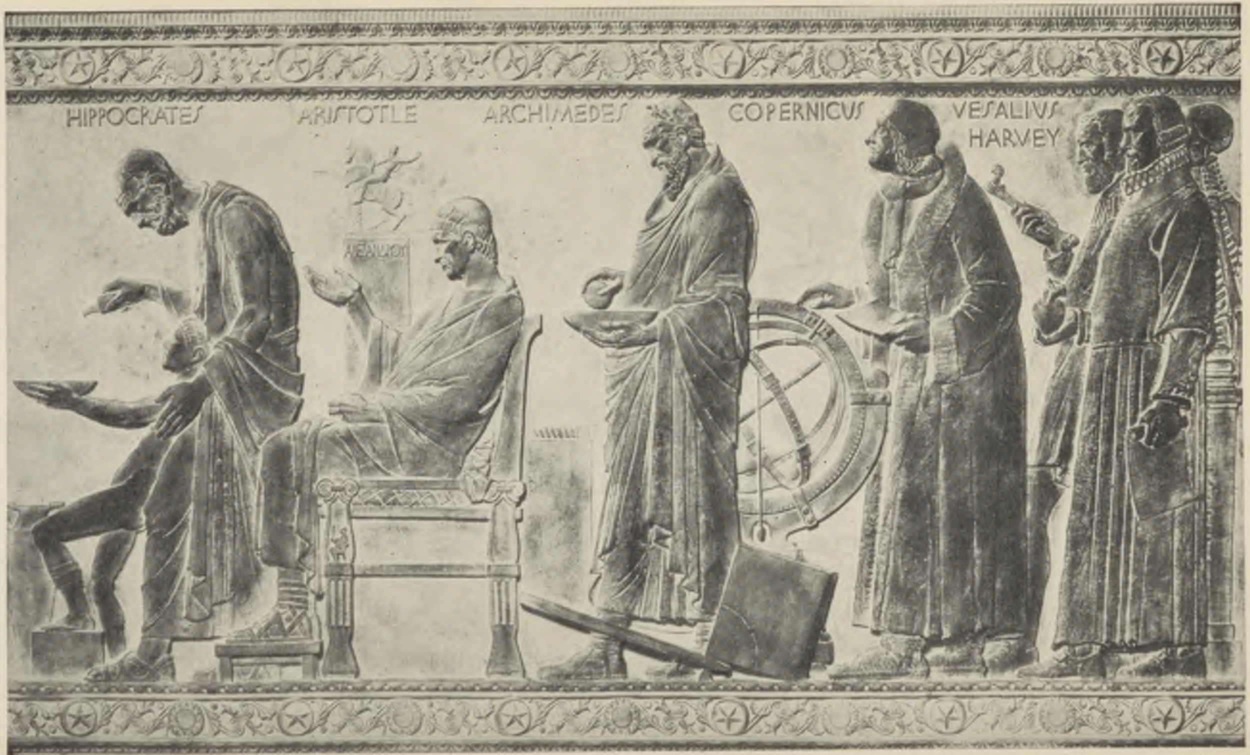
BEACON LIGHTS OF SCIENCE

BEACON LIGHTS OF SCIENCE


HIPPOCRATES
ARISTOTLE
ARCHIMEDES
COPERNICUS
VESALIUS
HARVEY

Frontis.

BEACON LIGHTS OF SCIENCE

A SURVEY OF HUMAN ACHIEVEMENT FROM THE EARLIEST RECORDED TIMES

BY

THEO. F. VAN WAGENEN

NEW YORK
THOMAS Y. CROWELL CO.
PUBLISHERS

Printed in the United States of America

INTRODUCTION

In the following pages the attempt has been made to sketch, in outline, the development of Science throughout the centuries, in the lives of those individuals who, in their time, have contributed notably to its progress. Naturally it has been impossible to include all who have taken some part in the great work. And also, many of the most prominent are still with us, their labors unfinished.

To the young man preparing himself for a scientific career, or entering upon its duties and obligations, the efforts of those thinkers and discoverers who have passed on and left to him the rich heritage of knowledge so far accumulated should be an inspiration and an incentive. Or, taking a lower view of the matter, he should at least know enough of their lives to be able to connect the discoveries with the discoverers and to have some conception of their personality. We cannot be too mindful of the difficulties with which they had to contend in their explorations in a field of mystery, where none before them had blazed a path.

Doubtless there were true scientists before Euclid. But of them so little is certainly known, and with their discoveries so much of mysticism has been blended, that their stories come to us enveloped in a haze through which it is difficult to arrive at a fixed starting point. It is also hard to draw a line which shall clearly leave on one side the conclusions of speculation, and on the other the logical deductions from correctly observed phenomena. It seems clear, however, that the habit of collecting and classifying observed facts of nature (mainly astronomical) began with the Semitic people, and from them passed to the Aryans by way of that first intellectual flowering of its civilization, the Greeks. But the latter lived in an environment so beautiful, and possessed—probably as a result of it—a temperament so aesthetic, that cold-blooded study of nature was uncongenial, and to all but a very few impossible. If the contents of the lost Alexandrian library could be restored intact and made accessible to the modern student, it would no doubt prove of surpassing interest, but probably also of little value to science.

As the glory of Greece faded under the stern shadow of Roman dominion, about all that the latter inherited from it, in the way of real knowledge, was the beginnings of the science of mathematics. Rome contributed practically nothing in its day to the explanation of natural phenomena, though it acquired a vast amount of empirical information through experience in dealing with its forces. And when, through the revival of mysticism, the Dark Ages came on, enveloping all Europe in their gloom, Science slumbered and dreamed for centuries, while Astrology and Alchemy wore its mask, and posed on the stage in the tinsel garments of a dead and forgotten past.

It is difficult for us today to believe that in Europe, for more than a thousand years, the children who were born into the world were taught by their elders that there was but one true source of knowledge—religion—and that it was not only useless but impious to seek for the explanation of natural phenomena elsewhere. When at last revolt against this monstrous misconception began, Science awoke from its long sleep; at first—as before—in the form of a revival of interest in the fundamental branch of mathematics, which was quickly followed by renewed activity in astronomy and mechanics, the two departments whose manifestations were most readily open to observation.

Once recalled to life, other departments of knowledge became recognized in turn as they appeared as true children of science, and worthy descendants of those few masters among the ancients who, brushing aside as unworthy of their time the delights of speculation, devoted their energies to observation, and to the drawing of conclusions from the marshaling and classification of well demonstrated facts, rather than from the processes of ratiocination. Yet the paths of these pioneers were beset with difficulties. Copernicus was proclaimed a heretic by both of the grand divisions of the Christian church, Galileo was compelled to recant on his knees, and Darwin of a much later time was called an atheist, though all were men of deep religious feeling whose lives were full of love and respect for their fellows.

In arranging the order of these sketches, the life period has determined the sequence. With a few unimportant exceptions this brings to the reader in turn the different branches of knowledge as they were developed. Thus, with the exception of the early Greek studies in anatomy, mathematics, mechanics, and astronomy were the only sciences in existence up to the early years of the seventeenth century, when Mersenne, Harvey, and Gunter led the way with discoveries in acoustics, physiology, and magnetism. During the remainder of that period optics and physics were added. The eighteenth century witnessed the beginnings of the electrical, chemical, and geological sciences, and towards its close physiology and anatomy had become well founded on demonstrated facts.

In the nineteenth century all these departments of research were greatly developed, and chemistry, the science of matter, easily took first place in importance, with physics a close second, and philology, embryology, meteorology, anthropology, ethnology, pathology, biology, and a host of minor "ologies" crowding upon the stage from the wings and demanding recognition. Towards its end, physics, the science of energy, displaced chemistry in importance, and at the present time is well in advance, while the thinkers of the world are reaching out into the new fields of psycho-physics and psychology in the hope—and the expectation—of being able to solve with their aid some of the mysteries behind those concepts of matter and energy whose laws and manifestations are now fairly well understood, but whose causes still remain unexplained.

T. F. V. W.

August 1, 1924.

CONTENTS

I. ANCIENT TIMES

II. THE MIDDLE AGES

III. THE SIXTEENTH CENTURY

IV. THE SEVENTEENTH CENTURY

V. THE EIGHTEENTH CENTURY

Contents

ILLUSTRATIONS

"THE FOUNDERS OF SCIENCE"

The above is the caption of a series of bas-relief portraits in bronze decorating the new million-dollar building of the National Academy of Sciences and the National Research Council, in Washington, D. C. Thirty-seven world scientists were chosen, only two of whom were American.

I

ANCIENT TIMES

For the purpose of this volume it will be convenient to define its first department (Ancient Times), as the epoch extending from the beginnings of recorded human history, up to the fall of the Roman Empire in the year 476 of the present era, a period covering certainly 6000 years; for inscriptions that are clearly alphabetical in their character appear on many of the Egyptian and Chaldean monuments, whose age has been determined as early in the 5th millennium B.C. And before them for an unknown time were the years of hieroglyphs.

But we may safely deduct at once at least four millenniums from this reckoning, as a period during which the art of writing was confined wholly within the priestly class, and employed only to record the principal acts of rulers, or startling occurrences like famines, floods, eclipses, etc. And about as safely another thousand, for the slow development of a script convenient enough in execution, to permit of the recording of conclusions arrived at by observers of those natural phenomena that were daily presented to the senses and minds of the civilized people among the ancients. This brings us down to a date somewhere between 750 B.C. and 500 B.C., at which time appeared Thales of Miletus, the first of whose story enough is known to warrant his inclusion in a list of scientists—that is, of collectors and classifiers of observed phenomena, apparent or real. Certainly there were students and scholars before his day, for by then much true knowledge of various kinds had accumulated, but their names and their histories have been lost.

During the eleven hundred years remaining of the period, namely, from 624 B.C. to 476 A.D., history has preserved less than a score of names worthy of enrollment as "Beacon Lights of Science." It is a significant fact that, of the total number, sixteen belonged to the Greek race, the other two, Thales and Ptolemy, being respectively of Phœnecian and Egyptian ancestry or birth. And, as showing the versatility of Hellenic culture, four of these attained eminence in mathematics, four in astronomy, two each in botany and the healing art, one each in general philosophy, mechanics and anatomy, while to Empedocles must be accorded the supreme honor of having formulated the first known conception of the theory of evolution.

BEACON LIGHTS OF SCIENCE

THALES (circa 624–560 B.C.)

PRIMITIVE THEORIES

Thales is reputed to have been a native of Miletus, a very famous ancient Greek city located on the western coast of Asia Minor at the mouth of the Maeander river. By race he was of Phoenecian ancestry. He seems to have been possessed of engineering capacity, for he was engaged to construct an embankment along a portion of the shores of the river Halys. He was also a merchant of importance, and traveled extensively, particularly in Egypt, where he became familiar with such astronomical and mathematical knowledge as by then had accumulated among the priesthood. In consequence, upon his return to Miletus, he was able to predict an eclipse of the sun, which actually occurred in the year 585 B.C., and acquired thereby a great reputation. Being a man of wealth and leisure he decided to devote the balance of his life to philosophy, and was regarded either then or later, as one of the six or seven wise men of ancient Greece.

He taught that the fundamental element of which all things was composed was water. That the earth floated upon it; that it was the cause of earthquakes and volcanos; that it was the main component of all vegetation—which apparently could not exist without it; of all animal life that lived on vegetable food, and hence by necessity, of all flesh-eating animals, including man. According to some of his commentators he regarded earth (soil and rocks), air and fire as also of elementary character, though of secondary importance. He is credited with having believed that the earth was of the form of a sphere, and that the year consisted of exactly 365 days. He expressed his views in words only and committed nothing to writing.

Thales, whether a real or a legendary character, represents the beginnings of Greek intellectual life. Before his day much information about the ordinary phenomena of life had been gathered in Egypt, Chaldea, Phoenecia, and to a lesser extent in India and China. But life was hard and unlovely among all those people, for they occupied regions where climatic conditions were severe, and the struggle for existence a pitiful one, except for the favored few. To the Greeks, however, had been given a pleasanter homeland, a more genial climate, and an environment that encouraged thoughtfulness and a desire to understand the causes of things. As their civilization advanced, a very considerable percentage of the mass of the population lived in comfort and comparative luxury. Out of such conditions arise appreciation of the beauties of nature, and a desire to produce beautiful things, in other words, the fine arts. Also a tendency to speculate about the mysteries of life and the universe, but without any observational foundation. These were the impelling and prevailing tendencies in Grecian life until the time of Aristotle (about 350 B.C), who taught a more correct way of looking at things.

ANAXIMANDER (610–546 B.C.)

MATHEMATICS

ANAXIMANDER was born at Miletus, one of the populous and famous ancient cities of the western coast of Asia Minor. Very little is known of his personal history beyond the fact that he became, after the death of the philosopher Thales, the head of the Ionian school of Greek thought. Aside from the reputation which this position brought to him, he is generally credited with having been the first among the ancients to proclaim that the axis of the earth must be inclined to the extent of about 23 degrees to the plane in which it stood (or moved) with respect to the sun. In other words, he taught as a fact the phenomenon we now call the obliquity of the ecliptic. Yet there is no clear evidence that he had any true conception of the shape of the earth, of its revolution on its own axis, or of its annual journey around the sun. Yet he is believed to have been the inventor of those old astronomical devices the gnomon and the polos. The views of the cosmos held in his day were full of strange contradictions. It is difficult to believe that a mind capable of reaching so close an approximation to the cause of the annual change of seasons, and of producing an instrument capable of indicating divisions of time by the changing positions of the shadow it cast, could have been wholly unacquainted with the causes behind these results. But, as was the case with most, if not all of the Greek philosophers, Anaximander seems to have held and taught, along with a few correct facts of Nature, many others that now seem absurd. For instance, his conception of the Universe appears to have been that of at least three concentric transparent and revolving cylinders, to the outer one of which the sun was firmly fixed, while the middle one carried the moon, and the innermost one the stars. Within these was the earth, also cylindrical in form, and either stationary or moving with the others. He was uncertain as to the position of the five planets then known. On the other hand, according to some of the ancient writings, he made some excellent approximations of their size and relative distances from each other.

PYTHAGORAS (c. 580–500 B.C.)

ASTRONOMY

Such accounts as have come down to us of the life and activities of this traditionally famous Greek, are not at all clear, and much is plainly pure myth. He appears to have been a native of Samos, an island off the west coast of Asia Minor; but of his ancestry and of his youthful years we have no reliable information. In his early maturity he appeared in the city of Cretona, in the southern part of Italy, which at the time was the seat of a Grecian colony. Here he founded a society or brotherhood, of the nature of an intellectual autocracy, which later took on a political cast, and became deeply involved in the fierce struggles then in progress throughout the Grecian world between democracy and plutocracy. In the end the few Pythagoreans who survived were driven from the country. It is not known whether Pythagoras escaped before the culmination of this event, or perished in it. Whichever was the case, Pythagorism represented subsequently some very strange conceptions of the Universe, which have come to us through contemporaneous and subsequent writers, but so alloyed with fable and nonsense that students of Grecian history and thought have found it very difficult to decide with any degree of certainty much more than the outline of his teachings. Not a word that could be safely ascribed to him personally has been preserved, and of the writings of his disciples we have only fragmentary remains. From these, and from later writers, two of the more startling of the tenets of the cult appear to have been as follows:

As to the substance of the world, they conceived it to be composed of material atoms, each one of which was so infinitesimally minute as to represent position only, without size. Two, side by side, expressed a line and conveyed the idea of direction, but again without magnitude. Three (one being at right angles to the other two) indicated surface, but without thickness, thus being merely the representation of area or extension; while four (the fourth at right angles to the other three) constituted a solid, or the conception of Form. Thus the three-dimensional property of Space was reached and explained. It was regarded as unlimited in extent, and filled with air, or, according to others, a void. As to the atom, if it were of earthy matter it was believed to possess the shape of a cube; if of fire, that of a tetrahedron or three-sided solid; if of water, that of an icosahedron or twenty-sided figure, while those of all other substances were twelve-sided masses. Out of all this rubbish the only item of importance is the conception of the atom as the ultimate component of matter.

In regard to the external Universe, the Pythagoreans taught that at its center there was a source of light and heat in the shape of a perpetual and intense fire, and that all the heavenly bodies—including the earth—revolved around this in concentric circles at various distances apart. That the earth was the nearest to this source, and made its revolution in such a way that one of its hemispheres always faced this source (just as one face of the moon only is presented to the earth), and was necessarily uninhabitable, on account of its intense heat. All the other celestial bodies shone by reflected light only, the earth obtaining its share by reflection from the largest of them, the sun. When the earth is on the same side of the central fire as the sun the phenomenon of daylight exists. When it is on the opposite side, that of night supervenes.

These examples of Pythagorean philosophy are sufficient to show that its founder and his disciples were people gifted with vigorous imaginations, but poorly equipped with demonstrated facts; just such a combination as might have been expected of the lively and speculative Greek mind at that age of the world; so different in its nature from that of the still older Egyptians and Babylonians, each of whom developed theories of the Universe of a very different kind.

Whether Pythagoras ever existed as an individual, or whether the name simply stands for a system of philosophy having for its object to account for the innumerable mysteries of existence, the cult very properly takes its place among the beginnings of science for, in spite of the mass of error it stood for, here and there appear conceptions and conclusions that have since been demonstrated as realities.

EMPEDOCLES (495–435 B.C.)

EVOLUTION

This Greek philosopher was born of a distinguished family whose home was in the city of Agrigentum in Sicily, when that island was a Grecian colony. In addition to having attained a high standing as a physician, he is regarded as one of the notable philosophers of the ancients. He also appears to have been a strong advocate of certain political doctrines of a democratic tendency, which he endeavored to put in practice in his native city. Very little reliable information of his life has been preserved, but many marvelous stories have come down to us relating to his beliefs and ideas, and to his powers as a physician. The most of these are simply exaggeration, though perhaps based on real facts of a less startling nature. Of the manner of his death several tales are told. The most common was to the effect that he leaped into the crater of Mt. Aetna. Another states that he experienced translation, after the manner of the Jewish prophet Elijah. He is said to have performed several miracles, one of which was to bring back to life a young girl long dead; and another to avert from Sicily a pestilence raging in southern Italy, by compelling a change in the direction from which the wind was blowing.

Amid all this legendary nonsense it seems to be a fact that he was one of those early thinkers who had grasped some germs of the idea of evolution, in his endeavor to account for the mysterious phenomena of the Universe. Aristotle was another. With Empedocles the theory took form in the saying that "Nature produces those things which, being continually moved by a certain principle contained in themselves, arrive at a certain end." To connect the rather obscure meaning of this sentence with the modern doctrine of evolution requires some knowledge of the brand of philosophy he represented. He held that "Being," by which he meant Matter, was eternal and imperishable. He considered it to be of four kinds or elements mutually independent, namely, earth, air, fire and water. He maintained the existence of two fundamental and opposing forces, which he typified as Friendship and Strife; the first of which was the indwelling and normal principle, and the second the external and abnormal one. These two, in their perpetual conflict, the one to maintain the status quo and the other to change it, produced all the phenomena of nature. He held that these changes were constantly and imperceptibly occurring, and had been throughout unknown ages in the past, with the effect of steady progress upward in all phases of existence. Finally, that man was, at the present, the highest product of the process. In thus indicating that the principle he called Strife—by which perhaps he intended to convey the idea of competition for existence or supremacy—was always in the end victorious, he may have grasped the germ of the idea at the foundation of Darwinianism, the survival of the fittest. With Empedocles chance, or accident was the cause of the successes of Strife over Friendship. Aristotle rejected this as of the nature of an impiety.

DEMOCRITUS (circa 470–400 B.C.)

NATURAL SCIENCE

THIS notable Greek, whose birthplace was the ancient town of Abdara in Thrace, went by the name of "The Smiling Philosopher" among his intimates, because of the geniality of his disposition and his optimistic temperament. About all that is known of the details of his life is that he was a man of high moral character and strong religious tendencies, was well educated according to the standards of the time, was deeply interested in mathematics and astronomy, wrote extensively on these subjects and on philosophy, and had traveled through much of the civilized world of his day. Only fragments of his writings have been preserved. These were collected and published by Mullach in Berlin in 1843. From them, aided by references in, and commentaries by other writers—both Greek and Latin, it has been possible to deduce the general system of philosophy which he held, and probably taught.

It was based on a theory of that aspect of matter which the mind receives from the five senses, the essential nature of which has been considered, until recently as unknowable; but which now seems to have been resolved into one of the manifestations of the equally unknowable entity we call Energy. In his system a material atom was postulated, infinite in multitude, not all of one size or kind, but each endowed with the power of motion, and the ability to unite into aggregates of all dimensions, forms and quantities, under certain pre-ordained laws; some of which eventuated in the phenomenon of life, and others in static conditions, which were apparent in those manifestations like rocks and metals, which plainly lacked the vital quality. For these reasons his philosophy was known among the Greeks as the Atomic System. To Democritus therefore belongs the credit of having first conceived the idea of the material atom.

To what the theory led, and what speculative structure he reared upon its foundation, is not clear. He denied the existence of Design in the Cosmos, but asserted that of immutable law. Animals, vegetation, moving air and water, he regarded as combinations of atoms of average quality. Consciousness and thought the product of the coming together of particles of a finer kind. And he postulated the existence of a third and superior class, of which the substance of the High Gods was composed. Happiness he considered as the supreme object of existence. To attain it, the passions must be controlled, and temperance made the rule in all departments of life. As to a possible future stage of being, he seems to have had no theory.

It is thought by some students of the Greek mind that Epicurus (circa 324–270 B.C.) was a believer in his philosophy, and taught it, with probably some amplifications of his own. According to him, fear of the Gods and fear of death were the two great destroyers of human happiness, and the main objects in life were to overcome these terrors, by rising superior to them. Believing that Personality ended with death, he argued against looking to the future for any amelioration of present condition; insisted that life was wholly an affair of to-day, that it was beautiful, that it was the summit of wisdom to enjoy its gifts as they came, but always temperately, and with consideration for others. He thought that the gods were imperishable, and could have nothing to do with us, inasmuch as they lived on a different plane. If these were also the ideas of Democritus, they were rather above the average of the time, but have little value for the present.

HIPPOCRATES (circa 460–375 B.C.)

MEDICINE

HIPPOCRATES, the most celebrated Greek physician of his time, who is called the Father of the Medical Art, was claimed by his contemporaries to have been the seventeenth or nineteenth in direct descent through his father from the mythical Aesculapius, and through his mother from the equally mythical Hercules. He was a native of Cos, one of the Aegean isles, where he practiced his profession, and was at the head of the medical school there until old age compelled retirement. Much of his supposed history is undoubtedly fabulous and unreliable, but that he was an unusual man for his time, and held some very advanced views in anatomy, and on the treatment of diseases, can hardly be denied. The latter, broadly, took the form of a strong reliance on the forces of nature, and on the power of the body itself, to eliminate or overcome disorders even of a serious kind, if aided by proper regimen and improved environment. With this was coupled an equally strong disinclination to interfere with the normal functions of the organism by the administration of drugs. Thus, he often prescribed merely a change of climate, or an altered and limited diet, or the securement of conditions that would provide absolute quiet and long hours of sleep. Frequent bathing of the entire body, sometimes in cold, and at others in warm or hot water, was also a favorite method adopted.

It was probably this very sensible system which, as is now well known, will cure a very large percentage of human bodily ills, that brought him the high reputation accorded by his contemporaries.

The writings that bear his name are seventy-two in number, but many of them are now ascribed to his sons, Thesalus and Draco, and his son-in-law, Polybus, all three of whom were his assistants in his practice. The fifteen to twenty that are considered actually his are marked with a sanity of view and an absence of mysticism unusual for his age, and point to the conclusion that his reputation was well earned, though probably not so astonishing as some biographers of his time and since would have us believe.

PLATO (427–347 B.C.)

PHILOSOPHY AND MATHEMATICS

The real name of this Greek philosopher was Aristocles. He was a native of Aegina, a small island just off the southeast coast of Greece, and a dependancy of Athens. His parents were large land owners of the upper class, and in consequence he was given the best education that the times afforded, the most of which was absorbed at the Lyceum conducted by Socrates. Of the details of his life little is known, but according to tradition he distinguished himself as a youth in athletics, and was a composer of poetry. But none of his productions in this line has been preserved, for at the age of twenty he became so interested in the philosophy of his great teacher, that he is said to have burned them as unworthy. He was so affected and even embittered against the authorities of the time at the judicial murder of Socrates, that it is thought he left Athens shortly thereafter, and spent the following ten to twelve years in travel in northern Greece, southern Italy, Sicily, Libya and Egypt, in the search of a civilization where more liberal and friendly and honest conditions prevailed. Of the truth of this quest there is no clear evidence, but in the year 387 B.C. he was again in Athens, at the head of an organization called the Academia, which held its meetings in a public garden or grove outside of the city, that formerly had been a semi-sacred place, dedicated to the memory of a mythical hero named Academus. There, for forty years, and until his death, Plato taught, and discussed with his pupils the questions of the day and, as was the custom of the time, instructing them during the periods of recreation in athletics, on the theory that the body and mind should be developed together. Among his more famous pupils were Aristotle, Demosthenes, Lycurgus the financier and Eudoxus the astronomer. It is believed that Plato exercised unusual care in admitting students to his lectures, and refused to take pay from them, on the theory that Truth should be imparted freely to all who were earnest seekers after it.

His standing as a scientist rests primarily on the well-attested fact that, for his day, he was a mathematician of a high order, though not a discoverer of any new principles in numbers, or the developer of any new system of working with them. Nor did he teach it directly. In fact no one was allowed to attend his classes who had not already become fairly proficient in the science. Regarding it as the one department of knowledge in which certitude of result could be obtained where correct premises had been employed, he endeavored to lay the foundations of a system of philosophy which could be depended upon with equal confidence. In this he attained a certain degree of success, yet by no means a complete one. For, though we can today read much of his writings with advantage, and admit the possibility of some of his conclusions, the best thought of the world at present is to the effect that certain conceptions of which the human mind is capable are scientifically unknowable, in the sense that their parts cannot be assembled, classified, grouped and organized into a coherent body of demonstrated fact, that can be relied upon as long as it continues to be satisfactorily explanatory of observed phenomena.

In a day when polytheism was the accepted religion of the educated, Plato taught what may be described as a pure theism, that is, belief in a Deity related closely to all living things, vegetable, animal and human, but at the same time he made no attempt to define the nature of the relationship and, in fact, asserted that definition was impossible. Beyond this in religion he did not go. But in ethics he felt justified in going to great lengths.

Plato wrote very extensively. But much has been lost, and much that was originally credited to him is regarded as spurious by present-day students. Rejecting the latter, the fundamentals of the philosophy he taught seems to have been about as follows:

Truth is hard to find, and in many cases impossible; but it is wise to discuss it in all its aspects because, by such a treatment, much of error can be avoided.

As to conduct, which he called the "Royal Art," he regarded it as a science, which must be learned through experience, just like a material art, as carpentering. Its basic principle, self-sacrifice when necessary, once grasped, must be obeyed relentlessly to the end.

Plato was inherently a metaphysician, and metaphysics is regarded today as a diversion, which leads nowhere, and to nothing except temporary mental amusement. In other words, it is not common sense to the average human mind as at present constituted. As it may with reason be asserted that individual mentality has evolved to a higher state than was existent among the Greeks, his philosophy can be admired as among the most advanced of that time, his ethics can be commended whole-heartedly, but many of his conclusions should be recognized as adolescent in character, and below the standard which should be held now.

ARISTOTLE (384–322 B.C.)

NATURAL SCIENCE

THE distinguished thinker, Aristotle, was a native of the ancient Greek city of Stagira, which was situated on that curious three-pronged peninsula projecting into the Aegean sea to the south of the present city of Saloniki. In olden times the region was a part of the kingdom of Macedonia. He belonged to an aristocratic and wealthy family in which learning had been hereditary for many generations, his father having been court physician to King Amyntas II. He received the best education that the times could afford. At the age of seventeen he went to Athens and associated himself with the school of which Plato was the head, and studied under that great teacher for nearly twenty years, becoming towards the last one of his chief assistants. After Plato's death Aristotle moved to Mysia on the northwestern coasts of Asia Minor. Three years later, just before the capture of that place by the Persians, he removed to Mitylene, the capital city of the island of Lesbos in the Aegean sea. In 342 B.C. he moved to Pella, then the capital of Macedonia, and for the next three years supervised the education of Alexander, the presumptive heir to the throne, who later became Alexander the Great. When, by the death of his father, this youth became king, Aristotle remained seven years longer, attached to his court, and held in high esteem by his former pupil, to whom, in that period, he acted as an adviser.

In 334 B.C., at the age of fifty, Aristotle returned to Athens, and opened a school of his own, which at once became famous, and where he taught for twelve years until the death of Alexander in 323 B.C., when he moved to the city of Chalcis in Greece, and gave up his school in the attempt to recover his failing health. There, however, he died in the following year, at the early age of sixty-three years.

Aristotle was probably the most voluminous writer of ancient times. In his works he dealt with almost every subject of which the people of his day had knowledge, or thought they had. These included religion, law, logic, rhetoric, metaphysics, physics, astronomy, meteorology, natural history, botany, zoology, anatomy, medicine, mechanics, ethics, politics, physiology, psychology, poetry and literature in general. In matters of science (except mathematics and geometry) his works have no value at the present time, yet all of them exhibit remarkable analytical power, and such as have come down to us either in part or complete, have exercised an enormous influence. In many cases he gave expression to thoughts and conclusions which contain germs of discoveries made since. Perhaps the most notable of these was his speculation on origins and growths, which come very close to the fundamentals that are at the basis of the theory of Evolution. According to him, Being, or Existence, was the summation or visible expression of four universal elements or principles, which he named as Matter (in all its manifestations), Form (in all its variation of shape), Causes (active forces) and Results (evident effects). At the beginning of things he postulated a definite plan which, at the end of things, was to produce a definite and foreordained result. This, for man, was happiness; and for all the other expressions or manifestations of matter, such as plants, animals, and all phases of inorganic nature from rocks to planets and stars, was perfect adaptation to environment. Change was everywhere in progress; had been from the beginning, and would continue until the end planned had been attained. This process of slow alteration advanced step by step through potentiality to actuality, never ceasing its march. For chance, or free will, which Empedocles regarded as the cause of changes, Aristotle substituted a potentiality in two directions—for good and for evil—maintaining that the choice of either resulted in the habit of either, culminating in the two extremest of self-indulgence and asceticism, both of which were abnormal, reprehensible and unfortunate, while virtue was a middle course between the two, that is, temperance in all things. As for the fundamental cause of the continual changes in progress everywhere, in both the animate and inanimate worlds, he contended that it must be found in the perpetual contest between the inherent, invisible and unknown potentialities for good and evil.

The ancients had no collection of demonstrated facts upon which to base their reasonings, such as the scientists of the present time possess. It is therefore not difficult to understand the very diverse conclusions reached by their philosophers in their search for Truth. These have no value at the present day beyond their literary merit, and the evidence they give of the gropings of the human mind in the darkness that then surrounded it. But for nearly two thousand years those of Aristotle were controlling influences in the drama of humanity.

THEOPHRASTUS (370–286 B.C.)

BOTANY

THEOPHRASTUS was born at Eresus, on the island of Lesbos, in the Aegean sea, and was of Greek parentage. He studied at Athens, at first under Plato, and then in the Aristotlean school, which was called—perhaps in a spirit of levity—the Peripatetics, because, during its lectures, it was the habit of its master to walk around the court, and in the gardens adjoining it, his pupils surrounding and following him. At the death of Aristotle, Theophrastus was elected its chief. In purely philosophical matters he followed the teachings of the departed leader; but, having himself decided inclinations to natural history in its botanical aspect, he emphasized that science in his lectures until the school slowly came to be regarded as a collecting center, to which specimens from the world of vegetation were brought for investigation, classification and determination of character.

Unlike the herbalist Dioscorides, whose interest in plants was confined to the uses to which they could be put in the practice of medicine, Theophrastus sought to discover their relationship to each other, and was but slightly interested in their virtues. His first step was to separate them into the three broad categories of trees, shrubs and herbs, a classification which continued supreme from his day until near the close of the 17th century, when the better system of Linnaeus superseded it. Theophrastus is thus very properly regarded as the founder of the science of botany, for before him no one had attempted an organization of the members of the vegetable world.

Lacking the enormous aid which even the crude microscope of the day of Linnaeus afforded in the study of plants, the discoveries made and recorded by Theophrastus are remarkable. They appear in his writings mainly as isolated statement, which must have been obtained in dissection and analysis by unaided vision. And while his system was crude, being based only on the external feature of comparative size, and was only carried a few steps further by the subdivision of these three major orders, it was a beginning in the process of organization which at once differentiated his work from that of the herbalists.

Two of his literary products have come down to us in complete condition. One, entitled "History of Plants," is in nine books. The other, called "Theoretical Botany" is in six books. Besides these, he wrote essays on Minerals, on The Physical Senses, on Fire, on Metaphysics and on several other subjects of minor importance. But of them only fragmentary remains are extant. A volume of his sketches has been preserved almost intact. In 1592 a complete edition of all his known writings was published in Leyden, and in 1818 and 1866 in Leipsic and Paris. The first is most famous and useful, because accompanied by commentaries. It is a remarkable fact that in its pages are to be found many accurate descriptions of details in plant anatomy, which were rediscovered by modern botanists only with the aid of the microscope.

ERASISTRATUS (335–265 B.C.)

ANATOMY

The Greek physician and anatomist, Erasistratus, was born on the island of Cos in the Aegean archipelago. The actual dates of his birth and death are unknown. But in 294 B.C., when presumably in his prime, he was employed as personal physician to Selucis Nikator, King of Syria. Subsequently he abondoned the active practice of his profession, and devoted himself exclusively to the study of anatomy, where he made a number of important discoveries. He seems to have been the first to comprehend and define the difference between the sensory and motor nerves of the body, and to trace both to their source in the brain, though there is nothing in what remains of his writings to indicate that he conceived the latter to be the seat of the mind. He also made a close approach to a correct understanding of the functions of the heart, and the duties of the veins and arteries which lead from it to all parts of the body, but did not appear to have comprehended the work of the blood which circulated in them. He was a voluminous writer, but only a few fragments of his treatises have been preserved. Perhaps, if more had come down to us it might appear that he preceded Galen nearly five hundred, and Harvey nearly two thousand years in the discoveries for which they have the credit.

So great was his reputation while living that, after his death, a School or Society of physicians and surgeons was organized who called themselves Erasistrateans, and who professed to practice and teach the physiological and anatomical principles for which he stood. But it did not last long, and there are indications that many of its members were practitioners of an inferior order, if not what we would now class as quacks, who merely joined to obtain the advantage in reputation which would be thought to attach to real pupils of a great master.

EUCLID (circa 300 B.C.)

MATHEMATICS

LITTLE is known of the ancient and famous mathematician, Euclid, beyond the fact that he was a Greek by birth, was living and teaching in Alexandria during the reign of the first Ptolemy (323–285 B.C) and was the most renowned writer of his day on his subjects. His extant works that are considered his own beyond question are: "The Elements," "The Data," "The Phenomena," "The Optics," "The Reflections," "The Divisions of the Scale," and "De Divisionibus." It is thought that he wrote several—perhaps many—others, which have been lost.

Of this list the first mentioned is the one that has immortalized him. It was in thirteen parts. Its reputation was so great that it was translated into Arabic under Haroun al Rashid (Aaron the Just), the renowned caliph of Bagdad (A.D. 786–809), and again under his son, Al Mamun. The latter version was rendered into Latin about A.D. 1120, and printed in Venice in 1482.

It is now more than twenty-two centuries since Euclid worked out his famous propositions in plane and solid geometry and trigonometry, yet today they are taught in our schools with but slight modifications. In the development of the sciences, mathematics is the first step. Without it, the second, mechanics, cannot be taught, nor can the third, astronomy, advance beyond the stage of observation. A Euclid was necessary before man could do much more than take notes and speculate on the phenomena of nature. It is true that there were mathematicians of sorts before his day, but he is rightly considered the father of that science. All of his propositions but two remain undisputed, and these two (which will be found under the chapter devoted to Lobatchevski) are still correct for plane surfaces, but not for curved ones.

The city of Alexandria where he taught, was founded by Alexander the Great in the year 332 B.C., and was therefore in its first youth in his time. It was laid out by the architect Dinocrates of Rhodes on mathematical lines, in the shape of a parallelogram, its streets crossing each other at right angles. Egyptians, Greeks and Jews were the principal elements of its population, the proportion of each being in the order given, the Greeks constituting the intellectual, the Jews the commercial, and the Egyptians the laboring classes. Under the dynasty of the Ptolemies it flourished amazingly, and rapidly became the foremost city of the ancient world both in commerce and culture. To it the scholars and students of all the civilized nations of the time flocked, the former to teach and the latter to learn. Euclid, as one of the first class, established his school in an inconspicuous locality, where it at once became so famous that the king (Ptolemy I, surnamed Soter, The Preserver), provided a special auditorium for his use, and conferred on him every privilege and honor that could be desired. His classes were taught in Greek. The desire to attend them was so great that language schools were immediately established in the city, where the Egyptians, Arabs, Hindus, Persians, and other non-Hellenic people could acquire the classic tongue of the time.

ARCHIMEDES (287–212 B.C.)

MECHANICS

ARCHIMEDES, who bears one of the most distinguished names among the ancients, was born at Syracuse in Sicily, at a time when that part of the island was still a colony of Greece, and under the rule of King Hiero II. As for several centuries it had been alternately in the possession of Greece and Phoenecia, it is possible that his ancestry was more or less of a mixture of the two races. His education was obtained at Alexandria, in Egypt, which was then a Greek colony under Ptolemy III, and ranked as the most famous center of learning in the world.

His achievements indicate the possession of a gifted mathematical mind, coupled with the imagination of the natural inventor. He was a brilliant geometer, ranking in his time next to Euclid. He explained the principle of the lever, which indeed, as a mechanical contrivance, had been employed since remote antiquity; but so far as the records go, had not previously been mathematically investigated. Concerning its powers he is supposed to have said: "Give me a place where I can stand, and a fulcrum, and I will move the earth." He also was the discoverer—or at least the first known employer—of the principle that "the weights of bodies are proportional to their masses," in which the word mass means "quantity of matter" and not volume. According to the story, the king had ordered a new crown, and had furnished the artificer with a definite weight of pure gold for its manufacture. When the article was delivered there was a suspicion that silver or even a base metal had been substituted to some extent for the precious one, and the matter was referred to Archimedes for investigation. As the geometer was stepping into his bath one day while the problem was under study in his mind, he was struck by the amount of water displaced by his body and spilled over the edge of the tub. At once he saw the solution of the problem. In his excitement he ran through the streets to his home entirely naked, and shouting "Eureka!" (I have found it).

To Archimedes was due the development of that department of geometry called "Conic Sections," treating of the circle, ellipse, parabola and hyperbola, all of which had of course been recognized before his time, but whose properties had not been mathematically studied. He was a voluminous writer for his day. Of his works that are extant, three are devoted to plane geometry, three to solid geometry, one to arithmetic and three to mechanics. Like all the earlier mathematicians he tried to square the circle, and as the result of his calculations announced that the value of π was somewhere between the figures 3.1408169 and 3.1428571, thus admitting in the end the insolubility of the problem, but indicating closely the ratio between diameter and circumference now employed. On the other hand, he succeeded in demonstrating that the area of a segment of a parabola is two-thirds that of the enclosing parallelogram, which was the first instance on record of the quadrature of a curvilinear surface. In his "Method of Exhaustion" he made an approach to the modern study of the Calculus.

He was killed during the sack of Syracuse by the Romans under Marcellus. When that famous commander learned of his death he expressed great regret, and ordered a monument to be erected to his memory. On it was engraved in stone a sphere inscribed in a cylinder. The great Roman statesman, Cicero, who was appointed governor of Sicily in 76 B.C., made a visit to this tomb, and gives a description of it in his "Tuscan Disputations." Its location at the present time is unknown.

ERATOSTHENES (276–196 B.C.)

ASTRONOMY

Eratosthenes was born at Cyrene on the north coast of Africa, in the ancient Greek province or colony called Cyrenica, the region now known as Barca. He was of pure Grecian ancestry, and was given an excellent education under the noted instructor Callimachus, who later became the chief at the Alexandrian library. Upon attaining manhood Eratosthenes went to Athens, and later to Alexandria, where he served under his old master; and finally in 240 B.C., succeeded him at his death. There he remained during the balance of his long life until, at the age of eighty or thereabouts, having become totally blind, he died of voluntary starvation. While in his prime he was a writer of note. Of his essays many fragments are extant, which indicate that his culture was an unusually broad one. He disliked to be called a philosopher, preferring the title of philologist (a lover of learning). He wrote on poetry, geography, mythology, anatomy, philosophy and literature in general.

In science he is remembered as the first to make an estimate of the size of the world, on the assumption that its shape was that of a perfect sphere; and also among the first to calculate the angle which its equator makes with the ecliptic, the plane of its orbit in its annual journey around the sun, a measurement which is technically called at the present day the "obliquity of the Ecliptic."

In regard to the first of these: having ascertained that at midsummer in the city of Syene on the upper Nile—now the modern city of Assuan—which is located at about latitude 24° North, the sun shone at the bottom of a deep well there, he properly concluded that at the moment its position must be vertically overhead, or in the zenith. On the same day he measured the altitude of the sun at the city of Alexandria, whose latitude is approximately 31° North. He found the altitude to be a little over seven degrees from verticality. Between Syene and Alexandria (which are nearly on the same meridian) the distance was regarded as about 5000 stadia. The arc of a circle subtended by an angle of seven degrees being approximately one-fiftieth of a circle, he concluded that the circumference would be fifty times five thousand, or 250,000 stadia. Unfortunately, the exact length of the Greek stadium is unknown. It was the length of the national straight-away race course, and was always the equivalent of 600 Greek feet, which, if of the same length as the Latin foot, would be 0.2957 meter, or say 11½ inches, making the stadium 177.42 meters or 586.3 feet. But the Greek foot was itself a variable measure. However, calling the stadium 600 modern feet, or about one-ninth of a standard mile, the result reached by Eratosthenes would be 27,700 miles, which is so close an approximation to the true figure of the polar circumference (24,806 miles) as to make the performance a most creditable one for the time, if we consider the crude instruments then available for measuring celestial altitudes, and the fact that the distance between the two cities was probably ascertained by pacing, and therefore certain to be quite inaccurate.

In the matter of the obliquity of the ecliptic he came much closer in his result, for his figure of 23° 51′ 19.5″ differed but little from accuracy. At the present time the angle is 23° 45′. As this angle, in consequence of the precession of the equinoxes, has been diminishing at the rate of about 50″ per century since Eratosthenes made his estimate, the true figure for the angle at his time would have been 23° 62′ 20″.

ARISTARCHUS (circa 265 B.C.)

ASTRONOMY

THE native place of Aristarchus was at Samos, on the island of Cephalonia off the western coast of Greece. He is distinguished as having made the first recorded attempt to ascertain the comparative distances of the sun and the moon from the earth, by geometrical means. Nothing else is known of his history, and all his writings have been lost except a short essay describing his solution of this problem. In his day the earth was regarded as fixed and immovable in space, while the sun, moon, planets and stars moved around it. But to him it seemed more reasonable that the earth was a satellite of the sun, and the phenomena of eclipses—which he seemed to have thoroughly understood—confirmed him in this belief, for at their occurrences it was evident that the shadows cast by the earth on the moon, and by the moon on the sun, indicated clearly the relative distance of each. He therefore reverted to the older theory, according to which the earth was not stationary but revolved daily on its axis, insisting that the central fire postulated by Pythagoras was a myth, and that the sun did not shine by reflected light, but was itself luminous and, in fact, the source of all light coming to the earth, not only directly, but by reflection from the moon, the planets and the stars.

Acting on this theory he reasoned that when the moon's phase was in its first or third quarter, at which times it showed itself as a half sphere, the position which the three bodies occupied with respect to each other must be those at the vertices of a right-angled triangle, the moon being at the right angle of 90°, the sun at the most acute of the other two, and the earth at the least acute. He then attempted to measure with such instrumental assistance as was available in his day, the amount of the angle between the sun and the moon at the earth, at the half-moon stage of the satellite, and after repeated observations concluded that it was in the close vicinity of 83°. As the sum of the angles of a plane triangle are invariably 180°, and as the angle at the position of the moon was, by assumption, 90°, that at the sun must be the difference between 83° and 90°, or 7°. Having then the three angles of the triangle, it was a simple geometrical problem to calculate the relative length of the line extending from the earth to the moon as compared with that extending from the earth to the sun, namely as one to twenty.

In theory Aristarchus was absolutely correct. But in his day no instrument for measuring angles accurately between bodies at great distances from each other was in existence. Moreover, and for the same reason, it was not possible then to determine exactly the half-moon stage. His data therefore were in error, and hence his conclusion. It is now known that the angle at the earth between the moon and the sun, at the half phase of the former, is only a fraction of a minute less than 90°, instead of 83°. In consequence, the comparative length of the two distances from the earth to the moon, and from the earth to the sun, is as one to four hundred in place of one to twenty.

His essay on this subject was published in Latin at Venice in 1498, and at Oxford in 1688 in the original Greek text.

APOLLONIUS (circa (225 B.C.)

MATHEMATICS

Apollonius was a native of the city of Pergamos, in Asia Minor. The date of his birth is unknown, and practically nothing of his personal history has come down to us except that he was the author of a treatise on the conic sections, which was so highly regarded in his time and for many centuries afterwards, that nearly the entire work of eight books was translated into Arabic, and later the fifth and seventh into Latin.

The conic sections are those curves produced at the intersection of a plane with an upright cone. If the latter is cut horizontally and at any point of its height, the curve resulting is a circle. If the intersection occurs at any angle below horizontal and above parallelism to the slope of the sides of the cone, the curve is an ellipse. These two are closed curves, as they return to themselves. If now the plane intersects the cone at an angle parallel to the slope of its sides, a parabola is produced; and finally, if the intersection is parallel to the vertical axis of the cone the resulting curve is the hyperbola. These two are open curves, not returning to themselves. All four were first described by a Greek geometer by the name of Menaechmus who lived at some time during the fourth century B.C. and about whom nothing is known beyond this fact.

They greatly interested the mathematicians of the day and many of their properties became known. Especially in the case of the ellipse, which Apollonius aptly described as the curve with two centers. When Kepler showed that the planets revolved around the sun in ellipses, and Halley that the periodic or returning comets did also, that curve became of greater interest than ever to astronomers. To the layman the properties of the parabola are perhaps most attractive. It might be called a curve of one center, though better described as a curve of one focus. If, for instance, a mirror is so constructed that all its axial sections are parabolas, and a beam of light is cast into it, all the rays will be reflected to the one point which is its focus. Or, conversely, if a source of light is set at the focus, all of it will be reflected outward in a beam whose rays are parallel to each other. This property is employed in the construction of searchlights and lighthouse reflectors, producing a beam that penetrates a long distance before suffering dispersion. Also, in a smaller way in locomotive and automobile headlights.

HIPPARCHUS (circa 161–126 B.C.)

ASTRONOMY

THE Greek astronomer and mathematician, Hipparchus, was born at Nicaea in Bithynia, a political division of Asia Minor lying along the shores of the sea of Marmora and the Black sea. All his astronomical work, however, was done on the island of Rhodes.

Of his personal history nothing is known. His writings also have been lost, but portions of them have come down to us through the works of Theon of Alexandria (circa A.D. 370), and of Ptolemy Philadelphus (A.D. 100–175). It is known that he wrote nine separate books, but of these only the "Commentary on Aratus" was reproduced complete by any subsequent writer.

He is regarded as the founder of the science of trigonometry. He computed a table of chords, and is credited with a knowledge of the quadratic equation. He was the discover of the phenomenon known as the precession of the equinoxes, and is supposed to have been the inventor of the astrolabe, that instrument of the ancients with which they took the altitude of the heavenly bodies, and which was employed for that purpose in navigation until superseded by the quadrant about 1730 and later the sextant. Hipparchus drew up a catologue of more than one thousand of the fixed stars.

The ecliptic is the name given to the great circle round which the sun seems to travel from west to east in the course of the year. It was so called because the ancient astronomers quickly observed that eclipses happen only when the sun and moon are in or close to that circle. As is now well known, it is really the plane along which the earth actually moves in its annual journey around the sun.

The plane of the earth's equator, which divides it into the northern and southern hemispheres, if it be imagined as extended out into space, would not coincide with that of the ecliptic. Instead, the angle between the two at the present time is about 23½ degrees, and is diminishing at the rate of about 50 seconds (or one-seventieth of a degree) per century; or say a degree in seventy centuries. If it kept on diminishing at that rate, in 1645 centuries the two planes would coincide. Fortunately this angle—which is called the obliquity of the ecliptic—has limits, which it does not and cannot pass. Astronomers calculate that it will reach its lowest possible amount of about 22¼ degrees in approximately 150 centuries from the present date, after which the motion will begin to reverse, and the angle between the two planes to increase until a maximum of nearly 25 degrees will be attained at the end of another 330 centuries, or 480 centuries from the present time, when again a reverse movement will be inaugurated.

Early in the history of astronomy it was observed that twice each year, namely, about the 21st of March and the

23rd of September, the sun is vertically overhead at noon on the equator. These are called the equinoctial dates, and mark those places on the plane of the ecliptic where the plane of the equator, if extended sufficiently outward, would intersect it. These two points are not invariable positions. Each year they move forward to the extent of about one-seventy-secondth part of a degree. As there are 360 degrees in a circle, it is plain that in about 25,920 years they will have made a complete circle of the plane of the ecliptic. This phenomenon is called the precession of the equinoxes. It is very remarkable that it was detected by this Greek astronomer over 2000 years ago, whose only observational instruments were the astrolabe, the gnomon and the polos. He was unable to explain its cause, which remained more or less of a mystery until Newton announced the laws that control the movements of the planets in space.

DIOSCORIDES (circa A.D. 64)

BOTANY

Pedanios Dioscorides was a native of the Greek city of Anazarbus in Asia Minor. His profession was that of a physician. In his day that occupation did not include the practice of surgery, nor require a knowledge of anatomy, though, in case of light injury, or in emergencies, he was allowed to do what he could to relieve suffering.

Of his early history, or of the degree of his educational equipment, nothing is known. He is first heard of as attached to the Roman army in his professional capacity, which took him to many parts of the known world of the day. Apparently he was a lover of nature, and used the opportunities his occupation provided to study vegetable life, and to make a remarkable collection of all the plants encountered which yielded, or were supposed to yield, medicinal virtues. These he listed and described in his monumental work entitled "De Materia Medica," after physical disabilties and advancing years compelled him to abandon army life.

So complete was this treatise that for fifteen centuries after his death it remained the standard work on the subject. It was written in the Greek language, but while the author was still living a Latin translation was made; and later, from this, was rendered into most of the tongues of western Europe, as well as into Arabic, which was then the classical language of the East, as Latin was of the West. It was not until 1829, however, that it appeared in print, by which time naturally it possessed value mainly as one of the curiosities of ancient literature.

Dioscorides was an observant man, and must have been as well educated for the duties of his occupation as could be expected for his time. But the knowledge of vegetable life that he gathered during his extensive journeyings was purely of the empirical kind, and in no sense scientific. While he discovered many plants of great value for their medicinal properties, and accurately described all that he collected, he made no attempts at classification, and was of course totally unaware of the chemical nature of the extracts and infusions he made from them, or why they produced the effects he observed. Nevertheless, his extraordinary industry in collecting, and his faithfulness in describing, as well as the methods he adopted for administering his medicines, were of enormous service to mankind during the Dark Ages, when science was non-existent, and superstition rampant. Even at the present time a few of his recipes are used in civilized countries, while most of them are rated as authoritative among the middle and lower class Turks and Arabs, and the people of North Africa.

PTOLEMY (circa A.D. 100–170)

COSMOLOGY AND GEOGRAPHY

Claudius Ptolemaeus was a native of Upper Egypt, having been born in the vicinity of ancient Thebes. There are no records extant of his parentage or early life, but in the year A.D. 139 he was a personage of note in intellectual circles of Alexandria, and evidence that he was still living there in 161 is believed to exist.

As a geographer, he appears to have been merely an editor or commentator on a work (which has been lost) on the subject by a Phoenecian navigator known as Marinus of Tyre, which must have been a production of considerable importance. Ptolemy's reproduction of it consisted of eight books. Five of these contain nothing but lists of place names which had evidently been visited by the original writer. In each case the latitude and longitude were given, together with a brief description of the locality and surroundings, of the people found there, of the productions of the vicinity, and such other items of information as might be gathered by the ordinary observant traveler. The other three—which perhaps were original with Ptolemy—were devoted to a description of the way to determine latitudes and longitudes; estimates of the size of the earth on the theory of its spherical shape, and a description of his (Ptolemy's) method of projecting points on a hemispherical surface upon a flat one, which he claimed was superior to those employed by either Eratosthenes, Hipparchus or Marinus. From these notes of the actual navigator he constructed twenty-six maps of the known world of the day. These, for many centuries, were regarded as standard geographical authorities.

In astronomy he originated the theory of the Cosmos which bears his name, and which was accepted as correct throughout Europe until the time of Copernicus and Kepler. This represented the Earth as immovably fixed in space, and as the center of the Universe, around which the sun, the moon, the five known planets and the stars, moved at uniform speed, carried by concentric transparent spheres or shells, to each of which they were attached more or less immovably. The first or innermost of these crystalline shells carried the moon. Beyond it in order came those bearing Mercury, Venus, the Sun, Mars, Jupiter and Saturn. In the eighth shell were all the fixed stars. To account for the alternate progression and recession of the planets, he originated his famous theory of epicycles.

In this he claimed that the planets were not immovably fixed in their respective shells, but that each one of them revolved in a circle of greater or less diameter, the center of which *was* immovably fixed on its particular shell. As to the Earth, he regarded it as the lowest and most stable of the elements of which matter in general was composed. Water, as exhibited in the ocean, and in lakes, rivers and rain, was the second element, and rested upon the first. Air was the third, being above these two, and fire the fourth. Beyond the last, and extending to the shell carrying the moon, was the blue sky, the vault of the heavens, to which he gave the name of the Ether. He appears to have made no efforts to explain the constitution or material of this last, nor to include it among his list of elements.

Astronomers living shortly after Ptolemy's day added in turn a ninth and tenth shell to the system. The first of these was to account for the phenomenon of the precession of the equinoxes; and the second to explain more clearly the alternation of day and night. This was accomplished by giving to it a daily circular motion from east to west during which, by virtue of some mechanism all the others were carried with it. Still later, as the science of astronomy progressed, and new discoveries were made that could not be accounted for by the theory as originally outlined, these were explained by its proponents by adding epicycle after epicycle to the scheme, until it became so complicated and so littered with these little circles as to draw from King Alphonso X of Castile—to whom it was being explained—the remark that "if he had been allowed to be present by the Deity when the Universe was being fashioned, he believed he could show him a better plan," or words to that effect. By the time of Copernicus the whole theory was ready to fall to pieces by its own weight, though still adhered to by conservative minds, and even by such a brilliant observational astronomer as Tycho Brahe.

To Ptolemy belongs the honor of having been the first to discover and describe that phenomenon called the moon's "eviction," but its cause was unknown to him, and to all astronomers, until the day of La Place who, in 1786, completely explained it. This is a perturbation or irregularity in the movement of the satellite due to the alternate increase and decrease in the eccentricity of the earth's orbit. When this is at a maximum, it is capable of displacing the moon from its normal or average position in space sufficiently to alter the time of occurrences of lunar and solar eclipses as much as six hours. As eclipses are systematically recurrent phenomena, occurring in cycles of approximately eighteen years; and as this fact was well known (for the moon but not for the sun) to the ancients, whose astronomers were tireless observers of celestial happenings, and who prided themselves on their ability to predict eclipses, Ptolemy's discovery was of much importance, as it enabled them to increase the accuracy of their prophesies.

GALEN (A.D. 130–201)

ANATOMY

CLADIUS GALENUS, as he was known in his time, appears to have been a native of Mysia, an ancient province in the northwestern corner of Asia Minor, bordering on the Aegean and the Marmora seas, and was of Hellenic ancestry. During his youthful years he studied medicine, and such surgery as was known at the time, in Smyrna, Corinth, Alexandria and other large centers, and at the age of thirty received the appointment of physician to the school of gladiators at Pergamos. A few years later he moved to Rome, remaining there four years, during which time his reputation increased so greatly that he was offered the position of physician to the Emperor. Having returned to Mysia in his thirty-eighth year, he had hardly settled down to the practice of his profession, before he was summoned peremptorily by the emperors Aurelius and Lucius Verus, to attend them during a military expedition they were about to make, and obeyed at once. But on arrival at the camp of the army he found that a pestilence had broken out there, and that the emperors had started on the return journey to Rome, whither he followed them. Little else is known of his movements, but it is generally believed that his death occurred in his 70th or 71st year, and that at the time he was in Sicily.

Galen was a student and a voluminous writer. There are still in existence 83 documents of his that are known to be genuine, besides more than 400 others, the authenticity of which is questionable, but which are preserved for what they may be worth in the collection of his writings. Very few of them have any value beyond that of ancient curiosities, for in his time, and for centuries after it, the medical art was in no sense a science. But Galen was also an anatomist of unusual ability and brilliancy for his day, and made one memorable discovery for which he has won immortal credit. This was, that the brain was the organ of thought.

Up to his time various opinions had been held as to the organ in the human body which was the seat of the mind. For instance, the word brain, or any word that might be thought to refer to that organ, is not to be found in the Bible or in any ancient literature. Among the Babylonians the liver was regarded as the thought center. With the Hellenes the heart was considered the home of the soul, and the kidneys that of the mind, while sentiment and the emotions were supposed to reside in the bowels. "Bowels of compassion." In Plato's time the brain, though well known as a separate bodily organ, was regarded as an extension, in the shape of a gland, of the marrow of the bones. And while he—for no reason that can be deduced from his writings—called it the seat of the soul, he exhibited no conception of it as the seat of thought. Aristotle later ridiculed the Platonic view (which certainly was nonsense), and said that the brain was simply a gland set at the top of the body, for the purpose of keeping the blood from acquiring too high a temperature, in other words, simply a cooling gland. It is true that one Alcmaeon, a Greek of Italian birth, who lived in the 6th century B.C., and who was recognized locally as a physician of ability for his time, had definitely taught that the brain was the seat of thought. But his opinion carried no weight with the philosophers, and was quickly forgotten. It required a man of the experimental habits and international renown of Galen, to overthrow the childish speculation of his day on the subject. Accordingly, when, in about the year A.D. 160, he announced his discovery in a monograph entitled "De Anatomicis Administrationibus," and elaborated it in a second one under the title of "De Usa Partium Corporis Humani," his conclusions were at once accepted, and have never since been questioned. But many centuries elapsed before any further discovery of equal note occurred regarding the human body. In fact, not until Harvey, in 1628, published his work on the circulation of the blood, did man begin to know much about the temple in which his mind and personality made their dwelling place.

DIOPHANTUS (circa A.D. 250–350)

MATHEMATICS

Diophantus was a distinguished Greek mathematician, about whose personal history almost nothing is known, except that he lived and taught in Alexandria, Egypt. He is called the "Father of Algebra," though that science is well known to have been developed to a considerable degree in India and Arabia centuries before his time. Of his three known works ("On Arithmetic," "On Polygonal Numbers" and "On Porisms") only six parts of the first mentioned are extant. These, however, display a remarkable grasp of algebra for the time, and fully warrant according to him the honor of having introduced the science to the European students of his day, and of having broadened its scope and capacity greatly.

Algebra, the second department of the science of mathematics, derives its name from the title of a work by the Arabian philosopher Al-Khuwarasmi, who lived in the ninth century of the present era and was regarded as a noted mathematician. His professional life was spent mainly at Bagdad, where he worked in the astronomical observatory there, and wrote several treatises on that science. Among them was one entitled "Al-jabr wa'l mugabalah (Re-integration and Comparison) signifying an investigation which had to do with the methods by which equations may be reduced to integral forms.

To exactly define the domain of algebra is not easy, for in one direction it shades into the higher departments of arithmetic, and in the other into the primary regions of the Calculus. Comte's definition is to the effect that while arithmetic is the calculus of values, algebra is the calculus of functions; the word calculus in both cases being intended to convey the idea of numbering or calculating, while function is used in the sense of a generalized quantity whose value at any given time depends upon the value of another quantity, also of a general kind. Thus, when it is said that the circumference or the area of a circle varies—in accordance with a fixed mathematical law—with the length of its diameter, both the circumference and the area are functions of the diameter. These functional relations when expressed in symbols are called equations.

The oldest known written equation appears in a manuscript attributed to an Egyptian scribe by the name of Ahmes, who lived about 1700 B.C. He claimed to have copied it from another manuscript dating back some seven to eight centuries. It reads:

> "The whole its seventh part, its whole, it makes 19."

Which, put in modern symbols would be $\frac{x}{7}+x=19$ this being the form of the simple equation, and the problem being to find the value of x, which is 16.625. In Euclid's day a knowledge of certain quadratic equations existed, but not until Diophantus does it appear that the science was taught in any organized way. In the century following his time the Hindu mathematician, Aryabhatta, made some important contributions to its growth, and from then until the writings of Al-Khuwarizmi appeared, no further progress seems to have been made. After him there was again a period of nearly seven hundred years until the Italian mathematicians, Tartaglia, Ferreo and others revived interest in it. Since then it has steadily advanced in capacity as a tool of science in all its departments.

II

THE MIDDLE AGES

Historically, this period begins with the fall of the Roman Empire in the year A.D. 476 and terminates at various dates between 1301 (which is regarded as the beginning of the Renaissance) and 1517, when Luther inaugurated the era of the Reformation. But as this work deals only with the subject of science, it is considered best to end with the life of Copernicus, the outstanding figure of the 15th century.

The notable historical events of this thousand years may be briefly summarized as follows. During the remainder of the 5th and most of the 6th centuries the Germanic or Teutonic people of central and northern Europe overran all of the European parts of the Roman empire, and towards the close of the 6th century the rise of the Arabian nationality began, which was destined during the following years to absorb all its Asiatic and African possessions. Through the 7th and 8th centuries, a process of fusion between conquerers and conquered was in progress, from which the latter emerged physically improved, and the former mentally, On the whole, the advantage remained with the conquered, and during the 9th and 10th centuries this was shown in the rise to supreme temporal power of the Roman church in Europe, and of Mohammedanism elsewhere. Towards the close of the 11th century, the two forces came into conflict with each other, in the episodes of the Crusades (1096-1272). These were inconclusive, but during their progress so much of new fact and new thought reached Europe, that its Dark Ages came to an end. With the opening of the 14th century, the learning of ancient Greece began to filter slowly back to Europe, and with that the modern era of Science may be said to have begun.

In the Middle Ages, Italy was the commercial and intellectual center of the civilized world. Its schools and universities became so noted, that students flocked to them from the surrounding countries. Yet the Italian race contributed only four men of marked scientific attainment to the period, while Arabia and Hindustan contributed five. However, the latter were merely bearers of ancient Greek knowledge, and since then these countries have added nothing to the accumulations of knowledge.

ARYABHATTA (476–550)

ASTRONOMY

A Hindu astronomer, who was born at Pataliputra in the upper valley of the Ganges river, Aryabhatta appears to have held in his writings—which were in the Sanscrit language and were translated into Arabic—that the earth had the form of a sphere, and revolved upon its axis. He also seems to have been the first to correctly account for the phenomena of solar and lunar eclipses, and consequently must have known and taught that the moon revolved around the earth, and the latter around the sun. His advanced ideas of the cosmos, though totally unknown in Europe in his day and for many centuries afterwards, were accepted without question among the educated classes in India and Arabia, and probably in China, largely because there was nothing to the contrary in the so-called sacred literature of these people, or for the reason that the literature of that kind among Oriental races was not regarded as inerrant in secular matters. A thousand years later, when the same beliefs were expressed by Copernicus, they were received with horror, because they were considered to be in opposition to the teachings of the Christian Scriptures.

His only worlk that has come down to us is known as the Aryabhattiya. It was written in verse, and was divided into four parts entitled respectively "Celestial Harmonics," "Elements of Calculation." "On Time and its Measures" and "Spheres." It was published in Sanscrit at Leyden, Holland, in 1874. A translation into French of the second part was made in Paris in 1879. His writings, and the views therein expressed, were held in high regard among the Arabs—to whom he was known as Argehir, and exercised a strong influence on their conceptions of the external universe.

BRAHMAGUPTA (598– ?)

MATHEMATICS

BRAHMAGUPTA was the most prominent of Hindu mathematicians. Somewhere about the year 628 he completed the writing (in Sanscrit) of a work entitled "Brahma-Sphuta-Sidhanta (The Improved System of Brahma), of which Chapters XII and XVIII were on mathematics. These have been translated into English, and were published in London in 1817. In them he gives evidence of a fair acquaintance with certain fundamentals of the science, such as arithmetical progression, methods of obtaining the areas of triangles, quadrilaterals and circles, as well as the surfaces and volumes of cones and pyramids. He understood equations up to those of the fourth degree. His value for π (the ratio between the diameter and the circumference of a circle) was 3.16. He was the first known mathematician to use the so-called Arabic numerals which, in reality, originated with old Sanscrit alphabetical forms, being the first (or other) letters of the words one, two, three, etc., in that language. By some, Hector Boece (or Boethius) is credited—rather uncertainly—with their reduction to approximately their present form about the year 1500. By others, the change is attributed to Fibonnacci (Leonardo of Pisa), who was in his prime early in the 13th century (1210–1220). What is important, however, is, that with this almost forgotten Hindu, the idea seems to have originated to adopt symbols for the words of the numbers from one to nine, to add the zero symbol, and finally to give all position value, by which, without the use of any more symbols, any numerical quantity in whole numbers up to infinity could be expressed with ease. As a conception it ranks in importance with the invention of the wheel in mechanics.

To him is also attributed the first employment of the common or vulgar fraction ($\frac{1}{2}$, $\frac{5}{8}$, $\frac{7}{12}$, etc.). In the early years of the 17th century (1612) Stevin began to employ the decimal form of the fraction, which, however, appears to have been originally conceived by the Hindu mathematician Bhaskara (circa A.D. 1150).

It seems certain that whatever of the science of mathematics existed in ancient times in India, owes its origin to the Greeks, who brought it there by travelers and traders, and when their armies under Alexander the Great invaded the country in 327 B.C. The Hindu made but little use of it as a tool. Yet its fundamentals survived there when Greece gave place to Rome; and when the southern and eastern portions of the Empire of the latter passed into the control of the Arabs under Mohammed and his successors. Then, through the latter, the Hindus passed such of it as they had not forgotten, slowly through the centuries of the Dark Ages back to Europe, and the most of it by way of the Spanish Moors.

AL KHUWARISMI (? –831)

MATHEMATICS

ABD ALLAH MOHAMMED IBN MUSA of Khuwarism was born in Khiva, in the region to the east of the Caspian sea, a very ancient town situated on the banks of the river Daria which, rising on the northern slopes of the Hindo Koosh mountains flows northward and empties itself into the Aral sea. By race he was an Arab, and consequently by religion a Mohammedan. During the caliphate of Al Mamun (783-833) he came to Bagdad, then the center of the Arabian world, and was connected with its astronomical observatory, where he wrote several books on mathematics. Among these was one devoted to setting forth the Hindu system of mathematical and algebraic notation and methods. Others described their sun dial, their astrolabe—an instrument employed to take the altitude of the sun, their current system of chronology, and what was known by them of the science of geometry. Such of his writings on algebra as have been preserved were translated first into Latin and from that language in 1831 into English. They exhibit a fairly complete knowledge among Hindu mathematicians of equations up to those of the fourth degree.

This individual—of whose personal history very little is known—was one of those few Arabian scholars who, when scientific knowledge was almost non-existent among their own race and in Europe, undertook to preserve parts at least of what had been accumulated among the Hindu philosophers who flourished in India a millennium previously, in the days of Greek intellectual supremacy. Another of the same class was Al Kinde (9th century), who is known to have written over two hundred treatises during his lifetime on almost every subject about which anything was supposed to be known in his day. Of these unfortunately only a few on medicine and astrology are extant.

In Al Khuwarismi's time Bagdad was a city of nearly 600,000 population, and both intellectually and commercially the center of Arabian nationality. Under the brilliant but despotic reign of the caliph Harun al Rashid (766–809) and his son Al Mamun (783–833), it attained its greatest magnificence and importance as the principal city on the caravan route between Europe and India.

The Arabs as a race have produced very few men of intellectuality through their entire history. Of their origin little is certainly known, except that they belonged to the Semitic race of people, whose primitive home was the Arabian peninsula. Their development began in the south, where, about 1500 B.C. a flourishing nationality known as the Himyarites existed. Previously to them (or possibly contemporaneously) were the semi-mythical Mineans; and succeeding them were the Sabeans, whose period continued well into the Christian Era. These latter, inhabiting the southern and western coasts of the peninsula, were an active maritime people, and for several centuries conducted a brisk trade between Egypt, Mesopotamia and India, and down the east African coast as far as the mouth of the Limpopo river. This nationality began to split up and decline in importance in the 5th and 6th centuries. Throughout central and northern Arabia the country has never been occupied except by wandering tribes continually at war with each other. But during the lifetime of Mohammed (A.D. 570–632) the race experienced a remarkable process of consolidation under the influence of the fanatical religion he inaugurated, and began a career of conquest which extended westward all through northern Africa and even into Spain, and in the other direction included the whole of Mesopotamia and Syria. When Alexandria in Egpyt fell under the attack of the caliph Omar in A.D. 641, the great library there was destroyed under his order, because, as he is reported to have said, "whatever in it agrees with the Koran is superfluous, and whatever disagrees is worse, and deserves destruction." For the knowledge that had been accumulated by the Greeks the Arabs apparently had a supreme contempt. But for that much less scientific culture that was of Hindu or even Chinese origin they had more regard. Of themselves they produced almost nothing in the way of discovery.

AL HAZEN (965–1039)

MATHEMATICS

El Hasan ibn el Hasan ibn el Haitam Abu Ali was a native of the city of Basra in the lower valley of the Euphrates, who ranked in his day as a mathematician and physicist of high repute, and also as a voluminous writer on general philosophy. His commentaries on the literary works of Aristotle, Galen, Ptolemy and Euclid are particularly illuminating as to the teachings and lives of those men. The most of his literary life was spent in Cairo, Egypt, where, among other activities, he wrote a notable treatise on the subject of optics, which ranks as the foremost production of his day in that department of science. In it he enunciated correctly many of the laws of the reflection of light from plane, spherical and parabolic mirrors, and also had much to say on the phenomenon of refraction. He is believed to have been the first physicist to note and discuss the magnification of images when viewed through crystals or glass cut into the form of lenses.

From these studies he was led to the investigation of the human eye, which he examined anatomically, discovering the lens in it, and partially explaining its operation in the phenomenon of vision. He recognized the fact that the image formed on the retina must be an inverted one, and admitted his inability to account for its transformation in the mind to a correct position.

BHASKARA (1144– ?)

MATHEMATICS

A HINDU scientist, who was the sixth successor of Brahmagupta as chief of the College or Society of learned men which, during part of the Middle Ages, was maintained in India; and in whose care was what remained of the knowledge that had come to them from Greece in the days of its intellectual supremacy. He was known by his contemporaries as Bhaskara Acharya (the Learned One), and was the author of a book entitled "Sidhanta-Ciromanti" (the Crowning of the System). Two chapters of this work were devoted to mathematics, a third to astronomical ideas, and the remainder to various religious and social subjects. In accordance with the Hindu custom the text was written in verse (blank) but, differing from the methods of his predecessors, Bhaskara added copious commentaries in prose.

The Hindus as a people should not be confounded with the other inhabitants of the peninsula of Hindustan—popularly called India. Their homeland was in the upper valleys of the Ganges and Indus rivers, a highland region bounded on the north by the vast uplift of the Himalaya mountains, and on the south by the much lower Vindhaya range. Into these parts, which now are called the principalities of Kashmir, Agra, Oudh and Punjab, embracing an area nearly twice as large as that of the state of Texas, an immigration of white-skinned Aryans from the northwest and west began about 2000 B.C. They found the country inhabited by a people of low civilization with very dark skins who have been called Dravidians by the ethnologists, and whose origin and racial relationship is still an unsettled problem. These, so far as the males, the invaders drove before them, but absorbed the females; with the consequence that the resulting Hindu race—constituting the highest class of the natives of India—possess the well-cut features and mental characteristics of the Aryans elsewhere, under the dark skin of the displaced aboriginals.

Of the early history of this composite race very little is known. The first reliable date is that of the birth of Buddha (557 B.C.) A century or so later they began to come into contact with Greeks, and from them, either in the way of friendly intercourse, or as conquerors, absorbed whatever of science has ever existed among them. About 100 B.C. the Scythians invaded the country from the north, and in the sixth century A.D., the Huns. Finally, during the reign of the Ghaznivides (1001–1185), an Arabian dynasty that had become established in Afghanistan, their country passed under the control of that race.

It is possible therefore that Bhaskara was part Hindu and part Arab in ancestry, and it seems quite certain that whatever scientific knowledge he possessed was of the nature of a legacy from Brahmagupta and his society, plus what he may have acquired himself. From the Arabs he gathered nothing, for as a race they have never been investigators or students. The fanaticism of their religion prevented any interest in science. But, unlike the same characteristic which prevailed among theologians in Europe during the Middle Ages, they were tolerant of Hindu science, apparently regarding it as child's play—which indeed the most of it was. This toleration permitted some of the old Greek learning to slowly filter back towards benighted Europe by way of the few Hindu-Arabians who, to the best of their ability, had kept the lamp of knowledge from total extinction.

Bhaskara is thought to have been the first suggestor of the decimal system. He certainly began to substitute symbols for words in algebraic problems. He wrote on weights and measures, square and cube roots, the rule of three, the methods of computing the surfaces and volumes of the common solids. His arithmetic was still very cumbersome; for instance, division was accomplished by a process of repeated subtractions. He also wrote on astronomy, reflecting phases of ancient Greek speculations on the subject. Nothing that he left defines clearly the conception of the nature of the universe that was current in his day among the few who observed and thought.

ROGER BACON (1214–1294)

SPECULATIVE PHILOSOPHY AND NATURAL SCIENCE

Roger Bacon was born at Ilchester, England, of highly respected parentage, and at a period of history when science, as the term is now understood, did not exist; but was represented among those who were eagerly—if somewhat blindly—groping for explanations of the mysteries of the universe under the name of alchemists and astrologers. He was well educated at Oxford in the classics, and later took his degree as doctor of theology at Paris. Returning then to England, he became a monk of the Order of the Franciscans, a religious society of the Roman Catholic church founded in 1209 by Saint Francis of Assisi.

To appraise properly the life and work of Bacon it is necessary to understand something of the principles of this Order, and of the objects for which it strove. In addition to the vows of poverty, chastity and obedience which its members took, its fundamental conception was that they should lead a life as completely comparable to that of Christ as existing circumstances would permit. A simple costume—that of a shepherd of the day—was adopted, the use of shoes and of horseback riding was prohibited, conversation with women absolutely forbidden, and complete fasting required on all Fridays from sunrise to sunset, coupled with limited abstinence between All Saint's day (Hallowe'en) and Christmas, and between Epiphany (Jan. 6th) and Easter. Beyond these observances their duties were to preach the doctrines of Christ, and to devote their lives to the service of their fellowmen in sickness and mental distress. The order grew very rapidly in number, and in extent of Europe covered by its branches, as evidenced by the fact that during the plague known as the Black Death, which ravaged that part of the world in the years between 1343 and 1351, no less than 124,000 Franciscans fell victims to it, in their zeal for the care of the sick, and for spiritual ministration to the dying.

As a voluntary member of such an organization, it may be inferred with confidence that Bacon was a kindly man of a deeply religious temperament. At the same time he was gifted with an inquiring disposition; and after joining the Order carried on studies and researches in alchemy and optics, wrote voluminously of his discoveries, and discussed them freely with his brother monks. These activities, in spite of the blameless life he led, aroused the jealousy and dislike of his associates to such a degree as to bring upon him the charge of dealing with the black art of magic. In consequence, in 1257, he was condemned by the General of the Order to imprisonment for ten years in Paris, and deprivation during that period not only of his books and instruments, but of writing material.

Upon the accession of Clement IV to the papacy (1265), Bacon managed to communicate with him, and the pope, a man of rather liberal tendencies, invited him to submit his writings for consideration. This Bacon did, in the form of a manuscript which later became known as his "Opus Majus." It was of the nature of a summation of all the conclusions reached up to that time in his studies and investigations in science, philosophy and religion. Shortly after its receipt, and before he had time to read it, Clement died. But the fact that he had desired to examine it, and to give the writer a hearing on its merits, secured his release from confinement and from open persecution until 1278, when he was again imprisoned under the sanction of the new pope (Nicholas III) for another decade, but this time allowed to continue his investigations and studies, and to write of them. At the end of this term he was given his liberty, and returned to England about 1288 where, in 1292, he completed his book entitled "Compendium Studii Theologiae," and shortly thereafter—probably in 1294—he died.

Like Leonardo da Vinci (1452–1519) Bacon was a natural genius, a man far ahead of his time. But unlike the former, he was unable to cut loose from the errors of his day. He was a firm believer in astrology and the "philosopher's stone," that mythical compound for which the alchemists sought during the Dark Ages which, when found, was expected not only to be capable of transmuting the base into the precious metals, but of acting as a panacea for all of the diseases and miseries from which humanity suffered during that sad era of intellectual twilight. Yet even with such handicaps, and the harsh treatment he suffered from his fellow Franciscans, his brilliant imagination remained unclouded, and his optimistic temperament undiscouraged. He was the first among Europeans since the days of Grecian intellectual supremacy who held and taught that correct knowledge of nature could only be acquired by observation and study of its phenomena. He was particularly interested in optics, held advanced views on the refraction of light, and gave a correct explanation of the apparent increase in the size of the sun and moon when on the horizon. He is believed to have learned—through the reading of Arabian documents that had been translated into Latin—of the explosive nature of a compound of sulphur, saltpeter and charcoal (gunpowder), and to have made and exploded some of it under circumstances that convinced the superstitious that he was a practicer of the so-called Black Art, and in league with the Devil. He was fully acquainted with the nature of the error in the condition of the calendar of his time—which was about eight days behind accuracy—and in the year 1263 prepared a rectified one, a copy of which is preserved in the library of the University of Oxford. It was not until 1582 that this error—which by then had amounted to ten full days—was corrected by order of Pope Gregory XIII, under the guidance of Clausius, the official mathematician of the Vatican at the time.

A thorough believer in the orthodoxy of his day, he was also one so deeply impressed with the wonders of nature, and the possibilities of achievement by man when control of its forces was gained by knowledge of their laws, that at times he became prophetic in his writings. Perhaps the best example of this is the following extract from one of his later manuscripts:

"First, by the figurations of art, there may be made instruments of navigation without men to rowe them, as great ships to brooke the sea, with only one man to steere them, and they shall sayle far more swiftly than if they were full of men; also chariots that move with unspeakable force, without any living creature to stirre them. Likewise, an instrument may be made to fly withall, if one sit in the midst of the instrument, and doe turn an engine, by which the wings, being artificially composed, may beat the ayre after the manner of a flying bird. . . . But physicall figurations are far more strange; for by that may be framed perspects and looking glasses, that one thing shall appeare to be many, as one man shall appear to be a whole army, and one sunne and one moone shall seem diverse. Also, perspects may be so framed, that things farre off shall seem most nigh unto us."

Because of his broad learning, and in disregard of the efforts of his brother monks to disparage his reputation, he was known to the general public of the day as "Doctor Admirabilis" and held by them in high esteem for his kindly and unassuming manners. All his manuscripts were written in the Latin language, in which he was very proficient. Six of these were published in the years between 1485 and 1614. In 1733 his "Opus Majus" was published, and in 1859 his "Opus Tertiam," "Opus Minus" and "Compendium Philosophiae" together, under the title of "Opera Inedita."

PEUERBACH (1423–1461)

MATHEMATICS

Georg von Peuerbach was born in the vicinity of Linz, Austria. He studied in Vienna, and afterwards traveled in Germany, France and Italy, delivering astronomical lectures in the large universities. In 1454 he became private astronomer to King Ladislas of Hungary, and later, professor of mathematics at the University of Vienna.

His notable accomplishment was the production of a table of Sines, which prepared the way for decimal fractions, which came into use early in the 17th century.

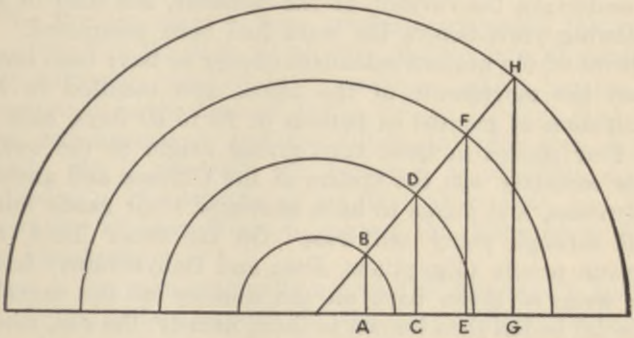
In the development of the science of mathematics the study of arithmetic and the properties of numbers was naturally the first step; plane geometry, or land measurement the second, and plane trigonometry or angle measurement the third. Hipparchus, the Greek (circa 161–126 B.C.) is regarded as the first trigonometer of note, though Euclid, in elucidating some of the properties of triangles, really was the leader in that direction.

Sines are one of the properties of angles. If two straight lines are so drawn on a piece of paper that they unite, the space included between them at the point of union is an angle, which may be of any size up to 180°. When of less than 90° they are called acute; when exactly 90° they are known as right angles, and when greater than 90° as obtuse. In the following figure of several concentric circles, in which a triangle is inscribed (one of the angles of the latter coinciding with the center of the circles), those lines drawn perpendicularly to one of the sides of the triangle and extending to the several circumferences, namely A-B, C-D, E-F, G-H, are called sines of the central angle of the triangle.

It is plain therefore that any angle we may choose to experiment with up to one of 90°, may have as many sines as we may care to ascribe to it by inscribing around it any number of concentric circles at various distances apart.

But an observation of the diagram will also show that all of them will bear a definite relation to the distance from the foot of each to the center of the circle. If this distance is, say 12 feet, the sine for an angle of 30° will have a length of 16 feet. If the distance is 96 feet the sine will be 128 feet; if 3072 feet the sine will measure 4096 feet.

If then it is desired to know the height of any object, and we can measure the horizontal distance from any given point to its base, and the angle between the horizon and its summit, the sine of the angle at that distance will be the altitude desired.



Peuerbach was the first mathematician to compute the sines for angles of all the degrees between 0° and 90°, and for a large number of distances.

MÜLLER (Regiomontanus) (1436–1476)

MATHEMATICS

JOHANNES MÜLLER—who became known later as Regiomontanus—was born in the vicinity of Königsberg, Austria, and was educated in Vienna under the famous teacher Peuerbach. Having become a fine Greek scholar, an enthusiast in the ancient literature of that country, and a lover of the science of mathematics, he collected numerous Hellenic manuscripts on that subject, and translated them into Latin; thus bringing to the attention of European scholars, at a time when a revival of learning in that part of the world was beginning, the best fruits of the days of Grecian intellectual primacy. Among them were those of Ptolemy Philadelphus, Apollonius Pergaeus, Archimedes, Hiero and Diophantus.

Müller became very eminent as a mathematician, and his principal work, entitled "Algorithmus Demonstratus," published in 1534, was among the first—if not actually the first—in which the present system of symbolic algebra was employed.

In 1475 he was called to Rome by the pope (Sixtus IV) to undertake the revision of the calendar, but died in the following year, before the work had been completed.

Some of the ancient calendars appear to have been based upon the movements of the moon, and resulted in the institution of months as periods of 29 to 30 days, each of its four phases in their turn giving origin to the weeks. This certainly was the system of the Chinese and ancient Peruvians, and seems to have answered their needs fairly well through many centuries. On the other hand, the Semitic people (Egyptians, Jews and Babylonians) based the week of seven days on the number of the movable celestial bodies then known to them, namely, the sun, moon, and the five planets, Mercury, Venus, Mars, Jupiter and Saturn. With the Babylonians every seventh day of the month (called Shabattu) was reckoned as a "mysterious" one, on which special care must be taken to placate the gods, or at least not to offend them. From this ancient superstitition undoubtedly came to the Hebrews the institution of the Sabbath, and the conception of the sacredness of the number seven. These ideas passed on to the Christian world in the establishment of Sunday, the first day of the modern week, instead of Saturday the last one, as the holy day.

But it was quickly noted among all the observant people of the olden days that these weekly and monthly periods could not be brought into agreement with each other, nor with the changes of the seasons plainly characteristic everywhere of the yearly period. Various means were adopted to harmonize the three. The Egyptians, estimating the year at 365 days, had 12 months of 30 days each, with 5 days added to the last one. The Jews reckoned the year as composed of twelve lunar months of 29 to 30 days alternately and at every seventh year added a thirteenth to balance up the account. The ancient Greeks adhered rigidly to lunar months as primary time divisions, until Solon introduced the Hebrew system about 594 B.C. Somewhat later the year was fixed by them as a period of 365¼ days, and to accommodate the lunar calendar to this, an extra month of 30 days was intercalated about three times in each eighth annual term.

The Romans seem to have originally regarded the year as a period of 355 days, which they divided into 10 months. This naturally resulted in a confusion which became so pronounced in the time of Julius Caesar (46 B.C) that reform was necessary, and the Julian calendar was established. By it the year was reckoned as of 365¼ days, divided into the months as we have them now, and the institution of Leap Year, to correct the discrepancy that still remained.

But as the year is actually a period of 365 days, 5 hours, 48 minutes and 46 seconds; by the time of Regiomontanus the calendar was out of order to the extent of about ten days. As the feasts and fasts of the Catholic church are all based on the coming of the spring equinox, due actually with our present calendar, on March 21st, but then coming on March 11th, something had to be done, and accordingly was done in the year 1582 when, by order of Pope Gregory XIII, advised by the astronomer Clavius (who took the place of Regiomontanus after his death), ten days were deducted from that year, by calling the 5th of October in it the 15th. As this over-corrected the matter, it was further provided that the century years (1600, 1700, 1800, etc.), though normally Leap Years, should not be counted as such, excepting every fourth century beginning with the year 2000. By this arrangement the difference between the civil and the natural year will amount to less than a day in 5000 years.

LEONARDO DA VINCI (1452–1519)

GENERAL SCIENCE

This remarkable man, who was a native of Tuscany, Italy, was the natural son of a Florentine notary and a peasant woman. In his youth Da Vinci was cared for by his paternal grandparents. As he grew towards manhood he became an acknowledged and honored member of his father's family, and was given the best education that the times could afford. Possessing naturally unusual physical power, charm and social graces, he responded eagerly to the efforts of his preceptors, becoming one of the most versatile and astonishing individuals of which history has preserved the records. At an early age he was deeply interested in nature and was known as an artist of note as well as an engineer of ability. Under his direction, and in accordance with his plans, the Martesana canal was constructed. He took an important part in the designing and building of the beautiful cathedral of Milan, and of several other notable public and private structures in that city and elsewhere. He was a keen student of human and animal anatomy—notably that of the horse—and completed the model of one 26 feet high, which would have been cast in bronze but for the capture of Milan in 1500 by the French, whose soldiery ruthlessly destroyed it. As a painter, his "Last Supper" and his "Mona Lisa" have immortalized him, though they were but two of the many beautiful paintings he executed.

With these accomplishments was combined an astonishing insight of nature and science, which led him to record in writing, and to express among his intimates, views and opinions far in advance of his time. If these had been widely disseminated or published, they could scarcely have failed to have revolutionized the knowledge of his day. But, strangely enough, when coupled with his extraordinary natural gifts in all other directions, he was not only left handed, but wrote in a back-handed style, and from right to left on the page. In consequence, his script was almost undecipherable, and it was not until three hundred years had elapsed after his death that his writings were put into print. Among the remarkable conclusions which these revealed that he had reached, may be mentioned the following: He asserted the sphericity of the earth, its daily revolution on its axis and its annual journey around the sun. He scouted the possibility of perpetual motion, which many of the mechanically minded of the time were attempting to attain, just as the alchemists were searching for a method of transmuting the base into the precious metals; asserting, as a reason for his contention, that "force is the cause of motion, and motion the cause of force," a view that would be expressed differently at the present time, but which contains the germ of what is known now as the conservation of energy.

Nearly a century before Harvey he had grasped the idea of the circulation of the blood, and described in part the work it performed in the body. He was the first to give the correct explanation of the partial illumination of the dark side of the moon, by reflected light from the earth, and to ascribe the tides to the gravitative action of that luminary, even going so far as to explain the high tides as the combined action of the sun and moon. He anticipated Galileo in discussing the mechanics of the lever, the wheel and the inclined plane, and the acceleration in the speed of falling bodies. He is considered the founder of the science of hydraulics, the probable inventor of the hydrometer, and proposed schemes for the canalization of rivers by dams and locks (slack water navigation) which are in use at the present time. One of his keenest remarks was, "Whoever appeals to Authority applies not his intellect, but his memory." Even in the domain of geology he gave expression to views in connection with the significance of fossils, the cause of earthquakes and volcanic eruptions, and the rise and subsidence of land areas, that slept for more than three centuries before restatement by Hutton and Lyell.

Yet with all his remarkable endowments of person and intellect, his influence on the advance of knowledge was comparatively insignificant. This was mainly due to the fact that his writings remained so long unpublished, but also because his achievements in art and engineering were so splendid as to overshadow his expressed views on science, the most of which could not be squared with the religious orthodoxy of the time, and hence were lightly received. Unlike Galileo, he made no effort to push these upon the world of his day, and so did not rouse the antagonism of the Church. On the contrary, up to the time of his death in Cloux, he not only retained his high standing in social and intellectual circles, but was court painter to the king of France (Francis I) at a liberal salary, and held the respect and friendship of his contemporaries both official and personal.

COPERNICUS (1473–1543)

ASTRONOMY

NIKOLAUS KOPPERNIGK (or Kopernik), of Teutonic ancestry, but born in the year 1473 in the little town of Thorn in Poland, became known as Copernicus when he attained eminence, according to the fashion of the day of Latinizing the names of learned men. Little is known of his ancestry, but as his father was a reputable citizen of Bohemia, and his mother a sister of the bishop of Ermeland—a province of East Prussia that was ceded to Poland in 1466—it may be assumed that they were substantial people of the upper middle class, whose men took to the professions of arms, medicine, law or church, as inclination or opportunity afforded. His father died when the boy was ten years old, leaving him to the care of his uncle, the bishop.

In his early youth Nikolaus received what was then regarded as an excellent education, namely, a thorough grounding in the Greek and Latin languages and literature, and the fundamentals of mathematics. At the age of eighteen he was sent to the University of Cracow, the capital of Poland, where, during three years he specialized in the higher mathematics and such of the sciences as were then taught. In his 22nd year he went to Italy to perfect himself in languages, law, medicine and astronomy in the schools of Padua and Bologna. A decided inclination towards the last of these led him, in 1500, to go to Rome, and place himself under John Müller, who, at the time, and under the name of Regiomontanus, had been engaged by Pope Sixtus IV to revise the calendar. In recognition of the ability he exhibited, he was appointed in 1503 Professor of Mathematics at the University of Ferrara, where his main duties were to expound the Ptolemaic system of astronomy to his pupils. But after serving there for less than two years he resigned, returned to Thorn, took the examination for holy orders, was ordained, and accepted the canonry of Frauenberg under the bishopric of his uncle. There he remained for the balance of his life, a period of thirty-eight years, devoting his time in about equal parts to the duties of his office, to the gratuitous practice of the medical art among the poor of his parish, and to the study of astronomy. At the end of twenty-five years, being then 58 years old, he had completed the Treatise which insured him fame. But shrinking from the controversies he felt it would cause, he deferred its publication for another twelve years, only then consenting to place it in the hands of the printer because he believed the end of his life was close at hand. And so it proved. For he died at the age of 70, a few hours after the first copy had been delivered to him.

This work, entitled "De Orbium Cœlestium Revolutionibus," was dedicated to Pope Paul III. In it he set forth and maintained with a great diffusion of argument, some of which at the present time would be lightly regarded, the four following main themes:

1. That the earth was a sphere. Knowing nothing of the laws of gravitation as set forth a century and a half later by Newton, or those of motion as exemplified by the centrifugal and centripetal forces, Copernicus argued that the earth *must* be of such a shape, mainly because that was the one perfect solid, its surface without beginning and

without end, and with all its parts in complete balance with each other.

2. That its orbit, as well as those of all the other members then known of the solar system, were circles, with the sun at their center, and that their motion therein was everywhere uniform in speed. This, he maintained, *must* be the case, because the circle, being the one perfect plain figure, was the only one that could account for observed periodicity. And for a like reason he held that the rate of motion for each must be uniform.

3. That the earth and the planets revolved on their axes. But again having no conception of the force of gravitation, he was unable to explain why the waters of the ocean and all loose bodies clung to them throughout their revolutions.

4. That the stars were at immense and varying distances from us.

On the foundation of these postulates, he explained the variation of the seasons, the movements of the planets, the phases of the moon, and the precession of the equinoxes. But his mathematical and observational equipment was not enough to enable him to do so with entire accuracy in all cases, and so, to account for some observed irregularities, he was compelled to fall back at times on one or more of the epicycles of Ptolemy.

Such in brief is one aspect of the life of a gentle, clean and unselfish man, of a thinker whose mind had grasped clearly certain verities, but was not always equal to the task of demonstrating them logically. His treatise, which is his monument, is therefore open to much criticism, but it should be considered in connection with the status of science of the time, and remembering that in his day all matters in nature calling for explanation must finally be squared with any and all statements in the Bible that directly or remotely touched the question at issue. If that was not possible, then the interpretation advanced must be considered erroneous, and subject to the condemnation of the Church. It seems certain that Copernicus had reached the conclusion that his elucidations of the observed celestial phenomena could not be so squared.

That he was a man of great modesty, is made clear by the fact that at the outset of his thesis he disclaimed originality, by calling attention to that theory of the cosmos believed to have been taught by Pythagoras 2000 years previously, which held that the earth was a sphere revolving around a central source of light and heat, as also the sun, the moon, the planets then known, and the stars; which source however was itself invisible, because towards it the under side of the earth was always turned.

The place of Copernicus in history is that of the man who took the first step in medieval times in setting forth the idea that some kinds of knowledge may be acquired by other means than through the study of the Scriptures, the writings of the Fathers of the Church, and the philosophies of the Ancients. In doing this he fairly earned the title of the Father of Modern Science, regardless of the many errors he made in his exposition of the Universe. Being unquestionably a devout and humble-minded man, as well as an officer in his church, his delay in giving publicity to his views until he believed himself to be on the verge of the grave, where he would be beyond the reach of those who could call on him to recant or suffer the consequences, may easily be understood, and condoned if thought necessary. We are not always required to proclaim our views from the house top. His epitaph, which he prepared himself, was thoroughly characteristic of the man.

"I do not ask the pardon accorded to Paul. I do not hope for the grace given to Peter. I beg only the favor which you have granted to the thief on the cross."

His book was condemned as heretical by Martin Luther, a contemporary, and in 1616 it was placed in the Index Expurgatorius by the Church of Rome.

FALLOPIUS (1490–1562)

ANATOMY

Gabriel le Fallopio was born in the country, in the vicinity of Modena, Italy. Nothing is known of the first half of his life, and even the date of his birth is uncertain, some historians placing it as late as 1523. This seems highly improbable, for on that basis he would have been only twenty-five years old when, in 1548, he was advanced from an assistant professorship in anatomy at the University of Ferrara to the rank of a full professor at the University of Pisa, from which, in a few years, he was called to take the very important chair of anatomy at Padua made vacant by the departure of Vesalius, who had been compelled by the court of the Inquisition to resign, on account of certain of his teachings which were averred to be in conflict with the religious orthodoxy of the day.

Fallopius was a writer on both anatomy and medicine, but his reputation rests almost wholly on the discoveries he made in certain of the organs of the human body, coupled with his exposition of their functions. These were of such importance as to place his name alongside of those of Vesalius, Eustacio and Fabricio as one of the four principal founders of the modern science of anatomy.

He was the first to accurately describe those two important bones—the ethmoid and sphenoid—which respectively form the outer and the inner frontal parts of the human skull, and which, combined with six others, enclose the brain. Through minute perforations in the former the delicate filaments of the olfactory nerves pass outward to their proper termination in the nose. In all animals where the sense of smell is especially acute, as with the dogs, the central part of this bone, which determines the division of the nostrils, is markedly developed. If it were not for this division, half of the area now occupied by the terminal buds of these nerves would not be available. The sphenoid, situated lower down towards the base of the skull, has roughly the shape of a moth at rest. Two of the wings form part of the floor on which the brain rests, and other parts constitute the outer rim of the orbits of the eyes. To surfaces of this bone are attached the powerful muscles that actuate the jaws in mastication. This bone also is perforated to pass five sets of facial nerves, including those of taste.

The canals through which the auditory nerves pass from the brain to the ear were discovered by him, and are known as the Fallopian aqueducts. His name is also preserved in the Fallopian tubes, whose function he demonstrated; and to his studies of the intestines we owe the discovery of those circular folds lying in series along their inner wall, and projecting somewhat into them, that add to their absorptive and secretive capacity. A complete edition of his writings in four folio volumes was published in 1600.

III

THE SIXTEENTH CENTURY

With the beginning of the 16th century, Europe, which then meant the civilized world, had emerged from the gloom of the Dark Ages. The Renaissance was in full flower.

However, the continual internecine wars greatly hampered the spread of learning. Beyond a few scattered colleges and the monasteries, education was almost unknown.

Despite the unfavorable soil, this century produced a small group of men of giant intellect who were to become pathfinders in their allotted fields. The work of the astronomer Copernicus was largely done in this century. Galileo discovered three of the moons of Jupiter. Kepler defined the laws of planetary motion. In physiology, Harvey discovered the circulation of the blood. In mathematics, Stevin introduced the decimal system, and Napier invented logarithms. There are only some dozen names all told in this century, but all are of high achievement.

TARTAGLIA (1500–1557)

MATHEMATICS

NICOLO TARTAGLIA—whose real name, however, was Nicolo Fortuna—was born in the city of Brescia in northern Italy. Practically nothing is surely known of his parentage, his early history or his educational equipment. That he possessed naturally high mathematical ability is clear, for he was a lecturer on the subject at the University of Verona, and later taught the science in Venice. He was also a writer on physics which was, at the time, beginning to emerge as a separate department of knowledge from its ancestry in mechanics, as various phenomena of motion, heat, etc., were subjected to preliminary mathematical analysis. His work on this subject, entitled "The New Science," published in 1537, shows that he had discovered (or, at least investigated), the law of falling bodies, and had applied its principles to the flight of artillery projectiles. From another volume on mathematics published in 1556, the degree of development of that science in Italy in his time can be fairly estimated.

He is principally remembered, however, in connection with the subject of the cubic equation, which was the algebraic conundrum of his time. According to general belief he discovered the method of its solution during the year 1541 and, as the story goes, gave it, under a solemn promise of secrecy, to one Girolamo Cardano, a fellow countryman and also a brilliant mathematician, but, in addition, a most disreputable and unscrupulous character. Cardano unhesitatingly violated the confidence reposed in him, and published the solution over his own name, and as his own discovery. In spite of the efforts Tartaglia made—even to the extent of carrying the question into the courts—Cardano succeeded so well in palming off the discovery as his own, that ever since it has been known in the books as "Cardano's Method," though it has been conclusively shown that the credit rightly belongs to Tartaglia. It was perhaps the most important—and certainly the most interesting—mathematical accomplishment of the sixteenth century.

VESALIUS (1514–1564)

ANATOMY

Andreas Vesalius was a native of the city of Brussels in Belgium. After studying at the Universities of Louvain, Cologne, Montpelier and Paris he became a lecturer on surgery and anatomy at several of the large universities in Italy where medicine was taught; and while so serving was offered the position of chief physician to King Charles V of Spain, and took up his residence at Madrid. In 1564 he was accused by envious enemies of having dissected a human body before life was extinct, and brought for trial before the officers of the Inquisition, who, though they did not hesitate themselves to torture heretics, condemned him to death. The King, however, secured the commutation of the sentence to one imposing a visit of expiation to the Holy Land. He made the outward trip safely, but on the return, the vessel in which he was traveling was wrecked on the rocky shore of Zante, an island off the west coast of Greece, and died there in consequence of exposure and injuries received.

Vesalius is regarded as the foremost of the anatomists of his time. He was a lecturer of unusual charm, and a writer of note in his specialty. He was the first to break away from the views held by the ancient Greeks as to the functions of the various organs of the human body.

Because of the lack of proper instruments for dissection, and of any such aid for the study of minute details as is at present available by the use of the microscope, comparatively little real knowledge of the human body had accumulated among the Greeks. Hipparchus (460–360 B.C.) is generally credited with a fair knowledge of the skeleton. At Alexandria, when in its prime (150-200 B.C.), it is known that dissection was practiced at the medical schools there, but did not go much farther than to expose the principal vital organs and speculate on their duty. Galen (A.D. 131–200) was the first to record with any degree of accuracy what he observed in his surgical work, but as his theories of the processes of digestion, and the work performed by the blood and the other bodily liquids, were almost entirely erroneous, the conclusions he passed on to his successors were of little real service in curing bodily ills. During the Dark Ages in Europe dissection was considered an impiety, and was only practiced in secrecy and at great peril. Early in the 13th century conditions in this respect began to improve, to the extent that the bodies of criminals were generally granted to surgeons for study. But even then, and through the three following centuries, clinics consisted of little more than the opening of the trunks of such subjects for the display of the organs contained, and explanation of their operation according to ancient views.

Vesalius advocated complete abandonment of these old conceptions. The result, as usual, was a storm of protest from those who clung to what was thought to be the superior wisdom of the ancients. The contest increased in violence until the Church was appealed to as the final authority, and to its credit it should be recorded that in 1556, after consideration of the arguments advanced by both parties, it held that since a knowledge of anatomy is useful to man, dissection may be allowed.

While in Palestine, and doing penance, Vesalius received and accepted an offer to occupy the chair of anatomy at the University of Padua in Italy, and was on his way there when shipwrecked. His writings, which were numerous and important, though containing many views since abandoned, were collected and published in Leyden in 1725.

GESNER (1516-1565)

NATURAL HISTORY

KONRAD VON GESNER was a native of the city of Zurich, in Switzerland, and was educated for the medical profession at the University of Basle. Incidentally he was a fine classical scholar, and also well posted in such of the discoveries in physics as had been made up to his time. But his favorite subject was animal life, not so much in its purely scientific aspect, as in the way life of any kind appeals to the man of a kindly nature. In 1541, after several years of travel and study, in Strassburg, Bourges, Paris, Montpelier and other educational centers, he accepted the position of professor of physics at the University of Zurich, and while fulfilling his duties as such began work on his "Historia Animalium." It was written in Latin according to the custom of the time, and was intended to be a description of every kind of animal known at the time by himself, or of which he could obtain an account from others that seemed to be sufficiently reliable. As planned, it was in six parts or volumes, the first on animals that bring forth their young alive, the second on quadrupeds hatched from the egg, the third on birds, the fourth on aquatic life, the fifth on serpents and the sixth on insects. The first four of these were completed and published in the years between 1551 and 1558, but the last two, as also a work on plants, were unfinished at the time when, taken ill with the return of the plague known as the Black Death, his active life came to an end.

In spite of the complete lack of technical knowledge of his subject, and his unscientific classification, Gesner rendered a real service to his generation in drawing the attention of those who could read Latin to the interesting facts of life all around us; and his work, like that of Aldrovandi the Italian (1522–1605) on mollusks and birds, and the very similar volumes by Buffon (1707–1788), did much to stimulate an interest in natural history, which bore fruit of better quality when Linnaeus (1707–1778) made his

Facing page 70

improved but still incorrect classification, and culminated with that of Cuvier (1769–1832), the first of the naturalists to base his groupings on the firm foundation of comparative anatomy.

Gesner's unfinished volumes were published some years after his death, in about the shape in which he left them.

EUSTACIO (? –1574)

ANATOMY

Bartolomeo Eustacio was an Italian by birth. Of his native city, his parentage and his youth practically nothing is known. But in 1562 he was a teacher of his art—medicine and surgery—at the Collegio della Sapienza at Rome where, on account of his great ability as well as personal charm as a lecturer, he had attained a high reputation. His name, and those of Vesalius and Fallopius are linked together in the annals of science as the founders of the modern school of anatomy. Vesalius, a Belgian (1514–1564), was the first of whom records have been preserved since the days of Galen (130–201) to dissect the human body, and to make accurate drawings of his sections. Having been accused after one of these operations of human vivisection, he was condemned by the College of the Inquisition to make a penitential journey to Jerusalem, and was lost through shipwreck on the return trip. Fallopius, an Italian (1490–1562), while lecturing at the Universities of Padua and Pisa in surgery, demonstrated the functions of the Fallopian tubes which conduct the human ovum to the uterus.

Eustacio, the most prolific of the three in the matter of important anatomical findings, was the discoverer of the eustachian tubes which connect the nasal cavity with the inner ear; of the rudimentary valves in the heart (which also bear his name), and was the first to call attention to the chain of small bones in the ear—the malus (hammer), incus (anvil) and stapes (stirrup), and to describe their several functions in the phenomenon of hearing. He also gave the earliest known accurate description of the thoracic duct, which connects the cavity of the chest in mammals with the abdominal cavity, and took a very prominent part in describing the development of the teeth, and also the structure and functions of the kidneys.

FABRIZIO (1537–1619)

ANATOMY

THE birthplace of Girolamo Fabrizio was Aquapedente, in Italy. He was the son of peasants but, nevertheless, was given a good primary education, and early evinced so marked an interest in natural history that the opportunity was afforded to attend the classes in medicine and surgery at the University of Padua. So greatly did he distinguish himself in research, and afterwards as an assistant instructor, that he ultimately rose to the position of professor of anatomy and surgery there and held it until incapacitated by old age.

He was an expert in diseases of the eye, ear, larynx and intestines, and in the development of the human foetus. His greatest discovery was that of the valves in the veins. But strangely, while he called attention to these in his lectures, he did not understand their use, and it remained for Harvey in 1615 to show that they prevented the backward flow of the blood and so compelled it to move onward towards the heart which, in its turn, forced it into the lungs.

In 1617 his great work, entitled "Opera Chirurgica," was published, and went through seventeen editions before the demand for it ceased. So highly was he esteemed by his countrymen when in his prime, that the Venetian republic built for him an anatomical amphitheater, where his lectures could be attended by a large audience, paid him a salary of 1000 crowns, and made him a knight of the order of St. Mark. In accordance with the custom of the times his name was Latinized, so that he was known throughout the educated world as Fabricius.

In the 16th and 17th centuries northern Italy was the commercial and intellectual center of the world, and its educational institutions at Padua, Bologna, Genoa, Modena, Parma, Pavia and Turin attracted students from all parts of Europe. Most of them originated in the 12th and 13th centuries, as outgrowths of schools that had existed prior to that date in connection with cathedrals and monasteries. In these only theology, medicine and ecclesiastical law were taught, and the student was expected at the end of his studies either to take active service in the Church, or to assume the vows of one of the many monastic orders then in existence. In their later development departments of philosophy, logic, rhetoric and civil law were established, and became important, and their direct supervision by the clergy was gradually abandoned. Finally the sciences in their then immature state, beginning with mathematics and astronomy, were introduced, and theology and church law relegated to seminaries connected with the monastic orders. In these medieval universities instruction was wholly by lecture, attendance was optional and the degrees of bachelor and master of arts were conferred only on those—comparatively few in number—who, by reason of the exhibition of marked capacity, were selected first as assistant instructors, and later rose to professorships: In some of them, as was the case at Bologna, the students themselves constituted the corporation, and arranged for all the instructional activities. In the majority, however, the tutors and professors and assistant lecturers or demonstrators gradually combined to form the governing body. In both, the reputation of the organization, and the numbers of students attracted, depended wholly on the standing of the lecturers in their different specialties, and the rivalry and competition between them for the services of a brilliant and interesting speaker was often strenuous. Fabricius was one of the most noted of these professors. Yet he failed to realize the importance of his great anatomical discovery.

The arteries, carrying freshly renewed blood from the lungs under the urge of the pumping heart, as they advance towards the extremities of the body, continually dividing and steadily decreasing in size, terminate finally at the extremities in the minute tubes called capillaries, which themselves connect there with equally small tubes leading into the veins. The latter, now continually enlarging in section as joined by other veins, have the task of carrying the dark and impure blood back to the lungs for purification, but no longer can depend upon the heart for motive power. Here then nature has solved the problem by providing in many of them a system of valves at regular intervals of their length which, aided by a slight involuntary contraction of the vein walls at regular intervals of time, forces the blood on to its proper destination.

GILBERT (1540–1603)

NATURAL SCIENCE

WILLIAM GILBERT was a native of Colchester, England, where his father held a public office. He was educated at Cambridge, from which institution he received the degree of M.D. in 1569. In 1573 he opened an office in London, and rapidly acquired so high a reputation that he was appointed court physician, a position which he retained for the balance of his life. In 1600 he became president of the London College of Physicians.

While making his living in the practice of his profession, he devoted all his spare time to researches in physics, confining them largely to electrical and magnetic phenomena, where he made several discoveries of importance. The principal one with which his name is properly connected was the recognition of the fact that the earth was itself a great magnet, and that the movements of the mariner's compass were due to that fact. He was the first student of the subject to use the term "electric force," and to point out that many substances besides amber could, by friction, be made to exhibit the presence of electricity on their surfaces. His treatise "De Magnetico," was the earliest publication of any importance in that branch of science. Naturally, some of the views and theories elaborated therein have not since been realized, but a surprisingly large proportion have been, for he was a close and keen observer, as well as a conscientious recorder of phenomena witnessed.

Columbus, the Navigator, is believed to have been the first to express the opinion that the compass does not point to the geographical pole, and that the magnetic pole to which it does point must be a movable location, because of the continual variations of the directions to which the magnet points. Norman, a London instrument maker, was the first to call attention to the dipping action of the instrument. To the astronomer, Halley, we owe the first magnetic charts. Another London instrument maker, Graham, discovered the diurnal variations. Gauss, the mathematician, made an exhaustive study of terrestrial magnetism, and to Humboldt is due the suggestion of making systematic observations of the daily and annual variations at all available points on sea and land.

The earth has a magnetic equator, where the needle, when freely suspended at its central point, remains in an absolutely horizontal position. This line is an irregular one, crossing and recrossing the geographical equator at many places, but never departing more than about a dozen miles from it. At all locations to the north of this wavy circle the south pole of the magnet not only points to the north magnetic pole, but dips towards it. South of it the needle points and dips to the south magnetic pole.

These magnetic poles do not coincide with the geographical poles. The northern one was discovered in 1831 by Sir James Clark Ross, on a peninsula called Boothia Felix projecting into the Arctic regions from the Canadian coast in latitude 70° N. and longitude 96° W., and hence is distant about 1375 miles from the geographical pole.

The south magnetic pole was discovered in 1842 by the same explorer. It lies on that part of the great Antarctic continent called Victoria Land at about latitude 73° S. and longitude 145° E., and is therefore about 1150 miles north of the geographical pole. In both cases it has since been discovered that these poles are not stationary localities, but wander irregularly from year to year within the limits of a circle of about 20 miles in diameter. In approaching the two localities the dip of the compass increases steadily and rapidly, and when the exact position for the time is reached, it assumes a vertical position. The cause of the wandering is ascribed to the continual slight changes in progress in the shape of the earth, each of which, to some extent, results in more or less of a displacement of its center of gravity.

BRAHE (1546–1601)

ASTRONOMY

Tycho Brahe was the eldest son of a Swedish nobleman, and was born on the family estate (Knudstrup) near the town of Helsingborg, which stands on the narrow strait between Sweden and Denmark. Twenty-three years previously the former had become independent of Danish sovreignty, and under the wise and capable reign of Gustavus Vasa, Tycho passed his youthful years. When the boy had reached the age of ten his father died, and he passed under the care of his uncle, Otto Brahe. By that time he had not only learned to read and write his native language well, but had begun the study of Latin, and by the age of thirteen was so well grounded in that language and the fundamentals of mathematics, that it was considered time to send him to the University of Copenhagen, to specialize in those studies which led up to the profession of the law, for which his uncle destined him. In the following year (1560), an eclipse of the sun had been predicted for August 21st, and the educated world of the day was naturally excited over the coming event. When it began precisely at the time set, Tycho was so moved, that he resolved to make himself the master of a science that could foretell accurately an event so marvelous.

In 1562 he was transferred to the University of Leipsic to finish in law. But he exhibited no inclination for the profession, and when his uncle died in 1565, leaving him, at the age of 19, in possession of a handsome income, he took his future into his own hands, and devoted his energies to astronomy, much to the disgust of all his relatives except a maternal uncle, Steno Bille, who unhesitatingly encouraged him to follow his natural bent. Leaving his native land he went to Wittemberg in Saxony, early in the spring of 1566, but moved to Rostock in Mecklenburg the following year. Here he became involved in a quarrel with a Swedish nobleman, with whom he fought a duel with swords in total darkness, with the result that his opponent sliced off the entire front of his nose, which naturally ended the contest. The damage was repaired by cementing on his face an artificial nose, constructed mainly of gold and silver which, for the balance of his life, was worn without serious discomfort or disfigurement.

Late in 1568 he journeyed to Augsburg in Bavaria, and there made the acquaintance of the brothers, John and Paul Hainzel, both astronomical enthusiasts, and also men of some means. To them he explained his desire to set up a quadrant of some twenty feet radius for observational purposes, the drawing for which so impressed them that they not only offered to bear the expense of constructing it, but to provide a suitable site for its installation in one of the suburbs of the city where Paul had a country home. To this was later added a sextant of 5-foot radius, and with these two primitive instruments many successful observations were made. Towards the end of 1571, by which time his fame had spread throughout Europe, he made a visit to his home town, and met with a warm reception from both friends and relatives, and particularly from his Uncle Steno, whose encouragement for his early ambitions was now fully justified. This relative now offered him quarters on his own extensive estates for an observatory, and when he learned that his gifted nephew was also interested in alchemy—which, at the time, was considered quite as reputable a field of inquiry as astronomy—agreed to provide him also with a fully equipped laboratory. This munificent offer was eagerly accepted by the young man, who was then in his 25th year, but was not immediately acted on. At the time Tycho was, of course, aware of the theories of the Universe that had been propounded by Copernicus a quarter of a century previously, but there are reasons for believing that he had never read the "Treatise" that set them forth, and it is certain that he rejected the general conclusions of the work, on the ground that they were contrary to the teachings of the Scriptures, and of the Church, of which he claimed to be a devout member.

In the fall of the year (1572) a "nova" suddenly appeared in the constellation of Cassiopeia. It was first seen by Brahe on November 11th, but had been detected by others as early as in August. It was an unusually brilliant one, remaining visible for over a year, and disappearing only in March, 1574. At its maximum it was the equal of Sirius in brightness. Tycho was wonderfully impressed with the phenomenon, and made observations every clear night during its continuance, which later were published. These added so greatly to his reputation that the King, becoming interested, asked him to deliver a course of lectures on the subject. Here it should be mentioned that about a year previously Tycho had married a girl of the peasant class, to the deep offense of his relatives. But the success of his lectures, and the favor with which they were received at Court, much more than overbalanced the displeasure of his relatives in the public mind. Tycho, however, was so angered at the slights his wife had received at their hands that he determined to abandon Sweden as a residence, and early in 1575 left for Germany to find a more congenial environment. Going first to Hesse Cassel he spent a week or more in delightful association with the Landgrave of that principality, who was one of the noted astronomical enthusiasts of the day. From there he traveled into Switzerland, and after deciding upon Basle as a desirable location, and making a short visit to Venice, he began his return journey to Sweden to fetch his family to the new home. While preparing for the move he received an offer from the King of Denmark and Norway of a grant for life of the island of Huen, situated in the narrow strait between Denmark and Sweden, on which would be erected at royal expense all the buildings for such an observatory and laboratory as Brahe might plan, and equipped with all the instruments and appliances necessary for his work. The offer also included a liberal subvention to cover operating and maintenance costs, a house for his family and a salary for his support. Naturally, such a flattering proposal was at once accepted, and before the end of the year construction upon a most elaborate scale began. The ultimate total cost of the establishment was close to one million dollars, of which Brahe contributed nearly one half, almost impoverishing himself in the operation. He gave it the name of Uranienborg.

Here Tycho passed the next twenty years of his life, during which he not only made a large number of valuable and important stellar and planetary observations that added greatly to the current stock of astronomical knowledge, but also spent much time in the laboratory in resultless experiments in alchemy. It was in fact his devotion to the latter that finally encompassed his downfall. In 1588 the King died, after a notable reign of 29 years. His son, Christian IV, who succeeded, was but 11 years old at the time, and naturally was easily influenced and controlled by those around him. In 1591 this boy sovereign made his first visit to Uranienborg, accompanied by a large party of courtiers, some of whom disapproved strongly of the favors that had been bestowed on Brahe, and most of whom were more interested in pushing their own fortunes than in advancing the cause of science. Furthermore, an opinion prevailed that no discoveries of any importance or value to the State had resulted so far from the extensive and costly laboratory experiments that Tycho had been conducting. It was not long before these unfriendly individuals began to make trouble for him, and in 1597 his situation became so unpleasant that he moved his family from the island to Copenhagen, taking with him his smaller instruments, and all his books and notes. A little later he appears to have chartered a vessel, loaded into it as much of his larger instruments and chemical apparatus as could be easily moved, and with his family sailed for

Rostock on the Mecklenburg coast. From there, having been cordially invited, he took his wife and children to the estate of his old friend Count Henry Rantzau, at the castle of Wandesburg, near the city of Hamburg, where he was made very welcome and urged to remain as long as he might desire. Rantzau suggested an appeal to Emperor Rudolph of Bohemia, who was a notable patron of the mystical arts, and to make this as strong as possible Tycho went to work at once to compile a memoir of the results of his life's labors to date. With that in manuscript he started for Prague, and received a most royal welcome from the sovereign. Rudolph at once gave him a pension, a country estate, and finally offered the castle of Benach, in the suburbs of the city, as a site for his instruments and apparatus. In August, 1599, he took possession, dispatched an assistant to bring his large instruments from the island of Huen, and his family from Wandesburg. Later, finding that the surroundings of Benach were not as suitable for his work as he at first thought, he begged the Emperor to allow him residence in Prague. He was at once permitted to establish himself temporarily in the royal edifice, and to set up his instruments in its gardens or park, and in the buildings surrounding it. The Emperor then crowned his benificences by purchasing a house for him in Prague, and into this Tycho moved with his family in February, 1601.

But before the year had come to an end, and just as he was beginning to enjoy the comforts and honors of his new home, he fell ill, and in less than two weeks passed away at the early age of less than fifty-five years.

Brahe was of medium height, with reddish-yellow hair, a ruddy complexion, and, if the portraits preserved of him are correct in detail, a dome-shaped head, a prognathous profile, with full lips (the upper unusually short) and the eyes deep set. These cranial characteristics indicate large observational capacity, combined with a vigorous physique, a sanguine and rather irritable temperament, and a love of the marvelous. In conversation he was brilliant rather than impressive or logical, somewhat impatient at opposition, yet generally kindly and generous to those around him.

In estimating his position as a scientific man it is necessary to remember that in his day the study of the heavens was carried on mainly in the hope of enabling the student to cast correct horoscopes, and that those who interested themselves in such work were really astrologers, and in no sense astronomers, as the word is used today. Furthermore, practically all the patrons of the art, the rulers and men of wealth who encouraged and supported celestial observation and study, did so mainly in the hope that discoveries might ensue that would redound to their material benefit, or enable them to avoid threatened danger or prolong life. The same was true of the alchemistic art, which had for its object the discovery of ways to transmute the base into the precious metals, and to produce elixirs or drugs that would prolong life or cure its ills. Neither astronomy nor chemistry as sciences had yet been born.

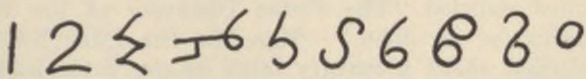
Brahe was really an astrologer and alchemist, and no more. He held to the Ptolemaic cosmology, and rejected that of Copernicus, not because the former appealed to his reason and the latter did not, but because the authorities of the Church of the day supported the one, and condemned the other. Into the matter of the reasonableness of this position he had no inclination to inquire. Hence, though he was a brilliant and ingenious inventor of appliances for observational use, and with their aid made a very large number of observations of note, they led to nothing in the way of a better understanding of the cosmos. The same may be said of his laboratory work, all records of which have disappeared, if notes were ever made. From this estimate of his character it is not to be concluded that he was a conscious pretender or charlatan. He deceived no one more than he deceived himself. He was the unconscious egoist of his day, yet one whose family life was clean and commendable, who attracted many sincere admirers, and who retained through life a few devoted friends.

STEVIN (1548–1620)

MATHEMATICS

SIMON STEVIN, better known among his contemporaries as Stevinus, was a native of Bruges in Belgium. Of his early life little is known, but that he was a man of good education and fine powers is proven by the fact that he held important positions under Prince Maurice of Orange in the capacity of civil and military engineer, where his scientific qualifications were exercised to the great advantage of his patron. He is best known as the introducer of the decimal system of notation now universally in use, and which he ventured to predict would ultimately result in the evolution of a decimal system of coinage, weights and measures, as has since been realized in the metric system. In addition to this very important forward step, he made a number of valuable contributions to the advance of knowledge in the domain of mechanics and physics, the most notable of which were those of the resolution of forces, the equilibrium of forces on the inclined plane, and the demonstration that the pressure of a liquid is independent of the shape of the containing vessel, and is determined only by the area of its base and the depth of the contained liquid. His writings were published in Holland in 1568, and in 1634 were translated into French and published in Paris.

The invention of numbers and of numerical systems is one of the earliest achievements of civilization. We owe to the Arabs our present list of nine digits and the cipher, but it is thought that they, in turn, derived them from India. Who first conceived the idea of representing these units by signs, instead of by the written word of their name, is unknown. Originally each probably consisted either of a rude pictograph of one or more of the fingers of the hand, or of the first letter of the written word. These everywhere became conventionalized sooner or later, until all semblance to origin disappeared. The cipher is supposed by some to represent the two hands closed and pressed together, with the fingers and thumbs interlocked. From the western Arabs our figures came to Europe via Spain and the Moors, under the name of the Gubar numerals, through the efforts at first of Pope Sylvester II (935–1003), who was a noted mathematician of his day, aided later by the labors of Leonardo of Pisa—better known as Fibonacci—about the year 1200, and in the following form:



When it occurred to Stevinus to place the decimal point on the right-hand side of one or more digits, and to establish the figures following it as representative respectively of tenths, hundredths, thousandths, etc., a wonderful step in advance was taken. The new notation met with immediate approval and adoption among the educated, while the old one of fractions (½, ¼, ⅛, etc.) was abandoned to the uneducated, and thus acquired their present name of common or vulgar fractions.

Among the ancient Egyptians and Babylonians the scales of 12 and of 60—and their multiples—were employed, and, to a much more limited extent, scales of two (binary) and three (ternary). It is interesting to note that the first has survived until today in the English system of money, and in the English and American systems of weights and measures; while the second remains with us in the divisions of the circle into degrees, minutes and seconds; and both combined, on the faces of the clocks and watches of the civilized world.

NAPIER (1550–1617)

MATHEMATICS

John Napier came of well-to-do parents, living in Murchison, a small town near Edinburgh, Scotland; and was educated at St. Andrew's University near Dundee, finishing off at the University of Paris. He was naturally endowed with fine mathematical faculties, and also with a disputatious and obstinate temperament, which inclined him to extreme views in religious and other matters. These characteristics involved him during the earlier parts of his life, at times, in awkward and regrettable situations, one instance of which was the publication in 1594 of a pamphlet entitled "The Plaine Discovery of the Whole Revelation of St. John." This, like Sir Isaac Newton's disquisition about a century later on the Bible books of Daniel and Revelations, was an example of the unfortunate trend of the day among men of speculative minds and deeply religious temperament, to attempt the explanation of assumed mysteries, by means of the few scientific principles by then available.

This phase of Napier's character lost its intensity as he neared middle age, by which time the idea of Logarithms had come to him, and engaged his attention so thoroughly that practically the balance of his life was devoted to the computation of logarithmic tables. His discovery of the system has justly earned for him an enduring fame.

The theory of Logarithms is one not easy of comprehension by the lay mind. Moreover, since its development by Napier, it has been further developed by later mathematicians, though the principle at its foundations remains substantially the same, as also the results sought. These, in effect, are the substitution in most cases of the easy processes of addition and subtraction, for the more difficult ones of multiplication and division, and the shortening of those of multiplication and division when they cannot be avoided.

Logarithmic tables give, for each rational number—whether an integer like 45 or 247832, or a fraction like 2.7 or 1846.432911—a logarithmic number, which is used in its place, as illustrated in the following example.

Let it be required to ascertain the circumference of the moon at the equator in inches, calling its radius 1061 miles. To determine the amount it will be necessary to multiply together the following natural numbers:

Radius of the moon in miles	1061
Ratio of diameter to radius	2
Ratio of circumference to diameter	3.1415927
One mile in feet	5280
One foot in inches	12

If now, instead of performing those multiplications, we find, in a table of logarithms, the logs of these natural numbers, the problem becomes one of simple addition as follows:

Log of 3958	3.0257154
Log of 2	0.3010300
Log of 3.1415927	0.4971499
Log of 5280	3.7226339
Log of 12	1.0791812
The sum of which is	8.6257104

Finally, looking again in the table for the natural number corresponding to this last logarithmic number, it is found to be between the numbers 422,387,444 and 422,-388,330, the mean of which would be 422,387,887, which is the answer.

The system is of extended use and advantage among astronomers, engineers, and others who have long and laborious computations to make, and also for the purpose of proving the accuracy of calculations made in the ordinary way.

GALILEO (1564–1642)

ASTRONOMY

One of the most illustrious of Italian scientists, Galileo lived in Pisa, and was the eldest of a family of six children. His parents belonged to the nobility, but their means were extremely limited. The boy, however, received a good education in the fundamentals, and at the age of 17 entered the University of Pisa with the intention of making the medical art his vocation. He had previously exhibited considerable ability in music and drawing. These predilections, added to a naturally inquiring mind, led him to the field of the higher mathematics, and to such instruction in physics as could be obtained at the time. In the latter he exhibited so much capacity and ingenuity as to attract the attention of Ferdinand de Medici, the reigning Duke of Tuscany, who secured him the post of lecturer (or tutor) in mathematics. By this time all thoughts of a medical career had been abandoned by both his father and himself, and all his youthful enthusiasm was applied to a critical examination of the philosophical systems—mainly Aristotlean—being taught at the time. These did not suit him, and with the ardor and indiscretion of youth he condemned them so openly and so vigorously, as to draw the return fire and ill will of all conservatives within sound of his voice. One of his major victories over the mechanical ideas of the day was his demonstration from the summit of the famous leaning tower of Pisa of the true law of falling bodies. By the Aristotlean doctrine, of two bodies of unequal weight, but otherwise similarly conditioned, the heavier would reach the earth the sooner. And though Galileo repeatedly demonstrated the inaccuracy of the theory, the enmity aroused against him was so great that when the chair of mathematics at the University of Padua was offered to him in 1592, he deemed it advisable to accept and move there, and take with him his mother and sisters, the care of whom had devolved upon him by the death of his father the year before. There, though his salary was but 180 florins (about $375), and he was compelled to undertake outside tutorial work, he found time to pursue his investigations into the laws of physics and mechanics, to perfect several inventions, and to complete a number of manuscripts of a controversial nature, nearly all of which were devoted to criticism of the current philosophies of the times. It was during this period that he became a convert to the Copernican theory of the Cosmos, nevertheless, for some time thereafter he continued to teach the Ptolemaic theory in his classes, excusing himself in a letter to Kepler written in the year 1597, by stating that he had not yet dared to publish his refutation of it. But he hoped to be soon firmly enough established to do so.

By this time Galileo had acquired so much celebrity as a polished and interesting lecturer that many members of the nobility attended his classes. This added so greatly to the reputation of the university that in 1598, when his contract was renewed for a second period of six years, his salary was doubled; and when that term came to an end in 1604, it was again increased to 520 florins, placing him, at the age of 40, in most comfortable financial condition. Possessed of a pleasing personality, and gifted oratorically, his lectures drew so well that no auditorium in Padua was large enough to hold those who wished to attend, and it was often necessary to adjourn to open-air meetings.

It was towards the latter part of the third term of his professorship, that the most interesting event in his career at Padua occurred. Throughout all he had retained the confidence and admiration of his former patron, the Grand Duke of Tuscany, who died in 1609. He was succeeded by his son, Cosmo, who, in his youth, had been a favorite pupil of Galileo. Cosmo, desiring greatly to have his former preceptor return to Pisa, made him a most flattering offer to that end. While the details of it were under consideration, Galileo paid a visit to a friend in Venice, and at his house heard of a curious instrument said to have been invented by a Hollander a year previously, which possessed the strange power of making things at a distance appear as if near by; and a few days afterwards he received a letter from a friend in Paris, giving a rough description of it, to the effect that it was a tube carrying a glass lens at both ends. Galileo, greatly excited, returned at once to Padua, and looking over the notes of his studies on the refraction of light, procured a couple of lenses from a spectacle maker (one of which was plano-convex and the other plano-concave), and set them in the opposite ends of a lead pipe. Then, applying his eye to that end which carried the latter, he found himself in possession of an instrument which produced the effect sought, though it magnified only to the extent of three diameters, as we would now say. Wonderfully excited he returned at once to Venice, and exhibited the instrument to his friends there. Among them it aroused intense interest, and when the news spread, hundreds of the upper class people of the city flocked to the house where he was lodged to see the device.

Galileo remained in Venice several weeks, exhibiting his invention. So greatly did it enhance his reputation that the Doge invited him to present it to the State, intimating at the same time that he would not regret the gift. Naturally, he complied at once, and in response he was appointed for life by the Senate to the professorship at the university, and his salary increased to 1000 florins. Of course, the instrument was a mere toy. But Galileo, who perhaps was the only man then living with some technical understanding of the optical principles involved in its construction, went to work at once to make another of greater power. The lenses that were sold in the spectacles of the day were very poor affairs. The glass of which they were made was good enough, but the art of grinding and polishing curved surfaces had been but slightly developed. However, in due time he had finished an instrument which, accerding to his calculations, should magnify to the extent of thirty diameters, and on the first clear night following he turned it on the full moon. His wonder and delight at what was then for the first time revealed to the eye of man, can better be imagined than described, for now the undefined markings that had baffled observers since the dawn of human time, were resolved into a multitude of gigantic mountain ranges, surrounding vast and deep crater-like valleys, across which the shadows of the craggy summits drifted as the satellite turned through space under the glare of the sunlight. Today the face of the moon is mapped almost as accurately as that of Africa. To Galileo it must have been, even under his crude telescope, like an apparition of a new world, of which he was the first discoverer.

But a still greater surprise was in store for him when he directed his instrument first, to such of the planets as were sufficiently above the horizon to be examined with advantage, and later to the fixed stars. For while the latter still remained simply minute and twinkling points of light, just as they appeared to the naked eye, the former were now revealed as well-defined disks, or parts of disks in the case of Venus and Mercury, whose phases were as clearly revealed as those of the moon.

Galileo, now thoroughly aroused, set to work upon the construction of a still more powerful telescope, and when it was completed he trained it on the night of January 7th, 1610, on the planet Jupiter, which was then in excellent position for examination. At once he detected three new stars close to it, and nearly on a line, two being east and the other west of it. Believing them to be simply hitherto undiscovered ones, he paid no particular attention to them. But on the following night, when he again examined the giant planet, he was surprised to see the stars differently arranged. All three were now on the west side, and were much nearer to each other. This astonished him greatly, and we can imagine his disappointment when the night of the 9th proved too cloudy for observation. But that of the 10th was all that could be desired, and when his instrument was placed, one of the supposed stars had totally disappeared, while the other two were on the east side of Jupiter. Galileo now began to fear that his telescope was in some way at fault, and was greatly disturbed. When he gazed through it again on the next night he still could find only two of these strange stars, and both to the east as before, yet one of them now seemed to be twice as large as the other, though heretofore all had appeared to be about the same size. On the night of the 12th he again found them in altered positions, and of changed magnitudes, and on the 13th he detected a fourth star in the same line as the other three.

At last the meaning of the phenomenon dawned on the mind of the delighted astronomer; but he continued his observations nightly until the 22nd, when, feeling certain of his facts, he gave publicity to them on the 24th, in a pamphlet under the title of Nuncius Siderius, dedicating it to his patron Cosmo. In effect the document stated that the planet had four satellites, which revolved around it as does the moon around the earth, and the planets around the sun.

This remarkable disclosure established forever the fame of Galileo, dealt a crushing blow to the Ptolemaic theory of the universe, and established that of Copernicus beyond any question, though the supporters of the former fought the change bitterly for some years, as he was to learn to his sorrow.

Being strongly urged to return to Pisa by his patron Cosmo, and also as sincerely invited to remain at Padua, and become an honored citizen of the Venetian republic, he found the choice a difficult one, which caused much disappointment in the latter when he decided in favor of Pisa. This passed away, however, with all except the unworthy, for it was recognized that upon equal terms, or even somewhat unequal, one would naturally prefer his native land to foreign residence. But the brilliancy of his discoveries now began to bring him enemies as well as friends, for Galileo was of a temperament that delighted in controversy, and an adept in the art. Having produced uncontrovertible proofs that the orthodox conception of the Universe could no longer stand, his strongest foes arose from the ranks of the Church; but so astonishing were the effects his discoveries had produced among intelligent laymen, that his opponents for some time made little progress. In fact, his reputation continued to grow, in consequence of his further discoveries. He was the first to detect the rings of Saturn, but having made his observations at a time when their plane was approaching parallelism to the line of sight, he misunderstood the phenomenon, and announced that Saturn had two moons, which chased each other at equal distances from it. Somewhat later, when the disk became simply a line, and then totally disappeared, he was nonplussed, and is said to have exclaimed: "Has Saturn indeed devoured his children?" He did not live to solve the mystery. Somewhat later he observed and studied in detail the phases of Venus, which exactly duplicate those of the moon as viewed from the earth.

In 1611 Galileo made a visit to Rome, taking with him one of his most powerful telescopes, and was accorded a most hearty welcome even from the dignitaries of the Church, who, though they feared the effects of his discoveries, could not deny his genius, nor the celestial phenomena which he made visible to them through his telescope. But in certain highly orthodox circles he was regarded as a dangerous enemy of revealed religion, and was closely watched in the expectation that sooner or later some speech or act would make him vulnerable. It was from these that danger was to be expected, and in due time it came.

At this stage of his career Galileo was approaching middle life, and had contracted a chronic ailment that was beginning to affect his temperament and judgment. Naturally impatient at opposition, as is often the case with men of high intelligence; confident of his own powers, proud of the discoveries he had made, and trusting too much to the towering position he had attained among thoughtful people everywhere, he displayed at times a recklessness in speech and action that caused distress to his best friends.

His troubles began when an open attack was made on him from the pulpit by a Dominican friar named Caccini. To this Galileo made a logical but rather intemperate and sarcastic reply, and the result was an appeal to the Inquisition. This body met in Rome in 1615, and after considering the evidence offered, passed judgment to the effect that Galileo must either renounce the Copernican theory and cease to teach it, or be imprisoned. Making mental reservations, the astronomer complied with the orders of the court, and was at once set free. But he did not keep his promise. In fact, he violated the spirit of it outrageously, as well as the letter, and this cost him the friendship of many churchmen who admired his genius, and who wished him well—among them the Pope himself. During the succeeding years, whenever the condition of his health permitted him to teach or write or engage in controversy, he did not hesitate to maintain his views of the nature of the Universe, and being by now a confirmed invalid, and regarded by many as mentally unbalanced, he was allowed much latitude of expression, on the theory that he could not live much longer anyway, and that if given enough rope he would hang himself. Galileo mistook this leniency for fear of his ability and standing with the intelligentsia, and went from one imprudence to another, without regard at times for even the ordinary courtesies, until it became impossible for the Church to ignore him any longer. And though the newly elected Pope (Urban VIII) was a strong friend and ardent admirer, Galileo did not hesitate to alienate even him by the publication in 1632 of a controversial pamphlet in which this valuable friend—under a fictitious name was held up to ridicule. This production, which was entitled "The System of the World, by Galileo Galalei," was presented in the form of a dialogue between three individuals, named respectively Salviate, Sagredo and Simplicio. The first represented himself, the second a friend of ability and wit who asks questions, suggests doubts, etc., while the third was the ardent but poorly equipped churchman who, adhering strictly to the outgrown theories of Aristotle, Ptolemy and the Fathers, gets the worst of it in all encounters and is mercilessly lampooned. The work was really a brilliant one, displaying Galileo's logical talents at their best, but also revealing, in its satire and contempt, the depth to which by that time his moral nature had sunk. It was impossible for the Church to ignore it without confession of total defeat, for the enemies of the astronomer did not hesitate to assure the Pope that the author of the pamphlet had purposely intended the character of Simplicio to be a representation of himself. In the spring of 1633, in response to the summons of the Holy Office, Galileo, then in his 69th year, presented himself for trial. His physical condition was deplorable, yet so strong was his self-esteem, and so astonishing his blindness to the position in which his folly had placed him, that he could not grasp the necessity on the part of his opponents to silence him forever at any cost. As the trial proceeded it slowly dawned on him that it was not a matter of argument as to the truth or falsity of the Copernican System, and his advocacy of it, but simply whether he or his accusers possessed the most power. And though his friends—of whom many in high places still remained faithful—made every possible effort to save him, they found against them a power which, at the time, when fairly aroused, was irresistible.

During his trial, Galileo was treated with extraordinary outward courtesy and consideration by his judges. Yet not for a moment was the issue in doubt, so far as they were concerned. No line of defense that he put forward could overcome the fact that he had broken the promises made at his first trial, and on the 22nd of June his sentence was pronounced. Galileo was both physically and mentally unable to resist. On his knees before the officials of the Inquisition, in the most solemn and impressive of surroundings, and with his hands upon the Bible, he vowed never again to teach the doctrine of the earth's motion and the sun's stability. After which he was committed to the prison of the Inquisition. From there, at the end of only a few days of confinement, he was allowed to go to the palace of the Tuscan ambassador at Rome, and later to the home of Archbishop Picolommini at Sienna. Here he was a welcomed guest for nearly six months, at the end of which time he was permitted to retire to his home near Florence. There, in strict retirement and seclusion from the world and all but the most intimate of his friends, he passed the remainder of his days. His death occurred in January, 1642, at the age of 78, nine years after the passing of the sentence which terminated his active career. Towards the end of it both his sight and hearing failed.

In person Galileo was of middle height and sturdy build, with a fair complexion, and hair of slightly reddish tinge. His features were strong, rather thin, finely cut, the lips were full, the nose broad at the nostrils, the ears rather prominent, and the eyebrows somewhat upturned outwardly. His temperament was a combination of the sanguine and choleric, which often led him into positions that would have been avoided by the exercise of a little tact. His intellectual equipment was of the highest order, but there was a deficiency of moral courage, and a disinclination to be bound by even such lax moral conventions as were current in his time. The ailment from which he suffered during the last third of his life, was one which it is now known clouds the moral nature as much as, if not more than, it impairs the physical, and to this must charitably be ascribed his failure to observe the promises made at his first trial, and his abject surrender at the second. His published letters to the Abbé Castellini and the Grand Duchess of Tuscany (1613), which brought about his first indictment, were placed in 1616 on the Index Expurgatorius, at the same time as the "Treatise" of Copernicus (published in 1543), and Kepler's "Epitome of the Copernican Theory," which appeared in 1614.

KEPLER (1571–1630)

ASTRONOMY

John Kepler, the son of upper class Protestant parents, was born in the city of Weil, in the duchy of Würtemberg, Germany. He was a premature child, and with difficulty survived his infancy. At the age of five his parents, being compelled to go the Netherlands, left him with his grandfather at Limberg. There he began to attend school at the age of six years. But in 1579 it became necessary for him to join his parents, and for a time aid them with his services. However, in 1586, they were able to place him in school again at the monastery at Maulbroom, which held the rank of a preparatory institution for the University of Tübingen. There he took his degree of Bachelor in 1588 and of Master in 1591, in both cases with credit.

His natural inclination during these student years was towards philosophy, but he was well advanced in the higher mathematics by the time he left, and had become an ardent advocate of the Copernican system of the Cosmos. In 1594, he was offered and accepted the professorship of astronomy at Gratz, in Styria; and though he frankly considered himself unfit for the position, he took it because of the salary it carried. But he worked and studied hard, and soon found his powers and interest growing. At this period of his life he devoted much thought to a fruitless effort to arrange the orbits of the five planets then known besides the Earth in some kind of a mathematical sequence or order, on the basis, first of the relations which plane figures —triangles, squares and polygons—bear to the circle, and then on the relations between solids—tetrahedra, cubes and polyhedra—and the sphere; and in 1596 published a pamphlet on the subject which, though it brought him a considerable notoriety among the undiscriminating public, had no real value.

In 1597 he married, and shortly thereafter, on account of religious quarrels between the Catholics and Protestants of Gratz, he, being an avowed Lutheran, thought it best to retire with his wife into Hungary. He was recalled in 1599, but finding conditions at Gratz still unsatisfactory, he decided to make a visit to Tycho Brahe, who was then living at Prague, under the patronage of Rudolph of Bohemia, and arrived there early in the year 1600. Here he passed two very disturbing years, at times on the most friendly terms with Tycho, and at others in violent enmity. The elder, recognizing the ability of the younger man, desired to help him, but feared his too speculative tendencies; while the younger, misinterpreting the motives of Tycho, became at times suspicious of his good faith. These differences, however, were finally composed with credit to both parties. In 1601 he became Tycho's official assistant, and on the death of the latter in the same year he was advanced into his position by the Emperor at a handsome salary, which, however, was always in arrears. Kepler now settled down to congenial work, and soon acquired an enviable standing, largely because of the valuable pamphlets and books he was able to publish, on the foundation of the enormous amount of observational data which had passed into his hands at the death of Tycho.

In 1604 the world was startled by the sudden appearance of a new star in the constellation of the Serpent, which rivaled in brilliancy that of 1572, but lasted only a few months. Kepler published an account of it, but the document was not a creditable one, because in it he indulged in many foolish and wholly unscientific speculations and predictions, which naturally were never realized. About this time, to relieve himself from pressing financial obligations, he undertook to cast horoscopes, which even at this stage of his development he certainly knew were entirely futile. But the age was one in which astrology still flourished, and credulity was rampant even among the educated classes. He simply took advantage of these circumstances, and of his reputation, to increase his income, while at the same time continuing his scientific studies. In 1606 he published a work of value on the refraction of light, and in 1609 his really great work appeared under the title of "The New Astronomy." For the data upon which his notable conclusions were drawn he was indebted to the observations made by Brahe and their extraordinary accuracy, considering the instruments employed in making them. Kepler, however, deserves the credit of having deduced from them at least two of the three laws which are known by his name. These are:

1. That all the planets travel around the sun in elliptical orbits (instead of in circles as Copernicus taught), with the sun at one of the foci.

2. That the radius vector joining each planet with the sun, traverses equal areas of the plane of the orbit, in equal periods of time.

3. That the square of the time of revolution of each planet around the sun, is proportional to the cube of its mean distance from that luminary.

The last was not given to the world until 1619.

In 1611 he added still further to his well-earned fame by publishing a work of high merit on the laws of vision, and the construction of the astronomical telescope, consisting of two convex lenses, instead of the plano-convex and plano-concave ones of the first Galilean instrument.

Kepler was now at the summit of his career, but continually harassed by financial difficulties, due to the failure of his patron to pay him his full salary. The Emperor, in his turn, was experiencing equal trouble in collecting his revenues, owing to the continual internal and external disturbances of the times. Kepler's domestic affairs were also in a pitiable state, through privations and illnesses, which culminated in the death of his favorite son from smallpox, and of his wife from one of the infectious fevers so prevalent in central Europe at the time. In his struggles against these misfortunes he endeavored to secure a professorship at Lenz, in Austria, but Rudolph was unwilling to have him leave Prague. In 1612 this enlightened ruler died, and was succeeded by his brother Matthias, who allowed Kepler to assume the position at Lenz temporarily, while still retaining his post as Imperial Mathematician in Bohemia.

At Lenz he remarried, and among other literary activities of a more dignified and worthy nature, he published an almanac, which he himself held in contempt, calling it, in a letter to a friend, "a vile, prophesying thing, which is scarcely more respectable than begging," but which, on account of his reputation, met with a lively reception among the masses, and so assisted him financially to a considerable extent. In 1617 he was invited to the chair of mathematics at the University of Bologna, but appreciating the persecution he would inevitably encounter in such a stronghold of Catholicism as Italy, he wisely declined the flattering offer. Even at Lenz he was harassed to some extent by bigots, nor was he much better off financially than at Prague, for his salary was always in arrears.

In 1619 Matthias died, and was succeeded by Ferdinand III, who continued Kepler as Imperial Mathematician, promised to try to pay up his arrears of salary, and to find money to publish the Rudolphine Tables, the completion of which had passed into his hands at the death of Brahe. Before returning to Prague, however, he published at Lenz, "The Harmonies of the World," in which he announced his celebrated third Law, already given. It was dedicated to King James I of England, perhaps in the hope that he might thereby secure a new patron. And in due time an offer did come to him from that monarch, which, very wisely, he declined. In 1618 the three first books of his "Epitome of the Copernican Astronomy" appeared, the other three being delayed until 1622. This work, much to his alarm, was at once placed on the Index Expurgatorius by Pope Urban VIII.

In 1622, through the persistent efforts of Ferdinand, part of the State's indebtedness to him was paid, and funds secured for the publication of the Rudolphine Tables; but on account of the disturbed political conditions in Central Europe at the time, they did not appear until 1627. Shortly before their issue from the press Kepler received from the Duke of Friedland, an offer to take up his residence at Sagan in Silesia. He accepted, arrived there with his family in 1629, was most cordially received, and given a professorship in the University of Rostock with a handsome salary, an assistant calculator, and a complete printing outfit. There were still some 8000 crowns due him from Ferdinand of Bohemia, and Kepler went to Ratisbon and endeavored to collect it, but without success. Depressed at his failure, and worn out with fatigue and his lifetime of struggle with inadequate means, he contracted a fever which, in his sixtieth year, brought to an end a most strenuous and troubled but honorable career.

Kepler was a man of tall and rather spare physique and, without subserviency, of strong inclinations towards peace with all men. His temperament was genial and even jocular, inclining him at times to conclusions on slender foundations. On the other hand, there was a degree of persistence and honesty in his make-up, which compelled him to re-examine all these, until he was satisfied of their truth; or to admit an error frankly as soon as it became clear that he had made one. A striking example of these characteristics was his announcement of an observation of a transit of Mercury which, by others, was declared to be the discovery of the now well-known belt of spots across the disk of the sun. When the latter was announced, Kepler immediately and publicly admitted his error, and commended the other explanation of the observed phenomenon. His was a mind free from the taint of jealousy, and unobscured by pride of opinion. In the early years of his public career he was undoubtedly much under the influence of the astrological tendencies of the age, but by middle life he had become thoroughly aware of their absurdity, though, unlike Galileo, he had no inclination to crusade against them. Having suffered from infancy with weak and defective eye sight, he was barred from attaining eminence as an observer of the celestial bodies. His great faculty was that of generalization, and of drawing conclusions from the observations of others; and these gifts, aided by a fine mathematical equipment, and persistency, enabled him to discover the three laws of planetary motion that constitute his enduring fame. His mortal remains rest in the churchyard of St. Peters at Ratisbon, but their exact location are unknown, because the bronze tablet set over his grave was destroyed or displaced in one of the battles the city went through. But nearby, in the Botanical Gardens of the old city, a beautiful monumental temple was erected to his memory in 1803, in which stands his bust in Carrara marble.

HARVEY (1578–1657)

PHYSIOLOGY

William Harvey was a native of Folkestone, England; and at the age of fourteen was sent to Cambridge University. After five years of study there he was provided with the means for traveling, and made a journey through France, Germany and Italy. What he learned on this trip inclined him strongly to the medical art, in consequence of which he enrolled himself at the University of Padua in Italy which, at the time, held perhaps the highest rank among the European schools in law and surgery. Here, while attending the lectures of Fabricius, the celebrated anatomist and surgeon, he learned of the existence of valves in the veins, the purpose of which at the time was not understood. But he was greatly impressed. Upon his graduation in 1602 he returned to England, and entered upon the practice of the profession in London, rapidly attaining such eminence that in 1607 he was elected a fellow of the Royal College of Physicians, and in 1616 to its chair of anatomy and surgery. During the intervening years he made a specialty of the study of the veins, arteries and heart, and finally announced his great discovery of the circulation of the blood. Before his time it was of course well known that the blood was constantly in motion in the living animal, but, because the arteries were always found empty after death, it was supposed that they were a part of the respiratory system, and carried air only.

Harvey's theory at first met with great opposition, and even ridicule, but in a short time that passed, and he had the satisfaction while still living of witnessing the complete and unqualified acceptance of his discovery. In 1628 his work on the subject entitled "Exercitatio de Motu Cordis et Sanguinis in Animalibus" was published in Frankfort, Germany, in Latin, as was the custom of the day with all literary productions of moment, that being the one language which all educated people in Europe were supposed to be able to read.

The commanding position his discovery won for him is shown by the fact that from 1632 to 1648 he was physician to the King (Charles I), and accompanied him at the battle of Edgehill, during which the Prince of Wales and the Duke of York were left in his care. In 1645 he was elected Warden of Merton College, Oxford.

Harvey's investigations in physiology and anatomy included other subjects in which he made valuable contributions to knowledge, but none of these were fundamentally so important and far reaching as his great revelation of the mechanics of the body. In this the outstanding feature was the explanation of the operation of the valves in the veins which, being so constructed as to be capable of passing the blood in one direction only, compelled it to keep moving onward. Without them it would never get back to the heart which, in its turn pumped it into the lungs where it experienced the rejuvenation of oxygenation. It was this question that so powerfully attracted his attention during his student days, and invited his continued investigation until the problem was solved. It is true that in his day oxygen was unknown, as well as carbon dioxide, so that the actual chemical reaction that occurred in the lungs could not be understood, but even in his time there was a general concurrence among physicians that the act of breathing was one which in some way resulted in a purification of the vapors and liquids of the body, for at its cessation at death decomposition was observed at once to begin.

MERSENNE (1588–1648)

PHYSICS

THE birthplace of Marin Mersenne was at La Soultière, France. He obtained his education at the College of La Flèche, where he met the mathematician, Descartes. The two became lifelong friends. Being a fine mathematician himself and also a lover of music, he naturally was attracted by the science of acoustics, and discovered the laws which express the dependence of the time of vibration of the strings of a musical instrument, upon the length, tension and density of the string, and formulated his deductions in what is known as Mersenne's Law, as follows:

The time of vibration varies directly as the length of the string and the square root of its density, and inversely as the square root of its tension.

In 1611 he joined the association called the Minim Friars, an order of monks founded during the 15th century, whose vows pledged them to the observance of a perpetual Lenten dietary régime, corresponding to what at the present time would be approximately that of a vegetarian, plus occasional fish food. From 1614 to 1620 he was a teacher of the philosophy of the day. He then removed to Paris, where he passed the remainder of his life, devoting his time outside of that required by his religious duties, to the study of mathematics and astronomy. He was the Parisian representative of Descartes when the latter was in Holland. He wrote and published several monographs on the phenomena observed in the production of musical sounds which, for his day and time, were notable productions.

Acoustics was one of the earliest of the sciences to receive attention in modern times. Brooks Taylor in 1715 and Daniel Bernouilli in 1755 deduced mathematically the laws of vibration of a stretched string which Mersenne had discovered experimentally a century before, while Chladni in 1637 exhibited the effects produced by the longitudinal and torsional vibrations of metallic bars and plates. Poisson in 1829 was the first to investigate the laws of vibrations in membranes. In Rayleigh's notable work entitled "Theory of Sound," which was published about 1880, the subject was exhaustively investigated.

But the ancients and the scholars of the Middle Ages were, experimentally at least, not without considerable knowledge of the subject. Music among all people has been the first of the arts to be developed. Pythagoras, the Greek (circa 600 B.C.), knew that two stretched strings of the same material, cross-section and density, would vibrate in harmony if their lengths were as one to two, as two to three, as three to four, etc., but was apparently unable to explain the phenomenon. It had also been known from remote ages among savages that an appreciable time was required for the transmission of sound through the air, and that it traveled more quickly through the water or the earth. But it was not until Chladni showed by his famous experiment of ringing a bell in a vacuum in a glass jar, that sound was due to vibrations set up in a suitable medium, and that no sound would arise if no medium for its transmission existed. In high altitudes, where the atmosphere is thin, the crack of a pistol is an insignificant affair, and the human voice becomes little more than a whisper or squeak.

The human ear is so constructed that vibrations less in number than 30 per second, or greater than 20,000 per second are inaudible. In the case of music as differentiated from mere noise, the limits are actually between 40 and 4000, the lower number producing the effect of the deepest bass notes, and the upper that of the highest treble. The speed of travel of sound through dry air in a normal condition is 1077 feet per second; through water 4664 feet; through steel 16,217 feet, and through glass 17,875 feet. The denser the medium (if also fairly elastic), the more rapidly will it carry sound. On the other hand hydrogen, the lightest and most tenuous of the elements, will transmit its vibratilons at the rate of over 4000 feet per second, which would seem to indicate that elasticity more than density was at the basis of the phenomenon.

DESARGUES (1592–1662)

MATHEMATICS

GERARD DESARGUES was born at Lyons, France. Of his youth little is known, but in his early maturity he was recognized as a distinguished engineer and architect, and a mathematician of unusual ability. To him and Pascal are accredited the foundation work in the science of descriptive geometry—popularly known as the art of perspective—which later was developed to a high degree by Descartes.

In mathematical investigations he reached some conclusions which, in his day, were not accepted; or, at least, were not confirmed; but which, at the present time (human mental capacity or scope having meantime perceptibly increased) have become partially comprehensible, as the result of the enlarged knowledge of the properties of those concepts called Space and Time. Three of these are as follows:

1. That a straight line, if produced to infinity, becomes a curve, whose two ends will meet and unite.

2. That parallel lines, if produced to infinity, will also meet and unite (or intersect).

3. That a straight line and a circle may become identical, or constitute two varieties of the same thing.

Such propositions to most of us, and even to many with a good mathematical equipment, are hard sayings, or even absurdities, yet to the mathematician of genius they may represent statements of real truths which are slowly in process of experimental confirmation and demonstration as the Universe becomes better understood. The work of Desargues can be properly appreciated only by those few individuals who, from time to time, arise from the common run of humanity, to whom pure mathematics is not only the queen of the sciences, but actually the only one capable of revealing absolute fact. Such geniuses are rare, but no matter how difficult their conclusions are to be understood, they are really of fundamental importance in the slow but steady advance of knowledge. We have at last reached the comprehension that in the affairs of the Cosmos there is no such thing as chance. Fixed and immutable law governs every phase of existence, from that of the infinitely small to that of the infinitely great. Effect follows cause with absolute fidelity and certainty. Appearances, the evidences of the senses, and even the conclusions of logic may, at times, seem to indicate otherwise; but the trained scientist in the quest of Truth at the present day will at once reject these if, in the smallest degree, they appear to indicate exceptions to the reign of unchangeable law. Or, as an alternative, will suspect that the law, as theretofore enunciated, has been incorrectly stated.

DESCARTES (1596–1650)

MATHEMATICS

René Descartes (Renatus Cartesius) was born at La Haye in France and was educated at the Jesuit college at La Flèche, where he exhibited special aptitudes in mathematics, the languages and astronomy. Upon the completion of his courses there he became dissatisfied with much of the teachings he had received which, in accordance with the ideas of the times, consisted largely of the Aristotlean philosophy combined with the doctrines of orthodox theology as laid down by the fathers of the Church. To clear his mind of these he entered the army as a volunteer. After several years of active service he resigned in 1621 and devoted the next eight years to travel, finally settling down in Holland in 1629 where, for the following twenty years, he devoted his life to giving expression in his writings to the conclusions he had reached. These, largely of a philosophical nature, took the form of a conviction that, because he was able to think, it was logically legitimate to conclude that he existed as a distinct Personality, a conviction which he put concisely in the phrase, *Cogito, ergo sum* (I think, therefore I exist); this being in contrast with the mental attitude of the lower animals, who he regarded as unconscious automata.

Descartes gave expression to opinions regarding the material and objective world which have borne good fruit in the labors of subsequent investigators. He was a mathematician of high order, and the inventor of that branch of analytical geometry which is known as the Cartesian, and which may be said to constitute the point of departure of modern mathematics.

In 1649 he was invited by Queen Christina of Sweden to visit that country, and accepted gladly the opportunity to escape hostile critics in Holland. But a few months after his arrival in Stockholm he died.

IV

THE SEVENTEENTH CENTURY

Historically this period was one of almost continuous war in Europe. At its beginning, Spain was the dominant nationality, but before its close had sunk to the status of a third-rate power. England, after a half-century of prosperity under Queen Elizabeth, was compelled to endure nearly a hundred years of troublous times, which culminated in the Cromwellian epoch. The Netherlands (Holland and Belgium), after throwing off the Spanish yoke and attaining freedom, were threatened with the growth of the power of France which, under Louis XIV began to dominate the continent in 1643. Germany, during the whole period, was little more than a collection of feeble states, each struggling for existence, for during the Thirty Years' War its population had been reduced more than half. At the foundation of all these miseries were the bitter animosities between the Catholics and Mohammedans in Spain, and Catholics and Protestants elsewhere.

Under such unfortunate political conditions it is a wonder that science survived. Yet it produced some remarkable men. In mathematics, Fermat, of the calculus of probabilities; and Newton, the formulator of the law of gravitation. In astronomy, Cassini, the discoverer of the satellites of Saturn, and Halley of cometary fame. In physics, Bradley the detector of the aberration of light; Guericke and Torricelli who demonstrated the weight of the atmosphere; and Roemer, the discoverer of the velocity of light. The work of De Jussieu, founder of botany, born at its close, was done in the 18th century.

All these men were developers of basic discoveries or conceptions. They were foundation builders. Upon it their successors in the fields of science erected a lasting and remarkable structure.

FERMAT (1601–1665)

MATHEMATICS

Pierre de Fermat was a native of the village of Beaumont-de-Lomagne in southern France. He was educated privately, but thoroughly, at home, and lived a quiet and retired life, devoting his time mainly to writings on his favorite subject—mathematics. In this branch of science his contributions to the advance of knowledge were very great, perhaps the most important being his "Commentaries of Diophantus," the father of algebra.

By some—Laplace and Lagrange—he was regarded as the inventor of the Calculus, or at least, in his methods of numerical analysis, the first suggestor of the modern form of that branch of mathematics.

To Fermat is generally ascribed the rise in importance of the theory of Probabilities. This subject at first would seem to be one quite outside of the domain of mathematics, which is properly regarded as the one exact science. Yet the contrary is true, as may be made clear by the following examples:

Suppose ten horses are entered for a race, one of them being a light bay in color and the property of an acquaintance. Assume no knowledge of the trotting capacities of any of them. What then, from our point of view, are the chances that our friend's horse will win? At first, it would seem to be simply as 1 to 10. But, the heat having been run, we learn that a bay has won, and on glancing over the list of entrants we find that six are so described. At once the probability is reduced to the proportion of 1 to 6. But immediately thereafter we learn that the winner was a light bay, and upon a re-inspection of the list we find that two are given that shade of color. The chances then are mathematically even, or as 1 to 2. At last we learn the name of the winner and recognize it as that of the horse of our acquaintance. This reduces the chance to the ratio of 1 to 1, or to that of certainty.

In a generalized way the theory is stated as follows: "If an event can occur in any one of a number of different ways equally likely to occur, the probabilities of its happening at all is the sum of the several probabilities of its happening in the several ways." The probability of an event not happening is found by subtracting from unity (1) the figure representing the probability that it will happen. If A's chance of hitting a target is one-third, and B's chance one-sixth, the chance that both will miss is 1, less ($\frac{1}{3}$ plus $\frac{1}{6}$), which is $\frac{1}{2}$. Or, the probability of drawing at one trial a white ball from a bag containing two white and three black balls is $\frac{2}{5}$, and the probability of drawing a black one is $\frac{3}{5}$. These several simple illustrations appear self-evident and hardly worth serious consideration, and especially so as a department of mathematical research. Yet the deductions from first axiomatic principles may be, and are applied to complicated conditions in insurance of all kinds, to games of chance and to certain astronomical problems with great advantage. In the last case consider a series of observations of a celestial phenomenon in which, from the nature of the case—known defects of telescopes, imperfection of vision, incapacity to record instantaneously, etc.—absolute accuracy is admittedly impossible. Here the employment of the data of the theory of probabilities as worked out by the mathematicians, has enabled the astronomer to reach a conclusion which he is entitled to consider as most probably correct, or one in which the chance of error is so small as to be negligible. The method of obtaining this least error quantity is called the "method of least squares." It was first developed by Legendre in 1805, and later elaborated by Adrian and Gauss.

GUERICKE (1602–1686)

PHYSICS

OTTO VON GUERICKE was a native of Magdeburg, Germany. He was liberally educated in the schools, and afterwards by travel in Holland, England and France. In 1646 he was elected burgomaster of his native town. About this time he became greatly interested in the experiments made a few years before by Galileo, Pascal and others, on the weight and pressure of the atmosphere, and in consequence initiated an attempt to produce a vacuum.

His first effort was made with a stout wooden barrel, which he filled with water, and from which he then exhausted the water with an ordinary water pump. But he found that though the barrel would hold the liquid without leaking, it could not be made tight enough to exclude an inrush of air, while the water was in process of being taken out.

His next attempt was made with a hollow copper globe, fitted at one place on its surface with an opening to which the suction of a water pump could be securely attached, and at another with a stopcock. Having filled the globe with water, attached his pump and started it in operation, he was much astonished on finding that after drawing out some of the water the only way in which he could extract the remainder was by letting in some air behind it, through the stopcock, through which it then passed with a whistling sound. Also, that after exhausting the water and closing the stopcock, his water pump would draw out the most of the air, as well as the water, until in fact the pump itself began to leak air, and the copper globe began to show signs of collapsing. To Guericke therefore belongs the honor of having put into operation the first air pump.

Convinced now that he had made a discovery of importance, and wishing to exhibit in a striking way the effect of atmospheric pressure, he built two stout hemispheres of brass, each about a foot in diameter, which fitted together accurately on their flanged edges, and provided one of them with a stopcock, and the other with a valved opening to which his pump could be connected. Each hemisphere also had at its pole a strong ring, to which the harness of a team of horses could be attached.

With this apparatus he appeared by request before the emperor Ferdinand III at Ratisbon, and operated it with great success. He first showed clearly that, if the stopcock was left open, the two hemispheres would fall apart, even when the flanged edges were heavily greased. But when the cock was closed, and the air pumped out, the two teams of horses provided for the experiment, and working in opposition to each other, were unable to separate them.

This famous experiment—which is known in the records as that of the "Magdeburg Hemispheres," created the greatest interest throughout intellectual Europe, and started a movement in physical investigations which led before long to other discoveries equally important and astonishing.

Von Guericke is also remembered as the first investigator to demonsrate that sound is the effect produced on the mechanism of the ear by vibrations of the air. This was accomplished by suspending a bell in an airtight glass vessel and in such a way that it could be rung from the outside of it. When the air was exhausted by a pump, and the ringing mechanism set in motion, the clapper could be seen plainly to be striking the rim of the bell, but no sound resulted. However, when the bell was so hung as to come in contact with the side of the glass container, so that the vibrations could be communicated to the glass, and then rung, it became at once audible.

TORRICELLI (1608–1647)

PHYSICS

Evangelista Torricelli was a native of Piancaldoli, a small town near Florence, Italy, and having studied mathematics and physics at Rome, under a favorite disciple of Galileo, he atracted the attention of the latter—now in his old age and blind—and was invited to join him at his

Florentine home and become his assistant and secretary or amanuensis. Upon the death of the philosopher, Torricelli succeeded to his professorship in the University of Florence, which position he held until his death at the early age of 39 years.

His principal contribution to science was the demonstration of the weight of the atmosphere by means of the mercurial barometer, of which he was the inventor. As far back as the days of the old Greek philosophers, Plato and Aristotle, it was known that the atmosphere possessed that quality, even when in a quiescent state, because it exhibited power when in motion; but the amount of its weight was unknown. Both Galileo and Torricelli were aware of the fact that, by suction, water could be lifted in a tube to the height of 32 to 33 feet, and had deduced from it that the pressure exerted by the atmosphere on the surface of the water in a well, must be in the vicinity of 15 pounds to the square inch; and the former had expressed the opinion that the principle, if accurately demonstrated, might be usefully employed in measuring the variations in this pressure due to storms, and to altitudes above sea level. But the mechanical difficulties connected with the manufacture and installation of a glass tube of that length, were not easy to overcome at the time.

In the year following Galileo's death Torricelli took up the problem again, and bethought him of the idea of substituting mercury for water. Knowing that the weight of the metal was thirteen to fourteen times that of an equal volume of water, he reasoned that a tube one-thirteenth the length of that which would be required if water was employed, or, about 30 inches, would answer when using mercury. Such a tube of glass with a fairly uniform bore was, by then, within the capacity of the manufacturers. Accordingly he procured one about a yard in length, closed it at one end, and filled it with the metal. Then, inverting it in a vessel filled with liquid metal, he had the satisfaction of seeing the column sink down to a height of about 30 inches as expected, leaving a vacancy above it in the tube, which became known as the Torricellian vacuum.

On the foundation of this simple principle, modified to meet the various demands made upon it as an instrument of precision, all the varieties of the modern mercurial barometer are based, which are used not only for ascertaining the changes in weight of the ocean of air surrounding the globe, but also the elastic pressure of all kinds of gases.

Torricelli is also thought to have been one of the first to work out correctly the principle of the simple microscope, and to construct one that would yield practical results. His principle was developed by Antony van Leeuwenhoek of Holland (1632–1723), who is said to have made over two hundred very efficient instruments of one lens only. For the modern high power microscope, however, the world had to wait until the first quarter of the 19th century (1812–1827), during which period the art of lens grinding and polishing was highly advanced, and makers of the instrument learned how to combine them, so as to correct almost perfectly their chromatic effect on light.

PASCAL (1623–1662)

MATHEMATICS

Blaise Pascal was born at Clermont-Ferrand in France, of a family of the old nobility who for generations had been prominent in government affairs. He displayed unusual mathematical capacity in his youth, and received his education mainly under private tutors at home. In 1631 his father removed the family to Paris where the boy, as he grew up, became deeply interested in physics. At the time this science was in its infancy, and was slowly developing along lines which called for a knowledge of the higher mathematics for solution of many of the problems that it was presenting.

In 1651 his father died, and shortly thereafter a sister named Jacqueline, to whom he was deeply attached, entered the Jansenist convent at Port Royal. For three years the young man remained practically alone at Paris. But finding life insupportable without her companionship, he also became a member of the order. To understand the effect of this step on his subsequent life, it is necessary to know something of the conceptions for which the society stood.

Jansenism was the name given to one of the many so-called schisms that have broken out from time to time throughout the history of the Church of Rome. The questions at issue were mainly those of the "efficacy of divine grace," and the meaning and limits of the doctrine of "free will." Over those abstruse problems—as might naturally have been expected—bitter controversies arose, which lasted through nearly a century, and out of which of course no settled conclusions were ever reached. Pascal's apparent mental attitude in joining the order was not so much to espouse the cause for which it stood, as the desire, in the quiet and seclusion of a monastic life, to labor for the progress of science, as the duty of a man to whom had been given an inquiring mind. Nevertheless, he seems to have held the opinion that mental and moral certitude could only be found in revelation, that is, in the teachings of the Scriptures.

The most powerful opponents of Jansenism were the Jesuits. With them, but anonymously, and rather at first by accident than design, he entered into a prolonged controversy. As it advanced it became, on his side at least, intensely bitter; revealing his real attiude as that of the protestant against the casuistry and illogicality of the theological discussions so prevalent in Europe during the 16th and 17th centuries. These writings, which were collected and published after his death, have value now only as literary curiosities, and as examples of a beautiful and incisive style.

In scientific matters Pascal, in a treatise entitled "New Experiments on the Vacuum," demonstrated that the conclusions reached by Torricelli a few years previously as to the weight of the atmosphere, were correct. In one of these he substituted wine for water in the barometrical tube, and in another had it (filled with mercury), carried to the summit of the French mountain called "Puy-de-Dôme," which rises to an altitude of 4086 feet, and where, as he expected, the pressure of the air was so much less, that the column of mercury it would sustain was considerably shorter than at sea level. Thus was at last completely solved the ancient puzzle as to why water can be lifted in a pipe by suction, but only to a maximum height of 32 to 33 feet.

Although a mathematician of unusual ability, Pascal took little pleasure in the exercise of the talent during the mature years of his life. In his early youth he published an essay on the "Geometry of the Conic Sections" which ranked high in its time; and in 1685 another one descriptive of his device known as "Pascal's Triangle," which solved graphically a rather complicated mathematical problem. He also took part with Descartes in extending the scope of the "Theory of Probabilities." But his heart was not in such work. Nor, towards the end, was it in the religious controversies to which he gave so much of his mature energies. Towards the latter part of his brief and troubled life he became an anchorite and a pessimist, uncomforted even by the beliefs on which he had placed so much reliance in his youth.

BOYLE (1627–1691)

CHEMISTRY

Robert Boyle was born at Waterford, Ireland. After passing through Eton College in England he traveled on the continent for six years when, by the death of his father, he came into possession of the family estate; the Manor of Stallbridge in Dorsetshire, England. Here he resided until 1654, when he moved to Oxford, and became one of the first members of that social group of scientific men which, at that time, held private and informal meetings at London and Oxford, and constituted the nucleus of the organization later known as the Royal Society.

Boyle took a very prominent part in laying the foundations of the coming science of physics, by experiments and investigations in pneumatics and allied subjects. His chief contribution was the enunciation of what has since been called the "Law of Boyle and Mariotte," because discovered independently by the two. It may be stated as follows: "When a gas is at a constant temperature, the product of the pressure and volume of a given mass of it remains constant." Or, as follows: "If the temperature of a gas is kept constant, and its volume changes, the resulting pressure and density are such that one is proportional to the other."

Investigation has shown that this law is only approximately correct in the case of high pressures, but it answered all purposes in Boyle's day, and for a century afterwards. Its inexactitude simply means that at high pressures gases are proportionately less compressible than they are at low pressures, a conclusion that might easily have been foreseen if, at the time the law was enunciated, the molecular nature of matter had been understood. For, as the molecules of a gas are brought by pressure into closer proximity with each other, a point is finally reached when mutual attraction between them becomes strong enough to effect a reduction of outward pressure. Ultimately, as we now know, if increase of external pressure continues, combined with gradual lowering of the temperature, a "critical point" is finally reached, at which the gas becomes a liquid, and incapable of exerting any outward pressure except that due to its weight.

The gaseous, being the simplest form or condition in which matter occurs in nature so far as at present known, is not only the easiest to investigate but, its laws when in that condition having been discovered, those which govern it in the liquid and solid state, and in that fourth state known as the colloidal—first recognized by Graham about 1845—and intermediate between the liquid and solid condition, can more readily be inferred. For these reasons, as soon as the common elementary gases (oxygen, hydrogen, nitrogen and chlorine) were discovered and investigated, and the composition of the atmosphere made clear, a sure foundation was laid upon which the structure of the science of chemistry could be raised.

In gases under normal conditions, such as is meant when speaking of the atmosphere as "free air," a state in which it is subject to no pressure or force beyond that of the attraction of gravitation, the molecules of which it is composed are separated from each other by spaces or voids so large, as compared with their size, that their mutual attraction—which constitutes the property called cohesion—is negligible, and consequently their movements among themselves are unlimited in complexity, and incessant; and the pressure they are capable of exerting against the sides of any vessel in which they may be confined, is that due only to the weight of the volume so enclosed which, itself, is solely the effect of the gravitational pull of the earth there. A vessel of thin glass filled with air at sea level and sealed, and then taken to a high altitude, will ultimately burst; first, because the surrounding free air being itself farther away from the earth, and so less under the influence of its attraction, has lost in density or, as is said, has become thinner, and so can exert less pressure per square inch on the outside of the walls of the vessel; and second, because the imprisoned air, being at a greater distance than before from the center of the earth, is less influenced by its gravitational pull, and consequently its molecules are more eager to separate from each other, and so press more urgently on its interior walls.

CASSINI (1625–1712)

ASTRONOMY

Giovanni Dominico Cassini was a native of Perinaldo, Italy; and after receiving an excellent education became professor of astronomy at the University of Bologna, where he acquired such a reputation as an observer of celestial phenomena that he was offered the position of director of the observatory at Paris, where he remained for the balance of his active life. At his death the office passed to his son Jacques who, in turn, yielded it to his son Jean Dominique. Thus, for a period of nearly a century the noted observatory was under the guidance of one family, all of whom greatly distinguished themselves in their work. To the oldest of the three, however, is due by far the largest number of important discoveries made and conclusions reached. Among the most notable of these were the determination of the motions of the satellites of Jupiter; the discovery of four of Saturn's family and the ascertainment of their periods of revolution; the rotational periods of Jupiter, Mars and Venus; the first systematic study of the zodiacal light; a close approximation of the parallax of the sun; a table of refractions; a complete theory of the phenomenon called the libration of the moon; a revised calculation of the obliquity of the ecliptic, making it 23° 28′ 42″ instead of 23.5 as previously determined, and an amended figure of 0.017 for the eccentricity of the earth's orbit which, by Kepler, had been assumed at 0.018. He is also remembered for having advanced the theory that the figure of the earth is not that of a sphere but of an oblate spheroid, flattened at the poles and bulging at the equator; the equatorial diameter being 7926 miles and the polar 7900 miles. Finally he was the discoverer or designer of the geometrical figure known as the Cassinian Oval, which may be described as a symmetrical bi-circular curve caused by the movement of a point the product of whose distances from two fixed points is a constant.

MALPIGHI (1628–1694)

ANATOMY

Marcello Malpighi was a native of Crevalcuore in Italy. He studied at the University of Bologna, was given his doctor's degree in 1653, and three years later became professor there, attaining a high reputation as a popular lecturer. In 1662 he was elected to the chair of anatomy at the University of Messina, where he remained until 1691, when he was called to Rome to occupy the position of personal physician to the Pope (Innocent XII). A few years later he died very suddenly of apoplexy.

Malpighi was a tireless investigator, and deeply in love with his profession which, at the time, was rapidly emerging from the ignorant empiricism of its past, and becoming an art based on a more extended knowledge of the constitution of the body, and the duty of its organs. He took a prominent part in the enlargement of this knowledge, dissecting animals and plants, as well as human bodies. He discovered the function of leaves in vegetation (as breathing organs); described the development of the chick in the egg, and the changes through which the silkworm passed in building its cocoon; and—what perhaps was his greatest achievement—demonstrated by the aid of the microscope the capillary circulation of the blood in the lungs. It could hardly be expected that all the conclusions of this celebrated morphologist would be confirmed by later investigations, for in his day the microscope was a most crude instrument. But a remarkably large proportion of them have been. One of the most interesting of the discoveries credited to him, was that of the spiral form of the muscles which control the movements of the heart.

His death at the early age of 66 was directly due to his intense devotion to research in his line. So engrossed would he become in a dissection that food and sleep were neglected, and eyesight strained beyond all reason. He was a direct victim to overwork. He was the author of a number of valuable monographs of which the two most notable were entitled "Observationes Anatomacae" (1661), and "Epistolae Anatomacae" (1665). In the latter he reported his discovery of the third and innermost layer of the human skin, which has ever since been known technically as the "Rete Malpighi." It is the one which contains the pigment that determines the color of the individual. The two layers that cover it are nearly transparent.

HUYGENS (1629–1695)

PHYSICS

Christian Huygens was the son of Constantine Huygens van Zuylichhem, a noted Dutch writer, and Counselor to the Princes of Holland, and was born at The Hague on April 14, 1629. During his adolescence he received a thorough education in fundamentals under private tutors, and at the age of 16 was sent to the University of Leyden to specialize in law and mathematics. Becoming unusually proficient in the latter, he published in his 22nd year (1651), his first work, entitled "Theorems on the Quadrature of the Hyperbola," a very creditable study for his age and time. In 1656, with a telescope of his own manufacture, he discovered the first of the nine satellites of Saturn, and in the following year he introduced the principle of the pendulum in the art of clock making, and some years later, the spiral spring in the manufacture of watches. In 1659 he published his "System of Saturn" in which a complete description of the rings was given, as the result of observations made through a telescope of 22 feet focal length. In the following year, at the invitation of Minister Solbert of France, he went to Paris, was given quarters for his studies in the Royal Library, and made a member of the Academy. In 1663, while on a visit to England, he was elected a Fellow of the Royal Society of London. Returning to Paris in 1665 he made it his home until 1681; when, recognizing that the disposition towards the persecution of Protestants in that country was growing, and anticipating the revocation of the Edict of Nantes (which gave them protection), he returned to Holland, and remained there during the balance of his life.

While living in France he demonstrated the laws under which force is transmitted from one body to another through impact; wrote and published a treatise on the laws of the refraction of light through transparent and translucent material; a monograph on the nature of the cycloidal curve, and another on centrifugal force as exhibited in circular motion around a fixed center or axis. Finally, in 1673, he gave to the world his great work entitled "Horologium Oscillatorium," in which the principle of the pendulum was exhaustively studied and applied, in marking divisions of time, and in the determination of latitudes.

On his return to his native land he undertook the construction of a planetarium, and also engaged in the manufacture—but for his own use only—of telescopes of great size, one of which had a focal length of 210 feet. In 1690 he published a treatise on the "Cause of Gravity" and another on "Light." In the latter he suggested the undulatory explanation, which is now universally held.

His death occurred in 1695. Three years thereafter his "Cosmotheoros" was published. This was a highly speculative and rather fanciful monograph, in which the suggestion was advanced that some, or perhaps all, of the planets of the solar system were inhabited, either by humans like ourselves, or by intelligent creatures of a similar kind, with bodies modified to conform to the special conditions of their environment.

Huygens was an aristocrat of the best character and kind, and when the estates and titles of his father passed to him in 1687 he was able to devote his energies to experimentation and study along those lines that interested him most highly, and used the opportunity well. He never married. His disposition was that of a quiet and somewhat reserved gentleman, with the inclination to use his own hands in experimentation, and equipped with a mind capable of interpreting results with much acumen. Towards his last years he became more speculative, as was displayed in his posthumous work, and there are reasons for thinking that he recognized the doubtful character of its conclusions. In several of his monographs he approached the vision that later blossomed in the mind of Newton.

LEEUWENHOEK (1632–1723)

MICROSCOPY

ANTONIUS VAN LEEUWENHOEK was a native of the city of Delft, in Holland. He received from his father an ordinary business education, and at his death an inheritance that made him financially independent. Following a natural inclination he engaged in the manufacture of lenses, and from that became interested in the phenomena of optics. This led ultimately to the discovery of the principles underlying the construction of telescopes and microscopes. Being more interested in the revelation of the latter than of the former, and an expert workman in the art of lens making, he produced remarkably fine microscopes for his time, and became such an ardent explorer in the field so opened for research, that he is rightly regarded as the founder of the science of microscopy. His individual discoveries in this department of knowledge were very numerous. Among them of great importance, were the identification of the red corpuscles in the blood, the striation of the muscle fibers, and the verification of Harvey's theory of the circulation of the blood, by showing its passage from the arteries to the veins by the connecting capillaries. He was also the first discoverer of many minute forms of life, such as hydra, infusoria, rotifers and spermatozoa. His studies in insect life led him to the discovery of the parthenogenetic reproduction of the aphides (plant lice), which disproved many supposed cases of spontaneous generation. His researches, though not always conducted along strictly systematic and scientific lines, were noted for their character of conscientious accuracy, and have been of great service in the development later of the study of minute things.

Long before the days of Leeuwenhoek it was known that lens-shaped pieces of transparent material—glass or crystals—and globules of water or other liquids, had the power of apparently enlarging the size of objects too minute to be distinguished in detail by the naked eye. In fact, a plano-convex lens of quartz less than two-tenths of an inch in thickness and one and four-tenths in diameter, with a focal length of four inches, was found by Ledyard in excavating the ruins of Nineveh, and is now in the British Museum. This probably was employed as an aid in executing the delicate engraving found on many of the seals and gems of the period, or possibly as a burning glass. For the capacity of lenses to collect and concentrate the heat rays of the sun, and start a fire in dry tinder, was well known to the Greeks and probably to the Egyptians and Mesopotamian people. But all knowledge on the subject, except in connection with the manufacture of spectacles, seems to have perished in Europe with the fall of the Roman Empire; and not until the latter part of the Middle Ages was the art recovered there. In 1590 a spectacle maker of Middleburg, Holland, named Janssen, is said to have constructed the first instrument with two lenses, the object glass and the eye glass. It was nearly six feet long. Later, Divini in 1568, Robert Hook in 1675 and Campani in 1686 brought out important modifications, but the serious difficulties due to the high aberration of light in passing through lenses of short focal length, made the use of their instruments very unsatisfactory. It was not until the principle of achromatic lenses was discovered in 1757 that this could be partially overcome by their use in the objective. In 1823 several pair of double lenses was first employed by makers, each consisting of a plano-convex of flint glass of high dispersive power, combined with a double convex of crown glass of low dispersion. This corrected aberration admirably. Since then, the miscroscope has been further improved, not only in the matter of lenses, but in focusing devices, the introduction of the cover glass over the objective, the reflecting mirror and the use of a glass made on principles especially suitable for microscopic research.

HOOKE (1635–1703)

PHYSICS

Robert Hooke was born in the Isle of Wight, in England, and was educated at Westminster School in London, and at Oxford. In 1664 he became an instructor in geometry at Graham College, London. In 1666 occurred the great fire in that city, which followed the great plague of the year before, in which nearly 100,000 of its citizens died, corresponding to about one-quarter of its population at the time. In the fire 1300 houses and 19 churches were burned. When at last its progress was stayed, Hooke tendered to the authorities—together with a model—a very well thought out plan for its rebuilding, which subsequent events clearly demonstrated should have been followed. But though he was appointed city engineer in 1667 his design was not adopted. From 1667 to 1682 he acted as secretary of the Royal Society. The last twenty years of his life were devoted to research, and to his many inventions. Hooke was a man of unusual ability, in fact, a genius. But unfortunately with this was coupled a temperament so irritable, and at times peevish, that he was constantly in trouble with associates, and even with intimates. Nevertheless, his acuteness of perception was so marked a characteristic, that he reached many important conclusions in science for which he should be accorded the credit. In 1665, in collaboration with Boyle, they perfected an air pump which was a vast improvement on the one designed and successfully operated the year before by Von Guericke in his classical experiments on the vacuum in Germany.

Hooke was really the first physicist to point out that the problems of planetary motion were purely matters of mechanics, and should be studied from that point of view, thus plainly intimating that forces of one or more kinds—as then unknown—were the agencies which compelled the heavenly bodies to travel through the paths that observation showed they followed; thus anticipating the work of Newton. But he failed to develop the conception mathematically. More than a century and a half before Rumford demonstrated the identity of heat and motion, Hooke derided the opinion of his day that it was a fluid, or any kind of matter, and even suggested that it might be "an effect of motion."

In his book entitled "Micrographia," which was published by the Royal Society in 1665, in describing his work with the newly invented microscope, and which with characteristic ingenuity he had improved by compounding its lenses, he clearly described what he called the "little boxes or cells" that were revealed in the leaves of plants under observation, and which have since become to the biologists of the present day the units of organized life. If the achromatic lens (which was only devised a century later) had been available to him, no doubt he would have discovered the minute particle of protoplasm that these "little boxes" contained, and detected their motion.

He must be credited also with some views on the subject of fossils that were at least of a prophetic nature. In his day all such objects, when found, were gravely discussed as evidences of the Noachian Deluge. But when whole formations of chalk were shown by the microscope to consist entirely of the shells of minute organisms, Hooke was among the first to declare boldly that some other and more reasonable explanation of their origin must be found, and even went so far as to express the opinion that it should be possible, through a study of the many different kinds of fossils then known, to arrive approximately at the relative ages of the rocks in which they occurred; a conclusion which has since been entirely confirmed.

To Hooke we owe the invention in 1658 of the balance wheel, which differentiates the watch from the clock, and made the former a possibility. A world without this marvelous little machine would be a difficult one to imagine.

NEWTON (1642–1727)

PHYSICS

The celebrated English scientist, Isaac Newton, was the son of a small freehold farmer, in Woolsthorpe in Lancashire, England. His early education was acquired at the grammar school at Grantham, near by, and at the age of 19 he entered Cambridge University. His inclinations were so distinctly mathematical, that before he had completed his course there he had not only mastered all that the university could give him in that science, but had gone beyond it, by extending the applications and usefulness of the Binomial Theorem, the method of Tangents, and that of Fluxions, which latter was the name then given to what is now understood as the Integral Calculus. It was in 1665 —according to the commonly accepted story, for which there is much foundation of authority—when his attention was directed, as he was sitting under an apple tree in his father's orchard at Woolsthorpe, to the fall of the fruit—and to speculations concerning the cause of it. Ever since the publication of the theories of Copernicus as to the movements of the heavenly bodies (if not centuries before among the Greek philosophers) the existence of a force of some kind had been postulated, to account for the movements of the planets in space, but it was left to Newton, not to explain it, but to state the laws under which it operated. For this task his exceptional mathematical equipment pre-eminently fitted him, but it was not until 1687, over twenty years after he began to study the problem, that he was able to announce the "Law" upon which his imperishable fame rests. In his early attempts at its solution, he was defeated by the fact that he employed a figure for the radius of the earth, which was derived from an erroneous valuation of the length of a degree of longitude. This figure produced only an approximate verification of the hypothesis he had conceived, and after going over his calculations with the greatest care, and finding no material mistake in them, he abandoned the quest temporarily, and turned his attention to other matters; investigating the nature of light, and the details of the construction of telescopes. In 1667, having procured a glass prism of good quality, and employed it in the separation of a beam of sunlight into the primary colors, he reached the obvious conclusion that the degree of dispersion varied for each color. This enabled him to account for the lack of definition of the image formed by the object glass of a refracting telescope. But, after making one experiment in the effort to correct the difficulty, and getting no result, he hastily reached the conclusion that the dispersive power of lenses was invariably proportional to their refractive power, and that in consequence the production of a perfect image of a distant object was an impossibility, with that kind of an instrument. It was thus natural that he should abandon the refracting telescope, and turn his attention to the reflecting variety which was then unknown. The instrument he constructed proved serviceable, and with it he made a careful study of Saturn and its satellites. Sixty years later the first achromatic lens was successfully perfected by Chester More Hull.

In 1672 he was elected a member of the Royal Society of London, and on the occasion of his installation read his famous paper on "The New Theory of Light and Color," in which he showed that sunlight is a commingling in definite proportions of all the primary colors and their intermediates, and in 1675 another paper on the same subject, calling attention to the phenomenon known as the Newton Rings. In connection with the latter he formulated the emission theory of light, on the foundation of calculations made some years before by Descartes. At the basis of this was the hypothesis that light consisted of material corpuscles, emitted by the luminous body. Hence, it is known as the "corpuscular" theory. It was universally accepted as a correct explanation, until superseded by the undulatory theory about 1815, which had been suggested first by Huygens in 1690.

In 1679 a new and much more accurate determination of the earth's diameter became available, and shortly thereafter Newton resumed his studies on gravitation. In 1684 his conclusions were confidentially given to Halley, the astronomer (after whom Halley's comet is named). An outline of them was first embodied in a monograph entitled "De Motu Corporum," but under the advice of Halley, he substituted for it a much more elaborate paper, which was entitled "Philosophiae Naturalis Principia Mathematica,"[1] now universally referred to as the "Principia," and gave it to the world in 1687.

This production, perhaps the most notable scientific work which the mind of man had so far brought forth, was in three parts, two of which were devoted to the subject of Motion in general, and its laws, while the third is confined to the movements of the members of the solar system. At

[1] The Mathematical Principles of Natural Philosophy.

the foundation of the discourse the universal law of gravitation was given as follows:

> "Every particle of matter attracts every other particle, with a force directly proportional to their masses, and inversely proportional to the square of the distances between them."

Since 1669 Newton had occupied the Leucanian chair at Cambridge, and had taken an active part in defending the rights of the university against the encroachments of King James II, who, being a Catholic, was not in sympathy with the liberal atmosphere of the great institution. The ability the astronomer had displayed in the contest led to his election to the Convention Parliament, in which he served from early in 1689 to its dissolution in 1690. In 1689 he was appointed Warden of the Royal Mint, and in 1699 was advanced to that of its Master, which office he retained during the balance of his life. In 1701 he was again the chosen reresentative of the university in Parliament, and in 1703 was elected President of the Royal Society, a position which he also held until his death, being re-elected for twenty-four consecutive terms of a year each. During this nearly quarter of a century of political and scientific activities he made it an invariable rule to subordinate his studies to his public duties, and yet found time to do much towards the advance of science. One of his important works during the period was the superintendence of the compilation and publication of the "Greenwich Observations."

His death occurred on March 20, 1727, at the ripe age of 85. His remains rest in Westminster Abbey, where a handsome monument was erected to his memory in 1731. At his death a cast was taken of his face, and from this a superb full-length statue was made by Roubillac, which stands in the ante-chapel of Trinity College at Cambridge. He was knighted by Queen Anne in 1705.

In person Newton was a man of medium height and robust build, inclining towards corpulency in his later years, though a light and almost spare eater. In his prime his countenance, which was finely and symmetrically cut, expressed thoughtfulness and mental repose. In manner he was affable and modest, rather reserved and dignified, but without the least implication of hauteur. In speech he was invariably moderate, even when giving expression to views strongly held. He never married. From early manhood he was always in comfortable financial circumstances, and left an estate estimated at about $150,000, which meant great affluence for his day. This was distributed by his will among his brothers and sisters and their children, with whom during life he was very liberal. In the matter of religion he was classed by his contemporaries as a devout and earnest man. Yet, though a member of the Anglican church, he declined to take orders (which were offered) in it, and evidently considered himself at liberty to stay in its fold without being expected to endorse all the tenets of its faith.

At the age of 60 to 65 his health began to fail, and while he did not allow the circumstance to interfere with his public duties, he began to abandon science as a field of thought, and to turn his mind to speculations regarding the future. Having a profound reverence for the Scriptures, these took the form of endeavoring to fathom the mysterious saying of the books of Daniel and of the Revelations of St. John, about which he wrote rather voluminously, but apparently with no intent of publication. Reference was made to some of these studies in letters to friends. As a result the impression went abroad that his mind was failing. There can be no doubt that during the last decade of his life his mental attitude was changing, for the disease from which he died (gout and allied distempers) invariably causes that effect. Nevertheless, barring short lapses of memory, he preserved his faculties to the end; though during the last year or two he suffered severely at times. In 1733, six years after his death, his scriptural studies were published under the title of "Observations on the Prophesies of Daniel and of the Book of Revelations." They are not regarded as possessing anything more than speculative value.

ROEMER (1644–1710)

VELOCITY OF LIGHT

Olaus Roemer was born at Aarhus in Denmark, was educated at the University of Copenhagen, and shortly thereafter went to Paris to become the tutor of the eldest son of the then King of France (Louis XIV). Here, being associated with Picard and Cassini in several discoveries of note, he acquired a high reputation as an astronomer, in consequence of which he was made a member of the Academy of Sciences in 1672.

The important discovery for which he has the sole credit was, that light, which up to that time had been regarded as a phenomenon of an instantaneous nature, required an appreciable time for its transference through space, and that it traveled at a speed of approximately 186,000 miles in a second of time. This conclusion came as the result of his investigations on the subject of aberration, a term expressing the apparent change in the position of stars during the year, and in connection with the eclipses of the satellites of Jupiter. The analogy of a man running through a rain storm, when the drops of rain are falling vertically, is generally employed to illustrate the phenomenon. To the man the drops appear to be falling slantingly, and from the direction to which he is moving, so that his face and the front of his clothing will receive a larger number of them than his back. In a like manner light, coming directly to an observer on the earth, will seem to arrive on a slant, because the earth is in motion at a velocity of 19 miles per second, either towards or away from the source of light, while simultaneously the source itself is also in rapid motion towards or away from the observer. The net result is the apparent movement of the star in the vault of the sky through the curve of a minute oval (circle or ellipse).

The nature of this curve, it dimensions, and the direction along which the star travels in it—with or opposite to that of the hands of a clock—afford data from which the velocity of light may be calculated.

The exact velocity is 186,350 miles per second (299,860 kilometers). This figure is the result reached after a large number of most careful observations, and appears to be invariable. It makes no difference whether the source is moving towards or away from us. In this respect the phenomenon is like that of sound, which travels at the invariable rate of 1100 feet per second through a normal atmosphere. If the source of the sound is approaching, more of the undulations in the air than otherwise reach the ear per unit of time, and the pitch of the note is higher. If it is receding, the contrary effect of a lower note is produced. It is the same with light. If we are approaching its source faster than it is receding from our position in space, more of its undulations per unit of time will arrive to the eye, and the effect produced will be that of unusual brightness. On the other hand, if the distance between the source and the observer is increasing, the opposite effect results.

There is, however, a marked difference in character between sound and light waves. The former are longitudinal, being impulses which travel forward and back in the direction in which the effect is propagated, resulting in vibrations which are alternately those of compression and release from compression. But light undulations are of a transverse kind, similar to those which pass along a rope when one end of it is fixed and the other shaken.

LEIBNITZ (1646–1716)

MATHEMATICS AND PHILOSOPHY

Gottfried Wilhelm von Leibnitz was a native of the city of Leipsic, Germany, the son of the professor of law in the local university. He was well educated in the expectation that he would follow the profession of his father, but at an early age exhibited decided inclinations towards literature and the sciences; and not being under the necessity of earning his living, he enrolled himself at the age of eighteen at the University of Jena as a student in the higher mathematics. In 1666 he received his degree of doctor of laws from the university of Altdorf, and in the following year entered the personal service of the Elector of Mainz, undertaking legal work, while at the same time employing his leisure hours in writing and publishing several treatises on theological subjects. In 1672 he undertook a political mission to Paris, but not meeting with the success hoped for, he journeyed to London, where he formed the acquaintance of Newton and Huygens, both of whom were attracted by his evident ability and charm of manner. In 1676 he accepted the position of librarian and privy councilor to the Duke of Brunswick, and while engaged in writing the history of this famous House he assumed the direction of the ducal mines in the Harz mountains which, for five centuries had been highly productive of copper, silver, lead, zinc and iron, but had been neglected, and were in a deplorable condition. Under his vigorous management they became again profitable.

Later, having moved to Berlin, he organized and was elected the first president of the Society of Sciences there, which in after years became the National Academy. Subsequently he was employed to organize similar institutions in Dresden, Vienna and St. Petersburg. In recognition of his success in the last case, he was given a pension by the Czar, and the title of Privy Councilor. In 1714 he wrote and published his most noted philosophical work entitled "Monadologie," in which he set forth the main details of his system. This drew him into a controversy with the English theologian and metaphysician, Samuel Clark, and while it was in progress his death occurred.

It will be evident from this brief résumé of his life activities, that Leibnitz was a man of ability and versatility. In his time the sciences—except mathematics—were in their infancy, and the aspect they now present, that of classified and organized knowledge gained by experience, had not been clearly recognized as a distinguishing feature. The influence of the Greek philosophers, and of the medieval metaphysicians and theologians, was yet paramount in the minds of the educated almost everywhere, and controversy or discussion was regarded as a more fruitful method of arriving at correct conclusions, than the study of nature, and of the causes underlying its observed phenomena. Therefore his fine mental equipment did not lead, during his life, to any notable addition to the current stock of knowledge, excepting in the department of mathematics, and in that branch of it which has become known as the Calculus, the invention of which is popularly ascribed to Newton. But its fundamental concept was really first definitely enunciated by Archimedes (287–212 B.C.), who, in his efforts to solve the ancient problem of the squaring of the circle, reached an approximately correct value of the relation of the diameter to the circumference (π), by assuming the latter to be the mean between the measurements of circumscribed and inscribed polygons with a continually increasing number of sides up to the limit of numerical representation. This was called the "Method of Exhaustions." The next step was not taken until Kepler (1571–1630) introduced the conception of infinity into geometry, by picturing the surface of a circle as composed of an infinite number of triangles, each with its apex at the center, and its base on the circumference; and the cone as a collection of an infinite number of pyramids. Further steps were taken in turn by Cavalieri, Wallis, Descartes and Fermat in the development of these ideas, but it was the part of Newton and Leibnitz, working separately on the conceptions of their predecessors, to invent a system of notation by the use of which their ideas could be organized into a comprehensive and practical method of reaching results. That of Leibnitz was published in 1684, while Newton's, though worked out a dozen years before, and exhibited privately to friends, did not appear in print until 1687. The fundamental ideas in the two were substantially the same, but the symbols and systems of notation differed. In consequence of his great reputation Newton's system was at first universally adopted, and the science went under his name of "Fluxions." On the continent the notation of Leibnitz was quickly recognized as the better of the two, but in England that of Newton continued to be employed for nearly a century before it was superseded by the other.

It is generally admitted that to Newton should be given the credit of developing the Calculus to a point where it became of practical use in solving problems of a general nature; while to the German belongs the honor of having devised the better system of symbols to conduct its operation.

HALLEY (1656–1742)

ASTRONOMY

THE astronomer, Edmund Halley, was a native of Haggerston, a suburb of London. He was educated at St. Paul's school in that city, and afterwards at Oxford. In 1678 he was elected a fellow of the Royal Society, and sent on an important mission by that organization to the vicinity of Dantzic in East Prussia. In 1682, in collaboration with the French astronomer, Cassini, at Paris, he observed the coming and going of the great comet of that year, which now bears his name. In 1699, for the purpose of investigating the variations of the magnetic compass, he made a long sea journey under government auspices, and collected such an extensive and valuable mass of data on the subject, that he was given the rank of captain in the Navy, with half pay for life. Shortly thereafter he made the survey of the coast of Dalmatia for the Austrian government. In 1703 he was appointed professor of geometry at Oxford, and in 1713 became secretary of the Royal Society. In 1721 he was made Royal Astronomer.

Halley's contributions to the advance of knowledge in his time were many and important, but the one that has brought him the greatest honor was his correct prediction of the return of the great comet of 1682. To Tycho Brahe was due the discovery that these bodies are extraneous to our atmosphere. Newton later showed that their movements are subject to the same laws that control the planets in their orbits. Halley, deeply impressed with what he had seen while working with Cassini, began to investigate the history of recorded observations in the past of these bodies, of which fortunately a large number were available. By these means he was able to identify the comet of 1682 with one which appeared in 1607, and another in 1531, whose orbital elements, in both cases, agreed with those he had recorded when working with Cassini. He then ventured to predict the return of the wanderer at the end of 1758 or early in 1759. It arrived and reached perihelion on March 12, 1759. Its next appearance was set by astronomers for a date between the 4th and the 13th of November, 1835. It passed the sun on the 16th of that month. And again, in the early summer of 1911 it arrived almost exactly on the hour prescribed. Its period is about 76 years. It is now known to be identical with the comets which appeared in 1456 and 1378, the last having been recorded by Chinese observers, and it is believed to be the same as those mentioned historically as of the years 1145, 1066, 986, and 12 B.C.

Halley was the first to suggest the observation of the transit of Venus across the face of the sun as a means of determining the sun's diameter.

BRADLEY (1693–1762)

ASTRONOMY

James Bradley was reared at Sherborn, England, was educated at Oxford, and in 1721 was appointed to the Savilian chair of astronomy there. In 1726 he announced the method—original with him—of obtaining longitudes by means of the eclipses of the satellites of Jupiter, and in 1729 his explanation of the phenomenon known as the Aberration of Light. These two notable contributions to the advance of knowledge won him the appointment in 1742, after the death of Halley, of the post of Royal Astronomer, a position which he filled with great credit to himself and the State during the remainder of his active career, accumulating a mass of accurate observations which have proved to be a perfect mine of data of the very highest value to the science of astronomy.

As light from the heavenly bodies requires an appreciable time to travel through space; as those luminous bodies are in motion; and finally as the earth, from which we view them, is itself continually traveling in its orbit around the sun and revolving on its axis, there is in progress at all times an apparent displacement of the fixed stars in the vault of the sky, from what would be their true position with respect to us, if all motion in the Universe ceased, and the transmission of light was an instantaneous phenomenon. It was Bradley who accounted mathematically for this perpetual slight displacement, which was revealed to observational astronomers whenever the position of any of them was accurately taken and compared with positions previously noted. Each appeared to move in a minute oval, which, in effect, was mainly a reproduction in minimum of the vast oval of the earth's annual path around the sun.

Yet even Bradley's first explanation was not wholly satisfactory, for the figure which he deduced as the "constant of aberration" did not account for all the facts observed. For nearly 20 years he studied the problem, and finally, in 1748, announced that all the elements of the phenomenon could be satisfactorily and perfectly explained, by assuming an oscillatory motion of the earth's axis, completed during a revolution of the moon's nodes, that is, in a period of about eighteen and a half years. He gave to this factor of the problem the name of the "nutation of the earth's axis." For this discovery he was awarded the Copley medal.

The value of the constant of aberration is 30.47 seconds. It represents the linear amount by which the position of a star will vary throughout the year from its average position. It is a very important figure in astronomical work. For, combined with the known velocity of light, it gives the earth's orbital velocity in miles per second, and from that, by a simple calculation, the semi-diameter of the orbit, which is the mean distance of the earth from the sun. This last is one of the fundamental astronomical units or yard sticks, and its exact evaluation is regarded as among the most important of astronomical problems.

MACLAURIN (1698–1746)

MATHEMATICS

Colin Maclaurin was a native of Kilmodan in Scotland, and was educated at the University of Glasgow. He exhibited unusual mathematical ability in early youth, and in 1717 became professor of that science in the University of Aberdeen. Two years later, through the kindly interest of Sir Isaac Newton, he was elected a member of the Royal Society. In 1726, having meantime traveled on the continent, he was appointed to the chair of mathematics at the University of Edinburgh, where he remained until that city was captured by the "Young Pretender" (Prince Charlie), who later met with decisive defeat at Culloden.

His principal contribution to the progress of science consisted in his development of the fluxional calculus, which gave him a standing at the time as a mathematician second only to that of Newton. Another important discovery, or rather deduction from his studies in the field of mathematical physics, was his demonstration of the fact that a revolving homogenous fluid or plastic substance would assume the shape of an ellipsoid, which threw a new light on the phenomena of the tides, as well as on the subject of the correct figure of the earth.

The Calculus is that branch of the science of mathematics which deals with quantities whose properties (dimensions, masses, volumes, positions, rates of motion, etc.) are constantly increasing or diminishing. Inasmuch as nature in practically all its phases is continually in a state of flux (growth or decay, enlargement or decrease of mass, approach or recedence, etc.) it is not difficult to understand the slow progress made by science before the Calculus came into existence as a mathematical tool.

For a simple illustration, take the case of the ball thrown by the pitcher towards the batter in the national game of baseball. It leaves the hand of the former at a certain initial velocity which may be ascertained, and reaches the place of the latter within a period of time which can also be determined. The distance between the two is known. From these elements it is a simple matter to figure the average speed of the missile during its flight. But, if it is desired to know either its position or its velocity at one or more places of the transit, the problem becomes more complicated. For, at the instant the ball leaves the hand of the thrower, not only does its velocity begin to vary, but also its height above the horizontal plane of the field upon which the game is played, besides being more or less affected by windage; and these changes continue to occur incessantly throughout its journey. Of course, a small problem might be approximately solved at several points experimentally, by taking photographs and time data along the route between the two stations. But if the movement of a bullet from a high power rifle, or of a shell from a cannon were under consideration, experimental solution would be practically impossible with any degree of accuracy.

When finally the problem is transferred into space, and becomes one related to the motions of the heavenly bodies, the true field of the Calculus is reached. It is the science of the infinite at both its extremities of minuteness and enormity; of variations of dimension so small as to be unimaginable by the mind, yet which exist as truly as does the sum of them, which become at length apparent to the senses as definite portions of space and time.

It is of course impossible at any reasonable length to explain even the fundamental principles of the Calculus, much less any concrete operations of them. Maclaurin was by no means the first to enter its domain. In the old problem of the squaring of the circle Archimedes made a notable beginning when he pictured the latter as a polygon with an innumerable number of sides. Kepler (1571–1730) took a further step by assuming the area it enclosed to be composed of an infinite number of triangles, with their vertices at the center and their bases on the circumference. Following him, Cavalieri (1598–1647), Descartes (1596–1650), Fermat (1601–1665), Leibnitz (1646–1716) and Newton (1642–1727) each took a hand in its development.

By the last the science was given the name of the "Fluxions," its basal idea to him being that of infinitesimal variations in velocity. Many other notable mathematicians have since contributed to its progress. As it stands today, still capable of growth, its power as a method of reaching out into infinity, and of obtaining reliable solutions from premises that can only be imagined, is one of the most remarkable proofs of the capacity of the human mind.

DE JUSSIEU (1699–1776)

BOTANY

Bernard de Jussieu was a native of Lyons, France, and graduated in 1720 at the University of Montpelier with the degree of M.D. From there he went to Paris, and becoming deeply interested in botanical research studied that science exhaustively at the Paris University. In 1722 he was appointed demonstrator at the Jardin du Roi (des Plantes). His devotion to botany—which at first was mainly due to a desire to learn the medicinal properties of herbs, was quickly merged into research for the purpose of acquiring a better understanding of the relation of plants to each other, and ended in a systematic classification of the members of the vegetable kingdom. He succeeded during his life in correctly laying a scientific foundation for his system. After his death this was elaborated and carried forward to completion by his nephew, Antoine Lamont. The latter, after thirty years of study, gave to the world his "Genera Plantarum," in which the classification now recognized was outlined, and detailed as far as members of the vegetable world then known would permit. To Bernard therefore is due the high honor of placing botany among the sciences, and to his nephew that of giving it to the world in detailed form.

The Greeks were probably the first who attempted botannical research. Aristotle and Theophrastus classified the vegetable world under the heads of trees, shrubs and herbs. As they had no basis of technical knowledge on

Facing page 140

the subject they could go no further. From their time until that of Linnaeus (1707–1778) the herbalists, who regarded plants chiefly if not wholly from the point of view of their possible medicinal virtues, were the only class of students who could be called botanists.

The Linnean classification, like that which he devised for animals, was based entirely on observation of external peculiarities. He grouped the vegetable world under twenty-four heads, depending upon the number, relative position and other visible qualities of the male and female organs, whenever these could be detected. This was of course an advance—and in the right direction—on the random work of the herbalists, and for nearly a century was regarded as satisfactory.

Under the system elaborated by De Jussieu and his nephew, and subsequently expanded by de Candolle (1818–1821), Endlicher (1836–1840), Brogniart (1843), Lindley (1846), Braun (1864), Eichler (1883) and Engler (1892), the kingdom of the plants is divided into four great groups, as follows: *Thallophytes,* such as sea weeds and fungi; *Bryophytes,* as mosses and liverworts; *Pteridophytes,* as ferns, etc.; and *Spermatophytes,* including all others. The last is sub-divided into *Anigosperms,* which includes all whose seeds are inclosed in a protecting vessel, as peas and apples; and *Gymnosperms,* whose seeds are not so protected. All of the latter are either trees or shrubs, and are mostly of the evergreen kind, and resinous in character. Of course, all of these six major groups are again and again sub-divided and, as knowledge of the vegetable world grows, will doubtless undergo further classification. But it is not thought that the foundations laid with so much patient study by De Jussieu and Lamont will ever require serious amendment.

V

THE EIGHTEENTH CENTURY

During this period science made remarkable progress in the matter of establishing fundamental principles. And, simultaneously certain racial movements occurred among the people of Europe that were to culminate in the following century in the rise to importance of that political doctrine called the "Balance of Power." As this exercised a marked effect on the development of the sciences it will be both interesting and instructive to note briefly the steps in the process.

Great Britain, under the reigns of William and Mary, Anne, George I, II and III (1689-1820), became strong and wealthy, but in the final quarter of the period lost its American colonies (1775-1783). France first rose to power under Louis XIV, XV and XVI, but its upper classes became idle and profligate. The Revolution, which began in 1789 and lasted until 1792, brought Napoleon to the surface. Under his leadership France became the predominant power of Europe. Austria, through the period, steadily lost ground in western Europe, but gained enough in the east to hold its position as a nationality of importance. In 1713 the first Hohenzollern (Frederick I) was crowned king of Prussia. He was followed in turn by Frederick the Great and Frederick William. Under these three, Prussia became the dominant element among the Germanic people. Italy during the century continued a divided nationality under the rule of France, Austria, and the Pope. Towards the end of the period the territories of the Papal States were considerably reduced.

Of some 63 scientists of note listed in this period, 23 were French, 16 British, 12 German, 4 American, 3 Swedish, 3 Italian, and 2 Russian.

GRAY (? –1736)

CHEMISTRY

Stephen Gray was a man of whose ancestry and birth practically nothing is known. He was in fact a Charterhouse pensioner in youth, which means that he was the son of paupers. However, he managed to acquire the rudiments of an education. With this meager equipment, and while earning his living by manual labor, he discovered certain basic facts in electrical phenomena. To him we owe the division of substances into the two grand classes of conductors and non-conductors, or, as he first termed them, into "electrics" and "non-electrics"; and the proof that many of the latter class could, by simple contact, be converted into the former. He demonstrated clearly the principle of insulation, and showed that it was an inherent quality resulting from the nature of the materials of which they were composed. Naturally, on account of his educational limitations, and the youth of the science in his time, several of the theories he advanced to account for some of the electrical effects he observed, have since been abandoned.

Now that the chemical atom has been decomposed into electrons and protons, and matter, as heretofore understood, has proved to be nothing more than a special manifestation of energy, the division of substances into electrics and non-electrics, or into conductors and non-conductors, does not possess the significance it did in the days of Gray. Nevertheless, it is still necessary to ascertain if possible why the electrical current will pass with ease along or through certain substances, and with difficulty or apparently not at all in the case of others. For upon the property called insulation depends the ability to compel the current to go where it is desired, and to keep away from places where its presence would be highly objectionable.

Broadly speaking, if the urge of the current is strong enough, it will pass along or through any known insulator. The fact that it exhibits disinclination to journey through certain substances, or, to put it the other way, that certain materials object most strenuously to its passage, is held by physicists to indicate a molecular state of affairs in non-conductors very different from that which exists in conductors. The metals as a class give easy passage to the current, silver possessing the capacity to the highest degree. Yet tungsten and several others exhibit the property to so limited an extent that they are used in the manufacture of resistance coils through which the current experiences such difficulty in passing that it becomes light and heat during the transit, returning instantly to the condition of electricity as soon as the detaining bridge is crossed.

On the other hand glass, porcelain, dry air, chemically pure water, and almost all the hydrocarbons like silk, paraffin, rubber, etc., are typical representatives of the non-conducting or insulating class. Yet moist air, impure water and hydrocarbons moderately adulterated with minerals will give easy transit to a strong current. Again, an increase of temperature above the normal decreases the conductivity of all the metals, but has the opposite effect upon the insulating substances. Glass loses the property almost completely at red heat, while copper under the same treatment becomes a very indifferent conductor.

BERNOUILLI (1700–1782)

MATHEMATICS

Daniel Bernouilli was a native of Gröningen, Germany, and was educated at home under private teachers. He belonged to a family noted for mathematical ability in several generations. Following his natural inclinations he specialized in that science and in medicine, and attained a high rank as an instructor and investigator in anatomy, physics and botany. He was successively a professor in one or more of those sciences in the Universities of St. Petersburg, Gröningen and Basle, became a member of most of the important European Academies of Science and a writer of note on his subjects. His principal literary production, entitled "Hydronamica," was published in 1745. In it he developed for the first time the kinetic theory of gases, which is regarded as his great contribution to the advance of knowledge.

As the comparatively modern science of organic chemistry is practically based upon a correct knowledge of the properties of gases, it will be clear how important was the foundation laid by Bernouilli. Unless the vacuum be regarded as material, the gaseous is the simplest form of matter. In it the molecules are most widely separated, and consequently their influence upon each other must be at a minimum. This means that the number of causes determining the properties of a gas must be fewer and much less complex than those in a liquid or solid, where the forces of mutual attraction are more powerful. Boyle, Dalton, Gay-Lussac, Avogadro and others discovered the laws which express the action of gases as a class when by themselves. It was the part of Bernouilli to first give expression in mathematical language to the principles underlying these; that is, the principles that govern the molecule of matter in its motions—as in gases and liquids—and which produce such phenomena as diffusion, osmosis, evaporation, dissociation, energy conduction, fluid pressure, viscosity, etc. From his analysis of the forces in action among them it has become possible to calculate the approximate number of molecules in any given volume at atmospheric pressure, their mean distance apart, the mean free path of each and the actual proportion of space occupied by them, which was found to be about one-four-thousandths part of the volume in which they were supposed to be confined. From this, of course, the actual molecular volume itself could be readily deduced.

FRANKLIN (1706–1790)

ELECTRICITY

Benjamin Franklin, born in Boston, was the fifteenth of a family of seventeen children. His father was an English emigrant, and conducted a manufactory where tallow candles were produced. His mother—a second wife, was also of British birth. Both parents were deeply religious, and as Benjamin was the tenth son he was dedicated from infancy to the ministry. But as he grew up, his active mind and inquiring disposition led him in a different direction. Leaving school at an early age, he worked for a year in his father's factory, and then apprenticed himself to an elder brother, who was a printer, and the founder of the *New England Courant*, one of the earliest American periodicals. After a while, finding the association irksome, he broke his indentures, and left by ship for New York. Finding no work there he went on to Philadelphia and arrived almost penniless. But he quickly found employment and made friends, and rapidly became an active force in the community. In 1725, under the advice of the governor of the colony, he went to England to purchase equipment for a newspaper venture he contemplated, but meeting with financial disappointments he was compelled to go to work at his trade in London. In the following year he was able to return to America, and in 1729, he obtained control of the *Pennsylvania Gazette*, and speedily made it a great success. In the following year he married, and during the next quarter of a century became known as the foremost literary character of the American colonies.

It was in this period of his life that science, and particularly that budding department of it clustering around the phenomena of electricity, attracted his attention. The well-known experiment with the kite, in which he proved the identity of lightning with the electrical current, took place in 1752, when he was at the age of 46. This brought him immediate recognition in every part of the educated world. It is properly regarded not only as one of the great discoveries of science, but as a most ingenious and effective method of establishing a theory evolved entirely from study. In recognition of its importance, he was given the degree of LL.D. by the Oxford, Edinburgh and St. Andrews universities, was made a fellow of the Royal Society of London, and awarded the Copley gold medal. The last consisted of the interest on a fund of £100, established by Sir Godfrey Copley for the encouragement of students in "natural knowledge." The first award was made in 1731, the second in 1734, and in 1736 the bequest was converted into a gold medal, to be awarded annually under the supervision of the Royal Society.

Besides this notable achievement, and the invention of the excellent Franklin stove, which is as much a favorite now as it was at first, wherever stoves have to be used, the remainder of his memorable life was devoted more to statesmanship than science. When the Revolutionary war was threatened, he made every honorable effort to avert it; but when it appeared inevitable, he took his stand firmly with the colonies, became a member of the Continental Congress, signed the Declaration of Independence, and was appointed the political representative of the new nation in Europe, where his reputation, his dignity of character, charm of manner and wisdom, enabled him to secure for his country the material and financial aid, which ultimately made it possible for Washington to bring the war to a successful end.

In 1785 he returned to America, and immediately assumed a prominent part in the establishment of the young republic. Though at the time nearly 80 years old, he became a member of the Executive Council of the nation, the Governor of the colony of Pennsylvania, and a member of the convention called to form the national constitution. In all these fields of activity he displayed extraordinary vigor and vision. One of his last acts was to sign a memorial by the Pennsylvania Society for the abolition of slavery. Upon his death at the ripe age of 84, his remains found a resting place in the graveyard of Christ's Church, in Philadelphia.

In stature, Franklin was a little under six feet, solidly built, with a fair complexion, and steady gray eyes. His manner was extremely affable and winning. Though unconnected with any religious organization, he displayed throughout his life all the characteristics of an honest, conscientious, and simple-minded gentleman.

BUFFON (1707–1788)

NATURAL HISTORY

Georges Louis Leclerc, Comte de Buffon, of wealthy and titled ancestry, was born at Montbard in central France. He was liberally educated both at schools and by travel, and became an eminent writer, especially on the subject of animals and animal life. His principal work entitled "Natural History" in 44 quarto volumes (a part completed after his death) was published in the years between 1749 and 1804, and for nearly a half century thereafter ranked as a classic, mainly because it was the first of its kind in which all the current knowledge of the day on the subject was collected and related in an interesting and non-technical way; in addition to which it was profusely illustrated with really good pictures.

Buffon was in no sense a scientist, not being by inclination or training either an observer or an investigator of natural phenomena. Inheriting both wealth and social position, and possessing an attractive personality, he devoted the whole of his maturity to studies in mathematics, literature and physics, and thus acquired a standing among students and investigators which secured his election in 1739 to the Academy of Sciences, and in 1763 to the French Academy; and through his social position the appointment of Keeper of the Royal Museum—which subsequently became the Museum of Natural History—and the Jardin des Plantes. In this pleasant environment where he passed his winters, he made those natural history notes which, during the summer, he worked up so delightfully at his ancestral home at Montbard.

In the character of a collector and compiler of information gathered by others, he performed a notable service for the increase of knowledge in his day among the masses to whom, for many years after his death, his volumes were standard publications on their subject. Even among scientists they met with favor for, making no pretense of being one himself, he gave expression in them to many thoughts which later bore interesting and valuable fruit. For instance, he called attention to the fact of the presence and absence of certain varieties of animal life in certain parts of the world, as elephants in Hindustan, the East Indian Isles and Africa coupled with their total absence elsewhere; the confinement of the lion to Africa; the wide distribution of the deer family, excepting Africa, where only two varieties have been found, and they only in the northern part, while the antelope is particularly abundant throughout the whole continent; and other similar peculiarities; and intimated that when the subject was thoroughly worked up it should lead to reliable conclusions as to the past history of the different and disconnected parts of the land surfaces; a view that has been amply verified since.

On the other hand, he did not hesitate to speculate most fantastically in the domain of geology, and on the causes of the distribution of human varieties. But it is to be remembered that then the age of the world, and of all the living beings upon it, was regarded as a matter definitely settled by the creation account in the book of Genesis, and its details by the computations of Bishop Usher. Also that he lived at a time when it was still unwise, if not unsafe, to express publicly opinions that to any appreciable extent ran counter to the orthodoxy of the day. In spite of this, however, there may be found in his volumes remarks which, if not intended ironically, may be construed into a belief in the mutability of species, and of their derivation by descent and variation from earlier forms, and thus to be to some extent anticipatory of the theories later advanced by Lamarck and Darwin.

It is generally thought, however, that the chief end sought by Buffon in his "History" was entertainment for the reader, and if so, he succeeded admirably, for it was the most widely read of all the pseudo-scientific literary products of the time, and for nearly a half century afterwards. It is a curiously interesting fact that Cuvier (1769–1832), the father of comparative anatomy, while calling attention to its many errors, commended it as a whole, because it clearly called attention in many places to the fact that the "history of life on the globe was really the account of a series of advancing changes"; and yet, when Lamarck drew his specific conclusions from this admission, Cuvier would not accept the implication, because of the strong influence of his early religious education on his mind.

LINNAEUS (1707–1778)

NATURAL HISTORY

Carl von Linne, better known by his Latinized name of Carolus Linnaeus, was born at Råshult in Sweden, and was destined by his parents—as their first born—for the ministry. But at a very early age he exhibited so decided a preference for the study of Nature in its aspect of plant life, that he was encouraged by friends to persist in his desires. One of these, a physician by the name of Rothmann, aided the boy materially with books on physiology, botany and medicine, and finally induced his father to allow the son to follow his own inclinations. These led him to place himself first under the instruction of a noted herbalist at Lund in 1727, after which he entered the University of Upsala, where the scientist Rudbeck occupied the chair of botany, physics and mathematics. Being entirely without means, and declining even the small allowance which his father's very limited means enabled him to offer, he soon found work as assistant to the historian, Celsius, and later to Rudbeck himself, who appointed him director of the garden of the institution.

In 1732, carrying his entire outfit on his back, and provided by the Academy of Sciences of Upsala with only the equivalent of $120 in Swedish money, he made a collecting trip of over 5000 miles in Lapland, and returned with material which enabled him to write and publish his first book—"Flora Lapponica." Following this, at the invitation of its governor, he made a second collecting tour through the province of Dalecarlia in central Sweden, giving lectures on botany and zoology whenever he could collect an audience. It was on this trip that he met, at Fahlun, the estimable lady who afterwards became his wife. Through the influence of her father he enrolled himself at the University at Harderwijk in Holland, where he gained his degree in medicine in 1735. In the same year he published his first notable work under the title of "Systema Naturae," which was received with so much favor that it ran through twelve editions before the demand for it was satisfied.

This work—the first of its kind to be written—attracted the attention of an Amsterdam banker, who was an ardent amateur botanist, and led to an association of the two under which Linnaeus, while supervising the rearrangement of the extensive garden, wrote and published in the years between 1735 and 1739 six more botanical monographs. These added so greatly to his reputation and finances as to enable him to travel in France and England, and study the plant life of those countries. In 1739 he returned to Sweden, married, and settled in Stockholm as a physician. In 1741 he was appointed to the chair of medicine at the University of Upsala, and in the following year to that of botany.

His reputation as a naturalist of a high order being now fully established, not only in consequence of the papers which, from time to time, he continued to publish, but also by his great charm as a teacher and lecturer, he began to reap the rewards of his previous years of hard work and comparative poverty. Students from all parts of Europe crowded to his lecture room, and many of these becoming enthusiastic naturalists, undertook journeys of research to remote regions, and sent their collections to their beloved instructor, enabling him to write and publish paper after paper on his specialty. These were translated at once into all the principal languages of Europe, giving him a world-wide reputation as the first naturalist of the day. In 1761 he was elevated to the nobility, and though in 1767 his memory began to fail, he remained a highly honored member of the Faculty of the Upsala University until his death.

The place of Linnaeus in history is that of the man who first introduced system in the classification of plant and animal life. And though his system was admittedly an artificial one for both, and was later displaced by those of Cuvier and others, the order which he inaugurated in a subject where before had been the greatest confusion and empiricism, was a long step in advance in the work of accumulating correct knowledge of organic life. His adoption of what is known as the binomial system of nomenclature, by which to each organism studied was given a specific and a generic name, the first conferring indexical, and the second individual value, coupled with the use of Latin roots and words for names, has been followed since everywhere, and has resulted in internationalizing the sciences where, previously, the bar of language had resulted in much unnecessary duplication of effort.

EULER (1707–1783)

MATHEMATICS

Leonhard Euler was born at Basel, Switzerland, and is regarded as one of the greatest of the mathematicians. He was educated in the university of the city of his nativity, and was so precocious as to win his degree of M.A. at the unusually early age of sixteen. After graduation he specialized in his favorite studies with private instructors, devoting also several years to theology, medicine, the Oriental languages and such science as the accumulated knowledge of the day provided.

At the age of twenty-eight, as the result of a severe illness, he lost the sight of one of his eyes, and about thirty years later became totally blind. In spite of this severe handicap he was, throughout his life, a persistent, undaunted and weariless investigator and teacher. At the age of twenty, and at the invitation of the Empress of Russia (Catherine I), he went to St. Petersburg, and became an associate of the Academy of Sciences there, serving first as a teacher of physics, then of mathematics, and finally inspector of the geographical department. In 1734 he was called to Berlin by Frederick II, and undertook the directorship of the department of mathematics in the Imperial University. In 1766 he returned to St. Petersburg, and remained there until his death, an honored member of the faculty of the university of that city.

Euler's writings on mathematical subjects were remarkably numerous, including 473 published during his lifetime, 200 shortly after his death, and 61 more since, at different times as they came to light. These are regarded as of the highest value, for he possessed a style of unusual clearness and easy intelligibility. Partial and even complete blindness did not lessen his mental vigor. When the latter misfortune overtook him, he employed as an amanuensis a young German who was, by trade, a tailor, and whose mathematical education had never progressed beyond the fundamentals. To him he dictated his remarkable "Introduction to Algebra," in terms so clear and simple that his assistant, as the work advanced, became an expert algebraist.

Euler carried his great mathematical faculties into the domain of physics. He was the first to deduce the equation of the curve of vibration in the phenomena of light rays, and to demonstrate their relation to, and dependence on the properties of density and elasticity in the medium that carried them—the ether of space. As a corollary from this, he showed mathematically that in the phenomenon of refraction it was the rays of greater length—those towards the red end of the spectrum—that underwent the smallest rate of dispersion in passing through the prism. In the face of the statement by the great Newton that a correction of chromatic aberration was unattainable, he investigated the subject so deeply and thoroughly, that he was able at the end to write a prescription under which Dollond, the distinguished English optician and instrument maker was able to construct a combination of lenses of different qualities of glass, which were practically achromatic.

In versatility of keen mental powers Euler ranks with Leonardo Da Vinci. Of all the great mathematicians that have arisen to date in the records of the science, he was preëminent in the faculty and habit of using that wonderful tool in solving practical problems in the arts. For example, he developed a method of determining longitude at sea, which brought him a share of the £20,000 prize offered by the British Parliament, the balance going to the instrument maker, Harrison, who constructed a chronometer sufficiently accurate to be used for the same purpose, the one checking the results indicated by the other.

CLAIRAULT (1713–1765)

PHYSICS

Alexis Claude Clairault was a native of the city of Paris. At an early age he exhibited unusual mathematical ability, and was afforded every opportunity to extend his education in that line, with the result that at the age of eighteen he was elected a member of the French Academy of Sciences. In 1736, as assistant to the astronomer, Maupertuis, he went to Iceland to measure a degree of the meridian. When its length was determined, the flattening of the globe towards the pole was demonstrated, which was contrary to the opinion that had been expressed by Cassini, but entirely in accord with the prediction made by Newton.

Clairault's chief accomplishments were his exposition of the nature and properties of curves of the third degree; and his explanation of the phenomenon of capillarity. He also was the first to complete such an accurate determination of the figure of the earth that practically no change has since been made in the result he arrived at.

Capillarity is a familiar phenomenon, and one that plays an important part in vegetable life and soil conditions, but is at the same time not easy to explain. At its foundation is the property that all liquids possess (in degree varying with their nature) of forming a skin of great tenuity and considerable tenacity on their surfaces, which always has a stronger tendency to contract than to expand, but which, when compelled to expand—as in the case of a soap bubble—does so at first by drawing some of the liquid from the under side of its skin to the outer side, that is, the skin becomes thinner. When all of it has come to the outer side of the bubble then, to some extent, but very slightly, stretching may ensue between the molecules. When the internal pressure exceeds their mutual attraction, the bubble bursts. This skin-forming property is called "surface tension." When a tumbler of water is carefully filled to its brim, it is possible, by delicate manipulation, to lay a perfectly dry steel needle on its surface, which will not sink until, as the result of a jar, the skin parts under its weight.

When a glass tube (open at both ends) is completely wetted inside and outside, a film of water remains on its surface. If now it is dipped vertically into a vessel of water, the latter will be seen to rise higher in the tube than its level in the vessel, and its shape will be concave, that is, lower in the middle than on the sides. This occurs because, when the film of water on the inside of the tube unites with the skin on the surface, the latter contracts as forcibly as it can, and draws the liquid up in the tube to a degree dependent on its character and also on the diameter of the tube. The smaller this diameter, and the greater the mobility of the liquid, the higher it will be drawn, until the action of the force of gravitation balances the strength of the surface tension, and stops the movement.

If now mercury be substituted for water, a directly opposite effect will follow. In the first place the tube, even if left for some time in the liquid metal, will retain none of it on the outside or the inside of its bore as a film, for clean mercury will not "wet" clean glass, as water will. When now the tube is dipped vertically into the vessel, the surface of the liquid metal in it will be lower than the surface outside, and convex in shape, that is, higher in the middle than at the sides. This is because the surface tension being stronger than in the case of water, and there being no surface film in the tube with which to attach itself, the urge to contraction draws it down to the main mass of the metal.

To demonstrate the contractile tendency of a liquid film, let a soap bubble be blown on the bowl of a clay pipe. When it seems to be at its largest possible size, let the aperture at the mouthpiece be closed with the tongue, so that no air can escape. At once the bubble will begin to decrease in size, and will compress the air it contains to an extent that will be quite appreciable when the tongue is removed so that it can escape confinement.

As the temperature of a liquid rises above normal, its surface tension lessens until, at the boiling point, the skin is ruptured by the bubbles rising through it to escape in the form of vapor. Cold water will therefore rise higher in a tube than when warm.

D'ALEMBERT (1717–1783)

MATHEMATICS

The real name of this brilliant Frenchman was Jean le Rond. He was abandoned by his parents as an infant on the steps of the chapel dedicated to that saint, but was kindly cared for by the motherly wife of a workingman, his father contributing secretly to his support, and later paying liberally for his education at one of the Jansenist colleges where, at an early age, he displayed unusual ability in mathematics and in the sciences. The name by which he later became known was an assumed one, the reason for its adoption never having been given by him. At the age of twenty-two he published a notable monograph on the integral calculus, and a couple of years later another on the refraction of light: In 1743 his treatise on dynamics appeared, which marked an epoch in the history of physics; for in it he gave expression to one of the fundamental principles of that science, to the effect that "impressed forces are equivalent to the effective force." Such a statement today would seem self-evident, but in the middle of the 18th century it was not only new, but the first one to epitomize what became later to be known as the theory of the conservation of energy. Another monograph published in 1744 contained the first conception of the calculus of partial differences, and a third which appeared four years later, contained the earliest analytical solution of the phenomenon of the precession of the equinoxes. In 1751, in association with Diderot, one of the most brilliant and versatile writers of the time, he undertook the editing of the great French encyclopedia, and contributed many articles on science and philosophy to its pages.

The name by which he was known was in no way connected with his parentage. In person he was a man of fine appearance, and in manners plain, independent and sometimes rudely bluff. He was a total abstainer from stimulants of an alcoholic nature, lived simply, and never married. During his later years he maintained a close, though entirely honorable, relationship with the noted littérateur, Julie Jeanne Elenore de l'Espinasse, who cared for him during a serious illness, and at whose early death he experienced a shock from which he never recovered. She also was without legal parentage, and though they were tenderly attached, and for the last seven years of her life were never separated and remained unmarried, not a breath of scandal was ever attached to them.

D'Alembert became a member of the Paris Academy of Sciences in 1741, and in 1754 of the French Academy, and was made its secretary for life in 1772. He was several times tendered the presidency of the Berlin Academy by King Fredrick II, and also a salary of 100,000 francs by Catherine II of Russia to act as tutor to her son, but declined both, being unwilling to leave the circle in Paris which had collected around him. There are few, if any, among the notables of his time, who were as highly respected for literary and scientific ability, and for the clean and honorable life led.

HUTTON (1726–1797)

GEOLOGY

James Hutton was a native of Edinburgh, and received his education at the university of that city, specializing in law. But, after a year's experience as an attorney's clerk, he abandoned the profession, and turned to medicine, taking courses at Paris and Leyden. But neither did this occupation interest him, and in 1750, at the age of 24, he went back to Scotland and took up agriculture as a vocation. Through it he became interested in geology, a science then in its infancy—if yet born—and dominated by the ideas of Abraham Gotlob Werner, who occupied the chair of mining engineering at the famous school at Freiberg in Germany. This notable man was an industrious and careful collector and classifier of facts, but as his field of observation was confined almost entirely to Saxony, they provided only a limited foundation for his conclusions, which have not been sustained by later investigations.

Hutton seems to have been among the first who opposed them, and in his "Theory of the Earth," which he read before the Royal Society in 1785, and which was later amplified and published in 1795 under the title of "The Theory of the Earth with Proofs and Illustrations," he laid a firm foundation for the young science, by showing the errors of the "catastrophic" theories of Werner, then universally accepted and approved by the Church as in accord with the teachings of the Scriptures; and substituting in its place a general theory which became known later under the unwieldy but expressive name of "Uniformitarianism."

This view of the past history of our planet assumes that its age has been enormous, its growth slow but persistent, and that the processes through which it has reached its present condition are the same as those now in operation. Such views naturally could not be brought into accord with the account in Genesis of the Creation, and when Hutton, in reading his paper before the Royal Society, condensed its concept into the phrase, "I can see no traces of a beginning, and no prospect of an end," he took a position which necessarily arrayed against him all the orthodox forces of the day.

The result was that his theory awakened almost no response at the time. It was regarded as an impiety, and its author as an atheist. Time, however, is a corrective of all things. In 1802, four years after Hutton's death, the noted Scotch mathematician, Playfair, boldly advocated the Huttonian theory, and shortly thereafter William Smith, the English geologist took the same position.

However, it remained for Sir Charles Lyell (1797–1875), a man whose unquestioned attainments in other lines compelled attention, to revive the almost forgotten ideas of Hutton. This he did without reservation, in his great work entitled "Principles of Geology," the first part of which appeared in 1830, the second in 1832, and the third in 1833. In this production, which is rightly regarded today as the most comprehensive single compilation of general geological data yet made, full credit is given to Hutton for having announced nearly half a century before, the true foundation upon which the observed facts in geology must be studied, if we are to succeed in interpreting them correctly.

HUNTER (1728–1793)

PHYSIOLOGY AND ANATOMY

John Hunter was born in Glasgow, Scotland, the youngest of a family of ten children. His primary education was of the most rudimentary kind, and family necessity compelled his apprenticeship in early youth to a cabinet maker. But at the age of twenty, with the aid of a brother who had become a doctor, he began the study of anatomy in the local hospital, and displayed so much aptitude that in 1756 he was appointed house surgeon at St. George's in London. Thereafter, his advance was extremely rapid. From 1761 to 1763 he served as army surgeon in the wars with France and Portugal, and at their close opened an office in London for general practice, where he quickly attained so great a reputation for skill in the art that in 1776 he was appointed Surgeon Extraordinary to King George IV, which was probably the way in which royalties in those days paid their medical bills.

Hunter is regarded as the greatest surgeon and anatomist of his time. One of his most noted feats was the tying of an artery on its heart side for the cure of a pulsating tumor (aneurism) which had formed in consequence of a weak spot in its wall. At the time it was regarded as a most remarkable accomplishment, and it still remains one of the most delicate and dangerous of operations. But he is best known by reason of the anatomical museum which he built up in London during the active years of his life. This contained, at the time of his death, 10,563 specimens and preparations illustrative of human and animal anatomy and physiology, and of natural history, and remains today perhaps the most remarkable individual collection of its kind in the world. Upon it he spent so freely the money he earned in his large practice, that he was continually in financial straits, and left practically no property but it at his death. Two years after that event it was purchased by the government for £15,000, and presented to the Royal College of Surgeons.

Hunter published during his lifetime a number of valuable monographs, among which of most importance may be mentioned the "History of the Human Teeth," "Venereal Diseases" and "Gunshot Wounds." In addition he was a notable contributor of papers to the "Transactions" of the Royal Society, of which he became a member in 1767, and from which he received the Copley medal in 1787.

BLACK (1728–1799)

CHEMISTRY

Joseph Black, of Scotch-Irish ancestry, was born at Bordeaux, France, where his father happened at the time to be engaged in his business. He was educated first at

Belfast, then entered the University of Glasgow, and finally that of Edinburgh, where he took his degree in the medical art. Becoming first a lecturer in anatomy at Glasgow, he was ultimately appointed to the chair of chemistry at Edinburgh where he remained during the balance of his life. His inclinations led to research, and resulted in several fundamental discoveries of importance. The most notable of these was the clear demonstration of the presence of the gas now known as carbon dioxide, as a component of those mineral substances called carbonates, of which limestone in its natural state is the most familiar example. He called this gas "fixed air," and ascertained some of its properties, but not its essential composition.

The better to understand the importance of Black's discovery, let us consider the case of producing quick (or caustic) lime by burning limestone in a kiln. Previous to his investigations it was taught by the chemists of the day that in the operation the fiery principle or substance called "phlogiston" entered into combination with the stone and imparted the heat-giving qualities to the calcined material when it was slaked with water. When Black demonstrated that the crude rock lost weight in the burning, it became evident that some other explanation was necessary. He was able finally to collect some of the escaping carbon dioxide, but succeeded only in ascertaining that it differed in physical characteristics from atmospheric air. Between the years 1759 and 1763 he announced and elaborated his theory of "latent heat," which met with almost universal acceptance at first, but later was shown to be merely a step—though an important one—towards a correct understanding of the phenomena at the foundation of all exhibitions of energy.

During the period 1766 to 1799, when he occupied the chair of chemistry and physics at the University of Edinburgh, he published several monographs on these subjects, one of which entitled "Observations on the More Ready Freezing of Water That Has Been Boiled," indicates the primitive state of the sciences at the time.

SPELLANZANI (1729–1799)

PHYSIOLOGY

Lazaro Spellanzani was born at Scandiano in northern Italy, and received his education at the universities of Modena and Bologna. After several years of private practice in the medical art, during which he devoted much of his time to private research, he assumed in 1761 the professorship of mathematics at Modena, and later the chair of natural history at Pavia, where he remained for the balance of his life. He was by inclination an experimental physiologist, and during his active years did notable work in enlarging and correcting current views on the subject of metabolism (digestion and assimilation of food), and in demonstrating the falsity of the beliefs held at the time by many in high places as to the possibility of spontaneous generation. In regard to the first, the science of chemistry had not yet advanced to a point where the reactions that occur in the alimentary tract, and result in nutrition, could be thoroughly explained, nor those that take place in the lungs and cause the purification of the blood. Nevertheless, enough had by then been revealed by the anatomists, of the nature of most of the organs of the body, to permit of a correct understanding of the duty performed by each, and it was his part to establish that the first step in metabolism was that of the solution of the assimilizable parts of food, effected at first by the combined action of the saliva of the mouth and the gastric juice of the stomach, and carried later to completion by the aid of solvents produced by the liver, the pancreas and the intestinal glands, by which it is finally converted into a fluid from which the intestines could extract those materials required by the body for its growth and repair. In other words, his investigations, while not explaining the chemical action, did much to abolish the mystery that up to then had surrounded the act of digestion, and destroyed many of the current beliefs in which ignorance and superstition had enshrouded the process.

In much the same way his researches cleared the path for those following him on the second subject. The doctrine that life (organized matter) could, in some mechanical or other way, be produced from inorganic or dead matter, is not only a very ancient but a most natural one, and was held almost universally until about the middle of the 17th century. Even since then it has been revived on different occasions, and by men of otherwise good standing in scientific circles. In fact, the tendency at the present time among biologists is decidedly to the effect that inasmuch as protoplasm, at some time in the remote past, must have been evolved naturally out of purely inorganic elements or compounds, in due time the chemist and physicist in collaboration, may fairly be expected to learn how to duplicate the feat. But in the day of Spellanzani, when several of the sciences were just in bud, many proofs were thought to have been produced of life arising spontaneously from infusions of vegetable or animal matter, that were thought to have been perfectly protected from external contamination. He was among the first to investigate this subject exhaustively. After long boiling of his infusions, instead of merely corking, he fused together the necks of the glass flasks containing them, with the result that no living organisms developed. Three quarters of a century later as additional evidence, the German chemists, Schultze and Schwann, repeated the test in a different way. After boiling their infusions, they admitted air to them, but previously passed it through red hot metal tubes. Under this treatment no life arose. Since then the matter has been tried out again and again in other ways, and invariably with negative results. So that at the present time, among biologists, the aphorism "no life without antecedent life" is held to be demonstrated, but with the reservation that some day it is not unreasonable to expect the synthesis of protoplasm to be effected.

CAVENDISH (1731–1810)

CHEMISTRY

Henry Cavendish was born at Nice in southern France, of English parentage, and was educated at Cambridge, but left without taking his degree. Inheriting ample means, and being of a retiring disposition, he settled quietly on his estates, and devoted the entire balance of his life to the study of mathematics, and to experiments and investigations in physics and chemistry.

In the latter department of science he made the discovery —very astonishing at the time—that water was composed of the two gases, hydrogen and oxygen, which, in his day, were known respectively as phlogiston and dephlogisticated air.

In the department of physics, following a suggestion made by a clerical friend—the Rev. John Mitchell—he devised in 1798 an apparatus which enabled him to determine with considerable accuracy the specific gravity or density of the globe. This consisted of a thin and symmetrical metallic rod, suspended horizontally at its center by a silk thread, and carrying at its extremities two small balls of lead. When this rod came to rest its compass direction was accurately noted with a surveyor's telescope. Directly underneath it was a revolving table or frame, the pivot of which coincided exactly with the prolongation of the suspending thread of the rod. When now larger balls of metal, of known weight and density, were placed on the table, and by revolving the latter, were brought into the vicinity of the small lead balls on the rod, more or less deflection of the latter from its compass position occurred, due to the mutual attraction, and the amount of this deflection was easily measurable. With the data so supplied it was possible to compute the attraction that would be exercised by a mass the size of the earth, and thus determine its density. The figure worked out by Cavendish was 5.45, which is slightly below that yielded by later investigators. The accepted figure at present is 5.59.

The meaning of this figure is that the earth weighs 5.6 as much as it would weigh if consisting entirely of water. Knowing its shape and dimensions, and the weight of a unit volume of water, it is a simple matter to arrive at the conclusion that its total weight is in the vicinity of 141,000,000,000,000,000 tons of 2000 pounds each.

Now it has been estimated, as the results of a large number of careful experiments, that the outer crust of the earth—say the outer 20 to 25 miles in depth of its substance—has a density of about 2.5. If its density as a whole is 5.6, it follows logically that towards the interior the density must gradually or suddenly increase, to compensate for its comparatively surface lightness. Hence, it is believed that the core of the globe is a mass of metal which, at the exact center, probably has the density of the heaviest of them, uranium, which is 18.68. From the varying rate of transmission of the vibrations of earthquake shocks around and through different sections of the globe, Professor Weichert has concluded that the earth's core is a mass of metal 5580 miles in diameter, and of about the weight of iron or steel, surrounded by a stone shell some 930 miles thick, around which is a molten liquid or plastic layer of about 166 miles in thickness, extending to within 20 miles or so of the surface.

PRIESTLEY (1733–1804)

CHEMISTRY

Joseph Priestley, the son of a woolen mill operative, was born at Fieldheld, England, and received his education at a Dissenters' Academy near Northampton. Here, showing great aptitude in the languages, mathematics and physics, and in spite of a serious impediment in his speech, and a strong antipathy to the Calvinistic brand of theology taught at the school, he sought the ministry as a profession, and at the age of 22 was at the head of a small congregation at Needham. From there, he went as a teacher of the languages and belles-lettres, to an academy at Warrenton, where he married, and made his home for six years. By this time, in addition to an excellent knowledge of Latin, Greek and Hebrew, he had taught himself to read Italian, French and German, and ultimately acquired Chaldean and Syraic. These unusual linguistic accomplishments were recognized by the University of Edinburgh, which granted him an honorary degree.

About this period of his career, having accepted the charge of a chapel at Mill Hill, which happened to be next door to a brewery, he became deeply interested in the abundant gas disengaged at such places, during the fermentation of grain (now known as carbon dioxide), and succeeded in forcing some of it into combination with water. He considered it to be some kind of impure air, and was unable to recognize its true character. The experience, and the interest aroused, led to other experiments. One of these had to do with the red oxide of mercury, a fairly well-known substance at the time, which occurs in nature as the mineral cinnabar, and from which the metal is easily reduced by heat. Priestley succeeded in effecting this reduction with a burning glass, and in collecting some of the escaping oxygen, which he called "dephlogisticated air." But while he noted some of its remarkable properties, it remained for the chemist, Steele, a few years later, to isolate it in larger quantities, and to announce its real character.

So far as known this was the first case of the isolation of this element (the most abundant in nature), and its recognition at this time (1774) was an event of primary importance in the development of science. It may be said to mark the birth of chemistry, and the death of the phlogiston theory, which up to that time had been generally accepted.

The discovery so enhanced the reputation of this versatile man, that he was offered the post of "literary companion" to Lord Shelbourne, and accompanied him on a journey through France, Holland and Germany. In 1777 he wrote and published a pamphlet entitled "Disquisitions Relating to Matter and Spirit," a production which had neither scientific nor religious value, even for its time, and was so repugnant to the orthodoxy of the day, that his relations with Lord Shelbourne were terminated. In 1780 he became the minister of a dissenting congregation at Birmingham, and preached there for three years. Finally, to escape persecution for his religious views, he emigrated to America, settling at Northumberland, Pa., and remained there until his death.

Priestley was a brilliant but also an erratic character. With vast learning, and a vivid imagination, was coupled a visionary temperament which constantly led him astray. Yet he fully deserves the credit of being the first to isolate the most abundant of the elements, and the one which plays the most important part in the maintenance of animal and vegetable life on the globe.

COULOMB (1736–1806)

PHYSICS

Charles Augustin de Coulomb was born at Angoulême, France, and after receiving a good education in the fundamentals, entered military life, and became an officer in the engineering corps of the army. Becoming interested in the phenomena of magnetism and electricity he studied the literature of those rapidly growing departments of science, and in 1777 was awarded a prize for an essay on the construction of magnetic needles. In 1779 he gained another, for a monograph on the theory of prime movers, and in 1781 a third for a paper on the subject of friction. These so established his reputation as a scientist of ability, that he was elected a member of the French Academy of Sciences, and called upon to solve a number of difficult problems in mechanical engineering.

His great accomplishment was that of the adaptation of the torsion balance (designed by John Mitchell, and perfected by Henry Cavendish, and employed by the latter to measure the force of gravitation), to the measurement of the strength and action of magnetic poles. For this purpose a long and thin magnet was suspended at its central point on a fine wire, the torsional capacity of which had been previously determined), so that it could revolve freely in either a horizontal or vertical plane. A similar magnet, suspended at one of its ends, was then placed near one of the poles of the other. The strength of the reaction resulting could then be determined by noting the angle through which it was necessary to turn the head screw carrying the wire for the horizontally disposed magnet, to maintain it in its original position. For this service to science, his name was adopted by the International Scientific Association, as the unit of that quantity of electricity which passes through a conductor of unit size in a second of time, an honor which will keep his memory alive as long as the electrical science endures.

While the phenomenon called magnetism is now recognized as one of the manifestations of that universal force which, in other aspects is exhibited to the senses as light, heat, electricity, etc., its cause is not yet completely accounted for. The latest theory on the subject is that of the English physicist, J. J. Thomson, who suggested that it might be explained by the rotation of the molecule, with its Faraday tubes connecting the atoms. Further light however is necessary.

Who first observed the properties of the natural magnet is unknown, though it has been recognized as a fact for at least three thousand years. The substance itself is technically known as the feroso-ferric oxide of iron, or the peroxide (Fe_3O_4), consisting of 72.4 per cent of the metal, and 27.6 per cent of the gas oxygen. It is black in color and abundant in nature, constituting, in fact, one of the important ores from which the metal is obtained. It occurs mainly in those oldest of the rocks that are grouped by the geologists as predominant in Archean time. The first literature on the subject was a book entitled "De Magnete" written by William Gilbert (1540–1603), in which he collected all the facts and fancies current up to that date on the mysterious properties of the natural lodestone.

WATT (1736–1819)

MECHANICS

James Watt, who was born at Greenock in Scotland, is often credited with the invention of the steam-engine. But the principles underlying its construction had been known for centuries before his time, and even before his birth engines of a sort were in operation in Cornwall. Nevertheless, to his genius and industry the world is indebted for vital improvements in their construction, without which the machine would never have amounted to much as a producer of power.

The earliest known application of steam to produce motion was that made by Hero of Alexandria, an Egyptian mathematician and mechanic living in the first or second century of the present era, who devised what he called an aeolipile. It consisted of a hollow metallic globe mounted on trunnions, and provided on opposite sides with tubular arms curved in opposing directions, each terminating in a small opening. When the globe was partly filled with water and heat applied, the escaping steam, reacting against the air, caused it to revolve. In 1629 an Italian named Branca made a windmill turn by projecting a jet of steam against its vane and may thus be regarded as the originator of the steam turbine idea. In 1698 a patent was granted to one Thomas Savery in England for a device in which steam was employed to raise water out of a forty-foot mine shaft in Cornwall, but no clear description of its mechanism has been preserved. It is generally agreed that to the French physicist Denis Papin belongs the credit (in 1690) of employing steam on one face of a piston confined in a cylinder, and of condensing the vapor at the end of the stroke by a jet of water, the piston then falling back to its initial position by its weight. The next step was taken in 1705 in the construction of the Newcomen engine, where the cylinder was mounted vertically over the boiler, and connected with it by a pipe fitted with a stop cock, which was manipulated by an attendant—generally a boy.

One of these youngsters, named Humphrey Potter, devised a combination of levers and cords attached to the piston rod by which, with improvements made later by the engineer, Henry Brighton, a fairly self-acting machine resulted. These, for more than the following fifty years, were quite extensively employed in the mining districts.

It was at this stage of its development that Watt's attention was drawn to the machine, and his work on it began. His first improvement was to arrange for the condensation of the steam outside of the cylinder, and in a chamber where a vacuum could be maintained. This was followed in turn by the introduction of the steam on both sides of the piston, which permitted the cylinder to be placed in a horizontal position if desired; the use of the steam expansively, and the employment of the flywheel to convert reciprocating into rotary motion. Confronted with a patent on the connecting rod or crank, that had been granted to a former employee—though Watt claimed to have originated the idea—he invented what became known as the "sun and planet gear" which answered well as a substitute. After these, he contributed the governor, the water and mercury steam gauges, and a number of other minor but important improvements. So great was the confidence inspired by his mechanical ingenuity that he had no difficulty in securing the capital required to embark extensively in the manufacture of engines; and when he retired in 1800, he was able to turn over to his two sons a large and highly remunerative business.

In 1784 he was elected a member of the Royal Society of Edinburgh, and in the following year of the Royal Society of London. In 1806 the degree of LL.D. was conferred on him by the University of Glasgow, and two years later he was made a foreign associate member of the French Institute. After his death a national memorial in his honor was placed in Westminster Abbey, and a fine statue, paid for by popular subscription, erected in Birmingham.

LAGRANGE (1736–1813)

PHYSICS

Joseph Louis Lagrange, although of French parentage, first saw the light in Turin, Italy, when the province of Piedmont in which it is situated was part of France, was the son of the war treasurer of the King of Sardinia, and was educated at the college of his native city. At an early age he exhibited unusual mathematical ability, and was able in his nineteenth year to send to Euler, the Swiss mathematician, a correct solution of what was known at that time as the isoperimetric problem, which he accomplished by supplying a notation for an extension of the principles of the calculus of variations. This notable step in the growth of the science gave him such a reputation among European mathematicians that he was offered the chair of mathematics in the military school at Turin.

In 1758 he founded the Royal Academy of Turin. In 1764-1766, as the result of studies on the phenomenon of the librations of the moon, and the system of Jupiter and its satellites, he succeeded Euler as director of the Academy of Berlin, and remained there until 1786, when he removed to Paris, and was elected a member of the French Academy. Upon the establishment of the Ecole Polytechnique he became one of its professors, and later received a similar appointment in the Ecole Normale. When Napoleon came into power he was given the rank of count, and became a member of the Senate. His most notable writings were "Mécanique Analytique" (1788), and "Théorie des Fonctions Analytique" (1799). These, added to many other studies in the science of numbers of lesser note but of undoubted value, established his standing as perhaps the greatest of all pure mathematicians of his day.

The accomplishment which entitles him to be regarded as one of the notable discoverers in the realm of the sciences was his development of the principles of "virtual velocities," a phrase or expression coined by Jean Bernouilli in 1717, most unfortunately, for it has nothing to do with velocities as the word is ordinarily used. The principle, as now understood, is as follows:

"If a body is in equilibrium, the sum of all the forces, each multiplied by the practical velocity of its point of application is, for every possible infinitesimal displacement of the body, equal to zero."

Expressed in this way the principle is not easy of comprehension. Perhaps the simplest illustration of the idea back of the phenomenon is to be obtained from the action of the movable pulley where, if the force applied to the cord (like a weight) moves down a certain distance, another weight fastened to the pulley must move up such a distance, that the product of each weight by its distance is the same.

GALVANI (1737–1798)

ANATOMY

Luigi Galvani was a native of Bologna, Italy, and was destined by his parents for the Church. But, preferring medicine, he made himself so proficient in that art, that he was offered and accepted the chair of anatomy at the university of his native ctiy, and while there published a number of valuable monographs on anatomical and surgical subjects.

In 1786, while studying the muscular system in the legs of frogs, he had suspended several freshly prepared specimens by wires alongside of the iron framework of a balcony, and his attention was attracted to the fact that when (moved by the wind) one of them touched the iron, the muscles contracted strongly, as if still alive, the action being repeated at each contact, until decomposition of the flesh had begun. He correctly ascribed the effect to a force traversing the nerves, but assumed its origin to be in the leg of the animal, and an indication of the existence of a vital force, and hence of the continuance of life for a considerable period after apparent death and dismemberment. This explanation of the phenomenon was later shown by Volta to be an error.

Aside from this more or less accidental discovery, Galvani made no other notable contribution to the advancement of science. But in the fields of anatomy and medicine his standing was so high, that in 1879 a long-overdue statue was unveiled to his memory in his native city.

The rather startling nature of his discovery, and the persistence through many years (as a result of his great medical reputation) of his theory of a "vital force," has won for his name a very extended notoriety. Thus, even today, we speak of the galvanic current when we should call it the voltaic current, and similarly we use the term galvanization in referring to the effects of the voltaic current as displayed in the various processes of metal plating. But Volta has been properly honored in another way. However, when we speak of an individual as having been galvanized into a temporary or fictitious display of activity, we correctly recall to mind the picture of Galvani's frogs' legs hanging on his balcony, and exhibiting unsuspected and adventitious indications of life.

HERSCHEL (1738–1822)

ASTRONOMY

William Herschel, the son of a musician, resided in Hanover, Germany. Expecting to follow the profession of his father, he was given a thorough musical training, in addition to the general education of his day. At the age of nineteen he moved to Leeds in England, and became a teacher of the art. After a few years there he secured a position at Halifax as organist, and in 1766 undertook the same kind of work at Bath. Here he became interested in astronomy, and being unable to purchase a telescope, he made one of five foot focal length. With this, in 1781, he discovered the planet Uranus, till then unknown, which brought him so much favorable notoriety, that he received and gladly accepted an offer from the King (George III) to become his personal astronomer. He set up his instruments at the little village of Slough in the vicinity of

Windsor, where (as now) was the residence of the ruler. Here, assisted by a younger sister Caroline, who had previously joined him at Bath, he remained for the balance of his life, engaged mainly in observational work, but also in the manufacture of mirrors for reflecting telescopes, of which he made a speciality, regarding them superior to the refracting variety. Here also he married, and having become rich thereby, as well as securing a life partner who was as thoroughly interested as his sister and himself in the study of the heavens, he began, in 1785, the construction of what was for its time, the largest and most powerful telescope in the world. Its mirror was 48 inches in diameter, and its focal length 40 feet. With this tremendous engine of discovery, and aided by his highly gifted sister, the two made a marvelous record in observational work, including the discovery of six satellites of Uranus, two (the 6th and 7th) of Saturn, the establishment of the rotational periods of Saturn and Venus, the first of binary stars, the location of over 2300 new nebulae, many remarkable studies of the Milky Way, and a voluminous catalogue of double stars.

It is not too much to say that the work of this notable pair of observers—devoted tenderly to each other, as well as heartily to their vocation—led to a comprehension of the immensity and wonders of the Universe, which had not previously been attained even by the greatest of their predecessors.

Herschel received the honor of knighthood from the King, and the degree of D.C.L. from the University of Oxford. He contributed 69 original papers to the Transactions of the Philosophical Society, and to the first volume of the Memoirs of the Astronomical Society a paper entitled "On the Places of 145 New Double Stars." His sister Caroline, on her completion of the catalogue of nebulae and star clusters detected by herself and her brother, was elected an honorary member of the Royal Society, and was presented with its gold medal. On the death of her brother she returned to her native land.

SCHEELE (1742–1786)

CHEMISTRY

CARL WILHELM SCHEELE was born at Stralsund, Sweden. Of his early life almost nothing is known. But at the age of twenty-five he opened an apothecary shop at Stockholm, and three years later moved to Upsala, presumably on account of the advantages to be gained at the university there, in prosecuting his studies in chemistry, which had begun some years previously, and for which he must have had some preliminary training. Whether this was the case or not, he quickly became known as the discoverer of a number of elements and compounds that proved to be of importance in the rapidly growing arts of his day.

The first of these was tartaric acid, a compound of carbon, oxygen and hydrogen which occurs abundantly in the vegetable world, and particularly in that product of the fermentation of grape juice which is known as argol. This substance had of course been known for centuries, and from it the commercial product called tartar and cream of tartar was prepared, consisting essentially of a combination of the tartrates of potash and lime. But the acid itself had never been isolated. That feat Scheele accomplished, recovering it in the form of colorless transparent crystals which, many years later, were found to possess the very curious property, when gently warmed, of becoming strongly electrified, the opposite sides of each crystal exhibiting the opposite states of that form of energy. He made no attempt to resolve this new compound into its component elements and, in fact, none of the three were then even known, except hydrogen, which went under the name of phlogiston.

His next important discovery, in 1774, was the gas chlorine, which he called "dephlogisticated marine acid gas," as he recovered it from sea salt. He did not become aware of its elementary character, and it was not until Davy, thirty years later, isolated it, that it was given the name it now bears. In the same year Scheele produced baryta for the first time. He extracted it from the mineral witherite, but did not push his investigation any further. It was to him simply a new substance. But again Davy, in 1808, following his lead, and using a powerful voltaic battery, separated the metal barium from it, and proved its elementary nature.

In 1775 he discovered the gas oxygen, without the knowledge that it had been discovered by Priestley in 1774. Scheele gave it the name of empyrial air. A little later the name of "vital air" was suggested for it, because not only could it be breathed to a limited extent with impunity, but when inhaled caused a wonderful sensation of exhilaration. Its true character as an element was demonstrated later by Lavoisier, who also gave it its present name. Finally, in 1770, Scheele produced accidentally in his laboratory a syrupy liquid with a sweet taste, which he called glycerin; and shortly thereafter, in much the same way, the highly poisonous compound hydrocyanic acid, which was popularly known in his time as prussic acid. In neither case was he able to determine its ultimate composition. Both of these substances are of importance in the arts, especially glycerin, which was thoroughly investigated by Chevreul.

Scheele was in no sense a chemist. In fact, that science had hardly come into existence in his time. But he was an earnest and tireless investigator of the alchemistic order, and while practically all his discoveries were chance ones, he deserves the credit for them. His position in the progress of science may be compared to that of the scout who, in the field, travels in advance of the main body of explorers, reconnoitering the country, and every now and then stumbling on a fact or principle which proves to be of importance when further examined by the investigators following. It was just in such a way that he happened to encounter that compound of arsenic and copper which is still known commercially as "Scheele's Green," and which is extensively used in the arts connected with the production of wall paper and printed calico.

HAUY (1743–1822)

MINERALOGY

René Just Haüy, a native of the little town of St. Just in France, was educated for the Church and took priestly orders. But, while teaching theology in Paris he became deeply interested in botany, as a result of attending the lectures of the noted naturalist, Dauberton. Sometime afterwards he happened to be handling a crystal of calcite, which dropped from his grasp and broke into fragments on the stone floor. While gathering these up he noticed that each fragment was, in its way, a crystal of the same form as that of the original. This interested him so greatly that he began the study of crystals of other minerals. Being a patient and keen observer he continued research in this branch of natural phenomena and became practically the founder of the science of crystallography, a department of knowledge which, since his day, has expanded and led to many important results in industry. In 1793, after the Revolution—during which he suffered imprisonment and came near to losing his life—he was appointed a member of the Commission on Weights and Measures, and in the following year became keeper of the Cabinet of Mines. In 1802 he was elected professor of mineralogy at the Museum of Natural History in Paris, to which institution he willed his remarkable collection of crystals. The beautiful and rather rare mineral "hauynite" (or hauyne as it was first called), a sodium, calcium and aluminum silicate and sulphite, pleochroic and generally found only in eruptive rocks, was named in his honor. Haüy (whose name is pronounced in French as if spelled "a-we") became a member of the French Academy, and published several books on his specialty, which are classic. In these he advanced the theory (which has since held good) that crystalline form should be the prinicipal element in the determination of a mineral.

Inorganic—that is, non-vitalized—material, when in the solid state, appears in nature in two ways, either as a crystal or as an amorphous body like a mass of glass which, in cooling, will take any shape desired. Each member of the first category has its own habit of body making. The cause back of this seems to be a definite property of the unit molecule, under the impulse of which, when an assemblage of one kind is gathering, each one will dispose of itself along certain lines and in certain invariable directions if free to do so. Why this is the law is, as yet, one of the unsolved problems of science, which the crystallographers deprive of some of its mystery by alleging varying "coefficients of expansion" in each kind of molecule. At times such substances are found to be apparently arranged otherwise, showing no faces, bounding lines or angles of crystals to the eye, or even under the microscope. This condition is the result of the crowding by each other while in the act of growing in a confined space. Under such circumstances the substance is capable of exerting enormous force in following out the law of its being, as is well known in the case of water freezing. Massive quartz is another good illustration. Even here the unknown force or habit or property has not been absent during the process of solidification. This may be demonstrated by means of a sphere cut from an apparently amorphous mass of such material. When heated it will become distorted, expanding in several directions and more in one than in another, with the result that the figure will become a spheroid. Whereas a globe of glass when given the same treatment will retain its spherical shape.

Crystallography is one of the exact sciences, with limited capacities, and these based upon mathematical laws. As knowledge in its phenomena increased, its devotees set to themselves the task of determining how many points in space were possible, under certain assumptions based on properties known by observation to be common to all crystals. It was found that only 32 could exist. Of these, 23 had already been recognized, and 6 more were found shortly thereafter. Probably the remaining 3 have since been located in nature. All so far detected correspond absolutely with the theory underlying the system. These

32 kinds of known and possible crystal symmetries are now grouped under six systems, into one of which every known or conceivable form of that kind of entity can be gathered. The recent employment of crystals of the metallic minerals in radio installations, has resulted in arousing renewed interest in this beautiful and somewhat neglected field of nature.

LAVOISIER (1743–1794)

CHEMISTRY

Antoine Laurent Lavoisier was a resident of Paris, and educated at the Collège Mazarin. He developed at an early age unusual mathematical capacity, and became also deeply interested in the science of physics. In 1768 he was elected a member of the Academy of Sciences. In the following year he was appointed to the governmental position called a "farmer general of the revenue," which yielded a good income, and at the same time enabled him to devote his attention to researches in science. In 1776 he added to his public duties the directorship of the national gunpowder factory, where he introduced several valuable improvements. In 1778 he was appointed one of the trustees of the Bank of Discount, and in 1790 became a member of the Commission on Weights and Measures, taking a prominent part in the movements which finally resulted in the establishment of the Metric System, now universally employed in scientific measurements, and in common usage throughout the civilized world except among the Anglo-Saxon nationalities.

When the French Revolution broke out Lavosier, as a member of the aristocracy, as well as the holder of several positions under the government, became obnoxious to the proletariat, and in 1794, along with twenty-six other revenue collectors, was guillotined under the accusation of Dupin, a member of the Convention, as "one of the enemies of the country." Desperate efforts were made by friends to save his life by urging his high professional rank and services.

But to all these the only reply of the Tribunal was, "We need no more scientists in France."

Lavoisier is regarded as the founder of the modern science of inorganic chemistry. Although, at the time, the principle of the indestructibility of matter—or the Conservation of Mass—had not been grasped as a whole by scientists, any more than the similar principle of the indestructibility of force—Conservation of Energy—yet he became aware, in his chemical work, of the fact that in all his experiments, whatever changes in kind occurred, if all the products of these changes were preserved, their combined weight exactly equaled that of the original substance under investigation, plus the weight of all reagents employed and retained, and demonstrated the fact by introducing the balance into his laboratory, and the principles of mathematics as its fundamental tool.

This idea, when once accepted, transformed the crude chemistry of the day into an exact science, and was quickly followed by the development of a system of nomenclature devised in collaboration with Berthollet and others, which was substantially identical with that employed ever since.

Lavoisier produced, during his comparatively brief career, a large number of scientific papers, the most of which were on purely chemical subjects. It will be interesting to note that in one of them he gave a list of the 33 elementary substances accepted as such at the time, two of which were caloric and light. At present 88 are known, and among them caloric and light do not appear.

LAMARCK (1744–1829)

NATURAL HISTORY

Jean Baptiste Pierre Antoine Lamarck was born at Bazintin-le-Petit in France. His parents designed him for the Church and entered him at the College of the Jesuits at Amiens; but at the age of sixteen he left the institution, enlisted in the army, distinguished himself, and rapidly rose to a lieutenancy. Being compelled to give up military life on account of an accident that disabled him physically, he went to Paris and began the study of medicine. From this he became interested in botany, and placed himself in the employ of Bernard de Jussieu, under whose guidance he studied that science for ten years. In 1778 he published his first work entitled "Flore Française," which was so well received that in the following year he was elected a member of the French Academy of Sciences, and two years later appointed Royal Botanist, commissioned to travel in foreign lands, and to investigate foreign public and private botanical collections. After reporting on those in Holland, Germany and Hungary, he was appointed in 1783 keeper of the Royal Gardens at Paris, which later became the famous Jardin des Plantes. This he built up into an institution of the highest order and service. After serving there for ten years, he was tendered the chair of invertebrate zoology at the Museum of Natural History at the capital, and retained his connection with it in various capacities for the remainder of his active life. In the years between 1815 and 1822 his principal work entitled "Natural History of the Invertebrates" was published. This, years after his death, gained him immortal renown, for in it he enunciated certain principles which are fundamental in the theory of evolution, as later worked out more thoroughly and correctly by Darwin.

Lamarck was a man of keen and broad observational powers, but in no sense an experimenter. He lacked the patience to collect, compare and test, which characterized the work of Darwin. Hence, though he held and expressed in his writings advanced views on many departments of science besides botany and zoology—including chemistry, meteorology, physics and geology—many of his conclusions have not been sustained, and so his general standing as a scientist has suffered. Nevertheless, he is fully entitled to rank as the founder of the science of invertebrate paleontology, and was among the first after Hutton to assert the great length of geologic time, the continuous persistence of organic life throughout the geologic periods, and the influence of environment on habits and physical modifications.

In the domain of chemistry and physics his speculations are of little account. From 1799 to 1810 he published annually a meteorological report, and was the first to attempt to foretell weather probabilities, but only of a general or seasonal kind. The latter third of his long life was saddened by bereavement and scarcity of means, and the final ten by blindness, compelling him to work with the aid of his daughter Cornélie as an amanuensis. But to the last he maintained his courage, his high standard of honor, and his imperturbability under misfortune. No finer character is to be found in the annals of science.

VOLTA (1745–1827)

ELECTRO-CHEMISTRY

Alessandro Volta lived at Como, in Italy. After receiving a good general education, he became deeply interested in the investigation of the phenomena of electricity, which were then just beginning to attract the attention of students throughout the educated world. In 1774 he was appointed to the chair of natural philosophy in the gymnasium at Como, and in 1779 was advanced to a professorship at the University of Pavia.

When Galvani, in 1790, announced his explanation or theory of the phenomena of the frogs' legs as an exhibition of a new force, which he called the "vital force," or "animal electricity," Volta took issue with him, claiming that the current exhibited in the batrachian's legs originated in the two metals involved, and not in the muscles or nerves of the animal. Not possessing at that time the high standing of a man of science that Galvani commanded, not much attention was paid to his theory. But by 1800 he had constructed what was at first called Volta's "crown of cups," and later known as the voltaic pile. As originally made, the device consisted of disks of two different metals (zinc and copper), arranged in couples, each couple separated from the one above and below it by a disk of cloth moistened with a weak solution of common table salt. Then, when the upper member (copper) of the couple at the top was connected with the lower member (zinc) at the bottom of the pile, by a copper wire, an electrical current was set up which could be felt, or made to ring a bell. When the details of this experiment came to the ears of Sir Humphry Davy, he is said to have remarked that "the voltaic battery was an alarm bell to experimenters in every part of Europe."

It was quickly shown that Volta's explanation of the cause of the current was no more correct than that of Galvani. For, when the metal couples were placed in cups—or cells as now designated—and connected up, and a weak solution of acid in each cell took the place of the cloth moistened with salt, not only was the current much stronger, but chemical action began, which plainly was the cause of the current. Several years elapsed before it was clearly understood just what was taking place, but by 1802 water had been decomposed by the current into its two constituent gases (hydrogen and oxygen), and in 1807 the first electric arc light was produced, in both cases the current coming from a large and powerful voltaic battery. This was the beginning of the science of electro-chemistry, which now plays such an important part in innumerable modern industries, where vast amounts of capital are invested.

Volta is also remembered as the inventor of the electrophorus, the condensing electroscope, the electrometer, the electric pistol, and the electric lamp. All these, in the form he gave them, would now be regarded more as toys than as scientific tools, for in his time, and for many years after it, electricity was regarded as a kind of fluid. Nevertheless, so remarkable were the manifestations resulting from his crude experiments that his name has been justly honored in the realm of the science, by adopting it (the volt) as the unit of electro-motive force, and he is properly regarded as the father of the science of electro-chemistry.

CHARLES (1745–1823)

AERONAUTICS

Jacques Alexandre Cesar Charles was a native of Beaugency in northern France, was well educated in fundamentals, and became an experimental physicist of note. His claim for honorable mention in the domain of science rests upon the fact that he was the first to use hydrogen to inflate balloons, and also the first to make a public ascent in one so filled. On the occasion, on December 1, 1783, he attained an altitude of 7000 feet.

There are no records of attempts at aviation among the ancients, though the Greek myth of Daedalus, who made wings of feathers cemented together with wax for himself and his son Icarus, and endeavored with that fragile equipment to escape from his Cretan captor, King Minos, shows that these imaginative people did some thinking on the subject. As the story is told, Daedalus succeeded in crossing the sea, and landing in Italy. But Icarus, in his youthful exuberance, mounted to such an altitude in his flight, that the heat from the sun was too much for the wax of his wings. When they collapsed, he fell into the sea and was drowned. From this pretty tale it may be inferred that the Greeks believed the sun to be but a short distance above the earth; and also that as a people they were not much given to mountaineering. For if they had been, they would have become acquainted with the fact that as altitude is gained the temperature of the air rapidly declines.

There are authentic records of attempts—which usually resulted disastrously—of gliding flights, during the Middle Ages; but they appear to have amounted to nothing; and it was not until the chemist, Cavendish, in 1766, succeeded in isolating the gas hydrogen by the electrolysis of water, and demonstating its extraordinary lightness, that interest in the subject of aviation revived with the experiments made by Cavallo, who filled bladders and paper bags with the gas, and succeeded in making them rise to the ceiling of a room. But in both cases the material proved to be so porous, that they sank quickly. The idea was then taken up by the Montgolfier brothers at Annonay in France, who, in June, 1773, after many trials, made a balloon 35 feet in diameter and filled with hot air, rise to a height of 1600 feet. When the news of this extraordinary event reached Paris, a subscription was at once taken up to raise means for a repetition of the experiment there under better conditions. The construction of the bag was entrusted to a firm of instrument makers of high reputation, and of the hot air to Charles, who had become known as a physicist of consequence. He determined to employ the newly-discovered gas hydrogen—then called "inflammable air"—for inflation, and after nearly a week of laboratory work, manufactured enough of it to fill a bag 12 feet in diameter, which had been constructed of silk covered with a flexible gum or varnish. This was taken to the Champs de Mars, and on August 27, 1773, in the presence of an enormous crowd, the balloon was cut loose and disappeared.

In September of the same year the Montgolfiers built a hot air captive balloon 72 feet high and 41 feet in diameter, which ascended successfully, but was destroyed when it was up by a heavy wind, followed by rain. A second one of nearly the same dimensions, to which was attached a basket containing a sheep, a cock and a duck, was sent up a week later, and after remaining in the air for about a quarter of an hour, was drawn to earth without injury to its involuntary passengers.

In November of the same year in another hot air balloon, 74 feet in height and 48 feet in diameter, to which a strong wicker work basket was attached, the first ascent by a human being (Pilatre de Rozier), was made. This one remained afloat for twenty-five minutes, sailed across the Seine, and finally came to earth without injury to its plucky occupant. In the following month, Charles, using a hydrogen-filled silk bag, and carrying a barometer, made the ascent to the great height mentioned. So intense was the interest excited by this event, that the sport was taken up by a number of enthusiasts, one of whom by the name of Blanchard, accompanied by an American named Jeffries, successfully crossed the English channel from Dover to Calais early in the year 1785. In 1795 the first descent in a parachute was accomplished.

MONGE (1746–1818)

MATHEMATICS

Gaspard Monge was a resident of Beaune in France. He was educated there, and at Lyons; and for a time taught physics and mathematics. Later he studied at the engineering school at Mézières, then became a tutor, and finally rose to the professorship of mathematics. In 1783 he was appointed examiner of naval pupils in Paris, and in 1792 became Minister of the Marine. In 1806 he was raised to the nobility, with the title of Comte de Pelouse.

He is regarded as the founder of the science of descriptive geometry, and of the modern system of teaching it. He introduced into the analytic geometry of three dimensions, a thorough treatment of linear equations; completed the study of surfaces of the second degree that had been begun by Euler, and established the principles of the integration of partial differential equations, in connection with the theory of surfaces.

Descriptive Geometry is that branch of the science which teaches methods of representing bodies of three dimensions—a cube, a bridge, a piano, etc.—on a flat surface, so that the effect produced in the mind of an observer is not that of a diagram, but of an outstanding object, casting shadows as does the real one of which it is the representation. Of course any one properly trained in the art of drawing, or possessing the faculty naturally, can produce this effect approximately; but to do so with mathematical accuracy a knowledge of the laws of perspective are necessary. The fundamentals of these are first, a base line, which limits the extent of the picture in the direction of the maker thereof, and is oftener called the ground line; second, the horizon line, which limits its extent in distance; third, the vertical line, which is at right angles to the other two, is not put on the paper, and need not be in the center of the picture, but is supposed to pass through the eye of the sketcher, and thus to constitute the point of sight or the center of the drawing. To it, all the vertical lines in the object being depicted must be parallel. The horizon line is generally set at about one-third of the height of the drawing. If the artist is sitting, this line will fall somewhat below that height. If he is standing it will rise slightly above it. In addition, are two points called points of distance, situated on the horizon line, one of them to the right of the vertical line, and the other to the left. If the object to be depicted is to be placed in the position called a half front or half profile, the distance of these two points from the vertical line is equal, but if the object is depicted as if in the three-quarter (or greater) position, one of them is farther away from the vertical line than the other, the most distant being on that side on which the largest area of the object is to be shown.

These points having been set, they now become what are called the vanishing points. To one of them—the most distant—all lines excepting verticals appearing in the front or face of the object must point, and to the other all lines appearing on its sides (or thickness, or depth). If these rules are followed in the process of representing any symmetrical body such as a building, the result will be found to correspond with the impression of it which the eye carries to the brain. If finally the usual shades and shadows are thrown in correctly—itself a mathematical process—the object will stand out from the flat surface on which it is drawn.

The Oriental races—Chinese, Japanese, Hindus, Mesopotamians, and Egyptians had no conception of perspective. Their drawings and paintings are absolutely flat. The Greeks and Romans had the idea, and made crude efforts to embody it in their pictorial work, but having no knowledge of its laws, exercised their artistic tendencies mainly in the direction of sculpture and architecture. In the art of the Middle Ages these laws were recognized experimentally, but not having been worked out scientifically, many of the productions of the famous painters were absurdly distorted. Only those few in those days—and even in the present time—who are natural geniuses, can make a picture approximating accuracy in its perspective. To the architect and engineer a knowledge of its laws are an absolute necessity.

BODE (1747–1826)

ASTRONOMY

Johann Ehlert Bode was a native of Hamburg, Germany; and became, even when a boy, an astronomical observer of note, with a telescope of his own make. In 1776 he founded the "Astronomische Jahrbuch," and continued to be its editor and principal contributor for many years.

His notable accomplishment was the publication, in 1801, of his "Uranographia," consisting mainly of a catalogue of 17,240 of the stars. The magnitude and value of this production will be better understood when it is compared with all previously made siderial charts, the most comprehensive of which included less than 6000 of the stars.

Bode is popularly remembered, because of his prediction of the existence of a planetary body in the solar system then unknown, between the orbits of Mars and Jupiter. This was verified by the discovery in 1801, by Pacini, of the planetoid (or asteroid as it was then called) Ceres, the first of the group of small planets, of which now nearly 500 have been detected. He was led to make the prediction because of a curious numerical relation in the position of the known planets with regard to the sun, which had been first noted by an astrologer named Titus, of Wittenberg, and in his day was thought to have considerable hidden significance. It is illustrated as follows: Write a row of nine fours, and under eight of them, beginning with the second, place three and its succeeding multiples by two. Then add the columns.

4	4	4	4	4	4	4	4	4
	3	6	12	24	48	96	192	384
4	7	10	16	28	52	100	196	388
3.9	7.2	10	15.2	26.5	52	95.4	191.8	300.5

If now the figure 10, in the third line, be taken as representing the distance of the earth from the sun, then 4 should represent the mean distance of Mercury, 7 that of Venus, 16 that of Mars, 28 of the planetoids, 52 of Jupiter, 100 of Saturn, 196 of Uranus and 388 of Neptune. In the fourth line of figures is given the actual mean distance of the planets from the sun, relatively to that of the earth, which is again taken as 10.

When Titus figured out this curious relationship, only the first four, and the sixth and seventh of the sun's family, were known, and the correspondences were sufficiently striking to be suggestive. In Bode's time Uranus had been located by Herschell (1781), and its computed distance from the center of the system corresponded so closely to the ratio shown by the table, as to excite renewed interest, particularly as the irregularities subsequently found in its movements, seemed to point strongly to the existence of still another undiscovered planet. But when Neptune was found by Leverrier (1846), the symmetry of the system was severely shaken. Bode's law, which had a great vogue in his day, was as follows:

"The distances of the orbits of the planets from the orbit of the first one (Mercury), are, respectively, twice, four times, eight times and sixteen times that of the second planet (Venus)."

It holds roughly for all except Neptune, and also for the moons of Saturn and Uranus, but not for those of Jupiter and Neptune. At the present time it has no standing as a law, but back of it there is probably some as yet undetected evolutionary sequence similar perhaps to that which chemists and physicists believe will ultimately be found behind the Periodic Table of the Elements, that was outlined in 1868 by Mendeleef.

WERNER (1748–1817)

GEOLOGY

Abraham Gottlob Werner was born at Wehrau in East Prussia. At the age of twenty he entered the famous mining school at Freiberg, and after graduating there with honor he supplemented his general educational equipment with a course at the University of Leipsic. His first published monograph on fossils won him the position of assistant instructor at the Freiberg mining school where, for forty years thereafter as major professor he taught his specialty so brilliantly as to gain for that institution a great reputation. It attracted students from all parts of the civilized world and, for a time, Werner was regarded as the supreme geological authority.

But there was a fatal error at the foundation of his system of rock genesis and classification. It was based on their mineral composition, rather than upon their age, origin, mode of occurrence and relative stratigraphical position. He taught that all rocks were deposited by the ocean in the form of chemical precipitates. That granite —for instance—has been in process of formation in various places throughout all the geological periods; the basalt was a sedimentary deposit, as well as gneiss, schists and all lavas; that originally a universal ocean (the Noachic Flood) extended continuously around the globe, and out of which all the varieties of rocks then known were deposited by chemical action. To him, a volcano pouring out a stream of lava, was simply an elevation under which was a vast coal deposit which, by some means, at the time of eruption, had caught fire, and was melting and forcing out the water-formed rocks above it. And he defended these curious ideas with remarkable ability.

The fact was that Werner, being a devout churchman, felt himself under obligations to employ his great powers and reputation in the construction and defense of a theory which could be squared with the orthodox concepts of Creation, as told in the book of Genesis. And for a time he succeeded brilliantly, for the influence of the Church in his day was supreme. Even the American geologist, Silliman (1779–1864), being a deeply religious man, clung to his views to the end of his days.

When Lyell's great work "The Principles of Geology" appeared in 1830, Werner's star began to set, and his theories are now almost forgotten. Nevertheless, he is entitled to be remembered as a man of high personal character and unusual ability as a teacher. In spite of the errors at the foundation of his theories he was the first geologist after Hutton to attempt to arrange systematically such facts about the past history of the globe as came to his knowledge in the rather limited region in which he made his observations. These he reported conscientiously, but erred in their interpretation.

BERTHOLLET (1748–1822)

CHEMISTRY

Claude Louis Berthollet lived in Talliore in southeastern France, and was educated at the University of Turin, where he graduated in 1768 with the degree of doctor of medicine. He then went to Paris, and while practising his profession became deeply interested in chemistry. In 1789 he was elected a member of the Academy of Sciences.

At this period chemistry was just beginning to emerge from its alchemistic ancestry, and Berthollet ranged himself at once with Lavoisier and others of the time, who were establishing the foundations of the new science. In 1785 he announced his adherence to the antiphlogistic doctrine of Lavoisier, but differed with him—and correctly—as to the part played by oxygen in the composition of acids. In the same year he published a highly valuable paper on the bleaching properties of chlorine—then called dephlogistigated marine acid—and announced the true nature of ammonia as a compound of nitrogen and hydrogen. In 1794 he was appointed to the chair of chemistry at the

Ecole Normale. After the Revolution, in 1815, he was created a peer by Louis XVIII.

To Berthollet is due the very important addition to the idea of chemical affinity, that of chemical equilibrium, which means in effect, that a chemical reaction is not mathematically complete, until all the affinities of the elements taking part in it are satisfied. This is the fundamental principle of the science of stoicheiometry. His principal literary work entitled "Essai de Statique Chimique" appeared in Paris in 1803.

Stoicheiometry is that branch of the science of chemistry which has to do with the calculation of the quantities of the elements involved in chemical reactions or processes. For example, a pure limestone consists of a combination in certain definite proportions of the metallic element calcium, the non-metallic element carbon, and the elementary gas oxygen. If now to a given weight of such limestone, there be added a certain definite weight of sulphuric acid (a compound of the non-metallic element sulphur and the gaseous elements hydrogen and oxygen), a reaction will take place. The limestone as such and also the sulphuric acid will disappear. In their place will come into existence a totally new substance with properties different with those possessed by the others, which is popularly known as gypsum, and technically as calcium sulphate. And while this transformation is in progress there will be observed a lively ebullition or bubbling, indicative of the passing away of a gas. If now the solid mass resulting from the reaction be weighed, it will be found to be considerably lighter than the combined weight of the limestone and sulphuric acid employed. But if the gas that comes away during the operation be caught and weighed, and added to that of the gypsum produced, the combined weight will then be exactly equal to that of the limestone and sulphuric acid before they were placed together.

In other words, matter, like force, is indestructible. It may change in place, in appearance and in its associations, but its quantity or mass as shown by its weight remains unaltered and unalterable, so long as it continues to exist as matter. In any chemical reaction, when account has been taken of all the changes that have occurred, the combined weights of the new substances formed is invariably exactly equal to the combined weight of the materials that took part in their formation. This is the doctrine of the Conservation of Matter which, in Berthollet's time, was just beginning to be grasped by the chemists of the day. If added proof of it were needed there is one which is unique, and not often called to mind.

The sun, as is well known, is the theater of physical and chemical activies of the most violent nature. Its surface is a sea of incandescent matter at a temperature estimated at not less than 6000° centigrade. Underneath this is a layer of unknown thickness at even a higher temperature, from which enormous masses of gaseous matter are continually breaking through the outer layer, and being projected thousands of miles into surrounding space in the form of jets and spurts, which are called the protuberances. Yet the mass and weight of the sun does not vary, and has not within historic times. For an appreciable change in these respects would involve a corresponding one in the length of the terrestrial day, and no such change has occurred during the last eight to ten thousand years.

JENNER (1749–1823)

PHYSIOLOGY

Edward Jenner, the son of a clergyman of the Anglican church, was born at Berkeley, in England. Exhibiting decided inclinations in his early youth to the study of medicine, he was apprenticed to a doctor in a nearby town, to learn the fundamentals of surgery and pharmacy. At the age of twenty-one he became a student at St. George's hospital in London, and was a resident for two years at the home of John Hunter, who, with his brother William, were the most notable anatomists and physiologists of their day. Upon the recommendation of the former, young Jenner was appointed to arrange the floral and faunal collection brought to England by Capt. Cook, from his first voyage of discovery (1768–1771). The task was accomplished so well, that he was offered the position of naturalist to the second expedition. But having little inclination for a life of adventure, and loving country life, he (fortunately for the world) declined the position, and settled himself as a surgeon in his home town of Berkeley, devoting his spare time to ornithology, botany and mineralogy. He appears to have been among the first—if not the first—to connect the ailment known technically as angina pectoris, with the condition popularly called hardening of the arteries. In 1792 he received the degree of M.D. from the St. Andrew's University of Scotland.

Twelve years previously, however, he communicated to the world his great discovery of the efficacy of vaccination. Small pox was very prevalent—almost endemic—in Europe at the time, and already before his day, attention had been called a number of times to the partial immunity to the disease enjoyed by communities where cattle raising was an extensive industry, and particularly among those (herders and milkers) who were constantly in association with the animals. What is known as cowpox, is a disease peculiar to the cow, taking the form of bluish vesicles or blisters on the udder, which, when they break, discharge a limpid fluid. As early as 1763, it was known that milkmaids in Germany had no hesitancy in handling animals suffering with this disease. In 1774, a Gloucestershire farmer by the name of Benjamin Jesty, accidentally innoculated himself while handling a cow infected with cowpox, and finding that it had rendered him immune during a severe run of smallpox in his neighborhood, had the courage or hardihood to apply the remedy to his wife and two sons, with whom it proved equally efficacious.

Jenner, living in the country, and having a large practice among farmers and dairymen, became acquainted with these facts, and many others of a similar nature, and began an exhaustive investigation of the subject, which, in the end, created in his mind such confidence in his discovery, that in 1796, after vaccinating an 8-year-old boy with the lymph obtained from a vesicle on the person of a milkmaid, who had been accidentally innoculated with cowpox in the course of her routine work, subsequently inoculated him with the smallpox virus, and found him to be completely immune. Here it should be stated that it had long been the practice in rural English communities (and perhaps elsewhere) to inoculate children with the smallpox virus, on the theory that they would come through the disease with less risk in infancy than later, and suffer less disfigurement. In 1798 he published his great work on the subject, which was entitled "An Inquiry into the Causes and Effects of Variolae Vacciniae Known by the Name of Cowpox." This book was translated into all the European languages, and attracted great attention. In 1803 Jenner founded the Royal Institution for the Extermination of Smallpox, and was its controlling director for many years.

It is interesting to note that, when he first came to London to demonstrate the truth of his assertions, he was bitterly assailed by city physicians and the clergy. Among the former, opposition died out quickly, but the latter as a class, with some notable exceptions, regarded vaccination as an act of gross impiety, just as the same class viewed life insurance when, a half century later, it became an established line of business.

Jenner was a man of the highest principles and purest motives, and devoted himself so unreservedly to the gratuitous exercise of his discovery, that his private practice was almost annihilated. The authorities of St. Thomas's Hospital in London invited him to remove to that city, and guaranteed him a practice of £10,000 a year. When he declined this, because of his dislike of the city, and love of the country, his friends secured him a grant of that amount from Parliament, and later a second one of £2000. In 1811, the Empress of Russia, in token of her admiration and gratitude, sent him a diamond ring of great value and beauty. In fact, he was accorded full reward during life for his great discovery. He became the first honorary member of the Physical Society, was elected mayor of his native town, was given the freedom of the cities of Dublin and

Edinburgh, was made an honorary fellow of the Royal College of Physicians of Edinburgh, and was given the degree of M.D. by Oxford. In addition, when vaccination was formally adopted in the Royal Navy, its officers and surgeons presented him with a gold medal. His system was also adopted in the navies of France, Italy, Spain, Germany, Russia and the United States, and also in China and India. In the latter country, large sums of money were raised by popular subscription, and presented to him.

His death resulted from an apoplectic stroke, in his 73rd year. Two statues, one in Gloucester, and one in London, were erected to his memory by popular subscription.

LAPLACE (1749–1827)

ASTRONOMY

Pierre Simon de Laplace, the son of a farmer, was born at Beaumont-en-Auge, in northern France. With the assistance of friends of his parents he secured a good primary education, and at the age of eighteen went to Paris. Being naturally a fine mathematician, he secured a position to teach that science at the Ecole Militaire, where he rapidly made valuable friends, and acquired a high reputation in his specialty. In 1785 he became a full member of the Academy of Sciences, and in 1794 was appointed professor of mathematical analysis at the Ecole Normale. In 1817 he was elected president of the Academy.

Laplace is popularly known as the author of the "Nebular Hypothesis," a theory of the origin and development of the solar system, which he enunciated in his "Exposition du Système du Monde" (1796), and elaborated in his great work entitled "Mécanique Céleste," which appeared in 1799–1825. For nearly a century this notable treatise has been considered one of the world's greatest contributions to the advance of knowledge, but during the last twenty years it has been subjected to much destructive criticism, and is not now regarded as a correct explanation of the way in which the sun and its family of planets and satellites came into existence. Nor has any other hypothesis been advanced that is not susceptible of more or less objection. In fact, the problem has not been solved to the satisfaction of astronomers, though the Planetismal theory is regarded as a nearer approach to a solution than the Nebular hypothesis.

Aside from this, Laplace contributed several important and thoroughly accepted discoveries to science. In 1786 he detected the dependence of the moon's acceleration upon the secular changes in the eccentricity of the earth's orbit, which is regarded as the keystone in the theory of the stability of the solar system. He also announced the laws of motion of the first three moons of Jupiter in the following terms:

1. The sum of the mean movement of the first satellite, and of twice the third, equals three times that of the second.

2. The sum of the mean longitude of the first satellite, and of double that of the second, diminished by three times that of the third, equals 180 degrees.

Laplace's theory, briefly outlined, was to the effect that the material of which the solar system is composed existed originally in the condition of an intensely hot and gaseous nebula of enormous extent and irregular shape, which gradually, under the action of gravitational forces, assumed a rotating and globular form. As it cooled it contracted, and from time to time successive rings of its substance were thrown off and left behind. These in turn consolidated into minor rotating nebulous masses and ultimately became the planets. Each of the latter, as the process proceeded, either themselves cast off rings to become satellites, as is the case with Neptune, Uranus, Jupiter, Mars and the Earth, or retained some of them as Saturn, with both satellites and rings, or consolidated into globes without satellites as was the case with Mercury and Venus.

LEGENDRE (1752–1833)

MATHEMATICS

Adrien Marie Legendre was a resident in Paris, and educated there, becoming later the professor of mathematics in the Military and the Normal schools. In 1816 he was appointed examiner for admission to the Ecole Polytechnique. In 1824, in an election at the Academy of Sciences, because he refused to vote for the candidate of the government, he was deprived of his pension, and died in poverty.

He was among the leaders in introducing the metric system and, in association with Prony, prepared the notable centesimal and trigonometrical tables. He was the originator of the method of least squares, and the discoverer of the law of quadratic reciprocity. His greatest work was a study on the "Elliptical Functions." His "Elements of Geometry" went through fifteen editions (the last being issued in 1881), and was a classic in the schools of the world for over a century.

When the French government in 1790 began to discuss the establishment of a new and modern system of weights and measures, the first point to be decided was the selection of a unit which should be based upon a fundamental fact of nature; so that if its visible representative was lost or destroyed, its dimension could be recovered. Three of this kind were taken under consideration, namely, the length of a pendulum which, at sea level, and in a vacuum, would tick seconds; a quarter of the terrestrial equator; and a quarter of a terrestrial meridian. The last was chosen, and a committee organized to make the measurement of the arc of the meridian extending from Dunkirk in France to Barcelona in Spain. When the task was accomplished, and the length of the terrestrial quadrant was computed from the measured length of this arc, it was found to be 32,808,922 English feet. One ten-millionth part of this, or 39.37079 inches, was adopted as the unit of length, and given the name of the meter. On this as a fundamental, all the other required units were based; namely, for land area, a square of 100 meters; for volume, a cubic meter; for weight, that of a cube of water at maximum density measuring one one-hundredth of a meter on all its edges, and called a gram; for capacity, a cube of water at maximum density measuring one-tenth of a meter on all its edges, and called a liter. Appropriate names were then given to decimal multiples and divisions of these units.

This system has since been made obligatory in most all the civilized nations except the United States and Great Britain, and in these two its use has been legalized, or made permissible, and is already almost universally employed by the scientific fraternity, and undoubtedly will ultimately be adopted in the common transactions of life for, after more than a century of experience, its advantages have become manifest.

However, it is now well known that the original measurement made of the arc of the meridian between Dunkirk and Barcelona was erroneous, and also that changes are constantly in progress in the shape and size of the globe, which makes it impossible to derive an unalterable unit of length from that source. For this reason, at the Paris Exposition of 1867, an international committee was appointed to arrange for the construction of a number of standard meters, to be distributed among the principal nations. This committee assembled in Paris in 1872, and settled upon an alloy of the metals platinum and iridium as the material to be employed in their manufacture, the meter to be in the form of a bar, and the gram (or kilogram) in that of a cylinder.

In recent years it has been suggested that a more perfect natural unit could be derived from the number of undulations per unit length characteristic of the light given by certain incandescent metals under given conditions, and one that could more easily be recovered or reproduced. But it is not at all likely that any such change will be made.

RUMFORD (1753–1814)

PHYSICS

Benjamin Thompson (Count Rumford), a native of the town of Woburn, Massachusetts, with a most engaging personality, and strong inclination towards such sciences as existed in his day, was compelled to go to work as a clerk at the age of thirteen. But three years thereafter he married a wealthy widow of Concord, New Hampshire, which not only relieved him from all financial worries, but gave him a social standing in the community, and resulted in his appointment by the governor of the colony to the honorable position of major of the militia. Being a pronounced royalist as well as a man of courage and determination, he and his wife—who shared his political views—found continued residence in Woburn distasteful, by reason of the decided inclination of a majority of the community to separation from the mother country. In consequence of this he moved to Boston, and when that city was evacuated by the British in 1776, he went to London, bearing important dispatches to the government. There, having made a most favorable impression, he was given a post in the Colonial Office, and later was advanced to the position of Under Secretary of State. In 1779, in recognition of scientific studies and experiments, he was elected a Fellow of the Royal Society.

Shortly before the close of the American Revolutionary War he returned to America, in the capacity of an officer of the English army, but upon the surrender of Cornwallis in 1781 he returned to Europe, took service in the army of Bavaria, and settled in Munich in 1784. Being a man of fine presence, attractive disposition, and excellent character, he rose rapidly in the profession of arms, attaining in turn the rank of major general, military councilor of State, lieutenant general, and Minister of War. Finally, in recognition of both his scientific and military eminence, he was created a Count of the Holy Roman Empire, choosing Rumford for his title, as that had been the name of the town of Concord, New Hampshire, previous to the year 1765, where he considered his good fortune to have begun. In 1799 he retired from military service in Bavaria, and went to London, where he took a prominent part in the founding and establishment of the Royal Institution. Later he moved to Paris where, his first wife having died, he married the widow of Lavoisier, the famous French chemist, and remained in that country until his death in 1814.

Aside from having led a most picturesque life, his title to recognition as one of the great discoverers arises mainly from his investigations and experiments on the subject of heat. Up to the year 1800, heat was regarded as a sort of fixed matter, which was inherent in all combustible substances. To it was given by Professor Stahl of the University of Halle (1660–1734), the specific name of "phlogiston." As an illustration of the concept as it existed in the minds of the pseudo-chemists of that day, the phenomena which occur in the reduction of an ore of iron (say hematite) to the metallic state, may be cited. To bring about the change, the ore is mixed intimately with charcoal, the latter induced to burn, and the combustion intensified with the bellows. Under such treatment both the charcoal and the phlogiston combined with the hematite disappear, leaving the pure metal behind, the inference being that there had been brought about a destruction of the compound of the phlogiston with the iron. To account for the fact that the resulting metal weighed somewhat less than the ore from which it came, it was taught that phlogiston was a substance of great tenuity, lighter even than air. Finally, when it was pointed out that the specific gravity of the metal was higher than that of hematite, it became necessary to advance the conception of phlogiston to that of a substance having no weight at all.

This pre-chemical theory of the nature of heat, was further elaborated by giving another name (caloric) to the phenomenon, and picturing it as a fluid of an elastic and self-repellent nature, which permeated all matter.

Although various scientists before his day (Descartes, Boyle, Francis Bacon, Hooke and Newton), either in so many words, or inferentially, had expressed the opinion that the phenomenon must be due in some way to motion in or of the substance heated, they had been unable to furnish any proofs of such a theory. It is to the credit of Rumford that he announced the definite conclusion that heat was merely a form of that force known as motion, and to prove his contention by boring a hole in a bar of soft iron, by means of a tool of steel, and inviting consideration of the heat produced by friction in both, without altering the appearance, the weight or nature of either. The demonstration was characteristic of the man, and before it the vagaries of the phlogiston and caloric hypotheses faded away like mist under the rays of the sun.

PROUST (1754–1826)

CHEMISTRY

Joseph Louis Proust was brought up in Angers, France, received his primary education there, and his higher elements in Paris, where he became chief apothecary to the Salpêtrière, a hospital for the helpless and insane.

He placed on a firm basis the chemical law of definite and multiple proportions, and discovered glucose in 1799. He greatly advanced the technic and knowledge of quantitative anlysis.

Glucose is one of the most interesting of natural organic products, and since it has been learned how to produce it synthetically has become an important article of commerce. It is one of those substances called carbohydrates or hydrocarbons indifferently, its molecule consisting of 6 atoms of carbon, 12 of hydrogen and 6 of oxygen. It occurs in most of the common fruits—grapes, cherries, bananas, apples, pears, plums, etc. It may often be found in the crystalline state in figs, raisins and dates, and in candied honey, and is the cause of the sweet flavor in all of them. It originally was called grape sugar. Yet it is not sugar, for the molecule of the latter contains 12 atoms of carbon, 22 of hydrogen and 11 of oxygen. It may be regarded as a halfway step on the part of nature towards the production of the true article.

Curiously enough, while the sugar produced from the cane and the beet is, so far as it goes, a perfect animal food—being completely assimilated—yet glucose is in no respect a food, and though very extensively consumed in the forms of candy and syrups, where it is an adulterant, passes through the digestive system unassimilated. In fact, if any of it is retained, it becomes the source or cause of several well-known diseases, one of which—diabetes—is often fatal.

On the other hand, glucose is a natural food for the vegetable world, which consumes it avidly, and transforms it into other members of the sugar family (including the genuine article), or into starch. Its relative sweetening power is estimated at from one-half to three-fifths of that of the true sugar.

In 1890 the chemist Fischer succeeded in making glucose. The raw material employed is any form of starch, in Europe mainly from the potato, in America from corn. The transformation into glucose is effected by the aid of a small quantity of either nitric, hydrochloric or sulphuric acid, in steam heated and closed converters, under pressures ranging from 30 to 45 pounds, and in the presence of a considerable quantity of water; and is completed in a half hour or less. The product is a white syrupy substance, which is loaded into barrels for shipment. The industry is now a very large one. On account of its property of moderate sweetness it is very extensively used in the manufacture of fruit jellies, candies, and practically all the many varieties of table syrup that are on the market.

PRONY (1755–1839)

MATHEMATICS

Gaspard Clair François Marie Riche Prony was born at Chamelot in France, was educated at the Ecole des Ponts et Chaussées as an engineer, and had charge of the restoration of the harbor of Dunkirk, afterwards becoming professor of mathematics at the Ecole Polytechnique at Paris. Later he was appointed chief of the Ecole des Ponts, and continued as a government official in one capacity and another during the remainder of his career.

His notable scientific accomplishment was the completion of a table of Logarithms based on the decimal system, and extended to the 25th decimal digit—a wonderful performance.

Logarithms are tables of numbers so constructed, that by their use various long arithmetical calculations may be shortened. Thus, multiplication can be performed by addition; division by subtraction; involution (powers) by a single multiplication; and evolution (roots) by a single division. John Napier, a Scotchman, is regarded as the inventor of the idea, having published his work on the subject in 1614.

Mathematically defined, the logarithm of a number is "the exponent of the base number which produces that number." For example: If 3 is selected as a base, and raised to its 5th power (243), it is then said that on a base of 3 the number 5 is the logarithm of 243. Or, for further elucidation, let 4 be taken as the base. Then 4 raised to its 8th power would produce 65,536, in which case the figure 8 would be the logarithm of 65,536. Thus it appears that by varying the base any desired number of logarithmic systems may be constructed, in each of which the logarithm of any given number will be different from that in all the other systems. As a matter of fact several such systems besides that of Napier were worked out with vast labor, among which may be mentioned those of Burgi, Speidell and Briggs. The last employed the figure 10 as a natural base, and calculated the logarithms of numbers from 1 to 20,000, and from 90,000 to 100,000 on that base, extending his calculations for each number to fourteen decimals. Vlacq and Gellibrand in collaboration worked out those omitted from his tables (20,001 to 89,999). The work of Prony consisted in extending the figures of these pioneers to the 25th decimal. By referring to the chapter devoted to Napier, an example will be found of the use of the system. The base of 10 is now universally employed.

CHLADNI (1756–1827)

PHYSICS

Ernest Florens Friedrich Chladni was a native of Wittenberg, Germany, and studied law there, and at the University of Leipsic, but abandoned the profession in order to devote himself to the physical sciences. Being a musician of ability he was naturally attracted particularly to the phenomena of sound, in which his investigations led him to the discovery of the laws governing the vibration of strings, rods and surfaces, under the influences of friction, percussion and other varieties of strain. He determined the velocity of sound waves in the air, and in other gases, and devised a number of apparatuses for exhibiting the visible effects of oscillations. Among these, perhaps the most notable was that which displayed the symmetrical formations assumed by grains of sand under the influence of rhythmical vibration, producing what were known as the "Chladni Figures." A thin plate of metal, glass or wood, of any symmetrical form—as a disk, square or polygon—was clamped at its central point horizontally to any firm support, and evenly sprinkled with fine and clean sand. When the edge was rubbed with a violin bow or set in vibratory motion by percussion, the sand disposed itself around the clamped center in symmetrical forms and figures, that exihibit the lines of strain and elasticity whereever the plate is free to respond to such.

Sound, like light, is (in one sense) a mental phenomenon. Neither exist for the deaf and the blind. Yet if there were no such things as ears and eyes in the world, the vibrations which are capable of affecting both would still be in existence. The assumed ether of space that transports light waves with such amazing speed will not carry those of sound. Nor will the dense matter which ordinarily conveys sound waves convey those of light, unless endowed with the character called transparency or translucency. Yet if one end of a metal bar be placed in strong sunlight and the rest of it carefully shielded, in due time the light, transformed into heat, will become apparent to the sense of touch at the protected end. On the other hand, the denser the material body—within certain limits of elasticity—the better conductor it becomes of the waves of sound, and without transformation into any other form of energy. The notable experiment made by Von Guericke showed that matter of some kind must be present if sound is to be transmitted. Right here, however, we are confronted with the recent discovery—apparently authentic—that matter of all known kinds is nothing more than a newly recognized manifestation of energy.

Water, being almost incompressible, will carry sound vibrations at the rate of about 4700 feet per second. This property has recently been employed in ascertaining ocean depths. The apparatus is attached to the under side of the ship, and is capable of emitting a sharp sound. The vibrations in the water so initiated are carried to the ocean floor beneath, which at once reflects them back. A membrane is provided to receive these returning waves, and to announce their arrival. The time required for the round trip is simultaneously recorded. Making such proper allowance for the slow but steady dissipation of the undulations as has been determined by experience, the results have been shown to be very accurate.

In the phenomenon of sound the matter of loudness is determined by the amplitude of the waves, that is, the distance from crest to crest. In the matter of pitch, that is, whether the note is a high or low one on the scale, the determining feature is the number of vibrations which reach the ear per second of time. A noise is an abrupt, irregular and very complex combination of vibrations. A musical note is a simple and regular train of them. A harmonious chord is a combination of the latter on strictly mathematical principles, while a discord is the exact opposite.

The acoustic properties of an auditorium are entirely independent of the location of the musical instrument or the speaker, or of the position of the hearer, unless the ceiling is specially constructed for sound transmission; but are dependent upon its size and shape, and the material of the walls, floor, ceiling and furniture. Thus, in an empty hall finished throughout in hard wood and without upholstered seats, the reverberations or echoes will be at a maximum, and will almost destroy the effect of any music or speech delivered in it. But if it be carpeted, if the walls are of plaster on wood or wire lath—the last preferable—if filled with a large audience and with hanging, house plants, etc., its acoustic properties will be vastly improved. Finally, if the walls and ceiling are covered with tapestry, or some form of rough finish plaster with hair or other fiber projecting slightly from its surface, reverberation and echo will be reduced to a minimum. And if in such a hall the audience is entirely of women, a still further marked improvement will be noticeable, due to the greater degree of fluffiness in their attire as compared with that of men.

WOLLASTON (1766–1828)

CHEMISTRY

William Hyde Wollaston was of English birth and ancestry, and after completing his education in medicine at Cambridge began practice in London. But meeting with a severe business disappointment he abandoned the profession and turned his attention to science, where he attained a high reputation in chemistry, physics and optics. He was the first to recognize and partially investigate the dark absorption lines in the solar spectrum, but for some unknown reason did not follow up the matter, which was forgotten until they were re-discovered and explained by Fraunhofer. His researches in optics yielded the invention of the camera lucida and the goniometer, the first of which is quite indispensable in microscopic work, and the latter in the measurement of the angles of crystals.

But in the annals of chemistry his name is associated more than that of any other scientist with that most interesting group of elements known as the platinum metals. These, in the order of their discovery are platinum (1750), palladium and rhodium (1803), iridium and osmium (1804) and ruthenium (1845). Of these Wollaston was the discoverer of only palladium and rhodium. But his isolation of them directed the attention of chemists at once to the group, which is one of very unusual properties. All but platinum are extremely rare in nature, and is itself found only in a few localities in amount sufficient to warrant commercial operations for its recovery. All are white in color except osmium, which has a distinct blue-white tint. They are almost universally found in the pure or native condition, associated more or less with each other and also with gold. There is much similarity in their properties, such as great hardness, high specific gravity, strong resistance to heat and to the attacks of air, moisture and the most powerful acids. Osmium has a specific gravity of 22.5, and is therefore, for equal volumes, the heaviest substance known, which means the most dense. Iridium requires a temperature of 2500° Centigrade (4704° Fahrenheit) before it will melt. So hard is this metal and so unalterable, that it is employed for the tips of gold pens. The high melting point of platinum (1800° to 2000° Centigrade), combined with its malleability, ductility and resistance to the attack of chemical reagents, makes it indispensable as a material for crucibles in the laboratory, and for conductors in electrical installations. An alloy of ninety parts of platinum to ten parts of iridium constitutes a metal so completely resistant to change, and so beautiful in appearance, that it was selected as the most suitable material for the standard bars and cylinders that were made in Paris and distributed among scientific societies of the civilized nations as the units of measure (the meter), and of weight (the kilogram), of the metric system. The outstanding property of palladium is its exceedingly fine molecular structure, surface hardness and brilliancy, which permits lines to be drawn upon it so close together and yet so permanent and true, as to make its use most desirable for the manufacture of fine scales for scientific instruments. In the form of a

Facing page 210

delicate wire it finds employment in dentistry on account of its hardness and resistance to corrosive action of all kinds. For ruthenium no uses have as yet been found in the arts. A small quantity of rhodium when added to steel in the melt, makes an alloy so hard, so elastic and so unalterable, as to be exceedingly desirable for the manufacture of certain surgical instruments, where a keen cutting edge must be maintained. Altogether these six rare metals seem to be set apart in their properties by nature for the especial service of science. An interesting feature in connection with ruthenium was its discovery by Osann in 1828, followed very shortly by a withdrawal of the claim, and its rediscovery in the same material on which Osann was working, by Claus in 1845.

Nearly all of the platinum heretofore produced has come from the placer deposits in the Ural mountains of Russia, but of recent years a steadily increasing amount has been produced from similar deposits in the Republic of Colombia. Tasmania is at present the source of almost all the iridium and osmium that is coming into the market, and Central Africa of the palladium.

DALTON (1766–1844)

CHEMISTRY

John Dalton, the son of a poor weaver, lived in Eaglesfield, England, and received his early education in his native town. At the age of sixteen he was sent to a boarding school at Kendal, a neighboring village. Here he exhibted such marked ability in mathematics and physics, that he was soon teaching those subjects to younger scholars, and at the same time increasing his own stock of knowledge by private study. This brought its appropriate reward in 1793, in the form of an offer of the chair of mathematics and natural philosophy in the New College just established in Manchester. He accepted this, and continued a resident of that city for the balance of his life.

He now had the opportunity, in the laboratory of this institution, to specialize in physical chemistry; and recalling the theories which had been expressed more than a century previously by Boyle (1627–1691), on the subject of the elements, and the conclusions reached by Lavoisier, Davy, and others of his own time, he announced in 1804, as a theory which he had demonstrated experimentally, his law of Multiple Proportions, which is expressed concisely as follows:

"When a given quantity of an element (as A) unites with several different quantities of another element (as B)" (on different occasions of course) "these several different quantities of B will bear a simple mathematical ratio to each other."

Perhaps the most familiar example of the law is presented in the case of the several ores of iron, as follows:

Ferrous oxide, black in color..................	FeO
Ferric oxide, red in color......................	Fe_2O_3
Magnetic oxide, black in color..................	Fe_3O_4

On the firm basis of this principle, Dalton was the first to establish a rational connection between the defective atomic hypotheses in existence at the time, and the real facts of chemical composition upon which the universally accepted Atomic Theory of the present day is securely founded, an achievement which establishes him as the real parent of that modern science. Between 1808 and 1810 he published his "New System of Chemistry," in which his atomic theory was elaborated on mathematical principles, and in such a way that an entirely new light was thrown on the composition of matter, and the relations of the elements to each other. And although the Daltonian system of "combining equivalents" has since been superseded by the system of atomic weights, the discovery of the principles at the foundation of both are due almost wholly to his investigations.

In 1817 he was elected president of the Literary and Philosophical Society of Manchester. Later he attained membership in the Royal Society of London, and the Paris Academy. In 1833 he received a government pension of

£150, which was afterwards raised to £300; and at the same time a statue to his honor was unveiled at the entrance to the Royal Institution in Manchester, at the cost of its citizens. He also received the degree of D.C.L. from Oxford, and that of LL.D. from the University of Edinburgh.

In person he was a man of simple, grave and reserved manners, yet kindly; and distinguished for integrity of character and modesty of demeanor. He wrote and published, in the scientific periodicals of the day, a number of valuable papers on gases (including steam), and on meteorological subjects, all of which were notable contributions to the advance of knowledge. Considering the limited and even hard conditions of his youth, few have made a record of accomplishments so notable, or that produced such results for those who since have followed in the path he blazed. At a blow, he changed the speculations of alchemy into the science of chemistry.

CUVIER (1769–1832)

ANATOMY

Georges Léopold Chrétien Frederic Dagobert Cuvier was a native of Montébeliard in eastern France. He was brought up very strictly in the Calvinistic faith, and at the age of fourteen was sent to the academy at Stuttgart, with the expectation that, after passing through its course, he was to study for the ministry. But he displayed so little inclination towards that profession, and so much enthusiasm and ability in natural history, that he was wisely allowed to have his way. In 1788 he became a tutor in the family of a Protestant nobleman living near Caen, on the coast of Normandy, where unusual opportunities existed for the study of marine life and fossils. In 1795 he went to Paris, and became assistant to the professor of comparative anatomy at the Museum of Natural History, and at once took a high position in scientific circles. In the following year he was chosen professor of natural history at the central school of the Panthéon, and in 1800 elected to the same position in the College of France. In 1802 he took charge of the Jardin des Plantes, and began his career as a political administrator, when he was appointed an Inspector of Education under the Consulate. When Napoleon became Emperor, he was appointed a member of the Council of the Imperial University, a position which compelled him to travel extensively in Italy, Holland and Germany. In 1814 he became a Counselor of State, and retained his position after the fall of Napoleon. In 1818 he was elected a member of the Academy of Sciences, and in the following year became president of the Committee of the Interior, and Chancellor of the University of Paris.

In 1822 he was appointed Grand Master of the Faculties of Protestant Theology. In 1826 he became a grand officer of the Legion of Honor, and in 1832 the King (Louis Philippe), made him a peer of the realm, and was considering him for the post of Minister of the Interior when he was seized with his final illness.

Few careers have been so uniformly brilliant and successful as that of Cuvier. And when it is remembered that he continued from first to last an openly professed Protestant of the most pronounced Calvinistic type, in a land overwhelmingly Catholic in its religion, it is impossible to avoid the conclusion, either that by then France had learned much of the lesson of tolerance, or that Cuvier was a man of very lofty character, and great personal charm. No doubt both are warranted.

His standing as a discoverer in the domain of science, rests mainly on the investigations detailed in his book entitled "Tablea Elémentaire de l'histoire Naturelle des-Animaux," which appeared in 1798. In it, he gave the outline of his system of classification of animal life. It was at once accepted throughout the intelligent world, as a revolutionary production. And when, in the years between 1800 and 1803, the five volumes of his "Leçons d'Anatomie" came one by one from the press, he was universally recognized as the founder of the science of Comparative Anatomy. His third great work "Le Règne Animal," published in 1816, remained the standard on its subject for many years.

Previous to his time, the classification of animal life by the Swedish naturalist, Linnaeus, had been accepted everywhere, being based upon the belief that each particular species was immutably established at the time of the creation of the world, as related in the Bible, and his system was therefore wholly a descriptive one, founded merely upon external appearances and habits. In his day little was known, and less understood, of the facts of anatomy.

Cuvier, however, was an anatomist, and his system of classification was the result of studies of the internal parts (the skeleton), as well as the external. Curiously enough, though his observations must have indicated the probability of the mutability of species, and the slow but steady development from simple forms of life to others more complex, yet his religious standards and convictions were so strong in consequence of his early training, that he was unable to see—or perhaps to admit—any possibility of development, or evolution as we would now call it; and so, when Lamarck the naturalist, boldly intimated a belief in the mutability of species, and advanced the theory that all life was derived from a primitive common stock, with man at the head of the order of Primates, Cuvier at once affirmed his belief in the Creation as described in the book of Genesis, and his great reputation caused the views of Lamarck to sink into obscurity and be forgotten, until revived by the genius of Darwin fifty-odd years later.

HUMBOLDT (1769–1859)

NATURAL HISTORY

Alexander von Humboldt was born in Berlin of wealthy and titled parents, received his education in fundamentals from private tutors, and in the higher branches at the Universities of Frankfort, Berlin and Göttingen. Becoming strongly interested in geology he took a course at the mining school at Freiberg in 1791, at the time when Werner was at the height of his reputation there as professor of that science and of mining engineering. In 1792 he was appointed government superintendent of mines for the principalities of Bayreuth and Anspach in Bavaria, which he held for five years. By that time his natural inclination towards travel and exploratory work led him to resign, and prepare for the great journey in Spanish America, his accounts of which have had most to do with making his name famous. Going first to Paris, where he made the acquaintance and secured the companionship of the botanist, Bonpland, and from there to Spain to obtain letters to the Viceroys of its colonies, they sailed from Corunna in the summer of 1799 for Venezuela, and landed at the Venezuelan port of Cumana. From there began their remarkable journey through the New World, which extended up the valley of the Orinoco to its southern head, through Ecuador, Peru and northern Bolivia, regions whose geography and physiography were then almost wholly unknown. From Peru they took ship to Mexico, landing at Acapulco in 1803, and after traveling for a year in that country, and collecting valuable information of its mineral resources, returned to Europe by way of Cuba, landing at Bordeaux in the autumn of 1804.

In 1829, having in the meantime worked up and published the notes of his American journey, he traveled through Russia and into Siberia as far eastward as the Yenesei valley, under the patronage of the government. The notes of this journey were published in the years between 1830 and 1843. The remainder of his long and active life was passed in Germany, and devoted mainly to the preparation and publication of his great work "Cosmos," which appeared in four volumes in the years between 1845 and 1858. These were translated as fast as they came from the press, into all the great modern languages, and created a profound impression. In it he attempted a physical description of the Universe, setting forth all the knowledge that had been acquired to his date in all the departments of science. Naturally, since then, some of his statements and conclusions have been found to be erroneous.

The life and career of Humboldt was, in many respects, a parallel to that of the famous Italian traveler of the

Middle Ages, Marco Polo (1254–1324). The latter had for his object to bring to the European world of his day a knowledge of that Asiatic world whose existence had long been known, but of which almost nothing had been learned except that it was densely populated, and supposed to contain enormous resources of wealth, of which at the time Europe was in dire need. Humboldt's journeyings on the contrary were, in both cases, to regions sparsely populated, and then mainly by savages, or very primitive people, yet also believed to be teeming with raw wealth. There was also this difference; that while each explorer was well equipped with the best education of his day, that of the Italian was of the old philosophical and theological order, while the German possessed in addition the new intellectual tool of science. In consequence, the accounts given to the world by Humboldt were of exceptional value as well as interest; for while he contributed little to the stock of pure science, his additions to geography, physiography, geology, ethnology and meteorology came at a time in the history of civilization when just that kind of information was needed, to enable Europe to put into practice in commercial ways the forces of nature which by that time had been brought under control by the physicist, the engineer and the chemist. Moreover, the new information was carefully gathered, accurately reported, and to a very large extent dependable. As a specific instance of these the discovery of the common source of the Orinoco and Amazon rivers may be mentioned.

OERSTED (1777–1851)

PHYSICS

Hans Christian Oersted was a native of Rudkjöbing in Denmark, and studied at the University of Copenhagen, where he received his degree of Ph.D. For a time he earned his living by lecturing on chemistry and natural philosophy. He then traveled for several years in Holland, Germany and France, after which, in 1806, he received the appointment of professor of physics at his alma mater.

Oersted's claim for honorable distinction in science is based upon his discovery in 1819 that a magnetic needle, if suspended by a silk thread, so that it rests in a horizontal plane, and if then surrounded with a coil of wire through which an electric current is passed, will be deflected from its normal north and south position. This was the first recorded experiment of note in electromagnetism, and at once made possible the galvanometer, the electromagnet and other devices of this kind; as well as establishing such an intimate relationship between the phenomena of electricity and magnetism, as led in a short time to the demonstration of the identity of the two forces. The details of the experiment were published by Oersted in a pamphlet entitled "Experimenta Circa Effectum Conflictus Electrici in Acum Magneticam." In recognition of the value and importance of this discovery, Oersted received the Copley medal from the Royal Society of London, and the mathematical prize from the Paris Institute.

He was an attractive lecturer and writer on scientific subjects, and devoted much of his time to the production and publication of scientific monographs written in non-technical language, and in courses of popular scientific addresses, which were eagerly attended and highly appreciated by the masses of the people.

The galvanometer is an instrument for detecting and measuring the presence and strength of an electric current passing along a wire. It consists of a magnet suspended horizontally at its center, in such a manner that it is free to move sideways in either direction. Around this, in a vertical plane, a coil of wire connected with a battery is wound. When the current is turned into it a magnetic field is created in the space in which the needle hangs. Immediately the latter begins to swing out of its true north and south direction, to an extent proportional to the strength of the current in the coil, and to its own length and strength as the result of the action upon it by the magnetic force of the earth. In operation, if the current in the coil is flowing from south to north, the north pole of the magnet will be deflected to the west; and to the east if it is flowing in the opposite direction; and the amount of deflection resulting is a measure of the relative strength of the two forces in action.

Several improvements on this primitive device have been made, one of which—by Nobili—employs two magnets suspended one above the other a short distance apart, and with their poles reversed, so that they neutralize each other, and will remain in whatever direction they are placed. This is called the astatic galvanometer. If now the coil conveying the electric current—suspended horizontally in this case—is so placed that the lower needle is within the plane of the coil, and the upper needle is above it, the deflection resulting is greater. Thus, in a general way, the astatic arrangement is more delicate, and will register the strength of a weaker current. A still more delicate device originated with Sir William Thomson, and is known as the reflecting galvanometer. In the D'Arsonval device the magnets are fixed, and the coil is suspended so as to be capable of moving. This form is perhaps more extensively used at present than any of the many other varieties that have been invented, but in all of them the principles involved are identical.

BROWN (1773–1858)

BOTANY

Robert Brown was born at Montrose, Scotland, and educated at the University of Aberdeen. After taking a supplementary course in medicine at Edinburgh he became attached, as assistant surgeon, to a Scottish regiment that was stationed in Ireland. He remained with them for five years, devoting all his spare time to the study of the flora of that island, which is largely composed of grasses, sedges, rushes and ferns, but very diversified within those limits. In 1800 he resigned his commission, and accepted the position of naturalist on an expedition to investigate the botanical conditions of the coasts of the Australian continent. When he returned he brought a collection of nearly 4000 specimens, of which more than half were entirely new to science. Shortly thereafter he was appointed librarian of the Linnaen Society in London, and settled down to the occupation of writing botanical monographs which were published in its "Transactions," and of geological essays for the Wernerian Society at Edinburgh, of which he was a member. But the influence and classification systems of both these worthy men were, at the time, fast undergoing eclipse under the newer and more scientific systems of De Jussieu and Lyell, and Brown himself was among the first to abandon the old masters and enroll under the new ones. His writings contributed very largely to their general acceptance in Great Britain. In 1827 he was appointed keeper of the botanical department of the British Museum. In 1834 he was awarded the degree of D.C.L. by Oxford, and in 1839 the Copley medal of the Royal Society.

Although fully entitled to rank as a collecting botanist of high ability, Brown's fame will rest mainly on the fact that he was the first to recognize, and to announce in 1831, that the cell nucleus was the life unit of the vegetable world, just as already it had been shown to bear that relation to animal structure and tissue. His discovery was quickly followed up and extended by the botanist Schleiden, and the zoologist Schwann; with the effect of making it clear that all forms of organic life, from the lowest to the highest, are built up on one and the same system, in which the cell, with its centrally placed nucleus of protoplasm, surrounded by the cytoplasm, is the unit. It is of microscopic size, and essentially the same in plants and animals, including man. The substance called plasm, which exists in both the nucleus and cytoplasm, is continually in motion so long as life exists.

Protoplasm is mainly composed of carbon, hydrogen, oxygen and nitrogen, the other ingredients usually present in minor quantities being sulphur, phosphorus, potassium, and sometimes a few other of the elements. But almost nothing can be learned of the nature of this substance by making a chemical analysis of it, for the instant that process begins its death occurs. It is the belief of physiologists that the evidence it gives of life in its motion is a molecular phenomenon, and must be studied mechanically as such. During recent years a very extensive literature has grown up on organic cells, which is absorbingly interesting to students of vital phenomena; but it cannot be claimed that as yet our knowledge of the nature of protoplasm is much more than of a preliminary kind.

YOUNG (1773–1829)

PHYSICS

Thomas Young was reared in Milverton, England, of Quaker parentage, and acquired his education at a small country school in the vicinity of his home, and later under a private tutor. At the age of twenty-one he began the study of medicine in London, continuing afterwards at Edinburgh, and finishing up at Göttingen in Germany, where he received his degree. He began to practice in 1799. In 1801 he was appointed professor of natural philosophy at the Royal Institution, and in the following year was elected Foreign Secretary of the Royal Society, a position which he retained for the remainder of his life.

Two notable discoveries stand to his credit, in the annals of the advance of knowledge. The first of these was a correct description of the cause of astigmatism, and with it a statement of the optical constants of the human eye. These have earned for him the title of the founder of the science of physiological optics.

The second was the demonstration of the undulatory theory of light, which had been suggested tentatively by Huygens in 1690. In making this demonstration he used the principle of interference. His announcement was that "radiant light consisted of undulation of the luminiferous ether." Up to the present time the existence of this "ether" has not been scientifically demonstrated, though believed in by most scientists. At present it is regarded by advocates of the theory of Relativity, to be unnecessary, as an explanatory hypothesis, though the effects ascribed to it are not questioned or in doubt.

Astigmatism is the name given to that defect in vision which is due to more or less absence of perfect symmetry in the construction of the two eyes; that is, the lenses are not similarly placed, or are of different size, thickness or clearness, or the corneas (their outward protective horny shield) are of different curvatures, or vary in degree of transparency. The effect produced on the brain is a distorted image of the object viewed. Some slight and negligible degree of astigmatism probably exists in all eyes. A simple test is to perforate a card with a pin, and examine the aperture so made alternately with each eye, and at varying distances. If at any position or to either eye the circular puncture appears elliptical in outline, astigmatism exists. Generally, when the exact cause of the trouble is ascertained, it is easily corrected by the use of properly constructed spectacles.

BELL (1774–1842)

ANATOMY

Charles Bell lived in Edinburgh, Scotland, and was educated in that city for the medical profession. At the age of twenty-three he became a member of the faculty of the Edinburgh College of Surgeons. In 1804 he moved to London, and for some years was a lecturer of the highest repute at the hospital clinics and medical schools of that city and vicinity.

To acquire a more thorough knowledge of the effects of gunshot wounds, he visited the hospitals on the south coasts of England, where the wounded from the battle of Corunna were under treatment; and again those in Brussels, to which the wounded were brought after the battle of Waterloo. In 1824 he became professor of anatomy at the Royal College in London, and subsequently a member of the Council. On the establishment of the London University in 1826, he was placed at the head of the department of medicine. In 1829 he received the medal of the Royal Society for his discoveries in anatomy, and in 1831, in company with four other notables of the day, he was given the order of knighthood. He was a voluminous writer on his subject, but is especially distinguished by his principal discovery in anatomy, a generalization on the functions of the nervous system which, once clearly recognized, led the way to other discoveries and conclusions of the greatest importance. The principle he revealed is expressed concisely as follows:

"The anterior spinal nerve roots belong to *motor* nerves, and the posterior ones to *sensory* nerves."

The development of the nervous system in man and in all animals begins at a very early stage of embryonic life. The evolution of the spinal cord is the first visible step, and at the upper end of this the brain begins to make its appearance. When the cord is well developed, it begins to send out branches to all parts of the embryo, which divide and subdivide again and again, and terminate finally in minute fibers, but these do not extend into the hair or nails, nor their analogues the feathers, claws, hoofs, scales, etc. Those which are to serve the purpose of conveying to the brain the stimuli received from the outer world by the sense of touch, are all rooted in the back parts of the spinal cord, and terminate just inside of the outer layer of the skin. Those which control the voluntary and involuntary movements of the body, proceed from the front areas of the spinal cord, and from there advance to every organ and muscle.

AMPÈRE (1775–1836)

ELECTRICITY

ANDRÉ MARIE AMPÈRE was a resident of Lyons, France, during the troublous times of the French Revolution. At the age of eighteen, the execution of his father under the guillotine for political reasons, affected him deeply, and saddened his whole life. Having received a good education, and being compelled to support himself, he undertook tutorial work in mathematics at first, and later became professor of physics at the central school at Bourg, near Lyons. From there, he advanced to a similar position in the Polytechnique school in Paris, and later took the chair of experimental physics in the Collège de France, a position which he retained during the balance of his life. In 1814 he was elected a member of the Academy of Science.

The high rank of Ampère among discoverers, is due in part to his clear exposition of the theory of electro-dynamics, but mainly to his demonstration of the identity of the phenomena of electricity and magnetism. And while his explanation of the latter, which was that "an electrical current is present in each molecule of a magnetized body, and flows in a fixed path," is not accepted at the present time, no other explanation has since been advanced which is considered wholly satisfactory. But there remains no question in the minds of scientists, that when the correct explanation is given, it will confirm Ampère's theory of the identity of the two forms of force.

There is no doubt that magnetism is a molecular property. If a bar magnet is broken in two, each half becomes at once a complete magnet, with a positive pole at one end and a negative pole at the other. Further, when a bar of soft iron is magnetized, its volume and elasticity changes; and if, by the action of an alternating current, it is rapidly magnetized and demagnetized, its temperature rises.

Ampère was the inventor of the astatic compass, which was employed in the early form of galvanometers, to detect very weak currents of electricity. He also originated the theory that electrical currents circulate in the earth, traveling in the same direction as the rotational movement (west to east), thus causing it to be a gigantic magnet, which, in its turn, would account for the movements of the mariners' compass. In recognition of the great value of his studies in the electrical sciences, his name, by international agreement, has been adopted to designate the unit of strength or intensity of an electrical current; that is, the *quantity* of electricity which passes the cross-section of a conductor in one second of time. Or, expressed differently, it is the current which flows through a conductor whose resistance is one ohm, and between the two ends of which the unit difference of potentials, one volt, is maintained.

He died at Marseilles at the age of 61, greatly mourned among his friends and scientists generally.

AVOGADRO (1776–1856)

PHYSICS

Amadeo Avogadro was a native of Turin, Italy, and after acquiring an excellent education, became a student of the physical sciences. In 1811 he announced his great discovery in connection with the molecular constitution of gases, which is known as Avogadro's law, as follows:

"Under similar conditions of temperature and pressure, equal volumes of gases and vapors contain equal numbers of molecules."

Avogadro was a contemporary of Gay-Lussac, who had discovered the law of combining volumes, and the law announced by the former was a logical deduction from that enunciated by the latter. But, unlike Gay-Lussac's, which can be demonstrated experimentally with ease, Avogadro's law was at the time incapable of such proof, because of the minuteness of the molecule, and the impossibility then of counting those existing in even the smallest of visible volumes.

But though Gay-Lussac at once accepted the deduction made by Avogadro, and Ampère a few years later (1814), it was some time before it was generally accepted.

The practical importance of the discovery lies in the fact that it permits of ascertaining the relative weights of the molecules of all substances that are capable of being examined in the condition of a gas or vapor. They are comparatively few in number, but as the entire structure of modern applied chemistry rests on our knowledge of gaseous phenomena, the importance of the law is evident. It will also be easily understood that, as in gases under normal conditions the molecules must be farther apart than in solids or liquids, their mutual interactions must be comparatively slight, and so the number of causes determining their properties must be fewer, the properties themselves less complex, and hence more easily understood. Thus the study of gases is the simplest and most direct way by which to approach the study of matter in general. In 1886 the Dutch physicist Van't Hoff demonstrated that the law was equally applicable to substances in solution.

Since Avogadro's day it has become possible to actually count the number of molecules in a given volume of rarefied gas. The result has demonstrated the accuracy of the law he enunciated over a century previously. The story of this journey into an unseen world and its accomplishments is interesting, and not so difficult to understand as might be imagined. But some preliminary explanations will be helpful.

The ultimate forms of matter as known until recently, have been the elementary atoms; and while these have now been resolved into combinations of electrons and protons, and when so resolved have passed from the domain of the chemist into that of the physicist, the atoms still constitute the only material of nature upon which, as matter, the chemist operates. In fact, he has comparatively little to do even with them. For, of the eighty-eight known, in less than one-quarter is the molecular condition identical with the atomic, and six of these are the inert gases, which refuse to react chemically either with the other elements or with themselves. In the majority of cases two or more atoms of the same kind invariably travel and act chemically together. These molecular families—as they might be called, together with the few bachelor or spinster elements who insist on traveling alone, constitute the citizenry of the molecular world which is the operative domain of the chemist.

In all cases these particles of matter (the molecules) are extremely small, so minute in fact as to be invisible under the highest power of the microscope; yet, as stated, their dimensions and weight, and the number of them in a given volume, have been determined with a high degree of accuracy.

One of the fundamental properties of matter when in the gaseous condition, that has been experimentally demonstrated in innumerable instances to be true, is that "at any given temperature its volume (the space it will occupy) is inversely proportional to the pressure under which it exists at the time." Or, expressed in another way, "that the product of the pressure under these conditions and the volume occupied is a constant," that is, for each gas, an unchangeable quantity. These statements mean that if a gas is confined in a gas-tight container, it will exert a pressure against the interior of its walls in exact proportion to the degree of compression applied in putting it there. Or, if no force is used in putting it there, no pressure will be exerted against the walls except that due to its weight. The weight of an empty, uncorked bottle is plainly that of the bottle, plus that of the air it contains, and when the latter is unconfined it expands until the force of gravitation stops the process. It is then in the state called "free air" by the mechanical engineer. Now the molecules of a gas—say the amosphere—are in constant vibratory motion back and forth in short paths, and are only prevented from traveling in longer paths by the attraction exerted by that great mass of matter near them, the earth. Let us now consider the case of a single molecule.

Under the above assumptions the exact space it occupies is determined by the length of its little vibratory journeys, minus its own size, which is so minute as to be practically negligible. If we begin to compress this air in the bottle, at once the travel of each molecule begins to be shortened, that is, the molecules are packed closer to each other and, in their turn, begin to exert pressure on the walls of the bottle. Continuing the compression, the pressure on the walls will steadily increase as the molecules are forced together more closely, until at last a point will be reached when they have been driven so near to each other that their mutual attraction is no longer negligible, and becomes of enough importance to neutralize to some extent the pressure the gas is exerting on the walls of the vessel. Just before this state of affairs is reached we have, in the vessel, what may be called the "ideal pressure," that is, the pressure determined alone by the vibratory movements of the molecules, undiminished by their mutual attraction, which plainly gives the length of the journey of each, and from which may be calculated the volume within which each one is free to move.

Returning now to the law enunciated at first, to the effect that "the product of the volume occupied by a gas and the pressure it then exerts on the walls of its container is a constant," it is plain that if the figure which represents that constant is known (which is the case, though it is different for each kind of gas), the dimensions of the volume in which each molecule is vibrating can be determined. Then, if the total volume within which the gas is confined is divided by the volume within which each molecule is vibrating, the quotient must represent the number of molecules present. Finally, if the total volume under confinement is divided by the number of molecules therein, the quotient must represent the volume of space actually occupied by each molecule.

Now let the bottle and its contents be weighed. From this deduct the weight of the bottle. The remainder will be the weight of the molecules. Knowing their number it is a simple matter to ascertain the weight of one of them. We now have the number in the bottle and the weight of each. From these, by a process difficult to describe without employing algebraic formulae, the fraction of the volume of a gas actually occupied by its molecules can be determined which, under the assumption that the molecule is a sphere, will permit of its size to be calculated. Other considerations rather too complicated to be explained here have led to the conclusion that under given conditions of heat and pressure one cubic meter of any gas contains approximately 54,000,000,000,000,000 molecules. Since one cubic meter of hydrogen weighs 0.00009 milligram, the weight of a single one of them should be 0.000,000,000,000,000,000,000,016,6 milligram.

GAUSS (1777–1855)

ASTRONOMY

Karl Friedrich Gauss was the son of a day laborer, of Brunswick, Germany. Nevertheless, he acquired an excellent education, and graduated with honors at the University of Göttingen in 1798, his specialty being mathematics. Before leaving there, he had solved for the first time the problem of dividing a circle into seventeen equal arcs, by already known and simple geometrical principles—the first extension of the ancient Greek knowledge in this particular.

On the first day (or night) of the 19th century, the astronomer Piazzi at Palermo discovered Ceres, the first of the planetoids, and continued his observations on this small member of the solar system until February 13th, when forced to discontinue them because of a serious illness. By the time the news of the discovery had reached the ears of other European observers, not only had the little planet moved so far away from its last observed position, that it could not be found, but had approached so close to the sun that observation was impossible. Nor did the astronomers of the day possess then a method of computing an orbit, from notes of position extending over so short a period of time as the five or six weeks—with frequent interruptions from cloudy weather—that had been allowed to Piazzi. Hence it was feared that by the time it became visible again, it could not be located. When Gauss was apprised of the situation, he devised a method of computation from Piazzi's notes, which enabled him to calculate the planet's path so accurately, that at the end of the year it was picked up again almost exactly in the position his figures assigned. His monograph on this problem, published in 1809, and entitled "Theoria Motus Corporum Coelestium," established his reputation as the first astronomical mathematician of his time.

Gauss is regarded as the discoverer of the mathematical theory of electricity; and he enjoys with Henry the credit of being among the first to employ the telegraphic art when, in association with Weber, he established in 1833, a wire connection between the magnetic and astronomical observatories at Göttingen, and employed it for signaling from one to the other by sound.

Gauss is also remembered as the developer of the mathematical device known as the Method of Least Squares, the application of the theory of probabilities to the deduction of the most probable value from a number of observations or results each of which, from the nature of the case, is liable to be slightly in error. The germ of the idea originated with Legendre in 1805, and was used by him in calculating the orbits of certain comets, but he gave no proofs of its accuracy, nor did he analyze its operations deeply enough to be prepared to formulate the mathematical law at its foundation. Adrian, a mathematical writer, gave two proofs of it in 1808, and Gauss a third in the following year, and then, by analysis, placed the theory and its methods of application so clearly before the mathematical world, that its value was at once clearly recognized. A simple illustration will reveal its use. Assume a circumference of size which is bisected by a diameter. Assume this circumference and the two semi-circumferences to be instrumentally measured. There have then been three measurements, none of which can be positively guaranteed as absolutely accurate. What then is the most probable true measure? This the Method of Least Squares gives. In astronomical work problems of this nature, but vastly more complicated, are of frequent occurrence, and their solution with absolute accuracy admittedly impossible, owing to defects of vision and of instruments. Yet it is highly desirable to approximate accuracy as closely as is mathematically possible. Hence, a large number of observations are taken and the measurements they yield are submitted with confidence to the Method of Least Squares. The result is not the average, but the most probable approach to the true value.

DAVY (1778–1829)

CHEMISTRY

Humphry Davy was a native of Penzance in England, his father being a carver in wood. He attended school at Truro up to the age of sixteen, and was then apprenticed to a surgeon and apothecary of his home town. During this period of his life he was an avid reader in many lines of speculative thought, but ultimately found himself more attracted to natural philosophy than anything else, and especially in that department or branch of it which was the budding science of chemistry at the time. Becoming associated in his nineteenth year as an assistant to a Doctor Beddoes at Bristol, who conducted an establishment called a "pneumatic institute," where patients were treated for ills of the respiratory system, by causing them to inhale medicated air; he became interested in the various fumes employed, and finally discovered, through an experience which nearly cost him his life, the exhilarating and anaesthetic properties of nitrous-oxide, which was at first known as "laughing gas." After investigating the subject thoroughly, he published an account of his experiments, which aroused so much interest, that he was appointed in 1801 a lecturer at the Royal Institution of London. Here his natural platform ability and charm of manner, coupled with the novelty of his subject, attracted large and brilliant audiences, and won him the appointment of professor of chemistry. Yet it was nearly forty years thereafter before anaesthetics, as a recognized valuable department of surgery, became established, and even then for some years only in dentistry. Davy himself does not seem to have appreciated the importance of his discovery, for in his lectures and writings he turned quickly to other subjects, where he made important and interesting announcements. Perhaps the most remarkable of these was contained in his paper entitled "On Some Chemical Agencies in Electricity," which was read in 1806. In this, he advanced the theory that chemical affinity was nothing but the mutual electrical attraction of the ultimate particles of matter, the atoms. He reached this conclusion after meeting with success in extracting the metals potassium, sodium, strontium and magnesium, from their oxides potash, soda, strontia and magnesia. And while, on account of the limited chemical and electrical knowledge of his day, the theory could not be experimentally demonstrated, except in a few simple cases, and was afterwards set aside and forgotten, yet at the present time it is recognized as one of the fundamental principles of matter, and appears to have been demonstrated beyond all question.

In 1812 Davy was knighted. In 1815 he invented his "safety lamp," for use in coal mines. In 1825 he suffered a paralytic stroke, affecting his right side, which a few years thereafter resulted in his death at the early age of 51. He is rightly regarded as one of the great men of science of his day.

GAY-LUSSAC (1778–1850)

CHEMISTRY

Louis Joseph Gay-Lussac was reared at Sainte Leonard-le Noblat in central France, and was educated at the Ecole Polytechnique, and after graduating became the assistant of the chemist, Berthollet.

In 1804, in association with Biot, the astronomer, he was commissioned by the French Institute to make a balloon ascension, to study the temperature, humidity and composition of the air at high altitudes, and to ascertain whether the magnetic force existed at considerable distance above the surface of the earth. They succeeded in reaching a height of 23,000 feet, in securing samples of the air there, in registering temperature and humidity at various stages of the journey, and in taking observations which showed that the magnetic activity was as great at the summit of their flight as on the surface of the ground. Somewhat later, while investigating the chemical composition of the air collected, he had occasion to measure the volume of the two gases (hydrogen and oxygen) which, when united chemically, form water, and determined the proportions as invariably two of the former to one of the latter. This impressed him greatly, and led him to make numerous experiments along the same lines with other gases, the result of which was his announcement in 1808, of the "Law of Combining Volumes," which is one of the most important in the whole domain of chemistry. In recognition of this fundamental discovery, he was appointed to the chair of chemistry at the Ecole Polytechnique. In 1818 he took charge of the government gunpowder manufactory, and in 1829 of the Mint. Ten years later he was created a peer of the realm.

His law may be stated as follows:

"When two or more gases react chemically with each other, their reacting volumes bear to each other a ratio that can be expressed by small integral numbers." Thus, when hydrogen (H), and chlorine (Cl), unite to form hydrochloric acid (HCl), the volumes of the reacting gases are equal, that is, their ratio is 1 to 1. Similarly, equal volumes of gaseous hydrochloric acid and ammonia combine to form ammonium chloride. In the formation of water (H_2O), the two gases unite in the simple ratio of 2 to 1.

This law was soon found to apply to all the elements, solid, liquid and gaseous, and to all the combinations which occur between them. Thus, pure limestone always consists of one part of the metal calcium combined with one part of the non-metal carbon, and three parts of the gas oxygen; cane sugar of twelve parts of carbon, combined with twenty-two parts of the gas hydrogen, and eleven parts of the gas oxygen; red iron rust of two parts of the metal iron combined with three parts of oxygen. In other words, the elements invariably unite with each other—if at all—in proportions which may be expressed by comparatively small integral numbers. Fractional combinations are unknown, and are believed to be non-existent. Common table salt when pure, if analyzed, will invariably yield exactly one part each of the metal sodium and of the gas chlorine,. Iron, it is true, will unite in three different ways with oxygen, called respectively the protoxide, the sesquioxide and the peroxide. But in each case the resulting compound is a totally different substance in appearance and properties from the other two, and in all three the proportions in which the iron and the oxygen unite are expressible by small whole numbers.

Gay-Lussac was the discoverer of the non-metallic element boron, which is the principal component of the well-known substance borax. He devised new and improved methods for the isolation and separation of the metals sodium and potassium. He was the first to produce iodic and hydriodic acids from iodine, and to make the very deadly but highly useful compound of equal parts of carbon and nitrogen that is known as cyanogen.

BERZELIUS (1779–1848)

CHEMISTRY

JONS JAKOB BERZELIUS was a native of Westerlösa in Sweden, and after graduating at the University of Upsala he went to Stockholm, and devoted himself to teaching, and to research in chemistry and medicine. In 1806 he was appointed lecturer in the former science at the Military Academy, and in the following year, professor of medicine and pharmacy. Shortly afterwards he became a member of the Stockholm Academy of Science, and from 1818 until his death was its secretary.

To a very large extent, the science of inorganic chemistry owes its foundation and growth to the labors of Berzelius. He was a keen and tireless investigator, the discoverer of the elements cerium, selenium and thorium, and the first to prepare and exhibit for examination, samples of many of the rare metals and elements, such as columbium, tantalum and silicon. The multitude of analyses made by him, and their accurate character, established the laws of the combinations of the elements then known with each other on a foundation that had not previously been approached. He also was largely instrumental in extending and perfecting the system of nomenclature now employed. He was an expert in the use of the blowpipe for the qualitative analysis of minerals in the field, and practically the founder of that branch of the science.

In 1812 he advanced a general theory of chemical combinations, based on the assumption that the atoms of the elements are charged with electricity, some being electro-positive, and some electro-negative. To hydrogen was assigned a central position in the scheme, because it seemed capable of yielding many varieties of compounds. Further, the extreme electro-positive position was assigned to the metal potassium, and the extreme electro-negative to the gas oxygen. This theory, further elaborated, was actively advocated by him, as an explanation of all chemical phenomena, and for a time was almost universally accepted. But between 1830 and 1840, it became evident that, as outlined by him, it was not a correct statement of the phenomena under consideration, and was gradually abandoned, though Berzelius himself clung to it throughout his life. During recent years it has become apparent that there was some prophetic truth in it, and in somewhat modified form it is in process of revival, especially since the atoms of his day have been split up into electrons, and have been shown to be constituted practically of electrical units, and nothing else.

SILLIMAN (1779–1864)

GEOLOGY

Benjamin Silliman, a native of the State of Connecticut, and the son of a general who served in the Revolutionary War, was a graduate of Yale University where, after serving for several years as a tutor, he was appointed in 1802 a full professor of chemistry, geology, mineralogy and pharmacy; a combination of instructional duties which not only indicates his broad proficiency as a teacher, but also the unspecialized nature of the scientific curriculum, even in institutions of high standing, in the early years of the last century. He was a man of unusual personal charm, highly honored by all who knew him for his ability, and greatly admired by his pupils. For sixty-two years he filled this position, the last eleven as professor emeritus. During that long incumbency, as might be expected, his instructional duties crystallized gradually towards geology, and finally were confined entirely to that subject, chemistry, mineralogy and pharmacy being taken over by others.

In the early years of his career he was a confirmed believer in the geological views held and taught by Werner at Freiberg; and when Lyell's great work "The Principles of Geology" appeared (1830–1833), in which totally different explanations were advanced to account for the observed facts in that branch of study, he was unable to fall in line with the new trend of thought, though many passages in his writings, and even in his lectures, may be cited, that indicate doubt as to Werner's theories. One of these, dated in 1821, is of peculiar interest. After giving a description of the vast areas in New England, New York and eastern Canada, over which are found the rounded boulders and pebbles, and the ridges and sheets of gravel, now summarized under the general name of "glacial drift," and accounted for by the well-established theory of continental glaciation, and which by Werner were ascribed to the Noachian Deluge, he wrote—"these have ever struck me as among the most interesting of geological occurrences, and as being very inadequately accounted for by existing theories."

In 1818 he founded, and for twenty years edited, the "American Journal of Science," which was continued by his son, and from its inception has ranked as a leading technical periodical. He was the inventor, with Dr. Hare, of the compound blowpipe, an improvement on the instrument designed by Plattner of the Frieberg Mining Academy in Saxony, a tool which was much in use during the last century among mineralogists, in the preliminary examination of ores of the metals, and of rocks in general. He was the first to identify that rather unusual variety of aluminum silicate which occurs in the form of long and slender crystals of a greenish brown color in the older rocks, and which, in his honor, was given the name of sillimanite.

As a lecturer on geology he was always able to command a large audience, and during his active years gave many courses that were very effective in disseminating among the people a knowledge of the discoveries constantly being made in those branches of science which he had made his specialty. And, like his great contemporary Faraday, he possessed the ability of talking to the people on technical subjects, in language that all could understand.

AUDUBON (1780–1851)

NATURAL HISTORY

JOHN JAMES AUDUBON was born at Mandeville, Louisiana, when that part of the United States was a colony of Spain. His father was a wealthy Frenchman, the owner of large estates in Santo Domingo. His mother was of pure Spanish ancestry. Many years before Louisiana passed from the control of Spain and France, the elder Audubon moved his family to France, and so the childhood and youth of John James was passed there. He received an excellent education, including special instruction in drawing under the noted artist David. During the American Revolutionary War his father acquired an estate near the city of Philadelphia. When the French Revolution broke out in 1789 he gave this land to the young man, who came to America in the following year and took possession of it. Here he lived for ten years, devoting the most of his time to the study of wild bird life, in which that part of the New World was then particularly rich. In 1808 he married, and finding the rapid settling up of Pennsylvania a serious bar to the prosecution of his studies in natural history, he sold his farm and moved across the Allegheny mountains into the new state of Kentucky, where he reinvested in land and became ostensibly a pioneer farmer.

But Audubon was in no sense a business man, nor a worker of any kind. With him the love of nature, and especially of avian life, was an obsession. In a comparatively few years he had lost all his real estate and other property, and was driven to the giving of drawing and even of dancing and fencing lessons, and the making of portraits, for support, and every hour that could be spared from these uncongenial but necessary labors was devoted to his studies in the untouched forests and beautiful valleys of the new land into which he had emigrated. The result was a collection of drawings which, of its kind, has never since been approached in accuracy and completeness, for he was a careful artist. With each sketch he made voluminous notes of colors and habits so far as he could obtain them. Throughout his long struggle for maintenance amid the crude conditions of frontier life, and under the handicap of an artistic disposition that would not be denied, he was so faithfully aided and encouraged by his devoted wife, that in 1824 he was able to take his collection to Philadelphia, which by then had become an intellectual center of considerable note. There he found friends who recognized its value, and who provided the means to take it to London in 1827, where he quickly was able to publish it under the title of "Birds of America." The prints, beautifully executed, came from the press in folio parts, at the rate of about five parts per annum, during the decade between 1828 and 1838, and proved so overwhelmingly a commercial as well as artistic success, that he was relieved from all financial worries for the balance of his life. In 1842 he purchased a small estate on the Hudson river (now within the limits of the city of New York), where he passed the remainder of his life with his two sons and their families.

Audubon would hardly be regarded at the present time as a scientist, nor even an artist of note. Yet his love of nature, and his devotion to that aspect of it which supremely enlisted his enthusiasm, fully warrants the inclusion of the story of his life and of his work in any list of those who have taken part in adding materially to the world's stock of classified knowledge. He was a man of simple and kindly disposition, attractive in person and in personality. In his prime he displayed all the vigor, virility and endurance of the typical pioneer. In his old age he was the pride of his descendants, and an honored friend of all who enjoyed the pleasure of his acquaintance. The actual results that he left to the world were not so important as the example of devotion to an ideal. Yet but for his labors we should know much less than we do of the abundant and very remarkable bird life which characterized the eastern parts of the North American continent in the years when it first became known to the white man. In contrast, it may be understood how much has been lost forever because, when the Spanish and Portuguese overran the rest of the New World there was no one with them of the type of Audubon to record its wild life except in words.

BREWSTER (1781–1868)

PHYSICS

David Brewster's birthplace was Jedburgh in Scotland, and he was educated for the Church. But being more attracted to science than theology, he became in 1808 the editor of the Edinburgh Encyclopedia, to which he also made extensive contributions. He was particularly interested in the phenomena of optics, was the inventor of the kaleidoscope, and published a book on it. Although this device is but a scientific toy, its ability to produce an infinite number of symmetrical figures has been extensively taken advantage of, to secure suitable and attractive designs and patterns for carpets, wall papers and other fabrics. He shares, with Wheatstone, in the invention of the stereoscope which, as devised by the latter in 1838, employed reflecting mirrors instead of lenses, and was successful only so long as the pictures to be operated upon were confined to representations of geometrical objects, which could be readily duplicated. But the exact duplication of complex objects, such as natural scenery, is beyond the skill of an artist, and at the time photography had not been developed to the point where it could be employed for that purpose. Brewster took up the matter in 1849, and substituted lenses for the Wheatstone mirrors, and being then able to resort to the photographic art for his pictures, produced remarkably satisfactory results.

His scientific work brought him many well-deserved honors. In 1815 he won the Copley medal for optical investigations, and in the following year he received half the prize bestowed by the French Institute, in recognition of important discoveries made in physics during the two preceding years. In 1819 he received the Rumford gold and silver medals, for his discoveries connected with the polarization of light. He was knighted in 1831. In 1849, on the death of Berzelius, he was elected one of the eight foreign associates of the French Institute. He was also a member of the scientific Academies of St. Petersburg, Berlin, Copenhagen and Stockholm, and an associate of the National Academy of Sciences of the United States. He was a voluminous writer.

The principle on which the stereoscope operates may be easily understood by looking at any solid object with one eye closed. It then gives merely the impression of a flat picture on a flat background. But when viewed with both eyes its three-dimensional quality is at once apparent. The reason is simple. The two eyes being separated horizontally by a space of several inches, we see with the right eye more of the right-hand side of a body under inspection than the left eye does, and the latter sees more of its left hand side than does the right eye. The two, operating together, produce the effect in the mind of a composite picture, in which we see around the corner—so to speak—on both sides of the object, with the result that it stands out in relief from its background.

The Brewster stereoscope employs two identical pictures of the object to be viewed. In front of them, on a sliding frame properly shielded, is set the two halves of a double convex lens, with their thin edges adjacent. Through this eyepiece the observer looks, and when their position is adjusted to the proper focus for the individual, the two pictures blend perfectly into one, and the effect of relief obtained naturally by the eye is now intensified, so that even distant objects in them, which the eye alone would hardly have the power to draw out of the background, are brought strongly into relief.

BESSEL (1784–1846)

ASTRONOMY

Friedrich Wilhelm Bessel was a native of Minden, Germany, and was destined by his father for a commercial life. But at a very early age he exhibited so strong an inclination to science, and particularly to astronomy, that he was ultimately and very wisely allowed to follow his natural tendencies. Having been given an excellent education in the fundamentals, he read and studied the higher branches by himself, and by 1810 his standing among observational astronomers had become so high that he was offered the directorship of the observatory at Königsberg in East Prussia, and the chair of astronomy in the university there. In these positions he added greatly to his reputation by the numerous discoveries made in the observatory, and by the publication of two notable works, namely, "Fundamenta Astronomiae" in 1818, and "Tabulae Regiomontanae" in 1830, both of which were unusually meritorious literary and scientific productions for their day.

His great achievement was the determination of the parallax of the star 61-Cygni. His method was not only entirely new, but extremely ingenious. He selected this particular star, because he suspected, for various reasons, that it was one of the nearest to the solar system, and hence might have a parallax capable of being measured with the heliometer. He then proceeded to determine every clear night, its position relative to two neighboring very small and dim stars, which he selected for the purpose, because he concluded they were so immeasurably farther away, that no change in their position could be detected. Accordingly, as he had hoped, he found that 61-Cygni was moving, with respect to these two, and, in fact, was describing a tiny elliptical curve in the sky, which was nothing more than a minute reproduction in space of the earth's orbit around the sun. This made it clear that the star had an apparent motion, due to the real motion of the earth, and this proved to be large enough to be measurable by the heliometer. Having then the area of two ellipses, whose relative dimensions were identical, it became a simple matter of calculation as to how far apart they were. 61-Cygni was thus found to be distant from the earth the equivalent of 8.1 light years, which meant that it lies approximately 500,000 times as far away from us, as our central orb, the sun.

Bessel's method is rightly regarded as one of the most ingenious in its conception, and famous in its results, in the annals of astronomical research. By its use, the parallax of a large number of the stars have since been determined, and consequently their distance from our system.

DULONG (1785–1838)

CHEMISTRY

Pierre Louis Dulong was a native of France, and was educated at the Ecole Polytechnique in Paris where, in 1820, he became professor of physics. In 1823 he was elected a member of the French Academy of Sciences.

He is chiefly known in connection with the physical law which, in collaboration with Petit, they discovered, and which is known as the Dulong and Petit law. It runs as follows:

"The product of the specific heat of any element, when in the solid state, and its atomic weight, is (approximately) a constant."

The inference from this law—which is universally accepted, but not yet explained—is that the atomic heat of all the elementary substances is practically identical.

Each of the eight-eight elements that have so far been discovered, has a property which is called its atomic weight. It is expressed by a number, which may either be a whole one, or one with a fraction. Thus, the atomic weight of oxygen being called 16 for the purpose of establishing a unit, that of carbon is 12; of gold 199.2; of lead 207; and of uranium, the heaviest element in the list, 238. These figures represent the relative weight (not the actual) as compared with that of the unit element oxygen, of the smallest amount of each that is capable of existing as a fixed quantity in a chemical compound or, as it is called, the atom. Thus common table salt is a compound of the metal sodium with the gas chlorine, and is expressed in the language of the chemist by the symbol "NaCl"; in which the "Na" stands for the sodium (formerly known as natron) and the "Cl" for chlorine. The union of the two is expressed numerically by adding together the atomic weights of sodium (23) and chlorine (35.5), making the atomic weight of the compound 58.5. Pure water, which is a compound of the two gases hydrogen and oxygen, is symbolically expressed as "H_2O, and numerically by the figure 18, which is the sum of 2 unit weights of hydrogen and 16, the unit weight of oxygen.

Another property, possessed by all the elements, is known as their specific heat, by which is meant the amount of heat required to raise the temperature of any one of them one degree Centigrade under certain specified conditions. This is different for each of the elements, but has a much smaller range of values. Thus the specific heat of hydrogen—the lightest of the elements—is 3.4090, while that of platinum—one of the heaviest—is 0.032.

Dulong and Petit's discovery was to the effect that if the atomic weight figure of any element is multiplied by its specific heat figure, the product in all cases will be approximately a constant, that is, an identical figure. It is 6.4, and is called the atomic heat figure.

CHEVREUL (1786–1889)

CHEMISTRY

Michel Eugène Chevreul was a native of Angers, France. Being the son of well-to-do parents, after completing his primary studies, he was sent to Paris to specialize in the physical sciences, and in 1813 was appointed professor of those branches at the Lycée Charlemagne. In 1820 he became an "examiner" at the Ecole Polytechnique, and in 1824 director of the dyeing department of the Gobelin tapestry manufactory. In 1829 he was elected to the professorship of applied chemistry at the Museum of Natural History, a position which he retained for a half century, retiring only at the age of 93.

His principal contribution to the advance of knowledge consisted in his successful investigation of the chemical nature of those products of the abattoir known as animal fats. He was the first to show that they were compounds of glycerin, with oleic, stearic and palmitic acids. Glycerin had been discovered by Scheele in 1784, but its usefulness was not immediately recognized, because no large source of it was known. When Chevreul found it in quantity in the animal fats, and in combination with the acids mentioned, a cheap and abundant supply of all was assured, in regard to the acids for the manufacture of soap, and as to the glycerin for the making of nitroglycerin.

At the time soap was a high priced commodity, available only to a limited degree among the poor. It now became possible to produce it very cheaply. As cleanliness has been ranked by a distinguished writer to be next to godliness in its benificent effects, the enormous value to the world of this part of his investigation is evident. Soap is perhaps the greatest civilizing agency that has been discovered, or invented. Since Chevreul's time the demand for it has increased so greatly that, years ago, the supply of these acids from the abattoirs became insufficient to meet the demand, and the world has been ransacked for new sources of them. At the present time, only the coarser varieties of soap are made from abattoir acids, while all the finer kinds for the toilet, are made from vegetable fats or oils (palm, olive, cottonseed, etc.).

As for glycerin, it was for some time a drug on the market until, in 1846, Sobrero discovered the explosive qualities of nitroglycerin, and in sixteen years later (1862)

Nobel devised a means of controlling its dangerous qualities. Since then, the demand for it also, has been constantly in excess of the easily available supply.

Chevreul lived to the great age of 103 years, and witnessed the tremendous growth of these two fundamental industries resulting from his investigations. Many honors came to him before he retired. He was of course a member of the French Academy, and the Royal Society of London. On the occasion of his one hundredth birthday, he received the degree of LL.D. from Harvard. A beautiful monument was erected in 1893 to his memory at Angers, the place of his birth; and a fine statue of him stands in the Museum of Natural History in Paris.

ARAGO (1786–1853)

ASTRONOMY

Dominique François Arago lived in the little town of Estagel, in southern France, and at the age of seventeen matriculated at the Ecole Polytechnique in Paris, where he exhibited such unusual mathematical ability that he was offered, in 1805, the position of secretary to the Bureau of Longitudes, and two years later was directed to complete the measurement of the arc of the meridian, which had been commenced by Delambre and Méchain. The unfinished part extended from the vicinity of Barcelona, Spain, due south, to the little island of Iviza, in the Mediterranean, the most southerly of the Balearic group, where it terminated. Establishing himself on the summit of a lofty mountain near the Spanish coast, he was able to maintain communication by signals across the 175 miles of water, with his collaborators on the island, and thus to carry on successfully the necessary observations. But before these were completed, war broke out between France and Spain, and Arago, because of his signaling operations, was charged by the ignorant local authorities with being a spy. However, he managed to escape to the island of Majorca—the largest of the Balearic group, where he voluntarily surrendered himself to arrest and imprisonment, pending consideration of his case by the central Spanish authorities. He was finally released, on promise to go direct to the city of Algiers, on the north African coast. On arrival there, he took a French vessel for Marseilles, which had the misfortune to be captured by a Spanish cruiser, whereupon Arago was sent to prison at Palamos. Again, after a time, he was released, and sailed once more for Marseilles. But almost as he was entering the port, a tempest arose that drove the ship back across the Mediterranean, to Bougia on the African coast. From there he made his way by land to Algiers, where he was compelled to wait nearly six months before he could secure passage to France. This was finally obtained, and in July, 1809, he at last landed in France. As a reward for his sufferings, the Paris Academy of Sciences elected him to membership, a most signal honor, as he was then only in his 23rd year. He was also simultaneously appointed professor of analytical geometry and geodesy, at the Ecole Polytechnique.

From this date onward, his attention was largely devoted to astronomy, magnetism, galvanism and the polarization of light, all but the first being new and budding branches of science. He became a tireless investigator of phenomena, and a brilliant lecturer, and made a number of discoveries of secondary importance, and one, in magnetism, of major value. Having heard of the discovery by Oerstead of the deflection of the magnetic needle, when surrounded by a coil of wire carrying an electrical current, he carried the investigation further, by showing that the same effect could be produced in an unmagnetized bar of soft iron or steel, and to a less degree, but definitely, when a bar of copper, carrying no electrical current, was rotated around the magnet. For this discovery he obtained the Copley medal, and several university honors in England and Scotland, and was elected permanent secretary of the French Academy, and director of the observatory at Paris, positions which he retained until his death.

Arago took a prominent part in political affairs in France, during the disturbed period of the Revolution, and the years that followed. He opposed the election of Louis Napoleon to the Presidency, and refused to take the oath of allegiance after the *coup d'état* of 1851. However, in recognition of his great services to science, and the State, and in admiration of his independence of spirit, and lofty personal character as a citizen, the Emperor had the good sense to excuse him from the obligation.

FRAUNHOFER (1787–1826)

PHYSICS

Joseph Fraunhofer was a native of Straubing, in Bavaria; and after receiving a good education in fundamentals, was apprenticed in his twelfth year to a glass cutter at Munich, where he learned the trade thoroughly. Being diligent and capable, he rose quickly, and by the time he was of age had attained the status of a working optician in a large glass-making establishment, of which, in 1819, he became the operating head, and principal owner. Here he not only made money, but acquired a high reputation for the excellence of the lenses, mirrors, prisms, and other scientific optical articles produced. To attain this end he had perfected himself in mathematics and physics, and had invented several machines and processes for turning out high quality articles in his line.

All this led up to more or less experimentation in his own laboratory, on the phenomena of light, and to his discovery in 1814, of the dark lines in the spectrum of the sunlight, which have ever since been known as the Fraunhofer lines. This discovery constituted the foundation and beginning of the science of spectroscopy. In 1821, using a diffraction grating, of which he was the maker, he was able to measure accurately the wave length of light. These two very important additions to the stock of knowledge, rendered Fraunhofer's name celebrated throughout the scientific world. He became a member of the Munich Academy of Science in 1817, and in 1822 conservator of its physical cabinet. An unfortunate accident led to his death at the age of 39 years, when he was in his prime.

It is true that the dark lines in the solar spectrum were noted by Wollaston in 1802, but he did not connect the observation with its cause, as Fraunhofer did. The latter gave the names of the letters to these lines, as found in the solar spectrum. He then studied the spectra of stars, and of various flames, and observing that the line "D" appeared in the spectrum of all flames that he tested, he began to search for the cause, and ultimately demonstrated that it was due to the metal sodium, which, being present almost everywhere, and at all times, in the form of sodium chloride (common table salt), is to be found in almost all ordinary cases of flame. Thus the "D" line in the solar spectrum indicated the presence of that element in the sun.

With this new key, it was not long before other elements were shown to be present in the sun, the stars and the nebulae; and thus at one leap it became clear that the material of the external universe, was identical with those forms of matter that by then were being detected and isolated from the substance of the earth. Fraunhofer's discovery was therefore epoch making, and one of the most wonderful in its results that are to date to the credit of the developing human intelligence.

OHM (1787–1854)

ELECTRICITY

Georg Simon Ohm was born, and received his early education, at Erlangen in Bavaria; and having natural ability in mathematics and physics, he taught these subjects in various small schools, until, in 1817, he was appointed to a professorship in the University of Cologne. Here he became interested in what was then known as galvanism, and the growing electrical revelations of his time, and in 1826, when he resigned his professorship, he published his great paper, under the title of "Bestimmung des Gesetzes nach welchem Metalle die Contakt-electricita Leiten, etc.," which gained him immortality among scientists. His law, therein set forth, which underlies all electrical theory and measurement, is substantially as follows:

"The capacity of any metallic conductor to transmit the electrical current varies directly as its length and inversely as its cross-section; and is different for different metals, and for the same metal at different temperatures."

This transmission capacity unit is called the "Resistance." For each substance employed in any branch of the electrical science, as for instance the filament of an incandescent light globe, or the heating coil of a toaster, its resistance to the passage of a current of an agreed standard strength, has been accurately determined, and is now expressed, by international agreement, as so many "ohms." Certain metals and metallic alloys (silver and copper for instance) transport the current with extreme rapidity and ease, also some non-metallics. Other metals (as tungsten), and most non-metallic substances (as mica, porcelain, etc.), are very poor conductors, or absolute non-conductors. When therefore any of these latter are interposed in an electrical current, they resist, or delay its passage. If, however, the resistance is only partial, the substance becomes incandescent, with the production of light and heat. Ohm's investigations on the conductive capacity of the metals enabled him to formulate the law which is now at the foundation of the art of electrical engineering. The adoption of his name to express the unit of electrical resistance will perpetuate his memory honorably through the centuries to come.

The resistance of a conductor to the passage of the electrical current varies with the temperature, becoming less as the latter increases. Lead, for example, is rated as a poor conductor, but will pass a current of moderate quantity (amperage) if there is enough push (voltage) behind it. But its resistance causes a rise of temperature, and if the push continues to increase, its melting point will ultimately be reached. A strip of lead therefore, or of some other metal or alloy of low fusibility and indifferent conductivity, if interposed in a copper circuit, will melt and break the circuit if, for instance, a bolt of lightning reaches the copper wire, and attempts to travel on it to the delicate machinery at its end. Such arresters are a part of all electrical installations for protective purposes, and are popularly known as fuses.

FRESNEL (1788–1827)

PHYSICS

Augustin Jean Fresnel was a resident of Broglie, in northern France, was educated at the Ecole Polytechnique at Caen, and at the Ecole des Ponts et Chaussées; and upon graduation entered the service of the government, as an engineer. For political reasons, he lost his position when Napoleon returned from Elbe, but returned to it after the Second Restoration, in 1815. During his enforced idleness, he devoted his time to the study of the phenomena of light, and, in ignorance of the work of Young, the English physicist, on the same and allied subjects, demonstrated the error of the corpuscular theory, and proposed as a substitute the undulatory theory, which is today regarded as the correct explanation. His crowning experiment in demonstration was with two mirrors disposed—with respect to each other—at an angle of nearly 180 degrees. On these, two beams of light were cast, and at such an angle that each was reflected to the point upon which the other was cast, producing alternate light and dark bands or fringes, caused by the interference of the waves with each other.

He served for several years as a member of the government Lighthouse Board, in which position his extensive knowledge of optical phenomena enabled him to improve the coast light system greatly.

So far as can be gathered from what remains of their writings, the ancients do not seem to have developed any theory of the nature of light, though they clearly understood that its rays were propagated in straight lines, that they would be reflected in definite directions from the surface of a mirror, and could be collected to a focus by such lenses as they were able to construct out of transparent natural material, or from glass after its manufacture became known. Curiously enough, among the Greek philosophers

—with the exception of Aristotle and his school—the idea seems to have been strongly held that vision was a purely mental phenomenon, and that the rays which produced it proceeded from the eye to the object seen, instead of from the object to the eye.

Nor does it appear that any explanatory theory was advanced during the Middle Ages, though Kepler correctly described the principles of the telescope, and made some excellent studies in colors, while Maurolyeus some time previously showed that the images formed on the retina of the eye are inverted.

By the time of Newton the science of optics had become well advanced through the labors of DeDominis, Snell, Descartes, Fermat, Barrow, Mariotte, Boyle and others, and feeling it incumbent on himself to offer some explanation of the phenomenon, that great mathematician advanced his corpuscular theory. On account of his high reputation it was given immediate acceptance. According to it, light was due to the emission of streams of minute particles of matter from its source. But the difficulties encountered in explaining refraction by this theory were so insuperable that, before he died, much controversy over it had arisen, and the scientists of the day were already looking for a better explanation. It remained for Hooke and Huygens, the first by a lucky guess, and the second after deep study, to originate in outline the undulatory theory, which was demonstrated experimentally by Young and Fresnel. When their results were published, doubts as to the ability of the new explanation to account satisfactorily for all known optical phenomena passed away, and the corpuscular hypothesis was relegated to the limbo of discredited ones.

DAGUERRE (1789–1851)

PHOTOGRAPHY

Louis Jacques Mandé Daguerre was a native of Cormeilles, in northern France, and was by occupation a scene painter, and a very successful one; for to him is ascribed the invention of that particular variety of spectacular delineation known as the diorama, which had a remarkable vogue in its day. From productions in this branch of art, where the contrasting effects of lights and shadows had so much to do with the impression made on the spectator, he gradually became interested in the phenomena of light. Entering into a correspondence with a certain Joseph Nicéphore Nièpce, a French inventor of note, who had been experimenting in the same direction for a number of years, and who had considerable empirical knowledge of chemistry, the two finally perfected their discovery of the art of photography, and announced it in 1839. Its value was immediately recognized, and Daguerre was made a member of the Legion of Honor, and voted a pension of 6000 francs ($1500).

His process was as follows: A copper plate was first coated with silver (by electric deposition), and then highly polished. It was next exposed to the vapors of iodine, followed by those of bromine, resulting in the production of a film of silver iodide and bromide. This is the cause of the iridescence on the plate, which all who have seen a dauguerreotype will recall. This preparatory work was, of course, done in a dark room. After exposure in the camera, the plate was subjected to the action of the vapor of mercury, whereupon a film of the metal was deposited on those parts of the plate which had been chemically affected by the action of the light, but not on the other parts. The silver film on the unaffected parts was then dissolved and washed away, by immersing the plate in a solution of hyposulphite of soda. Lastly, the picture was fixed and intensified, by flowing over the surface a solution of hypo and chloride of gold, and applying heat gently, until all moisture had disappeared. The effect of this last step was to deposit on the mercury a thin film of gold. The daguerreotype is therefore really a work of high art, and as such a great credit to its inventor. But it remained for others, and notably Dr. John Draper of New York, to so simplify the process, that it became a practicable art. And, of course, during the years that have since elapsed, it has been further developed to a marvelous degree, and in directions never contemplated even by Draper and his contemporaries.

FARADAY (1791–1867)

ELECTRICITY

Michael Faraday, the son of a blacksmith, was born in London of Irish parentage. At an early age he was apprenticed into the book-binding trade, but having an inquiring mind, he attended the lectures of Sir Humphry Davy in 1812, and devoted much of his leisure time to experiments in chemistry and electricity, with apparatus of his own manufacture. At the close of the Davy course, young Faraday ventured to send to him the notes he had made during their delivery, together with a modest expression of his desire to secure employment, in some intellectual capacity. Davy was so impressed, that he at once took him on as a general assistant at the Royal Institution; and later, finding his intellect a keen one, and his desire to learn strenuous, he advanced him to the post of his personal assistant and amanuensis, and explained his plans for making some experiments which ultimately concluded with the liquefaction of certain gases under pressure. In the construction of the apparatus required, and in its use, Faraday showed such ingenuity and ability, and was so highly commended by his generous patron, that in 1824 he was elected a member of the Royal Society, and a year afterward was appointed a director of the Royal Institution, where later, upon the untimely death of Davy, he succeeded to his post as professor of chemistry, which in those days included the young but very lusty science of electricity. In 1835 he was granted a life pension of £1500, and a home in Hampton Court for his residence and laboratory, and in the following year he became the scientific adviser (or, as we should call it, the consulting engineer) to Trinity House, a government organization, charged mainly with the erection and maintenance of lighthouses on the dangerous coasts of the British Isles.

Faraday's original discoveries and inventions were numerous and highly valuable. Most of them were in the domain of electricity and magnetism. All have been of great importance in the development of those sciences, but none was epochal. Thus, he was the discoverer in 1831 of electromagnetic induction, or the phenomenon by which a body having magnetic or electric properties calls forth similar capacities in a neighboring body without direct contact. In 1845, he demonstrated the ability of a strong magnetic field to rotate the plane of vibration of a polarized beam of light. To him we owe the useful terms "anode" and "cathode," and the phrase "lines of force," which he employed in his theory of the phenomena of electrostatic and electromagnetic induction. His studies and investigation of dia and para magnetism were of the greatest importance, leading him to the conclusion (now fully accepted), that all varieties of matter are influenced as universally—either attracted or repelled—by the magnetic force, as by the force of gravitation, yet not invariably, or even usually, to the same degree.

He was at once a brilliant as well as a thorough investigator, and at the same time, gifted with an imagination which inclined him to look beyond the immediate effects revealed by his experiments, and draw inferences, which in many cases were prophetic, but in some have not been realized.

He was a deeply religious man, belonging to a sect known as the Sandemanians or Glassites, which was founded about 1730 by a Scotch clergyman named John Glas, and carried on after his death by his son-in-law Robert Sandeman. It has long since disappeared. Its tenets, while in every way worthy, could only be held and practiced by individuals of an unusual temperament and aspect on life, and the fact that Faraday remained until his death an earnest believer in and practicer of them, reveals a phase of his character which probably had its influence in leading to some of the few conclusions which he made, but which have not been realized.

Towards the end of his long and most honorable life, his powers of mind began to fail, but fortunately he was granted his release before their decay became painful to his intimates. He was the author of numerous scientific monographs, and the complete and accurate record of his laboratory work as given in those published between 1835 and 1859, under the title of "Experimental Researches in Electricity" furnished a basis for the mathematical and theoretical conclusions on the subject of light, which have made forever famous the name of James Clerke-Maxwell.

In recognition of his numerous and important contributions to the advance of the science of electricity, particularly in the matter of electrical condensation, his name, shortened to "farad," has been internationally adopted to represent the "practical unit of electrical capacity," which may be defined as the capacity of a condenser whose potential is one volt, when charged by one coulomb. The term is most frequently used in the form of the "microfarad," which is the one-millionth part of a farad.

VON BAER (1792–1876)

EMBRYOLOGY

Karl Ernst von Baer was a native of Esthonia, one of the western provinces of old Russia occupying a part of the southern coast of the gulf of Finland. He was educated at the University of Dorpat for the medical profession, and after graduating studied anatomy at Wurtzburg. In 1817 he became an instructor at the University of Königsberg and later professor of zoology, and director of its Anatomical Institute. In 1834 he moved to St. Petersburg, became connected with the Academy there, and remained in that city during the remainder of his life.

He is recognized as one of the founders of the modern science of embryology, and was the discoverer of what is known as Baer's Law, as follows:

"The evolution of an individual of any animal form, is determined by two conditions: first, by a continuous perfecting of the animal body by means of an increasing differentiation—histological and morphological—or an increasing number and diversity of tissues and organic forms; and second, and at the same time, by the continuous transition from a more general form of the type, to one more specific."

Wilhelm His of Germany was the first writer of note on this subject. His book, which is a classic, appeared in 1885, and embodied all that had been discovered on its subject to that date, in all respects confirming the law that Baer had announced. Since then much new information has been gathered although, as subjects for investigation are naturally much more difficult to obtain than those of adults, the additions to knowledge of human embryonic life accumulate slowly. Much more is known of that phase in animals and in vegetable life.

The human period of parturition varies a few days either way from 270, or say 38½ weeks. The first stage, which has a length of about two weeks, is that of the ovum or egg. Of it almost nothing is known except of the last three or four days. At its termination the new organism has a length of not over one-tenth of an inch, and consists of a collection of minute cells enclosed in a bladder-like covering or skin. The second stage embraces the next three weeks. During it a length of nearly a half inch is attained, and most of the principal organs come into existence, and may be located. This is called the embryonic period, and is the one which displays signs of the animal ancestry of man, such as the gill clefts and arches, the limb buds, and the beginnings of the vertebral column or back bone. Before its termination the brain has grown so rapidly that the head is as large as all the rest of the body, a feature characteristic of the human embryo only. Also the gill clefts and arches have almost disappeared, the arms have grown faster relatively than the legs, and the general outlines of the skeleton can be traced in lines of cartilage, though no bones have yet appeared.

The organism now passes into the third and final stage, called that of the foetus. In its early weeks the sex characteristics are determined. Before that, their germ was a part of what is called the Wolffian body, which up to about the seventh week performs the functions of an excretory organ. All but a central part of this now disappears. The remainder is called the sexual gland. If the child is to be a boy, parts of it degenerate and the balance becomes the internal male organs. If a girl, the male part degenerates and those remaining become the internal female organs. Hair begins to appear on the scalp during the fourth month, and the cartilage of the skeleton here and there is slowly changing into bone. At the beginning of this stage a weight of about five ounces, and a length of about six inches has been attained, and the human features are discernible on the face. In the following month these measurements are nearly doubled. Hair is now well developed, and also the nails on hands and feet. The sixth months' child weighs a good pound and is eleven to twelve inches long. During the seventh weight increases to three or four pounds, and the length to thirteen to fifteen inches. If birth now occurs life is possible, for all the organs are in existence and capable of functioning, though but feebly. When the full period is reached the weight is normally from five to nine pounds, and the length from seventeen to twenty-one inches, boys weighing on an average about twelve ounces more than girls, and being four to five inches longer.

At the normal time of birth the bony skeleton is very incomplete, being still largely in the condition of cartilage. In fact the only bones entirely hardened at that time are those small ones of the internal ear. To this curious fact is due the extreme sensitiveness of infants to sound. Their earliest impressions of the astonishing world into which they have come reach them mainly through the sense of hearing. Long before the eye has learned to interpret the meaning of the inverted image it presents to the brain, the voice of the mother has become familiar, and is recognized as a symbol of protection.

LOBATCHEVSKY (1793–1856)

MATHEMATICS

NICOLAI IVANOVITCH LOBATCHEVSKY, the son of a peasant, was born at Nijni Novgorod in Russia. He received (or acquired), in spite of the handicap of poverty, a good education in the fundamentals, and having unusual mathematical ability became one of the noted geometers of his time. In 1816 he was appointed professor of this science in the University of Kazan, a position which he retained with great credit during the balance of his life.

His major achievement—aside from being a remarkably successful instructor, and the producer of numerous very valuable monographs on mathematical subjects—was the discovery and elaboration in a volume published in 1830,—of what is known as the Non-Euclidean system of geometry, that is, one not based upon the Euclidean postulate of parallel lines. In this enlargement of the field of the science he was, to a certain extent, anticipated by the investigations of the brilliant Hungarian mathematician, Janos Bolyai, but to Lobatchevsky properly belongs the credit of having developed the new system and bringing its advantages into practical use.

Geometry, the science of form, owes its beginnings probably to the necessities of the rural inhabitants of the valley of the Nile (and doubtless also those of the Tigris and Euphrates) to have their boundary lines re-set after each annual inundation; in other words, with the art of land surveying. This called for the ability to calculate correctly the areas of irregularly shaped plots of ground that were bounded by straight or curved lines, or both. Up to the early years of the 19th century, among the fundamentals of the science were two axioms, or apparently self-evident truths, which had been accepted along with the others without question. These were as follows:

(A) Two parallel lines cannot completely include a space between them; and

(B) If a straight line meets two straight lines in such a way as to make the two interior angles on the same side of it together less than two right angles, the two straight lines, if produced, will at length meet on that side on which are the angles whose sum is less than two right angles.

Both Legendre and Gauss, as well as a number of other noted mathematicians endeavored to show the dependence of these two propositions upon those preceding them. Lobatchevsky showed that they applied only in plane geometry, but not in spherical. For, on a sphere, it is evident that two parallels of latitude do really include a space between them, to which has been given the name of a zone; and it is equally clear that the angles made with two such parallels by a meridian crossing them perpendicularly, do not, on either side, amount together to the sum of two right angles; and yet that the parallels, no matter how large the sphere, will never meet.

WEBER (1795–1878)

PHYSIOLOGY

Ernest Heinrich Weber was a native of Witteberg, Germany, and after a thorough grounding in medicine and anatomy at the university of that city, and at Leipsic, was appointed professor of comparative anatomy, in 1818, at the latter, was advanced to the chair of human anatomy in 1821, and to that of physiology in 1840. In his investigations, he gradually specialized on the physiology of the organs of sense, which naturally in time led him into the domain of psychology, and resulted in his announcement of a generalization of great importance in psycho-physics, which is known as Weber's law. This has been exhaustively tested by contemporary and subsequent investigation, and is fully accepted at the present time.

By a direct experiment upon a living animal, Weber was the first anatomist to discover that the pneumogastric nerve, the longest and most widely distributed of those originating directly in the brain, extending from there downward through the neck and chest to the upper part of the abdomen, exercised an inhibitory or controlling action on the heart, and the respiratory organs, in effect, playing a part in connection with their movements similar to that of the governor to a steam engine. If a certain branch of that nerve is stimulated, either naturally by vigorous muscular action, or artificially by drugs, the pulsations of the heart are increased in number. If another branch is stimulated in either way, the heart throbs decrease in number. Weber's law is the formula expressing the relation of sensation to intensity of stimulus; in effect stating, "that the ratio of the increment of stimulus, necessary to give a noticeably different sensation to the original stimulus, is constant." The validity of this conclusion was confirmed by Fechner, who extended its range to all cases of sense perception; and Wundt gives a résumé of its applicability as follows:

"The law has its most satisfactory application, and its widest range, in noise intensities. It has a less extended application to the modalities of vision, touch, taste and smell, while its validities in temperature, and organic sensation, are as yet uncertain."

The phenomenon then lies in the domain of psychophysics, that branch of science dealing with the inter-relations of mind and body, which, during recent years, has increasingly attracted the attention of investigators. As our knowledge of it, and of its reactions grows, its conclusions are slowly but steadily displacing those of metaphysics, which is fading into the status of a pseudo science, as astrology and alchemy have. For many years after Copernicus announced the approximately correct theory of the Cosmos, and Dalton the correct theory of the chemical elements, both of those pre-scientific cults continued to influence the minds and actions of all but the most advanced intellects. So metaphysical theories still have their votaries. But with the establishment, on the basis of observed and demonstrated facts, of Weber's conclusions, the science of psycho-physics is taking its place.

Weber's law means, in effect, that stimuli reaching the brain through the sense organs (vision, hearing, taste, touch and smell) exert an immediate influence on the action of the heart and lungs, and reflectively result in the expression of what we call "emotions." These display themselves in various ways, sometimes causing death or insanity, or, as we say, breaking the heart. And further, of those organs, that of hearing, which conveys to the mind speech, music, and all other varieties of sound or noise, is by far the most responsive to such stimuli.

SADI-CARNOT (1796–1832)

PHYSICS

Nicholas Leonard Sadi-Carnot, the son of a celebrated French statesman, strategist and scientist, was born at Paris, received his technical education at the Ecole Polytechnique, and served in the corps of army engineers until his resignation in 1828. Years before he had become deeply interested in the performances of the steam engine, as constructed in 1782 by James Watt, and the phenomena of heat. In his day this force was still regarded as a form of matter, and was called "caloric." Carnot supported that view in his work entitled, "Thoughts Upon the Motive Power of Fire and the Proper Machine for Utilizing its Power," and maintained it with so much ability and logic, that his exposition, with a few changes in terminology, was capable of adaptation to the dynamical theory of heat shortly thereafter demonstrated, and accepted by himself before his death. For in it he showed, that the amount of work possible to be done by any heat engine, depends upon the quantity of heat transferred, and the difference in temperature between the source of heat, and that of the appliance in which its expansion and loss of temperature occurs, as in the cylinder of the steam engine. Which, in effect, was the second law of thermodynamics as later enunciated by Clausius, in 1850. It is plain from the language of his monograph mentioned, that Carnot had grasped the fundamental idea of the Conservation of Energy, for he stated therein "that motive power is, in quantity, invariable in nature, and can neither be produced nor destroyed." To demonstrate this principle he constructed what he called a reversible engine, where the amount of heat (caloric) applied, and the amount of motive power (energy) realized, could be observed and investigated under ideal conditions. In his early death at the age of 36, the world lost a clear and thorough thinker.

The true nature of heat as a form of motion began to be correctly understood when Rumford raised the temperature of a block of iron by drilling a hole into it with a steel bit. Following this demonstration, it was shown that two pieces of ice rubbed together would result in the melting of both, and that if a paddle was turned rapidly enough in a vessel of water, and long enough, the water could be brought to the boiling point. In all these cases the rise in temperature results from friction, by which the molecules of the substances affected are caused to vibrate more rapidly among themselves than they do under normal conditions. Ice is cold to the touch because, when taken into the hand, the normal vibrations in the flesh which produce the natural body temperature of about 98° Fahrenheit, are slowed down by the transference of part of that rate of vibration to the ice, the temperature of which at once begins to rise above its normal of 32° Fahrenheit. Heat is then said to pass from the body to the ice, but in reality only motion passes, and in the transit the work performed is that of the melting of the ice, consisting of its change from the condition of a solid to that of a liquid.

In interplanetary and interstellar space, where matter is believed to be non-existent, temperature also does not exist. The absolute zero has been calculated at minus 273° on the Centigrade scale, and minus 491° on the Fahrenheit. A close approach has been made to it when the elementary gas helium was liquefied in 1898 at the temperature of minus 250° Centigrade and the gas hydrogen solidified at minus 257° C. At the absolute zero it is believed that all molecular motion ceases, and simultaneously all capability of chemical action.

LYELL (1797–1875)

GEOLOGY

Charles Lyell was born at Kinnordy in Scotland. His early education was received at Midhurst in the south of England, after which he entered Oxford, receiving his degree of M.A. in 1821. He then enrolled himself as a student in law and was admitted to practice in 1824. During these seven student years he took an active interest in the meetings of the Geological and the Linnean Societies, and contributed a number of creditable articles on science to the technical periodicals of the time. In 1826 he was elected a member of the Royal Society. Two years later, in company with Sir Roderick Murchison, he traveled in various parts of Europe, and in Sicily became deeply interested in the many evidences of the slow but steady elevation of that island from the sea. These led him to the belief that geological changes are not catastrophic phenomena as was the general opinion of the day, but gradual movements, persisting through long ages. Finding ample confirmation of this theory wherever he went, and particularly in Germany, England and Scotland, where he made exhaustive study of the Tertiary formation and its fossils, he began the writing of his great work entitled "Principles of Geology," the first volume of which appeared in 1830, and the other two in 1832 and 1833. This production proved to be epochal in its effects. Previous to its issue the catastrophic theory advocated by the German geologist Werner had been accepted everywhere, partly because of the great ability with which it had been presented, but mainly because it was not antagonistic to the orthodox conceptions of the creation of the world. As Lyell's views could not be squared with the latter, his books precipitated as violent a controversy between the old and the new schools of thought, as did those of Darwin thirty-five years later. The demand for them passed all expectation, and before a decade had elapsed their conclusions were accepted everywhere outside of the most conservative circles. It should be here stated that Lyell did not claim originality for his beliefs. On the contrary, and in the most explicit terms he called attention to the fact that Hutton, nearly a half century previously, had been the first to advance the doctrine in his "Theory of the Earth," which appeared in 1795, but had attracted practically no attention because of the comparative social obscurity of its author.

Lyell is, however, popularly regarded as the founder of the modern science of geology. And because of his extensive travels, and the wide opportunities they afforded to present examples of the views he advocated, he was able to cite such abundant proofs, and to give them in language so simple and interesting, that denial of their verity in general could not logically be maintained. At the present time these, under the unwieldy name of "uniformitarianism," are everywhere accepted; though naturally, in many matters of detail, his conclusions have been modified, or even supplanted, as a result of the accumulation of new and more precise information as the science, and its allied branch paleontology, expanded.

When Darwin came upon the stage and enunciated his theories on Evolution, Lyell, then an old man, and the recipient of many honors from scientific societies all over the world, became one of his most enthusiastic supporters. He was knighted in 1848, and later received a baronetcy. Twice he came to America, in 1841 and 1846, and delivered lectures on geology which drew large and appreciative audiences. His mortal remains rest in Westminster.

HENRY (1799–1878)

ELECTRICITY

Joseph Henry, an American physicist, was born at Albany, in the state of New York, and received his education at the Academy of that city where, at the age of twenty-seven, he became professor of mathematics. In 1832 he was appointed to the chair of physics at Princeton University, form which post he went in 1846, to become Secretary of the Smithsonian Institute at Washington, a position which he held during the remainder of his active life. In 1849 he was elected president of the American Association for the Advancement of Science, and in 1858 to the same position by the members of the National Academy of Sciences. Upon the establishment of the Lighthouse Board in 1852, he became a member, and in 1871 its chief.

Throughout his whole professional career he was pre-eminently an experimenter of the highest order, specializing in the domain of electricity which, at the time, was attracting the attention of investigators throughout the educated world, to a greater extent than any other department of science. He is properly to be credited with the invention of a number of devices for enabling the electrical current to perform work, by far the most important of which was his installation of a mile or more of fine copper wire, between his residence and his laboratory at Princeton, which employed the earth for the return circuit, a completely new idea then. This construction, provided at one end with the equivalent of the telegrapher's key, and at the other with a crude form of the electromagnet and armature, was arranged to ring a bell, and constituted the first real telegraphic system, the foundation upon which, in 1837, Morse perfected the instrument, and invented the code of signals by which it became possible to transmit language. In other words, Henry was the first utilizer of the principle at the foundation of the telegraphic art, but Morse was the inventor of the apparatus by which it became a practical one.

In acknowledgment of the great part his labors had to do with the marvelous art of telegraphy, his name (henry) was adopted by the International Electrical Convention as the unit of induction in an electrical current, when the induced electromotive force therein is the equivalent of one volt, while the inducing current varies at the rate ot one ampere per second.

VI

THE NINETEENTH AND TWENTIETH CENTURIES

Most readers are already familiar with the political history of this century and a quarter; however, it may be of advantage to summarize its salient features.

Great Britain, despite numerous external wars, has preserved a large measure of domestic tranquillity and has remained the greatest colonizing nation in history. By the middle of the last century she had become the commercial and financial center of the world. In the field of science she has produced a noteworthy group, as the list shows.

Germany threatened for a time to wrest away Great Britain's commercial supremacy. Under the strong leadership of Prussia she attained political unity in 1870, and built up under a benevolent despotism a vigorous national life in which learning, commerce, and militarism worked conjointly. But militarism got the upper hand, and in the disastrous World War Germany lost ground in both the other fields, which it will take many years to regain.

The Napoleonic Wars of a century ago left France impoverished in many ways. The periods of domestic upheaval and outside wars, which have succeeded, have likewise seriously handicapped her scientific attainment. Yet of her small group of scientists at least six have been of the first rank.

The outstanding factor in this period is the rise of the United States from an untried nation to a great world power. The aftermath of war has given this country tremendous financial and political power. In the fields of invention and science the contribution has been likewise noteworthy—a promise of still greater things to come.

DUMAS (1800–1864)

CHEMISTRY

JEAN BAPTISTE DUMAS was born at Alais in southern France. His education in fundamentals was excellent, but in the higher branches not so good. Nevertheless, from early youth he was constantly experimenting in chemistry, and by reading acquired a thorough knowledge of its principles. Family necessities compelled his apprenticeship to an apothecary in Geneva, Switzerland. While serving there he privately carried on some chemical investigations which came to the knowledge of De Candolle, the botanist, and resulted in his removal in 1823 to Paris, where he secured the position cf tutor at the Polytechnic. This led later to the position of a professor at the Athenaeum, where his ability and charm as a lecturer soon secured his transfer to the university popularly knwon as the Sorbonne, and his election as a member of the Academy of Sciences.

The temperament of Dumas was that of the investigator, and in a very short time he became known internationally through his research work on the atomic weights of the elements, on the properties of sulphuric ether, and on the phenomena of substitution in organic chemistry. In his time the question of the relative atomic weights of those elements then known, was a matter of first importance to the chemist, for Dalton had but recently (1808) published his theory of atomicity, and demonstrated its vital relation in the processes of analysis. In accordance with the hypothesis put forward at the time by Prout, to the effect that all the elements were probably compounds of hydrogen, which was admitted then to be highly probable; to that gas, the lightest substance known, was given the weight of 1, and to all the others, as fast as determined, the higher number which, by comparing their weight to that of hydrogen, repeated determinations indicated they should have. By the early chemists these figures were preferably called "combining equivalents." Later, as hope for undoubted evidence of Prout's idea declined, and was practically abandoned—and by most students forgotten—it became more convenient for several reasons to adopt oxygen for the standard of relative equivalence. The change accordingly was made about 1868, and has remained in force ever since. But, curiously enough, the knowledge acquired during the last ten years or so of the nature of the chemical atom, has resulted in the revival of Prout's hypothesis, and led many physicists already to the belief that before long it will be clearly demonstrated to be true. However, when and if that occurs, it will effect no change in the methods and results of laboratory work, and, in fact will be a matter of indifference to the chemist, for the new atom will then have become purely a physical affair, a unit or a collection of units of energy, with whose behavior as such he will have neither the desire nor the power to deal, for the molecule will still remain—as now—his exclusive field, and will continue to respond as immutably as heretofore to his manipulations.

The compound upon which Dumas made his investigations under the name of "sulphuric ether," was the first of the anaesthetics, having been accidentally discovered by the alchemists as far back as some time in the 13th century. But by them neither its composition, nor a method of producing it with certainty, nor its properties of inducing temporary insensibility to pain, were known. They regarded it as a most dangerous substance, the equivalent of a deadly poison. It was assumed to contain sulphur in the form of sulphuric acid, but in the pure article neither are present. Its true composition was not known until early in the 19th century. As the result of the researches of Dumas its properties became sufficiently understood to permit of its employment in long surgical operations, where nitrous oxide cannot be used because its effects are too transitory.

In the early years of the science of organic chemistry, after the existence of organic radicals had been well established, and after the electronegative and electropositive theory of Berzelius had been applied to them without success, Dumas was able, as the result of experiments he had been making on acetic acid, where he found he could substitute chlorine for hydrogen, and still have a compound retaining most of the properties of the acid; to suggest, in 1839, that a like process of substitution should be possible with organic radicals, provided they were first catalogued into types. This was the fundamental step in the celebrated "theory of types," which was subsequently worked out with perfect success, and was recognized during the lifetime of its originator as one of the most important advances in the development of the science.

After the revolution of 1848, which overthrew the government of Louis Philippe, Dumas became a member of the Council of Education; and from 1849 until 1851 he was a member of the Department of Agriculture and Commerce. After the *coup d'état* in 1852, which revived the Empire and carried Napoleon III to the throne, he became a senator, and a member of the Council of Public Instruction. During the remainder of his active life, while contributing frequently to the pages of scientific periodicals, he served the public in various capacities, and was regarded as one of its foremost citizens.

WÖHLER (1800–1882)

CHEMISTRY

FRIEDRICH WÖHLER, a native of Frankfort-on-the Main, in Germany, was educated at the local gymnasium, and then studied medicine and chemistry at the universities of Marburg and Heidelberg. After graduation he became asisstant to the chemist, Berzelius, in Stockholm, Sweden. In 1825 he moved to Berlin, and became an instructor in chemistry at the newly established industrial school of that city. In 1836 he took the chair of chemistry at the University of Göttingen, where he remained until his retirement.

During the first quarter of the 19th century, the science of inorganic chemistry became well established. Most of the commoner elements had been recognized as such, the atomic theory of Dalton had been demonstrated beyond all question, Lavoisier had introduced the balance as the fundamental tool of the laboratory, Berthollet had made clear the principle of chemical equilibrium, and Gay-Lussac the law of combining volumes.

But in the domain of organic chemistry, which has to do with those forms of matter found in living things—plants an animals—the old alchemistic theory of a "vital force" as the cause of the myriad transformations constantly in progress in the world of life, still held sway.

When, therefore, Wöhler announced in 1828 that he had effected the synthesis of urea, a compound that derives its name because it was first found in human urine (of which it forms the most important and characteristic ingredient), the intellectual world of the day was notably startled, and the conservative part of it—as usual—rather shocked. When the discovery came to the notice of Liebig, who was perhaps the most widely known chemist of the time, and also a man wholly free from prejudice, he took it up with enthusiasm, and, working with Wöhler, laid broad and deep the foundations of the science of organic chemistry which, since then, has become the most comprehensive of all the sciences, without which the industrial life of the present time could not have arisen.

To Wöhler also belongs the credit of discovering the first case of isomerism, that is, the existence of organic substances or compounds which have identical composition, and yet entirely distinct properties. Since his day many hundreds of such have become well known.

In 1832, in collaboration with Liebig, they took up the study of a series of compounds allied to benzoic acid, an organic substance occurring naturally in certain gums, and found that they could be changed into one another, and that throughout these transformations a group of atoms consisting of carbon, oxygen and hydrogen remain unchanged. They called the latter the benzoyl radical. This was quickly followed by the discovery—also by them—of the ethyl radical, which is common to alcohol and ether; of the cacodyle radical by Bunsen, which is possessed in common by several compounds of arsenic; and a number of others, all of which, though themselves compounds, behaved like single atoms of an element. Berzelius took up this important discovery in his enthusiastic way, and at once began to classify these radicals into the two groups of electropositive and electronegative, as he had already classified the elements; and endeavored to isolate them, under the belief that they were really undiscovered elements. In this he was unsuccessful, and when his electrochemical theory was abandoned it was for a time believed, in the chemical world of the day, that the theory of organic radicals or pseudo-elements would also soon have to be given up. For a while Dumas' theory of type radicals seemed to be capable of at least deferring the demise of the whole theory. Finally, the conception of valency was introduced into that investigation, showing the different ways in which the atoms could be linked together into these radicals. This, in the end, has explained why and how the molecules of different substances can be composed of the same number and kind of atoms, and yet possess entirely distinct properties. But in recent years it has become apparent that something yet has to be learned about the nature and behavior of these compounds, before the chemist will have complete manipulative control of them.

MÜLLER (1801–1858)

PHYSIOLOGY

Johannes Müller was a native of Coblenz in Germany, and was destined for the ministry, but abandoned that profession for medicine and physiology, obtaining his education at the University of Bonn, from which he graduated in 1822. He then pursued his studies for a time at Berlin, but returned in 1826 to Bonn to become at first a tutor, then an assistant professor, and finally, in 1830, a full professor. In 1833 he went back to Berlin, and took the chair of anatomy and physiology at the university there, a post which he retained for the remainder of his life.

His great work, entitled "Handbook of Human Physiology," appeared in the years between 1833 and 1840, and is regarded as an epoch-making production in its specialty, as it embodies all his important discoveries. He was the founder of a new school of practice in his profession. To him physiology owes the foundation of Bell's law, the principle of reflex movements, and a knowledge of the composition and source of cartilage. He discovered the pronephric ducts in the kidneys, explained the nature of hermaphroditism, laid the foundation of the present knowledge of the embryology and the metamorphoses of the echinoderms, discovered the lymph hearts of the amphibious animals, the micropyle of the eggs of fishes, and made clear many other theretofore obscure living structures and organs.

Cartilage is a firm elastic substance of a pearly color and apparently uniform composition but, like all other varieties of bodily tissue, when examined under the microscope, is resolved into a dense collection of cells with a matrix of fine fibrous tissue, itself also cellular. In the unborn child the skeletal bones begin as cartilage and some, particularly those of the extremities, are not ossified at birth. In fact, the process of changing into bone is rarely complete before the age of puberty, and many instances have been recorded where it was still in progress at the age of twenty.

All of the cartilage that exists in the body of the infant does not alter into bone. Some of it, wherever the joints occur, retain the original cartilaginous characteristics of flexibility and moderate elasticity, and become ligaments, tying the bones together at their ends. Another variety of this useful body substance is called the non-articular cartilage, because, as in the case of the nose, it is attached to a bone at one end only, the other end forming the flexible tip of that organ; or, in the case of the ear, the external shell-like convolutions.

The processes by which the soft cartilage of the child changes into the hard bone of the adult, consist of the infiltration into it of earthy material, consisting mainly of the phosphates and carbonates of lime, which render the former flexible substance rigid. This change is continuous and progressive through life, so that the bones of elderly people become brittle and are easily broken, while in the infant and the youth they are so flexible that a clean fracture is almost impossible. To secure the best physical development, the food in youth should contain plenty of lime. After maturity foods containing a minimum amount are preferable.

If the well cleaned bone of an adult is treated with a dilute mineral acid, the lime salts in it will be dissolved out, but the flexible cartilage throughout it will remain unaltered. If, however, the bone is burned, the cartilage will be destroyed, while the mineral constituents will remain largely unaffected, so that the shape is preserved. But a slight blow or shock will cause a bone so treated to crumble into ashes. Throughout life the bones are nourished, and fractures are knitted together, by the unaltered cartilaginous material persisting in their structure.

ABEL (1802–1829)

MATHEMATICS

Niels Henrik Abel was a native of Findöe, Norway, and educated at the University of Christiana. After two years spent in study in Paris and Berlin, he was employed as an instructor at the school of Engineering in Christiana.

During his brief career he became known, through his literary contributions to technical periodicals, as one of the ablest mathematicians of his day. His principal attention was given to the theory of functions, of which he, with Jacobi, were the founders. An important class of these—the elliptical—are known as the Abelian Functions, and were developed by him. He was the first to demonstrate the impossibility of solving by the elementary processes of algebra, general equations of any degree higher than the fourth. He also extended the capacity of the Binomial Formula, by including in its scope the cases of irrational and imaginary exponents.

In mathematics a function is a quantity whose value depends upon the value of another quantity. Thus, when the statement is made that the circumference of a circle (called "c" for convenience) depends upon the length of its diameter (called "d" for the same reason), then "c" is said to be a function of "d," the relationship between them being expressed symbolically by the Greek letter π, which stands for the constant figure 3.1415926, it having been demonstrated that invariably the product obtained by multiplying the length of the diameter by this figure will give accurately the length of the circumference.

Abel and Jacobi studied the ellipse, just as the circle had been studied centuries previously, and as Legendre had been doing at least a quarter of a century before they began, as shown by his notable work published in 1828. But their results surpassed those of Legendre in that they discovered the double periodicity of elliptical functions. As the planets and the periodic comets, as well as all the satellites of the planets, revolve in elliptical orbits instead of circles as believed by Copernicus, the importance of understanding all the properties of that curve—which has been called the circle of two centers—can readily be understood.

An equation, as the word is employed in algebraic work, is a statement made by the use of symbols instead of words, of a condition of equality existing only for particular values of certain letters or symbols representing (for the time being) unknown quantities. For those whose numerical value is sought, the letters "x" or "y" are usually employed. Thus, $2x + 3 = 9$ is a simple equation, because the statement of equality is true only if the value of 3 is given to the symbol "x." On the other hand the statement $2 + 5 = 7$ is a numerical statement of equality, but not an algebraic equation, because all the quantities are positive, definite and known. But if we write $x + 5 = 7$ we have the true simple algebraic equation, because the unknown value of "x" depends upon the values of the numbers "5" and "7," and may be readily ascertained by transposing the form of the equation, thus: $x = 7 - 5$, which is 2.

WHEATSTONE (1802–1875)

PHYSICS

Charles Wheatstone lived in Gloucester, England, and was a maker of musical instruments, ultimately becoming deeply interested in, and a reliable investigator of, the scientific principles involved in their construction and use. He was the first to make the attempt to measure minute intervals of time. This he accomplished by a device which he called a chronoscope, of which various forms have since been constructed. All depend substantially upon a mirror mounted on a vertical or horizontal axis, and caused to revolve at a high rate of speed, by means of appropriate machinery. The problem he set out to solve was the duration of the flash of an electric spark, which he accomplished with a mirror revolving at a speed of 800 turns per second. His results were published in 1834, in a monograph entitled "Experiments to Measure the Velocity of Electricity." This attracted so much attention, that he was appointed professor of experimental physics at King's College in London. Here he continued his researches, and in 1837, in association with Sir William Cooke, took out a patent for an "improvement in giving signals, and sounding alarms in distant places, by means of electric currents transmitted through metallic circuits." From this crude instrument grew the system of telegraphy which, modified and improved as the art was developed, was extensively installed throughout the British Isles.

To him is due the original conception of the stereoscope, which was later improved by Sir David Brewster; also the Polar Clock, an ingenious device depending for its action on the polarization of light, which does not require (like the sun dial), direct sunlight for its operation, but which is today merely a scientific toy. In 1840 he originated and developed, the idea of connecting a number of clocks far apart with a central clock, by means of an electric circuit, so as to insure their synchronism. He improved the design of what is now called the Wheatstone bridge (originally the invention of Hunter Christy), and employed it successfully in the measurement of electrical resistance.

Wheatstone was really more of an inventor than a discoverer, but possessed the valuable faculty of adapting discoveries made by others to useful purposes in the investigation of scientfic phenomena, at the same time never failing to give due credit to the originator of the idea borrowed. This happy temperamental characteristic was recognized by the nation, when he was knighted by the King.

DOPPLER (1803–1853)

PHYSICS

Christian Doppler resided at Salzburg, Austria, received his education at the Polytechnic Institute of Vienna, and after graduation, became an instructor in mathematics there. Subsequently he held academic appointment at the Technical Institute in Prague, the Polytechnicum in Vienna, and the Vienna University.

His contribution to the advance of knowledge consisted in the enunciation of what is known as the "Doppler Principle," which is as follows:

"If a body which is vibrating, and therefore causing vibratory waves in the medium surrounding it, such as sound, heat, light, electricity, etc., and at the same time is moving away from an instrument capable of receiving and recording these waves, their number or frequency per second is apparently decreased. On the other hand, if the vibrating body is approaching the receiving instrument, the wave number is increased."

This, in effect, is simply a statement of an extension to heat, light, and electricity, of a principle which for a long time had been well known with regard ·und. For, if a sounding body—a whistling locomotive for instance—is approaching a listener, he perceives that the pitch of the note becomes higher as it nears his position, and lower as it recedes; which means that, under the first condition, more of the air waves per unit of time come to his ear and under the second, fewer of them.

The extension of the principle to those waves in the ether which are called light, when coming from a star, or from the edge of the rotating sun, makes it possible to determine, not only whether the source of light is approaching or receding from an observer, but to ascertain with considerable accuracy, the velocity with which it is moving in space. For when the beam of light is split up by the spectroscope into its component colors, there will be a slight shift towards the blue end in the case of approach, and towards the red end in the case of recession. And when a photographic plate is used to record the radiation, the actual change in wave number per second can be measured, and thus a close idea obtained of the velocity at which the luminous body is moving.

By the use of this principle, the drift in space of a large number of the stars, has been approximately determined.

LIEBIG (1803–1873)

CHEMISTRY

Justus Liebig was the son of a dealer in dyes, in Darmstadt, Germany. His early education was very limited, and at the age of fifteen he was bound to an apothecary in the near-by town of Heppenheim. Here, by diligent work and economy he accumulated enough to enable him to matriculate at the University of Bonn, and later at that of Erlingen, where he graduated in 1822 with the degree of M.D. His first research and publication in science was on the fulminates, those extremely unstable compounds the most familiar being the fulminate of mercury, which is employed in the manufacture of detonating caps for use with high explosives. These monographs attracted the attention of Alexander von Humboldt, through whom he secured favorable letters of introduction to several of the noted chemists of the time, and ultimately landed as an assistant in the laboratory of Gay-Lussac in Paris. From then on his rise was rapid, culminating in the appointment to the chair of chemistry at the University of Giessen in 1824. There he remained for a quarter of a century, and attained a reputation so high as a discoverer and a teacher of his science that in 1845 he was created a Baron, and in 1852 was tendered the professorship of chemistry at the University of Munich, where he remained for the balance of his active life. In 1860 he was elected president of the Bavarian Academy of Sciences.

Liebig is regarded as the man whose work in the early days of the science of chemistry placed it on its feet systematically. He was an originator of new methods of analysis and synthesis, especially in its organic department. Though a brilliant lecturer and teacher he was also a notable discoverer. To him, for instance, we owe the discovery of chloral, chloroform, aldehyde and a host of previously unknown carbon compounds of vast importance in the arts.

He was also a pioneer in the study of the phenomena of life, and of what was then called the "vital force," which was assumed to be the active principle or agency in all forms of living things. He succeeded in demonstrating beyond question that no such a force existed, and that the phenomena appearing to require its presence were simply exhibitions of energy liberated in the state of animal and vegetable heat and motion through the processes of digestion and assimilation of foods. He was the first to show that the transformation of inorganic into organic material is the exclusive duty of the world of vegetation, and that only by the consumption of the products of that department of life in the shape of fruits, vegetables and grains, was it possible for animal life to obtain foods that could be changed into tissue and necessary bodily fluids. In fine, the now extensive and numerous sciences relating to soil fertilization and nutrition have been largely built up on the foundation of his work. He is universally accorded the honor of having been the founder of the science of agricultural chemistry.

MAURY (1806–1873)

GEOGRAPHY

MATTHEW FONTAINE MAURY was a Virginian by birth, but was educated at the Harpeth Academy in Tennessee. At the age of nineteen he secured the appointment of midshipman in the navy, and in 1827 made a voyage around the world in the Vincennes. In 1839, having met with an accident while on duty in which his leg was broken, so that he became a cripple for life, he was given a post in the Naval Office in Washington, where he had access to the accumulation there of old ships' logs for many years previously. He became deeply interested in these; and from the weather records which they gave he constructed a series of wind and current charts, which were later embodied in his notable work entitled "The Physical Geography of the Sea." This was the first collected body of information in regard to marine phenomena. It was published in 1855 and marked the beginning of a new branch of meteorological science which, during the years that have followed has been extensively cultivated by a number of investigators.

To the mariner a knowledge of the location, direction and velocity of such major oceanic currents as the Gulf Stream in the Atlantic and the Kuroshiwo—better known as the Japan—current of the Pacific, is of vital importance, while data relating to the minor currents produced by the tides, the configuration of coast lines and the revolution of the earth on its axis, together with those periodical or seasonal atmospheric movements known variously as monsoons, typhoons, hurricanes, etc., are even more necessary to aid him in avoiding the perils of the sea. To Maury belongs the credit of having initiated the investigation of these phenomena which, since his day, have been studied and described by Ferrel in his "Winds of the Globe"; by Agassiz in his "Three Cruises of the Blake"; by Pillsbury in the Annual Reports of the U. S. Coast Survey, and by Thompson and Blake in their "Reports of the Scientific Results of H. M. S. Challenger."

When the Civil War broke out Maury offered his services to the Confederacy, who sent him in 1862 to Europe on a political mission. After its termination he went to Mexico, and took service under the Emperor Maximilian as Commissioner of Emigration. When the government of that unfortunate ruler was overthrown he returned to the United States, and was appointed to the chair of Physics in the Virginia Military Institute, where he remained during the balance of his life.

AGASSIZ (1807–1873)

GEOLOGY

Louis Agassiz was the son of a clergyman, in Motier, Switzerland. After completing his primary studies at Lausanne in that country, he followed up the higher branches at the universities of Zurich and Heidelberg, specializing in medicine and zoology. After taking his degree in 1830 he went to Paris, and studied under Cuvier, becoming his ardent disciple. From 1832 to 1846 he was professor of natural history at the University of Neuchatel, and during that period, in collaboration with James D. Forbes, and at times with Arnold Guyot, devoted his summers to studies of the Swiss glacial phenomena. The discoveries made by these three men have been of the greatest value to science in general, and especially to geology, archaeology and anthropology, in explaining the part that has been played by the Glacial Era in erosion, and in the history of mankind, and the animal world.

In consequence of his ability and charm as a lecturer, Agassiz was invited in 1845 to come to the United States, by the Lowell Institute of Boston. In 1846 he was appointed professor of natural history in the Lawrence Scientific School of Harvard University, a position which he retained for the remainder of his life.

Erosion is the process by which the surface of the earth is carved into the relief of plain and valley after its first distortion and wrinkling into ocean beds, mountain ranges and high plateaus by vulcanism, or contraction of the crust on cooling. It is the work of the winds, the rivers and streams, the falling rain and snow and the ice in glacial eras and local glaciers. The first of these agencies does mainly finishing work, piling up dunes in arid regions and along sea shores, and occasionally in confined areas acting like the familiar sand blast in sculpturing rocks into all kinds of fantastic shapes. The work done by the rivers and streams is necessarily confined to the deepening of their channels and the creation of bars along their sides, while the rain and snow do little more than fill up depressions, or find natural lines of travel which later become the channels of rivulets and creeks. The ice, however, is the great erosive agent, and no more impressive exhibition of its capacity in that line is to be found than in the northern parts of the North American continent, where the great sheets of the last glacial era have worn away several thousand feet in thickness of sedimentary rocks over hundreds of thousands of square miles of area, and carried the vast cargo of sand, gravel and boulders southward across the Canadian border into the United States, finally dropping it in the form of a terminal moraine over 2000 miles in length which today constitutes the southern divide of the St. Lawrence valley and the Great Lakes.

The erosive work performed by rivers, though insignificant as compared with that of ice, may yet be impressive and important. The Mississippi carries each year into the Gulf of Mexico nearly 270 cubic miles of fine debris. Its source in the state of Minnesota being 1462 feet above the waters of the gulf, and its length (including its windings) about 2500 miles, its average grade is less than 6 inches per mile, which makes it a very second rate eroder. Yet practically the whole state of Louisiana has been built up by it, and it is still steadily extending it into the sea.

The ocean along its shores, where wave action extends to the bottom, is also an active erosive agent, though of minor importance; while the tides and the shore currents carry away the material its waves break down, pulverizes it, and distributes it in layers on the near ocean floor.

GUYOT (1807–1884)

GEOGRAPHY

Arnold Guyot was born in Switzerland, near the town of Neuchatel. His early education was obtained at the local schools, and completed at the University of Berlin. From 1835 to 1839 he was a private tutor in Paris, and from the latter date to 1848, the professor of physical geography at the College of Neuchatel. He then emigrated to America, settling at Boston where, from 1848 to 1854, he lectured under the auspices of the Massachusetts State Board of Education. From 1855 until his death, he occupied the chair of physical geography at Princeton University.

Guyot's contributions to the advance of knowledge, were largely the outcome of his studies of the phenomena of glaciers which, among other matters of lesser importance, resulted in his announcement in 1838, in a paper read before the Geological Society of France, of the correct explanation of the laminated structure of these rivers of ice. Attention having thus been called to this line of investigation, the work was carried on by Agassiz and Forbes, and later by Tyndall. At the present time, almost entirely as the result of the studies of these four men, the work performed by ice in erosion, and by the Ice Age in the history of animal and vegetable life, has become fairly well understood.

To Guyot is very largely due the system of meteorological observation which has made the United States Weather Bureau such an efficient organization, and the model upon which practically those of all the other nations of the world have been built. He also made extensive barometrical surveys of the Appalachian mountain chain, and prepared meteorological and physical tables of the eastern coastal plain of the country, which have been used ever since.

In the lower portions—the foothills—of a high mountain range, the snowfall of a winter ordinarily disappears completely during the following summer; but in the higher parts, where the precipitation has been greater and the summer heat less, there is often a steady accumulation. If this process went on indefinitely, it is evident that in due time the entire upper parts of ranges and high plateaus would be buried under sheets of ice for, as snow accumulates in depth it packs under the increasing weight, and changes gradually into ice. And this is actually what has happened in the interior of Greenland and other broad areas in the polar regions, where the slope of the surface is gentle.

But usually a form of relief is provided. As the mass and weight increases, the ice begins to move downhill in all possible directions—which naturally are those of ravines and valleys—carrying with it, and imbedded firmly in its under side the gravel, sand and boulders of their slopes and floors; and on its surface such of the same materials as fall down upon it from higher parts. Thus the frozen stream becomes a gigantic rasp, or a section of very coarse sandpaper, each year cutting deeper and deeper into the bottom and sides of the gorge in which it flows.

When the river of ice reaches lower altitudes where summer temperatures prevail over those of winter, the ice melts, depositing the surface load of debris it has brought down from above, thus forming what are called lateral moraines, that is long lines of gravel sand and boulders on each side of its path, while at the end another mass of the same material is unloaded. So long as a glacier is advancing, that is, pushing its way out through the throat of a valley or ravine into lower altitudes where the slope of the surface is less, the former continue to grow in length and height, and no terminal moraine appears. But when, as the result of the amelioration of general climatic conditions, the glacier begins to retreat, the latter commences to form, steadily increasing in mass, height and width, until a wall or dam is built up across the valley, and a lake basin, or several of them come into existence.

DARWIN (1809–1882)

BIOLOGY

Charles Robert Darwin was reared in Shrewsbury, in the west of England, where he attended the public school. Following this, he worked through two sessions at the Edinburgh University, and then went to Cambridge, graduating in 1831 with the degree of B.A. Very shortly thereafter, he was offered the post of naturalist to the expedition which circumnavigated the globe in H.M.S. *Beagle,* taking five years for the journey.

Though he attained the age of 73, and in his appearance gave the impression of a rugged constitution, yet his frame was slight, and the long voyage, with the constant physical and mental worry it entailed, left him with an impaired digestion, from which he never recovered, and which permitted him only a limited amount of work per day. Nevertheless, between 1839 and 1881 he wrote and published eighteen books, practically all of which were based on the notes collected while on that memorable voyage, though also extensively supplemented by information collected afterwards, by personal observation, and through correspondence. All of these are notable productions. But the "Origin of Species," and the "Descent of Man," which appeared respectively in 1859 and 1871, are the two that gave him his world-wide reputation, as the discoverer of one of the great laws of nature, that of Evolution.

When the first of these appeared, it aroused the greatest interest among educated people everywhere, and largely through the extraordinarily able championship of Huxley, Spencer, and other leading thinkers of the time, its conclusions were widely accepted, in spite of the fact that it substituted a natural and orderly explanation of phenomena, that previously had been accounted for by a supernatural one. Instead of Creation it offered Development, as the actual cause of all forms of life. Naturally such a theory could not be harmonized with the teachings of the Church, and among its leaders arose its bitterest opponents.

When his second book appeared, advancing the belief that not only the human body, but the human mind, was an evolutionary product, and that we are akin to the animals of the field, the fowls of the air, the fishes of the sea, and the trees of the forest, a doctrine so revolutionary in all its aspects shook the world like an earthquake. But Darwin's conclusions were based on the firm foundation of observed facts, and could not be set aside. They are now universally accepted.

In all his writings, Darwin made no attempt to explain evolution. He advanced it as a fact, not as a theory, just as Copernicus did, in the case of the motions of the solar system, and as Newton in respect of gravitation. In each case the How and Why remain unexplained. Since his day evolution as a Cause, has been found to be active in every branch of science which is capable of being investigated by the human mind. It is one of the fundamentals of the Cosmos.

FORBES (1809–1868)

PHYSICS

James David Forbes was a native of Scotland, and was educated at the University of Edinburgh for the law; but his inclinations led to the study of physics, and in 1833 he became professor of natural philosophy there. His researches resulted in the important discovery of the polarization of heat rays, for which he was awarded the Rumford medal by the Royal Society of London.

During the years between 1836 and 1843, he devoted his summers to the investigation of glacial phenomena, at first in Switzerland, in association with Agassiz; and in 1844 published an account of them, under the title of "Travels through the Alps,'' which is regarded as a classical production on the subject. In 1851 he made a similar study of the glaciers of the Scandinavian peninsula. Two years later appeared his final work, ''A Tour of Mont Blanc and Monte Rosa,'' on the same subject.

Those undulations in the ether which affect our sense of vision or produce the sensations of heat, are like those which travel through a cord when one end of it is fixed, and the other vigorously shaken; waves which rise and fall at right angles to the direction in which they travel. There is no travel in the string, or in the ether, but the impulse in the latter does move from its source to the eye, as it does from the free end of the string to its fixed end. Each such impulse is called a ray and, according to the length from crest to crest of its individual undulations, it may be either a ray of light, or of heat, or of electrical energy. Space is filled with countless billions of them, coming from all directions, and moving with undulations whose crests and troughs point to all imaginable angles that might be conceived on the plane of a circle, perpendicular to their course.

Assume now that across the path of a beam of such rays, a thin slice of the apparently transparent mineral tourmaline is interposed at right angles to the direction of its travel. When it issues from it, it is found that all the rays composing the new beam are now undulating in waves whose crests and troughs are parallel to each other. Two inferences are permissible. Either the crystal, owing to the peculiar manner in which its molecules are arranged, has cut off and refuses to pass all except those vibrating in a certain plane; or else, in addition to passing them, it has compelled all the others to change the angle of their undulations. It is as if the crystal had a long and extremely narrow slit through it, which either cut off all rays except those vibrating in planes parallel to its length, or else, if passing them, compelled the others to accommodate themselves to the direction of that length. To determine which is the case, let there be interposed across the now ''plane polarized'' beam—as it is called—another slice of the same mineral, taking care that the face of this second slice is parallel to the face of the first. If now the second one is revolved in its plane it will be found that in a complete revolution of 360° there are two positions exactly 180° apart, in which the beam fails to pass through it, while halfway between these two it emerges with maximum intensity. Evidently then, while the tourmaline in thin slices is apparently transparent, because some rays are always striking it in the proper way to make the transit, yet it is completely so only in one direction.

Substances like well-made glass or pure water, being strictly homogenous in structure, pass freely—if not too thick—all the rays that impinge vertically on their surfaces, and may properly be called transparent. Crystallized substances are more properly spoken of as translucent. Each of the seven great crystallographic systems—the triclinic, monoclinic, orthorhombic, tetragonal, trigonal, hexagonal and isometric—if to any degree translucent, has its own way of dealing with the ethereal rays; and these having been learned by experience, it becomes possible in many cases to determine instantly the class of a mineral (and often its membership therein) by subjecting a thin slice of it to the action of a ray. Thus the polariscope which is the name given to the instrument for polarizing rays of all kinds, has become a valuable tool in the hands of the mineralogist and geologist. In the applied arts it is also extensively employed, as, for instance, in the testing of raw sugar, to determine the amount of crystallizable sugar it contains.

GRAY (1810–1888)

BOTANY

Asa Gray was a native of the little town of Paris, New York. He received a thorough medical education and intended to follow that profession, but was diverted to the study of plants, and became ultimately one of the noted botanists of his day. In 1842 he entered the faculty of Harvard College as professor of natural history, and remained in that position until 1873, when he resigned, and devoted the rest of his life to the care of his extensive herbarium, which at the time was the most complete on the continent. He was a voluminous writer on his specialty.

The work of Gray was mainly along the lines of classification and description, for which he had a real genius, and which led to several conclusions of great importance. One of them was to the effect that species in plants have but one place of origin, and spread from there as an effect wholly of physical causes, such as prevailing winds, etc. He was one of the first American scientists to espouse with vigor the doctrines of evolution as enunciated by Darwin. Yet having been brought up under strictly orthodox principles, he was unable to cast them aside entirely, and maintained to the last that variation in all departments of organic life was guided by a supreme and intelligent Power, and that evolution as a principle could thus be reconciled with the strictest of church creeds. This inability to differentiate between the Creator of the Law, and the effects of the law itself, has troubled too many otherwise clear-headed indivduals among earnest scientists, as witness, for instance, the cases of Cuvier, Lyell and even the great Newton himself.

Gray was a veritable apostle of classification in his specialty. Previous to his time great confusion had existed in the work of naturalists because no international system was in existence. About then the British Association for the Advancement of Science, in collaboration with like organizations in the United States, France and Germany, took the matter up in earnest, with the result that a system was devised which has since been rigidly followed with great advantage. Today a name for a new species is not recognized unless it is in the customary binomial form (which originated with Linnaeus), the two words being in the Latin language, and agreeing in number and gender. In botany the system begins with the four great classes of Thallophytes, Bryophites, Pteridophytes and Spermatophytes. Each of these is subdivided into Orders; the orders

Facing page 290

into Families; the families into Genera; the genera into Species; the species into Races, and the races into Individuals; the last being the popular or familiar name by which the plant is known, and which differs in each language. By comparing this with the simple system of Dioscorides of Trees, Shrubs and Plants the changes since his day become apparent.

From 1863 until 1873 Gray was president of the American Academy of Sciences and Arts, and in 1872 occupied that position in the American Association for the Advancement of Science. He was an honorary or corresponding member of many European scientific societies. His botanical investigations extended into fossil vegetation, and led to the direct conclusion that plant fossils from two consecutive geological formations were far more closely related than those of two remote formations. This, he naturally concluded, was confirmatory of the general principles of evolution.

ANDREWS (1810–1897)

CHEMISTRY

THOMAS ANDREWS was born at Belfast, Ireland, and studied medicine and the physical sciences at the universities of Glasgow, Edinburgh, Dublin and Paris. After practicing as a physician for several years in his native city he was appointed in 1845 professor of chemistry at Queen's College, Oxford, where he remained for thirty-four years. He then resigned and devoted the rest of his life to research.

In 1861, when investigating the properties of certain gases, he reached the important conclusion that for each one of them there is a definite degree of temperature (or absence of it), above which no amount of pressure will cause it to change into a liquid. Below that figure a gas will sometimes partially liquefy, but precisely at it—called the critical point—it passes at once into the liquid state. This point differs for each gas. Similarly it has since been found that for each of them there is also a definite pressure and temperature figure at which alone the liquid will become a solid. In consequence of this discovery, all the known gases have since been reduced to the liquid condition, and all but helium to that of a solid.

Andrews also made a special study of ozone, and to him is due the most of what is known at the present time of the properties of that substance. Technically considered, it is an allotropic form of the elementary gas oxygen; that is, one of the states which the element can assume without loss of its elementary character, but which is accompanied by marked differences in some of its physical properties. A number of the elements possess this capacity, notably sulphur, phosphorus and carbon, and many chemists hold that allotropism can occur with any of them, given the proper conditions, inasmuch as it seems to be wholly a molecular phenomenon. The molecule of normal oxygen consists of two atoms (O_2). When in that state it is colorless, tasteless and odorless. If reduced to a liquid it is transparent, displays a faint blue tint, and begins to boil and return to the gaseous form at $-181.4°$ C. In the solid state it presents a dead white appearance. The molecule of ozone consists of three atoms of oxygen (O_3), possesses a faint bluish color, but also a strong but not unpleasant odor. At $-100°$ C. it becomes, under the proper pressure, a very deep blue—almost a black—liquid, which begins to boil at the temperature of $-106°$ C.

Ozone was first observed in 1785 by the Dutch student Van Marum, who produced it undesignedly when passing an electrical current through some oxygen, and detected its peculiar odor. He also noticed that the same effect was always produced in the immediate vicinity of a frictional electric machine. In both cases he concluded that it was "the smell of electricity." In 1801 the same odor was observed by an English chemist named Cruikshank, who was engaged in decomposing some water by electricity. This time the phenomenon was ascribed to the accidental presence of a little chlorine which, if in very small quantities, has a somewhat similar effect on the olfactory nerves.

Finally, in 1840, the attention of the German chemist, Schonbein, was drawn to the matter, and after a prolonged research he announced in 1845 the discovery of a new gas, giving it the name it now bears. A few years later the French chemist, Soret, demonstrated its true character as merely an allotropic form of oxygen.

Ozone is always present in minute quantites in the atmosphere, and in much larger quantities after a violent thunder storm, during which it is produced, giving the characteristic fresh and clean effect so noticeable after such a storm has passed away. It is a more powerful oxidizing agent than normal oxygen. Under confinement it will reduce iron, copper, mercury and even silver from the metallic state to that of the oxide, and will rapidly destroy rubber and vulcanite. It is a powerful bleaching agent and germ destroyer. The latter property is sometimes employed in purifying the air in hospitals and clinical amphitheatres. Whenever and wherever the atmosphere produces an exhilarating effect, and impresses one as unusually fresh and clean, it will be found to contain temporarily more than its average content in ozone. The phenomenon is nature's way of purifying the sea of air we live in when, for any reason, it has become abnormally impure and unhealthful.

DRAPER (1811–1882)

CHEMISTRY

John William Draper was brought up near Liverpool, England; and received his education at a Wesleyan school, and at the London University. At the age of twenty he emigrated to America, entered the University of Pennsylvania, graduated there with the degree of M.D., and was at once appointed to the chair of natural philosophy at Hampton College, Virginia. In 1839 he became a member of the faculty of the University of New York. A little later, he joined with others in organizing the medical school of that institution, becoming its first professor of chemistry and physiology.

Dr. Draper's principal contributions to the increase of knowledge were in the field of physical and photo-chemistry. By means of his actinometer—produced in 1842—he effected the quantitative combination of hydrogen and chlorine for the first time, solely under the action of light; and while his apparatus and methods were much improved later by Bunsen, Roscoe, Elder and Rigolet, yet to him belongs the credit of having led the way. He was also the first to demonstrate that the different colored rays into which a beam of sunlight can be split, exercise an unequal influence on the decomposition of carbon dioxide by the green pigment (chlorophyl) of plants. He further showed that all parts of the solar spectrum (the invisible as well as the visible) are capable of initiating chemical action of some kind. Finally, though Daguerre was the real discoverer of the art of photography it was not until improvements were made in its technic by Draper, Archer, Maddox and others, that it became a practical one.

He was a voluminous writer on many different subjects, and perhaps is best known by his "History of the Intellectual Development of Europe," published in 1863, which, though somewhat discredited at the present time, was a most scholarly production, and is still read, because its main conclusions have been verified by the lapse of time.

LEVERRIER (1811–1877)

ASTRONOMY

Urbain Jean Joseph Leverrier spent his youth at Saint Lo in northern France, and after passing through the Ecole Polytechnique at Paris, where he exhibited high mathematical ability, became a government employee. At the age of thirty-five, in consequence of the publication of a monograph entitled "Tables de Mercure," and several others of note on the secular inequalities of planetary motions, he was elected a member of the French Academy, and at the suggestion of Arago the astronomer, undertook an exhaustive investigation of the perturbations that had been detected in the motions of the planet Uranus, and to a lesser degree in those of Saturn and Jupiter, the cause of which was conjectured to be due to the existence of another yet undiscovered member of the solar system, beyond the orbit of the three mentioned. After prolonged and laborious calculations, Leverrier indicated the boundaries of a region in space where the supposed planet should be found, and when this area was examined by the astronomer Galle of Berlin, the planet Neptune was discovered on September 26, 1846, in very close proximity to the exact location assigned by Leverrier.

It is proper here to note that while the latter was at work on this problem, the English astronomer, Adams, an equally gifted mathematician, was also engaged on the same calculation, and really finished it first. He gave his results to the English observer, Challis, who actually found the planet at the place indicated, and between the dates of August 4th and 12th of the same year. But Challis neglected working up the notes of his observations for more than a month, and so failed to recognize the object as a planet, until after its detection by Galle had been published.

As Neptune travels in an orbit whose mean distance from the sun is 2,800,000,000 of miles, and requires 164 years to complete one revolution around that luminary, its discovery by these two astronomers almost simultaneously, is rightly regarded as one of the most remarkable of human accomplishments in the domain of mathematics.

In recognition, Leverrier was given the grand cross of the Legion of Honor, a professorship in astronomy in the faculty of Sciences in Paris, and the directorship of the Paris Observatory, which honorable positions he held during the remainder of his life.

BUNSEN (1811–1899)

CHEMISTRY

Robert Wilhelm Bunsen was born at Göttingen, Germany, and educated at the University of Heidelberg. After having held professional positions at Cassel, Marburg, and Breslau, he was appointed to the chair of chemistry at Heidelberg, a position which he held until his retirement in 1880 from the field of instruction.

He was a noted investigator and experimenter in chemistry and physics, and contributed extensively to the advancement of science. One of the most useful of his devices is known as the Bunsen burner, by which, employing ordinary illuminating gas, an almost invisible flame of very high temperature is produced. Its principle is now universally employed wherever cooking with gas is done.

Bunsen's great achievement, however, was the development of the methods of spectrum analysis, the foundation of which had been laid by Fraunhofer's identification and explanation of the dark absorption lines in the solar spectrum. In collaboration with Kirchhoff—to whom almost equal credit is due—the investigations of the two, led first, to the discovery of the metals caesium and rubidium, and later of a number of others. In effect Bunsen and Kirchhoff were the developers of the science of chemical spectroscopy. Following their lead this department of science has since been extended into the field of astronomy with very marvelous results, so that today we know much as to the kind of matter of which the stars, the nebulae and the comets are composed.

Bunsen devised an economical method for the production of the metal magnesium from its ores, and was the first to employ the brilliant white light produced in its combustion (which is rich in actinic rays), in photography, thus making possible the taking of pictures indoors and underground. He also invented the filter pump, a form of galvanic cell which is much in use, and several other appliances that are indispensable in laboratory work.

The colorless flame of the Bunsen burner, and the blue and smokeless flame of the ordinary cooking range and open fireplace, are produced by allowing air to become well mixed with the gas before it issues from the aperture where combustion takes place. Being thus supplied freely with all the oxygen it requires, all the carbon it contains is completely converted into carbon dioxide, and all the hydrogen into water vapor, giving no opportunity for unburned carbon in the form of smoke or soot to form.

PACINI (1812–1883)

PHYSIOLOGY

Filippo Pacini was born at Portola, Italy, studied medicine at Florence and Pisa, and became professor of anatomy at the University of Florence, where he remained until he retired from active life.

He is noted as the discoverer of the peripheral nerve terminations, which are known as the "corpuscles of Pacini." These are minute bodies, attached to and enclosing nerve terminations in various parts of the body; in man chiefly in the subcutaneous tissues, and form little bulbs, with the axis cylinder of the nerve running into them. It is because of them that we possess the sense of touch.

This sense, which exists everywhere—but in different degrees—on the surface of the body, should not be confounded with the sensation of pain produced by a cut or bruise, or with temperature perception, though all three are carried to the brain by the same set of nerves. Certain of them terminating just under the outer skin and mainly in the extremities of the hands and feet, are also fitted with end bulbs. These are the true touch organs. On the other hand, the Pacini corpuscles are much more widely distributed over the body, but also lie deeper in the skin, and generally in the tissue under it. They are especially abundant on the palms and on the inner side of the fingers and under side of the toes. It has been suggested that these in man are degenerating organs which formerly came much closer to the surface, and were of great use in his life among the trees.

As to the true touch bulbs, it is the view of some physiologists that those at the end of the fingers have the special power of conveying to the mind what may be called "the impression of nearness" to an object being approached.

Whether or not there be any foundation for this, the fact remains that they can acquire the ability to achieve very remarkable feats. One has only to watch the performances of an expert piano player or typist, to become convinced that the fingers can learn to move from position to position on the keyboard of a piano or typewriter, without the aid of the eye, which, wholly preoccupied in reading notes or words, conveys their significance to the brain, and seems to leave with confidence to the latter the guidance of the wonderful muscles of the arms and hands.

An instrument called the aesthesiometer has been devised to ascertain the relative acuteness of the sense of touch on various points of the body. Excluding the eye as untouchable, the tip of the tongue is the most sensitive, and closely following in degree is the under side of the terminal parts of the fingers. Very much less sensitive is the end of the nose, and the white part of the lips. Least sensitive of all is the back, except directly along the spine.

DANA (1813–1895)

NATURAL HISTORY

James Dwight Dana was born at Utica, New York, his parents having been of New England nativity and ancestry. His early education was acquired in his home town, after which he entered Yale college. Upon graduation he was offered a position as instructor in the United States navy, which afforded him an opportunity for travel in several parts of Europe. In 1836 he was appointed assistant to Professor Silliman at Yale, and while serving in that capacity published his first important work "A System of Mineralogy," which at once became a standard reference book in its specialty throughout the world, and has remained so ever since. From 1838 to 1842 he was a member of the United States Exploring Expedition under Commander Wilkes—whose field was in the southern Pacific ocean—in which he specialized on the subjects of mineralogy, meteorology, hydrography, corals and crustacea. He brought back with him 230 entirely new species of corals, and 638 of crustacea. He also wrote the narrative of the journey. In recognition of his great services to science on this expedition, he was appointed in 1850 to the chair of natural history at Yale, where he remained for the succeeding forty years, an honored and highly appreciated member of its faculty.

Corals were originally classed as among the zoophytes by Cuvier, by which term he meant those low forms of animal life that are fixed to a definite position and place, and have the appearance in most cases of growing plants. The word is no longer used in the current system of classification. In its place the species it covered are known as hydroids, corals and sea anemones. The last two belong to the class anthozoa, and constitute one of the most wonderful divisions of the animal world.

Coral is a calcareous, galatinous or horny product, which is secreted from the water of the sea by that strange form of animal called the polyp (many footed). After passing through its organism, the refuse material is excreted, and deposited around it, after much the same process by which the oyster constructs its shell, except that in the case of the coral the structure keeps on growing indefinitely, and like a plant, while each polyp, during its brief existence, occupies a minute cell in the material so built up, reproduces itself by a process of budding, and then dies. The individual is little more than a minute and formless speck of protoplasm which, when taken out of the water when alive, drains away in the state of a watery slime from the little cell in the body of the coral which was its home. When alive, and in its normal condition and situation, it protrudes portions of itself like little fingers or hairs, from the entrance of its cell, and by means of these finds and absorbs its nourishment. These fingers or tentacles are supplied with nerves, and are extremely sensitive. If touched by a foreign and objectionable body they are immediately withdrawn, and only reappear slowly and cautiously. Under normal conditions they are continually protruded, and by waving about collect the nourishment necessary for their growth.

In most cases these polyps exist in colonies, each individual leading apparently a completely solitary life, and having no association with or relation to its immediate neighbors even though the cells which constitute their homes are very close together. The coraline forms produced are of almost infinite variety, and though the product of each individual in building is extremely small, the combined products are enormous, consisting of the formation of islands and groups of islands, and of barrier reefs hundreds of miles in length. They can live only in clean water, and in depths less than 125 feet, and also require a temperature of 68° F. or over, which is obtainable only in or near the tropics. The color of coral is generally some shade of white or gray. But in the Mediterranean and Red seas, and in the Persian gulf a red variety is found which is much prized for jewelry and ornamental purposes. At certain places in the Pacific a coal black kind occurs, which bring even a higher price than the red. Both of these will take a beautiful polish.

Dana's great services to science were recognized abundantly during his lifetime. In 1854 he was elected president of the American Association for the Advancement of Science, and later became a member of the Royal Society of London, the Institute at Paris and the Academies of Berlin, Vienna and St. Petersburg. In 1872 he was awarded the Wollaston medal of the British Geological Society, and in 1877 the Copley medal. He was the originator of the modern theory—now universally accepted—of mountain folding and formation as the result of lateral pressure; and taught that valleys are, with rare exceptions, entirely products of erosion; and that in fossils, the individuals that compose a species, are almost endlessly diverse in form detail.

BERNARD (1813–1878)

PHYSIOLOGY

Claude Bernard was brought up in the town of St. Julien in eastern France. He studied in Paris for the medical profession, received his degree in 1853, and in the following year was elected to the chair of physiology in the faculty of sciences in that city. Shortly afterwards he became a member of the French Academy, and in 1855 accepted the professorship of experimental physiology at the Collège de France, a position which he held for the balance of his active life, and where his researches on the functions of the liver and the alimentary canal, the action of the saliva and the gastric juice in the digestion of food, were epochal in their results, making clear for the first time in history the part taken by the organs of the trunk in the nourishment of the body by food, the replacement of worn-out tissue, and the elimination of material no longer needed or unsuitable for use. Of especial importance was his demonstration of the fact that the blood which enters the liver does not contain sugar, while that which leaves the organ and goes from there to the heart is well charged with that substance. He also made important discoveries in relation to the action of certain nerves on the digestive organs, showing, for instance, that the formation of sugar in the liver could be interrupted by the division of the pneumogastric nerve at a certain place; and that the disease known as diabetes could be produced by a puncture of the fourth ventricle of the brain, from which this nerve proceeds. In recognition of the great value and important character of these discoveries, Bernard was three times awarded the grand prize of the French Academy of Sciences. At his death, so high was his standing in the estimation of his countrymen that his funeral obsequies were conducted at the public expense, an honor which had never before been conferred on a scientific man in that country.

VON MAYER (1814–1878)

PHYSICS

Julius Robert von Mayer was a native of Heilbronn in Germany, and studied medicine at Tübingen and at the universities in Munich and Paris. He then went to Java (1840) and became interested in the subject of animal heat as shown in the temperature of the blood. This led to the study of the phenomena of heat in general, which in its turn drew his attention to other forms of force. In 1842 he published in *Annalen der Chemie* his preliminary conclusions of the fundamental identity of the forces behind the phenomena of heat and motion, which constituted the first public announcement of the character of these two exhibitions of energy. In 1845, and again in 1848 he published monographs in which his further theories on the subject were stated, and finally in 1851 his "Bemerkungen über das Mecanische Aequivalent der Wärme," in which he gave a figure for the mechanical equivalent of heat, that is, a calculation of the amount of motion that could be produced by a given quantity of heat properly applied. And while this result differed considerably from the figure accepted today, to him belongs very properly the credit of having first conceived the principle now known as the Conservation and Correlation of Energy, which was later expanded by Joule and brought to fruition by Helmholtz.

At the present time all the forms of force with which we are acquainted—motion, heat, light, magnetism, electricity and chemical affinity—are known to be different exhibitions of one universal entity called Energy. Less than a score of years ago the latter was defined as "a condition or attribute by which matter can effect changes in other matter." Since then, matter itself—the atoms of the various elements—has been shown to be nothing more than one or more protons (units of positive electricity), surrounded by one or more electrons (units of negative electricity), the nature and properties of each atom—as those of hydrogen, sulphur, gold, uranium, etc.—being determined solely by the number of protons and electrons of which it is composed. A marvelous advance for a period of eighty-odd years.

In Mayer's day it was believed that all the phenomena of life in the vegetable and animal world were exhibitions of a form of energy called the "vital force." Today we know that vitality, whether mental or physical, is the result of chemical action and reaction produced by the changes which food undergoes in its passage through the living organism. Yet back of all these wonderful revelations there remains in the mind of man the consciousness that the whole story has not yet been told; that there is still a revelation to come, sometime and somewhere, which will explain the sense of Personality that is inherent in all of us, and that seems to be separate from and above all present conceptions of that invisible entity we call energy, and its visible and tangible representative that is denominated matter.

ÅNGSTRÖM (1814–1874)

PHYSICS

ANDERS JONS ÅNGSTRÖM was born at Lödg, Sweden, and received his education at the University of Upsala. After graduation he became in succession, a tutor, the keeper of the astronomical observatory, and full professor in physics. From 1867 until his death he was secretary of the Swedish Royal Society of Science. He was a writer of note on the subjects of heat and magnetism, but his outstanding achievements were in the field of optics. In his book entitled "Studies on the Solar Spectrum" published in 1869, he gave his determinations of the wave lengths of those dark lines in the spectrum which, from the name of their discoverer, are known as the Fraunhofer lines. His researches and discoveries in this department of science were so novel, and so fruitful in extending our knowledge of the properties of light, that his name has been adopted among scientists to express the unit wave whose length from crest to crest is one ten-millionth part of a millimeter, the millimeter being the one-thousandth part of the meter, which, itself measures about 39⅓ inches, or say 3⅓ inches more than a yard.

Those ethereal undulations to which the human eye is sensitive, and which, when combined in sunlight, produce in the brain the sensation of white light, and when separated from each other in the spectrum (or in the rainbow), yield the impressions of the seven primary colors—violet, indigo, blue, green, yellow, orange and red—are so short that, in the case of yellow light, 1700 crests and troughs occur in the length of a millimeter. Now the human eye, and the brain behind it which interprets the impression of the outside world conveyed to it by the organs of vision, is so constituted that it can respond to (or see) only those undulations which number from 1350 to 2500 per millimeter, the lower figure corresponding to the deepest shade of red, and the higher to the deepest tint of violet that can be detected. But beyond these comparatively narrow limits at both ends of the color spectrum, lie regions of invisible light that have been unknown to man until within the last fifty years. Those beyond the violet are spoken of as the ultra-violet, or high frequency undulations, and among the first of them are the so-called actinic rays, which are responsible for what happens on the photographic plate when exposed. Beyond them are waves that can be detected by quartz prisms, glass prisms becoming opaque at frequencies of about 3300 per mm., with the fluorescent screen. But when the frequencies approached 5400 per mm. the quartz becomes also opaque to them. At this stage of the investigation a highly skillful German technician or instrument maker, named Schumann, devised in 1896 what is known as the diffraction grating, which proved to be a new door into the chamber of mysteries. This consisted of a plate of highly polished speculum metal —a special alloy of high reflective power composed generally of ten parts of copper to one of tin, but also of equal parts of steel and platinum—on which were engraved by a diamond point a series of parallel lines so close together that 15,000 of them were ruled side by side on each inch of its width. This plate was then placed in an air-tight metallic box fitted with a window made of the transparent mineral fluorite (fluorspar), and the air extracted until a high vacuum existed. When light was then admitted through the window and fell upon the plate, Schumann was able, by means of the reflections from it, to detect undulations so minute that 8500 of them were compressed within the length of a millimeter. Subsequently, Lyman, of Harvard University, by an improvement on this device, pushed his way still further into the ultra-violet region, until he was able to detect rays of nearly 10,000 frequency. Finally during the last ten years, Mosely, the American physicist, assisted by the German, Laue, and using a still more refined tool called the "crystal grating spectometer" reached wave lengths so minute that those ranging from 1,000,000 to 100,000,000 per millimeter could be detected. These proved to be the vibrations set up by the electrons and protons themselves which are now known to be the sole constituents of the atoms of the chemical elements, of which matter of all kinds known to our senses are composed.

In the other direction, that of the infra-red, Langley, the American physicist, began explorations in 1881, encountering first the so-called heat rays, which we cannot see until a dull red temperature is reached, but which we can feel with ease, thus indicating that in one direction our sense of touch is more delicate than that of vision. In his journey down these invisible parts of the solar spectrum he passed through ranges of undulations from those of 1350 per millimeter at the lowest border of vision, down to 190 for the same length, all being temperature rays, the presence and dimensions of which became appreciable by means of his device, the thermopyle. Following his lead, Rubens of Berlin, using the quartz-mercury lamp as a source of radiation, pursued the investigation down to waves as long as three per millimeter.

When the Hertzian ethereal undulations were detected in 1896, it was found that the shortest of them—as produced by the oscillation back and forth of electrical discharges between the condenser plates of a radio installation—was six-tenths of a millimeter in length, while beyond them were first the waves used in amateur telegraphy, with lengths ranging from 50 to 350 meters from crest to crest, and still further on those employed in long distance telegraphy and telephony, with lengths up to 3000 meters and more.

From this brief outline of the capacity of the ether of space to transmit under varying conditions undulations so small and so long, the conclusion has been drawn, first, that waves still longer will ultimately be detected; and second, that what is at present called by electricians a "static electric field," is nothing more than a region filled with ethereal undulations of unlimited, or perhaps more correctly, infinite length.

HOOKER (1817–1911)

BOTANY

JOSEPH DALTON HOOKER, the son of Sir William J. Hooker, the director of the famous Kew Gardens in London from 1841 to 1865, was born at Glasgow, Scotland, and was educated for the medical profession at the university in that city. But immediately upon his graduation in 1839 he announced his determination to devote his life to botanical research, and with that end in view joined the expedition then being fitted out by Sir John Ross in the two ships *Erebus* and *Terror,* for the exploration of the coasts of the Antarctic continent. On its return in 1843 he brought back 5340 plant specimens from that supposed region of desolation. These he described in six quarto volumes, which were published in the years between 1844 and 1860. In 1847 he undertook a three years' journey through the Himalaya mountains, where he made a large collection which was presented to the Calcutta Botanical Gardens. He then engaged in a study of the flora of peninsula India; and when that was completed went to Morocco, and explored the chain of the Atlas mountains for new plants, making, for the first time for a European, the ascent of its highest summit, known locally as the Jebel Ayashi, which towers to the height of 14,600 feet.

In 1855 he was made assistant director of the Kew Gardens under his father, and when the latter died in 1865, succeeded to his position, which he also retained during the remainder of his active career.

To the average reader the devotion of an entire lifetime to the collection and description of plants, may seem an excessive price to pay for the accumulation of details of knowledge that are, for the most part, embalmed in monographs and volumes written in a language so technical as to be quite beyond the grasp of all but a few who have also made a specialty of the subject, and many, even among the educated, will question the value of such efforts. Yet experience has demonstrated beyond controversy that only patient labor of that kind in any field of research will yield information of permanent value. No matter how trivial and unimportant at the time these may seem, every item of knowledge so gained takes its proper place, sooner or later, in the mosaic that science is steadily and humbly constructing as the representation or negative of the sublime work of the Creator of this marvelous world.

The Hookers, father and son, during the seventy years in which the Kew Gardens were continuously under their control, not only made it the greatest of botanical institutions and exhibitions, and one that is annually visited by thousands of students from all parts of the civilized world, but, as has been amply proved, a source from which the new knowledge of the properties and usefulness of plants, has resulted in an enormous extension of the commerce of Great Britain in products of the soil at home, and in her numerous colonies.

JOULE (1818–1889)

PHYSICS

James Prescott Joule was a native of Salford, in England, and though inheriting a handsome property and business, became deeply interested in physics and electricity. He was educated mainly at home, under private tutors. At the early age of nineteen he had invented an electromagnetic motor, and was able to demonstrate mathematically, that in the process of electrolysis, the amount of heat absorbed, was equivalent to that produced during the original combustion of the elements employed. He therefore was the first to announce a mechanical equivalent for heat, and though the figure he gave was considerably in error, yet the principle on which he based his calculations was right.

It was in the year 1847 that, in a public address, he stated the doctrine of the Conservation of Energy, to the effect that energy, like matter, can neither be created nor destroyed, and that the total energy of the universe was a fixed and constant quantity. From this premise results the following conclusions:

1. That energy, in any form, may be changed into energy of any other form; which is the doctrine of the Correlation and Transformation of Energy.

2. That when energy in any form apparently disappears, an exact equivalent of some other form or forms takes its place; which is the doctrine of the Conservation of Energy.

3. That when energy undergoes transformation, or transference from one body to another, the process is not completely reversible; but that if some of the energy is recovered in its original form, a residual portion reappears in what is called a lower form. This is the doctrine of the Degradation and Dissipation of Energy.

Joule's announcements on this important subject made practically no impression at the time, but was later taken up by other men more widely known (as Lord Kelvin), thoroughly approved, and due credit given him for the years of patient investigation and experimentation he had devoted to that, and other kindred subjects. In recognition of those in the field of the electrical sciences, his name has been adopted by the International Science Convention, like that of Watt, Ampère, Volta, Ohm, Faraday and Henry, to express the electrical unit of work, which is: "The work done in one second, when the rate of working is one watt," or, expressed in another way, "the work done in one second in maintaining a current of one ampere, against a resistance of one ohm."

Joule was awarded the Copley, and several other medals, and numerous honors from universities and scientific societies throughout the world.

FOUCAULT (1819–1868)

PHYSICS

JEAN BERNARD LÉON FOUCAULT was a native of Paris, and was educated for the medical profession; but becoming interested in physics, he devoted the most of his life to investigations in that department of science, and to the invention and perfection of devices and tools for physical experimentation. In 1845 he was appointed scientific editor of the *Journal des Debats,* and in 1850 received the decoration of the Legion of Honor. In recognition of his eminent services he was elected physicist at the Paris Observatory in 1854, a position which he held up to the time of his death.

Although Roemer had determined by calculation based on astronomical observation (the eclipses of the satellites of the planet Jupiter), that light travels in space at the approximate velocity of 186,000 miles per second of time, Foucault, working in friendly competition with Fizeau, demonstrated the fact by mechanical means. The apparatus devised by the former was so compact, and yet so delicate and exact, that it could be operated indoors. That of Fizeau, on the other hand, required much space, and was not quite as precise. In both, a narrow beam of light was thrown on a mirror revolving at high speed, from which it was reflected to a train of mirrors, which brought it back exactly to its source, or would do so if its velocity had been instantaneous. In both arrangements, devices were introduced between the start and the finish of the journey of the beam, which were capable of measuring the slight deflection resulting from the time consumed in the transit, from which its rate of speed could be calculated. The two results were in substantial agreement, and confirmed the figure deduced by Roemer in 1675. It is interesting to note that, when these conclusions were examined by the committee of the Academy of Sciences—who had offered a prize of 10,000 francs for a demonstration—the award was made to Fizeau, because his method was more easily comprehended by a layman, and was also more spectacular, while that of Foucault was adjudged more delicate and precise.

Foucault demonstrated the fact of the revolution of the earth on its axis, by means of the diurnal rotation of the plane of oscillation of a long pendulum. He was the inventor of the gyroscope, of the polarizing prism, and of the parabolic reflecting telescopic mirror. He also devised a modification of the Watt governor for steam engines, and a method of observing direct sunlight without injury to the eye.

ADAMS (1819–1892)

ASTRONOMY

JOHN COUCH ADAMS was a native of the county of Cornwall, England. He developed at an early age a fine talent in mathematics, and after completing his primary education in Cornwall entered Cambridge. Here he distinguished himself so greatly in his specialty that after graduation he was appointed a mathematical tutor.

The planet Uranus, which was discovered in 1781 by Sir William Herschel, which travels around the sun in 84 years at a mean distance of 1,782,000,000 miles, had exhibited from the first certain irregularities in its movements, that could not be accounted for satisfactorily by the gravitative action of the two large planets Saturn and Jupiter, whose orbits are within that of Uranus; and early in the nineteenth century astronomers reached the conclusion that the solar system must contain still another planet, with an orbit greater than that of Uranus. In 1843 Adams set himself the task of finding it by purely mathematical reasoning, based upon the laws of gravitation as deduced by Newton. The sole foundations for his calculations were the known perturbations exhibited by Uranus in a certain part of its orbit where, supposedly, the unknown body was at its nearest position.

Adams spent nearly two years in this study, and finally assigned a definite position in the heavens to a body of definite mass, and communicated this conclusion to the Royal astronomer, with the request that the sky be examined in the vicinity for a new planet. The search was made, and a moving body found within two degrees of the place assigned for it; but, unfortunately for Adams, the searcher deferred reporting his discovery until he could complete enough additional observations to enable him to assure the mathematician that the heretofore supposed star was really a planet, and to compute its orbit.

Meantime the French mathematician, Leverrier, had been studying the same problem, and had also figured out a position. His conclusion were communicated to the German astronomer, Galle, who not only found the planet within one degree of the place indicated, but immediately advised Leverrier, who at once made public his discovery before Adams was able to announce his.

The new planet, which was given the name of Neptune, was found to have a diameter of 34,800 miles. Its mean distance from the sun is 2,792,000,000 miles, and its period of revolution 165 years. It has one satellite, which travels around it in five days and twenty-one hours. It has been thought by a few astronomers that our system contains still another one with an orbit beyond that of Neptune. But it has not been found. And the heavens have, during recent years, been so accurately mapped photographically, that its existence is very doubtful. It is a curious and still unexplained fact, that while the satellites of Mars, the earth, Jupiter and Saturn travel from west to east around their primaries, those of Uranus and Neptune move in the opposite direction, from east to west.

STOKES (1819–1903)

PHYSICS

George Gabriel Stokes spent his early years at Sligo, Ireland, and received his educational equipment at Cambridge University, where he distinguished himself so highly as a mathematician that he was elected in 1849 to fill the

Leucanian chair there. He became president of the Royal Society in 1885.

Stokes was the first to explain the basic principles upon which the science of spectroscopy rests, namely, that absorption spectra and emission spectra are identical (a principle afterwards rediscovered by Kirchhoff), and published several very important papers on light and allied subjects.

His great discovery, however, was that of the cause of the phenomena of fluorescence, about which, up to his time, practically nothing was known. His explanation may be stated as follows:

All varieties of matter, when subjected to the action of a beam of sunlight, experience more or less of a rise in temperature. Some few are capable of absorbing the light rays almost as fast as they arrive, and exhibit mainly the transfer of that form of energy into motion; as, for instance, water, which, under the action of light, will show a slight increase of temperature it is true, but the principal effect is the change of some of it into the condition of a vapor, and the elevation of this into the air (evaporation). Other substances, as most solids, are unable to absorb light as rapidly as it reaches them. Some of these have the power to reflect nearly all of it, like good mirrors. Others absorb part, reflect part, and radiate the balance in the form of heat. Still another class possess the ability of absorbing the violet and ultra-violet (invisible) rays, without experiencing much of a rise of temperature, and then of returning the energy so absorbed in the shape of longer and visible rays of green, yellow and even pink. The mineral fluorspar possesses this power preeminently, and also certain liquids (quinine sulphate). This is the phenomenon called fluorescence. It is exhibited to a greater or less extent by a number of other familiar substances, ivory, dry bone, glass colored by uranium oxide (canary glass), and some varieties of paper.

Most of these fluorescent substances cease to emit light as soon as the incident ray is cut off. Others, and notably barium, strontium and calcium sulphides, diamonds, sulphur, sugar and many forms of animal life, retain the power for some time afterwards. The phenomenon is then known as phosphorescence, but has nothing whatever to do with phosphorus.

Stokes' explanation has been abundantly demonstrated, and is known as Stokes' law, which, in brief is: "That fluorescent light is of a longer wave length than that of the absorbed waves from which it is produced."

One of the results flowing from this discovery, is that a certain length of the ultra violet and invisible part of the solar spectrum, can be made visible, by throwing those rays upon a screen moistened with some fluorescent substance, which will then return them in the shape of rays of longer wave length, which produce in the eye the color effects we call green, yellow and pink.

TYNDALL (1820–1893)

PHYSICS

JOHN TYNDALL was brought up at Leighlin Bridge, in Ireland, received his primary education there, and at the age of twenty-four became a subordinate employee of the Ordinance Survey, and later of a firm of railroad engineers. In 1847 he went to England, and undertook the teaching of mathematics and surveying at Queenwood College at Stockbridge. After a year there he went to Marburg, Germany, and devoted a couple of years to study, returning to Queenwood in 1851. In 1852 he was elected to membership in the Royal Society, and largely as the result of his first paper read before it, on "Molecular Influences," and the delivery of a lecture before the Royal Institution, on "The Transmission of Heat Through Organic Substances," he was offered the chair of natural philosophy. This brought him into intimate relations with Faraday, who was also a member of the faculty. In 1856 he studied the Swiss glaciers, in company with Huxley, climbed the Weisshorn in 1861, and the Matterhorn in 1868; traveled in Algeria in 1870, and lectured in the United States in

1872. Upon the death of Faraday, in 1867, Tyndall succeeded to his position in the Royal Institution, and also to his post as scientific adviser to the government, in connection with the activities of Trinity House, which had charge of the Lighthouse Service.

In addition to his great ability as an investigator and experimenter in the fields of science, he possessed unusual capacity and charm of manner as a lecturer, having the power of interesting his audiences in science to a remarkable degree. This faculty brought him large financial returns, wherever and whenever he was willing and able to accept engagements among English speaking people. No man of his time contributed as much to the spread of knowledge of nature among the masses. While none of his discoveries were of a startling nature, yet he made several of importance, and all have been since fully confirmed. An example of these was his demonstration that in pure air, free from dust or germs, a beam of light is invisible, unless coming directly to the eye. This led to a recognition of the enormous amount of organic and inorganic impurities normally existing in the atmosphere, to a study of their character and effects, and to improvements in methods of sterilization, for the preservation of foods, the care of wounds, and the prevention of diseases of an infectional character.

Tyndall, like Huxley, was popularly classified while living as a materialist. This mental attitude at the time was defined by the orthodox as "the denial of the existence in man of an immaterial substance which alone is conscious, distinct, and separate from the body," and those who held it were assumed to be atheists. These two notable and reverent students of nature were, like their contemporaries, Darwin and Spencer, men of deep religious convictions, as anyone must be who makes a sincere study of any aspect of the Cosmos, and they properly resented the imputation of atheism. To counteract the unwarranted inference drawn by their critics, Huxley invented the word agnostic to express the attitude that he—together with most of the scientists of the time—took. Their school of thought, which has spread enormously since, holds that human knowledge is limited by experience, and that since the Absolute and Unconditioned cannot fall within experience, we have no warrant in asserting anything whatever with regard to it.

MÜLLER (1821–1897)

BIOLOGY

JOHANN FRIEDRICH THEODOR MÜLLER (known as Fritz Müller), was born at Windischholzhausen in Germany, and studied at the schools of Griefswald and Berlin. To escape the political troubles of 1848, he emigrated to Brazil, locating himself at Blumenau, on the island of Santa Catarina, where he lived the life of a colonist until 1856, when he became a teacher of mathematics and physics at the Gymnasium at Desterro, the principal town of the island. In 1874 he was appointed a traveling naturalist of the museum at Rio Janeiro, with residence at Itajahy. From this position he was removed several years later, for political reasons, and returned to Blumenau.

Müller became an intense advocate of the evolutionary theories advanced at the time by Darwin, and being an earnest and capable observer, and living in a place where he could study, with particular advantage, the marine crustacea, he made their investigation a specialty, and in 1864 published in Leipsic his one work entitled, "Facts for Darwin," in which he applied the Darwinian hypotheses to his years of research in that class of the division of the Arthropoda. This monograph won for him, not only the grateful acknowledgments of Darwin, but wide and well merited fame. In it, in the chapter on "Progress in Evolution," he made the first clear and concise statement of the biogenetic law, as follows:

"That the embryonic development of the individual is an epitome of the order or class to which it belongs."

At the foundation of this broad generalization was the assumption—now universally accepted by biologists—that all living things have had a common ancestry, which is made clear by the fact that, in all those cases whose embryological development has been carefully studied, it has been found that the embryo passes through stages, or temporarily inherits structures, which are permanent in, and characteristic of, the more primitive or ancestral members of the class to which it belongs.

HELMHOLTZ (1821–1894)

PHYSICS

HERMAN LUDWIG FERDINAND VON HELMHOLTZ, a native of Potsdam in Prussia, was educated in Berlin as a physician and surgeon, in which capacity he served in the army during the years 1843–47. At the close of the war he was appointed an assistant in the Berlin Anatomical museum, and filled in turn the chairs of physiology at the universities of Königsberg, Bonn and Heidelberg in the years from 1849 to 1871. In the latter he was elected to the professorship of physics at the University of Berlin and continued in that office until his death.

While not the discoverer of the principle of the Conservation of Energy, for which credit should be given to Joule; to Helmholtz rightly belongs the honor of establishing it on a firm and mathematical basis. In his monograph on the subject, entitled, "Ueber die Erhaltung der Kraft," which appeared in 1847, he discussesd all the facts that had been made known to that date, by numerous experimenters and investigators on the different varieties of force, and in a most masterly manner. This paper was at first considered by many as little better than a fantastic speculation, for it asserted the identity of motion, light, heat, electrical, magnetic and chemical action; but it was favorably regarded by such master minds as Rankin, Thomson (Lord Kelvin), Clausius, Maxwell, and others, and steadily won its way to acceptance because, being founded on demonstrated facts, it could not be logically disputed.

Force may be pictured in the mind, either as an effort made by something to do work, or as the inherent capacity of matter to exert energy. The first conception was the one prevalent in the day of Newton, when mechanics was the only physical science of which enough was known to allow the investigation of its phenomena with the tool of mathematics. But when it became evident, through the experiments of Rumford, Davy and many others, that motion could be transformed into heat, a new idea was launched among thinkers. However, it was not until 1845 that Mayer made an experiment, from which he deduced a definite numerical value for the mechanical equivalent of heat. His figure was 365 gram-meters, and was derived by observing the heat evolved in compressing air. Joule, after investigating the thermal and chemical effects of an electrical current, deduced the figure of 460 gram-meters. Then, by utilizing the force of gravity as the source of energy, he obtained the value of 423 gram-meters. Next, a Danish engineer named Colding announced the figure of 370 as the result of heat caused by the friction of solid bodies on each other, thus harking back to the primitive method of producing fire, by rubbing two pieces of wood together. Joule, undaunted by these discordant results, with indefatigable energy attacked the problem in several different ways, and finally announced in 1850 the figure of 423.55 gram-meters as his final conclusion. This stood, as accepted tentatively, for more than 20 years. In that interval the problem was studied by numerous investigators in the fields of the electric, magnetic and chemical sciences, and in 1877–1879, as the result of exhaustive reviewing experiments made by Professor Rowland at Baltimore, Md., the figure of 425.9 at 20 to 35 degrees centigrade, was adopted. Expressed in plain language, this means that the energy required to lift a weight of 1 gram to a height of 425.9 meters, or a weight of 425.9 grams to a height of one meter, is exactly sufficient in that form of energy called heat, to raise one gram of water, one degree centigrade in temperature.

In the days of Helmholtz, electricity, magnetism and light were still regarded, by all but a few, as subtle forms of matter, just as heat had been in the time of Joule; so it is not difficult to understand the revolution in thought required, to accept the idea that they, as well as all forms of chemical activity, were but different manifestations of that one form of force clearly comprehended under the name of motion. The fundamental principle is, that the total stock of energy in existence in the Universe is constant, that it is impossible to create or destroy it, and that all we can do is to change any one manifestation of it, into some other manifestation.

It is interesting to note here that this principle has, for considerably more than a century, been held to be true for all manifestations of matter, which, uncreatable and indestructible, may be changed from one form or condition to another, without loss or increase in quantity. And finally, physicists now appear to have shown that the supposed ultimate forms of matter, the atoms, are probably simply centers of force. How much further the inquiry may be pushed, and what will be the ultimate conclusion, is impossible to say.

Helmholtz discovered the principle of vortex motion. He developed the theory of Young on colors. His monograph on the "Sensations of Tone," which appeared in 1863, remained for many years thereafter as the most important work extant on acoustics. In 1883 he was elevated by the German Emperor into the nobility.

VIRCHOW (1821–1902)

PATHOLOGY

RUDOLPH VIRCHOW was reared at Schivelbein in Prussia. He graduated in the medical department of the University of Berlin, and became professor of anatomy there.

During the political disturbances of 1848–1849 in Prussia, he took a decided stand against the government, which cost him his position at the university, and led him to accept the chair of pathological anatomy at the University of Wurtzburg in Bavaria, where his reputation as a lecturer on his special subject—cellular pathology—became so great, that in 1856 he was recalled to Berlin, and his political views overlooked. In return, he made its medical school the most famous in Europe during his lifetime.

Retaining, with great independence, his position against the encroachments by the royalists on the liberties of the people, he was elected in 1862 as a Deputy to the Prussian Diet, and at once rose to the position of leader of the opposition. During the Franco-Prussian War (1870–1871), and the events which followed, resulting in the formation of the German Empire under the leadership of Bismarck, he continued active in politics, as a leading member of the Fortschrittspartei, or Progressists; while at the same time retaining the respect of the imperialists, as well as his connection with the University of Berlin, where he ranked, up to the last, as the most famous pathologist in Europe.

Before his time Pathology (the study of disease), was in no sense a science, that is, a classified collection of well demonstrated facts or phenomena. It was little more than a collection of theories, and guesses. Its remedies were drugs, whose chemical composition was unknown, and even the nature and action of foods were unexplained mysteries. It remained for Virchow to throw a strong—almost blinding—light on this darkness, by enunciating and demonstrating, such a conception of the constitution of the living body, as was fundamental in its character, and upon which as a basis, a rational system for the treatment of diseases of all kinds could be raised. This was the system of cellular pathology, which is not difficult to understand as a whole.

All parts of all organs, tissues, and liquids of the body, are either composed of cells, or are in part or wholly, the product of cells. This is the fundamental and demonstrated fact. The liquids of the body—as the blood—differ from the solider parts—as the flesh, bones, etc.—only in that they have fluid intercellular substance in their composition. Cells are the conductors or transporters of vital functions. The condition that we call health, is the result of normality in cell function; and that which we denominate disease, is due to cell functional abnormality. Whenever the latter state is apparent, as in fever, chill, pain, decay, etc., the ultimate cause is to be found in the cells of the deranged organ, tissue, or fluid, and the remedies indicated, are those which experience has shown will act upon those particular cells, or upon the cellular system as a whole.

Naturally, since Virchow's time, pathology as a science has been much enlarged, extended, sub-divided and specialized; but the basic principle upon which the structure of the medical art of the present day has been erected, remains as enunciated by him.

The Pathological Institute and Museum at Berlin, erected by the German government in accordance with his designs, is his greatest material monument. At the time of his death it contained over 23,000 specimens, which have been more than doubled since. So great was his renown, and so immense the benefits that his work has conferred upon the world of suffering humanity, that upon the occasion of the celebration of his 80th birthday by a complimentary dinner in Berlin, testimonial dinners were simultaneously held in many of the large cities of Europe and in several of those in the United States.

GALTON (1822–1911)

BIOLOGY AND PHYSICS

Francis Galton was a native of Birmingham, England, and was educated at King's College in London, and at Cambridge University. He was a man of many tastes in science with large experiences in many lines. In 1846 and 1847 he traveled in Egypt. In 1850 he began explorations in South Africa, landing at Walfisch bay on the west coast, and spending two years in the interior, which was then known as Demerara Land; where he discovered the Ovampo tribe of natives, a very interesting branch of the Bantu race of Africa which had become completely separated from the rest of their people and consequently developed different customs and habits. He published two books on the subject of his travels in the Dark Continent, and having become interested there in meteorology he published in 1863 his "Meteorographica," in which he outlined for the first time the theory of anti-cyclones, which has since become one of the fundamental principles of present day weather forecasting.

His attention then being turned to anthropology he became a voluminous writer on the subject, publishing in 1869 "Hereditary Genius"; in 1874 "Englishmen of Science"; in 1883 "Inquiry into Human Faculty"; in 1889 "Natural Inheritance"; in 1892 "Finger Prints" and "Index of Finger Prints"; and finally, "Law of Ancestral Inheritance." He is regarded as the great authority on the subject of human heredity, having put that science on a quantitative basis.

Galton also called attention, in his "Meteorographica," to the phenomena of atmospheric displacement and storms. He showed that dense air is warmer than normal air, and will hold in suspension in the form of vapor a higher percentage of water; that is to say, its degree of humidity is greater. As it expands it becomes cooler, loses a measure of this capacity, and precipitates more or less of the moisture it contains in the form of rain, hail or snow in parts or all of the surrounding region.

WALLACE (1822–1905)

NATURAL HISTORY

Alfred Russel Wallace was born at Usk, in the southwest of England near the border of Wales, and began his active life as a surveyor and engineer. For a short time he was Master in English in the Collegiate School at Leicester, where he became interested in botany and entomology. When Darwin's first book—"The Voyage of a Naturalist" —appeared, it attracted him so strongly that, with the naturalist Bates as an associate, he sailed early in 1848 for Brazil, the two planning to explore the Amazon valley. Shortly after leaving Para, at the mouth of the river, they parted company under a friendly agreement, Wallace taking as his field the country on the north side of the great stream, while Bates confined himself to that on the south.

Wallace followed the river to the mouth of the Negro, its main northern affluent, and traced the latter to its source in the great upland region of southeastern Colombia. Here he discovered the curious fact that its upper waters were at one place identical with those of the Orinoco. The fact is, that at a point about 150 miles below the main southern source of the Orinoco, and at an altitude about 1000 feet above the level of the sea, the stream forks, about one-sixth of its waters passing south through the Cassiquiare and thence into the Negro, and the remainder north, thus making it possible without portage except at the Atures and Maypures rapids on the Orinoco, to travel by boat of light draught from the mouth of one river to that of the other.

Wallace made a fine collection, but had the misfortune to lose it, as well as all his notes, by shipwreck, on his return trip to England. Nevertheless he published in 1853 a highly interesting and valuable account of the country through which he had journeyed. In the following year he went to the East Indies, and explored them from the peninsula of Malacca through Sumatra, Java, Borneo, the Celebes and the islands of the Banda sea to, and some distance into, New Guinea, devoting eight years to the trip, and finding himself more interested in ethnology and philology than in plant and insect life.

During a period of resting and recuperation at Sarawak in Borneo, he wrote an essay entitled "The Law which has Regulated the Introduction of New Species," which was published in 1855. But in it he went no farther than to deny that species were matters of special creation, and to assert that they were the result of slow and gradual development from one to the other, in accordance with some law as yet not understood. Somewhat later, having meantime read the work of Malthus on "Population," the reasons advanced by that economist to account for variations in number, and changes of character, in races of men and in nations, seemed so suggestive when applied to animal life in general (just as it had to Darwin who, however, had read it twenty years before), that he at once wrote another essay entitled "On the Tendency of Varieties to Depart from the Original Type," and sent it to Darwin, who was a personal friend. It arrived just at the time when the latter had arranged to read before the Linnaen Society his own preliminary paper on the subject, in which he presented substantially the same cause—though much more completely in detail—as an explanation of variation and mutation in species. It was an embarrassing situation, and to his great credit it should be remembered that Darwin offered to suppress his paper in favor of that of Wallace. But those who were close to him, and who knew that his conclusions had been reached independently, and after years of investigation, dissuaded him from such a course. The upshot was that both essays were read at the meeting, and printed in the Transactions for that year (1858), and in the following year Darwin's great work, "The Origin of Species," appeared.

As a result of his long and extensive travels in the far east, Wallace published several works of high value on the natural history of that part of the world. These gained for him a government pension sufficiently liberal to enable him to pass the rest of his life at home in comfort. He was a man of lofty personal character, and of an amiable and genial disposition. The long friendship between Darwin and himself was never interrupted. On the contrary, he admitted frankly that he had arrived at his conclusion almost entirely by accident, while Darwin had reached his only after years of patient observation and experimentation, and was unquestionably entitled to the greater credit.

The idea of evolution is a very old one. It was current and practically accepted in the golden age of Greece, but the cause of it was not even dimly suspected by the philosophers of the time. During the centuries that followed their eclipse, and all through the Dark Ages, the orthodox theory of a special Creation was received in Europe without question. When Lamarck (1744–1829) ventured to doubt it, and reasserted the older idea, the causes he assigned for it—changes of environment, climate, soil, food, temperature and cross-breeding, seemed inadequate. Cuvier himself would not accept them. And though Lamarck briefly touched on the competition for food as a factor, he evidently regarded it as a minor one, while for Malthus it was the principal one. The uncritical but alert Wallace seized on it as an inspiration, and without further study adopted it. Darwin, however, devoted nearly a score of years to its study, before announcing it as a conclusion that could be amply proved.

MENDEL (1822–1884)

BIOLOGY

George Johann Mendel was a native of Heinzendorf in Austria, was educated for the ministry, and became a priest in 1847. While faithfully performing the duties of his office he found time, in the garden of the cloister, to become deeply interested in botany, and particularly in that department of plant life which includes those variations resulting from cross-breeding among different varieties, species or genera. After nearly twenty years of patient study and experimentation, his great work on the subject appeared in 1865 under the title of "Versuche über Pflanzenhybriden." In this he summarized his conclusions into what has come to be known as Mendel's law which, in effect, may be stated as follows:

"In the second and later generations of a hybrid, every possible combination of the parent characteristics occur, and each combination appears in a definite proportion of the individuals. A parent character which is fully developed in the hybrid is said to be 'dominant'; if it is apparently absent it is said to be 'recessive.'"

This law has been expressed in more detail by Castle, thus:

"1. The law of dominance; when, for example, in the offspring of two parents differing in respect of one character, all resemble one parent, and possess therefore the dominant character, that of the other parent being latent or recessive.

"2. In place of simple dominance, there may be manifest in the immediate hybrid offspring an intensification of character, or a condition intermediate between the two parents; or the offspring may have a peculiar character of their own, technically known as 'heterozygotes.'

"3. A segregation of characters united in the hybrid takes place in their offspring, so that a certain per cent of these possess the dominant character alone, a certain per cent the recessive character alone, while a certain per cent are again hybrid, that is, possessing the characteristics of both parents."

Mendel's law attracted little attention at the time of its publication, but after thirty-five years of obscurity it was rediscovered by biologists and amply confirmed. But even before his pioneering labors had been recognized among scientists men like Burbank of California had experimented deeply on the subject, and produced remarkable results in plant life, and others in poultry and the domestic animal, so that at the present time the ability to bring about very extensive changes in both, and changes that can be predicted, is well demonstrated. It is safe to expect that in the not very distant future the discoveries in this branch of knowledge will be extended to the improvement physically and mentally of man. The science of eugenics is young but vigorous, and a very firm foundation has already been laid upon which to build.

CLAUSIUS (1822–1888)

PHYSICS

Rudolf Julius Emanuel Clausius was a native of Köslin, in Germany, was well educated, and became in turn professor of physics at the polytechnic institute at Zurich (1855), in the University of Wurtzburg (1867), and in the Bonn University (1869). He remained at the last until his retirement.

He was one of the founders of the comparatively modern science of thermodynamics, having, in a monograph read in 1850, before the Berlin Academy of Sciences, enunciated and demonstrated its second law, to the effect that "heat cannot itself pass from a colder to a hotter body."

Among the Greek philosophers, heat effects were believed to be due to the addition of a material substance to the body experiencing a rise of temperature. This conception was universally held until about the year 1800. In fact, somewhere about 1696, a Professor Stahl, of the University of Halle, in Germany, gave the assumed substance a name—phlogiston. Another name familiarly employed somewhat later for the same imaginary thing was "caloric." And though during the 17th and 18th centuries (1600–1800) certain of the philosophers of the time—among whom may be mentioned Descartes, Amontons, Boyle, Francis Bacon, Hooke and Newton—demurred at this view, and expressed the opinion that it must be something different, and probably was some form of motion, yet they were unable to furnish proof sufficient to discredit the popular conception current. It remained for Count Rumford, towards the end of the 18th century, to furnish the necessary evidence. Yet, millenniums before that, our savage ancestors had learned that fire could be produced by rubbing two pieces of wood together.

It is now known that all heat phenomena can be traced for their cause, to work of some kind having been done against the molecular forces of the body, by friction, compression, or the reception of energy by radiation, conduction or convection. In other words temperature is simply a question of molecular motion. As matter loses heat the motion of its molecules slows down, and at the absolute zero ceases entirely. As heat is acquired, molecular motion increases, leading first, in the case of most substances, to the change from a solid to a liquid state, and then from a liquid to that of a gas.

PASTEUR (1822–1895)

BACTERIOLOGY

Louis Pasteur spent his adolesence at Dôle, among the foothills of the Jura mountains in eastern France. At an early age he developed a strong interest in the sciences, particularly chemistry and medicine. He secured his doctor's degree at twenty-five, and at once became professor of physics at the University of Dijon. After a year there, he was offered and accepted the chair of chemistry at the University of Strassburg. In 1854 he became dean of the Faculty of Sciences of the State university at Lille. Three years later he took the post of science director at the Ecole Normale Supérieur, in Paris, and was elected a member of the French Institute of Arts and Sciences. In 1863 he was appointed professor of physics and chemistry at the school of fine arts, and from 1867 to 1875 occupied the chair of chemistry at the Sorbonne, one of the departments of the University of Paris. A little later he founded, and conducted during the balance of his active life, the Pasteur Institute; which became at once a very famous center of research in his particular line of investigation.

Pasteur is regarded as the originator of the science of stereo-chemistry, which has for its field the investigation of those substances of the isomeric category, which cannot be explained by the linking of their constituent atoms, but are explained on the theory that their combining powers act in certain definite direction, in space. This naturally leads up to the study of the phenomena of fermentation and putrefaction, and their relation to the micro-organisms in the atmosphere. By passing a current of air through guncotton, and then dissolving the latter in alcohol, an insoluble residue is obtained which, under the microscope, is found to consist largely of mature and immature living germs.

The study of these—a hitherto unknown field of life—occupied the remainder of Pasteur's days. The discoveries made therein by him, and by those who have followed in his steps, have profoundly affected individual humanity, and the industrial world. To mention a few of the most important will indicate the scope of his labors, and the gain that has resulted from them. His investigation of the diseases of wine and beer have made it possible to prevent them. The same has occurred in the case of the silkworm disease. In discovering the bacterial cause of anthrax and splenic apoplexy in cattle, and of fowl cholera, and the remedies in each case, enormous annual losses in domestic animals has been prevented, and a system of animal vaccination worked out, which has already done as much for the eradication of these diseases, as Jenner's discovery has in the case of smallpox. Nor should his well known and very successful treatment for hydrophobia be forgotten; nor the system of sterilization which is now universally adopted in the modern dairy. In fact, so numerous were the discoveries of this most noted physiologist in the domain of the micro-organisms, and so successful the remedies he devised to defeat or minimize their injurious action, that the terms pasteurizing, pasteurism and pasteurization as nouns, and the verb to pasteurize, together with similar words in all the modern languages of civilized people, have passed into common usage, to mean all preventative or prophylactic systems devised, either by him or since his time, to counteract the evil effects of those minute organisms which are always present in the purest air and the cleanest environment, and are every ready to attack and destroy.

LEIDY (1823–1891)

NATURAL HISTORY

Joseph Leidy was born in Philadelphia, Pa., and graduated in 1844 at the State University with the degree of M.D. But becoming at once more interested in natural history than in the practice of medicine, he was appointed in 1846 curator of the Academy of Natural Sciences, and a little later demonstrator of anatomy at his alma mater.

Six years afterwards he became full professor of anatomy there, and in 1882 professor of biology. In 1885 he was elected president of the Wagner Free Institute of Science in Philadelphia. In 1844, for distinguished contributions to the science of paleontology, he was awarded the Lyell medal of the Royal Geological Society of London, and in 1888 the Cuvier medal of the Institute of France.

He will be remembered largely in connection with the fossil history of the horse and camel, in the study of which he was associated with Marsh. Their field of exploration was those remarkable fossil beds in Wyoming and western Nebraska which yielded such an abundance of the remains of the two animals as to make it possible to trace their ancestry in the remote past, and their development up to the forms known at the present day.

The conclusion reached by Leidy was that the camel arose in early Tertiary time, contemporaneously with the pig family, and perhaps from common ancestry, and that the place of its origin was the ancient lake region of the Rocky Mountains. This was at first a well watered and even marshy country, but later became desiccated. Diminutive remains suggesting the camel have been found in the lower Eocene division of the Tertiary, and in the upper Eocene skeletons undoubtedly cameloid. These latter were about the size of a jackrabbit. They had four toes but used only two of them. Their dentition exhibited strong similarities to both the swine and camel type. In the upper Eocene was found the procamelus, as large as a sheep, and presenting many points of likeness to the llama of the present day as found only in South America. As the aridity of the region increased the large splayed feet with sole pads were shown in the skeletons found. At the close of the Miocene the climate again changed, becoming warmer and moister. This seems to have put an end to camel life in North America, for no further remains of the type have been found. It was the belief of Leidy that an emigration then took place of the existing type, some going to the south and becoming the ancestors of the three or four varieties now living in the highlands of the Andes, and others to the northwest, via the land bridge at Behring straits into Asia where, in the arid regions of Mongolia the double-humped Bactrian camel was evolved, and from it later the single-humped variety known as the Arabian camel.

The modern camel is a most remarkable case of adaptation to environment. The foot consists of two elongated toes, each tipped with a small nail-like hoof. The leg does not rest on this hoof but on the elastic pads or cushions under and back of them. In the Asiatic variety the toes are united by a common sole, thus presenting one broad pad for support on the loose sand of the desert. The thigh bone is unusually long, and the hind leg lacks that powerful muscular connection with the barrel of the animal which is so prominent a feature in the anatomy of the horse. In fact, the leg is almost disconnected from the body. In consequence, if the sand under a rear foot of a camel gives away, his body is not dragged down with it as that of a horse would be, unless the other foot also is undermined. Still more wonderful as an adaptation is the stomach. The camel is a ruminant and chews the cud. Like all others of this order the digestive organ is divided into four parts or chambers. Two of these in the camel are connected by separate passages with the mouth, into one of which the animal sends the solid food it gathers in the field, and into the other the water it drinks, though it has also the power to pass water into either at will. Both of these divisions of the stomach (but principally the one to which liquid food is generally sent) are provided with a number of pouches or cells in their linings, with muscular walls, and with orifices that can be opened or closed as desired. When water is available in plenty these are all filled to distention, and when the liquid is needed it is allowed to exude and mingle with the solid food, until enough has been provided for the time being for digestive and other bodily functions. By this arrangement a camel can live and travel without too serious discomfort for from five to seven days without drinking.

FABRE (1823–1915)

NATURAL HISTORY

JEAN HENRI CASIMIR FABRE was born at Sainte Leons in the south of France, the son of a small land owner with a family so large and an income so meager from his little patch of earth, that it became necessary at a very early age to send him to his grandparents in the neighboring village of Malaval where, by tending the geese and the ducks he could at least earn his keep. But when seven years old conditions at home being slightly improved, he was brought back and sent to the local primary school. In 1833 the family left their little farm and moved to the town of Rodez, where the father opened a café and the boy was able to attend school, where he made good progress. By this time his inclinations towards the study of natural history had become so strongly developed that the Latin he was forced unwillingly to study became a fascinating task as soon as he had advanced far enough to encounter the "Bucolics" of Virgil. Four years later the family moved again, to Toulouse, and in the following year to Montpellier. Jean was now a sturdy lad of fifteen, and felt under obligations to leave his home and earn his living wherever he could find employment. Being a companionable youth he made friends everywhere, and the outdoor life of a laborer brought him continually in contact with the nature he loved. Working conscientiously at every employment he secured, living simply, and saving his surplus earnings; when in his wanderings he reached the city of Avignon, and learned that at its normal school there was to be held an examination for a bursary, he boldly entered the race and won it with ease. This good fortune enabled him to abandon manual labor and take the full course that the institution provided. When he passed his final examinations in 1843 with credit and before he had attained his majority, he was offered the position of teacher at the primary school connected with the college in the town of Carpentras. There he taught with such success, while at the same time grasping every opportunity to increase his own stock of knowledge, that he was offered the professorship of physics, mathematics and chemistry at the Lyceum at Ajaccio, on the island of Sardinia. While serving there he had the good fortune to meet the botanist, Moquin-Tandon, and to be able to assist him in his work of collection in the wonderful flora of that island. Between them a strong and lasting friendship developed.

In 1852, in consequence of an attack of the malarial fever prevalent there in certain seasons of the year, Fabre decided to return to France, and through the aid of this friend was appointed to the professorship in physics and chemistry at the Avignon lyceum where formerly he had been a student. There, in a region thronging with insect and bird life he passed several comparatively happy years, devoting his leisure hours to investigations in natural history and chemistry.

By this time he had become so well known among scientists by his frequent small publications and contributions to current periodicals that he was elected a member of the Legion of Honor. In 1858 he won his degree as licentiate in natural history, and a little later the coveted doctor's degree, which he hoped would open to him a call to a university position. This not coming because, as he learned afterwards through a friend, of his limited means, he began the investigation of the coloring matter alizarin, with the intent of undertaking the business of dyeing as a means of making money. But just as he was getting well started the era of synthetic dyes began, with which he was unable to contend. Thus at last Fabre was compelled to take to his pen seriously as a means of support. He had already published a few school text books, but they added little to his income. In 1870 he moved to a house in the suburbs of Orange where, surrounded by his devoted family, and far away from the world of strife, he spent nine happy years studying and describing the abundant insect life of the region, and easily finding a market for his work at fair remuneration. These monographs were written in a style at once so simple, and yet so delightful, as to win for him a large circle of readers not only in France but throughout Europe and in America. Before he could fairly appreciate the fact he had become one of the most noted of naturalists.

After the death of his eldest son Jules in 1879—a severe bereavement—he moved to a still more secluded residence near the little village of Serignan, where the balance of his long life was passed. There he planned and executed his great ten-volume work which made his name famous. It was published under the title of "Souvenirs Entomologiques." In its composition he studiously avoided what he called the "official jargon" of science, adopting in its stead, and without the least sacrifice of accuracy, a style so charming as to bring his descriptions within the mental grasp of anyone who can read. No writer in his field since the far-off day of Virgil—who described so delightfully the life and doings of the bee, the grasshopper and the crow—has been able to convey to the masses so much, and so truthfully of the wonders of the world of small animate nature, in which he says he found a knowledge of Deity. Fabre, who was not what is called by theologians a religious man, was asked in his old age if he believed in God. His reply was—"I can't say I *believe* in him; I *see* him. Without him I understand nothing. You could take my skin from me more easily than my faith in God."

The most important strictly scientific result that was reached by his life studies was undoubtedly the light that he threw upon the nature of the faculty of instinct, as contrasted with that human one called reason. In his own words he regarded the former as proving, in the case of each individual studied "perfect wisdom, comparable with and even superior to human wisdom, within the customary conditions of their lives; and incredible stupidity outside of them." This is perhaps the most correct definition of the character and nature of instinct as a phenomenon that has been put into words.

HITTORF (1824– ?)

PHYSICS

JOHANN WILHELM HITTORF was a native of Bonn in Germany, received his education at the university in that city and in 1852 became the professor of chemistry in the University of Muenster, where he at once displayed his ability in original research. His investigations were mainly in the field of electricity, the earliest being on the phenomena of electrolysis, where he extended the work of Faraday in determining the mobility of ions of different substances in an electrolyte. In 1862, in collaboration with Plucker, the important discovery was made that the spectra of all substances differed materially under different conditions of temperature. In 1869, while investigating the passage of the electrical current through glass tubes containing a rarefied gas, he observed that by increasing the degree of exhaustion the dark space between the negative pole and the negative glow widened, and that fluorescence appeared when the discharge from the cathode impinged on the wall of the tube; and he further found that all these rays could be deflected by the magnet, thus anticipating the brilliant demonstrations on this phenomenon that were made by Crookes in 1878. Finally, in the field of chemistry, he was the discoverer of several hitherto unknown properties of phosphorus and selenium.

These two elements, which lie some distance apart in the Periodic system of Mendeleef, possess properties which, beside being of high interest, have made them useful in certain directions in the arts. Phosphorus was first encountered as a hitherto unknown substance by Brand, a German alchemist, in 1669. He was working in his laboratory on urine, striving to extract from it some principle or material that would effect the transformation of lead or copper into silver or gold which, in his day, was the principal end sought by all the devotees of what was called the "black art." Brand did not recognize his find as an elementary body, but in some way he managed to isolate considerable of it crudely from the other elements with which it was associated—mainly nitrogen and hydrogen in the form of ammonia, and magnesia—in the sediment from urine, into which it had come from the bones, the nerves, the brain substance, the blood and other of the body fluids, where it is a normal and necessary constituent, and one which must be taken into the body in food if the organism is to be properly nourished. Accordingly it is found in all kinds of plant life, and in the flesh of all animal, particularly fishes. Finally, it is always present in greater or less proportion in the soil, and in both fresh and salt water, the ultimate source being of course the rocks, where it occurs as phosphates combined with several of the common elements, but mainly with lime and magnesia. Brand exploited some of its remarkable properties, and about a century later the chemist Lavoisier demonstrated its elementary character. It is ranked as a non-metal, may be either red, yellow or black in color, crystalline or amorphous in structure, odorless, or with a distinctive odor, opaque or transparent, and must be kept under water free from air or will rapidly combine with oxygen and become phosphoric acid. It begins to melt and vaporize at 215 to 300 degrees Centigrade, and will catch fire and burn fiercely with an intense white light if given the slightest opportunity. No wonder Brand was able to amuse himself and astonish others with a material having such unusual properties. Until recent years practically all consumed in the arts has been produced from bones, but an increasing proportion is now coming from the rocks, of which enormous deposits have been discovered in various parts of the world.

Selenium was isolated and recognized as an element in 1817 by the chemist Berzelius. It is widely distributed in the material of the earth's crust, but in minute quantities. A very small percentage is found almost always in the ores of the metals copper, lead, silver, mercury and iron. When these are roasted preparatory to smelting, or during the latter process, the selenium passes away as a vapor, and when cooled settles down as a fine dust in the flue chambers with other easily vaporizable substances, from which it may be separated and recovered without difficulty. As with phospohorus, it can exist in several different allotropic conditions, in one of which it appears as a black, glossy and metallic looking mass, but lacking the other metallic peculiarities. If heated in air it begins to soften at 60 degrees Centigrade, and at 250 dgerees passes into a very mobile liquid. If the temperature continues to rise it shortly bursts into a lovely purple flaming vapor, which gives off the odor of horseradish. The crystalline variety of the element has the unusual quality of becoming instantly an active conductor of the electric current when exposed to sunlight rich in red rays, and of losing that property with equal rapidity when the light is removed. This property is now utilized in the transmission of pictures or writing by wire, a feat which no doubt will ultimately be accomplished as well by wireless.

KIRCHHOFF (1824–1887)

PHYSICS

Gustav Robert Kirchhoff was resident at Königsburg, in Germany, and completed his education at the university in that city. In 1850 he became professor of physics at the University of Breslau, in 1854 at Heidelberg, and from 1875 until his death he occupied the chair of that science at the University of Berlin.

In addition to being regarded, with Bunsen, as a founder of the science of spectroscopy, he was the discoverer of two of the elementary laws of electricity, which may be stated in brief as follows:

1.—At any junction point in a network of conductors, the sum of all the currents which flow towards that junction, is equal to the sum of all the currents which flow away from it.

2.—In any complete electric circuit, the sum of all the electromotive forces, reckoned in order around the circuit, is equal to the sum of the products of the current through, and the resistance of, each conductor forming the circuit.

The germ of the science of electricity was probably the discovery that amber, upon being rubbed, acquired the property of attracting certain light bodies to it. This substance is a fossil resin of vegetable origin, differing in that respect from ambergris, which is of animal origin. Its golden color, its transparency and the pleasant fragrance it gave off when burned, added to its comparative rarity, caused it to be highly valued by the ancients. It is thought that Thales of Miletus was among the first to become aware of its electrical capacity; and certainly Theophrastus knew of it for, in his treatise on Gems—to which category amber belonged in his day—he speaks of other substance as well as of it which possessed the mysterious power of attraction.

THOMSON (Lord Kelvin) (1824–1907)

PHYSICS

William Thomson (later Lord Kelvin) was born at Belfast, Ireland, and graduated in 1845 at Cambridge with high honors. In the following year he became professor of natural philosophy at the University of Glasgow, a position which he retained for fifty-three years, until his retirement from active life in 1899.

During his long career at this institution he was a voluminous contributor to the best technical periodicals of the day, and the inventor of a number of devices of great value in the operation of submarine telegraph cables, as well as a keen investigator in many other departments of physics. His most notable contribution to the increase of knowledge was in the field of thermodynamics. He was the first among his contemporaries to hark back to the doctrine of the Conservation of Energy as advanced by Joule in 1847, and lightly regarded at the time, and to proclaim its fundamental accuracy and importance. He also recalled to notice the brilliant essay of Sadi-Carnot on heat, published in 1820, and showed that it was, in effect, entirely in harmony with that theory. His notable monograph, entitled "On an Absolute Thermometric Scale," is rated as one of the classical documents in its line.

In his investigations of the phenomena of electricity and vortex motion, he made some remarkable discoveries. In the latter, he advanced for consideration an ingenious theory of vortex action, as a possible explanation of the properties of the hypothetical ether of space, which aroused great interest at the time among mathematicians and physicists, but was not found competent to explain satisfactorily all the admitted properties of that assumed substance.

He lectured in America in 1884, in 1897, and again in 1902, on each occasion visiting several of the principal cities of the United States and Canada, and always drawing large and appreciative audiences. In recognition of his great services to the telegraphic art, he was knighted in 1866, and raised to the peerage in 1902.

The absolute zero of temperature has been determined by the properties of gases to be at —273.04° C., which corresponds to —491° on the Fahrenheit scale. At this point all motion on the part of the molecule of matter is believed to cease, as the phenomenon called heat is, by definition, the effect produced by inter-molecular vibration. Lord Kelvin's contention was that all statements of temperature should begin with this zero, that the freezing point of water should be 273° on the centigrade scale, and its boiling point 373°, instead of respectively 0° and 100° as at present. From a purely scientific point of view no dissent from this suggestion is possible. But the task of changing the thermometric scales of the whole world, as well as the popular conceptions of heat, has been found to be too great an obstacle to overcome. In consequence, the freezing point of water still constitutes the zero of the centigrade system, and 32° below that point as the zero of the Fahrenheit. In both of them the temperatures below that are stated as minus quantities in degrees. In practice, the nearest approach to date to the absolute zero was reached at the solidification of hydrogen gas by Dewar at minus 256° C.

BROCA (1824–1880)

ANATOMY

Paul Broca was a native of Sainte-Foy-la-Grande, a small town near the city of Bordeaux, France. Exhibiting in his youth strong inclinations towards medicine and surgery, he was given an excellent education in these sciences in Paris, which was supplemented by extensive hospital experience. At the age of twenty-three he began to be interested in anthropology, and in 1859 founded the Anthropological Society of Paris. This organization, which was officially incorporated a couple of years later, marked the beginning of that study as a distinct and very important branch of modern science, and to its growth and advancement Broca was a large contributor. In 1872 he established the "Revue d'Anthropologie," in which for some time all his writings on that subject appeared. In 1876 he founded in Paris the Ecole d'Anthropologie, which is now known as the Anthropological Institute. It was well equipped with a library, museum and laboratory, and in the latter, Broca began those researches on the comparative anatomy of the primates, which led to the disclosure that has made his name memorable. In 1861 he announced his discovery of the location in the human brain, of the ganglion governing the faculty of speech, as being situated (for right-handed individuals) in the third convolution of the left frontal lobe, and for left-handed individuals in the same convolution of the right frontal lobe. This particular part of the brain is now universally referred to as Broca's convolution and its recognition has had a most remarkable effect. It is a development of gray matter not found in the brain of any of the anthropoid apes, nor in that of the lower animals. Nor does it exist in the brain of the human infant, but comes into being only when the child begins to learn to speak. It develops only in one of the two major lobes of the brain, and usually in the left lobe, because all but an insignificant number of individuals are more dexterous with the right hand than with the left. But in the case of those who are left-handed from infancy, the speech ganglion appears in the opposite lobe. In cases of ambidextry, which are extremely rare, and never have been known to present a case of perfectly equal capability with both hands, the development comes in that lobe opposite to the hand most employed. When the dexterous member is destroyed by accident, or in war, and ability to use the other is slowly acquired, the result is not the formation of a new speech center in the other brain lobe, nor any disability in the power of speech.

The effect of Broca's discovery has extended beyond the fields of anatomy and anthropology, into that of psychology. In that most interesting and valuable work entitled "Brain and Personality" the two sciences of physiology and psychology have been connected by means of the bridge revealed by him.

He was a man of unusually varied talents. His statue by Choppin, was unveiled in 1887, in the Ecole de Medecine in Paris.

HUGGINS (1824–1910)

ASTRONOMY

William Huggins was a native of London, and received a thorough academic and collegiate education. Inheriting ample means, and having a strong inclination towards astronomical research, he built an observatory close to his residence, in which he mounted an 8-inch reflecting telescope. With this he continued during his life to make observations in great number, and of unusual value to the science, in spite of the adverse weather conditions so prevalent in the vicinity of every large city. He was among the pioneers in using the spectroscope in connection with the telescope, and specialized on the study of the light coming to his instrument, from the celestial bodies. He was the first to detect that the spectra of some of the nebulae were of such a nature as to prove that the light emanated from heated matter in the condition of a gas, and that the principal constituent of the gas was hydrogen. Only two of these wonderful bodies are visible to the naked eye, and those but faintly; but many thousands have been located with the telescope. When they began to be observed and studied by astronomers, it was supposed that all were merely star clusters. When Huggins announced that some of them were wholly gaseous, the fact was regarded as confirmatory of the famous nebular hypothesis of Laplace, as to the origin of the solar system.

He was also the first to apply this method of investigation to the light emanating from comets, and showed that at least a part of it was not reflected sunlight, but originated in the nucleus of the comet itself. He was the first extensive employer of the Doppler principle, for the measurement of such stellar velocities as were ascertainable by that method. This field of study, calling as it did for very delicate and accurate observational work, and high mathematical ability in drawing conclusions from notes, led the way for the collection of data relating to the drift of the stars among themselves, which has added enormously to our knowledge of the nature and immensity of the Universe, in which our earth is such a comparatively minute speck.

He also made the earliest experiments in celestial photography. This line of research at first produced very unsatisfactory results, in fact, no results at all; because, in the immature condition of the art at the time, when only wet plates were known, long time exposures were an impossibility. But when the dry gelatin plate was invented by Goodwin in 1898, exposures for hours became possible, thus permitting the collection of enough light to reveal objects so faint, as to be beyond the ability of the most powerful telescopes to report to the human eye. Thus, step by step, has the mind of man been able to reach out farther and farther into the infinity of space, in which he finds himself a conscious atom.

In recognition of his great services to science, many honors came to Huggins. He was president of the Royal Astronomical Society from 1876 to 1878, and became head of the British Association for the Advancement of Science in 1891. He was the recipient of the Royal, the Copley, and the Rumford medals.

SCHULZE (1825–1894)

BIOLOGY

MAX JOHANN SIGISMOND SCHULZE was born at Freiburg in Germany, received a thorough technical education, and in 1859 became professor of anatomy at the University of Bonn, where he remained during the active balance of his life, and where he completed a number of important investigations on animal and vegetable life. Among his most notable writings on these subjects may be cited that on the Turbellarian Worms (1851), on the Foraminiferae of the Adriatic (1854), on the Embryology of the Lamprey (1860) and on the Electric Organs of Fishes (1867). His great accomplishment, however, was the establishment of the chemical and physical identity of protoplasm as found in the animal and vegetable world. This was set forth in a monograph published in 1863, which at once attracted the attention of biologists throughout the world, coming, as it did, nearly at the same time as the appearance of Darwin's great work on the Origin of Species.

The substance found in the minute cells, and which constitutes so far as at present known the ultimate material of all vegetable and animal life, was given the name of protoplasm by the German botanist Mohl, who was engaged at the time in investigating the nature of the chlorophyl grains in the leaves of plants. Before him, Conti, in 1772, and Treviranus in 1807, had detected the motion of these grains. Mohl showed that this motion was due to the movements of the substance in which they were contained as minute floating particles. Later, several observers (Siebold, Kolliker, Remak, etc.), discovered a similar appearing and continually moving substance in the cellular structure of certain animal tissues, and gave it the same name. Still later, in 1835, the French zoologist Dujardin, detected the same material in the bodies of certain members of the primitive animal order of protozoa, and gave the name of "sarcode" to it. The German botanist Cohn in 1850 advanced the opinion that sarcode and protoplasm were identical, and this was demonstrated to be the fact by Schulze in 1861.

In appearance protoplasm is a colorless liquid of about the consistency of thin syrup, through which are scattered highly refractive microscopic granules. It is regarded by biologists as the physical basis of all forms of living organisms, both animal and vegetable. It constantly exhibits motions of contraction, expansion, protrusion of parts, and other visible alterations of form by which translation from one place to another is effected. It reacts vigorously to touch, temperature and to chemical stimulus. Under analysis it yields mainly carbon, oxygen, hydrogen and nitrogen, and in smaller amounts phosphates and sulphates of potassium, calcium and magnesium, besides traces of sodium, iron and chlorine. Hertwig describes it as "not a chemical compound, but a morphological conception." Which is the same as saying that its properties are not explainable by chemical analysis, but must be—and doubtless will be in due time—by study of its activities as revealed by the microscope.

BATES (1825–1892)

NATURAL HISTORY

Henry Walter Bates was born at Leicester, England. His education was limited to the fundamentals, and at an early age he was apprenticed to a hosier, and later was a clerk in a commercial establishment at Burton-on-Trent. While there employed he became interested in the study of insect life, and devoted all his spare time and vacations to making collections, and reading such books as he could obtain on the subject. He finally met the naturalist Wallace. They became firm friends, and by the sale of duplicate specimens accumulated sufficient means to undertake a trip to Brazil, landing at Para at the mouth of the Amazon river in 1848, with the intention of exploring its valley. To accomplish this with the least risk and to the greatest advantage, they divided the country between them, Wallace taking that to the north of the river, and Bates to the south. The latter spent three years with Para as headquarters, and seven in the upper tributaries of the great stream.

The result of his work was an unusually fine collection, in which more than eight thousand specimens were entirely new to science. Included were five hundred of butterflies. These, in South America, attain remarkable size and extraordinary beauty. With this accumulation he returned to England in 1859, and in 1863 published "The Naturalist on the River Amazon," which was at once recognized as the most valuable work of its kind up to that date, and remains today a classic. A later work, published in 1865, and entitled "Contributions to Insect Life of the Amazon Valley," drew from Darwin very hearty congratulations. In it, in writing of the butterflies, he enlarged on the subject of mimicry among these beautiful creatures, and advanced a theory in explanation which, though ingenious, is not considered satisfactory. The butterflies belong to the order *Lepidoptera,* which also includes the moths. Both are characterized by the possession of four wings. In the former all are capable of separate motion. In the latter the two on each side are connected and move together. Other distinctions are that the moths are nocturnal in habit, and hold their wings horizontally outstretched when at rest; while the butterflies are day-loving insects, and when in repose hold their wings vertically against each other. Both are beautifully marked and colored in wing and body, but these features in the butterflies are far more elaborate and showy. Together they contsitute a most interesting and important order, and play a large part in the fertilization of plants. In tropical regions they attain great size and develop wonderful colorings. Specimens of the tiger Swallow-tail butterfly have been found with a wing extension of twelve to fourteen inches.

Bates's theory of mimicry was an effort to explain certain curious conditions which he found existing in connection with that species of the butterfly to which has been given the technical name of Helaconidae. These possess a very offensive odor, and an unpleasant taste, which renders them immune from the attack of insectivorous animals and birds. They seem to be aware of this, for, though brilliantly colored and marked, they make no attempts at concealment. Another species, called the Pieridae, has not been provided by nature with the protective odor and taste, and is eagerly hunted by its enemies as a choice morsel. To offset this disadvantage it has developed (or is naturally gifted with) markings and colorings which so closely resemble those of the Heliconidae as to aid them materially in the struggle for existence. How this mimicry is effected—if it is of that nature—has not yet been explained. It has been found to exist as a fact in other species of those insects, in certain varieties of bees and wasps, and to some extent even among vertebrates. Both Fritz Muller and Wallace attacked the problem, but their explanations are regarded as no better than that of Bates. At the present time the subject is considered an open question by naturalists.

HUXLEY (1825–1895)

BIOLOGY

Thomas Henry Huxley was born in a suburb of London of well-to-do parents, and received an excellent education in the sciences, graduating at the age of twenty from the Charing Cross medical school with the degree of A.B., and as a medalist at the University of London. In the following year he was appointed assistant surgeon on the *Rattlesnake* of the Royal Navy, which was ordered to Australia to survey and study the great barrier reef on the eastern coast of that continent. The task lasted four years, during which he devoted the most of his time to the study of the marine life of that interesting region. His first monograph, on the Medusae (jelly fishes), published during his absence, placed him at once in the front rank of living biologists, by reason of his demonstration in it that the inner and outer membranes of these organisms corresponded exactly to the two primary germinal layers of the vertebrate embryo, a discovery which was the basis of a true conception of the affinity of animal life.

On his return to England in 1851 he was elected a member of the Royal Society, and in the following year presented with its medal. In 1854 he was appointed to the chair of natural history and paleontology at the Royal School of Mines. Here his great ability, and unusual charm as a lecturer, at once attracted attention, and quickly brought him distinction and honor. In 1855 he was tendered the chair of comparative anatomy at the Royal Institution; in 1863 the Hunterian professorship at the Royal College of Surgeons; in 1868 the presidency of the Ethnological Society; in 1869 that of the Geological Society, and in 1870 of the British Association for the Advancement of Science. He was elected rector of the University of Aberdeen in 1872, the professor of biology at the College of the Sciences in 1881, the president of the Royal Society in 1883, and in 1892 a Privy Councilor of the Realm.

Aside from his very important discovery already mentioned, his exceptional ability as an expositor, coupled with the clarity and incisiveness of the language he used in his lectures and writings, has never been surpassed among his countrymen. Perhaps the most remarkable example of these qualities was displayed in his lecture in 1858 on the "Origin of the Vertebrate Skull." But he is chiefly remembered at the present day as among the first of those who accepted whole-heartedly the theory of evolution as outlined in Darwin's "Origin of Species." He undertook a veritable crusade in disseminating knowledge of its details and implications, among the masses by lectures, and among the intelligentsia by his writings. His book, "Man's Place in Nature," is rightly regarded as his greatest literary production. While he accepted tentatively Darwin's view of the cause of evolution, that is, Natural Selection, and the Survival of the Fittest, as most probably the correct one, he held that clear and undoubted proof of it had not yet been produced, and urged that the question be regarded as open and unsettled until further evidences were discovered. On the other hand, he dissented absolutely from the explanation advocated by Lamarck, that of "use inheritance."

In certain quarters Huxley was regarded for a time with suspicion, because of his invention and application of the word "agnostic," as an attitude of mind. By those he was ranked as an atheist, though his whole life as since studied reveals him to have been a man of strong religious tendencies. To him, knowledge must be a result of repeated experiences, and any mental conception which could not be so verified he thought should be placed in the category of unknown and perhaps unknowable things, belief in which could not be expected of rational beings. But simultaneously he insisted that the mind should always be held open for the reception of proofs through experiences, and should never be influenced by unsupported Authority. In this he represents correctly the mental attitude of the scientists of the present day.

BUCKLAND (1826–1880)

NATURAL HISTORY

Francis Trevelyan Buckland was born at Oxford, England, his father at the time occupying the post of canon at the cathedral of Christ's Church there. The latter was a man of considerable literary ability, and, in an amateur way, a student of geology. The lad's mother was a pearl among women, and the two were devoted to each other.

Francis early developed a taste for natural history in its aspect of animal life. His disposition was gentle and genial. Pets took naturally to him. He had no difficulty in winning the confidence of any of the smaller animals, even of those that had not been domesticated. He was naturally given an excellent education, entered Oxford College at the age of eighteen, took his degree with honor, and in 1848 was enrolled as a medical student at St. George's Hospital. While there he wrote an article on "Rats" which appeared in Bentley's "Miscellany," and inaugurated his career as an author. In 1854, having creditably completed his term at the hospital, he was appointed assistant surgeon of the Life Guards. While occupying this position he contributed many articles on natural history to current periodicals, entered the lecture field, and gradually became recognized as an authority of note in his subject.

In 1863 he resigned his position with the Guards, took up the study of fishes as a specialty, and traveled extensively on the continent collecting their eggs, investigating their habits, and taking notes of all devices encountered which had for their object their protection or improvement. One of his most interesting experiments was to freeze a quantity of fertilized trout eggs in ice, and ship the block to Australia in a refrigerator. The journey took more than three months in those days, but when what remained of the cake of ice was put into a weir properly provided with running water, and melted, the fish in a short time were hatched, and entered upon a healthy and vigorous life. In 1864 he turned his attention to oyster culture, and in 1867 attained the summit of his ambition by receiving the appointment from the government of National Inspector of Fisheries, a position which he held for the balance of his too brief life, and in which it is not too much to say, he conferred enormous benefits on his country, by enlarging to a remarkable extent the consumption and supply of sea food. In addition, through contributed articles to the press, the technical and outdoor life periodicals, and by lectures, he spread the knowledge he acquired so entertainingly, and at the same time so truthfully and accurately, that at the time of his death he ranked easily as the chief world authority on sea food. To him the American Fisheries Commission owes much in the way of advice for the protection and rearing of food fishes. He took a prominent part in securing an international agreement to prevent the extermination of the North Atlantic fur seal. He devised the best form of ladders to assist salmon in reaching their natural spawning grounds in rivers obstructed by falls or dams. He secured legislation for the protection of desirable sea birds. At the jubilee anniversary of the Society for the Prevention of Cruelty to Animals in 1874, he was perhaps the most prominent speaker, and easily the one who drew the largest audiences. His account of the life history of the crabs and lobsters is absorbingly interesting.

His premature death was the result of lung trouble, brought about by excessive work and exposure while prosecuting his investigations of marine life. With men of his temperament the search for knowledge becomes an obsession, which will not permit of rest, so long as a question that the mind has propounded remains unanswered, or death terminates the quest. Perhaps it merely forces a rest until, again refreshed, the loved work can be resumed in another phase of existence.

BERTHELOT (1827–1907)

CHEMISTRY

Pierre Eugène Marcellin Berthelot was a native son of Paris, and educated at the College of Henry IV in that city, graduating with high honors in 1854, upon which occasion he delivered a remarkable thesis on the synthesis of animal fats, the analysis of which had been effected in 1823 by Chevreul. In this essay he showed that glycerin was an alcohol, thus introducing for the first time the idea of polyatomic alcohols.

In 1851 he took the chair of organic chemistry at the Paris School of Pharmacy, and in 1865 the professorship in that branch of science at the Collège de France, which he held during the remainder of his active career. In 1873 he was elected a member of the French Institute, and in 1889 became permanent secretary of the Academy of Sciences.

Berthelot is regarded as the pioneer in the very modern science of organic chemistry, and one of the most brilliant of experimenters. The science of thermo-chemistry also owes much to his studies. In this department of investigation he announced what he called the third law of thermodynamics, namely, "that the heat evolved during a chemical reaction measures the power of the reaction." This principle, however, has since been found to be only partially true, or rather, true in many cases, but not in all, and hence is not at present considered in the category of demonstrated natural laws, as the term is understood.

Organic chemistry is that department of general chemistry which has to do with all those forms of matter—found exclusively in the animal and vegetable world—which are products of the phenomenon called life; as distinguished from inorganic chemistry whose domain is confined to the mineral kingdom, including water and the atmosphere. As late as 1825 it was believed, even among men of science, that a force existed entirely different in kind from all the forces then known, which was the cause back of all kinds of life, and as impossible to understand and manipulate as life itself. It was called the "vital force." In certain circles it was even deemed impious to investigate its operations, or to endeavor to modify its consequences. All such ideas have long since passed away. Today, while our horticulturists cannot make a loganberry in the laboratory, they can induce a blackberry bush to produce one, and all sorts of similar feats have been accomplished in the manipulation of animal life, as stock breeders well know. But it is mainly in the modern manufacturing arts, such as the production of dyes, drugs, perfumes and fibers, without the aid of life processes formerly relied upon, that the organic chemist of the present day has scored his greatest triumphs.

Comparatively few of the eighty-eight known elements of which all matter is composed are found in living organisms; if we exclude the skeletal parts such as bones, shells and the silicious integuments of trees, bushes and plants, ninety-five per cent of all animal and vegetable tissue is composed of the elements carbon, hydrogen, oxygen and nitrogen, with sodium, potassium, phosphorus, sulphur and chlorine constituting the most of the other five per cent. With the first four mentioned, and with the compounds of carbon preeminently, the science of organic chemistry has mainly to do. The first, so well known in its familiar form of charcoal and coal, is found in nature in two other forms, viz., graphite and the diamond. Associated with the coals are usually many impurities, yet the soot which, to some extent always, is produced during their combustion, is the pure element. Graphite, the material of which pencils are made, is also carbon in its native condition, and is always more or less contaminated with earthy impurities, but can generally be separated from them by mechanical means. Strangely enough, carbon, when in this allotropic form, is so incombustible as to be available and highly desirable in the manufacture of crucibles, in which metals of high infusibility can be melted. The diamond is the crystallized form of the element. In all organic compounds carbon is an invariable constituent, and generally much the largest.

LISTER (1827–1912)

MEDICINE

Joseph Lister lived at Upton, England, and received his early education at a school conducted by the Society of Friends (Quakers). From there he went to the University of London, where he took his degree in medicine at the age of twenty-seven. Specializing in surgery, he soon attained a high reputation, which was recognized by being appointed surgeon to the Queen. His eminence and success was due, not only to his manual skill, and knowledge of anatomy, but to his insistence on scrupulous cleanliness, and the large use of disinfectants in his hospital wards. He knew from extended experience the advantages of such a régime and perhaps had some idea of the reasons behind his methods, but he was not enough of a chemist to carry on the laboratory work necessary to explain them scientifically.

When, however, Pasteur gave to the world his great work on putrefaction and fermentation, he at once realized that the danger in wounds, and in all surgical operations, lay in infection from bacteria, and the other micro-organisms always present in the purest air, and under the most cleanly conditions possible, and that some method must be developed to combat this danger.

He at once set about the preparation of antiseptic liquids and disinfectants, and in devising methods of surgical practice which would exclude germs of all kinds from the vicinity of the patient under operation, or would cleanse a wound already infected. One of his first preparations was the well-known "listerine," a solution of boric and benzoic acid with thymol. He devised a method of conducting certain operations under an atomic spray of carbolic acid, and adopted many scheme for keeping instruments sterilized, for keeping his hands, and those of his assistants, free from germs, and the air in the operating room as pure as possible. Some of his early methods have since fallen into disuse, or have been improved by the employment of chemicals better adapted to the ends sought, but the recognition of the importance of the exclusion of living germs from wounds, of the danger of their introduction from the air, on the instruments employed, and by the hands of those operating, and of the value of germicidal drugs, has been a permanent acquisition of enormous value to the surgical art.

In 1880, both Cambridge and Oxford conferred the degree of LL.D. on Lister, and he received the gold medal of the Royal Society. He was made a baronent in 1883, and a peer of the realm in 1897. The noun "listerine" and the verb "to listerize" have both been incorporated into the English language, and constitute a permanent memorial to his honor.

KEKULÉ (1829–1896)

CHEMISTRY

Freidrich August Kekulé von Shadowitz was born at Darmstadt in Germany, and after passing through the course at Heidelberg became at first a tutor there, and in 1858 professor of chemistry at the University of Ghent. In 1865 he was transferred to the same post at the University of Bonn, and remained there for the balance of his career as an instructor, engaged, while not in the lecture room, in researches in the field of organic chemistry.

As the element carbon is present in all organic compounds to a greater extent than any other, it was quite natural that Kekulé's first discovery of importance should have been its quadrivalent property. By valence, in this connection, is meant the relative capacity of an element to combine with other elements. Valence is a conception which has sprung from the atomic and molecular theories of matter. The majority of the elements appear to have but one valency and hence are called univalent. Thus hydrogen can hold only one atom of any element with which it is capable of entering into a stable compound having properties entirely different from that of the atoms of which it is composed. Oxygen and sulphur, as well as the group known as the alkaline earths—sodium, potassium and lithium—are divalent. Aluminum and zinc are each trivalent. Many of the others have more than one valency. Carbon was shown by Kekulé to be quadrivalent, which means that its atom can combine chemically with four atoms of any univalent element, or with two of divalent ones, with which it can combine at all; for all of the elements refuse to combine in any way with some of the others. On the foundation of this discovery has been raised the modern "structural theory" of chemical compounds in a way the usefulness of which can hardly be overestimated.

On the other hand, valency as a general theory for all the elements is not yet thoroughly enough demonstrated or developed to be perfectly satisfactory in all cases. In fact, it is only so in the case of carbon and a few others, and even with carbon, in the case of the gas carbon monoxide (CO) it seems to act divalently, unless it be assumed in this instance that the oxygen (normally divalent) is here acting quadrivalently. Other exceptions might be cited. So that while Kekulé's discovery has been very fruitful, the subject is much in need of further and more profound research.

MARSH (1831–1899)

NATURAL HISTORY

Othniel Charles Marsh was a native of Lockport, New York, and after his graduation at Yale studied in Germany. When he returned from that country he was offered the chair of paleontology at Yale and the curatorship of its geological museum, and continued an honored member of its faculty for the remainder of his active life. In 1877 the Geological Society of London, of which he was a member, awarded him the first Bigsby medal. In the following year he was elected president of the American Association for the Advancement of Science, and served in the same capacity for the National Academy of Science from 1883 until 1895. He also was the recipient of the Cuvier prize from the French Academy of Sciences for his researches and discoveries in the field of zoology.

His outstanding achievements, however, were in the domain of paleontology, the science of fossilized and ancient or pre-historic animal life, and consisted largely in the exploration of localities in the Great Plains region of the United States, where he discovered and recovered from their graves in the rocks and unconsolidated sediments, the remains of over four hundred new species of vertebrates, among them being such interesting types as huge tapirs, flying lizards and toothed birds. His greatest discovery was the fossilized bones of the ancestors of the horse family.

Until Marsh's labors became known it was generally held that this beautiful and useful animal had been evolved in western Asia, and that vast upland area may yet prove to have been the real place of his origin; but up to date all indications are to the effect that it was on the North American continent, though he appears to have become extinct there many ages ago, and was unknown to the aborigines of both of the American continents when first introduced by the Spanish conquerors in the early years of the 16th century.

It is now held that the horse arose as a branch from the older family of the tapirs, one of the members of the order of *Pachydermata,* which includes the elephant, rhinoceros, hippopotamus and hog. The first known member of his stem was the *Hyracotherium,* an animal about the size of a rabbit. It is better known at present as the Eohippus. It had four toes on its front feet and three on its hind. Its bones were found in one of the early rocks (Wasatch) of the Eocene division of tertiary time which, according to present estimates places its age perhaps as much as ten million years in the past.

A complete skeleton of his successor, the Protohippus, found in Wyoming, is in the American Museum of Natural History in New York. It is about the size of a half-grown fox. It had four toes in front and three behind, but the two side toes of the last only just touched the ground. Following him, and in the Oligocene (White River) rocks of the middle Tertiary, the Mesohippus was found, of about the size of a sheep, with three toes in front but only one of them firmly touching the ground, and the same number similarly conditioned in the rear. In this animal the long skull of the modern horse began to appear as a marked feature. The first specimen was found by Marsh in 1875.

Next came the Protohippus, which had attained the size of a Great Dane dog or a small Shetland pony. He traveled on one toe (the middle) on all four feet, but still carried on each, two side toes well off the ground, and merely useless rudiments. His teeth now begin to show the shape and character of those peculiar to the horse, the crown longer, the ridges higher and more complicated, and strongly enameled, and between the last the dentine or cement begins to show, which, being softer, wears away faster than the enamel, and so makes the grinding teeth such effective tools for disposing of the hard silicious grains and grasses which had by then become his principal food.

In the upper rocks of the Tertiary and the lower ones of the Quaternary, that is, about the time when man began to appear, was found his successor, the Pliohippus, a little taller than his predecessor, his face a little longer, his side toes now mere rudiment, and his teeth approaching closely the shape and character of those of the existing animal.

The horse first appeared in historic time among the Assyrians, whose home was in the uplands of Armenia and Persia around the northern boundaries of the Mesopotamian valley. By that time—four to five thousand years ago—they had become domesticated, and it is considered that their ancestors were tamed and trained for the service of man by the semi-Mongolian people who, several millenniums previously, dwelt in that region to the east and northeast of the Caspian sea which is now called Turkestan, and was formerly known as Tartary.

The horse family has three other living members, the zebra, the ass and the donkey. The first has been found only in Africa, and is distinctly a dweller in mountain and forested areas, where it has acquired its peculiar coat as a protection against its natural enemy, the lion. The African wild ass often attains the height of fourteen hands (four feet, eight inches) or more, and is also distinctively a lover of hilly and well-timbered regions. His Asiatic relative, however, is smaller, and prefers semi-arid and treeless plains. The donkey is believed to be the domesticated variety of the African ass, which has lost size and spirit through centuries and probably millenniums of interbreeding, hard usage and abuse. But in recent years the species has been vastly improved in the United States in employing it for the breeding of mules.

MAXWELL (1831–1879)

PHYSICS

JAMES CLERK-MAXWELL was born at Edinburgh, Scotland, and secured his primary education at the academy of that city. At an early age he developed unusual mathematical abilities, which were zealously cultivated along with physics, chemistry, philosophy and laboratory work, as he passed through the university. From there, at the age of nineteen, he was sent to Cambridge, where he graduated in 1854 with high honors. Two years later he took the chair of natural philosophy at Marischal College, Aberdeen, and in 1860 the same position at King's College, London. From there in 1871 he went to Cambridge, to take the professorship in experimental physics, and the directorship of the Cavendish Laboratory, which was completed under his supervision, and placed at his command. He retained this position during the balance of his short life, passing away with the reputation of being the leading physicist and mathematician of his day, and one of the greatest of all time.

He published a number of scientific monographs, but the one that is regarded by long odds as his greatest, appeared in 1873, under the title of "Electricity and Magnetism." In this paper he developed his electro-magnetic theory of light, demonstrating mathematically the ultimate identity of the three phenomena, and showing that each was a manifestation in a different way of the energy existing in space. His conclusions were later confirmed experimentally by Hertz, who not only produced elctro-magnetic waves or undulations, but showed that they were propagated just as those of light are, experiencing reflection, refraction and polarization, and also moving at the same velocity.

Maxwell's calculations and investigations assume the existence of the universal ether of space, as a transporting medium. The actuality of this substance (like that of the force of gravitation) has never been scientifically demonstrated, and the theory of relativity recently advanced by

Einstein implies that neither (the ether or gravitation) are necessary hypotheses for a correct explanation of the phenomena of the universe. Einstein's conclusions have so far been experimentally confirmed, and it is the expectation of many scientists that they will continue to be. If, in the end, it becomes clear that the ether, or the force of gravitation, or both are unnecessary for a proper understanding of nature as it appears to the senses, it is not expected that the conclusions of Maxwell or Newton will be affected. On the other hand the scientists of today are looking for new light on both of these subjects, and are awaiting their coming with confidence and composure.

The conception of "action at a distance, without any connecting medium" is one that is at present incomprehensible to the human mind. But we have much good evidence to the effect that the mental capacity of man is greater now than it has been, from which it is a fair conclusion that it is capable of acquiring still further powers of understanding.

TYLOR (1832–1917)

BIOLOGY

Edward Burnett Tylor was a native of London, received his education in fundamentals in that city, and began his active business life as an operative in his father's brass foundry. But having a delicate constitution he was compelled to abandon the work, and was provided with the means for travel. In 1855 he came to the United States, and in the following year passed on to Mexico, where he became interested in the study of the ancient civilization of the Aztecs and Mayas, the remains of which are so abundant in the great Valley of Mexico, in the states of Campeche and Chiapas, and in the republic of Guatemala to the south of them. Finding in these the opportunity for congenial research and study he devoted the balance of his life to their investigation, and in 1859 began the publication of his discoveries in a volume entitled "Anahuac." This was followed in 1865 by his "Researches in the Early History of Mankind," in 1871 by "Primitive Culture," in 1881 by "Anthropology," and in 1900 by "The Natural History of Religion." In these books he opened a completely new field for investigation, and being a careful and keen observer as well as possessing a pleasant style, his writings have not only been widely read but have given such an impetus to the study of human antiquities in all parts of the world that he is regarded as the founder of the science of anthropology, as well as the supreme authority up to the present time on the prehistoric civilizations of Mexico and Central America. In 1896, in recognition of the value of his work in this direction, he was elected to the chair of the science at Oxford, and continued in that honorable position for the remainder of his active career.

Anthropology, the science of Man, should not be confounded with Archaeology, the science of the remains of the doings and acts of ancient man. While the former has to do more or less with those abstract physical phenomena like gravity, energy, affinity, vitality (in the vegetable world) and motility in that of animals (including man), it adds as its own particular subject that of mentality, and regards the latter as its exclusive field of research.

As man is a member of the animal world, a knowledge of zoology and comparative anatomy is at the foundation of anthropological science. To understand correctly the possible physical activities of the human body a thorough acquaintance with the nervous and muscular system is required, and to comprehend mentality the reactions of which the brain is capable must be known. Thus physiology and psychology are necessary tools of the anthropologist. On the other hand, as the subject enlarged under investigation, specialization began, so that today sociology, the science of human groupings; ethnology, the science of human races; philology, the science of human speech, and mythology, the science of religions, and others, have come into existence as sub-divisions of the main field of research.

In time and place anthropology has fundamentally to do with that specific era in the history of all the human races that have emerged from savagery and barbarism into more or less of civilization; when the man, by reason of his mental capacity, began to make and use tools, to form theories of nature and life, to provide somewhat for the necessities of tomorrow as a result of the experiences of yesterday, to scheme for something more than food and shelter, and to exhibit the germs of an appreciation of beauty and sentiment by the development of the arts of music, architecture, painting and sculpture. Above all, to devise means for recording his actions and thoughts in pictographs and in systems of script. When this stage of development is attained, history for him has begun, and the science of anthropology properly merges itself into that of archaeology.

CROOKES (1832–1919)

PHYSICS

William Crookes was born in London, and completed his education at the Royal College of Chemistry in that city. In 1854 he became connected with the Radcliffe Observatory at Oxford, and in the following year, the professor of chemistry at the Chester Training College. In 1859 he founded the *Chemical News*, and continued to be its editor during the remainder of his life.

He was a brilliant investigator in many departments of theoretical and applied chemistry, and the discoverer of several important principles. He was an authority on sanitation and the disposal of sewage. He devised the method of attaining a high vacuum, which made the incandescent light bulb a possibility. He discovered the rare metal thallium, and investigated its interesting properties. He was an important contributor to the science of spectroscopy, and of radiation, for the display of which he devised the radiometer, which has since been made so delicate as to be capable of registering the energy carried by ethereal undulations. He was not the inventor of the well-known apparatus for the study of rarefied gases which bears his name (Crookes' tubes), that idea having originated with Hithoff, a German chemist; but he took a large part in improving its construction, and employed it very extensively in his investigations of the phenomenon of fluorescence, the explanation of which was made by Stokes.

In 1879 he advanced for consideration by the scientific world his theory of a fourth, or ultra-gaseous state of matter.

He received many honors during his lifetime, among them being the Nobel prize of 1917 for chemistry, and the Order of Merit in 1910.

The metal thallium when pure is of a silvery white color, and so soft that it can be scratched with a piece of pure lead. It can be squeezed, but not drawn into the form of a wire, but has little tenacity or elasticity. It is slightly heavier than lead, melts at a lower temperature and tarnishes quickly in the air. Its compounds are extremely poisonous. In the Periodic System of the elements it is next to the bottom of the vertical group headed by boron, and which contains in the order given aluminum, scandium, gallium, yttrium, indium, lanthanum and erbium, and stands between mercury and lead in the eleventh of the horizontal series. So far little use has been found for it. During recent years, as a result of the discovery of radium and the series of disintegration products from it and the metal thorium, it has been thought by investigators of those phenomena that it may prove to be the final disintegration step of thorium, as lead has proved to be of radium.

When the flame produced by the combustion of thallium is examined in the spectroscope, a brilliant green line appears at one place, which is so characteristic that the presence of the metal in very minute quantities can be detected by the test. It occurs in nature in very few minerals, and almost always in combination with the non-metal selenium.

NOBEL (1833–1896)

HIGH EXPLOSIVES

Alfred Bernard Nobel was a native of Stockholm, Sweden. He acquired his education in St. Petersburg, to which city his father's business took him during his youth. In 1850 he came to the United States, and studied under the distinguished engineer, John Ericsson, for several years. It was during this period of his life that he became impressed with the great need in the engineering arts of an explosive of quicker action, and greater convenience in handling and usage, than the gunpowder that up to then was the only agent available.

The modern discovery of gunpowder is generally attributed to Roger Bacon, who wrote of it in 1270 as "a substance that, if confined and ignited, would explode with the noise of thunder, and tear to pieces the vessel in which it was stored." But there are manuscripts in existence which seem to indicate beyond question that an explosive compound of sulphur, saltpeter and charcoal, was known to the Arabs before that date. The Chinese are also believed to have been more or less acquainted with the substance centuries previously, and to have used it effectively in the siege of Lo-Yang and Pian-King in 1232. It is well attested that it was employed in cannon at the battle of Crécy in 1345. For 500 years thereafter, this comparatively mild article answered all the requirements for such a substance, being mainly demanded for destructive purpose in war.

In 1845 or 1846, a German chemist named Schonbein, discovered by accident the dangerously explosive qualities of the compound now called gun-cotton, and in the year following, the Italian chemist Sobrero, in the same fortuitous way, made the acquaintance of nitro-glycerin. Neither of these men pushed their investigations any farther, though Sobrera seems to have committed to writing the opinion that "if a way could be found to handle and use the article safely, it might be employed advantageously in rock blasting." Meantime, he prepared a very dilute alcoholic solution of it, for use in the medical art, where it still is employed for the relief of certain obstructions in the circulatory system, where it appears to have the power of dilating the arteries and capillaries, and so relieving the strain on the heart.

Nobel's attention seems to have been drawn to these discoveries, for in 1863 he took out a patent for the manufacture of a compound, consisting of a mixture of nitroglycerin and gunpowder. The former, being a liquid, and having the habit of exploding on the slightest occasion under the influence of a small shock, was exceedingly dangerous to handle. But when mixed with gunpowder it became a pasty solid, which was less dangerous, and was also capable of being molded and used in the form of a cartridge. However, gunpowder is in no sense an absorbent, and cartridges made of such a mixture had the unpleasant habit of sweating, and also leaking, at a little above the ordinary temperature, in which condition they were fully as dangerous as the liquid nitroglycerin. So many fatal accidents occurred when the article was used, that it was quickly abandoned. However, in 1867, he substituted a mineral product called kieselguhr, for the gunpowder, using about 25 per cent by weight of it, to 75 per cent of nitroglycerin, and gave the name of dynamite to the mixture. As kieselguhr consists of the minute and empty shells of infusorians, it possessed the absorbitive and retentive power required to produce a safe compound. Later wood pulp was substituted. The latter being itself capable of combustion, added to the power of the article, and at the same time proved entirely satisfactory as an absorbent.

In 1876 Nobel brought out his blasting gelatine, which, for certain purposes, is an improvement on dynamite. Pursuing the investigation farther, he took out a large number of patents for explosive compounds (129 altogether), established factories in all parts of the world where such an article is in demand for mining, quarrying, etc., and accumulated a large fortune, the major part of which, at his death, passed to the Nobel Prize Fund of $8,400,000, from the interest of which the trustees annually award five prizes of $40,000 each, to the most deserving persons in as many departments of human activity, namely, physics, chemistry, physiology or medicine, literary work of an idealistic nature, and in the interests of universal peace.

The world has benefited enormously by the discovery of safe ways of utilizing the power of high explosives. The arts of mining and of under water excavation have been completely revolutionized since their advent. And while, unfortunately, these substances—of which hundreds are now known—are also used to a considerable extent in the destructive art of war, yet their very terrible powers cannot fail ultimately to bring to an end the barbarous scourge of battle.

LUBBOCK (1834–1907)

NATURAL HISTORY

JOHN LUBBOCK (Lord Avebury) was the son of a London banker, himself an astronomer and mathematician of note. The young man was educated at Eton and Oxford, entered public life in 1858, and 1890 succeeded Lord Rosebery as president of the London County Council where, as a man of affairs and a wise legislator, he served his constituents to their great satisfaction.

Early in his career he became interested in the sciences of archaeology and entomology, and having the leisure and the means to indulge his inclinations, did much to advance the status of both. His "Prehistoric Times," published in 1865, was the first notable effort to collect and arrange all the information of reliability that had accumulated to that date on the subject of ancient human remains and artifacts, and for twenty years or more was a standard text book in its line. It was followed in 1870 by his "Origins of Civilizations," of equal value as an inspiration for others to follow.

In entomology he was the discoverer of the extraordinary fact that the common insect known as the May fly moults twenty-three times during the course of its larval life of from one to three years, while the fly itself lives but a few days after attaining its final term of existence. In 1867 he published a monograph on the life history of that very remarkable minute creature known as the pauropus which, though not over one-twentieth of an inch in length, and gifted at birth with only three pairs of legs, develops during its life nine additional pairs. This was followed in 1873 by the publication of his chief systematic work on the *Collembola* and the *Thysanura*, the lowest order of six-footed insects, and the ones which seem to represent the first structural advance on their ancestors, the worms. Although this work, as well as several others on similar subjects, is now considered somewhat out of date, it was an authority for many years, and did much to encourage study and research in the then obscure and little known field of an important department of organic life. Discoveries of this nature may seem trivial and scarcely worth recording, yet it has been shown by innumerable instances that knowledge gained of the minute and apparently insignificant in nature invariably leads in due time to revelations well worth while, and often of supreme importance to science as a whole. Much of Lubbock's work in entomology was of this inspirational kind. He was a man of wide learning for his time, and of broad sympathies and high intelligence.

WEISMANN (1834–1914)

ZOOLOGY

August Weissman was a native of Frankfort-on-the-Main in Germany, took his degree in medicine at the University of Göttingen, served for a time as clinical assistant at Rostock, and then for three years traveled and served in the hospitals of Vienna, Bologna and Paris. In 1863 he took a special course in geology at the University of Giessen, and in 1871 became a full professor of that science in the University of Freiburg.

When Darwin published his "Origin of Species," Weismann was among the first of German scientists to became an enthusiastic supporter of the views there advocated. In fact, he went somewhat beyond Darwin. The latter advanced natural selection as the main cause of variability, but believed that there were other contributing agencies which should not be ignored. Weismann insisted that it alone, as embodied in the phrase "the survival of the fittest" was the one and all sufficient cause of mutability. The controversy over these divergences was animated and is not yet ended. But while it was most actively in progress it had the effect of completely demolishing the old theory to the effect that each species arose as a separate and distinct act of creation. On the other hand, the debate brought to the surface the theory of "use-inheritance," which originated with Lamarck. According to this, character or form acquired during the lifetime of an individual could be, and often was transmitted to descendants. Weismann scouted this in toto, and considered that he had disproved it by docking the tails of white mice through nineteen generations without producing a tailess individual at the end of the experiment. However, it is held by modern evolutionists that characteristics of several kinds formed by adaptation to changes in environment, in climate, or by any species of external stimulus, may be, and often are transmitted. Many obvious examples of this kind can be cited. The pointer breed of dog, without training, holds his tail rigidly level and on a line with his nose, when he has located his prey by scent. In the whale, whose ancestors were land animals, and who still brings forth its young alive and nurses them, the legs have become fins.

Weismann's investigations in other lines were notable. His study of the embryology of the fly, which appeared in 1864, is considered very remarkable. He was the first to discover the real nature of the changes that occur in the metamorphosis of insects, by locating the germ of the final and perfect form (the imaginal bud) in the body of the larva. This led to the complete abandonment of the theory of preformation which originated with Malpighi (1628–

1694), and according to which—for instance—all the parts and organs of the chick were present in the egg. Weismann was a most enthusiastic microscopist, and pursued the extremely minute in organisms so persistently as to injure his eyesight beyond repair. Compelled then to continue his studies without the aid of observation, he became more speculative in conclusions, and in his later years expressed some opinions that have not been sustained. On the other hand, being a bold and keen theorist, most of them have been amply confirmed. Perhaps the most notable instance of the latter is the case of the phenomenon of heredity, which he was the first to announce as having a physical basis, as now universally held.

LANGLEY (1834–1906)

AVIATION

Samuel Pierpont Langley was born at Roxbury, Massachusetts, was educated in the Boston Latin School, and after some years of study and travel in Europe, became professor of mathematics at the United States Naval Academy at Annapolis, Md. In 1867 he took the chair of astronomy at the Western University of Pennsylvania, and in 1886 was elected president of the American Association for the Advancement of Science. In the following year he was appointed secretary of the Smithsonian Institution at Washington. In 1894 he was awarded the degree of D.C.L. by Oxford University, and became a member of the Royal Society of London, from whom he received the Rumford medal. He was also given the Janssen medal by the Institute of France.

Langley was an accomplished mathematician, and an observational astronomer of high reputation. He was the inventor of the bolometer, a wonderfully delicate instrument for the detection of minute changes in temperature, and particularly for such as are due to the absorption of radiant heat. With this instrument he made solar observations on Pike's Peak in Colorado (1878), on Mt. Etna in

Sicily (1878–1879) and on Mt. Whitney in California (1881), which added greatly to the stock of knowledge of solar energy. In this particular line of research his conclusions may be concisely stated as follows: Starting from the mathematical premise that the earth receives 1/2,300,000,000th part of the total solar radiation, he deduced the figure 3 as the most probable value of the solar constant, which is defined as "the amount of heat required to raise one gram of water three degrees centigrade per minute, for each normally exposed square centimeter of its surface." The present accepted figure is 3.127.

Langley is universally accorded the great honor of having been the founder of the science of aviation. During the latter part of his career he became deeply interested in this subject, greatly to the regret of many of his friends and associates, who regarded his activities in that direction as indications of the gradual failure of a brilliant mind. He was, however, a man with the courage of his convictions, and by 1897 had become so thoroughly convinced that mechanical flight was possible, that he built a machine on the principles he had worked out, which was wrecked in the attempt to put it into operation. It remained for the Wright brothers not many years later to demonstrate the accuracy of his predictions.

MENDELEEF (1834–1907)

CHEMISTRY

Dimitri Ivanovitch Mendeleef was a native of Tobolsk, Siberia. He studied in the local primary schools, and at the age of sixteen was sent to the Institute of Pedagogy at St. Petersburg, where he specialized in the natural sciences, his inclinations being strongly towards physics and chemistry. Upon his graduation in 1856 he was appointed a tutor in the university, and in 1863 took the chair of chemistry at the St. Petersburg Institute of Technology, and two years later the same post in the university. In 1876, under government authority, he made a technical study of the petroleum industries in the United States, and at the

Russian oil fields at the foot of the Caucasus mountains. In 1893 he became a government official in the Department of Finance, and remained there during the balance of his active life.

His claim for distinction as a noted discoverer in the domain of science, was firmly established upon the publication in 1868 of his "Elements of Chemistry," in which he set forth with remarkable clarity and ability what is now known as the Periodic Law of the Elements. This law, as stated by him, was as follows:

"The properties of the elements, as well as the forms and properties of their compounds, are in periodic dependence on, or constitute a periodic function of, their atomic weights."

In his day only 64 elements were known. At the present time they number 88. Of those that have been added to the list since the publication of his law, three—gallium, germanium, and scandium—were predicted by him, their place in his table, and their chemical properties accurately given, and the association (mineralogically) in which they should be found correctly indicated. All three were discovered during his lifetime. Those since discovered have all found a place in his table, but it became necessary to enlarge this, when the inert elementary gases were discovered by Ramsay in 1894, and to alter its arrangement somewhat, though without affecting the principle of periodicity which is at the foundation of the law. In fact these changes rather strengthen the system.

In extension of his general law as quoted, he announced upon its publication the following conclusions or deductions:

1. The elements which have the lowest atomic weights, are those most widely distributed in nature, and also represent the most typical characteristics found in the successive series of the table.

2. The atomic weight determines the character of the element.

3. From a consideration of their position in the system, new analogies can be discovered between elements.

4. It may be expected that new elements will be discovered to fill blank spaces within the table, and their properties can be predicted, from a consideration of those of the adjoining elements.

5. Errors in the assumed atomic weights may be detected through an irregularity in the position of an element in the system.

All of these conclusions have, in a broad way, been verified, though the anomalous positions of tellurium and iodine are still unexplained.

Although at the present time the so-called elements are known to be composites, and no longer are regarded as elementary, yet Mendeleef's law has lost none of its interest or value to the chemist, for it still correctly represents the fundamental units of matter upon which he operates, and probably always will. If, as seems now to be quite certain, the physicist succeeds in resolving these units into pure manifestations of energy, our conceptions of matter will undoubtedly require readjustment, but the methods of dealing with it in the laboratory are not likely to be altered.

HAECKEL (1834–1919)

EVOLUTION

Ernest Heinrich Haeckel was brought up at Potsdam in Germany, and completed his education at the Universities of Berlin and Jena, specializing in medicine and physiology. After practicing the profession for a year, and finding the work uncongenial, he decided to devote himself to the natural sciences, and particularly to zoology. With that end in view he studied marine life at the island of Heligoland, at Naples, and at Messina. As a result of the publication of his investigations at these places, he was appointed to the chair of zoology at the University of Jena, and while occupying that position he was able to make numerous journeys to other places where observations of oceanic life could be conducted advantageously, as the Canary islands, the Norwegian coast, the Red and Adriatic seas, Ceylon, and the East Indies. Each of these furnished the material for the publication of a monograph of great value to science, as he was a close and accurate observer, and a clear reasoner.

When Darwin's "Origin of Species" appeared, Haeckel became an enthusiastic and generous advocate of evolution, and did more than any other continental writer of the time to disseminate its principles among the intelligent classes of central Europe. He is now remembered mainly on account of his celebrated biogenetic law, the germ of which had already been hinted at by Baer, Agassiz and Fritz Müller. It may be concisely stated as follows:

"Every individual organism, in its development from the ovum, goes through a series of evolutionary stages, in each of which it represents a stage of the evolution of the class to which it belongs; and every such organism breeds true in so far as it is influenced by heredity, and becomes modified in so far as it is influenced by the conditions of its environment."

Haeckel also advanced for consideration what is called the "Gastraea Theorie," according to which the gastrula stage in the development of animal life is to be regarded as a recapitulation of a hypothetical common ancestor—the Gastraea—the primitive animal form possessed of an intestinal organ or system, technically known as a gastrula.

NEWCOMB (1835–1909)

MATHEMATICS

Simon Newcomb was a native of Nova Scotia, and received his primary education at a school conducted by his father. At the age of eighteen he came to the United States, became a citizen, and shortly obtained a position as teacher in a Maryland school. While there he became acquainted with some government officials who, recognizing his exceptional aptitude in mathematics, secured his appointment in 1857 to the position of computer on the staff of the *Nautical Almanac,* the headquarters of which at the time was at Cambridge in Massachusetts. Taking advantage of the proximity of the Lawrence Scientific School he enrolled himself there, and was able to graduate in the following year with such distinction as to bring him in 1861 the appointment to the chair of mathematics at the U. S. Naval Academy, where he superintended the installation of the new 26-inch telescope at its Observatory. He was later a member of two government expeditions sent out to observe the transits of Venus in 1874 and 1882, one of which took him to the Cape of Good Hope. In 1877 he was appointed director of the *Nautical Almanac* publication, and continued in charge of its preparation and issue until retired for age in 1897.

The *Nautical Almanac,* issued annually by the American government is, like similar publications by the British, French and German governments, a volume furnishing data required by navigators to enable them at any time to find their position at sea, and to know the state of the tides at all their ports of call. In addition, it supplies a great variety of general information as to currents, latest known positions of derelicts, changes in coast lights and signals, and other such matter. In the line of astronomical affairs it gives the position of the moon for every hour of the year, the latitude and longitude of the sun for every day, the place in the heavens of the most important of the stars, and full details of eclipses, occultations, transits, etc. It is generally issued two or three years in advance, for the sake of mariners contemplating long voyages.

It will not be difficult to understand that a publication of this kind calls not only for a thorough knowledge of nautical astronomy, and high mathematical ability, but also extreme accuracy in the details of editing. For over thirty years Newcomb conducted this very important department with success. During his incumbency he was also able to appreciably increase the world's stock of knowledge as to the peculiarities in the movements of the moon. Being the nearest celestial body to the earth, it is the most important factor in the phenomenon of the tides; while at the same time it is perturbed in so many ways during its monthly journey, by the combined gravitative powers of the earth and the sun, as to make a closely approximate statement of its position at any time a matter of most intricate computation. Elsewhere in this volume the details of the "Lunar Theory" and the "Problem of the Three Bodies in Space" will be found.

Newcomb's standing as a mathematician was amply recognized during his lifetime. He was elected to membership in nearly all the scientific societies in the world, and was the first American since Franklin to be made an officer of the French Legion of Honor. He was the recipient of the Copley, Huygens, Royal Society and Bruce medals, and served terms as president of five of the American scientific associations.

LOCKYER (1836–1920)

ASTRONOMY

Joseph Norman Lockyer was born at Rugby, England. He was given a general classical education at schools in his own country and on the continent of Europe; and while serving from 1857 to 1870 as an employee in the War Office, devoted his leisure hours to studies and investigations in astronomy. In the years 1870 and 1871 he was a member of Lord Devonshire's Commission on scientific instruction, and in 1875 was connected with the science and art department of the Kensington Museum, serving at the same time on the government eclipse expeditions. When the Royal College in London was established he was appointed its professor of physical astronomy, and made director of its observatory. From that time until he retired from active life he was one of the prominent figures among British scientists.

The discovery with which his name is most frequently associated is that of the elementary gas helium, in 1868. It was made on the sun, instead of on the earth, and by the use of that wonderful tool of modern science, the spectroscope. While studying the solar spectrum he detected a bright yellow line which did not correspond to those of any known element. The discovery was quite analogous to that of the element coronium which the same instrument reveals as existent in the solar corona, and which has not yet been found on the earth. But in 1895, nearly thirty years after Lockyer announced the existence of helium, Ramsay, while examining the rare mineral clevite, identified its content in helium. It has since been found in all ores of uranium, in many mineral waters, in some meteorites, in the atmosphere; and lately as a component of the output of several gas wells in Texas in sufficient quantity to make its recovery commercially practicable.

In his studies of the spots on the sun he reached another conclusion not so spectacular, but perhaps more important. This was to the effect that there exists a relation between the number and area covered by them, and the weather on the earth. They appear like holes or vast depressions in the photosphere. In the middle of each is a black spot, surrounded by a spiral or radial formation of a brighter appearance. In size their diameter ranges from 500 to 60,000 miles. They begin as mere dots, and after enlarging to a maximum, slowly decline in size and disappear. The majority occur in the vicinity of the sun's equator, and none have been observed at a greater distance from it than 45° N. or S. It is thought by astronomers that they represent eruptions of some kind from the innermost nucleus of the sun, into and through the intensely heated gaseous and luminous layer surrounding it called the photosphere. It had been known for a long time that the total area occupied by these spots varied periodically. During about a term of eleven years the surface spotted attains a maximum and a minimum condition. Lockyer perceived that at these extremes the precipitation of rain and snow on the earth was also at a maximum and minimum, and continued observation since has demonstrated that the connection between the two phenomena was real; but why, has not yet been ascertained. Nor has any satisfactory theory of the cause of the spots been advanced.

A third notable discovery of Lockyer's—made simultaneously also by the French astronomer Janssen—was a method of studying the solar corona without waiting for an eclipse. This has been developed to a high degree, and has been of great assistance in enlarging our stock of knowledge of the luminary.

Lockyer wrote and published numerous valuable astronomical monographs. He was awarded the Rumford medal by the Royal Society in 1874 and was subsequently knighted by the King in recognition of his services to the cause of science.

HILL (1838–1914)

ASTRONOMY

George William Hill was born in New York City, and received his education at Rutgers College in that city. In 1861 he became attached to the staff of the *Nautical Almanac,* and was elected a member of the National Academy of Sciences in 1872 in consequence of the excellent work done in that connection. He was a writer of note on celestial mechanics and mathematics, his most important work in these lines being "A New Theory of Jupiter and Saturn," published in 1890. In 1874 he was awarded the gold medal of the Royal Astronomical Society of England for his "conspicuously fine work on the mechanics of the Moon."

Although the nearest body to the earth in space, the peculiarities of the motions of the moon are not yet completely understood by astronomers. This is due to the fact that its movements are, to all intents and purposes, governed almost entirely by the sun and the earth. For though the other planets of the solar system also do act on it, their distance is so great, and their mass—relative to those of the sun and the earth—so small, that the effects are negligible.

But the mathematical problem of the "Three Bodies in Space," which is presented in this case, is one that has not yet been solved; and by some mathematicians is regarded as insoluble, though both Laplace and Clairault devised equations which produced approximately close results as checked up with observation. The difficulties in the way will be made clear through a statement of the fundamental conditions existing, using round numbers only. The mass of the sun is 330,000 times that of the earth, and its distance is 389 times that which separates the earth from the moon. Applying the laws of gravitation as stated by Newton to these figures, it will be found that the attraction exerted by the sun on the moon is 2.18 times that exerted on it by the earth. Hence, if the earth were fixed in space, the sun would inevitably pull the moon away from it. But the sun attracts both simultaneously, with the result that both fall towards it together. Combining that effect with the inertia (centrifugal force) of the two, the final result is the path in which the earth travels in its annual journey around the sun, carrying the moon with it.

At new moon and at full moon, when the moon, the earth and the sun are disposed along approximately a straight line with respect to each other, the attraction of the latter in the first case tends to pull the moon more than normally away from the earth, and in the second to assist it in holding it. At first quarter, when the moon is racing away from the sun, the pull of the latter on the satellite is at a minimum. At the third quarter, when the moon is racing towards that luminary, it is at a maximum. In the period of a lunar month, the net effect of these contending forces is, that during each lunar revolution, the attractive power of the earth is overbalanced by that of the sun, to the extent of about 1/360th, in consequence of which the lunar month is each time lengthened by about one hour.

A second cause of disturbance is due to the shape of the moon's orbit which, like those of all the planets and satellites, is an ellipse, and not a circle as thought by Copernicus. Therefore, at one place in its monthly trip it is at a maximum distance (apogee) from the earth, and at another, directly opposite, at a minimum distance (perigee). At the latter the pull of the earth is naturally greater than at the former. This produces an oscillation in the position of these two points (apsides), with the result that in a term of about nine years they make a complete revolution in the path of its orbit.

Five other causes of disturbance exist, all too complicated in their nature to be explained in the space that can be given here to the subject. One is called the "variation." Another the "regression of the nodes." A third the "eviction." The fourth is the "annual equation," and the fifth is the "secular variation." It is no wonder, therefore, that under such a complication of conditions the mathematicians have been unable so far to produce a complete solution of the problem of the movements. With all the planets of the solar system that have satellites these same perturbations exist to a greater or less extent, and the difficulties they cause to their astronomers may, without compunction, be left to them to solve. But with us, as the moon is the principal agent in producing the tides, the matter cannot be neglected by those whose business it is to predict (in the *Nautical Almanac*) the periods of high and low water at the principal ocean ports of the world. Hill's investigation of the subject led to conclusions which, while not perfect, were so much closer than those of Laplace and Clairault, as to bring him the recognition mentioned from the English Royal Society.

PERKIN (1838–1907)

CHEMISTRY

William H. Perkin was of English birth, the son of parents in comfortable circumstances, his father being a contractor and builder of standing, whose ambition it was to make an architect of his boy. With this end in view he was afforded as good an education in the fundamentals as could be procured, and was apparently quite willing to follow along the lines that had been chosen for him. But at the age of fourteen he chanced to witness at the home of a schoolmate some experiments in chemistry, and became so fascinated that he decided then and there to take up that science as a profession. At the time he was a student at the College of the City of London. Chemistry just then did not rank very highly as an art, nor present many opportunities for the earning of a living. But the teacher of it at the College happened to be an enthusiast. Noting the deep interest that Perkin took in his lectures he made him his assistant, and later advised him to attend those of Faraday at the Royal College, who was then at the summit of his career. After listening once to the course he attended it a second time, and by earnest pleadings induced his father to abandon the intention of making him an architect, and to back him for a full course at the Royal institution. In two years he had become so proficient in the art that he was made an assistant to the chief professor. At home he set up a laboratory in an unused room where he could work evenings and during the vacations. There, in the Easter holidays of 1856 he made his first great discovery.

His chief at the College had suggested to him as a vacation study, an attempt to produce synthetically from coal tar the drug quinine, which was then in great demand at a very high price. He did not succeed in accomplishing this; but in its place, and more by accident than design, he made the first of the analine colors, that lovely and highly prized reddish-purple dye now known as "mauve," but which at first went by the name of Perkin's Purple. Working on this for many days he at last ascertained its composition, and learned just how to make it from the raw material available. As soon as he had produced sufficient for a practical test, he submitted it for trial to one of the large establishments in England engaged in the dyeing business. They reported favorably on it, and in the strongest terms.

His next step was to procure his patent, and after that, the means to begin its manufacture. Here he encountered innumerable difficulties. Capital was not eager to back a new and unproved industry. But his father and an elder brother had by this time become so fully convinced of the importance of his discovery, that they joined him with all their available resources, and under the firm name of Perkin & Sons began the erection in 1857 of a building on a suitable site at the village of Greenford Green, near Harrow. Here young Perkin designed and installed the machinery of the plant, and after securing a supply of the raw material required from the gas works at Glasgow, and the nitric and sulphuric acids and hydrogen to extract the analine from the coal tar, was able to begin the production of the former in quantity, and from it to extract the coveted dye.

When first used with cotton goods it was found necessary to discover a new mordant, to render it "fast." Among those tried out tannin was found the most satisfactory, and Perkin was the first to employ it for that purpose. He also introduced the practice of using a soap bath in the treatment of silk fabrics. In the early stages of the enterprise dyers were chary of adopting this new laboratory product as a substitute for the vegetable and animal dyes that from ancient times had been their reliance, but their hesitation was finally overcome. The business became a great financial success, particularly after Perkin in his laboratory, and then in his factory, began the production of other colors. In a short time factories using the Perkin patents sprang up in various parts of Great Britain and on the continent, and the young chemist became recognized as the leading authority on dyes. In 1861, when only twenty-three years old, he was invited by the Chemical Society of London to deliver a lecture on his specialty. In the audience he had the unusual satisfaction of seeing his former preceptor, the distinguished chemist Faraday who, at its termination, warmly congratulated him on his work.

In 1866 Perkin was elected a fellow of the Royal Society. In 1874 he sold his plants and his patents, and retired from active business to enjoy the delights of a life of chemical research, and with ample means to satisfy the inclination. In 1879, in recognition of important new discoveries, he was awarded the medal of the Royal Society, and ten years later the Davy medal. In 1906 he was knighted. That year, being the fiftieth anniversary of his discovery of mauve, he was honored in various ways by chemical societies in all parts of the world. In America he was presented with the first impress of the Perkin medal, founded in his honor, and since awarded annually for distinguished service in the field of applied chemistry.

Unfortunately, on account of the indifference of the British government, and of the great English universities, to progress in applied science, which was ranked as a trade, and consequently somewhat beneath the dignity of gentlemen, the command of the dyestuff industry passed away from that country after the death of its founder, and was transferred to the control of Germany, where it expanded so enormously that, at the opening of the Great War the world was dependent on that country not only for its dyes, but for a long list of synthetic products the manufacture of which had sprung from the original impulse of Perkin's discovery and labor. Perhaps since then the valuable lesson has been learned, that it is more honorable to be a worker, than to be an idler living on the labor of others.

ABBE (1838–1916)

METEOROLOGY

Cleveland Abbe was a native of New York, and graduated in 1857 at the College of that city. Desiring to specialize in astronomy, he pursued that science for two years at the University of Michigan, and for the following four at Cambridge University in England. From there he went to the Pulkowa Observatory in Russia, where he served as assistant observer for two years, when he was offered the position of director of the observatory at Cincinnati, Ohio. There he began a system of daily weather forecasts, based upon simultaneous observations reported by wire from various points to the east and west of that city. For nearly five years he continued making these predictions until, by increased experience and the enlargement of facil-

Facing page 380

ities, the percentage of accuracy reached a figure that attracted the attention of the Federal government, and led to an invitation to remove to Washington and take charge of the Weather Bureau. Under his capable management this department at once became of great value to agriculturists and mariners. Its methods and principles have since spread into nearly all parts of the civilized world. Its forecasts in the United States for heavy storms, cold waves, injurious frosts and hot spells are now verified almost without exception, but those for rain not so successfully. In addition to the central station at Washington, and seven major sub-stations at Boston, Chicago, Galveston, Denver, Los Angeles, San Francisco and Portland, Ore., there are over fifty minor stations, including those at the Philippines, Guam, Hawaii, Cuba, Porto Rico and the Canal Zone, besides several in Alaska. As atmospheric disturbances and variations have been found to advance from the west to the east, and from the polar regions toward the equatorial regions, the position of the United States is such as to make it—with Canada—the natural starting point for observations of weather phenomena for practically the balance of the northern hemisphere of the globe.

In 1879 Dr. Abbe introduced the existing system of standard time and hourly meridians, which is universal over the North American continent. He published several interesting works, the best known of which is probably "The Mechanics of the Earth's Atmosphere," which appeared in 1891, has been translated into most of the European languages, and ranks as a classic on its subject. He received the degree of LL.D. in 1887 from the University of Michigan, and the same in 1896 from that of Glasgow. He has been a lecturer of note on the science of meteorology.

GIBBS (1839–1903)

MATHEMATICS

Josiah Willard Gibbs was born at New Haven, Connecticut, and graduated at Yale college in 1858. He then went to Europe, studying in turn at the universities of Paris, Berlin and Heidelberg. Returning to the United States in 1871, he was tendered the chair of mathematical physics at Yale, and remained there for the balance of his life. During that period of thirty-two years he published two notable works on his specialty. The first, which appeared in 1875, was entitled "Equlibrium of Heterogeneous Substances." The second was "An Elementary Treatise on Statistical Mechanics" and came from the press in 1880. In 1881 he began his studies on Vector Analysis, applying their conclusions to problems in crystallography, in light phenomena, and in the computation of the orbits of the planets and comets. These studies and investigations rank very high in the literature of mathematical physics, and have been drawn on extensively by scientific investigators throughout the world.

In mechanics, a vector is a member of a machine which conveys the power delivered at one point of it to the place where work is to be performed by its means. The most familiar examples are the connecting rods of a locomotive and the walking beam of a paddle-wheel steamboat. In mathematics the word is used to express a quantity such as has the properties of a straight line of a definite length, and extending in a definite direction. Or, differently described, a quantity which, being added to any point of space, gives as the sum another point which is at a certain distance and in a certain direction from the first one. In this the analogy with the connecting rod of the locomotive is more clearly brought out. Illustrations of this mathematical conception are linear displacements, linear momentum, linear acceleration, linear velocity and force acting on a particle. Remembering that a mathematical point has position but no magnitude, and that a straight line has direction but no thickness, it can be understood that a vector may be likened to one or an assemblage of points moving in a certain direction and for a certain distance.

It is of course out of the question in a work of this kind to go into a subject so technical in any detail. Nor would it be possible without using liberally the language of mathematics, that is, the diagrams of geometry and trigonometry, and the symbols of algebra and the calculus. But the average reader will have no difficulty in understanding that the properties of vectors are of importance in the construction and operation of complicated machinery, and of great value in comprehending the structure and unraveling the movements of that inconceivably vast mechanism the Universe, where suns and stars are to us but points, and whose motions—together with those of the planets and satellites they carry along in their train, may be investigated by vectors whose lengths and directions are constantly varying to the extent of a point at a time.

COPE (1840–1897)

NATURAL HISTORY

Edward Drinker Cope was a native of the city of Philadelphia. His primary education was received in private schools, following which he took a course in anatomy at the University of Pennsylvania. After devoting nearly thirty years to exploratory work in the fossiliferous regions of the western parts of the United States under Wheeler and Hayden, and to research in zoology and comparative anatomy, he was appointed professor of geology and paleontology of the University of Pennsylvania upon the resignation of Leidy. From 1878 until his death he was the editor of the *American Naturalist*.

As a collector and describer of fossils he ranked, at the close of the last century, at the head of international paleontologists. Though his work in that line did not result in discoveries so spectacular as those of Marsh and Leidy, yet the immensity of his collection was impressive, for it contained parts of almost all extinct animal forms discovered on the North American continent up to the time when he abandoned field work.

Of quite equal importance were his studies in the field of reptilian life. This was at the time a department of natural history where work was long overdue. The first attempt at a systematic arrangement of these creatures was made by the English naturalist Ray, in 1693. The classification principle which he adopted was correct, but his field of observation was too limited to permit of success. The system employed by Linnaeus was faulty, and had to be abandoned. Cope was able to add to a thorough knowledge of living forms, an unexampled collection of the remains of extinct ones; and as this order of animal life is very ancient—the first fossils being of early Permian age—attained its prime in Jurassic and Cretaceous time, and has since (comparatively speaking) almost disappeared, he was really the first of the naturalists to be in a position to arrange its membership properly.

As the order arose from the amphibians, and from it one branch evolved into the birds, and the other into the mammals, its importance as a connecting link between the remote past and the present can readily be understood. No department of the animal kingdom flourished to anything like its extent, or produced individuals as large, or species as diverse, grotesque and even horrible. At one period they dominated in the sea, on the land and in the air, and to such an extent that other orders were at times threatened with extinction, for their range at their prime was almost cosmopolitan.

The outstanding characteristics of reptiles are as follows: They are lung breathers, but the organs are not subdivided as with birds and mammals, nor are they provided with the means for the continuous introduction and expulsion of air which exists in the forms that have succeeded them. The skin, having no covering in the way of feathers or hair, is a poor preserver of bodily heat. Hence the blood has a temperature but little above the water or air in which they live, and they are known as cold-blooded creatures, like the fishes. They have no external ears, yet their sense of hearing is good. They are all egg layers, and with but few exceptions these are not incubated by the mother, but left to be hatched by the natural warmth of the sand or the decaying vegetation in which they are deposited. The skin of the egg contains little lime, is more like parchment than shell, and is always white.

Of the still living types, the snakes are the only ones that seem to be prospering. The heavily armored turtles and crocodiles are able to survive by having returned to the amphibian condition, and the land tortoises and lizards by becoming small, so that concealment from enemies is easier.

Cope espoused the cause of evolution eagerly, but held that the cause of the origin of species had been accounted for more satisfactorily by Lamarck than by Darwin.

KOVALEVSKY (1840–1891)

EMBRYOLOGY

ALEXANDER KOVALEVSKY spent his early years at Dunaberg, Russia. Having received a thorough education in fundamentals and the natural sciences, his tastes led him to specialize at first in zoology, and later in embryology, in which latter he became one of the eminent investigators and students of his day.

He was the first to demonstrate the relationship of the ascidians (popularly called the sea-squirts) to the amphioxidae (lances, or sand lances), and the close alliance of both with the vertebrates. He discovered the gill slits in that strange worm-like marine invertebrate called belanoglossus, thereby fixing its place in nature as in the line of vertebrate ancestry. In the embryology and post embryological development of insects, his work was fundamental, and he made important contributions to the knowledge of the development and structure of various annelids (worms), and coelenterates (sea-anemones, corals, sponges, etc.)

The science of embryology deals with the beginnings of individual life in the animal and vegetable worlds. In all cases the processes are fundamentally the result of similar causes, and may be of three kinds, namely, self-division, conjugation and sexual reproduction. The first is the primary or primitive method, and is the general system in that lowest division of animal life called the Protozoa, and also with the one-celled plants. The organism, after reaching maturity, simply divides into two organisms, each of which after maturing repeats the process. Or a budding process occurs, which is the method with all the higher plants. These two are known as the "fission" systems.

Conjugation may be considered as an anticipation of the sexual method, but differs from it radically in that the conjugating bodies are each an entire plant or animal, and both disappear in the act. It is the process in certain of the uni-cellular plants, and with the infusoria. Thus, for example, a free swimming individual of the *Heterometa* (an infusorian which is found abundantly in infusions of animal and vegetable matter in both fresh and salt water) approaches an anchored individual of its kind, the posterior ends coming into contact. They then coalesce, like two globules of water or mercury, into one mass. This moves around freely for a time, then rests, loses its external organs of locomotion, becomes coated with a comparatively tough skin, and finally bursts, pouring out a swarm of spores, each of which, like an egg or a seed, is capable of developing directly into a new individual.

In the sexual system, in both the male and female individual a cell, apparently identical at the start with all the other cells, appears to be told off for reproduction, and after passage through certain organs becomes fitted for that duty. In the female that cell becomes the ovum or egg, and in the male the spermatozoon. After fertilization each such egg (or its analogue in plants, the seed, develops gradually into a new individual. It will be observed that in the lower forms of animal life and very generally in plants, quantity production is the main desideratum, and quality of secondary importance; while in the higher forms the contrary is the case.

RAYLEIGH (1842–1919)

PHYSICS

John William Strutt (Lord Rayleigh) was born in England, and completed his education at Cambridge in

1865 with high mathematical honors. From 1879 to 1884 he occupied the chair of experimental physics there, and in 1887 assumed the professorship of natural philosophy at the Royal Institute in London. In 1896 he became technical adviser to the British Lighthouse Board, and continued in its service until his death.

Although the chemist Cavendish nearly a century before had detected a small difference in density between the gas nitrogen when prepared chemically, and when obtained from purified air by the removal of its oxygen, he was not able to explain the reason, and the matter had been forgotten. Rayleigh, apparently without any knowledge of this, but because there was considerable uncertainty at the time as to the density of nitrogen, undertook in 1885, in association with Ramsay, a redetermination of the properties of the gas. In the course of the investigation the inert element argon was discovered by them. Somewhat later, Ramsay, following up the lead so given, discovered four other inert gases, thus bringing to light for the first time a whole family or group of elements theretofore unknown, and to which a sixth has since been added. These are helion (formerly and still popularly called helium), neon, argon, krypton, xenon and niton, the last better known as yet as radium emanation. All exist normally in the atmosphere, argon to the extent of nearly one per cent, and the others in very much less quantity.

Nitrogen itself is not a very active element, that is, it will unite directly with but few of the others, and such compounds as it will form are generally unstable. But the six above mentioned refuse chemical action absolutely. For this reason, after the surprise caused by their discovery had subsided, not much attention was paid to them, because it did not seem that they could be put to any practical use. Since then, however, their very inertness has been recognized as a valuable property. Helion, fairly abundant, and the lightest, is the ideal gas for balloons and air ships. It possesses nearly the lifting power of hydrogen, and is non-inflammable. Argon, the most abundant of the six, and neon, much less so, have been found to be advantageous in illumination, and promise to be extensively employed as soon as they can be obtained in sufficient quantity and at moderate cost.

Rayleigh's investigations and discoveries in other departments of science were notable and fruitful, especially in the phenomena of acoustics and optics, and in connection with electrical standards. He was not a brilliant investigator, but a most painstaking and thorough one.

He became a fellow of the Royal Society in 1873, and was a member or corresponding member of several foreign scientific associations. In 1895 he received the Barnard medal of Columbia University for "conspicuous service to science."

DEWAR (1842–1923)

PHYSICS

James Dewar was born at Kincardine-on-Forth in Scotland and received his education at the University of Edinburgh where he became, after graduation, assistant professor of chemistry. Later he received the appointment to the chair of experimental philosophy at Cambridge, and of chemistry at the Royal Institution at London. In 1897 he was elected president of the British Chemical Society, and in 1902 of the British Association for the Advancement of Science.

His first notable research was in the department of optics, where he advanced views on the physiological effects of light of different colors which, for a time, attracted great attention, in the belief that many diseases could be cured (or at least benefited) by submitting the body daily to the action of sunlight passed through glass transparent only to certain rays. Members of the older generation among my readers will remember what was then called rather derisively the "blue glass craze." But after extended trial so little of benefit resulted that the idea was abandoned and quickly forgotten.

Subsequently he turned to the subject of low temperatures, in which he achieved a notable success in the liquefaction and solidification of the common gases.

The lowest temperature obtainable by the mixture of salt and ice is $-22°$ Centigrade. But as early as 1824 Bussy, by the rapid evaporation of sulphurous acid gas (SO_2), secured a temperature of $-65°$ C. Using this method he liquefied in turn chlorine, ammonia and cyanogen, and solidified the last. Ten years later Thilorier, by first compressing carbon dioxide and cooling it, and then allowing it to expand suddenly, succeeded in solidifying a portion of it. Faraday, by 1845, had liquefied all the gases then known except hydrogen, oxygen, nitrogen, nitric oxide and marsh gas, by combining high pressure with low temperatures, and expressed the opinion that these could be liquefied if certain temperatures and pressures could be realized which then were impossible. After his death the work was continued by Andrews, who reached the conclusion in 1869 that for each of the gases there was a certain temperature which must be produced, before any amount of compression would result in liquefaction. This he called its "critical temperature," and determined the figure for carbon dioxide at 31° C. This discovery, which has since been amply verified, explained the failure of Faraday, as mentioned, and led the way to the invention of what is known as the regenerative method, which was first put into operation by Houston in 1874, in the production of liquid air. By it, a portion of a gas under severe pressure is allowed to expand to a certain extent. In the act the temperature of the expanding part falls markedly. In that condition it is then caused to circulate around the vessel containing the remainder of the gas, whose temperature is thus materially reduced. This process is then repeated again and again until the critical temperature is reached, whereupon liquefaction ensues.

Using this method Dewar produced liquid oxygen, nitrogen and air in quantity, and by 1893 had solidified the last. By 1898 he was able to obtain a considerable amount of liquid hydrogen, and a couple of years later had reduced that gas and also oxygen to the solid condition.

It was during the course of these experiments that he devised the Dewar Bulb, the parent of the well-known Thermos bottle, to hold the gases he had liquefied, and to keep them as long as possible in that condition. His bulb was a double-walled glass bottle of spherical shape, with a small neck aperture, the space between the walls exhausted of air to a high vacuum, and the outside silvered so as to reflect radiation.

When Dewar produced solid hydrogen, he found its temperature to be —258° C., which is within 15° of the absolute zero. Up to date all the known gases have been reduced to solids except helium.

KOCH (1843–1910)

BACTERIOLOGY

Robert Koch was born at Klausthal, in Germany, was educated for the medical profession and gained an honorable position in its practice. In the years between 1872 and 1880 he became strongly interested in the subject of bacteriology, and decided to devote his life to it. His first investigations were in connection with that very fatal cattle and horse disease known as anthrax, the cause of which he discovered. In 1876 he published a history of the disease so complete and so informative as to at once establish his reputation as a bacteriologist on a firm foundation. In 1882 he isolated the bacillus of tuberculosis, and for a few years thereafter it was hoped that he might be able to discover a cure for the disease. He did in fact produce a lymph for inoculation against it, but found its application so dangerous that he abandoned the effort. In 1883 he went to India to study cholera in its home and while there discovered and isolated the comma bacillus, which is the cause of the disease. After returning to Europe he devised a method of inoculating for anthrax which has proved very successful. In 1904 he went to South Africa to study the fatal disease produced in cattle and horses by the bite of the tsetse fly. It had previously been believed that this insect was itself poisonous, but he demonstrated that it was simply the carrier of a parasite from already diseased animals.

Those minute organisms known as bacteria, bacilli and microbes were first noticed by the microscopist Leeuwenhoek in 1683. He regarded them as forms of animal life, and while his discovery created great interest at the time because it was believed that they represented the beginnings of life of all kinds, yet the science of the day was not advanced enough to follow up the subject systematically. But nearly a century later (1773) O. F. Müller established two genera, and fifty years thereafter Ehrenburg and Dujardin established a large number of them, which even by them were regarded as members of the animal kingdom, and classified as among the Infusoria. This last is the highest and most specialized division of the protozoa, individuals of a single cell, with apparently no organs or tissues, which are now classed as the lowest known forms of animal life. They are of microscopic size, and seem to be nothing more than particles of protoplasm, yet they are capable of motion from place to place.

Bacteria, bacilli and microbes, however, are now placed in the vegetable kingdom. They exist almost everywhere in countless numbers and variety, in the air, the water and the soil. Also in the bodies of the living. The part they play in the economy of life is that of regeneration, of the disposal of dead tissue when that is necessary for the protection and prolongation of life, and of its resolution into its component elements after death. Thus, to them are due the rancidity of butter, the putrefaction of cheese, the gamy flavor and high odor of meat kept too long, the blueness and yellowness of old milk, and the changes that ultimately take place in very stale bread. Considered as a whole their work is of a beneficial nature. Millions are always present in the mouth, the stomach and the intestinal canal, and it is beginning to be understood that the numerous tooth pastes and powders that are so extensively used at the present time, often do more harm than good by destroying so many beneficent scavengers of the system.

It was not until the middle of the last century (1853–1857) that their true position in natures as plants was definitely shown. They are classed among the fungi, which includes all those vegetable forms (except the algae) which lack the power to produce chlorophyl—the green pigment—and hence are forced to live either as parasites on living plants or animals, or as saprophytes on dead organisms.

MICHEL-LEVY (1847–)

GEOLOGY

Augustus Michel-Levy was born in Paris, and received his education at the university of that city. His inclinations led him to the profession of mining engineering, and from that into the general field of geology, where he rapidly acquired an international reputation, becoming in 1874 the Director of the French Geological Survey, and the National Inspector of Mines.

In southern France there is a region which was anciently the scene of intense eruptive action, in which the elevations known as Puy-de-Dôme (4806 ft.), Mont Dore (6187 ft.), and Plomb-du-Cantal (6096 ft.), represent the denuded cones of extinct volcanos. Around these are extensive areas of granite, gneiss and schists, overlaid in places by overflows of basaltic and trachytic lavas, the whole forming one of the most remarkable regions in Europe from the geological point of view. Dykes of pegmatite, ophite and eurite are common, and occasional occurrences of that curious rock called variolite.

Into this region he was naturally attracted, and made its study his specialty. He was the first to introduce the use of the polarizing microscope into the examination of mineral structure, by cutting rocks into very thin slices, so that they became translucent. He led the way in the artificial production in the laboratory of the rock forming crystallized minerals, such as the various feldspars, micas, hornblende, etc.; and was responsible for the introduction of the term granulite, to indicate that variety of the gneissoid rocks which contains, in addition to quartz and feldspar, minute crystals of garnet. He was a frequent contributor to the pages of the technical journals, and also a writer of several books on geology and mineralogy which are classics in their subject. His first volume "Micrographical Mineralogy," which appeared in 1879, marked a distinct epoch in the science of minerals. It was followed in 1882 by "Synthesis of Minerals and Rocks," and in 1880 by "Structure and Classification of Eruptive Rocks." In addition to these he prepared, in association with Lecroix, "The Manual of Rocks" and "Table of Rock Minerals," which were published in 1888 and 1889 respectively.

Towards the later years of his active life he undertook an investigation of meteorites in general, and particularly of specimens from the "falls" that had occurred in France in 1790, 1798 and 1803, and contributed several valuable moongraphs on the subject to current periodicals, which constitute the best general summary to date of what is known of the character of these bodies. Though a very large number have been analyzed, no new element has yet been found in them. They furnish no evidence of the existence of life on the body of which they originally must have formed a part. They contain no crystals except such as are found when a molten mass solidifies on cooling, nor any indication of having come into existence in a locality where water existed. They resemble strongly those rocks of terrestrial origin which are classified as igneous or volcanic products. They are of two kinds, called respectively siderites and chrondrites, which shade imperceptibly into each other. The former consist mainly of iron in the metallic state, with which nickel, cobalt, copper, tin and several other metals occur. The latter are of a stony nature, consisting mainly of the minerals enstatite, bronzite, chrysolite, etc., with which are frequently found small quantities of chromite, pyrrhotite and sometimes even graphite.

The largest meteorite whose fall has been observed and proved beyond question, came to earth in Emmett county, Iowa, and weighed 437 pounds and was composed largely of metallic iron. Many masses weighing tons (up to twenty-five), which are believed to be of meteoric origin, have been found in other parts of the world, and millions of fragments of smaller size. The origin of these visitors from space is still a matter of conjecture and speculation. The evidence that has accumulated to date seems to indicate that the region in the solar system between the orbits of Mars and Jupiter, where the asteroids are located, carries also several streams of bodies, too small and scattered to be detected by the telescope, and moving in orbits of high eccentricity, parts of which come occasionally or periodically within the field of attraction of the earth, and terminate their long journey on its bosom, unless vaporized while passing through its atmosphere.

BOLTZMANN (1844–1906)

PHYSICS

Ludwig Boltzmann, a native of Vienna, completed his education in the university of that city and in those of Heidelberg and Berlin. In 1869 he assumed the chair of mathematical physics at the University of Gratz, and in 1873 that of mathematics at the university of Vienna. From 1876 to 1890 he was a member of the faculty at Gratz; from 1890 to 1895 at Munich, and from 1895 to 1900 at Vienna. In 1900 he became connected with the University at Leipsic, but in 1902 was recalled to Vienna and continued a member of its faculty during the remainder of his career.

Boltzmann took a very conspicuous part in the study of molecular mechanics in liquids and solids. The molecule is defined as the smallest particle of any given kind of matter which retains the properties of the whole of it; as, for example, a molecule of water, of sulphur, of table salt. In the first and last of these instances the molecules are compounds in each case of two elements, into which they can be readily resolved by purely chemical methods; whereupon, their appearances and properties as water and salt disappear, and they then give evidence of their presence by exhibiting the appearance and properties of those elements (hydrogen, oxygen, sodium and chlorine) into which they have been decomposed. But sulphur is itself an element, and its molecule consists ordinarily of a union of two of its atoms, but under certain conditions may consist of six or even eight of them. Hence, if the sulphur molecule is broken up it still remains in its parted condition as sulphur.

Molecules of all kinds, and under normal conditions, are constantly in motion. Those of a gas move back and forth in rectilinear paths which are long as compared with their size, and were it not for the gravitative action of the earth they would fly off into space and disappear. The length of their paths is determined by the number of them existing in any given volume, which varies in the case of each known gas, and also with the external pressure under which it may be at the time.

In liquids the molecules move about in all sorts of ways, very much like those of a bunch of live angle worms, and so are able to conform themselves—as a mass—to the shape of the vessel in which the liquid is contained.

In a solid they are believed to be pressed so closely together that a new force—that of cohesion—comes into play. Cohesion is perhaps simply another word for the gravitative action which, according to the Newtonian laws of matter, every particle exerts on every other particle. These particles in a sold mass cohere so firmly that more or less force is required to separate them. Nevertheless, even then, it is believed that each molecule is in a state of intense vibratory motion back and forth along an infinitely minute path. If the temperature of the mass rises, these paths become a little longer, and exhibit the change of condition by the phenomenon of expansion. On the other hand, decrease of temperature results in contraction, as the effect of the shortening of these paths. At the absolute zero of temperature it is believed that all vibratory motion ceases.

It was into the field of these phenomena that Boltzmann, equipped with high mathematical ability, made deep exploration, using data already well demonstrated in the science of mechanics to light his path. For a time it was thought that he had secured some results of importance. But since the announcement of the quantum theory of Planck these expectations are not so strong, and some revision of his conclusions appear to be inevitable.

METCHNIKOFF (1845–1916)

BIOLOGY

ILIYA METCHNIKOFF was born in the vicinity of the town of Kharkov in southern Russia, and after receiving his primary education in the schools of that city, took special courses in natural history and physiology at the universities of Giessen and Munich in Germany. He was then appointed professor of zoology at the University of Odessa, and after serving there seven years, resigned to devote himself to research in the domain of sponges and coral polyps. In 1884 he published the result of his investigations on these low forms of animal life, in the course of which he announced the discovery that the individual cells of these organisms possessed the power of seizing, absorbing and digesting solid particles of food, and of excreting such parts of it as were unsuitable for their purposes of nourishment and growth. He called the phenomenon—which had not before been observed—"intercellular digestion."

Following up this important lead, he soon afterwards detected and described those remarkable cells residing free in the blood of all animals which are known popularly as the white corpuscles, and technically as "phagocytes." These are living organisms, whose function in the body is to destroy (by the process of eating and digesting) injurious or poisonous microbes and germs which may have gained access to the circulatory system, or the tissues, by accident or design, and which, if not removed or in some way counteracted, would produce disease and ultimately death.

Led by these observations—which he watched in progress under the microscope—he advanced the theory which has since been amply confirmed, that the well-known phenomenon of inflammation that invariably accompanies bruises and wounds in all animals and man, is due to the struggle that at once ensues between these white corpuscles and the disease germs that immediately attack the body at any place where the continuity of the protecting skin is broken. When such an injury occurs, new blood well charged with these phagocytes (eating cells) is at once sent by the heart to reinforce the protective army at the point of injury. This causes a wholesome congestion there, and the inflammation condition continues until either the invaders are destroyed and the wound healed, or the loss of blood becomes so great that the heart is unable to supply any more, and death ensues.

This discovery was considered of so much importance by biologists and physiologists, that in 1892 Metchnikoff was invited to come to Paris, and was offered the position of chief assistant to Pasteur. At the death of the latter in 1895 he succeeded him as Director of the Pasteur Institute, and remained its head through the balance of his life.

WROBLEWSKI (1845–1888)

PHYSICS

Zygmunt Florenty Wroblewski was born at Grodno in Poland, when that part of it was a province of the Russian Empire. He was of pure Polish ancestry. While a student at Kiev he took part in the insurrection of 1863, and was banished to Siberia. Six years later he was pardoned and resumed his studies, which were finally completed by taking special courses at the universities of Berlin, Heidelberg and Munich, at the last of which he received his degree, and became an assistant in its physical laboratory. Subsequently he served as lecturer and assistant lecturer successively at the Universities of Strassburg, Paris, London, Oxford and Cambridge, and finally in 1882 was appointed professor of physics at the University of

Cracow in his own home land, where he remained as a member of the faculty of that ancient institution until his death.

Although a brilliant and interesting speaker, with the command of several languages besides Russian and his own mother tongue, he is best known for his work on the liquefaction of gases. The first of the physicists to take up this important subject was a Belgian chemist by the name of Van Helmont, who attained some prominence about the year 1590, and who was responsible for the introduction of the word "gas" into technical use. He made a distinction between it and the word "vapor," using the latter for those that could be condensed into the liquid state, like steam, and the former for those that could not, like air. Dalton was the first to assert that all gases could be liquefied by the application by the proper degree of pressure and temperature. Faraday took the first steps towards the realization of this belief, and succeeded in liquefying chlorine, carbon dioxide, sulphur dioxide, cyanogen and several others, in fact, all then known except hydrogen, oxygen, nitrogen, nitric oxide and marsh gas. Andrews, in 1869, advanced the theory that for each gas there was a certain temperature and pressure which must be reached simultaneosuly, to secure liquefaction. With this new light on the problem, oxygen was reduced to the liquid state in 1877 by Callitet and Pictet, and in 1883, by employing improved methods and apparatus, Wroblewski and Olszewski at Cracow accomplished the transformation in quantity of oxygen, nitrogen and carbon dioxide, and reduced the last two to the solid condition. Since then Dewar and Onnes have completed the work with all known gases except helium.

The accomplishments of Wroblewski while spectacular, were also of great service indirectly, by giving physicists the command of a new tool—low temperature. With it much more correct determinations of specific heat become possible, and in several other directions some rather unexpected results are likely to accrue. For instance, it has already been shown that under a pressure of 300,000 pounds per square inch, water will become a solid at a temperature 73° C. higher than its normal or usual freezing point.

ROENTGEN (1845–1922)

PHYSICS

Wilhelm Konrad Roentgen was reared at Lennep in East Prussia, and received his doctor's degree at the University of Zurich, where he specialized in physics. After occupying subordinate professional positions at the schools in Hohenheim, Strassburg, Giessen, and Wurtzburg, he was appointed to the chair of experimental physics at the University of Munich, a position which he held during the remainder of his active life.

He was the discoverer (in 1895) of the X-rays, which brought him honors from institutions of learning throughout the world. The rays were so called by himself because, for some time, he was unable to explain them. They are now very properly known as the Roentgen rays, and are better understood. To produce them, a Crooke's tube is employed. This is a sealed tubular or globular glass vessel, from which the air has been withdrawn. Into its ends or sides have been sealed metallic conducting wires, connected with a source of the electric current. The incoming or positive current wire, may or may not be fitted with a small metal plate at its inside termination, and is called the anode. The other, by which the current leaves the tube, carries at its end a small concave metal plate, the concavity being turned towards the interior. This is called the cathode. When a current of electricity is passed through the apparatus, aside from the glowing effect produced, certain rays originate on the cathode plate which, being brought to a focus on the inside of the tube, pass through the glass. These are the Roentgen rays, and have very remarkable properties. They appear to be capable of passing through nearly all substances, but not with equal ease or speed, dense substances being less permeable than less massive ones. They also have the power of chemically acting on the sensitive photographic plate or film. As they pass freely through living flesh, but less freely through the bones, or any dense metallic or other substance, it became possible to make shadow photographs of the living body, in which the bony skeleton or any other body less permeable than the flesh, appears as shadows, while the normal fleshly outline of the figure is revealed as a much fainter shadow. This discovery has proved of great value in the surgical art, particularly in cases of bone fractures or displacements, or bullet wounds, and also of abnormal growths (tumors) in the tissues.

The exact nature of the Roentgen rays is still unexplained. Their discoverer received the Nobel prize for physics in 1901, and was elevated to the nobility by the German government.

EDISON (1847–)

ELECTRICITY

Thomas A. Edison was born at Milan, Ohio. At the age of seven his parents moved to Port Huron, Michigan. Here he secured the rudiments of an education, but was forced to get out into the world at an early age and earn his living. After working for a time as a train news agent on the Grand Trunk R. R. and simultaneously conducting a small newspaper enterprise, he turned his attention to telegraphy, quickly became a Morse-key expert, and easily secured the position of night operator at his home town. Having become interested in chemistry through the reading of books on that science, he was allowed by his parents to fit up a laboratory in the attic of the house they occupied, where he carried on his experiments during the day, instead of getting enough sleep to fit him properly for his employment at night. In consequence he soon lost his position by being caught asleep on duty. He then entered upon the life of a wandering telegraph operator, passing from one situation to another without difficulty, for at the time there was a great demand for experts at the key. After several years of that kind of life in what is now the Middle West, he drifted eastward, finally landing in Boston, and had the good fortune there to get hold of a copy of the works of Faraday, which impressed him deeply. In that city he made his first invention—a vote-recording machine for use in legislative bodies.

From Boston he went to New York, still in the character of a wandering operator, and continually short of money because his surplus earnings were spent as fast as they accumulated in books, experiments in chemistry and electricity, and in models of inventions. There, in 1869, he perfected certain improvements in stock tickers, which brought him quickly a considerable amount of money, some $40,000, and with it he opened a laboratory in Newark and began the manufacture of the numerous electrical devices which his fertile brain had conceived. But soon finding himself in financial straits because these did not sell fast enough, he called one day at the office of Dr. Norvin Green, the president of the Western Union Telegraph Co., to try to interest him in his patents. He found the doctor endeavoring to get into telegraphic communication with Albany. There was trouble somewhere along the line, and no one seemed to be able to locate the place or the cause. Edison asked to be allowed to solve the problem, and in two hours had located the difficulty within a few miles. Green was so impressed with the performance that he not only gave the young man the hearing he sought, but when it was concluded advanced the money Edison needed to relieve his financial difficulties and took an interest in his plant on behalf of his company. For it Edison invented and put into practice, in turn, his automatic duplex and quadruplex systems of telegraphy, by the latter of which, on one wire, two messages in each direction could be sent simultaneously, and recorded at the receiving end on chemically prepared paper, at the rate of 3500 words per minute. For these he was handsomely compensated.

Now at last in comfortable circumstances, he turned his attention from telegraphy to telephony. By then A.

Graham Bell had demonstrated the practicability of the latter, had devised an excellent receiver, but his transmitter was unsatisfactory. The Western Union Co. was backing him and called in Edison. The latter in a short time produced his carbon transmitter, which is in use at the present time, and sold it to the Company for $100,000. Shortly afterwards he perfected his electromotograph which brought him $250,000 for the American and English rights alone.

His next notable accomplishment was the production of the phonograph in 1877. When the first crude model had been constructed, the words spoken into it, and repeated from it, were those of the first verse of the familiar nursery rhyme "Mary had a little lamb," and the voice was that of Edison himself.

In the following year he turned his attention to the electric light. The arc light had already been invented, and put into practical use to a considerable extent for highway illumination. But it was too expensive, too brilliant and too noisy for interior use. In its stead Edison proposed and perfected the familiar small glass globe, exhausted of its air, and fitted with the now nearly forgotten carbon filament heated to incandescence. The first one devised, which was made of cotton thread, lasted only 40 hours. After a large number of trials of other materials, one that was constructed of bamboo fiber of a particular variety, stood the test and strain put upon it long enough to make the discovery commercially practical. From this beginning has sprung the highly perfected tungsten filament bulbs of the present day, which are in use by the hundred of millions throughout the world.

Of his many other inventions he most notable has been the cinematograph (first known as the vitascope), which was perfected less than twenty years ago. Others of note, though less well known, because of their limited fields of employment, are the alkaline storage cell and the magnetic ore separator. He was the discoverer of a method of making carbolic acid synthetically; and when the Great War broke out, cutting off the supply from Europe, he built a factory for its manufacture in an incredibly short time. Altogether he has taken out more than a thousand patents.

A man of tireless energy, and a sufferer from early manhood under the handicap of deafness, he has maintained throughout his maturity, and carried into his green old age, the individuality and the simplicity which is typically the heritage of the American. His name is a household word in all parts of the civilized world. In his own country he has been awarded by popular vote the title of its first citizen. Plain in manner and dress, and pithy in speech, his definition of genius as "one per cent inspiration and ninety-nine per cent perspiration" epitomizes his life and career perfectly.

ROWLAND (1848–1901)

PHYSICS

Henry Augustus Rowland was born at Honesdale, Pennsylvania, and graduated in 1870 at the Rensselaer Polytechnic Institute at Troy. In 1876 he was elected to the chair of physics at the Johns Hopkins Institute in Baltimore, and held that honorable position for the remainder of his life.

His reputation rests upon several achievements. By far the most important of these was the introduction of improvements in spectroscopic apparatus, which enabled him and others to reach accurate results in the measurement of the wave lengths of the spectral lines produced by the elements when heated to incandescence. At the time these were regarded as new and most interesting data, but of little practical use. Since his death, however, they have proved to be of extraordinary value in the study of the nature of the chemical atom, which is perhaps the outstanding achievement of the physicist of the present day. His improvement consisted in the discovery of the principle of the spherically concave reflecting grating, and the construction of a machine for drawing lines upon it so extremely close to each other, that fifteen thousand of them could be placed side by side within the space of an inch, and at exactly equal distances apart. When on such a surface—called a reflecting grating—a ray of light is thrown, the phenomenon called diffraction occurs.

Diffraction was first observed in 1665 by Grimaldi, an Italian landscape painter. It consists of the appearance on the edges of a shadow cast by an opaque body upon a screen, of a very narrow band of colors, so narrow in fact as to be almost unnoticeable unless very carefully looked for. It was also observed and studied by Newton, but as he was the originator of the corpuscular theory of light, and held that its rays moved in absolutely straight lines, he was unable to account for it. Fresnel, however, in 1819, correctly explained it by showing that it was an effect resulting necessarily from the undulatory character of light waves which, in passing the sharply defined edge of an opaque body, would be slightly bent inward, and to an extent proportional to the amplitude (distance from crest to crest) of the wave. As this dimension for the wave of each color differs, some of them would be bent more than others, and the combined result would be the narrow band of colors always to be found under the conditions stated.

Rowland made an exceedingly accurate measurement of the mechanical equivalent of heat; and of the value of the ohm, the electrical unit of resistance. His study of the magnetic properties of iron led to entirely new conceptions of the nature of magnetism. For his development of a system of multiplex telegraphy, he received the gold medal of the Paris Exposition of 1881. At the time of his death he was the president of the American Physical Society. He was a large contributor to technical publications, both in the United States and Europe. His collected physical papers, together with a biography, were published in 1902 by the Johns Hopkins Press.

MOISSAN (1852–1907)

CHEMISTRY

HENRI MOISSAN was a native of Paris, and after passing through the College of the Museum of Natural History, he joined the faculty of the School of Pharmacy, becoming professor of toxicology in 1886, and of mineral chemistry in 1889.

Becoming greatly interested in 1886 in the gaseous element fluorine, he was the first to isolate it, to reduce it to the liquid state, and to ascertain its properties. As fluorine is the most active, chemically, of all the known elements, and requires for its liquefaction a reduction of temperature to − 187° C. the accomplishment was a most notable one, and brought him the Lacaze prize in the following year. In 1894 he succeeded in making artificial diamonds, by the sudden cooling of molten iron that had been impregnated with carbon, but the crystals so produced, though perfect, were too minute to have any commercial value.

He also devised, and put into operation, a greatly improved process for the manufacture of acetylene gas. For these, and other researches in applied chemistry, he was awarded the Nobel prize in 1906.

The isolation of fluorine was an achievement of note because the intense chemical activity of the element compels it, when driven out of any compound of which it is a constituent (like fluorspar) to unite violently with almost any other that may be available. At normal temperatures it is a pale yellowish gas, with an unpleasant odor, and if put into a glass bottle will at once begin to eat its way out by decomposing the glass. In fact, about the only substances of which containers can be made that will hold it are lead, gutta percha, paraffin and the two minerals fluorspar and cryolite, of which it is already a part; the former being the fluoride of calcium, and the latter the fluoride of sodium and aluminum. Fluorspar is quite abundant in nature but cryolite is rare, the only deposit of size that is known being in Greenland.

In spite of its violent propensities, and in fact because of them, the element when combined with hydrogen in the form of hydrofluoric acid, has many uses in the arts. If a piece of glass is covered with a thin layer of mineral wax, and figures drawn upon the new surface so as to remove the wax along their lines, and the plate then exposed over a vessel containing this acid, and the latter gently heated, the fluorine will temporarily abandon the hydrogen and attack the exposed glass surface and lines, seize upon its silicon, carry their molecules back to the forsaken hydrogen, and unite again with it to a new compound called hydrofluosilicic acid. By this process all the well-known varieties of opalescent glass are produced. The action is known as etching. Porcelain of the densest kind may be etched the same way. The wax and the other protective substances mentioned do not seem to possess any attraction for the gas. But if allowed to meet antimony, arsenic, boron, iodine, silicon, or sulphur, so intense is its affinity for them, or they for it, that the heat produced in the reaction will cause all of them to burst violently into flames.

FISCHER (1852–1919)

CHEMISTRY

Emil Fischer was born at Euskirchen in Germany, was educated at the University of Strassburg, and in 1879 was appointed to the chair of chemistry at the university of Munich. In 1882 he was transferred to a similar post at Erlangen and in 1885 the same at Warburg. In 1892 he took the professorship of organic chemistry at the University of Berlin, where he remained for the balance of hls active career.

His specialty was synthesis, and his principal work was on the sugars, where he achieved remarkable success. He began his work on these in 1883 when almost nothing was known of their nature except their chemical composition. By 1908 when his work had been completed and its results published, he had been able to produce them all synthetically, and had determined the molecular structure of each kind. In the course of this very important work, the theories of stereo-isomerism that had already been advanced by Van't Hoff were confirmed and systematized. He also succeeded in producing synthetic caffeine, the alkaloid which is the active flavoring constituent in coffee, and made remarkable progress in the study of the proteins, succeeding, before he was compelled to abandon the work, in the synthetic preparation of the peptides, the active principle in the gastric juice, which has the property of converting the protein elements in food into peptones, a condition in which they are digested, and are then capable of assimilation by the rest of the alimentary system of the body. These discoveries were considered of such importance, that in 1902 he received the Nobel prize of $40,000 for distinguished services in chemistry for that year.

Those pleasant tasting vegetable products which are known as the sugars are a most interesting class of substances. In very olden days honey was the only variety known, and was so rare and valuable as to be procurable only by the wealthy; but in the time of Grecian national supremacy something became known in that country of the sugar cane, which seems to have been indigenous in India and southern China, and from which was extracted a coarse and crude product that by Arab traders was brought in small quantities to Greece under the name of "sukkar," and eagerly accepted in trade. When that brilliant nationality gave way to Roman rule, the knowledge appears to have been completely lost. But during the Crusades (1096–1272), samples of the cane extract were again encountered among the Arabian holders of the Holy Land, and finally the plant itself was introduced in Sicily and southern Spain, and from there gradually spread into other parts of the semi-tropical world. In 1747 a German chemist by the name of Marggraff called the attention of the Berlin Academy of Sciences to a variety of the beet which contains a notable percentage of sugar, and from which, a half century or so later, a pupil of his named Achard, succeeded in extracting enough of it to interest both German and French capitalists in its cultivation on a large scale. Since then the industry has expanded enormously, for the beet flourishes in temperate climates, and the plant has now been so greatly improved that its sugar content, originally less than 7 per cent, has been raised to 16 and 18 per cent.

There are many different varieties of sugar. All consist only of the three elements, carbon, hydrogen and oxygen, but not always combined in the same proportions. Cane and beet sugar, when prepared with equal care, are identical, and are represented in chemical language by the formula $C_{12}H_{22}O_{11}$, which simply means 12 parts of carbon, 22 of hydrogen and 11 of oxygen. Maple sugar and honey when pure are almost the same, but each contains certain additional ingredients to which they owe their distinctive flavor. Glucose, however, is not sugar, for though it has a sweet taste, and is the substance which produces the pleasant sweetness of the fruits, its formula is $C_6H_{12}O_6$. Curiously enough, while the true sugars are perfectly assimilated by the animal organism, glucose is not, but passes through the system without conferring advantage either in building up muscular tissue or adding energy. On the other hand, it is an ideal plant food, and has been advantageously employed in certain cases as a fertilizer.

RAMSAY (1852–1916)

CHEMISTRY

William Ramsay was a native of Glasgow, Scotland, acquired his early education there, and took his doctor's degree at the University of Tübingen, in Germany, at the age of twenty. From 1880 to 1887 he was professor of chemistry at the University of Bristol, and then took the chair in the same science at the London University. Here, working in association with Baron Rayleigh, they discovered in 1894 the gaseous element argon. In the following year, while working on the mineral clevite—a sample of which had been received from Norway—they extracted from it, and isolated, the element helium (also a gas at normal temperatures). This element had been detected spectroscopically in 1868 in the solar chromosphere, by the astronomer Lockyer. Its discovery on the earth, as a component of a well-known, though comparatively rare mineral, was an event of the very first importance in the scientific world.

In 1898 Ramsay detected, and isolated from the atmosphere, three additional new gaseous elements, to which he gave the names of krypton, neon and xenon.

The discovery, isolation and investigation of these five elements, marked a distinct and very notable step in the progress of the science of chemical physics. All are absolutely inert, refusing to react with each other, or with any of the other elements. To accommodate them in the Periodic Table of the elements (see Mendeleef), a new vertical series had to be inserted, which, however, instead of disarranging the system, had the effect of rendering it still more complete.

In the few years that have elapsed since this noted investigator died, so much has been learned of the nature of the chemical atom, that it is now possible to account for the inertness of these five gases and, as usual, when the explanation was reached, it was found to be of that simple nature which experience has taught us to expect in ultimate facts. It is now demonstrated that there must be at least 92 chemical elements or units of matter, of which some eighty-eight have so far been discovered and their properties more or less ascertained. There may be more, but for reasons that will be given it is not considered likely. At the top of the list is the gas hydrogen, the lightest substance known and the simplest in structure. At the bottom is the metal uranium, the heaviest and the most complex in composition with which the physicist is acquainted. Between these two, each in its own pigeon hole in the periodic system of Mendeleef are the others, listed according to their relative weights on the basis of 16 for oxygen. Apparently the most stable of them all is the gas hydrogen, being composed of just one proton and one electron; while the last three of the list (radium, thorium and uranium) are very unstable. For this reason it is believed that no more of greater weight can exist, for these, as a direct consequence of the complexity of their structure, are in a chronic state of falling into pieces.

Since this limitation in probable number has been recognized, and since the atom of each has been shown to be a mathematically arranged collection of those infinitely minute units of electrical force called protons and electrons, and since the number of these in each kind of atom has been definitely ascertained, it has been found that the inert gases are the only ones so structurally composed as to have acquired what might be called as a condition of perfect symmetry. They are elements so shapely, so organized as to the number and disposition of the protons and electrons of which they are composed, that they may be considered the aristocrats of the tribe, each one quite indifferent to all the others, even those of its own very limited class. The rest are more or less unsymmetrical in shape or unsatisfied in the matter of the disposition of their electrical units, and constantly exhibit an inclination either to pass some of their superfluous ones over to an element residing in another pigeon hole of the system, or to grab some of those possessed by another one. As the law of their existence so far as at present ascertained prohibits such inter-elementary gifts or thefts, their only alternative is to come out of their pigeonholes and form partnerships, when inclination and opportunity occurs to do so. This process is constantly going on in the world of matter. Those that have taken place in the realm of inorganic things are comparatively stable affairs, for quite an amount of force must be applied to break them up. But in the organic realm, that of vegetable and animal life, the change of partners is constantly in progress, quite as much after the arrival on the scene of the phenomenon we call death, as before its appearance. But through it all the inert gases stand haughtily aside from the bustle and turmoil, refusing to take any part in it, or even to be friendly and chatty among themselves. The amount of them in nature is extremely small, but already a use has been found for the lightest (helium), and if aviation is going to fulfill the promise of its youthful days a lot of it is sure to be demanded before long. There has also been found a field for the employment of one or more of the others in illumination. In fact inertness and unsociability has some few advantages in the world of the applied sciences as it has in social matters.

BECQUEREL (1852–1891)

PHYSICS

Antoine Henri Becquerel was a native of Paris, being educated at the École Polytechnique, and the École des Ponts et Chaussées, from the latter of which he graduated in 1877 as an engineer. In the following year he became professor of physics at the Museum of Natural History, from which he passed, in 1895, to the same post at the École Polytechnique. He became a member of the Institute in 1889.

He devoted himself during his career in a large degree to the phenomena of optics and phosphorescence, branching out into spectroscopy, and the effects of magnetism on polarized light. His most important discovery—made in 1896—and the one which brought him the Rumford medal of the English Royal Society, was that of the invisible rays which he found were emitted from ores of the metal uranium, and were capable of affecting the sensitized photographic plate. As these rays did not obey the known laws of light, and proved to be able to penetrate many bodies that are opaque to light, the greatest interest was excited in scientific circles by their discovery; which was heightened when, two years later (1898), the new element radium was shown by M. and Mme. Curie, to be the component in the ore that produced them. Thus, while Becquerel is justly entitled to the credit of having been the first detector of this new form of radiation, to the Curies belong the honor of ascertaining its origin, and of inaugurating the entirely new department of physical-chemistry or chemical-physics, which has for its field not only the evolution of the elements, but their devolution, or decomposition.

Radium is believed to be a metal, though it has not yet been isolated. But its position in the Periodic System of Mendeleef, and the behavior of such of its salts as have been produced—mainly the chloride and bromide—strongly indicate the metallic characteristics. Since its discovery an enormous literature in radio-activity has come into existence, and the subject is by no means exhausted as yet. It belongs to the vertical group that begins with beryllium and continues with magnesium, calcium, zinc, strontium, cadmium and barium, followed by two uncertain ones, and mercury, with radium as the last member; and in the 12th horizontal series, along with thorium and uranium. These three are respectively the 89th, 91st and 92nd in the list of the elements, and are of such high atomic weight, —226.4, 232.43 and 238.5 respectively, and possess such complicated atomic structure, as to be steadily undergoing the processes of devolution or breaking up into elements of lower atomic weight and greater stability.

Becquerel's discovery, followed by that of the Curies, furnished the key which has since unlocked the mystery of the chemical atom, and made it plain that matter, as the word has theretofore been understood, is no longer an entity. It is simply one of the manifestations by which the all-pervading energy of the Universe makes itself known to our senses.

VAN'T HOFF (1852–1908)

CHEMISTRY

Jakobus Hendrikus Van't Hoff was born at Rotterdam, Holland, and studied in turn at the universities of Delft, Leyden, Bonn, Paris and Utrecht, after which he became an assistant instructor in 1876 at the last named institution. Here he displayed so much ability that in 1878 he was called to the chair of chemistry and physics at the Amsterdam University from which he passed in 1896 to the same position at the University of Berlin.

In addition to having taken a high rank among recent investigators in the field of physics, his great contribution to the advance of knowledge consisted in important discoveries in the domain of stereo-chemistry, that branch of the science which has to do with those quite numerous cases of isomerism—substances identical in chemical composition but displaying different properties under certain optical and other influences—which cannot be explained under the doctrine of the linking of the atoms. As to these, he reached the conclusion in 1874 (which has since been amply corroborated) that all optically active compounds—and only such—contain one or more asymmetric carbon atoms or groups of atoms differing from one another. Several years later he succeeded in working out a theory of geometrical isomerism, which to date has been found capable of making clear all the phenomena so far observed in this department of research, which has now become an important branch of applied science. It was originally confined only to compounds of carbon, but has since been extended into those of nitrogen.

The department of physical chemistry is a comparatively recent addition to the roster of the sciences; but one that has become necessary to cover those many phenomena along the boundary between physics and chemistry that have arisen for consideration by the students of both. A few of these are, molecules and molecular weights, solutions, dissociation, thermo-chemistry, electro-chemistry, photo-chemistry, evaporation, distillation, freezing, melting, boiling and critical temperatures. Van't Hoff was regarded while living as its chief apostle, and certainly has done more than anyone else so far to raise it to the position of an independent branch of research. He was also the originator of the following generalization, which appears to be true in all departments:

"Whenever any change of any kind in the realm of Nature can accomplish work, that is, overcome resistance, it must proceed when the resistance is absent."

Shortly before his death he advanced a theory for explaining the space relations of the atoms in the molecules, which appears to give a correct answer to many questions where uncertainty existed, and which ultimately may afford a clearer insight into the as yet unsolved mystery of magnetism. But it must stand further critical tests before it will receive general acceptance.

THOMSON (1856–1907)

ELECTRICITY

Joseph John Thomson was a native of Manchester, England, and was educated at Owens College in that city, and at Cambridge, graduating from the latter in 1880. Four years later he became professor of experimental physics there, and remained in connection with that great institution of learning for the balance of his active life.

His special field of study and research was that of physics, where he made a number of brilliant discoveries. To him, more than to anyone else during his lifetime, is due the development of the ionic theory of electricity, and the electrical theory of the inertia of matter. His papers on these subjects, as also on radio-activity, have been epoch making.

The ionic theory of electricity as enunciated by him was to the effect that a current of electricity consisted of the motion of minute particles of matter which he called ions, each of which carried a charge of either positive or negative electricity, the movement of the oppositely charged particles being in opposite directions. These particles, however, were not molecules. He believed that ions were always present in all solid conductors, but not always in motion, in fact, were in motion only when a current was initiated from some external source. In liquids he thought that ions were brought into existence by dissolving in it some salt or acid that underwent the process called dissociation. This is a chemical process which, in the solid state, is illustrated in the familiar operation of transforming limestone—a combination of the oxide of the metal calcium with the gas carbon dioxide—by burning it in a kiln. When the proper temperature is reached the gas lets go its hold on the calcium oxide and the latter becomes quicklime, a substance so eager to find something to replace its former partner, that when water is offered it is accepted with avidity and the production of a considerable quantity of heat. An example almost equally familiar of the process in a liquid is that of ammonium chloride, commonly called sal ammoniac, consisting of a union of ammonia with hydrochloric acid. When this substance—which can exist in both the solid and the liquid state—is, in the latter, gently heated, the ammonia will release itself from the grasp of the acid and pass away. But if, in both these examples, the operation is carried on in a vessel so constructed that pressure can be applied at will; then, if it is applied after the process of dissociation is well under way, the two gases mentioned will go back to their former associates. It is impossible to transform limestone into quicklime in a closed vessel like a retort, no matter how high a temperature is employed.

Electrical dissociation as conceived by Thomson was a somewhat similar yet wholly different phenomenon, and it should here be remembered that while chemical dissociation is a well-demonstrated fact, the other was merely suggested by him as a theory to be proved or disproved by further investigation. According to it, when certain acids or salts were dissolved in water they became capable of breaking up (without the application of heat) into atomic groups, if provoked to do so by the attempted passage of an electric current through them, and when disruption of that kind was effected each atom so isolated carried, he thought, either a positive or a negative electrical charge, in consequence of which it became capable of transporting the electrical current and was an electrolyte. As an example, take the case of common table salt, a compound of the metal sodium and the gas chlorine. As ordinarly known it is a white grainy solid. Upon the addition of water it becomes a transparent liquid with a briny taste. In this state it was capable under his theory, when properly provoked, to dissociate into its atomic constituents, each then acquiring an electric charge, that of the metal being of the positive kind, and of the gas the negative, these then becoming ions.

Since Thomson's day the fact of this ionic dissociation has been amply demonstrated, but the cause of it has been shown to be different from that suggested by his theory. The elementary atoms which then were believed to be the ultimate forms of matter, are now known to be simply groups of electrons and protons, which themselves appear to be the ultimate forms of force. Thus, in the few years that have passed since his theory was advanced matter, as understood by every body in his day has totally disappeared. It is no longer proper to speak of the atom of sodium—for instance—as carrying a positive electric charge, or of the atom of the gas chlorine as carrying a negative electric charge, for in each case the atom and its assumed charge are identical, or one and the same thing.

HERTZ (1857–1894)

PHYSICS

HEINRICH HERTZ spent his early years in Hamburg, Germany. After obtaining a good primary education, he began the study of civil engineering; but finding the profession uncongenial, he turned to mathematics and the sciences, becoming finally in 1880 an assistant to Helmholtz at the University of Berlin. In 1883 he undertook tutoring work at the University of Kiel, and in 1885 was elected to the chair of physics at the Polytechnic Institute at Karlsruhe. Here, at last, he had the opportunity to carry on his investigations on electro-magnetic waves, and his discoveries in regard to them were so important and remarkable, that he was called to the chair of physics at the University of Bonn in 1889, a position which he held during the remainder of his brief life.

To Hertz is due the discovery of those electro-magnetic waves in the ether, which have made possible the sciences of radio telegraphy and telephony. These pulsations are known as the Hertzian waves. They can be propagated by the spark of an electrical machine, can be received on a wire made of a metal with good conducting properties, by the latter can be propagated into space in the form of pulsations which may be caught up again on another wire at a distance, and by it carried into a receiving device, where a duplicate of the original impulse may be repeated and made audible.

Hertz demonstrated that these undulations, like those which produce the sensation of light, can be reflected, refracted, diffracted and polarized.

Because it is quite impossible to imagine motion unless there is something capable of being moved; when the phenomenon of light was found to consist of waves or undulations, it became necessary to assume that the space between us and the sun and stars was not empty of all substance as had been believed, but must be filled with some material capable of vibrating and of transporting to us those movements which constitute light, heat and the effects produced by the other kinds of "rays" now known, the actinic, the Becquerel, the Roentgen and the Hertzian. To supply this deficiency a medium was assumed, and given the name of the ether, originally written æther, because derived from the Greek word "aitherios," which to them meant the upper air or, in general, the blue heavens that were supposed to extend to the sun, the planets and the fixed stars.

All attempts to date of modern scientists to demonstrate the fact or the nature of this hypothetical substance have failed; yet until the recently enunciated relativity theory it has not only been accepted by scientists as a necessity, but, on mathematical grounds many of its properties have been calculated. Thus Maxwell deduced figures expressive of its density, elasticity and rigidity, based upon its light carrying capacity, and expressed the opinion that it could not be of a grainy or discontinuous structure, but must be (as a whole) of the nature of an impalpable, imponderable, invisible jelly-like mass, through which the heavenly bodies (including the earth) could move without creating friction. Further it is thought that this mass is constantly and in every part throbbing with undulations, which produce and then instantly release, local stresses and strains, which in turn result in vortices, which it was suggested as perhaps capable of explaining the phenomena of electricity and magnetism.

The relativity theory does not specifically deny the existence of this assumed universal medium, any more than it denies the theory of gravitation, which is also a pure assumption, and has never been demonstrated as a fact, though its properties have been calculated mathematically, like those of the ether. The theory simply asserts that neither are necessary, and that because it has been impossible so far to demonstrate in the slightest degree the existence of either, it is not scientifically proper to assume it.

It is certain that investigation of these two mysterious phenomena will not cease, and that new information about them will gradually accumulate. An enormous step in that direction has been taken in the resolution of matter into energy. The next will probably be as startling. The human mind, now thoroughly awakened to its powers will not cease its questions of Nature so long as consciousness exists.

ARRHENIUS (1859–)

CHEMISTRY

Svante Arrhenius was born in the vicinity of Upsala, Sweden, and received the education of a chemist and physician at the university in that city. After a few years of travel and study in Germany, Holland and France he was appointed to the chair of physiology at the University of Stockholm where, for the balance of his career, he taught and conducted research in that science and chemistry. He is regarded as the founder of the art of the electrical dissociation of substances capable of carrying the electrical current when in the liquid state, into positive and negative ions. His investigations in this department of science have resulted in the development of valuable processes for the separation of many of the elements from their impurities, and from each other.

The particular service which he rendered to an art already fairly well established on an experimental basis, was the discovery and enunciation of the laws governing the changes occurring in the processes of dissociation, so that, under given conditions, results could be accurately foretold. Certain substances (common table salt, for instance) when dissolved in water, are found to be capable of carrying the electrical current, and, under proper conditions, will decompose into what are called "ions." These are exceedingly minute particles of matter—not molecules, however,—which, according to the material of which they are composed, carry, or consist of a charge of either positive or negative electricity; that is, of either a proton or an electron. If now this ionized liquid be connected, through opposite sides of the vessel containing it, with the two terminals of a battery of any kind capable of producing an electrical current, a current will immediately be set up in the liquid itself, the negatively charged ions (the electrons) moving to the positive terminal of the battery (its anode), while the positively charged ones (the protons) go to the negative terminal (its cathode). The liquid itself, when it has been brought into this state of electrical excitement, is called an electrolyte. Those ions which move to the anode have been given the name of anions. Those going to the cathode are called cations. One of the simplest examples of this act of dissociation is that of water, which is composed of the positive gaseous element hydrogen, and the negative elementary gas oxygen. When a current is passed through it decomposition at once begins, the hydrogen ions moving to the negative terminal and those of oxygen to the positive one. If these terminals are of platinum these gases, as they arrive, rise in bubbles to the surface of the liquid and float away.

A more complicated example would be that in which the electrolyte was a molten bath of the mineral cryolite—a composition of the elements, sodium, aluminum and fluorine. This compound, when employed in the recovery of the metal aluminum, though an electrolyte, does not itself undergo decomposition into ions under the influence of the electrical current. But it is capable, at the proper temperature, of dissolving alumina, the ore of the metal aluminum. When therefore that ore is added to a bath of molten cryolite held in a container lined with carbon, and the electric current turned on, the oxygen ions of the alumina pass to the positive pole of the battery (a carbon cylinder), uniting with it and forming carbon dioxide, while the abandoned ions of the metal sink to the floor of the vessel, to be later melted into commercial bars. This is the famous Hall process, which so reduced the cost of producing the metal that it became at once a desirable and much employed article of commerce.

BRAGG (1862–)

PHYSICS

William Henry Bragg was a native of the Isle of Man, which lies at the northern end of the Irish sea about equidistant from the coasts of England, Ireland and Scotland. After acquiring his preliminary education at King William's College there, he entered and graduated at the University of Cambridge with distinction in mathematics and physics. Shortly thereafter he was appointed professor of mathematics and physics at the Adelaide University in Australia, where his work was so highly satisfactory as to bring him in a few years the offer of the chair of physics at the University of London.

In addition to ranking as an authority on the phenomena of sound which, for several years, he investigated exhaustively, his outstanding accomplishment in research has been in connection with the properties of crystals, as exhibited in their capacities to diffract or break up into their component parts the Roentgen rays, in such a way as to explain the nature of that form of radiation, and at the same time the nature of the structure of crystals, two phenomena that for a number of years previously had been awaiting satisfactory elucidation. Roentgen rays may be produced by bombarding plates of metallic tungsten or platinum with electrons to which a high velocity has been given by the electro-motive force of an induction coil, the process being carried out in the partial vacuum of an exhausted glass bulb. According to the investigations of Barkla—which have been amply verified—"every substance, under the proper stimulus, is capable of emitting such rays, which are characteristic of that particular material."

To understand properly the importance of these discoveries, that valuable tool of the physicist called the "diffraction grating" will need to be recalled. In its construction the physical limit of delicate mechanical work had about been reached when one with 15,000 distinct and parallel lines to the inch had been successfully made by Rowland, and satisfactorily employed in measuring wave lengths. But even it was found to be unequal to the task of resolving the Roentgen ray.

In 1912, Dr. Laue, of the University of Zurich, discovered the diffractive power of crystals. As this power depends upon the ordered arrangement of the atoms or molecules of which the crystal is composed; and as this arrangement is revealed by its external characteristics in the symmetrical faces, edges and angles that bound it, all of which are capable of measurement as to relative position, length, area and angular quantities, the internal structure may be analyzed; and Laue succeeded in producing a mathematical expression which, as stated by Bragg, "gave the intensity at all points due to the diffraction of waves of known length incident on a set of particles arranged in a space lattice."

In following up this lead Bragg was the first to demonstrate that the Roentgen ray was identical in its nature with light, both being transverse undulations in the assumed ether of space; but with the difference that its wave length is about 1/5000 part of those in the visible spectrum. At the same time he showed that "while the ordinary line grating would give a series of spectra at whatever angle the incident rays fall upon it, the crystal, to produce a similar effect, must be interposed at exactly the right angle, and even then can only give a spectrum of one order at a time." But, in the operation of the device, using the diverse faces of the crystals one after the other, the absolute wave length of the various types of the ray may be found; and, at the same time, equally exact information acquired as to the arrangement of the atoms or molecules in the body of the crystal employed. The importance of these conclusions can hardly be overestimated. By them a path is indicated by which knowledge of the nature of atoms of the different elements has been gained, which is far-reaching in its implications as to atomic structure in general.

In 1914 Bragg was awarded the Barnard medal; and in the following year, in association with his son, who was his co-worker in the investigation, the Nobel prize in physics.

ZEEMAN (1865–1922)

PHYSICS

Pieter Zeeman, a native of Zonnemaire in Holland, was educated at the University of Leyden. In 1900 he became professor of physics at the University of Amsterdam, and remained there in that capacity until his death.

He was the discoverer, in 1897, of what is known as the "Zeeman Effect," which brought him the Baumgartner prize in Vienna, the Wilde prize at Paris, and half the Nobel prize of 1902 in physics.

The Zeeman effect consists of the doubling—or further multiplication—of the dark absorption lines of the spectrum of a substance raised to a state of incandescence, when the substance, or the light so produced, is placed in, or passed through, a powerful magnetic field. Each line in the original spectrum is split up into two or more lines, when the source is examined from a direction at right angles to the lines of magnetic force, and also when viewed along the lines, but differently in the two cases. The light in these component lines is also polarized. The great importance of the discovery lies in its bearing upon the ultimate cause of the vibrations of the ether which produce the sensation of light to the eye. The phenomenon seemed at the time to indicate that the actual source of these undulations is the vibrations of those minute portions of electrically charged matter which have been called electrons. And this has since been demonstrated to be the case, although it is no longer regarded as correct to speak of "minute portions of electrically charged matter" because it is now known that matter and electricity are identical, and that the former may be said to have disappeared in the latter. The discovery made by Zeeman then resolves itself in one of the earliest steps which led to this rather startling conclusion. By referring to the chapter devoted to Fraunhofer, it will be found that he was the discoverer in 1814 of the dark lines in the solar spectrum; which were not satisfactorily accounted for until 1859, when Kirchhoff and Bunsen took up the investigation, and showed that each one of them represented an element in the state of an incandescent vapor in the outer layer of the body of the sun, through which the undulations emitted by its still more intensely heated inner surface had to pass before they could emerge into unoccupied space, and begin their long journey to the earth.

STEINMETZ (1865–1923)

ELECTRICITY

Charles Proteus Steinmetz (christened Karl Heinrich) was born at Breslau in Germany. His father was an expert lithographer. The son received an excellent primary education, and entered the University of Breslau at the early age of seventeen. While a student there he became—like very many young Germans of his time—interested in the thoeries of socialism, as they had been set forth a generation before by Karl Marx (1818–1883), and advocated them boldly, yet not fanatically. In his last and graduating year he undertook temporarily the conduct of a socialist periodical, while its editor was serving a term of imprisonment for expressions regarded by the authorities as seditious, and himself incurred their displeasure. Anticipating arrest, he managed to get across the border into Austria, and from there went to Switzerland, where he managed to earn his living by tutoring and in literary work at Zurich, at the same time attending the lectures at the technical school there, where he became acquainted and intimate with an American student. When the latter left for his home at the end of his course, Steinmetz decided to go with him. Traveling by the most inexpensive conveyances, they took steerage passage at Havre, and landed in New York in June, 1889. Steinmetz had but $10 in his possession, and very little baggage, and was threatened with deportation as liable to become a public charge, because of his unfortunate physical disability (curvature of the spine). His companion, however, was better fixed financially, and was able to show to the authorities a good sized roll of money, which he insisted was joint property. This resulted in the admission of Steinmetz. His first act was to take out his preliminary naturalization papers, which he completed as quickly as the provisions of the law allowed.

Two weeks after landing he found employment as a draftsman in the establishment of Rudolf Eickemeyer at Yonkers, a manufacturer of general electric supplies and appliances, who was also beginning to specialize in the construction of electric cars. Here the value of his educational equipment and inventive mind was quickly recognized, and while learning to speak English he made himself so useful to his employer that when the latter, in 1892, sold his business to the General Electric Company, Steinmetz, by special agreement, went with it as a part of its "good will," to the Lynn works of that organization. In the following year he was transferred to the plant at Schenectady where he remained for the balance of his life, becoming almost at once its highly valued consulting engineer.

The scientific achievement with which his name will perhaps be most associated is the explanation of the phenomenon of hysteresis in metals, and particularly of that variety of it caused by magnetism. Hysteresis was first observed by Warburg in 1881, and later independently by Ewing in 1885. These investigators observed that when a rod of iron had been converted by induction into a magnet, by being surrounded by a metallic coil or helix through which a current of electricity was passing, when the current was decreased in strength, or reversed, or stopped, demagnetization did not immediately decline or disappear; and that when interruption or change occurred in the current an appreciable time elapsed before the effect that should have resulted was produced. In other words there was a "lag" of effect, which was believed to be due to friction in the molecules of the bar, which revealed itself in a rise of its temperature. The ultimate effect is a loss of power which, in most forms of electrical machinery or installations, amounts in a short time to a notable decrease of efficiency. Steinmetz made an exhaustive study of this phenomenon, and in the end was able to devise means by which the most of the losses it caused could be obviated.

In the early years of the science or art of electrical engineering, the direct current was universally employed. But as it advanced, it quickly became evident that advantages of importance could be gained by employing the alternating current, especially in long telegraph, telephone and power transmission lines, and ocean cables; and for all types of installations which operate most efficiently under a high voltage. But the laws under which the two varieties act, and the expression of them in formulæ, are very different, those for the alternating or impulse current being much more complicated. Steinmetz undertook the simplification of these, and being a mathematician of rare ability he succeeded to a very remarkable degree. Personally he regarded this as his chief accomplishment.

He must be ranked also among the great inventors, having taken out some 200 patents, nearly all of them connected with the field of electrical engineering. Throughout his life he retained his belief and interest in socialism as a theory of communal life, and practiced it. While his views on the subject were definite and strong, they were never extreme, nor of a fanatical nature. He frankly admitted that the world was not yet ready for the system, and would have to improve considerably in morality before it would be. He never ceased to be thankful—and to give expression to it—that he had been permitted to become a citizen of a land where views such as he held could be retained and expressed freely, without incurring political persecution and loss of standing as a citizen and patriot.

CURIE (1867–)

CHEMISTRY

MARIE CURIE was born at Warsaw, Poland, her father, Dr. Sklodowski, having been an instructor in general science in the local gymnasium (the name given in central Europe to the high schools where students are prepared for the universities). Often the young girl was his assistant in the laboratory, at first only in keeping the place in order and in cleaning the glass beakers, test tubes, etc., used in experimnetal work. But as she grew up and absorbed in school the fundamental principles of science, she became so deeply interested in chemistry as to be able to act as his assistant in preparing his experiments, and in carrying them on while he was delivering his lectures. Meantime her general education in school was advancing rapidly.

At this period of her life that part of the ancient kingdom of Poland in which she lived was a province of Russia, and under severe repression. To escape this, and having meantime earned and saved enough by work as a governess for several years, she went to Paris in 1885, and secured employment at that great institution of learning then and since known as the Sorbonne. Her work at first was only that which she had performed for her father in the early days of her service in his laboratory, but in a short time her knowledge of chemistry, and her experience in it became known, and she was advanced to the position of assistant to Pierre Curie, one of the research students there, who in 1895 became her husband. His interests at the time were mainly in the subjects of physics and electricity, while hers were to secure her degree. This she finally won with distinction in 1898.

In 1896 the French chemist Becquerel made his important discovery of the mysterious emanations that are constantly given off by ores and compounds of the comparatively rare element uranium, which have the power of penetrating many substances opaque to light, and of affecting the photographic plate in the same way as the Roentgen ray and the actinic rays of white sunlight. As will be seen in the chapter devoted to him he did not follow up the matter, but Mme. Curie became greatly interested in it, and after a certain amount of preliminary investigation with that ore of uranium called pitchblende, which is found in fair abundance in several of the European mining districts—notably in Bohemia, Cornwall and Norway—reached the conclusion that the Becquerel emanations did not come from that metal, but from some as yet unknown substance associated with it. At the time her husband was engaged in an investigation in physics, but this was temporarily set aside, and the two took up the new line of research, which culminated in 1898 in the discovery by them in the ore of two new elements, to one of which they gave the name of radium, and to the other that of polonium (in honor of her native land). These have since been shown to exist in all ores of uranium, and to be the product of its constant devolution. But, as they are themselves also constantly undergoing degradation or decomposition into other elementary conditions, they exist in quantities so comparatively minute that to secure enough for experimental purposes it was determined that a ton of the pitchblende ore must be obtained to work on. This was contributed by the Austrian government from one of its Bohemian mines, and after operating for nearly four years, Mme. Curie in 1903, in a thesis delivered at the Sorbonne, gave a description of the process by which the two new elements had been extracted from it, a statement of their properties as far as then ascertained, and a sample of both in the form of chlorides. For this achievement they were awarded the Davy medal of the Royal Society of London, and half of the Nobel prize of $40,000 in chemistry for that year, the other half very properly going to Becquerel. In 1906 her husband was accidentally killed by being run over in one of the crowded streets of Paris by a heavy truck. Mme. Curie, by then the mother of two children, disregarding this severe bereavement, continued her work on the two metals, and in 1910 succeeded in isolating radium in its metallic condition, and in determining its atomic weight and some of its properties. For this remarkable feat she was given the full amount of the Nobel prize in chemistry for that year. Simultaneously her name was presented for membership in the French Academy of Sciences, perhaps the most exclusive and notable society of its kind in the world but, on account of her sex, failed of election; a result which has since been deeply regretted by scientists everywhere. In 1915 a Radium Institute was organized in Paris, and Mme. Curie placed at its head, a position she has retained ever since with credit to herself, and great advantage to the rest of the world.

Radium is a true metal of a lustrous silver-white color, which melts at 700 degrees C., and tarnishes rapidly in the air. Its atomic weight is 226.5. Its place in the Periodic Table of the elements is in the vertical group which begins with beryllium and is followed in order by magnesium, calcium, zinc, strontium, cadmium, barium and mercury. Its atomic number is 89. It occurs in nature in all the ores of uranium and thorium, but in a very minute quantity. In a metric ton of pitchblende (which contains roughly 60 per cent of uranium) a shade over three grains (a teaspoonful) exists. To obtain the gram of radium chloride which was presented to Mme. Curie by the women of America in 1921, required the concentration of 600 tons of carnotite—one of its ores that is quite abundant in Colorado and Utah—and several months of laboratory work. Its high cost is thus easily apparent. The recovery of it without serious loss is a long and delicate process. As, one by one, the numerous other elements associated with it are eliminated, the residues become at each stage more powerfully radio-active, and towards the end dangerously so, for the emanations, unless properly controlled, are exceedingly corrosive to human flesh, while at the same time when some of them are cut off by suitable screens, have been found to be of help in destroying or temporarily weakening the growths of cancerous cells. The element does not come on the market in its metallic condition, for in that form it is chemically very unstable and hence unusable. But in the condition of the chloride or bromide it is chemically stable, while its radio-activity is as great as when in the metallic state. Polonium has not yet been isolated as a metal, but its atomic weight has been ascertained as about 222. It exists in quantities even more minute than radium. In addition to these two, the French chemist Debierne in 1899 found another radio-active element, to which he gave the name of actinium, and in 1907 Boltwood added a fourth to the list, which he called ionium. These three, however, appear to be simply members of a long list of disintegration products, a few of which possess enough inherent chemical stability to live for periods that may be expressed in years, but the most of them perish in a few days, or in a few minutes, or, in the case of four or five, their brief existence is measurable only in seconds.

The significance of the discovery of radium lies in the fact that it opened an entirely new field of research in science. Previously the chemical atom had been regarded as indestructible. Now it has become evident that at least the three heaviest of the known list are constantly undergoing a process of disintegration or devolution. Ever since the day of Dalton (1766–1844), whose work established the atomic theory, the belief has been held by many chemists that all of them are, in some way, but combinations of one of them—the lightest, hydrogen. This belief is stronger today than ever, though it is not yet proved. But the process of the devolution of the heavier element has now been established by the researches and discoveries of the Curies and those who have followed up their lead. If some can and do break up into elements of lower weight and less complexity of structure, it is plausibly reasoned that ultimately it will be demonstrated that all have been built up in the past; that the ultimate chemical particles of matter themselves are as subject in their most fundamental aspect to the great law of evolution, as those higher and more complex forms of it which we call organic life. The recent discoveries by which the chemical elements have been shown to consist of nothing more than units of positive and negative electricity (pure energy) combined in various ways, has converted the expectations of the early chemist into something akin to certainty in the minds of those of today.

MARCONI (1874–   )

ELECTRICITY

Guglielmo Marconi was born in the vicinity of the city of Bologna, Italy, his father having been a native of that country and his mother of Ireland. The family were large landed proprietors. His education in youth was under private tutors, one of whom, Professor Righi, was a scientist of some note. It was in 1886 that the German physicist Hertz began the series of experiments which, in the year following, revealed the existence of those electromagnetic undulations in the ether that had been postulated a quarter of a century before by the Scotch mathematician Maxwell, in his study of the nature of light. Young Marconi, then under fourteen years of age, became deeply interested in the published accounts of the discoveries, and repeated on his father's estate with crude aerials some of the experiments of the German, thus becoming the first radio enthusiast. As is often the case with men of science, Hertz made little if any attempts to put his discovery into practical use, but Marconi possessed the character of the practical inventor. Connecting one terminal of his induction coil to the sending aerial, he grounded the other, which had the effect of greatly increasing the capacity of his oscillator to produce the Hertzian waves. With this primitive installation, and using a simple form of resonator, he was soon able to send signals through several hundred feet of distance. From these small beginnings, improved year by year as he gained knowledge and experience, he advanced step by step in the path of his ambition until, in 1899, he established wireless communication across the English channel, and in the following year was sending and receiving Hertzian wave signals over much of western Europe.

By this time he had sold to the British government, and to several other nations, the right to use his patents, and the great value of his invention for establishing communication between vessels at sea, and between them and near coast stations, had been amply demonstrated. Many imperiled ships had been rescued. It had been learned that longer distances could be bridged by the construction and use of loftier aerial terminals; and so, in 1901, abandoning the narrow field of Europe, he turned his attention to the problem of establishing communication with the New World. At Poldhu, on the western coast of Cornwall, he had erected a sending station 210 feet in height, and equipped it with powerful operating machinery and appliances.

In December of that year he landed on the eastern coast of Newfoundland. There, using for an aerial the metal string of a kite which, after great effort, had been raised to and held at an approximate elevation of 400 feet, he received on the 12th of that month the first wireless signals across the 2000 miles of water, in the form of the three dot clicks of the Morse code which stand for the letter S; which the Poldhu operator had been directed to send out daily at an agreed hour. Their detection was effected by the use of an ordinary telephone receiver.

In 1914 Marconi was awarded the medal of the Franklin Society of America for his discoveries in the radio art. In the years that have followed his achievement in bridging the Atlantic, wireless has advanced with startling rapidity. In the Great War it was a terrible aid to destruction, but since then has been extended around the world in beneficence. In its development many new discoveries of importance have been made, so that today a wireless installation is a vastly different affair even from that notable one at Poldhu which had a range of two thousand miles. The coherer has been replaced by the crystal detector, which passes the Hertzian waves in one direction only, and converts the oscillation current of the antennae into a direct pulsation quite capable of producing audible signals in the Edison telephone receiver. For the induction coil, the vacuum tube detector and amplifier has been substituted. Generators and transformers have been vastly improved. Every step has been a marvel of advance, and the end that may be achieved is not yet in sight. In justice to the still young scientist the information should be published as widely as possible that he has never attempted communication with Mars. All statements to that effect have been manufactured out of the whole cloth.

EINSTEIN (1875-)

PHYSICS

Albert Einstein, of Jewish ancestry, was born in Switzerland. He received an excellent education, and graduated with honor at the University of Zurich. Subsequently he was a professor there, and later occupied the chair of mathematics at the University of Prague. Afterwards he became a member of the faculty of the University of Berlin. While holding this last position he published, in 1905, his first essay, on the Special Theory of Relativity. Very little notice of it was taken at the time. When the Great War broke out in 1914, and the professional class in Germany joined in a public protest against the opinion then universally held throughout the rest of the world that the action was unwarranted, Einstein was one of the few scientists of the nation that refused to sign it. In consequence of the disfavor with the authorities into which this action plunged him, he resigned his position and returned to Switzerland, where he remained throughout the contest. At its termination he was invited to return and resume his post at Berlin. Since then that city has been his home. And from there, in 1919, he published his General Theory of Relativity, which at once attracted the attention of the civilized world.

It will be impossible in the brief space that can be given in this volume to the story of his life, to do more than indicate the outline of his theory, and the conclusions he has reached. He is, above all things, a mathematician, and of a very high order. Such people think and speak in a language not understood by the average well educated individual, and commit their results to paper by the use of symbols with which he is generally totally unfamiliar. One of his most lucid commentators (Heyl), comparing his theory with that of Sir Isaac Newton says: "Where Newton's law takes the form of a single differential equation, that of Einstein is expressed by a set of ten simultaneous differential equations, each of so fearful and wonderful a structure that a most compact and unfamiliar notation is required to render it fit to print." Under such conditions no attempt will be made to translate his law into intelligible language. It would be, in fact, impossible to do it.

Nevertheless, his conclusions have so far been verified in two crucial tests, and can hardly be denied. Moreover, none of these do more than to add to those concepts of the nature of the universe which, for the last two centuries have been regarded as settled. They do not contradict or upset them, as has been too often claimed. On the contrary they support them up to a certain limit, and then, for reasons not difficult to grasp, assert that in consequence of the advance of knowledge during this period, the law can and should be stated in a more correct way.

Over sixty years ago Herbert Spencer, in an essay entitled "The Relativity of all Knowledge," gave clear and definite expression to the fundamental idea of Einstein's theory. It was not original with the latter, nor does he claim it to have been.

Heretofore those concepts which are called by the names of Space and Time have been regarded as absolute ones in their nature, representing actual facts; the former, an extension in all directions along straight lines to infinity, and the latter eternally into the past in one direction and into the future in another. No philosopher has yet arisen who has been able to form even mental pictures of these concepts, or to express their meaning in language. Nevertheless they have been accepted as truths. Einstein asserts, in effect, that Space is a relative concept, and instead of possessing the quality of indefinite linear extension, is that of curvilinear extension, which ultimately returns to itself. It may be likened to the summation of those innumerable lines on the surface of a perfect sphere which are called "great circles," each of which represents the shortest distance between points along it, on the curving surface. With him Time is but the place which a three-dimensional body occupies during each instant of its existence, and which, when considered in connection with those lines of direction which are called length, breadth and thickness, constitutes the fourth dimension, which he asserts to be the measurements of reality. Or, to put the matter in a different way, the four dimensions are—up and down, forward and backward, to the right and to the left, and towards the past and towards the future. Only by including the last, can the position of any point or event in space be accurately located.

Newton postulated a force (gravitation) to explain the fall of the apple, and stated the law of its operation. Einstein denies that such a force exists, but admits that the law which Newton enunciated is, for all practical purposes, a correct one, for all bodies in Space and Time as heretofore conceived. But, under the new conception of them it does not explain observed phenomena with absolute accuracy, when enormous distances and prolonged periods of time are involved. Under the latter conditions the element of curvature in Space, and its four-dimensional nature, compel a modification of the law.

Although many attempts have been made to account for the apparent fact of gravitation, no success has been attained. Similarly, the nature of that directly opposing apparent fact called centrifugal force remains wholly unexplained. Einstein denies the existence of both, as *forces,* thus accounting easily for the the difficulties experienced in trying to understand them. His contention is that they are no more than manifestations of that property of matter which is called inertia.

According to Newton, if a body is left to itself; it falls through space to the earth, in consequence of the force of gravitation. According to Einstein, the same body under identical conditions, falls through time-space along the shortest possible track. This, when the distance is small, is apparently that of a straight line, but when great, is that of a curve, which ultimately will return to itself if sufficiently prolonged. Gravitation and centrifugal force are then simply two aspects of the one entity, inertia. Both, as Heyl says, are "independent of the material, are not functions of temperature, and cannot be cut off by any form of screen. In fact, they seem to be functions only of the mass involved, and the space (and time) co-ordinates of the system." In other words they are not forces, but properties of the concept of mass. What then is mass? Until recently it has been defined as the quantity of matter (expressed in terms of weight) contained in any given volume of three-dimensional space. If, for the final word in this definition we substitute time-space, and at the same time remember that the latest discoveries in connection with the chemical atom has revealed it as simply a center of force, of the nature of one or more units of the two forms or manifestations of electrical energy (protons and electrons), it seems inevitable that the hitherto accepted definition of mass must be changed. For that component of it which has been called weight, and has been regarded as a purely gravitational effect, must now be substituted inertia, which, in its manifestation of centrifugal force, involves or implies the total absence of weight. And for volume of three-dimensional space, a corresponding bulk of time-space. These adjustments being made, the revised conception of the universe according to the theory of Relativity, begin to seem more reasonable and comprehensible.

There is but one pure (perfect) department of science; but one collection and organization of facts which, so far as it has been developed, has never required correction or revision. That is the science of numbers (mathematics). Conclusions correctly reached in its domain must be regarded as final statements of truth, no matter where they lead. The Einstein conclusions appear so far to be of such a character and, if so, incapable of denial. It is too early, however, to predicate his final place and rank among the masters of science. There are just as vigorous opponents as proponents of his theories. Nevertheless we can safely give him credit for presenting the most radical, and therefore the most interesting of new hypotheses, since Newton in 1687 gave to the world the law which apparently still controls the motion of the earth and all the heavenly bodies in space.

INDEX

F

G

H

J

K

L

M

V

W

Y

Z