explained by principles that would commend themselves to his common sense. This he was soon able to do. He was soon able to establish the facts that electricity is not created by the operator, and that on the other hand it cannot be destroyed, that it only can be made manifest. He also was able to establish conclusively what he had guessed from the beginning (and what others besides him had guessed, but never had been able to establish), namely, that the electricity excited in glass by rubbing it with silk, or in sealing-wax or amber by rubbing it with flannel, is identical with that fearsome phenomenon in the heavens which we call lightning. He made a kite of silk and furnished it with a long, slender pointed rod of steel, and sent it up in the sky in a thunder shower, and was able to obtain from a steel key at the lower end of the string that held the kite sparks and currents of sparks, just as he was able to obtain them from his electrical machine. Not only so, but he was able to charge with these sparks Leyden jars, and to do with the sparks so obtained exactly what he could do with sparks obtained from an electrical machine, or from rubbed sulphur, amber, sealing-wax, or glass. And not only this, but he was further able to show that the electricity obtained from the clouds in thunder storms is of two kinds, just as ordinary electricity is of two kinds—namely, one kind like the electricity obtained from glass rubbed with silk, and the other like the electricity obtained from amber or sulphur or wax rubbed with flannel. But Franklin's practical nature could not be content with the discovery of mere scientific facts like these. He at once set about seeing what useful invention could be devised from his new knowledge, and so contrived the lightning-rod as a protection from destruction by lightning of houses and ships.

These experiments of Franklin's were begun in 1746, but it was not until 1749 that he made his famous experiments identifying electricity and lightning. He had sent accounts of his earlier experiments to the Royal Society of London, but they were not looked upon by that body as being of much importance, and when he suggested that electricity and lightning might be identical his suggestion

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was received with derision as something ridiculous. The great experiments of 1749 by which that identification was established were therefore made with some secrecy; for Franklin, as every one is, was sensitive to ridicule. But he was soon able to turn the tables on those who derided him. Though the Royal Society had declined to publish his earlier experiments he had found publication for them in the Gentleman's Magazine of London; and they had scarcely been published before they began to attract attention throughout all Europe. When, therefore, the experiments of 1749 were published the name of Franklin was in every one's mouth. "The Philadelphia experiments," as they were called, were the rage. People of society as well as people of science, crowned heads as well as students and philosophers, made haste to repeat them, and when Franklin went to England in 1757 it was to find himself a famous man. Learned societies of every sort, not only in England but throughout all Europe, made haste to enroll him among their numbers. The University of Edinburgh and the University of Oxford bestowed upon him their honorary degrees. The Royal Academy of Sciences of Paris made him one of their eight foreign members. The Royal Society of London, repenting their earlier injustice, elected him first a member and then a fellow, and this without the requiring of the customary fee. They also granted him their Copley medal, and announced to him that they would send him their "*Transactions*" as long as he lived. And thus in every respect was Franklin's life full of renown and honor. At home he was respected for his character, loved for his personal qualities, admired for his abilities, and, because of his wisdom and discretion, entrusted with the most difficult and

honorable employments. Abroad he was looked upon, not only as the greatest man of his nation, but as one of the greatest men of the age—as uniting in himself, indeed, the wisdom of the sage, the observing and reasoning talent of the philosopher, the polish, the tact, the discretion, the shrewdness of the born diplomatist, the abounding common sense and practical discernment of the successful man of affairs, and the distinguishing intellectual qualities of the accomplished literarian. And with this estimation of his contemporaries, both fellow-countrymen and men of other nations, the estimation of all subsequent times substantially agrees.

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IV. BENJAMIN FRANKLIN

1706-1790

BIOGRAPHICAL STUDY

BY JOHN EBENEZER BRYANT, M. A.

Few men in the history of nations have deserved greater honor at the hands of their countrymen than Benjamin Franklin. Few men have received greater. It is over a hundred years since he died, and to-day his name and fame are more renowned than ever they were. Study and scrutiny of his life and deeds only make clearer and more indubitable the claims of his memory to the respect and admiration, the veneration and affection, of all his compatriots to the latest generation. It is true his character was not faultless. But his imperfections were those of common humanity, and, indeed, were only such as served to bring him within the range of the sympathies of common humanity. But he was so utterly without pretense and affectation that his imperfections were seen, as it were, through a full transparency. Nothing in him was hidden. Yet because of these imperfections attempts were made in his lifetime to lessen the public appreciation of his worth. Such attempts have been made even in our

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DIRECCIÓN GENERAL DE BIBLIOTECAS

own day. All these attempts have but increased the admiration of humanity for one who was great with a greatness that was apprehended by every one. For this was and is the essential characteristic of Franklin's renown. In all his multifarious and splendid achievements there was nothing the meaning and merit of which were not at once intelligible to the people. Even as a philosopher the end and aim of all his inquiries was the useful application of nature's laws so as to conduce to the common benefit. So likewise as a servant of the people, a public-spirited citizen, a statesman, an agent of the colonies, an ambassador of the republic, his one desire was to promote the popular welfare. So also as a writer, a journalist, a pamphleteer, a controversialist. Consummate skill in steering clear of visionary ideals, consummate power in seeing and grasping the immediately available common good—such were the distinguishing characteristics of Franklin. As such he was understood and believed in and followed and honored as no other man of his time was. And as such he is believed in and followed and honored to-day.

The details of Franklin's life scarcely need mentioning, for perhaps no life is better known to all worthy citizens of the republic than his. Born in Boston, January 17, 1706, the tenth and youngest son of a good and sober-minded couple who destined him as a tithe-offering to the church, but who by stress of circumstances were obliged to put him at an early age to labor in their own business—that of soap and candle making—his life, from the very beginning, was accustomed to industry, frugality, and morality. It was accustomed, too, to an intellectual outlook; for the father used to discuss with his children

at table, not trivial household affairs, but graver matters requiring both thought and speculation. Young Benjamin Franklin never knew the time when he could not read; and though he had but little formal education he grew up to be fond of books and of improving his mind by the acquisition of good, sound knowledge. At twelve years of age he became apprenticed to his brother, who was a printer and who soon started a newspaper, the second in America. Benjamin Franklin wrote for this paper—at first secretly, afterwards openly—and was for some time, indeed, its nominal editor and publisher. But his brother using him harshly, he left him and left his home—in fact, "ran away." This was in his 17th year. He went to Philadelphia, where he obtained employment as a printer. In 1724 he went to London, England. There he remained eighteen months, working at his trade and perfecting himself in it in every particular. In 1726 he returned to Philadelphia, where he was soon able to start business on his own account. By assiduity and discretion his business prospered, and it was not long before his press was the most distinguished and the best patronized in America. In 1729 he bought out and practically started the *Pennsylvania Gazette*, and this paper he edited and published until 1765. In 1732 he published the first issue of *"Poor Richard's Almanac,"* a publication that he continued for twenty-five years, securing for it a sale of 10,000 copies annually, which in that day was as remarkable as a sale of fifty times that number would be in our day. In 1736 he was chosen a clerk of the General Assembly of Pennsylvania. In 1737 he was made postmaster of Philadelphia. Not long afterward he was made a member of the Common Council of Phila-

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was received with derision as something ridiculous. The great experiments of 1749 by which that identification was established were therefore made with some secrecy; for Franklin, as every one is, was sensitive to ridicule. But he was soon able to turn the tables on those who derided him. Though the Royal Society had declined to publish his earlier experiments he had found publication for them in the Gentleman's Magazine of London; and they had scarcely been published before they began to attract attention throughout all Europe. When, therefore, the experiments of 1749 were published the name of Franklin was in every one's mouth. "The Philadelphia experiments," as they were called, were the rage. People of society as well as people of science, crowned heads as well as students and philosophers, made haste to repeat them, and when Franklin went to England in 1757 it was to find himself a famous man. Learned societies of every sort, not only in England but throughout all Europe, made haste to enroll him among their numbers. The University of Edinburgh and the University of Oxford bestowed upon him their honorary degrees. The Royal Academy of Sciences of Paris made him one of their eight foreign members. The Royal Society of London, repenting their earlier injustice, elected him first a member and then a fellow, and this without the requiring of the customary fee. They also granted him their Copley medal, and announced to him that they would send him their "*Transactions*" as long as he lived. And thus in every respect was Franklin's life full of renown and honor. At home he was respected for his character, loved for his personal qualities, admired for his abilities, and, because of his wisdom and discretion, entrusted with the most difficult and

honorable employments. Abroad he was looked upon, not only as the greatest man of his nation, but as one of the greatest men of the age—as uniting in himself, indeed, the wisdom of the sage, the observing and reasoning talent of the philosopher, the polish, the tact, the discretion, the shrewdness of the born diplomatist, the abounding common sense and practical discernment of the successful man of affairs, and the distinguishing intellectual qualities of the accomplished literarian. And with this estimation of his contemporaries, both fellow-countrymen and men of other nations, the estimation of all subsequent times substantially agrees.

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10. *Cleanliness.*

Tolerate no uncleanness in body, clothes, or habitation.

11. *Tranquillity.*

Be not disturbed at trifles, or accidents common or unavoidable.

12. *Chastity.*

13. *Humility.*

Imitate Jesus and Socrates.

The last of these virtues was added to the list at the suggestion of a Quaker friend. Franklin claims to have acquired a good deal of the *appearance* of it, but concluded that in reality there was no passion so hard to subdue as *pride.* "For even if I could conceive that I had completely overcome it, I should probably be proud of my humility." The virtue which gave him most trouble, however, was order, and this he never acquired.—DR. WILLIAM GARNETT.

FRANKLIN'S "POOR RICHARD," AND "FATHER ABRAHAM"

Nothing, perhaps, shows the fondness of the people for the sayings of Mr. Saunders [Poor Richard] better than the history of that famous piece in which the best of them are brought together. It came out in a day of darkness and of gloom. The French and Indian war had been raging for four years; and success was still with the French. Washington had been driven from Fort Necessity. Braddock had perished in the woods. The venture

against Niagara had failed. That against Ticonderoga had done little. The sea swarmed with French and Spanish privateers. Trade was dull. Taxes were heavy. Grumbling was everywhere. Men of all sorts bemoaned the hard times. The war ought to stop. The assemblies, the grumblers said, ought to put out more credit bills. The mother country ought to pay the cost of colonial troops. Were every one of these remedies used they could not, Franklin thought, cure the hard times. Economy and thrift alone could do so. Here, then, was a fine chance for a sermon by "Poor Richard" with a reasonable hope of being heard. A sermon was accordingly written, put in the mouth of a wise old man called Father Abraham, and published in the almanac for 1758. It was pretended that "Poor Richard" had heard the speech at an auction. A fitter place Father Abraham could not have chosen; for the auctions of those days were shameful scenes of extravagance and folly. Called thither by bell and crier, the people gathered long before the hour named, were plied with rum at the cost of the vendue master till, when the sale opened, they offered bids and paid prices such as never would have been had from them in their sober senses. To a throng of this sort Father Abraham spoke.

. . . . . .

The praise bestowed on Father Abraham, by those who heard him at the auction stand, was soon taken up by the civilized world. The sale of the almanac had always been large. Year after year ten thousand copies, or one for every hundred inhabitants of the land, came from the press. But ten thousand copies did not begin to meet the demand for "Poor Richard" of 1758. Such was the

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eagerness of the people to read the Address that the newspapers published it again and again. Franklin himself sent it forth as a broadside, and at last, in 1760, his nephew, Benjamin Mecom of Boston, made it into a pamphlet, adorned with a huge folding plate of Father Abraham in his study. The title is "Father Abraham's Speech to a great number of people, at a Vendue of Merchants' Goods; introduced to the public by Poor Richard (a famous Pennsylvanian conjurer and almanac-maker), in answer to the following questions: 'Pray, Father Abraham, what do you think of the times? Won't these heavy taxes quite ruin the country? How shall we be ever able to pay them? What would you advise us to?'" . . . . . Thus started by Mecom, the speech was quickly republished in the same form at New Haven, at New London, at Philadelphia.

Franklin was then at London, and thither his work followed him; was printed on a broadside, was widely circulated, was hung up on the walls of workshops and houses; crossed the channel; was done into French, and bought in great quantity by priests and nobles for distribution among the poor. Since that day it was spread over the whole of Europe, and may now be read in French, in German, in Spanish, in Italian, in Russian, in the language of Holland, in the language of Bohemia, in modern Greek, in Gaelic, and in Portuguese. Under the title *"La Science du Bonhomme Richard,"* it has been thirty times printed in French and twice in Italian. As *"The Way to Wealth,"* it has been issued twenty-seven times in English in pamphlet form, and innumerable times as a broadside. Never since 1770 has a period of five years been suffered to go by without a new edition of *"The Way to Wealth"* appearing in some form in some language. Printers have used it to advertise their business. Shorthand writers have issued it in phonetic characters. It may be found in the publications of societies for improving the condition of the poor; in "Prompters;" in "Immortal Mentors;" in "Moral Tracts;" in "First Notions of Political Economy;" in "Elements of Morals;" in "Whole Duties of Men and Women;" and as a rebus for the amusement of the idle. Without question, the speech of Father Abraham is the most famous piece of literature the colonies produced. After 1758, Franklin wrote no more for "Poor Richard." In 1796 the almanac ceased to appear.—JOHN BACH MCMASTER, *in "Benjamin Franklin as a Man of Letters," in "American Men of Letters" Series.*

FRANKLIN'S AUTOBIOGRAPHY

Since the day whereon Franklin's Autobiography was first made public, innumerable books written by our countrymen have come into fashion and gone out of fashion and all but disappeared. Hardly a man whose name adorns the American literature of the first half of the century but saw his books pass through a period of neglect. Irving did, and Cooper, and Halleck, and Willis, and Hawthorne, and many more. But the Autobiography of Franklin has suffered no neglect. With the great mass of our people it has always been popular, and has in the United States alone been republished fifty-one times. What is better, the people read it. Such records as can be had from public libraries all over the country reveal the fact that the book is read at each of them on an aver-

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age of once a month. At some, where the humblest and least educated come, its popularity is amazing. Indeed, at the Cooper Union Library in New York, the Autobiography, during 1885, was called for more than four hundred times, and the Life by Mr. Parton, upwards of one thousand. If it be put with books of its kind, and judged as an autobiography, it is beyond doubt the very best. If it be treated as a piece of writing and judged as literature, it must be pronounced the equal of Robinson Crusoe, one of the few everlasting books in the English language. Save "Poor Richard," no other piece of Franklin's is so widely admired, and on these two most unquestionably rest his literary fame.—JOHN BACH MCMASTER.

FRANKLIN AS A MAN OF LETTERS

The place to be allotted Franklin among American men of letters is hard to determine. He founded no school of literature. He gave no impetus to letters. He put his name to no great work of history, of poetry, of fiction. Till after his day, no such thing as American literature existed. To place him, with respect to Irving, Bryant, Cooper, Prescott, and the host of great men that came after him, is impossible. There is no common ground of comparison. Unlike them, he never wrote for literary fame. Had he cared for such fame, he would not have permitted friends and strangers to gather and edit his writings during his lifetime; he would not have suffered death to overtake him when the Autobiography was but half done; he would not have made it an invariable rule to never send anything to the press over his own name. His place is among the giant race of pamphleteers and

essayists, most of whom went before, but a few of whom came immediately after, the war for independence. And among them he is easily first. Their merit lies in what they said: the merit of Franklin's lies not only in what he said, but in the way in which he said it.—JOHN BACH MCMASTER.

FRANKLIN'S STYLE AS A WRITER AND KNOWLEDGE OF LIFE

Franklin produced little which did not serve an immediate and practical purpose, and which was not expressed in the plainest and clearest English. A metaphor, a simile, a figure of speech of any kind, is rarely to be met with. The characteristics of his writings are, short sentences made up of short words, great brevity, great clearness, great force, good-humor, apt stories, pointed allusions, hard common sense, and a wonderful show of knowledge of the practical art of living. Knowledge of life he had in the highest degree. He knew the world; he knew men and the ways of men as few have known them. No other writer has left so many just and original observations on success in life. No other writer has pointed out so clearly the way to obtain the greatest amount of comfort out of life. What Solomon did for the spiritual man that Franklin did for the earthly man. The Book of Proverbs is a collection of receipts for laying up treasure in heaven. "Poor Richard" is a collection of receipts for laying up treasure on earth.—JOHN BACH MCMASTER.

AN INSTANCE OF FRANKLIN'S WIT

On that memorable 4th of July, 1776, when the Declaration of Independence was signed Franklin took part in

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BENJAMIN FRANKLIN

SELECTED STUDIES AND REMINISCENCES

FRANKLIN'S MARRAIGE

Finding difficulties in the way of a financial alliance, Franklin appears to have bethought himself of affection as a substitute for dollars, so he blew into the ashes of an old flame and aroused some heat. Before going to England he had engaged himself to Miss Deborah Read; but in London he had pretty well forgotten her, and had written to her only a single letter. Miss Read, meanwhile, apparently about as much in love as her lover, had wedded another man, "one Rogers, a potter," a good workman but worthless fellow, who soon took flight from his bride and his creditors. Her position had since become somewhat questionable; for there was a story that her husband had another wife living, in which case of course her marriage with him was null. There was also a story that he was dead. But there was little evidence of the truth of either tale. Franklin, therefore, hardly knew what he was wedding, a maid, a widow, or another man's wife. Moreover, the runaway husband "had left many debts, which his successor might be called upon to pay." Few men, even if warmly enamored, would have entered into the

BENJAMIN FRANKLIN.
Painting by Duplessis.

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DIRECCIÓN GENERAL DE BIBLIOTECAS

matrimonial contract under circumstances so discouraging; and there are no indications, save the marriage itself, that Franklin was deeply in love. Yet on September 1, 1730, the pair were wedded. Mrs. Franklin survived for forty years thereafter, and neither seems ever to have regretted the step. "None of the inconveniences happened that we had apprehended," wrote Franklin; "she proved a good and faithful helpmate; assisting me much by attending the shop; we throve together, and have ever mutually endeavored to make each other happy." A sensible, comfortable, satisfactory union it was, showing how much better is sense than sensibility as an ingredient in matrimony. Mrs. Franklin was a handsome woman, of comely figure, yet nevertheless an industrious and frugal one; later on in life Franklin boasted that he had "been clothed from head to foot in linen of [his] wife's manufacture." An early contribution of his own to the domestic *ménage* was his illegitimate son, William, born soon after his wedding, of a mother of whom no record or tradition remains. It was an unconventional wedding gift to bring home to a bride; but Mrs. Franklin, with a breadth and liberality of mind akin to her husband's, readily took the babe not only to her home but really to her heart, and reared him as if he had really been her own offspring. Mr. Parton thinks that Franklin gave this excellent wife no further cause for suspicion or jealousy.—JOHN T. MORSE, JR., *in "Benjamin Franklin" in "American Statesmen" Series.*

FRANKLIN'S EFFORT AT SELF-IMPROVEMENT IN MORALS

After his marriage, Franklin conceived the idea of obtaining moral perfection. He was not altogether satisfied

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with the result, but thought his method worthy of imitation. Assuming that he possessed complete knowledge of what was right or wrong, he saw no reason why he should not always act in accordance therewith. His principle was to devote his attention to one virtue only at first for a week, at the end of which time, he expected the practice of that virtue to have become a habit. He then added another virtue to his list, and devoted his attention to the same for the next week, and so on, until he had exhausted his list of virtues. He then commenced again at the beginning. As his moral code comprised thirteen virtues, it was possible to go through the complete curriculum four times in a year. Afterwards he occupied a year in going once through the list, and subsequently employed several years in one course. A little book was ruled, with a column for each day and a line for each virtue, and in this a mark was made for every failure which could be remembered on examination at the end of the day. It is easy to believe his statement: "I am surprised to find myself so much fuller of faults than I had imagined; but I have the satisfaction of seeing them diminish."—WILLIAM GARNETT, M. A., D. C. L., *in "Heroes of Science—Physicists."*

FRANKLIN'S THIRTEEN VIRTUES

The senses in which Franklin's thirteen virtues were to be understood were explained by short precepts which followed them in his list. The list was as follows:

1. *Temperance.*

Eat not to dullness: drink not to elevation.

2. *Silence.*

Speak not but what may benefit others or yourself; avoid trifling conversation.

3. *Order.*

Let all your things have their places; let each part of your business have its time.

4. *Resolution.*

Resolve to perform what you ought; perform without fail what you resolve.

5. *Frugality.*

Make no expense but to do good to others or yourself; that is, waste nothing.

6. *Industry.*

Lose no time; be always employed in something useful; cut off all unnecessary actions.

7. *Sincerity.*

Use no hurtful deceit; think innocently and justly; and, if you speak, speak accordingly.

8. *Justice.*

Wrong none by doing injuries, or omitting the benefits that are your duty.

9. *Moderation.*

Avoid extremes; forbear resenting injuries so much as you think they deserve.

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the signing. As the patriots stood about the table ready to affix their signatures, Mr. Hancock remarked, "We must be unanimous; there must be no pulling different ways; we must all hang together." To which words of exhortation Franklin quickly replied, "Yes, we must indeed all hang together, or most assuredly we shall all hang separately."

FRANKLIN IN FRANCE

The choice [of commissioners to make a treaty with France] was made on the 26th of September [1776]. One month later to a day Franklin boarded the *Reprisal* and sailed for France. The passage was stormy and the sea covered with English cruisers. More than once the *Reprisal* was hotly chased. More than once Captain Wickes beat to quarters and made ready to fight. But he reached the coast of France in safety early in December, and dropped anchor in Quiberon Bay not far from the mouth of the Loire. There he was kept by contrary winds for four days, when Franklin, weary with waiting, landed at Auray and went on to Nantes.

At Nantes he was welcomed with every manifestation of delight, and he stayed there eight days. A story is extant that when Lord Stormont, the English minister, heard that Franklin had landed, he threatened to quit France if the American rebel was suffered to put foot in Paris; that to quiet him, messengers were actually sent to Nantes to forbid Franklin coming to the capital; that they were sent by one route when it was well known Franklin would travel by another; and that, being once at Paris, Vergennes protested that the laws of nations and of hospitality would not allow him to send the old

man away. But Franklin had no wish to embarrass the ministry, and, after a few days' stay at Paris, withdrew quietly to Passy, where he ever after remained.

His arrival at Nantes had created a great sensation. But his reception at Nantes was cold and tame compared with that which awaited him at Paris. Princes and nobles, statesmen and warriors, women of rank, men of fashion, philosophers, doctors, men of all sorts, welcomed him with a welcome such as had never yet fallen to the lot of man. To his house came Turgot, now free from the cares of state, and Vergennes, who still kept his portfolio; Buffon, first among naturalists, and Cabanis, first among physicians; D'Alembert and La Rochefoucauld, Raynal, Morellet, Mably and Malesherbes, for the fame of Franklin was great in France. Philosophers ranked him with Newton and Leibnitz. Diplomatists studied his answers in the examination before the commons of England. The people knew him as Bonhomme Richard. Men of letters pronounced "*The Way to Wealth*" "*un très-petit livre pour des grandes choses*," and, translated and annotated, it was used in the schools. Limners spent their ingenuity in portraying his features. His face was to be seen on rings, on bracelets, on the covers of snuff-boxes, on the prints that hung in the shop-windows. His bust was set up in the royal library. Medallions of him appeared at Versailles. If he made a jest, or said a good thing, the whole of France knew it. To one who asked him if a statement of Lord Stormont, the English ambassador, was true, he replied, "No, sir, it is not a truth, it is a—Stormont." And immediately a "Stormont" became another name for a lie. To another, who came to lament with him over the retreat through

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humor" was still unborn, amid contemporaries who have left no trace of a jest, still less of the faintest appreciation of humor, all which he said and wrote was brilliant with both these most charming qualities of the human mind. Though sometimes lax in points of grammar, as was much the custom in his day, he wrote as delightful a style as is to be found in all English literature, and that too when the stilted, verbose, and turgid habit was tediously prevalent. He was a man who impressed his ability upon all who met him; so that the abler the man, and the more experienced in judging men, the higher did he rate Franklin when brought into direct contact with him; politicians and statesmen of Europe, distrustful and sagacious, trained readers and valuers of men, gave him the rare honor of placing confidence not only in his personal sincerity, but in his broad fair-mindedness, a mental quite as much as a moral trait.

It is hard indeed to give full expression to a man of such scope in morals, in mind, and in affairs. He illustrates humanity in an astonishing multiplicity of ways at an infinite number of points. He, more than any other, seems to show us how many-sided our human nature is. No individual, of course, fills the entire circle; but if we can imagine a circumference which shall express humanity, we can place within it no one man who will reach out to approach it and to touch it at so many points as will Franklin. A man of active as well as universal goodwill, of perfect trustfulness towards all dwellers on the earth, of supreme wisdom expanding over all the interests of the race, none has earned a more kindly loyalty. By the instruction which he gave, by his discoveries, by his inventions, and by his achievements in public life, he earns

the distinction of having rendered to men varied and useful services excelled by no other one man; and thus he has established a claim upon the gratitude of mankind so broad that history holds few who can be his rivals.—JOHN T. MORSE, JR.

READERS' AND STUDENTS' NOTES

1. Franklin was such a many-sided man that the literature devoted to his work and memory is very copious. To understand Franklin properly, however, the first thing one should do is to read his "*Autobiography.*" Of this famous work many editions are published—not a few of them quite low priced. Some of these editions, however, are "garbled and incomplete." John Bach McMaster says, "Whoever would read the '*Autobiography*' as it was written must go to the 'Bigelow edition.'" (Hon. John Bigelow, U. S. minister to France in 1867 obtained the original of the "*Autobiography*" in France in that year.) This "Bigelow edition" of the "*Autobiography*" is published in 3 vols. by J. B. Lippincott Co., Philadelphia, at $4.50.

2. A standard "*Life of Franklin*" and the one perhaps that is best known, is that by Parton (Boston: Houghton, Mifflin & Co., 2 vols., $5.00).

3. A very sympathetic "*Life of Franklin,*" a "Life" in which due emphasis is laid upon Franklin's work as one of the founders of the republic, is that by John T. Morse, Jr. in the "*American Statesmen*" series (Boston: Houghton, Mifflin & Co., $1.25).

4. Another account of Franklin, not quite so sympathetic as the foregoing, but nevertheless scholarly and discriminating, is that by John Bach McMaster in the "*American Men of Letters*" series (Boston: Houghton, Mifflin & Co., $1.25). In this book, of course, the literary side of Franklin's work is specially noted.

5. A recent biography of Franklin, and an excellent all-round account of the great man's life and work, is that by Edward Robins entitled "*Benjamin Franklin, Printer, Statesman, Phi-*

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losopher, and Practical Citizen," in the *"American Men of Energy"* series (New York: G. P. Putnam's Sons, $1.50).

6. Another recent biography of Franklin is that entitled *"The True Benjamin Franklin,"* by Sydney George Fisher (Philadelphia: J. B. Lippincott Co., $2.00). This work is highly eulogized by some critics, and quite as strongly dispraised by others. No one, however, questions the author's honesty of purpose, or his painstakingness.

7. An account of Benjamin Franklin for boys, "a boy's book on a boy's own subject," is Henry Mayhew's *"Young Benjamin Franklin, or The Right Road Through Life"* (New York: Harper & Brothers, $1.25).

8. Popular accounts of Franklin—not whole books—are found numerously. In Philip G. Hubert's *"Inventors"* in the *"Men of Achievement"* series, the opening chapter is devoted to Franklin, the other chapters being devoted to other great American inventors from Fulton and Whitney to Edison and Bell (New York: Scribners, $1.50).

9. In Dr. William Garnett's *"Heroes of Science—Physicists"* (New York: E. & J. B. Young & Co.), Franklin has a place along with such other great physicists as Boyle, Cavendish, Rumford, Young, Faraday, and Clerk Maxwell—truly a noble company.

Sir William Herschel

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the Jerseys and the misery at Valley Forge, he replied, "Ça ira, Ça ira" ("it will all come right in the end"). Frenchmen took up the words, remembered them, and in a time yet more terrible made them a revolutionary cry.

To the people he was the personification of the rights of man. It was seldom that he entered Paris. But when he did so, his dress, his wigless head, his spectacles, his walking-stick, and his great fur cap, marked him out as the American. If he went on foot, a crowd was sure to follow at his heels. If he entered the theater, a court of justice, a public resort of any kind, the people were sure to burst forth into shouts of applause. Their hats, coats, canes, snuff-boxes, were all *à la Franklin*. To sit at table with him was an honor greatly sought. Poets wrote him wretched sonnets. Noble dames addressed him in detestable verse. Women crowned his head with flowers. Grave Academicians shouted with ecstasy to see him give Voltaire a kiss. No house was quite in fashion that did not have a Franklin portrait over the chimney-piece, a Franklin stove in one of the chambers, and in the garden, a liberty tree planted by his hand. The "Gazette" of Amiens undertook to prove that his ancestors had been French.—JOHN BACH MCMASTER.

FRANKLIN, THE YOUNG REPUBLIC'S GREAT FINANCIER

The plan which seemed most effective was to send a representative accredited to some foreign government, and instructed to raise the money at once. Without writing to see whether he arrived safely, or was received, or was successful in his negotiations, the next ship which

followed him brought drafts and bills which he was expected to accept, and at maturity to pay. Having thus skillfully shifted the laboring oar into his hands Congress bestirred itself no further. Poor Jay, in Spain, had a terrible time of it in this way. And if ever a man was placed by his country in a painful and humiliating position, it was he. He faced it gallantly, but had to be carried through by Franklin. From first to last it was upon Franklin that the brunt fell. He had to keep the country from financial failure as Washington had to save it from military failure. He was the real financier of the Revolution. Without him Robert Morris would have been helpless. Spain yielded but trifling sums in response to Jay's solicitations. Holland, which was tried by Adams, was even more tardy and unwilling, though towards the end, some money was got there. Franklin alone, at Paris, could tap the rock and make the waters flow. So upon him Congress sent in an endless procession of drafts, and compelled him to pay all their foreign bills and indebtedness. He gathered and he disbursed. To him were referred all the drafts upon Jay and others, which they themselves could not pay, and he discharged them one and all. A heavier task never fell upon any man, nor one bringing less recognition; for money matters usually seem so dry and unintelligible that every one shirks informing himself about them. We read about the horrors of the winter camp at Valley Forge, and we shudder at all the details of the vivid picture. The anxiety, the toil, the humiliation, which Franklin endured for many winters and many summers in Paris, in sustaining the national credit, do not make a picture, do not furnish material for a readable chapter in history. Yet many a man would

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DIRECCIÓN GENERAL DE BIBLIOTECAS

far rather have faced Washington's lot than Franklin's.—JOHN T. MORSE, JR.

FRANKLIN'S MANY-SIDED GREATNESS

To say that Franklin's life is the most interesting, the most uniformly successful, yet lived by any American, is bold. But it is nevertheless strictly true. Not the least of the many glories of our country is the long list of men who, friendless, half-educated, poor, have by the sheer force of their own abilities, raised themselves from the humblest beginnings to places of eminence and command. Many of these have surpassed him. Some have speculated more deeply on finance, have been more successful as philanthropists, have made greater discoveries in physics, have written books more commonly read than his. Yet not one of them has attained to greatness in so many ways, or has made so lasting an impression on his countrymen. His face is as well known as the face of Washington, and, save that of Washington, is the only one of his time that is now instantly recognized by the great mass of his countrymen. His maxims are in every man's mouth. His name is, all over the country, bestowed on counties and towns, on streets, on societies, on corporations. The stove, the lightning-rod, and the kite, the papers on the gulf stream, and on electricity, give him no mean claims to be considered a man of science. In diplomacy his name is bound up with many of the most famous documents in our history. He drew the Albany Plan of Union. He sent over the Hutchinson Letters. He is the only man who wrote his name alike at the foot of the Declaration of Independence, at the foot of the Treaty

of Alliance, at the foot of the Treaty of Peace, and at the foot of the Constitution under which we live. Nor is he less entitled to distinction in the domain of letters, for he has produced two works which of their kind have not yet been surpassed. One is "*Father Abraham's Speech to the People at the Auction.*" The other is "*The Autobiography of Benjamin Franklin.*"—JOHN BACH MCMASTER.

FRANKLIN, ONE OF THE WORLD'S GREATEST MEN

Intellectually there are few men who are Franklin's peers in all the ages and nations. He covered, and covered well, vast ground. The reputation of doing and knowing various unrelated things is wont to bring suspicion of perfunctoriness; but the ideal of the human intellect is an understanding to which all knowledge and all activity are germane. There have been a few, very few minds which have approximated toward this ideal, and among them Franklin's is prominent. He was one of the most distinguished scientists who have ever lived. Bancroft calls him "the greatest diplomatist of his century." His ingenious and useful devices and inventions were very numerous. He possessed a masterly shrewdness in business and practical affairs. He was a profound thinker and preacher in morals and on the conduct of life; so that, with the exception of founders of great religions, it would be difficult to name any persons who have more extensively influenced the ideas, motives, and habits of life, of men. He was one of the most, perhaps the most agreeable conversationist of his age. He was a rare wit and humorist, and in an age when "American

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DIRECCIÓN GENERAL DE BIBLIOTECAS

losopher, and Practical Citizen," in the *"American Men of Energy"* series (New York: G. P. Putnam's Sons, $1.50).

6. Another recent biography of Franklin is that entitled *"The True Benjamin Franklin,"* by Sydney George Fisher (Philadelphia: J. B. Lippincott Co., $2.00). This work is highly eulogized by some critics, and quite as strongly dispraised by others. No one, however, questions the author's honesty of purpose, or his painstakingness.

7. An account of Benjamin Franklin for boys, "a boy's book on a boy's own subject," is Henry Mayhew's *"Young Benjamin Franklin, or The Right Road Through Life"* (New York: Harper & Brothers, $1.25).

8. Popular accounts of Franklin—not whole books—are found numerously. In Philip G. Hubert's *"Inventors"* in the *"Men of Achievement"* series, the opening chapter is devoted to Franklin, the other chapters being devoted to other great American inventors from Fulton and Whitney to Edison and Bell (New York: Scribners, $1.50).

9. In Dr. William Garnett's *"Heroes of Science—Physicists"* (New York: E. & J. B. Young & Co.), Franklin has a place along with such other great physicists as Boyle, Cavendish, Rumford, Young, Faraday, and Clerk Maxwell—truly a noble company.

Sir William Herschel

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DIRECCIÓN GENERAL DE BIBLIOTECAS

present. There has perhaps been never another like it—in its singleness of purpose, its unresting industry, and its successful overcoming of difficulties, combined with the charm of personality which accompanied it and the greatness of real achievement which it won. All this can be only hinted at here. Frederick William Herschel, known to fame as Sir William Herschel, was born at Hanover November 15, 1738. His father, who was an oboist in the

LAPLACE

band of the Hanoverian guard, was an accomplished musician and a man of native ability, with a keen intellectual interest in many matters beyond those of his immediate business. The mother was a skillful, practical housekeeper. From the father Herschel inherited genius and an unquenchable thirst for knowledge; from the mother an instinct for mechanical contrivance, an inborn dexterity

in the use of tools, constitutional strength, and unbounded energy. His formal education was meager and wholly obtained in the regimental school of the guards. But he had a natural talent for music, and with his father's assistance he became an accomplished violinist, familiar also with the organ and several other instruments. For awhile he was a member of the band his father belonged to. But when he was nineteen his parents determined that he should not continue a soldier's life and they sent him to England. England and Hanover were at that time in close connection and the electors of Hanover were the kings of England. For some years after his emigration to England Herschel's life is obscure; but it must have been both industrious and self-helpful, for when opportunities for advancement arose he was able to take the fullest advantage of them. For some time he was bandmaster of a militia regiment. In 1765 he won by his skillful playing the position of organist at Halifax, in Yorkshire. In 1767 he was appointed organist to a chapel in Bath. Bath was then in the very height of its fame as a place of resort for people of fashion and wealth, and Herschel's talents soon became known and his life exceedingly busy. He gave lessons to private pupils. He trained and led choirs and orchestras. He conducted concerts and oratorios. He composed songs, glees, catches, and choruses, for his concert performers, concerted music for his orchestras, and psalm tunes, anthems, and even more difficult pieces, for his choirs. He had to engage and train soloists for all his public engagements, and even compose pieces suited to their particular voices or instruments. In short, his life was apparently as full and as preoccupied with its regular work as it was possible for a life to be.

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN
DIRECCIÓN GENERAL DE BIBLIOTECAS

But Herschel's devotion to his profession was only one part of his life. Another part of it, quite as exhaustive of time and energy, was his devotion to self-improvement. At first he studied Latin and Greek and French. He then turned his attention to the higher branches of his profession and became interested in the science of harmony. This led him to the study of mathematics. From mathematics he was naturally led to optics. In optics he was fairly entranced; and it was thence but a step to astronomy. Once introduced to the science of the heavens his love for it became a fervid, burning passion, which no difficulty could daunt, no obstacle restrain. The study of astronomy with him was at first principally observational. But for his observation he needed a telescope, and as he could not afford to buy one he made one. Having made one he made another, and then another, each time increasing his instrument's size and power. He made his own castings for the specula, and he did his own polishing. It was not, however, all a matter of easy success with him. Before he had got a satisfactory speculum for his first telescope he had suffered no fewer than 200 failures. And when afterward he was producing telescopes of larger size, over and over again would a speculum break down in the casting, or crack in the cooling, or show some hitherto unnoticed flaw in the polishing, which would entail his going through the whole work again, and so cost him weeks and often months of precious time. The work of polishing was especially arduous. Once it was begun his hands could not be removed from the metal without injury to the success of the result. At times he was known to sustain sixteen hours of continuous labor at a speculum in order to secure its perfect completion, his sister in the

meantime keeping up his strength by putting bits of food in his mouth as he wrought at the work. But the result of it all was that he became the most skillful telescope maker in Europe, and, for that matter, the most skillful the world has ever known. The art of shaping and polishing specula by hand, which he was so skillful in, became at his death a lost art, and the great forty-foot telescope which he completed in 1789, was, after his death, dismounted, because no one else could polish its mirror.

Herschel's first successful telescope was finished early in 1774, when he was in his 36th year. In March of that year he made his first important observation. Almost half a lifetime was already behind him when he began his new career, but never was a scientific career entered upon so late in life so gloriously blessed with rich achievement. His first task was to make a "review of the heavens;" that is, to bring under his telescope every part of the heavens visible in his latitude and to observe and carefully map down what he saw. This work, unattempted and unthought of previously, he performed no less than four times in his life, each time with instruments of greater power than before, and with increased skill and knowledge begotten of experience. On March 13, 1781, during the course of the second of these reviews, an event happened which at once made him famous throughout the civilized world. "A new planet swam into his ken." At first he was not certain that his discovery was a planet. Like the rest of mankind, he had supposed that all the planets had been known for ages. He therefore modestly gave his discovery to the world as "an account of a comet." It was not until a year and a half had elapsed that he felt sure enough of the planetary character of his

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DIRECCIÓN GENERAL DE BIBLIOTECAS

discovery to give it a name. Thus was Uranus found and admitted into the solar system. Herschel could no longer be a music master. Science claimed him wholly for her own. The Royal Society granted him a medal and elected him a fellow. Among opticians and astronomers nothing was talked of but the greatness of his discoveries. The king was desirous of seeing his telescope and asked him to bring it to London and show it to him. To London, therefore, Herschel went, taking his telescope with him. The king and the royal family looked through it and were enraptured. Herschel was made king's astronomer and royal telescope maker, and though the salary given him was not a large one it was enough to satisfy his simple needs. Besides, from the sale of his telescopes, which all the world wanted to buy, he soon had an income that was ample. The king bought four at $2,500 apiece, and ordered him to erect one for his own use at a cost of $20,000. In addition, he executed innumerable other commissions at prices varying from $1,000 to $15,000 each.

Herschel left Bath and removed to Datchet, near Windsor, in August, 1782, but his fame is principally identified with Slough, whither he removed in April, 1786. The house (now called "Observatory House") still stands in which he pursued his labors there, and no house in England has been the scene of more numerous or more renowned scientific achievements. The amount of work that Herschel accomplished is simply marvelous. For years he lost not a single hour of time suitable for astronomical observation. Calculations, the writing of his memoirs for publication, telescope making, business, the reception of visitors, eating, drinking, and sleeping, were all left to the daytime, or to be done at night-time when the

stars were invisible. His labor was incessant and no one not endowed with a constitution extraordinarily strong could have endured the strain of it. In all his work, however, he was assisted by his sister, Caroline Herschel, twelve years younger than himself, whom he brought over from Hanover to Bath to train for a concert singer, but

THE HERSCHEL HOUSE, BATH.

whom also he had trained to be an expert astronomer. Her labor and zeal were scarcely less incessant or remarkable than his; but they derived their inspiration from

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN
DIRECCIÓN GENERAL DE BIBLIOTECAS

her interest in him, but not from any real interest of her own in astronomical work. She discovered eight comets, however, and performed astronomical calculations that gained her the applause of astronomers the world over. But her real contribution to science was the work she did for her brother; for without her aid, which was as quick and accurate at the telescope as it was at the calculating table, he could have accomplished but a fraction of what he did.

Herschel's contributions to science were far too many and too complex to permit of summarization here. Besides the discovery of Uranus, and the "review of the heavens" four times repeated, he discovered two satellites of Uranus, and a fifth and sixth moon to Saturn. A great deal of his astronomical effort was spent in determining the nature of double stars. Of these he discovered and catalogued 806 pairs; and he proved that these star twins were not couples accidentally appearing so, due to a proximity of position in the visible firmament, but real twins, both in origin and constitution, that had a revolution about a common center. A second great department of his work was the identification and examination of star clouds, or nebulæ. Of these he catalogued no less than 2,500; and he proved conclusively that while many star clouds, or nebulæ, are in reality assemblages of stars whose tremendous distances make them appear dim and coalescent, there are many, many nebulæ which cannot be resolved into individual stars, but which are, in reality as in appearance, masses of luminous matter, gaseous, and without definite form. He was thus able to give physical demonstration, to give indeed ocular proof, of the reasonableness of certain parts of Laplace's "Nebular Hypothesis."

It is but right to state that the spectroscopic and photographic investigations of recent astronomers are wholly confirmatory of Herschel's conclusions in this matter. A third great department of Herschel's work was his star-gauging, or his endeavors to fix the relative distances of stars from the earth by means of comparisons of their relative brightnesses. Though his methods were imperfect, and his conclusions unsatisfactory (even to himself), yet they served to direct subsequent inquirers to the question, and lead to methods and results that are comparatively satisfactory. It must be remembered, too, that the question was first propounded by Herschel; and that it was, indeed, but a constituent part of the great problem of his life, namely the determination of the construction and organization of the universe as a whole. And though, of course, Herschel did not, and could not, reach a solution of his daring problem, yet, nevertheless, he deserves credit for propounding it, and for doing so much towards resolving it. The final achievement of Herschel's that may be mentioned, is one that bears on the same problem—namely the discovery of the motion of the sun (and, of course, with it, of the whole solar system) through space (at a rate now known to be probably 150,000,000 miles a year). This motion of the sun (which is but a star) is, of course, only the counterpart near by of similar motions to be observed in other stars, whose infinite distances, however, render their motion scarcely ascertainable. All this and much more did Herschel achieve, for his life was a long one, his industry untiring, his genius for his work unrivaled among the sons of men. He died August 25, 1822, in his 84th year. He had been made a knight in 1816.

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN
DIRECCIÓN GENERAL DE BIBLIOTECAS

V. SIR WILLIAM HERSCHEL

1738-1822

BIOGRAPHICAL STUDY

BY JOHN EBENEZER BRYANT, M. A.

Herschel is the founder of the science of sidereal astronomy. That is to say, he was the first observer of the heavens who studied their unfathomable depths and tried to determine the order and motions of the stars as distinct from the planets. Since the beginning of the modern science of astronomy all previous observers of the firmament had been concerned principally with the motions of the planets. Copernicus had propounded the theory of the revolution of the planets around the sun. Tycho Brahë had mapped out the actual courses of the planets. Kepler had discovered the conditions which the planets observe in these courses. Galileo had with his telescope, and his splendid genius for physical demonstration, established innumerable proofs in confirmation of the Copernican theory. Newton, with his matchless insight into the harmonies of nature, had divined the law of gravitation, and, with his matchless powers of mathematical reasoning, had shown that that law was sufficient to account

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN
DIRECCIÓN GENERAL DE BIBLIOTECAS

for the motions of the planets, including the so-called "laws" of Kepler, and also for all perturbations from perfect regularity in their motions due to mutual inter-attractions, etc. Also, he had predicted that when the constitution of the heavens should be studied it would be found that the same law which held the planets in their courses would be operative in the infinite spaces in which the starry worlds are situated. Later on the two French scientists, Lagrange and Laplace, had taken Newton's law, and with wonderful patience, mathematical skill, and astronomical learning, had worked out all conceivable problems of planetary motions and perturbations, and had shown that the law needed no corrective, as had been supposed by some, but that despite its simplicity it explains every variation from normal regularity which the planets in their courses can possibly take. Moreover, they had shown that these variations are "periodic;" that is to say, that they are mutually corrective, and not accumulative, and that therefore the solar system is perfectly stable and in no danger of self-destruction, as had sometimes been feared. Finally Laplace (sometimes, and deservedly, called the French Newton), looking beyond the planetary world, looking, too, away from the present, peering into the infinite past, peering also into the infinite future, and trying to account for the construction of the universe—no less for its origin and development than for its present constitution—had propounded the theory now known as the "nebular hypothesis"—the theory which, with Newton's law assumed to be general, goes far to explain not merely the construction of the solar system, with all its revolving planets and satellites, but also, so far as can be tested, the construction of the entire universe.

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SIR WILLIAM HERSCHEL

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN ®
DIRECCIÓN GENERAL DE BIBLIOTECAS

But neither Newton nor Laplace had any ocular knowledge of the heaven of stars beyond what other observers had obtained, and that had been almost wholly confined to the solar system. In fact all stars other than the stars of the solar system were called "fixed stars," and their fixedness had been taken by most astronomers to be so absolute that study of them had been considered unnecessary. Observers all the world over were engaged merely in problems connected with the motions of the planets, or with such obvious problems concerning the fixed stars, as their times of rising, meridian passing, and setting, as might be useful in navigation and surveying. But it happened that a new observer came into the astronomical world—one whose advent was as little to be expected, whose career was as much a matter for wonder and admiration, as ever were the advent and career of a comet in the world of stars. This was William Herschel, who, though favored neither with the education nor the training that an astronomer should have, and burdened also with the duties of another profession by which alone he could support himself, became one of the most technically learned and technically skilled astronomical observers the world has ever known; who enlarged the sphere of astronomical effort and made it include the whole universe; and who also by his discoveries and ocular demonstrations showed that the grand predictions of Newton and the even grander speculations of Laplace had the support of physical fact, and that the whole illimitable starry universe, no less than our own definite solar system, is under the domain of observable and determinate law.

Herschel's career was altogether too multifarious and brilliant to be adequately presented in a sketch like the

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN
DIRECCIÓN GENERAL DE BIBLIOTECAS

SIR WILLIAM HERSCHEL

SELECTED STUDIES AND REMINISCENCES

HERSCHEL'S DISCOVERY OF URANUS

Herschel began in 1780 his second review of the heavens, using a seven-foot Newtonian, of 6¼ inches aperture, with a magnifying power of 227. "For distinctness of vision," he said "this instrument is, perhaps, equal to any that was ever made." His praise was amply justified. As he worked his way with it through the constellation Gemini, on the night of March 13th, 1781 [in Herschel's forty-third year] an unprecedented event occurred. "A new planet swam into his ken." He did not recognize it as such. He could only be certain that it was not a fixed star. His keen eye, armed with a perfect telescope, discerned at once that the object had a disc; and the application of higher powers showed the disc to be a substantial reality. The stellar "patines of bright gold" will not stand this test. Being of purely optical production, they gain nothing by magnification.

At that epoch new planets had not begun to be found by the dozen. Five, besides the earth [and the moon—a secondary planet—seven in all] had been known from the remotest antiquity. Five, and no more, seemed to

have a prescriptive right to exist. The boundaries of the solar system were of immemorial establishment. It was scarcely conceivable that they should need to be enlarged. The notion did not occur to Herschel. His discovery was modestly imparted to the Royal Society as "An Account of a Comet." He had, indeed, noticed that the supposed comet moved in planetary fashion from west to east, and very near the ecliptic; and, after a few months, its true nature was virtually proved by Lexell of St. Petersburg. On November 28th, Herschel measured, with his freshly-invented "lamp-micrometer," the diameter of this "singular star;" and it was not until a year later, November 7th, 1782, that he felt sufficiently sure of its planetary status to exercise his right of giving it a name. Yet this, in the long run, he failed to accomplish. The appellation "Georgium Sidus," bestowed in honor of his patron, George III., never crossed the Channel, and has long since gone out of fashion amongst ourselves. Lalande tried to get the new planet called "Herschel;" but the title "Uranus," proposed by Bode, of Berlin, was the "fittest," and survived.—AGNES M. CLERKE, *in "The Herschels and Modern Astronomy," in "The Century Science Series."*

HERSCHEL'S FAME AFTER HIS DISCOVERY OF URANUS

This discovery [of Uranus] made the turning-point of Herschel's career. It transformed him from a music master into an astronomer. Without it his vast abilities would probably have been in great measure wasted. No man could long have borne the strain of so arduous a double life as he was then leading. Relief from it came just in time. It is true that fame, being often more of a hin-

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN
DIRECCIÓN GENERAL DE BIBLIOTECAS

scholar to another, or giving one the slip, he called at home to see how the men went on with the furnace, which was built in a room below, even with the garden."

At last, the concert season being over, and everything in readiness for the operation of casting, "the metal," we hear from the same deeply-interested eye-witness, "was in the furnace; but, unfortunately, it began to leak at the moment when ready for pouring, and both my brothers, and the caster with his men, were obliged to run out at opposite doors, for the stone flooring, which ought to have been taken up, flew about in all directions, as high as the ceiling. My poor brother William fell, exhausted with heat and exertion, on a heap of brickbats. Before the second casting was attempted, everything which could ensure success had been attended to, and a very perfect metal was found in the mould, which, however, had cracked in the cooling."—AGNES M. CLERKE.

HERSCHEL'S FAME AS DESCRIBED BY ARAGO

A telescope, a simple telescope, only two English feet in length, falls into the hands of Herschel during his residence at Bath. This instrument, however imperfect, shows him a multitude of stars in the sky that the naked eye cannot discern; shows him also some of the known objects, but now under their true dimensions; reveals forms to him that the richest imaginations of antiquity had never suspected. Herschel is transported with enthusiasm. He will, without delay, have a similar instrument but of larger dimensions. The answer from London is delayed for some days: these few days appear as many centuries to him. When the answer arrives, the

price that the optician demands proves to be much beyond the pecuniary resources of a mere organist. To any other man this would have been a clap of thunder. This unexpected difficulty, on the contrary, inspired Herschel with fresh energy: he cannot buy a telescope, then he will construct one with his own hands. The musician of the Octagon Chapel rushes immediately into a multitude of experiments, on metallic alloys that reflect light with the greatest intensity, on the means of giving the parabolic figure to the mirrors, on the causes that in the operation of polishing affect the regularity of the figure, etc. So rare a degree of perseverance at last receives its reward. In 1774 Herschel has the happiness of being able to examine the heavens with a Newtonian telescope of five English feet focus, entirely made by himself. This success tempts him to undertake still more difficult enterprises. Other telescopes, of seven, of eight, of ten, and even of twelve feet focal distance, crown his efforts. As if to answer in advance those critics who would have accused him of a superfluity of apparatus, of unnecessary luxury, in the large size of the new instruments, and his extreme minutiæ in their execution, Nature granted to the astronomical musician, on the 13th of March, 1781, the unheard-of honour of commencing his career of observation with the discovery of a new planet, situated on the confines of our solar system. Dating from that moment, Herschel's reputation, no longer in his character of musician, but as a constructor of telescopes and as an astronomer, spread throughout the world. The king, George III., a great lover of science, and much inclined besides to protect and patronize both men and things of Hanoverian origin, had Herschel presented to him; he was

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN
DIRECCIÓN GENERAL DE BIBLIOTECAS

charmed with the simple, yet lucid and modest account that he gave of his repeated endeavors; he caught a glimpse of the glory that so penetrating an observer might reflect on his reign, ensured to him a pension of 300 guineas a year, and moreover a residence near Windsor Castle, first at Clay Hall, and then at Slough. The visions of George III. were completely realized. We may confidently assert, relative to the little house and garden of Slough, that it is the spot of all the world where the greatest number of discoveries have been made. The name of that village will never perish; science will transmit it religiously to our latest posterity.—FRANCOIS ARAGO, *in "Biographies of Distinguished Scientific Men."*

HERSCHEL'S WONDERFUL ENERGY IN "REVIEWING THE HEAVENS"

"The man at the eye-end" is the truly essential part of a telescope. No one knew this better than Herschel. Every serene dark night was to him a precious opportunity availed of to the last minute. The thermometer might descend below zero, ink might freeze, mirrors might crack; but provided the stars shone, he and his sister worked on from dusk to dawn. In this way, his "third review," begun at Bath, was finished [at Datchet, near Windsor] in the spring of 1783. The swiftness with which it was conducted implied no want of thoroughness. "Many a night," he states, "in the course of eleven or twelve hours of observation, I have carefully and singly examined not less than 400 celestial objects, besides taking measures, and sometimes viewing a particular star for half an hour together, with all the various powers."

The assiduity appears well-nigh incredible with which he gathered in an abundant harvest of nebulæ and double stars; his elaborate papers, brimful of invention and experience, being written by day, or during nights unpropitious for star-gazing. On one occasion he is said to have worked without intermission at the telescope and the desk for seventy-two hours, and then slept unbrokenly for twenty-six hours. His instruments were never allowed to remain disabled. They were kept, like himself, on the alert. Relays of specula were provided, and one was in no case removed from the tube for repolishing, unless another was ready to take its place. Even the meetings of the Royal Society were attended only when moonlight effaced the delicate objects of his particular search.—AGNES M. CLERKE.

HERSCHEL'S GREAT "FORTY-FOOT"

Herschel trusted nothing to chance. "There is not one screw-bolt," his sister asserted [respecting the construction of the great forty-foot telescope], "about the whole apparatus but what was fixed under the immediate eye of my brother. I have seen him lie stretched many an hour in a burning sun, across the top beam, whilst the ironwork for the various motions was being fixed. At one time no less than twenty-four men (twelve and twelve relieving each other) kept polishing day and night; my brother, of course, never leaving them all the while, taking his food without allowing himself time to sit down to table."

At this stage of the undertaking it became the fashion with visitors to use the empty tube as a promenade. Dr.

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and Miss Burney called, in July, 1786, "to see, and *take a walk* through the immense new telescope." "It held me quite upright," the authoress of "Evelina" related, "and without the least inconvenience; so would it have done had I been dressed in feathers and a bell-hoop."

George III. and the Archbishop of Canterbury followed the general example; and the prelate being incommoded by the darkness and the uncertain footing, the King, who was in front, turned back to help him, saying: "Come, my lord bishop, I will show *you* the way to heaven." On another occasion "God save the King" was sung and played within the tube by a large number of musicians; and the rumor went abroad that it had been turned into a ball-room!

. . . . . .

The great telescope took rank, before and after its completion, as the chief scientific wonder of the age. Slough was crowded with sightseers. All the ruck of Grand Dukes and Serene Highnesses from abroad, besides royal, noble, and gentlefolk at home, flocked to gaze at it and interrogate its maker with ignorant or intelligent wonder. —AGNES M. CLERKE.

HERSCHEL'S CHARACTER

William Herschel was endowed by nature with an almost faultless character. He had the fervor without the irritability of genius; he was generous, genial, sincere; tolerant of ignorance; patient under the acute distress, to which his situation rendered him peculiarly liable, of unseasonable interruptions at critical moments: he was warm-hearted and open-handed. His change of country

and condition, his absorption in science, the homage paid to him, never led him to forget the claims of kindred. Time and money were alike lavished in the relief of family necessities.

On religious topics he was usually reticent; but a hint of the reverent spirit in which his researches were conducted, may be gathered from a sentence in a letter he once wrote. "It is certainly," he said, "a very laudable thing to receive instruction from the great work-master of nature, and for that reason all experimental philosophy is instituted."

To investigate was then, in his view, to "receive instruction;" and one of the secrets of his wonderful success lay in the docility with which he came to be taught.—AGNES M. CLERKE.

HERSCHEL'S WORK AND ITS INFLUENCE

Herschel was, in the highest and widest sense, the founder of sidereal astronomy. He organized the science and set it going; he laid down the principles of its future action; he accumulated materials for its generalizations, and gave examples of how best to employ them. His work was at once so stimulating and so practical that its abandonment might be called impossible. Others were sure to resume where he had left off. His son [John Frederick William Herschel—known to fame as Sir John Herschel] was his first and fittest successor; he was the only one who undertook in its entirety the inherited task. Yet there are to be found in every quarter of the world men imbued with William Herschel's sublime ambitions. Success swells the ranks of an invading army; and the

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DIRECCIÓN GENERAL DE BIBLIOTECAS

drance than a help, brought embarrassment in its train. In November, 1781, Herschel was compelled to break the complex web of his engagements at Bath by a journey to London for the purpose of receiving in person the Copley Medal awarded to him by the Royal Society, of which body he was, some days later, elected a Fellow. At home, he was persecuted by admirers; and they were invariably received with an easy suavity of manner that gave no hint of preoccupation. Every one of scientific pretension who visited Bath sought an interview with the extraordinary man who, by way of interlude to pressing duties, had built telescopes of unheard-of power, and performed the startling feat of adding a primary member to the solar system. Among the few of these callers whose names have been preserved was Dr. Maskelyne, then, and for thirty years afterwards, Astronomer-Royal. "With the latter," Miss Herschel relates, "he (William) was engaged in a long conversation which to me sounded like quarrelling, and the first words my brother said after he was gone were, 'That is a devil of a fellow!'" The phrase was doubtless meant as a sign of regard, for the acquaintance thus begun ripened into cordial intimacy. And William Herschel never lost or forgot a friend.—AGNES M. CLERKE.

HERSCHEL'S WONDERFUL ENERGY IN TELESCOPE-MAKING

The first of Herschel's *effective* twenty-foot telescopes was erected at 19 New King Street [Bath], in the summer of 1781. Enclosing a mirror twelve inches in diameter, it far surpassed any seeing-machine that had ever existed in the world. Yet its maker regarded it as only marking a step in his upward progress. A speculum of thirty-feet

focus was the next object of his ambition. For its achievement no amount of exertion was counted too great. Its composition was regulated by fresh experiments on various alloys of copper and tin. Its weight and shape were again and again calculated, and the methods appropriate to its production earnestly discussed. "I saw nothing else," Caroline Herschel tells us, "and heard nothing else talked of, but these things when my brothers were together."

"The mirror," she continues, "was to be cast in a mould of loam prepared from horse-dung, of which an

GARDEN VIEW, HERSCHEL HOUSE, SLOUGH.

immense quantity was to be pounded in a mortar and sifted through a fine sieve. It was an endless piece of work, and served me for many an hour's exercise; and Alex frequently took his turn at it, for we were all eager to do something towards the great undertaking. Even Sir William Watson [a neighbor—a gentleman interested in science who became a great friend of the Herschels] would sometimes take the pestle from me when he found me in the work-room."

The matter was never out of the master's thoughts. "If a minute could but be spared in going from one

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march of astronomy has, within the last decade [1885-1895] assumed a triumphal character. The victory can never be completely won; the march can never reach its final goal; but spoils are meanwhile gathered up by the wayside which eager recruits are crowding in to share. The heavens are, year by year, giving up secrets long and patiently watched for, while holding in reserve many others still more mysterious. There is no fear of interest being exhausted by disclosure.—AGNES M. CLERKE.

CAROLINE HERSCHEL'S DEVOTION TO HER BROTHER.

Miss Herschel was business-like and matter-of-fact. But her devotion [when William Herschel was in the first fervor of telescope making] triumphed over her common-sense. Keeping her misgivings to herself, she met unlooked-for demands with the utmost zeal, intelligence, and discretion. She was always at hand when wanted, yet never in the way. Through her care, some degree of domestic comfort was maintained amid the unwonted confusion of optical manufacture. During the tedious process of mirror-polishing, she sustained her brother physically and mentally, putting food into his mouth, and reading aloud "Don Quixote," and the "Arabian Nights." She was ready with direct aid, too, and "became in time as useful a member of the workshop as a boy might be to his master in the first year of his apprenticeship." "Alex," she continued, "was always very alert, assisting when anything new was going forward; but he wanted perseverance, and never liked to confine himself at home for many hours together. And so it happened that my brother William was obliged to make trial of my

abilities in copying for him catalogues, tables, and sometimes whole papers which were lent him for his perusal." —AGNES M. CLERKE.

CAROLINE HERSCHEL AS ASSISTANT KING'S ASTRONOMER

Miss Herschel [when officially appointed assistant to her brother who had been made the "King's Astrono-

CAROLINE HERSCHEL.

mer"] set to work with a will to learn all that was needful for her untried office. Not out of books. "My dear brother William," she wrote in 1831, "was my only teacher, and we began generally where we should have ended; he supposing I knew all that went before." The lessons were of the most desultory kind. They consisted of answers to questions put by her as occasions arose,

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tumn of 1783, two nebulæ of first rate importance. She was by this time more than reconciled to her astronomical lot; Von Magellan, indeed, reported in 1785, that brother and sister were equally captivated with the stars.

. . . . . .

On August 1st, 1786, her brother's absence leaving her free to observe on her own account, she discerned a round, hazy object, suspiciously resembling a comet. Its motion within the next twenty-four hours certified it as such, and she immediately announced the apparition to her learned friends, Dr. Blagden and Mr. Aubert. The latter declared in reply, "You have immortalized your name," and saw in imagination "your wonderfully clever and wonderfully amiable brother shedding," upon receipt of the intelligence, "tears of joy." This was the first of a series of eight similar discoveries, in five of which her priority was unquestioned. They were comprised within eleven years, and were made, after 1790, with an excellent five-foot reflector mounted on the roof of the house at Slough. Considering that she swept the heavens only as an interlude to her regular duties, never for an hour forsaking her place beside the great telescopes in the garden, her aptitude for that fascinating pursuit must be rated very high.—AGNES M. CLERKE.

READERS' AND STUDENTS' NOTES

1. For ordinary readers the standard life of Herschel is that by Dr. Edward S. Holden, director of the Lick Observatory, entitled "*Life and Works of Sir William Herschel*" (New York: Scribners, $1.50). It is a brief and eminently readable work and has the merit of containing an excellent bibliography of Herschel.

2. An excellent biographical sketch of Herschel, together with an account of his astronomical achievements, will be found in Arago's "*Biographies of Distinguished Scientific Men*" (London: Longmans). This work also contains biographical sketches and accounts of the achievements of Laplace, Joseph Fourier, Fresnel, Thomas Young, James Watt, and several other great men of science. These sketches and accounts are peculiarly valuable from the fact that the author was himself a distinguished man of science.

3. The latest biographical account of Herschel is that contained in a volume of "*The Century Science Series,*" entitled "*The Herschels and Modern Astronomy,*" by Agnes M. Clerke (New York: The Macmillan Co., $1.25). This excellent series of scientific biographies, edited by Sir Henry Roscoe, cannot be too highly commended. Each biography is the work of a specialist in the department of science to which the subject of the biography belonged. The work we are at present concerned with contains an account not only of Sir William Herschel, but also of his sister, Caroline Herschel, and of his son, Sir John Herschel. The authoress is well known for her "*Popular History of Astronomy During the Nineteenth Century.*" "*The Herschels and Modern Astronomy*" is an excellent work in every respect.

4. Morton's "*Heroes of Science—Astronomers*" (New York: E. & J. B. Young & Co.) already mentioned, devotes a chapter to Herschel. Herschel is also the theme of numerous paragraphs in Miss Buckley's "*Short History of Natural Science*" (New York: D. Appleton & Co.). For young people a capital account of both Sir William Herschel and Caroline Herschel is given in Sarah K. Bolton's "*Famous Men of Science.*"

5. Herschel is of course the subject of an important chapter in Sir Robert Ball's "*Great Astronomers,*" previously noticed.

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DIRECCIÓN GENERAL DE BIBLIOTECAS

during breakfast, or at odd moments. The scraps of information thus snatched were carefully recorded in her commonplace book, where they constituted a miscellaneous jumble of elementary formulæ, solutions of problems in trigonometry, rules for the use of tables of logarithms, for converting sidereal into solar time, and the like. Nothing was entrusted to a memory compared by her instructor to "sand, in which everything could be inscribed with ease, but as easily effaced." So that even the multiplication table was carried about in her pocket. She appears never to have spent a single hour in the systematic study of astronomy. Her method was that in vogue at Dotheboy's Hall, to "go and know it," by practicing, as it were, blindfold, what she had been taught. Yet a computational error has never, we believe, been imputed to her; and the volume of her work was very great.

Her aid was indispensable, and from December, 1783, she "became entirely attached to the writing-desk." She was no mere mechanical assistant. A wound-up automaton would have ill served William Herschel's turn. He wanted "a being to execute his commands with the quickness of lightning;" and his commands were various. For he was making, not following, precedents, and fresh exigencies continually arose. Under these novel circumstances, his sister displayed incredible zeal, promptitude, and versatility. She would throw down her pen to run to the clock, to fetch and carry instruments, to measure the ground between the lamp-micrometer and the observer's eye; discharging these and many other successive tasks with a rapidity that kept pace with his swift proceedings. Fatigue, want of sleep, cold, were disregarded; and although nature often exacted next day penalties of

weariness and depression for those nights of intense activity, the faithful amanuensis never complained. "I had the comfort," she remarked simply, "to see that my brother was satisfied with my endeavors to assist him." The service was not unaccompanied by danger. One night poor Caroline, running in the dark over ground a foot deep in melting snow, in order to make some alteration in the movement of the telescope, fell over a great hook, which entered her leg so deeply that a couple of ounces of her flesh remained behind when she was lifted off it. The wound was formidable enough, in Dr. Lind's opinion, to entitle a soldier to six weeks' hospital nursing, but it was treated cursorily at Datchet; the patient consoling herself for a few nights' disablement, with the reflection that her brother, owing to cloudy weather, "was no loser through the accident."

Busy days succeeded watchful nights. From the materials collected at the telescope she formed properly arranged catalogues, calculating, in all, the places of 2,500 nebulæ. She brought the whole of Flamsteed's "British Catalogue"—then the *vade mecum* of astronomers—into zones of one degree wide, for the purpose of William's methodical examination; copied out his papers for the Royal Society; kept the observing books straight, and documents in order. Then in the long summer months, when "there was nothing but grinding and polishing to be seen," she took her share of that too."—AGNES M. CLERKE.

CAROLINE HERSCHEL'S ORIGINAL WORK AS AN ASTRONOMER

Miss Herschel began, in 1782, to "sweep for comets," and discovered with a 27-inch reflector, in the au-

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John Dalton

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was conducted by a cousin of his. At nineteen years of age he became, with his brother, joint principal of this school. In this position he remained till 1793, or until he was twenty-seven years of age. During all the years of his Keswick life he was indefatigable in his studies, the natural sciences and mathematics being his principal pursuits, though he also studied Latin, Greek, and French. But early in his life at Keswick he began to study nature directly. His first interest was in meteorology. Meteorology, indeed, continued to be all through his life his great absorbing passion. He is said to have made personally over 200,000 distinct meteorological observations and records.

Dalton had few characteristics to win popularity, but his enthusiasm in the study of natural phenomena secured him friends wherever he was. Even as a boy in Eaglesfield he had the friendship of a distant relative who was a gentleman of wealth, leisure, and scholarly tastes, and who assisted him in his studies. At Keswick he had the friendship of a Mr. Gough, who, though blind, had extraordinary ability, and who, because of his attainments in science, was known as the "blind philosopher." Through Mr. Gough's influence Dalton, in 1793, secured the appointment of tutor in mathematics and natural philosophy in an academy at Manchester established by the Presbyterians, afterward known as New College. His salary here was only £80 ($400) a year, but Dalton's habits were simple and his expenses always frugal. The great advantage of the place was that it concentrated his energies wholly upon the kind of work that his genius was most in sympathy with. However, he remained in it only six years. In 1799 he resigned the post, and thenceforth supported himself wholly by taking private pupils. Even when in the very height of his fame as an original discoverer, even when eminent savants came from all parts of the world to visit him, he had no more important occupation than "helping," as he used to phrase it, young people in arithmetic, algebra, etc., and no more distinguished place to receive his guests in than a little room belonging to the Manchester Philosophical Society which he had fitted up as a laboratory.

Dalton went to Manchester in 1793. He remained there till his death, a period of over fifty years. He never married. For a long time he lived in the house of a Rev. William Johns, and to this gentleman's family he left a substantial legacy. The only hours he did not spend in his laboratory were those of Sundays and of Thursday afternoons, and meal times and sleeping times. His life went as by clockwork. "A lady who lived nearly opposite his laboratory used to say that she knew the time to a minute by seeing Dr. Dalton open his window to read off the height of his thermometers." In summer he spent a few weeks each year in the "lake country," but his passion even then was for meteorological observation. His only indulgence was the pipe; but even this he resorted to only in the companionship of old acquaintances like Mr. Johns. Of the pipe, however, he was really fond, and when he met Sir Humphry Davy he testified that the only defect in Sir Humphry's character was that he did not smoke! Even the Thursday afternoons that he took to play at bowls he spent in watching others play while he regaled himself with gentle pulls at his "churchwarden."

All Dalton's scientific work was given to the world in papers read before the Manchester Philosophical Society.

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DIRECCIÓN GENERAL DE BIBLIOTECAS

Of this society he was elected a member in 1794. He became its secretary in 1800, its vice-president in 1808, and its president in 1817. He remained president until the time of his death, a period of twenty-seven years. It was before this society, in 1803, that he first propounded his theory of atomic combination, although he did not publish a full account of it till several years later. The real introducer of the theory to the world was Dr. Thomas Thomson, a professor of chemistry at Glasgow. In August, 1804, Dr. Thomson spent some days with Dalton at Manchester, and learned of the theory, and he soon became an ardent disciple of it. He published an account of it, and almost immediately it was taken up by the great chemists Gay Lussac of France and Berzelius of Sweden. Sir Humphry Davy, in England, however, did not at once accept, it, but when he did so it was with a heartiness that made amends for his previous dubitancy.

Dalton's discovery of the law of atomic combination is such a great one that his other discoveries, which are by no means few or unimportant, are overshadowed by it. It was that discovery, however, that first made him famous, and which still keeps him so. In 1822 he was elected a member of the Royal Society. Four years later he was awarded the medal of the society. In 1830, upon the death of Sir Humphry Davy, he was elected one of the eight foreign associates of the French Academy of Sciences, an honor that Sir Henry Roscoe calls one of the very highest a man of science can receive. In 1832 Oxford made him a D. C. L., in company with Brewster and Faraday. A little later he received the degree of LL. D. from the University of Edinburgh. In 1833 the government granted him a pension of £150 a year, afterwards

increased to £250. He continued his simple life of study and experiment to the very end. On Friday, July 26, 1844, he recorded his meteorological observations as usual. The next morning he passed away—"imperceptibly, as an infant sinks to sleep." Manchester gave his remains a public funeral. Forty thousand people came to visit the place where his body lay before it was finally entombed. Such was the honor in death of the poor weaver's son of Eaglesfield.

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JOHN DALTON

SELECTED STUDIES AND REMINISCENCES

DALTON'S HUMBLE WAY OF LIVING

In the year 1826, when Dalton had achieved a European renown, M. Pelletier, a well-known Parisian *savant*, came to Manchester with the express purpose of visiting the illustrious author of the Atomic Theory. Doubtless, he expected to find the philosopher well-known and appreciated by his fellow-citizens—probably occupying an official dwelling in a large national building devoted to the prosecution of science, resembling, possibly, his own Collège de France or Sorbonne. There he would expect to find the great chemist lecturing to a large and appreciative audience of advanced students. What was the surprise of the Frenchman to find, on his arrival in Cottonopolis, that the whereabouts of Dalton could only be found after diligent search; and that when at last he discovered the Manchester philosopher, he found him in a small room of a house in a back street, engaged looking over the shoulders of a small boy who was working his "cyphering" on a slate. "*Est-ce que jai l'honneur de m'addresser à M. Dalton?*" for he could hardly believe his eyes that this was the chemist of European fame,

teaching a boy his first four rules. "Yes," said the matter-of-fact Quaker, "wilt thou sit down whilst I put this lad right about his arithmetic?"—SIR HENRY E. ROSCOE, LL. D., F. R. S., *in "John Dalton, and the Rise of Modern Chemistry," in "The Century Science Series."*

DALTON AS AN EXPERIMENTER

Although in all his experiments Dalton made use of rough apparatus—very different from that now necessary for physical or chemical research—it is interesting to find how nearly many of his numerical results approach those since obtained by much more careful work, and by infinitely more accurate methods and instruments. Moreover, Dalton was fully aware of the existence of the experimental errors which his processes involved. His mode of arriving at results was, however, always ingenious, though often rough; indeed, as Angus Smith says, he seems to have begun his experiments with his hands and finished them off with his head.—SIR HENRY E. ROSCOE, LL. D., F. R. S.

DALTON'S POWER OF PERSEVERANCE

Up to the year 1796 [Dalton was then thirty years old] we have no evidence that Dalton had taken any special interest in chemical research, or even had carried on any practical laboratory work. His first introduction to the science, giving him an impetus to its study, seems to have been a course of lectures on chemistry which he attended, given in Manchester by Dr. Garnet. From that time onwards, however, both his mind and his hands were alike

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN
DIRECCIÓN GENERAL DE BIBLIOTECAS

VI. JOHN DALTON

1766-1844

BIOGRAPHICAL STUDY

BY JOHN EBENEZER BRYANT, M. A.

Dalton, the discoverer of the great fundamental law upon which the science of modern chemistry is based, "the law of atomic combination," does not hold the commanding position in the temple of fame that his genius, and the merit of his work as an original investigator of nature, entitle him to. By those who know he is ranked as one of the most eminent men of science of this century. He is called, indeed, the "lawgiver" of chemistry. Sir Henry Roscoe, one of the most eminent chemists living, speaks of his discoveries as "the greatest landmarks" in the whole realm of chemical knowledge. Sir Humphry Davy, who was his contemporary, spoke of them as comparable only to the laws of Kepler in astronomy. The distinguished geologist, Professor Sedgwick, when president of the British Association for the Advancement of Science, at its meeting in Cambridge in 1836, spoke of Dalton as "having obtained a name not perhaps equaled by any other living philosopher in the

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DIRECCIÓN GENERAL DE BIBLIOTECAS

world." The distinguished French chemist, Wurtz, in his "*History of Chemistry*" speaks of his name as "one of the greatest in chemistry." The distinguished astronomer, Sir John Herschel, called Dalton's atomic theory an "immeasurable step in our knowledge of nature."

But this reputation which Dalton has among men of science has not extended to the general public. In his own city, indeed, Manchester, his memory is honored as the greatest of her sons. His statue, sculptured by Chantrey and costing $10,000, stands in the entrance of Manchester's magnificent Town Hall, the most highly prized of all her art possessions. A scholarship, subscribed for by the citizens to the amount of $20,000, established in the Victoria University of Manchester, commemorates by its perpetual aid to scientific research both the greatness of Dalton's name and the chief interest of his life. But the world in general knows little about Dalton. He lived a humble, almost an obscure life. He rarely appeared to public view in any capacity, and never either strikingly or interestingly. He made no discoveries or inventions that were of immediate practical use, or that impressed the popular imagination. For many years he was scarcely known even to other men in the same branches of science as he himself labored in. He was a self-contained, self-absorbed, self-directed, self-reliant man, who took but little interest in any work, even in science, that was not his own. Nor did he make haste to put his discoveries before the world, or claim for them the priority which was their due. His whole life, indeed, was such as won him neither reputation nor emolument, except what came to him spontaneously despite his indifference.

The greatness of Dalton's discovery of the law of

atomic combination lies in the fact that, like Newton's law of gravity, it is fundamental. It forms the basis upon which the whole science of chemistry rests. The doctrine that matter is composed of "atoms," infinitely small particles, incapable of division, and for each sort of matter, all alike, is, as the phrase is, "as old as the hills." It was Dalton, however, who first took this doctrine, barren and useless as it had always been, and made it the fundamental element in our conception of the constitution of the universe. For example, it was known before Dalton's time that water is a chemical compound; that is to say, a combination of two elementary sorts of matter—hydrogen and oxygen. But Dalton reasoned that if the elementary particles or "atoms" of hydrogen are all alike, in size, shape, weight, etc., and if the elementary particles or "atoms" of oxygen are all alike, in size, shape, weight, etc., then, since these elementary particles or "atoms" of hydrogen and oxygen are "indivisible," union between the two can be effected to form water only by one elementary particle or "atom" of hydrogen becoming united with one elementary particle or "atom" of oxygen, to form one elementary particle of water; or else by one of hydrogen uniting with two of oxygen to form one of water; or else by two of hydrogen uniting with one of oxygen to form one of water; etc. And continuing his reasoning he saw that if, for example, an elementary particle of oxygen were considered to be sixteen times heavier than an elementary paritcle of hydrogen (he knew that bulk for bulk oxygen is sixteen times heavier than hydrogen), the proportion (by weight) of hydrogen to oxygen in water must be as 1 is to 16, or as 1 is to twice 16, or as twice 1 is to 16, etc. Having got thus

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DIRECCIÓN GENERAL DE BIBLIOTECAS

JOHN DALTON

far he made an analysis of water and found that the actual ratio was as 1 to 8; that is, as 2 to 16. That is to say, if the "atomic" constitution of matter be admitted, and if, further, the theory of "atomic combination" be admitted, an elementary particle of water must consist of the union of two elementary particles or "atoms" of hydrogen with one elementary particle or "atom" of oxygen.

Having discovered what the "combining weights" of hydrogen and oxygen were for water, it was next his task to find what they were for other substances. And not only had he to pursue an investigation like this for oxygen and hydrogen, but he had to pursue similar investigations for nitrogen, carbon, sulphur, phosphorus, and every other element then known, and to test the results he obtained in these investigations by seeing if they would hold good in every compound, such as carbonic acid, nitrous gas, sulphuric acid, etc., that he could possibly examine. This, roughly explained, is the route Dalton had to pursue even to get "indications" of the truth of his theory. But Dalton was able to get not merely "indications;" he was able to establish the truth of his theory so firmly that it was accepted by most of the scientists of the world almost as soon as they had opportunity of examining it.

It must be remembered that what is called the law of "atomic combination" is in part only a "theory." That the elements of matter, as they are called—hydrogen, oxygen, nitrogen, carbon, sulphur, etc.—do enter into combinations with one another in the proportions 1, 16, 14, 12, 32, etc., or multiples of these numbers, and in no other way, has been established (first by Dalton and later by hundreds of other scientists) in thousands upon

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thousands of instances of analysis and synthesis beyond all possible doubt. This "law of multiple proportions," as it is called, is, strictly speaking, all of the Daltonian law that is established. The rest of it is only ingenious hypothesis. But it is to Dalton's undying honor that he did not rest satisfied with the discovery of a mere blind law. The greatness of his achievements lies in the fact that he saw that this "law of multiple proportions" could be explained, and explained only, by the assumption (or "hypothesis," as it is called) that matter in its "elementary" states is composed of "atoms," so that when different elements combine (inasmuch as the atoms are for each element all alike, in size, shape, weight, etc.) they must always combine in the proportions of their relative atomic weights. That is to say, if carbon and oxygen, for example, combine, the relative weights of whose elementary particles or "atoms" are as 12 and 16, they must always do so in the proportion of 12 to 16, or in the proportion of some multiple of 12 to some multiple of 16; the reason being that every elementary particle of matter which is composed of carbon and oxygen must consist of one or more (whole) atoms of carbon united to one or more (whole) atoms of oxygen, fractional atoms being, of course, impossible of existence.

The importance of the discovery of the law of atomic combination can only be very faintly indicated here. It at once lifted chemistry from approximation and conjecture to exactness and certitude. The processes of nature and of art are largely chemical processes—combinations of atoms, dissolutions, and recombinations. The growth of every animated being, of every living substance, the changes effected in the condition of all inert

matter by those great agents, heat, light and electricity, are all chemical changes; that is to say, once more, combinations of atoms, dissolutions, and recombinations. But in every chemical combination and dissolution the great law discovered by Dalton must hold good. Not a single change in the constitution of matter throughout the universe can take place except it be that in that change the law of atomic proportion is observed. Matter is indestructible. It disappears in one phase and reappears in another. But in every such disappearance or reappearance not an atom is lost, or increased, or diminished. Individual atoms remain in size, in shape, in weight, etc., yesterday, to-day and forever the same.

John Dalton was born in the village of Eaglesfield, near Cockermouth, Cumberland, England, September 6, 1766. His father was a weaver in the village. His mother helped to support the family by keeping for sale a little supply of stationery. The circumstances of the Dalton's were, as the general opinion of the world is, very humble. They were poor. And they had no outlook. But they were high-minded people, and sincerely religious. Besides, they were "Friends," or, as is generally said, "Quakers." And as many of the people of the vicinity were also Friends, and as the social feeling among Friends is always more or less fraternal, the Daltons were not without compensations in their poverty. The facilities for education, however, open to a family so very poor were not good, and John Dalton's whole education was obtained only in the little village school and from his father. At twelve years of age he opened a school on his own account, and he conducted it for two years. At fifteen years of age he went to Keswick and became a teacher in a school that

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DIRECCIÓN GENERAL DE BIBLIOTECAS

constantly occupied in endeavoring to obtain a knowledge of the laws which express the chemical and physical properties of gases. Here it was, he plainly saw, rather than in the case of solids or liquids, that light would come, and to this he bent all the powers of his being. These were sterling honesty of purpose, inflexibility of will, clear-sightedness, and complete devotion to his subject. "If," says he in his later life, "I have succeeded better than many who surround me, it has been chiefly—nay, I may say, almost solely—from unwearied assiduity. It is not so much from any superior genius that one man possesses over another, but more from attention to study, and perseverance in the objects before them, that some men rise to greater eminence than others." And these words are true enough, although perhaps not expressing the whole truth; for in order to accomplish the greatest things of all something more than mere plodding is wanted. The "Divinis Afflatus" must be there, and the scientific imagination must be vivid, if more than a glimpse of Nature's secret ways is to be disclosed. As to how far this power of inspiration was carried in Dalton's case, opinions may differ. Some may look upon him only as a slow-witted worker, having but little knowledge or interest beyond the immediate results of his experiments. Others may consider him as one of the great seers of science, dwelling constantly in a realm of thought far beyond the ordinary habitations of mankind, and bringing down for their benefit some of the sweet fruits of a higher world. Probably the truth will be found to lie between these two extremes. All, however, will agree that genius or intellectual insight can accomplish little without perseverance, and that this

latter was possessed in high degree by Dalton.—SIR HENRY E. ROSCOE, LL. D., F. R. S.

DALTON'S GREAT ACHIEVEMENT

Nevertheless, in spite of his rough methods of experimentation, Dalton's results stand out the greatest landmarks in our science. His great achievement was that he was the first to introduce the idea of quantity into chemistry. It has been said, and with truth, that the Atomic Theory is almost as old as the hills. True, but no one before Dalton used the theory of atoms to explain chemical phenomena. To him is due the glory of placing the science on a firm basis, by showing that the weights of the atoms of the different elements are not identical, but different, and that combination amongst these elements takes place, if more than one compound be formed of the same elements, in simple arithmetical proportion.

In the case of almost every great scientific discovery, many men's minds have been working in the same direction, and it often becomes a question of interest to discuss how far the acknowledged discoverer had been assisted, or even anticipated, by those who had gone before him. Such a discussion has been raised in this instance. Some have even asserted that Dalton was a plagiarist, and that the credit of the establishment of a chemical Atomic Theory belonged to others. This is not the place to discuss the question at length. It must suffice here to state that a careful consideration of all the circumstances has led to the conclusion that Dalton arrived independently at his important results, and that whilst others had ex-

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DIRECCIÓN GENERAL DE BIBLIOTECAS

pressed opinions which approached the complete theory, they certainly did not reach it.—SIR HENRY E. ROSCOE, LL. D., F. R. S.

READERS' AND STUDENTS' NOTES

1. The account of Dalton most readily available to the ordinary reader is Sir Henry Roscoe's "*John Dalton, and the Rise of Modern Chemistry,*" in "*The Century Science Series,*" edited by Sir Henry Roscoe (New York: The Macmillan Co., $1.25).

UANL
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DIRECCIÓN GENERAL DE BIBLIOTECAS

Baron Cuvier

teenth year; and as his father's pension had been lost it was necessary for him at once to begin to earn his own living. Accordingly he accepted a position as a private tutor in the family of a gentleman residing at Caen, Normandy.

It was at Caen that Cuvier first became known to the world as a naturalist. He spent six years there—from 1788 to 1794, the terrible years of the revolution—but his life, despite the storm and turmoil of the outside world, was quiet and wholly studious and contemplative. The proximity of the sea led him to give his attention to the study of marine plants and animals. Though he was without scientific books, and felt the need of intercourse with other men of science, yet the observations he made, and the descriptions he sent of them to learned societies, soon gave evidence of his remarkable powers. He was fortunate, too, in winning the notice and friendship of the celebrated Abbé Tessier, who was then in Normandy in disguise, sheltering himself from the fury of the revolution. Tessier wrote of him to scientific friends in Paris describing him as "a violet hidden in the grass." In particular, he secured for him the interest of the rising young naturalist, Geoffroy Saint-Hilaire. Finally, in 1795, when he was but twenty-six years old, by Saint-Hilaire's influence he was appointed assistant professor of comparative anatomy in the Museum of Natural History in the Jardin des Plantes.

Cuvier's history, from the time he first settled in Paris until his death, is wholly a record of honorable appointments and successful discharges of the duties of his appointments. He served the directory, he served Napoleon as first consul, he served Napoleon as emperor, and he

served Louis XVIII., Charles X., and Louis Philippe. But under whatsoever government he served, or whomsoever he served, his one thought was to promote the interests of science, and of scientific and general education. It was not long before he was made professor of comparative anatomy at the Jardin des Plantes. He was also appointed lecturer to the Central School of the Panthéon. In 1799 he was made professor of natural history in the College of France. In 1802 he was made one of the inspectors-general of public instruction. In 1803 he was appointed perpetual secretary of the Institute of France. In 1808 he was made a councilor of the Imperial University. In 1814 he was made by Napoleon a member of the Council of State, and this appointment was continued to him upon the restoration of the Bourbons. Other offices to which he was appointed were: Chancellor of the Imperial University, President of the Council of Public Instruction, and President of the Committee of the Interior, the latter being an important office of government administration, which he retained until his death. In 1826 Charles X. made him grand officer of the Legion of Honor, and in 1831 Louis Philippe made him a peer of France. Finally, in 1832 he was nominated to the high office of President of the Council of State—perhaps the most honorable public office in the gift of his country—but this position, owing to his untimely death, he never actually held.

These distinguished offices and honors indicate the esteem in which Cuvier was held by his countrymen. They were not mere compliments. They were bestowed upon him for his real worth as an administrative officer. Napoleon was careful in his choice of men for administrative positions, and when he selected Cuvier for the reorganiza-

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN ®
DIRECCIÓN GENERAL DE BIBLIOTECAS

tion of the educational systems of the country he selected the very best man he could lay his hands upon. As an instance of the amount of work which these administrative offices entailed upon Cuvier it may be mentioned that in the single position of President of the Committee of the Interior ten thousand distinct and separate matters came before him annually for his judgment and decision. But the honor of all these offices and dignities sinks into insignificance compared with the honor and grandeur of the work he was able to do for science—although this can only be touched upon here. There are, however, three things Cuvier did for science which at least must be mentioned. In the first place he substituted for the artificial classification of the animal kingdom which Linnæus had set up a natural classification based on fundamental anatomical resemblances and differences. Cuvier had the most profound knowledge of structural anatomy ever possessed by man. His gift for divining anatomical structure was indeed a sort of morphological instinct. This instinct led him to see that many animals, apparently unlike, were, on a closer examination of their parts, really alike, and that many animals, apparently alike, were really unlike. With him, therefore, classification had to rest upon considerations of morphology and homology—that is to say, upon consideration of structural form, and of likeness or unlikeness in the structural form. In this doctrine Cuvier has been wholly followed by all modern scientists. In the second place, it is to Cuvier that the world owes the science of comparative anatomy. It was he, for example, who first pointed out the correspondence between the arm of a man, the fore-leg of a quadruped, and the wing of a bird; and it was he who first established the now generally

BARON CUVIER.

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN
DIRECCIÓN GENERAL DE BIBLIOTECAS

admitted principle that there can be no real scientific zoological study that does not include the recognition of likeness in structure (whatever the functional unlikeness may be) of corresponding parts in different animals. Thirdly, it was Cuvier who first gave value and character to the science of palæontology—that is to say, the science which deals with forms of animal life now extinct and known to us only by their fossil remains. Before Cuvier's time, when fossil remains of animals were found they were usually crudely believed to be the remains of human giants, or the remains of giant specimens of animals now existing. The world was astonished beyond measure—the scientific world no less than the ordinary world—when Cuvier showed that these fossil remains (remains, for example, that the people of Luzerne, in Switzerland, fondly thought to be relics of their ancient kings) were the bones of huge rhinoceros-elephant-boars, bird-lizards, fish-lizards, fish-serpents, etc., all species of animals which no longer exist. Still more was the world astonished when Cuvier showed that the earth in former ages was peopled with whole genera of species which no longer exist, and that the true understanding of the characters and habits of these extinct species could be learned by the study of the characters and habits of species that do now exist.

These three things, thus crudely described, and also many others, Cuvier did for science. His life was a full one in every respect. It was fortunate and happy, too, in every respect but one. His children, whom he most fondly loved, all died before him. And when in 1828 his second daughter died, his only child that lived to maturity, his heart broke. He lived a few years longer; but his hair whitened with grief, and labor became a sorrow to him;

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN
DIRECCIÓN GENERAL DE BIBLIOTECAS

VII. BARON CUVIER

1769-1832

BIOGRAPHICAL STUDY

BY JOHN EBENEZER BRYANT, M. A.

The career of Cuvier was, perhaps, the most brilliantly successful in the whole history of science. There was scarcely any sort of honor or honorable estimation that he did not attain. As a careful and accurate original scientific observer and investigator he won the esteem of all other scientific observers and investigators. As a scientific teacher and lecturer he won the affectionate admiration of all his hearers, and this not more by the profundity of his knowledge than by the interest he always inspired in the subjects of his discourses, and the enthusiasm he constantly excited for the prosecution of scientific research. As a scientific writer he not only united the widest and soundest information with a graceful and pleasing style, but he was able by his indefatigable energy and industry to turn out whole libraries of classical productions, any one of which was of sufficient importance to have made any man famous. And further, by his scientific insight and discernment he was able to establish new

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN
DIRECCIÓN GENERAL DE BIBLIOTECAS

scientific truths, to present new views of scientific facts, to discover and invent new systems of scientific order and classification, which have justly entitled him to a leading place in the very first rank of the world's scientific philosophers. And yet all this was only one part of the work he did in the world. Cuvier was not merely a scholar and a scientist; he was a man of practical affairs. Although he lived and worked with an eye single to the cause of scientific truth, his genius for administration soon became recognized by his countrymen; and, first in the administration of affairs connected with higher education, then in the administration of affairs connected with general education, and finally in the administration of the affairs of state generally, he was given one public employment after another, until, in the end, if hard work and grief for the loss of his loved children had not cut off his years untimely, he would undoubtedly have had the administration of the whole internal affairs of his country upon his shoulders.

Léopold Chrétien Frédéric Dagobert Cuvier, afterward by the wish of his mother called Georges, which was the name of an elder brother, deceased, was born at Montbéliard, on the eastern border of France, August 23, 1769. His father was a retired Swiss officer. His mother, who was much younger than her husband, was also a Swiss. She was a woman of refined culture and noble character, and to her loving, watchful direction and supervision of his studies, to her loving counsels and precepts, to the influence of her long-continued companionship, he owed much of his early rapid mental development; much, too, of the sterling uprightness and sense of duty, the charm of manner, tactfulness, and discretion, which distinguished

him all through life. From the very first he was fond of nature, and his inborn faculty of observation was stimulated by the habit which his mother fostered in him of making drawings of natural objects, and coloring them to agree with nature. From his tenth to his fourteenth year he attended the high school of his native town, where his progress in the prescribed academic studies of the time was remarkable. But his progress in the studies that he pursued out of school was even more remarkable. He had found in the house of a friend a complete set of the works of the celebrated naturalist Buffon, and these he studied with such ardor, making copies of the illustrations and coloring them, that at the age of twelve he was an accomplished naturalist. In his fifteenth year his reputation as a lad of genius and industry had secured for him many friends, and one of these recommended him to the duke of Würtemburg, who placed him in his own academy in the University of Stuttgart. At this university, by the duke's kindness, he remained four years, taking not only the usual courses in philosophy, classics, mathematics, etc., but also special courses in political economy, finance, and jurisprudence. His university course was a very brilliant one; and yet once more his extra-academic studies were more remarkable and important than his academic studies. He collected an herbarium. He also studied and made drawings of animals, birds, insects, and plants. Of insects, indeed, he made a special study, and kept collections of living insects in his room, and fed them and watched their habits. As he afterward acknowledged, the foundations of his subsequent scientific fame were laid in these self-directed, voluntary scientific pursuits at Stuttgart. When he left the university he was in his nine-

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN
DIRECCIÓN GENERAL DE BIBLIOTECAS

and in the very height of his fame, in the very fullness of his usefulness, his strength failed him forever. He was seized with paralysis and passed suddenly away—May 13, 1832—the very day the king had approved of his nomination as President of the Council of State.

BARON CUVIER

SELECTED STUDIES AND REMINISCENCES

CUVIER AND NAPOLEON

Napoleon, who nearly always chose the best man for a place, made Cuvier a counsellor of the new Imperial University, and the two men thus came frequently in contact. Repeated personal interviews preceded Cuvier's appointment to organize new universities in the foreign states more or less under the sway of France. He undertook the reorganization of the old Italian universities of Piedmont, Genoa, and Tuscany. His reports of these missions speak of the enlightenment of his mind and his truly reasonable and very liberal spirit. Speaking of the universities of Tuscany, he deprecates a too hasty and rash interference with institutions which had been founded and maintained by so many distinguished men of old, and in which he found so much to praise and to retain. He examined into the condition of the universities of Holland, and finally those of lower Germany. These journeys were doubly useful, for they established his health and gave him plenty of opportunity of visiting museums. While at Hamburg, Napoleon gave him the title of chevalier, which was confirmed to him and his heirs. But such honors were not

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN
DIRECCIÓN GENERAL DE BIBLIOTECAS

set to work reading, but suffered the ladies to talk as much as they pleased. The family dinner hour was half-past six; and if Cuvier had a few moments to spare before that time he would occasionally join his friends in Madame Cuvier's room, but more frequently he seems to have given even this short time to study. One or two intimate friends joined the circle at dinner, and then Cuvier's conversation was delightful. On proceeding to the drawing-room Cuvier sometimes gratified his friends by an hour's stay among them before he retired to his occupation or his visits, but so untiring was his industry, that he often set the whole party to work aiding him in his researches. If he had any foreign works, he would often amuse his friends by verifying the figures in them, one after the other. It must be said that this everlasting work was trying to people who were with Cuvier, for no sooner did friends come to stay with him than he began to use them in tracing drawings on paper. He kept them at work, for when he returned from his labors he generally asked for the tasks he had thus set. Nevertheless, many found it a real pleasure to work for him, for he was very grateful for such assistance. Cuvier's hours of relaxation were few. Change of employment afforded him relief, and conversation still greater. At the close of the day's labor, when he found it impossible to work any longer, he was accustomed to throw himself on a sofa, hide his eyes from the light, and listen to the reading of his wife or daughter, and sometimes of his secretary. These nightly readings lasted two hours, and thus Cuvier became more or less acquainted with the current literature and good works of the day.—PROFESSOR P. MARTIN DUNCAN, F. R. S.

CUVIER'S PRIVATE AND DOMESTIC LIFE

When in the full swing of his career, Cuvier gave very interesting *soirées* on Saturday evenings, and it is said that they were the most brilliant and interesting meetings of their kind in Paris. They were much frequented by the scientific world of the time, and the rooms were as much open to the prince as to the last young student who had just begun to study natural history. In this society Cuvier was an amusing conversationalist, a great asker of questions; and as he could talk well on a great variety of subjects, he made his guests at home, and gave the meetings a character for freedom of expression of opinion. A light repast concluded the evening, and a select few remained to partake of it. The chat was amusing, curiosities were shown about, and the last anecdotes about nature and the newest ideas were shown and considered, and, reserving himself to the last, Cuvier would relate something that crowned the whole; and all around were struck by the occasional complete change given to the train of thought, or were forced to join in a general shout of laughter. The period of these brilliant *soirées* was that of the prime of the lovely daughter who was so fondly loved by Cuvier. A perfect lady, of great grace and goodness, was Clémentine Cuvier. She was a highly-gifted girl, and her resemblance to her father was remarkable. She had a delicate constitution, and gradually faded away, dying of rapid consumption at last amidst the joyful preparations for her marriage. A great change then took place in Cuvier, who mourned his daughter greatly. Society was given up for

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a long time, and when the evening meetings were resumed, the life of them seemed to be gone, and the dejection of Madame Cuvier added to the feeling. After the death of his own daughter, Cuvier became more than ever attached to his step-daughter, and his care and anxiety on her account manifested itself on all occasions. If she were ill he would be up and down stairs over and over again, and worried himself about even the most trivial symptoms. Although so greatly occupied and so often absorbed in scientific pursuits, he never neglected the opportunity of doing good in his way. His private charities were large and well-bestowed. His purse was ever open to the needy and unfortunate of all countries and stations; and the miserable inhabitants of the dens of Paris and the modest student struggling under adversity were alike the recipients of his bounty. Many hotels in the neighborhood of the colleges and institutions had students in them, living in the top stories, who were so poor that they had to subscribe to get a book or two between them. They would occasionally be surprised by a visit from their great teacher. He came to offer, with the greatest courtesy, the assistance he knew they required; and if they were ill, he did not rest satisfied until he had obtained advice and nourishment for them. Himself keenly alive to the slightest rudeness or neglect, and grateful for the smallest proof of affection, he knew how to give not only with a liberal hand, but with a delicacy which never wounded the most sensitive temper.—PROFESSOR P. MARTIN DUNCAN, F. R. S.

CUVIER'S DEATH AND FUNERAL

Convinced that all human skill was in vain, Cuvier nev-

ertheless submitted to treatment by his medical men. Paralysis crept on, and the legs were attacked, his speech was affected, and he muttered, "It is the nerves of volition that are affected." He spoke of his last lecture, and said to a friend who called, "Behold a very different person from the man of Tuesday; nevertheless I had great things still to do. All was ready in my head, after thirty years of labor and research; there remained but to write, and now the hands fail, and carry with them the head." Cuvier gradually sank, but kept his intelligence nearly to the last. It was his wish to be buried privately, interred in the cemetery of Père le Chaise, under the tombstone which covered his beloved child; but it was not possible to avoid the public demonstration of respect. The funeral procession was followed by the representatives of all the great learned bodies of France.—PROFESSOR P. MARTIN DUNCAN, F. R. S.

READERS' AND STUDENTS' NOTES

Popular accounts of Cuvier are not very accessible. The best perhaps are to be found in such works as the "*Encyclopædia Britannica.*" In P. Martin Duncan's "*Heroes of Science—Botanists, Zoologists, and Geologists*" (New York: E. & J. B. Young & Co.) a whole chapter, and a very readable one, is devoted to Cuvier. So also in Sarah K. Bolton's "*Famous Men of Science*" (New York: T. Y. Crowell & Co., $1.50). Cuvier's work will also be found duly chronicled in Miss Buckley's "*Short History of Natural Science*" (New York: D. Appleton & Co.).

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN
DIRECCIÓN GENERAL DE BIBLIOTECAS

destined to descend, for Cuvier lost his son in his seventh year. It was a great grief, and it saddened and subdued the man. This trial happened when Cuvier was at Rome, trying to arrange the universities there.—PROFESSOR P. MARTIN DUNCAN, F. R. S., F. L. S., *in "Heroes of Science—Botanists, Zoologists, and Geologists."*

CUVIER'S WORK FOR STATE EDUCATION

After the abdication of Napoleon and the defeat at Waterloo, it became necessary, in the ideas of Louis XVIII., that the universities should be remodelled, and a committee of public instruction was created to exercise the powers formerly belonging to the grand master, the council, and the treasurer of the University. Cuvier was one of the committee, and was made Chancellor of the University, a position which he retained under most trying circumstances until his death. No man did greater or better and more lasting work for state education than Cuvier. His heart was in the work of education; he had nothing but mental progress to desire; and it was a much more satisfactory thing for France to have a renowned, scientific man at the head of a great university, who, moreover, really controlled the education of the country, than to have such important offices held by mere politicians and soldiers.—PROFESSOR P. MARTIN DUNCAN, F. R. S.

CUVIER'S PERSONALITY

Cuvier was slightly built in his young days, and moderately tall; but the sedentary nature of his work, and his carelessness about taking proper exercise, produced corpulence in his later years, and his extreme near-sightedness brought on a slight stoop in his shoulders. His hair had been light in colour, and to the last it flowed in fine curls over one of the noblest heads ever seen. He was handsome and had regular features, with an aquiline nose, a broad forehead, and keen eyes. The love of order, which was his very peculiarity in his work, was seen in little things, for Cuvier was almost feminine in his attention to dress. He even took in hand the costume of the University and designed the embroidery of his court suits.—PROFESSOR P. MARTIN DUNCAN, F. R. S.

CUVIER'S HABIT OF CONTINUOUS WORK

Cuvier's domestic life was the kind of life that has to be led by most prominent men in science, art, and literature. Work, everlasting work, with but little relaxation! He certainly wasted no time. Before and after breakfast he saw anybody who wished to have an audience of him. By seven in the morning he was dressed, and began preparing his day's work and that of his assistants, so that by ten o'clock, when he breakfasted, he had time to look at the newspapers, to read correspondence, and look over any particular works. After breakfast he dressed for the day and began work. His carriage was punctual to a moment, and no one was allowed to keep him waiting. When the ladies were to accompany him, they made a point of being as exact to time as was possible; and he seems to have enjoyed the sight of his womankind rushing down stairs with their shawls streaming after them and their gloves half on their hands. The instant he had given his orders, he would thrust himself into a corner of the carriage and

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DIRECCIÓN GENERAL DE BIBLIOTECAS

Alexander von Humboldt

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in Paris, where, better than in Berlin, he was able to obtain scientific co-operation in arranging for publication the great mass of data he had collected. This task, which he hoped to accomplish in two years, occupied more than twenty; and it is an evidence of his strength of character that he accomplished this without yielding to the desire for further travel, while Bonpland left his work incomplete to return to South America.

The first work that he published is perhaps the best known of all of Humboldt's books. It was entitled "*Views of Nature,*" and was, to use his own words, "a series of papers which originated in the presence of the noblest objects of nature—on the ocean, in the forests of the Orinoco, in the savannahs of Venezuela, and in the solitudes of the Peruvian and Mexican mountains." Its object was "to heighten the enjoyment of nature by vivid representation, and at the same time to increase, according to the present state of science, the reader's insight into the harmonious co-operation of forces."

The purely scientific results of his travels he classified and published in separate volumes—two on astronomy and geography, two on zoology and comparative anatomy, two on the political economy of New Spain, one on the Cordilleras and monuments of the indigenous nations, seven of descriptive botany, one on plant geography, and one on geology; and then, as if this amazing activity, with its unprecedented contributions to almost every department of science, were not enough, he added, for the purpose of including such material as did not fall within the scope of these works, his "*Personal Narrative,*" begun in 1815 and continued until 1831. The works already mentioned, together with some separate volumes of plates,

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DIRECCIÓN GENERAL DE BIBLIOTECAS

made a library of twenty-six folio and quarto volumes, which by 1844 were valued at over $2,000. The books resulting from his travels in Asia are entitled "*Asiatic Fragments*" and "*Central Asia*," the former consisting of two and the latter of three volumes.

For many years Humboldt's chosen home was Paris, where he found, in far more generous measure than in Berlin, the congenial companionship and sympathy of fellow-workers in science. But Berlin was the home of his brother, his own native city, and there, too, was the king of Prussia, who had conceived a great liking for him and had determined to have him at hand as friend and scientific adviser. Yielding to his wishes, Humboldt, in 1826, took up his residence in Berlin, but much that he found there was not to his taste, and for a time he made frequent visits to Paris, where he could work better.

His later life at the Prussian court, where he was still retained by Frederick William IV., was one of indefatigable scientific work and involuntary discontent with the incongenial atmosphere by which he was surrounded. From his letters to his friend Varnhagen, to whom he opened his heart, we get a glimpse that prompts a suspicion that the king's jester may sometimes hold a more comfortable position than the king's scientist. His seat at the royal table, frequent journeys with the king, and the splendors of the court, made scanty amends for lack of intellectual sympathy. The two men were totally at variance both in politics and religion, and occasionally, in a half-desperate mood, Humboldt expressed himself in no measured terms regarding those with whom he had so little in common. He was no "king's gentleman," like Voltaire; the patronage was on both sides—an interchange of

the noblest mental powers and the highest social station—and Humboldt well knew the immeasurably greater worth of what he gave in the unequal compact.

But in spite of these hindrances his phenomenal intellectual activity and untiring scientific genius found continued and fruitful expression, now in a course of lectures that attracted scholars and the general public alike, now in a plan for a series of stations for magnetic and meteorological observations to encircle the globe, resulting in the actual establishment of such a chain of stations through Russia and northern Asia to the borders of China; in the midst of the distractions of the court sleeping but four or five hours out of the twenty-four, that he might give the more time to writing books; appointed to diplomatic missions requiring special knowledge and tact—in these and in many other ways for many years Humboldt served as no one else could his country and the cause of science. In the midst of these duties his life was saddened in 1836 by the loss of his brother William, between whom and himself there had always existed the most loving fraternal relations, and in whose death Humboldt lamented that he had lost half of himself.

Humboldt had reached the ripe age of seventy-six before he began to put into final form the great literary work of his life the "*Cosmos*." Before he was thirty he had outlined the work in a letter to a friend and his subsequent public lectures were really an epitome of it. In the introduction he says: "In the late evening of active life I offer to the German public a work whose undefined image has floated before my mind for almost half a century." The title of the book is its best description. After so many years of study and travel the author sought to

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN
DIRECCIÓN GENERAL DE BIBLIOTECAS

communicate to others in the supreme and final product of his genius the great thoughts of a lifetime. He had reached the point where he could "comprehend the phenomena of physical objects in their general connection, and represent nature as one great whole, moved and animated by physical forces;" and now he would cause this to pass before his readers as a panorama of the universe, lighted up by his own poetic spirit, but everywhere in conformity with the rigid scientific principles that it had been his mission to determine and elaborate. To this end he labored with unabated vigor until, in his ninetieth year, death ended his work. The last sheets were sent to the printer but two months before his death. The work is unique in its vast accumulation of scientific matter, in literary form, and the lucid expression that brings it within the intellectual range of ordinary minds.

The preceding sketch has presented Humboldt as an intrepid explorer, a universal scientist and author, and a trusted confidant in the diplomatic circles of two great empires; but to those who knew him best the man was more than the scientist, and the teacher's work has endured while that of the diplomat has passed away. Humboldt possessed a large humanity that made him the friend of the oppressed, an earnest advocate of political freedom, and a patron and helper of struggling students. Agassiz tells that when he was studying in Paris his funds gave out and he was about to return home. He told his instructor why he was leaving, and the instructor must have told Humboldt, for the next day his servant brought Agassiz an envelope containing a check for £50, with the request that he accept the money as a loan. Not many

loans have been more secure or brought greater interest in return.

It would be hard to overestimate his actual contributions to human knowledge. He discovered the increased intensity of the earth's magnetic force from the poles to the equator; he showed that volcanoes were arranged in lines and demonstrated the igneous origin of certain rocks; he recognized the physical factors determining the distribution of plants, and the existence of independent formations in the geological history of the earth, and drew the first isothermal and magnetic lines; and, finally, he practically created the sciences of physical geography and meteorology. But in its lasting results his work as a teacher overshadows that of the worker in science.

It is not those alone who meet students within the walls of a schoolroom or laboratory who are teachers. Humboldt never did this, but from the time that he bent his energies while inspector of mines to the establishment of a public school, to the last months of his life when in writing "*Cosmos*" he tried to bring the German people to see nature through his eyes, he showed the spirit and did the work of a teacher. He was eager to impart knowledge, and skillful in his methods of doing so.

For a short period of his life Humboldt came into direct contact with the public when he gave his courses of lectures in Paris and Berlin, which were eagerly listened to not only by scholars but by people of all ranks as well. His name became a household word, even among the unlearned and ignorant.

The whole German nation finally became pupils in Humboldt's school. When he was a young man Germany

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had lost for the time the spirit of scientific thought, and had become a center of synthetic philosophy. Poets and philosophers controlled the popular mind, and Humboldt went to a foreign country to find scientific co-operation and sympathy. Later, however, he returned to fulfill the greater work to which he was called, and it would be hard to imagine one better fitted than he to change the current of the national thought. His profound and powerful intellect, his poetic and artistic temperament, his noble birth, and above all his capacity for exact scientific thought, made him beyond all others "the man to lay the bridge between the old and the new time, between the philological, æsthetic Germany, as the turn of the century saw it, and the scientific, technical and inductive Germany of our day." This he accomplished, and not Germany alone but the world has shared the fruits of his toil and genius, and gladly joins with his fatherland to do him honor.

ALEXANDER VON HUMBOLDT

SELECTED STUDIES AND REMINISCENCES

HUMBOLDT AND THE HAPPY FORTUNE OF HIS BIRTH

Our researches into the phenomena of the physical and the human cosmos present us with many curious parallels. In those two distinct, yet inseparably united realms, there are periods when the creative energies seem to slumber, and periods when they seem to manifest themselves in splendid and unwonted energy. Like the aloe, which, according to popular belief, flowers but once in a hundred years, then puts forth a blossom of marvelous beauty, so nature atones for her seeming sleep by the creation of minds which become new vital forces in the world of man. One star does not rise alone in the twilight of heaven: great men dawn upon the world in constellations. Sometimes a decade of years sees the advent of those who are to give character to the century in which they live. Sometimes a single year is marked in this way; and such was the year 1769. Between the chimes of its New Year's morn and the last setting of its December sun, were born into the world Cuvier, Wellington, Napoleon; Sir Thomas Lawrence, long the first portrait-painter of the age, and President of the Royal Academy; William

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VIII. ALEXANDER VON HUMBOLDT

1769-1859

BIOGRAPHICAL STUDY

BY VOLNEY M. SPALDING, PH. D.
Professor of Botany, University of Michigan

Friedrich Heinrich Alexander, Baron von Humboldt, as his name stands in full, was born in Berlin in 1769. He was of noble parentage, his father having received the post of royal chamberlain as a reward for his services in the Seven Years' War. When he was ten years old his father died and the care of his education and that of his brother William devolved upon the mother.

As a child Alexander was frail and of little mental promise, and the two boys, instead of being sent to school, were taught at home by tutors. One of these was Campe, the editor of the German *"Robinson Crusoe,"* and it is very possible that in his earliest years Alexander Humboldt imbibed at his teacher's knee a love of travel and adventure. Later the two boys were sent to school—first at Berlin, then at Frankfort, and finally at Göttingen. His brother followed the bent of the age, giving himself to literature and philosophy, while Alexander, under the

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same influences, developed year by year a still stronger taste for natural phenomena. He was nineteen years old when he entered the University of Göttingen, and here he met and formed an intimate friendship with George Forster, one of Cook's companions on his second voyage.

This friendship was well calculated to heighten the desire for travel that now amounted to a passion with him. In one of his vacations, while still a mere boy in years, he made a scientific expedition up the Rhine, and published the results of his investigations in a paper entitled "*Mineralogical Observations on Some of the Basalts of the Rhine.*"

By this time his future lay clearly outlined in his powerful imagination. He was to be a scientific explorer, and from this purpose he never swerved, but bent every energy toward preparing himself for his chosen calling; and seldom have both nature and education combined to give greater fitness for such a career. He had a poetical, artistic temperament, an eye keenly alive to every impression, a rare power of language, and a sympathetic, kindly disposition. He studied with the best masters of the day, commerce, foreign languages, the use of scientific instruments, botany, chemistry, ethnology, and finally geology and palæontology at Freiberg, where he published a work on fossil plants that gained him the appointment of director-general of mines in the principalities of Anspruch and Bayreuth.

It was during this time that he became greatly interested in Galvani's discoveries in muscular irritability. He carried on an extended series of experiments while attending to his public duties, taking his instruments with him as he went from place to place on horseback, depopulating

frogponds at every stopping place, and finally in 1797 publishing the results of his investigations in two octavo volumes.

In the meantime he had formed the friendship of Goethe and Schiller, the one twenty and the other ten years his senior, but both of them gladly sharing their scientific and literary treasures with the young man whose life and teaching were to affect so fundamentally the intellectual life of Germany and the world. Schiller's previous medical studies gave him a sympathetic interest in Humboldt's experiments, and it may have been under the influence of this friendship that he wrote for Schiller's paper, "*The Rhodian Genius,*" a physiological allegory which embodied his idea of the vital principle.

In 1796 Humboldt's mother died. Up to this time he had refrained for her sake from carrying out his ambition to travel in distant lands; but now there was nothing to prevent its realization, and after a preliminary trip into Italy and Sicily for the purpose of examining their volcanic regions he turned his thoughts toward the accomplishment of his cherished purpose.

On the 15th of June, 1799, in company with the French botanist Aimé Bonpland, Humboldt sailed from Spain, armed with a permit from the government to visit and explore all the Spanish possessions in America. They landed at Cumana, in Venezuela, and after exploring the coast made a long journey inland, during which they discovered the connection between the water systems of the Amazon and Orinoco rivers. After this they spent several months in Cuba, then returned to Cartagena and made another inland journey over the mountains to Quito and Lima, whence they sailed to Mexico; and after a year

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there and a short visit to the United States they sailed for Bordeaux, where they landed on August 3, 1804.

Their zeal in collecting everything illustrative of the natural history of the regions visited, and the difficulties encountered, may be understood in part from Humboldt's own account. He says: "Our progress was often retarded by dragging after us during expeditions of five or six months, twelve, fifteen and sometimes more than twenty loaded mules," with collections that toward the close of the expedition "formed forty-two boxes containing an herbal of 6,000 equinoctial plants, seeds, shells, insects, and, what had hitherto never been brought to Europe, geological specimens from the Chimborazo, New Granada, and the banks of the Amazon." At the same time he was devoting himself with extraordinary outlay of care and labor to the observation of every form of natural phenomena and the preservation of accurate scientific records.

Humboldt was thirty-five years of age when he returned from his American travels, and he was sixty before he undertook another journey of exploration. The second one was across central Asia, the expense being defrayed by the Russian government. He was accompanied by Gustav Rose and Ehrenberg, and in this journey of eight months and a half, extending over 25,000 miles, he collected a mass of observations that required years to reduce to their published form. He said that this expedition enlarged his views "of all that concerns the formation of the earth's surface." More specifically, it helped him, among other important results, to explain the differences of the American and Asiatic climates, and he also made important discoveries in regard to the mineral wealth of the country.

After Humboldt's return from America he settled down

ALEXANDER VON HUMBOLDT.
From a daguerreotype.

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Smith, called the father of English geology; and Alexander von Humboldt. Various sciences and arts were thus represented. I would not attempt to trace characters so varied,—destinies so unlike; for me the life of Humboldt, in its consistency, its integrity, its success, and its rewards, possesses a complete power and symmetry which none of his renowned compeers could show. Few men have lived for so long a time under the eyes of the world. There is no life, however insignificant it may appear, which does not in some way advantage the world. But a life like Humboldt's, enriched with the experience of two centuries, and illuminated by a long series of splendid achievements, opened a new avenue into the realms of truth and of science. I would, therefore, attempt to speak of the mind and the heart of Humboldt; of his capacities, his ideas, his character; of his place, not merely as a man of science in the world of knowledge, but pre-eminently as a man in the world of men. It is good to contemplate the union of a well-balanced character with a completed and harmonious destiny. Like the Grecian mother, who feasted her eyes on perfect statues, that her unborn child might possess something of their beauty, so that divine order which Humboldt sought for with religious fervour throughout the material world, seemed at last to be reflected in the wonderful symmetry of his life. Fortune, however, was less partial than people were apt to suppose. And, though Humboldt was born under a happy planet,—and it is difficult to imagine circumstances more favorable than those which surrounded his childhood,—yet the same good fortune in hundreds of other instances would only have produced mediocrity. The germ of character lay far below the influence of circumstances.—F. A.

SCHWARZENBERG, *in "Alexander von Humboldt, or What May Be Accomplished in a Lifetime."* *

HUMBOLDT'S EARLY INTEREST IN NATURE

The history of Humboldt's early life, though meager and imperfect, yet furnishes the necessary clue to its grand development. His first teacher (J. H. Campe) was the translator [into German] of that wonderful fiction, more real than reality, *"Robinson Crusoe."* His friend and companion was George Forster, who had accompanied the celebrated Captain Cook in his second voyage round the world. All his early recollections were mingled with stories of travel, adventure, and discovery; and wandering among the pine woods of his father's estate, his imagination enlarged them into vast continents, the arms of the lake expanding into breadths of ocean, hiding somewhere in the distance unknown islands. And long afterwards, when much of his labor had been accomplished, and his sacred fame was all secure, he observed that the impression aroused within us in early childhood always took a graver direction in after-years. The educational method of Rousseau had already found entrance and acceptance in Prussia, and had given rise to more liberal plans for the education of youth; and to those ideas Humboldt was indebted for a course of training which developed his body and mind in an equal degree, and allowed

* "The reader will no doubt meet with many defects of style inseparable from efforts to think in one language and express those thoughts in another; and I therefore bespeak his indulgence for my attempt to write in a tongue I never learned from my mother's lips." *Extract from the Author's Preface.*

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HUMBOLDT'S DEVOTION TO SCIENCE

The most prominent traits in Alexander von Humboldt's character,—universally acknowledged,—were his sincerity and his simplicity. Possessed with all the tastes of a man of the world; endowed with all the graces which the best societies of Europe could impart; with all the prerogatives of his birth and position; with all the tempting prospects of an exalted position in his own country; he, with characteristic sincerity, followed the natural yearning of his soul, and consecrated himself as a servant of science and humanity. He sacrificed cheerfully ease and comfort, and laid upon the altar of science all in search for that knowledge which would expand the conceptions of ourselves and of the world in which we live; and this I consider to be his high moral position as a man in the world of men. Humboldt, in discovering the secrets of nature and in explaining them to mankind, caused of necessity a great change in the prevailing ideas of the human race. His object was to labor for the whole: his actions are interwoven with the history of mankind.—F. A. SCHWARZENBERG.

THE MAGNITUDE AND COMPREHENSIVENESS OF HUMBOLDT'S RESEARCHES

Humboldt and Cuvier entered simultaneously upon their researches as naturalists. Humboldt like Cuvier directed himself to facts; he examined and compared without ever taking a direct part in the battle of the philosophers, because he had entered upon a new road—a

higher and a more comprehensive point of view. He endeavored to comprehend the universe in all its grandeur. Nature should, through a perfect comprehension of its powers and its laws, in general and in particular, become a lively object of human knowledge—an open book in which the isolated and the small explains itself through the whole and the great. The immense territories of his researches were:—(1) The knowledge of the earth and its inhabitants; (2) the discovery of the higher laws of nature, which govern the universe, men, animals, plants, and minerals; (3) the discovery of new forms of life; (4) the discovery of territories but imperfectly known, and their various productions; (5) the acquaintance with new species of the human race,—their manners and languages, and the historical traces of their culture. In this extensive field Humboldt labored with unwearied activity, care, and perseverance. The natural consequences of his researches manifested themselves in all the branches of scientific and practical knowledge, and found application in numerous circles of life. His vivid and glowing descriptions, never yet surpassed, of scenes witnessed in different countries, awakened a desire for travel. They furnished new instruction. The charm of his descriptions inspired numerous youths with a love for nature's beauty, and many a thoughtful man with the resolve to study the laws of nature; and even many a female heart, attracted by the fabulous tropics and by the grandeur of tropical scenery, learned to pronounce with veneration the name of him whose person was surrounded, in their conception, with the enchanting brightness of the mysterious and the marvelous.—F. A. SCHWARZENBERG.

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READERS' AND STUDENTS' NOTES

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Sir Humphry Davy

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full play to the gratification of all his natural tastes. He was not the only child for which that crazy philosopher received a father's blessing; but in no other instance was his system so nobly justified as in Alexander von Humboldt. Noticing that the boy exhibited a more than ordinary interest in trees and plants, his teacher made him acquainted with the rudiments of botany, and explained to him the twenty-four classes of the Linnæan system. He soon perceived, however, child as he was, that one science was but a single door to the great temple of nature; and he was not satisfied without possessing the keys to all; and his researches, commencing with the blossoming of a nettle by the wayside, finished their course among the beams of the remotest star.—F. A. SCHWARZENBERG.

HUMBOLDT THE DISCOVERER OF AMERICA FOR SCIENCE

Humboldt broke through the barrier which separated science from actual life. His object was not only to labor for the advancement of science, but more for the benefit of humanity. From this point of view we must consider the expression of an enthusiast who somewhere exclaimed that Humboldt was related to, and identical with, a conqueror of worlds; a reformer, a founder of a religion. Few ever painted with so much fidelity the remarkable scenes he had witnessed. This faithful representation of nature is the rare and peculiar merit of Alexander von Humboldt. No one could reproduce with more power the fiery atmosphere of the South American valleys. His habits of observation as a naturalist aided in giving character to his descriptions of scenery. In his voyage on the Upper Orinoco, he referred again and again to the sad-

dening impression produced by those magnificent scenes, where a savage vegetation seemed to have usurped the whole earth, and man was nothing in comparison. In those reflections the man's heart seemed rather to speak than the philosopher's brain. This equinoctial journey may be considered the great personal achievement of Humboldt's life, consuming almost his entire fortune, and twenty years of labor. It caused a considerable sensation in Europe, because such a gigantic undertaking of a private individual was without a parallel,—free from all personal egotism, a voluntary sacrifice for science and humanity. Humboldt's travels, prepared for by the discovery of the western hemisphere in the fifteenth century by Columbus, reflected with peculiar interest on the consequences of these discoveries; because he became, in contrast to Columbus the geographical explorer of America, the scientific discoverer of these regions. Humboldt's name ought, therefore, to be placed at the side of Albertus Magnus, Roger Bacon, Vincent de Beauvais, Columbus, and Gama. The two latter are the discoverers of that space from which Humboldt dispersed the darkness; and, in reality, he discovered America for science.—F. A. SCHWARZENBERG.

HUMBOLDT THE REPRESENTATIVE OF THE AGGREGATE KNOWLEDGE OF HIS AGE

With, perhaps, the exception of Aristotle and Bacon, no man ever stood forward so prominently as the representative of the aggregate knowledge of his age. And it is impossible to estimate the influence he wielded in advancing the sciences—not only directly, but indirectly, in

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the impulse he gave to other minds, and in aiding by his counsel and his means those who were struggling against difficulties. Never was a man less exalted by his own individual achievements; never was there a teacher so eager to be taught in turn; never a mind so humble under its wonderful weight of knowledge. . . . All the labors of Humboldt's life were but colossal fragments of a plan too vast, perhaps too sublime, for any single life to complete. It is true he enjoyed a much longer life, more abundant opportunities, more vigorous and tractable powers of mind, than are [usually] given even to the most fortunate of men; but this was not enough. He desired not merely a scientific survey of the earth, but the discovery of those eternal laws which governed its creation, and which still regulate its existence.—F. A. SCHWARZENBERG.

HUMBOLDT'S NOBLE AMBITION

If his life and powers had been adequate to the task, Humboldt would have devoted several years to the exploration of Central Asia. After that he would have wrested from Africa the secrets it contained. He then, from the knowledge thus collected, could lay down the science of climate; sketch the geographical outlines of continents; define the boundaries of the various systems of plants, animals, and men; and from the height of his vast experience strive to comprehend the secrets of that divine system, according to which the whole order of creation moves. When the astronomer Kepler, after twenty-five years of labor and suffering, discovered those mathematical laws by which the planets are balanced in space, and the whole solar system was unfolded to his view, he cried out, in

truly religious triumph, "Oh, Almighty God, I think Thy thoughts after Thee." To Humboldt the active forces of nature were equally the thoughts of God. Such noble daring as urged him to comprehend them, was, indeed, one of the sublimest devotion.—F. A. SCHWARZENBERG.

HUMBOLDT'S COMPREHENSIVENESS OF KNOWLEDGE

The mind of Humboldt was in one respect almost a phenomenon,—in its power of generalization, and at the same time of entering into minute details. It was not inaptly described by Lady Morgan "as reminding her of the trunk of an elephant: it could snap an oak, and pick up a coin." As a proof of his marvelous intellect, I will here refer to a series of sixty-one lectures, delivered in Berlin, perhaps one of the most remarkable courses of lectures ever delivered. They were:

Five lectures treating of the Nature and the Limits of Physical Geography, and including a General Sketch of Nature.
Three on the History of Science in General.
Two on the Study of Natural Science.
Sixteen on the Heavens.
Five on the Form, Density, Latent Heat, and Magnetic Powers of the Earth; and the Polar Light.
Four on the Crust of the Earth, Hot Springs, Earthquakes, and Volcanoes.
Two on Mountains.
Two on the Form of the Earth, the Connection of Continents, and the Elevation of Ravines.
Three on the Sea, as an Elastic Fluid Garment of the Earth.
Ten on the Atmosphere, and the Distribution of Heat.
One on the Distribution of Matter in General.
Three on the Geography of Plants.
Three on the Geography of Animals.
Two on the Races of Men.

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These lectures formed the foundation of the stupendous production,—"*The Cosmos.*" Humboldt had previously delivered the same course in Paris.—F. A. SCHWARZENBERG.

HUMBOLDT'S FAME AND INFLUENCE AS A LECTURER

The first of this cyclus of lectures [as described in the previous selection] caused such an extraordinary sensation that not only all the men of learning in, and in the immediate neighborhood of, Berlin assembled, but from the most remote parts of Germany, the friends of science hastened to Berlin, in order to hear at least one of Humboldt's lectures, and to make his personal acquaintance. Night after night, the late King of Prussia, the members of the royal family, the principal members of the aristocracy, were present; and all the classes of the people, through the lively interest they took in these lectures, testified their pride in the celebrated Alexander von Humboldt. Nay, more, even the uneducated and the lower orders heard now his name. His personality appeared to them something wonderful and mysterious, and they were anxious to see him who had discovered a new world. Humboldt, unlike most other men of renown in the scientific world, in thus appearing publicly before the people, gave the noble and cheering example that a baron, a high officer of state, and a confidential counsellor of a king, did not consider it below his dignity to appear before the world as a teacher in the science for the advancement of which he had made such great sacrifices, and in which he occupied perhaps the most distinguished position; he testified that a true disciple of science ought not to consider

himself to belong to an exclusive class; that the representative of science should ignore all the prerogatives of his social position, if in the higher service of science. . . . . These lectures spoken of were commenced on the 3rd of November, 1827, and concluded on the 26th of April, 1828; developed extempore and without notes.—F. A. SCHWARZENBERG.

HUMBOLDT'S MARVELOUS MEMORY

The memory of Humboldt was really wonderful. Even Macaulay who could repeat the whole of "*Paradise Lost*" from beginning to end, correctly, would have to yield to him in that respect. His memory, even to the last, seemed as keen, as vigorous, and as active as ever. He never hesitated for a name or a date, and never confounded the order of events. A friend once called upon him to discuss some points relative to the topography of Jerusalem: and, astonished at what he considered his marvelous memory of the streets and the houses, of the Holy City, asked how long it had been since he was there. "I never was there," was the answer; "but I intended going sixty years ago, and therefore prepared myself." A still more striking instance of this power of memory was exhibited when some ladies were brought to his house to be introduced to him. Among them was the daughter of a gentleman in Philadelphia, with whom he had resided in 1804,—long before she was born. On entering the room, Humboldt exclaimed, without the slightest doubt or hesitation, —"You must be the daughter of my old friend in Philadelphia."—F. A. SCHWARZENBERG.

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Sir Humphry Davy

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guages, logic, rhetoric, astronomy, mathematics, etc.—and drew up methods by which, although unaided by teachers, he would endeavor to master them. Especially minute and careful was his scheme for attacking the physical sciences, although at the time several of these were little more than terræ incognitæ to the human intellect. Nor did this course, so grandly planned, remain a mere figment of an imaginative ambition. He actually in several of these branches of knowledge made his way unaided for a considerable distance, and in all of them showed an independence of judgment, and an originality of thought and conception, that in one so young were little short of marvelous.

Two pursuits, however, of those years had more fascination for Davy than all others. He was a poet born—in temperament and in mental constitution—and his notebooks, in addition to being replete with observations and reflections that bespoke his poetic feeling, were graced with not a few actual poems of real merit. For physical investigation, too, he showed a bent that was but the budding forth of genius; and even in those early years he became not merely an ardent but a successful chemist. His laboratory was only a corner of a back room in the apothecary's shop, or a garret in the house of a friend who, for his mother's sake, was kind to him. His apparatus consisted merely of bottles, wine glasses, cups, saucers, and tobacco pipes, with an occasional apothecary's crucible. With a physician's syringe, it is said, he had made a rude sort of air pump. And yet with such aids as these he pursued investigations that would have taxed the skill and ingenuity of almost any other physicist living, even with the resources of a kingdom to fall back on. Of course he

soon acquired a reputation, and one that grew apace; but at first he was only a local wonder. "This boy Humphry is incorrigible; he will blow us all into the air," was the frequent ejaculation of the good man Tonkin who had given him the use of the garret. "I tell thee what, Humphry, thou art the most quibbling hand at a dispute I ever met with in my life," was the frequent ejaculation of a Quaker friend who used to try conclusions with him in ethical and religious matters. All this, however, was at the beginning. Soon a Mr. Gilbert heard of him, a gentlemen of the place who had both a library and a laboratory—the library having books of science in it, and the laboratory a real air pump—and he invited him to make use of them. Then the young philosopher's reputation took on a larger scope. A Dr. Beddoes heard of him, a gentleman who was trying to interest people of liberal sentiments and an interest in science in a "pneumatic institution" he was establishing in Bristol that was intended for the cure of disease by inhalation of various sorts of gases. Dr. Beddoes sought out Davy and Davy showed him some essays he had written—one on "*Heat, Light and the Combinations of Light;*" another on "*The Causes of Color in Organic Beings.*" Dr. Beddoes at once recognized in Davy the sort of ability needed to make his institution a success, and he offered to place him at the head of it as experimenter and manager of the hospital. Davy was willing to accept the offer; the only bar was the indenture of apprenticeship. The apothecary, however, canceled the indenture—"on account of your excellent behavior," so he testified. And thus a youth not much past nineteen was put in charge of an institution established by philanthropic people for the purpose of healing

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the sick by means of remedies whose values were still unknown.

At first sight it would seem as if there were something of quackery in this new occupation of Davy's. But in reality there was none. Dr. Beddoes was a duly qualified physician, and he was sincerely desirous that his scheme should be a benefit to humanity. But, as he lamented on his deathbed, he was much given to "mental aberrations," and this "pneumatic institution" was one of them. It must be admitted, however, that in putting young Humphry Davy at the head of his institution he came as near making it a scientific success as was possible. Davy liked his place and work exceedingly. Mrs. Beddoes, who was a sister of the celebrated Irish novelist, Maria Edgeworth, was a woman of culture and great kindness of heart, and Davy found in his association with her an inspiration to do his very best. He also fell in with and became one of that remarkable literary coterie of the Bristol of that time, of which Coleridge, Wordsworth, and Southey, were the well-known leaders. And he found Beddoes willing to assist him in his work to the very utmost. But it was the interest that he took in his scientific investigations that was his principal inspiration to effort, and the principal source of his enjoyment of the place, as it was also his genius that gained for the institution while he was with it a reputation that crowded it with patrons. Medical science was, of course, much less understood then than now; and that much benefit was to be got from the inhalation of "factitious airs" was deemed highly probable. The patients were well housed and well attended to; and no doubt hygienic care effected cures that were supposed to arise from the respiration of novel gases. But

SIR HUMPHRY DAVY.
Painting by Sir Thomas Lawrence.

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more effective than anything else was the buoyancy of spirit caused by the wondrous enthusiasm, and the even more wondrous skill, of the young experimenter. His discovery of the exhilarating yet innocuous effects of nitrous oxide, a gas hitherto thought to be deadly poisonous, and the dangerous tests to which he submitted himself in this and other respects, soon gained for him a fame that spread throughout the kingdom. But still he kept on steadily with his labor of self-improvement. In addition to his experiments he spent much time in scientific speculation and the writing of scientific memoirs. He spent much time, also, in metaphysical speculation and in poetic composition, for his note-books of the time are full of philosophic reflections and fragments of poems. His life was in its very acme of youthful exuberance and ambitious endeavor.

But Davy was now transferred to a larger sphere of action. Count Rumford, a celebrated scientist of the time, had just succeeded in founding in London the Royal Philosophical Institution. It had been established with the philanthropic purpose of developing the application of science to art—that is, the application of scientific principles, especially newly discovered scientific principles, to processes used in domestic industry and in manufacture. Count Rumford had heard of the wonderful young chemist of Bristol; and he invited him to come to London to be director of the chemical laboratory and assistant professor of chemistry in the new institution. The hope was also held out that he would soon be appointed full professor. Davy accepted the offer, and in March, 1801, when but little past twenty-two, he was at his new post. But despite

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN
DIRECCIÓN GENERAL DE BIBLIOTECAS

IX. SIR HUMPHRY DAVY

1778-1829

BIOGRAPHICAL STUDY

BY JOHN EBENEZER BRYANT, M. A.

Sir Humphry Davy has a renown in the history of science that is almost unique. Born of humble parentage, in humble circumstances, and favored only with a short life —a life, too, that was shorter than its years because of the illness that preceded its termination—he yet became one of the most illustrious men of science of his age, and accomplished discoveries and inventions such as have fallen to the fortune of few of any age. Receiving only a very fragmentary school education—and one which, fragmentary as it was, was brought to a close before he had finished his sixteenth year—and having neither access to books, nor the use of apparatus, nor the advantage of association with men of philosophic aims like himself, he had, before he had completed his twentieth year, been appointed to a position that demanded of its incumbent both scientific scholarship and scientific experience; and when he had scarcely passed his twenty-second year had been appointed to a scientific

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN
DIRECCIÓN GENERAL DE BIBLIOTECAS

post which he was destined in a few years to make the most honorable and exalted in England, if not in the whole world. And though thus without those educational advantages which are supposed to be the parentage of culture, and though thus from an early age apparently so preoccupied in scientific experiment and discovery, he was yet able to impress those whom he met in familiar intercourse with a greatness of intellect in other directions, especially in poetry, quite as remarkable as that which he showed in scientific pursuits. Southey, for example, testified of him that he would have excelled in any department of knowledge to which he might have directed the powers of his mind. Coleridge said of him that if he had not been the first chemist of the age he would have been its first poet. And humble and destitute of social advantages though his beginning was, he was still only a young man, between twenty-five and thirty, when he had become one of the best-known figures of London society—equally sought for and admired in the idle fêtes and routs of the great and fashionable, and in those supposedly more intellectual forms of entertainment in which literature, science, art, and philosophy are fond of unbending—the soirée and the salon. In short, the transformation of Humphry Davy, apothecary's apprentice in the little Cornish fishing-town of Penzance, to Humphry Davy, professor of chemistry in the Royal Philosophical Institution of London, the most entrancing lecturer on scientific subjects in the whole kingdom, the discoverer of the chemical powers of the voltaic battery, the discoverer of potassium and sodium, the secretary of the Royal Society, the popular lecturer on agricultural chemistry to the Board of Agri-

culture (perhaps the most aristocratic association in the whole kingdom), the favorite lion in London drawing-rooms, not merely for his scientific renown but also for his charm of manner as a conversationist, his enthusiasm, and his magnetic influence—all this in a few years, scarcely more than what now-a-days are required for a young man to give to his college and university career before he starts the serious business of life at all—is more like a chapter from a fairy tale than a passage from real history.

Humphry Davy was born in Penzance, Cornwall, December 17, 1778. He was of yeoman stock that for 200 years or more had been settled in Cornwall—as a rule fairly well-to-do, fairly well educated, and very well thought of. His father, however, had made a break in the family record, and had managed to dissipate his property, and show himself idle, or worse than idle, in his habits. Humphry Davy had at first shown a disposition to follow in his father's foolish footsteps. But when he was in his sixteenth year his father died, and a great change took place in his habits and character. He became thoughtful of himself and self-helpful; and thoughtful, too, and helpful of others. He apprenticed himself to an apothecary, and comforted his mother with the assurance that not only would he take care of himself but that he would soon take care of his brother and his sisters. In pursuance of his purpose he laid out a course of study that for thoroughness and scope may be said to be unique in the annals of biography. He carefully mapped out the several provinces of knowledge —theology, ethics, the sciences belonging to his profession, the natural and physical sciences in general, the lan-

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN ®
DIRECCIÓN GENERAL DE BIBLIOTECAS

the reputation which he had gained for himself, when the directors of the Institution first saw their youthful appointee, his personal appearance made them incredulous of his ability to hold a public audience in interest, and so they had him give to them a preliminary lecture in private as a sort of trial. "Let this young man command anything the Institution can afford," was their joyous ejaculation when the trial was over. The full professorship was soon given to him, and every effort was made to supply him with apparatus and assistance. And their confidence was well placed. It was soon seen that Davy was the Institution. His lectures became the rage. Men and women of all ranks and professions, men about town no less than philosophers, and ladies of fashion equally with blue-stockings, crowded to hear him. "His youth, his simplicity, his chemical knowledge, his happy illustrations, his well-conducted experiments, excited universal admiration and unbounded applause." Such was the report of a contemporary. Nor was this enthusiasm a mere passing fad that had its day and died. Every day Davy's popularity grew greater. No doubt some of it was of sentimental origin, but most of it was based on a real admiration for his genius. Ladies sent him poems and composed sonnets in his honor replete with the tenderest emotions. But men, also, of the highest credit and standing, were proud to be thought his disciples or his associates. Even Coleridge testified: "I go to hear Davy to increase my stock of metaphors." And it is because of the enthusiasm for science which he inspired that the philanthropy of the time showed itself in the establishment of such institutions as the Zoological Gardens and the South Kensington Museum. When from overwork he broke down and became sick, bulletins had to be published hourly as to the progress of his illness or his convalescence. Nor was his popularity confined to individuals. Whole institutions, and those of the gravest sort, were affected by it. The Royal Society of London scarcely passed a year without making him its Bakerian lecturer, its highest scientific honor. The Royal Society of Dublin besought him to give courses in lectures on science in the Irish capital, and rewarded him munificently for doing so. In short, both in a popular sense and in a scientific sense, Davy's career during the twelve years he was professor of chemistry at the Royal Institution, beginning with his very first occupation of the position when he was but a young man of twenty-two, was one of wonderful and unexampled success.

Davy resigned his position in the Royal Institution early in 1812. The reason of his resignation was a change in his fortunes. On April 11 of that year he was married to a lady, described in a letter to a friend by Sir Joseph Banks, the president of the Royal Society of the time, as "a rich and handsome widow." This lady was a Mrs. Apreece, a "far-away cousin" of Sir Walter Scott's. Sir Walter, at the time of the marriage, wrote of her as having been during the preceding winter "a lioness of the first magnitude" in Edinburgh. She had come to London, and being fond of science had attended Davy's lectures. There were at the time many skits and squibs printed rallying Davy on his good fortune. One of them, said to have been indited by Maria Edgeworth, ran as follows:

"Too many men have often seen
Their talents underrated;
But Davy owns that his have been
Duly 'Apreeciated.'"

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN ®
DIRECCIÓN GENERAL DE BIBLIOTECAS

DAVY'S INTEREST IN SOCIETY

The stories told by Paris [his first biographer] of Davy's habits at this period [when he was in the height of his fame as a lecturer and discoverer], and of his various expedients to gain time—of his rushing off to dinner with persons of the highest rank with no fewer than five shirts on, and as many pairs of stockings, because in his haste he could not put on fresh linen without removing that which was underneath; of his continuing his chemical labors on his return to the laboratory until three or four in the morning; and of his then being up before the servants, are certainly much exaggerated, if not wholly apocryphal. He was, it is true, not very systematic in the disposal of his time, but he seldom entered the laboratory before ten or eleven in the morning, and rarely left it later than four, and he was scarcely ever known to visit it after he had dressed for dinner. Except when preparing a lecture, he seldom dined in his rooms at the Institution: his brother tells us that his invitations to dinner were so numerous that he was, or might have been, constantly engaged; and after dinner he was much in the habit of attending evening parties, and devoting the evening to amusement, "so that to the mere frequenters of such parties he must have appeared a votary of fashion rather than of science."—DR. T. E. THORPE.

FARADAY'S REPORT OF DAVY'S FAREWELL LECTURE
April 9, 1812

"Having thus given the general character of the metals, Sir H. Davy proceeded to make a few observations on the

connection of science with the other parts of polished and social life. Here it would be improper for me to follow him. I should merely injure and destroy the beautiful, the sublime observations that fell from his lips. He spoke in the most energetic and luminous manner of the advancement of the arts and sciences, of the connection that had always existed between them and other parts of a nation's economy. He noticed the peculiar congeries of great men in all departments of life that generally appeared together, noticed Anaximander, Anaximenes, Socrates, Newton, Bacon, Elizabeth, etc., but, by an unaccountable omission, forgot himself, though, I venture to say, no one else present did.

"During the whole of these observations his delivery was easy, his diction elegant, his tone good, and his sentiments sublime."—*Quoted by Dr. T. E. Thorpe, from Faraday's manuscript note-book, written when he was a book-binder's apprentice, and now preserved in the Royal Institution.*

DAVY AND FARADAY

The jealousy thus manifested by Davy [towards Faraday, when the latter was elected into the Royal Society] is one of the most pitiful facts in his history. It was a sign of that moral weakness which was at the bottom of much of his unpopularity, and which revealed itself in various ways as his physical strength decayed.

Greedy as he was of fame—that infirmity of noble minds—many incidents in his life up to this period prove that he was not wanting on occasion in a generous appreciation of the work of his contemporaries, even in fields he might reasonably claim as his own. But, although in

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DIRECCIÓN GENERAL DE BIBLIOTECAS

his intellectual combats he could show at times a certain knightly courtesy, it must be confessed that he was lacking in the magnanimity which springs from the charity that envieth not.

In genius he was unquestionably superior to Faraday; in true nobility of character he was far below him. It is almost impossible to avoid comparing him with Faraday. Indeed it is one of the penalties of his position that he has to be tried by so severe a standard, and it may well be that his good name has suffered unduly in consequence. His true place in the history of science is defined by his discoveries; it is a sad reflection that the lustre of his fame has been dimmed rather than heightened by what has been styled the greatest of them all—Faraday.

But there has undoubtedly been injustice in the comparisons which have been made. What Davy was to Faraday, Faraday would have been the first to admit. Davy made himself what he was by the sheer force of his unaided genius; what Faraday became was in a large measure due to his connection with Davy, and the germs of his greatest works are to be traced to this association. This fact has been frankly acknowledged by Faraday. To the end of his days he regarded Davy as his true master, preserving to the last, in spite of his knowledge of the moral frailties of Davy's nature, the respect and even reverence which is to be seen in his early lecture notes and in his letters to his friend Abbot. Faraday was not easily roused to anger, but nothing so effectually moved him as any aspersion of Davy's character as a man of science, or any insinuation of ungenerous treatment of himself by Davy.—Dr. T. E. Thorpe.

DAVY'S FONDNESS FOR ANGLING

The love of angling amounted to a passion with Davy; and he told Ticknor that he thought if he were obliged to renounce either fishing or philosophy he should find the struggle of his choice pretty severe. Whenever he could escape from town he would hie him to some favorite stream and spend the day in the practice of his beloved art. He was known to have posted a couple of hundred miles for the sake of a day's fishing, and to have returned contented although he had never a rise. When confined to Albemarle Street [the Royal Institution], and chafing at his inability to get away, he would sometimes turn over the leaves of his fly-book and derive much consolation from the sight of his hackles and harles, his green-tails, duncuts, red spinners, and all the rest of the deadly paraphernalia associated in his mind with the memories of pleasant days and exciting combats. He greatly prided himself on his skill, and his friends were often secretly amused to notice his ill-concealed chagrin when a brother-angler outvied him in the day's catch or in the narration of some piscatorial triumph. They were amused, too, at the costume which he was wont to don on such occasions—his broad-brimmed, low-crowned hat, lined with green and garnished with flies; his grey-green jacket, with a multitude of pockets for the various articles of his angling gear; his wading-boots and knee-caps—all made up an attire as original as it was picturesque. In these fishing expeditions he enjoyed some of the happiest hours of his life. At such times he threw off his cares and annoyances; he was

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cheerful even to hilarity, and never was his conversation more sprightly or more entertaining.—Dr. T. E. Thorpe.

READERS' AND STUDENTS' NOTES

1. Sir Humphry Davy has very frequently been made the subject of popular biography; especially of popular biography intended for young people. A work of this sort is "*The Wonders of Science, or Young Humphry Davy, the Cornish Apothecary's Boy*" by Henry Mayhew (New York: Harper & Brothers, $1.25). Another popular account of Davy will be found in Sarah K. Bolton's "*Famous Men of Science,*" already mentioned.

2. Dr. T. E. Thorpe's "*Humphry Davy, Poet and Philosopher*" in "*The Century Science Series*" is the latest biography of Davy. It is a sympathetic and appreciative, and yet a just and impartial, account of the life of a great man who, notwithstanding his greatness, was not without his weaknesses. (New York: The Macmillan Co., $1.25.)

John James Audubon

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The happy philosopher had been knighted a few days before his marriage. Not long afterward (October, 1813), in company with his wife, he made a prolonged tour in Europe. On this tour he took with him, as an assistant, Faraday, then a young man of twenty, thus giving rise to the saying that Faraday was the greatest of Davy's discoveries. It has also been said that this fortunate discovery was his last. But this latter statement is hardly true, though there is a lamentable measure of truth in it. Davy's fame was at its zenith at the time of his marriage. While on his tour in Europe he made some remarkable discoveries in the nature of fluorine. When he returned (in 1815), in response to the request of the coal owners of Britain, he made a number of investigations into the nature of the deadly fire-damp, and these led to his great practical invention of the safety lamp. In 1819, on the death of Sir Joseph Banks, he was elected president of the Royal Society, the highest scientific honor that it was possible for him to receive. But with this election Davy's work as a scientist practically terminated. The duties of his presidency engrossed his time and attention almost wholly. And besides it was not long before he fell into serious ill-health. It is said, too, that his married life, which at first was very happy, became in no long time a sad disappointment to him. "The finest nectars and ambrosias will all be spoilt by a few drops of bitter extract, and a bad temper has the same effect on life." These are his own sad words. In 1826, after seven years occupancy, he resigned his presidency; he was too ill to hold it longer. Once more he went to Europe, but his fast failing powers were beyond recuperation. On May 29, 1829, he died at Geneva, and there he is buried. His wife had rejoined him a few days before.

SIR HUMPHRY DAVY

SELECTED STUDIES AND REMINISCENCES

THE ROYAL INSTITUTION

The chemical laboratory of the Royal Institution, as the scene of Davy's greatest discoveries—discoveries which mark epochs in the development of natural knowledge—will forever be hallowed ground to the philosopher. The votaries of Hermes have raised far more stately temples; to-day they follow their pursuit in edifices which in architectural elegance and in equipment are palaces compared with the subterranean structure which lies behind the Corinthian façade in Albemarle street. But to the chemist this spot is what the Ka'ba at Mecca is to the follower of Mohammed, or what Iona was to Dr. Johnson; and, if we may venture to adopt the language of the English moralist, that student has little to be envied whose enthusiasm would not grow warmer, or whose devotion would not gain force, within the place made sacred by the genius and labors of Davy and Faraday.—T. E. THORPE, LL. D., F. R. S., *in "Humphry Davy, Poet and Philosopher" in "The Century Science Series."*

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John James Audubon

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poverty, could alienate him from the objects he had most at heart—the observation of the habits, the portraiture of the forms and the colors, of birds. So that in all those eighteen years of business misadventure the naturalist was constantly at his other work—constantly tramping through forests, and over prairies, and along water-courses, and on mountain sides, and in swamps and thickets, gun in hand, accompanied only by his dog, searching out the ways of birds, obtaining new specimens, writing down what he observed, and making drawings and paintings of his findings.

Audubon's principal title to fame is the beauty and accuracy of his ornithological portraiture. Even before he was seventeen he had made 200 drawings of the birds of France. And, not satisfied with mere facility, he aimed at perfection. In his younger years, with each returning anniversary of his birth, he would burn the drawings he had done, deeming them not good enough. And in later years he was always striving after greater and greater perfection. In time he reached a point when he was satisfied, and then he thought that he would make his portfolio represent a complete collection of the birds of the continent, and later, that he would publish this collection in a book. Thus arose within him the ambition to be what he afterwards became, the portrait painter and biographer of the birds of America. And in the pursuance of this idea, all labor or business that did not bear directly upon it was deemed a hindrance. He admits that his business affairs would have prospered had he attended to them, but birds were the only things that could claim his attention. "I shot, I drew, I looked on nature only, and I was happy

beyond conception." And no matter how precarious his affairs might be, in birds he found his unfailing delight.

> "In all my adverse circumstances, I never for a day gave up listening to the songs of our birds, or watching their peculiar habits, or delineating them the best way I could. Nay, during my deepest troubles, I would frequently wrench myself from the persons around me, and retire to some secluded part of our noble forests, and many a time at the sound of the wood-thrush's melodies have I fallen on my knees and there prayed earnestly to God."

Audubon's nature was intrinsically devout and reverential, and the wood-thrush's notes always incited it to thanksgiving and prayer. But his mind, apart from its special pursuit, was essentially impractical, and he never would have become known to fame, had it not been for the devotion and self-sacrifice of his wife. Her own people could see in her husband only the improvident and the visionary enthusiast, but she had faith in him always; and so soon as the idea of publishing the "*Birds of America*" came into being she, in spite of the opposition of her friends, encouraged him to carry it out. Encouragement and advice, however, could do little for so impracticable a soul, beyond sustaining him in his woodcraft work. So to support herself and her children, and to obtain money that would make publication possible, she set to work herself. First in Natchez, and then in Bayou Sara, near New Orleans, she obtained employment as a governess or teacher, and by 1826 had $3,000 saved up. Then she assisted her husband to organize a dancing school, by which $2,000 more was obtained. Finally, in April, 1826, Audubon was able to sail for England.

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN ®
DIRECCIÓN GENERAL DE BIBLIOTECAS

Audubon's going to England was for a double purpose. Publishers and printers, both in Philadelphia and in New York, had apprised him that to reproduce his drawings in America would be impossible—the engraving and the printing of them could be done only in Europe. Besides it was thought that it would be easier in England than in America to obtain subscribers for so expensive a work as his proposed publication would be. Audubon's hopes in these respects were not disappointed. In time, indeed, they were all gloriously fulfilled. His colored portraits of the birds of the new world excited an interest in the great cities of Britain that might almost be called a furore. At Liverpool, at Manchester, and at Edinburgh and other places where he exhibited them, he not only made a good deal of money by the admission fee that he was able to charge, but he was at once recognized as a scientific observer of the rarest ability and experience. Remaining in Edinburgh for some time he was able, in 1827, to issue his prospectus for his great work, and at once he began the preparation of the first volume. He had not gone on with it far, however, before he determined to bring out his work on a scale of magnificence greater than ever before attempted in any scientific publication in the world; and so he began it anew and made arrangements to publish it in London. It was to be printed in elephant folio, and the four volumes were to be sold at $1,000 (£200). The attentions that Audubon received from scientific and other learned men in England aided him in obtaining subscriptions for the book. But few scientific men could of themselves afford to buy so expensive a work. Audubon had himself to solicit subscriptions. This he did, and in the meantime supported himself and partly paid his engravers,

JOHN JAMES AUDUBON.

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN
DIRECCIÓN GENERAL DE BIBLIOTECAS

by painting and selling fanciful pictures of birds. He was often reduced to great straits for money; but he made friends in plenty, some of whom were very helpful to him. Among these may be mentioned "Christopher North," Sir Thomas Lawrence, the painter, and Lord Stanley.

Finally, in 1831 the first volume of the great work appeared. He had been issuing it in parts, 2 guineas a part, and in this way had been able to keep printers and engravers going. But the task of securing subscribers, attending to the business of printing and publication, and collecting subscriptions and settling accounts, was enormous, and only a man with consummate faith in his work could have carried it through. However, he was at last able to write as follows:

"I have balanced my accounts with the '*Birds of America*,' and the whole business is really wonderful; forty thousand dollars have passed through my hands for the completion of the first volume. Who would believe that a lonely individual, who landed in England without a friend in the whole country, and with only sufficient pecuniary means to travel through it as a visitor, could have accomplished such a task as this publication! Who would believe that once, in London, Audubon had only one sovereign left in his pocket, and did not know of a single individual to whom he could apply to borrow another, when he was on the verge of failure in the very beginning of his undertaking! And above all, who would believe that he extricated himself from all his difficulties, not by borrowing money, but by rising at four o'clock in the morning, working hard all day, and disposing of his works at a price which a common laborer would have thought little more than sufficient remuneration for his work!"

In the meantime he had gone home to New Orleans for Mrs. Audubon and had brought her to England. Her health was impaired and she needed careful medical at-

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DIRECCIÓN GENERAL DE BIBLIOTECAS

tendance, and he left her there. Then he made two long sojourns in America, searching for new birds in Florida, and in New Brunswick, Newfoundland and Labrador, with which to complete his work. Between whiles, in England, he supervised the bringing out of the second, third and fourth volumes of the work. He also had the task of obtaining new subscribers to take the place of those who during the long period of publication had withdrawn their subscriptions—fifty-six of them, meaning $56,000. In all, his work brought him in $100,000, but this only paid expenses. It was a mammoth undertaking. There were 435 colored plates with 1,055 bird portraits, every one in life size. In 1839 he returned to America to remain there till the end. Europe, however, had been kind to him. The most famous learned societies, including the Royal Society of London and the Academy of Sciences of France, had honored him with membership or medals or diplomas. Nor had he been lacking in personal attentions. Cuvier, Humboldt, Saint-Hilaire, the most celebrated scientists then living, all sought his acquaintance. Cuvier called his work "the most magnificent monument that art had ever raised to nature." Gérard, the famous French painter, called him "the king of ornithological artists."

The road for Audubon was now smoothed. His two sons had grown up to have similar tastes with his own, and they were also good men of business. By their aid a home was purchased on Manhattan island, near New York, in gratitude called "Minniesland," in honor of the mother, her name to her children being "Minnie," a diminutive for "mother." The "*Birds of America*" was brought out in octavo form, the engravings being reduced, and published at a price within the reach of persons of moderate means. Two other great works were projected and partly completed—the "*Quadrupeds of America*," portraits, in atlas folio, and the "*Biography of American Quadrupeds*." For the production of these works more long trips through primeval wildernesses were necessary, but in these a son was always a companion. Audubon's powers of endurance were remarkable. He was a true woodsman. His eyesight was like an eagle's. He could notice a squirrel sitting upon a fence 200 yards away, and even recognize its variety, and this when he was long past sixty. But at last, in his sixty-eighth year, he began to fail. His physical deterioration then was rapid. His ever faithful wife first used to read to him, and otherwise amuse him. Then she had even to give him his food. But the end came gently. He put one hand into that of his wife, he gave another to his sons, and so he passed away. It was sunset, January 27, 1851. He was buried in the cemetery of Trinity church.

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN ®
DIRECCIÓN GENERAL DE BIBLIOTECAS

X. JOHN JAMES AUDUBON

1780-1851

BIOGRAPHICAL STUDY

BY JOHN EBENEZER BRYANT, M. A.

Audubon, the greatest of American ornithologists, and one of the most remarkable of original ornithological observers, has an interest for the lover of science quite apart from his merits as a scientist. Indeed, as a scientist, strictly speaking, he does not stand in the highest rank. Neither by education nor by self-training was he fitted to become a lawgiver or a law-maker in the realm of scientific investigation. His great merit is the accuracy and the extent of his original observations. He had the ambition to become the most extensive ornithological observer of his time, and despite a thousand obstacles, he had the good fortune to succeed in this ambition. He had, further, the ambition to become for the world its most splendid ornithological portrait painter, and, despite a thousand even greater obstacles, he became that also. For the patient prosecution of a cherished pursuit throughout a lifetime, and for achieving success in that pursuit, although for

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN
DIRECCIÓN GENERAL DE BIBLIOTECAS

years and years success seemed utterly impossible, Audubon is an example worthy the emulation of every one.

Audubon's career had an element of romance in it. Indeed, if its history were properly told, few lives as portrayed in works of imagination would be able to show more strange vicissitudes of good fortune and ill fortune, more startling contrasts of difficulties and dangers rising up for encounter, and difficulties and dangers successfully met, with love as a pole-star, directing and illuminating all, than Audubon's real life actually showed. In this brief sketch, this romantic phase of Audubon's life can be only indicated. Nor can we do more here than allude to the exalted character of the man—his loving kindness, his tender-heartedness, his fidelity, trust and love, his singleness of aim, his faith in providence, his faith in divine justice, his sincerity, his real humility. It was a character, too, with many weaknesses; but these also can be only alluded to here.

John James Audubon was born in New Orleans, May 4 (or 5), 1780. His father was a remarkable man before him—one who, a poor French fisherman's son, the youngest of twenty-one children, with only a suit of clothes, a shirt, and a father's blessing as his patrimony, had gone out into the world at twelve years of age and had become a sailor, a ship-owner, a commodore in the French navy, and finally an admiral, the owner of estates in France, the West Indies, Louisiana, Virginia, and Pennsylvania, and had married, too, in Louisiana, a lady of wealth and beauty, who was the mother of his famous son. But this lady was not spared to rear the child she bore, being killed in a negro insurrection in San Domingo. Audubon, therefore, was brought up in France—by his father's second

wife, a woman who loved him as tenderly as if he were her own son, and indulged him in all his precocious fondness for making "collections" of birds' nests, birds' eggs, butterflies, beetles, etc., and everything else connected with natural history. His father, too, indulged this fondness, and gave him a set of ornithological plates, a present infinitely prized. But he also sent him to a good school, and had him take lessons in drawing and painting, the celebrated David being his instructor. He was instructed also in music and dancing, and became proficient on the violin, flute, flageolet, and guitar.

Audubon's father wished him to become a soldier or a sailor or an engineer. But the young lad's tastes were averse to every kind of business or profession. His father, therefore, sent him to America to look after one of his estates. This estate happened to be at Mill Grove, near the Schuylkill Falls, Pennsylvania. At Mill Grove Audubon lived a life that was to him ideal. He was surrounded by nature in its primeval freshness; and he was able to indulge his fondness for hunting, fishing, and making collections of birds and animals, to his heart's content. He also reared and kept innumerable kinds of fowl. He was young, handsome, and in perfect health. And as he had plenty of money and was fond of dress, he became, what he afterwards described himself to be, "a dandy of the woods:"—

"I went shooting in black satin small clothes or breeches, with silk stockings and the finest ruffled shirts that Philadelphia could afford. I purchased the best horses in the country. My guns and fishing tackle were equally good, always expensive, and richly ornamented, often with silver. I rode well and felt proud of it. I was as fair and rosy as a girl, though as strong, indeed stronger

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DIRECCIÓN GENERAL DE BIBLIOTECAS

than, most young men, and as active as a deer. . . . . I was extremely fond of music, dancing, and drawing. In all I had been well instructed, and not an opportunity was lost to confirm my propensities in these accomplishments. I was like most young men, filled with the love of amusement, and not a ball, a skating-match, a house or riding-party, took place without me. Withal, and fortunately for me, I was not addicted to gambling. Cards I disliked, and I had no other evil practices. I was besides temperate to an intemperate degree. I lived on milk, fruit, and vegetables, with the addition of fish and game at times, and never swallowed a single glass of wine or spirits until the day of my wedding. The result has been my uncommon, indeed iron constitution."

Such a life was indeed too ideal to last—and yet there was an interest in it sweeter than any above recorded. Upon an adjoining estate lived an English gentleman, a Mr. Bakewell, whose daughter, Lucy, a "being radiant with beauty," the young Frenchman came to know and love. She taught him English. He taught her French. They became engaged. Difficulties arose. The elder Audubon's agent in America did not countenance the match, and refused further supplies of money. Audubon walked to New York, borrowed some money, went home to France, explained matters to his father, and obtained his father's consent. Then, after spending a year at his father's home, "shooting birds and stuffing them," he returned to America again, and as a preparation for the serious affairs of life, entered a counting-house in New York. Here, however, he lost a large sum of money in an unfortunate indigo speculation. He then returned to Mill Grove, sold his estate and invested the money in goods with which to start business in Louisville. On April 8, 1808, he and Miss Bakewell were married. The happy

couple then set out for Louisville. Audubon was just twenty-eight.

This marriage was Audubon's one fortunate venture. Everything else that he essayed, apart from his work as a naturalist, was ill-fortuned. His life now for eighteen years was a series of misadventures. First his enterprise at Louisville failed. He then moved to Hendersonville, Kentucky, where failure again took place. Then, after one or two efforts elsewhere, he moved to New Orleans, and entered into a business there, embarking all his fortune in it, but only to lose it all. In the meantime his father had died and had left him an estate in France, and a business investment to the amount of $17,000 in Virginia. The estate in France he never looked after; the investment in Virginia was lost by insolvency. Children now were born to him and matters began to look serious. He made one more attempt at business—this time in Hendersonville again—a steam mill. But failure again resulted, and Audubon was left with but his dogs and his gun. Then for a number of years a wandering life ensued—Louisville, New Orleans, Cincinnati, and New Orleans again, being the principal places of abode. In these years he supported himself mainly by drawing and selling crayon portraits, though he also at times gave lessons in drawing, in French, and even in dancing. But as he traveled about much he was often in great straits for money—so much so that a night's lodging, a steamboat passage, and even a pair of boots or trousers, could at times be paid for only by the making of a portrait.

These eighteen years, however, were the years when Audubon's principal work as a naturalist was done. No pressure of business, no disaster of fortune, no distress of

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JOHN JAMES AUDUBON

SELECTED STUDIES AND REMINISCENCES

AUDUBON'S FIRST MEETING WITH HIS WIFE

"Well do I recollect the morning, and may it please God may I never forget it, when, for the first time I entered the Bakewell household. It happened that Mr. Bakewell was from home. I was shown into a parlor where only one young lady was snugly seated at work, with her back turned towards the fire. She rose on my entrance, offered me a seat, and assured me of the gratification her father would feel on his return, which, she added with a smile, would be in a few minutes, as she would send a servant after him. Other ruddy cheeks made their appearance, but like spirits gay, vanished from my sight. Talking and working, the young lady who remained made the time pass pleasantly enough, and to me especially so. It was she, my dear Lucy Bakewell, who afterwards became my wife and the mother of my children."

Mr. Bakewell speedily returned, and Lucy attended to the lunch provided before leaving on a shooting expedition.

"Lucy rose from her seat a second time, and her form, to which I had before paid little attention, seemed radiant with beauty, and my heart and eyes followed her every step. The repast being over, guns and dogs were provided, and as we left I was pleased to believe that Lucy looked upon me as a not very strange animal. Bowing to her, I felt, I knew not why, that I was at least not in-

different to her."—MRS. AUDUBON, *in "Life of John James Audubon, the Naturalist." The quotations are from "Audubon's Journals."*

AUDUBON AS A YOUNG MAN

"On entering the room I was astonished and delighted to find that it was turned into a museum. The walls were festooned with all sorts of birds' eggs, carefully blown out and strung on a thread. The chimney-piece was covered with stuffed squirrels, raccoons and opossums; and the shelves around were likewise crowded with specimens, among which were fishes, frogs, snakes, lizards, and other reptiles. Besides these stuffed varieties, many paintings were arranged upon the walls, chiefly of birds. He had great skill in stuffing and preserving animals of all sorts. He had also a trick of training dogs with great perfection, of which art his famous dog Zephyr was a wonderful example. He was an admirable marksman, an expert swimmer, a clever rider, possessed great activity, prodigious strength, and was notable for the elegance of his figure and the beauty of his features, and he aided nature by a careful attendance to his dress. Besides other accomplishments, he was musical, a good fencer, danced well, had some acquaintance with legerdemain tricks, worked in hair, and could plait willow-baskets."

He [William Bakewell, the brother of Lucy] adds further, that Audubon once swam across the Schuylkill river with him on his back,—no contemptible feat for a young athlete.—MRS. AUDUBON. *The quotation is from a description of Audubon as a young man, supplied by Mrs. Audubon's brother.*

AUDUBON AND HIS INHERITANCE

At this juncture the father of Audubon died; but from some unfortunate cause Audubon did not receive legal notice for more than a year. On becoming acquainted with

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DIRECCIÓN GENERAL DE BIBLIOTECAS

AUDUBON AT NIAGARA

"*August 24* [*1824*].—Took passage for Buffalo, arrived safely, and passed a sleepless night, as most of my nights have been since I began my wanderings. Left next morning for the Falls of Niagara. The country is poor, the soil stiff, white clay, and the people are lank and sallow. Arrived at the hotel, found but few visitors, recorded my name and wrote under it, 'who like Wilson* will ramble, but never, like that great man, die under the lash of a bookseller.'

"All trembling I reached the falls of Niagara, and oh, what a scene! My blood shudders still, although I am not a coward, at the grandeur of the Creator's power; and I gazed motionless on this new display of the irresistible force of one of His elements. The falls, the rainbow, the rapids, and the surroundings, all unite to strike the senses with awe; they defy description with pen or pencil; and one view satisfied me that Niagara never had been and never will be painted.

"I afterwards strolled through the village to find some bread and milk, and ate a good dinner for twelve cents. Went to bed at night thinking of Franklin eating his roll in the streets of Philadelphia; of Goldsmith traveling by the help of his musical powers; and of the other great men who had worked their way through hardships and difficulties, to fame; and fell asleep, hoping by persevering industry, to make a name for myself among my countrymen."—*From the "Journals."*

AUDUBON'S FINAL EFFORTS TO OBTAIN MONEY TO GO TO EUROPE

"LOUISVILLE, *November 20*, [*1824*].—Took lodgings at the house of a person to whom I had given lessons, and hastened to Shipping

*The Scotch ornithologist Wilson had recently been in America, and had visited Audubon.

Port to see my son Victor. Received a letter from General Jackson with an introduction to the Governor of Florida. I discover that my friends think only of my apparel, and those upon whom I have conferred acts of kindness prefer to remind me of my errors. I decide to go down the Mississippi to my old home of Bayou Sara, and there open a school with the profits of which to complete my ornithological studies. Engage a passage for eight dollars.

"I arrived at Bayou Sara with rent and wasted clothes and uncut hair, and altogether looking like a Wandering Jew.

"The steamer which brought me was on her way to New Orleans, and I was put ashore in a small boat about midnight, and left to grope my way on a dark, rainy, and sultry night, to the village, about one mile distant. That awful scourge, the yellow fever, prevailed, and was taking off the citizens with greater rapidity than had ever before been known. When I arrived, the desolation was so great that one large hotel was deserted, and I walked in, finding the doors all open, and the furniture in the house, but not a living person. The inmates had all gone to the pine woods. I walked to the post office, roused the postmaster and learned to my joy that my wife and son were well at Mrs. Percy's. . . .

. . . . . .

"It was early, but I found my beloved wife up and engaged in giving a lesson to her pupils, and, holding and kissing her, I was once more happy, and all my toils and trials were forgotten.

"*December 1.*—After a few days' rest I began to think of the future, and to look about to see what I could do to hasten the publication of my drawings. My wife was receiving a large income,—nearly three thousand dollars a year,—from her industry and talents, which she generously offered me to help forward their publication, and I resolved on a new effort to increase the amount by my own energy and labor. Numerous pupils desired lessons in music, French, and drawing. From Woodville I received a special invitation to teach dancing, and a class of sixty was soon organized. I went to begin my duties, dressed myself at the hotel, and with my fiddle under my arm entered the ballroom. I found

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN ®
DIRECCIÓN GENERAL DE BIBLIOTECAS

my music highly appreciated, and immediately commenced proceedings.

"I placed all the gentlemen in a line reaching across the hall, thinking to give the young ladies time to compose themselves and get ready when they were called. How I toiled before I could get one graceful step or motion! I broke my bow and nearly my violin in my excitement and impatience! The gentlemen were soon fatigued. The ladies were next placed in the same order and made to walk the steps; and then came the trial for both parties to proceed at the same time, while I pushed one here and another there, and was all the while singing myself, to assist their movements. Many of the parents were present and were delighted. After this first lesson was over I was requested to *dance to my own music*, which I did until the whole room came down in thunders of applause, in clapping of hands and shouting, which put an end to my first lesson, and to an amusing comedy. Lessons in fencing followed to the young gentlemen and I went to bed extremely fatigued.

"The dancing speculation fetched two thousand dollars, and with this capital and my wife's savings I was now able to foresee a successful issue to my great ornithological work."

The remainder of Audubon's residence at Bayou Sara was taken up with preparations for his intended voyages to England,—where he expected to find the fame given to all heroes so tardily in their own countries.—MRS. AUDUBON. *The quotations are from the "Journals."*

AUDUBON IN EDINBURGH

"*February 3* [*1827*].—Dr. Brewster, afterwards Sir David Brewster, proposed that I should exhibit the five plates of my first number of the "*Birds of America*" at the Royal Society this evening. He is a great optician, and advises me to get a camera-lucida, so as to take the outline of my birds more rapidly and correctly. Such an instrument would be useful in saving time,

and a great relief in hot weather, since outlining is the hardest part of the work and more than half of the labor. I visited the Royal Society at eight o'clock and laid my large sheets on the table. They were examined and praised.

"After this we were all called into the great room and Captain Hall came and took my hand and led me to a seat immediately opposite Sir Walter Scott, the President, where I had a perfect view of this great man, and studied nature from nature's noblest work. A long lecture followed on the introduction of the Greek language into England, after which the President rose, and all others followed his example. Sir Walter came and shook hands with me, asked how the cold weather of Edinburgh agreed with me, and so attracted the attention of many members to me, as if I had been a distinguished stranger."—*From the "Journals."*

AUDUBON AND SIR WALTER SCOTT

"EDINBURGH, *February 12*.—Began the day by working hard on the pictures at the rooms of the Scottish Society. And to-day the Antiquarian Society held its first meeting since my election. It is customary for new members to be present at such times, and I went, and though I felt rather sheepish, I was warmly congratulated by the members. At one o'clock I visited the rooms of the Royal Society, which were crowded, and tables were set, covered with wine and fruits and other refreshments. The ladies were mostly of noble families, and I saw many there whom I knew. Sir Walter Scott was present and came towards me and shook hands cordially, and pointing towards a picture, said: 'Mr Audubon, many such scenes have I witnessed in my younger days.' We talked much of all about us, and I would gladly have asked him to join me in a glass of wine, but my foolish habit [Audubon was a total abstainer] prevented me. Having inquired after the health of his daughters, I shortly left him and the room, for I was very hungry; and although the table was loaded with delicacies, and the ladies were enjoying them freely, I say it to my shame, that I had not the confidence to lay my fingers on a single thing."—*From the "Journals."*

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN ®
DIRECCIÓN GENERAL DE BIBLIOTECAS

AUDUBON AND HIS LONG HAIR

"[EDINBURGH], *March 19.*" Under this date we have an amusing entry. Audubon had been frequently importuned by his friends to cut his hair, which he had for years worn in ringlets falling to his shoulders. Hence the obituary:—

> EDINBURGH.
> March 19, 1827.
>
> This day my Hair was sacrificed, and the will of God usurped by the wishes of Man.
>
> As the Barber clipped my locks rapidly, it reminded me of the horrible times of the French Revolution, when the same operation was performed upon all the victims murdered by the Guillotine.
>
> My heart sank low.
>
> JOHN J. AUDUBON.

The margin of the sheet is painted black, about three-fourths of an inch deep all around, as if in deep mourning for the loss which he had reluctantly submitted to in order to please his friends. He consented, sadly, because he expected soon to leave for London, and Captain Hall persuaded him that it would be *better* for him to wear it according to the prevailing English fashion!—MRS. AUDUBON.

THE PROSPECTUS OF THE GREAT WORK

"To those who have not seen any portion of the author's collection of original drawings, it may be proper to state that their superiority consists in the accuracy as to proportion and outline, and the variety and truth of the attitudes and positions of the figures, resulting from the peculiar means discovered and employed by the author, and his attentive examination of the objects portrayed during a long series of years. The author has not contented himself, as others have done, with single profile views, but in very many instances has grouped his figures so as to represent the originals at their natural avocations, and has placed them on branches of trees, decorated with foliage, blossoms, and fruits, or amidst plants of numerous species. Some are seen pursuing their prey through the air, searching for food amongst the leaves and herbage, sitting in their nests, or feeding their young; whilst others, of a different nature, swim, wade, or glide, over or in their allotted element.

"The insects, reptiles, and fishes that form the food of these birds, have now and then been introduced into the drawings. In every instance where a difference of plumage exists between the sexes, both the male and the female have been represented; and the extraordinary changes which some species undergo in their progress from youth to maturity have been depicted. The plants are all copied from nature, and as many of the originals are remarkable for their beauty, their usefulness or their rarity, the botanist cannot fail to look upon them with delight.

"The particulars of the plan of the work may be reduced to the following heads:

I. The size of the work is double elephant folio, the paper being of the finest quality.

II. The engravings are, in every instance, of the exact dimensions of the drawings, which, without any exception, represent the birds and other objects of their natural size.

III. The plates are colored in the most careful manner from the original drawings.

IV. The work appears in numbers, of which five are published annually, each number consisting of five plates.

V. The price of each number is two guineas, payable on delivery."

Probably no other undertaking of Audubon's life illustrates the indomitable character of the man more fully than this prospectus. He was in a strange country,

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN
DIRECCIÓN GENERAL DE BIBLIOTECAS

the fact he traveled to Philadelphia to obtain funds, but was unsuccessful. His father had left him his property in France of La Gibitière, and seventeen thousand dollars, which had been deposited with a merchant in Richmond, Virginia. Audubon, however, took no steps to obtain possession of his estate in France, and in after years, when his sons had grown up, sent one of them to France, for the purpose of legally transferring the property to his own sister Rosa. The merchant who held possession of the seventeen thousand dollars would not deliver them up until Audubon proved himself to be the son of Commodore Audubon. Before this could be done the merchant died insolvent, and the legatee never received a dollar of his money. Returning from Philadelphia to Hendersonville [Kentucky], the unfortunate Audubon cheerfully endeavored to provide for the future, about which he felt considerable anxiety. Gathering a few hundred dollars, he purchased some goods in Louisville, and returned to business in Hendersonville.—MRS. AUDUBON.

AUDUBON AS A CRAYON PORTRAIT PAINTER

From this date [that of the failure of his mill at Hendersonville] Audubon's difficulties appeared to increase daily. Bills fell due, and unmeasured vexations assailed him. He handed over all he possessed, and left Hendersonville with his sick wife, his gun, his dog, and his drawings,—but without feeling really depressed at his prospects. The family reached Louisville, where they were kindly received by a relative, and Audubon had time to think over some scheme for raising support for his family. Possessed of considerable skill as an artist in crayons, he conceived the

project of setting himself up as a portrait draughtsman. As he started at very low prices, his skill soon became known, and in a few weeks he had as much work as he could do. His family were settled with him, and his business spread so far into Kentucky, that affluence was again enjoyed by the wanderer. Audubon succeeded so well in portraying the features of the dead, that a clergyman's child was exhumed in order that the artist might have an opportunity of taking a portrait of it.

In illustration of his reputation as a crayon drawer, Audubon relates that a settler came for him in the middle of the night from a considerable distance to have the portrait of his mother taken while she was on the eve of death. Audubon went with the farmer in his wagon, and with the aid of a candle made a satisfactory sketch. This success brought other successes, and the portrait painter seemed to have got a new start in life. Shortly afterwards he received an invitation to become a curator of the museum at Cincinnati, and for the preparation of birds received a liberal remuneration. In conjunction with this situation he opened a drawing school in the same city, and obtained from this employment additional emolument sufficient to keep his family comfortably. His teaching succeeded well until several of his pupils started on their own account. The work at the museum having been finished, Audubon fell back upon his portrait painting and such resources as his genius could command.—MRS. AUDUBON.

AUDUBON AT BAYOU SARA

Audubon's fortunes in New Orleans varied exceedingly. From the sorest penury and deepest distress he was sud-

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DIRECCIÓN GENERAL DE BIBLIOTECAS

denly raised by the happy spirit he possessed and the untiring energy of his character. One day he was going about seeking for a patron to obtain a few dollars by drawing a portrait; the next he was dining with Governor Robertson of Louisiana, who gave him a letter of recommendation to President Monroe in connection with the expedition to Mexico. He had determined to go to Shipping Port, Kentucky, [where his wife and family were], but his departure was hindered by an engagement from a few pupils.

It happened, however, that Audubon was not to return to his family as soon as he expected. The voyage to Shipping Port was cut off by the acceptance of a situation in the family of Mrs. Perrie, who owned a plantation at Bayou Sara, in Louisiana. The duties accepted by Audubon were apparently simple enough. He was to teach Mrs. Perrie's daughter drawing during the summer months, at sixty dollars per month. His lessons would absorb one half of the day, and with a young friend, Mason, he was to have the rest of the time free for hunting. Board and lodging were provided for the two friends, and Mrs. Perrie's aim appears to have been to provide an opportunity for Audubon to carry on his pursuits under the guise of an employment which would be congenial, and not interfere with his work.—MRS. AUDUBON.

AUDUBON IN NEW ORLEANS

"*October 20, [1821].* Left Bayou Sara in the Ramapo, with a medley of passengers, and arrived safely in New Orleans. My long, flowing hair, and loose yellow nankeen dress, and the unfortunate cut of my features, attracted much attention, and made me desire to be dressed like other people as soon as possible. My friends the Pamars received me kindly and raised my spirits; they looked upon me as a son returned from a long and dangerous voyage, and children and servants as well as parents, were all glad to see me.

"*October 25.* Rented a house in Dauphine street at seventeen dollars per month, and determined to bring my family to New Orleans. Since I left Cincinnati, October 12, 1820, I have finished sixty-two drawings of birds and plants, three quadrupeds, two snakes, fifty portraits of all sorts, and have subsisted by my humble talents, not having had a dollar when I started. I sent a draft to my wife, and began life in New Orleans with forty-two dollars, health, and much anxiety to pursue my plan of collecting all the birds of America."—*From the "Journals."*

AUDUBON AT NATCHEZ

"*March 16, 1822.* Paid all my bills in New Orleans, and having put my baggage on board of the steamer Eclat, obtained a passage to Natchez in the steamer, in return for a crayon portrait of the captain and his wife."—*From the "Journals."*

HOW MRS. AUDUBON ASSISTED HER HUSBAND

"*September 1.*—My wife writes to me that the child she was in charge of is dead, and that consequently she has determined to come on to Natchez. I received her with great pleasure at the landing and immediately got a house hired, that we might resume housekeeping. In the meantime my wife engaged with a clergyman named Davis, in a situation similar to that which she had held in New Orleans."—*From the "Journals."*

MRS. AUDUBON'S DEVOTION TO HER HUSBAND'S GENIUS

Mrs. Audubon was desirous that her husband should go to Europe, and obtain complete instruction in the use of oil; and with this aim in view she entered into an en-

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DIRECCIÓN GENERAL DE BIBLIOTECAS

gagement with a Mrs. Percy to educate her children, along with her own and a limited number of pupils. Mrs. Percy lived at Bayou Sara, and thither Mrs. Audubon removed, while her husband remained at Natchez, painting with his friend Stein, the artist whose instructions in oil painting had been so valuable. After enjoying all the patronage to be expected at Natchez, Audubon and his friend Stein resolved to start on an exhibition as perambulating portrait-painters; and purchasing a wagon, prepared for a long expedition through the Southern States.

"I had finally determined to break through all bonds and pursue my ornithological pursuits. My best friends solemnly regarded me as a madman, and my wife and family alone gave me encouragement. My wife determined that my genius should prevail, and that my final success as an ornithologist should be triumphant."—MRS. AUDUBON. *The quotation is from the "Journals."*

AN INSTANCE OF AUDUBON'S DIFFICULTIES

"*May 1, 1823.*—Left Mr. Percy's at Bayou Sara on a visit to Jackson, Mississippi, which I found to be a mean place, a rendezvous for gamblers and vagabonds. Disgusted with the place and the people I left it and returned to my wife. I agreed to remain with the Percys throughout the summer, and teach the young ladies music and drawing. I continued to exercise myself in painting with oil, and greatly improved myself. I undertook to paint the portrait of my wife's pupils, but found their complexions difficult to transfer to canvas. On account of some misunderstanding, I left the Percys and returned to Natchez, but did not know what course to follow. I thought of going to Philadelphia, and again thought of going to Louisville and once more entering upon mercantile pursuits, but had no money to move anywhere."—*From the "Journals."*

AUDUBON AS A PROFESSIONAL ARTIST

"*October 25, 1823*—I entered Louisville with thirteen dollars in my pocket. My son Victor I managed to get into the counting house of a friend, and I engaged to paint the interior of a steamer. I was advised to make a painting of the falls of the Ohio, and commenced the work.

"*November 9.*—Busy at work, when the weather permitted, and resolved to paint one hundred views of American scenery. I shall not be surprised to find myself seated at the foot of Niagara."—*From the "Journals."*

AUDUBON'S ENDEAVORS TO COMPLETE HIS GREAT WORK

Audubon reached Philadelphia on April 5, 1824. The journey to that city was undertaken as a desperate venture to obtain help to complete his ornithological work, and he was soon satisfied that the venture would be successful.

"*April 25, [1824].*—I am now determined to go to Europe with my 'treasures,' since I am assured nothing so fine in the way of ornithological representations exist there.

"*July 12.*—I have now in hand one hundred and thirty dollars to begin my journey of 3,000 miles. Before this I have often thought I could work my way through the world by my industry, but I see I shall have to leave here, as Wilson often did, without a cent in my pocket.

"NEW YORK, *August 9th.*—I have been making inquiries regarding the publication of my drawings in New York, but find there is little prospect of the undertaking being favorably received. Full of despair I look to Europe as my only hope."—MRS. AUDUBON. *The quotations are from the "Journals."*

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN ®
DIRECCIÓN GENERAL DE BIBLIOTECAS

with no friends but those he had made within a few months, and not ready money enough in hand to bring out the first number proposed, and yet he entered confidently on this undertaking, which was to cost over a hundred thousand dollars, and with no pledge of help, but on the other hand discouragements on all sides, and from his best friends, of the hopelessness of such an undertaking.—MRS. AUDUBON.

AUDUBON IN LONDON

"[LONDON], *September 20.*—Nearly three months since I touched one of the sheets of my dear book [his "*Journal*"] and I am quite ashamed of it, for I have had several interesting incidents to record, well deserving of relation, even in my poor humble style—a style much resembling my *painting in oil.* Now, nevertheless. I will recapitulate and note down as quickly as possible the primary ones.

"1. I removed the publication of my ornithological work from Edinburgh, to London; from Mr. Lizars to Mr. Robert Havell, No. 79 Newman street; because at Edinburgh it came on too slowly, and also because I can have it done better and cheaper in London.

"2. The King! My dear Book! Had my work presented to His Majesty by Sir Walter Waller, Bart., K. C. H., at the request of my most excellent friend J. P. Children, of the British Museum. His Majesty was pleased to call it fine, and permitted me to publish it under his particular patronage, approbation and protection; and became a subscriber on usual terms, not as kings usually do, but as a gentleman. And I look on such a deed as worthy of all kings in general."—*From the "Journals."*

AUDUBON IN PARIS

"[PARIS], *September 8* [*1828*].—Went to pay my respects to Baron Cuvier and Geoffroy St.-Hilaire; found only the former at

home; he invited me to the Royal Institute, and I had just time to return home and reach it before the sitting of the Royal Académie des Sciences. I took my portfolio, and on entering, inquired for Cuvier, who very politely came to me, made the porter put my book on the table, and assigned me a seat of honor. The séance opened, and a tedious lecture was given on the vision of the mole. Mr. Swainson accompanied me. Baron Cuvier then arose, and announced us, and spoke of my work. It was shown and admired as usual, and Cuvier was requested to review it for the memoirs of the Academy. Cuvier asked me to leave my book. I did, and he commended it to the particular care of the librarians, who are to show it to any who desire to see it; he also said he would propose to the Academy to subscribe to it, and if so, it will be a good day's work.

"*September 9.*—Went to the Garden du Roi, where I met young Geoffroy [St.-Hilaire], who took me to a man who stuffs birds for the Prince D'Essling. He told me the Prince had a copy of my work (probably Wilson's or Selby's), and said he would subscribe if I would call on him to-morrow with him. After this I walked around the boulevards, looking at the strange things I saw there, thinking of my own strange life, and how wonderful my present situation in the land of my fathers and ancestors. From here I went to the Louvre, and as I was about to pass the gates of the Tuileries, a sentinel stopped me, saying no one could enter there with *a fur cap!* I went to another gate, and passed without challenge, and went to the Grand Gallery. There, among the Raphaels, and Correggios, Titians, Davids and thousands of others, I feasted my eyes and enlarged my knowledge. From there I made my way to the Institute de France, and by appointment presented my prospectus to the secretary of the library. There I met young Geoffroy, an amiable and learned young man, who examined my work, paid me every attention, and gave me a room to myself for the inspection of specimens and to write in. How very different from the public institutions in England, where instead of being bowed to, you have to bow to every one. The porters, clerks, and secretaries had all received orders to do everything I required and I was looked

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN
DIRECCIÓN GENERAL DE BIBLIOTECAS

rivers, across its lakes, along its coasts, and up the Mississippi, until I reached Bayou Sara, and leaping on shore, and traversing the magnolia forests, bounded towards thee, my dearest friend,—when the clock struck and suddenly called me to myself in the Royal Institute, patiently waiting for the Baron.

"The number of savants increased, and my watch and the clock told that the day was waning. I took a book and read, but it went into my mind, and left no impression. The savants increased more and more, and bye and bye among them my quick eye discerns the Baron. I had been asked fifty times if I were waiting for him, and had been advised to go to his house; but I sat and watched like a sentinel at his post. I heard his voice and his footstep, and at last saw him, warm, apparently fatigued, and yet extremely kindly, coming towards me, with a 'My Dear Sir, I am sorry to know that you have waited so long here; I was in my cabinet; come with me.' During all this talk, to which I bowed, and followed him, his hand was driving a pencil with great rapidity, and I discovered that he was actually engaged in making his report. I thought of La Fontaine's 'Fable of the Turtle and the Hare,' and of many other things; and I was surprised that so great a man, who, of course, being great, must take care of each of his actions with a thousand times more care than a common individual, to prevent falls, when surrounded, as all great men are, by envy, cowardice, malice, and all other evil spirits, should leave to the last moment the writing of a report, to every word of which the 'Forty of France' would lend a critical ear. We were now in his cabinet; my enormous books lay before him, and I shifted swiftly the different plates that I had marked for examination. His pencil kept constantly moving; he turned and returned the sheets of his pamphlet with amazing accuracy, and noted as quickly as he saw all that he saw. We were both wet with perspiration. When this was done, he invited me to call on him to-morrow at half-past ten, and went off towards the council-room.

"*September 23*—I waited in Cuvier's departmental section until past eleven, when he came in, as much in a hurry as ever, and yet as kind as ever, always the perfect gentleman. The report had been read, and the Institute, he said, had subscribed for one copy;

and he told me the report would appear in next Saturday's 'Globe.' I called on M. Feuillet, principal librarian of the Institute, to inquire how I was to receive the subscription. He is a large, stout man, had on a hunting-cap, and began by assuring me that the Institute was in the habit of receiving a discount on all the works it takes. My upper lip curled, not with pleasure, but with a sneer, at such a request; and I told the gentleman that I never made discounts on a work which cost me a life of much trouble and too much expense ever to be remunerated; so the matter dropped."—*From the "Journals."*

READERS' AND STUDENTS' NOTES

1. The great storehouse of information in respect to Audubon is his own autobiography. Of this work, one of the most interesting and instructive in the whole range of autobiographical writing, many editions have been printed, some of them unauthorized and more or less incomplete. The original edition entitled "*The Life of John James Audubon, the Naturalist, Edited by his Widow,*" issued first in 1867, is published in this country by G. P. Putnam's Sons. (New York. $1.75.)

2. A complete edition of Audubon's autobiography is now to be obtained. "*Audubon and his Journals,*" by Maria R. Audubon, "with zoological and other notes by Eliot Coues, and with many portraits and other illustrations," is a sumptuous work, worthy of the great name it commemorates, first published in 1897. (New York: Scribners. 2 vols., $7.50.) Maria R. Audubon is the grand-daughter of J. J. Audubon.

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN ®
DIRECCIÓN GENERAL DE BIBLIOTECAS

upon with the greatest respect. I have now run the gauntlet of Europe, Lucy, and may be proud of two things—that I am considered the first ornithological painter and the first practical naturalist of America!"—*From the "Journals."*

AUDUBON'S DISAPPOINTMENT IN FRANCE

"[PARIS], *September 15.*—France is poor indeed. This day I have attended the Royal Academy of Sciences and had my plates examined by about one hundred persons. 'Fine, very fine!' issued from many mouths; but they said also, 'what a work! What a price! Who can pay it?' I recollected that I had thirty subscribers at Manchester, and mentioned it. They stared, and seemed surprised; but acknowledged that England, the little, island of England, alone was able to support poor Audubon. Some went so far as to say that had I been here four months ago, I should not have had even the Prince D'Essling for a subscriber. Poor France, thy fine climate, rich vineyards, and the wishes of the learned, avail nothing; thou art a destitute beggar and not the powerful friend thou were represented to me. Now it is that I plainly see how happy, or lucky, it was in me not to have come to France first; for if I had, my work would not now have had even a beginning. It would have perished like a flower in October; and I should have returned to my woods without the hope of leaving behind that eternal fame which my ambition, industry, and perseverance, long to enjoy. Not a subscriber, Lucy; no, not one!"—*From the "Journals."*

AUDUBON AND CUVIER

"[PARIS], *September 15.*—I have also been again at Cuvier's to-day, to introduce Mr. Parker, to begin his portrait. You would like to hear more of Cuvier and his house. Well, we rang the bell, and a waiter came, and desired that we would wipe our feet; we needed it; for we were very muddy. This over, we followed the man upstairs and in the first room we entered I saw

a slight figure in black gliding out an opposite door like a sylph. It was Miss Cuvier, not quite ready to receive company. Off she flew like a dove before falcons. However, we followed our man, who every moment turned to us, and repeated, 'This way, gentlemen.' Then we passed through eight rooms filled with beds or books, and at last reached a sort of laboratory, the sanctum sanctorum of Cuvier; nothing there but books, the skeletons of animals and reptiles. Our conductor bid us sit, and left us to seek for the Baron. My eyes were occupied in the interval in examining the study of this great man, and my mind in reflecting on the wonders of his knowledge. All but order was about his books, and I concluded that he read and studied, and was not fond of books because he was the owner of them, as some great men seem to be whom I have known. Our conductor returned directly, and led us to another laboratory, where we found the Baron. Great men show politeness in a particular way; they receive you without much demonstration; a smile suffices to assure you that you are welcome, and keep about their avocations as if you were a member of the family."—*From the "Journals."*

AUDUBON AND THE INSTITUTE OF FRANCE

"[PARIS], *September 22* [*1828*].—This was the grand day appointed by Baron Cuvier for reading his report on my work at the French Institute. The French Institute! By particular invitation of the Baron, I was at the Institute at half-past one, and no Baron there. I sat opposite the clock and counted the minutes one after another; but the clock, insensible to my impatience, moved regularly, and ticked the time just as if Audubon had never existed. I undertook to count the numerous volumes which filled the compartments of the library, but my eye became bewildered, and as it reached the distant center of the hall, rested on the figure of Voltaire! Poor Voltaire! Had he not his own share of troubles? how was he treated? Savants like shadows passed before me, nodded and proceeded to their seats, and resting their heads on their hands, looked for more knowledge in different memoirs. I, Lucy, began journeying to America, sailed up its

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN
DIRECCIÓN GENERAL DE BIBLIOTECAS

Michael Faraday

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UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN ®
DIRECCIÓN GENERAL DE BIBLIOTECAS

with a few things on the road until the party should get to Paris, doing those things which could not be trusted to strangers or waiters." At Paris he would "get a servant." But at Paris no servant was to be got, and so Faraday, out of gratitude to his patron, continued on in the anomalous position of being partly his patron's assistant in scientific work, partly his body servant. All this to a man of Faraday's humility of disposition and sensible understanding would have been natural and easy enough had it not been for the slights put upon him by Lady Davy. Unfortunately Lady Davy was a woman who could not recognize that genius and ability have rights which even money and social position must not ignore.

"The constant presence of Sir Humphry Davy," wrote Faraday to a friend, "is a mine inexhaustible of knowledge and improvement." But he added: "I have several times been more than half decided to return hastily home; but second thoughts have still induced me to try what the future may produce. The glorious opportunities I enjoy of improving in the knowledge of chemistry and the sciences continually determine me to finish this voyage with Sir Humphry Davy. But if I wish to enjoy these advantages I have to sacrifice much; and though these sacrifices are such as an humble man would not feel, yet I cannot quietly make them." And again: "Sir Humphry Davy has at all times endeavored to keep me from the performance of those things which did not form a part of my duty, and which might be disagreeable. I should have little to complain of were I traveling with Sir Humphry alone, or were Lady Davy like him."

Such was the unworthy treatment which social presumption and an undiscerning, unfeeling mind put upon one of the purest souls and most gifted intellects then living. But Faraday gained much from this "voyage," which lasted nearly two years, or until April, 1815. He was a

constant companion to Davy during the entire time Sir Humphry was engaged on the solution of a number of problems, several of which were difficult enough to add even to his already world-wide fame. Indeed, Faraday was a witness of the solutions of these problems during the whole process of their development from embryonic germ-thoughts to full fruition. No small opportunity of education, this alone! Again, in Davy's company he met the foremost men of science in France, Italy, and Switzerland, and got in touch with what they were doing to extend the boundaries of scientific knowledge. Among others he met the aged Volta, the discoverer of the "Voltaic pile," the founder of the modern science of chemical electricity, whose work he himself was destined to do so much towards extending and making more important. And when he returned to England it was with the authoritative reputation of being a "rising man." He was at once taken on again at the Royal Institution; and, although his position was not much improved, there was some improvement in it. Besides being reappointed to his old post of assistant in the laboratory he was made superintendent of apparatus. But his salary was only 30 shillings ($7.50!) a week, with apartments in the building.

Faraday's beginning at the Royal Institution was humble enough. The position which Davy's interest had first secured for him was only that of a menial assistant—bottle-washer, bulb-blower, etc. And when he returned to the institution after his two years of travel with Davy he was not relieved from menial drudgery even then. But his abilities were not long in manifesting themselves, and his promotion soon became rapid. In the year 1816 (one year after his return) he was chosen to deliver a course

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN ®
DIRECCIÓN GENERAL DE BIBLIOTECAS

of lectures on the general properties of matter at the City Philosophical Society—his first engagement as a lecturer. In the same year he began to publish results of experimental researches in the scientific journals of the day. In the year 1821, when he was but thirty years of age, he made his first discovery in the relationship between magnetism and electricity, showing that magnetic currents tend to move round and round each other in circles at right angles to each other. In 1825, twelve years from the time he had entered the Royal Institution as assistant, he was made director of the laboratory, the position that Davy had held. In 1829 he became for a time a lecturer at the Royal Military Academy at Woolwich. In 1831, after seven years of thought and experimenting, he completed those researches into the properties of magnetism and electricity by which he became the founder of the modern science of magneto-electricity. The publication of these researches placed Faraday foremost in the ranks of physicists throughout the world. In 1833 he was appointed to the newly established Fullerian professorship of chemistry in the Royal Institution, a position which he was to hold for life without the obligation of delivering lectures. The year previous the University of Oxford had bestowed upon him the honorary degree of D. C. L., a magnificent tribute from the most conservative degree-conferring institution in the world to the splendid position held in the realm of science by the quondam bookbinder's apprentice, whose only education had been what he could pick up by himself nights and mornings. Two years later the queen bestowed upon him a pension of £300 ($1,500) a year. Thus, successful, honored, respected, loved, and free from all pecuniary anxiety, he

lived his life to the end, devoting it wholly to the studies which he loved so well, and which he was so splendid an instrument in advancing. In the same Institution that has been the scene of his labors at the first he remained to the last. He had entered it in 1813. His connection with it was severed only by his death. The period of his service was fifty-four years, although during the last two years of his life, owing to failing powers, he was relieved from all actual service. He died August 21, 1867.

It is impossible here to do more than faintly indicate the greatness of Faraday's genius in the realm of physical science. He had always been an original investigator. Even as a boy, with a pile battery of copper pennies and bits of zinc, he had decomposed sulphate of magnesia. He had not long been working with Davy before he had repeated all Davy's wonderful chemical investigations and had extended them. But it is as an investigator of magnetism and electricity that Faraday is most distinguished. These sciences may be said to have taken their final shape in his hands. A favorite theory with him, one at that time new to the world, though now admitted by every one, was that heat, light, chemical affinity, electricity, and magnetism, are all so many different phases of one indestructible force—a force which when lost to view in one phase instantly reappears in another. This belief was the pole star by which he directed his course in all his investigations and by which he was led to most of his brilliant results. One aspect of the theory he was able himself to establish. He proved the complete identity of all the different sorts of electricity—frictional, chemical, magnetic, etc. He also went a long way toward proving the interchangeableness of chemical affinity and

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN ®
DIRECCIÓN GENERAL DE BIBLIOTECAS

electric force. These were, of course, among the titles to his more strictly scientific reputation. But Faraday had a reputation that was equally distinguished, though not of such scientific import. Like Davy, he became the most popular lecturer on scientific subjects of his day. Though by the terms of his professorship he was not obliged to lecture, yet he often did lecture, and his lectures at the Royal Institution on Friday evenings always drew crowds. He had all of Davy's brilliancy of conception in experimental illustration, and more than Davy's facility of manipulation. His especial delight was the making common things the basis of his scientific instruction. No courses of lectures ever delivered have been more popular, or more profoundly influential in enabling ordinary people to understand the laws of nature, than his lectures on "*The Chemistry of a Candle.*" And these lectures when published have been almost as popular and influential in book form as when they were the subject of spoken utterance.

MICHAEL FARADAY

SELECTED STUDIES AND REMINISCENCES

FARADAY'S EARLY LIFE AND EFFORTS AT SELF-EDUCATION

The home of Michael Faraday was in Jacob's Well Mews from the time he was five years old until he went to Blandford Street. Very little is known of his life during these eight years. He himself says, "My education was of the most ordinary description, consisting of little more than the rudiments of reading, writing, and arithmetic at a common day-school. My hours out of school were passed at home and in the streets."

Only a few yards from Jacob's Well Mews is a bookseller's shop, at No. 2 Blandford Street.

There Faraday went as errand boy, on trial for a year, to Mr. George Riebau, in 1804. He has spoken with much feeling "that it was his duty, when he first went, to carry round the papers that were lent out by his master. Often on a Sunday morning he got up early and took them round, and then he had to call for them again; and frequently, when he was told the paper was not done with, 'You must call again,' he would beg to be allowed to have it; for his next place might be a mile off, and then he would have to return back over the ground

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN ®
DIRECCIÓN GENERAL DE BIBLIOTECAS

XI. MICHAEL FARADAY

1791-1867

BIOGRAPHICAL STUDY

BY JOHN EBENEZER BRYANT, M. A.

Faraday is the scientist whose name and memory the world especially delights to honor. His life had such a humble beginning. It was advanced by such laudable and honorable means. It was distinguished by such splendid achievements, by such long-continued and ennobling success. It was pursued with such singlemindedness of purpose, such patient industry, such skill and fertility of resource in the use of simple means to accomplish wished-for ends. His character, too, was so essentially noble and sincere. His sense of right and wrong, of duty and justice and truth, was so impersonal, so unconsciously set to standards acknowledged as divine. In his whole career there was so much to love, so much to admire, so much for humanity to be proud of. Little wonder that his name and memory are held in honor.

Michael Faraday was born in Newington, in the Surrey side of London, September 22, 1791. His father was a journeyman blacksmith, whose delicate health made it

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN
DIRECCIÓN GENERAL DE BIBLIOTECAS

difficult for him to earn sufficient to support his family. But he was an honest-minded and sincerely religious man, who according to the scriptural injunction, "brought up his children in the way they should go;" and though he belonged to one of the smallest and most isolated sects of the time he had the gratification of seeing his son, even after he had become famous, remaining firm in the faith of his youth, and even taking upon himself the duties of "elder" in the humble congregation he worshiped with. Michael Faraday as a boy had little formal education. He learned to read and write and "cipher"—that was all. In his thirteenth year he became an errand boy to a bookseller and bookbinder, whose shop was near his home. But at the end of a year he was received by his employer as a duly bound apprentice to the bookselling and bookbinding trade—the premium usual to be paid upon such an engagement being remitted by the master because of the "faithful service" which his young apprentice had rendered him as errand-boy.

This apprenticeship was Faraday's real schooling. In the front shop he had access to many books, and his mind came in contact with the new ideas of the age. In the back shop he was trained to the use of tools and to transform by his own hands raw materials of various sorts into articles of use and beauty. He began immediately to apply himself sedulously to self-improvement. Almost from the very beginning his mind evinced its natural bent, and found its chief interest in those very subjects of nature-study which were destined to employ and make illustrious his maturer powers. In the bookshop were works on chemistry and electricity—both sciences at that time being new and but little understood depart-

ments of knowledge. These works, by the instinct of genius, young Faraday at once picked out and began to make his own. He devised simple apparatus and performed for himself the experiments which these works described. He persuaded his elder brother to purchase for him a ticket of admission to some lectures on natural philosophy which were being given in a private house in the neighborhood. He made notebooks for himself, and in these he wrote out abstracts of what he read in his books and of what he heard in the lectures. He saved a few shillings and took lessons in drawing so that he might make diagrams in his notebooks illustrative of his work. Then, as he grew older and became more skillful in the use of tools, he contrived apparatus of greater and greater difficulty. Finally he made an electrical machine, and made it so well—turned it out such a workmanlike piece of mechanism—that his employer became proud of him and used to introduce him to his customers and show off the machine to them as a specimen of his apprentice's cleverness. Finally, one of these customers to whom young Faraday was introduced in this way, a Mr. Dance—his name should be held in honor—was so much pleased with him, and with his intelligence, and with the evidences of his interest in science which his well-made apparatus and well-kept notebooks showed, that he presented him with tickets to the concluding lectures which Sir Humphry Davy was just then giving at the Royal Institution.

Faraday's privilege to attend these lectures of Sir Humphry Davy was the great opportunity of his life. Davy was the foremost man of science then living. But as a lecturer he was even more famous than as an original

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN ®
DIRECCIÓN GENERAL DE BIBLIOTECAS

discoverer. And as a lecturer he was not more noted for the beauty, brilliancy, and easy simplicity of his experiments, than for the enthusiasm for science with which he inspired his auditors and spectators. Faraday heard the lectures, and witnessed the dazzling experiments with which they were accompanied, enraptured. But his delight did not deter him from putting forth all his efforts to obtain the utmost possible advantage from them. He took full notes of the lectures. He afterward wrote his notes out carefully in a book—his memory aiding him to make almost verbatim reports of the distinguished lecturer's utterances. He embellished what he wrote with well-drawn illustrations of the apparatus used in the experiments. Then he added many observations and reflections of his own. Afterward, by the suggestion of Mr. Dance, he sent his book to Sir Humphry Davy. At the same time he accompanied it by a statement to the effect that he "desired to escape from trade and enter the service of science," and he expressed the hope that "if opportunity offered" Sir Humphry "might favor his views." Davy, to use the words of his own letter of reply, was "far from being displeased with the proof" which Faraday had given him of his interest in science. "It displays," he said, "great zeal, power of memory, and attention." He invited Faraday to come to see him, and in the end recommended the young enthusiast to the managers of the Royal Institution as assistant in the laboratory. This was in March, 1813, when Faraday was in his twenty-second year.

To those who do not know how hard—how almost impossible—it was, at the time of which we are writing, for a boy or young man to get on in the world unless he had

MICHAEL FARADAY.

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN ®
DIRECCIÓN GENERAL DE BIBLIOTECAS

friends to help him and money to pay for his instruction and his promotion, it may seem that the self-improvement that Faraday accomplished as above outlined was not extraordinary. But it must be remembered that in those days books were few and very high-priced. All apparatus for scientific experiments was elaborately made and very expensive. The wages of apprentices like Faraday were not more than enough for food and clothing. The hours they had to work were long and laboriously occupied. Fees for such lectures as those of the Royal Institution were utterly beyond their reach. But more than anything else as a deterrent was the feeling then prevalent that people in Faraday's position, humbly born and poor, had no right to hope or to wish to fill any other positions than those they were born into. Faraday had soon to prove by bitter experience how strong an element in the social relationships of life this feeling was. Not long before the date of Faraday's engagement at the Royal Institution Sir Humphry Davy had married—a "rich and handsome widow." Not long after Faraday's engagement had begun, Davy, having resigned his position as professor at the Institution, determined to set out, accompanied by Lady Davy, upon a long tour on the continent. As, however, Sir Humphry had discovered Faraday's worth, he wished to take Faraday with him as an assistant. Faraday on his part wished very much to go. Davy then applied to the managers of the Institution for leave of absence for Faraday, and the matter was arranged. But at the last moment, when the party was just ready to start, Davy's valet refused to go away from home, being afraid of Napoleon! Davy now asked Faraday if in the meantime "he would put up

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN
DIRECCIÓN GENERAL DE BIBLIOTECAS

again, losing much time, and being very unhappy if he was unable to get home to make himself neat, and to go with his parents to their place of worship."

In after life the remembrance of his earliest occupation was often brought to his mind: One of his nieces says that he rarely saw a newspaper boy without making some kind remark about him. Another niece recalls his words on one occasion: "I always feel a tenderness for those boys because I once carried newspapers myself."

Faraday's indentures as an apprentice are dated October 7, 1805: one line in them is worthy to be kept—"In consideration of his faithful service no premium is given." . . .

Faraday himself says, [in speaking of his early efforts to obtain knowledge]: "Whilst an apprentice I loved to read the scientific books which were under my hands, and, amongst them, delighted in Marcet's '*Conversations in Chemistry*,' and the electrical treatise in the '*Encyclopædia Britannica*.' I made such simple experiments in chemistry as could be defrayed in their expense by a few pence per week, and also constructed an electrical machine, first with a glass phial, and afterwards with a real cylinder, as well as other electrical apparatus of a corresponding kind." He told a friend that Watts "*On the Mind*" first made him think, and that his attention was turned to science by the article "*Electricity*" in an encyclopædia he was employed to bind.

"My master," he says, "allowed me to go occasionally of an evening to hear the lectures delivered by Mr. Tatum on natural philosophy at his house, 53 Dorset Street, Fleet Street. I obtained a knowledge of these lectures by

bills in the streets and shop-windows near his house. The hour was eight o'clock in the evening. The charge was one shilling per lecture, and my brother Robert (who was three years older and followed his father's business) made me a present of the money for several. I attended twelve or thirteen lectures between February 19, 1810, and September 26, 1811. It was at these lectures I first became acquainted with Magrath, Newton, Nicol, and others."—DR. BENCE JONES, *in "The Life and Letters of Faraday."*

FARADAY'S EARLY THOUGHTFULNESS

In his earliest note-book Faraday wrote down the names of the books and subjects that interested him: this he called "*The Philosophical Miscellany*," being a collection of notices, occurrences, events, etc., relating to the arts and sciences, collected from the public papers, reviews, magazines, and other miscellaneous works; intended," he says, "to promote both amusement and instruction, and also to corroborate or invalidate those theories which are continually starting into the world of science. Collected by M. Faraday, 1809-10."—DR. BENCE JONES.

A DAY WITH FARADAY IN THE ROYAL INSTITUTION

Let us watch him on an ordinary day. After eight hours' sleep, he rises in time to breakfast at eight o'clock, goes round the Institution to see that all is in order, and descends into the laboratory, puts on a large white apron full of holes, and is busy among his pieces of apparatus. The faithful Anderson, an old soldier, who always did exactly what he was told, and nothing more, is waiting

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN ®
DIRECCIÓN GENERAL DE BIBLIOTECAS

have ever since been most zealous in using it to the best advantage."

The peculiarity of his mind was indeed well known to himself. In a letter to Dr. Becker he says: "I was never able to make a fact my own without seeing it; and the descriptions of the best works altogether failed to convey to my mind such a knowledge of things as to allow myself to form a judgment upon them. It was so with *new things*. If Grove, or Wheatstone, or Gassiot, or any other told me a new fact, and wanted my opinion either of its value, or the cause, or the evidence it could give on any subject, I never could say anything until I had seen the fact. For the same reason I never could work, as some professors do most extensively, by students or pupils. All the work had to be my own."—Dr. J. H. Gladstone.

FARADAY'S WONDERFUL ACCURACY AS A PHYSICIST

"The thing I am proudest of, is that I have never been found to be wrong." This Faraday could say in the early part of his scientific history without fear of contradiction. After his death, Professor Auguste de la Rive wrote, "I do not think that Faraday has once been caught in a mistake; so precise and conscientious was his mode of experimenting and observing." This is not absolutely true; but the extreme rarity of Faraday's mistakes, notwithstanding the immense amount of his published researches, is one of those marvels which can be appreciated only by those who are in the habit of describing what they have seen in the mist land that lies beyond the boundaries of previous knowledge.—Dr. J. H. Gladstone.

FARADAY'S INTEREST IN THE PHYSICAL UNKNOWN

Into this unknown region [the region beyond ascertained knowledge] Faraday's mental vision was ever stretched. "I well remember one day," writes Mr. Barrett, a former assistant at the Royal Institution, "when as Mr. Faraday was by my side, I happened to be steadying, by means of a magnet, the motion of a magnetic needle under a glass shade. Mr. Faraday suddenly looked most impressively and earnestly as he said, 'How wonderful and mysterious is that power you have there! the more I think over it, the less I seem to know:'"—and yet he who said this knew more of it than any living man. —Dr. J. H. Gladstone.

FARADAY AND THE MATHEMATICIANS

The work of Michael Faraday introduced a new era in the history of physical science. Unencumbered by pre-existing theories, and untrammeled by the methods of the mathematician, he set forth on a line of his own; and, while engaged in the highest branches of experimental research, he sought to explain his results by reference to the most elementary mechanical principles only. Hence it was that those conclusions which had been obtained by mathematicians only by the help of advanced analytical methods, and which were expressed by them only in the language of the integral calculus, Faraday achieved without any such artificial aids to thought, and expressed in simple language, having reference to the mechanism which he conceived to be the means by which such results

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN ®
DIRECCIÓN GENERAL DE BIBLIOTECAS

were brought about. For a long time Faraday's methods were regarded by mathematicians with something more than suspicion; and, while they could not but admire his experimental skill, and were compelled to admit the accuracy of his conclusions, his mode of thought differed too widely from that to which they were accustomed, to command their assent. In Sir William Thomson, and in Clerk Maxwell, Faraday at length found interpreters between him and the mathematical world; and to the mathematician perhaps the greatest monument of the genius of Faraday is the "*Electricity and Magnetism*" of Clerk Maxwell.—WILLIAM GARNETT, M. A., D. C. L., *in "Heroes of Science—Physicists."*

FARADAY'S SENSE OF ORDER AND TENACITY OF PURPOSE

A family tradition exists that the Faradays came originally from Ireland. Faraday himself has more than once expressed to me his belief that his blood was in part Celtic, but how much of it was so, or when the infusion took place, he was unable to say. He could imitate the Irish brogue, and his wonderful vivacity may have been in part due to his extraction. But there were other qualities which we should hardly think of deriving from Ireland. The most prominent of these was his sense of order, which ran like a luminous beam through all the transactions of his life. The most entangled and complicated matters fell into harmony in his hands. His mode of keeping accounts excited the admiration of the managing board of this Institution [the Royal]. And his science was similarly ordered. In his "*Experimental Researches,*" he numbered every paragraph, and welded their various parts

together by incessant reference. His private notes of the "*Experimental Researches,*" which are happily preserved, are similarly numbered: their last paragraph bears the figure 16,041. His working qualities, moreover, showed the tenacity of the Teuton. His nature was impulsive, but there was a force behind the impulse which did not permit it to retreat. If in his warm moments he formed a resolution, in his cool ones he made that resolution good. Thus his fire was that of a solid combustible, not that of a gas, which blazes suddenly, and dies as suddenly away.—PROFESSOR TYNDALL.

FARADAY'S APPRECIATION OF LOVE AND SYMPATHY

Faraday prized the love and sympathy of men—prized it almost more than the renown which his science brought him. Nearly a dozen years ago it fell to my lot to write a review of his "*Experimental Researches*" for the "*Philosophical Magazine.*" After he had read it, he took me by the hand, and said, "Tyndall, the sweetest reward of my work is the sympathy and good will which it has caused to flow in upon me from all quarters of the world." Among his letters I find little sparks of kindness, precious to no one but myself, but more precious to me than all. He would peep into the laboratory when he thought me weary, and take me up stairs with him to rest. And if I happened to be absent he would leave a little note for me, couched in this or some other similar form:—"Dear Tyndall—I was looking for you, because we were at tea—we have not yet done—will you come up?" I frequently shared his early dinner; almost always, in fact, while my lectures were going on. There was no trace

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN ®
DIRECCIÓN GENERAL DE BIBLIOTECAS

of asceticism in his nature. He preferred the meat and wine of life to its locusts and wild honey. Never once during an intimacy of fifteen years did he mention religion to me, save when I drew him on to the subject. He then spoke to me without hesitation or reluctance; not with any apparent desire to "improve the occasion," but to give me such information as I sought. He believed the human heart to be swayed by a power to which science or logic opened no approach; and right or wrong, this faith, held in perfect tolerance of the faiths of others, strengthened and beautified his life.—PROFESSOR TYNDALL.

FARADAY'S OVERWORK AND ITS CONSEQUENCES

Faraday was now [about 1840] feeling the effects of the mental strain to which he had been subjected for so many years. During these years he repeatedly broke down. His wife alone witnessed the extent of his prostration, and to her loving care we, and the world, are indebted for the enjoyment of his presence here so long. He found occasional relief in a theater. He frequently quitted London and went to Brighton and elsewhere, always choosing a situation which commanded a view of the sea, or of some other pleasant horizon, where he could sit and gaze and feel the gradual revival of the faith that

> "Nature never did betray
> The heart that loved her."

But very often for some days after his removal to the country, he would be unable to do more than sit at a window and look out upon the sea and sky.—PROFESSOR TYNDALL.

WEALTH VERSUS SCIENCE IN FARADAY'S CAREER

While once conversing with Faraday on science, in its relations to commerce and litigation, he said to me, that at a certain period of his career, he was forced definitely to ask himself, and finally to decide, whether he should make wealth or science the pursuit of his life. He could not serve both masters, and he was therefore compelled to choose between them. After the discovery of magneto-electricity his fame was so noised abroad, that the commercial world would hardly have considered any remuneration too high for the aid of abilities like his. Even before he became so famous, he had done a little "professional business." This was the phrase he applied to his purely commercial work. His friend, Richard Phillips, for example, had induced him to undertake a number of analyses, which produced, in the year 1830, an addition to his income of more than a thousand pounds; and in 1831, a still greater addition. He had only to will it to raise in 1832 his professional business income to £5,000 [$25,000] a year. Indeed, this is a wholly insufficient estimate of what he might, with ease, have realized annually during the last thirty years of his life.

While restudying the "*Experimental Researches*" with reference to the present memoir, the conversation with Faraday here alluded to came to my recollection, and I sought to ascertain the period when the question, "wealth or science," had presented itself with such emphasis to his mind. I fixed upon the year 1831 or 1832, for it seemed beyond the range of human power to pursue science as he had done during the subsequent years, and to pursue

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN ®
DIRECCIÓN GENERAL DE BIBLIOTECAS

upon him; and as thought flashes after thought through his eager—perhaps impatient—brain, he twists his wires into new shapes, and rearranges his magnets and batteries. Then some conclusion is arrived at which lights up his face with a gleam of satisfaction, but the next minute a doubt comes across that expressive brow,—may the results not be due to something else yet imperfectly conceived?—and a new experiment must be devised to answer that. In the meantime one of his little nieces has been left to his charge. She sits as quiet as a mouse with her needlework; but now and then he gives her a nod, or a kind word, and throwing a little piece of potassium on to a basin of water for her amusement, he shows her the metal bursting into purple flame, floating about in fiery eddies, and the crack of the fused globule of potash at the end. Presently there is handed to him the card of some foreign *savant*, who makes his pilgrimage to the famous Institution and its presiding genius; he puts down his last result on a slate, comes up stairs, and, disregarding the interruption, chats with his visitor with all cordiality and openness. Then to work again till dinner-time, at half-past two. In the afternoon he retires to his study with its plain furniture, and the india-rubber tree in the window, and writes a full letter of affection to some friend, after which he goes off to the council meeting of one of the learned bodies. Then back again to the laboratory, but as evening approaches he goes up stairs to his wife and niece, and then there is a game at bagatelle or acting charades; and afterwards he will read aloud from Shakespeare or Macaulay till it is time for supper and the simple family worship which now is not

liable to the interruptions that generally prevent it in the morning. And so the day closes.

Or, if it be a fine summer evening, he takes a stroll with his wife and the little girl to the Zoological Gardens, and looks at all the new arrivals, but especially the monkeys, laughing at their tricks till the tears run down his cheeks.—J. H. GLADSTONE, PH.D., F. R. S., *in "Michael Faraday."*

FARADAY IN THE PUBLIC LECTURE-ROOM

But suppose it is his night to lecture. The subject has been carefully considered, an outline of his discourse has been written on a sheet of foolscap, with all the experiments marked and numbered, and during the morning everything has been arranged on the table in such order that his memory is assisted by it. The audience now pours in, and soon occupies all the seats, so that late-comers must be content with sitting on the stairs or standing in the gangways, or at the back of the gallery. Faraday enters, and placing himself in the center of the horse-shoe table, perfect master of himself, his apparatus, and his audience, commences a discourse which few that are present will ever forget. Here is a picture by Lady Pollock:— "It was an irresistible eloquence, which compelled attention and insisted upon sympathy. It waked the young from their visions, and the old from their dreams. There was a gleaming in his eyes which no painter could copy, and which no poet could describe. Their radiance seemed to send a strange light into the very heart of his congregation; and when he spoke it was felt that the stir of his voice and the fervor of his

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN ®
DIRECCIÓN GENERAL DE BIBLIOTECAS

words could belong only to the owner of those kindling eyes. His thought was rapid and made itself a way in new phrases—if it found none ready made—as the mountaineer cuts steps in the most hazardous ascent with his own axe. His enthusiasm sometimes carried him to the point of ecstacy when he expatiated on the beauties of Nature, and when he lifted the veil from her deep mysteries. His body then took motion from his mind; his hair streamed out from his head; his hands were full of nervous action; his light, lithe body seemed to quiver with its eager life. His audience took fire with him, and every face was flushed. Whatever might be the afterthought or the after-pursuit, each hearer for the time shared his zeal and his delight."—DR. J. H. GLADSTONE.

HOW FARADAY CAPTIVATED ALL HEARTS

We have heard much of Faraday's gentleness and sweetness and tenderness. It is all true; but it is very incomplete. You cannot resolve a powerful nature into these elements; and Faraday's character would have been less admirable than it was had it not embraced forces and tendencies to which the silky adjectives "gentle" and "tender" would by no means apply. Underneath his sweetness and gentleness was the heat of a volcano. He was a man of excitable and fiery nature; but through high self-discipline he had converted the fire into a central glow and motive-power of life, instead of permitting it to waste itself in useless passion. "He that is slow to anger," saith the sage, "is greater than the mighty, and he that ruleth his own spirit than he that taketh a city." Faraday was *not* slow to anger, but he completely ruled

his own spirit, and thus though he took no cities, he captivated all hearts.—PROFESSOR TYNDALL, *in "Faraday as a Discoverer."*

FARADAY'S SIMPLEMINDEDNESS

When, in the course of writing this book, I have spoken to his acquaintances about Faraday, the most frequent comment has been in such words as "Oh! he was a beautiful character, and so simple-minded." I have tried to ascertain the cause of this simple-mindedness, and I believe it was the consciousness that he was meaning to do right himself, and the belief that others whom he addressed meant to do right too, and so he could just let them see everything that was passing through his mind. And while he knew no reason for concealment, there was no trace of self-conceit about him, nor any pretense at being what he was not.—DR. J. H. GLADSTONE.

FARADAY'S METHODS OF ORDER AND EXACTNESS

The habit of Faraday was to think out carefully beforehand the subject on which he was working, and to plan his mode of attack. Then, if he saw that some new piece of apparatus was needed, he would describe it fully to the instrument-maker with a drawing, and it rarely happened that there was any need of alteration in executing the order. If, however, the means of experiment existed already, he would give Anderson [his attendant for nearly forty years] a written list of the things he would require, at least a day before—for Anderson was not to be hurried. When all was ready, he would descend

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN
DIRECCIÓN GENERAL DE BIBLIOTECAS

into the laboratory, give a quick glance round to see that all was right, take his apron from the drawer, and rub his hands together as he looked at the preparations made for his work. There must be no tool on the table but such as he required. As he began, his face would be exceedingly grave, and during the progress of an experiment all must be perfectly quiet; but if it was proceeding according to his wish, he would commence to hum a tune, and sometimes to rock himself sideways, balancing alternately on either foot. Then, too, he would often talk to his assistant about the result he was expecting. He would put away each tool in its own place as soon as done with, or at any rate when the day's work was over, and he would not unnecessarily take a thing away from its place: thus if he wanted a perforated cork, he would go to the drawer which contained the corks and cork-borers, make there what he wanted, replace the borers, and shut the drawer. No bottle was allowed to remain without its stopper; no open glass might stand for a night without a paper cover; no rubbish was to be left on the floor; bad smells were to be avoided if possible; and machinery in motion was not permitted to grate. In working, also, he was very careful not to employ more force than was wanted to produce the effect. When his experiments were finished and put away, he would leave the laboratory and think further about them up stairs.

This orderliness, and this economy of means, he not only practiced himself, but he expected them also to be followed by any who worked with him; and it is from conversation with these that I have been able to give this sketch of his manner of working.

This exactness was also apparent in the accounts which

he kept with the Royal Institution and Trinity House [a second great public institution—one that had the care of lighthouses, beacons, etc.—with which Faraday was connected for many years] in which he entered every little item of expenditure with the greatest minuteness of detail. —DR. J. H. GLADSTONE.

FARADAY'S PECULIARITY OF MIND

As to the mental process that devised, directed, and interpreted his experiments, it must be borne in mind that Faraday was no mathematician; his power of appreciating an *a priori* reason often appeared comparatively weak. It has been stated on good authority that Faraday boasted on a certain occasion of having only once in the course of his life performed a mathematical calculation: that once being when he turned the handle of Babbage's calculating machine. Though there was more pleasantry than truth in this professed innocence of numbers, probably no one acquainted with his electrical researches will doubt that, had he possessed more mathematical ability, he would have been saved much trouble, and would sometimes have expressed his conclusions with greater ease and precision. Yet, as Sir William Thomson has remarked with reference to certain magnetic phenomena, "Faraday, without mathematics, divined the result of the mathematical investigation; and, what has proved of infinite value to the mathematicians themselves, he has given them an articulate language in which to express their results. Indeed, the whole language of the 'magnetic field,' and 'lines of force' is Faraday's. It must be said for the mathematicians that they greedily accepted it, and

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DIRECCIÓN GENERAL DE BIBLIOTECAS

commercial work at the same time. To test this conclusion I asked permission to see his accounts, and on my own responsibility, will state the result. In 1832, his professional business income, instead of rising to £5,000, or more, fell from £1,090 4s. to £155 9s. From this it fell, with slight oscillations, to £92 in 1837, and to zero in 1838. Between 1839 and 1845, it never, except in one instance, exceeded £22; being for the most part under this. The exceptional year referred to was that in which he and Sir Charles Lyell were engaged by Government to write a report on the Haswell Colliery explosion, and then his business income rose to £112. From the end of 1845 to the day of his death, Faraday's annual professional business income was exactly zero. Taking the duration of his life into account, this son of a blacksmith, and apprentice to a bookbinder, had to decide between a fortune of £150,000 [$750,000] on the one side, and his undowered science on the other. He chose the latter and died a poor man. But his was the glory of holding aloft among the nations the scientific name of England for a period of forty years.—PROFESSOR TYNDALL.

FARADAY AND THE PRESIDENCY OF THE ROYAL SOCIETY

The outward and visible signs of fame were of less account to Tyndall than to most men. He had been loaded with scientific honors from all parts of the world. Without, I imagine, a dissentient voice, he was regarded as the prince of the physical investigators of the present age. The highest scientific position in this country he had, however, never filled. When [in 1858—Faraday was then 67 years of age] the late excellent and lamented Lord

Wrottesley resigned the presidency of the Royal Society, a deputation from the council, consisting of his Lordship, Mr. Grove, and Mr. Gassiot, waited upon Faraday, to urge him to accept the president's chair. All that argument or friendly persuasion could do was done to induce him to yield to the wishes of the council, which was also the unanimous wish of scientific men. A knowledge of the quickness of his own nature had induced in Faraday the habit of requiring an interval of reflection, before he decided upon any question of importance. In the present instance he followed his usual habit, and begged for a little time.

On the following morning, I went up to his room, and said on entering that I had come to him with some anxiety of mind. He demanded its cause, and I responded "lest you should have decided against the wishes of the deputation that waited on you yesterday." "You would not urge me to undertake this responsibility," he said. "I not only urge you," was my reply, "but I consider it your bounden duty to accept it." He spoke of the labor that it would involve; urged that it was not in his nature to take things easy; and that if he became president, he would surely have to stir many new questions, and agitate for some changes. I said that in such cases he would find himself supported by the youth and strength of the Royal Society. This, however, did not seem to satisfy him. Mrs. Faraday came into the room, and he appealed to her. Her decision was adverse and I deprecated her decision. "Tyndall," he said at length, "I must remain plain Michael Faraday to the last; and let me now tell you, that if I accepted the honor which the Royal Society desires to confer upon me, I would not answer for

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN ®
DIRECCIÓN GENERAL DE BIBLIOTECAS

matter in the lines of its motion. By this he enlarged and added to the subjects which he thought naturally possible for experiment to attack; and to experiment he went to test his ideas; and though he failed to realize his imaginations, yet, by his genius, and truthfulness, and handicraft, he filled his experimental researches with new and connected facts, and thus he left to science a monument of himself which will last in all its grandeur for ages.—DR. BENCE JONES.

FARADAY AS A MAN

As a man, the beauty and nobleness of Faraday's character was formed by very many great qualities. Among these the first and greatest was his truthfulness. His noble nature showed itself in his search for truth. He loved truth beyond all other things; and no one ever did or will search for it with more energy than he did.

His second great quality was his kindness (*agapê*). It was born in him, and by his careful culture it grew up to be the rule of his life; kindness to everyone, always—in thought, in word, and in deed.

His third great quality was his energy. This was no strong effort for a short time, but a lifelong lasting strife to seek and say that which he thought was true, and to do that which he thought was kind.

Some will consider that his strong religious feeling was the prime cause of these great qualities; and there is no doubt that one of his natural qualities was greatly strengthened by his religion. It produced what may well be called his marvelous humility.

That one who had been a newspaper boy should receive,

unsought, almost every honor which every republic of science throughout the world could give: that he should for many years be consulted constantly by the different departments of the Government, and other authorities, on questions regarding the good of others; that he should be sought after by the princes of his own and other countries; and that he should be the admiration of every scientific and unscientific person who knew anything of him, was enough to have made him proud; but his religion was a living root of fresh humility, and from first to last it may be seen growing with his fame and reaching its height with his glory, and making him, to the end of his life, certainly the humblest, whilst he was also the most energetic, the truest, and the kindest, of experimental philosophers.

To complete this picture, one word more must be said of his religion. His standard of duty was supernatural. It was not founded upon any intuitive ideas of right and wrong; nor was it fashioned upon any outward expediencies of time and place; but it was formed entirely on what he held to be the revelation of the will of God in the written word; and throughout all his life his faith led him to endeavor to act up to the very letter of it.—DR. BENCE JONES.

READERS' AND STUDENTS' NOTES

1. The life of Faraday is one of the most popular biographical subjects in literature. Such works as "*Clever Boys of Our Time and How They Became Great Men*," and Sarah K. Bolton's "*Poor Boys Who Became Famous*," are sure to contain accounts

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN
DIRECCIÓN GENERAL DE BIBLIOTECAS

of Faraday. A very excellent account of Faraday, with also a popular explanation of the nature of his physical and chemical discoveries will be found in Dr. William Garnett's "*Heroes of Science—Physicists*" (New York: E. & J. B. Young & Co.). The student will also find that Faraday occupies an important place in Miss Buckley's "*Short History of Natural Science*" (New York: D. Appleton & Co.).

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Sir Charles Lyell

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the integrity of my intellect for a single year." I urged him no more, and Lord Wrottesley had a most worthy successor in Sir Benjamin Brodie.—PROFESSOR TYNDALL.

FARADAY'S WORK FOR THE UNIFICATION OF SCIENCE

Faraday was pre-eminently a discoverer; he liked the name of "philosopher." His favorite paths of study seem to wander far enough from the common abodes of human thought or the requirements of ordinary life. He became familiar, as no other man ever was, with the varied forces of magnetism and electricity, heat and light, gravitation and galvanism, chemical affinity and mechanical motion; but he did not seek to "harness the lightnings," or to chain those giants and make them grind like Samson in the prisonhouse. His way of treating them reminds us rather of the old fable of Proteus, who would transform himself into a whirlwind, or a dragon, a flame of fire, or a rushing stream, in order to elude his pursuer; but if the wary inquirer could catch him asleep in his cave, he might be constrained to utter all his secret knowledge; for the favorite thought of Faraday seems to have been that these various forces were the changing forms of a Proteus, and his great desire seems to have been to learn the secret of their origin and their transformations.

"I delight in hearing of exact numbers, and the determination of the equivalents of force when different forms of force are compared one with another," he wrote to Joule, in 1845; and no wonder, for these quantitative comparisons have proved many of his speculations to be true, and have made them the creed of the scientific

world. When he began to investigate the different sciences, they might be compared to so many separate countries with impassable frontiers, different languages and laws, and various weights and measures; but when he ceased, they resembled rather a brotherhood of states, linked together by a community of interests and of speech, and a federal code; and in bringing about this unification no one had so great a share as himself.—DR. J. H. GLADSTONE.

FARADAY'S HONORS

When a comparatively young man Faraday was naturally desirous of appending the mystic letters "F. R. S." to his name, and he was balloted into the Royal Society in January, 1824, not without strong opposition from his master, Sir Humphry Davy, then president. He paid the fees, and never sought another distinction of the kind. But they were showered down upon him. The Philosophical Society of Cambridge had already acknowledged his merits, and the learned Academies of Paris and Florence had enrolled him amongst their corresponding members. Heidelberg and St. Petersburg, Philadelphia and Boston, Copenhagen, Berlin, and Palermo, quickly followed; and as the fame of his researches spread, very many other learned societies in Europe and America, as well as at home, brought to him the tribute of their honorary membership. No wonder the celebrated electrician, P. Riess, of Berlin, once addressed a long letter to him as "Professor Michael Faraday, Member of all Academies of Science, London." He thrice received the degree of Doctor, Oxford making him a D. C. L., Prague a Ph. D., and Cambridge an LL. D., besides which he

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DIRECCIÓN GENERAL DE BIBLIOTECAS

was instituted a Chevalier of the Prussian Order of Merit, a Commander of the Legion of Honour, and a Knight Commander of the Order of St. Maurice and St. Lazarus. Among the medals which he received were each of those at the disposal of the Royal Society—indeed the Copley medal was given him twice—and the Grande Médaille d'Honneur at the time of the French Exhibition. Altogether, it appears he was decorated with ninety-five titles and marks of merit, including the blue ribbon of science, for in 1844 he was chosen one of the eight foreign associates of the French Academy [of Sciences].—DR. J. H. GLADSTONE.

PROFESSOR TYNDALL'S FINAL ESTIMATE OF FARADAY

Taking him for all and all, I think it will be conceded that Michael Faraday was the greatest experimental philosopher the world has ever seen; and I will add the opinion, that the progress of future research will tend, not to dim or to diminish, but to enhance and glorify the labors of this mighty investigator.—*From "Faraday as a Discoverer."*

FARADAY AS A PHILOSOPHER

As a philosopher, Faraday's first great characteristic was the trust which he put in facts. He said of himself, "In early life I was a very lively imaginative person, who could believe in the '*Arabian Nights*' as easily as in the '*Encyclopædia*.' But facts were important to me, and saved me. I could trust a fact." Over and over again he showed his love of experiments in his writings and lectures: "Without experiment I am nothing," "But

still try, for who knows what is possible?" "All our theories are fixed upon uncertain data, and all of them want alteration and support from facts." "One thing, however, is fortunate, which is, that whatever our opinions, they do not alter nor derange the laws of nature."

His second great characteristic was his imagination. It rose sometimes to divination, or scientific second sight, and led him to anticipate results that he or others afterwards proved to be true.

Throughout his life his idea of force and of matter differed from those held by others; thereby he was led to form plans for the broadest and newest, as well as the exactest experiments. In one of his first lectures he spoke of realizing "the once absurd notion of the transmutation of the elements," and obtaining "the basis of the metals."

The discoveries of Davy and Oersted led him into more connected ideas of force, and he imagined that there might be one great universal principle from which gravity, heat, light, electricity, magnetism, even life itself, might come.

He hoped to prove by experiment that there was more than a connection between the imponderable agents. He worked to find more even than a relationship, more than a common origin, for the forces of nature. He wanted to establish an actual identity among them, and in his search for the unity of all force he made all his great discoveries.

Later in life a new image of matter came into his mind. He immaterialized matter into "centers of force," and he materialized the directions in which matter tends to move into "physical lines of force." What he took from matter at its centers and gave to force he partly gave back to

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XII. SIR CHARLES LYELL

1797-1875

BIOGRAPHICAL STUDY

BY JOHN EBENEZER BRYANT, M. A.

In the history of almost every science there has almost always been some one man to whom that science owes more than to any other—who found it based on wrong principles, and directed in its development to wrong ends, and who by his genius, his devotion, his industry, was instrumental in removing it from its false foundations and basing it on principles that are in harmony with nature. Such a man, in the history of the science of geology, was Charles Lyell. While not the historical founder of geology, nor, indeed, the first eminent worker in the science, nor by any means the only eminent worker in it during the epoch of his devotion to it, yet nevertheless he is justly to be considered the founder of the modern science of geology. When he began his career he found geology crude in its aims and scope, and in its methods more or less unscientific. When he finished his labors he left the science definite in both its scope and its aims, and as strictly

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DIRECCIÓN GENERAL DE BIBLIOTECAS

governed by the laws of inductive reasoning as any science in the whole realm of modern knowledge.

Lyell was a favored child of fortune. In addition to the ability and genius with which he was endowed, he was endowed with gifts and graces of disposition and character scarcely less remarkable. He had industry and zeal. He had judgment and tact. He had natural courtesy of manner and a kind heart. He had true nobility and dignity of soul. In the course of a long life he never made an enemy—he even had scarcely a detractor—and the friends he made comprised nearly every man of eminence in England, especially in the walks of science. He was peculiarly fortunate in his domestic relationships. His father, who was a man of scholarship and culture, and in his way a distinguished naturalist, was also a man of wealth. He was thus not only able to sympathize with his son's scientific aims, but he could do much more. In his lifetime he gave him such an allowance as made it possible for him to live in social dignity and comfort, and devote his whole time to his scientific pursuits. At his death he left him such an estate as made his pecuniary position more care-free and socially dignified even than before. Lyell, too, received a good education, and had in his scientific career the inestimable advantage of being well trained (as well as naturally gifted) in the art of expression. His marriage, too, was a happy one. His wife, who was also an exceptionally beautiful woman, was a woman of culture and of scientific tastes, like himself. In addition she was a woman of social tact and personal charm, both in conversation and in manner, and thus able to make his home what it in reality became—a social center for men and women interested in scientific pursuits throughout all the

kingdom. In only two things did fortune seem to restrain her hand in dealing with Charles Lyell. He had no children. But this privation was to some extent compensated for by the fact that it left him free to devote himself wholly to his science; and also by the fact that in the son of his brother, who was also the son of his wife's sister, he found talents, tastes, and a disposition, such as he could have but wished for in a son of his own. He also suffered more or less all through life from a weakness of the eyes. But in every other respect he was, through the working years of his life, both well and strong.

The details of Lyell's life are so few and unstriking that they can scarcely be made into a narrative. He was born at Kinnordy, Forfarshire, Scotland, November 14, 1797. The family estate was at Kinnordy; but soon after Lyell's birth his father moved to the south of England, where, in the New Forest, he resided for twenty-eight years. Lyell was sent to good schools, and though his record as a student was not remarkable, it was creditable. He used to gain prizes for speaking (reciting), and for Latin and original English composition. Once he won a prize for English verse. His principal delight as a boy was collecting, and he became an ardent though unscientific entomologist. It was not until he was at Oxford, whither he went soon after he had completed his eighteenth year, that his real interest in science began. In his twentieth year he attended the lectures of the enthusiastic geologist, Professor Buckland, and from that date forward Charles Lyell's whole soul was devoted to geology. In his twenty-first year he had the good fortune of accompanying his parents and his sisters on an extended tour through France, Switzerland, and Italy, and it was

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on this tour that he began that wonderful series of out-of-door observations for which his career is so distinguished. Shortly after his return from this tour he received his degree, and in deference to his father's wishes he began the study of law. The weakness of his eyes, however, prevented him from pursuing the study of his chosen profession steadily, and it was not until his twenty-eighth year that he was called to the bar. And even when at last he began the practice of his profession he devoted himself to its duties only perfunctorily. His principal affection was for geology. And though, still in deference to his father's wishes, who thought it would be best for him to have at least some nominal profession, he went on circuit for two years, the connection with law was never much more than nominal and soon was dropped altogether. But he had become a fellow of the Geological Society in his twenty-second year, and a fellow of the Royal Society in his twenty-ninth year, and was a regular contributor of scientific memoirs to the various scientific journals concerned with his specialty. In his thirty-third year (1830) the first volume of his epoch-making book, "*The Principles of Geology,*" was published. In the next year he was made professor of geology at King's College, London. And in the year thereafter (1832, at the age of thirty-five) he married, his bride being Miss Mary Horner, daughter of Mr. Leonard Horner, who was also an enthusiastic and distinguished geologist.

The geologic principle which Lyell was most concerned in establishing was briefly this: In the explanation of geologic records the causes of past geologic action are to be sought for by observing what means nature uses to effect her present geologic action. His theory summarized

may be stated in a single sentence—"All changes in the crust of our earth have been brought about by causes that are still in action." In other words, in the changes which nature produces to-day by ordinary causes—as, for example, the wearing away of rock or soil by the action of rain, snow, ice, etc., the washing of silt down river beds and its deposition over the surface of the sea at river mouths by the action of moving water, the growth of rock structure on mountain sides by the action of volcanoes, the growth of rock structure in the sea by the action of coral polyps—in changes such as these and others in infinite number that might be instanced—changes that are produced daily everywhere by causes that are easily observable and easily explainable—may be seen the counterpart of all the changes which can be discovered to have taken place in the whole earth's crust, with all its infinite stratifications, eruptive deposits, and modifications of structure of every sort. This theory was in direct opposition to the theory which at the beginning of Lyell's career was held by almost every eminent geologist living—for example, by Lyell's own preceptor, Buckland. The accepted theory was that in the main the changes observable in the earth's crust were the results of an adjusting power altogether different from what is commonly understood as the laws of nature. The Noachian deluge was the instrument most commonly accepted as having been concerned in effecting these changes. And when it was seen that this deluge could not possibly have been instrumental in effecting more than the smallest fraction of the changes that had taken place in the earth's crust, other deluges were brought in as assisting instruments. And, in addition to deluges, volcanic upheavals and continental

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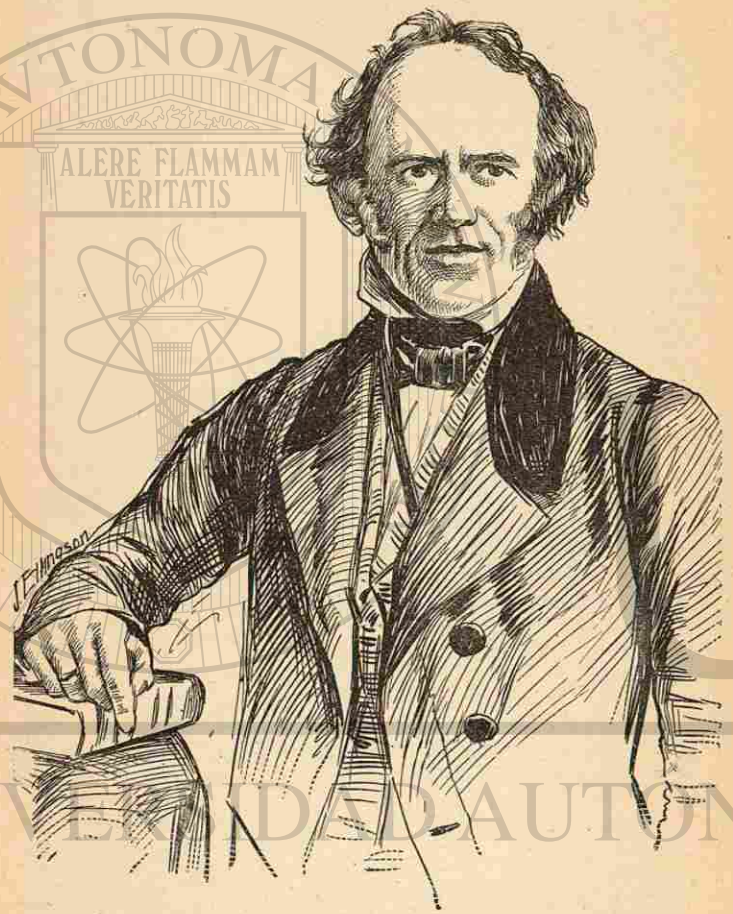

SIR CHARLES LYELL.

earthquakes were postulated. In short, instead of supposing that the operations of nature are uniform—yesterday, to-day and forever the same—it was supposed that nature worked by cataclysms. And thus, as soon as Lyell's theory was well understood, the scientific world was divided into two camps—the "cataclysmists" (or "catastrophists," as they were sometimes called) on the one side, and the "uniformitarians' on the other. Long, however, before Lyell had finished his geological labors the cataclysmic theory of geologic change was abandoned, and the scientific world became what it now is in its belief—that is to say, wholly uniformitarian.

Such, in bald language, is a brief statement of the great doctrine with which Lyell's name in the history of geologic science is principally associated. But this doctrine was not wholly original with Lyell. It had been announced as early as 1788 by the celebrated Scotchman, Dr. Hutton. Hutton's theory, however, had never been accepted by the scientific world; and by the time that Lyell began to devote himself to geology it had almost been forgotten. Lyell gave to Hutton the credit of first propounding the theory, and looked upon himself only as its expositor. It was Lyell, however, that established the theory. But it was not merely his statement of the theory in fascinating language, and the skillful deductive reasoning he used, that won for it its credit. It was his support of the statement by a wealth of observed geologic fact, obtained in every part of the globe, such as in the whole history of the science had never been got together before, that brought the world to see that the way to explain the conformation of the earth's crust is not by assuming that nature acts in spasms and paroxysms whose character, duration and extent are

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all unlike anything observable in her action to-day, but by watching closely how she performs her work at the present time, and then tracing carefully the relationship of her present action to her action in all past time. It must not be supposed that Lyell had his theory perfect in all its full development when in 1830, at the age of thirty-three, he first published his "*Principles of Geology.*" It is true that he had the germ of his theory fairly in his mind at that time. But he brought out no less than eleven editions of his famous book, and in every edition he made modifications in the statement of his theory, called for by newly discovered facts and newly ascertained principles. For example, in the beginning of his uniformitarian career he believed with Hutton that the geologic history of the world was made up of mere changes. He saw no beginning. He anticipated no end. What nature did with one hand she undid with the other; and this was always so. The world might have existed indefinitely in the past, just as it might exist indefinitely in the future—with slow upheaval followed by slow submersion, and all the minor changes that these greater changes might effect following one another in due succession. A "cosmogony," or theory of the development of the universe from a state of homogeneous simplicity to a state of heterogeneous complexity, and back again, perhaps, to a state of homogeneous simplicity, he never dreamed of. Also, the influence, in effecting changes in the earth's crust, of causes other than purely geologic ones he was disposed to ignore—as, for example, the influence of a possible change in the inclination of the earth's axis to the plane of the ecliptic. But long before he came to the end of his career Lyell saw good reason to modify his attitude toward such matters. And just as

in his youth he had been able to advance the kingdom of knowledge by keeping a mind open to the inspiration of truth, so in his later days he conceived that it was still his duty to evince a like willingness to be led when truth should appear to guide. Lyell, more perhaps than any other great scientist of modern times, was a learner until the day of his death. And no greater or more instructive example of true modesty of soul and open-hearted loyalty to truth is to be found in the whole history of science than is presented by his conduct when in the seventh decade of his life he openly retracted views that he had held for a lifetime, and formally avowed others that he had for a lifetime opposed, as soon as he saw that these newer views had the support of impregnable fact.

Lyell's personal history from the time of his marriage forward till his death was but the continuation of his history before his marriage, except that perhaps he devoted himself more exclusively than ever to his chosen life's work, and freed himself more wholly than ever from all cares and duties that might encumber him in his pursuit of it. He resigned his position as professor in King's College, and it was with difficulty that he could be got to accept even positions of honor connected with the various learned societies he belonged to. He was, however, for many years a member of the council of the Royal Society, and for several years he was elected chairman of the Geologic Section of the British Association. But the main effort of his life was spent in field explorations, in reducing his observations to writing and presenting them as memoirs to scientific associations, and in preparing for the press the successive editions of his "*Principles of Geology*" and its more technical companion, "*The Ele-*

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ments of Geology." His life, however, was one of great activity. His travels were almost continuous. He seems, in his geologic enthusiasm, to have visited every part of Europe except Russia, Turkey and Greece, again and again. In his sixty-first year he descended the crater of Vesuvius and spent fourteen days examining the craters of Aetna. He made several long visits to the United States and Canada, during which he examined the coal-fields of Pennsylvania, Ohio, Virginia, Alabama, and Nova Scotia, and studied such great geologic object lessons as the Dismal Swamp of Virginia, the earthquake region of New Madrid on the Mississippi, and the gorge at Niagara, besides doing innumerable other pieces of geologic work. Travel was, indeed, in his view the first, the last, and the constant duty of the geologist. Even when in 1873 his wife died, she who for forty years had been his working companion in almost every journey he had ever made, he still continued his habit, and visited from time to time old geologic haunts in Germany and Scotland. In 1863 he had published his second epoch-making book, "*The Antiquity of Man,*" and he prepared successive new editions of it up to 1873. But an end comes to all things, even to energy and activity such as Lyell's. In 1848 he had been made a knight. In 1864 he had been made a baronet. Oxford long ago had granted him her D. C. L. In 1874 Cambridge granted him her LL. D. And innumerable other honors he received. Finally, February 22, 1875, full of years as well as honors, he passed away. But by the unanimous desire of men of science everywhere one further honor was bestowed upon him. He was buried in the nation's mausoleum, Westminster Abbey. And as

an appropriate description of his work and aims, these words were engraved upon his tomb:—

"Throughout a long and laborious life he sought the means of deciphering the framentary records of the earth's history in the patient investigation of the present order of nature."

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SIR CHARLES LYELL

SELECTED STUDIES AND REMINISCENCES

LYELL'S SCHOOL-BOY DAYS

In his amusing history of his school-boy days, which is given in the "*Life of Sir Charles Lyell,*" edited by his sister-in-law, Mrs. Lyell, Lyell shows that he went through all the fun and trouble, the games by day and the bolsterings by night, the keeping of pets and the petty warfares, of the English schoolboy. When eleven years of age, Lyell got into indifferent health at school after measles, and this necessitated his being less pressed at his lessons. He was fond of study, however, and this enforced idleness made him take to some of his father's amusements, among them that of entomology.

Young Lyell studied butterflies, and chased them in the fields and woodlands of the New Forest in Hampshire. He soon began to study the changes of form which insects undergo in their short lives, and to watch, hour after hour, the habits of the water-beetles and other aquatic insects. After spoiling a considerable number of hats in chasing butterflies, Lyell was supplied with a net, and a cabinet in which to place his stores of insect wealth. Oddly enough, some of the varieties of the butterflies

which young Lyell collected were of use in after years to Curtis, the entomologist. The boy had no companions in these "un-English" amusements, and was very grateful for the assistance of his father's head servant, who knew a few plants by sight, and helped his young master. "Instead of sympathy," wrote Lyell, "I received from almost every one beyond my home, either ridicule, or hints that the pursuits of other boys were more manly. Whether did I fancy that insects had no feeling? What could be the use of them? The contemptuous appellation of 'butterfly hunting' applied to my favorite employment, always nettled me." However, Lyell persisted, and when he got back to school he used to work at his favorite subject out of school hours.

Finding a number of expensive books in his father's library on entomology, with beautiful plates in them, the boy's common-sense told him that somebody prized all this knowledge, and that it must be valuable. Oddly enough, he took to reading Linnæus for descriptions of insects, and hunted up pictures of his captured butterflies in the plates of the more modern authors. Recovered in health, and fairly strong, Lyell, at thirteen years of age, was again sent to school. But the new school had all the demerits of the schools of the day, fighting, fagging, and bullying, being rampant. Lyell however came off well, although a weak and short-sighted boy.—PROFESSOR P. MARTIN DUNCAN, F. R. S., F. L. S., *in "Heroes of Science—Botanists, Zoologists, and Geologists.*

THE PUBLICATION OF THE "PRINCIPLES"

The publication [in May, 1833—when the author was in his thirty-sixth year] of the last volume of the "*Principles*

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DIRECCIÓN GENERAL DE BIBLIOTECAS

of Geology" formed an important epoch in Lyell's life. It brought to a successful close a work on which his energies had been definitely concentrated for nearly five years, and for which he had been preparing himself during a considerably longer time. It placed him, before his fourth decade was completed, at once, and beyond all question, in the front rank of British geologists; it carried his reputation to every country where that science was cultivated. It proved the writer to be not only a careful observer and a reasoner of exceptional inductive power, but also a man of general culture and a master of his mother tongue. The book, moreover, marked an epoch in geology not less important; it produced an influence on the science greater and more permanent than any work which had been previously written, or has since appeared.—PROFESSOR T. G. BONNEY, D.Sc., LL. D., F. R. S., *in "Charles Lyell and Modern Geology," in "The Century Science Series."*

THE DEATH OF LADY LYELL

In January, 1873, an unexpected and irreparable bereavement darkened the evening of Lyell's days. On April 24th Lady Lyell, the companion and helpmate of forty years, was taken from him after a few days' illness from an inflammatory cold. The shock was the more severe because the loss was so unforeseen. Lady Lyell was twelve years his junior, and had always enjoyed good health—"youthful and vigorous for her age," as he writes—so that he "never contemplated surviving her and could hardly believe it when the calamity happened." He bore the blow bravely, consoling himself by reflecting that the separation, at his age—nearly seventy-six—could not be

for very long, and, as he writes, endeavoring, "by daily work at my favorite science, to forget as far as possible the dreadful change which this has made in my existence."—PROFESSOR T. G. BONNEY, LL. D., F. R. S.

LADY LYELL AND HER HELPFULNESS TO HER HUSBAND

Lady Lyell was a woman of rare excellence. "Strength and sweetness were hers, both in no common degree. The daughter of Leonard Horner, and the niece of Francis Horner, her own excellent understanding had been carefully trained, and she had that general knowledge and those intellectual tastes which we expect to find in an educated Englishwoman; and from her childhood she had breathed the refining air of taste, knowledge, and goodness. Her marriage gave a scientific turn to her thoughts and studies, and she became to her husband, not merely the truest of friends and the most affectionate and sympathetic of companions, but a very efficient helper. She was frank, generous, and true; her moral instincts were high and pure; she was faithful and firm in friendship; she was fearless in the expression of opinion without being aggressive; and she had that force of character and quiet energy of temperament that gave her the power to do all that she had resolved to do. She had more than a common share of personal beauty; but had she not been beautiful, she would have been lovely, such was the charm of her manners, which were the natural expression of warmth and tenderness of heart, of quick sympathies, and of a tact as delicate as a blind man's touch."—PROFESSOR T. G. BONNEY. *The quotation is from an obituary notice by G. S. Hillard, in the Boston "Daily Advertiser."*

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LYELL'S PERSONALITY AND HABITS OF COMPOSITION

Lyell would have been a man of commanding presence, if his extremely short sight had not obliged him to stoop and peer into anything he wished to observe. This defect, in addition to the weakness of his eyes, was a serious impediment in field work. As Professor Ramsey remarked in 1851, after spending a few days with him in the south of England, he required people to point things out to him, and would have been unable to make a geological map, "but understood all when explained, and speculated thereon well." This defect of sight, according to Sir J. W. Dawson,* who had been his companion in more than one excursion in Canada, was at times even a source of danger. "The expression of his face was one of thoughtful power and gracious benignity. In his work, Lyell was very methodical, beginning and ending at fixed hours. Accustomed to make use of the help of others on account of his weak sight, he was singularly unconscious of outward bodily movement, though highly sensitive to pain. When dictating, he was often restless, moving from his chair to his sofa, pacing the room, or sometimes flinging himself full length on two chairs, tracing patterns on the floor, as some thoughtful or eloquent passage flowed from his lips. But though a rapid writer and dictator, he was sensitively conscientious in the correction of his manuscript, partly from a strong sense of the duty of accuracy, partly from a desire to save his publisher the expense of proof corrections. Hence passages once finished

* Late principal of the University of McGill College, Montreal.

were rarely altered, even after many years, unless new facts arose." *—PROFESSOR T. G. BONNEY, LL.D., F.R.S.

LYELL'S THIRST FOR KNOWLEDGE AND OPENNESS OF MIND

The characteristic with which any one who spent some time in Charles Lyell's company was most impressed, was his thirst for knowledge, combined with a singular openness, and perfect fairness of mind. He was absolutely free from all petty pride, and from "that common failing of men of science which causes them to cling with such tenacity to opinions once formed, even in the face of the strongest evidence." No man could have given a stronger proof of candor and plasticity of mind, and of his care for truth alone, than Lyell did in dealing with the question of the origin of the species. From the first he approached it without prejudice. So long as the facts adduced by Lamarck and others appeared to him insufficient to support their hypotheses, he gave the preference to some modification of the ordinarily accepted view—that a species began in a creative act—but after reading Darwin's classic work [*the "Origin of Species"*], and discussing the subject in private, not only with its author, but also with Sir Joseph Hooker and Professor Huxley, he was convinced that Darwin was right in his main contention, though he held back in regard to certain minor points, for which he thought the evidence as yet insufficient. Of his conduct in this matter, Darwin justly wrote: "Considering his age, his former views, and position in society, I think his action has been heroic." Dean

* The sentences in quotation marks were supplied by Miss Buckley, Lyell's secretary. [T. G. B.]

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Stanley, in the pulpit of Westminster Abbey, on the Sunday following the funeral, summed up in a few eloquent sentences the great moral lesson of Lyell's life. "From early youth to extreme old age it was to him a solemn religious duty to be incessantly learning, fearlessly correcting his own mistakes, always ready to receive and reproduce from others that which he had not in himself. Science and religion for him not only were not divorced, but were one and indivisible."—PROFESSOR T. G. BONNEY, LL. D., F. R. S.

LYELL'S RELIGIOUS VIEWS

Lyell's views on religious questions accorded, as might be expected, with the general bent of his mind. He was a member of the Church of England, appreciated its services, the charm of music, and the beauty of architecture, but he failed to understand why nonconformity should entail penalties, whether legal or social. His mind was essentially undogmatic; feeling that certainty was impossible in questions where the ordinary means of verification could not be employed, he abstained from speculation, and shrank from formulating his ideas, even when he was convinced of their general truth. He was content, however, to believe where he could not prove, and to trust, not faintly, the larger hope. So he worked on in calm confidence that the honest searcher after truth would never go far astray, and that the God of Nature and of Revelation was one. He sought in this life to follow the way of righteousness, justice, and goodness, and he died in the hope of immortality.—PROFESSOR T. G. BONNEY, LL. D., F. R. S.

LYELL'S CHIEF TITLE TO RENOWN

Sir Charles Lyell taught men to read the true history of the earth. It is difficult in the present day to understand rightly how great a work he accomplished, for though his ideas were ridiculed in the beginning, yet he lived long enough to see all men agree with him, and his doctrines received as self-evident truths. Like all other great men, he was humble and reverent in his study of nature. His one great desire was to arrive at truth, and by his conscientious and dispassionate writings he did much to persuade people to study geology calmly and wisely, instead of mixing it up with angry disputes, like those which, in the time of Galileo, disfigured astronomy. He traveled a great deal, especially in America, and worked out a great many facts in geology. But in future ages his name will stand out among those of other geologists chiefly as having shown that the *changes in the crust of our earth have been brought about in the course of long ages by causes like those which are still in action.*—ARABELLA B. BUCKLEY, *in "A Short History of Natural Science."*

READERS' AND STUDENTS' NOTES

1. The standard life of Lyell is the "*Life, Letters and Journals,*" edited by his sister-in-law, Mrs. (Colonel) Lyell. But for the ordinary reader the best and most readable life of Lyell is the work by Professor Bonney in "*The Century Science Series,*" entitled "*Charles Lyell and Modern Geology.*" (New York:

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The Macmillan Co. $1.25). Professor Bonney's book is an exceedingly appreciative and instructive work.

2. The student who wishes to know how Lyell's work fitted in with that of other great men in the development of modern science will do best to read Miss Arabella B. Buckley's "*Short History of Natural Science.*" (New York: D. Appleton & Co.) Miss Buckley was for a long time secretary to Sir Charles Lyell, and her work—the best of its kind ever written—is dedicated to the memory of Sir Charles and Lady Lyell.

3. Professor Duncan's "*Heroes of Science—Botanists, Zoologists, and Geologists,*" is practically a history of the development of the sciences of botany, zoology, and geology. The author is himself a distinguished geologist. The concluding chapter of the book is devoted to an account of the life and work of Lyell. In great part this chapter is made up of Lyell's own writings. (New York: E. & J. B. Young & Co.)

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XIII. LOUIS AGASSIZ

1807-1873

BIOGRAPHICAL STUDY

BY PHILIP R. UHLER
Provost of Peabody Institute, Johns Hopkins University.

The year 1848 was made memorable in the history of science in America by the coming of a naturalist to Harvard University who was to revolutionize the methods and direction of studies of natural science. A robust man, forty-one years of age, a chief among the devotees of zoology and geology in his native Switzerland, he came to this country in the full vigor of his life, equipped with the rich experience of comprehensive researches, endowed with a marvelous memory, gifted with never-flagging interest, and glowing with a personal magnetism which drew every one toward him in enduring friendship. Such a massive chest, crowned with head of corresponding magnitude, marking a brain of unusual grandeur, and withal the soft, warm heart abounding in expression of refined and tender nature, gave him at once the mental grasp of a giant with the gentleness of a child. He was naturally a moving force in scientific progress, both in thought and

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action. His time was devoted to the discovery of plans in nature, and he could never be satisfied so long as materials were wanting to fill out the extensive theories which were frequently arising in his mind. In the old world he spent the earlier years of his manhood in studying the fishes of Central Europe and those collected in Brazil by Spix and Martius. Such extensive resources for investigation might have disconcerted a less tenacious mind, but Agassiz brought order out of this mixed assemblage, and found time besides to fit together and classify the exceptionally large collection of fossil fishes gathered by the efforts of his friends. His beautifully illustrated work on these fossil creatures still remains a classic in this branch of inquiry. While professor at the Academy of Neufchatel, he was the leading spirit, incessantly active in building up a school of the natural sciences; and, in spite of slender pecuniary support and frequent drawbacks, he succeeded in establishing an institution which not only drew to it the most distinguished students of Switzerland, but also made it one of the scientific centers of the world.

It was here, in the year 1836, that his attention became directed to the wonderful phenomena displayed by the glaciers in the valleys of the Alps. He was not the first to make observations upon the movements of the glaciers, but by his acute perception and persistent study he was enabled to build up and establish the theory of a once extended thick mantle of ice which covered Europe from the north to a point as far south as the shores of the Mediterranean Sea. Such an astonishing theory met with immediate opposition from many of the most accomplished geologists; but further studies in company with distinguished scientists prepared the way for wider knowl-

edge of the subject, so that later his main propositions met with general acceptance.

In the midst of a most honorable career, after he had succeeeded in publishing several important illustrated books, and when he had brought the pictorial representation of fishes and other creatures to an unexampled degree of excellence, financial distress put a stop to his progress and caused him to look abroad for the means to continue scientific pursuits. To this crisis America owes the presence of the "Master Teacher" who sacrificed his former plans in order to advance learning in his adopted country. Coming to Boston to deliver a course of lectures under the patronage of Mr. Lowell, he became so acceptable to the authorities of Harvard University that he was invited to accept a professorship of zoology and geology in the newly founded Lawrence Scientific school. To make himself more readily accessible to the American people he lost no opportunity to become fluent in speaking the English language. In this he was so successful that in a short time he had acquired great readiness therein, and, although never entirely freed from a slight foreign accent, this peculiarity served only to give a pleasing picturesqueness to his expression. As a speaker his ready command of language was remarkable, his voice rich and clear, his eloquence stirring, and his logical directness forcible and conclusive. His popular lectures were delivered without the use of manuscript and were always fully illustrated by painted sketches or by chalk drawing on the blackboard. He drew forcibly and with facility while speaking to his audiences in a very audible tone.

Prior to the arrival of this gifted naturalist natural science in America was almost confined to the descriptive

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN ®
DIRECCIÓN GENERAL DE BIBLIOTECAS

stage, content with making known the superficial characteristics of the curious or remarkable animals so abundant in the new world. No far-seeing vision of the succession of life from the beginning to the consummation of later times had been revealed. But Agassiz had not been long in this country before students began to realize that hidden lines of structure held together large groups of creatures which apparently had close affinities. From this time forward Agassiz was gathering about him a group of young naturalists, who, stimulated by his ardent enthusiasm and spurred by his determined will, labored with indomitable energy to discover the underlying ties of relationship which bound animals in natural groups. Plan of structure was the appeal of his instruction, and his assistants were expected and encouraged to pursue and extend the methods of study which he had disclosed.

His method of teaching in the laboratory was intended to draw forth the capabilities of the student by causing him to observe details of structure with extreme care. A single specimen of some natural object was placed before the beginner and he was asked to examine it carefully in order to give soon after an account of his observations. By skillful questioning the professor next drew from his pupil such particulars as he had noticed; and then successively he was drawn on to see more and more of the deeper-seated elements, until at length he had recognized the plan of structure of the creature. A single valve of an oyster or clam, the shell of a crab or sea-urchin, or the body of a fish, told the story of a great group of the animal kingdom, and his student must be trained to perceive and recognize its plan. No book was allowed to be used for

reference in this work, and no other specimens were supplied for comparison. The training of the eye and awakening of the attention were fundamental, and the discipline, however protracted, was thorough and never to be forgotten. To discover and to equip a naturalist was a triumph in the estimation of Agassiz.

Wherever he went crowds flocked to the lecture hall and listened with enthusiastic interest to his eloquent presentation of the peculiarities of the types of the animal kingdom. His own unassuming lecture room in the Museum of Comparative Zoology at Cambridge was the meeting place of poets and authors, as well as the classroom of his assistants and students. There might be seen Longfellow, Holmes, Wyman, and other eminent scholars of the neighborhood, dwelling with rapt attention upon the vivid pictures of animal life which he was presenting. If the subject were the nautilus, a specimen of the creature would be held up to show its general form, then one after another in regular order the several points of structure would be displayed, drawings of allied objects made, and then a comparison of the known living species of this type developed. Every essential part of the creature was shown and finally traced back through all its modifications to its first appearance. It was his custom to carefully consider his subject, and to arrange it in mind before entering his lecture room. In doing so he paced forward and backward in some one of the large study rooms of the museum for about fifteen minutes, then going from one room to another inviting his assistants to attend the lecture.

Agassiz's devotion to his adopted country was intense. No sordid thought found a lodgment in his mind. Even when offered the lofty position of professor of palæon-

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN
DIRECCIÓN GENERAL DE BIBLIOTECAS

tology in the Museum of Natural History at Paris by the Emperor of France, he declined to accept it because he knew that the great work of his life was centered in America; that here he could be more widely useful and the results of his labors more enduring than any which might be accomplished within the limitations of imperial influence. But at this time (1857) Professor Agassiz still lacked adequate facilities for the preservation and display of the large collection of animal forms already brought together in his laboratories. Only a small building, constructed of inflammable material, liable to be destroyed at any moment, was at his service. Undaunted he pursued his way with undiminished activity, and by degrees men began to appreciate the grandeur and importance of his purposes and the value of his services as a popular educator. He needed money to place before the public his precious collections, but he was obliged to expend vital energy in securing it for immediate use, and so his mind was continually drawn away from most important life work of investigation to urge feebly appreciative men to realize the necessity for a substantial building and appliances to make these precious objects useful. A "magnificent beggar" he was called by some of his most appreciative friends, but never did he request a penny for himself; the money was wanted to educate and uplift the people.

Perhaps the grandest conception of his fertile genius was the plan of a universal museum of natural history, to be arranged comparatively and historically. It was to embrace a systematic series of the whole animal kingdom, both fossil and recent; then a collection of forms peculiar to each fauna of the earth's surface; and, finally, an assemblage of types of all the great groups of animal life,

for the ready reference of teachers. The establishment of this great plan began to be realized in 1860, when the first wing of a large brick building in Cambridge was made ready for occupation. Thus the first stage in the great purpose of his life was made possible, and Agassiz unaided could not arrange and display the vast number of animal forms which he had already brought together. By the aid of his assistants, even before the end of the first year, many of the rooms in the museum were stocked with instructive and typical representatives of the animal kingdom. Vast numbers of wooden trays and boxes held the corals and fossils, long ranges of glass jars, kegs, and bottles, contained the creatures in alcohol, and numerous wooden boxes were stored with insects and crustacea. Arrangement of the collections proceeded with vigor, and they were exhibited in the glass cases of the several rooms, in accordance with the instructions of Professor Agassiz. Ten years later money for an extension of this building was available, and again the overworked and almost exhausted Agassiz was occupied anew with the great problem of correctly exhibiting the vast collection of animal forms which he had continued to gather. With the passage of time his plans have been more fully carried out under the direction of his son and successor, Professor Alexander Agassiz, so that to-day the museum which was the object of his deepest and most solicitous thought stands as the best exponent of animated nature that has yet been produced for the instruction of humanity.

Tablets have been reared to his memory in some of the great universities of the country, and one of the granite boulders from his own native Switzerland covers his dust in Mount Auburn; but the most enduring tablets yet con-

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN ®
DIRECCIÓN GENERAL DE BIBLIOTECAS

secrated to his immortal being are graven on the hearts of those who assisted him, and who have helped to distribute to later times the fruits of his spirit which ripened in their labors.

LOUIS AGASSIZ

SELECTED STUDIES AND REMINISCENCES

AGASSIZ'S EARLY LOVE OF NATURE

Agassiz's love of natural history showed itself almost from infancy. When a very little fellow he had, beside his collection of fishes, all sorts of pets: birds, field-mice, hares, rabbits, guinea-pigs, etc., whose families he reared with the greatest care. Guided by his knowledge of the haunts and habits of fishes, he and his brother Auguste became the most adroit of young fishermen,—using processes all their own, and quite independent of hook, line, or net. Their hunting grounds were the holes and crevices beneath the stones, or in the water-washed walls of the lake shore. No such shelter was safe from their curious fingers, and they acquired such dexterity that when bathing they could seize the fish even in the open water, attracting them by their little arts, to which the fish submitted as to a kind of fascination. Such amusements are no doubt the delight of many a lad living in the country, nor would they be worth recording except as illustrating the unity of Agassiz's intellectual development from beginning to end. His pet animals suggested questions to answer which was the task of his life; and his in-

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN
DIRECCIÓN GENERAL DE BIBLIOTECAS

timate study of the fresh-water fishes of Europe, later the subject of one of his important works, began with his first collection from the Lake of Morat.

As a boy he amused himself also with all kinds of handicraft on a small scale. The carpenter, the cobbler, the tailor, were then as much developed in him as the naturalist. In Swiss villages, it was the habit in those days, for the tradespeople to go from house to house in their different vocations. The shoemaker came two or three times a year with all his materials, and made shoes for the whole family by the day; the tailor came to fit them for garments which he made in the house; the cooper arrived before the vintage, to repair old barrels and hogsheads, or to make new ones, and to replace their worn-out hoops—in short, to fit up the cellar for the coming season. Agassiz seems to have profited by these lessons as much as by those he learned from his father; and when a very little fellow, he could cut and put together a well fitting pair of shoes for his sisters' dolls, was no bad tailor, and could make a miniature barrel that was perfectly water-tight. He remembered these trivial facts as a valuable part of his incidental education. He said he owed much of his dexterity and manipulation, to the training of eye and hand gained in these childish plays.—ELIZABETH CARY AGASSIZ, *in "Louis Agassiz—His Life and Correspondence."*

AGASSIZ AS A STUDENT AT MUNICH

"I soon found myself engaged four or five hours almost daily in painting for him fresh water fishes from the life, while he was at my side, sometimes writing out his descriptions, sometimes directing me. . . . He never lost his temper, though often under great trial; he remained self-possessed and did everything calmly,

having a friendly smile for everyone, and a helping hand for those who were in need. He was at that time scarcely twenty years old, and was already the most prominent among the students at Munich. They loved him, and had a high consideration for him. I had seen him at the Swiss Students' club several times, and had observed him among the *jolly* students; he liked merry society, but he himself was in general reserved and never noisy. He picked out the gifted and highly learned students, and would not waste his time in ordinary conversation. Often, when he saw a number of students going off on some empty pleasure-trip, he said to me, 'There they go with the other fellows; their motto is, "Ich gehe mit den andern" ["I go with the crowd"]. I will go my own way, Mr. Dinkel,—and not alone: I will be a leader of others.' In all his doings there was an ease and calm which was remarkable. His studio was a perfect German student's room. It was large, with several wide windows; the furniture consisted of a couch and about half a dozen chairs, beside some tables for the use of his artists and himself. Dr. Alex. Braun [subsequently his brother-in-law] and Dr. Schimper lodged in the same house, and seemed to me to share his studio. Being botanists, they, too, brought home what they collected in their excursions, and all this found a place in the atelier, on the couch, on the seats, on the floors. Books filled the chairs, one alone being left for the other artist, while I occupied a standing desk with my drawing. No visitor could sit down, and sometimes there was little room to stand or move about. The walls were white, and diagrams were drawn on them, to which, by and by, we artists added skeletons and caricatures. In short, it was quite original. I was some time there before I could discover the real names of his friends; each had a nickname,—Molluscus, Cyprinus, Rhubarb, etc."

From this glimpse into "The Little Academy" we return to the thread of the home letters, learning from the next one that Agassiz's private collections were assuming rather formidable proportions when considered as part of the household furniture. Brought together in various ways, partly by himself, partly in exchange for duplicates,

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN ®
DIRECCIÓN GENERAL DE BIBLIOTECAS

partly as pay for arranging specimens in the Munich Museum, they had already acquired, when compared with his small means, a considerable pecuniary value, and a far higher scientific importance. They included fishes, some rare mammalia, reptiles, shells, birds, an herbarium of some three thousand species of plants collected by himself, and a small cabinet of minerals.—ELIZABETH CARY AGASSIZ, *in "Louis Agassiz—His Life and Correspondence." The quotation is from an account of Agassiz's student days supplied to Mrs. Agassiz by Mr. Joseph Dinkel, an artist, who for many years, beginning when he was quite a young man, Agassiz had in his employ.*

AGASSIZ'S "LITTLE ACADEMY" AT MUNICH

"Among my fellow-students [at Munich] were many young men who now rank among the highest lights in the various departments of science, and others, of equal promise, whose early death cut short their work in this world. Some of us had already learned at this time to work for ourselves; not merely to attend lectures and study from books. The best spirit of emulation existed among us; we met often to discuss our observations, undertook frequent excursions in the neighborhood, delivered lectures to our fellow-students, and had, not infrequently, the gratification of seeing our university professors among the listeners. These exercises were of the highest value to me as a preparation for speaking, in later years, before larger audiences. My study was usually the lecture-room. It would hold conveniently from fifteen to twenty persons, and both students and professors used to call our quarters 'The Little Academy.' In that room I made all the skeletons represented on the plates of Wagler's '*Natural System of Reptiles;*' there I once received the great anatomist, Meckel, sent to me by Döllinger, to examine my anatomical preparations and especially the many fish-skeletons I

had made from fresh-water fishes. By my side were constantly at work two artists; one engaged in drawing various objects of natural history, the other in drawing fossil fishes. I kept always one and sometimes two artists in my pay; it was not easy, with an allowance of $250 a year, but they were even poorer than I, and so we managed to get along together. My microscope I had earned by writing."—*From Agassiz's "Autobiography," quoted by Mrs. Agassiz in the "Life and Correspondence."*

AGASSIZ AT TWENTY-ONE YEARS OF AGE

"I cannot review my Munich life without deep gratitude. The city teemed with resources for the student in arts, letters, philosophy, and science. It was distinguished at that time for activity in public as well as in academic life. The king seemed liberal; he was the friend of poets and artists, and aimed at concentrating all the glories of Germany in his new university. I thus enjoyed for a few years the example of the most brilliant intellects, and that stimulus which is given by competition between men equally eminent in different spheres of human knowledge. Under such circumstances a man either subsides into the position of a follower in the ranks that gather around a master, or he aspires to be a master himself.

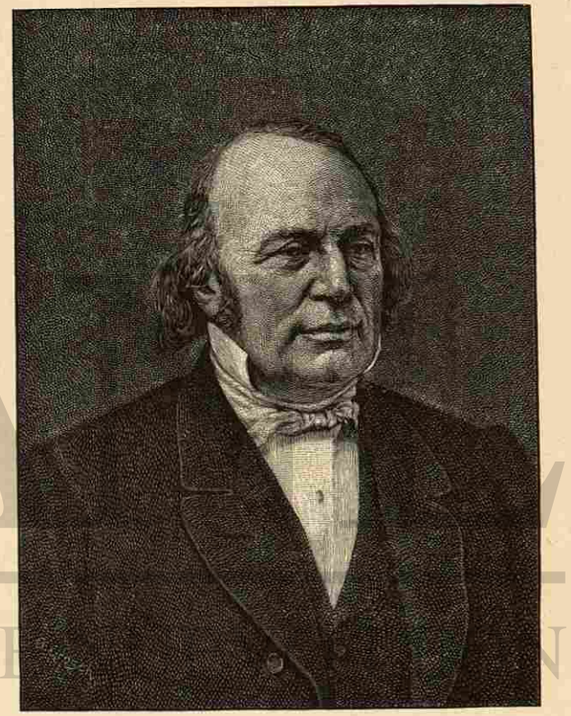
"The time had come when even the small allowance I received from borrowed capital must cease. I was now twenty-four years of age. I was Doctor of Philosophy and Medicine, and author of a quarto volume on the fishes of Brazil. I had traveled on foot all over southern Germany, visited Vienna, and explored extensive tracts of the Alps. I knew every animal, living and fossil, in the museums of Munich, Stuttgart, Tübingen, Erlangen, Wurzburg, Carlsruhe, and Frankfort; but my prospects were as dark as ever, and I saw no hope of making my way in the world, except by the practical pursuit of my profession as physician. So, at the close of 1830, I left the university and went home, with the intention of applying myself to the practice of medicine."—*From Agassiz's "Autobiography," quoted by Mrs. Agassiz in the "Life and Correspondence."*

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN
DIRECCIÓN GENERAL DE BIBLIOTECAS

AGASSIZ AS A TEACHER

In Neuchâtel [where at twenty-five years of age Agassiz had been appointed professor of natural history in the Lyceum] the presence of the young professor was felt at once as a new and stimulating influence. The little town suddenly became a center of scientific activity. A society for the pursuit of the natural sciences, of which he was the first secretary, sprang into life. The scientific collections, which had already attained, under the care of M. Louis Coulon, considerable value, presently assumed the character and proportions of a well-ordered museum. In M. Coulon, Agassiz found a generous friend and a scientific colleague, who sympathized with his noblest aspirations, and was ever ready to sustain all his efforts on behalf of scientific progress. Together they worked in arranging, enlarging, and building up a museum of natural history which soon became known as one of the best local institutions of that kind in Europe.

Beside his classes at the gymnasium, Agassiz collected about him, by invitation, a small audience of friends and neighbors, to whom he lectured during the winter on botany, on zoölogy, on the philosophy of nature. The instruction was of the most familiar and informal character, and was continued in later years for his own children and the children of his friends. In the latter case the subjects were chiefly geology and geography in connection with botany, and in favorable weather the lessons were usually given in the open air. One can easily imagine what joy it must have been for a party of little playmates, boys and girls, to be taken out for long walks in the country over the hills



LOUIS AGASSIZ.

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN ®
DIRECCIÓN GENERAL DE BIBLIOTECAS

about Neuchâtel, and especially to Chaumont, the mountain which rises behind it, and thus to have their lessons, for which the facts and scenes about them furnished subject and illustration, combined with pleasant rambles. From some high ground affording a wide panoramic view, Agassiz would explain to them the formation of lakes, islands, rivers, springs, water-sheds, hills, and valleys. He always insisted that physical geography could be better taught to children in the vicinity of their own homes, than by books or maps, or even globes. Nor did he think a varied landscape essential to such instruction. Undulations of the ground, some contrast of hill and plain, some sheet of water with the streams that feed it, some ridge of rocky soil acting as a water-shed, may be found everywhere, and the relation of facts shown perhaps as well on a small as on a large scale.

When it was impossible to give the lessons out of doors, the children were gathered around a large table, where each one had before him or her the specimens of the day, sometimes stones and fossils, sometimes flowers, fruits, or dried plants. To each child in succession was explained separately what had first been told to all collectively. When the talk was of tropical or distant countries, pains were taken to procure characteristic specimens, and the children were introduced to dates, bananas, cocoanuts, and other fruits, not easily to be obtained in those days in a small inland town. They, of course, concluded the lesson by eating the specimens, a practical illustration which they greatly enjoyed. A very large wooden globe, on the surface of which the various features of the earth as they came up for discussion could be shown, served to make them more clear and vivid. The children took their own

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN
DIRECCIÓN GENERAL DE BIBLIOTECAS

share in the instruction, and were themselves made to point out and describe that which had just been explained to them. They took home their collections, and as a preparation for the next lesson were often called upon to classify and describe some unusual specimen by their own unaided efforts. There was no tedium in the class. Agassiz's lively, clear, and attractive method of teaching awakened their own powers of observation in his little pupils, and to some at least opened permanent sources of enjoyment.

His instructions to his older pupils were based on the same methods, and were no less acceptable to them than to the children. In winter his professional courses to the students were chiefly upon zoölogy and kindred topics; in the summer he taught them botany and geology, availing himself of the fine days for excursions and practical instruction in the field. Professor Louis Favre, speaking of these excursions, which led them sometimes into the gorges of the Seyon, sometimes into the forests of Chaumont, says: "They were fête days for the young people, who found in their professor an active companion, full of spirits, vigor, and gayety, whose enthusiasm kindled in them the sacred fire of science."—ELIZABETH CARY AGASSIZ.

AGASSIZ'S COMING TO AMERICA

Agassiz arrived in Boston during the first week of October, 1846. He had not come to America without some prospect of employment beside that comprised in his immediate scientific aims. In 1845, when his plans for a journey in the United States began to take definite shape, he

had written to ask Lyell* whether, notwithstanding his imperfect English, he might not have some chance as a public lecturer, hoping to make in that way additional provision for his scientific expenses beyond the allowance he was to receive from the king of Prussia. Lyell's answer, written by his wife, was very encouraging.

LONDON, *February* 28, 1845

. . . . . My husband thinks your plan of lecturing a very good one, and sure to succeed, for the Americans are fond of that kind of instruction. We remember your English was pleasant, and if you have been practising since, you have probably gained facility in expression, and a little foreign accent would be no drawback. You might give your lectures in several cities, but he would like very much if you could give a course at the Lowell Institute at Boston, an establishment which pays very highly . . . . . In six weeks you might earn enough to pay for a twelve months' tour, besides passing an agreeable time at Boston, where there are several eminent naturalists. . . . . As my husband is writing to Mr. Lowell to-morrow upon other matters, he will ask him whether there is any course still open, for he feels sure in that case they would be glad to have you. . . . . Mr. Lowell is sole trustee of the Institute and can nominate whom he pleases. It was very richly endowed for the purpose of lectures, by a merchant of Boston, who died a few years ago. You will get nothing like the same remuneration anywhere else. . .

Lyell and Mr. Lowell soon arranged all preliminaries, and it was understood that Agassiz should begin his tour in the United States by a course of lectures in Boston before the Lowell Institute.—ELIZABETH CARY AGASSIZ.

AGASSIZ AS A LECTURER

Never was Agassiz's power as a teacher, or the charm of his personal presence more evident, than in his first course

* Sir Charles Lyell, the geologist.

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN
DIRECCIÓN GENERAL DE BIBLIOTECAS

of Lowell Lectures. He was unfamiliar with the language, to the easy use of which his two or three visits in England, where most of his associates understood and spoke French, had by no means accustomed him. He would often have been painfully embarrassed but for his own simplicity of character. Thinking only of his subject and never of himself, when a critical pause came, he patiently waited for the missing word, and rarely failed to find a phrase which was expressive if not technically correct. He often said afterward, that his sole preparation for these lectures, consisted in shutting himself up for hours and marshaling his vocabulary, passing in review, that is, all the English words he could recall. As the Lyells had prophesied, his foreign accent rather added a charm to his address, and the pauses in which he seemed to ask the forbearance of the audience, while he sought to translate his thought for them, enlisted their sympathy. Their courtesy never failed him. His skill in drawing with chalk on the blackboard was also a great help both to him and to them. When his English was at fault, he could nevertheless explain his meaning by illustrations so graphic that the spoken word was hardly missed. He said of himself that he was no artist, and that his drawing was accurate simply because the object existed in his mind so clearly. However this may be, it was always pleasant to watch the effect of his drawings on the audience. When showing, for instance, the correspondence of the articulate type, as a whole, with the metamorphoses of the higher insects, he would lead his listeners along the successive phases of insect development, talking as he drew, and drawing as he talked, till suddenly the winged creature stood declared upon the blackboard, almost as if it had burst then and there from the chrysalis, and the

growing interest of his hearers culminated in a burst of delighted applause.

After the first lecture in Boston there was no doubt of his success. He carried his audience captive. He had the rare gift of divesting his subject of technicalities and superfluous details. His special facts never obscured the comprehensive outline, which they were intended to fill in and illustrate.—ELIZABETH CARY AGASSIZ.

AGASSIZ'S SOCIABLE DISPOSITION

In 1854 Agassiz moved to a larger house [in Cambridge] built for him by the college. [In 1848, Agassiz had been appointed Professor of Natural History in the Lawrence Scientific School, Cambridge.] Though very simple, it was on a liberal scale with respect to space; partly in order to accommodate his library, consisting of several thousand volumes, now for the first time collected and arranged in one room. He became very fond of this Cambridge home, where, with few absences, he spent the remainder of his life. The architect, Mr. Henry Greenough, was his personal friend, and from the beginning the house adapted itself with a kindly readiness to whatever plans developed under its roof. As will be seen, these were not few, and were sometimes of considerable moment. For his work, also, the house was extremely convenient. His habits, in this respect, were, however, singularly independent of place and circumstance. Unlike most studious men, he had no fixed spot in the house for writing. Although the library, with the usual outfit of well-filled shelves, maps, large tables, etc., held his materials, he brought what he needed for the evening by preference to the drawing-

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN
DIRECCIÓN GENERAL DE BIBLIOTECAS

room, and there, with his paper on his knee, and his books for reference on a chair beside him, he wrote and read as busily as if he were quite alone. Sometimes, when dancing and music were going on among the young people of the family and their guests, he drew a little table into the corner of the room, and continued his occupations as undisturbed and engrossed as if he had been in complete solitude,—only looking up from time to time with a pleased smile or apt remark, which showed that he did not lose but rather enjoyed, what was going on about him.

His children's friends were his friends. As his daughters grew up, he had the habit of inviting their more intimate companions to his library for an afternoon weekly. On these occasions there was always some subject connected with the study of nature under discussion; but the talk was so easy and so fully illustrated, that it did not seem like a lesson. It is pleasant to remember that in later years, Mr. Ralph Waldo Emerson revived this custom for his own daughters; and their friends (being, indeed, with few changes, the same set of young people as had formerly met in Agassiz's library), used to meet in Mr. Emerson's study at Concord for a similar object. He talked to them of poetry and literature and philosophy as Agassiz had talked to them of nature. Those were golden days, not to be forgotten by any who shared their happy privilege.—ELIZABETH CARY AGASSIZ.

AGASSIZ'S FIFTIETH BIRTHDAY

Agassiz had promised himself that the first volume of his new work [*"Contributions to the Natural History of the United States"*] should be finished in time for his fiftieth birthday—à milestone upon the road, as it were, to mark his half-century. Upon this self-appointed task he spent himself with the passion, dominated by patience, which characterized him when his whole heart was bent towards an end. For weeks he wrote many hours of the day and a great part of the night, going out sometimes into the darkness and the open air to cool the fever of work, and then returning to his desk again. He felt himself that the excitement was too great, and in proportion to the strain was the relief when he set the seal of *finis* on his last page within the appointed time.

His special students, young men who fully shared his scientific life, and rewarded his generosity by an affectionate devotion, knowing, perhaps, that he himself associated the completion of his book with his birthday, celebrated both events by a serenade on the eve of his anniversary. They took into their confidence Mr. Otto Dresel, warmly valued by Agassiz both as friend and musician, and he arranged their midnight programme for them. Always sure of finding their professor awake and at work at that hour, they stationed the musicians before the house, and as the last stroke of twelve sounded, the succeeding stillness was broken by men's voices singing a Bach choral. When Agassiz stepped out to see whence came this pleasant salutation, he was met by his young friends bringing flowers and congratulations. Then followed one number after another of the well-ordered selection, into which was admitted here and there a German student-song in memory of Agassiz's own university life at Heidelberg and Munich. It was late, or rather early, since the new day was already begun, before the little concert was over and the

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN
DIRECCIÓN GENERAL DE BIBLIOTECAS

guests had dispersed. It is difficult to reproduce with anything like its original glow and coloring a scene of this kind. It will no more be called back than the hour, or the moonlight night, which had the warmth and softness of June. It is recorded here only because it illustrates the intimate personal sympathy between Agassiz and his students.

For this occasion also were written the well-known birthday verses by Longfellow, which were read the next day at a dinner given to Agassiz by the "Saturday Club." In speaking of Longfellow's relation to this club, Holmes says: "On one occasion he read a short poem at the table. It was in honor of Agassiz's birthday, and I cannot forget the very modest, delicate, musical way in which he read his charming verses." Although included in many collections of Longfellow's poems, they are reproduced here, because the story seems incomplete without them:

THE FIFTIETH BIRTHDAY OF AGASSIZ

MAY 28, 1857

It was fifty years ago,
  In the pleasant month of May,
In the beautiful Pays de Vaud,
  A child in its cradle lay.

And Nature, the old nurse, took
  The child upon her knee,
Saying: "Here is a story book
  Thy father has written for thee."

"Come, wander with me," she said,
  "Into regions yet untrod;
And read what is still unread
  In the manuscripts of God."

And he wandered away and away
  With Nature, the dear old nurse,
Who sang to him night and day,
  The rhymes of the universe.

And whenever the way seemed long,
  Or his heart began to fail,
She would sing a more wonderful song,
  Or tell a more marvellous tale.

So she keeps him still a child,
  And will not let him go,
Though at times his heart beats wild
  For the beautiful Pays de Vaud.

Though at times he hears in his dreams
  The Ranz des Vaches of old,
And the rush of mountain streams
  From the glaciers clear and cold;

And the mother at home says, "Hark!
  For his voice I listening yearn;
It is growing late and dark,
  And my boy does not return!"

—ELIZABETH CARY AGASSIZ.

AGASSIZ'S INCULCATION OF THE IMPORTANCE OF "LOOKING"

The story of the next three years [1860-63] was one of unceasing but seemingly uneventful work. The daylight hours from nine or ten o'clock in the morning were spent, with the exception of the hour devoted to the school, at the Museum, not only in personal researches and in lecturing, but in organizing, distributing, and superintending the work of the laboratories, all of which was directed by him. Passing from bench to bench, from table to table,

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with a suggestion here, a kindly but scrutinizing glance there, he made his sympathetic presence felt by the whole establishment. No man ever exercised a more genial personal influence over his students and assistants. His initiatory steps in teaching special students of natural history were not a little discouraging. Observation and comparison being in his opinion the intellectual tools most indispensable to the naturalist, his first lesson was one in *looking*. He gave no assistance; he simply left his student with the specimen, telling him to use his eyes diligently, and report upon what he saw. He returned from time to time to inquire after the beginner's progress, but he never asked him a leading question, never pointed out a single feature of the structure, never prompted an inference or a conclusion. This process lasted sometimes for days, the professor requiring the pupil not only to distinguish the various parts of the animal, but to detect also the relation of these details to more general typical features. His students still retain amusing reminiscences of their despair when thus confronted with their single specimen; no aid to be had from outside until they had wrung from it the secret of its structure. But all of them have recognized the fact that this one lesson in looking, which forced them to such careful scrutiny of the object before them, influenced all their subsequent habits of observation, whatever field they might choose for their special subject of study. One of them, who was intending to be an entomologist, concludes a very clever and entertaining account of such a first lesson, entirely devoted to a single *fish*, with these words: "This was the best entomological lesson I ever had—a lesson whose influence has extended to the details of every subsequent study; a legacy the professor has left

to me, as he left it to many others, of inestimable value, which we could not buy, with which we could not part."

But if Agassiz, in order to develop independence and accuracy of observation, threw his students on their own resources at first, there was never a more generous teacher in the end than he. All his intellectual capital was thrown open to his pupils. His original material, his unpublished investigations, his most precious specimens, his drawings and illustrations were at their command. This liberality led in itself to a serviceable training, for he taught them to use with respect the valuable, often unique, objects entrusted to their care. Out of the intellectual good-fellowship which he established and encouraged in the laboratory, grew the warmest relations between his students and himself. Many of them were deeply attached to him, and he was extremely dependent upon their sympathy and affection. By some among them he will never be forgotten. He is still their teacher and their friend, scarcely more absent from their work now than when the glow of enthusiasm made itself felt in his personal presence.—ELIZABETH CARY AGASSIZ.

AGASSIZ AND CUVIER

Agassiz was not a good practical geologist like Cuvier. His active spirit did not allow him to follow patiently the always long, tedious, and often too-fatiguing researches of practical geology. He wanted the results which he could promptly obtain in the drawers, on the shelves, and in the glass cases, of large collections. There Agassiz had not his equal, being even quicker than Cuvier.

Cuvier was very grave, while Agassiz, on the contrary, was always laughing, or, at least, smiling. Cuvier had a

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special aptitude for all kinds of knowledge, and possessed talents to fill any official position, such as professor, general inspector of public instruction, state councillor, great chancellor of the University, or secretary of public instruction, peer of France, perpetual secretary of the Academy of Science, etc., etc., while Agassiz limited himself all his life entirely and exclusively to natural history. Both possessed an extraordinary memory, and both were remarkably gifted with the faculty of order; both were capable of long labor, and at the same time both worked with great facility. With them work was always easy. They did it without effort; it was natural to them. But neither was inventive; both saw facts and observed them sharply, but neither thought to link them by theories calculated to conduct to the discovery of other facts. They were "*terre à terre*" naturalists, while Lamarck, Geoffroy Saint-Hilaire, Darwin, Huxley, looked forward to the future, prophesying, and always ready to call to their help suppositions and probabilities.

Physically, Cuvier and Agassiz resembled each other in possessing enormous heads and largely developed brains, while neither Lamarck nor Darwin were abnormal as regards size and development of the head. In a crowd Cuvier and Agassiz always attracted attention, and were distinguished at once as uncommonly fine-looking men, while Lamarck, Darwin, and Huxley passed unnoticed.

Agassiz did not possess the original ideas, or the great sagacity, or the depth of view of Cuvier. He did not open new roads to natural history, but he enlarged greatly all those which were pointed out by others. If Cuvier had an enormous influence on the future of science and on the savants themselves, Agassiz had more influence on the

masses; he made science more popular, gave a strong impulse to the development of questions very little known before him, and created a more elementary method of teaching. Agassiz delighted in making pupils, and was always on the lookout for applause from all his hearers, whoever they might be, savants or populace. Cuvier, on the contrary, never took the trouble to make pupils, although he left several after him, among them Agassiz and Richard Owen; he never courted applause nor popularity. Cuvier took care to screen himself, and preferred the solitude of his laboratory and library, while for Agassiz solitude was insupportable; he wanted to be surrounded at all times by pupils or admirers. He courted bustle. This is a very unusual characteristic among savants, who are generally more or less retiring, and conduct their researches in the solitude of a laboratory, far from all distractions. As soon as Agassiz had found something new, he proclaimed it even before he had obtained all the proofs. He was always anxious to make an impression on his surroundings and his contemporaries. He was a leader of men, and above all a charmer. Cuvier, on the contrary, was difficult to reach, always on his guard, and very reserved. He did not care about publicity, but he was extremely desirous to make discoveries and keep them secret, until he had deduced all the consequences, and proved them beyond question.

If Cuvier showed great superiority and inventive genius in his classification of the animal kingdom, in his comparative anatomy, his restoration of fossil vertebrates, his description of the geology of the Paris basin, and his celebrated lectures at the Jardin des Plantes and at the Collège de France, Agassiz rose very high in his study of "Fossil

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Fishes," the living fishes, the echinoderms, the embryology of the turtle, in the description of the glacial epoch, and in his popularization of natural history in North and South America, and finally in his creation of a great museum at Cambridge and of a great marine biological laboratory at Penikese. Both were creators, each in his own way. From 1795 to 1873 these two savants "of mighty wings" gave to natural history the most important impulse which it has ever received, divulging facts more numerous and more clearly founded on exact principles than any other naturalists who preceded them. If Cuvier was superior to Agassiz as a classifier and a creator of several parts of natural history, Agassiz was above Cuvier as a lover of nature, and a popularizer of science. No naturalist has admired every object of natural history with the enthusiasm of Agassiz. He stood in ecstacy before a zoölogical specimen; whether it was living or fossil was of no importance to him. I doubt if any one has ever handled a specimen with such reverence and veneration as Agassiz did. Cuvier will always occupy a very exalted position in natural history. He is above the rank and file; while Agassiz is only in the first rank of Cuvier's pupils. Agassiz is a brilliant satellite who has moved in the orbit traced by Cuvier; but what an orbit! and what a brilliant light!—JULES MARCOU, *in "Life, Letters, and Works of Louis Agassiz."*

READERS' AND STUDENTS' NOTES

1. The life of Agassiz by his widow, Elizabeth Cary Agassiz, entitled "*Louis Agassiz, His Life and Correspondence,*" with

portraits and illustrations, is the "life" most people will care to read first. It is partly autobiographical, and is especially full in regard to Agassiz's early years. (Boston: Houghton, Mifflin & Co. 2 vols., $2.50.)

2. "*Louis Agassiz, His Life and Work,*" by Charles Frederick Holder, is a popular life of Agassiz, written, like the author's "*Life of Darwin,*" as much for young people, as for their elders—"in the hope that they may be tempted to emulate the lesson the life of the great naturalist presents." Like the corresponding Darwin book this work is freely and beautifully illustrated. (New York: G. P. Putnam's Sons, $1.50.)

3. "*The Life, Letters, and Works of Louis Agassiz*" in two volumes, by his friend, Jules Marcou (New York: The Macmillan Co., $4.00) may be described as the "standard" biography of Agassiz. It is an attempt to portray the life, character, and work of the great naturalist, "in a true light, in correct perspective," to put him "in his true place in the field of the history of natural science." Though in many respects an interesting work it is perhaps better suited to the needs of the professed student than to the general reader. It is furnished with a very full and carefully prepared Agassiz bibliography.

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Charles Darwin

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XIV. CHARLES DARWIN

1809-1882

BIOGRAPHICAL STUDY

BY DAVID STARR JORDAN, LL. D.
President of Leland Stanford University

In the "*Life and Letters of Charles Darwin,*" published by his son, is given a brief sketch of Darwin's life, written by himself for the use of his children. It is written, as he says, "as if I were a dead man in another world looking back on my life." The main outlines of Darwin's life have been given many times, but nowhere so charmingly and so vividly as in his own biography. From this sketch I make some quotations in the following notice:

Charles Robert Darwin was born in Shrewsbury, England, on February 12, 1809. His father, Robert Waring Darwin, was an eminent physician. His mother, who died in Darwin's youth, was Susannah Wedgwood. The most noted of Darwin's ancestors was his grandfather, Dr. Erasmus Darwin, known in the last century as poet and philosopher, and as the author of ingenious speculations some of which resemble the views of his distinguished grandson.

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Darwin's early school days were marked mainly by a love for collecting and finding the names of things—shells, beetles, postage stamps, minerals—and by his passion for hunting, angling, and other field sports.

He was sent first to a boys' school in Shrewsbury, and afterward to the universities of Edinburgh and Cambridge. In his own estimation none of these schools was of much use to him. Of the boys' school he says: "Nothing could have been worse for the development of my mind than Dr. Butler's school, as it was strictly classical, nothing else being taught except a little ancient geography and history. The school as a means of education to me was simply a blank."

He used to work at chemistry in a little laboratory fitted up by his brother in the garden at home, and this unprecedented taste caused his school-fellows to give him the nickname of "Gas."

"I was once," says he, "publicly rebuked by Dr. Butler for thus wasting my time on such useless subjects."

Later, in the University of Edinburgh, he found the instruction even in natural history "incredibly dull." The sole effect produced upon him by the lectures in geology was "the determination never, so long as I lived, to read a book on geology or in any way to study the science."

After two years in Edinburgh he changed his early determination to become a physician and prepared himself for the career of a country clergyman.

Of this three years at Cambridge Darwin says: "My time was wasted, so far as the academical studies were concerned, as completely as at Edinburgh or at school. . . . The careful study of these works (Paley's '*Evidences of Christianity*,' '*Moral Philosophy*' and '*Natural Theology*') . . . was the only part of my academical course which, as I then felt and still believe, was of the least use to me in the education of my mind."

The real value of his stay at Cambridge came from his association with scholars; above all, from his acquaintance with the famous botanist and still more famous teacher, Professor Henslow. Here, too, he met the geologist Adam Sedgwick, whose accuracy of observation and devotion to truth had a marked influence in Darwin's early training.

In 1831, while still engaged in preparation for the ministry, Darwin received from Captain Fitzroy the appointment as naturalist on board the ship *Beagle*. This vessel was to spend some five years in a cruise around the world, mainly for the purpose of exploration and examination of harbors. The story of this famous voyage Mr. Darwin has told in a most charming way, and its value to science has been beyond calculation. Darwin's experiences and discoveries on the coast of South America decided him to give his life to science. His questionings in regard to the relations of the present and past inhabitants of that continent started him on that line of investigation which has made "Darwinism" almost a synonym for modern biological science.

The *Beagle* returned in 1836. Within the next five or six years the results of the voyage were published. The "*Journal of Travels*," "*Coral Reefs*," "*Geological Observations on South America*," with numerous minor papers, at once placed Darwin in the front rank of English men of science.

Darwin was married in 1839 to his cousin, Julia Wedgwood. Their married life was a most happy one, and her

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unwearying devotion was one of the great elements of his success. In 1846 Darwin purchased a large mansion, beautifully situated in the outskirt of the little village of Down, in Kent, and here, in the seclusion which his physical sufferings rendered necessary, the rest of his life was spent. His son, Francis Darwin, tells us: "For nearly forty years he never knew one day of the health of ordinary men, and thus his life was one long struggle against the weariness and pain of sickness; and this cannot be told without speaking of the one condition (the devotion of his wife) which enabled him to bear the strain and fight out the struggle to the end."

While in Chile Darwin had become interested in certain forms of cirripedes or barnacles, and in 1846 he began a monographic account of the group. It is one of the most perfect pieces of work ever accomplished. In one of his letters Darwin doubts whether this work, which occupied him during eight years, was really worth the time and strength spent on it. It is, however, the testimony of his fellow-naturalists that these years were well spent. The training thus secured in the exact statement and the systematic arrangement of facts was of the greatest help to him in his later studies.

The problem of the origin of species now began to occupy almost exclusively the time and attention of Mr. Darwin. Year after year was spent in the patient gathering of facts, and in drawing from these facts their natural conclusions. The strength of his work lay in the fact that he rejected all unverified speculation. He was the faithful mirror of nature, and in all the years since then no important statement of fact admitted by Darwin has been cast aside as spurious. As the years went on the amount of

his material became enormous. The greater the accumulation of facts the more distinctly they seemed to point to the truth of the theory of descent as forming the bond of union among species. The amount of Darwin's manuscript soon exceeded the bounds of a single book; so in 1856 he was compelled to begin the laborious task of selecting, rewriting and condensing. Before his manuscript, as abridged, was ready for the printer another naturalist, engaged in another field, had independently come to the same conclusions. A friend of Darwin—Alfred Russell Wallace—then engaged in explorations in the East Indies, had prepared a paper on "The Tendency of Varieties to Depart Indefinitely from the Original Type." This paper he sent in 1858 to Mr. Darwin for examination and for publication in such way, as Mr. Darwin might think advisable. This essay contained exactly the same theory of the formation of species by "natural selection" that Mr. Darwin had spent so many years in elaborating.

It was thought best by the friends of Darwin and Wallace to have the publication of the theory of "natural selection" by the two authors simultaneous. A brief extract of Darwin's studies was therefore published in 1858, side by side with the paper of Mr. Wallace. The generosity with which Mr. Wallace has set aside his own claims in favor of those of his greater friend and noble rival is one of the most charming incidents in the history of zoölogy.

In 1859 Darwin had finished the condensation of his manuscript and it was given to the public under the name of "*The Origin of Species.*"

Let me speak of certain traits of this work which gave it a position almost alone among books of science. There is in it no statement of fact of any importance which dur-

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ing the twenty-five years since it was first published has been shown to be false. In its theoretical part there is no argument which has been shown to be unfair or fallacious. In these twenty-five years no serious objection has been raised to any important conclusion of his which was not at the time fully anticipated and frankly met by him. Indeed, there are but few of these objections which with our present knowledge are not much less weighty than Darwin then admitted.

There is in this work nowhere a suggestion of special pleading or of overstatement. The writer is a judge and not an advocate, and from his decisions there has been no successful appeal. There is in this or any other of Darwin's works scarcely a line of controversial writing. He has been the faithful mirror of nature. The relations of nature to metaphysics he has left to others. The tornadoes which have blown about the "*Origin of Species*" have left him undisturbed. The word "evolution" is not his word. He felt, perhaps, that most systems of philosophy are like air-plants, which thrive equally well in any soil. With just facts enough for their roots to cling to they may grow and bloom perennially without other food than the air. From the standpoint of the naturalist the greatest work of Darwin has been the total change in our conception of species. It was declared by Linnaeus, and repeated by his successors, that "there are as many different species now as there were different forms created in the beginning by the Infinite Being." In accordance with this statement we have been taught to look upon a species in biology as a fixed entity, a perennial succession of individuals, similar to one another, from the creation at one end of the series to the extinction at the other. We have been told

over and over again that the variations of a species are kept within fixed limits by definite laws, and that one species can never encroach on the traits of another species, nor ever permanently assume any characters other than those with which it was created. Darwin maintained that the form under which any species is known to us is simply a phase in the history of the succession of living forms which constitute that species. He has shown that in fact species are not thus held in check—that with the line of descent goes gradual modification. Thus the living representatives of no species to-day are quite like their ancestry of centuries ago.

This publication of the "*Origin of Species*" marks the beginning of the modern era in biology and in the related sciences. Its theories ran counter to the preconceived opinions of most men learned of science as well as of philosophy. It met with a storm of adverse criticism, some of it well-meaning, much of it ferocious, and unreasonable to an extent that now seems hardly possible. On the other hand, the more able, and especially the younger workers in biology, one or another, gave their assent to its general propositions. This was especially true in England, Germany and the United States. Darwin had felt that a crucial test of his theory would be his ability to convince Lyell, Hooker and Huxley in England, and Asa Gray in America. These four illustrious men were among his first converts.

For the rest of the scientific world Darwin thought the adoption of the theory of descent must be a mere question of time, and that the younger and more observant could not fail to find in their own work confirmation of his conclusions. Nothing in the history of science is more re-

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markable than the calm patience and humility with which Darwin awaited the verdict of posterity on the main question involved in his theory of the origin of species. The main question, I say, for as Francis Darwin observes: "It comes out very clearly * * * that he did not rejoice over the success of his own theory of evolution—that modification is mainly due to 'natural selection.' On the contrary, he felt strongly that the really important point was that the doctrine of descent should be accepted."

From the first the growth of the acceptance of the theory of descent has been steady and sure. It is now universal among men whose studies in any line are such as to give them a right to an opinion. No man who has studied animal life would hold the old notion of the special creation of species and look an animal in the face.

The rest of Darwin's life was spent in the preparation and publication of various special works, most of which I need not name here, and which are the overflow of the material gathered for the "*Origin of Species.*"

In the "*Descent of Man,*" the most important of these, he showed that the human race could be no exception to the common unity of life. For the human race is likewise a species and from its physical side it must be discussed with other species. The study of these relations gave us in 1871 the volumes on the "*Descent of Man.*" If we suppose, as we must, that the various forms of lower animals and plants had their origin in pre-existing forms, more or less unlike them, we may conceive it to be true of man also. That it is in fact true of man we know; for not many thousands of years ago our ancestors in Europe were barbarians, cave-dwellers, lake-dwellers, and dwellers in hollow trees, with only the rude implements they shaped from metal and flint. Surprisingly like us in form and structure, though far below us in skill and intelligence, are the many races of apes and monkeys. And among these, or, rather, behind them, for they, too, are changing with the changing conditions of life, must our ancestry be traced.

If anything is certain in science it is this. What we call homology represents something real, some law of nature, something other than the mere results of chance. When I compare my arm with that of my neighbor I find some differences—differences in size and in proportions. But these are superficial and there is the underlying correspondence of bone and muscle, each nerve fiber, artery, and vein. When I compare my arm with the fore leg of a dog I find more striking differences, for the dog's station in life is quite unlike my own, and his arm he uses for quite different purposes. When I compare my arm with the wing of a bird, or the pectoral fin of a fish, the results are still similar. Though the differences in each case become more and more striking, and the resemblances less easy to trace, yet the same resemblances exist, and a closer study shows that these resemblances far outweigh the differences.

We say, then, that homology is real, and whatever power or influence or cause has acted on fishes to provide them with pectoral fins, has given to birds wings, to the dog forelegs, and to me and my neighbor arms. The arms are appendages more highly finished and suited to more purposes; but all are formed of the same pieces, arranged in the same way, and all bear the stamp of the same maker. But when I compare my arm with the claw of a lobster, the

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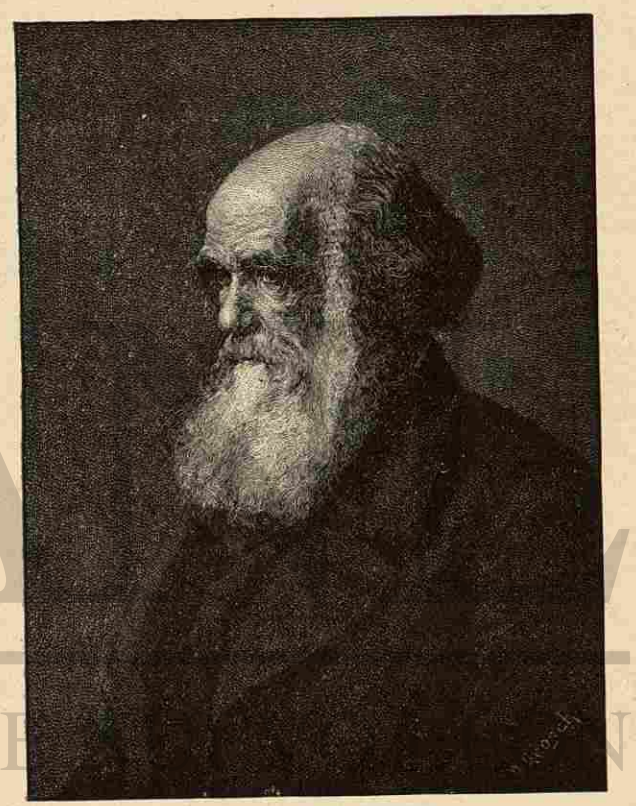
limb of a tree, the arm of a starfish, or an arm of the sea all resemblances in structure disappear and we have only chance analogies.

This, then, is certain: In nature homology exists, and among us backbone animals all structures, all functions, and at least some of the mental operations, show distinct homology. The essence of the development theory is this: Homology is the stamp of heredity. Homology means blood relationship. No other meaning has ever been shown, nor is there the slightest evidence that any other interpretation is possible. Blood relationship implies a common action of heredity, and heredity is the only known source of the likenesses we call homology.

Not only the lower races of men but the lower animals in their degree show in their structure the unmistakable evidence of kinship by blood. In every bone and muscle my dog shows his likeness to me, and even in every function of his feeble little brain the resemblance is apparent. Let me say again, we have no other explanation of homology than that of kinship by blood. This is Darwinism and this is the lesson of all biological science. There is substantially the same evidence—the same in kind and not much less in degree—for believing that my dog and myself are related by blood in some form of distant cousinship as there is to show a similar relationship between myself and any one of my neighbors about me to-day.

One of the ablest of recent writers on evolution (Dr. Edwin Grant Conklin) has used these words: "On the whole, the facts which are at present at our disposal justify a return to the position of Darwin. Neither Weismannism nor Lamarckism alone can explain the causes of evolution. But Darwinism can explain those causes. Darwin endeav-



CHARLES ROBERT DARWIN.
Painting by G. F. Watts, after the etching of Rajon.

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DIRECCIÓN GENERAL DE BIBLIOTECAS

ored to show that variations, perhaps even adaptations, were the result of extrinsic factors acting upon the organism, and that these variations or adaptations were increased and improved by natural selection. This is, I believe, the only ground which is at present tenable; and it is but another testimony to the greatness of that man of men, that, after exploring for a score of years all the ins and outs of pure selection and pure adaptation, men are now coming back to the position outlined and unswervingly maintained by him."

Says Mr. Darwin: "To my mind it accords better with what we know of the laws impressed on matter by the Creator that the production and extinction of the past and present inhabitants of the world should have been due to secondary causes, like those determining the birth and death of an individual. When I view all things, not as special creations but as the lineal descendants of some few beings who lived before the first bed of the Silurian was deposited, they seem to me to become ennobled. There is a grandeur in this view of life, with its several powers having been originally breathed by the Creator into a few forms or into one, and that, while this planet has gone cycling on according to the fixed laws of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been and are being evolved."

Darwin died at Down on April 19, 1882, at the age of seventy-three years. Among all men of science none have been so great as he and none more lovable. No one who knew him has ever had a word to say against his personal character. He was the greatest of naturalists by virtue of sheer greatness of soul.

Among the last words which he wrote were these: "As

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for myself, I believe that I have acted rightly in steadily following and devoting my life to science. I feel no remorse from having committed any great sin, but I have often and often regretted that I have not done more direct good to my fellow creatures."

A Chinese sage, whose words remain, but whose name has been lost in the ages between him and us, has said: "He cannot be concealed: he will appear without showing himself, effect renovation without moving, and create perfection without acting. It is the law of heaven and earth, whose way is solid, substantial, vast, and unchanging."

Not long ago I walked across the Kentish pastures to the little village of Down. I visited Darwin's home, a stately old-fashioned country mansion surrounded by trees and shut in by an ivy-covered wall. I talked with the villagers, who had been his neighbors all their lives, and to whom he was not the world-renowned naturalist but the good gray man whom everybody knew and loved. I learned some things which the books do not tell us of his simple, kindly ways, his warm friendships, and his quiet but wide-reaching charities. I have from this a clearer picture of Darwin as he was. His love for his wife and children, his love for birds and flowers and trees, his love for simplicity and truth—all these stand as the clear background before which rises the noblest work in science.

Twenty-five years ago obloquy, ridicule and abuse were heaped on the name of Darwin from all sides, sometimes even from his scientific associates. He has outlived it all, and a few years ago his mother country paid him the highest tribute in her power. He lies in Westminster Abbey by the side of Isaac Newton, one of the many noble prede-

cessors who have made his own life possible. Among all who have written or spoken since then, whatever their religious or scientific faith, by none has an unkind word been said. He was a gentle, patient and reverent spirit, and by his life not only science, but our conception of Christianity, has been advanced and ennobled.

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CHARLES DARWIN

SELECTED STUDIES AND REMINISCENCES

DARWIN THE REVOLUTIONIZER OF MODERN THOUGHT

If ever a man's ancestors transmitted to him ability to succeed in a particular field, Charles Darwin's did. If ever early surroundings were calculated to call out inherited ability, Charles Darwin's were. If ever a man grew up when a ferment of thought was disturbing old convictions in the domain of knowledge for which he was adopted, Charles Darwin did. If ever a man was fitted by worldly position to undertake unbiased and long-continued investigations, Charles Darwin was such a man. And he indisputably found realms waiting for a conqueror. Yet Darwin's achievements far transcend his advantages of ancestry, surroundings, previous suggestion, position. He stands magnificently conspicuous as a genius of rare simplicity of soul, of unwearied patience of observation, of striking fertility and ingenuity of method, of unflinching devotion to and belief in the efficacy of truth. He revolutionized not merely half-a-dozen sciences, but the whole current of thinking men's mental life.—G. T. BETTANY, *in "Life of Charles Darwin," in "Great Writers" Series.*

DARWIN'S SIMPLICITY AND MODESTY OF CHARACTER

"Arrogance, irritability and envy, the faults that ordinarily beset men of genius, were not so much conquered as non-existent, in Darwin's singularly simple and generous mind. It never occurred to him that it would be to his gain to show that he and not some one else was the author of a discovery. If he was appealed to for help by a fellow-worker, the thought never passed into his mind that he had secrets to divulge which would lessen his importance. It was science, not the fame of science, that he loved, and he helped science by the temper in which he approached it. He had to say things which were distasteful to a large portion of the public, but he won the ear, even of his most adverse critics, by the manifest absence of a mere desire to shine, by his modesty, and by his courtesy. He told honestly what he thought to be the truth, but he told it without a wish to triumph or to wound. There is an arrogance of unorthodoxy as well as an arrogance of orthodoxy; and if ideas that a quarter of a century ago were regarded with dread are now accepted without a pang, the rapidity of the change of opinion, if not the change itself, is largely due to the fact that the leading exponent of these ideas was the least arrogant of men."—*"The Saturday Review." Quoted by G. T. Bettany.*

DARWIN'S PERSONALITY

"In Darwin's own carriage, which he had thoughtfully sent for my convenience to the railway station, I drove

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DIRECCIÓN GENERAL DE BIBLIOTECAS

one sunny morning in October, through the graceful, hilly landscape of Kent, that with the chequered foliage of its woods, with its stretches of purple heath, yellow broom, and evergreen oaks, was arrayed in its fairest autumnal dress. As the carriage drew up in front of Darwin's pleasant country house, clad in a vesture of ivy, and embowered in elms, there stepped out to meet me from the shady porch, overgrown with creeping plants, the great naturalist himself, a tall and venerable figure, with the broad shoulders of an Atlas supporting a world of thought; his Jupiter-like forehead highly and broadly arched, as in the case of Goethe, and deeply furrowed with the plough of mental labor; his kindly, mild eyes looking forth under the shadow of prominent brows; his amiable mouth surrounded by a copious silver-white beard. The cordial, prepossessing expression of the whole face, the gentle, mild voice, the slow, deliberate utterance, the natural and naïve train of ideas which marked his conversation, captivated my whole heart in the first hour of our meeting, just as his great work had formerly, on my first reading it, taken my whole understanding by storm. I fancied a lofty world-sage out of Hellenic antiquity—a Socrates or Aristotle—stood before me."—PROFESSOR ERNST HAECKEL, *Author of "The History of Creation." Quoted by G. T. Bettany.*

DARWIN'S INTRINSIC NOBLENESS AND LOVABLENESS

Of Darwin's pure and exalted moral nature no Englishman of the present generation can trust himself to speak with becoming moderation. His love of truth, his singleness of heart, his sincerity, his earnestness, his modesty,

his candor, his absolute sinking of self and selfishness—these, indeed, are all conspicuous to every reader, on the face of every word he ever printed. Like his works themselves, they must long outlive him. But his sympathetic kindliness, his ready generosity, the staunchness of his friendship, the width and depth and breadth of his affections, the manner in which "he bore with those who blamed him without blaming them in return," these things can never so well be known to any other generation of men as to the three generations who walked the world with him. Many even of those who did not know him loved him like a father; to many who never saw his face the hope of winning Charles Darwin's approbation and regard was the highest incentive to thought and action. Towards younger men, especially, his unremitting kindness was always most noteworthy: he spoke and wrote to them, not like one of the masters in Israel, but like a fellow-worker and seeker after truth, interested in their interests, pleased at their successes, sympathetic with their failures, gentle to their mistakes. Not that he ever spared rightful criticism; on the contrary, the love of truth was with him so overpowering and enthralling a motive that he pointed out what seemed to him errors or misconceptions in the work of others with perfect frankness, fully expecting them to be as pleased and delighted at a suggested amendment of their faulty writing as he himself was in his case. But his praise was as generous as his criticism was frank; and amid all the toil of his laborious life in his study at Down, he could always find time to read and comment at full length upon whatever fresh contributions to his own subjects the merest tyro might venture to submit for his consideration. He had the

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN
DIRECCIÓN GENERAL DE BIBLIOTECAS

sympathetic receptivity of all truly great minds, and when he died, thousands upon thousands who had never beheld his serene features and his fatherly eyes felt that they had lost indeed a personal friend.

Greatness is not always joined with gentleness: in Charles Darwin's case, by universal consent of all who knew him, "an intellect which had no superior" was wedded to "a character even nobler than the intellect."—GRANT ALLEN, *in "Charles Darwin," in "English Worthies" Series.*

DARWIN'S USE OF THE IMAGINATION

As to Darwin's place in literature, that is due supereminently to his thoughts. In his expression of them he had the saving quality of directness, and usually wrote with simplicity. Incisive he was not, ordinarily; caution of his type harmonizes ill with incisiveness. But what he lost thereby he gained in solidity and in permanence. Sometimes, as we have pointed out, his imagination carried him beyond his usual sober vein, and then he showed himself aglow with feeling or with sympathetic perfection.

But when we speak of his imagination we pass at once to the other side of his mind—if indeed any such patient inquiry as his could have been maintained except for the imaginative side of him. This lit up his path, buoyed him in difficulties and failures, suggested new expedients, experiments, and combinations. The use of imagination in science has never been more aptly illustrated nor more beneficial than in his case. Darwin, more than any other man, perhaps, showed the value, if not the essentiality, of

"working hypotheses"; and if any man now wants to progress in biology, he will be foolish if he does not seek such, and use them freely, and abandon them readily if disapproved.—G. T. BETTANY.

DARWIN ON MAN'S LOWLY ORIGIN

In summing up on the entire subject [of the "Descent of Man,"] Darwin expresses himself with more than his wonted vigor and point. On the one hand he endeavors to disarm opposition by quoting heroic monkeys as contrasted with degraded barbarians; on the other hand, he welcomes the elevation of man so far above his barbarous ancestors. Finally, he stands upon truth, as against likes and dislikes. "The astonishment which I felt on first seeing a party of Fuegians on a wild and broken shore will never be forgotten by me, for the reflection at once rushed into my mind—such were our ancestors. These men were absolutely naked and bedaubed with paint; their long hair was tangled, their mouths frothed with excitement, and their expression was wild, startled, and distrustful. They possessed hardly any arts, and, like wild animals, lived on what they could catch. They had no government, and were merciless to everyone not of their own small tribe. He who has seen a savage in his native land will not feel much shame if forced to acknowledge that the blood of some more humble creature flows in his veins. For my own part, I would as soon be descended from that heroic little monkey, who braved his dreaded enemy in order to save the life of his keeper; or from that old baboon, who, descending from the mountains, carried away in triumph his young comrade from a crowd of

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN
DIRECCIÓN GENERAL DE BIBLIOTECAS

astonished dogs—as from a savage who delights to torture his enemies, offers up bloody sacrifice, practices infanticide without remorse, treats his wives like slaves, knows no decency, and is haunted by the grossest superstitions.—Man may be excused for feeling some pride at having risen, though not through his own exertions, to the very summit of the organic scale; and the fact of his having thus risen instead of having been originally placed there, may give him hopes of a still higher destiny in the distant future. But we are not here concerned with hopes or fears, only with the truth as far as our reason allows us to discover it. I have given the evidence to the best of my experience; and we must acknowledge, as it seems to me, that man, with all his noble qualities, with sympathy that feels for the most debased, with benevolence which extends not only to other men, but to the humblest living creature, with his God-like intellect which has penetrated into the movements and constitution of the solar system—with all these exalted powers—man still bears in his bodily frame the indelible stamp of his lowly origin." —G. T. BETTANY. *The quotation is from Darwin's "Descent of Man," first published in* 1871.

DARWIN'S SUCCESS

Darwin won, as far as a man can win, success during his lifetime. As Professor Huxley said, in lecturing on "The Coming Age of '*The Origin of Species*,'" "the foremost men of science in every country are either avowed champions of its leading doctrines, or at any rate abstain from opposing them." His prescience has, in less than a generation, been justified by the discovery of intermediate fossil forms of animals too numerous to be here recounted. The break between vertebrate and invertebrate animals, between flowering and non-flowering plants, between animal and plant, is now bridged over by discoveries in the life histories of animals and plants which exist to-day. Embryo animals and plants are now known to go through stages which repeat and condense the upward ascent of life; and they give us information of the greatest value as to lost stages in the past. We can, as it were, see the actual track through which evolution may have proceeded. "Thus," says Professor Huxley, "if the doctrine of evolution had not existed, palæontologists must have invented it, so irresistibly is it forced upon the mind by the study of the remains of the Tertiary mammalia which have been brought to light since 1859."—G. T. BETTANY.

DARWIN'S TRUE POSITION WITH RESPECT TO THE THEORY OF EVOLUTION

In the public mind Darwin is, perhaps, most commonly regarded as the discoverer and founder of the evolution hypothesis. Two ideas are usually associated with his name and memory. It is believed that he was the first propounder of the theory which supposes all plant and animal forms to be the result, not of special creation, but of slow modification in pre-existent organisms. It is further and more particularly believed that he was the first propounder of the theory which supposes the descent of man to be traceable from a remote and more or less monkey-like ancestor. Now, as a matter of fact, Darwin was not the prime originator of either of these two great

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN
DIRECCIÓN GENERAL DE BIBLIOTECAS

cardinal ideas. Though he held both as part of his organized theory of things, he was not by any means the first or the earliest thinker to hold them or to propound them publicly. Though he gained for them both a far wider and more general acceptance than they had ever before popularly received, he held no sort of claim himself to originality or proprietorship in either theory. The grand idea which he did really originate was not the idea of "descent with modification," but the idea of "natural selection," by which agency, as he was the first to prove, definite kinds of plants and animals have been slowly evolved from simpler forms, with definite adaptations to the special circumstances by which they are surrounded. In a word, it was the peculiar glory of Charles Darwin, not to have suggested that all the variety of animal and vegetable life might have been produced by slow modifications in one or more original types, but to have shown the nature of the machinery by which such a result could be actually attained in the practical working-out of natural causes. He did not invent the development theory, but he made it believable and comprehensible. He was not, as most people falsely imagine, the Moses of evolutionism, the prime mover in the biographical revolution; he was the Joshua, who led the world of thinkers and workers into full fruition of that promised land which earlier investigators had but dimly descried from the Pisgah-top of conjectural speculation.—GRANT ALLEN.

DARWIN'S INFLUENCE UPON THE SPREAD OF THE DOCTRINE OF EVOLUTION

It is to Darwin, and to Darwin almost alone, that we owe the present comparatively wide acceptance of the all-em-

bracing doctrine of evolution. No other man did so much, or could have done so much, to ensure its triumph. He began early in life to collect and arrange a vast encyclopædia of facts, all finally focussed with supreme skill upon the great principle he so clearly conceived, and so lucidly expounded. He brought to bear upon the question an amount of personal observation, of minute experiment, of world-wide book-knowledge, of universal scientific ability, such as never perhaps was lavished by any other man upon any other department of study. His conspicuous and beautiful love of truth, his unflinching candor, his transparent fearlessness and honesty of purpose, his childlike simplicity, his modesty of demeanor, his charming manner, his affectionate disposition, his kindliness to friends, his courtesy to opponents, his gentleness to harsh and often bitter assailants, kindled in the minds of men of science everywhere throughout the world a contagious enthusiasm, only equalled perhaps among the disciples of Socrates and the great teachers of the revival of learning. His name became a rallying-point for the children of light in every country; and what philosophers and speculators might have taken a century or two more to establish in embryo, was firmly grounded, never to be overthrown, by the vast accumulations of fact and argument in the "*Origin of Species*," and its companion volumes.—GRANT ALLEN.

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN ®
DIRECCIÓN GENERAL DE BIBLIOTECAS

READERS' AND STUDENTS' NOTES

1. With respect to Darwin there is of course an extent of literature exceeding that devoted to any other scientist on our list. We shall mention only those works that are of popular interest; that is, those in which the general reader, as distinguished from the special scientific student, will take an interest.—The standard life of Darwin is "*The Life and Letters of Charles Darwin,*" edited by his son, Francis Darwin. (New York: D. Appleton & Co. 2 vols., $5.00.) This "life" is especially valuable because of its autobiographic chapter. What is practically an abridgment of this "life" is the work in one volume entitled "*Charles Darwin's Life, Edited by his Son.*" (New York: D. Appleton & Co. $1.50.)

2. One of the most useful and most interesting of the short "lives" of Darwin is Grant Allen's volume in the "*English Worthies*" series, entitled simply "*Charles Darwin.*" Grant Allen, himself a distinguished naturalist, and one of the most instructive and entertaining writers in the whole realm of scientific literature, has made of this little book a veritable classic. (New York: D. Appleton & Co. 75 cents.)

3. G. T. Bettany's "*Life of Darwin,*" in the "*Great Writers*" series, is also an excellent account of Darwin's life and work. Apart from its other merits this work is especially valuable for its bibliography. It must be stated, too, that both the preceding work and this one give the reader a pretty good idea of what is meant by "Darwinism," and the principle of "natural selection," and so on.

4. A more recent work on Darwin and "Darwinism" is the volume in "*The Century Science Series,*" entitled "*Charles Darwin, and the Theory of Natural Selection,*" by Edward B. Poulton, F. G. S., F. R. S., etc., Professor of Geology at the University of Oxford. (New York: The Macmillan Co. $1.25.) This work is divided up into a great many chapters, and in consequence every phase of Darwin's life, character, and work, is duly emphasized.

5. Other works of popular interest bearing on Darwin's work, and the exposition of the theory of natural selection, etc., are the following: "*Darwinism Stated by Darwin Himself,*" being characteristic passages from the writings of Darwin, selected and arranged by Professor N. Sheppard (New York: D. Appleton & Co. $1.50); "*Darwinism and Other Essays,*" by John Fiske (Boston: Houghton, Mifflin & Co.); "*Darwiniana,*" essays and reviews pertaining to Darwinism, by Asa Gray (New York: D. Appleton & Co.); "*The History of Creation,*" a "popular exposition of the doctrine of evolution in general and that of Darwin, Goethe, and Lamarck in particular" by Ernst Haeckel (New York: D. Appleton & Co. $5.00): and "*Darwiniana*" and "*Man's Place in Nature,*" by Professor T. H. Huxley (New York: D. Appleton & Co. $1.25 each). Huxley's "*Darwiniana*" contains an excellent biographical sketch of Darwin, prepared for the "*Proceedings*" of the Royal Society.

6. A most important work on Darwinism in particular, and the history of the doctrine of evolution in general—important, that is to say, with respect to the needs of the general reader—is Edward Clodd's "*Pioneers of Evolution from Thales to Huxley.*" (New York: D. Appleton & Co. $1.50.) In this work the relative parts borne in the development of evolution by Darwin, Alfred Russell Wallace, Herbert Spencer, and Huxley, are duly considered. The volume is beautified by some exceedingly good portraits.

7. A life of Darwin prepared for young readers, or rather for young readers as well as old, deserves special mention. This is "*Charles Darwin, His Life and Work,*" by Charles Frederick Holder, LL. D., in "*Leaders of Science*" series. (New York: G. P. Putnam's Sons. $1.50.) In the preface the author says: "I was particularly gratified with the suggestion by the publisher that the work should be adapted to young readers as well as old. It has always seemed to me that the life of Charles Darwin was one essentially fitted to be held up as an example to youth." The author has excellently carried out his idea, and his work is to be commended highly. The publishers have illustrated the book most sumptuously.

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN
DIRECCIÓN GENERAL DE BIBLIOTECAS

John Tyndall

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DIRECCIÓN GENERAL DE BIBLIOTECAS

XV. JOHN TYNDALL

1820-1893

BIOGRAPHICAL STUDY

BY JOHN EBENEZER BRYANT, M. A.

A brief presentation of the main facts of Tyndall's life will make it easier to set forth the main significances of his life:—John Tyndall was born in the village of Leighlin-Bridge, county of Carlow, Ireland, August 21, 1820. He claimed descent from that early reformer, William Tyndale, who first translated the New Testament into English, and who was burned at the stake for heresy in 1536. His father, who because of some difference with his grandfather had received no patrimony and was in humble circumstances, was a man of great independence of character—a quality in which his famous son was also distinguished—and in his way, too, a man of great ability and acquirements, being, indeed, an ardent theological controversialist, with all the opinions and doctrines of the fathers of the English church at his fingers' ends. Young Tyndall himself was schooled in theological controversy, but, what was better, he was also schooled in the teachings and literature of the Bible. Because of his theological

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN
DIRECCIÓN GENERAL DE BIBLIOTECAS

knowledge his father used frequently to call him "Stillingfleet," after the learned English divine of that name. What is of more significance, however, is that he used frequently to call him "Newton," because of his interest in seeking to get at the causes of natural phenomena. Mr. Tyndall's only formal education was obtained at a school near Leighlin, where, however, he remained until he was nineteen, his father in this respect doing the very best he could for him. He then obtained employment upon the Irish Ordnance Survey. He remained in this service for five years. During the second year of his service an incident occurred that was the turning point of his life. A kind-hearted official in the service, noticing that young Tyndall had considerable spare time on his hands, one day inquired of him how he employed it. The reply showing that it was not spent very satisfactorily, the official impressively said: "You have five hours a day at your disposal. This time ought to be devoted to systematic study. Had some friend advised me in this way when I was your age I should now be at the head of the Survey." Tyndall took the hint. The very next morning he was at his books at 5 o'clock, and "for twelve years he never swerved from that practice." He was then in his twenty-first year.

Mr. Tyndall's career in the Ordnance Survey was very characteristic. He made himself master of every duty that was intrusted to him, and the consequence was that he rapidly rose through all the grades of the service—draughtsman, surveyor, computer, trigonometrical surveyor, etc.—as far, indeed, as a young man like him, without influence or special training, could possibly rise. Seeing in the service, however, no future for him, he after five

years' trial quitted it. Railway construction being then a mania in Britain he became a railway engineer. After three years' work at this business, still feeling that he had not yet got at his life's vocation, he became a teacher in Queenswood College, Hampshire, an institution devoted to technical education in agriculture and engineering. Here, indeed, he did find what seemed to be his life's work; but he soon recognized that he was not sufficiently well prepared to pursue it properly. Accordingly, though his work in Queenswood was eminently successful, he resigned his position after one year's service, and went to Germany to attend the University of Marburg in Hesse-Cassel, the celebrated physicist, Bunsen, then being there. In making this move he had but one object, the perfecting of his natural powers as well as he could so that he might best do the work in life that might afterward open up for him to do. "I had been reading Fichte and Emerson and Carlyle, and had been infected by the spirit of these great men. The alpha and the omega of their teaching was loyalty to duty. Higher knowledge and greater strength were within the reach of the man who unflinchingly enacted his best insight. It was a noble doctrine. It held me to my work."

Mr. Tyndall remained in Marburg until he obtained his degree—two years. His store of money was very small. He had never had much chance of earning anything. When he was on the Ordnance Survey, even after four or five years' service, his salary was only twenty shillings ($5) a week. But he had managed to accumulate some savings and to enjoy life as well. "I have often since wondered," he said many years afterward (in 1884), "at the amount of genuine happiness which a young fellow

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN
DIRECCIÓN GENERAL DE BIBLIOTECAS

of regular habits, not caring for either pipe or mug, may extract even from pay like that." So that he got through his two years at Marburg upon a sum that would to-day be scarcely more than enough to give most young men a good vacation trip. Then he went to Berlin, where he pursued his studies in the laboratory of Professor Magnus. In 1851 he returned to London, where he became acquainted with Faraday. He had already prepared some scientific papers of merit, and he was soon elected a fellow of the Royal Society. And now the second turning point in his life occurred. He was invited, at Faraday's suggestion, to give a "Friday Evening" lecture at the Royal Institution. The lecture was given February 14, 1853. It proved to be a pronounced success. The audience, the governors, Faraday himself, were all delighted. Mr. Tyndall was at once offered the position of Fullerian professor of physics at the Institution, and in June he entered upon his new duties. He was then scarcely thirty-three. A few years later (in 1861) when Faraday retired from his active charge of the Institution, Mr. Tyndall took upon himself the duty of supervisor; and when, in 1867, Faraday died, Mr. Tyndall succeeded to his office as director. His connection with the Royal Institution continued for thirty years, and then he, too, had to retire owing to ill-health, brought on by overwork. His life thenceforward until the end was that of an invalid.

Mr. Tyndall married late in life, but his marriage was an unspeakable blessing to him. In a letter to Mr. Herbert Spencer, written some half-dozen years before his death, "in referring," to use Mr. Spencer's words, "to Mrs. Tyndall's self-sacrificing care of him," he said: "She has raised my ideal of the possibilities of human

JOHN TYNDALL.

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN ®
DIRECCIÓN GENERAL DE BIBLIOTECAS

nature." To use the words of Professor Huxley, another of Mr. Tyndall's intimate friends, "her whole life for many years was devoted to the one object of preserving that of her husband." She had been "his secretary, his nurse, his tireless watcher—even his servant in case of need." "If I pull through this it will be all your care, all your doing," were the grateful words he addressed her the night before he died. Unfortunately, the very next morning, Mrs. Tyndall gave her husband a large dose of chloral, instead of some sulphate of magnesia which she had intended giving him. Everything that medical science or skill could do, of course, was done to avert the tragic consequences of this sad mistake; but to no avail. He died in ten hours—at 6:30 p. m., December 4, 1893.

Mr. Tyndall's great merit as a scientist did not lie in the number or magnitude of his scientific discoveries. Though these were neither few nor unimportant, he was not a great original scientific investigator like Faraday or Davy. Nor was he a great scientific law-giver like Darwin or Dalton. But perhaps more than any one else of his time he was seized with a clearness of view as to the limits of the scientific domain. Perhaps more than any one else did he seek to make those limits clearly visible to others. He recognized the region where physics ends and metaphysics begins, and he was outspoken in his assertions that many problems concerned with the constitution of the universe are insoluble. And this was true, in spite of the fact that he had a poet's nature, and loved to extend, by way of analogy or illustration, the certain laws of physical fact to the explanation of metaphysical uncertainties. But only by way of analogy or illustration; for no man's sense of logic was stronger. It was this clearness of view as to

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN
DIRECCIÓN GENERAL DE BIBLIOTECAS

matters of positive knowledge, joined to his power of illustration, and to his faculty for seizing upon and making use of analogies, which made him the popular teacher and lecturer he was. In the Royal Institution he had a difficult standard to maintain. His predecessors, Davy and Faraday, had been the most skillful scientific expositors in Europe. Tyndall's merit in this respect was on the whole quite the equal of theirs. While, perhaps, he did not possess in full degree their faculty of original scientific insight, he surpassed both of them in the clearness of view he had of the educational conditions of scientific teaching. So that while a lecture by Davy or Faraday was sure to delight, to astonish, and to impress, a lecture by Tyndall was sure to instruct.

In fact, it is upon his work as a teacher or instructor in science that Mr. Tyndall's claim to enduring fame most solidly rests. His knowledge of his own specialties—heat, light, magnetism, electricity, and sound—was as minute and profound as that of any man of his time. His original investigations in these specialties placed him in the rank of the foremost scientists of his age, even if they did not quite lift him above that rank. When, therefore, he came to instruct either classes or popular audiences, or, through his books, the general public, he was listened to and read, not as an ordinary teacher, but as a teacher bearing the mandates of authority and original investigation. But apart from his knowledge and his power of original insight, Mr. Tyndall was no ordinary teacher. He possessed what only the best teachers possess, that influence over his students which is called personal magnetism. But even this was not his distinguishing quality. It was something far more peculiar and distinctive. It was the in-

sight, then almost new to the world, that led him to see that good teaching takes place only when the comprehension of truth is effected by natural development—from the familiar to the unfamiliar, the concrete to the abstract, the simple to the complex. And even this was not all. He made his pupils actual explorers with himself in the realm of physical phenomena. He awakened within them their own powers of investigation. He exercised them in that faculty of constructive imagination which was his own distinguishing faculty, not merely as a scientific explorer but also as a scientific experimenter and instructor.

Fortunately for the world and for his enduring fame, a great part of Mr. Tyndall's educational work was effected by means of the books he wrote. His "*Heat as a Mode of Motion*," first published in 1863, has almost every merit that a scientific textbook should have, except the merit of being of much use to any one who wishes to quickly cram for a written examination. Besides it had, at the time of its first appearance, the additional merit of bringing under general consideration a doctrine, then but little known or indeed believed in—the great fundamental doctrine that the totality of energy in the universe remains forever the same; that energy can never be created and never be destroyed, but only changed from one form to another; that heat is but one form of energy, just as electricity, light, magnetism, etc., are also forms; that all forms of energy are interchangeable; and that the particular form of energy which we call heat is a motion of the elementary molecules of matter. He was thus able to bring our conceptions of many of the simplest and commonest phenomena of nature under the domain of a great, all-pervading, ever-existinglaw. But what Mr. Tyndall did for the

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN ®
DIRECCIÓN GENERAL DE BIBLIOTECAS

study and teaching of heat he also did, only in a more marked degree, for the study and teaching of light, and electricity, and sound. A sentence or two of his own will explain the ideals that he had in mind in the preparation of his textbooks:

> "I am trying very hard on a boy's book on optics. Ostensibly for boys but equally for teachers, for boys thus far do not know how to learn and teachers do not know how to teach. I am so treating the subject that boys and teachers may make the experiments for themselves. My aim is to teach them both to experiment and to reason upon experiment. I suppose a boy to be alongside and that we are working together. I try to overcome the apathy and the repugnance arising from awkwardness in the first stages of experiment. I speak, therefore, not only to the boy's 'brain' but to his 'blood'—stirring him to action."

These educational ideals may to-day seem quite ordinary, but thirty years ago they were wholly new.

One of the most notable incidents in Mr. Tyndall's life was his visit to America. This took place in the winter of 1872-3. There was great difficulty in persuading him to come, as his time was always much occupied by investigations which he did not care to interrupt. At last, however, he yielded to the desire of all people of culture and scientific interest throughout the continent generally, and came. He had prepared a course of six lectures—upon heat, light, electricity, magnetism, and sound—and had prepared, also, magnificent apparatus with which to illustrate the lectures. He gave these lectures in Boston, Philadelphia, Baltimore, Washington, New York, Brooklyn, and New Haven. It is safe to say that no other European man of science—not even Huxley or Spencer—was ever more heartily received by the American public. Crowded

audiences greeted him at every appearance, even when, as once in New York, the weather was so unfit that not a soul was expected to be present. And at a public dinner given to him before he returned, almost every American eminent in science was present to wish him a happy voyage and to pay his respects to him in person. A pleasing feature of this visit, and one very honorable to Mr. Tyndall, was that the whole proceeds of the lectures were devoted by him to the encouragement of scientific study in America. The amount at first was $13,000, but by good investment this was afterward increased to $32,400. Accordingly, three great universities—Harvard, Columbia, and Pennsylvania—each received the sum of $10,800 for the endowment of permanent fellowships for the benefit of students in physical science. The good that some men do lives after them.

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DIRECCIÓN GENERAL DE BIBLIOTECAS

JOHN TYNDALL

SELECTED STUDIES AND REMINISCENCES

PROFESSOR HUXLEY'S CHARACTER SKETCH OF TYNDALL

My elder by some five years, Tyndall's very marked vigorous personality must have long taken its final set when we foregathered in 1851. The dyer's hand is subdued to that it works in; and, it may be, that much occupation with types of structure, elsewhere, is responsible for a habit of classifying men to which I was, and am, given. But I found my new friend a difficult subject—*incertae sedis*, as the naturalists say; in other words, hard to get into any of my pigeon holes. Before one knew him well it seemed possible to give an exhaustive definition of him in a string of epigrammatic antitheses, such as those in which the older historians delight to sum up the character of king or leading stateman. Impulsive vehemence was associated with a singular power of self-control and a deep-seated reserve, not easily penetrated. Freehanded generosity lay side by side with much tenacity of insistence on any right, small or great; intense self-respect and a somewhat stern independence, with a sympathetic geniality of manner, especially towards children, with whom Tyndall was always a great favorite. Flights of

imaginative rhetoric, which amused (and sometimes amazed) more phlegmatic people, proceeded from a singularly clear and hard-headed reasoner, over scrupulous, if that may be, about keeping within the strictest limits of logical demonstration, and sincere to the core. A bright and even playful companion, Tyndall had little of that quick appreciation of the humorous side of things in general, and of one's self in particular, which is as oil to the waves of life, and is a chief component of the worthier kind of tact; indeed, the best reward of the utterer of a small witticism, or play upon words, in his presence, was the blank, if benevolent, perplexity with which he received it. And I suppose that the character-sketch would be incomplete, without an explanation of its peculiarities by a reference to the mixture of two sets of hereditary tendencies, the one eminently Hibernian, the other derived from the stock of the English Bible translator and reformer.

To those who have been privileged to become intimate with Tyndall, however, sketch and explanation will seem alike inadequate. These superficial characteristics disappeared from view, as the powerful faculties, and the high purposes of the mind, on the surface of which they played, revealed themselves. And to those who knew him best, the impression made by even these great qualities might well be less vivid than that left by the warmth of a tenderly affectionate nature.—PROFESSOR HUXLEY, *in "The Nineteenth Century."*

TYNDALL'S SINCERITY AND LOVE OF TRUTH

I say, once more, Tyndall was not merely theoretically, but practically, above all things sincere; the necessity of

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doing, at all hazards, that which he judged, rightly or wrongly, to be just and proper, was the dominant note of his character; and he was influenced by it in his manner of dealing with questions which might seem, to men of the world, hardly worth taking so seriously. Of the controversies in which he became involved, some of the most troublesome were undertaken on behalf of other people who, as he conceived, had been treated with injustice. The same instinct of veracity ran through all Tyndall's scientific work. That which he knew, he knew thoroughly, had turned over on all sides, and probed through and through. Whatever subject he took up, he never rested till he had attained a clear conception of all the conditions and processes involved, or had satisfied himself that it was not attainable. And in dealing with physical problems, I really think that he, in a manner, saw the atoms and molecules, and felt their pushes and pulls. A profound distrust of all long chains of deductive reasoning (outside mathematics), unless the links could be experimentally or observationally tested at no long intervals, was simply another manifestation of the same influential quality. I was not over-burdened with love for such dialectic festoon work myself, but I owe a little to my friend for helping to abolish as much as remained.—PROFESSOR HUXLEY.

TYNDALL IN THE ROYAL INSTITUTION

This quality of active veracity, the striving after knowledge as apart from hearsay, lay at the root of Tyndall's very remarkable powers of exposition, and of his wealth of experimental illustration. Hence, I take it, arose the

guarded precision of the substance of a lecture or essay, which was often poetically rich, sometimes even exuberant, in form. In Sir Humphry Davy and Mr. Faraday the Royal Institution had possessed two unsurpassed models of the profound, yet popular, expositor of science. Davy was before my time, but I have often had the delight of listening to Faraday. An ineradicable tendency to think of something else makes me an excellent test-object for oratory; and he was one of the few orators whom I have heard to whom I could not choose but listen. It was no mean ordeal, therefore, to which Tyndall was subjected when he was asked to give a "Friday Evening" in 1852; but he captured his hearers so completely that his appointment to the Fullerian professoriate of physics, with the use of a laboratory such as he needed for the original work he loved, soon followed. And for more than thirty years he held his own. From first to last the announcement of a "Friday Evening" by Tyndall meant a crammed theatre.—PROFESSOR HUXLEY.

TYNDALL AND HUXLEY AND THE "X CLUB"

In the sketch [in the "*Nineteenth Century*" for January, 1894] he has recently given of our late friend, who was one of the small group known as the "X Club," Professor Huxley has given some account of that body. Further particulars may not unfitly be added; one of which may come better from me than from him. The impression that the club exercised influence in the scientific world (not wholly without basis, I think) was naturally produced by such knowledge as there eventually arose of its composition. For it contained four presidents of the

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DIRECCIÓN GENERAL DE BIBLIOTECAS

British Association, three presidents of the Royal Society, and among its members who had not filled these highest posts, there were presidents of the College of Surgeons, the Mathematical Society, the Chemical Society, etc. Out of the nine I was the only one who was fellow of no society, and had presided over nothing. I speak in the past tense, for now [March, 1894] unhappily, the number of members is reduced to five, and of these only three are in good health. There has been no meeting for the past year, and it seems scarcely likely that there will ever be another. But the detail of most interest which Professor Huxley has not given, concerns a certain supplementary meeting which, for many years, took place after the close of our session. This lasted from October in each year to June in the next, and toward the close of June we had a gathering in the country, to which the married members brought their wives: raising the number on some occasions to fifteen. Our programme was to leave town early on Saturday afternoon, in time for a ramble or a boating excursion before dinner; to have on the Sunday a picnic in some picturesque place adjacent to our temporary quarters; and, after dinner that evening, for some to return to town, while those with less pressing engagements remained until the Monday morning. Two of our picnics were held under Burnham Beeches, one or more on St. George's Hill, Weybridge, and another in Windsor Forest. As our spirits in those days had not been subdued by years, and as we had the added pleasure of ladies' society, these gatherings were extremely enjoyable. If Tyndall did not add to the life of our party by his wit, he did by his hilarity. But my special motive for naming these rural meetings of the "X" is that I may mention a fact which, to not a few, will be

surprising and perhaps instructive. We sometimes carried with us to our picnic a volume of verse, which was duly utilized after the repast. On one occasion, while we reclined under the trees of Windsor Forest, Huxley read to us Tennyson's "Aenone," and on another occasion we listened to Tyndall's reading of Mrs. Browning's poem, "Lady Geraldine's Courtship." The vast majority of people suppose that science and poetry are antagonistic. Here is a fact which may, perhaps, cause some of them to revise their opinions.—HERBERT SPENCER, *in "McClure's Magazine."*

TYNDALL THE REPRESENTATIVE PHYSICIST OF HIS TIME

It was at the Royal Institution that Tyndall became really a power in the land. Endowed with a marvelous gift of clear presentation, and with a rare faculty for holding the interest of an audience, he was soon recognized above all things as the popular exponent of physical science. When one comes to ask, "What one great work did Tyndall perform in life?" it would be difficult for any man to give a definite answer. He advanced many branches of science in different directions, but, for the most part, those directions had been amply indicated beforehand by others. His observations on glaciers took up the varied threads of Agassiz, Forbes, and Faraday; his researches on heat were in the direct line of Count Rumford, and Joule, and Melloni. It is the same throughout. We cannot say of him that he gave us any one great conception, like natural selection, or the conservation of energy; any one great discovery, like spectrum analysis, or the meteoric nature of comets; any one great invention,

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like the telephone or the phonograph. But his personality and his influence were persuasive and important; his powers of exposition were in every way remarkable; and his investigations, though never quite reaching the first rank in value, stood very high, indeed, in the forefront of the second. Above all, London, that great heterogeneous London, accepted him frankly as the representative physicist. Of Joule, of Thompson, of Tait, of Clerk Maxwell, of Balfour Stewart, it knew little or nothing personally; even Helmholz was to it but a great distant name. Tyndall was there on the spot, audible and visible. He was the Royal Institution. He was also physics. This counted for much when the day of battle came, and when the forces of darkness were gathered together to crush down the forces of light in the sixties and seventies. While the orthodox physicists of the universities and of the North were willing to stand aside and let the biologists bear the whole brunt of the battle, Tyndall, who to London was the representative physicist, gave the weight of his name and his personal importance to the side of the evolutionists.—GRANT ALLEN, *in "The Review of Reviews."*

TYNDALL'S WORK FOR THE DOCTRINE OF EVOLUTION

Tyndall's action in this matter [the discussion *re* evolution] was no doubt largely influenced by his close personal association with Spencer and Huxley. Both those thinkers influenced him deeply. In 1856, Huxley and he went to Switzerland together, and there began those observations on glaciers which finally resulted in their joint work on the structure and motion of those moving ice-rivers. Later still, when the International Scientific Series was

projected, Tyndall popularized these investigations in his charming little book on *"Forms of Water."* Meanwhile, the evolutionary wave was gathering force and volume. Darwin had long been prosecuting his researches into the origin of species, but as yet had published nothing on the subject. Herbert Spencer, who had already proclaimed himself a thorough-going evolutionist, was at work on his great scheme of the *"Synthetic Philosophy.'* Lyell was pursuing his investigations into the antiquity of man. The new ideas were in the air. At last, in 1859, the wave which had been so long advancing curled and broke visibly. Darwin, on the crest of the movement, published in that year his *"Origin of Species."* It was the greatest epoch in science since Newton advanced the theory of gravitation. Immediately the thinking world was divided into two sides. Owen and most of the physicists were in open opposition. Huxley and Hooker gave in their adhesion instantly. Lyell hesitated and wavered, but, soon convinced, accepted the new views as the necessary complement of his own uniformitarian concept of nature. At this crisis it was highly important to the evolutionists that students of biology and geology should not seem to stand alone in their acceptance of the new doctrines. Tyndall came boldly out among the physicists at the moment of need as the ally and champion of the rising movement. His aid was invaluable, and did much to help forward the triumph of that school of thought which is now for all practical purposes universally accepted. A few elder men still higgle and doubt; the younger generation, whatever science they may take up, are to a man evolutionists. Indeed, the very rapidity and certainty of the victory has made the men who gained it half outlive their fame; thou-

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sands of people who now implicitly accept modern views of life, hardly know how much they owe them to Darwin, Huxley, Spencer, Tyndall.—GRANT ALLEN.

TYNDALL'S PLACE IN THE SCIENTIFIC MOVEMENT OF HIS AGE

What was Tyndall's place in the [scientific] movement of our period? Every great onward march of the human mind is like a wave on the ocean. It begins small, gathers strength and volume as it grows, and breaks at last in a conspicuous crest, visible to all men. It was so with the evolutionary movement. Erasmus Darwin sowed; Buffon, Lamarck, Robert Chambers, watered. In the fullness of time Charles Darwin, Herbert Spencer, Alfred Russell Wallace, came to crest the wave. But evolution existed before Darwin, and Darwin himself was but the man who finally made a rising cause triumph. It is the same, once more, with the other great generalization of our age, the conservation of energy. In a certain dim sense, Kepler, Newton, Laplace, saw the way that led towards it. Count Rumford had clearer glimpses of it. With Grove it began to take definite form. Joule, Helmholz, Clerk Maxwell, Balfour Stewart, consummated it. But to no one man can the glory be given. More and more, as time goes on and co-operation increases, is this the case with science. Nobody can really say in one word who invented the steam-engine, the locomotive, photography, the telephone. People who know nothing about it will tell you glibly enough: Watt, Stephenson, Talbot or Daguerre, Bell or Edison. People who know more about it know that many separate inventors contributed many separate parts to each of these

inventions; and most of these parts could only be explained to technical readers.

Now, Tyndall was one of those men who bear a large share in the actual technical work of such great discoveries. But it is hard to put one's finger upon any single point easily to be apprehended by the ordinary intelligence. He taught us much, for example, about the way radiant heat is propagated through the atmosphere; about the objects which are, so to speak, opaque or transparent to it; about the effects it produces on the surface of our planet. He taught us much about how glaciers are formed, move, and are retarded, break into crevasses and freeze together again, compress themselves through gorges, or spread themselves, though solid, into lake-like expansions; and he did more towards explaining these singular phenomena than any other observer. His contributions to the sciences of light, of sound, of electricity, of magnetism, of heat, and even of biology (so far as regards the diffusion of the germs of minute organisms), are all of them most valuable. He was a fellow-worker in the triumph of evolutionism, and of just and sound views about energy. But for the most part he led up towards great developments in physical and electrical knowledge which have not yet been made, and towards practical inventions which have not yet been invented. This sort of work is the most valuable of all, but it is often the most inglorious. So it comes about that Tyndall, who was himself a most careful, accurate, and patient investigator, was best known as a popular expounder, and an almost sensational orator. He would not have been so famous if he had not superadded Belfast addresses and Royal Institution lectures to his real work in the laboratory and on the mountain. In these addresses, indeed, we

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get the man himself at his highest development.—GRANT ALLEN.

READERS' AND STUDENTS' NOTES

1. Biographical notices and critical estimates of Tyndall are to be found innumerably in magazines and other periodicals, but perhaps the most interesting and most complete account of Tyndall's life and work available to ordinary readers is the "*Character Sketch*" by Grant Allen in "*The Review of Reviews*" for February, 1894. Grant Allen, distinguished both for his knowledge of science and his literary style, writes of his subject—it goes without saying—appreciatively and interestingly.

2. An intimate friend and associate of Tyndall throughout almost the whole of his scientific career was Professor Huxley. When Tyndall died Huxley was importuned to write his biography. He did not write his biography, but he wrote a slight sketch in which he sought among other things, "to illustrate and emphasize the fact" that in Tyndall the world lost "a man of rare and strong individuality." This sketch is the opening number of "*The Nineteenth Century*" for January, 1894.

3. Herbert Spencer was also an intimate friend of Tyndall for almost as long a period as Huxley was. In fact the three great scientists were the closest of friends for over forty years together. When Tyndall died Spencer also wrote an appreciative sketch of the character and achievement of his friend as a tribute to his memory. This sketch is to be found in "*McClure's Magazine*" for March, 1894.

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XVI. THOMAS HENRY HUXLEY

1825-1895

BIOGRAPHICAL STUDY

BY DAVID STARR JORDAN, LL. D.
President of Leland Stanford University

Thomas Henry Huxley was born at Ealing, a suburb of London, on May 4, 1825, and died at Eastbourne, June 29, 1895, aged seventy years. He was the seventh son of George Huxley, a schoolmaster in Ealing. Why he was christened Thomas he says he never knew; "but it is a curious chance that my parents should have fixed for my usual denomination upon the name of that particular apostle with whom I have always felt most sympathy."

In a charming autobiographical sketch addressed as a letter to Louis Engel and published in Mr. Engel's volume, "*From Handel to Hallé*," Huxley gives this account of his parentage:

"Physically I am the son of my mother, so completely, even down to peculiar movements of the hands, ...that I can hardly find any trace of my father in me, except an inborn faculty for drawing, unfortunately .. .. .. uncultivated, a hot temper, and that amount of tenacity of purpose which unfriendly observers sometimes call obstinacy.

"My mother was a slender brunette, of an emotional and ener-

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DIRECCIÓN GENERAL DE BIBLIOTECAS

getic temperament, and possessed of the most piercing black eyes I ever saw in a woman's head. With no more education than other women of the middle classes in her day, she had an excellent mental capacity. Her most distinguishing characteristic, however, was rapidity of thought. If one ventured to suggest that she had not taken much time to arrive at any conclusion she would say: 'I cannot help it; things flash across me.' That peculiarity has been passed on to me in full strength. It has often stood me in good stead; it has sometimes played me tricks; and it has always been a danger. But, after all, if my time were to come over again, there is nothing I would less willingly part with than my inheritance of mother wit."

Of his early schooling Huxley spoke with no pleasure. His teachers "cared about as much for our intellectual and moral welfare as if they were baby-farmers." The boys were left to the struggle for existence among themselves, and "bullying was the least of the ill practices current" among them.

Young Huxley's ambition was to become a mechanical engineer, but early associations brought him to the study of medicine. He was strongly attracted by physiology, which he called "the mechanical engineering of living machines." Notwithstanding, he says, the fact that "natural science has been my proper business, I am afraid there is very little of the genuine naturalist in me. I never collected anything, and species work was always a burden to me. What I cared for was the architectural and engineering part of the business—the working out of the wonderful unity of plan in the thousands and thousands of diverse living constructions and the modifications of similar apparatuses to serve diverse ends."

The only teacher of whom Huxley spoke with pleasure was Wharton Jones, lecturer on physiology in the Charing

Cross School of Medicine. "The extent and precision of his knowledge impressed me greatly, and the severe exactness of his method of lecturing was quite to my heart. I do not know that I have ever felt so much respect for anybody before or since."

On finishing his medical course Huxley was appointed surgeon of H. M. S. *Victory*, on duty at Haslar hospital, where his official chief was the wise and capable naturalist explorer, Sir John Richardson, the author of the excellent "*Fauna Boreali-Americana.*" At Richardson's suggestion Huxley was afterward made assistant surgeon on H. M. S. *Rattlesnake*. In this service he spent four years at sea, chiefly about Australia and the neighboring islands, and here he made the studies of marine life which gave him a high reputation in the scientific world before he returned to England to become aware of the fact.

In 1850 he returned to England, and in 1853 resigned from the naval service, determined to trust to his pen until other means of support should come to him. Apart from its rare scientific opportunities the experience of the cruise of the *Rattlesnake* gave him valuable personal discipline. It was good, he says, "to be down on the realities of existence by living on bare necessaries, to find out how extremely well worth living life seemed to be when one woke from a night's rest on a soft plank with the sky for canopy, * * * and more especially to learn to work for the sake of what I got for myself out of it, even if it all went to the bottom and I along with it. * * * When I hear some of my young friends complain of want of sympathy and encouragement I am inclined to think that my naval life was not the least valuable part of my education."

Huxley was now candidate for the chair of natural his-

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DIRECCIÓN GENERAL DE BIBLIOTECAS

tory in the University of Toronto, his friend, Professor Tyndall, being at the same time an applicant for the chair of physics. In both cases the applicants failed, for in 1853 the names of Tyndall and Huxley were unknown in academic circles. Had both been successful the whole intellectual life of Canada would have been changed by their presence.

In 1854 Huxley was appointed palæontologist and lecturer on natural history at the Royal School of Mines, a position held by him until 1885. After that date many honors and duties came to him, the most distinguished of which was the presidency of the Royal Society.

At the beginning of his professorship, he tells us in his autobiography: "I disliked public speaking and had a firm conviction that I should break down every time I opened my mouth. I believe that I had every fault a speaker could have (except talking at random and indulging in rhetoric)." But these two faults alone are incurable in a public speaker and unpardonable to a man of science. The other faults, whatever they may have been, were overcome by persistent effort and experience.

"His writings," says Professor Lankester, "are marked by his individuality—clear, graceful, humorous, incisive. He had a very large share of the artistic temperament, as was apparent both in his skill in the use of the pencil and in his extraordinary aptitude in the use of language. He had a fine innate taste which demanded excellence in form of expression. This was gradually cultivated by his efforts to expound scientific thoughts and methods to a degree which gave him an unrivaled position as a speaker and writer. His grace and artistic finish of expression were the more noticeable from the rigid adherence to truth

and moderation which characterized all his utterances. * * * He never delivered an attack without keeping shot in his locker." His strength of speech was that which has been called "honest eloquence," making his facts tell for themselves, and carrying his point by the weight of the truth on which he rested his opinions. As Professor Michael Foster has said: "One guiding principle in Huxley's life was the deep conviction that science was meant not for men of science alone but for all the world; and that not in respect to its material benefits only, but also and even more for its intellectual good."

Huxley was married in 1853 to Miss Henrietta O. Heathorn, whom he had met in Sydney while on the voyage of the *Rattlesnake*. His married life was most peaceful, and his wife, with one son and three daughters, survive him.

With the publication in 1859 of Charles Darwin's "*Origin of Species*" Huxley became one of the first and most ardent converts to the new doctrine. By Darwin's investigations a great flood of light was thrown on the problems to which Huxley had given his life. To the diffusion of the knowledge thus received he gave the whole strength of his voice and pen. He became at once the apostle and the expositor of the science of evolution.

Of his work for popular science Huxley thus speaks in the closing paragraphs of his remarkable autobiography:

"The last thing that it would be proper for me to do would be to speak of the work of my life or to say at the end of the day whether I think I have earned my wages or not. Men are said to be partial judges of themselves—young men may be; I doubt if old men are. Life seems terribly fore-shortened as they look back; and the mountain they set themselves to climb in youth turns out

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to be a mere spur of immeasurably higher ranges, when, with failing breath, they reach the top. But if I may speak of the subjects I have had more or less definitely in view since I began the ascent of my hillock they are briefly these: To promote the increase of natural knowledge and to forward the application of scientific methods of investigation to all the problems of life to the best of my ability, in the conviction—which has grown with my growth and strengthened with my strength—that there is no alleviation for the sufferings of mankind except veracity of thought and action and the resolute facing of the world as it is, when the garment of makebelieve, by which pious hands have hidden its uglier features, is stripped off.

"It is with this intent that I have subordinated any reasonable or unreasonable ambition for scientific fame which I may have permitted myself to entertain to other ends; to the popularization of science; to the development and organization of scientific education; to the endless series of battles and skirmishes over evolution; and to untiring opposition to that ecclesiastical spirit, that clericalism, which in England, as everywhere else, and to whatever denomination it may belong, is the deadly enemy of science."

In a letter to Professor Lankester, Huxley says that he "has never valued the discoveries of science so much as her methods." The methods by which truth may be won and used in the conduct of life constituted the first aim of all his efforts. In his plea for the study of biology in the schools he says somewhere that he would not "turn his hand over" to have zoology introduced in all the schools of Great Britain if it is to be taught in the old, stupid way, blind memorizing of the conclusions of some authority.

"If a man," he says, "asks me what the politics of the inhabitants of the moon are and I reply that I do not know; that neither I nor any one else have any means of knowing; and that under these circumstances I decline to trouble myself about the subject at all—I do not think that he has any right to call me a skeptic. On the contrary, in replying thus, I conceive that I am

THOMAS HENRY HUXLEY.

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN
DIRECCIÓN GENERAL DE BIBLIOTECAS

simply honest and truthful, and show a proper regard for the economy of time."

This is the spirit of that which Huxley termed "agnosticism," a word which has been woefully abused by its friends and enemies since Huxley first adopted it for himself.

With Emerson, he would have no one "pretend to know or believe that which he really did not know or believe." And to get rid of all shams, to strip off all "garment of makebelieve," is the first requisite to any honest and saving faith, whether in science or in conduct or in religion.

Huxley's life work was that of a teacher of the people rather than that of a trainer of individual men. He was a lecturer to many rather than a teacher of a few, and for this reason he has left no school of followers, no band of disciples. As an expositor of popular science only Tyndall and Agassiz in modern times can be compared with him. As an essayist he stands in the front rank among English writers. As an original investigator his rank was very high, though not the highest. As a controversialist he has had no rival among men of science. His resources were unbounded; his blade was sharp; and, like a true Briton, he loved a fight. But unlike most famous debaters he was always on the right side. He never sacrificed truth or justice to make his point. It is in his power of exposition and his lifelong insistence on right thinking as fundamental to right living that Huxley's influence is greatest and most lasting.

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THOMAS HENRY HUXLEY

SELECTED STUDIES AND REMINISCENCES

HUXLEY'S EARLY ACQUAINTANCE WITH ILL-HEALTH

"The extraordinary attraction I felt towards the study of the intricacies of living structure nearly proved fatal to me at the outset. I was a mere boy—I think between thirteen and fourteen years of age—when I was taken by some older student friends of mine to the first post-mortem examination I ever attended. All my life I have been most unfortunately sensitive to the disagreeables which attend anatomical pursuits; but on this occasion, my curiosity overpowered all other feelings, and I spent two or three hours in gratifying it. I did not cut myself, and none of the ordinary symptoms of dissection poison supervened; but poisoned I was somehow, and I remember sinking into a strange state of apathy. By way of a last chance I was sent to the care of some good, kind people, friends of my father's, who lived in a farmhouse in the heart of Warwickshire. I remember staggering from my bed to the window on the bright spring morning after my arrival, and opening the casement. Life seemed to come back on the wings of the breeze; and, to this day, the faint odor of woodsmoke, like that which floated across the farm-yard in the early morning, is as good to me as the "sweet south upon a bed of violets." I soon recovered; but for years I suffered from occasional paroxysms of internal pain, and from that time my constant friend, hypochrondriacal dyspepsia, commenced his half century of co-tenancy of my fleshly tabernacle."—*From Professor Huxley's "Autobiography" in Louis Engel's "From Handel to Hallé."*

HUXLEY'S CHARACTER

No subtle analysis is needed to explain Huxley's character, the beauty of which consisted in being completely natural, and much that he says of David Hume, in one of his "*Essays,*" might be applied with equal justice to himself. He possessed in a high degree that rare but open secret to which General Gordon owed so much of his marvelous influence; he was always himself, the same to young and to old, to rich and to poor, to men and to women, and had his lot been cast like Gordon's in Asia, or in Africa, he would doubtless have been the same to Orientals as to Europeans. He was frank because he was fearless; he inspired confidence because he was evidently a true-hearted man; his native self-respect was set off by a respectful manner towards others; his intolerance of sophistry sometimes betrayed him into undue vehemence in controversial writing, but there was no pettiness in his *odium scientificum,* and a pure love of truth shone through all his most trenchant diatribes, political or theological. As I shared most of his convictions on politics, we talked over such questions without reserve, but I forbore, and never had occasion, to discuss with him questions concerning religious doctrine. I have, therefore, no right to speak from personal knowledge of his attitude towards them. I cannot doubt, however, that whatever his creed, his inner life was that of a good Christian, and that his hopes went beyond his beliefs, though he was too honest to mistake hopes for beliefs, or beliefs for demonstrations.—HON. GEORGE C. BRODRICK, D. C. L., *Warden of Merton College, Oxford, in "The Fortnightly Review."*

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN
DIRECCIÓN GENERAL DE BIBLIOTECAS

HUXLEY IN HIS OWN HOUSE

Mr. Huxley's relations with his friends were of a kind which may be called affectionate. It was a pleasure to see him among them and among his own family. During many years while he lived in London, I saw him often in these agreeable circumstances. His house was in Marlborough Place, St. John's Wood, a neighborhood which, though esteemed a little remote and well out of touch with the merely fashionable world, had attractions of its own. There is a St. John's Wood "set" of artists, Mr. Alma-Tadema then and now at the head of them. There is, or was, a literary set, of which the most distinguished figure was George Eliot. Then comes a very miscellaneous company of people who liked the district because it has air and space, and is not too dear. Mr. Huxley's house stood in its own grounds, of moderate size; the house itself roomy enough, well but plainly furnished. Here there used to be, every Sunday evening, a dinner, followed by a reception. You would be wrong, if you supposed that these terms implied state or ceremony. There was none, though the number of people who sat down at dinner was often as many as sixteen or eighteen, sometimes more. Mr. and Mrs. Tyndall were among the most frequent. Tyndall and Huxley were as brothers. The public looked on them as rivals, and so perhaps in a sense they were; but the rivalry, if it existed consciously to either, never affected their relations to each other. They were comrades; co-workers in a great common cause, and they loved each other. Mr. Herbert Spencer came less often. His health has never been such as to allow of much dining out, even with intimate friends.

When he came, there was almost always a discussion of high matters relating to science or philosophy, which commonly, at least often, on Mr. Spencer's part, degenerated into argument. To that, also, his health was unequal, and a sleepless night was the penalty he paid. But there was in Mr. Spencer's loyalty to his convictions, and in his belief that in all circumstances the right opinion, which of course was his own, must be defended and the wrong combated, something pathetic. The gallantry of his struggle against physical weakness touched you; it touched Mr. Huxley, who never forgot that he was host. At his own table he avoided arguments when he could. Others, or all others, did not. Mr. Huxley sat there with a serenity and patience which were admirable, joining in discussions in a way to mitigate their severity; he himself, too, of a nature averse to all compromise, but keeping under the purely intellectual view and reviving the social view, when too eager disputants seemed in danger of taking some other. If I were to name all those who used to assemble in this easy way in the reception-rooms of the house in Marlborough Place, it would be a long catalogue.—GEORGE W. SMALLEY, *in "Scribner's Magazine."*

HUXLEY'S ONE INDULGENCE—HUXLEY AS A WORKER

Neither Tyndall nor Mr. Herbert Spencer smoked. Mr. Huxley liked his pipe, and would never admit that tobacco in moderation could hurt anybody. He rallied me when I gave it up, as if to abandon this consolation of life were to confess a defeat; and I suppose it was. But he was not a man to generalize about individuals. He was a physiologist, and a very great one, with, in that as in everything

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN
DIRECCIÓN GENERAL DE BIBLIOTECAS

else, the infusion of common-sense which saved him from over-confidence. Each must judge for himself what suits him was his maxim.

In his own case he carried it very far. His life was almost ascetic. Tobacco was perhaps his one indulgence. A great part of the work by which the world knows him was done after dinner, and after a hard day's work in the lecture-room and laboratory. He never spared himself. Often and often have I known him leave the circle of family and friends, of which he was the life, very early in the evening, and betake himself to his library; a room of which the only luxury was books. If remonstrated with, or appealed to for another half-hour, he would only shake his head. There was something to be done. And it would be midnight, or one or two o'clock, before it was done, and then he was up at seven in the morning. I sometimes thought he had no higher happiness than work; perhaps nobody has. He would dine on a little soup and a bit of fish; more than that was a clog on his mind. "The great secret," he said, "is to preserve the power of working continuously sixteen hours a day if need be. If you cannot do that you may be caught out any time."—GEORGE W. SMALLEY.

HUXLEY'S PAINSTAKINGNESS AS A WRITER

An infinite capacity for taking pains—that, I think, he valued himself on. His literary work shows it in a degree not less than his scientific. He must be placed very high among contemporary writers. Contrast his style with that of the ordinary writer on science, who has no style, or with a very extraordinary man's, Darwin, who had a very bad style. Tyndall wrote admirably, with perhaps an exuberance of rhetoric, inevitable to an Irishman. But Huxley dealt in the simplest, most lucid, most effective manner with the most difficult subjects. You were never at a loss for his meaning; if you were, it was your fault, not his. He had a sobriety of ornament which was more to his taste and more to his readers' than the Corinthian style. He had vigor and that imaginative use of language without which the full value of words is never brought out. He hated writing and forced himself to write, and also taught himself. Somewhere he tells how, on his return, I think from the *Rattlesnake** voyage, he had all his material ready, which had cost him ten times more labor than the writing it out would require. But he could not bring himself to write. He early conquered that repugnance, though I doubt whether he ever wrote fluently or easily. I once asked him. "Oh, I can write fast enough if that is all," was his answer, "but if it is anything important, I take as much time as I need." A letter of his had just appeared in *The Times*, an important one on a controverted topic. I asked how much trouble he had taken with it. "Why, I wrote that over three times." The quality he valued most in style was, perhaps, precision. That and perfect clearness and perfect sincerity.—GEORGE W. SMALLEY.

HUXLEY AS A DEBATER

I saw a good deal of Professor Huxley during the years when his great gifts and energies were at their meridian, especially between the years 1870 and 1877; for in 1869 we both took part in the formation of a society of which he

* Huxley when a young man had been on a four years' scientific voyage in a government ship called the *Rattlesnake*.

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was one of the most brilliant members—the Metaphysical Society; and in 1876 we sat side by side on a Commission in which he happened to represent diametrically opposite points of view,—the Commission to inquire into the character of painful experiments on living animals, and the desirability of imposing, on those who make them, such limitations as might prevent the infliction of the kind of torture of which there are in Europe, and even in England, too many instances. In both cases I had many opportunities not only of observing him closely, but of entering with him into those more conversational discussions which were not limited by the conventional rules of even semi-public debate. And my own impression certainly was that an abler and more accomplished debater, was not to be found even in the House of Commons, and that he was never more effective than when he diverged from the narrower field of the specialist into the wider fields of popular interest. He made extraordinarily effective use also of his very wide and accurate reading in his own special studies, a kind of use which often puzzled the so-called metaphysicians, and reduced them to bewildered silence. For example, I shall never forget the dismay with which many of us heard his paper on the question, "Has the frog a soul, and of what nature is that soul, supposing it to exist?"—RICHARD HOLT HUTTON, *in "The Forum."*

HUXLEY'S MOTHER-WIT IN ARGUMENT

It need hardly be said that Huxley, a scientific fighter, if there ever was one, was in his element in resisting any attempt to overbear the new Anthropology by philosophical declamation or claim of authority. Many who were present

still remember with amusement a scene at the British Association meeting at Exeter in 1869, when Anthropology, then represented by a sub-section of biology, drew dense crowds assembled to hear the anthropologists have it out with the parsons. A theologico-metaphysical attempt to sweep away the development-theory before a gale of declamatory appeal to orthodoxy, backed by the irrefutable combination of intuition and the evidence of sensation, brought up Huxley. With calm seriousness he performed the familiar experiment of touching the tip of his nose with his crossed fingers, inviting his delighted audience thus to satisfy themselves that each of them had two noses, unless indeed they were willing to admit that the systematic comparison of observations, which is called science, had something to do with the formation of a reasonable judgment.—PROFESSOR E. B. TYLOR (*of Oxford*), *in "The Nineteenth Century."*

HUXLEY AS A LECTURER

At the outset of Huxley's public career lecturing was as distasteful to him as in earlier years the trouble of writing was detestable. But mother wit and "needs must" trained him in a short time to win the ear of an audience. One evening in 1852 he made his début at the Royal Institution, and the next day he received a letter charging him with every possible fault that a lecturer could commit—ungraceful stoop, awkwardness in use of hands, mumbling of words, or dropping them down the shirt front. The lesson was timely, and its effect salutary. Huxley was fond of telling this story, and it is worth recording—if but as encouragement to stammerers who have something to say

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—at what price he "bought this freedom" which held an audience spell-bound. How he thus held it in later years they will remember who in the packed theater of the Royal Institution listened on the evening of Friday, 9th of April, 1880, to his lecture "*On the Coming Age of the Origin of Species.*"—EDWARD CLODD, *in "Pioneers of Evolution from Thales to Huxley."*

HUXLEY'S MEMORABLE ADDRESS ON "THE COMING OF AGE OF DARWINISM"

On the platform Mr. Huxley was a commanding figure. He had in him the gift of oratory, had he cared to cultivate it. Of course he was at home in the lecture-room; he had spent half his life in it. Some of his appearances there will be forever memorable. There have been few evenings in the well-like auditorium of the Royal Institution in Albemarle Street comparable to that when Huxley delivered his discourse on "*The Coming of Age of Darwinism.*" Many a brilliant audience has that hall seen—it is the meeting-ground of Science and Society—perhaps never one which surpassed this. It was known that he had chosen this subject; it was inferred that he would review the controversy in which he had been a foremost champion, and there was an expectation, not to be disappointed, that he would fight some of his many battles o'er again. So Society, ever on the alert for a fresh sensation, thronged to the scene.

At the Royal Institution more than almost any where else, the lecturer, on whom the concentric circles of spectators in their steep amphitheater look down, focuses the gaze. Huzley never seemed aware that anybody was looking at him. From self-consciousness he was, here as elsewhere, singularly free, as from self-assertion. He walked in through the door on the left, as if he were entering his own laboratory. In these days he bore scarcely a mark of age. He was in the full vigor of mature manhood, and looked the man he was. Faultlessly dressed,—the rule in the Royal Institution is evening costume—with a firm step and easy-bearing, he took his place apparently without a thought of the people who were cheering him. To him it was an anniversary. He looked, and he probably was, the master. Surrounded as he was by the celebrities of science, and the ornaments of London drawing-rooms, there was none who had quite the same kind of intellectual ascendancy which belonged to him. The square forehead, the square jaw, the tense lines of the mouth, the deep, flashing dark eyes, the impression of something more than strength he gave you, an impression of sincerity, of solid force, of immovability, yet of the gentleness arising from the serene consciousness of his strength—all this belonged to Huxley and to him alone. The first glance magnetized his audience. The eyes were those of one accustomed to command, and of one having authority, and not fearing on occasion to use it. The hair swept carelessly away from the broad forehead and grew rather long behind, yet the length did not suggest as it often does, effeminacy. He was masculine in everything—look, gesture, speech. Sparing of gesture, sparing of emphasis, careless of merely rhetorical or oratorical art, he had nevertheless the secret of the highest art of all, whether in oratory or whatever else—he had simplicity. The force was in the thought and the diction, and he needed no other. The voice was rather deep, low, but quite audible, at times sonorous, and always

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full. He used the chest-notes. His manner here, in the presence of this select and rather limited audience—for the theater of the Royal Institution holds, I think, less than a thousand people—was exactly the same as before a great company whom he addressed at Bristol, as President of the British Association for the Advancement of Science. I remember going late to that, and having to sit far back, yet hearing every word easily; and there, too, the feeling was the same, that he had mastered his audience, taken possession of them, and held them to the end in an unrelaxing grip, as a great actor at his best does. There was nothing of the actor about him, except that he knew how to stand still, but masterful he ever was.—GEORGE W. SMALLEY.

READERS' AND STUDENTS' NOTES

1. The account of Huxley's life, like that of Tyndall's, is to be sought for principally in biographical notices in periodicals and magazines. But of Huxley there is also a very interesting autobiography. In that curiously entertaining book of Mr. Louis Engel's, entitled "*From Handel to Hallé,*" a book for the most part made up of biographical accounts of musicians, there is a chapter contributed by Professor Huxley relating to himself. He has prefixed to it these characteristic words: "You put before me the alternative of issuing something that may be all wrong, unless I furnish you with something authoritative. I do not say 'all right,' because autobiographies are essentially works of fiction, whatever biographies may be. So I yield, and send you what follows, in the hope that those who find it to be mere egotistical gossip will blame you and not me." (New York: Scribner & Welford.)

2. In "*Scribner's Magazine*" for October, 1895, is a sketch of Huxley by Mr. G. W. Smalley. This sketch is certainly as interesting and instructive as to its subject as it is possible for a

short sketch to be. It takes up Mr. Huxley's personality and characteristics in many phases; and every phase is illustrated by personal reminiscences.

3. Other sketches of Huxley's personality and estimates of his work are to be found as follows: (1) in "*The Forum*" for September, 1895, by the well-known writer, Richard Holt Hutton; and (2) in "*The Fortnightly Review*" for August, 1895, by the Hon. G. C. Brodrick, Warden of Merton College, Oxford, Professor E. B. Tylor, the anthropologist, and W. L. Courtney, the editor of "*The Fortnightly Review.*"

4. A slight biographical sketch of Huxley, together with an extensive examination of Huxley's work as "a pioneer of evolution" (66 pages), is to be found in Edward Clodd's "*Pioneers of Evolution from Thales to Huxley,*" previously mentioned (New York: D. Appleton & Co. $1.50).

THE END

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