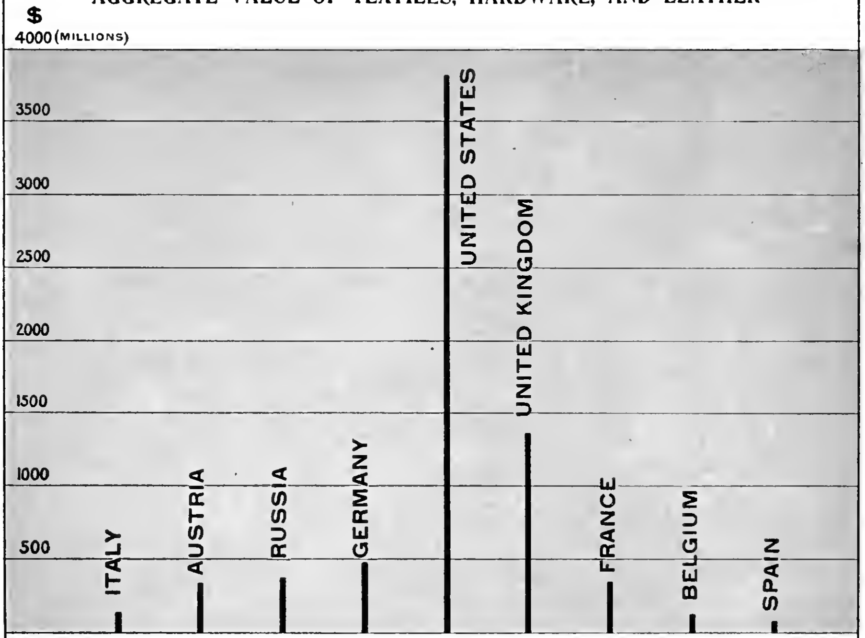
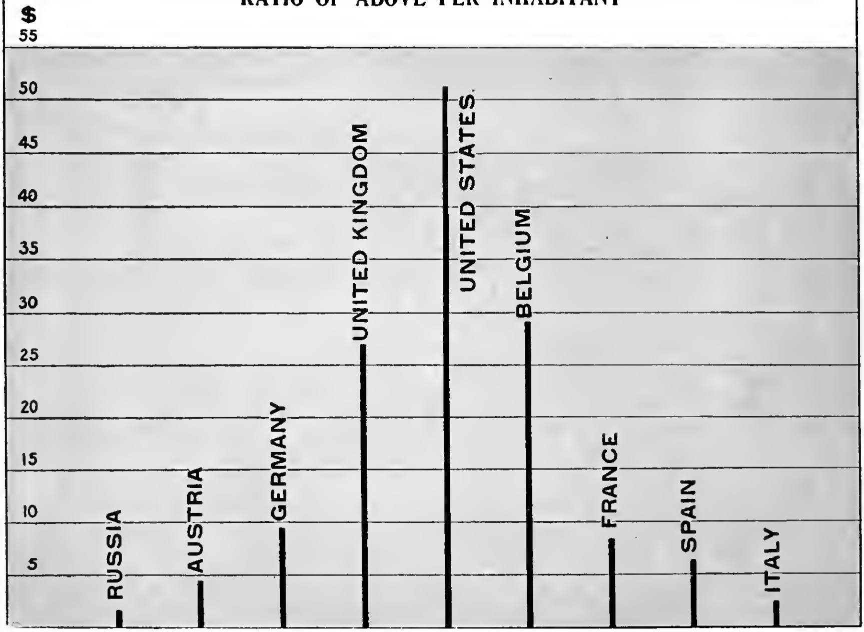
MANUFACTURES

AGGREGATE VALUE OF TEXTILES, HARDWARE, AND LEATHER



RATIO OF ABOVE PER INHABITANT



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VOLUME VII.

SCIENCE AND INVENTION.

FIFTY YEARS OF AMERICAN SCIENCE.

BY W. J. MCGEE.

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On April 2, 1840, eighteen American savants met in Philadelphia and organized themselves into "The American Society of Geologists." Within two years the association extended its field of activity, and added "and Naturalists" to its title. Still later other sciences were given hearing, and at a notable meeting held in Boston in 1847 it was decided to remodel the organization on the lines of a British association that had been a power in shaping intellectual progress for a quarter century. In accordance with this action, the leading scientific men of the country met in Philadelphia, September 20, 1848, and instituted "The American Association for the Advancement of Science." Such was the origin of the leading American scientific society, a distinctively American body, meant to increase and to diffuse exact knowledge among the people.

Scientific progress, especially in a land of free institutions, is so closely interwoven with industrial and social progress that the advance of one cannot be traced without constant reference to the other. Indeed, the statement of our national progress during the past half century is little more than a summary of results and practical applications of scientific research. Fifty years ago our population was hardly more than twenty millions, now it is eighty millions;

then our wealth was less than seven billion dollars, now it is eighty billions. At the beginning of 1848 there were fifty two hundred and five miles of railway in the United States, now there are far more than any other country has, more than all Europe; nearly as many miles, indeed, as all of the rest of the world put together. Some of those who attended the first meeting of the association made their journey, or part of it, by stage coach or in the saddle. They met many a boy riding to the neighborhood mill with a bag of corn as grist and saddle, and the itinerant doctor or minister on horseback, with his wife on a pillion behind; they passed by farmers swinging the back breaking cradle or wielding the tedious hoe, while lusty horses grew fat in idleness; they caught glimpses of housewives spinning and dyeing and weaving with infinite pains the fabrics required to clothe their families; they followed trails so rough that the transportation of produce to market multiplied its cost, and carrying back family supplies was a burden; everywhere they saw hard human toil, enlivened only by the cheer of political freedom, and they did not even dream of devices whereby nature should be made to furnish the means for her own subjugation. Most of the mails were carried slowly by coaches and postboys; the telegraph was little more than a toy; the telephone, the trolley car, and the typewriter had not begun to shorten time and lengthen life; and steel was regularly imported from Sheffield, and iron from Norway. The slow and uncertain commerce of interior navigation was the pride of publicists, and Chicago boasted a population of twenty five thousand; a shallow wave of settlement was flowing over the vast interior to break against the bluffs of the Missouri, though the pioneers still feared to pitch tents on the broad prairie lands, and chose rather the rugged and rocky woodlands skirting the water ways as sites for homesteads; the fertile subhumid plains, with ten million buffalo feeding on their nutritious grasses, were still mapped as the great American desert; the Rocky mountain region beyond was a mystical land, yielding the wildest and weirdest of travelers' tales; California was an

Ultima Thule more remote in thought and interest than are Hawaii or even the Philippines to-day.

Then, as now, the nation was in the throes of growing pains, acuter than now, because territorial expansion was more rapid; Texas had recently given its empire—an empire of barren breadths and bloody bandits, according to the critics—and Florida had lately come to us from Spain; Iowa and Wisconsin had entered the family of states, and Oregon had become a troublesome territory; and the treaty of Guadalupe-Hidalgo had just been approved, bringing California and New Mexico (with most of what is now Arizona) into our possession—adding the care of hopeless deserts and the control of treacherous tribes and an alien population to the duties of an overworked legislative and administrative government, and preparing the way for the witticism, "Mexico will be forgiven all if she will only take back her lands." In truth, there was danger, painfully manifest thirteen years later, of disruption through overgrowth of the local interests and provincialisms always straining our theoretic union—a danger happily removed forever a quarter century later by the railway and the telegraph, which gave a stronger unity than political faith or governmental doctrine.

The progress of the nation during the half century is beyond parallel. By normal growth and peaceful absorption without foreign conquest the population has trebled, and the national wealth has increased tenfold. The subjugation of natural forces has proceeded at a higher rate, and the extension of knowledge and the diffusion of intelligence have gone forward more rapidly still. This advance, so great as to be grasped by few minds, is the marvel of human history. The world has moved forward as it never did before. Yet fully half of the progress of the world, during the last fifty years, has been wrought through the unprecedented energy of American enterprise and genius, guided by American science.

It is to a great degree through special research that knowledge advances; yet it is by no means to be forgotten that the specialty is but a column in the fane of science, and that arcades and keystones and swelling dome hold higher places. Worthy has been the work of specialists in the extension of knowledge, during the half century; but nobler still have been the tasks of the fewer searchers who have been able to span two or more specialties, and to simplify knowledge by co-ordination. The solidarity of science is well illustrated by the work of the physicist Bunsen and the chemist Kirchoff, both of Germany, who in 1859 combined their specialties (as few great men are able to do) and blent ideas in the invention of the spectroscope, which has revolutionized several sciences. By aid of this device, later chemists and physicists have discovered new facts and made some of the most important generalizations of the time; by its daily aid, the metallurgist applies the Bessemer process, which has revolutionized the steel production of the world; aided by a derivative device (the bolometer), Langley has been able to measure and weigh the light and combustion rate of the firefly lamp, and thus to gain a new point of view in physiology. Still greater has been the service of the spectroscope to the astronomer; for it has brought, as it were, to the test tube and crucible, our sun and other suns, and the luminous planets and comets, so that their substance may be analyzed hardly less definitely than the rocks beneath our feet; it even enables the astronomer to read from the shifting lines of the spectrum the relative motions of stars long enough to be fixed. This application of the spectroscope marks the most noteworthy advance in astronomy not only of the half century but of all time. No key ever unlocked sublimer revelations or more inspiring vistas than this instrument which opened the door of the new astronomy.

A few of the principal advances in science, made in the last fifty years, may be noted.

Europe and America have contributed to astronomy in fairly equal measure. The spectroscope was the gift of the older country, and some of its most brilliant products were brought forth by Huggins and other transatlantic students; yet spectroscopy was revolutionized by the American physicist Rowland, with his exquisitely delicate diffraction gratings and his marvelous mechanism for producing them. So, too, the photometric work of the Pickerings in Harvard observatory, with its adjunct in Peru, and the star catalogues of the lamented Gould and his successors in Cordova, are unexcelled, while the best inventory of modern star science, The New Astronomy, is the work of the American astronomer Langley. Some part of the success of cisatlantic astronomers must be ascribed to the mechanical ingenuity which seems to spring up spontaneously with intellectual freedom, and which enabled the Alvan Clarks, father and son, to produce the finest telescopic lenses the world has seen, with no less excellent fittings. Yet there has been no lack of patient waiting and minute scrutiny of the stolid mid European type, as shown by the half century's discoveries of asteroids and planetary satellites and comets, of which America has done the greater part. The prophecy of American prestige in astronomy came in 1860, when Newcomb reduced the orbits of the asteroids to a simple system; and it is just now fulfilled beyond all early anticipation in a recomputation of the elements of the solar system by the same indefatigable delver among definite quantities. This work alone marks an epoch; the sun and moon and planets have been weighed as exactly as sugar and tea at the grocer's, and their paths measured as precisely as silks and woolens at the draper's. Most of the ships of civilized nations set their courses by nautical almanacs computed on the Newcombian basis; and the name of Newcomb is more widely known than the name of any other astronomer, and has brought tribute to America from every civilized country. Characteristically American is the work of Chandler, who, first following and then outstripping the brilliant Euler, has reconciled the discrepancies in latitude records of European and American observatories, and discovered a new law of planetary motion, expressed in periodic wandering of the terrestrial poles. Equally characteristic is the work of Young on the sun, Newton on meteoroids, Barnard on comets, and a dozen others in as many special lines, including the suggestive results of Percival Lowell in his observatories on both American continents.

The genius of American astronomers has brought appreciation from laymen as well as investigators, and their labors have been rewarded by increased facilities; America is better endowed to-day with observatories and apparatus than any other country—nearly as well as all the rest of the world. Most of our rapidly growing universities have their own observatories. Twenty years ago the installation of Lick observatory was an event in the scientific world, and attracted such public attention as to leave little for the two observatories installed within the year—Flower observatory in Pennsylvania, and Yerkes observatory, an adjunct of the University of Chicago. Fifty years ago astronomy was a sober and sluggish science, far removed from practical everyday interests, cultivated respectably in Europe and beginning to attract serious attention in this country. To-day its data are doubled and its activity is tripled; it touches industry and the public welfare at many points, and advances more rapidly than ever before; and a full share of this progress is due to American genius and industry.

Half a century ago, Dr. Joule, of England, was engaged in a series of physical experiments, beginning with solids and ending with liquids, which indicated that while force may be controlled, it cannot be created or destroyed. Faraday, Helmholtz, and Grove repeated and extended the experiments, and through the combined efforts of the four masters in physical science the law of the conservation of energy was developed, and a new era in the history of science was opened. Half a century earlier, chemistry had established the indestructibility of matter, and incidentally proved that the material world is a world of law, and not of chance. The complementary demonstration of the indestructibility of force completed the groundwork for rational thought, and a phalanx of exponents and defenders of the doctrine of the uniformity of nature, marshaled under John Tyndall, was soon in the field. By timely chance they fell in with an equally vigorous phalanx headed by Huxley, who were expounding and defending the Darwinian doctrine of derivation, or the law of the uniformity of nature applied to organic species; and the joint forces quickly consummated the most sweeping intellectual revolution in history. Unhappily, ecclesiasticism was aroused and for a time Tyndall and Huxley were denounced as destroyers of the eternal peace of their converts; but the balm of personal association soon smoothed the acerbities and aided in fixing the respective bounds of science and faith, and serious antagonism to applied physics came to an end. Meantime, the mechanician found himself in line with the thinker, the student turned from hereditary introspection of the supernal toward the new found beauties of the real world, and gradually teachers came to be esteemed for what they knew rather than for what they conjured; practical men became thinkers, and thinking men became practical; industry was regenerated, and the real glory of the Victorian era began. At first the law of the conservation of energy was not the counterpart of the law of the conservation of matter recognized by chemists; for the ultimate and persistent basis of matter is the atom, while the physicists held only that the sum of energy persists in the universe. Recently, Powell has revised the law in the light of generalized human experience, and suggested that motion, like matter, inheres and persists in the ultimate particle; and thereby chemistry and physics, and the other sciences as well, are brought into harmony. This rendering of the fundamental law of physics is accepted by several savants; it is in accord with the lines of intellectual and industrial progress, and gives brilliant promise as a means of extending conquest over nature. Physical science has been the giver of many generous gifts, but the goodliest of all was the gift of right thinking, which was a by-product of the law of the conservation of energy.

The formula of physical science came to America as a mariner's compass to a crew of maroons. Already a nation of inventors inspired by intellectual freedom, Americans were still blind leaders of the blind; for invention is impossible without at least intuitive recognition of the uniformity of nature, while without conscious recognition of this law the inventor drifts in a sea of uncertainties, making port only by chance. The newly formulated doctrine was seized and assimilated with such avidity that within a decade it was more generally understood and adopted in this country than in all Europe. Under its stimulus invention throve and manufacturing grew apace: the crude reaper was made a self raker, next a harvester or header, then a self binder or field thresher, according to local needs; the hoe gave way to the horse cultivator, and the flail to the horsepower thresher, the neighborhood water mill to the steam driven roller mill grinding for all the people of a whole state; and the farmer learned to live by the strength of his beasts and the craft of his machines merely guided by his own intelligence. The mechanic arts were regenerated; steam was harnessed more effectively than before, and our railway making and locomotive building became and remain a revelation to the world; for only recently European engineers have been compelled to swallow incredulity as to the rapidity of American bridge building, while British promoters hastening to supply Egypt with locomotives have saved half the time required for delivery, despite the doubling of distance, by ordering from American builders. The tide of foreign importation was soon stayed, and then turned, and now American steel tools are sold in Sheffield and fine American hardware in Norway, while the products of American machines in the form of foodstuffs and fabrics are carried into every quarter of the globe. The characteristic of American inventiveness is its diffusion. Invention is as free as the franchise, and open competition gives life to genius no less than to trade. American devices (temporarily protected by patents) are so diffused that every citizen is in contact with the products of physical science and mechanical skill; everybody may have a machine made watch better than the average hand made product of Geneva, nearly equal to the tested Swiss chronometer; every family may have its sewing machine and telephone; and every man, woman, and child wears machine made buttons, pins, hats, and textile fabrics.

A typical American device is the bicycle. Invented in France, it long remained a toy or a vain luxury. Redevised in this country, it inspired inventors and captivated manufacturers, and native genius made it a practical machine for the multitude. Typical, too, is the bicycle in its effect on national character. It first aroused invention, next stimulated commerce, and then developed individuality, judgment, and prompt decision on the part of its users more rapidly and completely than any other device; for although association with machines of any kind (absolutely straightforward and honest as they are all) develops character, the bicycle is the easy leader of other machines in shaping the mind of its rider, and transforming itself and its rider into a single thing. Better than other results is this: that the bicycle broke the barrier of pernicious differentiation of the sexes and rent the bonds of fashion, and daily impressed Spartan strength and grace, and more than Spartan intelligence, on the mothers of coming generations. So, weighed by its effect on body and mind as well as on material progress, this device must be classed as one of the world's great inventions.

With the advance in simply applied mechanics, there have been still greater advances in the knowledge of the more obscure powers of nature, manifested in electricity and magnetism, in sun and wind and storm, even in vitality and mental action. Some of these have been made in Europe, but more in America. Fifty years ago Morse and Henry were doing the final work required to transform the electric telegraph from a physical experiment to a commercial agency, and soon nerves of steel and copper, throbbing with intelligence, were following the pioneer into the remotest recesses and pushing beneath the ocean; Faraday, the Siemens brothers, Helmholtz, and later Sir William Thomson (Lord Kelvin) freely gave genius and toil; then came Edison with an eruption of brilliant inventions; and to-day time and space are as if they were not, and from sea to sea our subjects of thought are as one. It was but yesterday that half our world knew not how the other half lived· now both halves read the same items at breakfast.

Themselves harvesters after the experimentalists in physics, the early telegraphers were planters for Graham Bell, and the telephone came to carry the word of man afar, and the graphophone to perpetuate it forever, and thus to complete the annihilation of space and time as obstacles to the diffusion and unification of intelligence. Inspired by success in conveying thought, inventors sought to convey grosser powers, and dynamos were invented to furnish light better and cheaper than the world had known before; devices for warming and even for cooking, and for lowering temperature by fans and refrigerant pipes, quickly followed; and now the lightning is harnessed in our houses as the thunder is subdued in telephone and graphophone. Meantime, motors and transmitters were perfected, and electric transportation came into successful competition with steam locomotion, while the power derived from waterfalls and central plants was made divisible, so that units of power are now sold as freely as pounds of tea or sugar were fifty years ago; and a way has been found to counteract the concentration of artisans in factories located by waterfall or engine. The conquest of nature by electric power, gained through controlling an infinitesimal part of the vibrant atomic energy of our corner of the cosmos, has come rapidly, and so steadily as almost to escape notice; yet it is a marvel beside which the magical lamp of Aladdin and all other figments of Oriental fancy are as nothing.

In 1848 a Frenchman and an Englishman made advances in the new art of photography, developed partly by Professor Draper of New York, a few years before. In 1850 a journal of photography was established in this country, and the art became the property of the people. Its progress well illustrates the growing solidarity of nations, for contributions have been made by England, France, Germany, and other countries, as well as America, and parts of the same apparatus are often the handiwork of two or more countries. America's contributions to the art are characteristic in that they have reduced the cost and increased the use of the apparatus so far that every village and a tenth of our families have their cameras. Recent events indicate that a new field is opening for the picture maker, and the next half century may see advances much greater than those of the last; for while photography has been limited to luminous rays and to portraiture of external surfaces, Roentgen has proved the possibility of using other phases of radiant energy, and of depicting internal structures as well as outer forms.

Half a century ago Joseph Henry published the plan of the Smithsonian institution, and his first mentioned means of increasing knowledge was a "system of extending meteorological observations for solving the problem of American storms." So began a line of research which has added much to science, and is daily contributing to personal comfort and material prosperity. Of old the wind blew where it listed, the rain fell on the just and the unjust alike, and men recked no more of the hurricane than of the earthquake, for both were ascribed to malevolent and unavoidable fate. The dark confession of weakness still clings to those who go down to the sea in ships, making them the most superstitious of modern folk, and it crops up uncannily in the exemption phrase of even modern transatlantic contracts, "acts of God excepted." Against this blighting faith in the malign Franklin set himself a century before Henry, when he led lightning from the skies on a kite string, and invented the lightning rod; but the real awakening began with the Smithsonian institution. For twenty years the work was little more than observation in eastern cities, giving data for laws, but not the laws themselves. During the reaction from the civil war several military men turned toward nobler conquest, and observation was extended and systematized in a science so definite as to confer the gift of prevision. Up to the present generation the principal contributions to meteorology came from Europe, and such names as Buys-Ballot, Buchan, Dove, and Delaunay were better known in this country than those of our own investigators, while so late as 1875 the data for Coffin's Winds of the Globe were submitted to the Russian Weikoff for discussion before they were issued by the Smithsonian institution.

Now the tide has turned. Generals Hazen and Greely and the civilians Harrington and Moore have built up the largest weather bureau in the world, and with the aid of physicists like Ferrel, Abbe, and Mendenhall have shaped weather science; while Langley has led thinkers into new paths by his studies of the internal work of the wind, and their application to problems of aerial flight. Much of the success of American air science must be ascribed to the accident of geography, which gives a broader field for the study of the atmosphere than any other nation enjoys—more favorable, even, than the two empires of Russia. Yet geographic bigness is but one of the elements of American greatness, in this as in other departments of knowledge, such as engineering, geology, and anthropology. To-day a central office co-ordinates observations not only from the Atlantic to the Pacific and from the great lakes to the gulf, but, through international comity, from Canadian territory on the north to Mexican territory on the south. The observations yield predictions benefiting agriculture and shipping to the extent of millions annually. They yield also principles which are enlightening the world, mitigating faith in Moloch and strengthening confidence in human might, and so preparing the way for still more brilliant conquest by generations yet to come.

Meteorology does not give control of the powers of the air and the vapors within it (pseudo-science to the contrary notwithstanding), but only enables men so to adjust themselves to these agents as to gain benefit and to avoid injury; yet conquest over the immeasurable potentialities of the atmosphere is extending in other ways. Half a century ago gases were the most elusive of substances, seldom allied in thought to liquids save in loose speculation, hardly brought from the domain of mysticism into the realm of reality. Now the continuity of the gaseous condition with liquidity and solidity has been established for the more important terrestrial substances. A dozen years ago Cailletet in France and Pictet in Switzerland liquefied various gases by high pressure and low temperature. Dewar, of England, followed in a striking series of operations, liquefying gas after gas, until within a few weeks hydrogen—most refractory of the elements and the unit of matter—has been brought into liquid form, and the American Tripler has devised means of liquefying air in large quantities at limited cost. To-day scientists find themselves on the threshold of a new prospect opened by these conquests. The possibilities of future applications cannot be presaged clearly, but there are indications that they will equal those made through the control of electricity. Liquid hydrogen is only one fourteenth the weight of water; it boils at —238° C. (—396° F.), or only 35° C. above absolute zero, while liquid air is a little lighter than water, and boils (or vaporizes) at —191° C. (—312° F.). In the abstract the figures carry little meaning, but made concrete they signify that just as the astronomer finds himself approaching the limits of the material universe through the telescope and the spectroscope, and just as the morphologist is approaching actual vision of molecular constitution through the microscope, so the physicist finds himself nearing the point at which the definite constitution of matter must begin—the real sunrise of the material universe, beyond which lies chaos only. Considered in their concrete application, the figures are still more significant. The uses of liquid air for wholesale cooling, as an adjunct in chemical and metallurgical operations, and even as a terrible instrument of war, have already been tested or suggested; yet the stimulus of discovery has hardly begun to affect the mass of inventors.

As doctrinal prejudice melted, and as chemistry established the continuity between organic and inorganic substances, the sum of experience and weight of reason wrought a revolution in thought, and the dominion of law over living matter was soon accepted implicitly, if not explicitly. The extension of law into the realm of intellectual processes came later, and more tediously and haltingly. A noteworthy step was taken in 1859, when Joseph Le Conte illustrated certain cases of interconvertibility of physical and mental forces. His exposition was republished and widely reviewed and discussed in Europe, where it inspired experiments and the making of special apparatus—always the strong side of transatlantic research; for the European pioneer puts stepping stones where the American lays a bridge. Meantime, Barker, after demonstrating the interconvertibility of physical and vital forces in 1875, passed into the higher realm, and definitely extended the correlation to mental force. Other contributions followed; and while there are still those who dread to lift the veil of mystery above a certain point—perchance through confounding mental process and intellectual product—the more vigorous investigators recognize the physical basis of mentation, and a science of psychology has arisen, standing to metaphysical psychology much as astrology stood to astronomy and alchemy to chemistry. It is represented fittingly in America. The consequences and applications of this advance of the half century may no more be foretold than those of others newly made; yet even if it mean no more than the extension of law into a new realm, and the replacement of chaos by order in human thought, it must take an important place in the history of science.

An important advance in chemistry was forecast in 1811 by the Italian Avogadro, and soon after by the Frenchman Ampère, through the discovery that equal volumes of all substances, when in the gaseous state and under like conditions, contain the same number of molecules; that is, that the constitution of matter is connected with its own inherent motion. The discovery was barren until fertilized by the law of the conservation of energy, and became fully fruitful only under the skillful treatment of the American Cooke, who used it as the basis of the new chemistry about the middle of the last century. The advance marked the extension of natural law into a field long cumbered by the mystical wreckage of alchemy, and signalized the lifting of interpretation from the plane of the material to that of the kinetic. A new chapter in the history of chemistry was opened by Kekulé, of Flanders, in 1858. This was the discovery of valence, or the law of proportion under which atoms combine to form substances—a far reaching, though possibly not final law governing the constitution of matter. The laws of Avogadro and Kekulé yielded a larger view of the unknown; and by their aid Mendelejeff, of Russia, and almost at the same time (1869–70) Lothar-Meyer, of England, discovered that the known elementary substances fall naturally into groups displaying certain family resemblances, while the groups fall into series defined by properties of the atoms; and these facts were formulated in the remarkably comprehensive periodic law, or law of Mendelejeff.

From the culminating point of view afforded by this law the domain of chemistry may be surveyed, as was the domain of astronomy through aid of Kepler's law, and the endless actions and reactions involved in the making and decomposition of materials, in growth and decay, are found to be no less orderly and harmonious than the swing of satellites and planets and suns in our solar and stellar systems; chemists can now invade the unseen universe, and determine the proprieties of elements not yet discovered, as Adams located Neptune by formulas before it was detected by lenses. The power of prevision possessed by chemists, under the periodic law, has been established over and over again by successful predictions.

One of the results of these epoch making discoveries was increased confidence on the part of the organic chemists, who, beginning with Wöhler and Berzelius, were cautiously creating by laboratory synthesis compounds previously held to transcend simple nature. Within the half century the laws of the inorganic world have been extended, first to organic compounds, then to organic processes, and finally to the essentially vital processes exhibited by both plants and animals; to-day the chemist and physicist stand on common ground to sustain and explain physiology, and even the modern psychology which finds the source of mentation in cerebral decomposition and recomposition.

During recent decades the applications of chemistry have multiplied and extended in various directions. The new alloys required for novel physical and industrial devices have been produced; high explosives innumerable have been compounded; and the chemist has co-operated with the physicist in liquefying gases, and with the astronomer in analyzing suns and comets and the rings of Saturn. Meantime, chemistry has been brought into touch with daily life as an adjunct to medicine, and as a means of testing foods and drugs in public sanitation. Perhaps the most brilliant applications of chemistry sprang from researches concerning the hydrocarbons preserved in the rocks of the earth as records of vitality during ages past; and the coal tar products have been made to yield dyes rivaling the rainbow in brilliancy and range of color, perfumes stronger than musk and sweeter than attar of roses, flavors more sapid than sugar and spice, and a plenteous series of unguents and medicaments—indeed, every material requisite for life and luxury except food.

The contributions of chemistry to knowledge and welfare during the half century have been many, yet relatively fewer and poorer than the rich returns from other sciences; and it is a conspicuous fact that few American names are connected with the greater advances in the science. While America's additions to astronomy, physics, geology, and anthropology have been of the first magnitude, modern chemistry remains a monument to European genius almost alone. In connection with this fact—perhaps in explanation of it—it is to be noted that there are no great chemical laboratories in this country, no institutions comparable with the astronomical observatories and geological surveys and natural history museums which have given prestige to American science.

Half a century ago geology was on the plane to which it had been raised by Lyell's law of uniformism—a law which contributed much to the cult proclaimed by Tyndall and Huxley; and this plane was effectively expanded by the efforts of several American geologists. With singular perspicacity and pertinacity, Hall and his associates developed an American scheme of rock classification (the New York system), which was expounded and crystallized by Dana, and has since served as the model for the continent; and in an address delivered in 1857, though not printed for a generation, Hall foreshadowed the laws of mountain making and other distinctive principles of modern geology. Thus, within the first decade of the half century the earth science of America had come to stand well abreast of that of Europe. Checked by the social shock of the early sixties, research rested; but toward the end of the decade it began anew, and as exploration pushed into the Cordilleran region, where the stone book lies open, it sprang forward with unprecedented vigor. Hayden, King, and Powell in the territories, and Whitney in California, were the principal pioneers in the field, while Powell, Gilbert, and Dutton led in lifting the science to the third plane in its development; for, through recognition of the "baselevel of erosion," they laid the foundation for the new geology, which reads earth history from the forms of hill and vale as well as from the formations and fossils of past ages. Within a dozen years the principles have been applied and extended in the coast plains of the southeastern states, where they have made both land forms and uncomformities eloquent records of continent growth; while Davis, of Harvard, has successfully employed the same principles in reading from topographic maps the later chapters of earth history.

Meantime, the glacial theory, imported by Agassiz from Switzerland, rooted kindly in American soil, and soon bore fruit; Chamberlain, Shaler, Salisbury, and a score of others have scanned our incomparable drift plains and drumlins, moraines and kames, sand plains and paha, and have solved the riddle of the loess; and during the last quarter century the records of the ice ages have been more thoroughly scrutinized and more fully interpreted in America than in all the rest of the world. Meantime, too, geology ramified in other directions, and its applications multiplied; the second half of the nineteenth century is distinguished by activity in investigation of rocks and resources in every country, but especially in America, with its federal survey and score of state surveys, maintained at a cost of more than a million dollars annually, and enriching the nation at an indefinitely larger rate. It is fair to remember that the success of the science on this continent is largely due to the great continental expanse and the wide distribution of resources in the rocks; that the plateau region and the canyon country of the southwest furnish the best known record of geologic process; that the Appalachian region affords the world's finest example of a distinctive type of structure; that the glaciated plains of the northern United States are among the widest in the world, by far the widest of those equally accessible; also, that our coal and iron, gold and silver, oil and gas, and numberless other valuable minerals tempt curiosity and cupidity, as well as serious inquiry from sea to sea. While the opportunities are unsurpassed, there has been no dearth of genius to seize them; and while America may still take lessons from Europe in mineralogy and perhaps in petrography, the relation is reversed in other departments and in the principles of the science, and leading European geologists take frequent field lessons on this side of the Atlantic.

Hardly a serious question as to the eternal fixity of species and genera and orders had been raised in scientific minds before 1848, save by Lamarck and a few other quasi visionaries, while conservative leaders like Agassiz in Switzerland, Cuvier in France, and Owen in England were so deeply grounded in the philosophy of fixity as only to be the more firmly set by each shock of new discovery. Just ten years later Darwin and Wallace independently announced the inconstancy of species and the derivation of organic units through successive changes; and the idea grew, until it wrought, within a quarter century, the most profound revolution in the history of human thought. This effect was not due alone to Darwin's wealth of facts and uprightness of record, nor was it due in more than partial measure to Huxley's eloquent and aggressive advocacy. The discovery of the conservation of energy by Joule and Grove, and its exposition by Tyndall, contributed much; Lyell's doctrine of uniformism strengthened the movement in many circles; the extension of chemistry to organic compounds was a potent factor; the enlargement of the known universe by the spectroscope had its effect; while all these combined with the habit of thought established through larger associations of thinkers with practical men and with mechanical devices, so that the formula "the uniformity of nature" won common assent. The wide and ready acceptance of the Darwinian doctrine was but the co-ordination of knowledge already gained. Yet the revolution would have been long delayed had Englishmen alone contributed to it, or even men of continental Europe; for, with a half dozen exceptions, the earliest and strongest apostles were Americans, with Asa Gray and Morse among the leaders. The free, vigorous, and trenchant American mind was peculiarly hospitable to the tenets of the new law; and it was accepted here as the foundation for the cult of science years before it was similarly accepted in Great Britain. Seen in the perspective now possible, Darwin's doctrine is but the extension into the organic realm of the laws of action and sequence which form the basis of all definite thought, and find their highest expression in that power of invention which enables man to dominate duller nature for his own behoof. Thus, the rise of the doctrine merely marked a normal and necessary stage in the development of knowledge concerning the several realms of nature.

Made definite by the recognition of action and sequence, biology has advanced apace during the last quarter century. The causes of most ills to which flesh is heir have been traced to germs and microbes, and modes of prevention and cure have resulted; the nature of sepsis has been found out, and anti-sepsis has been perfected with such rapidity that its leader (Lord Lister) has lived to see the average civilized life lengthened by months through efforts initially his own; and both medicine and surgery have been reconstructed. Entomology has traced the laws governing insect life, suggesting methods of successfully opposing physical force to insect activity, and even of opposing insect to insect in such manner as to protect and multiply the crops on which the nations are fed. Phytology has made clear the laws of plant life, indicating ways of fertilizing and hybridizing and even reproducing useful plants—ways more economical than those of nature; while zoölogy is daily applied in re-creating and perpetuating needful domestic animals. The science of living things is too broad and its lines are too many for full statement in a brief summary; but its results may be summed up in saying that it has taught man to control life almost at will—annihilating it if bad, and preserving it if good—and has enabled him to subjugate vitality to his needs even more completely than the physical forces are subjugated. As a science simply, biology abounds in problems of profound interest; as an applied science, its uses and benefactions are incalculable.

Half a century ago a shadow obscurea a considerable part of the field of science, seriously obstructing its cultivation; it was the shadow cast by man himself, then held too sacred to serve as suitable subject for scientific research. In 1863 Huxley published Man's Place in Nature, and an anthropological society was instituted in London and began the issue of a journal; eight years later Darwin published The Descent of Man. These events marked the gradual lifting of the shadow from science, the slow extension of the law of the uniformity of nature to the human organism. Contributions came from other countries; Herbert Spencer bent his fertile mind and facile pen to inquiry and exposition; America awoke rapidly; and within a quarter century anthropology was regularly classed as one of the sciences. At first man was studied simply as an animal, and men were classed in races defined by characters shared with brutes. A notable advance was forecast when students perceived that man occupies a distinct plane, in that his essential attributes are collective rather than individual; and the American

Morgan laid the foundation for objective sociology in his work on Ancient Society in 1877, while the Frenchman Comte formulated a subjective sociology, and the Briton Spencer pushed forward his imposing folios on Descriptive Sociology. Then came the creation of the Bureau of American Ethnology in 1879, and the beginning of the classification of the American aborigines by human activities rather than by animal features. So arose a new ethnology, in which men are classified by mind rather than by body, by culture rather than by color; and the rise marked the most notable advance in the history of anthropology. Under this classification, the peoples of the earth fall into four culture grades, which are also stages in development, namely: (1) savagery, with a social organization resting on kinship reckoned in the female line; (2) barbarism, in which the social organization is based on kinship reckoned in the male line; (3) civilization, in which the organization has a territorial basis; and (4) enlightenment, in which the laws and customs are based on intellectual rights.

The principal advance in anthropology was distinctly American; it grew out of conditions existing alone on this continent, and could not well have originated elsewhere; indeed, it is not yet fully appreciated in any other country. Like the American geologist, the cisatlantic anthropologist found the finest field the world affords. With a population coming from every European country, with an aboriginal people of threescore tongues and a thousand tribes always on his frontier, with the denizens of the dark continent long chained to his footstool, with representatives of China and Japan and the islands of the seas constantly competing in his industries, and with a more extensive and intimate blending of bloods than any student had seen before, his opportunities for testing ethnic principles were unparalleled; when lost in the labyrinth of meaningless distinctions of color and hair, of cranial form and capacity, of stature and length of limb, and in need of new criteria, he was inspired to note what men do rather than what they are, and soon followed the physicist and the chemist and the geologist into kinetic interpretation. Then he found a third of the thousand aboriginal tribes in the stage of maternal organization, and the remaining third ranging through transitional conditions of such sort as to show the course of development. At the same time, he found inbred traditions of territorial organization shaping habit and thought in the million immigrants and visitors from monarchical nations; and he alone had constantly before him the object lesson of governmental control despite—and indeed by virtue of—intellectual and social and political freedom. Our physical progress has been great because invention is encouraged by free institutions; our progress in geology has been rapid by reason of intellectual freedom and a vast domain; while our progress in anthropology has been marvelous because of the elevated point of view and an incomparable range of types both of blood and of activity.

The main movements made way for others, especially in connection with the aborigines; the sources of æsthetics and ethics have been successfully sought, the early steps in the course of industrial development have been traced, the beginnings of law have been analyzed, and the course of human development has been brought to light; and it is now known that the lines of human progress in the arts and industries, in sociology, in language, and in thought are convergent, rather than divergent like the lines of development among beasts and plants, and that the unification of ideas by telegraph and telephone and press is but a ripple marking the course of the great stream of human activity. The convergent lines of progress suggest multiplicity of cradle places for the American tribes, as recently expounded by Powell, and still more for mankind in general. Endogamy and exogamy have been defined, in the light of careful observation, as correlative regulations among given peoples rather than developmental stages; matriarchy has been shown to be the complement of patriarchy, and not a rival of avuncular control; while the trite "marriage by capture" has been reduced to due place as an incidental development rather than a primitive condition of mating. Meantime, a sound basis has been given to American archæology, as attested by the award of the first Loubat prize to Holmes in recognition of distinctly American work. The view afforded by the recognition of the collective character of mankind has guided inquiry concerning the individual, and now bodily structures are studied as products of mind led activity, while the brain is studied as a mechanism more complex, but otherwise no more mysterious, than the structures of plants and animals, or devices which men have made. So in the science of man as in the other sciences the magician's wand has been cast aside, and the veil of mystery has fallen away forever, and the early shadow is gone from the field of definite knowledge.

Such have been a few of the advances in science in a half century; the discovery of the persistence of motion, the invention of spectroscopy, the control of electricity, the discovery of the periodic law, the recognition of evolution, and the culture classification of mankind may be considered the first half dozen. If summed in a single term, the half century's advance in science may be expressed as recognition of the uniformity and potentiality of nature; while the applications are invention on the practical side, and kinetic interpretation (or interpretation in terms of motion and sequence) on the philosophic side. Most of the advances began in Europe, to be hastened in America, and a full half of the progress must be credited to cisatlantic genius and enterprise.

In truth, America has become a nation of science. There is no industry, from agriculture to architecture, that is not shaped by research and its results; there is not one of our fifteen millions of families that does not enjoy the benefits of scientific advancement; there is no law in our statutes, no motive in our conduct, that has not been made juster by the straightforward and unselfish habit of thought fostered by scientific methods. A nation of free minds will not be selfish or cruel; and the sense of uniformity in nature finds expression in national character—in commercial honesty, in personal probity, in unparalleled patriotism, as well as in the unequaled workmanship which is the simplest expression of straight thinking. Every step in our national progress has been guided by the steadfast knowledge born of assimilated experience. The trebling of population in a half century, raising the republic from an experiment in state making to a leading place among the nations, is the wonder of history; the thrice trebled wealth and educational facilities gained through application of new knowledge are a marvel, before which most men stand dazzled at home, and wholly blinded abroad; the three times thrice trebled knowledge itself, lifting the nation high in enlightenment and making way for still more rapid progress, is a modern miracle wrought by scientific work; but greatest of all in present potency and future promise is the elevation of moral character attained by that sense of right thinking which flows only from consciously assimilated experience—and this is the essence of science now diffused among our people.

THE DEBT OF THE WORLD TO PURE SCIENCE.

BY JOHN J. STEVENSON.

[John J. Stevenson, geologist; born New York, October 10, 1841; educated in private schools, and graduated from New York university in 1863; United States geologist, 1873–74 and 1878–80; geologist Pennsylvania geological survey, 1875–78 and 1881–82; New York Academy of Sciences, 1896–98; president Geological Society of America, 1898; professor of geology, New York university, since 1871. Author of many reports on geological investigations, especially in Pennsylvania and Colorado.]

The fundamental importance of abstruse research receives too little consideration in our time. The practical side of life is all absorbent; the results of research are utilized promptly, and full recognition is awarded to the one who utilizes while the investigator is ignored. The student himself is liable to be regarded as a relic of mediæval times, and his unconcern respecting ordinary matters is serviceable to the dramatist and newspaper witlet in their times of need.

Yet every thoughtful man, far away as his calling may be from scientific investigation, hesitates to accept such judgment as accurate. Not a few, engrossed in the strife of the market place, are convinced that, even from the selfish standpoint of mere enjoyment, less gain is found in amassing fortunes or in acquiring power over one's fellows than in the effort to solve nature's problems. Men scoff at philosophical dreamers, but the scoffing is not according to knowledge. The exigencies of subjective philosophy brought about the objective philosophy. Error has led to the right. Alchemy prepared the way for chemistry; astrology for astronomy; cosmogony for geology. The birth of inductive science was due to the necessities of deductive science, and the greatest development of the former has come from the trial of hypotheses belonging in the borderland between science and philosophy.

My effort in this paper is to show that discoveries, which have proved all important in secondary results, did not burst forth full grown; that in each case they were, so to say, the crown of a structure reared painfully and noiselessly by men indifferent to this world's affairs, caring little for fame and even less for wealth. Facts were gathered, principles were discovered, each falling into its own place until at last the brilliant crown shone out and the world thought it saw a miracle.

This done, I shall endeavor to draw a moral, which it is hoped will be found worthy of consideration.

The heavenly bodies were objects of adoration from the earliest antiquity; they were guides to caravans on the desert as well as to mariners far from land; they marked the beginning of seasons, or, as in Egypt, the limits of vast periods embracing many hundreds of years. Maps were made thousands of years ago showing their positions; the path of the sun was determined rudely; the influence of the sun and moon upon the earth was recognized in some degree, and their influence upon man was inferred. Beyond these matters, man, with unaided vision and with knowledge of only elementary methematics, could not go.

Mathematical investigations by Arabian students prepared the means by which, after Europe's revival of learning, one, without wealth, gave a new life to astronomy. Copernicus, early trained in mathematics, during the last thirty years of his life spent the hours, stolen from his work as a clerk and charity physician, in mathematical and astronomical studies, which led him to reject the complex Ptolemaic system and to accept in modified form that bearing the name of Pythagoras. Tycho Brahe followed. A mere star gazer at first, he became an earnest student, improved the instruments employed, and finally secured recognition from his sovereign. For twenty five years he sought facts, disregarding none, but seldom recognizing economic importance in any. His associate, Kepler, profiting by his training under Brahe, carried the work far beyond that of his predecessors—and this in spite of disease, domestic sorrows, and only too frequent experience of abject poverty. He divested the Copernican hypothesis of many crudities, and discovered the laws which have been utilized by astronomers in all phases of their work. He ascertained the causes of the tides, with the aid of the newly invented telescope made studies of eclipses and occultations, and just missed discovering the law of gravitation. He laid the foundation for practical application of astronomy to everyday life.

In the eighteenth century astronomy was recognized by governments as no longer of merely curious interest, and its students received abundant aid. The improvement of the telescope, the discovery of the law of gravitation, and the invention of logarithms had made possible the notable advances marking the close of the seventeenth century. The increasing requirements of accuracy led to exactness in the manufacture of instruments, to calculation and recalculation of tables, to long expeditions for testing methods as well as conclusions, until finally the suggestion of Copernicus, the physician, and of Kepler, the ill fed invalid, became fact, and astronomical results were utilized to the advantage of mankind. The voyager on the ocean and the agriculturist on land alike reap benefit from the accumulated observations of three centuries, though they know nothing of the principles or of the laborers by whom the principles were discovered. The regulation of chronometers as well as the fixing of boundary lines between great nations is determined by methods due to slow accumulation of facts, slower development in analysis and calculation, and even slower improvement in instruments.

Galvani's observations that frogs' legs twitch when near a friction machine in operation led him to test the effect of atmospheric electricity upon them. The instant action brought about the discovery that it was due not to atmospheric influence, but to a current produced by contact of a copper hook with an iron rail. Volta pursued the investigation and constructed the pile which bears his name. With this, modified, Davy, in 1807, decomposed potash and soda, thereby isolating potassium and sodium. This experiment, repeated successfully by other chemists, was the precursor of many independent investigations, which directed to many lines of research, each increasing in interest as it was followed.

Volta's crown of cups expanded into the clumsy trough batteries which were displaced finally in 1836 by Daniel's constant battery, using two fluids, one of which was cupric sulphate. De la Rue observed that, as the sulphate was reduced, the copper was deposited on the surface of the outer vessel and copied accurately all markings on that surface. Within two or three years Jacobi and Spencer made the practical application of this observation by reproducing engravings and medals. Thus was born the science of electro metallurgy. At first mere curiosities were made, then electroplating in a wider way, the electrotype, the utilization of copper to protect more easily destructible metals, the preparation of articles for ornament and utility by covering baser metals with copper or silver or gold, while now the development of electro generators has led to wide applications in the reduction of metals and to the saving of materials which otherwise would go to waste.

Oersted, in 1819–20, puzzling over the possible relations of voltaic electricity to magnetism, noticed that a conductor carrying an electrical current becomes itself a magnet and deflects the needle. Sturgeon, working along the same lines, found that soft iron inclosed in a coil through which a current passes becomes magnetic, but loses the power when the current ceases. This opened the way for our own Henry's all important discovery of the reciprocating electromagnets and the vibrating armature—the essential parts of the magnetic telegraph. Henry actually constructed a telegraph in 1832, winding the wires around his class room in Albany and using a bell to record the making and breaking signals. Here, as he fully recognized, was everything but a simple device for receiving signals.

Several years later Professor Morse, dreaming night and day of the telegraph, was experimenting with Moll's electromagnet and finding only discouragement. His colleague, Professor Gale, advised him to discard the even then antiquated apparatus and to utilize the results given in Henry's discussion. At once the condition was changed, and soon the ingenious recording instrument bearing Morse's name was constructed. Henry's scientific discoveries were transmuted by the inventor's ingenuity into substantial glory for Morse and proved a source of inconceivable advantage to the whole civilized world. Steinhal's discovery that the earth can be utilized for the return current completed the series of fundamental discoveries, and since that time everything has been elaboration.

Oersted's discovery respecting the influence of an electric current, closely followed by that of Arago in the same direction, opened the way for Faraday's complete discovery of induction, which underlies the construction of the dynamo. This ascertained, the province of the inventor was well defined —to conjure some mechanical appliance whereby the principle might be utilized. But here as elsewhere the work of discovery and that of invention went on almost pari passu; the results of each increased those of the other. The distance from the Clark and Page machines of the middle thirties, with their cumbrous horseshoe magnets and disproportionate expenditure of power, to the Siemens machine of the fifties was long, but it was no leap. In like manner slow steps marked progress thence to the Gramme machine, in which one finds the outgrowth of many years of labor by many men, both investigators and inventors. In 1870, forty years after Faraday's announcement of the basal principle, the stage was reached whence progress could be rapid. Since that time the dynamo has been brought into such stage of efficiency that the electromotor seems likely to displace not merely the steam engine, but also other agencies in direct application of force. The horse is passing away and the trolley road runs along the country highway; the longer railways are considering the wisdom of changing their power; cities are lighted brilliantly where formerly the gloom invited highwaymen to ply their trade, and even the kitchen is invaded by new methods of heating.

Long ago it was known that if the refining of pig iron be stopped just before the tendency to solidify became pronounced the wrought iron is more durable than that obtained in the completed process. Thus, imperfectly refined metal was made frequently, though unintentionally and ignorantly. A short railroad in southwestern Pennsylvania was laid in the middle sixties with iron rails of light weight. A rail's life in those days rarely exceeded five years, yet some of those light rails were in excellent condition almost fifteen years afterwards, though they had carried a heavy coke traffic for several years. But this process was uncertain, and the best puddlers could never tell when to stop the process in order to obtain the desired grade.

When a modification of this refining process was attempted on a grand scale almost contemporaneously by Martien in this country and Bessemer in England, the same uncertainty of product was encountered; sometimes the process was checked too soon, at others pushed too far. Here the inventor came to a halt. He could use only what was known and endeavor to improve methods of application. Under such conditions the Bessemer process was apparently a hopeless failure. Another, however, utilized the hitherto ignored work of the closet investigator. The influence of manganese in counteracting the effects of certain injurious substances and its relation to carbon when present in pig iron were understood as matters of scientific interest. Mushet recognized the bearing of these facts and used them in changing the process. His method proved successful, but, with thorough scientific forgetfulness of the main chance, he neglected to pay some petty fees at the patent office and so reaped neither profit nor popular glory for his work.

The Mushet process having proved the possibility of immediate and certain conversion, the genius of the inventor found full scope. The change in form and size of the converter, the removable base, the use of trunnions, and other details, largely due to the American, Holley, so increased the output and reduced the cost that Bessemer steel soon displaced iron and the world passed from the age of iron into the age of steel.

Architectural methods have been revolutionized. Buildings ten stories high are commonplace; those of twenty no longer excite comment, and one of thirty arouses no more than a passing pleasantry respecting possibilities at the top. Such buildings were almost impossible a score of years ago, and the weight made the cost prohibitive. The increased use of steel in construction seems likely to preserve our forests from disappearance.

In other directions the gain through this process has been more important. The costly, short lived iron rail has disappeared and the durable steel rail has taken its place. Under the moderate conditions of twenty five years ago, iron rails rarely lasted for more than five years; in addition, the metal was soft, the limit of load was reached quickly, and freight rates, though high, were none too profitable.

But all changed with the advent of steel rails as made by the American process. Application of abstruse laws, discovered by men unknown to popular fame, enabled inventors to improve methods and to cheapen manufacture until the first cost of steel rails was less than that of iron. The durability of the new rails and their resistance to load justified increased expenditure in other directions to secure permanently good condition of the roadbed. Just here Mr. P. H. Dudley made his contribution, whose importance can hardly be overestimated. With his ingenious recording apparatus it is easy to discover defects in the roadway and to ascertain their nature, thus making it possible to devise means for their correction and for preventing their recurrence. The information obtained by use of this apparatus has led him to change the shape and weight of rails, to modify the type of joints and the methods of ballasting, so that now a roadbed should remain in good condition and even improve during years of hard use.

But the advantages have not inured wholly to the railroad companies. It is true that the cost of maintenance has been reduced greatly; that locomotives have been made heavier and more powerful; that freight cars carry three to four times as much as they did twenty five years ago, so that the whole cost of operation is very much less than formerly. But where the carrier has gained one dollar the consumer and shipper have gained hundreds of dollars. Grain and flour can be brought from Chicago to the seaboard as cheaply by rail as by water; the farmer in Dakota raises wheat for shipment to Europe. Coal mined in West Virginia can be sold on the docks of New York at a profit for less than half the freight of twenty five years ago. Our internal commercial relations have been changed, and the revolution is still incomplete. The influence of the Holley-Mushet-Bessemer process upon civilization is hardly inferior to that of the electric telegraph.

Sixty years ago an obscure German chemist obtained an oily liquid from coal tar oil, which gave a beautiful tint with calcium chloride; five years later another separated a similar liquid from a derivative of coal tar oil. Still later, Hofmann, then a student in Liebig's laboratory, investigated these substances and proved their identity with an oil obtained long before by Zinin from indigo, and applied to them all Zinin's term, aniline. The substance was curiously interesting, and Hofmann worked out its reactions, discovering that with many materials it gives brilliant colors. The practical application of these discoveries was not long delayed, for Perkins made it in 1856. The marvelous dyes, beginning with magenta and solferino, have become familiar to all. The aniline colors, especially the reds, greens, and blues, are among the most beautiful known. They have given rise to new industries and have expanded old ones. Their usefulness led to deeper studies of coal tar products, to which is due the discovery of such substances as antipyrin, phenacetin, ichthyol, and saccharin, which have proved so important in medicine.

One is tempted to dwell for a little upon meteorology, that border land where physics, chemistry, and geology meet, and to speak of the signal service system, the outgrowth of the studies of an obscure school teacher in Philadelphia, but the danger of trespassing too far upon your endurance makes proper only this passing reference.

While men of wealth and leisure wasted their energies in literary and philosophical discussions respecting the nature and origin of things, William Smith, earning a living as a land surveyor, plodded over England, anxious only to learn, in no haste to explain. His work was done honestly and slowly; when finished as far as possible with his means, it had been done so well that its publication checked theorizing and brought men back to study. .His geological map of England was the basis upon which the British survey began to prepare the detailed sheets showing Britain's mineral resources.

In our country Vanuxem and Morton early studied the New Jersey Cretaceous and Eocene, containing vast beds of marl. Scientific interest was aroused, and eventually a geological survey of the state was ordered by the legislature.

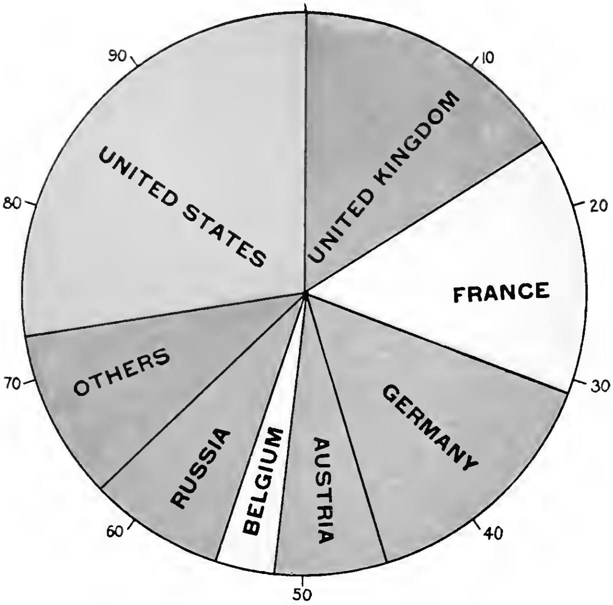
The appropriation was insignificant, and many of the legislators voted for it hoping that some economic discovery might be made to justify their course in squandering the people's money. Yet there were lingering doubts in their minds and some found more than lingering doubts in the minds of their constituents. But when the marls were proved to contain materials which the chemist Liebig had shown to be all important for plants, the conditions were changed and criticism ceased. The dismal sands of eastern New Jersey, affording only a scanty living for pines and grasses, were converted by application of the marl into gardens of unsurpassed fertility. Vanuxem's study of the stratigraphy and Morton's study of the fossils had made clear the distribution of the marls, and the survey scattered the information broadcast.

Morton and Conrad, with others scarcely less devoted, labored in season and out of season to systematize the study of fossil animals. There were not wanting educated men who wondered why students of such undoubted ability wasted themselves in trifling employment instead of doing something worthy of themselves so as to acquire money and fame. Much nearer to our own time there were wise legislators who questioned the wisdom of wasting money on pictures of clams and salamanders, though the same men appreciated the geologist who could tell them the depth of a coal bed below the surface. But the lead diggers of Illinois and Iowa long ago learned the use of paleontology, for the lead fossil was their guide in prospecting. The importance and practical application of this science, so largely the outgrowth of unappreciated toil in this country as well as in Europe, is told best in Professor Hall's reply to a patronizing politician's query: "And what are your old fossils good for?" "For this: Take me blindfolded in a balloon; drop me where you will; if I can find some fossils I'll tell you in ten minutes for what minerals you may look and for what minerals you need not look."

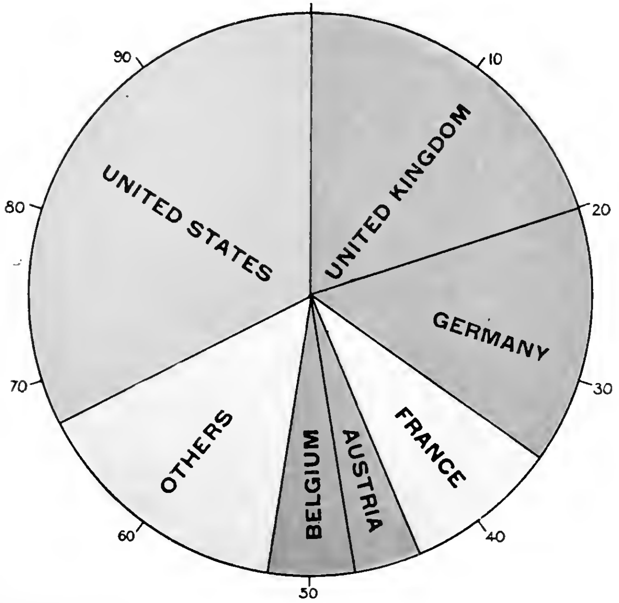
Many regard botany as a pleasing study, well fitted for women and dilletanti, but hardly deserving attention by strong men. Those who speak thus only exercise the prerogative of ignorance, which is to despise that which one is too old or too lazy to learn. The botanist's work is not complete

MANUFACTURES

TEXTILE VALUE



HARDWARE VALUE



when the carefully gathered specimen has been placed in the herbarium with its proper label. That is but the beginning, for he seeks the relations of plants in all phases. In seeking these he discovers facts which often prove to be of cardinal importance. The rust which destroys wheat in the last stage of ripening, the disgusting fungus which blasts Indian corn, the poisonous ergot in rye, the blight of the pear and other fruits, fall as much within the botanist's study as do the flowers of the garden or the sequoias of the Sierra. Not a few of the plant diseases which have threatened famine or disaster have been studied by botanists unknown to the world, whose explanations have led to palliation or cure.

The ichthyologist, studying the habits of fishes, discovered characteristics which promptly commended themselves to men of practical bent. The important industry of artificial fertilization and the transportation of fish eggs, which has enabled man to restock exhausted localities and to stock new ones, is but the outgrowth of closet studies which have shown how to utilize nature's superabundant supply.

The entomologist has always been an interesting phenomenon to a large part of our population. Insects of beauty are attractive, those of large size are curious, while many of the minuter forms are efficient in gaining attention. But that men should devote their lives to the study of the unattractive forms is to many a riddle. Yet entomology yields to no branch of science in the importance of its economic bearings. The study of the life habits of insects, their development, their food, their enemies, a study involving such minute detail as to shut men off from many of the pleasures of life and to convert them into typical students, has come to be so fraught with relations to the public weal that the state entomologist's mail has more anxious letters than that of any other officer.

Insects are no longer regarded as visitations from an angry deity, to be borne in silence and with penitential awe. The intimate study of individual groups has taught in many cases how to antagonize them. The scab threatened to destroy orange culture in California; the Colorado beetle seemed likely to ruin one of our important food crops; minute aphides terrified raisers of fruit and cane in the Sandwich islands.

But the scab is no longer a frightful burden in California; the potato bug is now only an annoyance, and the introduction of lady birds swept aphides from the Sandwich islands. The gypsy moth, believed for more than a hundred years to be a special judgment, is no longer thought of as more than a very expensive nuisance. The curculio, the locust, the weevil, the chinch bug, and others have been subjected to detailed investigation. In almost all cases methods have been devised whereby the ravages have been diminished. Even the borers, which endangered some of the most important timber species, are now understood, and the possibility of their extermination has been changed into probability.

Having begun with the infinitely great, we may close this summary with a reference to the infinitely small. The study of fermentation processes was attractive to chemists and naturalists, each claiming ownership of the agencies. Pasteur, with a patience almost incredible, revised the work of his predecessors and supplemented it with original investigations, proving that a very great part of the changes in organic substances exposed to the atmosphere are due primarily to the influence of low animals or plants, whose germs exist in the atmosphere.

One may doubt whether Pasteur had any conception of the possibilities hidden in his determination of the matters at issue. The canning of meats and vegetables is no longer attended with uncertainty, and scurvy is no longer the bane of explorers; pork, which has supplied material for the building of railroads, the digging of canals, the construction of ships, can be eaten without fear. Flavorless butter can be rendered delicious by the introduction of the proper bacteria; sterilized milk saves the lives of many children; some of the most destructive plagues are understood and the antidotes are prepared by the culture of antagonistic germs; antiseptic treatment has robbed surgery of half its terrors, and has rendered almost commonplace operations which, less than two decades ago, were regarded as justifiable only as a last resort. The practice of medicine has been advanced by outgrowths of Pasteur's work almost as much as it was by Liebig's chemical investigations more than half a century ago.

In this review the familiar has been chosen for illustration in preference to the wonderful, that attention might not be diverted from the main issue, that the foundation of industrial advance was laid by workers in pure science, for the most part ignorant of utility and caring little about it. There is here no disparagement of the inventor; without his perception of the practical and his powers of combination the world would have reaped little benefit from the student's researches. But the investigator takes the first step and makes the inventor possible. Thereafter the inventor's work aids the investigator in making new discoveries, to be utilized in their turn.

Investigation, as such, rarely receives proper recognition. It is usually regarded as quite a secondary affair, in which scientific men find their recreation. If a geologist spends his summer vacation in an effort to solve some perplexing structural problem he finds, on his return, congratulations because of his glorious outing; the astronomer, the physicist, and the chemist are all objects of semienvious regard, because they are able to spend their leisure hours in congenial amusements; while the naturalist, enduring all kinds of privation, is not looked upon as a laborer, because of the physical enjoyment which most good people think his work must bring.

It is true that investigation, properly so called, is made secondary, but this is because of necessity. Scientific men in government service are hampered constantly by the demand for immediately useful results. Detailed investigation is interrupted because matters apparently more important must be considered. The conditions are even more unfavorable in most of our colleges and none too favorable in our greater universities. The literary leisure supposed to belong to college professors does not fall to the lot of teachers of science, and very little of it can be discovered by college instructors in any department. The intense competition among our institutions requires that professors be magnetic teachers, thorough scholars, active in social work, and given to frequent publication, that, being prominent, they may be living advertisements of the institution. How much time, opportunity, or energy remains for patient investigation some may be able to imagine.

The misconception respecting the relative importance of investigation is increased by the failure of even well educated men to appreciate the changed conditions in science. The ordinary notion of scientific ability is expressed in the popular saying that a competent surgeon can saw a bone with a butcher knife and carve a muscle with a handsaw. Once, indeed, the physicist needed little aside from a spirit lamp, test tubes, and some platinum wire or foil; low power microscopes, small reflecting telescopes, rude balances, and homemade apparatus certainly did wonderful service in their day; there was a time when the finder of a mineral or fossil felt justified in regarding it as new and in describing it as such; when a psychologist needed only his own great self as a basis for broad conclusions respecting all mankind. All of that belonged to the infancy of science, when little was known and any observation was liable to be a discovery; when a Humboldt, an Arago, or an Agassiz was possible. But all is changed; workers are multiplied in every land; study in every direction is specialized; men have ceased the mere gathering of facts and have turned to the determination of relations. Long years of preparation are needed to fit one to begin investigation; familiarity with several languages is demanded; great libraries are necessary for constant reference, and costly apparatus is essential even for preliminary examination. Where tens of dollars once supplied the equipment in any branch of science, hundreds, yes, thousands, of dollars are required now.

Failure to appreciate the changed conditions induces neglect to render proper assistance. As matters now stand, even the wealthiest of our educational institutions can not be expected to carry the whole burden, for endowments are insufficient to meet the too rapidly increasing demand for wider range of instruction. It is unjust to expect that men, weighted more and more by the duties of science teaching, involving, too often, much physical labor from which teachers of other subjects are happily free, should conduct investigations at their own expense and in hours devoted by others to relaxation. Even were the pecuniary cost comparatively small, to impose that would be unjust, for, with few exceptions, the results are given to the world without compensation. Scientific men are accustomed to regard patents much as regular physicians regard advertising.

America owes much to closet students as well as to educated inventors who have been trained in scientific modes of thought. The extraordinary development of our material resources—our manufacturing, mining, and transporting interests—shows that the strengthening of our educational institutions on the scientific side brings actual profit to the community. But most of this strengthening is due primarily to unremunerated toil of men dependent on the meager salary of college instructors or government officials in subordinate positions. Their aptitude to fit others for usefulness, coming only from long training, was acquired in hours stolen from sleep or from time needed for recuperation. But the labors of such men have been so fruitful in results that we can no longer depend on the surplus energy of scientific men, unless we consent to remain stationary. If the rising generation is to make the most of our country's opportunities it must be educated by men who are not compelled to acquire aptness at the cost of vitality. The proper relation of teaching-labor to investigation-labor should be recognized, and investigation, rather than social, religious or political activity, should be a part of the duty assigned to college instructors.

Our universities and scientific societies ought to have endowments specifically for aid in research. The fruits of investigations due to Smithson's bequest have multiplied his estate hundreds of times over to the world's advantage. He said well that his name would be remembered long after the names and memory of the Percy and Northumberland families had passed away. Hodgkins' bequest to the Smithsonian institution is still too recent to have borne much fruit, but men already wonder at the fruitfulness of a field supposed to be well explored. Nobel knew how to apply the results of science; utilizing the chemists' results, he applied nitroglycerin to industrial uses; similarly he developed the petroleum industry of Russia and, like that of our American petroleum manufacturers, his influence was felt in many other industries of his own land and of the continent. At his death he bequeathed millions of dollars to the Swedish Academy of Sciences that the income might be expended in encouraging pure research. Smithson, Hodgkins, and Nobel have marked out a path which should be crowded with Americans.

The endowment of research is demanded now as never before. The development of technical education, the intellectual training of men to fit them for positions formerly held by mere tyros, has changed the material conditions in America. The surveyor has disappeared—none but a civil engineer is trusted to lay out even town lots; the founder at an iron furnace is no longer merely a graduate of the casting house—he must be a graduate in metallurgy; the manufacturer of paints cannot entrust his factory to any but a chemist of recognized standing; no graduate of the pick is placed in charge of mines—a mining engineer alone can gain confidence; and so everywhere. With the will to utilize the results of science there has come an intensity of competition in which victory belongs only to the best equipped. The profit awaiting successful inventors is greater than ever, and the anxious readiness to apply scientific discoveries is shown by the daily records. The Röntgen rays were seized at once and efforts made to find profitable application; the properties of zirconia and other earths interested inventors as soon as they were announced; the possibility of telegraphing without wires incited inventors everywhere as soon as the principle was discovered.

Nature's secrets are still unknown and the field for investigation is as broad as ever. We are only on the threshold of discovery, and the coming century will disclose wonders far beyond any yet disclosed. The atmosphere, studied by hundreds of chemists and physicists for a full century, proved for Rayleigh and Ramsay an unexplored field within this decade. We know nothing yet. We have gathered a few large pebbles from the shore, but the mass of sands is yet to be explored.

And now the moral has been drawn. The pointing is simple. If America, which, more than other nations, has profited by science, is to retain her place, Americans must encourage, even urge, research; must strengthen her scientific societies and her universities, that under the new and more complicated conditions her scientific men and her inventors may place and keep her in the front rank of nations.

SCIENTIFIC WORK OF THE GOVERNMENT.

BY MICHAEL A. LANE.

[Michael A Lane was born at St. Louis in 1867; educated in the classics at the University of St. Louis; studied theoretical biology privately; studied practical anatomy and physiology at the University of Illinois, and, later, practical histology and neurology at the University of Chicago; worked for eight years to identify the facts of social evolution in man and lower animals with the law of natural selection; published his theory in a work entitled "The Level of Social Motion" in 1902; contributor to American magazines, 1893 to 1905.]

Patronage of science and philosophy has always been one of the distinguishing characteristics of an enlightened state. This was no less true of the great university at Alexandria than of the earlier scientific foundations in Europe, when the princes of Germany, Sweden, France, Italy, Spain, and England gave their substantial help to the patient researchers who devoted their lives to the discovery of the true interpretation of nature.

For its most vigorous growth science must be removed from all thought of sordidness, selfishness and profit.

"The man of science," said a distinguished German visitor to the United States recently, "must have a light heart. He must be free from the cares of mere money making, and his small personal wants must be supplied by others whose spirits are large enough to look forward to the future good of the human kind. In return he gives to the human kind, free, the results of his labors."

In America the great patrons of science have been the kings of commerce rather than the sovereign whom, here, we name the state, or the people. Until recently the American government has not been forward in works of this kind, but it is now fairly on the way toward making the United States the center of scientific research of almost every kind. The government has found that science has wonderfully practicable possibilities, and at the present time the government spends nearly $15,000,000 yearly for scientific work of various kinds. This is a larger sum than is spent by any other government in the world, and the prospects are that it will be increased year by year until the scientific budget will take its place in magnitude besides appropriations for the navy, army, and other departments, and ultimately become the chief item of expense which the government has.

There is one thing significant, however, about the scientific work of the United States government. It is nearly all of a practical, useful character. If you can show the average American that a scientific enterprise of any kind has some useful, practical bearing, he is with it heart and soul. But he cares very little for pure science—that is, science pursued for its own sake, without the slightest regard to use or profit. And yet it is this pure, unpractical, and absolute science that makes practical science possible. When members of congress come to understand this remarkable fact, and come to understand also the fact that the man of science cares very little for the profits that may be in his discoveries, congress will suppress all its watchdogs of the treasury—well named as they are. For your watchdog, especially if it be of the bull variety, is quite as apt to bite the man who is bringing gifts to its owner as it is apt to guard its owner's premises from thieves.

We have made a good start, however, with our $15,000,000, and the watchdogs who barked loudly at every new proposal for increasing the government's scientific expenditures are now happily either dead, or old and toothless.

And here, we may remark, that the soul of all the scientific work of the government is an institution which has pure science for its object—an institution which, sad to relate, was not founded by the government—although the government has charge of it—but by the benefaction of a private individual; I mean the Smithsonian institution. The Smithsonian institution should be taken over by the government and given an enormous income for the pursuit of pure science—an income large enough to attract the Kochs, the Pasteurs, the Ehrlichs, the Kelvins and the other great men of Europe to these shores. In which case Washington could be made the world's center of pure science as it is now the world's center of applied science.

To the work in pure science done by the Smithsonian institution we owe the existence of the United States geological survey, of the weather bureau, of the bureau of fisheries, and of the bureau of ethnology.

Professor Samuel Pierpont Langley was one day inspired with the idea that he could invent a flying machine. And now congress gives him a substantial sum every year to experiment with his idea. Mr. Langley may never succeed. But congress takes no account of that possibility. On the other hand, if it should turn out that he can make good, nobody will object to the expenditure of this insignificant sum for such a big desideratum.

Mr. Langley is the godfather of "the new astronomy" and some of his discoveries are highly important, although it would be hard to imagine their practical uses. For instance, as one of the research men of the Smithsonian, Mr. Langley is looking into the ultra-red of the solar spectrum—the unseen part of the rainbow at the red end—from which most of the sun's energy proceeds. He has invented a method by which he can trace the spectrum a distance of forty feet beyond the red—a performance the importance of which can be better understood if we assign to the visible spectrum a length say of 40 inches.

Another step in the right direction is the appropriation of $40,000 a year which congress makes for the ethnological work of the institution. Not much practical use can be made of a thorough knowledge of the folk lore, the institutions, and the somatic and sociological characters of the American Indians, and yet congress pays the bill for this work. The result of this generosity is the high reputation which America has abroad for the genuine ethnological work it has done. Dr. Deniker, the great French anthropologist, mentions this work in his latest published text book in which he accepts the theories of the American ethnographers concerning the existence of the mounds.

The casual visitor to St. Louis seldom expresses a desire to be shown the wonderful structures which have given St. Louis its name of Mound City. And yet, perhaps, there is nothing in St. Louis, in the way of sights as interesting as these mounds. The mound builders were supposed to be a strange, mysterious, extinct race who had their own civilization; and it was once believed that the American Indians destroyed them and most of their works.

American ethnologists, however, have satisfactorily solved the problem by showing that the mound builders were none other than our own American tribes who built the mounds for religious and funerary purposes, but whose peaceful ways of life were disturbed by the advent of the white marauders who came from Europe after the discovery of America. Another cause of the disruption of this Indian custom was, it is held, the arrival of the buffalo in large numbers, which moved the mound builders to take to a hunting life, and thus caused them to become out and out nomads.

So much for the unpractical part of the government's patronage of science. When we come to the practical, however, there is no lack of government support. The government spends every year upwards of $75,000 on astronomy, the center of activity being the national observatory, which serves the useful end of keeping the national time. It is a comfort to know that you can set your watch by the sun—or, rather, let us say, by the stars, for time is corrected by the stars. Every day at noon the national observatory sends out its time over the wires of the Western Union company which are, at that moment, cleared of all messages to all parts of the country. This correct time goes to all seaports, all cities, and all other places that can find a use for it.

Perhaps the most fetchingly practical work of government science, however, is that done by the various bureaus of the department of agriculture, which uses up more than one half of the total expenditures for scientific purposes made by the government. At the present rate of progress in this direction, the agriculture of the United States will, within less than twenty five years, become as nearly an ideal system as present individualistic methods of industry will permit. Should the government itself go into the farming business—as some bold theorists suggest—it would only be following up the logical trend of what it is now actually doing—for there is nothing that the American farmer wants in the way of new and improved methods of work that the government is not giving him now for no fee.

An entire library would be the result were one to undertake a full account of the way in which the department spends the $6,000,000 or so that is appropriated annually for the work. In the chemistry bureau alone the activities of the government experts cover a vast range of experiment and investigation. All sorts of experiments with bacteria are going on there, looking to the production of new ferments. Among these may be mentioned the manufacture of twenty five yeasts which have been grown by cultures in apple juice with a view to making new ciders. In this way the experts can take a barrel of apple juice and, dividing it up into twenty or twenty five different parts, produce as many ciders, all with new and different flavors and all from the same juice.

The department, against much strenuous objection from reformers and opponents of intemperance, is experimenting with certain drugs, including opium; so that the poppy industry can soon be introduced into this country. It is also working on the pineapple in the hope that the fiber of this plant can be used in the manufacture of fine cloth, much as it is in the Philippine islands at present.

Our relations with the West Indies and the Philippine islands have caused a new interest to spring up in the cultivation of spices, flowers, fruits, and other products of tropical countries, particularly tobacco, with which the department is experimenting for the purpose of producing a fine quality of this drug from home grown plants. One item alone is worth consideration, as an index of what may be done in the future. In the early seventies the department of agriculture lent its assistance in the introduction to this country of the navel orange which was found growing in Brazil. In thirty five years the cultivation of the navel orange has added something like $60,000,000 to the wealth of the state of California.

The orange industry suggests the work of the department in the business of protecting crops from destructive insects. Not long ago the orange growers of California were appalled by the prospect of utter ruin from an insect parasite. In their despair they appealed to the department, which remedied the evil by calling in the aid of a little beetle from Australia which eliminated the destructive parasite in one season. The department has done other work, equally valuable, in this line.

Another practical work carried on by the department is that done by the bureau of animal industry. This bureau looks out for the public safety by inspecting the meat products of the country, but it also does excellent service in the stamping out of diseases which afflict cattle and especially in the improvement of breeds of cattle, sheep, and horses.

The weather bureau, which was included in the signal service of the United States army, is now a division, and one of the most important divisions, of the department of agriculture. It spends more than a million and a quarter of national money, but it saves twenty times that sum to the merchants and the shipping of the country.

Of practical and scientific use is the United States geological survey, which has done so much to classify the mineral regions and resources of the country, and to study the water distribution of the continent. As a side line to this work much original research has been done in geology, which has largely added to the reputation of American geologists. The geological survey has concerned itself, with excellent results, about the important question of irrigation which, upon suggestions from the bureau, contemplates the transportation of the arid regions of the west into vast productive gardens of agriculture and viticulture.

For this work will be required a vast sum of money which is ready and waiting in the treasury. It is the proceeds, amounting to some $20,000,000, of the sale of public lands.

The experts of the survey have made valuable discoveries, now and then, in the way of the precious metals; notably, the finding of a great deposit of gold bearing rock in Alaska. This deposit is more than 500 miles long, stretching clear into British territory, across the Yukon, and ranging through easily accessible mountains.

Another important discovery was that made by one of the precious stone experts of the survey who found a new kind of gem, resembling the diamond and the emerald, in considerable quantities near San Diego, Cal. Still another discovery, which may eventuate in the establishment of an entirely new American industry, is that of a mineral rubber, found in a crude state in Utah by one of the survey's men. The material is thought to be of vegetable origin and the quantity is large enough to last indefinitely. When worked up and made fit for use it can replace rubber in most of its rougher functions.

Continental Europe, and the whole world of science, is waiting for the United States to get into line with a national system of weights and measures. At the present time we have in Washington a bureau of standards which costs the country nearly $200,000 a year. Uniformity is thus maintained, but the people are still chained to the old system of pounds, ounces, quarts and pints, when the metric system, were it adopted, would simplify everything. The metric system is legal in the United States, but it is tolerated rather than sought for by the people.

If the United States were to abolish the old standards and enforce the French system there would be no such thing as cheating or lack of uniformity in weights and measures, and the last vestige of the crude, antiquated, and barbarous system now in use would vanish from the earth.

It may be said, in view of the various possibilities suggested in the foregoing paragraphs, that the United States has made a fair start as a nation of science. Already in the lead of the world, so far as practical, or applied, science is concerned, the American government, it is to be hoped, will soon widen its sphere as a patron, and begin the encouragement on a large scale, of science for the pure sake of science. Forge ahead! should be the bugle note of America in science as well as in industry. Doing which, American inventiveness will take care of the practice.

GEOLOGY IN THE UNITED STATES.

BY ROZELLE PURNELL HANDY.

[Rozelle Purnell Handy, author; born Richmond, Va.; educated at Frederick (Md.) female seminary; special writer for Chicago newspapers, 1892–1902; removed to Berlin, Md., where she has become a practical scientific farmer and contributor to agricultural periodicals; also contributor to magazines; author, Girls of the Bible, Tales from Longfellow, A Girl's Year on a Farm.]

The science of modern geology dates from the publication, in 1830, of Sir Charles Lyell's Principles of Geology. Previously to that time geology had its distinguished investigators in America, and since then the United States has taken its place at the head of the world's nations as the country productive of the most important discoveries in that department of science. The earliest records of geological research in this country were made when the American Philosophical society of Philadelphia had begun the publication of geological papers very early in the century, and on January 10, 1809, William Maclure read at one of its meetings his memorable essay entitled, Observations on the Geology of the United States, Explanatory of a Geological Map. The author had undertaken a gigantic task—one infinitely greater than was occupying William Smith in England. Alone and at his own expense he made a geological survey of the entire United States, a work which earned for him the name he has received of the "father of American geology." The work was one of many years' duration. He crossed the Allegheny mountains fifty times, and visited almost every state and territory in the union. He traced the great groups of strata then designated as the transition, secondary and alluvial, from the gulf of Mexico to the St. Lawrence. After an exhaustive exploration of our own country he went to Europe in order to recognize the corresponding formations of the other continent, and in 1816 and 1817 he studied the formations of the Antilles.

About this time the importance of geological surveys, with the view of ascertaining the agricultural and mineral resources of large and unexplored regions, was beginning to be appreciated by the United States government. The first geological survey made by state authority was that of North Carolina in 1824 and 1825, and the example was soon followed by more or less thorough surveys of the New England and middle states, and later of the great Mississippi valley and the Rockies. In 1841, shortly after the appearance of another great work, entitled Elements of Geology, Lyell visited America, where he was received with great acclaim. Thirteen months were spent in the United States, Canada and Nova Scotia, during which time he worked hard as an observer and recorder. The science had meanwhile grown to gigantic proportions since he had issued the final installment of his Principles, in 1833. The subordinate branches of geology were being studied with enthusiasm, and the importance of paleontology for chronological purposes had become recognized. It was now possible for the geologist to trace the changes which the earth's crust had undergone, and to describe in minute detail the character of the plant and animal life peculiar to each of the great epochs into which time had been divided.

The solving of the mystery of the coal formation was attended by the most marvelous revelations. The fossiliferous strata of the subcarboniferous age bore mute testimony that the greater part of North America, Europe, and Great Britain had been submerged to a considerable depth under the sea, immediately preceding the coal bearing period. Then there were gentle oscillations, and in time the continents had uplifted themselves to the water's surface, and in this condition they had remained for a very great period of time. The interior of the North American continent from eastern Pennsylvania to central Kansas was one vast jungle of luxuriant vegetation. The Green mountains separated the New England and the Nova Scotia areas from the marshes of Pennsylvania, and the Michigan coal area was an isolated marsh region. The plants and trees that flourished in these great marshes during the progress of the carboniferous age were of a luxuriance that has never been approached in any later period. The fossil remains found in coal beds indicate that palms, phenogams, or flowering trees, and conifers, or plants of the pine tribe, attained a colossal size. It is impossible for the imagination to conceive of the gorgeousness that then clothed mother earth. There must have been great numbers of immense floating islands, carrying groves, in the inland seas that the marsh regions enclosed, and the warm humid atmosphere was no doubt heavy with the perfumes of myriad flowers of gigantic proportions.

When the plants and trees died their remains fell to the ground of the forest, and soon became decomposed into a black pasty mass, to which was added year by year the continual accumulation of fresh carbonaceous matter. Thus this process of decay and disintegration went on among the shed leaves and trees until a bed of uniform thickness would be formed over a wide area. The eras of verdure during which these plant beds were in progress were alternated by periods of inundation by salt water from the oceans, that destroyed all terrestrial life. The accumulations of thousands and thousands of years of vegetable growth and decay became covered up with deposits of sediment. Then the continental surface, or wide portions of it, would again slowly emerge and a new era of verdure appear. Thus the alternations continued until all the successive coal beds were formed. The ever increasing pressure of the accumulated strata above them compressed the sheddings of a whole forest into a thickness in some cases of a few inches of coal, and the action of the internal heat of the earth caused them to part, to a varying degree, with some of their component gases. The coniferous trees, such as the living larches, pines, firs, etc., gave rise for the most part to the mineral oils, their sheddings having been subjected to a slow and continuous distillation, the oil so distilled accumulating in troughs in the strata, or finding its way to the surface in the shape of mineral oil springs. The nature and property of the coal to be formed depended upon the original substances of the living plant. One of the most remarkable things in connection with coal is the state of purity in which it is found. Owing to the fact that the forests must have abounded with streams and rivers, it is surprising that so little sediment found its way into the coal beds. This puzzled the geologists until Sir Charles Lyell explained it. He noticed on one of his visits to America that the Mississippi river is highly charged with sediment where it flows through the cypress swamps, but that when it passes through the close undergrowth the sediment becomes precipitated, and the water filters through in an almost pure state. This accounts for the presence of thin partings of sandstone and shale which frequently occur in coal deposits.

The seas of the carboniferous age abounded in animal life, as is evidenced by the organic remains found in the alternating strata. Fishes and sharks of mammoth size inhabited the warm waters of the deep oceans and crinoids and corals, an infinite variety of articulates, crustaceans, and trilobites infested the more shallow salt water areas. The forest jungles teemed with insect life—spiders, scorpions, centipides, mayflies, cockroaches, and crickets. There were also numerous varieties of land snails. In this age reptiles make their appearance for the first time. Their footprints as impressed on the carbonaceous beds of Pennsylvania indicate that they were large animals and that they had tails, tail marks being discernible on the mud flats over which the reptiles marched. In the Nova Scotia coal measures fossils have been found of the sea saurian, a species of reptile that had paddles like a whale. Before the last period of the carboniferous age had passed away, there were still higher reptiles—those that lived on the land, but so far there is no indication that birds or mammals existed as early as this period. To account for the stupendous movements which must have happened in order to bring about the successive growths of forests one above the other, the geologist attributes them to the action of heat and to volcanic activity, as is evidenced by the frequent occurrence of what is known as faults.

A glance at any modern geological map evidences the bountiful manner in which nature has laid out beds of coal upon the ancient surfaces of our earth, America alone containing no less than 196,660 square miles of coal bearing territory.

More important even than the determination of the coal making processes, was the promulgation of the glacial theory. In 1835 De Charpentier, a Swiss geologist, advanced the idea that the erratics and bowlder clays of his country had been deposited by glaciers at some remote period. This led all the geologists of Europe and America to investigate a question that had been puzzling scientists for a long time. In America and Europe, over the northern latitudes, stones, gravel, and sand, as well as masses of rocks hundreds of tons in weight, are found as far as a hundred miles and more south of the region where they were originally formed. That transported material was called drift, and the stones and bowlders were formerly claimed as proofs of the tumultuous action of an universal deluge. In 1840 Agassiz, of Neuchâtel, in company with J. D. Forbes, noted as an expert in the physics of glacier ice, and W. Buckland, began a systematic study of the alpine glaciers. Their gigantic task led to startling results. It seemed an impossibility for science to accept as a fact that nearly all of Europe and North America had been enveloped in a great ice sheet many miles in thickness, and in a comparatively recent period. That ages of tropical splendor should have been succeeded by such frightful desolation was beyond all conception, but as the investigation proceeded the fact was proved beyond the shadow of a doubt. A study of the topography of North America revealed the fact that an immense glacial deposit had embraced the whole continent from Labrador and Newfoundland to the western borders of Iowa, and even farther west, and that it extended southward to the parallel of 40 degrees. In Europe it extended down to 50 degrees, where the temperature corresponds to that of the parallel of 40 degrees in North America. The stupendous ice fields did not remain stationary, but in time began to transport themselves either in a southward, southeastward or southwestward direction. The highest mountains were no obstacle to their progress, and they moved over the great summits of the White mountains and the Green mountains as if they had been so many mole hills, and left as souvenirs of their visit bowlders picked up 200 miles north. The direction of transportation was determined by tracing the rocks and bowlders to those parts of the continent where they were derived. Masses of native copper have been found in Indiana and Illinois that were transported from the Lake Superior region. From the Connecticut valley bowlders of red sandstone were carried to Long island, and giant masses of rock have been found in the Mississippi valley 1,000 miles away from their native stratum. As reasoned by Agassiz, moving ice is the only known agent adequate for transportation on so vast a scale. The reason given for the uniformity of the direction of moving is the immutable law that a glacier moves in the direction of the slope of its upper surface. The snows being more abundant to the north during the glacial area, and the temperature being lower than at the south, the accumulation naturally became greater in the north; as a result, the movement would be southward. South America had its corresponding glacial era, transportation taking place in the direction of the equator. The cold of the era is attributed to the elevation and extension of Arctic lands and a corresponding increase in Arctic land ice.

In 1862 Prof. A. Ramsay aroused a great controversy among geologists regarding this glacial theory. He claimed a new and novel effect for glaciers, and set forth his opinion in a paper read before the London Geological society. The basins of the Alpine and various British lakes he attributed to the erosive action of ice, while his opponents held that the effect of ice is abrasive, not erosive. Although Ramsay's theory won many supporters among his contemporaries, it is generally rejected by the best geologists to-day.

The logical confirmation of the glacial theory added one more period to the history of the earth, which modern geology has now divided into four grand epochs—archæan time, paleozoic time, mesozoic time, and cenozoic time. These epochs are divided into periods, with reference to the character of the fossil evidence of former organic life contained in their respective strata. Paleozoic time, which was probably three times longer than all later time, contains three ages: the silurian, or age of invertebrates; the devonian, or age of fishes, and the carboniferous. Mesozoic time consists of but one age, the age of reptiles. Cenozoic time is divided into two ages, the tertiary, or age of mammals, and quaternary, or age of man. This classification represents more than fifty years' indefatigable labor on the part of the paleontologists of Europe and America. The impetus which the publication of Lyell's Principles gave to the study of fossils has never abated, and every available region in England, France, Germany, and the United States has been thoroughly explored. An enumeration of those who have contributed to this gigantic undertaking would be but a mere catalogue of names.

In America the progress of discovery and research has been unparalleled, until it has become par excellence an American subject. In 1859 Joseph Leidy discovered the bones of a prehistoric quadruped in the basin of an ancient Rocky mountain lake. A vigorous exploration of all the older lake basins of Wyoming, Utah, New Mexico, and Dakota revealed the fact that the western part of North America had once been the home of mammoths, rhinoceroses, tapirs, horses, and other quadruped animals. The two men who have probably done more than any others to develop American paleontology are Professor Marsh, of Yale college, and the late Professor E. D. Cope, of Philadelphia, vertebrate paleontologist of the United States geological survey, both men of immense fortune. From 1876 to 1885, Professor Cope had from three to five expeditions always in the field, the expenses of which he bore himself. When the fossil beds of Kansas, Colorado, Dakota, and Wyoming, the greatest known, were discovered, Professor Cope and Professor Marsh assumed the mighty task of excavating, shipping, and classifying these remains of the reptilian and mammalian ages. Thirty seven species of serpents were found in Kansas alone, varying from ten to eighty feet in length, and representing six orders. Some of them were terrestrial in habit, many were flyers, and the others inhabited the salt ocean. The extent of the sea westward was vast and geology has not laid down its boundary, but it has been conjectured to be a shore now submerged beneath the waters of the North Pacific ocean. Out on the expanse of this ancient sea huge, snake like forms rose above the surface, and stood erect, with tapering neck and narrow shaped head, or swayed about describing a circle of twenty feet radius above the water. This extraordinary neck was attached to a body of elephantine proportions, the limbs were two pair of paddles, and a long serpent like tail balanced the body behind. The total length of the elasmosaurus platyurus, Cope, for such it has been named, was fifty feet. In many places as many as eleven of these leviathan monsters would be discovered curled up together among the rocks. It was indeed an age of reptiles. Flying saurians filled the air, and flesh eating lizards, from twenty four to thirty five feet long, crawled over the earth, bearing burdensome tons of flesh on two birdlike feet. A flying saurian of the mesozoic period, discovered by Marsh, spread eighteen feet between the tips of its wings, while the pterodactyl umbrosus, Cope, covered nearly twenty five feet with its expanse.

The most important discovery made by Cope was the skeleton of the phenacodus primævus, considered the ancestor of all hoofed animals. In life it was four and a half feet long, not quite as large as a yearling calf, and when it skipped along it fluttered a pair of wings. This strange animal belonged to the first period of the tertiary age, during which time the American continent began to assume its present outlines. Only the borders of the Atlantic, the gulf of Mexico, and the Pacific were covered by the sea. The Rocky mountain region was above the sea. The Ohio and Mississippi were independent streams emptying into the gulf, and the great lakes began to assume their present form. Great forests extended from one end of the continent to the other, and giant sloths, mastodons, elephants, rhinoceroses, and camels roamed the length and breadth of the land. Immediately after this age of abnormal life came the glacial period, which was in turn followed by the age of man.

The progress of the science of geology in the United States was greatly accelerated by the establishment of the office of director of geological survey on March 3, 1879; the department being placed under the direction of the secretary of the interior. The survey was organized in four branches, geological, topographical, publication, and administrative, and within each of these are several divisions. Since its establishment, nearly fifty thousand square miles have been surveyed topographically, the survey being of special service during the past two years in the development of mineral resources, as well as contributing a vast amount of knowledge to the science in general.

THE BEGINNINGS OF AMERICAN ASTRONOMY.

BY EDWARD S. HOLDEN.

[Edward Singleton Holden, astronomer; born in St. Louis November 5, 1846; graduated from Washington university, 1866; graduated from West Point, 1870; engineer United States army, 1870–73; professor mathematics United States navy, 1873–81; director Washburn observatory, 1881–85; president University of California, 1883–88; director Lick Observatory, 1888–98; librarian United States military academy since 1901; author, Bastion System of Fortification; Index Catalogue of Nebulæ; Life of Sir William Herschel; Writings of Sir William Herschel; Astronomy; Briefer Astronomy; Mountain Observations; Earth and Sky; Elementary Astronomy; Family of the Sun; and other astronomical books.]

It is impossible, even in the briefest sketch, not to emphasize the debt of American science and learning to the intelligent interest and patronage of our early presidents—Washington, John Adams, Jefferson, Madison, Monroe, John Quincy Adams. The powerful impetus given by them and through them has shaped the liberal policy of our governments, national and state, toward education and toward science. Sir Lyon Playfair, in his address to the British association for the advance of science (1885) has recognized this influence in the truest and most graceful way. He said: "In the United kingdom we are just beginning to understand the wisdom of Washington's farewell address to his countrymen (1796) when he said: 'Promote then, as an object of primary importance, institutions for the general diffusion of knowledge. In proportion as the structure of a government gives force to public opinion, it is essential that public opinion should be enlightened.' "

Until the revolution (1776) American science was but English science transplanted, and it looked to the royal society of London as its censor and patron. Winthrop, Franklin, and Rittenhouse were, more or less, English astronomers. Franklin was the sturdiest American of the three. As early as 1743 he suggested the formation of the American Philosophical society of Philadelphia. John Adams founded the American academy of arts and sciences in Boston in 1780. These two societies, together with Harvard college (founded in

1636), Yale college (1701), the university of Virginia (founded by Jefferson in 1825), and the United States military academy at West Point (1801), were the chief foci from which the light of learning spread. Other colleges were formed or forming all over the eastern and middle states during the early years of the century.

The leading school of pure science was the military academy at West Point, and it continued to hold this place until the civil war of 1861. From its corps of professors and students it gave two chiefs to the United States coast survey; and the army, particularly the corps of engineers, provided many observers to that scientific establishment, besides furnishing a large number of professors and teachers of science to the colleges of the country. The observatory of the academy was founded by Bartlett in 1841, and much work was done there, only a small part of which is published. The coast survey was a school of practice for army officers, and their experience was utilized in numerous boundary surveys during the period 1830–1850. Col. J. D. Graham, for example, was astronomer of the survey of the boundary between Texas and the United States in 1839–40; commissioner of the northeast boundary survey, 1840–1843; astronomer of the northwest boundary survey, 1843–1847; of the boundary between the United States and Canada, 1848–1850; of the survey of the boundary between Pennsylvania and Virginia, 1849–50; of the boundary survey between Mexico and the United States, 1850–51. The names of Bonneville, Talcott, Cram, Emory, and other army officers are familiar in this connection, and their work was generally of a high order. It was in such service that Talcott invented or reinvented the zenith telescope, now universally employed for all delicate determinations of latitude. The mechanical tact of Americans has served astronomy well. The sextant was invented by Thomas Godfray, of Philadelphia, in 1730, a year before Hadley brought forward his proposal for such an instrument. The chronograph of the Bonds, the zenith telescope of Talcott, and the break circuit chronometer of Winlock are universally used to-day. The diffraction gratings of Rutherfurd were the best to be had in the world till they were replaced by those of Rowland. The use of a telescope as a collimator was first proposed by Rittenhouse. The pioneer opticians of the United States were Holcomb (1826), Fitz (1846 or earlier), Clark (1845), Spencer (1851). Only the Clarks have a world wide reputation. Würdemann, instrument maker to the United States Coast Survey (1834), had a decided influence on observers and instrument makers throughout the United States, as he introduced extreme German methods and models among us, where extreme English methods had previously prevailed. The system of rectangular land surveys, which proved to be so convenient for the public lands east of the Rocky mountains, was devised and executed by Mansfield, a graduate of the military academy.

The list of army officers who became distinguished in civil life as professors in the colleges of the country is a very long one. Courtenay (class of 1821 at West Point) was professor of mathematics at the university of Pennsylvania, 1834–1836; at the university of Virginia, 1842–43, and was the author of admirable text books. Norton (class of 1831) became professor at New Haven, and wrote a very useful text book of astronomy in 1839; and the list could be much extended. The excellent training in mathematics at West Point (chiefly in French methods) early made itself felt throughout the whole country. The mathematical text books of Peirce, of Harvard, and of Chauvenet, of the Naval academy, brought the latest learning of Europe to American students. Mitchell (class of 1829 at West Point) was the only graduate who became a professional astronomer (1842–1861). His direct service to practical observing astronomy is small, but his lectures (1842–1848), the conduct of the Cincinnati observatory (1845–1859), and his publication of the Sidereal Messenger (1846–1848), together with his popular books, excited an intense and widespread public interest in the science, and indirectly led to the foundation of many observatories. He was early concerned in the matter of using the electric current for longitude determinations, and his apparatus was only displaced because of the superior excellence of the chronograph devised by the Bonds. His work was done under immense disadvantages, in a new community (Ohio), but the endowment of astronomical research in America owes a large debt to his energy and efforts.

The navy and the United States naval academy (founded by Bancroft in 1845, at the suggestion of Chauvenet) were very active in astronomical work. Chauvenet published a text book of trigonometry in 1850, which had an important share in directing attention to rigid, elegant, and general methods of research. His astronomy (1863) is a handbook for all students. Walker, Gilliss, Coffin, Hubbard, Ferguson, Keith, Yarnall, Winlock, Maury, Wilkes, were all connected with the navy, more or less intimately. Walker's career was especially brilliant; he graduated at Harvard college in 1825, and established the observatory of the Philadelphia high school in 1840. He was the leading spirit in the United States naval observatory at Washington (1845–1847) and introduced modern methods into its practice at the beginning. From the observatory he went to the coast survey to take charge of its longitude operations, and he continued to direct and expand this department until his death, in 1853. To him, more than to any single person, is due the idea of the telegraphic method ("the American method") of determining differences of longitude. His assistant in this work was Gould, who succeeded to the charge of it in 1853. His researches extended to the field of mathematical astronomy also, and his theory of the planet Neptune (then newly discovered) marks an important step forward. His investigations and those of Peirce were conducted in concert and attracted general and deserved attention.

The exploring expedition of Wilkes required corresponding observations to be made in America, and during the period 1838–1842 William Bond, at Dorchester, and Lieutenant Gilliss, at Washington, maintained such a series with infinite assiduity and with success. The results of Gilliss' astronomical expedition to the southern hemisphere (Chile, 1849–1852) were most creditable to him and to the navy, though his immediate object—the determination of the solar parallax—was not attained.

The coast survey began its work in 1817 under Hassler, a professor from West Point, who impressed upon the establishment a thoroughly scientific direction. Bache, his successor (a grandson of Benjamin Franklin), was a graduate of West Point in the class of 1825, and took charge of the survey in 1843. He is the true father of the institution, and gave it the practical efficiency and high standard which characterized its work. He called around him the flower of the army and navy, and was ably seconded by the permanent corps of civilian assistants—Walker, Saxton, Gould, Dean, Blunt, Pourtales, Boutelle, Hilgard, Schott, Goodfellow, Cutts, Davidson, and others.

Silliman's (and Dana's) American Journal of Science had been founded at New Haven in 1818, and served as a medium of communication among scientific men. A great step forward was made in the establishment of the Astronomical Journal by Dr. Gould on his return from Europe at the close of 1849. Silliman's journal was chiefly concerned in the non mathematical sciences, though it has always contained valued papers on mathematics, astronomy, and physics, especially from the observers of Yale college—Olmstead, Herrick, Bradley, Norton, Newton, Lyman, and others. In Mason, who died in 1840 at the age of 21, the country lost a practical astronomer of the highest promise. Gould's journal was an organ devoted to a special science. It not only gave a convenient means of prompt publication, but it immediately quickened research and helped to enforce standards already established and to form new ones. The astronomical notices of Brünnow (1858–1862) might have been an exceedingly useful journal with an editor who was willing to give more attention to details, but in spite of Brünnow's charming personality and great ability, it had comparatively little influence on the progress of the science.

The translation of the Mécanique Céleste of Laplace by Nathaniel Bowditch, the supercargo of a Boston ship (1815–1817), marks the beginning of an independent mathematical school in America. The first volume of the translation appeared in 1829. At that time there were not more than two or three persons in the country who could read it critically. The works of the great mathematicians and astronomers of

France and Germany—Laplace, Lagrange, Legendre, Olbers, Gauss, W. Struve, Bessel—were almost entirely unknown.

Bowditch's translation of the Mécanique Céleste, and, still more, his extended commentary, brought this monumental work to the attention of students and within their grasp. His Practical Navigator contained the latest and best methods for determining the position of a ship at sea, expressed in simple rules. American navigators had no superiors in the first half of this century. Nantucket whalers covered the Pacific, Salem ships swarmed in the Indies, and the clipper ships made passages round the Horn to San Francisco, which are a wonder to-day. Part of their success is due to the bold enterprise of their captains (who were said to carry deck loads of studding sail booms to replace those carried away!), but an important part depended on their skill as observers with the sextant. One of the sister ships to the one of which Bowditch was supercargo was visited at Genoa by a European astronomer of note (Baron de Zach), who found that the latest methods of working lunar distances to determine the longitude were known to all on board, sailors as well as officers. His bewilderment reached its climax when the navigator called the negro cook from the galley and bade him expound the methods of determining the longitude to the distinguished visitor.

On Bowditch's own ship there was a "crew of twelve men, every one of whom could take and work a lunar observation as well, for all practical purposes, as Sir Isaac Newton himself." Such crews were only to be found on American ships in the palmy days of democracy. All were cousins or neighbors and each had a venture in the voyage. But these anecdotes may serve as illustrations of the intellectual awakening which came about as soon as our young country was relieved from the pressure of the two wars of 1776 and 1812. An early visitor, Baron Hyde de Neuville (1805) felt "an unknown something in the air," "a new wind blowing." This new spirit, born of freedom, entered first into practical life, as was but natural; science next felt its impulse, and, last of all, literature was born. Emerson hailed it (in 1837) "as the sign of an indestructible instinct." "Perhaps the time has already come," he says, "when the sluggard intellect of this country will look from under its iron lids and fill the postponed expectation of the world with something better than the exertions of mechanical skill. Our day of dependence, our long apprenticeship to the learning of other lands, draws to a close. The millions that around us are rushing into life can not always be fed with the sere remains of foreign harvests."

Benjamin Peirce, a graduate of Harvard in the class of 1829, had been concerned with the translation of the Mécanique Céleste, and was early familiar with the best mathematical thought of Europe. He became professor in Harvard college in 1833, and, after the death of Bowditch in 1838, he was easily the first mathematical astronomer in the country. His instruction was precisely fitted to develop superior intelligences, and this was his prime usefulness. Just such a man was needed at that time. Besides his theoretical researches on the orbits of the planets (specially Uranus and Neptune) and of the moon, his study of the theory of perturbations, and his works on pure mathematics and mechanics, he concerned himself with questions of practical astronomy, although the observations upon which he depended were the works of others. He was the consulting astronomer of the American Ephemeris and Nautical Almanac from its foundation in 1849, and its plans were shaped by him to an important degree. His relative, Lieutenant Davis, United States navy (the translator of Gauss's Theoria Motus Corporum Cœlestium, 1857), was placed in charge of the Ephemeris, and the members of its staff—Runkle Ferrel, Wright, Newcomb, Winlock, and others—most effectively spread its exact methods by example and precept. Professor Peirce undertook the calculations relating to the sun, Mars, and Uranus in the early volumes of the Ephemeris. As a compliment to her sex, Miss Maria Mitchell was charged with those of Venus; Mercury was computed by Winlock, Jupiter by Kendall, Saturn by Downes, Neptune by Sears Walker.

The Smithsonian institution was founded in 1846, and Joseph Henry was called from Princeton college to direct it. There never was a wiser choice. His term of service (1846–1878) was so long that his ideals became firmly fixed within the establishment and were impressed upon his contemporaries and upon a host of younger men. The interests of astronomy were served by the encouragement of original research through subsidies and otherwise, by the purchase of instruments for scientific expeditions, by the free exchange of scientific books between America and Europe, and by the publication of the results of recondite investigations. It is by these and like services that the institution is known and valued among the wide community of scientific men throughout the world.

But this enumeration of specific benefits does not convey an adequate idea of the immense influence exercised by the institution upon the scientific ideals of the country. It was of the first importance that the beginnings of independent investigation among Americans should be directed toward right ends and by high and unselfish aims. In the formation of a scientific and, as it were, a moral standard a few names will be remembered among us, and no one will stand higher than that of Henry. His wise, broad, and generous policy and his high personal ideals were of immense service to his colleagues and to the country.

The establishment of a national observatory in Washington was proposed by John Quincy Adams in 1825, but it was not until 1844 that the United States naval observatory was built by Lieutenant Gilliss, of the navy, from plans which he had prepared. By what seems to have been an injustice Gilliss was not appointed to be its first director. This place fell to Lieut. M. F. Maury. Gilliss had been on detached service for some years, and a rigid construction of rules required that he should be sent to sea, and not remain to launch the institution which he had built and equipped.

The first corps of observers at Washington (1845) contained men of first class ability—Walker, Hubbard, Coffin. Gilliss' work as astronomer to Wilkes' exploring expedition (1838–1842) at his little observatory on Capitol Hill had shown him to be one of the best of observers, as well as one of the most assiduous. His study and experience in planning and building the naval observatory had broadened his mind. To the men just named, with Peirce, Gould, and Chauvenet, and to their coadjutors and pupils, we owe the introduction of the methods of Gauss, Bessel, and Struve into the United States, and it is for this reason that American astronomy is the child of German and not of English science.

The most natural evolution might seem to have been for Americans to follow the English practice of Maskelyne and Pond. But the break caused by the war of independence, by the war of 1812, and by the years necessary for our youthful governments to consolidate (1776–1836) allowed our young men of science to make a perfectly unbiased choice of masters. The elder Bond (William Cranch Bond, born 1789, director of Harvard College observatory, 1840–1859) was one of the older school and received his impetus from British sources during a visit to England in 1815.

In estimating the place of the elder Bond among scientific men it is necessary to take into account the circumstances which surrounded him. He was born in the year of the French revolution (1789); he was absolutely self taught; practically no astronomical work was done in America before 1838. When Admiral Wilkes was seeking for coadjutors to prosecute observations in the United States during the absence of his exploring expedition he was indeed fortunate in finding two such men as Bond and Gilliss. Their assiduity was beyond praise and it led each of them to important duties. Bond became the founder and director of the observatory of Harvard college, while Gilliss is the father of the United States naval observatory at Washington, as well as that of Santiago de Chile, the oldest observatory in South America. Cambridge, though the seat of the most ancient university in America, was but a village in 1839. The college could afford no salary to Bond, but only the distinction of a title, Astronomical Observer to the University, and the occupancy of the Dana house, in which his first observatory was established. His work there, as elsewhere, was well and faithfully done, and it led the college authorities to employ him as the astronomer of the splendid observatory which was opened for work in 1847. At that time the two largest tele-

ANNUAL VALUE OF PRODUCTS OF MANUFACTURES

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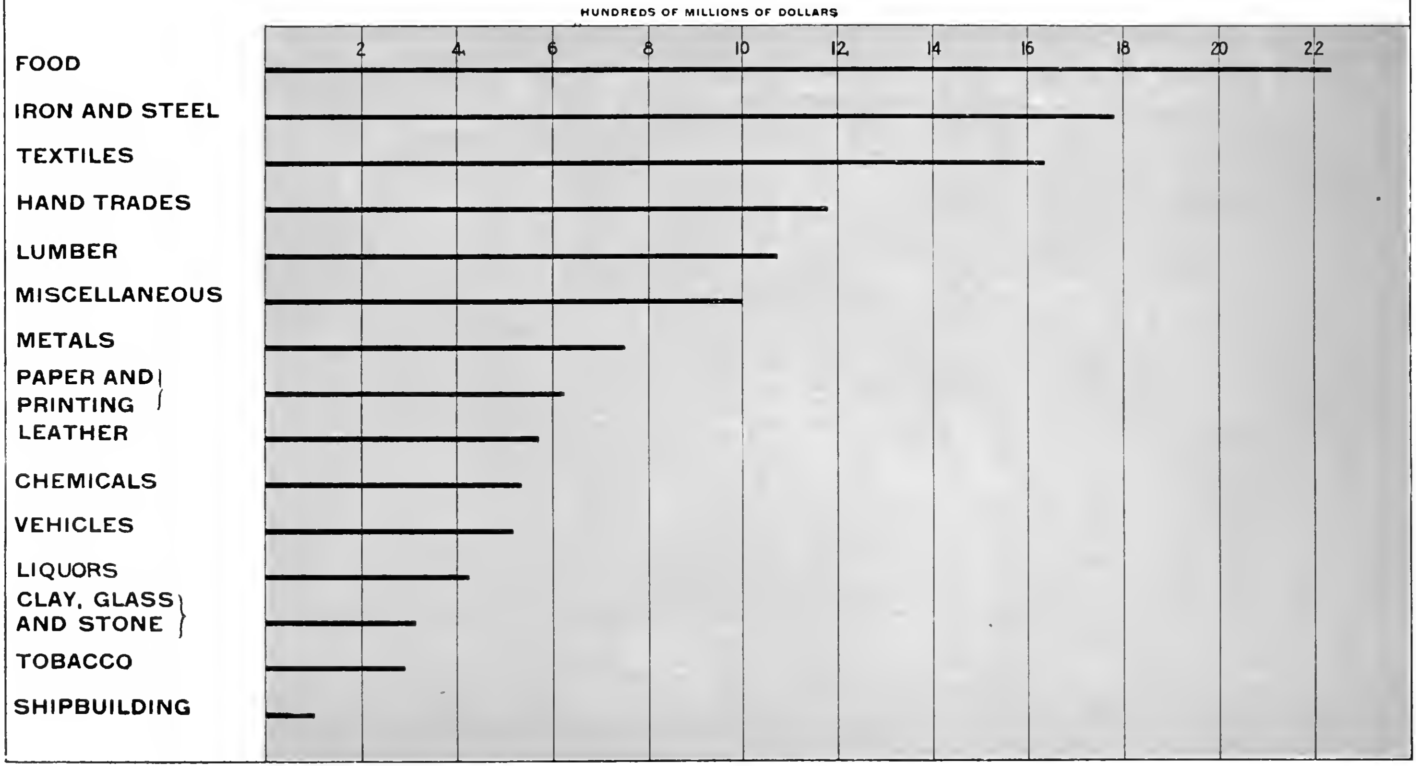


scopes in the world were those of the Imperial observatory of Russia (Poulkova) and its companion at Cambridge. Each of these instruments has a long and honorable history. Their work has been very different. Who shall say that one has surpassed the other? We owe to Bond and his son the discovery of an eighth satellite to Saturn, of the dusky ring to that planet, the introduction of stellar photography, the invention of the chronograph by which the electric current is employed in the registry of observations, the conduct of several chronometric expeditions between Liverpool and Boston to determine the transatlantic longitude, and a host of minor discoveries and observations.

Gilliss visited France for study in 1853, before he took up his duties at Washington. The text books of Bond and Gilliss were the Astronomies of Vince (1797–1808) and of Pearson (1824–1829). The younger Bond (George Phillips Bond, born 1825, Harvard college, 1844, director of the Harvard college observatory 1859–1865) and his contemporaries, on the other hand, were firmly grounded in the German methods, then, as now, the most philosophical and thorough.

It was not until 1850, or later, that it was indispensable for an American astronomer to read the German language and to make use of the memoirs of Bessel, Encke, and Struve and the text books of Sawitsch and Brünnow. This general acquaintance with the German language and methods came nearly a generation later in England. The traditions of Piazzi and Oriani came to America with the Jesuit fathers of Georgetown college (1844), of whom Secchi and Sestini are the best known.

The dates of the foundation of a few observatories of the United States may be set down here. Those utilized for the observation of the transit of Venus in 1769 were temporary stations merely. The first college observatory was that of Chapel Hill, N. C. (1831); Williams college followed (1836); Hudson observatory (Ohio) (1838); the Philadelphia High school (1840); the Dana House observatory of Harvard college (1840); West Point (1841); the United States naval observatory (1844); the Georgetown College observatory (1844); the Cincinnati observatory (1845); the new observatory of Harvard college (1846); the private observatory of Dr. Lewis M. Rutherford in New York city (1848); the observatory at Ann Arbor (1854); the Dudley observatory at Albany (1856); and that of Hamilton college (1856).

These dates and the summary history just given will serve to indicate the situation of astronomy in the United States during the first half of the present century. A little attention to the dates will enable the reader to place an individual or an institution on its proper background. It must constantly be kept in mind that the whole country was very young and that public interest in astronomical matters was neither educated nor very general. The data here set down will have a distinct value as a contribution to the history of astronomy in America. The developments of later years have been so amazing that we forget that the first working observatories were founded so late as 1845.

American science is scarcely more than half a century old. The day will soon come—it is now here—when we shall look back with wonder and gratitude to ask who were the men who laid the wide and deep foundations which already maintain so noble an edifice.

SOME ASPECTS OF AMERICAN ASTRONOMY.

BY SIMON NEWCOMB.

[Simon Newcomb, astronomer; born Wallace, N. S., March 12, 1835; educated by his father and came to the United States in 1853; teacher in Maryland, 1854–56; computer on Nautical Almanac, 1857; graduated from Lawrence scientific school of Harvard, 1858; professor mathematics United States navy, 1861; secretary United States transit of Venus commission, 1871–74; observed transit of Venus at Cape Good Hope, 1882; director Nautical Almanac office, 1877–97; retired in 1897 at the age of 62; president A. A. A. S., 1876–77; member of nearly all the national academies of science of the world; has received the Copley, Huygens, Royal Society and Bruce medals; author, Popular Astronomy; Calculus; Principles of Political Economy; Elements of Astronomy; Astronomy for Everybody, etc.]

A little more than two centuries ago Huygens prefaced an account of his discoveries on the planet Saturn with the remark that many, even among the learned, might think he had been devoting to things too distant to interest mankind an amount of study which would better have been devoted to subjects of more immediate concern. It must be admitted that this fear has not deterred succeeding astronomers from pursuing their studies. The enthusiastic students of astronomy in America are only a detachment from an army of investigators who, in many parts of the world, are seeking to explore the mysteries of creation. Why so great an expenditure of energy? Certainly not to gain wealth, for astronomy is perhaps the one field of scientific work which, in our expressive modern phrase, "has no money in it." It is true that the great practical use of astronomical science to the country and the world in affording us the means of determining positions on land and at sea is frequently pointed out. It is said that an Astronomer Royal of England once calculated that every meridian observation of the moon made at Greenwich was worth a pound sterling on account of the help it would afford to the navigation of the ocean. An accurate map of the United States can not be constructed without astronomical observations at numerous points scattered over the whole country, aided by data which great observatories have been accumulating for more than a century, and must continue to accumulate in the future.

But neither the measurement of the earth, the making of maps, nor the aid of the navigator is the main object which the astronomers of to-day have in view. If they do not quite share the sentiment of that eminent mathematician who is said to have thanked God that his science was one which could not be prostituted to any useful purpose, they still know well that to keep utilitarian objects in view would only prove a handicap on their efforts. Consequently they never ask in what way their science is going to benefit mankind.

As the great captain of industry is moved by the love of wealth, and the politician by the love of power, so the astronomer is moved by the love of knowledge for its own sake, and not for the sake of its application. Yet he is proud to know that his science has been worth more to mankind than it has cost. He does not value its results merely as a means of crossing the ocean or mapping the country, for he feels that man does not live by bread alone. If it is not more than bread to know the place we occupy in the universe, it is certainly something which we should place not far behind the means of subsistence. That we now look upon a comet as something very interesting, of which the sight affords us a pleasure unmixed with fear of war, pestilence, or other calamity, and of which we therefore wish the return, is a gain we can not measure by money. In all ages astronomy has been an index to the civilization of the people who cultivated it. It has been crude or exact, enlightened or mingled with superstition, according to the current mode of thought. When once men understand the relation of the planet on which they dwell to the universe at large, superstition is doomed to speedy extinction. This alone is an object worth more than money.

Astronomy may fairly claim to be that science which transcends all others in its demands upon the practical application of our reasoning powers. Look at the stars that stud the heavens on a clear evening. What more hopeless problem to one confined to earth than that of determining their varying distances, their motions, and their physical constitution? Everything on earth we can handle and investigate. But how investigate that which is ever beyond our reach, on which we can never make an experiment? On certain occasions we see the moon pass in front of the sun and hide it from our eyes. To an observer a few miles away the sun was not entirely hidden, for the shadow of the moon in a total eclipse is rarely 100 miles wide. On another continent no eclipse at all may have been visible. Who shall take a map of the world and mark upon it the line on which the moon's shadow will travel during some eclipse a hundred years hence? Who shall map out the orbits of the heavenly bodies as they are going to appear in a hundred thousand years? How shall we ever know of what chemical elements the sun and the stars are made? All this has been done, but not by the intellect of any one man. The road to the stars has been opened only by the efforts of many generations of mathematicians and observers, each of whom began where his predecessor had left off.

We have reached a stage where we know much of the heavenly bodies. We have mapped out our solar system with great precision. But how with that great universe of millions of stars in which our solar system is only a speck of star dust, a speck which a traveler through the wilds of space might pass a hundred times without notice? We have learned much about this universe, though our knowledge of it is still dim. We see it as a traveler on a mountain top sees a distant city in a cloud of mist, by a few specks of glimmering light from steeples or roofs. We want to know more about it, its origin and its destiny; its limits in time and space, if it has any; what function it serves in the universal economy. The journey is long, yet we want, in knowledge at least, to reach the stars. Hence we build observatories and train observers and investigators. Slow indeed is progress in the solution of the greatest of problems, when measured by what we want to know. Some questions may require centuries, others thousands of years for their answer. And yet never was progress more rapid than during our time. In some directions our astronomers of to-day are out of sight of those of fifty years ago; we are even gaining heights which twenty years ago looked hopeless. Never before had the astronomer so much work—good, hard, yet hopeful work—before him as to-day. He who is leaving the stage feels that he has only begun, and must leave his successors with more to do than his predecessors left him.

To us an interesting feature of this progress is the part taken in it by our own country. The science of our day, it is true, is of no country. Yet we very appropriately speak of American science from the fact that our traditional reputation has not been that of a people deeply interested in the higher branches of intellectual work. Men yet living can remember when in the eyes of the universal church of learning all cisatlantic countries, our own included, were partes infidelium.

Yet American astronomy is not entirely of our generation. In the middle of the last century Professor Winthrop, of Harvard, was an industrious observer of eclipses and kindred phenomena, whose work was recorded in the transactions of learned societies. But the greatest astronomical activity during our colonial period was that called out by the transit of Venus in 1769, which was visible in this country. A committee of the American Philosophical society, at Philadelphia, organized an excellent system of observations, which we now know to have been fully as successful, perhaps more so, than the majority of those made on other continents, owing mainly to the advantages of air and climate. Among the observers was the celebrated Rittenhouse, to whom is due the distinction of having been the first American astronomer whose work has an important place in the history of the science. In addition to the observations which he has left us, he was the first inventor or proposer of the collimating telescope, an instrument which has become almost a necessity wherever accurate observations are made. The fact that the subsequent invention by Bessel was quite independent does not detract from the merits of either.

Shortly after the transit of Venus, which I have mentioned, the war of the revolution commenced. The generation which carried on that war and the following one, which framed our constitution and laid the basis of our political institutions, were naturally too much occupied with these great problems to pay much attention to pure science. While the great mathematical astronomers of Europe were laying the foundation of celestial mechanics their writings were a sealed book to every one on this side of the Atlantic, and so remained until Bowditch appeared, early in the last century. His translation of the Mécanique Céleste made an epoch in American science by bringing the great work of Laplace down to the reach of the best American students of his time.

American astronomers must always honor the names of Rittenhouse and Bowditch. And yet in one respect their work was disappointing of results. Neither of them was the founder of a school. Rittenhouse left no successor to carry on his work. The help which Bowditch afforded his generation was invaluable to isolated students who, here and there, dived alone and unaided into the mysteries of the celestial motions. His work was not mainly in the field of observational astronomy, and therefore did not materially influence that branch of science. In 1832 Professor Airy, afterwards astronomer royal of England, made a report to the British association on the condition of practical astronomy in various countries. In this report he remarked that he was unable to say anything about American astronomy because, so far as he knew, no public observatory existed in the United States.

William Bond, afterwards famous as the first director of Harvard observatory, was at that time making observations with a small telescope, first near Boston and afterwards at Cambridge. But with so meager an outfit his establishment could scarcely lay claim to being an astronomical observatory, and it was not surprising if Airy did not know anything of his modest efforts.

If at this time Professor Airy had extended his investigations into yet another field, with a view of determining the prospects for a great city at the site of Fort Dearborn, on the southern shore of Lake Michigan, he would have seen as little prospect of civic growth in that region as of a great development of astronomy in the United States at large. A plat of the proposed town of Chicago had been prepared two years before, when the place contained perhaps half a dozen families. In the same month in which Professor Airy made his report, August, 1832, the people of the place, then numbering 28 voters, decided to become incorporated, and selected five trustees to carry on their government.

In 1837 a city charter was obtained from the legislature of Illinois. The growth of this infant city, then small even for an infant, into the great commercial metropolis of the west has been the just pride of its people and the wonder of the world. I mention it now because of a remarkable coincidence. With this civic growth has quietly gone on another, little noted by the great world, and yet in its way equally wonderful and equally gratifying to the pride of those who measure greatness by intellectual progress. If it be true that—

In Nature nothing is great but man; in man nothing is great
but mind—

then may knowledge of the universe be regarded as the true measure of progress. I therefore invite attention to the fact that American astronomy began with Chicago and has slowly but surely kept pace with it until to-day our country stands second only to Germany in the number of researches being prosecuted and second to none in the number of men who have gained the highest recognition by their labors.

In 1836 Prof. Albert Hopkins, of Williams college, and Prof. Elias Loomis, of Western Reserve college, Ohio, both commenced little observatories. Professor Loomis went to Europe for all his instruments, but Hopkins was able even then to get some of his in this country. Shortly afterwards a little wooden structure was erected by Captain Gilliss on Capitol Hill, at Washington, and supplied with a transit instrument for observing moon culminations, in conjunction with Captain Wilkes, who was then setting out on his exploring expedition to the southern hemisphere. The date of these observatories was practically the same as that on which a charter for the city of Chicago was obtained from the legislature. With their establishment the population of the city had increased to 703.

The next decade, 1840 to 1850, was that in which our practical astronomy seriously commenced. The little observatory of Captain Gilliss was replaced by the naval observatory, erected at Washington during the years 1843–44 and fitted out with what were then the most approved instruments. About the same time the appearance of the great comet of 1843 led the citizens of Boston to erect the observatory of Harvard college. Thus it is little more than a half century since the two principal observatories in the United States were established. But we must not for a moment suppose that the mere erection of an observatory can mark an epoch in scientific history. What must make the decade of which I speak ever memorable in American astronomy was not merely the erection of buildings, but the character of the work done by astronomers away from them as well as in them.

The naval observatory very soon became famous by two remarkable steps which raised our country to an important position among those applying modern science to practical uses. One of these consisted of the researches of Sears Cook Walker on the motion of the newly discovered planet Neptune. He was the first astronomer to determine fairly good elements of the orbit of that planet, and, what is yet more remarkable, he was able to trace back the movement of the planet in the heavens for half a century and to show that it had been observed as a fixed star by Lalande in 1795, without the observer having any suspicion of the true character of the object.

The other work to which I refer was the application to astronomy and to the determination of longitudes of the chronographic method of registering transits of stars or other phenomena requiring an exact record of the instant of their occurrence. It is to be regretted that the history of this application has not been fully written. In some points there seems to be as much obscurity as with the discovery of ether as an anæsthetic, which took place about the same time. Happily no such contest has been fought over the astronomical as over the surgical discovery, the fact being that all who were engaged in the application of the new method were more anxious to perfect it than they were to get credit for themselves. We know that Saxton, of the Coast Survey; Mitchell and Locke, of Cincinnati; Bond, at Cambridge, as well as Walker and other astronomers at the naval observatory, all worked at the apparatus; that Maury seconded their efforts with untiring zeal; that it was used to determine the longitude of Baltimore as early as 1844 by Captain Wilkes, and that it was put into practical use in recording observations at the naval observatory as early as 1846.

At the Cambridge observatory the two Bonds, father and son, speedily began to show the stuff of which the astronomer is made. A well devised system of observations was put in operation. The discovery of the dark ring of Saturn and of a new satellite to that planet gave additional fame to the establishment.

Nor was activity confined to the observational side of the science. The same decade of which I speak was marked by the beginning of Professor Pierce's mathematical work, especially his determination of the perturbations of Uranus and Neptune. At this time commenced the work of Dr. B. A. Gould, who soon became the leading figure in American astronomy. Immediately on graduating at Harvard in 1845, he determined to devote all the energies of his life to the prosecution of his favorite science. He studied in Europe for three years, took the doctor's degree at Göttingen, came home, founded the Astronomical Journal, and took an active part in that branch of the work of the Coast Survey which included the determination of longitudes by astronomical methods.

An episode which may not belong to the history of astronomy must be acknowledged to have had a powerful influence in exciting public interest in that science. Prof. O. M. Mitchell, the founder and first director of the Cincinnati observatory, made the masses of our intelligent people acquainted with the leading facts of astronomy by courses of lectures which, in lucidity and eloquence, have never been excelled. The immediate object of the lectures was to raise funds for establishing his observatory and fitting it out with a fine telescope. The popular interest thus excited in the science had an important effect in leading the public to support astronomical research. If public support, based on public interest, is what has made the present fabric of American astronomy possible, then should we honor the name of a man whose enthusiasm leavened the masses of his countrymen with interest in our science.

The civil war naturally exerted a depressing influence upon our scientific activity. The cultivator of knowledge is no less patriotic than his fellow citizens, and vies with them in devotion to the public welfare. The active interest which such cultivators took, first in the prosecution of the war and then in the restoration of the union, naturally distracted their attention from their favorite pursuits. But no sooner was political stability reached than a wave of intellectual activity set in, which has gone on increasing up to the present time. If it be true that never before in our history has so much attention been given to education as now; that never before did so many men devote themselves to the diffusion of knowledge, it is no less true that never was astronomical work so energetically pursued among us as now.

One deplorable result of the civil war was that Gould's Astronomical Journal had to be suspended. Shortly after the restoration of peace, instead of re-establishing the journal, its founder conceived the project of exploring the southern heavens. The northern hemisphere being the seat of civilization, that portion of the sky which could not be seen from our latitudes was comparatively neglected. What had been done in the southern hemisphere was mostly the occasional work of individuals and of one or two permanent observatories. The latter were so few in number and so meager in their outfit that a splendid field was open to the inquirer. Gould found the patron which he desired in the government of the Argentine republic, on whose territory he erected what must rank in the future as one of the memorable astronomical establishments of the world. His work affords a most striking example of the principle that the astronomer is more important than his instruments. Not only were the means at the command of the Argentine observatory slender in the extreme when compared with those of the favored institutions of the north, but, from the very nature of the case, the Argentine republic could not supply trained astronomers. The difficulties thus growing out of the administration can not be overestimated. And yet the sixteen great volumes in which the work of the institution has been published will rank in the future among the classics of astronomy.

Another wonderful focus of activity, in which one hardly knows whether he ought most to admire the exhaustless energy or the admirable ingenuity which he finds displayed, is the Harvard observatory. Its work has been aided by gifts which have no parallel in the liberality that prompted them. Yet without energy and skill such gifts would have been useless. The activity of the establishment includes both hemispheres. Time would fail to tell how it has not only mapped out important regions of the heavens from the north to the south pole, but analyzed the rays of light which come from hundreds of thousands of stars by recording their spectra in permanence on photographic plates.

The work of the establishment is so organized that a new star can not appear in any part of the heavens nor a known star undergo any noteworthy change without immediate detection by the photographic eye of one or more little telescopes, all seeing and never sleeping policemen that scan the heavens unceasingly while the astronomer may sleep, and report in the morning every case of irregularity in the proceedings of the heavenly bodies.

Yet another example, showing what great results may be obtained with limited means, is afforded by the Lick observatory, on Mount Hamilton, Cal. During the ten years of its activity its astronomers have made it known the world over by works and discoveries too varied and numerous to be even mentioned at the present time.

The astronomical work of which I have thus far spoken has been almost entirely that done at observatories. I fear that I may in this way have strengthened an erroneous impression that the seat of important astronomical work is necessarily connected with an observatory. It must be admitted that an institution which has a local habitation and a magnificent building commands public attention so strongly that valuable work done elsewhere may be overlooked. A very important part of astronomical work is done away from telescopes and meridian circles and requires nothing but a good library for its prosecution. One who is devoted to this side of the subject may often feel that the public does not appreciate his work at its true relative value from the very fact that he has no great buildings or fine instruments to show. I may therefore be allowed to claim as an important factor in the American astronomy of the last half century an institution of which few have heard and which has been overlooked because there was nothing about it to excite attention.

In 1849 the American Nautical Almanac office was established by a congressional appropriation. The title of this publication is somewhat misleading in suggesting a simple enlargement of the family almanac which the sailor is to hang up in his cabin for daily use. The fact is that what started more than a century ago as a nautical almanac has since grown into an astronomical ephemeris for the publication of everything pertaining to times, seasons, eclipses, and the motions of the heavenly bodies. It is the work in which astronomical observations made in all the great observatories of the world are ultimately utilized for scientific and public purposes. Each of the leading nations of western Europe issues such a publication. When the preparation and publication of the American ephemeris was decided upon the office was first established in Cambridge, the seat of Harvard university, because there could most readily be secured the technical knowledge of mathematics and theoretical astronomy necessary for the work.

A field of activity was thus opened, of which a number of able young men who have since earned distinction in various walks of life availed themselves. The head of the office, Commander Davis, adopted a policy well fitted to promote their development. He translated the classic work of Gauss, Theoria Motus Corporum Cælestium, and made the office a sort of informal school, not, indeed, of the modern type, but rather more like the classic grove of Hellas, where philosophers conducted their discussions and profited by mutual attrition. When, after a few years of experience, methods were well established and a routine adopted, the office was removed to Washington, where it has since remained. The work of preparing the ephemeris has, with experience, been reduced to a matter of routine which may be continued indefinitely, with occasional changes in methods and data and improvements to meet the increasing wants of investigators.

The mere preparation of the ephemeris includes but a small part of the work of mathematical calculation and investigation required in astronomy. One of the great wants of the science to-day is the re-reduction of the observations made during the first half of the last century, and even during the last half of the preceding one. The labor which could profitably be devoted to this work would be more than that required in any one astronomical observatory. It is unfortunate for this work that a great building is not required for its prosecution because its needfulness is thus very generally overlooked by that portion of the public interested in the progress of science. An organization especially devoted to it is one of the scientific needs of our time.

In such an epoch making age as the present it is dangerous to cite any one step as making a new epoch. Yet it may be that when the historian of the future reviews the science of our day he will find the most remarkable feature of the astronomy of the last twenty years of our century to be the discovery that this steadfast earth of which the poets have told us is not after all quite steadfast; that the north and south poles move about a very little, describing curves so complicated that they have not yet been fully marked out. The periodic variations of latitude thus brought about were first suspected about 1880, and announced with some modest assurance by Küstner, of Berlin, a few years later. The progress of the views of astronomical opinion from incredulity to confidence was extremely slow until, about 1890, Chandler, of the United States, by an exhaustive discussion of innumerable results of observations, showed that the latitude of every point on the earth was subject to a double oscillation, one having a period of a year, the other of four hundred and twenty seven days.

Notwithstanding the remarkable parallel between the growth of American astronomy and that of Chicago, one can not but fear that if a foreign observer had been asked only fourteen years ago at what point in the United States a great school of theoretical and practical astronomy, aided by an establishment for the exploration of the heavens, was likely to be established by the munificence of private citizens, he would have been wiser than most foreigners had he guessed

Chicago. Had this place been suggested to him, I fear he would have replied that were it possible to utilize celestial knowledge in acquiring earthly wealth, here would be the most promising seat for such a school. But he would need to have been a little wiser than his generation to reflect that wealth is at the base of all progress in knowledge and the liberal arts; that it is only when men are relieved from the necessity of devoting all their energies to the immediate wants of life that they can lead intellectual lives, and that we should therefore look to the most enterprising commercial center as the likeliest seat for a great scientific institution.

Twenty-seven years ago there was in Chicago a modest little instrument which, judged by its size, could not hold up its head with the great ones even of that day. It was the private property of a young man holding no scientific position and scarcely known to the public. And yet that little telescope is to-day among the famous ones of the world, having made memorable advances in the astronomy of double stars, and shown its owner to be a worthy successor of the Herschels and Struves in that line of work.

A hundred observers might have used the appliances of the Lick observatory for a whole generation without finding the fifth satellite of Jupiter; without successfully photographing the cloud forms of the Milky Way; without discovering the extraordinary patches of nebulous light, nearly or quite invisible to the human eye, which fill some regions of the heavens.

In Zurich I paid a visit to the little but not unknown observatory of its famous polytechnic school. The professor of astronomy was especially interested in the observations of the sun with the aid of the spectroscope, and among the ingenious devices which he described, not the least interesting was the method of photographing the sun by special rays of the spectrum, which had been worked out at the Kenwood observatory in Chicago. The Kenwood observatory was not, I believe, in the eye of the public one of noteworthy fame, and yet this invention has given it an important place in the science of our day.

The constitution of the astronomer shows curious and interesting features. If he is destined to advance the science by works of real genius, he must, like the poet, be born, not made. The born astronomer, when placed in command of a telescope, goes about using it as naturally and effectively as the babe avails itself of its mother's breast. He sees intuitively what less gifted men have to learn by long study and tedious experiment. He is moved to celestial knowledge by a passion which dominates his nature. He can no more avoid doing astronomical work, whether in the line of observations or research, than a poet can chain his Pegasus to earth. I do not mean by this that education and training will be no use to him. They will certainly accelerate his early progress. If he is to become great on the mathematical side, not only must his genius have a bend in that direction, but he must have the means of pursuing his studies. And yet I have seen so many failures of men who had the best instruction, and so many successes of men who scarcely learned anything of their teachers, that I sometimes ask whether the great American celestial mechanician of the twentieth century will be a graduate of a university or of the backwoods.

Is the man thus moved to the exploration of nature by an unconquerable passion more to be envied or pitied? In no other pursuit does success come with such certainty to him who deserves it. No life is so enjoyable as that whose energies are devoted to following out the inborn impulses of one's nature. The investigator of truth is little subject to the disappointments which await the ambitious man in other fields of activity. It is pleasant to be one of a brotherhood extending over the world, in which no rivalry exists except that which comes out of trying to do better work than any one else, while mutual admiration stifles jealousy. And yet, with all these advantages, the experience of the astronomer may have its dark side. As he sees his field widening faster than he can advance he is impressed with the littleness of all that can be done in one short life. He feels the same want of successors to pursue his work that the founder of a dynasty may feel for heirs to occupy his throne. He has no desire to figure in history as a Napoleon of science whose conquests must terminate with his life. Even during his active career his work may be of such a kind as to require the co-operation of others and the active support of the public. If he is disappointed in commanding these requirements, if he finds neither co-operation nor support, if some great scheme to which he may have devoted much of his life thus proves to be only a castle in the air, he may feel that nature has dealt hardly with him in not endowing him with passions like to those of other men.

In treating a theme of perennial interest one naturally tries to fancy what the future may have in store. If the traveler, contemplating the ruins of some ancient city which in the long ago teemed with the life and activities of generations of men, sees every stone instinct with emotion and the dust alive with memories of the past, may he not be similarly impressed when he feels that he is looking around upon a seat of future empire—a region where generations yet unborn may take a leading part in molding the history of the world? What may we not expect of that energy which in sixty years has transformed a straggling village into one of the world's great centers of commerce? May it not exercise a powerful influence on the destiny not only of the country but of the world? If so, shall the power thus to be exercised prove an agent of beneficence, diffusing light and life among nations, or shall it be the opposite?

The time must come ere long when wealth shall outgrow the field in which it can be profitably employed. In what direction shall its possessors then look? Shall they train a posterity which will so use its power as to make the world better that it has lived in it? Will the future heir to great wealth prefer the intellectual life to the life of pleasure?

We can have no more hopeful answer to these questions than the establishment of the University of Chicago in the very focus of the commercial activity of the west. Its connection with the great Yerkes observatory suggests some thoughts on science as a factor in that scheme of education best adapted to make the power of a wealthy community a benefit to the race at large. When we see what a factor science has been in our present civilization, how it has transformed the world and increased the means of human enjoyment by enabling men to apply the powers of nature to their own uses, it is not wonderful that it should claim the place in education hitherto held by classical studies. In the contest which has thus arisen I take no part but that of a peacemaker, holding that it is as important to us to keep in touch with the traditions of our race, and to cherish the thoughts which have come down to us through the centuries, as it is to enjoy and utilize what the present has to offer us. Speaking from this point of view, I would point out the error of making the utilitarian applications of knowledge the main object in its pursuit. It is an historic fact that abstract science—science pursued without any utilitarian end—has been at the base of our progress in the utilization of knowledge. If in the last century such men as Galvani and Volta had been moved by any other motive than love of penetrating the secrets of nature they would never have pursued the seemingly useless experiments they did, and the foundation of electrical science would not have been laid. Our present applications of electricity did not become possible until Ohm's mathematical laws of the electric current, which when first made known seemed little more than mathematical curiosities, had become the common property of inventors. Professional pride on the part of our own Henry led him, after making the discoveries which rendered the telegraph possible, to go no further in their application, and to live and die without receiving a dollar of the millions which the country has won through his agency.

In the spirit of scientific progress thus shown we have patriotism in its highest form—a sentiment which does not seek to benefit the country at the expense of the world, but to benefit the world by means of one's country. Science has its competition, as keen as that which is the life of commerce. But its rivalries are over the question who shall contribute the most and the best to the sum total of knowledge; who shall give the most, not who shall take the most. Its animating spirit is love of truth. Its pride is to do the greatest good to the greatest number. It embraces not only the whole human race but all nature in its scope. Should you ask me how it is in the future to use its influence for the benefit of humanity at large, I would say, look at the work now going on and study its spirit. Here are the agencies which will make "the voice of law the harmony of the world." Here is the love of country blended with love of the race. Here the love of knowledge is as unconfined as your commercial enterprise. Let not your youth learn the forms of vertebrates and the properties of oxides, but rather to imbibe that catholic spirit which, animating their growing energies, shall make the power they are to wield an agent of beneficence to all mankind.

CHEMISTRY IN THE UNITED STATES.

BY F. W. CLARKE.

[Frank W. Clarke, chemist; born Boston, March 19, 1847; graduated from the Lawrence scientific school at Harvard in 1867; instructor at Cornell, 1869; professor of chemistry, Howard university, Washington, 1873–74; professor of chemistry and physics, University of Cincinnati, 1874–83; chief chemist United States geological survey since 1883; author, Weights, Measures, and Money of All Nations; Elements of Chemistry; Constants of Nature; Report on the Teaching of Chemistry and Physics in the United States; Laboratory Manual; Elementary Chemistry, etc.]

If we consider the subject of applied chemistry at all broadly, we shall at once see that it has several distinct aims —such as the discovery of new products, the improvement of processes, and the utilization of waste materials. It seeks also to increase the accuracy of methods, to make industrial enterprises more precise, and therefore more certainly fruitful; in short to replace empiricism by science.

It is, perhaps, in this direction that applied chemistry has made its most notable advances in America, and that within comparatively recent years. Three decades ago even our greatest manufacturing establishments employed chemists only in a sporadic fashion, sending occasional jobs to private laboratories, and then only after counting the cost most parsimoniously. Except in a few dyehouses and calico printeries, the chemist was not fully appreciated; great losses were often sustained for lack of the services which he could have rendered, and the cost of goods was, therefore, higher than necessary. By degrees, however, a change was brought about. One effect of industrial competition was to narrow margins and to render greater accuracy of manipulation imperative, and so the chemist was brought upon the scene. To-day it is almost the universal custom among manufacturers to maintain chemical laboratories in connection with their works, and this is especially true with regard to metallurgical establishments, oil refineries, soap, candle, and glass works, in the making of paints, varnishes, and chemicals, and so on in many directions. Even the great firms whose industries are connected with the Chicago stock yards, with their artificial refrigeration and their manufacturing of lard, lard and butter substitutes, meat extracts, pepsin, and fertilizers, all employ skilled chemists and provide well equipped laboratories. In the making of steel and iron the processes are followed by analyses from start to finish, from ore, fuel, and flux, to the completed billets; and the chemists who are thus occupied have gained marvelous dexterity. The analytical methods have been reduced to great precision, and are extraordinary as regards speed, work which once required a day to perform being now executed in less than twenty minutes. Exact measurement has replaced rule of thumb, certainty has supplanted probability, industry has become less wasteful and surer of a fair return, and to all this the chemist has been the chief contributor.

Without his aid the manufactures of the world could never have been developed to their present magnitude and efficiency. His influence reaches even beyond the furnace or the factory and touches the greatest economic questions. Take, for example, the financial agitation through which our country has so recently passed, with its discussion of monetary ratios. Chemical processes have profoundly modified the metallurgy of gold and silver, cheapening the production of both metals and changing the commercial ratio of their values. Can the bimetallic question be intelligently investigated with the chemical factor left out? Furthermore, chemistry has created new industries in which both gold and silver are employed, and so, affecting both supply and demand, touches their ratios still more deeply. When politics becomes true to its definition, when it is really the science and art of government, then we may expect politicians to consider questions like these and to study the evidence which chemistry has to offer.

One other phase of applied chemistry, chiefly developed in this country, remains to be mentioned. In 1875 the Pennsylvania railroad company opened a laboratory at Altoona, in charge of Dr. C. B. Budley; and eight or nine other railroads have since followed its lead. In these railroad laboratories, which employ many men, all sorts of supplies are tested, and large contracts for purchases depend upon the results of analysis. Among the articles regularly examined, preliminary to buying, are iron, steel, various alloys, paints, varnishes, soap, wood preservatives, disinfectants, etc. On the Pennsylvania system alone the purchases controlled by these tests amount to from two to three million dollars annually and the saving to the company is undoubtedly very great. In many cases other purchasers adopt the specifications of the railroad, and base their contracts upon the same standards, the analyses to be made the same way. Adulteration is thus discouraged and prevented, and the moral effect upon the seller, who must be honest, is most salutary. When detection is certain, the temptation to commit fraud vanishes.

To the improvement of analytical methods the railroad laboratories have contributed materially, so that their work has true scientific significance as well as practical value.

Now, although we may properly take pleasure in the advances which American chemists have made, we have no right as yet to be fully satisfied. We have done much, but others have done more, and until we stand in the front rank we should not relax our efforts. The competition of research is fully as keen as the competition of trade and even if we may win the lead we must work hard to keep it. In spite of all that I have said of its growth, industrial chemistry in the United States is still in its infancy, and comparison with other countries is in some respects wholesomely humiliating. England and France have built up chemical industries vastly greater than ours, and in certain directions Germany leads them both. Moreover, the German industries and the trade depending upon them are increasing at a marvelous rate, and in England the chemists at least have taken serious alarm at the growing competition. Branches of manufacture which were once almost wholly English are now mainly German; discoveries which were made in England have been developed in Germany; and now the British economists are seeking the reason.

To the chemist the reason is plain, and is to be found by a study of the two systems of education. The English universities and schools have clung to obsolete methods, and have attached great importance to examinations and the winning of honors. To the honor men positions and preferment are open; but honors are awarded in the wrong way. In Germany, on the other hand, the pathway to success lies through research, honors are given to the men who have increased knowledge, and the effect of this policy is felt by every manufacturer upon German soil. Take, for example, the great chemical works at Eberfield, in which about one hundred scientific chemists are employed, in addition to a great force of laborers. Every one of these chemists received a training in research, every one is expected to make discoveries, and the results of their investigations are immediately applied in the manufacture of new preparations and the improvement of processes. The German employer does not ask the chemist to do for him what he can do already, but rather to supply the greater forces by which he can rise above his competitors and command the custom of the world. To that policy we have not yet fully risen in America; our technical schools have thought too much of routine drill and discipline, and until we have profited by the example of Germany more thoroughly than we have done, we cannot hope to rival her in chemical industries. Our practical men value science for what it can do directly in their interest, and rarely look deeper into the possibilities of abstract investigation. In reality, pure science and applied science are one at the root; the first renders the second possible, and the latter furnishes incentives for the first. Where science is most encouraged for its own sake, there its applications are most speedily realized. This is a lesson which America has yet to learn, at least to the point of full and complete appreciation.

What, now, have we done, and what should we do? We have made a great beginning; we have built up good laboratories, backed by richly endowed institutions of learning; millions of dollars have gone into the teaching of chemistry, and the stream of research flows on with ever increasing volume. American investigations and investigators are well known throughout the civilized world; their credible standing is fully recognized; our analysts are among the best, and yet—and yet—something is wanting. A great mass of good work has been done, beyond question; but no epoch making generalization, fundamental to chemistry, has originated in the United States, nor has any brilliant discovery of the first magnitude been made here. The researches of American chemists have been of high quality, but not yet of the highest; there is solidity, thoroughness, originality, but with all that we cannot be satisfied. The field is not exhausted, there are great laws and principles still to be discovered; the statical conceptions of to-day are to be merged in wider dynamical theories; for every student there are opportunities now waiting. Shall we do our share of the great work of the future, or shall it be left to others. Shall we follow as gleaners or lead as pioneers? He who has faith in his own country can answer these questions only in one way.

At present American chemists labor under some disadvantages which have not been fully outgrown. Research with most of them is at best encouraged, but not expected as an important professional duty. The teacher must first teach, and in too many cases the routine of instruction takes all his strength and time. The resources available for education have been scattered by sectarian rivalry; several schools are planted where only one is necessary, and the teachers, duplicating one another's work and furnished with slender means, cannot specialize. Two chemists dividing the work of one institution can do more than four who labor separately. The field is too large for one man to cover alone, and yet most of our men are expected to do it. This evil, however, is growing less and less, and in time it may cease to operate. With the increase of the true postgraduate instruction, the work of American chemists will improve, for in that part of the educational domain, research is an essential feature. Give our men the best opportunities, the best environment, and they will do their share of the best work.

In one direction, perhaps, the possibility of advancement is greatest, and that is in the institution of laboratories for research. At present the labor of investigation is unorganized, unsystematic—a little here, a little there, but without co-ordination—and consequently our knowledge is after all a thing of shreds and patches.

In making this statement I do not exaggerate. Take any class of scientific data, examine any series of chemical compounds, and note the gaps which exist in it. A chemist in Berlin has studied one of the compounds, another in Paris has prepared a second, many bits of information have been gathered by many individuals, and so knowledge slowly accumulates. The organization of research is to be one of the great works of the future, when discovery shall have become a profession, and groups of students shall co-operate toward the attainment of clearly specified ends. To some extent this work has already been done for astronomy, and more than one observatory could exemplify what I mean. In a fully manned and equipped observatory great investigations too large for one astronomer to handle alone, can be carried out systematically; and this is actually done. In mapping the heavens, even, several observatories can combine their forces, each one covering a definite part of the field; but in chemistry no policy of this kind has yet been possible. The extension of the observatory method to other departments of science is the advance for which I plead.

Suppose now, we had a great laboratory, fitted up for chemical and physical work together, well endowed and well manned, what might we not expect from it? Great problems could be taken up in the most orderly and thorough fashion, methods of work might be standardized, and groups of physical contents determined. The results would aid and stimulate individual students everywhere, and applied science, too, would receive its share of the benefit. There is to-day a growing demand for accurately determined constants, and no institution in which the demand may be adequately supplied. At Charlottenburg, in Germany, there is a beginning; in London the munificence of Ludwig Mond has made possible a similar start; but nowhere is such a plan as I propose in full and perfect operation. The United States has great laboratories, fine museums of natural history, and flourishing universities. Why should it not have institutions for physics and chemistry also? These sciences touch many industries at many points; their applications have created wealth beyond all possibility of computation; now let that wealth do something for them in return. Half the sum that the nation spends in building one battle ship would erect, equip, and endow a laboratory more complete than any now existing, whose influence would be felt throughout all civilized lands and endure as long as humanity. In this the United States might take the lead and set a good example to all other nations. The United States has long been a follower in science; may she soon take a higher place as teacher.

THE AMERICAN SOCIOLOGIST OF THE TWENTIETH CENTURY.

BY MICHAEL A. LANE.

[Michael A. Lane was born at St. Louis in 1867; educated in the classics at the University of St. Louis; studied theoretical biology privately; studied practical anatomy and physiology at the University of Illinois, and, later, practical histology and neurology at the University of Chicago; worked for eight years to identify the facts of social evolution in man and lower animals with the law of natural selection; published his theory in a work entitled "The Level of Social Motion" in 1902; contributor to American magazines, 1893 to 1905.]

Madame de Staël, in her criticism of the manners and morals of the Germans, shrewdly observed the causes underlying the very rapid progress of science in Germany, by noting that the Prussian state, while discouraging political liberty, had always been forward in encouraging intellectual liberty. Free speech, indeed, has been ever the prerogative of the German man of science, and wherever free speech has flourished intellectual progress has been rapid.

There is, however, in the peculiarly rapid development of science in Germany, something more than this German tradition of free speech, and it is upon this significant fact that I wish to touch before speaking of the American scholar.

In Germany there is found a state of affairs not altogether unlike that of ancient Athens, when the philosopher was the most honored of all men. I will venture the assertion that in Germany, during the past century and more, not even royalty itself has been more honored than the eminent scholar. Scholarship is the ideal of the German family, as the ministry is the ideal of the Scotch family. To the idealistic mind of Fichte scholarship was something above merely human, worldly things, and the life of the scholar was a high manifestation of the divine idea. In a people, which, more than a century ago, could produce a man with notions as inflamed as this, there is something that is quite beyond the comprehension of utility—a something that is very difficult for the popular mind in America to understand.

We are often moved to ask the question, Why is it that America has not produced a scholar of world wide renown, whose name is known to everybody that reads the newspapers; a Huxley, a Darwin, a Helmholtz, a Humboldt? Why is it that the United States has not been able to give birth to a man of science from whose work a new period of knowledge is dated, with whose discoveries a new vista of nature has been opened up to the human eye?

I think an answer to the question will be found if we turn to the achievements of American genius in that line which is peculiarly America's own. We are an industrial people; hence we have produced the greatest masters of industry in the history of the world. We are a busy people; hence we have produced men who, by their ingenious inventions, have doubled the productivity of industry and reduced the working time by one half. We are a wealth loving people; hence our ideal has been that of commercial supremacy for the nation and of fortune for the individual man.

In these circumstances it could hardly have been expected that we had been competent successfully to cultivate in our intellectual garden such rare plants as the great men whose names are mentioned above; nor is it any derogation of our dignity that such is the fact.

And yet, within comparatively recent years, there has grown up in America a cult—if I may so call it—which promises, with time, to produce a scholar who will take his place beside the fathers of supreme generalizations, and who will probably be the first American man of science of that kind.

If we strike out of our considerations a very few of the more widely known American astronomers, the original scientific work thus far done in America will be found to have been done by investigators who have devoted their attention almost wholly to the science of economics and to the broader science that is growing out of economics. I mean that young and vigorous science that is now called sociology. If the United States is to produce a master mind in scholarship, I fancy that it will be in this line, or rather that the first of the great American scholars of the future will be a sociologist. There are many excellent arguments to support this view, the principal one of which lies in the fact that sociology is, in a way, a science which finds its richest fields and its most numerous cultivators here in America. The richest and strongest growths in art or in science are always found upon the soils in which the seed first sprouted. For science cannot be learned out of books any more than art can be mastered in the same way. This truth finds its vindication in the fact that our physicists, physiologists, anatomists, pathologists and chemists, go abroad for their finishing touches. The sciences named have been born and have grown up in Europe. All the new methods of research—or virtually all—have been originated in Europe, and in Europe alone can the student find the masters, or the men who have had the advantage of working with the masters, and in this way have perpetuated the methods of the masters or improved upon them. Art and science are thus handed down from generation to generation, and with every new generation new and better methods originate, and wider knowledge and capacity ensue.

Now here in America sciences, for the most part, are only transplanted. Our work has been more in the way of imitation than of origination, and such origination as we have been able to make has been largely of an utilitarian kind. Scientific research—with a few notable exceptions, such as in astronomy—has the stamp of utility upon its forehead. It is essentially Baconian. It is founded upon the practical bearings of society rather than upon pure intellectualism. And even in the case of astronomy and physics our work has been of a corollary nature rather than of a kind comparable with the great achievements of European scholars in times past and present. And the immediate outlook for the development of really prime research is not particularly bright.

In sociology, however, we have a very different story to tell. A noted European sociologist, not very long ago, remarked to me that in America alone there existed an intimately associated body of thinkers who were capable of receiving and appreciating any considerable theory of social life and laws; that here alone was the soil from which would grow up a scientific method whereby man would be led to know himself socially as in Europe he had been led to know himself individually. And as America is the true cradle of sociology, so we may rationally expect that here the baby will grow up into the matured and strong science.

In his great work, Political Science and Constitutional Law, Prof. John W. Burgess of Columbia university, modestly calls attention to the interesting fact that he had been compelled to originate a new terminology in order clearly to set forth the ideas he had elaborated concerning the natural causes that underlie the evolution of government. The work in question has been variously criticized, but so far as I know there is no single work that could take its place were it once eliminated from our American libraries. Professor Burgess writes as a lawyer, and perhaps there are those who will look askance at our classification of him here with American sociologists, but I fancy there is no American sociologist but will agree that Political Science and Constitutional Law is par excellence a sociological work which can be separated from the science of sociology no more than the work of Harvey or of Boyle can be separated from physiology or chemistry.

I doubt gravely whether any British or continental authority can wholly appreciate the long step forward which Professor Burgess has taken, and what I say here of Burgess may be repeated of a few well known American scholars in political economy. We all know that Plato could not imagine a state of society without slaves; and this broad fact will doubtless assist us in understanding the more modern fact that the European economist, historian, and sociologist are unquestionably the product of their environment, quite as much as Plato was of his own.

In surveying the broad stream of political progress in America, Burgess was deeply impressed with a succession of singular facts which were taken into account nowhere in the previously written literature of his subject. Here was a mass of facts, or more properly speaking, a continuous movement or procession of social facts, unclassified, unnamed, and in a word, wholly unrecognized as yet, in any methodical or scientific way. And why? Simply because the facts which Burgess saw were new. Now, facts, or new perceptions of familiar facts, require a new terminology the very moment we try to correlate them or trace out their causal nexi. And in doing this work Dr. Burgess has made for himself a niche rather high up in the temple of early American scholarship.

If political science in Europe cannot understand, in its full meaning, the highly original work Professor Burgess has done, so may we say that political economy in Europe cannot fully comprehend the work that has been done by American economists. Jenks of Cornell, whose name is associated rather closely with examination of this phase of modern industrial life, has made many suggestions of preparatory value, and Clark of Columbia has made a noteworthy attempt to trace down all processes of labor and capital to their roots in primitive conditions; and this contribution of Clark's is perhaps the broadest contribution as yet made to the philosophy of economics. If we now make due note of the fact that Dr. Ely of Wisconsin has suggested the possibility of competition in a state of society closely bordering upon socialism itself, we have taken a glance, I believe, at the most conspicious original work that has been done by American scholars in political science and political economy. Before leaving these topics, however, perhaps it would be well to say a few words in reversion to the bearing of freedom of speech upon intellectual progress.

Speech from the chairs of political economy in America has been anything but free. That important fact is due, oddly enough, to the more remote fact that in America we live under a democratic rule. So far as legal freedom goes, why, of course, the teacher can say whatever he likes. But in a democratic community the real rulers are the people and not the central mechanism called government. No government in America could guarantee a chair to that professor who would teach or publish views conflicting with the personal opinions of the men who pay the bills for the school. We all remember how, a few years ago, Dr. Andrews was disciplined for advocating free silver. And it is natural that the rich men who are supporting an university should feel that they ought to be given something to say about the doctrines taught in the school. Had we a king, or an emperor, here, who could overrule such a state of affairs, perhaps many of our economists would be more outspoken.

There is a smack of the Spanish inquisition about the fact that a great university will close its libraries to a book of world wide repute simply because the book is denunciatory of certain great companies of capitalists called trusts. Why should any university bar out of its library a work like the late Mr. Lloyd's Wealth versus Commonwealth, when this very work is indispensable to the scholar who would compile a history of the trust movement in America?

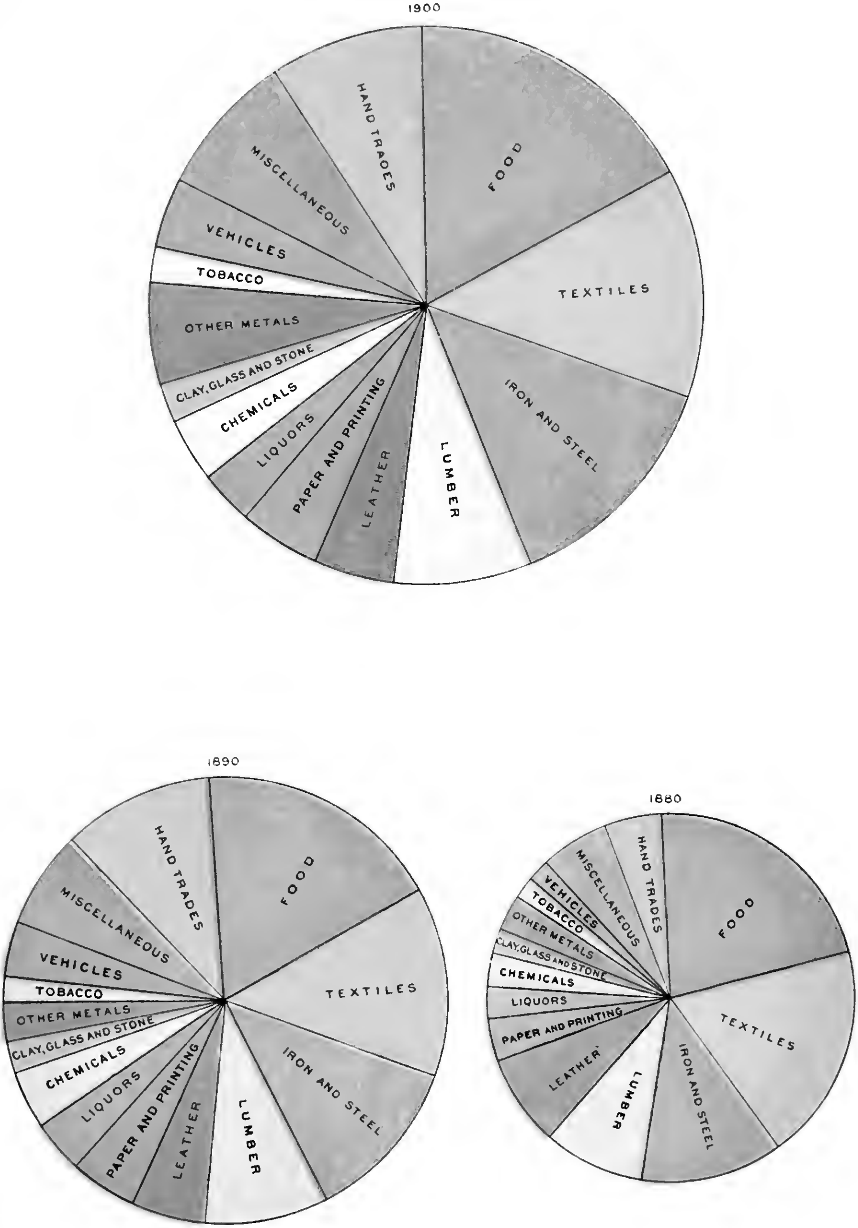
The political economist in America suffers from this sort of lordship which, while it lasts, will have a deterrent effect upon the rapid progress of original work in economic science here at home.

American sociologists, however, have no general complaint to make in this respect; chiefly for the reason that much, perhaps all, of their philosophy is quite beyond the ken of the average capitalist, howsoever rich, and secondly, because the American sociologists have not yet turned their hand to a serious consideration of the trust in its purely sociological bearings.

The truth is that American sociologists are not yet ready to consider the trust and the labor union as specific causes in social progress. I am convinced that this work is reserved for the younger generation of sociologists. The present leaders of American thought in this line began their work more than twenty years ago and they began at the bottom. Practically, they had to clear the ground for the new science which they saw and knew must come and come with comparative swiftness. It was not a question of soll und haben they were confronted with, but rather with the most difficult task conceivable, namely, of reducing to order, or to something akin to order, the bewildering complexities of the motions of human society, not only, but of all social action wherever found.

In doing this they found that they were led backwards instead of forwards; downwards instead of upwards; outwards instead of inwards. They found that properly to understand such a simple thing as the reason why women weep spontaneously at a funeral—quite without regard to the relationship of the dead person to themselves—they were compelled to dig up the entire zoölogical history of the human race and to

VALUE OF ALL MANUFACTURED PRODUCTS AND PROPORTIONAL VALUE OF EACH GROUP: 1880 TO 1900



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open up a sort of cosmic science that led them every whither into all sorts of remote places, and into the most discouraging deviations from commonplace things.

A case in point is that of Professor Mark Baldwin's Theory of Imitation in which the profound psychologist attempts to explain social action by a theory, which, if logically followed up, will land us cheek by jowl with the radioactivity men and the physicists.

There is one American sociologist who deserves special mention in this huge work of pioneering; and I venture the prediction that a century from now his name will be a thousand times more widely known than it is at present in his own day. The man to whom I refer is Lester F. Ward, the tireless and highly original scholar of the Smithsonian institution. Professor Ward, we may say, was the founder of American sociology; or let us say that he was the first American to attempt a rational inquiry into causes and to suggest a practical method by which human society could reach a stable and physiologically satisfactory state. Ward's now famous book Dynamic Sociology was published more than twenty years ago, and although it was widely read it did not sell like a successful historical romance. It is essentially a pioneer work and the stamp of originality it bears is found in the new terms which the author found needful to create for his peculiar purpose. Since the first publication of Dynamic Sociology, Ward's ideas have expanded in every direction, but I think he will bear me out when I say that his original practical idea has remained unchanged. A study of Ward's work impresses the thoughtful reader with the notion that under his euphemistic term collective telesis, there abides a socialism far deeper than any socialism that has as yet gone current by that name.

In plain speech, telesis is a process of doing something from a distance. The management of a great business by the individual who owns it would be, I take it, individual telesis. What then are we to understand by collective telesis?

Ward is not only too deep for the average man, but he sometimes offers the specialist a rather hard nut to crack, and his implied conclusions are often too difficult for the busy man to work out for himself. And yet, he who even glances over the works of this singular man feels instinctively that there is a powerful, original and bold mind at work here; and a mind too that approaches its subject reinforced with a knowledge of the older sciences rare among men. In his last work of note, Pure Sociology, Ward considers the science of society apart from dynamics—to use that word in the Wardian sense.

This work—with one exception, which I shall speak of later—is perhaps the largest single contribution to the critical literature of sociology and is already a classic. It is to the future perfected sociology what the works of Galen, or better still, the works of Vesalius, are to modern anatomy; and Ward can be (and in the future will be) classified with pioneers such as Vesalius, Schleiden, Linné, and others in the zoölogical sciences. Ward, like most men of his peculiar kind, is a vigorous, combative, highly critical, indefatigable and above all voluminous writer. The most picturesque of American pioneers in sociology, he is at the same time a botanist of considerable ability and his work in the Smithsonian institution is that of a botanist. His work in sociology, so far as it is possible to see from a distance, is a work of love. This versatility will be recognized as the common possession of most originals in science.

Ward, I believe, is the only prominent sociologist who does not occupy a chair of a university. American sociologists for the most part are teachers in universities and colleges, and although few of them have the picturesqueness and the pungency of Ward, many of them are not without their own peculiar originality, force, and charm. There are perhaps ten such men in America, and of these the one next to Ward, who has probably done the most original and striking work, is Professor Simon N. Patten of the University of Pennsylvania.

Like many of the later acquisitions to the cultus of American sociology, Patten was formerly an economist, and of very recent years, I am told, he is reverting to that science, taking with him the larger views he gained in his long and painstaking investigations as a sociologist. Patten writes books. In his own words, he has "recently taken to a book writing epoch." I have not read all his productions, but in the comparatively large amount of his writings that have come before me, I have been struck by two salient ideas which seem to me to be ideas of prime order. The first is the peculiar importance he attaches to fire, not only in its function as an instrument, or means, of economic progress, but also to its purely emotional value and significance in domestic and religious life. We have here a notion that carries us far back in the phylogeny of the human race and that binds together things very remote from one another in point of historical time and of the geographical distribution of men upon the earth. Patten has paid some attention to the nervous system and is familiar, in a superficial way, with the nervous mechanism and some of its more obvious workings. His principal work (although a small one) is The Theory of Social Forces, in which he suggests the second of his two prime ideas mentioned above. This is the quite simple and highly significant fact that social environment continuously changes (in a static condition) without an accompanying change of place whereupon the society lives. Patten does not develop this idea, although it is difficult to understand how a man who could be struck with the fact would not be led to pursue it. Patten, in fact, has bridged over the gap between the societies which have a history and those which have not. He apparently did not see the social importance of fire as an instrument which would of necessity compel men to wander from warm into colder climates and thus make possible the development of the tall, blonde, dolichocephalic races of northern Europe; nor has he seen fit to connect the idea of fire with his earlier investigations into the spatial relations of the environment to man. But even if we overlook this neglect, we cannot but admire the depth of his thought and the singularity of his observations as a sociologist. If there be a man in America who deserves the title American Scholar, and deserves it without qualification, Dr. Patten is unquestionably fit for that honor.

The mention of Dr. Patten's name suggests that of his neighbor, Professor Giddings of Columbia university. Giddings, more than any other one man in America has attempted to lay down a complete sociology without once discussing method. In this respect he differs from most of our sociologists who have not tried so much to do something as tried to tell others how to do something. Giddings has been a great gatherer of facts and he has assembled his facts with very great power. He has suggested that a reduction of population will be brought about—if it is not now being brought about here in America—by the high tension under which Americans, as a people, live. But perhaps this is his only speculation on the future. His main thought has been directed toward an effort to synthesize or systematize the main facts of anthropology, so as to give us a complete social interpretation of these facts; in other words he has attempted to construct a theory of social phylogeny, much as the zoölogists have constructed an organic phylogeny.

Another American sociologist who has made an attempt to correlate human facts is Professor Ross of Nebraska. Ross was a sufferer from democratic institutions, as noted above, for he was closed out of his chair at Leland Stanford, Jr., university because of his endorsement of the popular prejudice against Chinese labor. Those who have an eye to history can see in Ross the martyr of reform, who, in all times and countries, suffers for his opinions. The impression I have always received from the writings of Ross is that of a young scholar entirely devoted to his work; realizing to the utmost the perfect truth of a new iconoclasm, and endeavoring like Des Cartes, to carry water on both shoulders. In short Ross reduces God to an idea, and then goes on discussing God long after everybody has forgotten his original definition.

It is difficult to put an estimate upon his one work, Social Control. I am not sure that I have been able to understand that remarkable book. I read it in the installments published in the American Journal of Sociology, and subsequently reviewed it between its covers as a book; but if Ross has done more than demonstrated his extraordinary mastery of the English language, and his ability to say the same thing in ten or fifteen wholly different periphrases, I have not had the competency to take it in. He seems always upon the verge of laying his hand upon some mighty correlation which always escapes him, like the grapes of Tantalus. And yet a review of American scholarship would be incomplete without mention of Ross.

Of the younger men perhaps Professor Ellwood of the University of Missouri is the most forward. Ellwood has studied sociology to some purpose. He is, it may be, the only one in America who seems perfectly convinced that human society must be regarded as being constructed essentially on the plan upon which the individual man is constructed. He seems to be convinced that when we have found out the why and the how of human society we will have found out that society is a great individual in itself—an indivisible organic being with parts so closely related that certain of them cannot be removed without causing the death of the whole body. Ellwood is an earnest, careful worker, intently busy with vast conceptions which are slowly taking form and outline in his fruitful mind and which he will probably publish some day in a form which will mark a new epoch in social science.

Critical sociology in America has its two apostles. With one of these we have met in the personality of Lester F. Ward. The other is Albion W. Small, of the University of Chicago. Dr. Small has not, like Ward, contributed in a concrete way to the sum of sociological investigation, but his influence as a maker of sociologists has been incalculable. He is a sharp, unbending critic, perfectly careless whom he hits, perfectly content with his own views of the work of others. His one great critical work is that in which he outlines the method of sociology after the manner which Bacon uses in Novum Organum. I doubt whether Small had the slightest notion of Bacon in his mind when he wrote his methodology. It is probable that Small's work was as spontaneous and original a conception as was Novum Organum itself. How indeed can we doubt it when we consider the fact that sociology at present is very much in the same formative, growing condition as was that of science at large in the time of Bacon. For a score of years Dr. Small has stood at the gateway of sociology in America and challenged everybody who would enter the academy. A vigorous bold man, as ferocious in his criticism as he is gentle, one is informed, in his private life.

The above mentioned men are the leaders in sociological thought in America. As teachers they dominate the rapidly growing cultures and their influence extends abroad, not so much to Great Britain as to continental Europe, where is found here and there in some university a sociologist so called.

These scholars meet in two fora. One is the American Journal of Sociology, edited by Dr. Small, who is advised and assisted by a large corps of sociologists in America, reinforced by a few distinguished professors in European universities. The other forum is the celebrated Journal, or Annals, of the American Academy of Political and Social Science. The academy was founded several years ago by Edmund J. James—at present the president of the University of Illinois, more recently president of Northwestern university, and formerly head of the political science department of the University of Chicago. For some time during its earlier life the academy, like many institutions of its kind, had a struggle for existence; but the tentative stage of its life was happily passed and to-day it is a living factor in the intellectual growth of the country. It is a record of the best thought in sociological speculation and many of its contributions come directly from economists. Its strongest rivals are the Political Science Quarterly, Quarterly Journal of Economics, Yale Review and the American Journal of Sociology. But it is not unfair to say that the Annals will live long as the earliest records of the formative period in American speculation upon the larger questions of social science.

The discussions carried on in the Journal and in the Annals can hardly be said to be of a popular character. The new science of sociology has its special terminology and its own peculiar concepts, and an understanding of the discussion implies considerable study, if not a special training. Many of the papers published in the Annals and in the Journal are really adventitious—that is to say, they emanate from men who as lawyers, business men, or financiers, imagine they have something of value to say in the general round-up of opinion. The free publication of such inexpert views only goes to prove the rather diffuse character of sociological thought at the present time. It proves that sociology is to-day in the same broad channel in which the sciences of physiology, anatomy and chemistry ran three or four centuries ago. Early in the sixteenth century the study of anatomy was really a popular pastime, in which any man who was in the humor could constitute himself an original investigator. Anatomy was a popular amusement, and lectures in anatomy were given freely before lay audiences. At the same time, the specialist was beginning to emerge, and specialism became more and more prominent and esoteric as the sum of anatomical knowledge increased.

Now the very same is true of the new science of sociology here in America. The public is rapidly becoming possessed of a curious interest in the causes of social phenomena, and in the structure of the body social, and the social philosopher is listened to with attention wherever he can be induced to make a public address or to share with the laity some of the fruits of his thought. But the prospect is that sociology, like anatomy, will soon pass beyond the reach of the popular mind, even in its simplest conceptions. Indeed, we may say that in its deeper currents it has already acquired a highly esoteric character. This esotericism must inevitably increase with time, and this increase in specialization will only serve so to narrow its channels that it will ultimately become a science for the very few who will devote themselves to its special cultivation.

A severe criticism, perhaps, may be made upon the view of American scholarship taken in this paper. It may be argued that to prefer the sociologists mentioned herein to the world renowned statesmen and jurists produced by the United States, is narrow to an intolerable degree. And yet if the matter be sifted out it will be seen that the view here taken of scholarship is necessary and logical. It is a fact that this soil has given birth to no science; that it has produced no great generalizer, of a fame commensurate with that of the European masters. The scientific work of the world is done to-day in Europe and not elsewhere. Scientific traditions exist in Europe only. If there is any scientific tradition whatsoever in this country it is economic and sociological. In this country alone abides an institution such as the American Academy of Political and Social Science. Here only has every university a chair of sociology, and if America is destined to produce a scholar who will take his place beside the great ones of the past and present, in what science are we to look for him to arise if not in this?

WIZARD OF THE GARDEN.

BY HOLLIS W. FIELD.

[Hollis W. Field, author and editor; born Williamsburg, Mo., April 10, 1865; educated in the public schools of Missouri; began his career as a writer on the Kansas City Times, and afterwards became city editor of the San Antonio Express; removing to Chicago, he became connected with the Chicago Record, of which paper he became editorial writer and literary editor; writer of many articles for magazines and periodicals, chiefly on scientific and business topics.]

Considering mother nature as occupying a distinct personality with some of the characteristics of her human progeny, perhaps nothing since the exposures made by Darwin could be better calculated to disturb the equanimity of the old lady than to be shown a white blackberry. Not that Luther Burbank of Sonoma county, Cal., has not been exhibiting even stranger things to the old dame, but in the white blackberry the practical joke is so markedly evident from Mr. Burbank's own explanation of the circumstance, that mother nature has had every reason to rise in her wrath and administer a rebuke that is lasting.

"I made the experiment merely to satisfy my own curiosity," said Mr. Burbank, smiling upon a laden bush bearing the phenomenal fruit. "It is simply the inverse application of the Darwinian philosophy. I kept on selecting berries which, in ripening, did not turn pure black, and it was only a matter of time and selection until I had a berry which passed from its grass green immaturity to the pure white of ripened flavor."

But he is more than a joker—more than an experimenter in the mysteries of plant life. Forty years ago he had given the Burbank potato to the western world as his first practical contribution to the world's commissary, and through these later years, in which he has earned the title of Wizard of the Garden, he has kept before him the time when man shall "offer his brother man, not bullets nor bayonets, but richer grains, better fruits, and fairer flowers." That he has before him the utilitarian values of his knowledge may be seen in his utterance:

"It would not be difficult for a man to breed a new rye, wheat, barley, oat, and rice, each of which would produce an average of one more grain to each head, one more grain could be added to each ear of Indian corn, and in like manner another potato could be added to each hill. Yet think of the results in the granaries of this country alone! In only five staples we should have annually, without effort and without cost, more than 15,000,000 additional bushels of wheat, 20,000,000 bushels of oats, 1,500,000 bushels of barley, 5,200,000 bushels of corn, and more than 21,000,000 bushels of potatoes."

Yet this busy man has neighbors in adjoining fields who look over his boundary fences to see the thin, stooped figure, whom they recognize as having fooled away a lot of time producing a fadeless flower, and as they look they smile commiseratingly, in spite of the fact that last year his Santa Rosa farm received a pilgrimage of 6,000 men, many of them the pick from the scientific life of two hemispheres.

On this California farm Mr. Burbank has produced more than 2,000 varieties of vegetables, fruits, and flowers, in some of these demonstrations breaking all traditions of the florist and gardener regarding the production of new species. Some of the cuttings from his plants have sold readily at $100 a running foot. A rose plant brought $800 from a seed house, while the right of exclusive handling and sale of a single new variety has brought thousands of dollars. In spite of this, however, the Sonoma county farm frequently has brought the wizard of the garden into debt, and recently the Carnegie institute, recognizing the work of the man, set aside $10,000 a year for ten years to further his efforts.

How much time and patience and active effort are exacted from the man may be suggested in his production of the white blackberry. Mr. Burbank has said that he did this for his own curiosity, yet before he found the first blackberry bush with a fruit at all lighter than the normal he had examined 25,000 of these bushes in bearing. Seventy five thousand other bushes were subjected to the same patient scrutiny and selection, to say nothing of patient crossings and fertilizers, until at the end of three years of effort he had the white blackberry, which after all was merely to satisfy his curiosity.

Ten years were required to produce a cactus that was without thorns and spines, yet in the production of this species, which shows no disposition to revert to its former armored state, the western desert country may become a paradise for the herds of the rancher. Not only have these cacti become easily edible for stock, but in the processes this desert plant has increased in nutritive qualities as a plant, while the fruit which it bears is of a flavor to appeal to the palate of a Lucullus.

In the consideration of the cactus Mr. Burbank had sought the reason of the thorns. The habitat of the plant being the barren desert sands, where scant nourishment was to be found for itself, and where, on the other hand, the herbivorous creatures that might have need of sustenance might so prey upon it as to destroy the species, the plant had need of its prickly weapons of defense. Putting the plant into an environment where no natural protection was demanded for it, nature was brought to understand that she need not waste her strength upon the growth of a useless armor. For this armor will remain useless when the ranchman once takes the plant under his selfish protectorate.

Burbank's hybrid English walnut is regarded as one of his most extraordinary accomplishments in the development of a food to the best advantages of the needs of man. The English walnut long has been one of the most valuable of after dinner nuts. Those who have not cared for it as a food, ordinarily have found objection to its bitterness. When Mr. Burbank undertook to improve the nut his object was to eliminate the hard husk in the kernel, thus destroying the bitter after taste, to increase the size of the fruit, and incidentally to make the shell thinner. All of this was done to the point of making the shell so thin that the birds broke into the kernels, necessitating the breeding back to a stronger shell. And, above all, he brought the walnut tree to a rapidity of growth and bearing in which it leads any other known tree in the temperate zones of the world. This tree at six months old has borne nuts.

To eliminate seed from a fruit is one of the easy propositions which has confronted Mr. Burbank. To change size and color of a flower and to intensify an odor that has proved pleasing and yet elusive, have been labors of love with him. A seedless prune is an accomplishment appreciated in California horticulture. His plumcot, obtained from the crossing of the plum and prune, is a new fruit with a flavor that is all its own.

From one of his developed plum trees on one occasion 22,000 green plums had to be stripped from the overburdened branches in order that the tree might develop properly its normal load of plums. The late Cecil Rhodes in South Africa received from Mr. Burbank some plum trees which were set out in Rhodesia and from which Mr. Rhodes afterward sent fruit in a basket to Mr. Burbank at San Francisco, the plums arriving in perfect condition after a voyage of 18,000 miles.

How were these things accomplished?

Through a knowledge of plants gained through his own painstaking efforts, many of these serving only to overturn principles and theories that had been advanced by others before him. He recognizes the importance of the old phrases natural selection and survival of the fittest, but above these in importance and effectiveness are the most artificial of crossings.

It is in this crossing of species that he breaks up the tendencies of a plant's life through all its ages of environment, habit, and heredity. Not in the first generation may the sharpest variations appear, but in the succeeding generations those mutations and variations that are prompted by heredity far back into either branch, may be expected to develop, often in wholly unexpected forms. All characteristics which are thus transmitted, he holds to have been acquired, and in the crossing he hastens processes which nature, unaided, might be thousands of years in bringing about.

Mr. Burbank recently has been at work upon the tobacco plant with a view to increasing its size, improving its flavor, and at the same time making it responsive to wider climatic zones. A plant ten feet high, with leaves two feet wide and four feet long has resulted.

HISTORY OF ELECTRICITY IN AMERICA.

BY GEORGE HERBERT STOCKBRIDGE.

[George Herbert Stockbridge, electrical engineer, born July 2, 1863, at Cincinnati, O.; educated at Ohio state university and the Massachusetts Institute of Technology; entered upon the practice of his profession as electrical engineer, to which he has devoted most of his business life, though occasionally writing articles for technical and general periodicals.]

It happens that the first great name in electrical science in America is one of the first and greatest in electrical science everywhere. Benjamin Franklin began to devote himself to electrical studies at a time when scarcely more than half a dozen investigators had contributed anything of permanent value to the science; while his hypothesis of a single electrical fluid subsisting in positive and negative states marks a turning point toward the modern science, and his demonstration of the identity of lightning and electricity outranks in popular and scientific interest every experiment before or after, prior to the discovery of current electricity by Volta and Galvani, fifty years later. Priestly says of his theoretical work: "Dr. Franklin's principles bid fair to be handed down to posterity as equally expressive of the true principles of electricity, with the Newtonian philosophy of the true system of nature in general." Beyond such praise as this it is impossible to go; but Dubourg justifies it when he says that the doctrine of Franklin taught us to discriminate and to foresee. The course of scientific progress from the beginning until now has been lighted from point to point by a few golden lamps answering to that simple touchstone of Dubourg's. No wonder Priestly thought of comparing Franklin to Newton, as an Italian might have likened him to Galileo, or a German to Kepler and Copernicus.

The circumstance that Franklin's work was done in the early and elementary days of electrical knowledge adds to the audacity of his famous experiment with the kite; which quality was, indeed, from the first, one of the chief reasons for the great popularity of that particular piece of history. Franklin was fortunate in having demonstrated an important scientific truth in a manner which appealed to the imagination, and for this reason the unscientific mind was more impressed by it than by any other discovery in natural philosophy during the 18th century. "The Philadelphian experiments," says the Abbé Mazéas, in a letter which was read to the Royal Society in May, 1752, "having been universally admired in France, the king desired to see them performed."

It has been characteristic of electrical discoveries from the beginning that they have lent themselves to startling effects; but this experiment of drawing lightning from the clouds involved the human interest quite as strongly as the scientific. It was not alone a scientific achievement; it was an act of personal daring which, in the public mind, at least, approached very near to the moral sublime. Hence it is the one portion of electrical history with which everybody is familiar.

The earliest reference in Franklin's writings to the notion which afterwards led to his experiment appears in his note book, under date of November 7, 1749, as follows:

Electrical fluid agrees with lightning in these particulars: 1. Giving light. 2. Color of the light. 3. Crooked direction. 4. Swift motion. 5. Being conducted by metals. 6. Crack or noise in exploding. 7. Subsisting in water and ice. 8. Rending bodies it passes through. 9. Destroying animals. 10. Melting metals. 11. Firing inflammable substances. 12. Sulphureous smell. The electrical fluid is attracted by points —we do not know whether this property is in lightning. But since they agree in all the particulars wherein we can hardly compare them, is it not probable that they agree likewise in this? Let the experiment be made.

At this time, Franklin had been engaged for nearly three years in the most absorbed pursuit of electrical experimentation, which commenced when his friend Peter Collinson, a Fellow of the Royal Society, sent from London to the Library company in Philadelphia an "electrical tube," about the beginning of the year 1747. In a letter to Collinson, dated March 28, of that year, Franklin declares that he has already become wholly given up to the study of electrical phenomena. He says:

"For my own part, I never was before engaged in any studies that so totally engrossed my attention and time, for what with making experiments when I can be alone, and repeating them to my friends and acquaintances, who, from the novelty of the thing, come continually in crowds to see them, I have, during some months past, had little leisure for anything else."

From this time on for several years, his letters to Collinson are filled with wonderfully clear details of numberless experiments coupled with brilliant deductions and speculations of a scientific nature. Here, in this offhand, private correspondence, Franklin sets forth the doctrine which was to change permanently the course of electrical science, and describes the most remarkable electrical experiment that was ever tried.

Through Collinson, accounts of Franklin's work were laid from time to time before the Royal Society, where, however, they excited little favorable attention, and in some instances derision. Franklin's suggestion of the possibility of rendering lightning discharges harmless by conducting them through an easy medium to the earth was the subject of special hilarity on the part of Collinson's learned associates. Collinson himself seems to have held his friend's labors in high esteem. At all events, through him Franklin's letters were published in London, though without the authoritative inscript of the Royal Society. In this form, or, rather, in the form of a bad French translation, they came under the eye of the celebrated French naturalist and philosopher, Buffon, who at once saw their value, and advised that an accurate translation be made. And the reputation which Franklin thus, and by his later scientific work, acquired in France contributed not a little to his influence in after years when he appeared at the court of Louis the Sixteenth in the rôle of a diplomat.

It was in this roundabout way that the French savants learned of Franklin's determination to test the identity of electricity and lightning by actual trial; for, closely following the note book entry in November, 1749, were letters of Collinson, enlarging upon the idea and suggesting ways of carrying it out. The correspondence shows that the notion was gradually approaching the moment of fructification. Notably in a letter of July 29, 1750, Franklin gave the complete details of a plan for making the test. He says:

"To determine the question whether the clouds that contain lightning are electrified or not, I would propose an experiment to be tried where it can be done conveniently. On the top of some high tower or steeple, place a kind of sentry box, big enough to contain a man and an electrical stand. From the middle of the stand let an iron rod rise and pass bending out of the door, and then upright twenty or thirty feet, pointed very sharp at the end. If the electrical stand be kept clean and dry, a man standing on it, when such clouds are passing low, might be electrified and afford sparks, the rod drawing fire to him from a cloud. If any danger to the man should be apprehended (though I think there would be none), let him stand on the floor of his box and now and then bring near to the rod the loop of a wire that has one end fastened to the leads, he holding it by a wax handle; so the sparks, if the rod is electrified, will strike from the rod to the wire and not affect him."

The French publication of Franklin's letters led to the curious result that his suggested plan was first tried in France, and not in America. Both Monsieur d'Alibard, at Marly, and Monsieur de Lor, at Paris, preceded Franklin in carrying out the experiment which owed its suggestion to him, but with a generosity not always shown in similar circumstances, Monsieur d'Alibard admitted that he only carried out Franklin's proposition, and French writers generally have not attempted to obscure Franklin's part in the results. The mode of procedure of both the French experimenters was, indeed, so similar to that suggested by Franklin, that it would have been hard to make a denial of their indebtedness to him appear credible. The report of the Abbé Mazéas to the Royal Society, already quoted, related to the Paris and Marly trials, yet he mentions them as the "Philadelphian experiments."

The real "Philadelphian experiments" were made about a month later, and were modestly announced to Peter Collinson by Franklin, under date of October 19th, 1752.

Franklin gives a characteristic account of the foreign publication of his letters, the close of which reminds us, though in much better temper, of certain recent complaints in literary quarters on both sides of the Atlantic. After saying that the papers were first shown to Dr. Fothergill and that he "advised the printing of them," he adds:

"Mr. Collinson gave them to Mr. Cave for publication in his Gentleman's Magazine; but he chose to print them separately in a pamphlet, and Dr. Fothergill wrote the preface. Cave, it seems, judged rightly for his profession; for, by the additions that arrived afterwards, they swelled to a quarto volume, which has had five editions, and cost him nothing for copy money."

In his new discovery, Franklin immediately saw the means for producing something "of use to mankind," which, as he had written to Collinson in April, 1749, he was "chagrined a little" that he had hitherto been unable to do. His speedy invention of the lightning rod gave to the world the only apparatus directly applicable to the service of man that has ever yet been devised for utilizing or controlling any of the forms of electricity known to Franklin and his contemporaries. In this haste of the philosopher to make his discovery serve a practical end, we recognize the man, Franklin—the man who exhibited in so many ways the characteristics of a later time—the twentieth century American. Scientist and engineer, literary man and journalist, philosopher and man of affairs, Franklin was by nature what society and the growth of the great newspapers, and the stimulating rewards of the patent system make so many of his successors. Franklin's discussions of the single fluid theory of electricity and his whole writing upon the subject of his electrical labors show that he possessed in a large degree the scientific mind. But he also had the inventive faculty and the will to exercise it. The natural union of these attributes is not so common as might seem to one of our generation. The modern way of life tempts every scientific searcher to turn his laboratory into a workshop, just as the allurements of journalism tempt the majority of the poets and historians away from their natural callings. A sure sign of the tendency here pointed out is that, whereas the main and almost the only sources of information about scientific progress used to be the transactions of royal or similar societies, or the technical press, these enlighteners of the public mind now lag behind the patents, which might otherwise be endangered. But the genius of Franklin was many sided, and as in philosophy and statesmanship one is compelled to admire both the keenness of his insight, and the readiness with which he is able to reduce his philosophy to maxims of statecraft or of personal conduct, so in science one can but marvel at his large comprehension, and at the ease with which he deduces underlying principles or applies them in a perfected apparatus.

William Sturgeon's electromagnet, invented in 1825, consisted of a core of soft iron coated with an insulation of varnish, and wound with a single spiral of bare wire. With his first magnet the inventor sustained a weight of nine pounds. One of the earliest and most important services rendered by Joseph Henry to the progress of electrical knowledge consisted in increasing the capacity of the Sturgeon magnet by winding the core with many coils of wire previously insulated with silk, the spiral being wound as nearly as possible at right angles to the core. Henry began his investigations of the Sturgeon magnet soon after the year 1826, when he became a teacher in the Albany academy; and he pursued them with such success that within five years he had constructed a magnet capable of sustainiing three thousand six hundred pounds.

The activity of Henry during these and the years immediately following was marvelous. Side by side with his labors in improving the magnet went countless experiments to determine the best relations between the length and arrangement of the coils, and the number and mode of coupling of the battery plates. That this was not an obvious course of investigation appears from the fact that, in the early days, Henry was the only philosopher who gave adequate attention to it. The battery as a source of energy was another subject of exhaustive research; the maximum efficiency of a galvanic couple, and the cost of a system of motive power depending upon the consumption of zinc, also received from his hands that sufficient treatment which leaves nothing to be desired. The last named investigations were instigated by his success, in 1831, in constructing an electromagnetic motor—the first of its kind that the world had ever seen. Though of great historic importance, the apparatus, which is still to be seen at Princeton college, possesses now merely an antiquarian interest.

In the same year Henry set up in "one of the upper rooms in the Albany academy," the first electromagnetic telegraph. The circuit was more than a mile long, and the sounder was a bell. For striking the bell he employed a pivoted steel bar, permanently magnetized, and "placed with its north end between the two arms of a horseshoe magnet." "When the magnet was excited by the current," continues Henry, in his own account of the experiment, "the end of the bar thus placed was attracted by one arm of the horseshoe, and repelled by the other, and was thus caused to move in a horizontal plane, and its farther extremity to strike a bell suitably adjusted."

In view of this experiment at Albany, it is often asserted that the credit of originating the electromagnetic telegraph, by which is meant the telegraph in all essential features as we know it to-day, is due to Joseph Henry. But in making such a claim, the fact is overlooked that this apparatus of Henry's resembled the needle telegraph which Ampère invented a dozen years before, nearly as much as it did the telegraph of Morse and Vail. Henry's steel bar was in effect nothing more or less than Ampère's magnetic needle. It is not difficult to see that the introduction of the electromagnet as an intermediary between the coil and the needle gave the apparatus greater power and begot other mechanical advantages, adapting it, for example, to be used more readily for a striker; but Henry's invention remained, in part, a needle telegraph, having in some measure the comparative insufficiencies which have resulted in the gradual displacement of the needle by the electromagnet for signalling purposes. There was still lacking, as we shall see, the one feature which makes the electromagnet, as Vail left it, one of the happiest of modern inventions, fitting it to be the hand of the far writer, the tongue of the far speaker, the member which translates volition into mechanical movement a hundred miles away, betrays the guilty step of the burglar without his knowledge, and utters the note of warning when a switch is misplaced or a dam threatens to give away.

Fortunately, Professor Henry's services to the telegraph rest on a surer basis than the Albany trial system alone. Morse, who knew nothing of any other electromagnet but that of Sturgeon, was brought to a desperate standstill in his search for the electric telegraph, by learning that he could produce electromagnetic effects only through a short length of wire. It was through Professor Gale's making him acquainted with the Henry improvement that his despair was changed to hope, and that the work was resumed. An indispensable link in the telegraphic chain was wrought by Henry in his development of the Sturgeon magnet.

The other labors of Professor Henry are only less noteworthy, because they happened to be concerned with matters of less popular and industrial interest. His investigations in magnetoelectric induction along the line of Faraday's work are so important that an effort is now being made to secure recognition for them by the general adoption of the term "Henry" as the designation of the unit of electrical inductance. In fact, Henry was within a few weeks of the great Faraday in the discovery of the means for converting magnetism into electricity—"the greatest experimental result," says Tyndall, "ever obtained by an investigator."

He also went far towards anticipating Dr. Hertz and later investigators, when he proposed the hypothesis of an "electrical plenum," to account for an inductive effect similar to that which is utilized in telegraphing to and from railway trains, where the results are brought about by the induction of a current in a parallel circuit through wide spaces of air. In a word, the contributions of Professor Henry to pure science and to the electrical arts were many in number, and they are ranked, both at home and abroad, with the most original and valuable of his day and generation.

In taking up for brief review the story of the modern telegraph, we leave behind us, for a time, the purely scientific phase of electrical advancement. Samuel F. B. Morse, as is well known, conceived the idea of an electromagnetic telegraph in the year 1832, on board the packet, Sully, as he was returning from Havre to his native land. He made a sketch in his notebook at the time, illustrating devices which he thought might serve for recording signals at a distance. The central organ of the telegraph, as Morse conceived it, was the Sturgeon electromagnet, which he had seen exhibited by Professor Dana, at Yale college, in 1827. He knew that the soft iron core would attract magnetic material while an electric current was passing through the coil, and would release it when the current ceased. Why could not this power be utilized to cause a to-and-fro motion of an armature which should make a record on a strip of paper fed forward by machinery? Morse did not purpose making a scientific investigation to discover a new property of the electric "virtue," but to apply already known laws and principles to the end of conveying intelligence quickly over long distances. The electric telegraph, so-called, was an invention, and not a discovery; the result of an exercise of inventive genius, not of the passion for research. The distinction is important, because it will help us presently to understand the part which Morse played in the actual development of his conception. No comparison is here instituted to the disparagement of Morse or any one else between the relative value or dignity of invention and purely scientific achievement. The introduction of movable types for printing did not increase the world's stock of scientific knowledge, but it marks an epoch, nevertheless. The point is that the idea of a great and revolutionizing invention had its birth in the mind of a man singularly deficient in inventive ability and mechanical skill. The career of Morse has frequently been cited as an instance of what a man can do late in life without previous special training. The true story of the telegraph enforces once more the wholesome lesson that genius works no miracles. The strength of purpose with which Morse pursued his object, his unfaltering faith and his absolute engrossment for many years in the notion which took possession of him on that return voyage, were evidences and elements of Morse's personal greatness and power, to which the world will always be indebted; but to Morse the inventor the world owes little by comparison, because he was not able to give abundantly from that source.

Nevertheless, in 1837, Morse, then a professor in Columbia college, had constructed a crude apparatus which embodied in operative form the principle of the electromagnetic recording telegraph. He first showed it to his associate, Professor Gale, and later in the same year to Professor Daubery of Oxford university, and others in Professor Gale's laboratory of the college. The Western Union Telegraph company has fortunately succeeded in getting possession of the identical apparatus used on this occasion, and it may still be seen by the curious at their office in New York. The to-and-fro motion which Morse sought was obtained by the movement of a pendulum toward the magnet when the current was on, and its return by gravity when the current was removed. By means of the pencil these movements were recorded on the moving strip. In connection with the mechanism, which constituted the receiving apparatus, Morse supplied a transmitter. This consisted of a forked lever suspended over a pair of mercury cups, and a type rule laid on an endless band which passed around two rollers, and was moved by a crank. The type rule was provided with raised type, the order of which was understood to represent one or more symbols or parts of a message. As the raised type passed successively under a projection at the bottom of the forked lever, the fork was depressed far enough to close the electric circuit, which was again opened as the type moved by.

Such was the Morse telegraph as it existed when Alfred Vail happened in at the exhibition in Professor Gale's lecture room, September 2, 1837. The first important improvement was made when Gale suggested the employment of Henry's magnet in place of that of Sturgeon, and the use of many cells of battery coupled together in place of the single pair of plates which Morse had experimented with. From that point the telegraph was developed, largely through Vail's labors, to a practical and commercial success.

Alfred Vail was by training and endowment an inventor. His father, Judge Stephen Vail, was the proprietor of the Speedwell Iron works at Speedwell, N. J., and young Alfred had spent a great deal of time as a boy in his father's factory, indulging his inherited taste for mechanical pursuits. Simultaneously with his work in the factory, he had been an ardent student of scientific matters, and had become thoroughly grounded in the basic principles of natural philosophy. So that, later, when, as a student of Columbia college, he went to call on Professor Morse on that memorable second of September, he was prepared not only to grasp the magnitude of the conception, but to understand perfectly the operation of the apparatus and the problems still awaiting solution. He says:

"I saw this instrument work, and became thoroughly acquainted with the principles of its operation, and, I may say, struck with the rude machine, containing, as I believed, the germ of what was destined to produce great changes in the condition and relation of mankind."

There were still doubts to be resolved; but in the end he decided to embark in the enterprise, and sink or swim with it. The enthusiasm of his son soon won over Judge Vail, and on September 23, 1837, an agreement was entered into between Professor Morse and Alfred Vail, by the terms of which Vail was to receive a one fourth interest in the invention in the United States in return for his time and services for constructing at his own expense, and exhibiting before a congressional committee, one of the new telegraphs, and for procuring the necessary domestic patents. To explain the proviso regarding the exhibition of an apparatus, it should be stated that the house of representatives in February, 1837, had taken steps to the establishment in the United States of a suitable system of telegraphy, and had appointed a committee to investigate the subject.

When Vail had once committed himself to the new work, his devotion to it assumed the character of a passion. The shoot planted by Professor Morse had sprung up in the young man's mind as an independent growth equal in strength and vigor to the original tree. If the conception had had its birth with Vail, he could not have taken more interest in its development. The elation and depression which alternated in his mind from time to time were intensely personal. It is doubtful if the history of these months, whilst Vail and young Baxter, a confidential assistant, were at work in their locked room at Speedwell, can be adequately explained except upon the hypothesis that the successes and failures were really Vail's and not Morse's. The gradually changing relations of the two men, Vail's undefined feeling, which finally grew into expression, that Morse had not given him due public credit for his services, tell a story of natural jealousy on Morse's part, and of an outraged sense of justice on Vail's part, which, not having received its proper comedy denouement in a generous acknowledgement from Morse, has lately risen to do poetic justice of the retribution sort by exposing Morse's misdemeanor.

There remains barely space to catalogue the inventions by which Vail revolutionized the telegraph and made it practically what it is to-day. The first alteration which Vail made in the Morse machine was accomplished by substituting a fountain pen for the recording pencil. This proving unsatisfactory, he hit upon the key to the whole trouble by dispensing with the pendulum, and using instead an armature lever having a vertical motion, so that it could be brought down upon the record strip instead of being carried across it. It was this invention more than any other which not only made the telegraph possible, but gave birth to nearly all the modern arts of signalling. The typical form of this magnet has a retractile spring normally pulling the pivoted armature away from the core, and adjustable front and back stops for limiting the to-and-fro movement. In some form or other, it constitutes the translating medium in the most used systems of annunciators, alarms, and signals, and in every portion of the telegraph; and it is practically identical with the receiver of the telephone. This simple electro mechanical movement enters as an element into the electrical arts with the same frequency as does the lever into the arts purely mechanical. It is, in fact, the first of the electro mechanical powers. Vail perceived in it at the time mainly a means for making dots and dashes and spaces on the record strip. Elaborating this idea, he invented the telegraphic alphabet which, equally with the Vail magnet, was indispensable to the success of the telegraph, and which, being originated to serve the needs of the electric telegraph, has proved to be the means of giving inconceivably wider scope and capacity to systems that had been in existence thousands of years. When Vail made the alphabet, which is still known as the Morse code, he expected to employ in transmitting it a "mechanical correspondent" constructed much like the Morse type rule. But in actual practice, Vail learned to mark the necessary intervals by his inward sense of time, finding that he could operate perfectly by using his hand alone to control the dipping of the wires into the mercury cup. Still later he constructed a spring finger key, which is the same in all essential particulars as that now in use.

We have seen that the pencil and the fountain pen were alike objectionable as recording devices, and they were both ultimately superseded by a steel embossing point, beneath which was the strip of paper running over the grooved roller. In most cases where the alphabetic code is recorded to-day, the mechanism is substantially that last described, which Vail expressly claimed to have invented. The recording instrument used by Vail at Baltimore in 1844, and now at the national museum in Washington, includes Vail's improvements both on the magnet and the recorder. But, as neither Morse nor Vail foresaw, the whole mechanism so carefully devised for recording the messages was soon discovered to be useless. Operators began to read by sound, as they still do, and the register under ordinary conditions fell into disuse.

The telegraph which Morse set out to invent was a recording telegraph, and this he actually embodied in the working model of 1837. Thus much—and it is much—measures his claim as an inventor. The recording principle, first utilized by Harrison Gray Dyar, of New York, in 1827, is of importance in itself, and because it led to better things, but it is not an essential element of the modern telegraph. The key, the telegraphic alphabet, the electromagnet with the spring retracted armature, are due to Alfred Vail; the improved winding of the magnet is the result of Henry's labors; and many needed improvements in the batteries employed, are Professor Gale's; in a word, all the indispensable portions of the so-called Morse telegraph were suggested or invented by others.

The most important of Vail's contributions, the alphabet and the improved electromagnet, were completed and ready for service in an incredibly short period. He showed them working to his father, January 6, 1838, and a few weeks later he erected a complete working apparatus, including them, at Columbia college. The performance of the improved telegraph there, and afterwards at the Franklin institute in Philadelphia, was highly satisfactory to all concerned. The results of those preceding four months of labor are a tribute, which cannot well be overestimated, to the inventive genius of Alfred Vail.

It will be a surprise to many to learn that the alphabet code was not the production of Professor Morse. The code which Morse devised was numerical, every word in the English language being represented by a distinct number. The number being transmitted, the corresponding word could be found by reference to a laboriously prepared telegraphic dictionary. It is needless to say that such a code was a practical absurdity.

The struggles and disappointments of Morse and his associates between February, 1838, when Vail fulfilled his agreement to exhibit a telegraph to a committee of congress, to March 3, 1843, when, during the last hour of the session, a bill was passed appropriating thirty thousand dollars to aid in establishing the enterprise, are better known to the public than the scientific facts and incidents. Morse was reduced to his last dollar, and the Vails were nearly discouraged. Even after the good fortune came, and the work on the experimental line from Washington to Baltimore was nearly completed, they were once more thrown into despair by finding that the insulation was worthless, and that twenty three thousand dollars had been spent for naught. The wires were finally strung on poles and the historic message, "What hath God wrought!" was successfully transmitted on the 23d of May, 1844.

Even here the fertility of Vail's invention was constantly exhibited. He discovered the axial magnet, and made working drawings of an ampère meter, in which its principle was to be utilized. He became an original, though not the first inventor of the automatic, vibrating circuit breaker. Other important improvements were devised by him to meet the exigencies of the work as it went along, marking him as an inventor of a very high order.

There is danger that a comparison of the sort which has been instituted may have resulted in an unjust reflection on Professor Morse. If this has been the case, the injustice must be set right. It may not be forgotten that the original conception of the electromagnetic telegraph was Morse's, and that he actually constructed a working recording apparatus. It is true that the recording feature is now disused, but it is a question whether it did not play an important part in securing the interest of congress, without which the whole scheme would have been a failure. Mistrustful as they still were, the members of the congressional committee would have been far more ready to suspect collusion, if an operator had professed to read by the mere sound of a metallic hammer a message sent by a distant confederate. Regarded as a concrete embodiment of a natural principle, the modern telegraph is mainly Vail's and Henry's; regarded as a commercial enterprise to be floated or, better, regarded as a great idea permeated through and through with the imagination that rules the world, the telegraph is distinctly Morse's and rightly bears his name. No better statement of the true position of Morse can be given in a few words than has been made by Mr. Charles L. Buckingham.

"The world has lost nothing, nor is it less to his credit, if parts of the invention which he esteemed most, have, like the false works of an arch, been removed. When they become an incumbrance their absence was as important as had been their presence, to give the structure its original shape and strength."

Charles Grafton Page might have fitly paraphrased Hawthorne, by claiming that for many years at the outset of his career he had enjoyed the distinction of being the obscurest man of science in America. The statement would be made more accurate by adding the Hibernianism that his obscurity was entirely transoceanic, and that Henry suffered in much the same way. The whole truth is that the old world paid little attention in the thirties to what was going on in America. For, while many (American) writers agree in saying that the researches of Henry in electromagnetism gave him at once a world wide fame, yet it remains to be explained why, so late as 1837, men like Wheatstone and Cooke were entirely ignorant of them or quite unimpressed by them. Page was even more unfortunate. While a medical student in Salem, Mass., in 1836, he took up the induction apparatus of Faraday and subjected it during several years following to the most careful and exhaustive study. At the beginning, his object was to adapt the Faradic coil to the production of enhanced therapeutical effects. He soon learned, however, to take a scientific as well as a professional interest in his experiments. The discoveries and improvements which he made gave the induction coil its permanent form and well nigh its present efficiency; yet nearly fifteen years later, the results of his labors were appropriated by M. Ruhmkorff, a Paris instrument maker, whose name is still attached descriptively to the invention of Page. Mr. Edward S. Ritchie, a Boston inventor, should be named in connection with Page for his improvements in the induction coil. Among other things it may be mentioned that Page first wound a secondary coil outside the primary, that he first produced all the phenomena of static electricity from the induced current, and that he first discovered the increased electrostatic effects rising from giving the secondary a greater length than the primary. These are only a few of many alterations and discoveries, more or less radical, which Page embodied in working apparatus. Incidentally, the necessity arose for an automatic circuit breaker, and Page was actually the first to invent this device, which has since been so widely applied in the electrical arts.

Page afterwards distinguished himself by constructing an electric locomotor with which he drew a train of cars on the Baltimore and Ohio railroad between Washington and Bladensburg at a maximum rate of nineteen miles an hour. This was in 1851, after congress had appropriated $30,000 to further the project. At this time Page was an examiner in the United States Patent office, having entered it in 1841 as one of the two principal examiners then employed in the office. Page was so deeply interested in the scheme of electric locomotion, and had so much faith in its future, that he withdrew from the patent office in 1852 in order that he might devote his whole time and attention to it. For reasons which are now well understood, his hopes were destined to disappointment. Still he accomplished much, and succeeded in convincing a senate committee, of which Mr. Benton was chairman, that electricity as a motive power had great possibilities which the government ought to assist in developing. Before this committee he exhibited a reciprocating electric engine which operated a planing machine. On another occasion he showed them an electric motor running a Napier printing press at the rate of twelve hundred impressions an hour. But the appropriation which these experiments succeeded in calling forth from congress was insufficient, necessarily, to accomplish the impossible. A friend of Professor Page's, who also withessed many of the experiments referred to, as well as the trial on the Baltimore and Ohio railroad, states the situation with tolerable exactness as it appeared to an intelligent observer writing before the perfection of the dynamo.

"Although Professor Page failed to realize his first cherished hope of seeing electricity take the place of steam for a motive power on a large scale, for which he underwent so much labor, and for the pursuit of which he relinquished his hold upon a lucrative office, yet his labors had this result: the concentration within a moderate space, and by simple means, of a large amount of electro-mechanical power; and so soon as a galvanic battery shall be discovered which is easy to manage at the same time that it gives its current by the consumption of cheap materials, or as incidental to some extensive chemical manufacture, his engine is ready, we think, to perform a large part of the work done by the steam engine.

The central feature of Page's motor was the axial magnet which, as we have seen, was invented by Alfred Vail.

While a principal examiner in the patent office, Page became professor of chemistry in the medical department of Columbian college at Washington. In 1861, having found that his anticipations regarding the success of the electric motor were premature, he returned to the patent office and remained there till his death in 1868. As an examiner in the patent office, Page was debarred by law from protecting his inventions, so that they went into wide public use without his realizing any substantial returns in money. The public use itself constituted a further bar even in case he should have decided to resign his official position for the purpose of securing a patent. By a special enabling act congress permitted the granting of a patent to Page for his circuit-breaker and induction coil inventions, at the discretion of the commissioner. It appearing that no other statutory bar would be infringed by the grant, he received his patent, and immediately sold it to the Western Union Telegraph company for a considerable sum of money. A large amount of valuable experimental apparatus which Page had stored on his premises in the suburbs of Washington was unfortunately destroyed in 1863 by a party of Union soldiers who supposed it to belong to a confederate sympathizer.

Page's services to science were ultimately acknowledged in Europe as well as in America. Sturgeon wrote of him in 1850:

"I know of no philosopher more capable of close reasoning on electromagnetics and magnetic-electrical physics than Professor Page, M.D."

But so far as the electrostatic coil is concerned, the proper credit has never been given to him abroad. The memory of Page's services to acoustics is still preserved in the name "Page effect" given to the musical sound resulting from the rapid magnetization and demagnetization of a piece of soft iron.

Mr. Franklin Leonard Pope has recently made some important researches which render it probable that the electric motor was first brought to perfection by Thomas Davenport and Orange A. Smalley of Brandon, Vt. It has long been known that Davenport constructed the first model electric railway, as far back as 1835, but if Mr. Pope's conclusions are correct, we must add still another important apparatus to the already long list of electrical inventions having their origin in America. Mr. Pope also credits Davenport with priority over Vail in the invention of the axial magnet.

By an awkward use of terms, the designation magneto-electric machine has been made to apply to an electric generator in which the primary exciting agent is a permanent magnet, while the name dynamo-electric machine is given to a generator wherein an electromagnet, self excited, furnishes the initial magnetic force. The fault is with the distinction; the difference is there, and is highly important. But it was not known to exist until Moses G. Farmer, another Salem inventor, discovered the self exciting power of the magnet, in the year 1866. It was afterwards discovered independently by Varley and Wheatstone in England, and Werner Siemens in Germany, the last named of whom first suggested the term dynamo in distinction from the older magneto. As nearly all of the powerful modern electric machinery, which has revolutionized the electrical industries within the past few years, belongs to the class dynamo, it will be seen that Farmer assisted very materially at the birth of a new and important art. The electric light, and the electrical transmission of power, were made commercially possible by the invention of the dynamo-electric machine. Farmer's own labors in electric locomotion, made in 1847, when he succeeded in carrying four passengers on a track one and a half feet wide, were practically nullified, because Farmer's discovery of twenty years later had not pointed the way to the perfected dynamo.

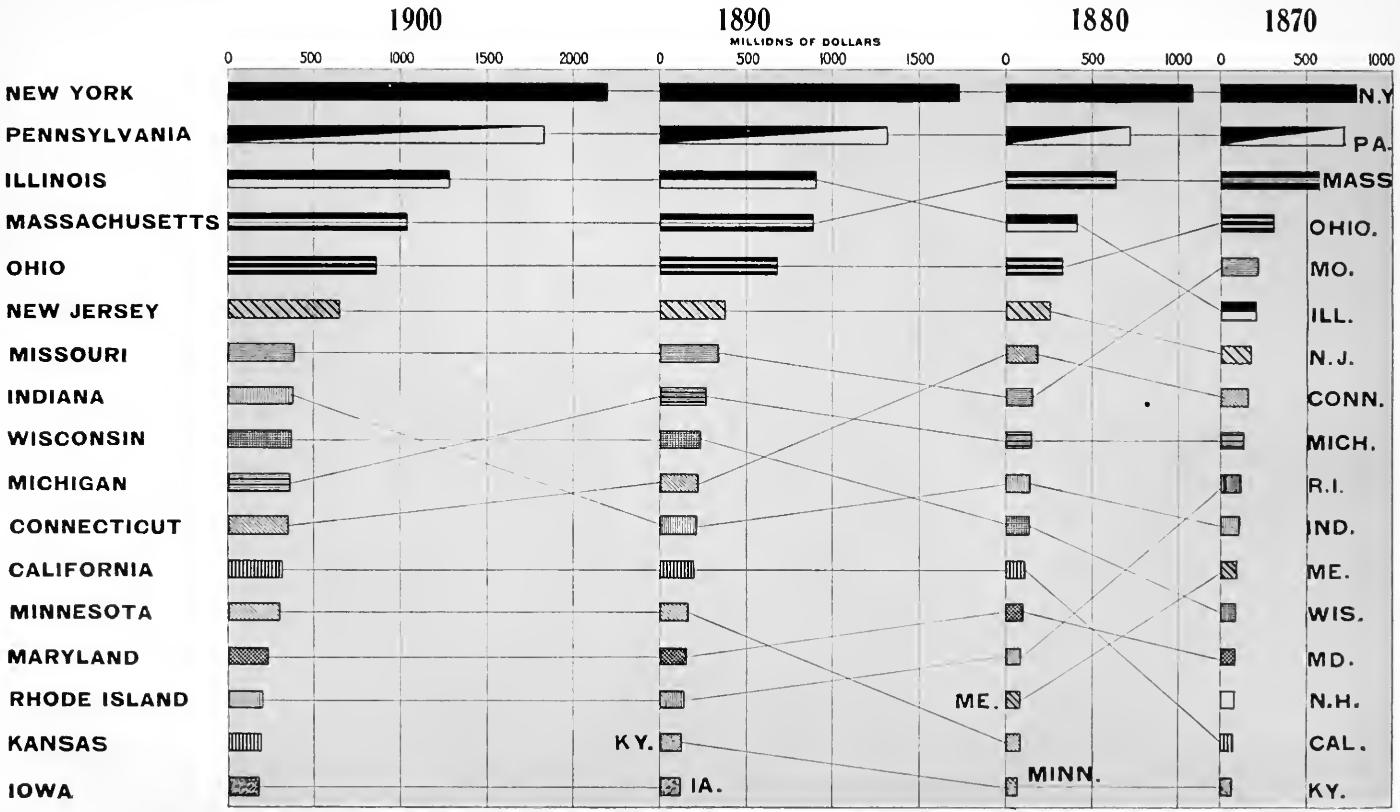
Farmer was also a pioneer in the art of electric incandescent lighting. Not least worthy of mention is the fact that, in 1862, himself and W. F. Channing set up in Boston the first system of fire alarm telegraphs in which distinctive signals for different fire precincts could be transmitted. This was the starting point of a system which has since spread to every town and city in the United States. The question has been raised as to which of the two joint workers really first invented the modern fire alarm system. The evidence points strongly toward Farmer as the man who both conceived and worked out into practical shape the entire system in all its essential features independently of any other inventor and in point of time before any other.

In the same year Farmer gained fresh distinction by inventing the first multiple telegraph for transmitting simultaneously two or more messages over the same wire. It belonged to the synchronous multiple type, lately developed to marvelous capacity for short lines by Mr. P. B. Delaney.

In considering the comparatively recent history of electrical progression, therefore, one is at once attracted to the commercial telegraph, which marks an epoch in the history of the world. For military and strictly governmental uses, some sort of signalling and telegraphic service have been known from the earliest times; but the conception of a telegraph which should furnish the means for private and business correspondence, and for informing the public press, belongs to the nineteenth century. It naturally follows from this that the telegraph as a medium for the quick transmission and delivery of messages, and as an investment, is of very recent origin. It dates, in fact, from the time when electricity was trained to be the carrier.

The ancient telegraph was a part of the military armament, an incident to the need of being constantly prepared for offensive and defensive warfare. And very clumsy apparatus they had, even at the end of the 18th century. But, such as it was, it served tolerably well, so long as no more was expected of it. It was not suited to supply the service of a commercial telegraph, but the majority of men did not realize then that a commercial telegraph was a thing greatly to be

VALUE OF PRODUCTS OF MANUFACTURES IN THE SEVENTEEN LEADING STATES: 1870 TO 1900



desired. In this view, it is not so much to be wondered at that in 1816 the British admiralty should have declared the existing system of telegraphy to be quite good enough. No human being, at that time, could have foreseen the immense demands for a commercial telegraphic service which would arise as soon as there was a source of supply. It remained for electricity both to create the supply and to prove in land service that a telegraphic system could be made to yield a generous return on the necessary investment.

Without that lesson, the larger venture of an Atlantic telegraph would hardly have been realized so soon as it was. The scheme of connecting two of the greatest nations of the world by a system of telegraphic intercommunication would have seemed to be the proper occasion for the tradition of government control to reassert itself; but the conditions had fortunately become so altered that this gigantic enterprise was taken up by a few wealthy capitalists as a promising investment, while the governments interested looked on and waited. That was a marvellous revolution to have taken place within a dozen years!

Be it said to the credit of the men who risked their dollars in laying the first Atlantic cable, that the hope of gain was supplemented by a large measure of genuine public spirit. Dr. Henry M. Field, the historian of the enterprise, calls attention to this on the occasion of describing Mr. Cyrus W. Field's first proposition to Peter Cooper.

"The first man whom he addressed was Mr. Peter Cooper, who was then and is still [1869] his next door neighbor. Here he found the indisposition which a man of large fortune—now well advanced in life—would naturally feel to embark in new enterprises. The reluctance in his case was not so much to the risking of capital, as to having his mind occupied with the care which it would impose. These objections slowly yielded to other considerations. As they talked it over, the large heart of Mr. Cooper began to see that, if it were possible to accomplish such a work, it would be a great public benefit; this consideration prevailed, and what would not have been undertaken as a private speculation was yielded to public interest."

The history of this colossal undertaking, of which Cyrus W. Field was the originator and moving spirit, can only be given in the barest outline. The first thing to do was to build a telegraph line from New York to the farther shore of Newfoundland. This alone cost a million dollars, and took two years of time, being completed in 1856. The rest of that year and a part of the following were occupied by Mr. Field in organizing the Atlantic Telegraph company in London, and in securing, from both Great Britain and the United States, the promise of ships for laying the cable, and of subsidies from both governments when the work should have been completed. Mr. Field was successful in both undertakings.

The first actual attempt to lay an Atlantic cable was made in the summer of 1857, the start being made from the Irish coast on the 6th of August. This cable parted after more than two hundred miles had been paid out, and the expedition was compelled to return to Ireland, unsuccessful. A second failure was registered in the following year, but the third attempt was successful, and the cable was safely landed on the 5th of August, 1858. It continued in operation less than a single month, and then suddenly ceased to work forever. This event was followed by a season of profound discouragement covering several years, but in 1865, a larger and stronger cable stowed away in the vast hold of the Great Eastern was unrolled into the ocean, and, though it broke at last, yet the experiment had succeeded so far that the confidence of all concerned was increased, rather than shaken. The year following, the Great Eastern laid a cable which is still at work, and it also picked up and completed the broken cable of 1865.

The success of Mr. Field's efforts to secure congressional aid was due to the strong support given it by many of the men whose names Americans delight to honor. The bill which finally passed was introduced by Mr. Seward, whose speech in support of it summarizes all that can now be said concerning one of the greatest commercial undertakings in history. He says:

"Now, there is no person on the face of the globe who can measure the price at which, if a reasonable man, he would be willing to strike from the world the use of the magnetic telegraph as a means of communication between different portions of the same country. This great invention is now to be brought into its further, wider, and broader use—the use by the general society of nations, international use, the use of the society of mankind. Its benefits are large—just in proportion to the extent and scope of its operation. They are not merely benefits to the government, but they are benefits to the citizens and subjects of all nations and of all states."

A list of five hundred patents and more than three hundred pending applications for patents comprises, according to a recent authority, only a part of the inventions of Thomas A. Edison. Those who have been associated with the wizard of Menlo Park can easily believe that they constitute only a small part. Edison is doubtless the most prolific of inventors,—a true genius developed to full flower by rare and wonderful opportunities. Yet here, again, the rational explanation supervenes that the master is master because he excels in every kind of equipment for his special work. Du kannst weil du kennst is the secret of the personal element in Edison's success. Though his schooling ended after a two months' term, Edison has always been an insatiable student. At the hearing of the arguments in an important suit against the Edison company, at Pittsburgh, something more than a year ago, it was observed that Edison, who had travelled from his home in New Jersey to be present, spent little time in court, preferring to keep his room and the company of a trunk full of books, which he had carried with him. And this zeal for study is habitual.

Unlike many school taught men, Edison is not satisfied to stop with the end of the day's lesson. "I only go a little farther than some of the others," he once said. But that little farther is a vast distance. In the industry of electric lighting by incandescence it meant all the way from a state of mere experiment to a practical and economical system of electric light distribution. And it involved improvements in the dynamo, in means for subdividing the light, in exhaust apparatus, in the filament to be white heated, and in every minutest detail and every broadest combination; and it involved also the expenditure of over $2,000,000 in money.

Especially exceptional are Edison's powers of observation, quick conception, and selection. Being always by nature and by his responsibilities in the creative state of mind, his observing powers are kept in constant play, while his exhaustless knowledge of the needs of his art and of the aptitudes of contributory arts enables him to gauge with marvellous quickness the possibilities of a new discovery and to choose just the elements and combinations which will enable him to embody his conception. And once started on the track of a new idea of this sort, he pursues it with unresting energy until he has demonstrated its practicability. It was in this way that he applied the telephonic diaphragm to the creation of the phonograph. In this way, too, he employed Hughes' discoveries regarding certain qualities of carbon to the production of the Edison telephonic transmitter. Dr. Otto A. Moses, himself an inventor of note, gave to the New York Electrical society not long ago, an account of Edison's invention of the so-called "Motographic relay." This invention, of striking originality, was, according to Dr. Moses, the sequel of Edison's having observed, while moving a spoon over a sheet of paper which was resting on a brass plate joined to a battery, that the sheet seemed to slide more freely while a current was passing. The completed relay was ready in a few days. Some time after this, being challenged to show that he could produce a new order of telephonic receiver as he had in the case of the transmitter, he converted the motographic relay into a sound receiver of marvellous sensitiveness and efficiency. These anecdotes reveal the true characteristics of Edison's genius,—the qualities already noted, and his alertness of mind, his pride in his work, his readiness to accept a challenge, his chess player's delight in the solution of new problems.

It could hardly be avoided that some great inventions should be popularly assigned to Edison exclusively, the credit for which is partly due to others. Thus, the origination of the duplex telegraph, for which Dr. Joseph N. Stearns of Boston prepared the way, is generally ascribed to Edison alone; and the quadruplex is likewise associated with his name exclusively, the services of Mr. Henry C. Nicholson of Kentucky being overlooked. A popular misconception of the facts also leaves out of account the work of William Wiley Smith of Indiana, and Lucius J. Phelps of New York, in perfecting the well known system of train telegraphing by induction. But with all that, the fame of the wizard rests on a sure basis of marvelous accomplishment in the service of mankind.

Reference has been made to Edison's powers of selection for inventive ends. These are essential to every great inventor, and it was these that Professor Morse distinctly lacked. Whence, indeed, should he have acquired them in a life devoted to pictorial art? On the other hand, Edison is master of his tools. He works toward the embodiment of his idea just as an accomplished writer works toward the clothing of his mental conception, not without rejections and reshapings, but with confidence that, in the end, he will have said—in levers and pulleys, or in the words of human speech—just what he started out to say.

Edison has devoted his life, actually and avowedly, to applying science to the benefit of mankind. His dominant instinct is to reduce his knowledge of scientific facts to a practical, useful embodiment, to find expression for it, so to speak, in an appliance that will conduce to man's comfort, convenience, or amusement,—in a word, to invent.

We come now to an electrician of another type, who, with an inventive record and experience second only to that of Edison, has preserved his interest in the speculative phases of his work, and has made important contribution to theoretical science, the value of which has received world wide recognition. There is no one else in America to whom the younger generation of electricians look with so much of expectation and confidence as to Professor Elihu Thomson. He has been connected since 1880 with the Thomson-Houston Electric company of Lynn, Mass., and both there and elsewhere has taken the highest rank as an inventor who could adapt the most thorough knowledge of principles to the practical needs of the situation. His most notable work in this kind has been the invention and practicalizing of the electric welding process which is, so far, the last of the great electrical inventions of this electrical century. The electric light, the dynamo-electric machine and the electric motor, both direct and alternating, and, indeed, the whole apparatus of electric locomotion have received radical improvement at his hands.

Thomson has been from boyhood an enthusiastic inventor, showing great originality in all his work. While a professor at the Central High school of Philadelphia, he worked out, in conjunction with his colleague, Professor Houston, "a machine for the perfectly continuous centrifugal separation of substances of different densities." An apparatus embodying the same principles is now extensively used in dairies for separating cream from milk.

But it is not intended here, if it were possible, to discuss Professor Thomson's labors as an inventor. It is no disparagement to them to say that it is his achievements in the field of theoretical science that give rise to the enthusiastic hopes of the young men. The situation may be expressed in Professor Thomson's own words:

"Our science of electricity seems almost to be in the condition that chemistry was in before the work of Lavoisier had shed light on chemical theory. Our store of facts is daily increasing, and apparently disconnected phenomena are being brought into harmonious relation. Perhaps the edifice of complete theory will not be more than begun in our time, perhaps the building process will be a very gradual one, but I cannot refrain from the conviction that the intelligence of man will, if it has time, continue to advance until such a structure exists."

Professor Thomson has already supplied some of the materials for this edifice, and is more likely than any other living American to furnish many more. His habit of mind tends strongly toward classification. He is a scientist of rare ability and remarkable powers of literary expression, living amidst surroundings where more electrical phenomena pass under his review in a single day than Henry could have observed in a series of months. It is this consideration, strengthened by his brilliant work already accomplished, that turns expectation toward him in so high a degree. The language in which Professor Thomson's deductions are presented to scientific listeners, while sufficiently technical in detail, is built into a whole which is constructed on the best literary models. No other speaker is so welcome to an audience of electrical engineers. He gives them the peculiar gratification which tends to express itself in applause. He creates the expectant mood, and now and then—at the proper moment—he gratifies it, suddenly, with the usual result. A good example of his admirable treatment of an abstruse subject is a lecture on Magnetism in its Relation to Electromotive Force and Current, delivered before the American Institute of Electrical Engineers, of which he was then president. Starting with Faraday's theory of universal ether in which magnetic and electrical phenomena appear, Professor Thomson here gathers together illustration after illustration, each of which suggests, in a manner quite delicious to the scientific mind, a confirmation of his theory, and the cumulative effect of which is strongly convincing. In this particular instance, however, Professor Thomson expressly disclaims having attempted a final solution of the problems attacked. But the lecture remains full of suggestion, a laborious accumulation of facts, finely ordered, and with the labor all disguised in the beauty of the presentation. Perhaps the most important theoretical work done by Professor Thomson has been in connection with the alternating current motor which has risen to industrial prominence only within the last few years, and that chiefly through the labors of Professor Thomson and of Nikola Tesla, a naturalized citizen of the United States.

Owing to the association of the two names in the title of the company with which Professor Thomson is still connected, his labors are sometimes confounded in the public mind with those of Professor Houston of the Philadelphia Central High school, of whom there will be occasion to speak later. Their joint work really ceased more than ten years ago, with the formation of the company whose name is responsible for the confusion.

Professor Thomson has already been honored with the highest marks of distinction for his scientific achievements. In 1889, he received from the French government the decoration of an Officier de la Legion d' Honneur. In the same year he was awarded the Grand Prix at the Paris Exposition for his electrical discoveries and inventions. The electrical jury headed by M. Mascart, gave a special dejeuner in his honor, and in London he was one of the speakers at the Guildhall dinner, on which occasion he reflected honor upon American science, by making a very happy speech before six hundred of the foremost engineers and scientists of the world. Yale college, in 1890, gave Professor Thomson the honorary degree of Master of Arts.

Whatever may be said about journalism as a school of literary training, or the world of affairs as a kindergarten of social and political philosophy, it is pretty well established by experience, in America, that the factory is a bad scientific school. We do not need to inquire how the habits of Franklin's mind or expression were affected by his journalistic and his political duties, but we know that the invention of the lightning rod did not make him a scientist; he was that before. Scientists often become inventors, but inventors rarely become scientists. Out of the large number of electrical inventors—some of them of great prominence—who have obtained their knowledge of electricity mainly from practical experience in the workshop, it would be hard to select a single example of a man who has added to the general knowledge of electrical laws and principles. This function is confined almost exclusively to those who are, or have been, laboratory workers. It may be stated broadly that the only electricians who are now devoting their attention seriously to the formulation of electrical science as such, either are or have been schoolmen, and most of them bear a title indicating the teacher. Some, like Professor Thomson, have been called from their scholastic duties by the large manufacturing companies. Professor Anthony, formerly of Cornell, and now with the Mather Electric company, is another case in point. Dr. Louis Bell, who was at one time a professor in the Northwestern university at Evanston, is now the editor of a well known electrical journal.

But the list of prominent schoolmen still identified with institutions of learning includes, with the exceptions noted, nearly or quite all the names which really fill a place in electrical science. Such are Prof. H. A. Rowland and Dr. Louis Duncan, of Johns Hopkins; Prof. John Trowbridge, of Harvard; Prof. C. F. Brackett, of Princeton; Prof. George F. Barker, of the University of Pennsylvania; Prof. Charles R. Cross, of the Massachusetts institute of technology; Prof. Henry Morton and Prof. A. M. Mayer, both of the Stevens institute; Prof. A. E. Dolbear, of Tufts; Prof. E. L. Nichols, of Cornell, and Prof. H. J. Ryan, his associate; Prof. Edwin J. Houston, already mentioned; Prof. L. I. Blake, of the University of Kansas; and Prof. H. S. Carhart, of Ann Arbor.

By common consent, the most unexpected, the most wonder compelling invention of all time, the one of all which, when realized, seems most unreal, is the electric telephone. After years of constant familiarity with the fact of talking with a distant friend, it still seems, at first thought, incredible and impossible. It is still more like one of Puck's fancies, which we shall see the absurdity of, as soon as we are released from the spell. The marvelous invention has had an equally marvelous history. It has been claimed for a German professor and for three different Americans of the same guild, for a French private in the African army, for an Italian refugee, and variously, for a model maker, a music teacher, an upholsterer, barber, and many others. Every detail of the entire history has been brought to light by interested parties in the attempt to overthrow the patent of Alexander Graham Bell, whose predominating claims as inventor have been authoritatively sanctioned by the Supreme court of the United States. The undoubted fact that Elisha Gray filed a caveat for the same invention on the same day that Bell lodged his application, and the resulting legal complications, are ranged side by side with claims from other inventors which are manifestly untrustworthy and fraudulent. But this, the most interesting chapter in the history of invention, must here regretfully be suppressed.

The general judgment of those best informed on the subject is, that the credit for the invention in a commercial practical form, has been rightly bestowed on Professor Bell. In any event, the originality of Bell's work, and the marvelous character of the results that flowed from it are not affected in any degree by experiments which the scientific world either knew nothing of or had forgotten all about. No mere legal technicalities will ever convince men that the invention of the telephone was not a stroke of genius, and they will be inclined also to honor most the man who actually put the marvel into their hand. We need not, in fairness, ascribe less praise to Philip Reis, or Elisha Gray, or Professor Dolbear; but we cannot quarrel with the public, if it chooses to single out Professor Bell for the highest homage.

All three of the American inventors mentioned have displayed inventive capacity in other ways, Mr. Gray, especially, being a fertile inventor in many different fields.

Charles F. Brush has done for arc lighting what Edison did for incandescent. It grew under his hands into a usable system of light distribution which is now a necessity. Brush also made early improvements in storage batteries, but his best work has been done in connection with the arc lamp and the dynamo-electric machine. The high resistance shunt, if not absolutely introduced into the arts by him, is, at least, his, in every proper sense, so far as it applies to the purpose of arc lighting. And in the same way the universally used means for controlling the feed of the positive carbon, are his contribution to the are lamp. Mr. Brush gave his name many years ago to one of the most successful electrical corporations in the country, the Brush Electric company, of Cleveland, Ohio.

The prominence of Edward Weston, for many years as electrician of the United States Electric Lighting company, would call for notice here, even if his successes in improving the electric light and the dynamo-electric machine did not themselves merit it. But his prominence, as is usually the case where large business interests are involved, has been fairly and fully deserved. The Weston dynamo is one of the standard machines for generating the electric current.

In view of the number of electric railroads in this country in actual operation or in process of construction, it seems hardly credible that the first experimental road since the dynamo gave the experiment significance and promise was constructed so short a time ago. This was the Edison road at Menlo Park. A year later, Mr. Stephen D. Field had a road in successful operation at Stockbridge, Mass., and, an interference being carried through in the patent office to decide the rival claims of the two inventors under their applications for patents, it was discovered that the title to priority in the invention belonged to Field. The latter inventor afterwards put up a railway in the main exposition building at Chicago in 1883. On this railway were carried in the two weeks of its service more than twenty five thousand passengers from whom, for the first time on an electric road, a small fare was collected. Mr. Field, conjointly with Mr. Rudolph Eickemeyer, has recently made what appears to be a valuable improvement in electric cars, which consists in coupling a slow speed motor directly upon the car axles, all gearing being dispensed with. In 1883, Mr. Leo Daft conducted several successful experiments in electric railroading, and in 1885 he built at Baltimore a road which carried the regular traffic of the Hampden branch of the Baltimore Union Passenger Railway company for nearly five years. Prior to this time—in August, 1884—Messrs. Edward M. Bentley and Walter H. Knight had built a conduit electric railway on the tracks of the East Cleveland Horse Railway company at Cleveland, Ohio.

Early in 1885, John C. Henry built at Kansas City the first overhead wire electric railway.

Another pioneer inventor in the line of electric locomotion is Mr. Charles J. Van Depoele. His first road was laid in Chicago early in 1883, and he exhibited another at the exposition later in the same year. Since then many roads have been constructed under his patents. It is probably only just to Mr. Van Depoele to say that he is entitled to more credit than any other man for the exploitation of electricity as a motive power. He has devised ingenious improvements in electric drill machinery which for the first time make it practically successful.

THE DEVELOPMENT OF INDUSTRIAL ELECTRO-CHEMISTRY.

BY E. F. ROEBER.

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While of all branches of electrical engineering electrochemistry has been the last one to achieve commercial successes on a large scale and may justly be considered to be still in the first phase of its industrial development, yet its fundamental principles were long exactly known (electrolytic action —Faraday's law, electro-thermic action—Joulean heat). Moreover, at the beginning of the nineteenth century the very first experimental applications of the newly discovered electric current were of an electrochemical nature. Shortly after the primary battery had been invented by Volta, Nicholson and Carlisle succeeded in decomposing water by electrolysis, and in 1807 Sir Humphrey Davy delivered his famous lecture on some chemical agencies of electricity. Yet (to quote from the recent Bradley patent decision) "Davy's experiments were permitted to lie dormant during seventy six years of intense activity," and in general the progress in the development of industrial electrochemistry and electrometallurgy was extremely slow for a long period. In fact, thirty one years ago, when the first issue of this journal appeared, there did not exist any electrochemical industries, with the single exceptions of electroplating and primary battery manufacture.

It is now not difficult to see what held the development of industrial electrochemistry back. In nearly all electrochemical and electrometallurgical processes the cost of the electric power is a large fraction of the total cost of operation, often 25 per cent or more, and even up to 90 per cent. Cheap electric power is, therefore, the fundamental requirement for the economical working of an electrochemical process, in exactly the same way as it is for electric lighting, traction, and power purposes in general. Before the advent of the dynamo, the primary battery was the only available source of the electric current, if we except a limited use of the thermopile, and its limitations are obvious. The operation of a primary cell meant and still means essentially oxidation of zinc. When zinc changes from the metallic state into bivalent ions, 1.22 grams are oxidized, according to Faraday's law, for every ampère hour; we know that, with all possible combinations of zinc with other materials in a primary battery, we never get much more than 2 volts, and if we assume the useful e.m.f. to be 1 volt (which is very fair for such an estimate), then every kilowatt hour produced means the oxidation of 1.22 kg (or $2\frac{3}{4}$ pounds) of zinc. This is the theoretical value which really represents a minimum of actual consumption; moreover, it does not include the cost of the other materials in the cell, nor the cost of construction and attendance; but it is sufficient to indicate the inherent limitations of the zinc primary battery.

So long as primary cells were the only commercial sources of electric current, the applications of electrical engineering were thus necessarily restricted to those cases in which a very small amount of power only is required. That is especially the case in telegraphy, and, in the field of electrochemistry, in those cases of electroplating in which a soluble anode is used of the same metal which is to be deposited upon the cathode. Here the voltage required at the terminals of the plating bath is consumed in overcoming the internal resistance only, which may be made small, and, therefore, the power may also be insignificant.

It is quite natural that after the dynamo had made its commercial appearance, electric lighting and the mechanical applications of electricity, such as traction and power transmission and distribution, first attracted the inventive talents of electrical engineers. Nevertheless, as we were reminded by the institute dinner to Mr. Edison, the incandescent lamp is now only 26 years old. It is, therefore, not surprising that our electrochemical industries are still young, since their development depended rather on chemists and metallurgists, who were attracted by the possibilities of the application of the electric current which had proven to be such a manageable and thoroughly reliable agent in other fields of engineering.

The following sketch naturally does not aim at completeness, and no attempt will be made to give details of processes. The object is rather to bring out some general principles which have manifested themselves all along during the development of the electrochemical industries—leitmotives, to borrow a word from Wagner's operas. At the same time, we will try to arrive at a convenient classification of the whole subject. One general subdivision of all electrochemical processes and phenomena into two large classes offers itself. In the first class electrical energy is consumed to produce chemical effects, while in the second class chemical energy is changed into electrical energy. Thus, the second class comprises the whole field of primary cells and storage batteries, while in the first class we have all those more or less novel processes which are now mostly thought of when one speaks simply of electrochemical and electrometallurgical industries.

Chemical effects may be produced by means of electrical energies in various ways. We can change the electrical energy into heat, which is then consumed in producing the desired chemical effect; or we can change electrical energy into chemical energy directly by electrolysis; or we may use a combination of both methods; finally, a fourth method of producing chemical effects is by passing an electric discharge through gases. Before giving a cursory review of applications of these various principles, a general remark should be made on the nature of chemicals produced by such methods.

Many of these processes consume a considerable amount of electrical energy. In the discussion of furnace processes from the ordinary chemical point of view, we may, of course, say that the energy is expended to produce a certain temperature which is required to start the process. This, however, does not tell the whole story. We expend a certain amount of electrical energy which is lost while the process is going on. What becomes of it? If the process is conducted under fairly economical conditions most of the electrical energy is changed into chemical energy and is stored up in this form in the chemicals produced.

In other words, if an electrochemical process requires the expense of an appreciable amount of electrical energy, then the products of the process possess a higher content of chemical energy than the starting materials. This explains why electrochemical methods give us substances of strong chemical affinity. Moreover, these substances represent in a sense a storage of energy, which at the same time enables one to ship readily the stored energy to a point where it may be wanted. Two examples may explain this.

Aluminum does not occur free in nature and its separation from its compounds requires a considerable amount of energy. It we electrolyze aluminum oxide dissolved in a bath of fluorides, we get aluminum and oxygen; the formation heat of Al_2O_3 is 392,600 calories; hence, according to Thomson's rule (which is fully good enough for this purpose) we must apply at least 2.8 volts at the terminals of the cell. This voltage, multiplied by the coulombs passed through the cell, represents the electrical energy which is changed into chemical energy. That is what Hall does in producing aluminum in his cell. Now, we may ship the aluminum somewhere and may then allow it to combine again with oxygen to form back Al_2O_3. Then we get back our energy in the form of most intense heat. This is what Goldschmidt does in his thermit process. (Of course, he loses the energy which is required to reduce the iron oxide in the thermit; but this is small, compared with the formation heat of Al_2O_3.)

In the Union Carbide works in Niagara the energy of the falls after conversion into electrical energy, is stored in form of chemical energy in calcium carbide. As long as we keep it separate from water, the calcium carbide represents a storage of a distinct amount of energy. We can afterwards use it for the production of energy by generating acetylene from the carbide and water and using the acetylene for lighting; and we may do this anywhere, since the carbide can be easily shipped.

These two examples, while simply given to illustrate the energy point of view, are also suggestive as to what we may expect from future electrochemical developments. The achievements of the past have given us new methods of storing and transmitting energy; they have enormously cheapened the production of known substances, like aluminum, and have given us new substances of great commercial usefulness.

In this respect the industrial development of the electric furnace is very instructive. As the pioneers of electric furnace work, the two brothers, Eugene H. Cowles and Alfred H. Cowles, have slightly distinguished themselves, especially in the production of aluminum alloys. For the industrial development of the resistance furnace, the highest credit is due to the persevering work of Edward Goodrich Acheson. The extended laboratory researches of the French professor, Moissan, have thrown much light on the production of carbides.

The distinction between arc and resistance furnaces is so familiar that it is unnecessary to dwell on it here, nor shall details of design be discussed. But we may record the gradual change of the purpose to which the electric furnace is being put in practice. In the early days the intention was to produce as high a temperature as possible, and the result was the foundation of entirely new industries, like those of calcium carbide, carborundum and artificial graphite. For the production of these substances temperatures were required that could not be obtained by any other means but the electric furnace. In more recent years the intention has been rather to design furnaces so as to allow exact regulation of the temperature, and the electric furnace has thus been found suitable for reactions which do not require abnormally high temperatures.

The effect of regulating exactly the furnace temperature is very instructively shown by the example of treating a mixture of silica and carbon, which has been one of Acheson's fields of special research. By changing the conditions (by an appropriate design of the furnace so as to meet the special conditions of each case) it is possible to produce any one of the following substances: Carborundum, "white stuff," graphite, silicon, siloxicon.

The abnormal boom of calcium carbide in Europe, which naturally led to overproduction, resulted in various European furnace plants, originally erected for carbide, becoming free for other purposes. In looking for new processes it seems that nothing has more attracted the interest of European electrometallurgists than the possibilities in the electrometallurgy of iron and steel. Actual success has been achieved in the production of special steels (tool steels, crucible steel). A very great variety of arc and resistance furnaces have been developed for this purpose and in all of them care is taken to prevent contaminations of the bath from the carbon electrodes. Of special interest in connection with this latter point is the use of a resistance furnace, based on the induction principle, the fused steel forming the single secondary turn of a transformer, no electrodes whatever being used in this case.

While the above processes are all purely electro-thermic, the most notable example of a combination of an electrothermic with an electrolytic process is the manufacture of aluminum. The electrolyte from which the aluminum is deposited is a solution of alumina in a bath of fluorides, and its discovery, which made the manufacture of the cheap aluminum of to-day possible, is due to Charles M. Hall in this country and to P. L. T. Héroult abroad; both arrived independently of each other at the same solution. By a recent court decision the electro-thermic side of the process was held to be covered by the internal heating patent of Charles S. Bradley. What the electrochemical method of manufacture has done for aluminum is perhaps best indicated by the fact that the price of one kilogram was $250 in 1855, against 50 cents now. The Pittsburg Reduction company has now something like 22,000 horsepower in operation for the production of aluminum, and it is evident that the greatest efforts are to be made to push the use of aluminum for all possible purposes.

Other examples of a combined electrolytic and electrothermic reaction are the production of metallic sodium by the Castner process of electrolyzing fused caustic soda, and the Acker process of producing caustic and chlorine by electrolyzing fused sodium chloride with a cathode of molten lead.

While the Acker process is the latest and one of the most carefully developed processes for the electrolytic production of caustic and bleaching powder, it is by no means the only one, since there is an abundance of processes in which an aqueous solution of sodium chloride is electrolyzed. We thus come to the class of purely electrolytic processes. Of course, Joulean heat and a certain electro-thermic effect is here not absent, simply because it is impossible to avoid it. But it is generally so small as to be neglected, and, in fact, there are many cases in which it is necessary to make it small, since the output would be decreased by increased temperature.

One preliminary remark may be made on electrolytic processes in general. An electrolytic cell represents an electrochemical system, and it is mostly possible to arrange it in such a way that when electrolysis begins we get the products which we want. But when electrolysis is continued we have no longer our original electrochemical system and the products of electrolysis may no longer be pure; we may now get something we do not want. The first condition that must be fulfilled for the successful working of an electrolytic process on an industrial scale is to have the conditions good at the start, to begin with pure solutions and to maintain them pure during electrolysis. As F. Haber says, everything can be accomplished with pure solutions; nothing with foul solutions. In many cases in which a process looked promising from the experiments made on a small scale in the laboratory, it turned out to be afterwards a failure on a large scale, because the electrolyte soon became impure and its purification required expense and the overcoming of difficulties which had not been expected in advance. The same fundamental principle of the working of electrochemical processes is expressed by D. H. Browne in a slightly more general form when he asserts that the keynote of success in electrolysis is to keep initially good conditions permanently good. Close experiment will almost always reveal the proper conditions under which certain work can be done, but the continuance of these conditions is attainable only by continual vigilance.

To return to the electrolysis of an aqueous solution of sodium chloride, the products of electrolysis are caustic soda and hydrogen at the cathode and chlorine at the anode. This is what is wanted if our final products are to be bleaching powder and caustic. But if we did not remove the caustic soda and chlorine from our cell we would have a new electrochemical system. The catholyte would then be a mixture of caustic soda and sodium chloride and the ions of caustic soda would participate in the conduction of the current and hydroxyl ions would travel towards the anode and produce new reactions. New reactions of a secondary nature would also be started by the mixing of the chlorine and caustic in the solution, due to diffusion and convection currents. It is thus clear that since our electrochemical system has changed we get new products which we do not want. The technical problem is, therefore, to keep the anodic and cathodic products of electrolysis separate from each other. It has been solved in three essentially different ways.

The first is to separate both compartments mechanically by a diaphragm. As an early pioneer of diaphragm processes, E. A. Le Sueur has been active in this country. The largest American plant using a diaphragm process (that of the Dow Chemical company) is situated in Midland, Mich., while various diaphragm processes are in successful use in numerous paper and pulp mills, notably in New England.

The second general method is to keep the anodic and cathodic liquids separate from each other by making use of their different specific gravities (Glockenprocess, gravity process). This method is specially interesting as one of the comparatively few cases in which scientific research (in this case the determination of the transport numbers of the ions) has finally led to a new industrial process. While this process is in successful operation abroad, it has not yet been introduced into this country.

The third general method is to eliminate the sodium ions which are discharged at the cathode by alloying them with the mercury cathode. This process in the form developed by Hamilton Young Castner and C. Kellner is in use on a large scale in Niagara Falls. The elimination of the sodium from the cell by alloying it with a fused lead cathode in the Acker process is, of course, quite analogous.

In the manufacture of caustic soda and bleaching powder by electrolysis of sodium chloride, the electrolytic methods, sketched above, had to compete with one of the most firmly established chemical industries. The outcome of the war between the old chemical and the new electrochemical methods has been a victory for the latter, although the financial returns have been comparatively small, on account of the demoralization of the market.

While in the production of caustic and chlorine the purpose is to separate and maintain separated the anodic and cathodic products, just the reverse is the case when we want to obtain bleaching liquors or hypochlorites, since they are produced by the reaction between the chlorine and caustic. For this purpose it is evidently necessary to have the electrodes near together and to aid the above reaction by stirring. Several forms of hypochlorite apparatus are in use abroad, but have not yet found any extended use in this country. By modifying the conditions of operation, it is possible to produce chlorate, the main points being the use of a moderately high temperature and precaution for preventing reduction. This example shows how completely the results of a reaction may be changed, by varying the conditions, and it emphasizes the necessity, pointed out above, of carefully maintaining the original conditions of the system unchanged during electrolysis, if we invariably want to get the same results.

In electroplating, the problem is to have always a sufficient number of the metallic ions to be deposited in close proximity to the cathode. The tendency of the current is to impoverish the solution near the cathode. This tendency must be counteracted. Stirring the solution and revolving the electrodes are suitable means and care must be taken to obtain proper corrosion of the anode which has to supply new metallic ions to replace those deposited at the cathode. There are now more than 1,200 electroplating establishments in the United States and in recent years a tendency has manifested itself to give up the old rule-of-thumb methods and to work according to exact principles.

Of much greater industrial importance, however, is the kindred art of electro-refining. In 1879 an experimental copper refining plant was in operation for a short time at Phœnixville, Pa., but the first commercial copper refining plant in America was erected in the early '80's. This is the Balbach works in Newark. To-day there are in operation in this country ten electrolysis refineries with a total daily copper output of 764 tons, or 279,000 tons per year. At the same time 27,000,000 ounces of silver and 346,020 ounces of gold are recovered per year in these refineries.

There is a very peculiar difference in the details of operation of the different refineries. Two plants use the series arrangement of electrodes, all others the multiple system. There is a considerable difference in the current density used; of two plants in the west, in close proximity, one uses 40, the other 12 amperes per square foot. The list of variations in the methods of operation could be easily enlarged. In other words, the art of copper refining is far from being standardized. Since it is known that for a number of years the different refineries have very carefully and systematically studied the best conditions of operation in their own case, the difference in the methods of the different refineries may be attributed to a difference in the given conditions in each case. If this is so it emphasizes the complexity of the economical working of even so simple an electrolytic problem as copper refining.

Recently the Betts process of lead refining has aroused very great interest. The essential point is the electrolyte, which is a solution of lead fluosilicate, containing an excess of fluosilicic acid. It is easily prepared from inexpensive materials, it conducts the current well and it dissolves other metals but lead only in very small quantities. The last point is of great importance in view of the fundamental requirement that the solution should remain pure during operation. In a similar way, for copper refining, the possibility of continually renewing the electrolyte is essential.

The Wohlwill process of gold refining is in operation at the Philadelphia mint, using an electrolyte of gold chloride, rather strongly impregnated with free hydrochloric acid. The addition of the free hydrochloric acid in this case, like that of fluosilicic acid in the Betts process, is necessary to produce the proper corrosion of the anode and to maintain the electrolyte in its original condition. Much special study has been devoted in recent years to the question under what conditions dense solid cathodic deposits of metals are obtained. The simple method, by which in the case of lead Betts overcomes all difficulties in this respect—by providing a reducing action, practically accomplished by the addition of gelatine or glue—seems very encouraging.

As the reverse case of electroplating, we may consider the electrolytic stripping of metals. The production of tin from tin scrap has achieved considerable commercial success, first in several plants in Germany, from where it was recently imported to this country. An interesting similar process, although of much less industrial importance, is the method of Burgess, which was used in bicycle manufacturing works for removing the thin layer of brass on the surface of the frames by electrolysis, with a sodium nitrate solution as electrolyte. This example is mentioned to show how electrochemical methods may be applied to details in various manufacturing processes and may effect an important economy of labor.

In their application to the metallurgy of gold, the use of electrolytic methods has been confined to the cyanide process, as far as commercial success has been obtained. Electrolytic precipitation has been used successfully in the Siemens & Halske process in South Africa, although side by side with zinc precipitation. The latter method is nearly exclusively used in this country. But it should not be overlooked that the latter method is also essentially an electrochemical phenomenon. Chemically pure zinc is inactive as a precipitating agent. What is needed is commercial zinc containing small particles of impurities, or specially prepared zinc couples, like zinc lead. Thus, while with electrolytic precipitation we have the source of the electric current outside of the precipitating vat, we have with zinc precipitation an immense number of small short circuited galvanic couples in the precipitating vat itself.

In the production of metals from ores, much research has been devoted to the problem of getting copper and nickel from the Sudbury ores. The late Dr. Hoepfner did highly valuable pioneer work in this line, but full commercial success was obtained by David H. Browne, who, in working out his process in which chlorine passes through an ingenious cycle, paid proper attention to the fundamental requirement that pure solutions must be provided and maintained.

An interesting and novel electrometallurgical process which, however, has not yet attained industrial importance, is Salom's reduction of lead from galena by direct cathodic reduction.

That class of processes in which chemical efforts are produced by discharges through gases is the youngest in the development of industrial electrochemistry. Commercial success has been achieved abroad with the production of ozone from air and the subsequent use of ozone for sterilizing water. If the cost is not prohibitive, there should be a commercial future for such processes in this country. Great interest has been aroused by the Bradley-Lovejoy process for the fixation of nitrogen from the air. The process is still in its experimental stage and a successful issue would have a revolutionary effect in many branches, particularly in agricultural chemistry. The variety of possible methods is indicated by the utilization of the silent discharge in ozonizers, while Bradley and Lovejoy produce arcs, but so finely subdivided as to give a large surface for small energy.

This cursory review does not nearly exhaust the subject of producing chemical effects by electrical means, but it is hoped that it gives at least a general idea of the achievements of the past and of the possibilities of the future, together with some general principles which should always be kept in mind in connection with this subject. We may be permitted to treat even more briefly the reverse problem, that of producing electrical from chemical energy.

There is not much to be said concerning primary batteries. Their limitations, if zinc is used as fuel, have been pointed out above. The problem has, therefore, been to substitute carbon for zinc and to devise a carbon cell. The effect would be commercially far reaching. At present we burn the coal in connection with boilers, steam engines and dynamos and thus produce electrical energy by a roundabout method, with a low efficiency, since the efficiency of the steam engine is limited by the principles of thermodynamics. There would be no such limitations with a carbon cell. But the trouble is that such a cell is still a dream. Theorists and practical men have attempted the solution of the problem, but have equally failed.

On the other hand, storage battery engineering has passed with success through an extremely active career and the outlook is bright for the future. As early as 1856 Gaston Planté began his extended investigations on the formation of the lead accumulator. His method was purely electrochemical. Starting with metallic lead sheets, he submitted them to the action of the electric current in dilute sulphuric acid. But since the cell had to be charged and discharged a great many times, his method of formation required a very long time and was expensive. The technical problem was, therefore, to shorten the time of formation.

Faure abroad, and Brush in this country, devised in the early 80's an improvement of the Planté cell, which consisted in mechanically applying active material to a conducting support. They thus produced instantly a plate, the manufacture of which by the Planté process would have required several months. Immediately afterwards an extreme activity began in storage battery invention, the goal being to avoid the claims of the Brush patent. The outcome was a modification of the original electrochemical Planté formation by replacing the electrolyte of pure dilute sulphuric acid by an oxidizing electrolyte. Moreover, purely chemical formation without any current was also found practical.

Along these general lines the successful lead battery of to-day was developed. The number of United States patents on this subject is legion, but the patents generally refer either to details of construction or to composition of the electrolyte for formation. Storage batteries have found very extended use in direct current central stations and substations. In fact, stationary batteries for such work represent at present 75 per cent of all the storage batteries manufactured, and for this purpose the position of the lead cell seems secure.

In recent years, however, the possibilities of electric automobilism have encouraged inventors to search for a battery of light weight and small size. The use of lead was considered as essentially unsuitable for this purpose. The researches were mostly made along the lines of alkaline batteries. Finally the aim was the design of an oxygen lift cell, with potassium or sodium hydroxide as electrolyte and electrodes simply undergoing oxidation and reduction and insoluble in the electrolyte in all states of oxidation. Several inventors have worked along this line, among them Jungner. But commercial success was first attained by Thomas A. Edison with his nickel iron battery, which, it seems, will have a field of its own, especially for automobile work.

A QUARTER CENTURY OF ELECTRIC LIGHTING.

BY LOUIS BELL.

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The growth of a new art is a startling phenomenon. The familiar manufacturing enterprise of a nation may, under normal conditions, be expected to keep pace with the growth of the population in numbers and in wealth and save for commercial disaster now and then, or for artificial stimulus by governmental action, to move forward at a fairly regular rate. But the irruption of a new art like electric lighting is a very different matter. It grows in response to a law of demand that bears no definite relation to anything and while, of course, this growth is affected by local causes and by the conditions of general prosperity, it depends largely on intrinsic factors in the art itself, the effect of which cannot be predicted, but becomes visible in the fullness of time.

One may study the phenomenon of such growth as a pure matter of statistics, but while such an examination may, like other statistics correctly show effects, it fails utterly, as statistics usually do, in showing the causes which produce them. Cause and effect can be correlated, but only by studying the circumstances which are current with the figures. The relations between figures and facts are far too complicated to be self evident.

Starting, then, with the broad facts that about twenty six years ago incandescent lighting by central stations began, and that to-day the whole business occupies 3,700 stations, represents an investment of more than half a billion dollars, and draws a gross yearly income of nearly ninety million dollars, it is worth the while to attempt to trace the reasons for so prodigious a growth and the factors which have gone to produce it.

In that quarter century the population of the country has increased about 80 per cent, and few large industries have exceeded this rate of growth; but electric lighting, starting from absolute nonexistence, has risen to an industry of first rank in the face of strong competition from other illuminants, and what is more, in the face of a cost which throughout its whole early history was undeniably higher than that of any other illuminant. It has made its way through the operation of favoring factors other than economy, ranking as a luxury rather than a necessity, and only within a few years being able to meet competition on a simple basis of cost. These facts are very unusual in the history of a great industry and deserve careful consideration. They are the more extraordinary when one considers that for some years electric lighting was not only upon the whole the most costly but the least reliable form of illumination, was fought viciously by the fire underwriters, suffered from ferocious internecine war among its exponents, and had been a very Gettysburg of patent litigation.

When late in 1879 the incandescent lamp appeared as a commercial possibility, the arc lamp had already been for some years in slowly increasing use both here and abroad, mostly for small private installations, for the quite sufficient reason that the largest arc dynamos would handle but a few lamps, not enough to cut any figure at all for anything but the smallest plants. Nevertheless it was perfectly evident that the arc had come to stay. It had the inestimable property of giving white light in the form of a very intense and powerful unit. Before the electric arc came into use, lights of similar power were practically nonexistant, and the arcs could therefore give a brilliancy of effect hitherto unknown. This fact of itself accounted for their rapid growth in popularity and when their accurate rendition of color values is taken into account, it is small wonder that they made a sensation. The Jablochkoff candle, practically the earliest commercial form of arc, was, in spite of its limitations, altogether remarkable in the quality of the illumination given, and, in fact, would be difficult to surpass in this particular. It is interesting to note that it has continued in limited use even up to the present time.

The arc lamp therefore did the pioneering for the incandescent lamp. It educated the public to the appreciation of the importance of color values in illumination, drew once for all a line between weak illuminants and powerful ones, and caused all eyes to be turned to electricity as the coming source of illumination.

Then came the incandescent lamp in response to the demand for smaller electric lights. The subdivision of the electric light was the problem of the day, and very fortunately this problem was solved by the glow lamp instead of by arcs of small candle power, which could not then have been, and, in fact, never have been, satisfactory illuminants. The incandescent lamp nearly equalled the arc in rendering color values, and enormously surpasses it in convenience and steadiness.

It was far less economical than the arc and was not for some time on public circuits able to compete with gas, but made its way by reason of its better color, its steadiness and its freedom from vibration of the air, and from overheating. These good qualities carried it ahead in spite of all opposition. It is hard to realize to-day how much these gains meant in the way of exterior illumination, but they were fully realized at the time, and they unquestionably won the day for electric lighting. Looking over some ancient history recently the writer came across a printed letter reporting results from one of the early isolated plants, that in the Pemberton mills, installed in October, 1881. Although in this case two four-foot gas jets were replaced by each "A" lamp of 16 candle power, a great improvement was noted in the conditions of illuminations, especially in regard to color vision in work on colored fabrics, and in the purity of the atmosphere. Further, it was shown that the cost of the electric light, including interest and depreciation at 12 per cent, and lamp renewals at $1.00 apiece, was less than the cost of gas for the burners replaced by more than a half.

One smiles nowadays at the idea of replacing two four-foot gas jets by one 16 candle power lamp, but the fact of doing so was a valuable lesson in illumination—proof that a steady light, good in color, can actually with positive advantage replace lights of greater gross intensity, but lacking these two things.

A good many people who ought to know better, but have not learned this lesson, still foster the idea that illumination intrinsically bad can be made good by merely increasing its quantity.

The incandescent light practically won its way through quality, for only under rare conditions could it at first show economy over gas at the prices generally current. Once introduced and appreciated it was rapidly pushed ahead. It was a thing to advertise in one's business and to brag about to one's neighbors, and its use thus spread with the added momentum due to fashion. With it came increased use of arc lamps, partly in competition, but still consistently backing up the public demand for bright light and more of it. Pretty bad some of those early arcs were too, but they did what gas had never done—they really lighted large areas effectively by dint of sheer brilliancy. Between the arcs and incandescents there was awakened a demand for public electrical supply, though, by a strange streak of fate, the arc and the incandescent systems, beautifully fitted to supplement each other's work, fought like cat and dog, damning each other with an ingenuity of objurgation that would be worthy of a unique position in profane history. Apparently this mutual abuse simply served to make violent partisans and both systems flourished. Forward steps were rapid, and on one hand arc machines carrying a respectably large series of lamps soon came into use, and the carbons, at first horribly bad, were so improved in manufacture as greatly to better the steadiness of the light. On the other hand, incandescent lamps were greatly improved in manufacture so that their useful life was largely increased, the bamboo filament was fashioned into as good practically working form as its nature permitted, and the invaluable three-wire distribution was brought into wide use. In large cities incandescent lighting was giving good account of itself in competition with gas, but it was not yet able on account of the inheritant limitations of a low pressure distribution to work advantageously in the smaller places where absence from gas would give it an advantage of competition. At the present time over three quarters of the central stations are in such places and have the field to themselves.

Desperate efforts were made, with indifferent success, to build up an incandescent light system on arc circuits. Such lights have never been wholly satisfactory even for street lighting, and the danger of high potential wires kept them for the most part out of buildings. The greatest impetus that the art of electric lighting received after the invention of the incandescent lamp was the introduction of the alternating current transformer system in 1885, when the first plant went into operation in Great Barrington, Mass. The next two years saw the system put into practical shape, and thereafter the growth of small stations was startlingly rapid. The number of new plants started in 1885 was but 55, the next year it was 100, the next 147, the next 160, and in 1889 it arose to 208. A large part of this activity was represented by small alternating current plants. Bad as they were from our modern standpoint, their old 50-volt lamps did good service, for they were far easier to turn out successfully than the more delicate 110-volt lamps of the direct current system. It is interesting to note that in some of the very earliest Edison plants 8 and 10 candle power lamps were freely used, but difficulties of manufacture and the customary gas standard of 16 candle power soon forced the small lamps out of use only to appear years later.

Meanwhile, arc lighting had prospered, machines capable of operating forty lights or so in series had come into use; the lamps were of far better quality than before; and, reinforced by the power of working an incandescent system with alternators, the old arc stations took on a new activity. With the alternating system, too, came alone by stress of competition, various improvements in incandescent lamps, including the flashing process now universally used, and Mr. Weston's structureless cellulose filament, now, after various modifications, in universal use. These improvements are the basis of scientific lamp manufacture, and the fierce fight that was waged between the natural and artificial filaments now seems a curious bit of ancient history. The first ten years of central station lighting, with their ferocious strife of systems, were years of tremendous progress, and desperate competition, often unwise and injurious, but serving to keep the art moving forward and strengthened its hold upon the public.

Fortunately, the one great improvement in gas lighting, the introduction of the incandescent burner, had not yet come to active service, else electric lighting would have had a far harder struggle for existence than it actually found. And when the incandescent burner actually did come into competition with electric lighting, its life was so uncertain and its color so vile that it made small headway until electric lighting was in better shape for hard fighting. Even now, in spite of repeated alleged improvements, the color of the incandescent gas lamps is ordinarily so bad as to put them at a hopeless disadvantage.

But better things were in store for electric lighting. The war of systems drew to a close by the crippling of some combatants and honorable truce among others. The electric railway had come to strengthen the hands of the electrical industries in general, and the troublesome problems of alternating current distribution, of proper insulation for machinery and for lines, and of machine design, were being rapidly threshed out. There is no absolute dividing line between the old and the new, but about 1890 electric lighting took a firmer hold and began the period of its most effective growth.

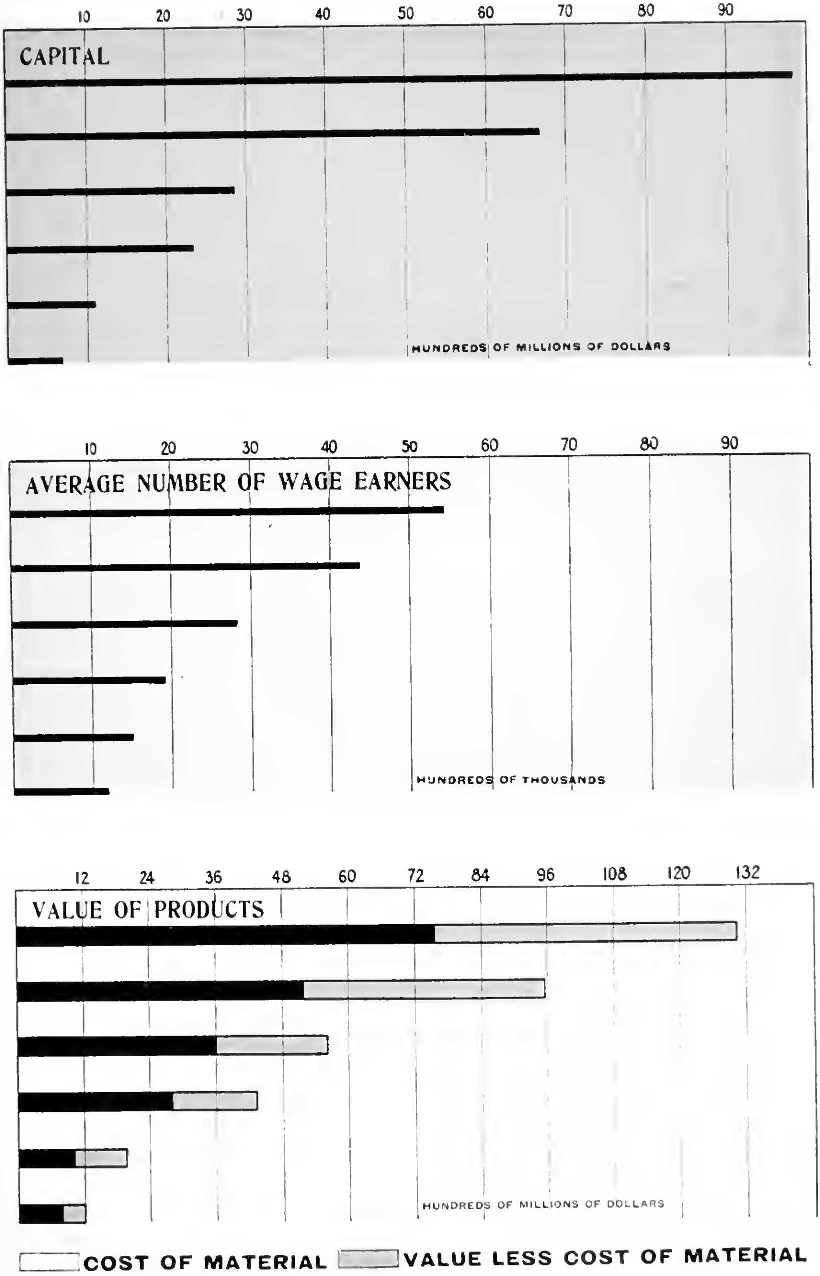
The period was not signalized so much by brilliant discovery as by the application of sound common sense. The first step of importance was the introduction of large dynamos, generally direct coupled. Although direct coupling had been tried by Edison in the very beginning of central station work, dynamo design was not then far enough advanced to ensure success, but these later direct coupled units revolutionized the central station business, simplifying problems of distribution, improving regulation, increasing station efficiency, and generally putting incandescent electric lighting on an economical and business like basis. Arc lighting, too, was proceeding on broader lines with larger units, and presently came the successful constant potential arc, putting it in the power of the incandescent lighting station to do all classes of business over the one network. This unification was perhaps the most important step that has been taken in central station practice, and it immediately gave electric lighting an economic lift that was very quickly felt. It became possible to put prices at a point that attracted business, and in the early nineties not only was building active, but there was an extensive course of rebuilding and change of equipment which really inaugurated the modern period of electric lighting.

The idea of unification of service was extended to alternating current practice by the introduction of polyphase apparatus. The first applications were to power transmission plants, which did not in themselves affect the lighting industry very greatly; but a little later the very extensive adoption of polyphase transmission in central station working via substations rose to great importance in increasing the facilities of the large urban plants. At the present time more than 60 per cent of the total dynamo capacity in the central stations of the country is in the form of polyphase and other alternating current generators. The introduction of these big modern alternators has enabled conditions of good regulation to be maintained on alternating current distribution systems, and has, by improving the service, greatly stimulated incandescent lighting on such systems. The substitution of large transformers feeding secondary mains for the house to house distribution has also had a most important effect in improving business and in increasing station economy so as to give more encouraging financial returns.

Arc lighting was much less stimulated by these changes than was incandescent lighting, for the alternating arc has never obtained a firm hold upon public popularity. Nevertheless, about 30 per cent of all the arc lights are to-day operated by alternating current, a proportion which is due to secondary rather than to primary causes. The incandescent lamp has undergone in these years a far less extensive evolution than the arc lamp. It is now pretty nearly the same

MANUFACTURES

VALUE, CAPITAL, WORKERS, IN THE UNITED STATES



thing that it was ten years ago, save that improvements in manufacture have rendered the product somewhat more uniform. Chief among these we must reckon the almost universal use of the squirted cellulose filament and the introduction of the chemical method of final exhaustion. Various efforts have been made to introduce incandescent lamps of about double the usual voltage. The difficulties of construction of such lamps, their relatively low efficiency and the use with which an alternating distribution at the usual voltages is effected constitute ample reasons for the small use of these high voltage lamps; while the vigorous objections of the fire underwriters have discouraged any extensive exploitation of them.

The greatest change of recent years in general lighting has been the introduction of the enclosed arc lamp, which has worked a revolution in indoor lighting at constant potential as well as in street lighting. It has on the whole stimulated incandescent lighting, however, by raising the common standard of brilliancy, and by aiding in the unification of service. Considerably more than half the arc lights in use are enclosed, the bulk of the open ones being used for street lighting by companies not yet quite ready to undertake re-equipment. Of the alternating arcs more than nine tenths are of the enclosed type, a result due almost to necessity. The introduction in recent years of series alternating arcs fed from constant current transformers is responsible for most of the use of alternating current arcs, and practically all such are enclosed.

Through all these years of progress the incandescent lamp has held its own and has grown in relative popularity. The same virtues that gave it its start in life have kept its fortunes in the ascendant. With all its failings in points of efficiency it is to-day, as it was in the beginning, the best available illuminant in point of quality and general usefulness. Within very recent years determined efforts have been made to obtain other electric lamps of equally good qualities and of higher efficiency, but up to the present these efforts have not been crowned with success. The Nernst lamp, most admirable in some respects, is at its best in competition with the arc rather than the incandescent lamp, and is still a rarity, not yet seriously to be considered in the grand total of electric illumination. The mercury arc, another recent candidate for lighting honors, has little yet to show in the way of results, and its color is so hopelessly bad that unless remedied by some very radical step, the lamp will entirely fail of material usefulness as a general illuminant. If the public could be educated up to the point of liking the color of the mercury arc, it would already have welcomed the incandescent gas mantle to the exclusion of nearly everything else.

The incandescent lamp is then to-day as it has been all through its history, the mainstay of modern illumination so far as interior lighting is concerned. It may in due season be supplanted by something better, but that something will have to be equally steady and simple and convenient and good in color. At the present time there are nearly twenty million incandescents in lighting service from central stations in this country alone—how great a harvest from the seedtime of 1879! Electric lighting has won its way into the front rank of American industries, and there it is likely to stay. Its full history cannot be written apart from that of the country's industrial growth with which it has more than kept pace.

THE TRANSMISSION OF ELECTRIC ENERGY WITHOUT WIRES.

BY NIKOLA TESLA.

[Nikola Tesla, electrician; born Smiljan, Lika, 1857; educated in the public schools of Gospich; graduated from Real Schule, Karlstadt, 1873; studied at Polytechnic school, in Gratz, to become a professor of mathematics, but later changed and completed the engineering course; studied languages and philosophy at Prague and Buda-Pesth; was for a time assistant in government telegraph engineering department, where he invented several improvements; afterwards became engineer for a lighting company in Paris; afterwards came to the United States and was employed by Edison company; later became electrician for the Tesla Electric Light company and established the principle of the rotary magnetic field embodied in the apparatus used in transmission of power from Niagara Falls; inventor of various forms of dynamos, induction coils, transformers, etc.]

Towards the close of 1898 a systematic research, carried on for a number of years with the object of perfecting a method of transmission of electrical energy through the natural medium, led me to recognize three important necessities: First, to develop a transmitter of great power; second, to perfect means for individualizing and isolating the energy transmitted; and, third, to ascertain the laws of propagation of currents through the earth and the atmosphere. Various reasons, not the least of which was the help proffered by my friend Leonard E. Curtis and the Colorado Springs Electric company, determined me to select for my experimental investigations the large plateau, two thousand meters above sea level, in the vicinity of that delightful resort, which I reached late in May, 1899. I had not been there but a few days when I congratulated myself on the happy choice and I began the task, for which I had long trained myself, with a grateful sense and full of inspiring hope. The perfect purity of the air, the unequaled beauty of the sky, the imposing sight of a high mountain range, the quiet and restfulness of the place—all around contributed to make the conditions for scientific observation ideal. To this was added the exhilarating influence of a glorious climate and a singular sharpening of the senses. In those regions the organs undergo perceptible physical changes. The eyes assume an extraordinary limpidity, improving vision; the ears dry out and become more susceptible to sound. Objects can be clearly distinguished there at distances such that I prefer to have them told by someone else, and I have heard—this I can venture to vouch for— the claps of thunder seven and eight hundred kilometers away. I might have done better still, had it not been tedious to wait for the sounds to arrive, in definite intervals, as heralded precisely by an electrical indicating apparatus—nearly an hour before.

In the middle of June, while preparations for other work were going on, I arranged one of my receiving transformers with the view of determining in a novel manner, experimentally, the electric potential of the globe and studying its periodic and casual fluctuations. This formed part of a plan carefully mapped out in advance. A highly sensitive, self restorative device, controlling a recording instrument, was included in the secondary circuit, while the primary was connected to the ground and an elevated terminal of adjustable capacity. The variations of potential gave rise to electric surgings in the primary; these generated secondary currents, which in turn affected the sensitive device and recorder in proportion to their intensity. The earth was found to be literally alive with electrical vibrations, and soon I was deeply absorbed in this interesting investigation. No better opportunities for such observations as I intended to make could be found anywhere. Colorado is a country famous for the natural displays of electric force. In that dry and rarefied atmosphere the sun's rays beat the objects with fierce intensity. I raised steam, to a dangerous pressure, in barrels filled with concentrated salt solution, and the tinfoil coatings of some of my elevated terminals shriveled up in the fiery blaze. An experimental high tension transformer, carelessly exposed to the rays of the setting sun, had most of its insulating compound melted out and was rendered useless. Aided by the dryness and rarefaction of the air, the water evaporates as in a boiler, and static electricity is developed in abundance. Lightning discharges are, accordingly, very frequent and sometimes of inconceivable violence. On one occasion approximately twelve thousand discharges occurred in two hours, and all in a radius of certainly less than fifty kilometers from the laboratory. Many of them resembled gigantic trees of fire with the trunks up or down. I never saw fire balls, but as a compensation for my disappointment I succeeded later in determining the mode of their formation and producing them artificially.

In the latter part of the same month I noticed several times that my instruments were affected stronger by discharges taking place at great distances than by those near by. This puzzled me very much. What was the cause? A number of observations proved that it could not be due to the differences in the intensity of the individual discharges, and I readily ascertained that the phenomenon was not the result of a varying relation between the periods of my receiving circuits and those of the terrestrial disturbances. One night, as I was walking home with an assistant, meditating over these experiences, I was suddenly staggered by a thought. Years ago, when I wrote a chapter of my lecture before the Franklin institute and the National Electric Light association, it had presented itself to me, but I had dismissed it as absurd and impossible. I banished it again. Nevertheless, my instinct was aroused and somehow I felt that I was nearing a great revelation.

It was on the third of July—the date I shall never forget—when I obtained the first decisive experimental evidence of a truth of overwhelming importance for the advancement of humanity. A dense mass of strongly charged clouds gathered in the west and towards the evening a violent storm broke loose which, after spending much of its fury in the mountains, was driven away with great velocity over the plains. Heavy and long persisting arcs formed almost in regular time intervals. My observations were now greatly facilitated and rendered more accurate by the experiences already gained. I was able to handle my instruments quickly and I was prepared. The recording apparatus being properly adjusted, its indications became fainter and fainter with the increasing distance of the storm, until they ceased altogether. I was watching in eager expectation. Surely enough, in a little while the indications again began, grew stronger and stronger and, after passing through a maximum, gradually decreased and ceased once more. Many times, in regularly recurring intervals, the same actions were repeated until the storm which, as evident from simple computations, was moving with nearly constant speed, had retreated to a distance of about three hundred kilometers. Nor did these strange actions stop then, but continued to manifest themselves with undiminished force. Subsequently, similar observations were also made by my assistant, Mr. Fritz Lowenstein, and shortly afterward several admirable opportunities presented themselves which brought out, still more forcibly, and unmistakably, the true nature of the wonderful phenomenon. No doubt whatever remained: I was observing stationary waves.

As the source of disturbances moved away the receiving circuit came successively upon their nodes and loops. Impossible as it seemed, this planet, despite its vast extent, behaved like a conductor of limited dimensions. The tremendous significance of this fact in the transmission of energy by my system had already become quite clear to me. Not only was it practicable to send telegraphic messages to any distance without wires, as I recognized long ago, but also to impress upon the entire globe the faint modulations of the human voice, far more still, to transmit power, in unlimited amounts, to any terrestrial distance and almost without any loss.

With these stupendous possibilities in sight, with the experimental evidence before me that their realization was henceforth merely a question of expert knowledge, patience and skill, I attacked vigorously the development of my magnifying transmitter, now, however, not so much with the original intention of producing one of great power, as with the object of learning how to construct the best one. This is, essentially, a circuit of very high self induction and small resistance which in its arrangement, mode of excitation and action, may be said to be the diametrically opposite of a transmitting circuit typical of telegraphy by Hertzian or electromagnetic radiations. It is difficult to form an adequate idea of the marvelous power of this unique appliance, by the aid of which the globe will be transformed. The electromagnetic radiations being reduced to an insignificant quantity, and proper conditions of resonance maintained, the circuit acts like an immense pendulum, storing indefinitely the energy of the primary exciting impulses and impressing upon the earth and its conducting atmosphere uniform harmonic oscillations of intensities which, as actual tests have shown, may be pushed so far as to surpass those attained in the natural displays of static electricity.

Simultaneously with these endeavors, the means of individualization and isolation were gradually improved. Great importance was attached to this, for it was found that simple tuning was not sufficient to meet the vigorous practical requirements. The fundamental idea of employing a number of distinctive elements, co-operatively associated, for the purpose of isolating energy transmitted, I trace directly to my perusal of Spencer's clear and suggestive exposition of the human nerve mechanism. The influence of this principle on the transmission of intelligence, and electrical energy in general, cannot as yet be estimated, for the art is still in the embryonic stage; but many thousands of simultaneous telegraphic and telephonic messages, through one single conducting channel, natural or artificial, and without serious mutual interference, are certainly practicable, while millions are possible. On the other hand, any desired degree of individualization may be secured by the use of a great number of co-operative elements and arbitrary variation of their distinctive features and order of succession. For obvious reasons, the principle will also be valuable in the extension of the distance of transmission.

Progress though of necessity slow was steady and sure, for the objects aimed at were in a direction of my constant study and exercise. It is, therefore, not astonishing that before the end of 1899 I completed the task undertaken and reached the results which I announced in my article in the Century magazine of June, 1900, every word of which was carefully weighed.

Much has already been done towards making my system commercially available, in the transmission of energy in small amounts for specific purposes, as well as on an industrial scale. The results attained by me have made my scheme of intelligence transmission, for which the name of World Telegraphy has been suggested, easily realizable. It constitutes, I believe, in its principle of operation, means employed and capacities of application, a radical and fruitful departure from what has been done heretofore. I have no doubt that it will prove very efficient in enlightening the masses, particularly in still uncivilized countries and less accessible regions, and that it will add materially to general safety, comfort and convenience, and maintenance of peaceful relations. It involves the employment of a number of plants, all of which are capable of transmitting individualized signals to the uttermost confines of the earth. Each of them will be preferably located near some important center of civilization and the news it receives through any channel will be flashed to all points of the globe. A cheap and simple device, which might be carried in one's pocket, may then be set up somewhere on sea or land, and it will record the world's news or such special messages as may be intended for it. Thus the entire earth will be converted into a huge brain, as it were, capable of response in every one of its parts. Since a single plant of but one hundred horsepower can operate hundreds of millions of instruments, the system will have a virtually infinite working capacity, and it must needs immensely facilitate and cheapen the transmission of intelligence.

The first of these central plants would have been already completed had it not been for unforeseen delays which, fortunately, have nothing to do with its purely technical features. But this loss of time, while vexatious, may, after all, prove to be a blessing in disguise. The best design of which I knew has been adopted, and the transmitter will emit a wave complex of a total maximum activity of ten million horsepower, one per cent of which is amply sufficient to "girdle the globe." This enormous rate of energy delivery, approximately twice that of the combined falls of Niagara, is obtainable only by the use of certain artifices, which I shall make known in due course.

For a large part of the work which I have done so far I am indebted to the noble generosity of Mr. J. Pierpont Morgan, which was all the more welcome and stimulating, as it was extended at a time when those, who have since promised most, were the greatest of doubters. I have also to thank my friend, Stanford White, for much unselfish and valuable assistance. This work is now far advanced, and though the results may be tardy, they are sure to come.

Meanwhile, the transmission of energy on an industrial scale is not being neglected. The Canadian Niagara Power company have offered me a splendid inducement, and next to achieving success for the sake of the art, it will give me the greatest satisfaction to make their concession financially profitable to them. In this first power plant, which I have been designing since a long time, I propose to distribute ten thousand horsepower under a tension of one hundred million volts, which I am now able to produce and handle with safety.

This energy will be collected all over the globe preferably in small amounts, ranging from a fraction of one to a few horsepower. One of its chief uses will be the illumination of isolated homes. It takes very little power to light a dwelling with vacuum tubes operated by high frequency currents, and in each instance a terminal a little above the roof will be sufficient. Another valuable application will be the driving of clocks and other such apparatus. These clocks will be exceedingly simple, will require absolutely no attention and will indicate rigorously correct time. The idea of impressing upon the earth American time is fascinating and very likely to become popular. There are innumerable devices of all kinds which are either now employed or can be supplied, and by operating them in this manner I may be able to offer a great convenience to the whole world with a plant of no more than ten thousand horsepower. The introduction of this system will give opportunities for invention and manufacture such as have never presented themselves before.

Knowing the far reaching importance of this first attempt and its effect upon future development, I shall proceed slowly and carefully. Experience has taught me not to assign a term to enterprises the consummation of which is not wholly dependent on my own abilities and exertions. But I am hopeful that these great realizations are not far off, and I know that when this first work is completed they will follow with mathematical certitude.

When the great truth accidentally revealed and experimentally confirmed is fully recognized, that this planet, with all its appalling immensity, is to electric currents virtually no more than a small metal ball and that by virtue of this fact many possibilities, each baffling imagination and of incalculable consequence, are rendered absolutely sure of accomplishment; when the first plant is inaugurated and it is shown that a telegraphic message, almost as secret and non-interferable as a thought, can be transmitted to any terrestrial distance, the sound of the human voice, with all its intonations and inflections faithfully and instantly reproduced at any other point of the globe, the energy of a waterfall made available for supplying light, heat or motive power, anywhere—on sea, land, or high in the air—humanity will be like an ant heap stirred up with a stick. See the excitement coming!

BEGINNINGS OF THE TELEPHONE.

BY ALEXANDER GRAHAM BELL.

[Alexander Graham Bell, scientist and inventor; born Edinburgh, Scotland, March 3, 1847; educated at Edinburgh and in London university; went to Canada in 1870; and to Boston, 1872, where he became professor of vocal physiology at the Boston university; invented the telephone and was granted a patent Ferbuary 4, 1876; invented the photophone, induction balance and telephone probe for painless detection of bullets in the human body; author of Memoir on the Formation of a Deaf Variety of the Human Race, and other scientific articles.]

Many years ago my attention was directed to the mechanism of speech by my father, Alexander Melville Bell, of Edinburg, who made a lifelong study of the subject. Many may recollect the invention by my father of a means of representing, in a wonderfully accurate manner, the positions of the vocal organs in forming sounds. Together we carried on quite a number of experiments, seeking to discover the correct mechanism of English and foreign elements of speech, and I remember especially an investigation in which we were engaged concerning the musical relations of vowel sounds. When vocal sounds are whispered, each vowel seems to possess a particular pitch of its own, and by whispering certain vowels in succession a musical scale can be distinctly perceived. Our aim was to determine the natural pitch of each vowel; but unexpected difficulties made their appearance, for many of the vowels seemed to possess a double pitch—one due, probably, to the resonance of the air in the mouth, and the other to the resonance of the air contained in the cavity behind the tongue, comprehending the pharynx and larynx.

I hit upon an expedient for determining the pitch, which at that time I thought to be original with myself. It consisted in vibrating a tuning fork in front of the mouth while the positions of the vocal organs for the various vowels were silently taken. It was found that each vowel position caused the reinforcement of some particular fork or forks.

I wrote an account of these researches to Mr. Alexander J. Ellis, of London. In reply, he informed me that the experiments related had already been performed by Helmholtz, and in a much more perfect manner than I had done. Indeed, he said that Helmholtz had not only analyzed the vowel sounds into their constitutent musical elements, but had actually performed the synthesis of them.

He had succeeded in producing, artificially, certain of the vowel sounds by causing tuning forks of different pitch to vibrate simultaneously by means of an electric current. Mr. Ellis was kind enough to grant me an interview for the purpose of explaining the apparatus employed by Helmholtz in producing these extraordinary effects, and I spent the greater part of a delightful day with him in investigating the subject. At that time, however, I was too slightly acquainted with the laws of electricity fully to understand the explanations given; but the interview had the effect of arousing my interest in the subjects of sound and electricity, and I did not rest until I had obtained possession of a copy of Helmholtz's great work "The Theory of Tone," and had attempted, in a crude and imperfect manner, it is true, to reproduce his results. While reflecting upon the possibilities of the production of sound by electrical means, it struck me that the principle of vibrating a tuning fork by the intermittent attraction of an electromagnet might be applied to the electrical production of music.

I imagined to myself a series of tuning forks of different pitches, arranged to vibrate automatically in the manner shown by Helmholtz—each fork interrupting, at every vibration, a voltaic current—and the thought occurred, why should not the depression of a key like that of a piano direct the interrupted current from any one of these forks, through a telegraph wire, to a series of electromagnets operating the strings of a piano or other instrument, in which case a person might play the tuning fork piano in one place and the music be audible from the electromagnetic piano in a distant city.

The more I reflected upon this arrangement the more feasible did it seem to me; indeed, I saw no reason why the depression of a number of keys at the tuning fork end of the circuit should not be followed by the audible production of a full chord from the piano in the distant city, each tuning fork affecting at the receiving end that string of the piano with which it was in unison. At this time the interest which I felt in electricity led me to study the various systems of telegraphy in use in this country and in America. I was much struck with the simplicity of the Morse alphabet, and with the fact that it could be read by sound. Instead of having the dots and dashes recorded on paper, the operators were in the habit of observing the duration of the click of the instruments, and in this way were enabled to distinguish by ear the various signals.

It struck me that in a similar manner the duration of a musical note might be made to represent the dot or dash of the telegraph code, so that a person might operate one of the keys of the tuning fork piano referred to above, and the duration of the sound proceeding from the corresponding string of the distant piano be observed by an operator stationed there. It seemed to me that in this way a number of distinct telegraph messages might be sent simultaneously from the tuning fork piano to the other end of the circuit by operators, each manipulating a different key of the instrument. These messages would be read by operators stationed at the distant piano, each receiving operator listening for signals for a certain definite pitch, and ignoring all others. In this way could be accomplished the simultaneous transmission of a number of telegraphic messages along a single wire, the number being limited only by the delicacy of the listener's ear. The idea of increasing the carrying power of a telegraph wire in this way took complete possession of my mind, and it was this practical end that I had in view when I commenced my researches in electric telephony.

In the progress of science it is universally found that complexity leads to simplicity, and in narrating the history of scientific research it is often advisable to begin at the end.

In glancing back over my own researches, I find it necessary to designate, by distinct names, a variety of electrical currents by means of which sounds can be produced, and I shall direct your attention to several distinct species of what may be termed telephonic currents of electricity.

The graphical method of representing electrical currents thus shown is the best means I have been able to devise of studying, in an accurate manner, the effects produced by various forms of telephonic apparatus, and it has led me to the conception of that peculiar species of telephonic current, designated as undulatory, which has rendered feasible the artificial production of articulate speech by electrical means.

A horizontal line is taken as the zero of current, and impulses of positive electricity are represented above the zero line, and negative impulses below it, or vice versa.

The vertical thickness of any electrical impulse, measured from the zero line, indicates the intensity of the electrical current at the point observed, and the horizontal extension of the electric line indicates the duration of the impulse.

Nine varieties of telephonic currents may be distinguished, but it will only be necessary to show six of these. The three primary varieties are designated as intermittent, pulsatory, and undulatory.

Subvarieties of these can be distinguished as direct or reversed currents, according as the electrical impulses are all of one kind or are alternately positive and negative. Direct currents may still further be distinguished as positive or negative, according as the impulses are of one kind or of the other.

An intermittent current is characterized by the alternate presence and absence of electricity upon the circuit.

A pulsatory current results from sudden or instantaneous changes in the intensity of a continuous current; and

An undulatory current is a current of electricity, the intensity of which varies in a manner proportional to the velocity of the motion of a particle of air during the production of a sound: thus the curve representing graphically the undulatory current for a simple musical note is the curve expressive of a simple pendulous vibration—that is, a sinusoidal curve.

And here I may state, that, although the conception of the undulatory current of electricity is entirely original with myself, methods of producing sound by means of intermittent and pulsatory currents have long been known. For instance, it was long since discovered that an electromagnet gives forth a decided sound when it is suddenly magnetized or demagnetized. When the circuit upon which it is placed is rapidly made and broken, a succession of explosive noises proceeds from the magnet. These sounds produce upon the ear the effect of a musical note when the current is interrupted a sufficient number of times per second. . . .

The discovery of "galvanic music" by C. G. Page in 1837 led inquirers in different parts of the world almost simultaneously to enter into the field of telephonic research; and the acoustical effects produced by demagnetization were studied by Marrian, Beatson, Gassiot, De la Rive, Matteucci, and many other eminent scientists. Gore obtained loud musical notes from mercury, accompanied by singularly beautiful crispations of the surface during the course of experiments in electrolysis. Sullivan discovered that a current of electricity is generated by the vibration of a wire composed partly of one metal and partly of another. The current was produced so long as the wire emitted the musical note, but stopped immediately upon the cessation of the sound.

It was found by practical experiment that it was difficult, if not impossible, to transmit the number of musical tones that theory showed to be feasible. The difficulty, shown after a time, lay in the nature of the electric current employed, and finally was obviated by the invention of the undulatory current.

It is a strange fact that important inventions often are made almost simultaneously in different parts of the world, and the idea of multiple telegraphy as developed above, seems to have occurred independently to no less than four other inventors in America and Europe. Even the details of the arrangements upon circuit are extremely similar in the plans proposed by Cromwell Varley of London, Elisha Gray of Chicago, Paul La Cour of Copenhagen, and Thomas Edison of Newark, N. J. Into the question of priority of invention, I shall not go at present.

For several years my attention was almost exclusively directed to the production of an instrument for making and breaking a voltaic circuit with extreme rapidity, to take the place of the transmitting tuning fork used in Helmholtz's researches. The great defects of this plan of multiple telegraphy were found to consist, first, in the fact that the receiving operators were required to possess a good musical ear in order to discriminate the signals; and secondly, that the signals could only pass in one direction along the line (so that two wires would be necessary in order to complete communication in both directions). The first objection was got over by employing the device which I term a "vibratory circuit breaker," whereby musical signals can be automatically recorded. . . .

I have formerly stated that Helmholtz was enabled to produce vowel sounds artificially by combining musical tones of different pitches and intensities. Tuning forks of different pitch were placed between the poles of electromagnets, and are kept in continuous vibration by the action of an intermittent current from one fork. Resonators are arranged so as to reinforce the sounds in a greater or less degree, according as the exterior orifices are enlarged or contracted.

Thus it will be seen that upon Helmholtz's plan the tuning forks themselves produce tones of uniform intensity, the loudness being varied by an external reinforcement; but it struck me that the same results would be obtained, and in a much more perfect manner, by causing the tuning forks themselves to vibrate with different degrees of amplitude. I therefore devised the apparatus which was my first form of articulating telephone. A harp of steel rods was employed, attached to the poles of a permanent magnet. When any one of the rods is thrown into vibration an undulatory current is produced in the coils of the electromagnet, and the electromagnet attracts the rods of the harp with a varying force, throwing into vibration that rod which is in unison with that vibrating at the other end of the circuit. Not only so, but the amplitude of vibration in the one will determine the amplitude of vibration in the other, for the intensity of the induced current is determined by the amplitude of the inducing vibration, and the amplitude of the vibration at the receiving end depends upon the intensity of the attractive impulses. When we sing into a piano, certain of the strings of the instrument are set in vibration sympathetically by the action of the voice with different degrees of amplitude, and a sound, which is an approximation to the vowel uttered, is produced from the piano. Theory shows that, had the piano a very much larger number of strings to the octave, the vowel sounds would be perfectly reproduced. My idea of the action of the apparatus was this: utter a sound in the neighborhood of the harp, and certain of the rods would be thrown into vibration with different amplitudes. At the other end of the circuit the corresponding rods of the harp would vibrate with their proper relations of force, and the timbre of the sound would be reproduced. The expense of constructing such an apparatus deterred me from making the attempt, and I sought to simplify the apparatus before venturing to have it made.

It is well known that deaf mutes are dumb merely because they are deaf, and that there is no defect in their vocal organs to incapacitate them from utterance. Hence it was thought that my father's system of pictorial symbols, popularly known as visible speech, might prove a means whereby we could teach the deaf and dumb to use their vocal organs and to speak. The great success of these experiments urged upon me the advisability of devising a method of exhibiting the vibrations of sound optically, for use in teaching the deaf and dumb. For some time I carried on experiments with the manometric capsule of Köenig and with the phonautograph of Léon Scott. The scientific apparatus in the institute of technology in Boston was freely placed at my disposal for these experiments, and it happened that at that time a student of the institute of technology, Mr. Maurey, had invented an improvement upon the phonautograph. He had succeeded in vibrating by the voice a stylus of wood about a foot in length, which was attached to the membrane of the phonautograph, and in this way he had been enabled to obtain enlarged tracings upon a plane surface of smoked glass. With this apparatus I succeeded in producing very beautiful tracings of the vibrations of the air for vowel sounds. I was much struck with this improved form of apparatus, and it occurred to me that there was a remarkable likeness between the manner in which this piece of wood was vibrated by the membrane of the phonautograph and the manner in which the small bones of the human ear were moved by the tympanic membrane. I determined therefore, to construct a phonautograph modeled still more closely upon the mechanism of the human ear, and for this purpose I sought the assistance of a distinguished aurist in Boston, Dr. Clarence J. Blake. He suggested the use of the human ear itself as a phonautograph, instead of making an artificial imitation of it. The idea was novel and struck me accordingly, and I requested my friend to prepare a specimen for me, which he did. The stapes was removed and a stylus of hay about an inch in length was attached to the end of the incus. Upon moistening the membrana tympani and the ossiculæ with a mixture of glycerine and water the necessary mobility of the parts was obtained, and upon singing into the external artificial ear the piece of hay was thrown into vibration, and tracings were obtained upon a plane surface of smoked glass passed rapidly underneath. While engaged in these experiments, I was struck with the remarkable disproportion in weight between the membrane and the bones that were vibrated by it. It occurred to me that if a membrane as thin as tissue paper could control the vibration of bones that were, compared to it, of immense size and weight, why should not a larger and thicker membrane be able to vibrate a piece of iron in front of an electromagnet, in which case the complication of steel rods shown in my first form of telephone could be done away with, and a simple piece of iron attached to a membrane be placed at either end of the telegraphic circuit.

The form of apparatus that I was then employing for producing undulatory currents of electricity for the purpose of multiple telegraphy consists of a steel reed, clamped firmly by one extremity to the uncovered leg of an electromagnet, and the free end of the reed projected above the covered leg. When the reed was vibrated in any mechanical way the battery current was thrown into waves, and electrical undulations traversed the circuit, throwing into vibration the corresponding reed at the other end of the circuit. I immediately proceeded to put my new idea to the test of practical experiment, and for this purpose I attached the reed loosely by one extremity to the uncovered pole of the magnet, and fastened the other extremity to the center of a stretched membrane of gold beaters' skin. I presumed that upon speaking in the neighborhood of the membrane it would be thrown into vibration and cause the steel reed to move in a similar manner, occasioning undulations in the electrical current that would correspond to the changes in the density of the air during the production of the sound; and I further thought that the change of the density of the current at the receiving end would cause the magnet there to attract the reed in such a manner that it should copy the motion of the first reed, in which case its movements would occcasion a sound from the membrane similar in timbre to that which had occasioned the original vibration.

The results, however, were unsatisfactory and discouraging. My friend, Mr. Thomas A. Watson, who assisted me in this experiment, declared that he heard a faint sound proceed from the telephone at his end of the circuit, but I was unable to verify his assertion. After many experiments attended by the same only partially successful results, I determined to reduce the size and weight of the spring as much as possible. For this purpose I glued a piece of clock spring about the size and shape of my thumb nail, firmly to the center of the diaphragm, and had a similar instrument at the other end; we were then enabled to obtain distinctly audible effects. I remember an experiment made with this telephone which gave me great satisfaction and delight. One of the telephones was placed in my lecture room in the Boston university, and the other in the basement of the adjoining building. One of my students repaired to the distant telephone to observe the effects of articulate speech, while I uttered the sentence, "Do you understand what I say?" into the telephone placed in the lecture hall. To my delight an answer was returned through the instrument itself, articulate sounds proceeded from the steel spring attached to the membrane, and I heard the sentence, "Yes, I understand you perfectly." It is a mistake, however, to suppose that the articulation was by any means perfect, and expectancy no doubt had a great deal to do with my recognition of the sentence; still, the articulation was there, and I recognized the fact that the indistinctness was entirely due to the imperfection of the instrument. I will not detail the various stages through which the apparatus passed, but shall merely say that after a time I produced a different form of instrument which served very well as a receiving telephone. In this condition my invention was, in 1876, exhibited at the Centennial exhibition in Philadelphia. The lecture room telephone was used as a transmitting instrument, and the other as a receiver, so that vocal communication was only established in one direction.

The articulation produced from the instrument was remarkably distinct, but its great defect consisted in the fact that it could not be used as a transmitting instrument, and thus two telephones were required at each station, one for transmitting and one for receiving spoken messages.

It was determined to vary the construction of the lecture room telephone, and I sought, by changing the size and tension of the membrane, the diameter and thickness of the steel spring, the size and power of the magnet, and the coils of insulated wire around their poles, to discover empirically the exact effect of each element of the combination, and thus to deduce a more perfect form of apparatus. It was found that a marked increase in the loudness of the sounds resulted from shortening the length of the coils of wire, and by enlarging the iron diaphragm which was glued to the membrane. In the latter case, also, the distinctness of the articulation was improved. Finally, the membrane of gold beaters' skin was discarded entirely, and a simple iron plate was used instead, and at once intelligible articulation was obtained. The new form of instrument was made, and, as had been long anticipated, it was proved that the only use of the battery was to magnetize the iron core, for the effects were equally audible when the battery was omitted and a rod of magnetized steel substituted for the iron core of the magnet.

It was my original intention and it was always claimed by me, that the final form of telephone would be operated by permanent magnets in place of batteries, and numerous experiments had been carried on by Mr. Watson and myself privately for the purpose of producing this effect.

At the time the instruments were first exhibited in public the results obtained with permanent magnets were not nearly so striking as when a voltaic battery was employed, wherefore we thought it best to exhibit only the latter form of instrument.

The interest excited by the first published accounts of the operation of the telephone led many persons to investigate the subject, and I doubt not that numbers of experimenters independently discovered that permanent magnets might be employed instead of voltaic batteries. Indeed, Professor Dolbear of Tufts college, not only claims to have discovered the magneto-electric telephone, but, I understand, charges me with having obtained the idea from him through the medium of a mutual friend.

A still more powerful form of apparatus was constructed by using a powerful compound horseshoe magnet in place of the straight rod which had been previously used. Indeed, the sounds produced by means of this instrument were of sufficient loudness to be faintly audible to a large audience, and in this condition the instrument was exhibited in the Essex institute, in Salem, Massachusetts, on the 12th of February, 1877, on which occasion a short speech shouted into a similar telephone in Boston sixteen miles away, was heard by the audience in Salem. The tones of the speaker's voice were distinctly audible to an audience of six hundred persons but the articulation was only distinct at a distance of about six feet. On the same occasion, also, a report of the lecture was transmitted by word of mouth from Salem to Boston, and published in the papers the next morning.

From the iron plate form of telephone to the present form of the instrument is but a step. It is, in fact, the arrangement in a portable form, the magnet being placed inside the handle and a more convenient form of mouthpiece provided. . . . .

It was always my belief that a certain ratio would be found between the several parts of a telephone, and that the size of the instrument was immaterial; but Professor Peirce was the first to demonstrate the extreme smallness of the magnets which might be employed. And here, in order to show the parallel lines in which we were working, I may mention the fact that two or three days after I had constructed a telephone of the portable form containing the magnet inside the handle, Dr. Channing was kind enough to send me a pair of telephones of a similar pattern, which had been invented by experimenters at Providence. The convenient form of the mouthpiece adopted by me, was invented solely by my friend, Professor Peirce. I must also express my obligations to my friend and associate, Mr. Thomas A. Watson, of Salem, Massachusetts, who for two years gave me his personal assistance in carrying on my researches.

THREE GREAT ACHIEVEMENTS IN ELECTRICAL SCIENCE.

BY RAY STANNARD BAKER.

[Ray Stannard Baker, author; born Lansing, Mich., April 17, 1870; graduated from Michigan Agricultural college, B. S., 1889; also studied law and literature at University of Michigan; has written a large number of articles and stories for American and English magazines, prominent among which is a series on The Great Southwest in the Century, 1902, and a companion series for the same magazine on The Great Northwest; at present is associate editor of McClure's magazine, from which the following article is republished. Author of Our New Prosperity, Seen in Germany, etc.]

One after another, almost within the space of a single year, Mr. Peter Cooper Hewitt, of New York city, gave the world three remarkable electrical inventions. Any one of them would be sufficient to make a man famous; the three have placed Mr. Hewitt in the very front rank of present day inventors and scientists. So high an authority as Lord Kelvin, the greatest of living electricians, said after his recent visit to this country:

"What attracted me most in America was the work of Mr. Peter Cooper Hewitt and his vacuum lamp."

And the public at large is quite as deeply concerned as the scientists, for the new inventions have an intimate importance for every man, woman, and child in the country.

Briefly, before taking up the noteworthy story of the experiments, this is the essence and significance of the inventions:

First—The new electric lamp.

On an evening in January, 1902, a great crowd was attracted to the entrance of the Engineers' club in New York city. Over the doorway a narrow glass tube gleamed with a strange blue green light of such intensity that print was easily readable across the street, and yet so softly radiant that one could look directly at it without the sensation of blinding discomfort which accompanies nearly all brilliant artificial lights. The hall within, where Mr. Hewitt was making the first public announcement of his great discovery, was also illuminated by the wonderful new tubes. The light was different from anything ever seen before, grateful to the eyes, much like daylight, only giving the face a curious, pale green, unearthly appearance. The cause of this phenomenon was soon evident; the tubes were seen to give forth all the rays except red—orange, yellow, green, blue, violet—so that under its illumination the room and the street without, the faces of the spectators, the clothing of the women, lost all their shades of red; indeed, changing the very face of the world to a pale green blue. The extraordinary appearance of this lamp and its profound significance as a scientific discovery at once awakened a wide public interest, especially among electricians who best understood its importance. Here was an entirely new sort of electric light. The familiar incandescent lamp, the invention of Thomas A. Edison, though the best of all methods of illumination, is also the most expensive. Mr. Hewitt's lamp, though not yet adapted to all the purposes served by the Edison lamp, on account of its peculiar color, produces eight times as much light with the same amount of power. It is also practically indestructible, there being no filament to burn out; and it requires no special wiring. By means of this invention electricity, instead of being the most costly means of illumination, becomes the cheapest—cheaper even than kerosene. No further explanation than this is necessary to show the enormous importance of this invention.

Second—A new, cheap, and simple method of converting alternating electrical currents into direct currents.

At first glance, an invention of this sort makes little appeal to the non-scientific world, though every electrician is instantly cognizant of its great importance and significance. The chief pursuit of science and invention in this day of wonders is the electrical conquest of the world, the introduction of the electrical age. The electric motor is driving out the steam locomotive, the electric light is superseding gas and kerosene, the waterfall must soon take the place of coal. But certain great problems stand like solid walls in the way of development, part of them problems of science, part of mechanical efficiency. The battle of science is, indeed, not unlike real war, charging its way over one battlement after another until the very citadel of final secret is captured. Mr. Hewitt with his simple converter has led the way over one of the most serious barriers in the progress of technical electricity, enabling the whole industry, in a hundred different phases of its progress, to take a long step forward.

The converter is simplicity itself. Here are two kinds of electrical currents—the alternating and the direct. Science has found it much cheaper and easier to produce and transmit the alternating current than the direct current. Unfortunately, however, only the direct currents are used for such practical purposes as driving an electric car or automobile, or running an elevator, or operating machine tools or the presses in a printing office, and they are preferable for electric lighting. The power of Niagara falls is changed into an alternating current which can be sent at high pressure (high voltage) over the wires for long distances, but before it can be used it must, for some purposes, be converted into an alternating current of less pressure and for others into a direct current. The apparatus now in use is cumbersome, expensive, and wasteful. Mr. Hewitt's new converter is a mere bulb of glass or of steel, which a man can hold in his hand. A three pound Hewitt converter will do the work of a seven hundred pound apparatus of the old type; it will cost dollars where the other costs hundreds; and it will save a large proportion of the electricity wasted in the old process. By this simple device, therefore, Mr. Hewitt has in a moment extended the entire range of electrical development. As alternating currents can be carried longer distances by using high pressure, and the pressure of voltage can be changed by the use of a simple transformer and then changed into a direct current by the converter at any convenient point along the line, therefore more waterfalls can be utilized, more of the power of coal can be utilized, more electricity saved after it is generated, rendering the operating of all industries requiring power so much cheaper. Every electric railroad, every lighting plant, every factory using electricity, is intimately concerned in Mr. Hewitt's device, for it will cheapen their power and thereby cheapen their products to you and to me.

Third—The third invention is in some respects the most wonderful of the three. Technically, it is called an electric interrupter or valve. "If a long list of present day desiderata were drawn up," says the Electrical World and Engineer, "it would perhaps contain no item of more immediate importance than an interrupter which shall be . . . inexpensive and simple of application." This is the view of science; and therefore this device is one upon which a great many inventors, including Mr. Marconi, have recently been working; and Mr. Hewitt has been fortunate in producing the much needed successful apparatus.

The chief demand for an interrupter has come from the scores of experimenters who are working with wireless telegraphy. In 1894 Mr. Marconi began communicating through space without wires, and it may be said that wireless telegraphy has ever since been the world's imminent invention. Who has not read with profound interest the news of Mr. Marconi's success, the gradual increases of his distances? Who has not sympathized with his effort to perfect his machine, to produce a tuning apparatus by means of which messages flying through space could be kept secret? And here at last has come the invention which science most needed to complete and vitalize Marconi's work. By means of Mr. Hewitt's interrupter, the simplicity of which is as astonishing as its efficiency, the whole problem has been suddenly and easily solved.

Mr. Hewitt's new interrupter may, indeed, be called the enacting clause of wireless telegraphy. By its use the transmission of powerful and persistent electrical waves is reduced to scientific accuracy. The apparatus is not only cheap, light, and simple, but it is also a great saver of electrical power.

Mr. Hewitt's achievements possess a peculiar interest for the people of this country. The inventor is an American of Americans. Born to wealth, the grandson of the famous philanthropist, Peter Cooper, the son of Abraham S. Hewitt, one of the foremost citizens and statesmen of New York, Mr. Hewitt might have led a life of leisure and ease, but he has preferred to win his successes in the American way, by unflagging industry and perseverance, and has come to his new fortune also like the American, suddenly and brilliantly. As a people we like to see a man deserve his success! The same qualities which made Peter Cooper one of the first of American millionaires, and Abraham S. Hewitt one of the foremost of the world's steel merchants, mayor of New York, and one of its most trusted citizens, have placed Mr. Peter Cooper Hewitt among the greatest of American inventors and scientists. Indeed, Peter Cooper and Abraham S. Hewitt were both inventors; that is, they had the imaginative inventive mind. Peter Cooper once said:

"I was always planning and contriving, and was never satisfied unless I was doing something difficult—something that had never been done before, if possible."

The grandfather built the first American locomotive; he was one of the most ardent supporters of Cyrus Field in the great project of an Atlantic cable, and he was for a score of years the president of a cable company. His was the curious, constructive mind. As a boy he built a washing machine to assist his overworked mother; later on he built the first lawn mower and invented a process for rolling iron, the first used in this country; he constructed a torpedo boat to aid the Greeks in their revolt against Turkish tyranny in 1824. He dreamed of utilizing the current of the East river for manufacturing power; he even experimented with flying machines, becoming so enthusiastic in this labor that he nearly lost the sight of an eye through an explosion which blew the apparatus to pieces.

It will be seen, therefore, that the grandson comes naturally by his inclinations. It was his grandfather who gave him his first chest of tools and taught him to work with his hands, and he has always had a fondness for contriving new machines or working out difficult scientific problems. Until the last few years, however, he has never devoted his whole time to the work which best pleased him. For years he was connected with his father's extensive business enterprise, an active member, in fact, of the firm of Cooper, Hewitt & Co., and he has always been prominent in the social life of New York, a member of no fewer than eight prominent clubs. But never for a moment in his career—he is now forty two years old, though he looks scarcely thirty five—has he ceased to be interested in science and mechanics. As a student in Stevens institute and later in Columbia college, he gave particular attention to electricity, physics, chemistry, and mechanics. Later, when he went into business, his inventive mind turned naturally to the improvement of manufacturing methods, with the result that his name appears in the patent records as the inventor of many useful devices—a vacuum pan, a glue clarifier, a glue cutter and other glue machinery, and numerous others. He worked at and learned many sorts of trades with his own hands; machine shop practice, blacksmithing, steamfitting, carpentry, jewelry work, and other work-a-day employments. He worked in a jeweler's shop, learning how to make rings and to set stones; he managed and hired a steam launch; he was for eight years in his grandfather's glue factory, where he had practical problems in mechanics constantly brought to his attention. And he was able to combine all this hard practical work with a fair amount of shooting, golfing, and automobiling.

Most of Mr. Hewitt's scientific work of recent years has been done after business hours—the long, slow, plodding toil of the experimenter. There is surely no royal road to success in invention, no matter how well a man may be equipped, no matter how favorably his means are fitted to his hands. He worked for seven years on the electrical investigations which resulted in his three great inventions; thousands of experiments were performed; thousands of failures opened the way for the first glimmers of success.

His laboratory during most of these years was hidden away in the tall tower of Madison Square Garden, overlooking Madison Square, with the roar of Broadway and Twenty third street coming up from the distance. Here he has worked, gradually expanding the scope of his experiments, increasing his force of assistants, until he now has an office and two workshops in Madison Square Garden and is building a more extensive laboratory elsewhere.

Of all the power used in producing the glowing filament in the Edison bulb, about ninety seven per cent is absolutely wasted, only three per cent appearing in light. This three per cent efficiency of the incandescent lamp compares very unfavorably, indeed, with the forty per cent efficiency of the gasoline engine, the twenty two per cent efficiency of the marine engine, and the ninety per cent efficiency of the dynamo.

Mr. Hewitt first stated his problem very accurately. The waste of power in the incandescent lamp is known to be due largely to the conversion of a considerable part of the electricity used into useless heat. An electric lamp bulb feels hot to the hand. It was therefore necessary to produce a cool light; that is, a light in which the energy was converted wholly or largely into light rays and not into heat rays. This, indeed, has long been one of the chief goals of ambition among inventors. Mr. Hewitt turned his attention to the gases. Why could not some incandescent gas be made to yield the much desired light without heat?

This was the germ of the idea. Comparatively little was known of the action of electricity in passing through the various gases, though the problem involved had long been the subject of experiment, and Mr. Hewitt found himself at once in a maze of unsolved problems and difficulties.

"I tried many different gases," he said, "and found that some of them gave good results—nitrogen, for instance—but many of them produced too much heat and presented other difficulties."

Finally, he took up experiments with mercury confined in a tube from which the air had been exhausted. The mercury arc, as it is called, had been experimented with years before, had even been used as a light, although at the time he began his investigations Mr. Hewitt knew nothing of these earlier investigations. He used ordinary glass vacuum tubes with a little mercury in the bottom which he vaporized under the influence of heat or by a strong current of electricity. He found it a rocky experimental road; he has called invention systematic guessing.

"I had an equation with a large number of unknown quantities," he said. "About the only thing known for a certainty was the amount of current passing into the receptacle containing the gas and its pressure. I had to assume values for them (in every experiment) and you can understand what a great number of trials were made, using different combinations, before obtaining results. I presume thousands of experiments were made."

Many other investigators had been on the very edge of the discovery. They had tried sending strong currents through a vacuum tube containing mercury vapor but had found it impossible to control the resistance. One day, however, in running a current into the tube Mr. Hewitt suddenly recognized certain flashes; a curious phenomenon. Always it is the unexpected thing, the thing unaccounted for, that the mind of the inventor leaps upon. For there, perhaps, is the key he is seeking. Mr. Hewitt continued his experiments and found that the mercury vapor was conducting. He next discovered that when once the high resistance of the cold mercury was overcome, a very much less powerful current found ready passage and produced a very brilliant light; the glow of the mercury vapor. This, Mr. Hewitt says, was the crucial point, the genesis of his three inventions, for all of them are applications of the mercury arc.

Thus, in short, he invented the new lamp. By the use of what is known to electricians as a boosting coil, supplying for an instant a very powerful current, the initial resistance of the cold mercury in the tube is overcome and then, the booster being automatically shut off, the current ordinarily used in incandescent lighting produces an illumination eight times as intense as the Edison bulb of the same candle power. The mechanism is exceedingly simple and cheap; a button turns the light on or off; the remaining apparatus is not more complex than that of the ordinary incandescent light. The Hewitt lamp is best used in the form of a long horizontal tube suspended overhead in a room, the illumination filling all the space below with a radiance much like daylight, not glaring and sharp as with the Edison bulb. Mr. Hewitt has a large room hung with green material and thus illuminated, giving the visitor a very strange impression of a redless world. After a few moments spent here a glance out of the window shows a curiously red landscape, and red buildings, a red Madison

Square, the red coming out more prominently by contrast with the blue green of the light.

"For many purposes," said Mr. Hewitt, "the light in its present form is already easily adaptable. For shopwork, draughting, reading and other work, where the eye is called on for continued strain, the absence of red is an advantage, for I have found light without the red much less tiring to the eye. I use it in my own laboratories and my men prefer it to ordinary daylight."

In other respects, however, its color is objectionable, and Mr. Hewitt has experimented with a view to obtaining the red rays, thereby producing a pure white light.

"Why not put a red globe around your lamp?" is a common question put to the inventor. This is an apparently easy solution of the difficulty until one is reminded that red glass does not change light waves, but simply suppresses all the rays that are not red. Since there are no red rays in the Hewitt lamp, the effect of the red globe would be to cut off all the light.

But Mr. Hewitt showed me a beautiful piece of pink silk, colored with rhodimin, which, when thrown over the lamp, changes some of the orange rays into red, giving a better balanced illumination although at some loss of brilliancy. Further experiments along this line are now in progress, investigations both with mercury vapor and with other gases.

Mr. Hewitt has found that the rays of his new lamp have a peculiar and stimulating effect on plant growth. A series of experiments in which seeds of various plants were sown under exactly the same conditions, one set being exposed to daylight and one to the mercury gaslight, showed that the latter grew much more rapidly and luxuriantly. Without doubt, also, these new rays will have value in the curing of certain kinds of disease.

The discoveries which resulted in the production of the new lamp, were the stepping stones to the production of the converter, both being applications of the study and development of the mercury arc. Mr. Hewitt found that the mercury bulb, when connected with wires carrying an alternating current, had the curious and wonderful property of permitting the passage of the positive half of the alternating wave when the current has started and maintained in that direction, and of suppressing the other half; in other words, of changing an alternating current into a direct current. In this process there was a loss, the same for currents of all potentials, of only 14 volts. I have already spoken of the very great importance of this invention.

Following close upon the announcement of the new converter, Mr. Hewitt found that his mercury tube could be also transformed into a nearly perfect electrical interrupter. As I have already shown, the mercury vapor opposes a high resistance to the passage of electricity until the current reaches a certain high potential, when it gives way suddenly, allowing a current of low potential to pass through. This property can be applied in breaking a high potential current such as is used in wireless telegraphy, so that the waves set up are exactly the proper lengths, always accurate, always the same, for sending messages through space. By the present method an ordinary arc or spark gap—that is, a spark passing between two brass balls—is employed in sending messages across the Atlantic. Marconi uses a spark as large as a man's wrist, and the noise of its passage is so deafening that the operators are compelled to wear cotton in their ears, and often they must shield their eyes from the blinding brilliancy of the discharges. Moreover, this open air arc is subject to variations, to great losses of current, the brass balls become eroded, and the accuracy of the transmission is much impaired. All this is obviated by the cheap, simple, noiseless, sparkless, mercury bulb.

"What I have done," said Mr. Hewitt, "is to perfect a device by means of which messages can be sent rapidly and without the loss of current occasioned by the spark gap. In wireless telegraphy the trouble has been that it was difficult to keep the sending and the receiving instruments attuned. By the use of my interrupter this can be accomplished."

And the possibilities of the mercury tube, indeed of incandescent gas tubes in general, have by no means been exhausted. A new door has been opened to investigators, and no one knows what science will find in the treasure house—

perhaps new and more wonderful inventions, perhaps the very secret of electricity itself. Mr. Hewitt is still busily engaged in experimenting along these lines, both in the realm of abstract science and in that of practical invention. He is too careful a scientist, however, to speak much of the future, but those who are most familiar with his methods of work predict that the three inventions he has already announced are only forerunners of many other discoveries.

THE BEGINNINGS OF THE INCANDESCENT LAMP.

BY THOMAS A. EDISON.

[Thomas Alva Edison, electrician; born Milan, O., February 11, 1847; became a railway newsboy at the age of 12; later learned telegraphy and worked at this in various places in United States and Canada; invented the automatic repeater, printing telegraph, quadruplex telegraph, etc.; established workshop at Newark, N. J., afterwards going to Menlo Park in the same state, and later to West Orange; invented machines for quadruplex and sextuplex telegraphic transmission, the megaphone, carbon telegraph transmitter, the phonograph, incandescent lamp and light system, and other inventions; honorary chief consulting engineer, Louisiana Purchase exposition at St. Louis. The following article was written for the Electrical World and is published by special arrangement.]

I am glad to put on record a brief personal narrative of the details connected with what was to me a very interesting period of electrical development. The occasion is not only a reminder of the rapid flight of time, but of the fact that since 1874—the year of the quadruplex, by the way—all the great modern departments of electrical industry have sprung into vigorous being.

My experiments on carbon began in 1876, when I had the idea of making carbon wire, etc., for various electrical and chemical purposes. Even at that early time Messrs. Charles Batchelor and E. H. Johnson were with me, and we saw quite a business ahead in carbon novelties. I had familiarized myself with the properties of carbon, particularly that made from paper and Bristol board, and this led on very naturally to my work on the carbon telephone or microphonic transmitter, early in 1877. In the fall of that year I was pretty well through with studies and inventions in that line, but had several other ideas that I wanted to work up. One of these was the subdivision of the electric light, and I began experimenting with that purpose. My records and the voluminous testimony in litigation, now happily long past, show that in the fall of 1877, about September, strips of carbonized paper were tried as an incandescent conductor suitable for use in lamps, and the work was followed up until January of 1878, when the general excitement over my invention and exhibition of the phonograph out at old Menlo Park frustrated serious or continuous work for a time, in any other direction. In fact, my health gave way under the strain, and in July I broke away for a western trip as far as California.

Of course my mind was turning the subject over, and when I got back in August we immediately went at it again. Around October and November Batchelor made a great number of paper carbons, at least 50, from tissue and other kinds of paper, coated over their surface with a mixture of lampblack and tar, rolled up into the fine long form of a knitting needle, and then carbonized. These we put into circuit and brought up to incandescence in vacuo; although they would last but an hour or two. We tried a great many experiments with paper carbons, wood carbons and some made from carbonized broom corn. What we desired at that date, and had settled our minds upon as the only possible solution of the subdivision of the electric light, was that the lamps must have a high resistance and small radiating surface. About December, 1878, I engaged as my mathematician Mr. Francis R. Upton, who had lately studied under Helmholtz, in Germany, and he helped me greatly in calculations of the multiple arc problem. Our figures proved that the lamp must have at least 100 ohms resistance to compete successfully with gas; for if the lamps were of low resistance the cost of the copper main conductors would be so great as to render the system uneconomical and commercially impracticable. In this direction we tried platinum also; and when working on incandescent platinum we had procured a Sprengel mercury pump and had ascertained that we could thus get exceedingly high vacua. It occurred to me that perhaps a filament of carbon could be made to stand in the sealed glass vessels or bulbs, which we were using, exhausted to a high vacuum. Separate lamps were made in this way independent of the air pump, and in October, 1879, we made lamps of paper carbon, and with carbons of common sewing thread, placed in a receiver or bulb made entirely of glass, with the leading-in wires sealed in by fusion. The whole thing was exhausted by the Sprengel pump to nearly one millionth of an atmosphere. These filaments of carbon, although naturally quite fragile owing to their length and small mass, had a smaller radiating surface and higher resistance than we had dared hope. We had virtually reached the position and condition where the carbons were stable. In other words, the incandescent lamp as we still know it to-day, in essentially all its particulars unchanged, had been born.

We began immediately to make vacuum pumps and to produce these paper filament lamps on them. During that November we made perhaps as many as 100 of such lamps, and the same month saw us plunged deep in experiments and inventions on dynamos, regulators, meters, circuits, etc., all just as necessary to the success of the art as the little lamp itself. Some of those paper filament lamps had a remarkably long life. Each yielded from 12 to 16 candle power and they were burned on chandeliers until they gave out. The average life was about 300 hours. One of them lasted 940 hours and another 1,350 hours, so that commercial success and a new industry were already well in sight.

But I was not quite satisfied as to paper, or even with the more regular and homogeneous wood fibre filaments, and thus came to take up bamboo. We happened to have a palm leaf fan on one of the tables. I was then investigating everything with a microscope, so I picked it up and found that it had a rim on the outside, of bamboo, a very long strip cut from the outer edge. We soon had that cut up into blanks and carbonized. On putting these filaments into the lamps we were gratified to see that the lamps were several times better than any we had succeeded in making before. I soon ascertained why and started a man off for Japan on a bamboo hunt. Before I got through I had tested no fewer than 6,000 vegetable growths, and had ransacked the world for the most suitable bamboo. The use of bamboo was maintained for many years until other processes dealing with such material as cellulose had been perfected. We tried even at the earliest moment of success a number of experiments and things afterwards taken up again or followed through, as for example, burning the paper filaments in a vacuum charged with inert gas; and a little later, in 1880, we also flashed the filaments with gasoline vapor.

The furore that followed the announcements from Menlo Park as to the successful subdivision of the electric light in a commercial incandescent lamp will be well remembered by many of the readers of this. The feasibility of such a thing had been denied by some of the greatest minds in electricity, but here it was; and along lines that have endured to this day. The best story at the time was given to the world by the New York Herald in December, 1879, and on Christmas day I had already lighted up my laboratory, my offices, two or three houses about one fifth of a mile from the dynamo plant and some twenty street lights. On the last day of the year some 3,000 people flocked out to Menlo Park to see it for themselves —and the rest everybody knows.

It is interesting to note that in addition to those mentioned above, I had around me other men who ever since have remained active in the field, such as Messrs. Francis Jehl, W. J. Hammer, Martin Force, Ludwig Boehm, not forgetting that good friend and co-worker, the late John Kruesi. They found plenty to do in the various developments of the art, and as I now look back I sometimes wonder how we did so much in so short a time. Early in the spring of 1880 I lighted up for Mr. Villard the Oregon Steam Navigation company's steamer Columbia, and it was not long before the Edison plants began to multiply. Meantime lamp making took on large proportions in two factories of mine, one at the Menlo Park and the other at Newark, and much of my energy was being devoted to cheapening the price of the lamp as well as increasing its life and its candle power per watt. I am told that upon a moderate computation the production of incandescent lamps in this country since my first success has reached a total of 250,000,000 lamps, or not less than 10,000,000 a year for each of the 25 years. Essentially, the lamp has remained structurally the same ever since 1879, in the elements then demonstrated to be essentially vital and necessary to commercial success.

THE TRIUMPH OF THE AMERICAN IDEA.

BY ALEXANDER H. FORD.

[Alexander H. Ford, journalist; born Buffalo, N. Y., June 11, 1858; educated in the public schools and at Brown university; became connected with the New York Times and has since written much for newspapers and periodicals, chiefly on foreign topics and their relation to the United States in industry and political life. The following article is from the New England magazine by special permission.]

The third quarter of the last century closed with the old world still treating with contempt the idea that anything good could ever come from America. To-day, at the dawning of the new era, however, the situation is exactly reversed; America leads the world, while every country of Europe seeks to imitate our methods and regain in a measure the prestige that has suddenly crossed the Atlantic.

England is astonished that we can pay our miners twice the wages she gives her colliers, and yet send shipload after shipload of coal to New Castle to undersell the products of the adjacent parts. France is startled that our excellent wines from artificially irrigated lands can undersell the vintages of Burgundy in Paris itself. Germany is suffering from business stagnation because we now send her the thousand different kinds of tools and mechanical toys that were once her prized monopoly. Russia, with the most extensive wheat fields in the world, marvels that our finest flour undersells her coarsest native grain, even in remote districts. In far off eastern Asia, the inventive Japs eagerly purchase Yankee machine made imitations of the gewgaws that Jap artists have made by hand for centuries. To Bagdad, we send new lamps in exchange for old, while to Egypt we send not only the trolley cars that run from Cairo to the pyramids, but in Connecticut is a factory equipped with marvelous modern machinery that turns out ancient Egyptian scarabæ, which are chipped automatically, besides being given at the same time the color and appearance of age. These Yankee made Egyptian relics are sold by the cask to the Arabs, who devoutly bury them at the base of Cheops, accidentally to discover and sell them to the Frankish infidel, who is witness to the find, and can therefore have no doubt as to the authenticity of his treasure.

Turning once more to the serious, however, we find that American inventions have rapidly made our foreign commerce supreme; within three years we have passed all our rivals, until to-day the one great topic of international discussion is the triumph of the American idea.

But what is the American idea? For while it is proving itself the great moving force of the world to-day, debated upon in every civilized country from pole to pole, no one as yet seems to have given any concise, concrete definition of the term. The most apt illustration to come under my observation was in England. Two manufacturers, a British and an American, stood waiting for a bus and a trolley car respectively. The Britisher, who owned one of the largest mechanical plants in England, was explaining to his brother manufacturer from America that he could not understand how in the states they could pay workmen twice the wages he did, and yet undersell him in every market of the world, including that of his native English city.

"There is the whole story illustrated," quickly replied the American, pointing across the street to a workman who was perched on a stepladder washing the windows of a dwelling, while another on the ground held the ladder steady so that his companion would not fall. "That is the English way, two men to a ladder," said the American, "our workman would use a ladder that would steady itself, and if there were no such article in the market, he would invent it—that is the American idea."

Labor saving devices, individualism, and an ambition on the part of both master and man to accomplish the most work in the least possible time; these are the American ideas that are disturbing the slow going, leisurely, old world workmen, and causing them to put on a spurt, if only to show that there is still young blood left in the old countries.

But in England and continental Europe, where consumers have been trained for generations to ask for goods of certain brands, refusing indignantly all substitutes warranted to be just as good, the manufacturers who can force all middlemen to sell their products at a stable fixed price, still find it hard to believe that in Yankeeland, the moment a new invention renders a piece of machinery antiquated, the American manufacturer relegates it to the junk pile. Foreigners are astonished to learn that it is for this reason and not for the pleasing effect on the eye that American machinery is built as lightly as possible, not a superfluous pound of metal being retained. In fact, in the states, a machine is often guaranteed to last but for ten years at most, the buyer and seller both realizing that in all probability new inventions will make it obsolete within that period. On the other hand, the British or European manufacturer, not converted to the American idea, resents the invention of any machinery that will tend to make less valuable his heavy, ponderous plant, installed to last for all time. That is why the foreign inventor receives so little encouragement at home and so invariably sends his model to America and floats the parent company here, being sure of attracting capital if his device will save even a few seconds in the manufacture of any necessary or popular article. In fact, the striking difference in appearance between the American and foreign workshop is in the relative number of men and machines used. In America there are often more machines than men, while abroad it is almost invariably the other way. Even where the American idea has been received with favor, the daring of American inventors is always a subject of more or less distrust. For instance, our milling machines now being introduced abroad, still astonish the world—accomplishing work declared impossible by British machinists until they came in actual contact with the machines. What would they say to our spindles that rotate 100,000 times a minute, and other apparatus so delicate as to grind to the thousandth part of an inch with exact precision? These have not as yet found favor abroad, however, as no foreign workshop is so equipped as to make use of our most advanced appliances. As an instance, abroad we install only complete shoemaking plants, which we lease to our British brother manufacturer on royalty, with the understanding that no other kind of machine is to be used in his factory, and so fierce is the competition the American made shoe is creating that he has no other resource but to submit to our arbitrary demands.

Notwithstanding this victory in England, the introduction of American machinery has not proved so successful there as it has in other countries. The British trades unions fight the American invasion tooth and nail, regulating the number of machines each man is allowed to operate, and their output per diem. In Russia, however, Yankee ingenuity is welcomed from one end of the empire to the other. American lathes, the largest in the world, bore cannon for the army and turn out screw shafts for the navy at St. Petersburg; Yankee ice plants exist in Siberia, our cotton presses are sent to Central Asia, while the rapid development of Manchuria is entirely due to the adoption of American machinery of every kind.

In Italy, Finland, and other continental countries the story is the same, while at the Paris exposition, owners of American screw making machines offered to turn all brass rods brought by visitors into screws of any desired size, taking no other payment for the work than the waste filings left over.

It is needless to say that America is carrying the idea of labor saving machinery into her new colonial dependencies. The largest sugar mills in the world, thoroughly equipped with electrical devices, are going up in Cuba; to build these more rapidly, American workmen are sent to Cuba and paid several times the wages asked by the native workmen, yet the high priced men have proved less expensive. Moreover, men who spend millions on these works in Cuba employ experts to travel everywhere seeking out any new invention that will cause the monster rollers to turn out a greater volume of molasses for sugar making. At any moment a successful working model may cause millions of dollars' worth of machinery sent to Cuba in the past two years to be relegated to the junk pile. In our far off Philippines, hundreds of miles of trolley lines are to be built, while many other improvements are projected on an equally gigantic scale.

In fact, everywhere, to the furthermost corners of the earth, the American idea makes new triumphs every day.

In South Africa we proved ourselves equal to the emergencies attendant on the peculiar methods of Boer warfare. To Buller, we shipped steel tents to be used in the battle fields for the protection of officers and men from the bullets of the persistent Boer marksmen. Van Waldersee ordered duplicates of these for his compaign in China, and both China and South Africa owe the development of their mines to modern American machinery. In Mongolia, our Yankee capitalists are introducing millions of dollars' worth of gold mining machinery, while in every part of Siberia, claims long neglected are being equipped with labor saving devices from the new world.

In fact, it was the quickness of the Russian engineers in the far east in casting aside antiquated European tools and methods to adopt American machinery and equipment for the Chinese Eastern railway that first brought the American idea prominently before the confounded manufacturers of Europe, who suddenly found a most lucrative market completely lifted from their sphere. From cross ties to locomotives, the railroad through Manchuria was built with American material. American pneumatic hammers that gave Yankee railroad spikes 800 taps a minute caused even the drummers for German factories to wonder, the heavy cranes that lifted ponderous locomotives all by the power of compressed air, caused the engineers to marvel, while it was the American idea of tunneling the mountains of Manchuria with air drills that caused the first railway strike known to have occurred in Asia. The success of the idea, however, brought about the completion of the trans-Siberian railway several years in advance of the time originally set for its formal opening.

These achievements at once created a great demand for our machinery and machine making tools all over the civilized world. The American idea was abroad in earnest.

However, the fact that European manufacturers are at last refitting their plants with American installations need give us little fear as long as they are content to imitate—it is only when America ceases to originate that the danger point is approached, but that European manufacturers by merely copying our methods are stimulating us to renewed efforts is demonstrated by the fact that while we drove all competitors out of the far east once we began sending our wonderfully finished tools to Manchuria, now that American lathes are being introduced into Germany, Berlin, and Hamburg manufacturers are enabled to imitate our tools to a nicety, laying their products down in the far off Asiatic markets for 25 per cent less than we can afford to sell them. This fact is causing the overhauling of many an American machine shop, new machinery is being invented and installed as rapidly as possible, and every device for cheapening the cost of production is eagerly investigated, so that our tool trade may once more recapture the markets of the far east.

Our success in the far east seems to have encouraged our manufacturers to attack everywhere independently. We have actually begun within the past few years to send fashion plates to Paris. Instead of imitating, we dared to originate for the Parisiennes, until to-day we are actually making fashion plates for the world, from London to Yokohama, and from Bergen in Norway to Capetown, South Africa. We set the fashions because we make the plates—the mechanical part, mark you—more cheaply, rapidly, and better than any country of the globe. So far ahead are we in art printing that Europe sends to America for the making of her catalogues to advertise the articles that go broadcast through the world to compete with our own products.

But America does not utilize her ideas merely to astonish foreigners. They are utilized at home in many most daring and useful ways. Both at home and abroad, we now harvest the world's crop by machinery, thus more than trebling the possible food supply of the globe. In this country, where the idea originated and reaches its highest development, California now contemplates sending figs, irrigated, gathered, and dried by machinery to undersell the hand gathered crops of Smyrna, while a company has actually been organized to introduce the date palm on our irrigated western deserts, with the avowed purpose in view of sending machine picked and packed dates to Arabia and Egypt to compete with the native fruit. There are evidently no Micawbers in America, for when it seemed impossible that silk could be raised profitably in this country so as to allow the silk manufacturer to undersell the Asiatics in their own markets, our inventors turned their minds to inventing a machine that would do the work of the coolie and separate the fibers of the ramie which grows wild in many parts of America. After years of seemingly hopeless experimenting, success has at last crowned their efforts, and now a vegetable fiber finer than silk and much more durable, can be placed on the market at a price within reach of the poorest man. Again the American idea has triumphed, a new crop will henceforth be grown in our southern states, for the separator bears the same relation to ramie that the gin does to cotton, and like the cotton gin, promises to create another industrial revolution.

The American contractor has such complete confidence that the inventor will find a way that he often accepts contracts which at the time of signing, seem impossible of accomplishment. The digging of the Chicago drainage canal caused the invention of many improved dredges and rock cutting machinery, so that it was not so strange after all, when foreign contractors and engineers refused to attempt the design of dredges powerful enough to remove the sandbars of the mighty Volga, that the Russian government, after first sending its minister of rail and waterways to America to learn our methods, imported a young engineer from the banks of the Chicago river, commanding him to accomplish what Europe had declared impossible. It is not strange that his success, which was marked, caused the governments of India and Australia to rescind their determination not to spend another pound on dredges for their rivers, so that to-day American dredges are accomplishing results in Europe, Asia, and Australia, which were despaired of by British mechanics. These mighty dredges, patterned after, but much larger than those on the Mississippi, are as completely automatic in their working as the latest inventions in electricity and compressed air devices can make them.

In many American shops, to encourage the men to make improvements in the machinery, the inventor of any new labor saving device is allowed to draw the wages he has saved the firm, and the foreman encourages the man of ideas, because it reflects to the credit of his department. In conservative England and on the continent, suggestions from employees are looked upon as impertinence, while the foreman treats those who make them as aspiring rivals for his position—this is the reason given by one of the oldest employees of Pain's fireworks for the fact that every important invention in the improvement of fireworks made in the last decade has been made by English employees in America, and the results tested here and then sent back to the parent company abroad. Similar reasons account for the fact that the men transplanted from Belfast and the Clyde are bringing American shipping to a place where it will soon threaten the commerce of the world.

In spite of our advanced methods, however, we still do fear the pauper labor of other countries. When Japan built in her American equipped ship yards, several immense steamships to run across the Pacific and lower the freight rates on flour and all other commodities, we had a problem to solve, for in addition to the low cost of operating these vessels with coolie labor, every one of them receives a subsidy from the government—but quickly enough the American idea triumphed. The Great Northern railway at once grappled with the situation, four of the largest steamships ever designed were ordered. Each of these vessels is 26,000 tons burden, or nearly twice the carrying capacity of any steamship entering New York harbor, and over four times as large as the Japanese boats, so that they can carry freight in such bulk as to make the possibility of the small boats competing all but hopeless. This is one way our master workmen overcome the differential of the subsidy. To carry freight across the continent for these great leviathans, the same railway is constructing immense steel freight cars of three times the capacity hitherto known. Thus by maintaining steamships and freight cars of several times the carrying capacity of those operated by any other country, the handicap of distance is overcome and the way prepared for a further and more thorough application of the American idea at home and abroad.

New lines of steamships are to be established between American and Russian ports on both the Atlantic and Pacific, for despite our tariff war with the Czar's government, Russia continues our great land of promise. In fact, immediately following Minister Witte's edict directed against American imports, we sent to Russia the three largest shipments of machinery that ever left one country for another. Twenty thousand tons of agricultural machinery for the mujiks in less than a month, and the demand increasing by leaps and bounds, for the American harvesters, reapers, sowers and binders, each doing the work of scores of peasants, release myriads of men from the slavery of the soil to take their places in the workshops, which, equipped with American machinery, are springing up everywhere in Russia.

But the American idea on foreign soil needs American brawn and brain to get the most perfect results; it is cheaper in the end to send our own active workmen abroad to put together locomotives and install Yankee plants. The Westinghouse people find it economy to place American workmen at the heads of departments of the great air brake works at St. Petersburg. And in England, the Maxim works would gladly use only American workmen, the English trades unions having refused to permit its members to utilize more than a very limited amount of the labor saving power of the magnificent American installation. In vain has Sir Hiram Maxim sought to introduce the American idea among his workmen. The representatives of the trades unions insist that dire laziness is at the root of the American idea, and that the restless American workman merely wears himself out inventing improvements, so that he may be enabled to loaf while still drawing wages, while the British workman's love of fair play forbids him doing more work than the weakest individual can accomplish. I know that this idea is carried out to such an extent, in fact, that many unions will not permit workmen in large factories to turn out more work on a machine of new invention than can be done as of old by hand, yet both the Germans and English now imitate our tools, even to the trade marks, and in canny Scotland the reputation of America for perfect workmanship stands so high that a Scotch firm makes an imitation of one of our western stoves, advertising it broadcast as the simon pure imported article, and sweeps the field.

The value of the American workman and his ideas is demonstrated in many strange ways. In the Urals, with magnificent iron ore deposits close by, it costs the government with cheap native labor, twice as much to turn this ore into rails and bridge girders as it does to import the finished product direct from America. In Shanghai, we undersell the output of the great Shanghai cotton mills worked with pauper labor, and in Burmah we build bridges in half the time for half the price demanded for the same work by British firms. In India, our locomotives are the cheapest and the best, our rails the most satisfactory, while in Calcutta the American idea of the skyscraper is being introduced by a shrewd Yankee, and the trolley line in Bombay is owned in New York. The American idea is making a triumphant sweep the world over, and protest as they may, the old world nations realize the situation.

That American machinery of all kinds is the best in the world, there can be no longer any doubt. The exhibits at the Paris and Glasgow expositions convinced even the most skeptical manufacturers of Europe of this fact. But why is it so? Foreign visitors to our machine shops often ask why it is that a German, Frenchman, or Russian on American soil can turn out better work, and that more rapidly, than he can elsewhere. There are those who attribute this fact to the effect of our wonderful exhilarating atmosphere, but the truth is that their speedy adoption of the American way of doing things is at the root of it all. In America, the workman to secure good wages, or even to hold his job, must show that he is a better craftsman than those about him, or when slack times come he will inevitably be dropped. Again, piecework prevails, so that a powerful incentive exists to turn out as much work as it is possible to perform. Moreover, in America, one man learns to master the machine that turns out the cogwheel of a watch, another the making of a cycle sprocket, or the cylinder rod of a locomotive; this may be all he knows about the making of a watch, cycle, or locomotive, but he knows it thoroughly and understands how to get the utmost work out of the machine he runs, whether it stamps out 100 watch wheels at a stroke or makes but a single cylinder rod in a day. The British workman might know how to create every part of the whole, but would scarcely become an expert in the making of any one part. As has been already stated, the American manufacturer offers his workmen every inducement to improve the equipment of his plant. In the making of spokes, for instance, the American manufacturer who purchased an English invention for his factory was disappointed with the amount of work it turned out, although four machines managed by one man turned out 3,500 spokes per day. He worked with his men making improvement after improvement until the machine was so perfected that one man could turn out 18,000 spokes a day; still the American is not satisfied, and is offering his men substantial rewards for any new improvement they may suggest, while in England the old machines are still in use, and seem to give satisfaction.

It is the American idea, however, never to be satisfied. It is the fundamental belief of the Yankee that whatever is good is worth improving. As an illustration, nothing can exceed the care with which locomotives are built in England and on the continent of Europe; every part is designed in accord with the particular work required of that engine. Each workman consumes time inspecting his work and lovingly polishing the parts by hand, until months go by, and finally a magnificent and durable piece of work is turned out. How different in an American shop. The largest of our locomotive works, situated in Philadelphia, keeps 7,000 men employed all the time, working them in day and night shifts, the two shifts working in partnership, so that no time is lost in changing the men. Everything seems to be done automatically, the men merely guiding the great machines that really do the work; great electric and pneumatic cranes lift tons of metal as lightly as a child picks up a straw. Compressed air sends great pieces of machinery sailing along trolleys to distant parts of the vast shop. Powerful vises automatically seize uncouth masses of metal, feed them to an immense milling machine that turns out the material fashioned in the desired shape for grinders to smooth the rough edges, while the workman looks on at the several machines doing the work, ready when occasion demands to lend a helping hand. In many of the larger American plants, there are automatic machines for making nuts, screws, bolts, and various other necessary parts, that are merely fed with metal and do the work without any attention or direction from the man who watches over them, merely ringing a bell to call his attention when more raw material is needed.

Nowadays the world moves more rapidly than ever before. Nations are willing to pay large prices for bridges, railways, and machine shops that can be delivered and erected quickly. Orders will continue to be placed with those who can turn out satisfactory work most rapidly. America has demonstrated her ability to accomplish every kind of skilled work more speedily and more cheaply than any other nation. Her ideas are original, and while the fight for their recognition abroad still goes on, the fact remains that the world turns to America for almost every manufactured commodity known to commerce.

That part of this continent known as the United States has becomes the workshop of the world. What matters the protest of the old countries against the introduction of our system abroad? Already thorough and complete—mother earth turns to us for the improvements that help her to go round the faster.

The vast and seemingly limitless resources of America make her prominently the land of promise for all time, and when to this is added the intelligent, almost divinely inspired population we possess, always ready to keep both brawn and brain in perfect working condition by constant exercise from the moment our little men begin their march toward the public schools to the day they reluctantly lay down the tools of their chosen craft to enjoy eternal rest—can such a country produce any other than a race of master workmen? The superiority and finally world wide triumph of the American idea is inevitable and must last until a younger and greater nation is born, grows, and attains its vigorous majority.

POWER EMPLOYED IN MANUFACTURES.

BY EDWARD H. SANBORN.

[Edward H. Sanborn, statistician; has had charge of important work in the United States censuses of 1890 and 1900, most of it being in connection with the manufactures division of the bureau; he was and is an expert in the iron and steel industry, and in the last census was in charge of the investigation into the use of power by manufactories.]

The aggregate motive power employed in manufacturing establishments in the United States during the census year was 11,300,081 horsepower, as compared with 5,954,655 horsepower in 1890, 3,410,837 horsepower in 1880, and 2,346,142 horsepower in 1870. The increase from 1890 to 1900 was 5,345,426 horsepower, or 89.8 per cent; from 1880 to 1890, 2,543,818 horsepower, or 76.6 per cent; and from 1870 to 1880 1,064,695 horsepower, or 45.4 per cent.

Of the total power used in manufactures during the census year, steam engines furnished 8,742,416 horsepower, or 77.4 per cent of the aggregate; water wheels supplied 1,727,258 horsepower, or 15.3 per cent; electric motors, 311,016 horsepower, or 2.7 per cent; gas and gasoline engines, 143,850 horsepower, or 1.3 per cent; and other forms of mechanical power 54,490 horsepower, or five tenths of 1 per cent. In addition to the above power, which was generated by the establishments by which it was used, rented power was used to the extent of 321,051 horsepower, or 2.8 per cent of the total. Of this rented power 183,682 horsepower was electric, and 137,369 horsepower was other power.

These figures do not by any means represent the total use of power in the United States. In fact, the rapidly increasing application of power to other industrial uses than manufacturing has steadily reduced the ratio of power used for driving machinery in mills and factories to the total power applied to all uses. This condition was even more marked at the twelfth census than when the eleventh census was compiled; and it is no longer safe to take the power employed in manufacturing as a basis upon which to make calculations concerning the aggregate power requirements of the country.

A few decades ago the use of power in any considerable quantity was limited practically to manufacturing operations. Within the past twenty years, and more particularly during the last decade, the use of electricity for lighting and for the operation of street railways has developed enormously, and has resulted in the utilization of power in an entirely new field to an extent that exceeds the total amount of power used in many of the larger manufacturing industries.

During 1900 over 1,200 electric railway lines were in operation in the United States, and the total capacity of their power plants exceeded 1,000,000 horsepower. There are over 3,300 central stations for the distribution of electric current for lighting and power purposes, and the total amount of steam power used to generate it is estimated to be more than 1,500,000 horsepower. One company alone, in New York city, operates several central stations, aggregating nearly 250,000 horsepower. Independent isolated electrical plants, which furnish light and power for stores, office buildings, hotels, public buildings, etc., constitute another item of power of great magnitude. There are no data available for even approximating the amount of power thus utilized in the entire United States; but a recent canvass of New York city by one of the electrical companies showed that the isolated electrical plants in that city represented over 100,000 horsepower thus applied.

The modern office building, often housing a population equal to that of a small town, is almost wholly a creation of the past fifteen years, and the power required in these great structures, not only for lighting purposes, but for the operation of elevators, pumping water, compressing air, and operating refrigerating and ventilating machinery, forms a large item when the number of these buildings in the United States is taken into consideration.

As illustrative of this, the power plant of one sixteen story modern building, containing 560 offices, may be of interest. In this building there are 4 engines, 3 of 150 horsepower each, and 1 of 75 horsepower, which are used to drive dynamos. Four small engines connected to ventilating fans represent about 50 horsepower. For the hydraulic elevator service there are 5 pumps, 1 of about 150 horsepower, 1 of 105 horsepower, 1 of 100 horsepower, and 2 of 40 horsepower each. Altogether, the engines and pumps in this one office building represent an aggregate of about 1,000 horsepower. A considerable part of this equipment is duplicate machinery, provided for emergencies, but not less than 700 horsepower is used continuously in the building. From this may be judged the importance of this use of power, which has developed almost entirely since 1890.

The use of steam power, either directly applied or electrically transformed and transmitted, is becoming more and more general in mining and quarrying, in public works of every description, in the sinking of foundations, in the erection of buildings, and in nearly every branch of industry, and the amount of power used, apart from manufacturing operations, is increasing steadily.

The application of power to diversified operations as indicated above, has been most noteworthy during the past fifteen years; and it is easy to see, even without any definite statistical presentation, that while the power used in manufacturing in 1890 probably embraced by far the largest part of the motive power applied to all purposes, similar figures for 1900 represent a much smaller proportion of all the power used in the United States.

In view of the generally prevailing belief that mechanical power has been and still is very largely supplanting hand labor in almost every branch of industry, it may appear strange that with an increase of 101.8 per cent in the total number of manufacturing establishments between 1880 and 1900, and with an increase of 142.2 per cent in the total value of products during the same interval, the proportion of manufacturing establishments reporting the use of power was the same in 1900 as in 1880—about one third. In 1880 the use of power was reported by 85,923 out of 253,852 establishments, or 33.8 per cent. In 1890, 100,735 out of a total of 355,415 establishments reported the use of power, or 28.3 per cent of the aggregate. The reduced proportion was doubtless due to the more thorough canvass and the consequent inclusion of a larger number of small plants. In 1900 the proportion of establishments using power increased again to 33.1 per cent, or 169,409 out of a total of 512,254.

This indicates that while the substitution of power-driven machinery for hand labor has unquestionably taken place to a very great extent—which can be demonstrated by a study of many branches of manufacture—at the same time the increase of hand labor shops and small factories using some machinery but no mechanical power has also been continuous, with the result that at the present time the numerical proportion of manufacturing establishments operating without any mechanical power is as large as it was twenty years ago.

How small a proportion the products of this class of establishments are of the total value of manufactured products for all industries is shown by the fact that the group of industries classed as "hand trades" in 1900, contributed only $1,183,615,478 to the total of $13,004,400,143, the value of the products of all manufacturing industries. Although there were 215,814 establishments classified as "hand trades" out of a total of 512,254, or 42.1 per cent, the value of the products of such establishments was only 9.1 per cent of the total for all establishments. The classification of "hand trades," however, does not embrace all establishments operating without mechanical power, nor do all establishments otherwise classified use power, but this illustration suffices to show the minor importance of the industries which do not use power, as compared with those that use power in some form.

The following table shows the average horsepower per establishment for 11 of the principal industries for 1880, 1890, and 1900.

The increasing importance of the larger plants is manifest in the continuous increase in the average of power per establishment. In 1880 the average power of the establishments which reported its use was 39.7 horsepower; in 1890 it was 59.1 horsepower; and in 1900 it was 66.7 horsepower. There was, therefore, in the twenty years from 1880 to 1900 an increase in the average power per establishment of 27 horsepower, or 68 per cent.

Average Horsepower per Establishment in Selected Industries: 1880 to 1900.

Industries.	Average Horsepower per Establishment.		
	1900	1890	1880
All industries	66.7	59.1	39.7
Agricultural implements	129.7	66.3	34.9
Boots and shoes, factory product	39.7	22.5	15.6
Cotton goods	840.4	527.1	288.2
Flouring and grist mill products	42.1	41.0	31.8
Hosiery and knit goods	69.8	58.9	51.2
Iron and steel	2,508.3	1,156.3	508.6
Lumber and timber products	50.9	49.6	32.0
Paper and wood pulp	1,002.4	471.1	179.1
Silk and silk goods	129.3	77.2	44.7
Woolen goods	136.4	99.2	53.7
Worsted goods	526.4	410.9	216.3
All other industries	46.3	42.7	28.3

Steam still continues to be pre-eminently the primary power of greatest importance, and the census returns indicate that the proportion of steam to the total of all powers has increased very largely in the past thirty years. In 1870 steam furnished 1,215,711 horsepower, or 51.8 per cent of a total of 2,346,142; in 1880 the amount of steam power used was 2,185,458 horsepower out of a total of 3,410,837, or 64.1 per cent; in 1890, out of an aggregate of 5,954,655 horsepower, 4,581,595, or 76.9 per cent, was steam; while in 1900 steam figured to the extent of 8,742,416 horsepower, or 77.4 per cent, in a total of 11,300,081. This increase in thirty years, from 51.8 per cent to 77.4 per cent of the total power shows how much more rapidly the use of steam power has increased than other primary sources of power.

The tendency toward larger units in the use of steam power is shown inadequately by the increase in the average horsepower per engine from 39 horsepower in 1880, to 51 horsepower in 1890, and 56 horsepower in 1900.

The tendency toward great operations, which has been such a conspicuous feature of industrial progress during the past ten years, has showed itself strikingly in the use of units of larger capacity in nearly every form of machinery, and nowhere has this tendency been more marked than in the motive power by which the machinery is driven. At the same time there has been an increase in the use of small units, which tends to distort the true tendency in steam engineering in these statistics. For example, a steam plant consisting of one or more units of several thousand horsepower may also embrace a number of small engines of only a few horsepower each, the use of which is necessitated by the magnitude of the plant, for the operation of mechanical stokers, the driving of draft fans, coal and ash conveyors, and other work requiring power in small units. On this account the average horsepower of steam engines in use at different census periods fails to afford a true basis for measuring progress toward larger units during the past ten years.

Developments of the past few years in the distribution of power by the use of electric motors have served to accelerate the tendency toward larger steam units and the elimination of small engines in large plants and to change completely the conditions just described. For example: In one of the largest power plants in the world, all the stokers, blowers, conveyors, and other auxiliary machinery are to be driven by electric motors. Such rapidly changing conditions tend to invalidate any comparisons of statistical averages deduced from figures for periods even but a few years apart.

Comparison of two important industries will illustrate the foregoing. The average horsepower of the steam engine used in the cotton mills of the United States in 1890 was 198, and in 1900 it was 300.

In the iron and steel industry the average horsepower per engine in 1890 was 171, and in 1900 it was 235. In the cotton mills the use of single large units of motive power, with few auxiliary engines of small capacity, gives the largest horsepower per engine of any industry; while in the iron and steel industry the average of the motive power proper, although probably larger than in the manufacture of cotton goods, is reduced by the large number of small engines which are used for auxiliary purposes in every iron and steel plant.

The decade between 1890 and 1900 was a period of marked development in the use of gas engines, using that term to denote all forms of internal combustion engines, in which the propelling force is the explosion of gaseous or vaporous fuel in direct contact with a piston within a closed cylinder. This group embraces those engines using ordinary illuminating gas, natural gas, and gas made in special producers installed as a part of the power plant, and also vaporized gasoline or kerosene. This form of power appears for the first time as an item of consequence in the returns of the last census, and the very large increase in the horsepower in 1900 as compared with 1890 indicates the growing popularity of this class of motive power.

In 1890 the number of gas engines in use in manufacturing plants was not reported, but their total power amounted to only 8,930 horsepower, or one tenth of 1 per cent of the total power utilized in manufacturing operations. In 1900, however, 14,884 gas engines were reported, with a total of 143,850 horsepower, or 1.3 per cent of the total power used for manufacturing purposes. This increase from 8,930 horsepower to 143,850 horsepower, a gain of 134,920 horsepower, is proportionately the largest increase in any form of primary power shown by a comparison of the figures of the eleventh and twelfth censuses, amounting to 1,510.9 per cent.

Within the past decade, and more particularly during the past five years, there has been a marked increase in the use of this power in industrial establishments for driving machinery, for generating electricity, and for other kindred uses. At the same time, internal combustion engines have increased in popularity for uses apart from manufacturing, and the amount of this kind of power in use for all purposes in 1900 was, doubtless, very much larger than indicated by the figures relating to manufacturing plants alone.

The average horsepower per gas engine in 1900 was 9.7 horsepower. There are no available statistics upon which to base a comparison of this average with the average for 1890, but it is doubtful if there has been any very material change in ten years; for while gas engines are built in much larger sizes than ever before, there has been also a great increase in the number of small engines for various purposes.

The large increase in the use o˙ internal combustion engines has been due to the rapid improvements that have been made in them, their increased efficiency and economy, their decreased cost, and the wider range of adaptability that has been made practicable.

The statistics relating to the use of water power for manufacturing purposes in 1900, compared with corresponding figures for 1890, 1880, and 1870, are significant of an interesting phase of power utilization, particularly during the past ten years.

The total amount of water power reported as used by manufacturing establishments in 1900 was 1,727,258 horsepower; 1,263,343 horsepower in 1890; 1,225,379 horsepower in 1880; and 1,130,431 horsepower in 1870. The increase from 1890 to 1900 was 463,915 horsepower, or 36.7 per cent. From 1880 to 1890 the increase was 37,964 horsepower, or 3.1 per cent, while from 1870 to 1880 there was an increase of 94,948 horsepower, or 8.4 per cent. In 1900 water power constituted 15.3 per cent of the total, as compared with 21.2 per cent in 1890, 35.9 per cent in 1880, and 48.2 per cent in 1870. Apparently the use of water power for manufacturing purposes has decreased relatively in thirty years from nearly one half of the total motive power to less than one sixth.

The decrease in the actual importance of waterpower is evidently less marked than these figures would seem to indicate; for consideration should be given to the fact that a very large portion of the electric motors reported in 1900 were driven by current developed by water power. For example, almost all the power developed by the great hydraulic installation at Niagara falls is electrically transmitted, and consequently is reported as electric power by the manufacturing establishments in which it is used. Many textile plants are operated by electric current from distant generators driven by water power. In this way a large portion of the water power actually used in manufacturing operations does not appear in the census returns because it is electrically transmitted and is accounted for in the motors that are reported. It is obvious, therefore, that the use of water power in 1900 was considerably larger than indicated by the amount reported.

While the number of water wheels in use has decreased from 55,404 in 1880 to 39,182 in 1900, a loss of 16,222 wheels, or 29.3 per cent of the number in use in 1880, the aggregate power of the wheels in use increased during the same interval from 1,225,379 horsepower to 1,727,258 horsepower, a gain of 501,879 horsepower, or 41 per cent. This very large decrease in the number of wheels and great increase in the aggregate power points to the large increase in the size of the units, which in 1880 averaged only 22.1 horsepower each, but which in 1900 was 44.1 horsepower, or twice as large. This is due to the abandonment of many small wheels of antiquated type and the substitution therefor of fewer units of larger size and greater efficiency. In many instances, too, it has been necessary to abandon entirely the use of water power, either because of failing supply or the larger requirements of expanding industry, and this has removed a considerable number of wheels, mostly of small size.

The use of water as a primary source of power has undergone a complete transformation recently, both in the methods of its utilization and in the manner of transmitting and applying the power. Prior to 1890 the largest use of water power was in its direct application to machinery in manufacturing establishments at the immediate point of development. During the past fifteen years, however, the use of electricity as an agency for the transformation and transmission of the energy developed by falling water has entirely changed the conditions under which such primary power can be utilized to advantage. The practical possibility of transmitting power thus developed over long distances has removed the necessity for building mills immediately adjacent to water powers, often so located as to present serious physical obstacles to the economical arrangement and construction of manufacturing plants. This has rendered available many water powers which otherwise could not have been utilized to advantage, and thus has largely increased the industrial possibilities of many localities where a limited or expensive fuel supply has made the use of steam power impracticable.

Electrical transmission has rendered possible the advantageous utilization of water power in several distinctly new forms, such as the large central stations for the distribution of power to numerous plants, as, for example, at Niagara Falls; the use of remote mountain water powers for the operation of single plants, often many miles distant, of which so many notable examples are to be found in the far west; and the more advantageous use of larger streams on the Atlantic coast, usually in closer proximity to the mills, but under conditions which would present many difficulties without the useful agency of the electrical current.

The significant increases in the use of water power are readily accounted for by the growth of certain industries, mainly the manufacture of paper and wood pulp. In the paper and pulp mills in New York, water power was used to the extent of 65,052 horsepower in 1890, and 191,117 horsepower in 1900. This industry alone, therefore, accounts for 126,065 horsepower of the increase of 134,661 horsepower in that state from 1890 to 1900.

In Maine, where the next largest increase took place, the cause was the same, the use of water power in paper and pulp mills having increased from 20,320 horsepower in 1890 to 75,839 horsepower in 1900, an increase of 55,519 out of a total increase of 60,744 horsepower.

In the paper and pulp mills in New Hampshire 38,200 horsepower was used in 1900, as compared with 4,405 horsepower in 1890, an increase of 33,795 horsepower, which accounted for the major part of the total increase of 43,722 horsepower in that state.

The increase of 28,061 horsepower in the use of water power in Massachusetts from 1890 to 1900 was due to the larger use of this power in the paper and cotton industries. In 1890, 29,148 horsepower was reported in paper mills, and 44,935 horsepower in 1900, an increase of 15,787 horsepower. In the cotton mills of this state water power to the extent of 55,944 horsepower was used in 1890, and 64,158 horsepower in 1900, an increase of 8,214 horsepower. Together these industries account for 24,001 horsepower of the total increase of 28,061 horsepower.

In Wisconsin the entire increase in the use of water power is attributable to the growth of the pulp and paper industry, in which 61,287 horsepower was used in 1900, compared with 19,131 horsepower in 1890, an increase of 42,156 horsepower. The total increase for the state was 42,166 horsepower.

In North Carolina, where there was an increase of 25,210 horsepower, the conditions were somewhat different. Water power reported in cotton mills increased from 7,959 horsepower in 1890 to 19,225 horsepower in 1900, or 11,266 horsepower. The amount of water power reported in flour and grist mills in 1890 was 19,874 horsepower, and in 1900, 28,658 horsepower, an increase of 8,784 horsepower. The increase in the two industries was 20,050 horsepower out of the total increase of 25,210 horsepower.

The most notable phase of the application of power to industrial uses is the use of the electric current for the transmission and subdivision of power. This form of power transmission and distribution is almost wholly a development of the past fifteen years, although the principles involved were known and their practical utility demonstrated at a much earlier period. Prior to 1890 the census returns did not state separately the number of motors in use or the amount of electric power utilized in manufacturing establishments, such power being merged in the group of "other power."

The development of electric motors in this country has been accompanied by a corresponding development of the art of power transmission. But for the higher perfection of the electric motor since 1890, it may be doubted whether the transmission of electric energy would have been undertaken on anything like so large a scale as was witnessed at the close of the century. During the ten years preceding 1890 the development of motors and of power transmission work was chiefly by means of direct current, but the last decade has seen a remarkable change in methods of current generation, enabling the creation of new centers of manufacture around water powers and permitting the transmission of electricity over distances which were previously deemed utterly prohibitive.

The great bulk of electric motor work is still done with direct current, there being no alternating current motors in use for railway work; and in stationary work, that is, in mills, factories, mines, etc., the utilization of alternating current motors, measured by their number and value, is only about 25 per cent as large as that of the direct current.

The development of electric power transmission at Niagara Falls has been the largest, and the most conspicuous of its kind, and the work done there is in many respects typical of that done in other sections of the country where water power is abundant, although as to the length of transmission and the voltage at which the current is sent over long distances, it is by no means the best example that can be found.

The utilization of Niagara has in fact gone on for some time, and there are at the present time two separate and distinct enterprises on the American side, one above and the other below the Horseshoe falls. The plant below the falls has the water of the Niagara river brought to it by a long canal which taps the upper Niagara river, runs through the city of Niagara Falls, and then discharges the waste water at the cliff just below the first suspension bridge. Here there is a fall of about 215 feet, considerably more than at the plant above, but there is the disadvantage that the turbines and dynamos are located in the gorge, which the buildings disfigure, and that the conditions are not so favorable for the operation of machinery as in a plant at the surface.

It is the plant above the falls, developed by the Niagara Falls Power company, the current of which, while used locally in large amounts, is also transmitted to Buffalo, 26 miles distant, that has attracted the greatest public attention. This includes a short service canal, 250 feet wide at its mouth, 1¼ miles above the falls, the intake being inclined obliquely to the Niagara river. The canal extends inwardly 1,700 feet, with an average depth of 12 feet, and holds water adequate to the development of over 100,000 horsepower. On each side is a power house, the ultimate capacity of each being

50,000 horsepower, one of which is in full operation and the other in course of equipment with machinery.

The electric generators are at the surface, and the water wheels which drive them are in a wheel pit 150 feet under ground, being connected by a steel shaft; the water reaches the wheels through steel tubes. After the water has delivered up its energy, it is carried off by means of a tunnel 7,000 feet in length, with an average slope of 6 feet in 1,000. This tunnel, which has a net section of about 386 square feet, empties just under the first suspension bridge, where the waste water rushes out with a speed of nearly 20 miles an hour.

The Niagara Falls Power company has under its charter the right to take sufficient water from the upper river to develop 200,000 horsepower, and has large franchises also on the Canadian side. The development of its work has gone on without in anywise marring the beauty of the spot, while the diversion of water is obviously too small to make any perceptible difference in the amount passing over the crest of the Horseshoe or American falls; the potential power of the main stream is estimated to be equal to at least six or seven million horsepower.

The first power house of the company, which has now been in operation for some time, contains 10 dynamos of 5,000 horsepower each. Between this and the other is a large transforming station, at the end of the canal, where huge transformers are grouped for raising the current of 2,200 volts to a pressure of 22,000 volts for transmission to Buffalo, and to 11,000 volts for utilization on the company's own factory land, and by a large variety of industries already concentrated along the bank of the Niagara river toward Tonawanda.

These are the leading features of the generation of current above the falls on the American side, but the American company has already given out contracts for a large plant on the Canadian side, where the current will be developed by the largest dynamos in the world, built in the United States, and can, if necessary, be brought across the river for use in this country. The dynamos, 3 in number, will each deliver 10,000 horsepower to the circuits, returning 98 per cent of the shaft horsepower in the form of current generated at a potential of 12,000 volts, thus dispensing with transformers, which otherwise would be required to raise it to that voltage for transmission.

A large amount of Niagara current is employed in electro chemical and electro metallurgical operations. This work, however, is far from exhausting the possibilities of Niagara development by electricity. In the immediate vicinity of the falls, the current is now used for electric lighting, and about 1,000 horsepower is also delivered to the street railway trolley system. Factories on the spot working up raw material into food, textile fabrics, etc., utilize several hundreds of horsepower, and the current is also used for the manufacture of "merry-go-rounds," as well as for operating ventilating blowers in the public schools.

It is the transmission to Buffalo, however, which more particularly justifies the utilization of the energy of the great cataract, and illustrates the remarkable manner in which electric power is modifying the methods of American manufacturing and mechanical industries. The current from Niagara to Buffalo is carried over aerial circuits and delivered to transformer stations which lower the pressure for local distribution. The Buffalo street railway system has five of these substations, so that at all hours of the day and night, Niagara is transporting the public of a great city more than 20 miles distant.

There are a number of miscellaneous industries and manufactures in which blocks of Niagara current are used at prices which compete so favorably with those of steam, oil, and natural and artificial gas, that the demand is rapidly increasing. Among these may be mentioned large flouring mills and a plaster making plant.

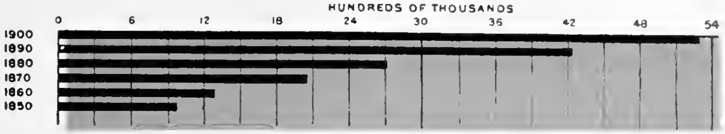
Not only is grain ground to flour by electrical power, but it is handled by electricity in some of the largest grain elevators for which Buffalo is famous, one of them, the "Great Northern," having 20 induction motors of an aggregate capacity of 1,200 horsepower. Another large utilization is at the plant of the Buffalo Dry Dock company, where 40 motors of upward of 500 horsepower capacity are employed in the process of building some of the largest steel steamships that ply the great lakes.

An advance beyond the utilization of the power of Niagara falls is that developed during the census year, and more recently perfected, by means of which electric current is transmitted from the Sierras in eastern California as far as San Francisco and other cities adjacent to the Pacific seaboard. This constitutes the longest electric power transmission in the world, the distance being nearly ten times that on the American side of Niagara falls. A further striking difference is that, whereas the development at Niagara is due to the falling of water in huge volume under a head of only from 150 to 200 feet, in California large enterprises depend upon the utilization of relatively small bodies of water, but with heads of from 500 to 1,500 and 1,800 feet. In that state, where fuel is still scarce and dear, a great many mining plants have been brought within the sphere of feasibility by this electric power transmission, and a large amount of miscellaneous work throughout the state is now tributary to these long distance transmissions, which excel in daring, in number, and in commercial success anything attained elsewhere in the world.

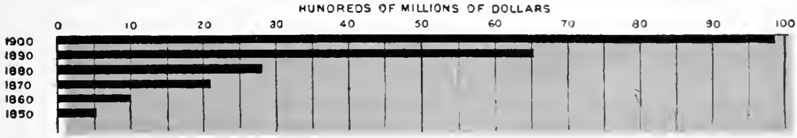
The transmission of the power of the North Yuba river, in the Sierras, to San Francisco, above referred to, effected by the Bay counties and Standard systems, stretches across and ramifies through no fewer than 16 counties, containing property to the amount of three fifths of the assessed valuation, and about one half of the population of the state. The systems have two sources of supply, one at Colgate, over 200 miles from the Golden Gate, and the other at Electra, about 150 miles distant, these systems meeting on San Francisco bay, at Mission San José and at Oakland.

The power plant at Colgate is situated at the base of a 1,500 foot hill, down the side of which extend five steel pipes, each 30 inches in diameter, delivering water to the turbines. Water is brought to these pipes from the impounded river and from a remote watershed by means of a timber flume over 7 miles in length with a capacity of carrying 23,000 cubic feet of water per minute. The turbines drive 3 gener-

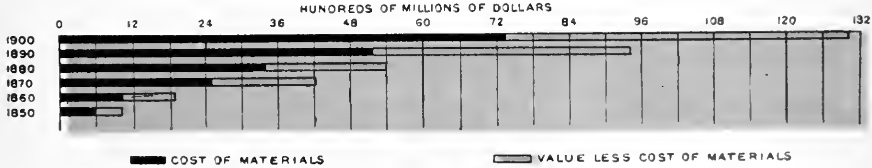
AVERAGE NUMBER OF WAGE EARNERS EMPLOYED IN MANUFACTURES: 1850 TO 1900



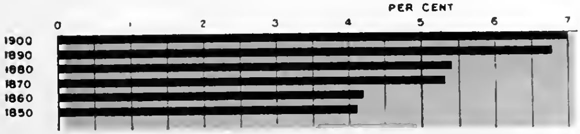
CAPITAL INVESTED: 1850 TO 1900



VALUE OF PRODUCTS: 1850 TO 1900



PROPORTION OF AVERAGE NUMBER OF WAGE EARNERS EMPLOYED IN MANUFACTURES TO POPULATION: 1850 TO 1900



ator dynamos of 3,000 horsepower each, and 4 of 1,500 horsepower each, these being of the "three phase" current type. The current is generated in these dynamo machines at 2,400 volts pressure, and is then raised by transforming apparatus to a pressure of 40,000 and 60,000 volts, even 80,000 volts having been reached, while the lowest pressure named is normal. This current is delivered to two circuits of 3 wires each, one being composed of copper and the other of aluminum. The wires are carried upon Oregon cedar poles averaging from 25 to 60 feet high, upon which are screwed porcelain and glass umbrella insulators 12 inches in diameter.

The transmission current is carried across the well known Straits of Karquines in an enormous span of 4,448 feet, supported 200 feet above the rapid waters emptying into San Pablo bay by means of steel latticed towers, the circuits being composed of stranded plow steel to obtain the requisite tensile strength.

The efficiency of the transmission system is such that 1,000 horsepower at the Colgate wheels nets about 750 horsepower at San Francisco, 6 per cent being lost in the generators, 2 per cent in the step up transformers, 2 per cent in the step down transformers at the receiving substations, and 15 per cent in regulation and in the line.

The employment of the current is not less varied than at Niagara, ranging from the operation of street cars in Oakland to the running of a flourmill at Stockton, and from use in mines in various parts of the state to use in miscellaneous industries at Sacramento, Benicia, San José, and elsewhere. The plants must be maintained in regular and systematic operation, and as their initial base of dependence is the water supply, storage reservoirs have been provided in the high Sierras in Alpine county, 6,000 to 8,000 feet above the sea level, furnishing a supply equal to one hundred and fifty days, which is the maximum dry period of the state as recorded in its annals.

The third type of power transmission plant which deserves mention is that at the Snoqualmie falls, Washington, where the dynamo room with 10,000 horsepower of electrical apparatus is situated 250 feet below the surface in a large whitewashed cavern, blasted and hewn from the solid rock. This unique location is due to the fact that the spray from the falls rendered it impossible to locate any power house at the surface. The current is transmitted across the Cascade Mountains through dense forests to the cities of Seattle and Tacoma, where electric lights, railways, and motors are operated; and, here again, it is to be noted that aluminum is used for transmission circuits.

The Saint Mary river, which flows from Lake Superior into Lake Huron and separates the upper peninsula of Michigan from Canada, has been utilized for power development upon an extensive scale during the last few years. The conditions here are somewhat different from the illustrations previously described, as instead of a comparatively small flow of water at great head, an enormous volume of water with a comparatively small head is used. The difference in the levels of the two lakes is about 20 feet, most of the fall occurring in the rapids known as Saint Mary's falls, or Sault Sainte Marie, at the outlet of Lake Superior. On the Canadian side of the river a power canal has been in use for several years, yielding about 20,000 horsepower, a large portion of which is used direct from the turbines for driving wood pulp grinders. The remainder is electrically transmitted to various industries.

On the American side of the river a much larger power development is approaching completion. A canal about 2¼ miles in length, from 200 to 250 feet in width, and of an average depth of about 20 feet, has been cut from Lake Superior to a point on Saint Mary's river below the rapids. A massive power house of steel, stone, and concrete, over 1,300 feet in length, will contain 320 horizontal turbines, capable of developing about 50,000 horsepower. All of this power will be transmitted by electricity to industries in the vicinity on both sides of the river.

A third canal of similar proportions is to be constructed on the Canadian side of the river, paralleling the one now in operation on that side.

A unique feature of this great development is the precaution taken to prevent possible lowering of the level of

Lake Superior or interference with the vast steamship traffic which passes through the locks at the rapids. Lest the increased outlet afforded by canals should lessen the flow of water through the steamship locks and their approaches, compensating works are being constructed at the head of the rapids for the purpose of reducing, by means of movable gates, the outflow over the falls in proportion to the increased outlet created by the power canals. It is designed, by this means, to maintain the flow of water from Lake Superior as a fixed quantity, regardless of the new outlets afforded by the power canals.

In cotton goods manufacture electric power is being rapidly adopted, not only in New England, but in the south; perhaps the most conspicuous examples can be found in the latter region, where water power has been largely utilized.

One of the earlier and larger plants at which water power was utilized for the generation of electric power is the Ponemah mills, at Taftville, Conn., where the energy from the water power at Baltic, 4½ miles away, has been used for years to run the weaving mill of 1,700 looms, and to operate 1,200 incandescent lights. The generating plant consists of two alternating current generators of 350 horsepower each, and these drive two 350 horsepower motors at Taftville. A street railway system is operated in connection with the mill, and an electric locomotive is employed to haul freight cars a distance of one mile.

The typical Southern mills utilizing water power are those at Columbia, and at Pelzer, S. C., the former requiring about 1,400 horsepower and the latter, 3,000 horsepower.

Electric motors doing miscellaneous work in manufacturing establishments are scattered so widely throughout the field of industry that it is impossible to consider them all in detail. It will suffice, perhaps, to note the figures given by Mr. W. H. Tapley, electrician of the government printing office, at Washington, D. C., where the advantages have been so marked that the new office, the largest of its kind in the world, is being equipped throughout with electric power. At the time Mr. Tapley made his report—the period of the census year—the office had, connected with the power circuits, 575 electrical horsepower of motors for presses, etc., and 125 horsepower of motors for elevators. The most marked feature of economy mentioned by Mr. Tapley is in the increase of 15 per cent in the output of the press room. If there is any printing office where trustworthy power conditions must be had, it is that of the government, the plant being run twenty four hours daily during the sessions of congress. Mr. Tapley states that there has never been a hitch in the motive power. "In fact, such a freedom from interruption of power has not been known in the history of the office as during the three years, since we adopted electric power."

The economies introduced into the manufacturing processes of the United States by electric power may be summed up generally or may be treated under separate heads; perhaps the best methods of consideration is to cite the arguments usually advanced and then to mention a few typical cases in support of them.

Prof. F. B. Crocker, of Columbia university, in a classical discussion of the subject before the Franklin institute, Philadelphia, Pa., enumerated the principal advantages obtained by employment of electric power in mills and factories as follows:

1. A real economy in amount of power used.
2. A reduction in cost of the construction of buildings, which can be lighter, owing to the fact that there is no need to install heavy lines of shafting and pulleys.
3. A reduction in expense of service, such as oiling, depreciation, etc.
4. More efficient arrangement of machines and tools, which need no longer be placed in straight lines parallel with the shafting, but can be located exactly as desired.
5. Access to the machinery is easier from the suppression of belts and pulleys.
6. Greater cleanliness, as there is less dust and no scattering of oil or steam, etc.
7. Hygienic conditions are improved, owing to the diminution of dust and dirt; better light, owing to the absence of shafting, pulleys, etc.; the lessening of noise, etc.

8. Greater ease of placing different shops in separate buildings and in locating them according to the strict requirements of the work and without regard to the necessities of the motive power.

9. Greater facility in the increase of establishments.

10. Localization of accidents due to motive power, with consequent less injury to individuals and the stoppage of work only at the point where an individual motor is incapacitated.

11. Greater control of the speed of the tools.

12. A marked increase in the product of any given establishment.

In signalizing these advantages Professor Crocker divided the application of motors to manufacturing into three classes. The first method consists in connecting the motor directly with the machine. The second consists in the interposition of gearing to reduce or increase speed. The third depends upon the utilization of auxiliary shafting and belting. The cases cited herewith of the application of electric motors come within the range of the points enumerated.

At the thirty third annual convention of the American Railway Master Mechanics' association in 1900 an elaborate and interesting report was made by a special committee on power transmission by shafting versus electricity for railroad shops. One of the most significant cases cited was that of the Baldwin Locomotive works, where not quite 1,000 horsepower in electric current was utilized at the time for power purposes. Electricity was first introduced in the erecting shop for driving two 100 ton cranes, and an immediate saving of 80 men was effected. In the wheel shop the "common labor" force was reduced from 40 men to 6; the time consumed in reloading a lathe was cut down from 30 minutes to 5; and the saving in power in that shop was estimated at fully 50 per cent. In the frame shop the laboring force was reduced 60 per cent. The fuel economy, involving a possible reduction of $120 per week, was but one item. The saving on labor was stated at $1,800 per week. The increase in output was large.

The manufacture of paper and wood pulp shows the largest percentage of increase in the amount of power used in 1900 compared with 1890—from 297,724 to 764,847 horsepower, an increase of 467,123, or 156.9 per cent. This increase was chiefly in the use of water power, which amounted in 1900 to 504,762 horsepower, compared with 203,896 in 1890, a gain of 300,866 during the ten years. In no other industry has there been so large an increase at any time during the thirty years.

The largest use of power, however, in 1900 was in the manufactures of iron and steel—1,670,547 horsepower compared with 745,824 in 1890, an increase of 924,723, or 124 per cent. This is a larger absolute increase than in any other industry. Next to the largest use was in the manufacture of lumber and timber products. For the sawmills of the country there was used in 1900 a total of 1,613,747 horsepower, compared with 961,316 in 1890, a gain of 652,431, or 67.9 per cent. This increase was almost wholly in the use of steam, which in 1900 was 1,401,883 horsepower, and in 1890, 759,078, an increase of 642,805, or 84.7 per cent. The use of water power in this industry has shown a continuous decrease during the past thirty years, having fallen from 326,781 horsepower in 1870 to 200,983 in 1900, or 38.5 per cent. In no other industry of magnitude has there been such a substitution of steam for water power.

Flouring and grist mills rank next, with 1,016,859 horsepower in 1900, an increase of 264,494 over 1890, or 35.2 per cent. This increase was more largely in steam than in water power, as the former constituted 167,168 horsepower of the increase, while the latter contributed only 67,506 horsepower.

In the manufacture of cotton goods, in which there has been a large increase in the use of power during the past thirty years, steam has increased far more rapidly than water. From 1890 to 1900 the amount of power increased from 464,881 to 811,347 horsepower, a gain of 346,466, or 74.5 per cent. In this increase steam figured to the extent of 266,102 horsepower, while water represented 52,868 horsepower. The large increase from 1890 to 1900 in other forms of power used in the cotton manufacture is worthy of note, as these, which were only 390 horsepower in 1890, amounted to 27,886 horsepower in 1900, a gain of 27,496. The classification of "other power" consisted chiefly of electrical power, the use of which, as noted elsewhere, has increased in this industry very rapidly during the past ten years.

The following table shows the total horsepower employed from 1870 to 1900 in a few of the larger industries, the percentage of increase, the average number of wage earners employed, the amount of power used per wage earner, the value of products, and the horsepower per $1,000 of products.

TOTAL HORSEPOWER IN SELECTED INDUSTRIES, WITH PER CENT OF INCREASE, POWER PER WAGE EARNER, AND PER $1,000 OF PRODUCTS: 1870 TO 1900.

Selected Industries.	Year.	Amount of horsepower.	Per cent of increase in total horse power.	Average number of wage-earners.	Power per wage earner.	Value of products.	Horse-powerper $1,000 of products.
Agricultur'l implements	1900	77,189	53.2	46,582	1.7	$101,207,428	0.8
	1890	50,395	12.7	38,827	1.3	81,271,651	0.6
	1880	44,731	71.5	39,580	1.1	68,640,486	0.7
	1870	26,082	....	25,249	1.0	52,066,875	0.5
Boots and shoes, factory product.......	1900	51,073	66.4	142,922	0.4	261,028,580	0.2
	1890	30,686	165.1	133,690	0.2	220,619,358	0.1
	1880	11,574	278.9	111,152	0.1	166,050,354	0.1
	1870	3,055	....	91,702	(*)	146,704,055	(*)
Cotton goods†	1900	811,347	74.5	302,861	2.7	339,200,320	2.4
	1890	464,881	68.7	218,876	2.1	267,981,724	1.7
	1880	275,504	88.7	185,472	1.5	210,950,383	1.3
	1870	146,040	....	135.519	1.1	177,489,739	0.8
Flouring and grist mill products..........	1900	1,016.859	35.2	37,073	27.4	560,719,063	1.8
	1890	752,365	‡2.5	47,403	15.9	513,971,471	1.5
	1880	771,201	33.7	58,407	13.2	505,185,712	1.5
	1870	576,686	....	58,448	9.9	411,985,143	1.3
Hosiery and knit goods	1900	58,087	68.2	83,387	0.7	95,482,566	0.6
	1890	34,538	198.8	59,588	0.6	67,241,013	0.5
	1880	11,561	77.9	28,885	0.4	29,167,227	0.4
	1870	6,498	....	14,788	0.4	18,111,564	0.4
Iron and steel............	1900	1,670.547	124.0	226,161	7.4	835,759,031	2.0
	1890	745,824	87.8	148,715	5.0	478,687,519	1.6
	1880	397,247	132.8	140,978	2.8	296,557,685	1.3
	1870	170,675	....	77,555	2.2	307,208,696	0.6
Lumber and timber products...............	1900	1,613,747	67.9	283,260	5.7	566,832,984	2.9
	1890	961,316	17.0	311,964	3.1	437,957,382	2.2
	1880	821,928	28.1	147,956	5.6	233,268,729	3.5
	1870	641,665	....	149,997	4.3	210,159,327	3.1
Paper and wood pulp...	1900	764,847	156.9	49,646	15.4	127,286,162	6.0
	1890	297,724	140.3	31,050	9.6	78,937,181	3.1
	1880	§123,912	128.3	25,631	4.8	55,109,914	2.3
	1870	54,287	....	18,021	3.0	50,812,415	1.1
Silk and silk goods......	1900	61,395	107.2	65,416	0.9	107,256,258	0.6
	1890	29,638	236.4	49,382	0.6	87,298,454	0.3
	1880	8,810	361.0	31,337	0.3	41,033,015	0.2
	1870	1,911	....	6,699	0.3	12,210.662	0.2
Woolen goods...........	1900	139,645	14.0	69,350	2.0	120,038,792	1.2
	1890	122,501	15.0	76,915	1.6	133,577,977	0.9
	1880	106.507	25.2	86,504	1.2	160,606,721	0.7
	1870	85,101	....	77,870	1.1	155,405,358	0.6
Worsted goods..........	1900	97,383	69.9	56,551	1.7	118,705,710	0.8
	1890	57,111	247.5	42,978	1.3	79,194,652	0.7
	1880	16.437	105.1	18.803	0.9	33,519,912	0.5
	1870	8,016	....	12,920	0.6	22,090,331	0.4

*Less than one-tenth of 1 per cent.
†Includes cotton small wares.
‡Decrease.
§H.P. exclusive of wood pulp, for which figures not accessible.

These figures show, in nearly every case, a continuous increase during the past thirty years in the power per wage earner and also in the power required for $1,000 of products. It might be assumed that this showing indicated a decrease in mechanical efficiency, or the requirement of much more power to operate the machinery, were it not too obvious to require proof that in nearly every important industry there has been a continuous substitution of power driven machinery for hand labor, with a consequent increase in the amount of power required, and at the same time an increase in the productive capacity of each operative.

Any calculation of the ratio of power to product in different years should take into consideration the continuous decline in the value of products. If it were possible to measure the output of each industry by units of quantity rather than value, there would not appear to be any such large increase in the amount of power required as is indicated by these figures.

Possibly the most striking increase in the use of power shown in this table is in connection with the manufacture of boots and shoes. In 1870 there were reported for this industry 3,055 horsepower and 91,702 wage earners, or only three hundredths of a horsepower per wage earner; while in 1900 there were 51,073 horsepower and 142,922 wage earners, or four tenths of a horsepower per wage earner. The increase in horsepower per $1,000 of products was from two hundredths to two tenths of a horsepower. This is a more striking showing of the displacement of hand labor by power driven machinery than is furnished by any other of the large industries. It is worthy of note that the increase in the value of products per wage earner in the boot and shoe manufacture from 1870 to 1900, with this very large increase in the use of power, was from $1,600 to $1,826, without making allowance for the very large decrease in the value per unit of product, that is, in the selling price during the thirty years.

In contrast with the small amount of power per wage earner and per $1,000 of products in the boot and shoe industry is the showing of the paper and pulp mills. The very heavy power requirements of the pulp grinders and the comparatively small number of wage earners required for them show a high proportion of power to wage earner, or 15.4 horsepower for each wage earner in 1900 compared with 3 horsepower in 1870. Again, the enormous power requirements of this industry, with the comparatively low price of the products, show a larger amount of power required per $1,000 of products than in any other large industry. In 1900 it required 6 horsepower to produce $1,000 in value of wood pulp and paper, compared with 1.1 horsepower in 1870.

The relations between power and labor, and between power and product appear to have been more nearly stationary in the manufacture of lumber and timber products during the past thirty years than in any other of the more important manufactures. While the amount of power per wage earner in this industry appears to have increased from 4.3 horsepower to only 5.7 horsepower in thirty years, there has been an actual decrease in the amount of power required per $1,000 of products, which was only 2.9 horsepower in 1900, compared with 3.1 horsepower in 1870. In spite of this very small increase in the amount of power per wage earner, the value of products per wage earner increased from $1,401 in 1870 to $2,001 in 1900, and this with an actual decrease in the ratio of power to product.

The iron and steel industry, the largest user of power, shows an increase in thirty years from 2.2 horsepower per wage earner to 7.4 horsepower. The increase in horsepower per $1,000 of products during the same period was in about the same ratio; namely, from six tenths of a horsepower in 1870 to 2 horsepower in 1900.

In the manufacture of cotton goods the amount of horsepower per wage earner has increased in thirty years from 1.1 to 2.7, while during the same time the amount of horsepower per $1,000 of products has increased from eight tenths to 2.4 horsepower.

There is a striking evidence of continuous progression in the manufacturing industries in the fact that, during the decade from 1870 to 1880, in only 3 states was there any decrease. From 1880 to 1890, in only one instance was there any decrease in the amount of power used, and that was so small as to be of no significance. During the decade ending with the census year 1900, the only decrease in the amount of power used in manufactures was in the District of Columbia, which is without any particular significance from an industrial standpoint, as the District of Columbia does not rank as one of the prominent manufacturing centers of the country.

The largest increase in power in the past decade was in the state of Pennsylvania, which in 1890 reported 986,789 horsepower, and in 1900 a total of 1,859,265 horsepower, showing an increase in the ten years of 872,476 horsepower, or 88.42 per cent. This increase is more than twice as large as the gain in the next largest state—Ohio—which showed an increase during the decade of 431,817 horsepower.

The very large increase in horsepower in Pennsylvania was due to the great development of the iron and steel industry between 1890 and 1900, which more than doubled its motive power during that period, the increase being from 404,871 to 840,616, showing a gain of 435,745. This industry thus accounts for one half of the total increase in power reported for Pennsylvania. Other industries which contributed largely to the increase were the lumber and woodworking industries, which showed an increase of 27,516 horsepower; the paper and pulp industry, which showed a gain of 19,537 horsepower; and the silk industry, showing an increase of 19,270 horsepower. A large number of minor industries, all of them showing a considerable increase, make up the remainder of the very large gain which Pennsylvania shows.

In Ohio, also, the iron and steel industry accounts for more than one half of the increase in power during the last decade. Out of a total increase of 431,817 horsepower, the iron and steel industry represents 225,677 horsepower. The lumber and woodworking industries show an increase of 23,952 horsepower, and the flouring and grist mill industry gained 13,526 horsepower in the ten years. The large expansion of the industries using iron and steel is shown by the increase in the amount of power used by the foundries and machine shops of Ohio, which in 1900 reported a total of 53,928 horsepower, as compared with 23,292 horsepower in 1890, an increase of 30,636

New York shows an increase of 404,549 horsepower from 1890 to 1900. The largest item of this increase is represented by the paper and pulp industry, in which there has been a very striking development during the past ten years, based upon large areas of pulp wood and an abundance of water power, which has been utilized to a very large extent. In 1890 the manufacture of paper and wood pulp in the state of New York employed 75,870 horsepower, while for this industry there was reported in 1900 a total of 228,478 horsepower, showing an increase of 152,608 horsepower, or more than one third of the total increase in the state. The lumber and wood working industries show an increase of 23,453 horsepower, and the chemical industries an increase of 22,219 horsepower. The remainder of the increase is made up by a large number of small industries.

Illinois shows an increase in the amount of power used in manufactures amounting to 328,989 from 1890 to 1900. The largest items in this increase are a gain of 81,565 horsepower in the iron and steel industry, and 19,265 horsepower in foundries and machine shops.

Massachusetts shows an increase of 306,207 horsepower in the ten years, the larger portion of which represents the growth of a few of the leading industries. The manufacture of cotton goods contributed the largest increase during the decade, viz., from 171,924 horsepower in 1890 to 281,032 horsepower in 1900, a gain of 109,108 horsepower. Next to this was the paper and pulp industry, which increased its power requirements of 44,836 in 1890 to 82,893 horsepower in 1900, a gain of 38,057 horsepower. While the woolen industry of Massachusetts shows an increase of only 1,674 horsepower in 1900, as compared with 1890, the worsted industry shows an increase from 16,835 to 38,611, a gain of 21,776 horsepower. The remainder of the increase in Massachusetts is distributed over a large number of industries, all of which have contributed their quota to the large gain in the aggregate of motive power used by the manufacturing establishments of the state.

A striking illustration of the influence of a single industry is shown in the large increase in the amount of power used in the state of Louisiana, which in 1890 amounted to 30,184 horsepower, while in 1900 a total of 217,125 horsepower was reported. Examination of the detailed statistics by industries shows that the sugar refining industry in Louisiana, for which in 1890 was reported a total of only 3,578 horsepower, returned in 1900 a total of 120,277 horsepower, a gain of 116,699 horsepower in a single industry.

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THE UTILIZATION OF NIAGARA POWER.

BY H. W. BUCK.

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The utilization of the power of Niagara falls has for years been the dream of engineers and of all those interested in the industrial development of that section of the country. In the past, many schemes for the purpose have been suggested by inventors and others, but never, until the advent of the modern era in electrical engineering, has the proposition, on a large scale, been able to stand upon a basis attractive to the capitalist. It may, therefore, almost be claimed that the problem of utilizing the power of Niagara has been solved technically by the profession of electrical engineering.

The difficulty in the past has not been to apply the water to the turning of a water wheel, for many of the schemes suggested would have accomplished this successfully, but what to do with the power when developed at the water wheel shaft was the problem before the engineer. Obviously, here the question of transmission arose as of prime importance.

Among the numerous early plans will be found extensive systems of pneumatic tubes operated by turbine driven air compressors, the pipes leading to factories located in the vicinity of a power house. Each factory was to have its own air motor thus operated. It may be of interest to note that one of these plans contemplated the transmission of power to Buffalo by this means.

Another plan consisted in lines of countershafting bracketed on columns extending radially from a central power station, this long shafting to be driven by the water wheels through a system of gearing. Factories were to be located along these lines of shafting and were to receive their power supply by clutches connected to these shafts.

Still another plan involved the construction of a network of surface canals fed from a common intake from the Niagara river. Factories were to locate along these canals and take water from them for the operation of individual turbines, the water to be discharged into branch tunnels connected to a main trunk tunnel leading to the lower river.

These plans now look grotesque, but at that time, 20 years ago or so, they were seriously considered by good engineers. They were discarded largely for financial reasons, the plans showing low efficiency and high cost of construction and maintenance.

We are all familiar with the final solution of the problem, and the power house of the Niagara Falls Power company need not be described in detail. The electrical solution seems almost ideal as a means of distributing the power. A dynamo has no links, gears or valves to wear out. It revolves day in and day out, with almost no attention, and its efficiency is so high that 98 per cent of the energy of the turbine shaft is delivered at the terminals of the dynamo. From the electric generator the current is carried over wires and cables which afford almost the limit of simplicity as a means of transmitting power to the user.

Many who come for the first time to the Niagara power house are surprised to find the plant located so far from the falls. They have always associated the use of Niagara's power with the falls themselves, and it is difficult for them to understand that the power is derived from the difference in level between the upper and the lower river, of which the falls are merely a result.

The person who originated the conundrum about not being able to dam Niagara knew very little about hydraulic conditions there. The falls are the direct result of an enormous dam which extends from Buffalo to the brink of the falls for its thickness, and for its length it has the length of the entire Niagara escarpment itself, the spillway being the Niagara river. If it were not for this dam the waters of Lake Erie would be discharged abruptly into Lake Ontario.

The ultimate hydraulic conditions at Niagara, therefore, are so different from those of other water power plants, except in the matter of size and from the fact that the dam has been built by nature and not by man.

From the electrical distribution of Niagara power has resulted a radical and essential advantage which was not fully recognized at the time of its first adoption. As its uses have developed, it has been found that not only was power wanted for industrial purposes, but primarily electric power. This is especially true in the case of the electrochemical and electric lighting applications. If pneumatic, hydraulic or mechanical shaft power had been supplied for use it would have been necessary for all the electrochemical plants to convert this power into electric current before they could use it, with all the loss in power which would result from this conversion. So also with the electric lighting and electric railway applications, where power is wanted in the form of electric current.

The first power house of the Niagara Falls Power company has a capacity of 50,000 horsepower, made up of 10 generating units of 5,000 horsepower each. The second plant of this same company, which is located on the opposite side of the inlet canal, has just been completed, and its capacity is 55,000 horsepower from 11 generators of 5,000 horsepower each.

The general features of this plant are the same as those of the older power house, the difference being in a few details. The turbines are operated with draft tubes which increase the effective head of water and consequently the power for a given amount of water. The water is drawn from the old canal, led through penstocks to the turbines and discharged through them into a branch tunnel. This connects with the main tunnel at a point near the end of wheel pit No. 1.

Electrically, the arrangements of power house No. 2 differ materially from those of the old plant. There are two types of dynamos. The first six are very similar to the ten machines in plant No. 1, but the last five are entirely different in construction; in them the field revolves inside of the stationary outside armature.

In the new plant the generators are all wound for the same voltage, phase and frequency as in the old plant machines, so as to permit of interchangeable operation on the system.

The switchboard arrangements are different and in accordance with the most approved modern methods of construction.

In addition to power house No. 2, the Niagara Falls Power company is developing, through its allied company, the Canadian Niagara Power company, 110,000 horsepower on the Canadian side of the falls. The hydraulic features of this development are very similar to those on the American side, which have proved so successful in operation. A wheel pit has been excavated in Victoria park at a place about 1,700 feet above the Horse Shoe falls. Into this pit the water is discharged from a short intake canal and forebay, and carried off through a tunnel to the lower river.

The essential difference involved in this plant is in the size of the generating unit. The installation will consist of eleven units of 10,000 horsepower each. When the power development was first started on the American side, a unit of 5,000 horsepower was selected as being a convenient subdivision of the total power development then contemplated, viz., 100,000 horsepower. Now that more than 200,000 horsepower is to be developed, a 10,000 horsepower unit can be installed and its relation to the capacity of the whole system will remain the same. Furthermore, great economy in cost of construction results in the use of this larger unit. A 10,000 horsepower turbine and dynamo occupy only slightly more space than one of 5,000 horsepower capacity. This effects a considerable saving in length of power house, forebay, wheel pit, etc., for a given plant outfit. Also the cost of one 10,000 horsepower turbine and dynamo is less than the cost of two 5,000 horsepower units. The advance in the art of turbine and dynamo manufacture in the last ten years has been such that the construction of 10,000 horsepower machines now is not as difficult a problem as was that of the 5,000 horsepower size when the first American power house was built.

The electric generators in the Canadian plant are wound for 11,000 volts, three phase. This voltage, which is five times as high as that of the American plant dynamos, was selected for reasons of economy in power distribution. This is about the highest voltage which is considered safe for underground distribution, and all the power will be taken out from the Canadian plant underground, necessarily, on account of the power house being in the park.

For very long distance transmission, transformation will take place to a much higher voltage in a transformer station located on the plateau above the park. Transformation will be made to 22,000, 40,000, or 60,000 volts, depending upon the transmission distance.

The Canadian plant will be electrically interconnected with both of the American power houses by cables across the upper steel bridge arch, so that three large independent generating stations will be available for the supply of power to the system of the Niagara Falls Power company. This is a matter of the greatest importance to the Niagara frontier. In case of some unforeseen accident to any one of the plants, interconnections could at once be established so that the most important users of power, supplied normally by the disabled plant, could be supplied with power without interruption. This is especially important where the public utilities are involved, such as the electric railways and electric lighting companies.

One naturally asks where this 215,000 horsepower is going to be used. The same question was asked in regard to the 50,000 horsepower for which the first power house was constructed. The latter has been quickly answered by the fact that the load this winter exceeded 75,000 horsepower. At the present rate of increase it will not be many years before the capacity of all three plants is reached.

The use of machine tools and mechanical processes in factories nowadays consumes a large amount of power, and the cost of power has therefore become a very important item to the manufacturer. It has made him investigate carefully the question of power cost, and the saving in this account which results from the use of power from the Niagara system as compared with that from an isolated plant. The central locality in the country of the Niagara frontier is also attracting attention in the industrial world, and I should not be surprised to see, during the next ten years, a great influx of all classes of manufacturing concerns, attracted to this locality by the advantages named. Electrochemistry is only just beginning to open up as an enormous user of electric power, and it is likely that many processes will be invented which will require the cheap power of Niagara to render them commercially operative.

All such industrial development means more homes and more people, which in turn require more electric lighting and more street railway traffic, which again increase the use of power. An enormous field for the use of Niagara power, which is only just beginning to open up, is the electric operation of the passenger and freight traffic on the great steam railroad trunk lines. In my opinion this is sure to come in the near future.

If you will draw a circle around Niagara falls as a center, with a radius equal to about 100 miles, which might be considered as a fair limit of economical transmission under present electrical conditions, and assume all the trains in this circle to be operated by Niagara power at approximately 500 to 1,000 horsepower per train, you will see the possibilities in this direction for the consumption of power from the falls.

In spite of the possibilities for long distance transmission use, I believe, nevertheless, that the bulk of Niagara power will always be used within a radius of a few miles of the falls. It is cheap power that the manufacturers want, especially those of electrochemical products, and the nearer they get to the falls the cheaper will be the power.

Transmission of power for long distances is expensive at best. Take the case, for instance, of the Niagara-Buffalo transmission. The current, after it leaves the generators, is transformed to 22,000 volts by expensive step-up transformers, which not only waste some of the power, but must be operated and maintained, and interest must be paid upon their cost. From here the current traverses the transmission line over a private right of way. This also must be operated and maintained, and interest must be paid upon a large investment in line as well as for right of way. Furthermore, power is lost in the transmission. After reaching the city line of Buffalo, the current is again transformed for distribution throughout the city. This distribution is accomplished by means of an extensive system of underground cables. All this apparatus must have fixed interest charges paid upon it and it requires a large force of experienced men for its operation. When, therefore, the statement is made that not over ten per cent is lost in transmitting power from Niagara to Buffalo, it does not mean that power will cost only 10 per cent more in Buffalo than at the falls; for the difference will be much greater than this.

However, even with this transmission cost added, Niagara power is delivered in Buffalo to-day to customers more cheaply than they can produce it themselves by isolated plants. The saving in cost is not the only advantage. The elimination of the steam boiler and engine outfit in a factory by the use of Niagara power is a luxury and a convenience which has many incidental commercial advantages.

When the Niagara enterprise was first started there was a great deal of talk about operating all the factories in New York state by Niagara power. Such a possibility, under the present state of electrical science, is theoretical only; for electric power, transmitted to such distances by present methods, could not possibly compete with steam. In theory, Niagara power can be sent to San Francisco in any amount, but its cost, when it got there, would be prohibitive.

Another argument against transmitting Niagara power to a long distance from the falls, is that it is not commercially necessary to do so. There will be probably a sufficient market for power within a fifty mile radius of the power house to use up all the power which has thus far been developed, and it is likely to continue so. It is cheaper for the factories to locate near the falls than to carry the power a long way to the factories.

One exception to this general tendency against the transmission of Niagara power to long distances is in the case of the steam railroads mentioned above. If they change over to the use of electric power, it is likely that they will use Niagara power within a circle of wide radius about the falls, possibly 100 to 150 miles. In their case the conditions are peculiarly favorable for long distance transmission. They will use power on a large scale, and will have their own private rights of way, without extra cost for the installation of their overhead circuits. Furthermore, they will have to compete electrically only with steam power as developed in the locomotive, which, as is well known, is a very expensive method of utilizing the energy of coal, as compared with a stationary engine.

At present the power distributed by the Niagara Falls Power company might be divided into three classes.

First. The local service to electrochemical and other industries within the city limits of Niagara Falls. This at present aggregates about 45,000 horsepower, divided among thirty industries. The largest users are the electrochemical plants, which require current either for electrolysis or for the production of the very high temperatures obtainable in the electric furnace by which the reactions in their processes are brought about.

Second. The Canadian service across the upper steel arch bridge to industries and electric railroads in Canada, reaching as far as St. Catharines. This use is small at present, but it is the beginning of an industrial growth on the Canadian side of the river, which, in my opinion, will be very extensive in a few years. It now amounts to about 2,000 horsepower.

Third. Long distance service to Buffalo, Tonawanda, Lockport, and Olcott, which now amounts to a total of about 30,000 horsepower. In Buffalo approximately 24,000 horsepower is used, divided among a very large number of customers, making use of the power for all kinds of purposes. This includes the power for operating the Buffalo street cars and the electric lights in the city.

In Tonawanda, about 4,000 horsepower is used for railway lighting and miscellaneous power purposes.

In Lockport the use amounts to about 1,500 horsepower for railway and miscellaneous purposes. Five hundred horsepower is used at Olcott for operating one of the substations of the International Railway company. This station is 39 miles from the falls, which is perhaps the longest distance to which power is transmitted at this writing. All the freight on the International railroad between Olcott and Tonawanda is handled by Niagara power by means of electric locomotives.

It is hoped that this brief outline will give an idea of the present status of the Niagara Falls Power company system. It represents, however, merely the beginning. In this country great cities have grown up in localities for reasons far less important commercially than the conditions which exist on the Niagara frontier to-day. It is the center of population of the continent, approximately a focus of all the great trunk line railroads, and unlimited cheap power for manufacturing is available. It is also the eastern terminus of the great lakes commerce. This latter, if the Niagara river is deepened, will be extended almost to the brink of the falls themselves, affording twenty miles of sheltered dock front.

The day will come when we shall see a steamless city reaching unbroken from Buffalo to the falls, the industrial triumph of Niagara's power.

COMPRESSED AIR AND ITS APPLICATION IN MECHANICAL LINES.

BY W. O. DUNTLEY.

[W. O. Duntley, vice-president and general manager of the Chicago Pneumatic Tool company; born Wyandotte, Mich., July 21, 1867; educated in the public schools of Detroit; began his business career in an electrical supply house in that city and in 1887 removed to Chicago and became connected with Baggot & Co.; joined the Pneumatic Tool company in 1895, becoming vice-president in 1899 and adding the duties of general manager in 1902.]

The power of the winds, and a very uncertain power at that, has, it is true, from the earliest times lent man some aid in the lifting of water and the locomotion of his ships, but it has served him in its own whimsical fashion, compelling him to await its pleasure; in other words, to adapt himself and his work to the natural conditions. Much the same may be said of water power which is, if anything, less amenable to direction than the winds, and which has only within the last two decades been really harnessed to the chariot of progress. For many years we have been dependent upon a combination of heat and water for our great power, which in that time we have learned to control remarkably well, but which we have not yet been able to utilize at anything but ruinous expense. Experimenters are day and night working upon ideas or plans to make available a greater percentage of the heat units in a pound of coal. Through all the stages from the open exhaust steam engine, the condensing compound, triple, quadruple, even to quintuple expansion engines has the race been run until now the latest is the turbine whose only merit thus far seems to be high speed without vibration. But is it economical to run? Already in the closing years of the nineteenth century steam had its rivals; gas, electricity and air. These did not materially affect its popularity at first as an original power; for gas was too little known and except in isolated cases, electricity and air were dependent upon steam for their generation as compression, yet the tread of the movement was surely toward a displacing of steam as a motive power and the installation of a cheaper substitute.

All sorts of chemical reagents have been pressed into service to oust steam from its supremacy without avail, yet there is no doubt, but, with a highly developed gas engine together with the more modern application of the almost inexhaustible water power running to waste throughout the world, for the generation of electricity or the compression of air, steam will have two opponents in the race which will make it a poor third. Though, if expensive, steam has been and still is a most useful servant. It runs our mills, draws our trains, propels our ships, hoists our heavy weights, and, through the medium of shafting, pulleys and belts or chains, drives an endless variety of machines for drilling, boring, turning and burnishing metals, operates pile drivers, punches for perforating enormous steel plates, huge hammers, shears, rollers and carriers in foundries, forges and steel rolling plants. All this it does well and probably will continue to for some time to come; but there is a lack of flexibility about it all. Every operation is fixed, rooted to the spot, and because of the ponderous tools in use and their manner of obtaining their power everything must be brought to the tool. With the exception of some undersized steam engines and pumps, steam can scarcely be said to be applicable to small tools. These, it is true, may be moved from place to place, and by the use of rubber steam hose the same may be done with rock drills, well and prospecting boring apparatus; but the intense heat which is the life of these tools makes them disagreeable neighbors and very inconvenient to handle. This seemingly greatest inconvenience was thought to have been overcome when, with the development of electrical devices conduction and power, small electric motors were placed about in the shops for intermittent use, yet because of the initial weakness of this agent which required high gearing to make it effective the motors became very cumbersome as soon as much of an output was demanded. They, too, were fixed and the only flexibility about the installation was the possibility of bringing the power to them through insulated wires. This, too, called for a rubber hose, though of such small diameter that it received the name of insulator instead, and still the proper flexibility in the power plant was wanting. The work must still be brought to the tool. Thus far the shop or mill owner had profited only in the saving in cost of his transmission.

All the small work such as boring, drilling, chipping, cutting, calking, riveting, upsetting and 101 other operations were still dependent upon the muscular arm of the mechanic whose slow and measured stroke consumed valuable time. True flexibility is only reached when the tool may be brought to the work as the hammer, chisel, brace, screw driver, plane, etc. Just here the third entry in the great race for supremacy made its appearance. Coming upon the scene scarce a decade ago, with rapid bounds it reached the home stretch and is now running under the wire several lengths ahead.

This competitor for utility and popularity is air—compressed air—and it enters into the struggle well adapted in every particular for the sharp contest. If its expansibility be not so great as steam, it is for that reason a much safer agent to confine, and its compression may be run up far beyond the safety line of steam. An explosion of a vessel containing compressed air, even up in the hundreds of pounds to the square inch, is rarely attended with serious consequences to bystanders or operatives. Unless carried to excessive pressures it is not inconveniently warm to handle, a circumstance which militates greatly against the use of steam; moreover, it even becomes cooler while doing its work, and is for this reason used for ventilation in mines and closed caissons. For the uninitiated it is absolutely impossible to conceive of the revolution in all lines of trade and manufacture that these pneumatic tools have caused. At first the use was confined to larger operations and we had such tools as pneumatic rock drills, both rotary and percussive, channellers, gadders, etc., for ordinary excavating and quarry work, for which rough work large and unwieldy tools were made. Later these tools were made in smaller sizes adapted to the use of one man for coal mines and the mining of mineral ores, and these tools have continually decreased in size until now they are made almost as diminutive as a watchmaker's hammer. Steam engines of most approved types, common water wheels, Pelton wheels, or the more modern turbines furnish the power for compressing the air. Air compressors or pumps are constructed to be driven from belting, with gears or combined direct with a reciprocating steam engine. The initial power being settled upon, it only remains to lay the mains about the plant, provided at convenient distances with valves, to which, by means of rubber hose, the individual tools may be connected.

This gives a flexibility to the plant hitherto unknown, for the mains once laid and convenient openings provided any desired tool may be brought to bear at any part of the shop, yard, building, bridge or roadbed. Think of the variety of work done in a shipyard, most of which was until recently done by hand. There are so many operations going on simultaneously that it is difficult to find a starting point. Pneumatic punches of all sizes are now portable, adapted to be hung from cranes or bars or supported in any way at any angle, and may be used either in the shed, in the open, outside or inside the ship's hull, wherever, in fact, the ponderous plates may be or the holes needed. Similarly, pneumatic riveters are portable, and, with a velocity scarcely conceivable, they either press in a glowing rivet by sheer force or through a series of rapid percussions set it much better than by hand and quicker than the old fashioned hydraulic press used tools. Visit the boiler shop and view with amazement how easily the pneumatic tools clip off the huge rivet heads, upset stay bolts, calk seams, chip out a manhole or cut a strip from the edge of a nine foot plate in one piece without breaking it, as easily as the ordinary planer would do without all the necessary adjustment. Witness, if you please, the cutting of the hundreds of side lights in the ship's side with pneumatic tools and then if possible find a yard which still adheres to the hand ratchet drill and "old man" chipping out with the chisel and hammer so common only a year or so ago, if you wish to realize how compressed air and the tools which it actuates have revolutionized this one industry. For smaller work than boiler making or ship building, the pneumatic tool is also in evidence; take the construction of a modern steel sky scraper, or descending to the less elevated but eventually more useful structure, the rapid transit subway tunnel, and your ears will be struck with the rumbling noise of the hand pneumatic tools such as hammers and riveters, permanently uniting the various elements which go to make up such a structure.

The arduous work of removing rust from plates or columns, either by pickling in acids, scouring with stone or chipping away with hammer and chisel, is now better done, in one tenth of the time and with one fourth the labor with a pneumatic tool using a blast of sand. Boiler tubes are expanded with a pneumatic roller. The fins on large castings, such as fly wheels, columns, pulleys, statues, and what not, are chipped away with pneumatic tools. Not only in the ironworker's hands do these tools prove ready servants, stonemasons, architectural stonecarvers, granite facers find them the most serviceable tools ever invented. These tools have simply to be held up to the work while the oscillating or reciprocating piston within, which performs the function of the hammer set in motion by the compressed air, does the rest. Woodworkers make use of them for boring, turning, mortising and any class of work where the brace and bit or hammer and chisel have hitherto held undisputed sway. The painters' trade, too, has been invaded by the so-called air brush, which, as we understand it, is not a brush at all, at least, not made of bristles. With this pneumatic tool, freight cars, their running gear, dwellings, barns, outhouses (inside and out), chicken coops, poultry houses, long stretches of surface like fences, the street railway tunnel, the elevated structure, the viaduct at One Hundred and Fifteenth street, New York —any surface, in fact, to be coated with plain colors, may be covered.

There is scarcely a mechanical trade in which these tools are not now used for one or more processes. It would hardly be possible to give a complete list of the tools invented for and applied to this purpose—in fact, their number is legion and they are increasing every day.

One of the recent special applications of compressed air power is the invention of a railroad man, Mr. T. W. Younger, master mechanic of the Southern Pacific railway at Portland, Ore., known as the Redfield pneumatic saw. An outfit usually consists of a traction engine to which are attached two Westinghouse air pumps supplying the air to the pneumatic engines operating the same. The size and capacity of these engines are as follows:

Weight, including frame, 150 pounds.
Length of stroke, 30 inches.
Diameter of piston, 2½ inches.
Air pressure required, 75 pounds.
Capacity, 50,000 feet in logs per day.

The main feature in connection with light weight of engine is the valve, which, it is claimed, is of new design and is perfectly balanced under all conditions, thus permitting the engine to work in any position. The valve motion and running gear are very simple and easily repaired, therefore has no complication of valves and ports. The tubular valve is actuated by a rocker arm that receives its motion by two cams fastened to the guide rod.

The saw used is the ordinary Kelly five or six foot drag saw and test has proven that one of these saws will cut through a pine tree five feet in diameter in five minutes. A gang numbers seven men in place of 14, as required when hand methods are in vogue, and when the compressed air plant has been transported to the desired location the saws are connected up. One saw is generally used with two frames, thus permitting the removal of the engine and saw blade to the waiting frame immediately after the first cut has been completed. Two men using a saw with frame adapted for felling trees immediately start to work preparing material for the remainder of the gang to cut up to the desired dimensions. In cutting up the fallen logs two men generally operate one saw and an extra frame or frames, as may prove desirable. The frames are first placed in position on the log, then the cut is started in the first frame; moving the engine and blade to the second frame after completing the first cut and continuing in this manner, one man arranging the frames and the other simply controlling the pneumatic engine, while both assist in moving the engine and blade from frame to frame.

Where it is desirable to employ a number of these saws an air compressor transported by means of an ordinary drag attached to the engine is preferable, admitting of the operation of the compressor independent of the engine, and with a plant of this character a number of saws can be operated with very satisfactory results.

The distance from the base of air supply at which the saw can be operated is limited only by the amount of piping available and it is claimed that from 20 to 30 acres can be cleared with this device without moving the base of air supply.

Pneumatic hammers are extensively used for cutting hitches in mines for timbering up shafts.

Pneumatic hoists are used for transporting, loading and unloading lumber to and from ships.

Jam riveters are used quite extensively for cleaning crown sheets of locomotives.

One man in Australia writes that he has accomplished the same work with a portable pneumatic drill that heretofore it was considered could only be done with the radial drill.

One of the latest applications of air is for street sweeping. This is accomplished by two steel tanks on a wagon, the larger for water and smaller containing compressed air. When the driver moves a lever the nozzles beneath the wagon are opened and, driven by compressed air, the water rushes out on either side, sweeping all the dirt to the gutters. The force of water is regulated by the driver and the space cleaned is from 30 to 40 feet on each side. One supply of air is sufficient for several tanks of water. There is practically nothing to wear out, the first cost being much less than the revolving broom wagons, and the expense of compressing the air is comparatively small.

Coal boring by a portable pneumatic drill is being successfully accomplished. The only change necessary is the removal of feed screw and application of breastplate. One of our correspondents writes that he can drill a two inch hole six feet deep in three quarters of a minute.

A pneumatic motor is used by manufacturers of pool tables in operating a saw for sawing out pockets. One of these pockets can be finished in 30 seconds by the use of a motor, whereas it takes 12 minutes to accomplish the same work by hand.

There are many other applications of compressed air, but we believe we have cited a few that are not generally known.

In conclusion it must suffice to say that but for the pneumatic tools such stupendous public and private works as we are witnessing every day, viz.: the Chicago drainage canal, wheel pit extension for the Niagara Falls Power company, New York rapid transit subway, Panama canal and the mammoth hotels and office structures of steel rising all over the country, would perhaps never have been undertaken, and, hence, we may maintain that the changes in all mechanical trades are so great as to be termed revolutionary.

THE TURBINE ENGINE.

BY CHARLES C. FITZMORRIS.

[Charles C. Fitzmorris, journalist; was born May 1, 1884, at Fort Wayne, Ind.; educated at the public schools; became a member of the staff of the Chicago American in 1902; has been staff correspondent for that paper and is author of many articles for newspapers and magazines.]

Hero, an ancient Roman, living in the last generation but one before the beginning of the Christian era, placed a wheel without a rim in a stream of water and invented, B.C. 120, the first power producing machine—the water wheel. Almost seventeen hundred years later, in 1829, Branca, a Spaniard, substituted a jet of steam for the stream of water, drove the steam, at an angle, against depressions in the rim of the wheel and invented the turbine engine.

To-day, two thousand years after the invention of the water wheel, engineers, working with the same principle, using steam instead of water, as Branca did, have developed the turbine engine to a point where it produces as high as 8,000 horsepower. Yet, in its present stage, the turbine engine is so far from being a perfected piece of machinery that engineers style this the beginning of the age of the turbine engine.

George Westinghouse, in an interview, said of the turbine: "We need not call the turbine engine a new or an untried invention. Its period of usefulness is but beginning. We shall build up a great turbine industry in these United States. There are turbines in the United States in operation now that produce, combined, 60,000 horsepower, and there are 150,000 horsepower more contracted for at Pittsburg alone. The importance of the turbine, especially the marine turbine, cannot be overestimated. For passenger ships, freight ships, yachts, and for battle ships, not less than torpedo boats, the turbine is unquestionably the best engine. Its compactness recommends it for all classes of boats and its freedom from all vibration makes it the best for pleasure craft particularly."

The Westinghouse Air Brake company, at Wilmerding, Pa., put the first steam turbine in America of large size into operation, using it for their electrical power distribution.

The turbine engine, however, while rapidly forging towards the front rank of power producing machines is still more or less in the experimental stage, as will be explained hereafter. The steam engine, for all its complicated mechanism, is the most widely known of all the really useful power machines. The steam engine is a reciprocating engine, that is to say, the power produced by the steam is a backward and forward motion, transformed to a rotary motion by a crank attached to the piston at one end and a point between the center and circumference of a fly wheel at the other. There are many forms of steam engines, but all work on the same principle. Steam is admitted through a sliding valve to one end of the cylinder in which the piston head is set. The pressure of the steam forces the piston head along the cylinder towards the other end. When it has traveled about one third of the distance the hole through which the steam was admitted, called a port, is closed by the sliding valve, which is moved automatically. The expanding force of the steam drives the piston head to the end of the cylinder, and as it reaches there a port is opened and steam is again admitted, this time on the other side of the piston head. Simultaneously the valve uncovers a third port through which the steam already used escapes into the open air or is returned to the boiler to be used again. In compound engines this steam, which has not yet lost its expanding power, is admitted into a second, third, and occasionally a fourth cylinder before returning to the boiler. Five cylinder engines are not considered successful although used in several ocean going steamships. The power that is developed by the steam working against the piston head is transferred by the piston and a crank to a fly wheel, whence it is distributed by belts and pulleys or inter working gears to various machines.

In theory the steam engine is simple; in practice it is extremely complicated, and the wear upon the different working parts, of which there are a great number, makes it an expensive machine. In spite of efforts to perfect it the steam engine is wasteful, and it is only possible to obtain a fraction of the theoretical power in the coal by which the steam is made. Friction, radiation especially, and atmospheric conditions in general make it impossible to secure all the power of the coal. Yet there are more steam engines in the United States than any other form of power producing machinery. While inventors have directed their efforts to improve the reciprocating engine, many persons have tried to devise a rotary engine, but none have succeeded, unless the turbine may be called a rotary engine. The piston, in the rotary engine, is in the form of a wheel, flanged at both ends and with a central web. Steam is admitted through this piston wheel, which is revolved by the expansion of the steam before it passes out through the exhausts. Extreme friction or loss of steam or both have been the chief arguments against rotary engines, and the arguments are as good now as they ever were. But the development to its present stage of the turbine engine is directly traceable to the efforts of inventors to provide a rotary engine to supplant the reciprocating steam engine, and the turbine is by far the best result of these efforts.

There is much to be said for the turbine engine and a great deal that is not so favorable. The engine exists in many forms, but all of them follow the same principles. The first practical turbine was developed by De Laval, in 1883. The principal part of the turbine engine in its simpler form is a wheel, around the periphery of which are small buckets. Steam escapes from a nozzle against the buckets, whirling the wheel at terrific speed. The wheel, being imperfect as all wheels are, and heavier in some parts than in others, is mounted upon a long, slender shaft, which enables it to find its center of gravity quickly, and prevents bursting from centrifugal force.

One of the greatest objections to the turbine engine is the impossibility to control its speed with any degree of certainty. The steam escapes from the nozzles, with a velocity of something like 1,500 feet per second, against the turbine. This difficulty has been partly overcome by using several wheels fixed upon the same shaft with stationary wheels, upon which are cups or depressions curved in the opposite direction, fixed between the movable wheels. This has had the effect of reducing the speed so that, through gearing and helical spur gears, the speed may be made as low as fifty revolutions a minute. A more highly developed form of turbine is after the plan of the reciprocating engine in the use of the steam, several wheels being fixed upon a shaft and each using the steam, one after the other, until its force has been exhausted.

The advantages of the turbine engine over the reciprocating engine are manifold. Its construction is much simpler and cheaper. The steam is applied to the turbine directly, without the use of mechanism that involves friction, lost motion, or expense through wear. It has no dead center and will start from a position. All parts are rotating, permitting the highest speed. The condensing of steam in the engine does it no harm as in reciprocating engines. It is cheaper to buy than the steam engine of the other type, and much cheaper to maintain.

There are as many forms of turbine as there are forms of the reciprocating engine, but, as with the latter, all work on the same principle, and few have any advantage that the others have not. They are becoming more widely introduced every year and already are installed in several ocean liners, where they are declared to have given entire satisfaction.

The phenomenon of cavitation is one of the discoveries, and perhaps the most interesting, that has resulted from the installation of turbine engines into steamboats. The discovery places a practical limit upon the speed of propellers on ocean going steamers. The Parsons turbine on the Turbinia developed such a speed that instead of exerting a pushing influence upon the water it tended to create a vacuum after a certain number of revolutions per minute had been made. With this style of turbine, however, the Turbinia succeeded in making a mile in 104 seconds in April, 1897, after a trial trip in which the mile was finished in 110 seconds.

A type of turbine engine that has for its motive power water instead of steam, has been used with great success in many parts of the country where the water supply furnishes power for such machinery. In the vicinity of Niagara falls and along the river above the falls hundreds of factories receive their power from water turbines placed in the stream, or in canals dug for the purpose. A series of these water turbines has been installed at Niagara falls in such a position that they receive the impact of water after a fall of 136 feet. These turbines are all of 5,000 horsepower. Other forms of water turbines resemble closely the ancient water wheels. These wheels, formed similarly to the wheel in the steam turbine, are placed in streams or beneath falls to receive the impact of the water and develop an extraordinary number of horsepower. A three foot wheel, receiving water from one nozzle, which delivered a half inch stream under a water head of 2,100 feet, developed 100 horsepower.

There are tidal and wave engines that depend for their power upon the movements of the tides and the waves, but these, besides being capable of operation only at intervals, are expensive, complicated, and easily damaged, and, exposed as they are to the elements, are constantly in need of repairs.

The mostly widely known engine after the steam engine, and probably better known than the turbine, is the gas engine, which works much after the manner of the reciprocating steam engine. Its power is furnished by the explosion of a mixture of gas and air in the cylinder. The gas, manufactured previously, or formed from gasoline, or some other substance in the cylinder, is admitted together with a quantity of air. The mixture is exploded by an electric spark and force is developed that drives the piston rod forward. A fly wheel controls the speed to a certain extent and keeps it steady. The common form of gas engine receives an impact against the piston head but once during each complete strike. Other forms of engines, however, receive the impact every other stroke of the cylinder, while in a new form, the double acting gas engine, the gas is admitted at the center of the cylinder, making it double acting—on the same principle as the steam engine after which it is patterned.

The gas engine is being built larger every year, chiefly because of the fact that gas is a much cheaper source of power than coal. New forms of gas have been invented recently and this has added to the economy of the gas engine. An Allis-Chalmers gas engine of 2,000 horsepower was exhibited at the St. Louis world's fair, while another, of German make, on exhibition near by, was guaranteed to develop 1,750 horsepower.

Compressed air engines, working upon the same principle as the reciprocating steam engine, are extensively used and with considerable expense. The air which is first compressed is stored in steel tanks under as high as 2,000 pounds pressure to the square inch, and cooled before being passed through the cylinders, where heat is used to add to its expansive powers.

Oil engines, using kerosene and other oils, ammonia, and even ether engines, have been successfully operated on a large scale, but, while the principle in all of them is intrinsically the same as in the steam engine, their success has been far less.

One of the newest forms of power producing machinery is the sun motor. This is essentially an engine which is run by steam heated by the sun's rays, which are concentrated upon the boiler by an ingenious arrangement of a system of mirrors. The sun motor has become so successful that companies have been organized for the purpose of establishing it throughout sections of the country where there is plenty of sunshine. The most successful of the motors now in operation is located at Los Angeles, Cal. The engine consists of an immense reflecting surface composed of mirrors so arranged as to focus the rays of the sun upon a boiler in the center. The boiler holds a hundred gallons of water and has several cubic feet for steam. From cold water a pressure of 150 pounds is obtained in an hour. The entire apparatus is on a turntable that keeps it facing the sun all day. This size of motor has an average capacity of about fifteen horsepower.

The sun motor, however, has its limitations already fixed. Of all the modern power machinery the one that engineers confidently expect to see outstrip all the others in the race for supremacy is the steam turbine, as yet in its early, if not to say experimental, stages.

THE COPYING OF AMERICAN MACHINES.

BY JOSEPH HORNER.

[Joseph Horner, the British economist, is a well known manufacturer and writer on manufacturing; he has contributed many articles to periodicals and is in demand as a lecturer on the economics of industry. Several of his articles have appeared in Cassier's Magazine, among them the following.]

When a really good thing is put on the market, some people imitate it; others try to go a point better. Some, wedded to ancient ways, do not, or will not, see much in it, until they find themselves and their interests hard hit by the innovation. These represent the various attitudes of British manufacturers towards American machinery.

It is well, in the interest of a nation's industries, and of the highest national and industrial life, that the burden of the human drudge shall be lessened to the last limits. At the present time, from that point of view, America occupies the foremost position. Ten years ago little of the automatic machinery which has been so highly developed in that country was known in Great Britain, outside of the small arms factories. Half a dozen years since it was finding its way into the cycle shops. Now it has found a welcome in many of our leading engineering establishments that were destitute of it five years ago.

The result is, that British machine tool makers are copying much of this machinery when it is not protected by existing patents. In some instances resemblances are so close that it would be difficult for any one not an expert to detect the difference between the original and the copy. In numerous cases, however, British firms have produced modified types, which, while possessing the essential elements embodied in the original machines, have details worked out differently. In some instances the copies are real improvements on the American originals; but these are exceptional.

American machinery has made its way in England in spite of the strongest prejudices. I know firms, who, having vented their antagonism in spiteful terms against American machinery, have afterwards labored with feverish haste to copy, and, if possible, to improve upon it, for sale in Great Britain. The number of firms who now manufacture machines which are modelled after those of successful American types is constantly increasing, and a considerable business is now being done with these in this country. These efforts, however, do not result from any love which was borne to American designs in the first place, but because of the pressure of their competition which is making itself felt here.

Neither is it in Great Britain alone that American machinery is being imitated. The Paris exposition was an eye opener in this respect. Many of the leading continental firms have adopted American designs, sometimes absolutely, in other cases in the matter of certain details only.

The two main reasons why these machines are imitated are either because they produce more cheaply than those which they displace, or they yield more accurate results. But a cheaper and a better product also often go hand in hand as a result of employing the best modern machines. The following are a few of the more notable examples of British imitation of American inventions.

To cut a long screw in a British lathe, a certain number of toothed or cog wheels have to be set up by the workman, —a different set also for every different class of screw. This change of wheels seldom occupies less than fifteen minutes, and may take half an hour. It is repeated many times a day in a large shop. A few years ago an American devised a permanent arrangement of wheels by which the changes for different screws could be effected within a minute by the simple movement of a handle. This excellent device is now copied on several lathes, both British and continental.

Machines for making small screws in large quantities in place of producing them singly by the older and inaccurate processes, were invented and highly developed in America before British firms took them up. The Cleveland, the Hartford, the Brown & Sharpe, the Spencer, the Acme, are

American machines, nearly as well known now in Great Britain as in the United States. The marvelous economies of these are scarcely conceivable by those who have not witnessed their rapidity of operation; and though designed primarily for making screws, any other class of small work involving turning, screwing, boring, and so forth, is done upon them cheaper than in any other way.

A leading American firm was producing brass collar studs on a screw machine at the Paris exposition. These studs were being turned off at the rate of two and a half a minute, or 1,500 in a day of ten hours. Each one involved the separate action of six tools, and included stamping the firm's name upon each stud, after which they were delivered by the machine, cleaned from chips and oil, for presentation as souvenirs to visitors. I was informed that machines of this class had been designed to run quicker than the earlier types in order to meet the demands of the German clock makers, who had bought several hundreds of them.

Yet 1,500 articles for a day's work is not by any means a big record with regard to number, because six tools have to come into operation. In cases where fewer tools are used, plenty of instances could be given of the product of such a machine ranging as high as 5,000 pieces in ten hours! On another type of American machine—the Acme—the day's work has run as high as 9,600, or nearly sixteen a minute! The makers of this last machine execute orders on curious terms. A customer sends brass rod to the factory to have screws made from it. He receives his screws, and leaves the brass chips only as payment!

American screw machines are stocked and sold by dozens of British agents in London, Birmingham, Manchester, Glasgow, and other big cities. Many hundreds of them are found in British shops. They are being imitated by our manufacturers and in nearly every continental country, copied, in some cases, very closely; in others, with variations. But the American machine still holds its place by very long odds. In turret machines several tools are caused to operate in rapid succession on a piece of work by the turret, or capstan—a device which is applied to turning lathes and to screw making machines. In place of the single tool used in a common lathe, six, eight, ten, and in a few instances as many as twenty tools are taken in charge by a revolving turret which brings them round, each to fulfill its own proper function at the exact instant when it is required to come into action. Each tool fulfills its own distinct duty, and the result is, that when the turret has revolved once, a single article of manufacture will have had the half dozen, dozen, or more separate cutting operations performed on it necessary for its completion. In some instances two separate pieces will be produced during a single rotation of the turret.

This device also originated in America previous to the middle of the last century, and that country reaped the solid advantages of its successful employment for many years before British firms saw much in it. When the manufacture was at last taken up in Great Britain, it remained in a crude form, while American firms still went on improving until they made the movement of the machine wholly automatic. Now many British firms are wisely following that example with beneficial results. But here also much leeway has to be made up.

Toothed or cog wheels are used in very large quantities in machinery. The common British practice has been to cast them roughly and inaccurately from patterns; the American, to cut the teeth cleanly and truly from solid iron, steel, or brass. In the exceptional British practice the machines designed for cutting teeth have, until very recent years, required the constant attendance of one man, and the majority made do so now. American machines, on the contrary, are so constructed that the attendant need not come near them from the time of putting in the wheel which has to be cut until all the teeth are finished. The machine rings a bell to let him know when the work is finished, and then it stops forthwith. I was in a shop where a machine of this kind was left to run all night, doing work without any attendance.

The bevel cogwheels that drive some of the chainless cycles afford a remarkable illustration of the highest specialization in this line of American manufacture. For cutting the teeth of these a special machine, which I have seen in operation, has been designed. Any number of wheels can be cut in it, all exactly alike, and absolutely correct, without any attendance, save that of putting the pieces in the machine and taking them out again. But these machines are built to cut one kind, and one size of wheel only, and no other.

Slowly, and but very slowly, are British firms awakening to the importance of good wheel teeth. Only a very few firms here as yet make high class machines for this work. They cannot imitate the latest and best American machines, for they are covered by patents. The automatic types, therefore, which are used in the best British shops to-day, still come chiefly from the United States. This case is paralleled by that of the gauges for measurement. The Americans have got a big headway, and have acquired so much and so rich experience that it seems nearly hopeless to try to oust them from their supremacy in this line. Certain continental firms also have developed the manufacture of gear cutting machines more highly than the British firms have done, and they, too, will have to be counted on in the years to come.

A milling machine is one in which rotary cutting tools are employed. Improved and developed in scores of forms, it is the most important machine tool, the lathe excepted, in the American shop. Its keen, strong, tireless cutters will tear off great, curling, stubborn chips of hard steel, or the finest films. Imagine a small circular saw increased in thickness to several inches, and you have the typical milling cutter which has supplanted the single cutting tool, It matters not how large or how small the work, whether a width of one inch, or one of twenty four inches, it is all the same, for machines are made to take it. Two years ago most British firms looked askance at this milling machine; it is even now distrusted in some of our shops. Even in many of those where it is appreciated and used, it is not employed to one half, indeed, one fourth, of the extent to which it might be with advantage. Thousands of these machines have come across from the United States, and hundreds, modelled on identical lines, are being made to-day and offered for sale by British tool makers.

Machines, too, for grinding tools, gauges, and the finest class of work to precise dimensions, were developed in America long before British firms took up their manufacture. The wonderful precision of these machines is such that it is easy to grind work on them definitely within a thousandth part of an inch, and less, to actual measurement. The spindles of many rotate at speeds ranging from 10,000 to 30,000 times in a minute. In some specially fine machines they will make 100,000 revolutions in a minute. And some of these highest American types are not yet copied here. When a British shop is advanced enough in its ideas to require such machines, the order goes to America.

It would be easy to speak of other classes of work in which America has led and Britain is toiling after. Mention only may be made of the application of electricity to the driving of machines; that of compressed air for actuating drills, hammers, cranes, and much besides; of certain types of hoisting machines which are quicker in action and more adaptable than our own; of machines for foundry work, for woodworking, for boot and shoe making, and much more.

In conclusion, the question arises whether the British imitation of American rivals will save the situation. Imitation is the sincerest form of flattery, and yet this may not prove to be an unmixed good. Possibly it may not be the most excellent way in the end.

British firms appear to believe that, by copying improved machines, they will always be able to retain or recover their menaced position. Those who do this—buying a machine, pulling it to pieces, and imitating it—forget that though it is easy enough to imitate, lost trade is not regained in that way. Imitators generally fail. Britain's supremacy was not won thus. She led the van. America is not gaining ground by following Great Britain, but by getting ahead of her.

Further, if a firm, having found its business damaged by the superior designs of a rival, endeavors to regain that business, it becomes the proverbial stern chase. The problem, then, is not that of making goods as well as one's rivals, they must be better, or cheaper, or both. And, again, the firm which is already in possession of a market holds the best position for its retention.

The firm or nation, therefore, which has a good start of its rivals will have the better chance to hold its own. This is the case now with the leading American makers of machine tools. They have secured a good market in Great Britain and abroad. In a dilatory way British manufacturers are waking up to the gravity of the situation, and are offering rival tools, of a class similar to those which find a ready sale here. But the necessity for producing something better still is generally neglected; and while they imitate existing machines, the American firms advance, constantly devising improved forms. While British firms are panting to recover lost ground, the Americans are still forging ahead, and scoring new triumphs year by year.

INVENTION AS A FACTOR OF AMERICAN NATIONAL WEALTH.

BY W. C. DODGE.

[W. C. Dodge, economist; has been a close student of the history of invention and of the effect of patents on industry and has investigated the subject more thoroughly perhaps than any other man in the United States. He has embodied the results of his investigations in several articles for magazines and reviews. The one presented herewith is published by special arrangement with Cassier's magazine.]

Much has been said and written of late in regard to the increase of America's foreign trade, and expansion has been urged mainly on the ground that it will furnish new markets and increase foreign trade. It is not the writer's object to discuss that question, but instead to show briefly what it is that has increased America's productive capacity, the part that the patent system of the country and its resulting inventions have had in that increase, and that in future dependence must, more than ever, be placed upon inventions for ability to compete for the trade of the world.

To do justice to this subject would require far more space than can be given here, for the history of inventions and the part they have played in the prosperity and growth of the United States would be to write the history of the country. Indeed, the history of invention is the history of civilization, for together they have marched down the ages, and will so continue to do while time lasts or man exists.

The writer knows of no better way to illustrate the beneficial effects of the patent system in the United States than by a brief review of the growth and prosperity of the country, and the part that patented inventions have had in that growth and prosperity. Going back but a little over a century, we find the United States consisting of the original thirteen states, with a population of less than 4,000,000 people, living in sparse settlements scattered along the Atlantic seaboard, the most western of which scarcely reached half way to the Mississippi river. Moreover, it must be borne in mind that this small number of settlers had the whole continent to subdue, the forests to clear, farms to open, houses, roads, bridges, schools, churches to build—in fact, everything to create from the ground up, with the savages to contest every foot of advance; and that they had neither the accumulated capital nor the surplus labor of the old world with which to accomplish this gigantic task.

Their condition was well described by Senator Thomas C. Platt at the United States patent centennial, when he said that "manufactures were practically unknown; that there were no mechanics, as we now understand the term; that men knew how to plow and sow, hoe and chop, reap, mow and cradle, break flax and hackle it, thresh with the flail, winnow with the blanket or fan, and to shell corn by hand. The women knew how to spin, card, weave, and knit. Mechanical knowledge was monopolized by the blacksmith, the carpenter, the millwright, and the village tinker. Production was a toilsome, weary task, limited by the capacity for muscular endurance."

It should also be remembered that such things as steamboats, railways, electric power and light, reapers, mowers, cultivators, threshing machines, and the thousand and one appliances which, of late years, have contributed so much to prosperity, were then unknown; and that when Fulton built his steamboat the engine had to be brought from England, there being no means for making it in the United States.

But that was not all, for, in order to get a clear idea of the conditions under which the United States began their existence as a nation, one must also consider the restrictions placed upon the colonists by the mother country. Her policy was well expressed by Sir William Pitt, who said:

"It is the destiny of America to feed Great Britain, and the destiny of Great Britain to clothe America."

In other words, America was to remain for all time an agricultural country, furnishing the people of Great Britain with food and the raw material for her manufacturers, while she was to do the manufacturing. Her policy as to manufactures in the colonies was well expressed by Lord Chatham, who said:—"I would not allow the colonists to make so much as a hobnail for themselves."

In accordance with this policy, Great Britain enacted laws prohibiting every species of manufactures in the colonies. Even a hat factory in Massachusetts was declared a nuisance, and its existence ordered abated. When the colonists began to make iron and nails for their own use, the house of commons resolved that "none in the plantations should manufacture iron wares of any kind out of any sows, pigs, or bars whatsoever," and the house of lords added that "no forge going by water, or other works, should be erected in any of the plantations for the making, working, or converting of any sows, pigs, or cast iron into bar or rod iron." A bill was also introduced in parliament which prohibited the erection of any mill for slitting or rolling iron, for the manufacture of spikes or nails, or any plating forge to work with a tilt hammer, or any furnace for making steel, and also proposed to abolish the few which had been built; and by the act of 1750 the further erection of all such was prohibited.

It was the same with the textile industries. Not only were the colonies prohibited from transporting any manufactured articles abroad, but also from one colony to another; and to still further cripple the growth of manufactures, an act of parliament forbade, under severe penalties, even to outlawry, the departure from Great Britain of any artificer in any of the various branches, and also the exportation from Great Britain of "any machine, engine, tool, press, paper, utensil, or implement, or any part thereof, which then was, or thereafter might be, used in the cotton, woollen, silk or manufacture, or any model or plan thereof," under a penalty of forfeiture, a fine of £200, and a year's imprisonment, and the like penalty for anyone "having, collecting, making, applying for, or causing to be made any such machinery;" and when, in 1684, the colony of Virginia passed an act to encourage the manufacture of textile fabrics, the act was annulled by parliament.

When coal was discovered and began to be used, an act of parliament prohibited any collier or miner from leaving the kingdom under similar penalties.

Nor was this policy confined to manufactures alone, for as early as 1622 the exportation of tobacco from Virginia was prohibited, unless first landed in Great Britain, and a duty paid there. These laws were enforced long after American independence. As late as 1830, Hugh Wagstaff was imprisoned for putting on board the American vessel Mount Vernon, for New York, twenty three boxes of spindles to establish a cotton factory in the United States, and the spindles were confiscated. And when the Hon. Tench Coxe, the coadjutor of Alexander Hamilton, entered into a bond with a party in London to send hither models of Arkwright's patented spinning frame, they were detected and confiscated.

As late as 1832 the model of a roller for printing calico, to be used at Lowell, was obtained only by concealing it in a lady's trunk; and, still later, when Messrs. Sharp and Roberts, of Manchester, England, who in 1841 patented their self acting spinning mule in the United States, sought to send the patterns to their partner, Bradford Durfee, at Fall River, Mass., they succeeded only by smuggling them through France. The laws prohibiting the emigration of artificers were not repealed until 1825, and that prohibiting the exportation of machinery, etc., not until 1845.

Under these conditions the colonists could do nothing but produce food and raw materials for the manufacturers of Great Britain, and even those had to be shipped in British vessels, of which the officers and three fourths of the crew must be British subjects.

During the American revolution manufactures were established to partially supply American needs; but as under the confederation, which was simply for mutual defence, congress had no power to regulate commerce or impose duties on imports, and as those colonies which were interested in commerce favored free trade, the country was soon flooded with cheap foreign goods to such an extent as to destroy what manufactures there were, and bankrupt the merchants who had stocks on hand. The country was drained of its money, and the condition became such that laws were passed suspending the collection of debts, and making cattle and other kinds of property a legal tender. Petitions were sent to congress asking it to issue fiat paper money and loan it to the people, and Pennsylvania actually did this.

It was this condition of affairs that finally resulted in the constitutional convention of 1787, which conferred on congress the powers under which the United States have since grown to their present estate. Among those powers the two most important, so far as national prosperity is concerned, are, the power to regulate commerce and impose duties on imports for the twofold purpose of raising revenue and protecting the then infant industries, and the power to promote the progress of science and useful arts by the grant of patents.

Under the exercise of those powers America has grown and prospered as no other nation on earth has. What that growth has been may be epitomized by saying that from that little beginning in 1790, the United States have grown until to-day they do one third of the world's manufacturing, one third of its mining, one fifth of its farming, and possess one fifth of its wealth.

Years ago, Gladstone, in his book entitled Kin Beyond the Sea, said: "America will probably become what we are now—the head servant in the great household of the world, because her service will be most and the ablest."

Already America has reached that point, for as Mulhall, the British statistician, recently said: "If we take a survey of mankind in ancient or modern times, as regards the physical and intellectual force of nations, we find nothing to compare with the United States. The physical and mechanical power which has enabled a community of woodcutters and farmers to become, in about 100 years, the greatest nation in the world, is the aggregate of the strong arms of men and women, aided by horsepower, machinery, and steam power, applied to the useful arts and sciences of everyday life."

When the writer was born there was not a mile of railway in the United States. To-day there are 186,000 miles in daily use, with a total of nearly 250,000 miles of track—as much as all the rest of the world. A locomotive running 30 miles an hour, 24 hours a day, without a single stop, would consume almost an entire year to traverse the whole extent. One of these roads alone carries more tonnage annually than all the merchant vessels of Great Britain; and, according to Mulhall, the amount of merchandise carried by the railways of the United States is double that of all other railways collectively. And, as has been said, "the railroad, from the steel rail to the top of its smokestack, from its headlight to the signal light on the platform of the last car, is but one aggregation of patented inventions."

The internal and coastwise commerce of the United States by water and rail amounts to more than the foreign commerce of Great Britain, France, Russia, and Belgium combined. Every year there are over 60,000 passages of vessels through the Detroit river, carrying over 40,000,000 tons of freight, and over 80,000 passengers, or nearly fifteen times as many as through the Suez canal.

The American people write 40 per cent of all the letters in the world, and the American postal service is the greatest in the world, the travel on all the routes being enough to reach 17,000 times around the globe each year; and there are more miles of telegraph and telephone wires than in all other countries.

The annual gain in wealth is about $2,000,000,000; and in one year the earnings amounted to $14,500,000,000, one half of which was paid to labor. Each working day adds $6,000,000 to the nation's wealth. The capital has been multiplied more than threefold since 1870, and at that rate there will be added in the next ten years as much as the entire capital was in 1870.

These facts are mentioned not by way of boasting, but as showing the marvelous growth of the country during its first century. Now what has done all this? What force, what power has been at work? In the words of Senator Platt, the writer answers, "it is the spirit of invention, the creative faculty in our people, that hath wrought these wonders." It is the result of American inventions fostered by the American patent system—the best in the world.

As illustrating the part that patented inventions have had in the growth and prosperity of the country, let me mention a few: Take the cotton gin, invented in 1793. When eight bales of cotton were first sent from Georgia to Liverpool, in 1784, they were seized by the customs officers, who did not believe it possible that so much cotton could be grown in America. At the present time the American cotton crop amounts to 11,000,000 bales. To remove the seed from that amount of cotton by hand would require the labor of 18,000,000 persons, working every week day for the entire year. And to card, spin, and weave it by hand would require more than the entire population of the country; and yet, by the aid of inventions, America manufactures annually about one fourth of the world's consumption.

Never was there a truer sentence written than that of the biographer of Whitney, the inventor of the cotton gin, when he said: "This inventor created both personal and national wealth." As Mr. Justice Johnson, of South Carolina, said, Whitney's invention had trebled the value of the lands in the south; and it was shown by statistics that the pecuniary benefit to the country during the first forty three years was $1,400,000,000, and since it has amounted to many times that. As was well said by Mr. Lanman, "Whitney's invention had given an impulse to the agriculture of the south which has remained unimpaired to this day, and which would endure while the cotton plant whitens the plantations with its snowy blossoms, or the machinery of the cotton mill continues its clatter at the waterfalls."

And though the south was slow to avail itself of the benefits to be derived from the manufacture of the cotton there, she has now taken hold of it with a will, for she already has 450 cotton mills, with about 5,000,000 spindles. And it is a singular fact that South Carolina, which, in 1828, threatened nullification because of the tariff designed to build up American manufactures, now ranks next to Massachusetts in the number of her cotton mills.

In 1870 Great Britain produced nearly 59 per cent of the world's supply of pig iron, and the United States but 15 per cent. Since 1870 Great Britain's product has increased but 29 per cent, while that of the United States has increased 460 per cent. To-day the United States is the ironmaster of the world, and that fact is mainly due to American inventions; for, as the superintendent of one of the large steel works recently stated, by the adoption of the latest inventions they were able to produce a ton of steel with one third of the manual labor that was required at another works built twenty years before.

In 1824 a member on the floor of congress contended that America could never compete with Europe in the production of iron, because of the cheaper European labor. Little he knew the power of invention, backed by American enterprise and energy; for, by its aid, America in a single year not only supplied her own needs, but sent pig iron, rails, locomotives, bridges, machinery, and tools of all kinds, not only to Europe, but to Asia and Africa, to the amount of over $105,000,000; and, while doing that, paid her operatives nearly double the wages paid in Europe. Only recently a vessel left Philadelphia for a European port, carrying a cargo worth nearly half a million dollars, in which were thirty locomotives and tenders, with other machinery and tools.

Again, take the tin plate industry. Up to 1890 America produced but one per cent of the tin plate that she used. In 1891 there were imported nearly thirty six million dollars' worth, but since then that industry has so grown that the import is reduced to less than $4,000,000, and that is mainly used for the shipment abroad of oil and other canned goods, and on which tin a drawback is allowed. Not only does America now supply herself, but the export of tin plate has commenced, and is growing.

While it is, no doubt, true, as claimed, that the establishment of the industry was due to the protection afforded by the tariff of 1890, its unexampled growth and prosperity are largely due to invention. It has been claimed that there have been more improvements in the manufacture of tin plate in the United States in eight years than there have been in Wales in two hundred years; and these improvements consist mainly in the use of labor saving machines and tools patented by American inventors.

A very remarkable fact in connection with this is that while the hours of labor have been reduced 25 per cent, the product per hand has increased 40 per cent, and the wages 48 per cent; or, if measured by the purchasing power of a dollar, 68 per cent. The world has never before witnessed such results anywhere.

Now what is it that enables an operative in three fourths of the time to produce nearly double what he did forty years ago? It is simply invention—the inventions embodied in improved machines, tools, and processes. Ten years ago the American import of manufactures was double the export; today the export is double the import.

That this wonderful increase in American manufactures is mainly due to inventions encouraged by the patent system, cannot be doubted by any one who will examine the subject. Commissioner Leggett, in his report for 1873, said that from three fourths to nine tenths of all American manufacturing is based on patents—that is to say, patented articles are manufactured, or patented machines and processes are used to manufacture articles that are not patented.

The Iron Age has said: "It should not be forgotten by those who sneer at inventors that out of the $8,000,000,000 invested in manufacturing in the United States, patents form the basis for the investment of about $6,000,000,000, or three fourths of the whole." And it adds: "The one thing that has enabled our manufactures to make so wonderful a progress has been our patent system."

But the benefits of the patent system have not, as many suppose, been confined to manufactures. The system has done as much for agriculture. The American corn crop amounts to over 2,000,000,000 bushels per annum. Were it not for corn planting and cultivating machinery what would the corn crop amount to, and, without the corn, where would be the pork and beef, either for use or export. Suppose we were to strike out of existence the dozen or more leading inventions used in the preparation of the soil, the seeding, harvesting, threshing, storing and transporting of the crop, what then? Not a bushel could be exported, because, by hand, it could not be produced; and even if produced, it would cost so much that it could not be delivered in Europe cheaply enough, and Europe would, therefore, not buy it.

In the words of Senator Vance, "American labor saving inventions form an epoch in the history of the race;" and, as another has said, "Americans use implements that cheapen the cost of production, and make the labor of harvesting seem like the sport of the fairies in the story book. As with manufacturing, so with farming, inventions have so reduced the cost of production that there is more propriety in saying that we manufacture wheat than in saying that we raise it."

Indeed, there is scarcely a thing done on a farm to-day in which patented machinery does not perform the greater part of the labor. The grain is sowed, cut, bound, threshed, cleaned, sacked, stored, and transported by machinery, the corn is planted, cultivated, and cut by machinery, while the mower cuts, the tedder spreads, the horserake gathers, the hayloader loads, and the carrier unloads the hay. The potatoes are planted and dug by patented machines or implements, and even the hogs are slaughtered and the chickens hatched by machinery.

In the household we have the sewing machine, the washing machine and wringer, the egg beater, the nutmeg grater, the meat grinder, the potato shredder, and countless other implements, all the result of the patent system. In fact, one cannot touch a thing in the factory, on the farm, in the office, or the household, that does not bear the impress of patented invention. Without the patent system these inventions would probably not have existed.

A European expert who recently visited the United States to study American industries, said that in Massachusetts, where the operatives in a shoe factory are paid $15 per week, the cost of labor on a pair of shoes was 40 cents, while in Germany, where the wages were but $3.80 per week, the cost was 60 cents, and that this was due to American inventions. Pages could be filled with similar testimony from competitors of the old world.

One of the best results of the extensive use of inventions is, that while nearly everything has been greatly cheapened, the purchasing power of a day's wages has been increased 72 per cent, and, as shown by a report of the United States labor bureau, the introduction of labor saving machinery, instead of displacing labor, has increased the number employed in a much greater ratio than the increase of population. Since

1865 the productive capacity of skilled laborers has been increased threefold, and that is mainly due to the adoption of labor saving machinery invented by Americans.

According to a recent statement of the commissioner of labor, by the use of labor saving machinery operated by 6,000,000 horsepower, less than four and one half millions of operatives produced in one year of manufactured articles an amount that would have required 36,000,000 operatives using the old hand methods. Thirty six million operatives represent a population of 180,000,000,—two and a half times as many people as there are in the United States.

Commenting on this, the commissioner says the statement seems fantastical, and is difficult to comprehend. The truth even smacks of fairy tales, or the statements of a statistical Munchausen, and yet it is based upon figures produced by the bureau of labor under authority of congress.

All great writers agree that invention is not only one of the noblest avocations, but that it is one of the greatest factors in the increase of national wealth. The founders of the United States government builded better than they knew when they placed in the constitution that little clause authorizing congress to promote the progress of science and the useful arts by the grant of patents, for then and there they laid the foundation for the material prosperity of the country. And while giving full credit to statesmen and soldier heroes, it may safely be asserted that no class of citizens has done more for the prosperity and glory of the United States than its inventors.

The patent office is the only self sustaining bureau the government has or ever had. Besides paying a large portion of the cost of the erection of the patent office building, it has defrayed its own expenses since the enactment of the law of 1836 which required it to be self sustaining, and to-day has a surplus in the United States treasury of over $5,000,000, every dollar of which has been paid by the inventors and those interested in patents, and who, in addition, have paid their full share of the expenses of the government the same as all other citizens.

AMERICAN STEAM ENGINEERING.

BY PHILIP DAWSON.

[Philip Dawson, engineer; born in Paris, and educated in continental schools graduating at Ghent and Liége; made an exhaustive study of traction work in the United States, Canada, and the continent during 1894-5; has been intimately connected with the carrying out of the following power stations and traction contracts: Bristol, Dublin, Cork, Liverpool, London limited, Central London, Glasgow, Liége, Rheims, etc. Author of many technical papers and published volumes. The following article is republished from the Engineering Magazine.]

American steam engine power house practice may properly be taken up from the point of the introduction of the Corliss valve. Probably the most important development in steam engineering since the days of James Watt was made by Joe Corliss in 1849, when he introduced his now so famous drop cut-off valve gear. The main features of this gear were the rapid and wide opening of the steam ports, the shortness and directness of these ports (which reduced the clearance to as little as 2½ per cent of volume in the high pressure and 4 per cent in the low pressure cylinder), the quickness of closure of the steam valves, and the adaptation of the main valve to the functions of a cut-off valve. This type is eminently a slow revolution engine—for small sizes, not above 250 kilowatts, reaching as many as 135 revolutions per minute, for 800 kilowatts as much as 100 revolutions, for sizes up to 1,000 kilowatts running as high as 90 revolutions, and for larger sizes not above 75 revolutions per minute.

In the early days of dynamo construction up till, we may say, ten years ago, generators were small, a machine of 500 kilowatts being considered enormous, whereas generators of as much as 5,000 kilowatts have been installed to run the Manhattan elevated railway at New York. The smaller dynamos of earlier days were all bipolar, running a very large number of revolutions, certainly above 200, per minute. Accidents to the electrical portions were frequent when it was customary, as it was in large installations, to drive two or more dynamos off one engine; and indeed in traction stations the use of a countershaft which enabled any steam engine to drive any set of dynamos was nearly universal.

As dynamo construction improved, engineers rapidly perceived the advantages to be gained by doing away with belts and ropes and by coupling the steam engine direct to the dynamo. America developed for this purpose a special type of high speed engine, the first successful type of which was the Porter-Allen engine and the peculiarity of which was what is known as the fly wheel type of governor. The first engines of this form were shown at the Philadelphia exhibition in 1876. In this form of governor, weights revolving round the shaft in a vertical plane automatically vary the travel of the valve and cut off by turning the eccentric round on the shaft. Then followed a host of inventors and of new types of engines such as the Armington & Sims, the Buckeye, the McIntosh & Seymour, the Ball, the Ide, the Westinghouse, and many others. With this type of engine, however, the steam economies obtained with the Corliss type of valve gear could not be rivalled. As dynamos grew in size and in economy and efficiency, and especially with the introduction of electric traction and power transmission, which necessitated dynamos running in many cases at an average load equal to 75 per cent of their rated capacity, the question of steam engine and consequent fuel economy became of the greatest importance. This necessity had been grasped much earlier by Germany than the United States, and in 1888 Corliss engines direct coupled to Siemens generators were already being run to light Berlin. The first use on any scale of such direct connected units was at the world's fair in Chicago, in 1893, where a 1,500 kilowatt generator was mounted directly on the shaft of a horizontal cross compound Allis engine running at 75 revolutions per minute. Then followed directly the plants installed under F. S. Pearson for the Brooklyn stations, and the replacing of the belted by direct driven sets on the West End street railway of Boston. Vertical engines, till within quite recent time, were far rarer in the United States than either in England or on the continent. It would seem in the light of recent experience that for properly designed engines, certainly for sizes of 1,000 kilowatts and over, vertical engines should always be employed. The wear on the cylinder is reduced, as also the quantity of oil required, and with an automatic oiling system and a well laid out station the supervision of such engines will not be greater than would be the case with horizontal ones. America now possesses a large number of stations in which vertical engines are running. No better example of such a station can probably be found than the 96th street station of the Metropolitan street railway of New York.

The boiler house of this station contains three tiers of boilers, and above them, two large coal pockets or bins, each having a capacity of 5,000 tons. From these the coal is led to the boiler furnaces by chutes. The boilers are fired by mechanical stokers of the Vickars type for the most part, but there are some box stokers and some boilers are hand fired. The boiler equipment consists of eighty seven Babcock & Wilcox boilers arranged, as mentioned above, in three tiers. These boilers have a heating surface of 2,665 square feet each; the drums 42 inches in diameter and 23 feet 4 inches long. The gases from the boilers are led to a large smokestack made of brick, and measuring 353 feet in height and 22 feet internal diameter throughout. The condensing plant consists of Worthington surface condensers and independent combined air and circulating pumps, each engine having its own condenser.

There are eleven engines, made by the Allis-Chalmers Co., of Milwaukee, each direct coupled to one generator. These engines are of the vertical cross compound condensing type, with the generator mounted on the shaft between the cylinders. Normally the engines give 4,500 indicated horsepower when running at 75 revolutions per minute, with steam at 160 pounds per square inch; but they are capable of running continuously at 6,000 indicated horsepower or for short periods at 7,000 indicated horsepower. The cylinders measure 46 inches and 86 inches in diameter by 60 inches stroke. The shaft measures 34 inches at the journals, 30 inches at the cranks, and 37 inches where the generator and fly wheel come; it is 27 feet 4 inches long, and has a 16 inch diameter hole through its length. The connecting rods are

13 feet 8 inches between the centers. Both the crosshead and crank pins measure 14 inches diameter by 14 inches long. The fly wheel is 28 feet in diameter and weighs 150 tons. The total weight of the engine and generator is 700 tons. The cylinders are not steam jacketed; a reheating receiver is interposed between the high and low pressure cylinders.

The following details of the weights of the various portions of these engines may be of interest:

Name of Piece.	No. of Piece.	Weight in lbs.
Wheel center, small half	1	21,000
Wheel center, large half	1	2,900
Segments of wheel (11 segments)	11	12,000
Lower frame	11	21,000
Slide section of frame	2	36,000
Bedplate, large half	2	59,000
Bedplate, small half	2	24,000
Low pressure cylinder	1	28,000
High pressure cylinder	1	15,000
Low pressure cylinder heads	2	26,000
High pressure cylinder heads	2	7,500
Shaft	1	72,000
Cranks, each	2	23,000
Connecting rods	2	9,000
Receiver	1	20,000

The steam piping is of wrought iron with steel flanges riveted on; Van Stone joints are used. The drum of each boiler is connected to a 16 inch ring main by an 8 inch header; there are six of these rings in all, two for each tier of boilers. The rings are interconnected by eleven vertical 16 inch mains, which pass into the engine room and lead to the engines, one main supplying each engine. The exhaust piping is of cast iron and is supported by hangers.

In comparing this station as a whole with similar installations in Great Britain and on the continent, say with the Glasgow corporation tramways or Liverpool stations, or with the Berlin or Hamburg plants, it cannot be said that taken as a whole, the comparison is entirely favorable to the New York plant. The individual items, such as engine, steam piping, dynamos, switch boards, transformers, are beyond criticism; but the putting together seems in many instances to have been not as carefully thought and drawn out beforehand as is generally the case with a European plant. No pipe, however small—no individual wire—is put into a European installation without a drawing being got out beforehand. Great trouble is constantly being experienced with American goods owing to the drawings, which the makers have supplied and which have been approved by the customer, differing widely from the real article when it comes over. It seems impossible to convince the American that, no matter how small the detail, it has been carefully laid out on the plans before construction commences, and that a difference in the goods he supplies from the drawings approved will throw out the whole system. Indeed in some cases, particularly on the continent, working drawings have to be approved by the police authorities and the slightest deviation from them may entail the throwing out of the whole plant.

It is undoubtedly a fact that as regards finish, the European stations are far ahead of American. It is, however, also true that where, as is the case in Glasgow and Central London stations, European methods of installing American apparatus have been used, the finest results have been obtained.

The largest power plant in the world is that of the Manhattan elevated railway, and a few details regarding this interesting railway are here given.

Steam is generated in sixty four Babcock & Wilcox horizontal water tube boilers, arranged in batteries of two boilers each; they are fitted with Roney mechanical stokers. The furnace gases pass through Green's economizers on their way to the chimney stacks, one economizer being provided for every two batteries. There are four brick stacks, each 278 feet high and 17 feet inside diameter. Forced draught is furnished by sixteen blowers installed by the Sturtevant Co., but the stacks are of sufficient dimensions to furnish the required draft under ordinary circumstances.

The steam piping is divided up into eight sections, each section dealing with four batteries of boilers and one of the main engines. Wrought iron pipes up to 5 inches in diameter have cast iron screwed flanges; from 5 inches diameter upwards, the flanges are welded on.

The engines were constructed by the Allis-Chalmers company, of Milwaukee, and are eight in number. In design they are a radical departure from anything hitherto used in railway power plants. They are four cylinder combined horizontal and vertical engines, consisting practically of a horizontal cross compound engine and a vertical cross compound engine, both working upon the same crank shaft, except that the two vertical cylinders are both low pressure cylinders and the other two both high pressure. The cylinders measure 44 and 44 and 88 and 88 inches in diameter by 60 inches stroke. The speed is 75 revolutions per minute. The cranks, of which there are two, are set at 135 degrees with each other. The power developed under normal conditions of running is 8,000 indicated horsepower per engine. The exhaust steam is dealt with by jet condensers, driven by electrical motors.

The Westinghouse Machine company has recently built and erected some engines at Willesden for the Metropolitan Electric Supply company, which should be briefly noticed. At these works there are four direct coupled units, both engines and dynamos being of Westinghouse manufacture.

The engines are 2,500 horsepower, vertical cross compound marine type, with the alternator and exciter armature at the low pressure end of the crank shaft, and a heavy fly wheel governor at the other end. The cylinders measure 35 inches and 55 inches in diameter by 36 inches stroke. The crank shaft is 14 inches in diameter. The engine runs at 116 revolutions per minute. The exhaust steam passes into a Wheeler surface condenser, the circulating water being cooled in three Barnard water cooling towers.

American engine builders as a rule use larger shafts and main bearings than is usual on the eastern side of the ocean. This is due to the fact that Americans have realized the necessity of fly wheel effect, and that the engine and dynamo are built so as to be able to run 25 per cent overload continuously, and 50 and 75 per cent overload for short periods without injury. Furthermore, cross compound engines are largely used with only two bearings—the armature and fly wheel, which are next each other, being located between the bearings. The slightest wearing of the bottom shells or sinking of foundation might produce very heavy stresses due to magnetic pull. What these may amount to is shown from the following figures:—

Pull on shaft (from actual practice) due to 1-32 inch displacement of constant current railway generator armature.

Kilowatts.	Revs. per min.	Weight of armature in pounds.	Magnetic pull in pounds due to $\frac{1}{32}$ in. displacement.
100	250	3,000	3,500
150	225	4,000	5,000
200	180	8,000	7,000
250	100	15,000	10,000
300	160	12,000	8,000
1,500	75	70,000	40,000

The clearance all around between the armature and pole pieces would be about $\frac{3}{8}$ inches.

In consequence of marine engines having been built so successfully in Great Britain, when direct connected generator sets had first to be considered, the large shafts and bearing surface asked for were much ridiculed by many engine builders. To a certain extent the same thing obtained on the continent, owing to storage batteries being nearly universal and heavy overloads necessitating heavy fly wheels therefore nearly unknown. It was contended that a marine engine driving a propellor had quite as hard work to fulfill as an engine direct connected to a railway generator. Three things, however, were overlooked in this comparison.

First. A marine engine has a maximum load but cannot ever be instantaneously overloaded as much as 100 per cent, as often happens in traction work.

Second. The shaft, and consequently the bearings, have not to carry a heavy fly wheel and armature.

Third. An immense extra stress can be exerted on the shaft should the armature get out of center.

The pressure on the projected area, that is to say, on the area equal to diameter and length, of a main journal, should in no case exceed 150 pounds per square inch. As regards crank pins and crosshead pins, American practice might with much advantage be altered, and the pressure per square inch of projected area decreased. The standard English mill engine practice perhaps goes to extremes, but it is preferable to the American practice. As an example we will consider a cross compound vertical engine designed to work at a steam pressure of 150 pounds per square inch running 80 revolutions per minute. The crosshead pin in British practice would be 7 by 10 inches and the crank pin 9 by 11 inches. The corresponding dimensions of an Allis engine to do the same work and with same dimensions as regards cylinders, stroke, speed and steam pressure would be:—crosshead pin 6½ by 6½ inches; crank pin 6½ by 6½ inches. That this is large enough to avoid heating is undoubted, but if knocking is to be prevented the liners of these smaller pins will require taking up much oftener than would be the case with the British engine. Taking another example, say an engine designed to develop 800 indicated horsepower and able to develop 1,000 horsepower continuously at a pressure of 150 pounds steam at 90 revolutions per minute; this would have cylinders 22 by 44 inches and 42 inch stroke, crosshead pins of 6½ inches diameter by 7 inches long, and crank pins of 7 inches diameter by 7 inches length would give complete satisfaction. The standard American practice for such an engine would be crank and crosshead pins both 6 by 6 inches. Or, in other words, and in round figures, the projected area of the crosshead pin should be 20 per cent greater and that of the crank pin nearly 30 per cent greater than standard American practice.

The outside finish of continental engines, particularly, is much better than is usual with Americans. Nearly all bright parts are polished. The rim of the fly wheel is polished. Burnished or Russian steel sheathing is used, and all the hand rails are bright. In connection with German engines it is interesting to notice that, owing probably to the prevailing depression in Germany which forces them to sell at any price, they have secured orders for steam engines in the heart of Lancashire at prices lower than either British or American tenderers, and besides they have accepted one third of their payments in debentures.

Horizontal and vertical engines. In Germany some engineers state they will always use horizontal engines with tail rods carried on regular crossheads and slides, because their original cost is less, and because the machine is less complicated and its working and supervision when running are easier. Had such complicated structures with two cylinders, one above the other, and highly complicated valve gear not been originally installed, it is doubtful whether such a conclusion would have been reached.

Continental engineers like to place a dynamo on each side of the engine. In some cases in cross compound engines, as for instance Tosi, the two cylinders are side by side, and to look symmetrical some engineers have even gone as far as to place the dynamo on one side and the fly wheel on the other side of the engine, which it need hardly be pointed out is very bad practice.

In connection with the large combined horizontal vertical engines which are being installed in the power stations of the Manhattan elevated railroad at New York, it should be noted that the design there adopted is by no means novel, but is to be found, in much smaller engines it is true, in Germany, at Halle, where a similar type, although of relatively very small size, was installed about 1892. Germany has adopted triple expansion engines both for traction and lighting work. Also the use of superheated steam is greatly on the increase. The steam pressure used with these engines is 12 kilogrammes per square centimeter, about 175 pounds per square inch, and the temperature at the throttle 280 to 324 degrees centigrade, or a superheating of about 130 to 200 degrees Fahr. It is this degree of superheating which accounts, notwithstanding the complications frequently introduced, for the nearly universal use of poppet valve systems on the continent. To increase the efficiency of steam plants, the continental engineer has increased the vacuum of the condensers as much as possible and a far greater quantity of condensing water is used than is usual in America, the continental practice being about in volumes 30 to 1 as compared to the American of 25 to 1.

Examining the types of engines in use. What is economy in a power and traction station? Engine economy guarantee at rated load is not the real measure, as loads are very variable. To ascertain what the real economy is we must know what is the variation in large plants and what is the average loads on engines in these circumstances. Cross compound condensing units give good results. The variation of temperature in the low pressure cylinder is very small because of the reheater receiver. Such an engine is practically two single engines with each cylinder acted upon by a governor; it consists of two engines with smaller ranges of temperature variation. This is American practice. Engines for this class of work necessitate ample receiver capacity.

It has been suggested to adapt triple expansion to traction work and variable loads by using a throttle governor on the high pressure, an automatic on the intermediate, and fixed cut-off on the low pressure. A sudden overload would quickly raise the initial steam pressure and let out the cut-off on the high pressure; the intermediate automatic cut-off would provide the balance of power and deliver a fairly constant volume of steam at a slightly varying pressure; the cut-off being fixed and the vacuum constant, the range of temperature would be fairly constant. During the overloads such an engine would not be economical, but it would be so for the average load for which it was designed and to which it had been regulated.

German and continental engineers generally try to secure absolutely steady load by the use of large storage batteries, in which case triple expansion condensing units are to be recommended, and also the use of superheated steam; but although this reduces the cost of the power generated, we must consider the extra cost of the power supplied, due to loss in accumulators and to interest, maintenance, and sinking fund involved by the installation battery. Where money is to be got at a low rate of interest, expensive fuel and water may indicate the use of batteries.

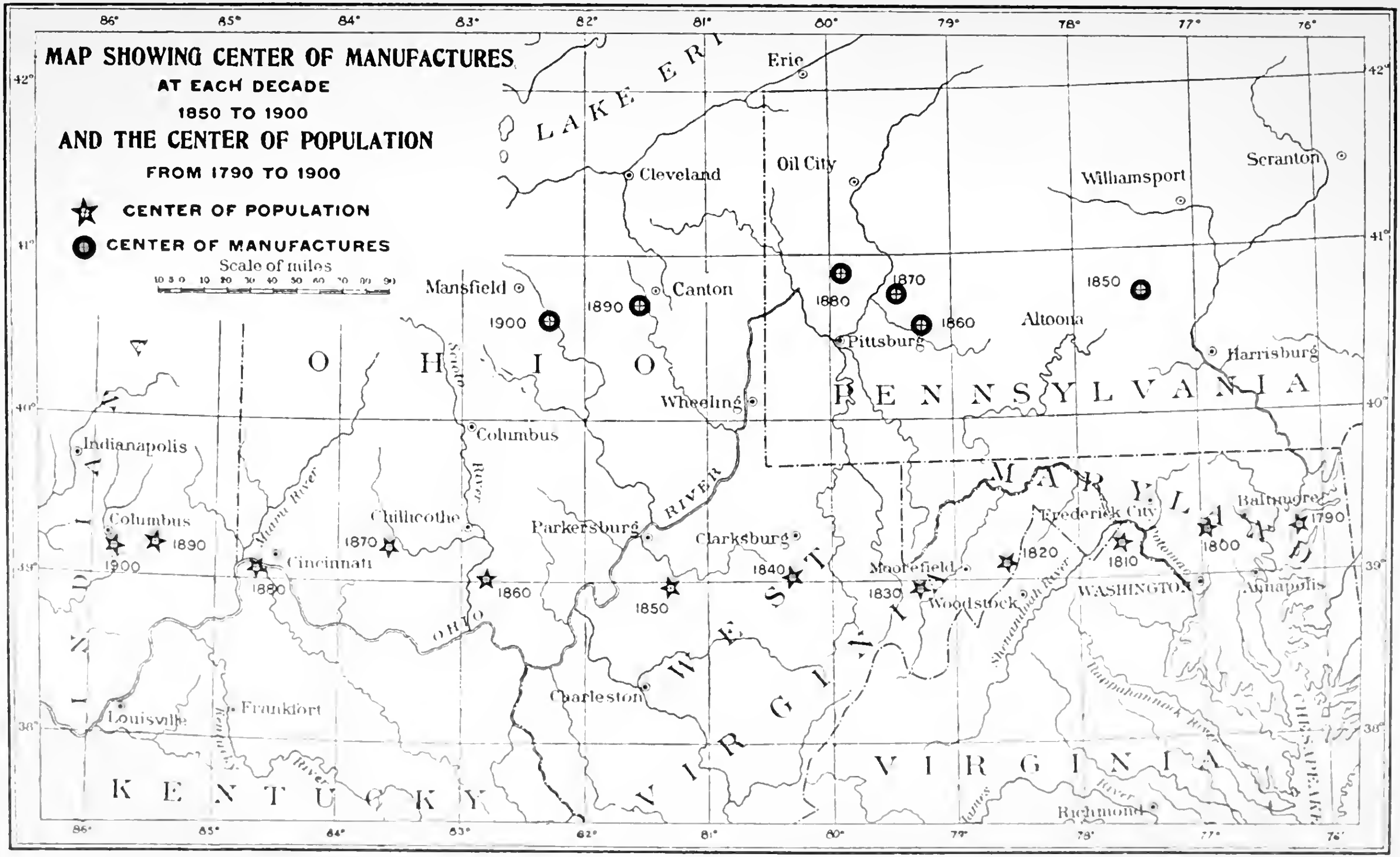
If superheaters are used in the boiler flues, economizers are not much good. If a separate superheater is used the cost of extra fuel, interest, maintenance, and sinking fund must be taken into account in considering economy in steam and coal.

In Great Britain, superheated steam is generally only used with the idea of getting absolutely dry steam at the engines and doing away with the bother always caused by steam traps and separators. Consequently economizers are much used, and it is undoubtedly a fact that for compound condensing plants, economizers, when used in connection with mechanical stokers, give the best results.

Cooling towers and cooling ponds for condensing water are much in vogue on the continent. In America cooling towers are also used as designed by Worthington-Wheeler Condenser company, and others, but with the difference that mechanical draft is created by the use of fans, whereas continentals build their towers of wood and of sufficient height to create a sufficient draft.

It is curious to note that in the case of the Berlin Electricity works, where the greatest care has been taken owing to the cost of coal (over 20 shillings a ton) to reduce fuel consumption, and where in view of the size of the plants small economies would soon mount up, the engineers in charge of these stations have stated to the writer that after careful tests they find it cheaper to stoke by hand, which they do in all their stations. British experience, which is confirmed by American practice, is to use mechanical coal and ash conveyors, in conjunction with weighing machines over each boiler, and to employ exclusively mechanical stoking.

The waste heat engine being experimented with in Berlin is an entirely novel departure, and as it is being taken up by the Allgemeine Elektricitäts Gesellschaft on a commercial scale, I shall say a few words about it. Speaking broadly, the principle of this engine is as follows:—The exhaust steam from a steam engine is condensed in a surface condenser, which uses, instead of water as in the ordinary way, some liquid of a very low boiling point. The heat of the exhaust steam evaporates the cooling liquid and the vapor



MAP SHOWING CENTER OF MANUFACTURES
AT EACH DECADE
1850 TO 1900
AND THE CENTER OF POPULATION
FROM 1790 TO 1900

thus obtained is utilized in a separate cylinder, and useful work obtained from it. After a considerable amount of trial and experiment on the part of Professor E. Josse, of Berlin, SO_2 was selected as the most suitable material with which to work. Liquid SO_2 is therefore used to condense the exhaust steam, and being vaporized in the process is capable of doing useful work, either in a supplementary cylinder to the steam engine, or in a separate engine.

It is hoped that the foregoing remarks will be taken in the spirit in which they are written, namely, of friendly criticism and praise—an attempt to point out the faults and good points in all cases. That the engine builders of all countries have succeeded in developing in their respective branches and countries such magnificent machines is a fact of which all engineers without national distinction should be proud,

PROGRESS IN ENGINEERING.

BY ROBERT HEYWOOD FERNALD.

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The past century has been a period of special significance in the development of technical education, and is properly regarded as the era of its most important advancement. Reviewing the history of this period, we find ourselves, even at its beginning, a long way from the original source of technical education, which is, in fact, prehistoric. A brief sketch of the earliest known results of this type of education is of value as revealing the foundation of its more recent accomplishments.

The Bible states that Tubal-Cain, the inventor of the art of forging metals, was "an instructor of every artificer in brass and iron"—and this nearly 4,000 years B.C. The building of the great cities of the ancients required a knowledge of materials and methods of construction which seem marvelous to-day, and manufacturing and other industries must have formed a necessary part of the evidently active life of ancient communities. The cutting of the great monoliths from the quarries of Syene, together with the inscriptions wrought upon their faces; the raising of these huge masses of stone to form the pyramids; the building of great tombs in these structures, as well as the excavating into the mountains of the region for a like purpose, and the application of the mechanic arts in ways more refined and delicate, but nevertheless enduring, lead directly to the conclusion that the foundation of technical training and a knowledge of technical principles are as old as civilization; and in tracing the history of engineering education in any country one is taken back to the ancient cities of Assyria, Babylonia, India, Egypt, Greece or Italy.

Some 1,500 years B.C. a great university, supported by the Pharaohs is shown to have existed by records since found. Dormitories, for those able to pay the necessary fees, were erected. Over eight hundred instructors were enrolled as members of the faculty, and schools of art, painting, sculpture, architecture and engineering, so far as developed, were included within this wonderful institution.

As early as 1,300 years B.C. the University of Rameses was planned, and one thousand or more years later the great University of Alexandria was founded. In this latter university technical education seems to have been a more prominent feature, and more than ever before was there an effort to give instruction in all the forms of the arts, literature and sciences, and the modern sciences can easily be traced back to these ancient efforts. The work of Plato, Aristotle, Archimedes and Euclid was directly in the line that eventually developed into the various technical branches. These men and their associates had much to do in originating and investigating the scientific theories of that day, and many of their conclusions have stood the tests of time.

It was Galileo who, in 1590 A.D., ventured to question the possible mistakes in Aristotle's statements, and to him dynamic engineering owes its possibility. To the priest and monk is due the credit of having kept alive the mechanic arts during many centuries, for it was through the church hat educational movements and developments were kept rom total destruction.

What is to-day called the new education is really not new, but simply a recent revival and development of an ducation which dates back many hundred years before he Christian era; for, as Riedler has said in disputing the act that medicine was the oldest science, "older still is technical development; civilization began with man."

It is not the purpose of this paper to trace the development of engineering education as a whole, but rather to note he progress of such education in the United States.

Before beginning the historical portion which applies to the United States alone it is of interest to inquire what is regarded as the proper education for an engineer, and later to observe, as far as space will permit, the conditions prevailing in the technical institutions of this country, to ascertain whether these institutions are doing all in their power to meet the educational demands of the present generation of engineering students.

To educate her youth should be one of the highest privileges of any state. Whether in peace or in war, the engineer is found to be an indispensable factor in a nation's efficiency. Naval battles are fought by the engineer, the manipulation of the land forces is possible only through the work of the engineer, and, in times of peace, manufacturing, commerce, and, in fact, nearly all the arts and sciences depend upon the engineer. What is more natural than the tendency of a large percentage of the young men of to-day to train themselves along the lines offering such vast opportunities?

What then should be the nature of this education? Should the engineer be a specialist only, or should he have a broad and liberal education coupled with special training?

Ruskin says that "An educated man ought to know these things: First, where he is—that is to say, what sort of world he has got into, how large it is, what kind of creatures live in it, and how; what it is made of, and what may be made of it. Secondly, where he is going—that is to say, what chances or reports there are of any other world. Thirdly, what he had best do under the circumstances—that is to say, what kind of faculties he possesses; what are the present state and wants of mankind; what is his place in society, and what are the readiest means in his power of attaining happiness and diffusing it. The man who knows these things and who has his will so subdued in the learning of them that he is ready to do what he knows he ought, is an educated man, and the man who knows them not is uneducated, though he could talk all the tongues of Babel." Even after settling to his own satisfaction these three conditions of Ruskin it is still a difficult question for a young man to determine what should be his courses of study best to prepare him for the greatest usefulness and the highest possibilities.

It must be borne in mind that an education is not a collection of facts stored away, to be drawn upon as desired and used as mere facts with no development or improvement, but rather a condition of the mind which enables one to develop systematically and symmetrically such problems and conditions as may come before him for solution or investigation. This, it seems, marks the distinction between a special and a liberal education, the one giving a supply of facts and information, the other teaching the student to use his own powers of observation and judgment. It is Huxley who so well defines the liberally educated man. He says: "That man, I think, has a liberal education whose body has been so trained in youth that it is the ready servant of his will, and does with ease and pleasure all that, as a mechanism, it is capable of; whose intellect is a clear, cold logic engine, to be turned to any kind of work and to spin the gossamers as well as forge the anchors of the mind; whose mind is stored with the knowledge of the great fundamental truths of nature and of the laws of her operations; one who, no stunted ascetic, is full of life and fire, but whose passions have been trained to come to heel by a vigorous will, the servant of a tender conscience; one who has learned to love all beauty, whether of nature or of art, to hate all vileness, and to esteem others as himself."

This powerful description applies with equal force to the engineer, the clergyman or the man of letters; and no one aiming toward a life of great usefulness and power can question the superior strength and nobility of him who is able to follow such a course as shall develop, as completely as the natural endowment of the individual will allow, the broad, well balanced and liberally educated man. This broad, liberal education produces a truer conception of the truth of existing laws, the application of better judgment in thought and a clearness of apprehension and comprehension not possible in the case of the recipient of a narrow special education.

The engineer should be a man of large conceptions and sound judgment, with a thorough knowledge of the truths of nature and the ability to convert the results of her laws into channels best adapted to the needs at hand. His resources must be unlimited. His associations are such that culture and refinement are of great moment, and a well defined knowledge of the conditions and resources of the world at large is indispensable. Business training is also very essential, and, in fact, there is probably no other profession in which the cultivating influences of a general education are more necessary than for the man who has to cope with the greatest problems of civilization and progress—the engineer.

Is it possible for the average student of engineering to obtain such an education? It is, of course, necessary for him to be conversant with his special lines, and the average time taken for a college education will not admit of thorough training in one particular direction as well as years of unknown value that may be devoted to general and culture subjects. What the proportion should be and the order and relative value of different subjects is outside the province of this paper, but it will prove of interest to note later the general tendency, in this regard, of the engineering institutions of the United States. The more one studies the subject, the more information one gathers from those in positions of responsibility, and the more one watches the careers of young men, the more convinced does he become of the misfortune which has befallen those who have neglected the cultivating influences of such educational advantages as were within their reach. It is true that many a young man, through force of circumstances, cannot avail himself of the opportunities for such education, and is forced to fight his own way as best he can, securing only, if any at all, such special training and education as will best fit him for his particular chosen profession. Such a young man is unfortunate, but not to be blamed, and may far outstrip, both in natural ability and application, the young man of more desirable opportunities who has ignored his chances for development.

Misfortunes and difficulties do not necessarily strengthen a man. The strong man only can overcome such obstacles, and while he may, by virtue of his strength, accomplish much, yet it is a question whether the same man with such qualities would not have been greater had he been allowed the opportunities and privileges of a better and more liberal education. Much more estimable, however, is the man who has come up under such hardships than he whose ease and luxury have killed worthy ambition and have made the want of the best possible education a matter of indifference and neglect. In speaking of a liberal education, President Timothy Dwight, of Yale, has said: "He may not be a philosopher, or a poet, or a statesman, or a scholar; but as educated, and because he is educated, he is thoughtful, rich in his resources for himself and for others. This is what the higher education means, and it has no truest and deepest meaning apart from this. This developed power of serious thought is the essence of educated life. It is the foundation of living water within the mind, which is for every educated man the blessing of such life. To have rich thoughts, serious thoughts; in the sense of calm, serene, earnest, intelligent, cultured, generous, manly thinking on any and all themes which are worthy of human thought, what blessing for the mind can be greater, or can contain in itself more truly the secret of the best living?

"Who knows that results are greater when the man understands only one thing and thinks only one? The results that are seen may, perchance, be greater; though this, as relating to all cases, will need proving. But those that are unseen, who can tell of them? And the unseen results are often, if not always, the greatest and most important. In the unseen region is influence. It is itself, in the largest working and measure of it, the most unseen of all things. But what influence is, and from the nature of influence will ever be, so wide reaching as that of a rich mind and soul which are filled out by education on every side to their fullness of culture and beauty?"

Never has the lack of a college education been more keenly felt than by the young men of the present day who have either neglected opportunities or have been prevented from securing those advantages which are so gratifying to the educated and which money cannot buy. Sympathy is indeed due the young man who feels his lack of appreciation and knows his limitations to be due to the want of a proper education. Very few there are who would not give all they possess, when they realize their limitations, to feel that they had the power to discuss the momentous problems of the day with the educated and prominent men of the land, or could at least carry on a pleasing conversation with men of deep thought and keen perception. If in addition they can acquire the ability to appreciate the best literary, musical and artistic productions, the sacrifice is great that will not be made for such an end. "The more one has the more one wants," is strikingly true in educational circles, and it is a question whether the average young man without a college education feels more keenly his lack than does the young man who has risen relatively higher, but has pursued a single narrow line, leaving out the subjects which tend to broaden his views and to open for him vast possibilities in the world of refinement and culture, because his absorption in the work of his own special field has entirely shut them from view. When he awakes to find himself far behind his more fortunate fellows, then he catches glimpses of the great opportunities that might have been his, had he but realized earlier the difference between the educated man and the man whose whole aim and study have been cramped into one narrow line. This is not saying that the specialist is not needed, and to-day more than ever before, but the specialist whose educational foundation is broad and liberal, who is a well rounded man, who can appreciate the necessity of, and understand, in a general way, the work of others in fields which are possibly very remote from his own, is a man of larger resources and possibilities, and is a much greater power in the world than the mere specialist can be. His own special line need not suffer on account of his broad conception of life and study, but on the contrary, the deductions and results of his specialized efforts will bear a truer and more direct relation to existing facts and conditions than otherwise would be possible. The following words from Bishop Henry Potter, delivered at the one hundredth commencement of Union college, at Schenectady, carry out this thought: "The time will never come when a man who has not merely learned certain chemical combinations so that he can manufacture a fertilizer, or certain mathematical combinations so that he can build a railroad, but has also learned what made a little peninsula in the Adriatic the mistress of the world, or how Roman law became the basis of the jurisprudence of Christendom, or how the fall of empires was foreshadowed in the republic of Plato, or how the growth of a corrupt and privileged ecclesiasticism brought about the transformation of modern Europe, the time will never come, I say, when the man who has learned these things, not a parrot like learning, but in the length and breadth of their vast and enduring significance, will not be, in every highest sense, the master of him who has not."

Literature, languages, philosophy, and mathematics do not make the well rounded, cultured man any more than do special technical courses. The field of information and training is unlimited, and there is no one field or branch so broad that great advantage cannot be gained by investigation in the others, and that man may count himself fortunate whose early years are well directed and well employed in the serious pursuance of study in the courses best fitted to develop and mold the man, for that training is indisputably the most noble and most desirable which has for its aim the development of those facilities and powers which shall first make the student a man, and secondly fit to undertake work in his special lines.

To what extent this idea has been carried out by the engineering institutions of the United States can be shown only by a sketch of the growth of such institutions, and by observing the demand for and the success of young men whose lives have been molded in these engineering schools. The healthy growth of the technical school is marked with keen interest, and the following brief sketch of its development during the past century shows at once the imperative need of such institutions and the excellent quality of their work, together with the fact that progress in engineering education has kept pace with the development of the country.

At the very beginning of the nineteenth century the need of engineering education was felt, and the United States Military academy at West Point, being the only institution fitted to give such training, took the initiative, and in 1802 conferred degrees upon the first two engineers graduated in the United States.

A few years later an effort toward engineering education was made by Thomas Jefferson, and, although he was unable to secure the carrying out of his plans, it is of interest to note his advanced ideas upon this subject, for in 1818 he included in an outline of the scope of higher education this expression: "To harmonize and promote the interests of agriculture, manufacturing, and commerce, and to enlighten our youth with mathematical and physical sciences, which advance the arts, and administer to the health, the subsistence, and comforts of human life."

In attempting to organize the University of Virginia, he so planned that four of its ten courses should be scientific. He spoke of it as a school of technical philosophy, and desired instruction in the sciences of geometry, mechanics, statics, hydrostatics, hydraulics, hydromechanics, navigation, astronomy, geography, optics, pneumatics, acoustics, physics, chemistry, natural history, botany, mineralogy, and pharmacy, and also in writing of his plans said: "The use of tools, too, in the manual arts is worthy of encouragement by facilitating to such as choose it an admission into the neighboring workshops."

So closely allied with engineering training are the schools of manual training that the mention of the founding of the early schools is of interest historically. Probably the first institution of this class in the United States was organized in 1833 at Penfield, Ga. It was conducted by the Baptist church and was known as Mercer institute. Prof. J. J. Wilmore, in writing of Some Phases of Engineering Education in the South, adds in reference to Mercer institute: "A student at that time, writing many years afterward, feelingly says: 'The work was on the farm. There was also a sort of mechanical department. A preacher thirty years old, parrot-toed, a carpenter—he bossed it. For a long time I worked at the whipsaw.'" This institution was followed by Wake Forest institute the next year.

Not long after this a great advance in higher technical education was made, for in 1840 Rensselaer Polytechnic institute, of Troy, N. Y., came to the front with the first civil engineers to be graduated, not only in the United States, but in any English speaking country—graduating a class of thirteen that year.

The opportunities of obtaining training in engineering lines previous to this time were very limited, as the only institution giving any such instruction was at West Point, and the only other means of obtaining any such education was by entering the office of some civil engineer. As this latter system existed in New England, no formal articles were drawn, but the arrangement was understood to be for three years, during which period the student was charged $100 per year for his tuition and was credited with the liberal sum of 12½ cents per hour for actual work in the field, office work being gratis. The terms varied at times, particularly after the war, when office work received the same compensation as field work. The student was allowed to ask questions and to pick up what information he was able.

Previous to 1850 the important engineering positions were held largely by graduates of West Point, but since the establishment of the institutions especially adapted to give instruction in engineering lines this institution has furnished few engineers. Of the first thousand graduates of West Point some one hundred and fifty became civil engineers, but of the second thousand, only fifty, and since the class of 1863 few have become civil engineers of prominence.

The condition of the country prior to 1840 was such that there was little demand for engineers. There were practically no railroads and the general development was not such as to require the services of such men to any extent, outside, possibly, of the canals.

In founding Rensselaer Polytechnic institute Hon. Stephen Van Rensselaer did much for the cause of engineering. The institution was founded by him in 1824–25, but in the first copy of the act of incorporation and in the constitution and laws of the school the word engineering or engineer does not appear. In 1828 these words made their appearance, as the senior professor was to lecture on chemistry, natural philosophy, geology, land surveying, and civil engineering.

It was October 14, 1835, that the first prospectus in English of a school of civil engineering was issued. Among other things it stated that the degree of civil engineer would be conferred upon candidates of seventeen years and upwards who are well qualified in that department. One year is sufficient for obtaining the Rensselaer degree of bachelor of natural science, or of civil engineering for a candidate who is well prepared to enter. Graduates of colleges may succeed by close application during the twenty four weeks in the summer term. Candidates are admitted to the institute who have a good knowledge of arithmetic and can understand good authors readily, and can compose with considerably facility. The degree of master of arts is conferred after two years of practical application. Rensselaer graduated from six to thirteen engineers a year, and these, with the few from West Point, made up the list of directly trained engineers for a period of some ten years, when the school of engineering of Union college entered the field in 1845, with the distinction of being not only the second engineering school, but the first to be organized as a branch of a classical college. The success of this institution was not marked, as it graduated only two or three students of engineering a year for a long period and remained very small until about 1860.

In 1846, the year following the organization of the engineering department of Union, the Lawrence Scientific school became a branch of Harvard university, and was the third institution to introduce engineering. The history of this institution has been until within a recent period most unfortunate, and in referring to it some writer has said: "By others' faults wise men correct their own, and as an example of the noble art of how not to do it, it is perhaps without a parallel." The conception of Hon. Abbott Lawrence, the donor, was exceptionally fine, and had his wishes in the matter been fulfilled the history of the engineering department of Lawrence Scientific school might have been very different. The following extracts from his letter of donation leave no doubt as to his personal views and wishes. He desired it to be a school for the purpose of teaching the practical sciences. There existed a pressing want of an increased number of men educated in the practical sciences or in the practical applications of science. He desired the school to educate our engineers, our miners, machinists, and mechanics. He further says: "I have thought that the three great branches to which a scientific education is to be applied amongst us are, first, engineering; second, mining, in its extended sense, including metallurgy; third, the invention and manufacture of machinery."

In 1849 Prof. Henry L. Eustis, second lieutenant of engineers, was appointed professor of engineering, and gave for some years very excellent instruction, and the failure of the school to live up to the wishes of Mr. Lawrence was in no way due to Prof. Eustis. The money was devoted to various other branches, and after his death no professor was appointed, and Harvard, in failing to live up to the letter of the bequest, forfeited an opportunity of having one of the most successful engineering departments of this country.

In spite of lack of funds and demands in other directions, the engineering courses had been established, and the first class of four was graduated in 1853. For a few years the school prospered, but in 1859 the decline began. Prof. Eustis went to war and returned much out of health and unable to fill the position. He died in 1885, and the engineering department disappeared for some time. Finally, under the guidance of Prof. W. S. Chapin, followed by Prof. N. S. Shaler, as dean of the scientific schools, and Prof. I. N. Hollis, now professor of engineering, the department is coming to the front again, and Harvard may, even at this late day, partially redeem the unfortunate mistake in disregarding the wishes of Mr. Lawrence.

In 1847 what is now Sheffield Scientific school of Yale university followed, but did little before 1852, and then was forced to economize in every way until 1859, when Mr. Joseph E. Sheffield reorganized the school. As an engineering school it did not get well under way before 1861, but the possibilities of this progress were brought about by earlier efforts, and much credit is due the institution for having maintained an existence until Mr. Sheffield's interest was secured in its behalf.

By a bequest from Mr. Abiel Chandler, the Chandler school of science and the arts was founded in 1851 in connection with Dartmouth college for "a permanent department of instruction in the practical and useful arts of life," under which head Mr. Chandler mentioned particularly mechanical engineering, civil engineering, carpentry, masonry, architecture, drawing, and modern languages, together with bookkeeping and such other branches of knowledge as may best qualify young persons for active life.

Located also at Dartmouth college is the Thayer school of civil engineering, founded by Brig. Gen. Sylvanus Thayer, U. S. A., who was graduated in 1807 from Dartmouth and founded the Thayer school in 1867.

To Michigan belongs the honor of starting the first engineering school on other than private donations, and upon an equal footing with the other departments of the university. This was done in 1852 at the state university, and the first degrees of civil engineer were granted eight years later—1860. Michigan may well claim the distinction of founding the second strong engineering school in the United States, and this in the face of the poor and unsettled condition of the state prior to 1860.

No other institution giving engineering courses appeared until Brooklyn Polytechnic began graduating students in 1866, and this was soon followed by the Columbia college school of mines, which was the first school of mines organized in America, although Michigan graduated a class the same year, 1867, and the Massachusetts institute of technology followed a year later.

To Prof. Thomas Eggleston belongs the honor of being the pioneer in organizing a school of mines. His plans for Columbia were made in 1863 and he was appointed professor in 1864. In speaking of the school of mines at Columbia, the writer in the Engineering News says: "It needs only to add a course in mechanical engineering and the school will cover as broad a field as any other, and a broader than most." The course in mechanical engineering has now been added, and the school of applied science is in excellent condition.

The next institutions to present graduates were the Massachusetts institute of technology and Washington and Lee university, in Virginia, both of which graduated classes in 1868. From this organization the institute of technology was recognized as a remarkably strong institution, and it is still looked upon as a leader among engineering schools. Much of the success in founding this institution is due to Prof. Wm. B. Rogers. The organization meeting was held on January 11, 1861, and the act of incorporation gave the institute and the Boston society of natural history the site occupied by the buildings, two thirds for the institute and the other third to the society of natural history.

Owing to the war of the rebellion the school was not started until 1864, and meantime the land grant bill—to be discussed later—had been passed, and the Massachusetts institute of technology received a portion of the aid from this act. A class of thirteen was graduated in 1868. The first catalogue showed a list of seventy two students, nearly all from the field that should have been covered by Lawrence Scientific school had that institution but taken advantage of its opportunities. The six courses originally outlined by Prof. Rogers have formed the basis of instruction, although others have been added from time to time. The institution has been most prosperous, and has proved a credit not only to Boston and Massachusetts, but to the country.

Since 1862 a large number of institutions having engineering departments have been organized, many of which resulted from the land grant bill. Between 1865 and 1870 as many as eighteen were founded.

Stevens institute, organized in 1871, has the distinction of giving instruction in mechanical engineering only, and of conferring but one degree, that of mechanical engineer.

Probably no other single act has done more to advance the possibilities of engineering education than the bill introduced into congress by Hon. Justin Morrill, of Vermont, and commonly known as the land grant bill. The original bill, introduced in 1858, was vetoed by President Buchanan, but in 1862 Senator Morrill again presented the bill, and on July 2, President Lincoln's signature made the bill a law.

Times were hard; the country was in a state of confusion and uncertainty; the interpretation of this law as passed was different in various states, and many sad mistakes were made during the history of the founding of these institutions. The conception was in itself wonderful, and, in spite of many serious mistakes on the part of the different states, a new era was opened to engineering education by the passage of the bill. The conditions of the law were that for each senator and representative in congress the state should receive 30,000 acres of public lands, open for sale at $1.25 per acre, or instead each state was to receive scrip to be sold for the benefit of the state. For various reasons—misunderstanding of the law, a feeling of impatience or uncertainty, trickery or bad management—nearly all of the states failed to realize the full $1.25 per acre, and the majority received but a very small portion of this amount, one state receiving as little as 41 cents per acre. One state stands as a marked exception, viz., New York. Through the wisdom and caution of Mr. Ezra Cornell the investment was made to realize between $6 and $7 per acre on all but a small portion, which had been sold before Mr. Cornell secured control at 53 cents per acre. The result was that New York state received 42 per cent of the amount realized from the total grant from her share of scrip, which was only about ten per cent of the total. The benefits resulting from the wisdom of Mr. Cornell have been most apparent in the progress of the excellent institution bearing his name. Nine states only succeeded in securing as much as the $1.25 per acre, and of these Tennessee received the least, $1.34½. The nine states to invest to good advantage were Tennessee, Wisconsin, Florida, Michigan, Iowa, Minnesota, California, Kansas, and New York, the last three receiving more than $5 each per acre. These nine states received for 2,459,920 acres the sum of $10,633,860, while the remaining twenty nine received for 7,117,920 acres only $5,232,512. Considering this most unfortunate start, the positions occupied by the various state institutions at the present day are most flattering, as each state has since endeavored to live up to the letter of the law, and has made up the initial loss to a certain extent by liberal appropriations from time to time.

The clause of especial interest in the Morrill act refers to the use of the funds derived from the proposed sale of lands, and states that the income should be appropriated "to the endowment, support, and maintenance of at least one college where the leading object shall be, without excluding other scientific and classical studies and including military tactics, to teach such branches of learning as are related to agriculture and other mechanic arts in such manner as the legislatures of the states may respectively prescribe, in order to promote the liberal and practical education of the industrial classes in the several pursuits and professions of life."

The states accepted the responsibility and each state established its institution. In most states one institution only, including the courses in agriculture and the mechanic arts, was established, but Massachusetts made an exception, granting to the institute of technology, which was then coming to the front, a portion of the fund for its technical departments, the remainder going to establish the Agricultural college at Amherst. In a few states the fund was directed toward the development of the necessary departments in institutions already established. Thus came into existence a large number of colleges, the majority of which were to advance the interests of engineering education and many of which were destined to become leaders among the numerous universities of learning of the present day.

From time to time since the advent of these institutions, institutions founded by private funds have been organized, until to-day the opportunities for study in the varied lines of engineering are so numerous and of such excellent quality as far to surpass the wildest dreams of the early promoters of such education. Not alone are there modern institutions where these various branches form the principal courses of study, but the old conservative universities have opened their doors and are striving to establish departments of engineering that shall rival those of the leading technical institutions.

The following statistics, secured directly from the institutions, serve to emphasize the wonderful progress that has been made. Although the list, of necessity, is incomplete, the general deductions are not seriously affected. Definite information was received from about 85 per cent of the institutions giving technical instruction, and of the 15 per cent from which no replies were received a few only could furnish information of material value in these deductions.

Many of the statistics for the civil, mechanical, and mining departments prior to 1890 were taken from articles published in the Engineering News for 1892, thus saving much annoyance to the institutions that kindly filled the remaining blanks.

No attempt has been made to supply the desired data from the catalogues of the colleges from which no replies have been received. While in some cases this might be done to advantage, yet in general the results would be far too inaccurate to add value to these records.

Considering the courses offered, the returns show that at the close of the nineteenth century about 70 per cent of the institutions considered offer a course in civil engineering, 64 per cent offer mechanical engineering, while electrical engineering follows closely, being offered by nearly 60 per cent. Mining engineering is the only other course given by any large number of institutions, some 34 per cent reporting such a course.

Architectural departments are listed from about 17 per cent of the institutions, and it is interesting to note that fully half of the architectural courses were established within the last ten years of the century. Naval architecture has but recently entered the field, but three institutions reporting courses, Cornell university having established a course in 1890, the Massachusetts institute of technology in 1895 and the University of Michigan in 1900. Courses in chemical and sanitary engineering seem also to be limited in number, but six institutions reporting courses in the former and four only in the latter.

It is of interest to note the increase in the total number of graduates of the eighty colleges represented for the last twenty years of the century. The total for 1880 is lower than for some years previous and the increase from 1880 to 1885 should perhaps be modified. The eighty colleges considered graduated from engineering courses.

	No.	Increase.	Per cent Increase.
In 1880	148	...	...
In 1885	269	121	82
In 1890	618	349	130
In 1895	1,076	458	74
In 1900	1,217	141	13

From about '83 to '90 civil engineering had a prosperous growth, but from '90 to '95 a serious falling off in the number of graduates is observed. Ninety six saw a decided improvement, which was necessarily cut short by the results of the hard times four years previous.

The number of graduates in electrical engineering increased from the first with remarkable rapidity until the natural falling off in '96–'97. The growth in mining engineering has been small from the beginning, but the demand for the past ten years seems to be stimulating an advance of this department.

The closing decade of the century presents some very interesting statistics, as noted below. In Table I. is given the number of classified students in engineering courses in 1889–90 and in 1899–1900 in the eighty colleges from which returns were received.

TABLE I.

	1889–1890.	1899–1900.	Increase.	Per cent Increase.
C. E.	1,647	2,432	785	48.0
M. E.	1,345	2,935	1,590	118.0
Mn. E.	599	1,441	842	140.0
E. E.	855	1,960	1,105	129.0
S. E.	7	16	9	13.0
Ch. E.	21	16	5	24.0
A.	268	299	31	11.5
N. A.	....	51	51	.....
Totals	4,742	9,150	4,408	93.0

These figures do not in most cases include the first year men, as in but few institutions are the courses determined before the second year.

In like manner Table II. presents the number graduated in engineering courses in 1890 and in 1900 from the same eighty colleges.

TABLE II.

	1890.	1900.	Increase.	Per cent Increase.
C. E.	265	287	22	8
M. E.	219	418	199	91
Mn. E.	25	139	114	456
E. E.	66	283	217	329
S. E.	...	4	4	...
Ch. E.	...	15	15	...
A.	43	62	19	44
N. A.	...	9	9	...
Totals	618	1,217	599	97

The percentages both in Tables I. and II. show, for the most part, very satisfactory increases. The increase in the number of graduates in mining engineering during the decade is certainly surprising. Although the increase in electrical engineering is very large, the result is not beyond expectations, as electrical engineering was in its infancy in 1890. Especial attention should be directed to the percentages of increase shown in the total attendance and total number of graduates in the engineering branches, Table I. showing the percentage of increase in attendance for the decade to be 93 and Table II. that for the increase in graduates 79, results which compare very favorably.

It is of interest to note the proportion of graduates to undergraduates, both in 1890 and 1900, as shown by Table III.

TABLE III.
PERCENTAGES OF GRADUATES TO UNDERGRADUATES.

	Per Cent C. E.	Per Cent M. E.	Per Cent Mn. E.	Per Cent E.E.	Per Cent S. E.	Per Cent Ch. E.	Per Cent A.	Per Cent N. A.	Per Cent Total.
1890	16	16	4.2	7.7	..	..	16	..	13
1900	12	14	9.6	14.0	25	94	21	18	13

Glancing at the columns marked totals, it is seen that the ratio of the total number of graduates to the total number of undergraduates in the courses considered in the eighty institutions for 1890 and 1900 is exactly the same, the number of graduates being 13 per cent of the number of undergraduates. Considering that the figures given for undergraduates are in most cases from three classes and the number graduating from one, this would indicate that the percentage of those taking these courses to graduate is about 39. This figure would be somewhat reduced were the first year men considered, as the proportion to drop out during the first year is greater than during succeeding years.

It is hardly necessary to emphasize the fact that during this most healthy growth the standards of the various institutions have been constantly raised. This condition would naturally follow the general progress of the country as a whole, as well as the progress in engineering education.

Passing through the period when text books were few, instructors poorly trained, illustrative apparatus and opportunities for research almost unknown, the engineering institutions awoke to find themselves among the leaders, with books of reference and text books prepared by the best authorities; their instructors men of culture, experience and technical education; apparatus of the best, and, finally, engineering laboratories equipped for research work and practical illustration of the important principles and facts of engineering.

Of recent developments in connection with the advance of engineering education, the engineering laboratory is probably the most important. Such laboratories were proposed by Prof. W. B. Rogers about 1861, and in 1874 a steam engineering laboratory was established at the Massachusetts institute of technology. Prof. Channing Whitaker was placed in charge of this laboratory, which was probably the first ever established. The influence of such laboratories has been very great, until to-day no institution of recognized standing in engineering can maintain a high position without well equipped laboratories, as they are of the greatest importance as factors in instruction and training.

The development of some institutions to-day is such that they not only carry on their regular courses of instruction during the college year, but summer courses in the field, shop or mine are conducted, to give the student what practical experience is possible during his course of training. The regular recitations, lectures and laboratory work are supplemented by addresses by active men of experience and reputation, and by visits to manufacturing establishments and other places of interest for observation of the practical working out of the principles and methods of the classroom, together with the necessary modifications and changes to be made in formulas when applied to practice.

In addition to the regular undergraduate courses, some institutions are offering graduate courses in engineering leading to the master's degree, and in some cases to the doctor's degree. Although the number of students pursuing graduate courses in technical lines is small, yet Table IV. is not without interest, showing as it does the number of graduate students in engineering courses in 1889–90 and in 1899–1900 in the eighty colleges previously considered.

TABLE IV.

	1889–1890.	1899–1900.	Increase.	Per cent Increase.
C. E.	32	45	13	41
M. E.	21	49	28	133
Mn. E.	17	35	18	106
E. E.	19	27	8	42
S. E.	..	..	..	..
Ch. E.	1	..	—1	—100
A.	..	2	2	..
N. A.	..	..	..	..
Totals	90	158	68	76

The sums spent annually upon the engineering institutions of this country are almost fabulous, yet the results seem to warrant such expenditure, for, judging from the past, much of the progress and welfare of the nation depends upon the successful education and training of its engineers.

An attempt was made to ascertain not only the annual tuition, but also the other fees that are charged to the student, and the annual cost to the institution per year per capita for running its technical department. It was intended to determine as closely as possible the excess in the cost to the institution for each student over the amount received. Several difficulties have arisen in this effort, the chief one being that ten institutions only gave any figures regarding the cost per year per capita. The annual fees were found to be so variable that little of definite form could be obtained, but it seems that in most cases the fees are for materials used, or for breakage, and, with the possible exception of matriculation or graduation fees, the income and output would about balance. The ten institutions that reported upon the approximate cost per year per capita for running their engineering departments are listed below. R. indicates resident, N. R. nonresident.

COLLEGE.	Charge for Tuition.	Approx. Cost per Year per Capita.	Cost to Institution above Tuition.
Alabama Polytechnic Institute.....	(R.) Free, (N. R.) $20	$ 25	(R.) $25, (N. R.) $5
Case School of Applied Science....	$100	350	$250
Colorado School of Mines............	(R.) Free, (N.R.) $100	200	(R.) $200, (N.R.) $100
Kansas Agricultural College........	Free	39	$ 39
Mass. Institute of Technology......	$200	335	135
Michigan College of Mines..........	(R.) $25, (N.R.) $150	385	(R.) $360, (N.R) $235
Montana Agricultural College......	$12	150	$138
Rose Polytechnic Institute..........	75	350	275
Stevens Institute......................	(R.) $100, (N.R.) $225	275	(R.) $175, (N.R.) $50
Worcester Polytechnic Institute...	$150	290	$140

Of the sixty six institutions reporting upon the amount of tuition, sixteen offer free tuition and seven others offer free tuition to residents but charge tuition to non-residents. In all thirteen of the sixty six seem to discriminate between residents and nonresidents.

About 20 per cent of the institutions reporting charge at least $100, but not over $150, while only three receive more than $150, and each of these makes its tuition $200. One institution, charging $100 for residents, advances its tuition to $225 for nonresidents.

The development of the various departments of engineering has been closely connected with similar progress in the practical application of these branches in the engineering world. Which may be considered the result of the other is not definitely determined; that is, did the demand necessitate education in these special lines, or did the development of certain special features in the educational institutions lead to the discoveries and application of the new methods and processes? The two conditions are closely related, and it is probable that the one stimulated the other. In this connection Professor F. R. Hutton has said: "It has been well pointed out that the industrial development of a country is progressive, and begins with a call, first, for the hunter and trapper; secondly, for the pioneer settler; thirdly, for the mining engineer and agriculturist; fourthly, for the civil engineer and specialist in transportation problems, and lastly, for the engineer who will develop manufacturing. It is presumed that this historical trend explains the development, throughout New England and the eastern and middle states, of the colleges and courses in mechanical and electrical engineering. It explains in part why one course catches up to, transcends and falls behind another, in spite of the best reputation, equipment and facilities of that other."

The recognized standing of the graduates of these engineering schools to-day is without question, a great change for the better having taken place in the past twenty years, and to-day the technically educated man of ability is looked upon with favor by the officials of large corporations, and his position is practically assured. The very fact that he has to apply himself more closely and finds his course of training more rigorous than in the older courses for corresponding training in law, medicine or similar professions, has tended to place the work of the engineer upon a basis not only commanding respect, but making the profession a learned profession in the highest sense, for to-day no other department requires more work or a better quality of work of its students than is required of the student of engineering.

Possibly the most unfavorable criticism that can be offered concerning the present engineering school is its tendency to become too technical, in some cases not devoting the attention necessary for developing the man, as a man, in addition to developing him as a machine. The limited time at command and the extensive ground that must be covered make the avoidance of this tendency a serious question. The cultivation of those qualities which make the man is of the greatest importance, and should not be lost sight of in the endeavor to secure what appears to the average young man of immature development and restless ambition as the so-called bread and butter education. Unfortunately, there is a tendency on the part of many students in technical institutions to look upon general or culture subjects with disfavor, or at least with the thought that they are of no direct value in earning a living, and hence would better be left out of the course, or, if taken, should be regarded as secondary.

It is Pope who says:

"A little knowledge is a dangerous thing.
Drink deep or taste not the Pierian spring,
There shallow draughts intoxicate the brain,
And drinking deeply sobers it again."

The condition above referred to can be changed only by degrees. The experience of former generations will tend to correct this fault to some extent in the future, but the opportunity for direct improvement lies within the institutions themselves. Some institutions are at present fairly rigid in regard to requirements in courses of a purely general character, but with many these requirements are too easily modified, while with some, if not all, the tendency to specialize is so strong that the greater portion of the culture subjects have been forced from the curriculum.

The results of the excellent work of these progressive institutions are readily seen in the great engineering feats of the past few years, in the growth and prosperity due to such achievements, in the accomplishments due to engineering training in our recent war, and one need only trace these results to their sources to be convinced that the engineering school of to-day is a powerful factor in a nation's civilization and development, as well as in the general progress of the world. For the men who are achieving these results are men whose earnestness of purpose and appreciation and respect for the laws governing existing conditions have been guided and strengthened by these institutions—institutions whose aim has been to develop serious thought, power to weigh facts, ability to probe the reasons and laws producing given conditions, a true respect for the opinions and judgment of others—a comprehension of facts and conditions as they exist to-day, and the power so to modify, improve or take advantage of these facts that new and better conditions and opportunities shall be open to him who enters the world to-morrow.

Herbert Spencer, in referring to the schools of England, might have referred with equal force to the schools of the United States when he wrote: "That which our school courses leave almost entirely out we thus find to be that which most nearly concerns the business of life. All our industries would cease were it not for that information which men begin to acquire as they best may after their education is said to be finished. And were it not for this information, that has been from age to age accumulated and spread by unofficial means, these industries would never have existed." It is this very field that the engineering schools have filled and are filling so acceptably to-day. Their wonderful growth has exceeded all expectation, and the quality of their work has made for them a position surpassed in importance by no other educational development of the past century. No finer tribute to the work of the engineering school can be paid than the following from an address delivered by that able and noted educator, Gen. Francis A. Walker, at McGill university in 1893.

"The growth of scientific and technical schools on this continent during the past thirty years has savored of the marvelous.

"The notion that scientific work was something essentially less fine and high and noble than the pursuit of rhetoric and philosophy, Latin and Greek, was deeply seated in the minds of the leading educators of America a generation ago. And it has not even yet wholly yielded to the demonstration offered by the admirable effects of the new education in training young men to be as modest and earnest, as sincere, manly and pure, as broad and appreciative, as were the best products of the classical culture, and withal, more exact and resolute and strong. We can hardly hope to see that inveterate prepossession altogether disappear from the minds of those who have entertained it. Probably these good men will have to be buried with more or less of their prejudices still wrapped about them; but from the new generation scientific and technical studies will encounter no such obstruction, will suffer no such disparagement.

"The practical uselessness, for any immediate purpose, of a given subject of study may be no reason why it should not be pursued; but, on the other hand, the high immediate usefulness of a subject of study furnishes no ground from which the educator of loftiest aims and purest ideals should regard it with contempt or distrust. In either case, the question of real import is in what spirit the study is pursued.

"I know the scientific men of America well, and I entertain a profound conviction that in sincerity, simplicity, fidelity, and generosity of character, in nobility of aims and earnestness of effort, in everything which should be involved in the conception of disinterestedness, they are surpassed, if indeed they are approached, by no other body of men."

HOW THE AMERICAN SHOE HAS BECOME STANDARD.

BY GEORGE HOUGHTON.

[George C. Houghton, secretary of the New England Shoe and Leather association, is the leading authority on the subject in the United States and has written the most authoritative historical sketches of the industry and descriptions of its methods. He has been a prominent factor in the extension of the foreign market for shoes and in this connection has made several trips abroad for the association. He has also had charge of government investigations into the industry.]

Few industries, in their evolution, offer a more interesting history than the manufacture of boots and shoes. Supplying, as the shoemaker does, a necessity common to all civilized people, his progress is due to the fact that the number of wearers increases each year, and the demand for his products continues in an ever widening ratio. The history of this branch of manufacturing, as it has progressed from the shoemaker's bench, where shoes were turned out one at a time, to the modern factory with its output of thousands of pairs daily marks, as do few others, the remarkable industrial progress of the present age.

The introduction of the boot and shoe industry in America is almost coincident with the first settlement of New England, for it is a matter of history that in the year 1629 a shoemaker named Thomas Beard, with a supply of hides, arrived on board the Mayflower. This pioneer of the American boot and shoe trade was accredited to the governor of the colony, by the company in London, at a salary of £10 per annum and a grant of 50 acres of land, upon which he should settle. Seven years after the arrival of Beard, the city of Lynn saw the inception of the industry which has given it a world wide fame, for there, in 1636, Philip Kertland, a native of Buckinghamshire, began the manufacture of shoes, and fifteen years later the shoemakers of Lynn were supplying the trade of Boston. As early as 1648, we find tanning and shoemaking mentioned as an industry in the colony of Virginia, special mention being made of the fact that a planter named Matthews employed 8 shoemakers upon his own premises. Legal restraint was placed upon the business of the cordwainer in Connecticut in 1656, and in Rhode Island in 1706, while in New York the business of tanning and shoemaking is known to have been firmly established previous to the capitulation of the province to the English, in 1664. In 1698 the industry was carried on profitably in Philadelphia, and in 1721 the colonial legislature of Pennsylvania passed an act regulating the materials and the prices of the boot and shoe industry.

During the revolutionary war most of the shoes worn by the continental army, as well as nearly all ready made shoes sold throughout the colonies, were produced in Massachusetts, and we find it recorded that for quality and service they were quite as good as those imported from England. Immediately after the revolution, in consequence of large importations, the business languished somewhat. It soon recovered, however, and was pursued with such vigor that in 1795 there were in Lynn 200 master workmen and 600 journeymen, who produced in the aggregate 300,000 pairs of ladies' shoes. One manufacturer in seven months of the year 1795 made 20,000 pairs. In 1778 men's shoes were made in Reading, Braintree, and other towns in the old colony for the wholesale trade; they were sold to dealers in Boston, Philadelphia, Savannah, and Charleston, a considerable portion being exported to Cuba and other West India islands.

About the year 1795 the business was established in Milford and other Worcester county towns, where brogans were made, and sold to the planters in the southern states for negro wear. The custom at this time was for the manufacturer to make weekly trips to Boston with his horse and wagon, taking his goods in baskets and barrels, and selling them to the wholesale trade.

Prior to 1815 most of the shoes were hand sewed, a few having been copper nailed; the heavier shoes were welted and the lighter ones turned. This method of manufacture was changed, about the year 1815, by the adoption of the wooden shoe peg, which was invented in 1811 and soon came into general use. Up to this time little or no progress had been made in the methods of manufacture. The shoemaker sat on his bench, and with scarcely any tools other than a hammer, knife, and wooden shoulder stick, cut, stitched, hammered, and sewed, until the shoe was completed. Previous to the year 1845, which marked the first successful application of machinery to American shoemaking, this industry was in the strictest sense a hand process, and the young man who chose it for his vocation was apprenticed for seven years, and in that time was taught every detail of the art. He was instructed in the preparation of the insole and outsole, depending almost entirely upon his eye for the proper proportions; taught to prepare pegs and drive them, for the pegged shoe was the most common type of footwear in the first half of the last century; and familiarized himself with the making of turned and welt shoes, which have always been considered the highest type of shoemaking, requiring exceptional skill of the artisan in channeling the insole and outsole by hand, rounding the sole, sewing the welt, and stitching the outsole. After having served his apprenticeship, it was the custom for the full fledged shoemaker to start on what was known as whipping the cat, which meant travelling from town to town, living with a family while making a year's supply of shoes for each member, and then moving on to fill engagements previously made.

The change from which has been evolved our present factory system, began in the latter part of 1700, when a system of sizes had been drafted, and shoemakers more enterprising than their fellows gathered about them groups of workmen, and took upon themselves the dignity of manufacturers. The entire shoe was then made under one roof, and generally, from leather that was tanned on the premises; one workman cut the leather, others sewed the uppers, and still others fastened uppers to soles, each workman handling only one part in the process of manufacture. This division of labor was successful from the very start, and soon the method was adopted of sending out the uppers to be sewed by the women and children at their homes. Small shops were numerous throughout certain parts of Massachusetts where the shoemaker, with members of his family or sometimes a neighbor, received the uppers and understock from the factories near by, bottomed the boots and shoes, and returned them to the factories, where they were finished and sent to the market packed in wooden boxes. Thus the industry developed and prospered and was carried on without any further improvement in methods until the introduction of machinery a little more than a half century ago.

The first machine which proved itself of any practical value was the leather rolling machine, which came into use about 1845 and with which it was said a man could do in a minute what would require half an hour's hard work with a lapstone and hammer. This was closely followed by the wax thread sewing machine, which greatly reduced the time required for sewing together the different parts that formed the upper, and the buffing machine, for removing the grain from sole leather. Then came a machine which made pegs very cheaply and with great rapidity, and this in turn was followed by a hand power machine for driving pegs. In 1885 there was introduced the splitting machine, for reducing sole leather to a uniform thickness. Peg making and power pegging machines were soon perfected and there had appeared a dieing out machine, which was used for cutting soles, taps, and heels by the use of different sized dies. The year 1860 saw the introduction of the McKay sewing machine, which has perhaps done more to revolutionize the manufacture of shoes than any other single machine. The shoe to be sewed was placed over a horn and the sewing was done from the channel in the outsole, through the sole and insole. The machine made a loop stitch and left a ridge of thread on the inside of the shoe, but it filled the great demand that existed for sewed shoes, and many hundreds of millions of pairs have been made by its use.

At the time of the introduction of the McKay machine, inventors were busy in other directions, and, as a result, came the introduction of the cable nailing machine, which was provided with a cable of nails, the head of one being joined to the point of another; these the machine cut into separate nails and drove automatically. At about this time was introduced the screw machine which formed a screw from brass wire, forcing it into the leather and cutting it off automatically. This was the prototype of the rapid standard screw machine, which is a comparatively recent invention and is very widely used as a sole fastener at the present time on the heavier class of boots and shoes. Very soon thereafter the attention of the trade was attracted to the invention of a New York mechanic for sewing of soles. This device was particularly intended for the making of turn shoes and afterwards became famous as the Goodyear turn shoe machine. It was many years before this machine became a commercial success, and mention of its progress is made later.

Closely following the Goodyear invention came the introduction of the first machine used in connection with heeling —a machine which compressed the heel and pricked holes for the nails—and this was soon followed by a machine which automatically drove the nails, the heel having previously been put in place and held by guides on the machine. Other improvements in heeling machines followed with considerable rapidity, and a machine came into use shortly afterwards which not only nailed the heel but was also provided with a hand trimmer, which the operator swung round the heel immediately after nailing. From these have been evolved the heeling machines in use at the present time.

Notable improvements had during this time been made in the Goodyear system, and a machine was made for the sewing of welts, which was the foundation of the Goodyear machine now so universally used. This machine sewed from the channel of the insole through upper and welt, uniting all three, and was a machine of the chain stitch type which left the loop on the outside of the welt. This machine was closely followed by the introduction of one which stitched the outsole, uniting it to the welt by a stitch made from the channel in the outsole, through outsole and welt. This machine afterwards became famous as the Goodyear rapid outsole lock stitch machine. The great demand that existed for shoes of this type made it necessary that accessory machines should be invented, and those which prepared the insole, skived the welt, trimmed the insole, rounded and channeled the outsole, as well as a machine which automatically rolled or leveled the shoe, and the stitch separating machine, were soon produced. These formed the Goodyear welt system which has been the subject of constant improvement up to the present time and is now in use wherever shoes of a higher class are made.

At the time the first standard screw machine was attracting attention, the heel trimming and forepart trimming machines were brought out. This part of the work had previously been done by the hand workman, using a shave or knife for trimming, and as he was entirely dependent upon the eye for the proper proportions of the finished sole, the work was not often of a very uniform nature. The heel and forepart trimming machines greatly reduced this part of the labor, and their adoption was very rapid.

In the early seventies came a change in a department of shoemaking which, prior to that time, had been regarded as a confirmed hand process. This was the important part of the work known as lasting; and a machine was introduced at that time for doing this work. This machine, as well as those which followed afterwards for a period of twenty years, was known as the bed type of machine, in which the shoe upper was drawn over the last by either friction or pincers, and then tacked by the use of a hand tool. At a comparatively recent period another machine which revolutionized all previous ideas in lasting was introduced. This machine is generally in use at the present time and is known as the consolidated hand method lasting machine. It was fitted with pincers which automatically drew the leather round the last, at the same time driving a tack which held it in place. This machine has been so developed that it is now used for the lasting of shoes of every type, from the lowest and cheapest to the highest grade, and it is a machine that shows wonderful mechanical ingenuity.

The perfecting of the lasting machine has been followed recently by the introduction of a machine which performs in a most satisfactory way the difficult process known as pulling over, which consists of accurately centering the shoe upper on the last and securing it temporarily in position for the work of lasting. The new machine, which is known as the hand method pulling over machine, is provided with pincers, which close automatically, gripping the shoe upper at sides and toe. It is fitted with adjustments by which the operator is enabled to quickly center the shoe upper on the last, and, on the pressing of a foot lever, the machine automatically draws the upper closely to the last and secures it in position by tacks, which are also driven by the machine. The introduction of this machine marked a radical change in the one important shoemaking process that had up to this time successfully withstood all attempts at mechanical improvement. At about the time that lasting was first introduced there came the finishing machines, which were used for finishing heel and forepart. These machines were fitted with a tool, which was heated by gas and which practically duplicated the labor of the hand workman in rubbing the edges with a hot tool for the purpose of finishing them. From these early machines have been evolved the edge setting machines which are in use at the present time.

The lasting machine to attract the attention of the trade is one which, in the opinion of those well qualified to judge, is destined to revolutionize the making of that class of shoes which has heretofore been made on the McKay sewing machine. It is known as the universal double clinch machine, and forms a fastening of wire which is taken from a coil corrugated in the machine, and driven, one end being clinched back into the leather of the insole while the driven end is clinched into the leather of the outsole. It is further provided with an attachment which makes the channel in which the fastening is driven and afterwards closes it automatically. It makes a very comfortable, flexible, and durable shoe, and is being rapidly adopted by manufacturers.

At the present time the genius of the American inventor has provided for every detail of shoemaking, even the smallest processes being performed by mechanical devices of some kind. This has naturally made the shoemaker of to-day a specialist, who very seldom knows anything of shoemaking apart from the particular process in the performance of which he is an adept, and from which he earns a livelihood. The American shoe of to-day is the standard production of the world. It is in demand wherever shoes are worn, and although the tools which have made its production possible have been perfected in the face of most discouraging conditions and opposition, they are to-day classed among the most ingenious productions of a wonderfully productive epoch.

In 1855, William F. Trowbridge, of Feltonville, Mass. (then a part of Marlboro, now the town of Hudson), a partner in the firm of F. Brigham & Co., conceived the idea of driving by horsepower the machines then in use. In a building attached to the factory he established a sweep, around which a horse known for a score of years in that section as the "Old General" provided the first power other than manual which ever drove shoe machinery. For some years prior to that time two or three stout Irishmen had supplied the motive power in this factory. Soon afterwards steam power was used in the factory of John Hill & Co., of Stoneham; and one after another of the larger manufacturers throughout the eastern states found it necessary to adopt modern methods, so that after the year 1860 there were very few of any pretensions who did not use either steam or water power to drive their machinery. This opened up the way for numerous improvements. None was of more importance than the Howe sewing machine, which was now brought into general use. Waxed thread sewing machines were also introduced in 1857, by which the uppers of nearly all heavy shoes are stitched together. Buffing machines had been run by foot as far back as 1855, but were now all driven at high speed by power. Power machines for dieing out soles and heels were introduced in 1858.

An important feature of the boot and shoe industry is the use of lasts and the system of last measurements adopted by manufacturers. In the early fifties the methods in last and pattern making were very crude, although some of the boots and shoes made in those days were very fine in workmanship, and the amount paid to a workman for simply putting on the bottoms which was done by hand would, at the present time, purchase a good pair of shoes. Lasts were then made only in whole sizes, such a thing as half sizes being unheard of, and were of curious shapes; first, they would have very broad toes, then would go to the other extreme and run out so thin at the end that it was necessary to iron plate them. There were only two or three styles and widths, and one pattern would fit them all. Many of the women's lasts were made straight. Very little attention was given to the saving of stock in those days, and in the making of patterns one had only to get them large enough. At the present day the saving of stock in the making of patterns is of the greatest importance. The measurements must be absolutely retained. The character and style must be kept up; and the lines, proportions, and graceful curves must receive the most careful attention in all their details, as these are necessary to make up the symmetrical whole. The early method of producing patterns was largely by guess, and some, it is said, still cling to the old way. At one time what was called the English system was considerably used, the method being to take a piece of upper leather, wet and crimp it over the last, and let it dry. This gave the form of the last, and then the pattern was cut from stiff paper allowing for laps, seams, and folds. This method gave good results, providing that the person using it had good taste in putting style into the pattern. Later came the Radii system, which some are using at the present day. Still later came the Soule method, and a book was published describing that system. This method, which is said to produce very good results, is still being used by many pattern manufacturers, and also by local shoe pattern makers in many of the shoe factories of the country. Some of the most enterprising pattern makers of to-day, however, are using more modern methods. It is conceded that America leads the world in the manufacture of shoes, principally on account of superior style and workmanship; and the American last and pattern makers are entitled to a large degree of credit in establishing the character and style of the American shoe.

The following gives a fair idea of how a pair of shoes is turned out under modern methods in the factory of to-day: First, the cutters are given tickets describing the style of shoe required, the thickness of sole, and whatever other details are necessary. From this ticket the vamp cutter blocks out the vamps and gives them with the ticket to the upper cutter, who shapes the vamps to the pattern and cuts the tops or quarters which accompany them. The trimming cutter then gets out the side linings, stays, facings, or whatever trimmings are needed. The whole is then made into a bundle and sent to the fitting department. Here they are arranged in classes by themselves. Pieces which are too heavy are run through a splitting machine, and the edges are beveled by means of the skiving machine. Next they are pasted together, care being taken to join them at the marks made for that purpose. After being dried they go into the hands of the machine operators. The different parts go to different machines, each of which is adjusted for its particular work. The completed upper next goes to the sole leather room, in which department machinery also performs the major part of the work. By the use of the cutting machine the sides of leather are reduced into strips corresponding to the length of the sole required. These strips are passed through a powerful rolling machine, which hardens the leather and removes from its surface all irregularities. They are then shaved down to a uniform thickness, also by machinery, and placed under dies which cut them out in proper form. The smaller pieces are died out in the form of lifts, or heel pieces, which are joined together to the proper thickness and cemented, after which they are put in presses which give them the greatest amount of solidity. The top lift is not added to the heel until after it has been nailed to the shoe. The remaining sole leather is used for shank pieces, rands, and bottom leveling.

For the insole, a lighter grade of leather is used, which, being cut into strips and rolled, is cut by dies to the correct shape, shaved uniformly, and channeled around the under edge for receiving the upper. The counters are died out and skived, by machine, and the welts cut in strips. The uppers and soles are then sent to the bottoming department, where the first operation is that of lasting, the uppers being tacked to the insole. From the laster they go to the machine operator, where the upper, sole, and welt are firmly sewed together by the machine. The bottom is filled and leveled off and the steel shank inserted. Next, the bottom is coated with cement, and the outsole pressed on it by a machine. Thence it is sent through the rounding machine, which trims it and channels the sole for stitching. From there it goes again to the sewing machine, which stitches through the welt outside of the upper. The next step is that of leveling, then heeling, both of which processes are accomplished by machinery. The heels are nailed on in the rough and afterwards trimmed into shape by a machine operating revolving knives; a breasting machine shaping the front of the heel. Still another machine drives in the brass nails and cuts them off flush with the top pieces. The edging machine is next used, which trims the edges of both sole and heel. The sole bottom is then sandpapered, blacked, and burnished by machinery, after which the shoe is cleaned, treed, and packed.

The total floor space occupied by the shoe factories of the United States is practically 24,000,000 square feet, or about 550 acres.

The statistics of boot and shoe manufacture furnish an interesting commentary upon American enterprise, showing, as they do, the evolution of an industry from the smallest beginning and with the crudest appliances to a position that up to recent years equaled in importance that of any of the great industries of the country.

NEEDLES AND PINS.

BY CHARLES M. KARCH.

[Charles M. Karch, lawyer and statistician; born Mt. Hope, Ohio, January 13, 1873; educated at St. Lawrence university and Georgetown Law school; has been private secretary to Congressman John A. McDowell and John W. Cassingham; was employed as a statisticial expert at the twelfth census of the United States during which he made an investigation for the government of the manufacture of needles and pins.

The familiar and very commonplace article known as a pin is not without a history and an ancestry as old as the oldest. When pins were first used is difficult to determine, but it is safe to assume that in some form they were used by our remote ancestors. Nature gave man the pattern for a pin in the thorn, and the first pin used was, undoubtedly, this natural article, but later other materials were introduced for its construction. In the overhauling of ancient ruins, pins made of bone, ivory, bronze, copper, and iron have been found. The most prominent discoveries made in this line were in Egyptian and Scandinavian tombs and on sites of the ancient lake dwellings of central Europe. From the lacustrine stations in Switzerland alone more than 10,000 pins have been taken. These ancient pins are in various forms, and in cases where the ornamental head is used they are very curious and beautiful. They are longer than those now in use and differ from the modern pattern in that they taper gradually from the head to the point. Some were found in central Europe with double stems like the modern hairpin, and a few were found at Peschiera, Italy, fashioned like the modern safety pin. Many of the single stemmed pins varied in thickness, and others had heads formed of a loose ring in an eye at the blunt end.

The invention of the process of wiredrawing marked the beginning of the modern pin manufacture. The process originated in France and Germany, and for two centuries these countries monopolized all industries dependent upon it. The first man to manufacture brass pins in England was John

Tilsby, who, in 1626, established a plant in Gloucestershire, where he met with remarkable success, and his make of pins became famous. By 1636 the industry was so well established that the pin makers of London formed a corporation, and the trade soon found its way to Bristol and Birmingham, where, in connection with other ironwork manufacture, the industry became localized. In those cities pins were made for some time by hand labor. The construction of a single pin required from 14 to 18 different operators, and involved the following processes: Straightening and cutting the wire; cutting, printing, twisting the heads; cutting the heads; annealing the heads; stamping or shaping the heads; cleaning the pins; whitening or tinning the pins; washing, drying, and polishing; winnowing and pricking the papers to receive the pin. This method was improved upon by Timothy Harris, in 1797, who made the solid headed brass pin by laying the blanks into a two part mold in which prints representing the heads were cut. When the mold was closed an alloy of lead and antimony was poured in, and as soon as the pins were released the gets were cut off and the pins were cleansed by immersion in a solution of sulphuric acid and water, and then dipped into a solution of sulphate of copper and finished in the same way as other brass pins.

In 1812 Bradbury and Weaver conceived the idea of heading by means of an automatic machine. After the shanks were pointed and the heads prepared they were put into separate hoppers, where a mechanical device placed the shank and head into relation with each other. In this position the pins were pressed by screws against dies, which made the head and bound it to the shank, when they were withdrawn by hooks operated upon by parallels worked by the machine.

In 1817 Seth Hunt invented a machine to make the pin with head, shaft, and point from one piece, but his invention was not a success. In 1824 W. L. Wright, an American, a native of New Hampshire, invented the solid headed pin making machine, which entirely revolutionized the pin manufacture. He did not have his machine patented in America, but took it to England and put it into operation. He formed in London a company with a large capital, and built a good sized factory in Lambeth. A plant was fitted up at great expense with 60 machines, but they were never put into successful operation, as they failed in pointing the pin. Although Wright remedied this defect by a supplemental machine, the company did not succeed, and suspended operations with a great loss to those interested in the enterprise.

As early as 1812 the inventors of this country were using their energies to construct a machine for the manufacture of pins. The first machine made here, which was brought out by Moses L. Morse, of Boston, Mass., sometime during the war of 1812, proved too delicate and intricate to be used to much advantage and was soon abandoned. The man who did more to place the manufacture of pins by automatic machinery on a practical and successful basis in this country than any other one individual was Dr. J. I. Howe. In 1830 he began his labor in this direction, spending some of his time in Europe studying the methods employed there, and by the year 1832 he had patented in this country, France, and England, a machine designed to make pins similar to the English diamond pins, with heads formed of coils of small wire fastened upon the shank by pressure between dies. He brought the business to a successful issue in 1836, when the Howe Manufacturing company was formed in New York and began operations at Birmingham, Conn. At first automatic spun head machines were used, but in 1840 they were converted into solid headed machines. These latter machines at first made from 40 to 50 pins per minute. They were later improved so that they made from 60 to 70 per minute.

About 1835 Samuel Slocum, an American, obtained a patent in England for a machine to make solid headed pins. In 1838 he began with this machine the manufacture of pins in Poughkeepsie, N. Y. As he never had the machine patented here, it was operated secretly for a number of years. Until 1842 the industry made little progress because of discriminating tariffs. In this year, however, a new tariff law went into effect which was more favorable to this industry than the previous tariff act, and the business became very profitable. Led by exaggerated ideas which became prevalent as to the extent of the business and the profit made in it, many persons in different parts of the country invented machinery for the construction of pins. Attempts in this direction met with varying success, but the articles turned out were, with a few exceptions, inferior, and the market became overstocked. In consequence of this overproduction, by 1848 all parties engaged in pin making, except the two old companies at Poughkeepsie and Birmingham, suspended operation. In the year 1850 there were four establishments engaged in this industry, and the success attending them led to further improvements in the machines. A Mr. Fowler and a Mr. Atwood perfected machines to make 160 to 170 pins a minute which, on account of their capacity, soon replaced the early machines.

Following the successful introduction of a machine for making the pins, the next important step was to invent a machine that would stick them on paper. Howe and Slocum gave their attention to this matter as early as 1840. Dr. Howe invented the device for crimping the paper, and this was followed by the distributer of Mr. Slocum. The two inventions were combined and effected a great increase in the number of pins that could be stuck on paper in a day. These devices were improved upon by Mr. De Grasse Fowler, who invented the goose neck or runway. For many years the sticking machines consisted of a combination of these three devices, but more recently machines of various styles have come into use that will stick from 500 to 600 packages a day, far more than the early combined machine of Howe, Slocum, and Fowler.

The old process of pin manufacture by manual labor was very slow and tedious, since each pin passed through the hands of from 14 to 18 individuals. The modern pin is made in the United States by the improved Atwood or Fowler machines. The process of pin manufacture by modern machines may be briefly described as follows: Coils of wire are placed upon a reel, whence the wire is drawn automatically by a pair of pincers between fixed studs that straighten it. A pin length is then seized by a pair of lateral jaws, from which a portion of the wire is left projecting, when a snaphead die advances and partially shapes the head. The blank is then released and pushed forward about one twentieth of an inch, when the head is given another squeeze by the same die. By this repetition of the motion the head is completed and the blank is cut off the wire in the length desired. About one eighth of an inch of wire is required to make a pin head. If the attempt were made to upset this with a head in one motion the wire would be more likely to double up than to thicken as desired.

These headed blanks then drop into a receptacle and arrange themselves in the line of a slot formed by two inclined and bevel edged bars. The opening between the bars is just large enough to permit the shank of the pin to fall through, so that the pins are suspended in a row along the slot. When the blanks reach the lower end of the inclined bar in their suspended position they are seized between two parts of the machine and passed along, rotating as they move, in front of a cylindrical cutter, with sharp grooves on its surface, that points the pins. They are then thrown from the machine properly shaped, and if they are brass pins they are cleaned by being boiled in weak, sour beer. After they are cleaned they are coated with tin. This is done by placing alternate layers of pins and grain tin in a copper can and adding water, along with some bitartrate of potash. Heat applied to this produces a solution of tin which is deposited on the surface of the pins. The pins are then taken from this solution and brightened by being shaken in a revolving barrel of bran or sawdust. Lastly the operation of papering takes place. This process is performed now by an automatic papering machine something in the following manner: The pins to be stuck are placed in a hopper, in connection with which a steel plate is used, with longitudinal slits corresponding to the number of pins which form a row in the paper. The pins in the hopper are stirred up by a comb like tool, the shanks drop through the slits in the steel plate, and the pins are suspended by their heads. Long narrow sheets of paper are presented by the operator to the action of the machine, by which two raised folds are crimped, and the row of pins collected in the slit steel plate is then, by being subjected to the same action, pressed through the two crimped folds. These operations are repeated until the requisite rows of pins are stuck in each paper.

Needle making was one of the first arts practiced by man, and no doubt dates back to the remote period when man first strove to shape clothing to his figure.

In its primitive pattern the needle was an awl shaped instrument, which merely perforated the materials meant to be fastened together along their edges, so that they could be laced together by hand. As the use of this needle involved two operations, it was soon displaced by a needle which had a circular depression near the blunt end for holding the thread, and thus did away with the lacing operation. Since this needle, though it did well enough for coarse work, was inadequate for finer work, the needle with the eye was introduced.

Since the introduction of the steel needle the model has remained the same and progress in the art of needle making has been confined to devices for perfecting the material used and the methods of construction. In the early days of needle manufacture, when the trade was practiced at home or in small shops, the materials and devices used were very crude. After the manufacture of the needle was started in plants provided with conveniences and facilities for its production, improvements were slowly introduced in performing the different operations.

The most notable improvements prior to 1870 may be summarized as follows: Drill eyed needles were first made in 1826 and were followed two years later by the burnishing machine, by means of which the eye secures its beautiful finish. In 1840 the process of hardening in oil succeeded the former method of hardening in water, in which a large percentage of the needles became crooked, so that their straightening involved considerable time and expense. The stamp to impress the print of the groove and the press with a punch to pierce the eye, though suggested as early as 1800, were not in general use until 1830, and by 1886 were superseded by an automatic machine. In 1839 a simple method was invented by a Mr. Morrall for polishing many thousands of needles simultaneously, and in 1869 a machine was brought out by a Mr. Lake for doing many of the operations previously performed by hand. The more recent improvements have been made in devices for heating and ventilating, and for getting rid of the injurious dust which rises from the emery wheel in the grinding process.

To what extent, if any, the making of hand sewing needles was carried on in America during colonial times we have no means of knowing, but it is safe to assume that they were manufactured to some extent, for Bishop in his History of American Manufactures, Volume I., states that as early as 1666 Lynn artificers applied to the court of Plymouth colony for the sum of £15 for the purchase of tools for wiredrawing to make pins and needles; which sum being granted, the tools were bought and the manufacture began. He further states that Jeremiah Wilkinson, of Cumberland, R. I., made needles in that place in 1775 from wire drawn by himself; and that the colonists of the Carolinas at a convention at Newbern, on the 3d of April, 1775, encouraged the manufacture of pins and needles by offering a bounty to the person who should manufacture the first of these articles equal to those made in England.

Needle manufacture as an industry, however, was not put on a permanent basis in the United States until after 1852, when the peculiar kind of needles used in machinery was introduced. As the sewing machine is essentially an American production, and the most important feature of the invention of the machine was the needle constructed by Elias Howe for the making of the lock stitch, it was very natural that this part of the sewing machine should be manufactured in this country. It is estimated that from 6 to 8 per cent of all the operative labor involved in the construction of the sewing machine is employed in making the needle. With the successful manufacture of the different varieties of sewing machine needles, began the manufacture of needles for knitting machines. As the demand for sewing and knitting machines increased there was a corresponding demand for the needles used in these machines, and the industry developed rapidly.

The needles made are of various lengths and patterns to suit the requirements of the different sewing machines. Besides those differing generically, such as straight and curved, or specifically, such as long, short, round pointed, and chisel pointed, there are many peculiar patented needles for use in particular sewing machines. Among the endless varieties of sewing machine needles the most prominent is the common needle used in the household sewing machine. This needle has the eye at the pointed end, with a long groove on one side and a short groove on the opposite side, and is used in connection with a shuttle or other device for carrying a second thread, which is passed through a loop of the thread in the needle, thus forming the double lock stitch. The purpose of the grooves is to protect the thread from wearing or tearing in the operation of the machine.

In addition to the common household sewing machine needles there are needles for use in sewing leather, including many varieties to suit the various machines. Some of these needles, in distinction from the common sewing machine needles, have a hook instead of an eye. The material to be sewed is perforated with an awl, and the thread is then pulled through by the hook. In most leather sewing machines, however, the needle itself perforates the material and pulls the thread through. In sewing cloth only the needle with a round point is used; but for sewing leather there are points of various shapes, known as twist, reverse twist, wedge, cross, chisel, reverse chisel, and diamond. A very interesting needle, used in the manufacture of boots and shoes, is that of the Goodyear welting machine. This needle is a segment of a circle in shape and puts welts upon boots and shoes with remarkable rapidity and accuracy.

The steel spring and latch needles used in making hosiery and in stockinet work are extensively manufactured in the United States. The former is constructed by reducing the working end on a taper to an approximate point, and then bending the reduced portion over upon itself so as to form an open loop, a groove having been previously made in the needle so as to come opposite the point. In the operation of the needle the point stands out at the proper time for the yarn to be taken, which is to be carried through to form the stitch. As the forward motion continues the point is depressed into the groove by coming in contact with mechanism arranged for the purpose, and thus the passage through the loop is secured without catching. The latch needle has, instead of the spring barb, a short rigid hook, which is formed by tapering the working end to an approximate point and bending it in combination with the latch. The latch is contained in a groove milled in the body of the needle and is pivoted upon a rivet which passes through the wall of the groove. As the latch, the walls between which it is riveted, and the diameter of the rivet are extremely delicate, each part being but one one hundredth part of an inch thick, great care and skill must necessarily be exercised in manufacturing this needle. The purpose of the latch is to aid in forming and casting off the stitch by preventing the yarn from being caught under the hook except at the proper time.

When the sewing machine needle was first made here the processes of its manufacture were similar to those employed in England in making the common hand sewing needle, and required a great deal of manual labor. The reducing of the shank to the required size and putting in of the grooves on the sides of the needle was accomplished by stamping between dies. By this method the superabundant material was thrown out at each side as a fin, cut off by hand shears, and later removed by means of a die and punch in a press, after which the needles were rounded up and pointed by filing. Gradually these operations were replaced by rolling, grinding, turning, and milling, and finally machinery was invented to do the work.

In the course of the manufacture of the sewing machine needle it passes through the following states: Blank, reduced blank, reduced and pointed blank, grooved, eye punched, hardened and tempered, hard burr dressed, brass brushed, eye polished, first inspection, hard straightened, finish pointed, and finished. There are two methods in use for the manufacture of the modern sewing machine needle. In most respects these processes are similar, but they differ in the manner of forming the blade. In one method the blade is formed by cutting the blank down to its required size, and in the other method the wire is cut into short pieces about one third the required length of the needle when finished, and then by a process known as cold swaging these are brought to the proper length.

As the modern machinery used in the first process mentioned is largely of private designs, the manufacture can not be described in detail, but it may fairly be inferred from the following method used a few years ago: At that time the needle was made from the best quality of crucible steel wire, which was received in coils, and after being straightened by means of automatic machinery was fed into a machine devised to form the large end of the needle and cut off blanks of the required length. The blanks were then sent to machines, three in number, for roughing, dressing, and smoothing. The first two worked with coarse and fine emery wheels, respectively, and the third with an emery belt. Into these machines the blanks were fed from a hopper onto a grooved endless traveling carrier, which exposed to the action of the emery wheel that portion of the blank which was to be reduced in diameter to form the shank of the needle. The portion not reduced was that designed to be placed in the end of the needle bar of the sewing machine. As the needles passed the emery wheel they were rotated by a pair of reciprocating plates, so that they were equally ground on all sides. After the process was completed by the emery wheel belt in the third machine, the needles were passed on to another machine where the taper pointing was done. When taper pointed the blank was passed to a machine where the two grooves on the sides of the needle were made by two circular saws past which the blank was fed automatically. The saws were pressed in against the needles and then withdrawn at such times as would give the required depth and contour to the groove. The eye was then punched by a belt driven punching machine, after which the needles were heated to a cherry red in a reverberatory furnace with a charcoal fire, taken out and immersed in whale oil. They were then placed in sheet iron pans suspended from the arms of a revolving shaft, and tempered in an oven heated by the surplus heat of the furnace. Next, the needles were cleaned on an emery cloth, being held in bunches of about 20 between the finger and thumb and rotated while being pressed upon the cloth. They were then taken, with the grooves upward, by flat jawed tongs carrying 70 at a time, and held against a scratch brush of brass wire, which revolved 8,000 times a minute, to polish the grooves. The brush of brass wire was soon replaced by a bristle brush, which finished the polishing of the grooves. While yet held in the clamps these needles were threaded in gangs on cotton thread, which was covered with oil and emery, and then drawn back and forth in various slanting positions so that the polishing powder would act on all parts of the eye. When removed from the thread the needles were cleaned by a revolving hairbrush, and the eyes, points, and blades inspected. Imperfect ones were thrown aside and the good ones sent to the hand straightener, who rolled them on an anvil at the level of the eye of an operator, who detected any curvature and corrected it by a tap of a small hammer. The final operations were finish pointing, which was done on a fine emery wheel, and finish polishing, done by a revolving hairbrush with crocus and alcohol.

In the second method of manufacture the wire is fed into a machine called the straightener and cutter, which straightens the wire and cuts the blanks into pieces about one third the length required for the finished needle. The blanks are then placed in small iron cylinders rotated in such a manner as to keep the blanks in constant friction, and thus remove the scale and dirt. They are then ready for the cold swaging machine. The blanks are placed in a hopper, from which they are taken automatically, one at a time, and their ends are presented to the action of a set of revolving sectional steel dies. By the constant opening and shutting of these dies while in rotation the ends of the blanks are compressed and drawn out to form the blades. After swaging the blank is stamped in order to identify it. In the process of swaging there results a slight variation in the length of the needles, and they are trimmed to a uniform length by the clipping and straightening machine. The prominent feature of this machine is the arrangement of the screw feed for simultaneously carrying the needles across, so that the ends of the shanks are aligned against a fence, and forward, so that the points are presented to a cutter which trims all to a uniform length. After passing the cutter each needle is struck by a die that stamps upon its shank the descriptive number. The other processes involved in this method of needle manufacture are similar to those described in the first method.

Since the invention of automatic machines for the different processes, the mechanism employed has been so combined as to effect a transfer of the blank from one operation to the next without the intervention of hand labor. In such combination of machinery there has been marked development during the past fifteen years, and the industry has fully kept pace with the progress of other wireworking processes.

THE SEWING MACHINE.

BY JOHN A. BOSHARD.

[John A. Boshard, statistician and expert in the history and manufacture of sewing machines; born in Utah; after doing work for newspapers and magazines entered the manufactures division of the United States census office; was employed in the compilation of statistics relating to sewing machines and in behalf of the government made a thorough investigation also of the history of the invention and its improvements, preparing a monograph on the subject for publication by the department of commerce and labor.]

The mechanical development of the sewing machine has been almost wholly confined to the United States and has been accomplished within the last half century. The census of 1860 for the first time shows the statistics of sewing machine manufacture. From the time the first sewing machine patent was issued to John J. Greenough in 1842, until the year 1900 the total number of patents issued in the United States on sewing machines and attachments was 8,493, of which only 10 were issued prior to 1850. During the four decades following 1850 the increase in the number of patents issued was remarkable, especially between 1870 and 1880, and 1880 and 1890, the number of patents issued during those decades being 2,327 and 2,807, respectively.

It was little over fifty years ago that Elias Howe, Jr., patented his first sewing machine, which event marks the actual beginning of the industry in the United States. Previous efforts to produce machines for stitching cloth and other materials had either resulted in failure or met with but temporary success. Only the most important of these will be discussed. One of the earlier principles whose application to mechanical sewing was attempted was that of the through-and-through stitch and short thread, and this principle was persistently followed up by inventors long after the introduction of the eye pointed needle and continuous thread.

The double pointed needle with the eye located in the center was the first to be applied to mechanical sewing, and was introduced by Charles F. Weisenthal in England, where he secured a patent June 24, 1755. The needle was intended only for hand embroidery, and not until 1770 was the principle applied to sewing machines. In this year Thomas Alsop patented a machine in England which used the double pointed needle for embroidery purposes. Later, in 1804, a machine for embroidering in a loom with a large number of needles was conceived by John Duncan, and the idea was still further carried out and perfected in Heilman's embroidering machine patented in England in 1829. The first officially recorded attempt made in the United States to construct a sewing machine on the principle of the short thread and double pointed needle was by John J. Greenough, who built and patented a machine in 1842. It was designed for sewing leather and other hard material, an awl piercing a hole in advance of the needle. The material to be sewed was held between clamps provided with a rack, which was moved both ways alternately, to produce a back stitch, or continuously forward to make the shoemaker's stitch. The material was fed automatically the length of the rack bar, at a rate determined by the length of stitch required. The needle was passed through and through the material by means of pincers traveling on a rack, the thread being drawn out by weights. When the thread became too short or was broken, the machine stopped automatically.

Greenough's sewing machine, like similar attempts at mechanical stitching which embodied the features of the through-and-through stitch and short thread, was of no practical use; but it possessed some valuable points, and holds a creditable place in the history of the industry.

Inventors early sought to apply the old crochet stitch to mechanical sewing. Among the records of the English patent office has recently been found the design of a sewing machine intended to execute the old crochet stitch, which was patented by Thomas Saint, July 17, 1790. This machine is the first attempt at mechanical sewing, so far as any official record shows, and this makes more remarkable the fact that many of the essential features of the modern sewing machine are embodied in the design of the Saint machine. These features are crude, it is true, and may never have been practical in their operation; but the fact remains that the horizontal feed plate, the overhanging arm carrying on its end a vertically reciprocating straight needle, and the intermittent automatic feed were first incorporated in a design of over a century ago. It is not known that the machine of Thomas Saint ever existed save on paper, as the only history of the inventor or his machine is the record in the English patent office. If this record had been discovered twenty years earlier it might have changed the entire course of the sewing machine trade of the world, and would have weakened, if not destroyed, more than one of the patents since granted.

The first machine on official record which was put to practical use was patented by Barthelemy Thimonnier in France in 1830, and subsequently in the United States and England. This invention was so far successful that in 1841, 80 of the machines made of wood were in use for sewing army clothing in a shop in Paris. These were destroyed by a mob, as had been the Jacquard loom and similar labor saving devices years before. Thimonnier made another attempt in Paris to introduce his sewing machine and apply it to practical uses. He succeeded in producing a set of machines capable of making 200 stitches a minute, and sewing and embroidering any material, from muslin to leather. This set of machines was constructed of iron and followed the general model of the original machine, but with several improvements. In 1848 the inventor was again assailed by a mob, which destroyed all his machines and barely allowed him to escape with his life. The mob was composed of misguided champions of labor who feared that the introduction of this labor saving device would destroy the occupation of the seamstress. Time and experience have proven the fallacy of their judgment. The development of the sewing machine has opened up new fields of industry in all parts of the world and given employment to thousands of laborers. Its scope of usefulness is continually increasing, and it is constantly being introduced in varying forms into new channels of mechanical industry.

Thimonnier's machine, like the machine designed by Saint half a century earlier, was in the form which subsequent experience has justified; that is to say, it had the vertical needle descending from the end of an overhanging arm and piercing the goods, which were fed beneath upon a flat table. The needle was depressed by a treadle and cord and returned by a spring. This needle, which was a barbed or crochet needle, plunged through the goods, caught a lower thread from a thread carrier and looper beneath, and brought up a loop which it laid upon the upper surface of the cloth; descending again, it brought up another loop and enchained it with the one last made, forming a chain stitch consisting of a series of loops on the upper side.

Thimonnier's efforts to introduce his sewing machine were made very difficult on account of his poverty, and the repeated destruction of machines built with money solicited from friends, wearied at last even the admirers of his genius and energy, and he was left, in 1857, to die in poverty.

In England, in 1841, Newton and Archbold patented a chain stitch machine, using the eye pointed needle. The needle passed the thread through the cloth and formed a loop which was seized by a hook and carried forward. On its next trip the needle would pass through the loop thus made and form a single chain stitch.

The great advantages of the eye pointed needle, however, were never fully appreciated until the invention of the lock stitch, which is made by passing the thread through the fabric by means of an eye pointed needle, and then passing another thread through the loop thus formed, the second thread interlocking with the first in the middle of the fabric. This idea was first conceived about 1834 by Walter Hunt, of New York. He built a machine embodying the eye pointed needle and the shuttle, which, so far as is generally known, was never sufficiently perfected for practical use. He failed, however, to protect his ideas by patents, as required by law, and consequently failed to reap the reward of his genius. Hunt never fully appreciated the importance of the opportunity he had allowed to slip by until years later, when Elias Howe, jr., patented a machine which was similar in the results accomplished to his own. He then attempted to assert his prior claims to a patent, which was denied him on the ground of abandonment.

The sewing machine patented by Elias Howe, jr., September 10, 1846, technically marks the beginning of the industry in the United States. At this time the sewing machine was still in the experimental stage, and it was not until several years later that its manufacture became an established industry. After that its growth was rapid; and owing to the untiring energy and the ability of the inventors who applied themselves to the work of perfecting the sewing machine, it has attained in a few years a very important place among the industries of the country, and has come to be regarded as almost a household necessity.

Howe's invention combined the eye pointed needle with the shuttle for forming the stitch and the intermittent feed for carrying the material forward as each stitch was formed. The device for thus feeding the cloth consisted of a thin strip of metal provided with a row of pins on one edge, upon which the material to be sewed was carried in a vertical position. The cloth was fed the length of the plate, and had to be rehung as often as the plate had traversed its full length on the machine. The curved, eye pointed needle used was carried on the end of a vibrating lever, which also carried the upper thread. The shuttle, which passed the lower thread between the needle and the upper thread, was driven in its race between two strikers carried on the end of vibrating arms worked by cams. It is not known that any of Howe's machines were ever put upon the market. In his application for renewal of patent he only claims to have built three machines, and one of these was deposited as a model in the United States patent office.

Not meeting with any success in securing capital in this country with which to forward his plans, Mr. Howe was compelled to dispose of his patent, and with the proceeds went to England, where his rights to a patent had been sold to a corset manufacturer for about one thousand dollars. Mr. Howe engaged to work for this manufacturer at a small salary, while perfecting the machine, and adapting it to the manufacture of corsets. Failing in this he returned to the United States in extreme poverty, and upon his arrival at Boston, found that sewing machines infringing on his patents had been manufactured. He succeeded in securing a half interest that had been conveyed to his father before his departure for England, and commenced suits in the Boston and New York courts to enforce his rights. In the long and bitterly contested legal controversy which ensued, Mr. Howe succeeded in establishing his claims, after which manufacturers using his patents were compelled by the inventor to pay the exorbitant bounty of $25 for each machine manufactured.

The next fundamental and important step in the improvement of the sewing machine was conceived by John Bachelder, and patented May 8, 1849. His machine was the first to combine the horizontal table and continuous feed device. The feed consisted of an endless band of leather set with small steel points. These points projected up through the horizontal table and penetrated the material to be sewed, carrying it by an intermittent motion to and beyond the needle. This device has been entirely superseded by Allen B. Wilson's patent, November 12, 1850, of a four motion feed, which is noted for its simplicity of action and admirable adaptability to the purpose for which it was designed. Wilson's feed device consists of a serrated plate, which rises through a grove in the table on which the material is fed, and by a horizontal motion carries the material forward the length of the stitch, when it drops below the surface of the table and is carried back to its former position at the end of the groove, thus describing a motion following the four sides of a parallelogram. The cloth is held in place by means of a presser foot descending from the head of the overhanging arm. The motion which carries the cloth forward is so regulated as to take place while the needle is above the surface, and by limiting the extent of this motion the stitch is easily adjusted. The highest degree of credit as an inventor is due to Mr. Wilson for the ingenuity displayed by him in making and perfecting the four motion feed. His efforts, however, were not confined to this feature alone. In 1851 he patented a device for executing the lock stitch which consisted of a rotating hook used in place of a shuttle for interlocking the upper thread with the lower. This device, with some modifications and improvements, has become the distinguishing feature of certain modern sewing machines.

In September, 1850, Isaac M. Singer, a mechanic of New York, who had become interested in sewing machine experiments and was familiar with one of the machines then on the market, constructed a machine from a design of his own, which was a great improvement, in many ways, over previous machines. This was the first machine which had the rigid overhanging arm to guide the vertical needle, in combination with a shuttle, and was called a wheel feed. A patent for this machine was issued August 12, 1851. The general style of the original Singer sewing machine serves as a model for a large proportion of the sewing machines that are being manufactured throughout the world to-day. A straight shaft in the overhanging arm imparted the motion to the needle, and the shuttle was driven in its race below the feed table by a mechanism deriving its motion from the shaft by means of gearing. The feed consisted of an iron wheel with a corrugated surface, the top of which was slightly elevated above the level surface of the table. By an intermittent motion the feed carried the cloth forward between stitches without injury to the fabric. This device permitted the cloth to be turned in any direction by the operator while sewing, which was impossible with the styles of feed which perforated the goods. The material was held in place by a presser foot alongside the needle. This presser foot embraced an important feature possessed by no other sewing machine up to that time—the yielding spring, which would permit of passage over seams, and adjust itself automatically to any thickness of cloth. In addition to this original lock stitch machine, Mr. Singer afterwards contrived several inventions which contributed materially toward the improvement of the sewing machine. He produced a sewing machine which used the single chain stitch, and also a double chain stitch machine for ornamental work and embroidery.

The sewing machine had now arrived at a stage when all its essential features had been discovered by inventors and so far perfected as to demonstrate their practicability. It only remained for men of energy and business ability to apply themselves to the work of manufacture and to the development of facilities for marketing their products. Men who early appreciated the importance of the sewing machine as a factor in the commercial advancement of the world applied themselves with great zeal to the promotion of the industry. Factories were established in Bridgeport, Boston, New York, and other cities for the exclusive manufacture of sewing machines. Bridgeport has always held a conspicuous place in the industry, and the history of the development and manufacture of the sewing machine will always be closely associated with that city. The importance of New York city as a commercial center was early appreciated by sewing machine manufacturers, and it was made the principal sales depot for that industry by establishments located throughout New England. One of the leading concerns then in existence for the manufacture of sewing machines carried on its operations in New York city.

In 1855 litigation arose, involving three of the principal sewing machine companies then in existence. It was claimed by each of the parties concerned that the others were infringing upon certain of their patent rights. Numerous suits were instituted on these patents, and when the contesting parties finally came together in 1856 for trying some of the cases in court, an amicable settlement was agreed upon whereby the parties to the suits were to pool their patents, thus permitting any one of them to use the patents of all the others so far as might be necessary in the construction of their sewing machines, and to protect the interests of all from infringements by outside parties. These patents and privileges were not confined to the three original parties to the combination, but were available to all manufacturers upon the payment of a fee, which was very small compared with the exorbitant bounty collected by Howe. No restrictions were placed upon manufacturers in regard to the price at which their products were to be sold, and the markets were open to fair competition by all on the merits of the several machines. The combination continued in existence, with Mr. Howe as a member, until the expiration of the extended term of his patent in 1867, and was then continued by the other members until the expiration of the Bachelder patent in 1877.

The sewing machines manufactured prior to the Singer and many of them long after, used the vibrating arm for imparting motion to the needle. This result was accomplished either by means of the vibratory arm actuating a needle bar carrying a straight needle, or by means of the vibratory arm and curved needle. It is obvious that sewing machines constructed on either of these principles could not be enlarged or decreased in size without destroying their effectiveness; on the one hand the lengthening of the arm would naturally increase both the power required to operate it, and its liability to spring, and thus affect the proper action of the needle; on the other hand, decreasing the size of the arm would necessarily increase the curve of the needle and contract the space for turning and handling the work. Singer's arrangement of the rigid overhanging arm made it practicable to enlarge the machine to any desired extent, and added great solidity and strength to the machine, thus making it available either for doing the heaviest kind of work or for sewing the lightest fabrics. The general style of the original Singer machine has been universally copied, and serves as a model for most of the machines now manufactured.

The work of adapting the sewing machine to the various kinds of stitching required in the variety of manufacturing and mechanical industries to which it has been applied, was early taken up by Isaac M. Singer, Allen B. Wilson and others, and has been successfully continued by later inventors. Machines for stitching with waxed thread have been perfected for use in the factory manufacture of boots and shoes, as well as in the manufacture of saddlery and harness and various other articles of leather. Heavy power machines are used in the manufacture of awnings, tents, sails, canvas belts, and articles of a like nature. Specially constructed machines for stitching gloves, and others for sewing the seams of carpets, sewing the ends of filled bags, stitching brooms, embroidering, and doing various other work, are produced by the leading sewing machine manufacturers.

Machines for working buttonholes and sewing on buttons have been made very effective in their operation, and produce a quality of work equal to the hand product at a greatly increased rate of speed.

Inventions covering the sewing machine and its attachments are numerous, and patents for them are continually being granted. The same is true of the machinery used in producing the various interchangeable parts of the sewing machine. The American principle of making all parts of the machine interchangeable has been carried to the fullest extent in this industry. Machines for producing the most intricate parts of the sewing machine are so perfected that they perform their work with remarkable speed and exactness. The special tools required to make the various parts of sewing machines often require more inventive talent in their construction than the machine manufactured. In the larger factories the experimental department is one of the most important and expensive. Here the inventor has every facility for developing new ideas and putting the results to preliminary tests. When, after a great deal of time and labor has been expended on an invention, and it has reached an apparently perfect condition, it is sent to a factory engaged in the class of work for which it is designed, and is thoroughly tested. If its operation proves satisfactory, a special plant of machinery is installed for the manufacture of the new machine or attachment, so that any number of duplicates can be made. After all this expensive preparation and experiment the invention may be soon replaced by something better, and abandoned.

The American sewing machine from the first has enjoyed a large foreign sale on account of its recognized superiority over the machines manufactured abroad, which are usually copied after the models of the American machines. This is especially true in regard to the cases and wooden parts of the machine. The great abundance of timber products suitable for sewing machine woodwork produced in this country, and the superiority of the methods used in their production, have made possible competition by American manufacturers in the markets of Europe and elsewhere.

The cases and cabinets for export are usually forwarded in a rough or unfinished state for greater convenience in shipping, and for the further reason that the labor required to complete them can be secured much cheaper abroad than in this country.

A great deal of attention has been given by inventors to the production of a suitable means of propulsion for the sewing machine, thus doing away with the labor of operating it by the ordinary foot treadle. A great number of experiments have been tried with water motors, air engines, steam engines, and springs and weights, but no effective motor was produced until the introduction of electricity for power. Electric sewing motors are now produced which are very effective in their operation and can be readily used in their smallest form in connection with the ordinary household machines, while larger sizes are available for the larger machines used for manufacturing purposes. Steam power is also extensively used in connection with the larger machines in factories, this power usually being applied by means of shafting under the long rows of tables bearing the machines, one row of shafting operating two rows of machines.

The introduction of the sewing machine has had a tendency to concentrate certain industries into large establishments, thus reducing the cost of production. This is especially true in the case of clothing manufacture, and in that of the manufacture of boots and shoes. Where formerly the manufacture of clothing was carried on in small shops employing hand labor, and in the household, it is now frequently done in immense establishments employing a great number of operatives and using hundreds of machines.

In recent years American sewing machine manufacturers, finding it impossible, on account of the difference in the rates of wages, to compete by home manufacture with the manufacturers of Europe in the markets of the other continents, were forced to extend their manufacturing operations to foreign countries. Some of the leading American manufacturers now have branch establishments in Europe and elsewhere, where labor can be secured more cheaply than at home, and have them equipped with American machinery and tools for producing duplicates of the home product for the foreign markets. In some cases, these establishments are of immense proportions, their output equaling that of the home plants. It is estimated that the number of American sewing machines sold abroad each year, including the American machines made in foreign countries, is about equal to the number disposed of in the home markets by all of the American companies. The exports of American sewing machines since 1860 will aggregate about $90,000,000 in value. No greater testimony of the superiority of the American sewing machine could be demonstrated than its enormous foreign sale, as shown in part by the exports.

THE REVOLUTION IN WATCHMAKING.

BY WILLIAM A. COUNTRYMAN.

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The watch came to the United States from the old world perfect in principle. There have been no improvements for many years in arrangement of train, in escapements, or in other parts of movements. Its evolution from the clock with its pendulum, through the table clock with its lever, and thus to the perfect pocket timepiece, is a part of the history of Germany, of Great Britain, of France, and of Switzerland.

The English are said to have been the first successful watchmakers, and about a century and a half ago applied to the industry a division of labor which at one time had multiplied into 102 distinct branches. The Swiss adopted this principle and extended it, giving employment to families—men, women, and children—at their homes. As the price of this labor was very low, and there were few other industries at which employment could be found, the Swiss became the watchmakers of the world, not only furnishing some of the most costly timepieces, but also some of the cheapest and most worthless. While the Swiss still manufacture a great many watches, which are sent to many parts of the world, it is a significant fact that some jobbers, who handled their goods a few years ago under an American name, advertised that the movements were made by the most improved American automatic machinery, insuring accuracy and precision. It is said to be a common practice thus to advertise Swiss movements, excepting those of the costliest varieties, upon which the hand work is of the most skillful and painstaking character or expended in fanciful combinations. It is asserted by manufacturers in the United States that the American machinery used in Switzerland has been rendered obsolete here by the advance of invention; but its adoption there is a most substantial recognition of the superiority of machine made watches. It is also asserted that, while the Swiss watch trade fell off a few years ago, this loss has been partly recovered by the adoption of these American machines and American methods.

The earliest watches made in Europe took a year, it is said, in their making, cost the equivalent of $1,500 apiece, and varied in their timekeeping from forty minutes to an hour a day. At the Waltham, Mass., factory nearly 600,000 watch movements were made during a single year, or nearly 2,000 complete movements for each working day—not quite one a day per employee—more than any other factory in the world and a greater yearly production than any other country except Switzerland. The cost of these movements varies from $3 to $75, and their timekeeping quality is best shown by the fact that the three American watches which received the highest award for accuracy of rate at the centennial exposition at Philadelphia in 1876, showed an average daily variation of only twenty three hundredths of a second.

The unanswerable arguments showing the superiority of machine made watches are now widely known and admitted, but they were made only a few years ago with most disheartening results. Almost everybody preferred a handmade watch, notwithstanding its greater cost, when of any worth as a timepiece, and the lack of interchangeable parts with which it could be cheaply repaired, on the theory that hand work was more accurate; but now conditions are reversed, and an American machine made watch is preferred by the great number of persons who desire accuracy and durability at a reasonable price. An inventor puts the argument briefly thus: "If one of the qualities demanded in any certain kind of work be the highest attainable degree of uniformity, it will be readily admitted that the individual workman, with the certainty of constantly recurring periods of fatigue, which make imperative corresponding periods of rest, is at a great disadvantage when in competition with an impersonal and tireless machine which is capable of producing work of a like kind. It is also evident that if the large number of required pieces, whose function is the same, can be made with dimensions exactly uniform, there would result a great reduction in cost of manufacture because of the avoidance of any individual or special fitting of the various parts." In the hand system it is impossible that parts, upon which a hundred different personalities have been stamped, should come together with the precision required for such a delicate mechanism as a watch. The further the division of hand labor is carried the greater become the chances of imperfection; but with automatic machinery the most delicate processes are accomplished with complete uniformity and finish.

M. Edouard Favre-Perret states that 40,000 workmen in Switzerland each make an average of 40 watches yearly. But the average in the United States in 1880 was 150; at Waltham it is over 250. It takes about five months to complete a single watch of the highest grade; but all processes are going on simultaneously, and the flow of the product is therefore continuous. In a lecture before the Horological institute of London, more than thirty years ago, an English watchmaker who had visited the Waltham factory remarked: "On leaving the factory, I felt that the manufacture of watches on the old plan was gone."

Various sporadic attempts, beginning, it is said, as early as 1809, had been made in this country to manufacture watches by hand, but all had ended in dismal failure, owing to inability to compete in price with the Swiss made watch. When competition with Europe was thus found impossible, inventors in the United States thought they might construct them successfully by machinery, and in 1838 Pitkin Brothers established a plant at Hartford, Conn., for the manufacture of watches by machinery. After manufacturing about eight hundred movements, they were compelled to abandon their project. At this time the Swiss were using machines for special operations in making watches. In 1839 Gischot established a factory at Geneva, Switzerland, for making the movements of a watch by machinery, and a few years after F. P. Ingold, another Swiss, elaborated a series of both case and movement machines, but they never made a success of their manufacture in factories.

The systematic beginning of watchmaking by machinery in the United States was in 1851, at Roxbury, Mass., and the machinery then used, while advanced for the times, now seems crude, so great have been the improvements. It is difficult to realize the primitive conditions of fifty years ago, and a half century hence the machines of to-day may likewise seem crude, for at no time have changes been so numerous or so radical as during the last few years. The effort has been not only to make a cheaper watch, but to make it a more accurate timepiece, and in effecting these results the great system of interchangeable mechanism in manufacturing has been promoted in a remarkable manner. Prof. W. P. Trowbridge, of the Sheffield Scientific school of Yale university, a chief special agent at the census of 1880, in submitting the report on the manufactures of interchangeable mechanism, compiled under his direction by Mr. Charles H. Fitch, wrote that "it may not be too much to say that, in some respects, this system has been one of the chief influences in the rapid increase of the national wealth; that the growth of the system is due to the inventive characteristics of our people, and their peculiar habit of seeking the best and most simple mechanical methods of accomplishing results by machinery, untrammelled by traditions or hereditary habits and customs; and that the art of making complete machines or implements, each part of which may be introduced into any machine of the same kind, and especially the adaptation of special tools, by which hand work in fitting the parts is often entirely avoided, is, I believe, of American origin." One of the manufactures briefly treated in that report was the manufacture of watches.

To Aaron L. Dennison, born in Freeport, Me., in 1812, belongs the honor of founding the systematic manufacture of watches by automatic machinery in the United States. He learned the watchmaker's trade, and while a journeyman in Boston became impressed, by his experience with Swiss and English watches, with the necessity of securing greater uniformity of parts. At the United States armory at Spring-field, Mass., muskets were made upon the interchangeable plan, and it was while working there that he became confirmed in his belief that a machine made watch was a possibility. In 1849 he succeeded in impressing Edward Howard, a practical clock maker of Boston, with the importance of his undertaking, and these two interested a capitalist, Samuel Curtis, of the same city, who invested $20,000. Mr. Howard himself says of this interesting beginning: "Mr. Dennison being a watch repairer, and myself a clock maker, we made a good combination to systematize watchmaking, and to invent labor saving machinery for producing perfect and interchangeable parts. . . . It is almost needless to say that we met with many obstacles. We were told by importers and dealers in watches that we would never be able to carry out our plans, and that our project would be an utter failure. Some of our friends even told us we were crazy to attempt such an undertaking, but we were Yankees, both of us, and had sufficient quantity of the proverbial grit, and at least believed in ourselves, even if others did not have so much faith."

Mr. Dennison went to Europe, where he investigated the English division of hand labor, cheerfully writing back that his theory of Americans not finding any difficulty in competing with the English, especially if the interchangeable system and manufacturing in large quantities was adopted, may be accepted as reasonable. A factory was built at Roxbury, Mass., and in 1851 a model watch was completed. It was an eight day watch, but, being found impracticable, was abandoned for the ordinary thirty six hour watch. The first hundred movements were finished and put on the market in 1853. The factory at Roxbury was in a dusty place, and this drawback, together with the necessity of more room and the desire to make homes in a pleasant spot for the operatives, led to a removal to the present site at Waltham, on the Charles river, about ten miles west of Boston.

As a result of the founding of the watch manufacture at Waltham a number of experts from the parent factory started an establishment at Nashua, N. H., but this was not a success and the Waltham company bought it in 1862 and consolidated it with the home shop, retaining also the services of some of the experts. This Nashua watch was a valuable three quarter plate movement, highly esteemed by the public. Some of the people who had been interested in the Nashua company went to Chicago and, with other experts, founded the now well known factory at Elgin, Ill., one of the leading establishments in the manufacture. Other enterprises were offshoots of the Waltham idea, but many of them proved only experiments. It is noteworthy that the centers of the manufacture are still in the states of Massachusetts and Illinois.

It is said that the number of scientific and mechanical appliances that have been brought out in the manufacture of watches is greater than in any other industry, with the possible exception of the production and use of electricity. And it is probable that the ingenuity of inventors of automatic machinery is shown to greater advantage in this industry than in any other. The processes required are of the most perfect kind, and some of the products are so small as to be distinguishable in character under the glass only. The watch factories of the United States are filled with these automatic and semi-automatic machines, which not only make large numbers of parts of perfect uniformity at small cost, but have, in many cases, done away with the need of special skill in the individual workman. Frequently an operator can care for six or seven machines, and sometimes, as in the pioneer factory at Waltham, a track is laid on the floor and chairs are provided with grooved rolls, so that the attendant can glide easily and quickly the whole length of the line.

The only practicable way of treating the evolution of automatic machinery in watchmaking is to consider certain representative machines accomplishing certain representative results, and thus going from headland to headland, bridge the half century of progress and triumph in the United States. This Edward A. Marsh, of Waltham, has done. First he presents the draw-in-chuck and lathe, tracing their development by Ambrose Webster, Charles V. Woerd, and Charles S. Moseley, into the self closing, three bearing slide spindle lathe, with its application to the manufacture of watch plates. Within seven years two wholly automatic machines have been built for plate turning, their novelty being in the number of turnings they perform. Six recesses are turned in the train side of the pillar plate—for the barrel, escape wheel, pallets, balance, and for the center pinion, and a bearing for the intermediate setting wheel. The blank plates, faced on both sides, are taken from a tube at the left end of the machine one at a time by a swinging carrier arm and placed in spindle after spindle until the six recesses are made, each unlike in size, position, and form. Bossing, when desired, is accomplished through a modification of the tool movement. By a change of chucks the turnings on the dial side of the plate can be made in a similar manner. The boldness in the conception of this machine will be appreciated when it is realized that the watch plate must be placed in each succeeding chuck in a different position, and that it is required to be placed on three pins which fit in the three dial feet holes. This is the work of one of these machines; the other by a somewhat similar process, utilizing self closing chucks instead of pins, receives and faces the plates on both sides.

The history of watchmaking in the United States also goes back to the time when the arbors, staffs, and pinions, which constitute the moving parts of the watch, were made by the lathe and slide rest, the feed screw of which was operated by hand. The first improvement was the semiautomatic turning lathe; then came an improved form in which there was a combination of levers designed to provide for turnings of various lengths without changing feed cams. But the great defect was that each piece had to be affixed by hand to its appropriate dog, making it impossible for one operator to run more than a single lathe; and, owing to the minuteness of the smaller staff blanks, like pallet arbors, only a small amount of metal could be removed at each turning. In some cases ten or twelve turnings were required, and they had to be alternated from end to end to avoid springing. Mr. Woerd some twenty years ago invented an automatic machine to make the rough turnings; but each of the finish turnings still required the application of a driving dog.

The evolution of this into the Church battery of staff turning lathes all on a single bed and driven by a single belt was a noteworthy event, but the dog was still essential. The triumph came within the past five years, when Mr. Church produced a completely automatic machine, adapting it to the most difficult, delicate, and complicated staff in the whole watch movement, namely, the balance staff. Four hundred of these, completely turned from start to finish, including both pivots, are made by each machine each day. This machine is one of the wonders of the Waltham factory, where automatic wonders abound, and it is asserted that nothing in the way of turning has heretofore been done which could at all compare with the work of these machines in delicacy, complexity, and accuracy. The balance staff is so minute that it can be handled only with great difficulty, having a diameter scarcely larger than that of a No. 9 sewing needle, and requiring a magnifiying glass for its inspection.

For the cutting of pinions the Church automatic cutter is a higher development, as it secures axial truth by performing the cutting, in direct connection with the turning, from a long rod of wire. The evolution of the crown wheel cutter is nearly as interesting a study, while the machines for the manufacture of the minute screws and stud pins, and those for vibrating balances and hairsprings, furnish a rare collection of ingenious American inventions.

Watch hairsprings were imported years ago, but for over a quarter of a century they have been made in the United States. The pioneer machine has been improved into a series of machines now nearly automatic in their action. The wire is drawn to the exact diameter required, then flattened by repeated rollings and polished. It is admitted that the coiling of hairsprings seems to be susceptible of no marked improvement in processes of production. A notable device for forming and confining the overcoil of the Breguet spring so that it can be tempered complete is that of the late John Logan, of Waltham. It is said of Mr. Logan and his brother that they have probably made more watch hairsprings than all the other makers in the world put together, all of them high class springs. Until within a few years the adaptation of these hairsprings, which requires absolute exactness, an indispensable requisite for correct time, was secured by repeated trials, a spring being found to meet the requirements of the individual balance. Mr. Logan devised a system of tests of springs by a standard balance, and of all balances by a standard spring, and then grading the springs according to strength. Resort to a schedule of gradings indicates at once the proper spring for any balance.

The minuteness of some of the screws made in a watch factory may be measured by the statement that it takes nearly 150,000 of a certain kind to weigh a pound. Under the microscope they appear in their true character—perfectly finished bolts. The pivot of the balance wheel is only one two hundredths of an inch in diameter, and the gauge with which pivots are classified measures to the ten thousandth part of an inch. Each jewel hole into which a pivot fits is about one five thousandth of an inch larger than the pivot to permit sufficient play. The finest screw for a small sized watch has a thread of 260 to the inch and weighs one one hundred and thirty thousandth of a pound. Jewel slabs of sapphire, ruby, or garnet are first sawed into slabs one fiftieth of an inch thick, and are shellacked to plates so that they may be surfaced. Then the individual jewels are sawed or broken off, drilled through the center, and a depression made in the convex side for an oil cup. A pallet jewel weighs one one hundred and fifty thousandth of a pound; a roller jewel a little more than one two hundred and fifty six thousandth. The largest round hairspring stud is four hundredths of an inch in diameter and about nine hundredths of an inch in length.

It is only the finishing department of a watch factory in the United States that requires the service of skilled watchmakers. Even the assembling of a watch is done by others, the hairsprings being selected by girls with the aid of machines and put in on the balance, within an error of ten seconds per hour or four minutes per day, which is readily corrected by the time screws of the balance. The finishing department is of most interest to watchmakers, because it is in this that the movement is adjusted, being put through all the tests for heat and cold, from 95° down to 38° or 40°; tests in three vertical positions, and in dial up and dial down. The balance in most modern watches is required to make 18,000 vibrations an hour. The change of one beat will cause an error of four and four fifths seconds at the end of twenty four hours. This statement indicates the extreme delicacy of the tests and the necessity of the demagnetizing of all the parts of the escapement so that electrical disturbances in whatever form will have no effect whatsoever. Not many years ago a watch would have been ruined by magnetic influences. Now it is made with a balance, roller, hairspring, pallet, and fork of non-magnetic metals or alloys which are elastic in just the proper proportions to meet the varying conditions of heat and cold.

Between the manufacturers of the higher grades of watch movements and what may be called the dollar grade, including case, are a number who make a variety of grades of great utility and of considerable value. Much of the work is done by automatic machinery, but the hand finish is not so complete nor the testing so minute. These manufactures are a development of the cheap watch. Such movements are made largely by regular watch establishments, but in one case at least, possibly in others, are made by clock companies and classed as a by-product.

The rise of the low priced grade of watches dates from the time of the long wind Waterbury watch. The foundation patent for this was issued to D. A. A. Buck, May 21, 1878. The feature that made the watch a success was the improvement of the old duplex escapement, by which the parts were simplified so that they could be cheaply stamped out. None of these watches are now made. They have given place to a much higher grade, in which, however, the improved duplex escapement is still used. But the demand they excited continued and had to be satisfied. A number of clock companies now make the low priced watches, case and all, as a by-product. Whether the evolution can be traced wholly to the Waterbury may be questioned. The clock companies for years have been making clocks of increasingly small dimensions, all with lever movements, such as the marine and the small shelf and alarm clocks. Some of these sizes become quite small for clocks, and at least one was made as an experiment for a pocket piece. It was thick and large, and used as a toy and for advertising purposes, retailing in some instances for $2.50, whereas to-day a much better watch, both in appearance and in accuracy, can be bought for $1, guaranteed for a year. But it was a beginning. The movement was that of a clock, with a pin escapement. Hence the cheap watch is sometimes called a clock watch, although it is true that the high grade watches of to-day are also a development of the clock idea, but at a long remove, the definite line of variation having appeared many years ago. The secretary of a clock company making these low priced watches writes: "In the evolution of this article from our regular goods, the progress has been so gradual that at no distinct time have we felt that we could draw the line where the clock stopped and the watch began. It is identical in character with our small clocks, and we have felt that the term pocket clock was a legitimate and more accurate description than to class it as a watch. It does not have the element of value and solid construction usually associated with a watch."

The cheap watches are now made as small as ladies' size, are stem winding, and will last, it is said, five years, including a year or two of fairly accurate timekeeping. The dials are of various colors and designs, the effort now being, in some instances, to make railroad and world's time dials. The remarkable cheapness of the low grade watch is chiefly due to automatic machinery and the factory system. Not much finish, which is a costly matter, is possible. There are no jewels used against which the pivots may rest, as in the higher grade watches, to insure close accuracy and durability by lessening friction; nearly all parts are stamped out, not cut out; the mainsprings and hairsprings are of the quality required for comparatively rough work, and have been greatly reduced in cost by modern processes of manufacture in the United States; and the time devoted to testing and adjustment is necessarily limited. What can be expected in a movement and case which, perhaps, must be sold at wholesale at the rate of 60 cents the watch? The marvel is that it is possible to give so much.

The manufacture of these watches is limited to Connecticut and New York. At one establishment the maximum daily product is stated to be 2,000 watches. The demand for them in the United States is constant and it is yet far from being fully supplied. They are urged upon the public as really better than the cheapest of Swiss watches, which are so imperfect as frequently to require expensive repairs. Exportations of them have been made ever since the beginning of their manufacture, and the demand has been increased of late, it is said, by the presence of the American soldier abroad. When the home market becomes better supplied manufacturers assert that they will take up the export problem in earnest. The question arises: Will the clock manufacturers, with whom watches are a by-product, come to be watch manufacturers, with clocks as a by-product? The answer to this, as given by a clock manufacturer, is that it is not probable, at least in the immediate future. The destruction of clocks seems to be greater than that of watches. A person gets attached to a watch, even a cheap watch, and will expend much more than its cost in repairs, but when a clock becomes out of order he will buy another. There is, therefore, a greater proportional consumption of clocks than of watches, and, other things being equal, this will keep the cheap watch a by-product when made in a clock factory.

The imports and exports of watches and parts thereof vary with a variety of causes, but it is noteworthy that the net imports decreased from $3,018,447 in 1870, to $1,403,302 in 1900, or 53.5 per cent, while during the same time the domestic exports increased from $4,335 to $787,620, or over one hundred and eighty fold. Of the imports in 1700, those from Switzerland were valued at $1,023,967 and constituted 73 per cent of the total net imports; France sent a value of $140,067; Germany, $114,886; and Great Britain, $89,525. Watches from the United States are now exported to most of the countries of the world. In 1900 Canada received a value of $274,537, or 34.9 per cent of the total; Japan, $162,014; South America, $125,692; Great Britain, $82,315; British Australia, $36,995; British Africa, $32,174; the Philippines, $18,003; China, $9,170; Hawaii, $8,341; and Cuba, $1,006.

When pocket timekeepers first came into general use, the cases were made with exposed fronts over the face and hands, now distinguished by the term open face. That style prevailed in the United States as late as seventy years ago. The style called hunter's or hunting case was invented to accommodate the demands of Englishmen, whose vigorous riding in the hunting field necessitated better protection for their watches. In the United States a similar necessity arose, particularly among the more active classes—the pioneers and hunters of that period. In consequence of the frequent breaking of the crystal the idea of an entire metallic covering was naturally suggested. But there is a rapidly growing demand for open face watches, the use of thick beveled edge glasses rendering the case quite as reliable a protection as the cover of a hunting case, besides being more nearly dust proof.

Few, if any, watchcases are now made by the high grade watch movement factories, the manufacture having become specialized. Watch movements and watchcases are made for each other according to standard sizes, so that the jobber or dealer may order them to fit, in style according to the caprice of himself or his customer, just as he can order interchangeable parts of the watch movement by number for repair work, with no misgivings as to their fitting. The watchcase industry shows the same kind of evolution as the manufacture of watch movements. The effort has been to lower the cost, improve the quality, and increase the uniformity of the product by automatic machinery and at the same time to furnish a rich variety of effects. In old times crude tools were used, but when the machine made watch appeared improved methods became necessary to meet the increased demand. Cases were made at first by watch movement factories, but their manufacture was gradually dropped for the more delicate fabrication. The automatic machines devoted to watchcase making are marvels, and the system of interchangeable parts prevails as in the manufacture of watch movements. The general system of division of labor is similar in the two manufactures. The metal for the cases undergoes several processes, from the furnace where it is melted, mixed, and shaped, through the cutting, rolling, turning, and stamping, until it reaches the several skilled mechanics who finish it in its final beauty of design.

One of the revolutionizing events in the history of the case industry was the invention of the popular filled case, about the year 1859. By this the people are provided with a tasty, serviceable, and durable gold case at about half the cost of a solid gold one. Besides the gold filled, the kinds of cases in most common use are silver, nickel—including silverine, silverore, silveroid, and nickel silver, which are the same under different trademarks—and German silver. Gun metal is also used, and in the very low priced grades, brass, nickel plated, is employed.

The gold case gives the artisan excellent opportunities for ornamentation, by its beautiful luster and richness of color. It is often delicately enameled or exquisitely engraved, and ornamented with gems. The prime requisite, however, in selecting material for the case, is to have it of sufficient stiffness to protect the delicate interior from injury by external pressure. The case should also be so constructed as to exclude all dust and moisture, two great hindrances to perfect timekeeping.

THE DEVELOPMENT OF THE TYPEWRITER.

BY HARRY E. BARBOUR.

[Harry E. Barbour, statistician; has made a specialty of the history of the typewriter and its effect upon business life in America; he was employed by the United States government to make an investigation along these lines for the twelfth census.]

While many patents have been granted in Europe for writing machines, the real history of the typewriter belongs to the United States; it was in this country that the first practical typewriter was made, and from the very beginning the superiority of the American machine has been recognized in all parts of the world. Therefore the history of the evolution of the practical typewriter of to-day may be gleaned from an account of the failures and successes of American inventors. It is impossible to mention here the numerous attempts to construct a practical typewriter, or the various inventors who labored patiently toward that end. While most of these men failed to produce a perfect machine, their efforts contributed to the final success, and to each of them a share of the credit is due. In this connection, however, it may prove interesting to consider briefly some of the earlier types of the machine and to note various changes in its development.

The first typewriter invented in the United States, called the "typographer," was patented in 1829 by William Austin Burt, of Detroit, Mich., also the inventor of the solar compass. This machine was a primitive affair, and could be manipulated only slowly. No practical results were accomplished by the Burt machine, and to-day it is known merely as the starting point of a great American industry. In 1843 Charles Thurber of Worcester, Mass., patented a writing machine which produced good results in every respect except speed. This machine was constructed with a horizontal wheel, on the periphery of which were a number of perdendicular rods having types at the bottom and finger keys at the top. In operating this machine the wheel was turned until the rod bearing the desired letter was directly over the printing point, when, by pressing the key, the character was printed on the paper, being aided in the alignment by fixed guides. A ratchet and pawl device served to move lengthwise the cylinder bearing the paper, thus producing the proper letter spacing, while interlinear spacing was secured by turning the cylinder. An inked roller, over which the face of the type passed, produced the inking. Although this machine was a failure because of its lack of speed it will readily be seen it embodied some of the principles involved in the construction of the modern typewriter.

Another step in the evolution of the present day typewriter was the invention of A. Ely Beach, of New York, who in 1847 and in 1856 secured patents on a machine involving the system of type bearing levers arranged in a circle, swinging toward and printing at a common center. The inked ribbon, and also the bell indicating the end of the line, were features of this machine, which, although slow in action, embodied principles which have since been successfully utilized and are to-day prominent features of the typewriting machine. In 1857 Dr. S. W. Francis, of Newport, R. I., patented a machine provided with a circle of type bearing hammers attached to a keyboard. Pressure on a key caused the type to strike upward, making an impression on the paper through an inked ribbon, the printing point being the center of the circle. This machine was fitted with the bell attachment and also with a coiled spring which moved the frame bearing the paper, rewinding when the frame was drawn back after reaching the end of the line. It was large and cumbersome, and only one was ever constructed under this patent.

In 1868 C. Latham Sholes, Samuel W. Soule, and Carlos Glidden, all of Milwaukee, Wis., were granted a patent on a machine which was a decided improvement over its predecessors. This typewriter embodied an extension of many of the principles involved in former inventions, together with certain features of its own. The inventor continued to make improvements and succeeded in bringing it to a state of practical usefulness, crude though it was when compared with the finished typewriters of the present day. James Densmore became interested in the Sholes patents; he made a contract with E. Remington & Sons, gun manufacturers at Ilion, N. Y., for the manufacture of typewriters on a large scale, and the improved machine has ever since been called the Remington. In 1873, George W. N. Yost, then connected with the Remington factory, was actively engaged in the manufacture of one of the early machines.

The first person to make a practical business use of the typewriter was Mr. S. N. D. North, of Boston, Mass. This was in 1872, at Utica, N. Y. "I have often wished that I had kept that original machine," wrote Mr. North in 1896, "for it would have illustrated better than any other mechanism with which I am familiar the marvelous rapidity with which American ingenuity advances to the point of perfection any labor saving instrument, the underlying principle of which has been successfully worked out. This machine was heavy and cumbersome in comparison with the delicate mechanism of to-day, but the principle of construction was essentially the same, except that the carriage, instead of being restored to position by the hand at the end of each line as now, was brought back by means of a foot pedal, and it came with a jar that made the machine tremble in every part. My machine did neither elegant nor uniform work, but after a week or two I was enabled to accomplish all my editorial writing upon it, and I began to realize dimly what an unspeakable boon to all weak-eyed persons lay here in embryo."

It was not until 1874 that the typewriter was placed on the market for general sale. Like many other inventions which have grown to be considered indispensable, the typewriter was first greeted by the public with scepticism. The use of the machine involved such radical changes in certain methods of business that its advantages had to be clearly demonstrated before the business world would accept it. The first machines wrote only with capital letters, and were otherwise imperfect, but these imperfections were soon remedied. Even then but few persons saw the advantages of the typewriter, and during its first few years in the market only a small number were sold. People were not merely indifferent, but were antagonistic. But the typewriter had a usefulness which was not to be ignored; among the first to recognize this fact were court stenographers, who found that with the aid of the typewriter several copies of the record could be turned out at once with neatness and dispatch. Lawyers, having the advantage of the machine thus brought home to them, soon began to adopt it for private use. Courts of law, which for centuries had required all papers to be submitted in handwriting, began to require such papers to be typewritten; and to-day the handwritten legal document is the exception rather than the rule. The large business houses, having an extensive correspondence, being always ready for improvements and time saving methods, were next to adopt the typewriter, and the commercial world in general soon followed their example. The work of the typewriter was its own best recommendation, as typewritten letters and papers were spread throughout the country there was awakened a general interest in the machine and its work. It began to find its way into every branch of business and professional life; authors and newspaper men have adopted it; telegraph companies have made it a part of their equipment, for so rapidly can messages be transcribed that the receiving operator can not only keep pace with the sender, but can maintain speed so great as to bring about the abbreviation of the telegraphic code. In fact, there is not a single business or profession in which the typewriter has not established its usefulness.

The use of the typewriter for miscellaneous correspondence became general in all the departments of the government, except the department of state, during the early eighties; it was first used for instructions to diplomatic and consular officers of the United States by the department of state, in April, 1895. The official communications of the department to diplomatic officers of foreign countries accredited to the United States continued to be handwritten until May, 1897. Ceremonial letters addressed to sovereigns are still handwritten.

One of the advantages of the use of the typewriting machine over hand labor has been demonstrated in an interesting manner by an investigation by the United States department of labor. In this instance the unit required was the copying of 1,000 words of statute law; this was accomplished by the typewriter in 19.5 minutes, or at the rate of 51 words per minute, while a copyist with a pen required 1 hour and 14.8 minutes, or about four times as long. The quantity of work done by the typewriter depends to a great extent upon the skill of the operator, but it is true also that the proficiency of the copyist enters largely into the quantity of work performed by him. However, it is possible to determine an average, and the figures given may be accepted as a fair and reasonable comparison of the two methods.

The rise of the typewriter has been most remarkable. Looked upon at first as rather an article of amusement than one of any practical value, it has received, within the past quarter of a century, the unqualified approval of the commercial and professional worlds; it has been given the sanction of statute by almost every state and national legislature, and adopted by every civilized government in the world, thousands of the machines being used by the United States government. It promises soon to become, if it is not already such, the universal writing machine. During the past twenty-five years hundreds of patents have been granted for improved attachments, and new styles of typewriters. Many of these have proved useful, and there are to-day several different types of the machine on the market, all of which are doing excellent work.

An aspect to be considered in connection with the typewriter is its industrial effect. Not only has the steadily increasing demand opened a new field for skilled labor in the manufacture, but the effort to secure the best possible results from the use of the machine has created a new profession. Not long after the machine was introduced, the need of skilled operatives became apparent. The result of this has been the giving of employment to thousands of persons. Business colleges and private schools have introduced courses which train students to become expert operatives, and, in many cities, similar courses have been introduced in the public schools.

LABOR SAVING SYSTEMS REVOLUTIONIZE OFFICE WORK.

BY HUGH S. FULLERTON.

[Hugh S. Fullerton, author and editor; born 1871, Hillsboro, O.; educated at the University of Wooster, Ohio State university, Williams college; began his journalistic career as a writer on the Cincinnati Tribune, 1891; became connected with the Chicago Record, 1893, and since then has contributed to newspapers and magazines; had prominent part in the national business system and office appliance exhibitions of New York and Chicago and is an author of many articles on business topics.]

The merchant of a score of years ago who took a day off and bought a supply of ink, paper and pens when he wanted to write to his customers in the country, would meet with considerable of a shock were he to be transported suddenly to the executive position in one of the big offices of to-day and confronted with its system and its array of time and labor saving appliances. For that matter the average business man of to-day would experience much the same sensations upon being introduced into an office equipped with all the known devices for expediting work and minimizing the expenditure of time and labor.

The ingenious efforts of inventors who believe that the greater return comes to them from products of their brains that affect and make lighter everyday labor, have resulted in inventions that have practically revolutionized office work. Within the last five years—the records in the patent office in Washington show—8,174 different appliances and devices have been patented to systematize, hasten, or prevent errors in business.

The typewriter is of course recognized by this time as one of the necessities in office work in the United States, but even its speed falls short of the demand, and to meet the cry for a machine that will do more rapid work inventors have brought forth the mimeograph. Probably two hundred inventors grasped the mimeograph idea at once and the market became flooded with their manifolding machines. The perfected mimeograph of to-day, however, is a machine that in form resembles somewhat an ordinary job printing press. Its principal features consist of two long hollow cylinders, each about ten inches long and eight in diameter, revolving on the same axis. One of the cylinders is grooved lengthwise, the grooves being about as far apart as the lines of typewritten matter. The other cylinder contains metal type with shoulders upon it to permit of its being run into the grooves of the type cylinder. The type is set up in this cylinder in the form of a letter without address or signature. The rest of the process is simplicity.

An office boy, or an electric motor, furnishes the motive power that revolves the cylinders. Paper is fed into the machine automatically, and the letters, written so perfectly as to convince each recipient that he has been the object of a personal letter, are reeled of at the rate of 1,000 an hour.

The letters are addressed, each differently, as they are printed. The addresses, stencilled on cards, are mounted upon an endless chain that is fed across the printing machine and as each letter is printed it is addressed. The addresses upon the envelopes are printed in the same way, the latter being fed into a machine across which the endless chain of addresses runs. The signature to the letters may be made by hand, or, there is still another machine that will do that, even writing the signature in different colored ink from the letter.

After the letters have been written they are taken to a machine that folds them. Here, as at the other machine, an office boy to turn a crank, or an electric motor, is all the attention that the machine requires. The machine is a little larger than a typewriter. Letters are piled in front of it and the machine starts. A metal arm picks up each sheet separately, places it in the machine and it is turned out neatly folded, ready for the envelope. The machine folds 5,000 letters in an hour.

After the letters have been written and placed in their addressed envelopes—and this is done by hand, no machine having been invented to do the work satisfactorily—the envelopes must be sealed. The machine for sealing letters is a small contrivance of brass, steel, and rubber into which the envelopes are fed automatically, or by a boy. They are sealed and turned out at the rate of from 3,000 to 10,000 an hour, depending upon the efforts of the boy who feeds the machine and the speed with which it is run. As a final touch there is a machine, not entirely successful as yet, however, that stamps the letters. Machines that stamp letters at the rate of 1,000 an hour are in use and giving satisfaction.

Another invention, in use in several offices, and which the promoters claim will come into general use, is the talking telephone, a combination of phonograph and telephone, that is a comparatively new device. The invention is the work of a German, but the machine was perfected and is being manufactured by an American firm. A small phonographic recorder is placed at the receiver of the telephone. When the owner of the telephone leaves his office, or decides that he is too busy to answer the phone, he throws a switch that places a mechanism in readiness. A friend or customer calls him up. The completion of the circuit animates the phonographic device, and the person at the other end of the telephone speaks his message as if the person were at the other end of the wire. The machine faithfully records his words. Then he hangs up the receiver. A dozen messages may be received this way, and when the owner of the phone desires to listen to them, he removes the cylinder, places it in another machine and turns the switch. In the space of a few minutes he hears all the messages that have accumulated since he placed the machine at the phone.

Another office device in which the phonograph figures largely, is a new invention known as the talking postal card, the invention of a New Yorker, which has been placed on exhibition and on the market. The machine resembles to some extent a phonograph into which a specially prepared postal card is inserted. The machine is started and a message is dictated into the machine, the merchant speaking as rapidly as he can, giving instructions or making business offers. The postal card, apparently as blank as before, is addressed and dropped into a letter box and sped on to John. He receives it, places it in a machine in his office, starts the mechanism, and hears the message as plainly as if his friend were beside him. The postal cards may be purchased for 10 cents each, but the machines cost a considerable sum. They are becoming cheaper however as the demand for them increases.

A machine that is one of the marvels even in this age of rapid business, is known as the circular mailing machine, a device to fold, stamp, address, and paste newspapers and circulars that go through the mails rolled in cylindrical form. This machine, almost as large as a good sized newspaper press, picks newspapers from a table at one end of it, rolls them, pastes wrappers on them, addresses and stamps them and deposits them in a mail bag at the other end, handling 1,000 or more an hour without making a mistake or requiring any attention except to the pile of papers placed in front of the machine.

There have been invented many machines that are in universal use to-day, designed to handle statistics and add, multiply, or subtract large sums of figures. All of them are exceedingly complex in their mechanism, but in operation so simple that an office boy may operate them with the same certainty of correct results as an expert mathematician. The adding machine is probably used more widely than any of this class of machines. In appearance it is somewhat of the general outline of a typewriter, although slightly larger, and with a keyboard much the same as that on a typewriter. If the capacity of the machine is 99,999,999 or $999,999.99 the keyboard has eight rows of keys. There are nine keys in each row, numbered from 1 to 9. The first row at the right is units, the second tens, the third hundreds and so on. Each row operates a wheel upon which are the figures from 0 to 9. When it is desired to operate the machine the numbers to be added are struck off on the keys. The numeral wheels revolve correspondingly; every time a wheel revolves once it moves the next highest wheel upward one figure. When all the figures to be added are set down, a lever is touched and the result is printed at the bottom of the column. Multiplying and subtracting machines work much upon the same principle, the arrangement of the numeral wheels and their mode of operation being about the only difference in their construction from the adding machines.

United States government officials have adopted the mechanical adder and multiplier in the census department, where statistics affecting every country in the world are gathered and compiled in list form. These machines can multiply numbers like 87,498,796 by 93,875,987 as fast as the operator can write them down. Some of the machines in use in insurance offices do work at such a rate as would astonish the most successful lightning calculator. Machines of this sort are costly and are made to order, the company manufacturing them taking orders for a machine first before constructing it. This enables the firms to construct them to any capacity required by their customers.

One of the most extraordinary machines in use in this class of work is installed in the census department of the government in Washington, where, daily, it astonishes hundreds of visitors by its seemingly superhuman power. The machine records upon cards facts pertaining to the different statistics of various countries, then perforates each card, passes it along and finally tabulates the different cards, arranging them in groups by themselves in boxes attached to the machine. Without once being touched by the hands of the operator or by anyone else, the cards are printed, tabulated, and placed in groups by the machine; more—the machine sets down the figures on each card in the different classifications in list form and finally prints the grand totals of all the figures upon the cards in each classified list.

The cards after being printed—which printing is done by working a keyboard much the same as that of a typewriter—are passed along into a portion of the machine known as the pin box. Before reaching it, however, they are perforated—each card being punched in a different manner, according to its classification. Upon reaching the pin box the cards are passing before a set of pins that enter the perforations and lift the cards into the pile where they belong, at the same time adding the figures upon each card to the list that it makes of that classification. So delicate is the entire mechanism of this machine that if, by any chance a mistake is made, the machine at once stops and throws out a card, notifying the operator that something is wrong.

There are many other devices that materially aid or expedite office work, including automatic interior telephone systems, time registers, check protectors and detectors, recording clocks, automatic check filers for use in banks, telautograph, and electric writing machine. There are many patents for machines, that while working well enough as models, have not been successfully introduced into office work. Among these is the combination automatic post card writer and phonograph, which, in model form, writes a message upon a postal card and addresses it from dictation, the mechanism being attached to a phonographic device, and actuated by the vibrations of the sensitive disc in the phonograph, which responds to the sound of the speaker's voice.

That all devices, no matter how simple, have an easy road to popularity when they succeed in facilitating business work, is proved by the fact that one inventor, whose claim to fame is his invention of a pencil that is always sharpened, is rapidly amassing a fortune of good proportions.

The immense increase of business in the last fifteen years has demanded mechanical contrivances to aid man in turning out the work. Great mail order houses, the huge offices of the gigantic industrial concerns, even with forces of 400 to 5,000 men and girls, could not handle their business. The demand for mechanical devices was promptly met. Now, even with devices that aid one boy or girl to do accurately and inerrantly the work that required ten to twenty persons ten years ago, the firms find difficulty in handling the enormous bulk of business.

Business must be done twice as fast as in the previous decade—the machines are doing it. The modern office machinery is the result of an evolution, that despite its wonders, appears to be still in its infancy.

THE UNITED STATES PATENT LAWS: HISTORICALLY AND PRACTICALLY CONSIDERED.

BY CYRUS N. ANDERSON.

[Cyrus N. Anderson, lawyer, is one of the best known patent attorneys in the United States; he is a member of the firm of William C. Strawbridge of Philadelphia; besides his work as an attorney he has made a careful study of patents from a historical standpoint and has embodied the result of his investigations in writings for the reviews.]

Several years ago a writer in the Iron Industry Gazette, an English publication, said: "Disparagement of patents is common and easy, but it should not be forgotten by those who sneer at inventions that, out of a total of eight billions of capital invested in manufacturing in the United States, patents form the basis for an investment of about six billions. Evidently, the United States system of encouraging invention that has resulted in the patenting of over 500,000 inventions is a system which is exceedingly wise and valuable. The only thing that has enabled manufacturers to make so wonderful a progress in the United States is its patent system."

Up to the present time, there have been granted in the United States nearly 800,000 patents, and, while I have no recent figures, there is no doubt but that the proportion of capital invested in manufactures with patents as a basis is as great, if not greater, now than it was when the foregoing statement was made.

At a time when the right of property in patents, or rather in patented inventions, is so well recognized, it strikes one as a curious fact that there ever was or should have been a time when a right to such property was not recognized. Yet the fact is that in comparatively recent periods, considered in the light of the world's history, property rights in connection with inventions were not recognized, and if a man was possessed of an inventive turn of mind and was an inventive genius, and made inventions or improvements in machines or in mechanical devices or in the art of doing things, he had to stand by and see others enjoy equally with him the benefits of his intellectual thought and effort.

In the very earliest history, the right of property in tangible things was recognized, but an exclusive right in intellectual property, such as inventions and writings, was not regarded as a natural right, and the right to such property was only established as a result of advancing and improved civilization.

It seems that quite early in England the practice grew up under which the crown, as a matter of grace and favor, but not of right, granted to the inventor of a new manufacture or a new art, the exclusive right for limited periods to his invention or improvement, and it is reported that in the fourteenth century, in the reign of Edward III. some wise subjects of the realm, alchemists they were, invented or discovered a philosopher's stone. A commission was appointed by the king, consisting of two aldermen and two friars, who, after an investigation, which, of course, was very carefully made, reported that the philosopher's stone possessed merit, and upon this report the king granted an exclusive right to the discoverers to manufacture and sell the philosopher's stone.

When the nature of intellectual property is considered, it seems somewhat anomalous that rights of property therein should not have been recognized from the very earliest times.

Professor Shaler has said: "When we come to weigh the rights of the several sorts of property which can be held by men, and in this judgment take only the absolute questions of justice, leaving out the limitations of expedience and prejudice, it will be seen clearly that intellectual property is, after all, the only possession in the world. The man who brings out of nothingness some child of his thoughts has rights therein which cannot belong to any source of property."

Mr. Fessenden, in his work on patents, published in 1821, says: "In a moral as well as in a political point of view, the author of a new and useful invention has the best of all possible titles to a monopoly of the first fruits of his ingenuity. The invention is the work of his hands and the offspring of his intellect; and after he is allowed a temporary monopoly, becomes at the expiration of the patent a valuable donation to society."

At least as early as about the year 1600 the right of property in invention was well understood and had a well-established and defined standing in the common law. As indicating that in the common law of England at that time the reason for granting exclusive privileges to inventors, and that the rights of property in inventions were fairly understood, I will quote what was said by the court in the case of Darcy vs. Allin: "Where any man, by his own charge and industry, or by his own wit or invention, doth bring any new trade into the realm, or any engine tending to the furtherance of a trade that was never used before; and that for the good of the realm; that in such cases the king may grant to him a monopoly patent for some reasonable time, until the subjects may learn the same, in consideration of the good that he doth bring by his invention to the commonwealth; otherwise not."

Sir Edward Coke said of patent privileges that "The reason wherefore such a privilege is good in law is because the inventor bringeth to and for the commonwealth a new manufacture by his invention, costs and charges, and therefore it is reason that he should have a privilege for his reward (and the encouragement of others in the like) for a convenient time."

It does not appear that there was any statutory law passed in England concerning the patenting of inventions until the year 1623, in the twenty first year of the reign of James I., at which time the statute of monopolies was passed, which declared certain monopolies to be void, and prohibited the grant of such monopolies in the future. One section of this statute, however, related to patents and read as follows:

"Provided also, and be it declared and enacted: That any declaration before mentioned shall not extend to any letters patent and grants of privilege, for the term of fourteen years or under, hereafter to be made, of the sole working or making of any manner of new manufactures, within this realm, to the true and first inventor and inventors of such manufactures, which others, at the time of making such letters patent and grant, shall not use, so as also they be not contrary to the law, nor mischievous to the state, by raising prices of commodities at home, or hurt of trade, or generally inconvenient: The said fourteen years to be accounted from the date of the first letters patent or grant of such privilege, hereafter to be made; but that the same shall be of such force as they should be, if this act had never been made and of none other."

I quote this section of the statute in full because it is the first English statute on the subject, and is the very foundation of our own laws on the subject of patents. These laws are the result of development and evolution.

Mr. Robinson, the author of one of our most elaborate treatises on the subject of the patent laws, has said that in this statute, as interpreted by the English courts, are found the sources of the patent laws of the United States.

The 150 years following the statute just referred to covered the colonial period of the United States. During that period of our existence there was, as is well known to all, very little manufacturing within the present borders of the United States, and very little improvement in the manufacturing arts was made by the colonists. The country was very thinly and sparsely settled; the colonists, our forefathers, had duties to perform which were much more pressing upon them than the making of inventions or improvements in the method or art of doing things in the manufacturing world. The colonists were making a continual fight for existence and constant effort to subdue the many obstacles incident to the development of a new country, and had no time to engage in the fascinating and frequently profitable pursuit of making improvements and inventions in existing devices in the manufacturing arts.

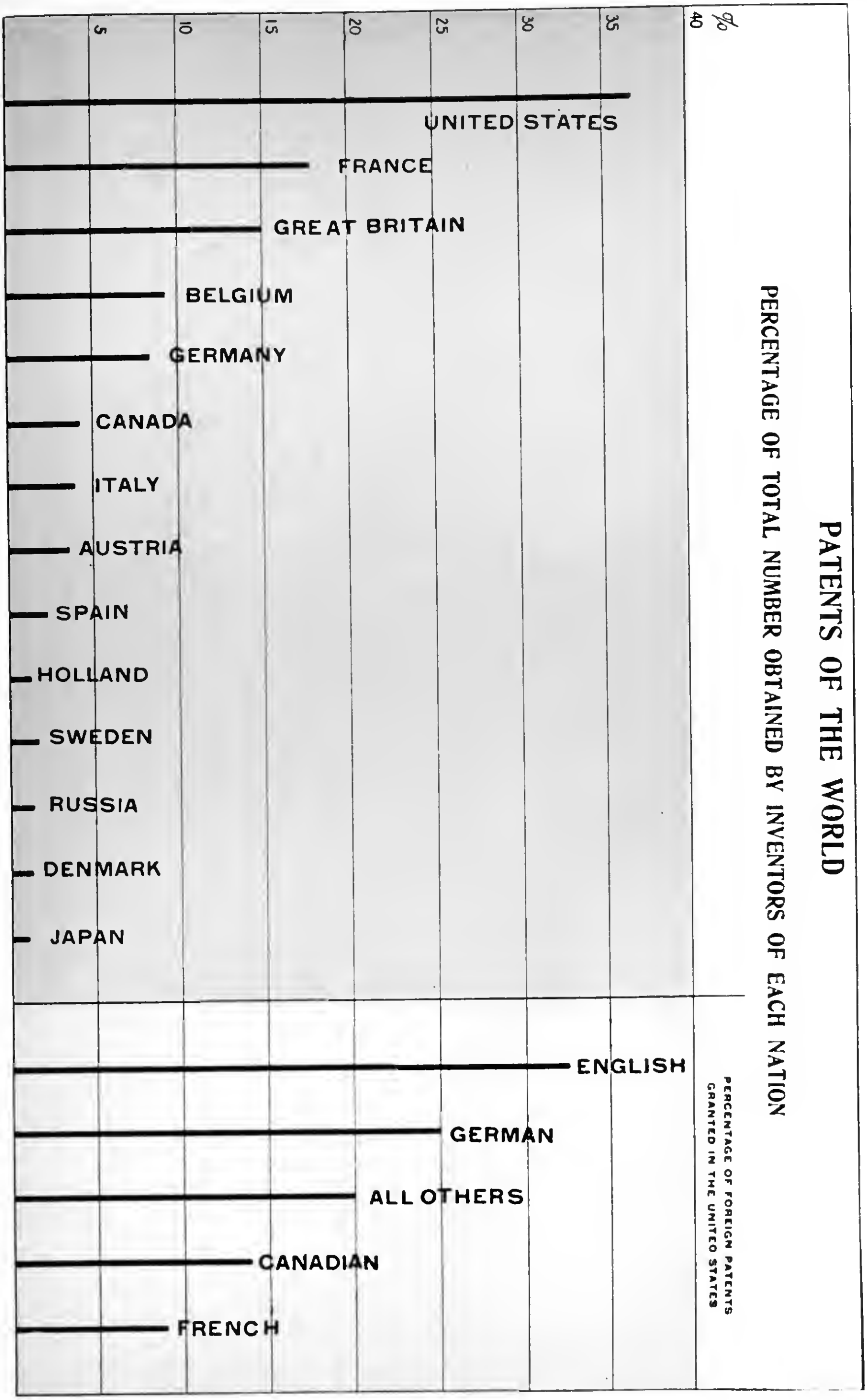
It is not surprising that under these conditions the colonists made few inventions. But there was still another obstacle in the way of improvement by the colonists of the manufacturing arts. This obstacle was the attitude of England toward the colonists upon this matter. It was England's idea that the colonists should supply raw articles of commerce, such as the products of the farm, and that England should furnish to the colonists all such manufactured articles as might be needed or demanded by the colonists. England's policy toward the colonists was expressed by Sir William Pitt, when he said: "It is the destiny of America to feed Great Britain, and the destiny of Great Britain to clothe America." Lord Chatham said, "I would not allow the colonists to make so much as a hob nail for themselves."

Laws were enacted by England prohibiting every species of manufactures in the colonies. When the colonists began to make iron and nails for their use, the house of commons resolved that "none of the plantations should manufacture iron nails of any kind out of any sows, pigs, whatsoever." And the house of lords added, "No forge going by water, or other works, should be erected in any of the plantations for the making, working or converting of any sows, pigs, or cast iron into bar or rod iron."

By an act of 1750 the erection of buildings and mills for making iron was prohibited. There were corresponding restrictions imposed upon the colonies with respect to all sorts of manufacturing arts. For instance, in 1684, Virginia passed an act encouraging the manufacture of the textile fabrics which was annulled by parliament. The condition of manufactures in the colonies has been well set forth by Senator O. H. Platt, of Connecticut, as follows:

"Manufactures were practically unknown;. . . . . there were no machines as we now understand the term;. . . . . . men knew how to plow and sow, hoe and chop, reap, mow and cradle, break flax and hackle it, thresh with the flail, winnow with the blanket or fan and to shell corn by hand. The women knew how to spin, card, weave and knit. Mechanical knowledge was monopolized by the blacksmith, the carpenter, the millwright and the village tinker. Production was a toilsome, weary task, limited by the capacity for muscular endurance."

It is probable that the first patent granted within the limits of the United States was by the general court of the colony of Massachusetts, under date of May 6, 1646, to one



PATENTS OF THE WORLD

PERCENTAGE OF TOTAL NUMBER OBTAINED BY INVENTORS OF EACH NATION

PERCENTAGE OF FOREIGN PATENTS GRANTED IN THE UNITED STATES

Joseph Jenckes, of Lynn, for a scythe. In his petition or prayer, he prayed for protection for "Fowerteen yeeres, without disturbance by any other setting up the like inventions, so that his study and cost may not be in vayne or lost."

Before proceeding to a discussion of the laws relating to patents which have been enacted by the United States government, I desire to call attention briefly to some of the objections which have been made to patents. The objection has been made that th re is no such thing as intellectual property, and that ownership of such property restricts common rights. Also that the granting of a patent is a creation of a monopoly. Patents have been compared to letters of marque, which allowed the holder to prey upon honest industry. It has been urged that patents increase the price of commodities, and that they encourage labor saving inventions and take opportunities from the artisan.

It is needless to say that the last objection is utterly without foundation. Exactly the reverse has been proved adequately. It has been urged that patented inventions reduce or sink man to automata, and that the granting of a patent enables one man to say to another that he shall not carry on his business in the best way, and that by granting a patent the idea involved in the patent is tied up, and the course of thought in that direction is stayed. A Frenchman has advanced a picturesque objection that patents give undue advantage to their possessor by "making a golden bridge for him who enters the arena with arms more subtle and more finely tempered than those of his adversaries."

The foundation of all the patent law legislation in the United States is the clause or phrase in the constitution which vests in congress power "to promote the progress of science and useful arts by securing for limited times to authors and inventors the exclusive right to their respective writings or discoveries."

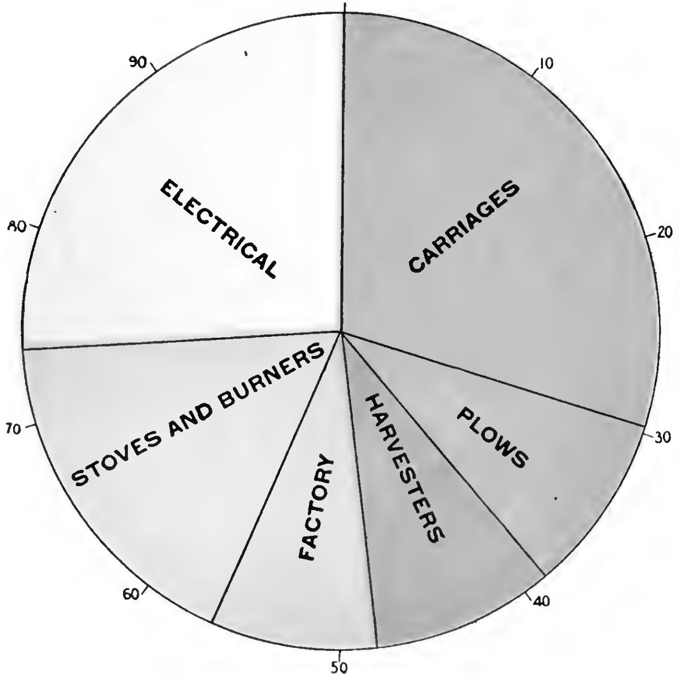
The first patent law of the United States was enacted in the year 1790, April the 10th. It followed in a general way the law then in existence in England authorizing the grant of patents without an examination of the prior art, as is now the case. The authority to grant patents was conferred upon the secretary of state, the secretary of war and the attorney general of the United States.

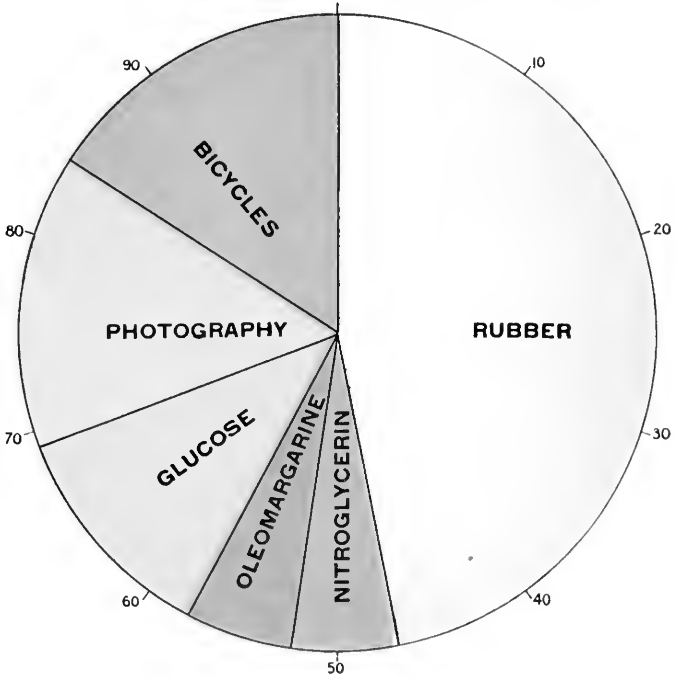
It appears that Mr. Jefferson, who was at that time secretary of state, took great interest in the patent laws, and regarded them and the granting of a patent as of the very greatest importance, and he is generally referred to as the Father of the United States patent laws.

In the official gazette of the United States patent office, published September 24, 1877, an interesting description of the early practice under the act of 1790 occurs: "By act of April 10, 1790, the first American patent system was founded. Thomas Jefferson inspired it, and may be said to have been the father of the American patent office. He took great pride in it, it is said, and gave personal consideration to every application that was made for a patent during the years between 1790 and 1793, while the power of revision and rejection granted by that act remained in force. It is related that the granting of a patent was held to be in these early times quite an event in the history of the state department, where the clerical part of the work was then performed.

It is a matter of tradition, handed down to us from generation to generation, by those who love to speak of Mr. Jefferson, his virtues, and his eccentricities, that when an application for patent was made under the first act, he would summon Mr. Henry Knox, of Massachusetts, who was secretary of war, and Mr. Edmund Randolph, of Virginia, who was attorney general—these officers being designated by the act, with the secretary of state, a tribunal to examine and grant patents—and that these three distinguished officials would examine the applications critically, scrutinize each point of the specification and claims carefully and rigorously. The result of this examination was that during the first year, a majority of the applications filed failed to pass the ordeal, and only three patents were granted. In those days every step in the issuance of a patent was taken with great caution, Mr. Jefferson seeking always to impress upon the minds of his officers and the public that the granting of a patent was a matter of no ordinary importance."

PATENTS


INDUSTRIES CLAIMING MOST PATENTS


DEVELOPMENT OF INDUSTRIES THROUGH PATENTS

It is not to be understood that the examination referred to an investigation of the prior art. The only examination required was of the petition, description, drawing, etc., of the application.

The next patent act was amendatory in its nature, and was passed in 1793. Among other changes, it imposed the duty of issuing patents upon the secretary of state, subject, however, to the approval of the attorney general.

From 1793 down to 1836, various unimportant amendments to the patent laws were enacted. In the last mentioned year, however, the first comprehensive law was passed relating to the granting of patents. This law remained in force until 1870, and was in fact in substance very much the same as our present laws.

By the enactment of 1836, a sub-department of the state department was created, which was known as the patent office. Provision was made for the appointment of a commissioner of patents, and the commissioner of patents was required to make or to have made an examination of the alleged new invention or discovery to determine whether or not the same had been invented or discovered by any other person in the United States prior to the alleged invention thereof by the applicant and to determine whether or not in view of the prior art, the applicant was entitled to a patent.

Prior to this act examinations were not required, and if the applicant averred that his alleged invention was new and novel, the commission or the secretary of state was required to grant or issue a patent upon his application, provided the discovery or invention of the applicant was deemed of sufficient importance.

It will readily be seen that a patent granted under such circumstances was necessarily of very small commercial value, because it would not be reasonable to expect men to invest their capital in a species of property good title to which and the value of which were so uncertain.

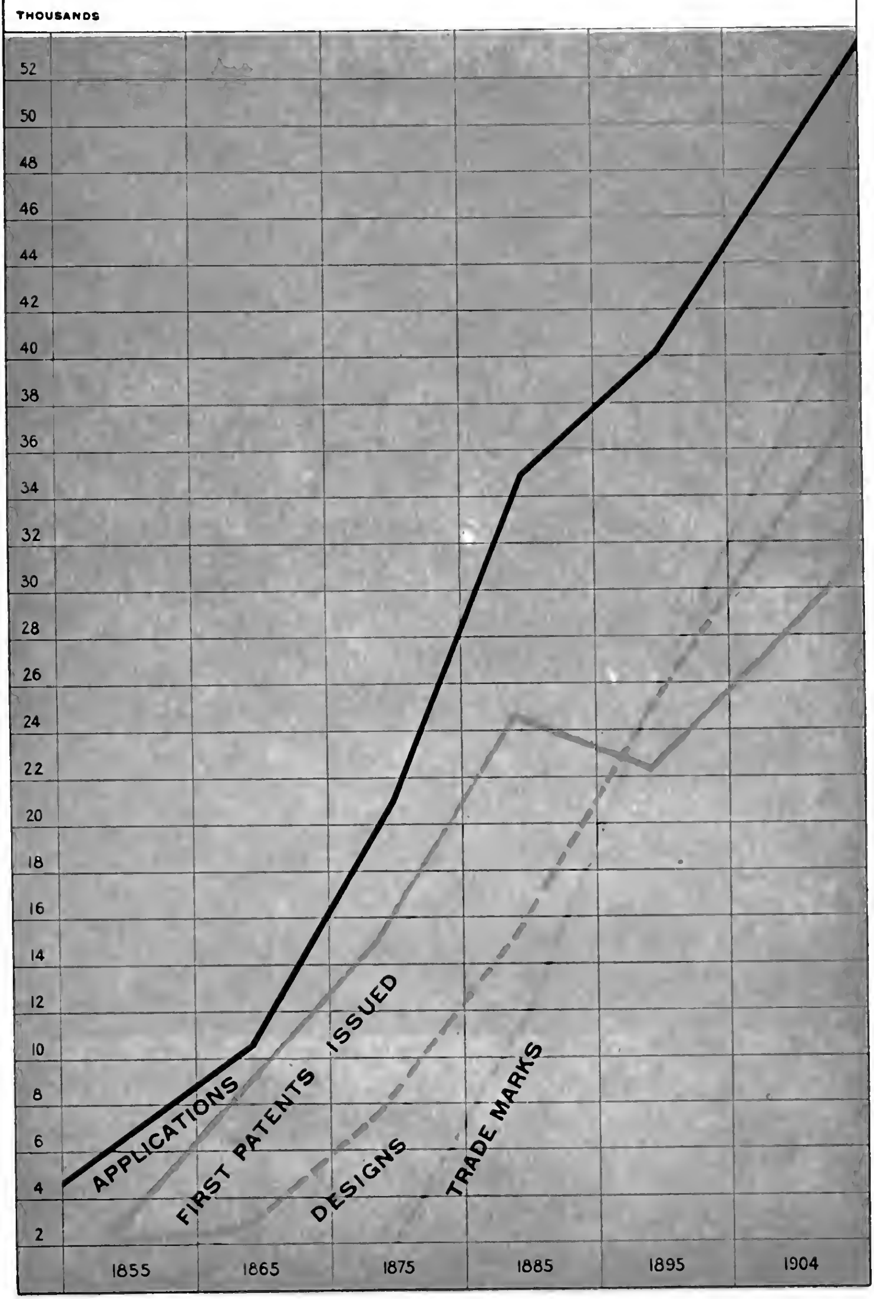
The act of 1836 established patent property upon a higher plane than it had ever before occupied and it is believed that the importance of this act to the people of the United States cannot be overestimated.

Senator O. H. Platt, speaking in 1884, referring to this act, said:

"To my mind, the passage of the act of 1836 creating the patent office marks the first important epoch in the history of our development—I think, the most important event in the history of our government from the constitution until the civil war. The establishment of the patent office marked the commencement of that marvelous development of the resources of the country which is the admiration and wonder of the world, a development which challenges all history for a parallel; and it is not too much to say that this unexampled progress has been not only dependent upon, but has been coincident with, the growth and development of the patent system of this country. Words fail in attempting to portray the advancement of this country for the last fifty years. We have had fifty years of progress, fifty years of inventions applied to the everyday wants of life, fifty years of patent encouragement, and fifty years of a development in wealth, resources, grandeur, culture, power which is little short of miraculous. Population, production, business, wealth, comfort, culture, power, grandeur, these have all kept step with the expansion of the inventive genius of the country; and this progress has been made possible only by the inventions of its citizens. All history confirms us in the conclusion that it is the development by the mechanic arts of the industries of a country which brings to it greatness and power and glory. No purely agricultural, pastoral people ever achieved any high standing among the nations of the earth. It is only when the brain evolves and the cunning hand fashions labor saving machines that a nation begins to throb with new energy and life and expands with a new growth. It is only when thought wrings from nature her untold secret treasures that solid wealth and strength are accumulated by a people."

Under the patent laws now in force in the United States any person who has invented or discovered any new and useful art, machine, manufacture or composition of matter, or any new and useful improvement thereof, not known or used by others in this country before his invention or dis-

GROWTH OF PATENTS AND TRADE MARKS, 1855-1904



covery thereof, and not patented or described in any printed publication in this or any foreign country, before his invention or discovery thereof, or more than two years prior to his application, and not in public use or on sale in this country more than two years prior to his application, unless the same is proved to have been abandoned, may, upon payment of the fees required by law and other due proceedings had, obtain a patent therefor.

It may be remarked here that the word "discovered" in this section of the statute means "invention."

It will be noted that foreigners have the same rights under this law as citizens of the United States.

The first requisite to the securing of a patent is the making of an invention. Just what invention is or what it takes to constitute an act of invention is a question that has been discussed by the courts and by text book writers many, many times, and it is a question which cannot be answered by definition. I say this, notwithstanding that definitions of the term "invention" will be found in many text books, and in many decisions of the courts. Suffice it to say that invention comprehends a new idea of means and it must be something beyond the scope of merely mechanical effort.

Having made an invention, the next step in the process of securing a patent consists in the preparation of an application and the filing of the same in the patent office. This application comprises a petition to the commissioner of patents, requesting the grant of the patent for the invention disclosed in the application, an oath answering to the requirements of the statutes, a specification descriptive of the invention, and such specification must be concluded with a claim or claims specifically pointing out the improvement or invention. If no application has been made in a foreign country, the oath should set forth that the applicant is the original and first inventor of the invention disclosed in the application and described and claimed in the specification; that such invention was never known or used before his invention or discovery thereof; that such invention had not been patented or described in any printed publication in the United States of America or any foreign country before his invention or discovery thereof, or more than two years prior to his application; that the said invention had not been in public use or on sale in the United States for more than two years prior to his application, and that no application for foreign patent had been filed by him or his legal representatives or assigns in any foreign country prior to his application in the United States. If, however, applications for patents in countries foreign to the United States have been made at the time of the filing of an application in the United States, it is necessary for the applicant to name the foreign country or countries in which such applications have been made, giving the date of the filing of the same.

The claims are necessary to a complete specification. The specification must, of course, be signed by the applicant, who in nearly all cases is the inventor, and the application when forwarded to the patent office must be accompanied by the first government fee of $15. Where the application relates to an invention which can be graphically depicted, it is necessary to prepare and file drawings with and as a part of the application.

If any one of the parts above referred to are omitted, the application will not be accepted by the patent office, and the same will not be filed until all of the parts have been received by the patent office.

After an application has been received by the patent office, it goes to the application division, where it is classified, and is then forwarded to the division in the patent office in which is to be found the class of machine or art to which the invention belongs. Applications received in the office are examined in regular order, according to their filing dates.

Before the claims of an application are allowed, careful examination of the prior art is made, and only such claims are allowed as distinguish from the constructions disclosed by the patents and other publications discovered by the examiner in his search of the art.

As a rule these examinations are carefully made, though, as you will readily understand, where several hundred examiners and assistants are employed, some of them are more careful in their work than others. The more care taken in the search and examination of the records in the patent office, the more likely is it that the patented claims will be valid.

It frequently becomes necessary to amend the claims perhaps many times, before they can be brought into such shape that they distinguish from the art.

There is one thing that should be understood by all applicants for patents, and that is that the claims of a patent are of the very greatest importance; in fact, I should regard the claims as the most important part of a patent. Unless the claims are well drawn and unless they cover well the invention forming the subject matter of the patent, the patent loses much of its value.

The phraseology of the claims should be accurate. It is as necessary that the elements or parts entering into and forming the combination set forth in a claim should be stated and put together with exactness and precision as it is that the same elements be fitted together with exactness and precision in the machine itself.

As I have already said, the claims of a patent should be drawn with very great care, and should be made as accurate and as exact and as much to the point as it is possible.

I am sorry to say, however, that in many, many instances claims are vaguely and loosely drawn. This in some instances is due to a lack of knowledge of what the invention really is; in others it is a lack of ability to express ideas clearly in writing; in others it is perhaps a lack of effort; and in others it is perhaps due to a lack of proper time; but whatever the cause may be, failure to secure good claims is a misfortune so far as the patentee is concerned.

A writer in the Forum, referring to the difficulty of claim writing, has said: "It takes a very experienced hand to avoid defects which will nullify the patentee's proper advantage. An omission is fatal; an addition is fatal; and a vagueness is fatal."

Broadly considered, the claims of an application may be divided into generic and specific claims. If the invention disclosed in an application will support a broad or generic claim, such a claim should by all means be included. But in addition to such claim, specific claims also should be included because it is very much easier to anticipate a broad claim in the prior art than it is to anticipate a specific claim, and it may happen, if the claims of the patent are ever subjected to litigation, that the patentee would be able to sustain the validity of the specific claim but would be unable to sustain the validity of the generic claim. In such case, the patent, by reason of the presence of the specific claim, would still be of value to the patentee, while, on the contrary, if it had included only the generic or broad claim or claims, which had been anticipated, the value of the patent would be entirely destroyed.

It is not always so, but, generally speaking, a broad claim includes a small number of elements in combination, while a specific claim will include a greater number of elements in combination, and these elements may be still further affected and narrowed by qualifying limitations.

It sometimes happens that an inventor, who fully understands the details and principles of his invention, concludes that he is better fitted to write his specifications and claims, that is to say, is better fitted to prepare his application for the patent office than some one who has had experience in the writing of specifications and the drawing of claims, and therefore undertakes to do this work. It is very unusual to find an inventor who has had sufficient experience to prepare the specification and claims of an application properly, and the chances are about one hundred to one against his succeeding in drawing claims which adequately protect his invention.

After the application has been placed in condition for allowance, it is allowed by the examiner, after which it goes to the issue division of the patent office. Then, upon the payment of the final fee of $20, the patent is printed, the grant is prepared and is signed by the commissioner of patents, and the patent is issued under the seal of the patent office.

Many inventors suppose that when they have secured their patents their troubles are over, but the fact is that if the invention is of any considerable value or worth, the patentee will be beset by a horde of infringers who will attempt to use the invention and secure the benefit of the inventor's thought and ingenuity.

The patentee can protect his rights only by bringing and prosecuting a suit in the federal courts and securing an injunction against infringers.

It seems strange that a person who would not think of trespassing upon the real property of another person, or who would not think of interfering with ordinary chattel property belonging to a stranger, will not hesitate to trespass upon the patented property of another, whenever it appears to him that such trespassing would inure to his advantage, considered from a business and financial standpoint.

Notwithstanding the fact that patented property is constantly being subjected to the attacks of infringers, such property is very valuable, and, as has already been pointed out, constitutes the basis of investment of many millions of dollars in the United States, and it has been asserted in a comparatively recent annual report of one of the commissioners of patents "that we mainly owe to our patent system such foothold as we have gained during the past fifty years in foreign lands for our manufactured products."

THE WORK OF THE WEATHER BUREAU.

BY THEODORE WATERS.

[Theodore Waters, author and lecturer; born Philadelphia, April 10, 1870; educated in the public schools of that city and privately; after several years' work as a contributor to newspapers and magazines he became editor of the McClure Syndicate in 1897; press secretary for the University of Pennsylvania, 1900; associate editor Everybody's, 1904; Pearson's magazine, 1905; is press secretary for the American Association for the Advancement of Science. Author of Six Weeks of Beggardom, The Profession of Getting Hurt, etc.]

If you could be perched high above the north pole, and with an all seeing eye could gaze upon the general atmospheric condition of the northern hemisphere, you would see a panoramic succession of storms and fair weather sweeping around the earth in one direction as regularly as the hands of a clock. The intensity of the succession might be marred here and there by eddies, but even the eddies would be found to have laws of their own. Those of January would be typical of that month, and would take typical courses. So would those of every other month, and the paths marked out by these storms would be followed accurately year by year. These details would have special lines of conduct, just as planets have individualities, but they would be found subservient to a great general movement, just as the planets all together revolve around the sun.

You must assume this north pole attitude when considering the weather. It is impossible to analyze a rainstorm with an umbrella above your head. You must get above the rainstorm. This is the keynote of the United States weather service.

The forecast room of the weather bureau is long and wide. Down its center extends a double line of standing desks, placed back to back. Men are working at these desks, and the forecaster stands at the head of the line. A telegrapher is clicking a Morse instrument in one corner of the room, and a man is distributing odd looking type at a case in another corner. On the wall is an immense map of North America—twelve feet long by eight feet high. The states, counties, cities and lakes are sketched dimly in aluminum paint. Weather conditions are marked on the map as they are received by telegraph, and are altered or rubbed off as later reports suggest. Men walk up to the map at all hours of the day and mark on it queer symbols, which, interpreted, mean rain, snow, cloudiness, heavy winds, fog, hot or cold waves, as news of their existence is received. Of course they are marked on that part of the map corresponding to the part of the country from which they are received, and during the day every part of the map is reconstructed. The men are enabled thus to keep track of the condition of the country, because in the United States there are two hundred branch meteorological stations; 250 special stations which display danger warnings to mariners; 260 special stations for observing certain conditions of temperature and rainfall in the cotton, corn and wheat regions, and over 3,000 stations where volunteer observers make daily records. If any change takes place, the fact is telegraphed at once to the central office, and the big map on the wall is altered accordingly. This does not mean that each of the 4,000 is in individual communication with Washington. Every state has its own bureau, in which all messages from its own territory are received, and at the discretion of the state forecaster are transmitted to Washington. Some of the outlying stations are on mountain peaks; some are on gulf coast islands; some are in the arid regions of the southwest; some are on the lakes, and some are in the West Indies, where the men watch for hurricanes, but all figuratively are at the finger's end of the man who operates the telegraph sounder in the corner of the room.

Twice every day—at 8 A. M. and at 8 P. M., Washington time—every telegraph line in the country must be left open for the business of the weather bureau. Eight o'clock in Washington, D. C., is 7 o'clock in Chicago, 6 o'clock in Denver, and 5 o'clock in San Francisco. At those hours the 4,000 weather watchers take an observation in their vicinity. They note whether it is raining or clear, or, if cloudy, the kind of clouds and their direction. They scan the thermometer and read the barometer, and they telegraph the result to their state centers. Each state expert sifts the accumulated data until he has a composite account of state conditions. This in code form is telegraphed to Washington. It is then that the work of the forecaster general begins.

In front of each of the men at the standing desks is a blank chart. The contours of the states are fairly printed on it, and the cities, unnamed, are indicated by little quarter circles. One man marks down the temperature; another man, the pressure; another, rain or snow; still another, the wind direction, and so on through the list. At the head of the line stands the forecaster with a blank chart of his own. He is about to make his chart a composite of all the others. Yesterday's chart hangs up in front of him, and behind it are the charts for preceding days. At his elbow is a stenographer ready to take notes. And now the men who have been making up their charts by reading, as it were, between the clicks of the sounder, begin calling off the result to the forecaster, who seems able to hear and to comprehend all voices at once, and who shows an ability to leap from swift contemplation of Maine temperatures to California pressures, or from swifter consideration of Florida humidity to Dakota blizzards. It is all somewhat chaotic to a layman who has not the peculiar mental training of the forecaster. But to him it seems plain. As he mutters conditions and possibilities, and arrives at conclusions, you can see in his face the expression of the doctor who is making a diagnosis. The forecaster knows the symptoms of storms as the doctor knows those of fevers. His head, apparently, is full of figures and calculations; but across the subconscious area of his mind is floating a complex picture of adaptable facts which, could it be recorded, would constitute a working primer of practical meteorology. And since it is so necessary to the forecaster, let us glance hurriedly at this picture before going on.

First, there is the principle of the storm. Let us suppose there is a storm of wind and rain in the Mississippi valley, an area of clear, cool weather on the Atlantic coast, and another area of clear, cool weather on the Pacific coast—in other words, a stormy section of country between two clear sections. Now, this is how the storm is formed. The tendency of cool, clear air is to fall. Being heavy, gravity pulls it down from the regions above the clouds to the earth. When it strikes the ground, having no other course left open to it, it flows out over the surface of the earth from the center of each clear weather region in all directions. As the air travels outward it picks up moisture and becomes warm, and the barometers show that it is becoming lighter and lighter as it flows away from the fair weather centers. It is inevitable that part of the air which traveled west from the Atlantic fair weather section should come into contact with air traveling east from the Pacific fair weather section. The contact at once causes a mixup, which takes on a gyratory motion. The two currents of air rush together and begin rotating in a great circle. Having become heated in traveling, the whirling column of hot air ascends, dropping moisture in the form of rain, until it is dissipated far above the earth.

So we have the low pressure or storm area situated between two high pressure or fair weather areas and receiving its energy from them. While this relation may be constant as regards the areas themselves, yet the whole system moves slowly across country. That is, there is a constant succession of fair and stormy areas traveling eastward at intervals of three days, and at the rate of twenty two miles an hour in summer and thirty seven miles an hour in winter. Storms always move to the eastward, and no matter where in the United States they form, they always curve in the direction of New England. It is an invariable law.

This is the background of the panorama that flits across the forecaster's mind. On this background he sees the shadowy paths of monthly storms; for each month of the year has its own class of storms. These storms enter the country at certain places, and follow well defined courses. United States storms, according to Professor Bigelow, have nine average places of generation. The great majority form in Alberta, north of Montana, and after coming into the United States, travel eastward. A few come in over the North Pacific coast. A third group forms on the northern Rocky Mountain plateau. A fourth forms in Colorado, being born on the very high mountainous elevations. A fifth forms in the Texas lowlands, and catching the gulf winds and moisture moves eastward. West Indian hurricanes form the sixth class. The South Atlantic coast storms make up the seventh class. Storms which come in from the Pacific on the southwest form the eighth, and finally a class of minor storms is generated in our central valleys. Some of these storms come across the Pacific from the Asian coast, and after sweeping across the country, go out over the Atlantic to Europe, and even to Asia again, but there is no record of a storm having circumnavigated the globe. But no matter where these storms are generated, they always converge towards New England. New England, in fact, seems to be the stormiest spot in the United States. A record of ten years ending with 1893 shows 1,143 storms, all of which headed toward, and most of which reached, New England.

The forecaster must consider the general configuration of the country in reckoning for cold or hot waves, blizzards, northers and other manifestations peculiar to certain localities. An inexperienced prophet might predict, for instance, a long record for a peculiar class of Pacific storm, whereas many of them come in over the seaboard, whirl violently until they strike the Rocky mountains, when, in endeavoring to climb the divide, they are dried out and dissipated in the upper air and are never heard of in the valley beyond. Sometimes they break through and head wildly for New England. But the forecaster must know of these storm gateways. He must reckon with the climatic properties of the cold pole of temperate America, that peculiar region surrounding Lake Winnepeg, where the range of temperature is 150 degrees, the thermometer rising to 105 degrees above in summer and dropping to 45 degrees below zero in winter. As Professor Bigelow puts it, the giants of heat and cold stagger back and forth across the country in perpetual contest, and the forecaster must be a good judge of the staying power of each.

This and much more is constantly in the vision of the forecaster as the men call out the daily data. He traces the progress of the storm center in about the same way that a railroad manager would trace the progress of an overland express. Like the railroad man, he knows how much fuel his storm had to start with, how much it may gather by the way, the grades it will have to take, where it may be switched from the main line; and, like the railroad man, he is being constantly informed by telegraph of the condition of the right of way, as well as of the condition of the wind column itself.

By the time the forecaster has reached his general conclusion it is half past eight, and the four thousand weather watchers are waiting for the composite report. It is necessary not only that the forecast shall be sent far and wide, but also that charts depicting the whole aërial condition of the United States at the time the forecast was made shall be printed and posted all over the country. It is manifestly impossible to print within an hour the required 18,000 charts in Washington, D. C., and transmit them to all parts of the country. So information for making charts is sent to all state centers and from them in turn to the various sections of the states. The telegraph operator in the corner of the room has turned to the transmitter, and is distributing this information in code over all the telegraph trunk lines. The local forecaster in each state has been making a special state forecast of his own, which, with the corroborative general information received from Washington, he transmits to every one of his state stations.

Now, a man who was distributing type in the other corner of the room has meantime gotten data which enable him to set a chart. He does not set type like an ordinary printer. His stick is a large plate similar to those from which charts are printed, but in many places in the face of the plate are little holes. Into these holes the printer puts his type. Each type face is a symbol indicating much or little temperature, pressure, rain, wind, or fog. There are holes for type along the Atlantic seaboard, in the Mississippi valley, along the lakes and the gulf, on the Pacific slope, along rivers and on mountain tops. Every large district center has a printer working in unison with the man in Washington. But the small outlying distributing stations cannot afford to print by this process, and there the local weather watcher prints his charts on a typewriter.

The chart making typewriter has been especially designed for the government. It looks like an ordinary typewriter, but you could not write a letter on it, for instead of ordinary type, the characters are like the printer's queer type—arrows, circles, squares, dashes, etc. The local official inserts a blank chart in the machine and writes aerial conditions on the face of it. The large offices print their charts on a press; the smaller stations mimeograph the typewritten chart. The whole operation carried on simultaneously all over the country is completed in half an hour. Each station scatters its charts and predictions over the district of which it is the center, so that in one hour from the time the observations are made, the whole country has documentary evidence of the weather probabilities for the succeeding twelve hours. How really remarkable is this distribution is shown by the fact that in addition to the thousands of governmental observators above mentioned, 31,000 addresses are served daily with the weather forecast by telegraph, telephone, mail, and railway train service without cost to the government except for stationery. In fact, not counting newspaper circulation, the United States weather forecasts must reach at least 50,000 central points of distribution; many of them twice a day. Besides the bureau has an adjunct department devoted to crop reporting. There are 10,000 crop correspondents scattered throughout the country—men who report weekly the state of the crops as affected by climatic changes. These reports are compiled into bulletins, which are issued by thousands in the form of 168 different state monthly crop bulletins, and forty two monthly general bulletins.

In connection with the forecaster's prediction of usual weather conditions, it is interesting to note this statement of Prof. Bigelow on the approach of hurricanes:

"The physical features of hurricanes are well understood. The approach of a hurricane is usually indicated by a long swell on the ocean, which forewarns the observer by two or three days. A faint rise in the barometer occurs before the gradual fall which becomes very pronounced at the center; fine wisps of cirrus clouds are first seen, which surround the center to a distance of 200 miles; the air is calm and sultry, but this is gradually supplanted by a single breeze, and later the wind increases to a gale, the clouds become matted, the sea rough, rain falls, and the winds are gusty and dangerous as the vortex core comes on. Here is the indescribable tempest, dealing destruction, impressing the imagination with its wild exhibition of the forces of nature, the flashes of lightning, the torrents of rain, the cooler air, all the elements in an uproar, which indicate the close approach of the center. In the midst of this turmoil there is a sudden pause, the winds almost cease, the sky clears; but the waves rage in great turbulence. This is the eye of the storm, the core of the vortex, and it is perhaps, twenty miles in diameter, or one thirtieth of the whole hurricane. The respite is brief, and is soon followed by the abrupt renewal of the violent wind and rain, but now coming from the opposite direction, and the storm passes off with the several features following each other in the reverse order."

Cyclones or general storms may be 1,000 miles in diameter. Hurricanes operate on a path averaging 600 to 800 miles wide. Tornadoes are much smaller. They may be only a mile wide at the top and but a few feet at the bottom, but they are much more dangerous than either a cyclone or a hurricane. They form in all parts of the temperate zone—at sea they are water spouts, and on the desert they are sand storms. Sometimes a whole family of tornadoes will be born at once from the same cloud. As many as fifteen tubes have been observed at one time. In winter months they occur only in our gulf states, but in summer they occur in the north, in Nebraska, South Dakota, Iowa and Minnesota. The average is twenty five a year. They are simple examples of vortex motion. A mass of air rotating at a low level runs into a vortex, and a tube is projected downward. The velocity of the lower end of the tube may reach 200 miles an hour, and it is the partial vacuum caused by the whirl and the sudden inrush of the outside air that causes the disastrous explosive effects. Tornadoes wrecked $31,000,000 worth of property in this country during the years from 1889 to 1896. Twenty three million dollars of this amount was destroyed by three whirls alone. The Louisville tornado, March 27, 1890, destroyed property worth $3,000,000. The St. Louis tornado, May 27, 1896, caused a loss of $13,000,000. A tornado swept from Cedar Keys to Washington, D. C., September 29, 1896, which caused a loss of $7,000,000. But the most interesting fact concerning tornadoes is the record of how one began. The account was sent to the weather bureau by one of its observers. The following is an abstract:

By A. H. Gale, Voluntary Observer at Bassett, Nebraska.
Dated, July 28, 1899.

"Mr. A. Brown, 5½ miles northwest of Johnstown, saw the tornado form. He was at work in his barnyard and noticed it coming across his field as a light summer whirlwind such as is noticed on any still hot day. Air at the time was calm. Mr. Brown says he was harnessing a horse, and as the light whirl passed him it gently lifted the straw edges of the roof of his cow shed, but had not enough strength to lift his hat, and passed on. At this point it was devoid of any color, and was mainly noticed by the whirl it made among the grass, straw, and chaff on the ground; he watched its onward movement indifferently, and soon saw it gather a color which made it definable. He then paid close attention to it and noticed it becoming black, angry, and gyrating vigorously, chips, straws, and dirt fell into it, and were absorbed by it and a smoky veil began to envelop the whirling column as it mounted upward. At the same time a funnel began to lower itself from a turbulent low hanging cloud of an area of about forty acres; the column and funnel soon connected and with this union the thing took on a terrifying aspect; up to this time he had no feeling of apprehension. When the whirl passed him he said he was aware of its passage only by its action on the ground. No color. A black cloud above, in commotion, followed the whirl on the ground, which latter was eight or ten feet in diameter. This cloud was alone, separate, and clear from a higher strata of storm clouds above. When passing his point, and as long as within his line of view, he estimated the speed at 10 miles per hour, line of path east by south. I will say here that the entire path from start to end was 18 to 19 miles, and in that distance it made a southing from a due east course of 2¾ miles, and ranged from 1 to 3 rods in width. Two and one half miles from Mr. Brown's point it crossed a large cornfield and here it received much coloring matter. That the affair was at this time in comfortable order was demonstrated by the shock it gave the first house it struck as it left the cornfield, Mr. John Strohm's. Mr. Strohm and his family saw it as it rose along the slant of the cornfield to his house on its edge, and dove for the cellar. The destruction at this place was complete; house of heavy logs, windmill, and tower, and stable, in all seven buildings, completely leveled to the ground, fences upset, broken down. Fence wire woven and interwoven with broken lumber, straw, debris of all sorts, plastered with mud. Every fence post standing in the track formed a dam around which was massed debris of everything imaginable, the whole daubed with mud; it was a picture of desolation and ruin—dismal in the extreme."

A reference to lightning brought out the fact that the bureau is using its ponderous organization for the collection of lightning statistics. The officials are less concerned with the identification of the thunderbolt than they are with its disastrous effects. According to lightning statistics, 312 inhabitants of the United States, on an average, are struck by lightning each year. Twenty five hundred were struck during the last nine years. Farmers suffered most, probably because of their exposed occupation, for the danger from lightning is found to be four times as great in the country as in cities. January naturally is the least dangerous month, and July is the most dangerous—123 persons were killed during July, 1893. During the eight years ending with 1897, 7,558 buildings, valued at $17,672,772, were destroyed by lightning; 4,891 of these were barns. Comparatively few churches were struck. In 1898 buildings valued at $1,441,880 were destroyed. New York state headed the list with 395. There were no disastrous strokes in Idaho, Arizona, California, Oregon, Nevada or Utah. In the same year, 1,842 animals, valued at $48,000, were killed by 710 strokes of lightning. This mortality was unequally divided among cattle, horses, mules, pigs and sheep, whole flocks of the latter being killed by single bolts. There is no means of finding out the exact number of trees struck, but it is interesting to know that the list of liability is headed by the oaks. Firs, beeches, pines, larches, ash and birch trees are most liable to be struck in the order named, on account of their conducting qualities. The records show an increase in the number of damage dealing lightning strokes, especially in Europe. But the cause of this has not yet been discovered. The only definite fact observed by the bureau is that these violent manifestations seem to occur in connection with the movement of sluggish cyclonic areas across the country during the warmer months.

The weather bureau also tells people how to avoid danger. For the farmer it issues a pamphlet, advising protection against frost by means of a blanket of smoke. It tells him how to utilize fog for irrigation by erecting wire gauze screens on his farm so that the fog will be condensed. The bureau tells the people in tornado districts how to escape these whirling monsters; how to construct cellars; how the sucking action of a tornado draws all the air out of a closed up house, and by creating almost a vacuum collapses the walls. It cautions, therefore, that every door and window should be kept open to allow a free passage of air. It tells the shippers of perishable goods how those goods may be protected from heat and cold. It issues suggestions for the closing and opening of the hatches of freight steamers in certain kinds of weather, and sends these vessels from port with certain signals flying, so that incoming craft may be warned and may act accordingly. In the lakes it has a regular corps of safe conductors of merchandise, who go on board passing vessels and give valuable advice to captains in view of certain weather conditions. A vessel bound from Buffalo to Duluth is really protected as much by constant watchfulness of alongshore weather men as she is by the sagacity of her captain. Thus it will be seen that the work of the bureau is not confined to the comparatively passive business of predicting storms.

Although this system of weather forecasting is a source of great expense to the government, yet there are many instances where a single warning sent out by the bureau has saved more money to the property owners of the country than would have paid the expenses of the bureau for years. Take the matter of West Indian hurricanes. Every one of these storms which have visited our coast in recent years has been predicted by the bureau, and ample warnings have been issued. It has been estimated by maritime property owners that the absence of warnings in the face of one of these storms would result in not less than $3,000,000 worth of wreckage. Twice has the weather bureau taken a census of the amount of property held in port as the result of hurricane signals. In the first instance, the value was held to be $34,000,000. In the second instance the estimate was $38,000,000. Ample warning was given of the approach of the great hurricane of August, 1899. Many lives were lost and much property was destroyed, particularly at Ponce, but the result would not have been nearly as disastrous had not the alcalde at Ponce withheld the warning until it was too late to be of use. In January, 1898, a severe cold wave swept across the country from the Rocky mountains to the Atlantic. Professor Moore, the chief of the bureau, secured estimates from shippers in one hundred large cities which indicated that $3,400,000 worth of merchandise was saved through these signals. The California raisin growers estimate that the bureau has saved them many millions of dollars. It is almost impossible to estimate how much property was saved during the great Mississippi river flood of the spring of 1897. When the water had risen at New Orleans to the highest point ever known, advices were sent to the city that in five days it would rise still one foot higher. The prediction proved true, but in the meantime the levees had been raised and strengthened. There was at least $15,000,000 worth of stock and property in the flooded district, and the greater part of this was moved in time to places of safety.

MEDICINE IN AMERICA.

BY TWING B. WIGGINS.

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The history of the progress of medicine in America, as distinguished from surgery, is essentially the history of the men who practiced medicine. It had a beginning when Thomas Wotten came out with the expedition which sailed from England on December 19th, 1606, for Jamestown. This was before Harvey had announced his great discovery of the circulation of the blood. The world was new, doctors many, but scientists were few. The many theories and systems of the time may be compared to their religious creeds, and interest us no more. Wotten, the first of our pioneer doctors, with an education such as the England of that day afforded, probably was able to do little to help those of the colonists who fell sick. The high courage and vigor however which impelled him to the voyage to the distant and unknown land, seemed to make him a worthy predecessor to the long line of able men who have honored American science. Soon after came Doctor Walter Russell, Doctor Lawrence Bohn, and Doctor John Pott. Whatever their value or merit, they made a beginning of one good work, the completion of which lies with us of the present time. In 1639 they stirred up the assembly, then but twenty years old, to pass laws regulating medical practice. That first law was an act to compel physicians to declare on oath the value of their medicines. Virginia must be remembered as the landing place of our first physician, and that there the first law demanded better things of medical men. It was not until 1620 that Dr. Samuel Fuller brought the science of Europe to

Plymouth, where he practiced for thirteen years. The mental state of these ancients when they planned their curious remedies may be imagined by reading the following receipt taken from the receipt book of John Wadsworth of Duxbury: "This Receipt cost me fifty pounds by count, and I pray you would not expose the same without good fee: This for Canser proves exelant, and if in the time applied, will cure a canser humor. Take 3 frogs and put them into a deep earthen basen and power upon them as much sweet oyel as will cover them, put yt into a hot oven and let yt stand a quarter of an houre; then turn off the remaining oyel and dip towl in it and apply to the canser; and for a plaster you must take the yolks of two eggs, Bur tallow, 1 oz., coal armonick, 1 oz., Bay salts ½ oz. Bruse all to a fine powder and mix up with yt yolks of eggs and apply in form of a plaster to the sore every 3rd day. Give a portion of a spoon of salts to cool the hete of the blood; this alwaise will carry off the canser humor if timely applied. The person must make them constant drink the canser roots tea—we may att sartain times apply a tode cutt in two to the wound, two or three times a week the nature of yr tode is such yt will draw out the sharp hot canserous and pysonous and if you proseded in this matter, you may cure any canser."

This carries us back into the dark ages. The absolute ignorance of the nature of cancer and its diagnosis is not surprising; but the credulity of the writers is amazing. It was an age of barbarism, but Harvey was living and his famous contemporary, Rene Descartes, who was the first to show that vital phenomena, like all other phenomena in a physical world, are resolvable finally into matter and motion. Truth was being sought, but in America all was crudeness and error. For near a hundred years the births of children were in the hands of the women, midwives so-called. Medicine was largely the work of ministers, and statesmen took a hand. Nevertheless by 1692 the records show one hundred and thirty four men doctors—in name at least. Many of these had their patrons. To us, this may seem humiliating, but our art held no great place in those times. The church came first and then the law. The surgeon was subordinate to the physician until many years later. The pompous, mysterious physician was a great man, the practical, useful surgeon a humble barber. That shows us why surgery so outstripped medicine in real advance. The surgeon must prove what he knew. The vaporings of theorists gave medicine no foundation upon which to build. The first real progress in medicine began when physicians learned that they must use their senses in examination of those diseased, and when to these they could add instruments of precision, a genuine advance began.

In those early years the story of American medicine was the story of the separate colonies, which were isolated and held little communication with each other. Thus prior to the Revolution there were six principal medical centers, those in New York, Philadelphia, Boston, Charleston, Virginia and Maryland.

In New York the names of M. La Montagne and Colden, lieutenant governor of New York, deserve mention. In Philadelphia Dr. Thomas Wynne, Shippen and Morgan; Boylston and Mather in Massachusetts, and Chalmers, Bull, Moultrie, Lining and Garden in South Carolina. To these men American medicine in this period owes much. They introduced inoculation for smallpox, made a beginning of our medical literature, established medical schools and laid the foundations of hospitals. Boylston on the 27th of June, inoculated his thirteen year old son with smallpox virus. This was six weeks after Lady Mary Wortley Montague was the subject of the first inoculation in London. It took great courage, even though backed by the redoubtable Cotton Mather, for Boylston was antagonized by the doctors and the public. The results obtained by Boylston and his friends in the first year of their work speak for themselves. Two hundred and eighty six persons were inoculated, of whom six died or one in forty eight; and of those who died, it was asserted three had contracted smallpox before inoculation. In the same year five thousand seven hundred and fifty nine took the disease in the ordinary way and of these eight hundred and forty died, or one in seven. For Boylston the glory was great, as he was called to London where the inoculation controversy was still raging with little of the same definite results seen in America. He told his story and demonstrated his method, was made a member of the royal society—the first American so honored, and was given a thousand guineas by the king. He will be ever remembered for his good work as the first American physician of note and an honor to his profession. Colden of New York was among the first to do much medical writing, publishing his first paper in 1720, an "Account of the Climate and Diseases of New York." Of the Charleston group, Lining was the first American physiologist, and published in 1753 the first American account of yellow fever. He preached the theory of immunity after attack and his descriptions of the disease are graphic for us to this day.

Another member of this group, Lionel Chelmers, wrote an "Account of the Weather and Diseases of South Carolina" published in 1776. Prior to this he published an article on "Opisthotonos and Tetanus," and an "Essay on Fevers". In this latter essay he anticipated the ideas of Cullen, as he believed the immediate cause of fever to be a "Spasmodic Contraction of the Arteries and other Muscular Membranes." The last and most famous of the Charleston group was Alexander Garden. He was a highly gifted, widely read and cultured man. He was familiar with the Latin and Greek classics and what was more rare, with French and Italian. His studies embraced medical science, botany, mathematics, philosophy, belles lettres and history. Linnæus, who was his friend, gave the name Gardenia in his honor to one of the most beautiful of flowering shrubs. Garden discovered that very useful vermifuge, spigelia, and wrote an elaborate medical paper on that subject. John Mitchell, of Virginia, was one of the few eminent American scientists of those days; a member of the royal society, and an especially fine botanist, publishing a work on that science and describing several new genera of plants. He also wrote an "Account of Yellow Fever, which prevailed in Virginia in the years 1737-41-42." Soon after in Philadelphia there was established the first great American hospital and as a natural sequence to that, in that city was the first of our great medical schools. The Pennsylvania hospital was the result of the efforts of Dr. Thomas Bond, who interested Benjamin Franklin in the project. Franklin saw at once the value of the proposal and to his influence and shrewd knowledge of men, was due the money obtained half by popular subscription and half by vote of the assembly,which enabled a house to be rented, and made ready for patients in February, 1752. The rules provided for the reception of acute cases only, except the contagious, and that the city poor should be received without charge, at least one bed should be provided for accidents that required immediate relief. Pay patients could only be received after all charity cases were taken care of, and such should be allowed to pay their own physician or surgeon. The last three rules were to the effect that the patients may not swear, curse, get drunk, behave rudely or indecently, on pain of expulsion, that there should be no card playing or dicing, and such patients as are able shall assist in nursing the others, washing and ironing the linen and cleaning the rooms, and such other services as the matron shall require. Rules not unlike those in force to-day were drawn up, governing the appointment of physicians and their conduct. The managers retained all power in their own hands, with the right of dismissal at any time, although the services of the attending physicians were gratis, a custom which still prevails.

Very soon, through the efforts of John Morgan and William Shippen, Jr., both of good families and having the advantage of several years' training in Europe, the medical department of the College of Philadelphia was established, about ten years before the Revolution, the pioneer medical college of this country. The college was to confer the bachelor's and the doctor's degrees in medicine, but the former was soon abandoned. The candidate for the bachelor's degree, should, at matriculation, show efficiency in the natural sciences and in Latin, during his studies he should attend at least one course of lectures in anatomy, materia medica, chemistry, the theory and practice of physic, and one course in clinical lectures, and should attend the practice of the Pennsylvania hospital for one year, after which he should be admitted for examination for the degree. He must further have served an apprenticeship with some physician. For the doctor's degree the candidate must wait three years, and write and defend a thesis. Morgan was chosen for the chair of the theory and practice of medicine, Shippen became professor of anatomy and surgery and to these were shortly added Adam Kuhn, professor of materia medica and botany, and Benjamin Rush, professor of chemistry. In June of 1771 there returned for the doctor's degree, four men who had been graduated bachelors of medicine in 1768: Jonathan Elmer, Jonathan Potts, James Tilton and Nicholas Way—the first doctors of medicine graduating in Philadelphia. Though Philadelphia thus established the first medical school and granted the first degrees of B. M. it was the medical school of New York, established in 1768 and granting the B. M. in 1769, that bestowed the first doctor's degree granted on this continent upon Robert Tucker in 1770. The first struggle of the Revolution disrupted the faculty of the Philadelphia school and later the new university was the favorite of the patriots. After the war was over, through the efforts of Benjamin Franklin the charter was restored to the college, the old professors reinstated and finally the two schools were united under the title of the University of Pennsylvania, which still lives. In New York at this time, Dr. John Bard was a truly eminent man, and proved himself our earliest efficient quarantine officer. He was the first president of the New York medical society and the father of an even more distinguished son, Samuel Bard. With the single exception of Benjamin Rush, Dr. Samuel Bard was the most eminent American physician of his time. During his long life his services to American medicine were of the greatest value. Among them perhaps the most notable was the founding of the medical school and hospital in New York, and his efforts were unwearied through more than forty years to foster and promote medical education. Among those who aided him to establish the medical school of King's college in 1768, were Samuel Clossy, professor of anatomy, John Jones, who held the chair of surgery; Peter Middleton, professor of physiology and pathology; James Smith, chemistry and materia medica; John V. B. Tennant, midwifery; Bard taking the chair of theory and practice of physic. In connection with the founding of the two schools of Philadelphia and New York, it is of interest to note that great stress was placed upon the value of a broad preliminary education—an equipment which we are only of late years beginning to demand of our matriculants. The few conspicuous men whom we have mentioned thus far, were men of wide culture for their time, and would even now be so considered. We must not omit to note that the rank and file of the doctors of that time were very ignorant and poorly trained. Quackery was even more flourishing then than now. The distance from Europe and the lack of schools in America had so reduced the standard of requirement that the lapse of over a century has hardly availed to raise us to the European standard and to place physicians as a whole on a plane with the other professions. Better schools than our best do not exist, but at the same time the world contains no schools so bad as our worst.

So much for the planting of medical science in America. At first it compared favorably with what was known and practiced in Europe, for many of the pioneer doctors were men of education and others returned to the old world for their training. As these first mentioned died out, there came a decline in the standard, and aside from the foreigners who came to us, and the few who went abroad to study, the medical attainments of our ancestors were not high. Such a condition could only be relieved by the rise of the schools and the spread of a higher learning. Thus in the war of the American revolution the physicians played but a sorry part. The services rendered the troops were slight and crude. It is true drugs were few and bad, and hospital supplies were not to be had. The one disease which was successfully combated was smallpox, for which inoculation was practiced. With the ending of the Revolution the tale of American medicine really begins. The colonies were provincial in science, dependent on Europe for everything; but with the rising of the nation, the science of medicine rose too; and although many of our young men continued to study and travel in Europe, we early developed a type of doctor of our own, and American practice became well and favorably known more than a century ago. Medicine was from the first a favorite profession. In colonial days theology, the law, the army and the navy led it, but to political freedom was added religious freedom, and the class that formerly recruited the clergy came in a very few years to embrace medicine. That class was the strongest and finest that our race has yet produced. They were virile and enterprising, country born mostly, but with traditions of education and good breeding. They took up life's work with a zest and a dogged resolution to succeed that brought the best of them to a position of importance in the community such as the medical men of no other country have yet attained. The profession became popular, and scarce a family in the land of importance but counted one or more of its members among its number. Social prejudice, as known in England, was abolished along with titles and primogeniture. The doctor was often the most important man in the community. Life was simple, the largest city small, and the man of science was often distinguished in literature and politics. Indeed, it was rare that the doctor was not also engaged in some other occupation. They thus were most intimately concerned in all the interests of the people and though their technical attainments were slight, they knew life, the people, and by virtue of their keen wit and common sense, developed a successful practice which was really remarkable.

The establishment of medical schools and hospitals coincident with the Revolution, and especially the Philadelphia institution, brought some men of genius to the front. Among these no man succeeded in leaving such an impression upon the teaching and practice of the whole country as Benjamin Rush. He has been dubbed the American Sydenham, the Hippocrates of Pennsylvania, and the American Fothergill, by various writers. Nor was that all, as he was almost equally distinguished in fields other than medicine. Like all men of genius he made warm friends and bitter enemies. A patriot, yet at one time at odds with Washington, a physician of fine attainments, yet hated by many of his colleagues; a faithful student of science, yet tied to a system; a philanthropist, yet good men accused him of ruining the community; a great teacher, yet shamed by the acts of his disciples. Truly a man of many parts, and an actor of no mean ability upon the limited stage of that time. He was a student of Dr. John Redman of Philadelphia, a disciple of Boerhaave and Sydenham. After six years of close application, during which he missed only two days from work, he went to Europe in 1766. There he became one of the favorite pupils of the famous Cullen of Edinburgh. Returning home in 1769 he filled the chair of chemistry and later, that of theory and practice of medicine in the College of Philadelphia. When the united schools became a part of the University of Pennsylvania, Rush became professor of the institutes of medicine and clinical medicine and later added to this the chair of practice. Rush was a great teacher. He carefully prepared his lectures. He had a voice mellow and pleasing, and above all a personality and manner of delivery that captivated and held his students enslaved. He inspired his hearers to renewed efforts, gave them new ideals, revealed to them the meaning of science and the value of human life. His pupils carried with them throughout the land, new ideas of the dignity of their profession, the joy of achievement and the necessity of constant, hard work to true progress in medicine. He wrote much and talked ably in favor of the war of the Revolution, was a signer of the Declaration of Independence, and was surgeon general and physician general of the middle department under Shippen. In medicine, Rush, first the pupil of Cullen, was attracted later by the theories of John Brown, Cullen's pupil, rival and enemy. Brown's theory was that nearly all diseases must be met by stimulating, and as it made alcohol the summum bonum it was an easy, pleasant doctrine. Rush could never completely accept these theories, and indeed finally came to stand for a simplified method, a return to normal conditions, a wholesome hygienic life, air, water, exercise, and vis medicatrix naturæ. He added to this the over use of certain drugs, as calomel and jalap, and advocated bleeding. One of the errors universal to his time was to confuse symptoms with diseases. He was unable to escape this, and so built up a system which only his own sound sense and great experience could control. He wrote a truly great history of an epidemic, "An Account of the Bilious Yellow Fever as it appeared in Philadelphia in 1793," and upon this his fame mainly rests. He also wrote the first systematic treatise upon insanity and its treatment, and was a constant preacher of temperance, far in advance of his day. He was our first great medical teacher. In the years following the Revolution, a new generation with new ideas of medicine took the place of the old leaders, among whom Elihu Hubbard Smith is to be remembered, for it was he who established the first American medical periodical, the New York Medical Repository. This journal, and the New York hospital took up most of his time and energies. He was among the first to appreciate that a hospital should be a school of learning as well as a refuge for the sick. At the end of the eighteenth century Waterhouse of Harvard introduced vaccination and Jackson soon after began the practice in Boston. This was two years before Jenners' first announcement of his famous discovery of vaccination. In New York at this time David Hosack was chief editor of the American Medical and Philosophical Register.

But in spite of the eminent men spoken of, the general practice and knowledge of the early part of the nineteenth century was to be deplored. In 1813 David Hosack wrote: "The great disparity in the merits of those who belong to the medical profession is a topic of daily converse and public notoriety." Quackery was abroad in the land and such men as Hosack, deploring the general ignorance of the time, confidently indicated the only remedy—a more thorough education. He, himself, graduating from Princeton in 1789, received his medical degree from Philadelphia in 1791. After a few years' practice in New York, he spent some years at Edinburgh and London, and returned well equipped for practice to New York in 1794. From this time until his death in 1830, he was probably the best known, most accomplished, and most useful physician in that city. In his teaching he grouped in a clear way the best thought of his time and saw that science must be based upon accurately observed and recorded facts The physician of Alexander Hamilton and Aaron Burr, his interests were numerous. He founded a humane society, and urged the establishment of municipal hospitals for contagious diseases, national quarantine regulations and a proper system of city drainage.

Contemporary with Hosack was Nathan Smith of New England. He established a medical school in connection with Dartmouth college, himself filling all the chairs. After building up here a strong and vigorous school, he was called to Yale, whose medical school was founded in 1813. Among his notable writings is a treatise on typhus fever, or typhoid, as we should now call it, which is a classic, and gives us at this day a picture of the disease, which is well-nigh complete, and a treatment which is essentially that of to-day.

Jacob Bigelow, of Boston, was one of the most distinguished of the doctors of the last century. Born in 1787 and dying in 1879, his life of ninety two years embraced all the greatest events of our country's history. He was wonderful as an old man, with a mind keen and alert to the end. What he did made an enormous impression upon the community and upon the profession. The friend of John Adams, Thomas Jefferson, Daniel Webster, and the familiar of Lincoln and Grant, he was ever a promotor of reforms, municipal, social, educational and scientific. At the age of thirty, he was chosen professor of materia medica and botany in Harvard college, and held the chair for forty years. Later he was the first Rumford professor and lecturer on the application of science to the useful arts at Harvard. He published an elaborate series of volumes under the title, "American Medical Botany," which not only covered the ground in an exhaustive way, but is distinguished by an elaborate system of plates, designed and largely executed by the author. He was an editor of the first edition of the United States Pharmacopœia, published in 1820, and did much to simplify the nomenclature. In 1832 he founded Mount Auburn cemetery, the first extra urban forest cemetery, after much agitation. Not only this, but he laid out the grounds, surveyed roads and paths, and designed the ornamentation. He became thus the first of our landscape architects. He should be remembered above all for the great reforms he instituted in the practice of medicine. He was early led to a habit of observation and just conclusion and to a belief in the self limited character of disease. In an address on "Self Limited Diseases" delivered before the Massachusetts Medical society in 1835, he struck the keynote, and the effect was far reaching in promoting the radical change in medical practice which has prevailed among us for two generations, and which has popularly been ascribed to homœopathy.

He urged upon his students in 1852 the great importance of a thorough scientific training, twenty years before that beginning of reform in medical education in America, which was initiated by Harvard in the early seventies. He urged longer courses of study and anticipated that development of special instruction to which we are now turning. He recognized the usefulness and importance of didactic lectures; but original research on the part of students and personal investigation in laboratories, in small groups, under the personal direction of competent teachers, he regarded as most important of all. This is now the view of our leading scientists, and it is of interest to recall that Huxley, forty years ago, insisted on the personal, rather than second hand methods of study. Bigelow went on to define the exact and the speculative sciences; preeminent among the latter, he placed practical medicine, a science older than civilization, cultivated and honored in all ages, powerful for good or for evil, progressive in its character, but still unsettled in its principles, remunerative in fame and fortune to its successful cultivators, and rich in the fruits of a good conscience to its honest votaries. Encumbered as it is with difficulty, fallacy and doubt, medicine yet constitutes one of the learned professions. It is largely represented in every city, village and hamlet. Its imperfections are lost sight of in the overwhelming importance of its objects. The living look to it for succor; the dying call on it for rescue. He then proceeded to explain the difficulties of therapeutics, and finally came to the inevitable conclusion that "he is the great physician who above other men understands diagnosis." His last great work was for educational reform, and the Massachusetts Institute of Technology stands to-day a monument to the energies of this distinguished man.

Nathaniel Chapman, of Virginia and Philadelphia, became a figure of national prominence because of his conception of medical journalism and the impulse he gave it through many years of hard work. In 1820 he became the editor of the Philadelphia Journal of the Medical and Physical Sciences. In 1827 the name was changed to that by which we now know it, The American Journal of the Medical Sciences. In 1817 Chapman founded the Medical Institute of Philadelphia, known also as the summer school. It was intended only for undergraduate students, but was of value also as a training school for teachers, and was our first post graduate school. Among the men who made it famous were W. P. Horner, W. P.

Dewees, Samuel Jackson, J. W. Mitchell, John Bell, H. L. Hodge, and most notable of all, W. W. Gerhard. Gerhard was the first man to distinguish clearly the difference between typhus and typhoid fever and the merit of having demonstrated this difference belongs to him and so honors American medicine. Much might be said of John W. Francis, of New York, and of Wm. Gibson, of Baltimore and Philadelphia, both distinguished contemporaries of Chapman and men who shed a luster upon medicine and were able and brilliant practitioners and teachers. James Jackson, of Boston, left behind him the name of the "beloved physician," and though a man of action and of brains, will be longest remembered as a healer of the sick. He left his knowledge of the subject in a collection called "Letters to a Young Physician just entering Practice," which for years were the vade mecum to every New England practitioner. With J. C. Warren he was one of the founders of the Massachusetts general hospital and reorganized the Massachusetts Medical society. His son, Joseph Jackson, Jr., was a most brilliant young man, and his early death was a sad blow to his father and a distinct loss to the profession. During this period in the east, Daniel Drake was a splendid example of that western type which built up a great empire out of the wilderness. A self educated man, he developed in middle life into a man of broad culture, a scientific writer well known in Europe, a famous teacher, a man who impressed thousands of men in our middle west in his day. He taught medicine in the schools of Cincinnati, Lexington, Louisville, and Philadelphia, founded and edited several medical journals, and wrote a great work, entitled "Diseases of the Interior Valley of North America."

We now come to the crowning glory of American medicine, the discovery of ether. Many wandering lecturers throughout the country had brought the attention of the public to the intoxicant effects of inhaling ether, especially in the state of Georgia in 1842. Clifford W. Long, a young doctor living at Jefferson, Jackson county, Georgia, had his attention called to the ether frolic of the young people as they often finished the evening by inhaling ether. Some would laugh, some cry, fight, or dance. On one occasion they caught a negro boy peeping through the door. They seized him and while he fought and struggled, etherized him into insensibility. He fell into such a deep quiet sleep that they, being frightened, called in Dr. Long. The victim soon came to his senses. In the next year the lad who had been chiefly concerned in the above exploit took up the study of medicine with Dr. Long. The two in talking over the action of ether determined to try it in a suitable surgical case, and did so on March 30, 1842. On that date Long took a small cystic tumor from the jaw of John M. Venables and the patient declared that he felt no pain.

Long failed to appreciate the importance of his discovery and did nothing for many years to inform a suffering world, though his claims were admitted publicly in 1861 by Charles T. Jackson. In December, 1844, a wandering lecturer gave a public exhibition of nitrous oxide gas in Hartford as an anesthetic, and Horace Wells, a young dentist, who was in the audience was greatly impressed with the possibilities of the new medicine. So the next day he had Colton, the lecturer, administer it to himself when a brother dentist extracted one of his teeth. Wells exclaimed, on coming to himself, "It is the greatest discovery ever made; I did not feel so much as the prick of a pin."

Wells then began using the gas as an anesthetic, and looking about for some similar drug, his attention was called to sulphuric ether. One of his associates, a physician, E. E. Marcy, used the latter at Wells's suggestion, in removing a wen of the scalp. Valentine Mott heard of this and referred to it in an article in the Boston Medical and Surgical Journal, June 15th, 1845, the earliest American publication on the subject. Its use was not persevered in, however, as it was thought too dangerous. William T. G. Morton, a dentist in Boston, entered his name in the office of Dr. Charles T Jackson in 1844, as a student of medicine. Through former association with Wells he was familiar with his experiments with nitrous oxide and ether. He was destined to bring ether to the notice of the scientific world, and a student of his own, Thomas R. Spear, Jr., was able to furnish him the needed stimulus to the discovery. Spear related to Morton how he had amused and exhilarated himself by the inhalation of ether as a school boy. Morton began to etherize animals and so became convinced of the value of the drug. He interviewed Jackson, who was a prominent chemist, as to the nature of ether, and Jackson explained to him how it could be inhaled from a dry folded towel without danger. This was enough for Morton, who went home and etherized himself into unconsciousness, reviving in a few minutes without any ill effects. He was now ready to try it on a patient and that very evening a man of the name of Frost applied to him for the extraction of a painful tooth. Frost was frightened and asked if mesmerism might not be tried. Morton replied that he had something better, and the man consenting, he applied to his nostrils a towel saturated with ether. The patient became unconscious and a deeply adherent bicusped tooth was extracted, the patient quickly regaining consciousness. He vowed he felt no pain and readily gave Morton a certificate of his experience. The feat was performed in the presence of an assistant and of A. G. Tenney, a reporter for the Boston Journal, and soon was widely advertized in the newspapers. Soon after he successfully anesthetized a patient in the Massachusetts general hospital, and the eminent surgeon, J. C. Warren, successfully removed a vascular tumor situated just below the jaw on the left side of the neck. The patient, Gilbert Abbott, after he had recovered his faculties, said that he had experienced no pain, but only a sensation like that of scraping the part with a dull instrument.

A second and more complete demonstration was made the following day and from that time on, the number and scope of these operations increased as the use and physiological properties of ether became better known. The next step in the exploitation of this great discovery was made when Henry J. Bigelow in an able paper, read before the American Academy of Arts and Sciences on November 3, 1846, announced the facts to the world. This paper was published in the Boston Medical and Surgical Journal on November 18. Bigelow wrote an account of it to Francis Boott, a well known physician of London, and through him its value was soon known to the hospitals of London and Europe, where it was taken up with enthusiasm. When Jackson saw that the discovery was likely to make Morton famous and rich, he tried in every way, even by blackmail, to steal the honor from him. The authorities of the Massachusetts general hospital were, however, unanimous in recognizing Morton as the true discoverer. On October 16, 1896, fifty years after Morton's famous demonstration, representatives of all the scientific world gathered in the Massachusetts general hospital to celebrate the semi-centennial of anesthesia. Among them the name of Morton only was heard, and the words of Jacob Bigelow—written thirty years before—heartily seconded: "The suffering and now exempted world have not forgotten the poor dentist who, amid poverty, privation and discouragement, matured and established the most beneficent discovery which has blessed humanity since the primeval days of Paradise."

Over fifty years ago the young doctors of the country, stimulated by the world wide movement of scientific advance, resolved to form a national organization for the uplifting of the profession. The state of medical education troubled men then, as now. Most of the schools were private enterprises for the purpose of making money, little calculated to give their matriculants more than a smattering of the science and art of medicine. There were no uniform requirements for a degree, and no preliminary requirement whatever for matriculation. The college term was from thirteen to sixteen weeks long. Many efforts were made to get the colleges together into an association for the remedy of this condition, without avail. The movement could not be suppressed, however, and since the colleges made no move, the various societies in the states, counties and towns, began to agitate the question. The first to take action was the medical society of the state of New York at its annual session in February, 1839. They declared that it was unwise for those who did the teaching to be allowed to confer the degree, which at that time carried with it the license to practice. As a result of this feeling the society passed a resolution calling for a national medical convention. The scheme fell through, but the agitation continued throughout the country. Finally in 1844 the New York society passed resolutions offered by Alexander Thompson and N. S. Davis, stating that a four months term of schooling was too short, and that combining teaching and licensing powers in the same body of men was liable to grave abuse. In the following year, 1845, Davis rose and offered resolutions calling for a national convention to meet in New York the following May, the delegates to be from the medical colleges, societies and institutions of all the states, and that a committee of three be appointed to carry the resolutions into effect. Davis's motion marks the beginning of that great organization, the American Medical association, and it brings into our medical history for the first time, a distinguished man, who is known to all as the father of the American Medical association.

After great discouragements and much labor the convention met on May 5, 1846, in New York. The next year on May 5, 1847, a permanent national association was perfected which has continued to this day a course of ever widening importance and usefulness. The immediate result was a great improvement in the work of the colleges, the course being increased to six months, three entire years being required for its completion. The subjects taught and the minimum number of professors was increased to seven. From that time to the present, lecture terms have been lengthened, professorships subdivided, new ones added; hospitals have been utilized for clinical instruction; the curricula of study has been progressively enlarged, and at length summer instruction added to the winter's work; museums have been established, chemical laboratories formed, microscopical departments created and all the appliances attached to the schools, necessary in the investigation of structure, life and disease. The process of growth is going on vigorously. Harvard in 1876 was the pioneer in requiring its students of medicine to undergo a systematic course of training under the supervision of a corps of teachers of its own appointment. With the knowledge that we all possess of the fine and adequate equipments and high standard of requirements of such schools as the University of Pennsylvania, Johns Hopkins hospital, and many others, we can see that the progress of the age in medical education is not below the average advance in other branches of human endeavor. Merely to enumerate and describe in halting fashion, the many men of worth and ability who have given of their labor in the production of this result would fill many a large work. The names of Pascalis, Wistar and Coxe; of John Eberle, T. R. Beck and Franklin Boche; of John K. Mitchell, John D. Godman and Robley Dunglison; of Alonzo Clark, Henry Bowditch and Austin Flint will ever occupy a niche in the hall of fame concerning things medical in America.

Without too much detail it is well worth our while to glance over the positive advance in the science and art of medicine which is due directly to American initiative. Prior to 1822 the process of stomach digestion was but little understood. During that year Alexis St. Martin, a Canadian boatman, eighteen years of age, was injured by the accidental discharge of a shotgun, the muzzle of which was not more than two or three feet from him. Dr. Beaumont, surgeon to the United States post at Ft. Mackinaw, where the accident happened, thus describes the wound: "The wound was received just under the left breast and was supposed, at the time, to be mortal. A large portion of the side was blown off, the ribs fractured, and openings made into the cavities of the chest and the abdomen, through which protruded portions of the lungs and stomach, much lacerated and burnt. The diaphragm was lacerated and a perforation made directly into the cavity of the stomach, through which food was escaping. When the wound healed, there remained in his side a permanent opening 2½ cm. in diameter, which communicated with the cavity of the stomach."

Dr. Beaumont, and later others, carried on a series of experiments and observations extending through years, and the present knowledge of the stomach digestion is largely based upon this remarkable case. Dr. Johns Neill, of Philadelphia, contributed an original study of the structure of the mucous membrane of the stomach. Cannon published valuable data on the movement of the stomach and intestines. Dr. Leidy's paper on the comparative structure of the liver was the most complete work on the microscopic anatomy up to 1848. Later Dr. Austin Flint, Jr., first demonstrated cholesterin in the bile, and Dr. John Dalton, of New York, was the first man to demonstrate the presence of sugar in the living liver. In 1847 Dr. Jos. Leidy, of Philadelphia, proved the presence of trichina spiralis in pork, and its communicability to man. Dr. John Dalton in two valuable papers read before the American Academy of medicine in 1864, pointed out the history and best method of preventing trichina spiralis in men. Dr. Oliver Wendell Holmes, in 1843, proved that puerperal fever was contagious, and Dr. Thomas C. Minor, of Cincinnati, later proved the connection between puerperal fever and erysipelas. Dr. William Horner, of Philadelphia, first detected the fact that the rice water discharges of Asiatic cholera resulted from the stripping of the epithelium of the small intestines. Our present knowledge of dysentery was greatly helped by the encyclopedic work on "Camp Diseases of the Civil War" published in 1864 by Dr. J. J. Woodward. Early in the nineteenth century Dr. Gerhard first clearly pointed out the essential connection of hydrocephalus with tubercles of the pia mater and the dependence of the former upon the latter. At about the same period Dr. James Jackson wrote a paper upon the subject of a prolonged expiratory sound in the clavicular region as an early sign of the first stage of phthisis. Dr. C. M. Pennock, of Philadelphia, was the first to use a flexible tube stethescope which was afterward improved by Dr. Camman of New York into the binaural stethescope in use at present. The condition now known as irritable heart, resulting from prolonged and violent exercise, was first recognized by Dr. Henry Stille, of Philadelphia. Dr. Da Costa afterward traced its connection with organic disease of the organ, and from a study of 300 cases, showed that it resulted also from exhausting diseases and from strains and blows. He also made more exact our knowledge of the action of remedies on the heart, and called attention to forced respiration in diagnosticating diseases of the chest. Dr. Austin Flint called the attention of the profession to the value of variations of pitch elicited on percussion, as an aid in recognizing diseases of the heart and lungs.

Dr. Alonzo Clark, of New York, first described the method of determining the boundaries of the heart by auscultatory percussion. The way for modern laryngology was opened by the practice and writing of Dr. Horace Green, of New York, long before the laryngoscopic mirror was discovered. The value of the expectant treatment in delirium tremens was first proved by Dr. John Ware, of Boston, and is still practiced. Dr. J. K.

Mitchell, of Philadelphia, determined, as early as 1831, the connection between disease of the spinal cord and joint disease.

In the line of nervous diseases the life and work of Dr. S. Weir Mitchell are well worth close study. He not only originated the famous rest treatment, but his early observations in connection with injuries to nerves have been pregnant of great results. In the same line of original research the work of Dr. Wm. A. Hammond has been of great benefit. He was one of the first to ascribe normal sleep to an anemia of the brain, and his investigations of the physiological action of alcohol, colchicum, juniper, digitalis, squills and a host of other remedies, entitle him to a high place among the elect.

In the way of new remedies and the better application of old ones, America has been in the van. Dr. Charles E. Morgan did much to unravel the mysteries of electro-therapeutics, while Dr. Stearns recalled ergot to the knowledge of medical men the world over, and gave it many new uses. Chloroform was discovered by Samuel Guthrie, of Sacketts Harbor, New York, in 1831.

Beginning in 1630, with the discovery of cinchona in South America, the materia medica has been enriched by the addition of podophyllum, wild cherry, veratrum viride, sanguineria canadenses, spigelia, apocynum cannabinum, senega, serpentaria, eupatorium, lobelia, sassafras, gaultheria and a host of other remedies, whose use is as wide as the world.

In the line of original research Professor James Law, of Ithaca, demonstrated the existence of the fungus of actinomycosis and in 1884 W. T. Belfield and J. B. Murphy, of Chicago, demonstrated the disease in the human subject, and the specific microbe was identified by Christian Fenger of the same city. Relapsing fever was thoroughly studied in 1869 by E. Rhoads and William Pepper in Philadelphia. As early as 1848 North maintained that both yellow fever and malaria were transported by mosquitos. The proof of this statement required nearly a half century of toil on the part of the world of science. W. G. MacCallum, of Baltimore, in 1897, first described the significance of the crescented and flagellated bodies of the plasmodium malariae. The remarkable series of experiments reported by the yellow fever commission of the

United States army, consisting of Drs. Walter Reed, Carroll, Lazear and Agramonte have been conclusive and convincing. They show that yellow fever can only be transmitted by means of an intermediate host—probably the mosquito, culex fasciatus, which has previously fed on the blood of infected persons. The death of Lazear from the disease during the investigations adds one more name to the martyrs to science.

At this time the founding of endowed laboratories for original research, together with the high requirements set by the great schools of Baltimore, Philadelphia, New York and Chicago, and at least one school of the same rank in each state, make it possible for every diligent student to find a scientific education of a high order. In several of our best schools a preliminary degree in arts or sciences is a pre-requisite for admission. This must in time be the practice of all.

In 1898-99 there were 151 medical schools with 23,778 students in attendance. There were 4,389 instructors and 4,911 students graduated, of whom 480 held the degree of A. B. or B. S. All but fifteen of the above schools gave a graded course of four years, and in some the months of required attendance in one year are equal to the total required attendance of twenty years ago. All this shows true progress and it is interesting to note that among even the most highly trained men, only about one in five becomes a specialist. The rewards which come to the physician who truly understands his mission, are many and various. Aside from the livelihood which affords him subsistence, he has the higher reward of work well done. He belongs to a brotherhood of earnest seekers after truth, which embraces the whole world, and whose unselfish ambition it is to prevent disease and banish human suffering.

ACHIEVEMENTS OF SURGERY IN AMERICA.

BY BAYARD HOLMES.

[Bayard Holmes, surgeon; born N. Hero, Vt., July 29, 1852; graduated from Paw Paw institute, B. S., 1874; Chicago Homeopathic college, 1885; Northwestern university medical school, 1888; began practice in 1886; was for years member of the surgical staff of the Cook county hospital; secretary University of Illinois, 1891–5; now senior professor of surgery medical department; organized the Chicago Medical Library association, and other medical societies; editor North American Practitioner, 1889–92. Author, Surgical Emergencies, etc.]

Of the learned professions in America, none has achieved greater or more universal recognition than the profession of medicine, of which surgery forms an inseparable but ever increasing part. The conditions of American life have been particularly favorable to the growth of a capable, commanding, self reliant and venturesome body of surgeons. Every boy in the colonies and the early life of the states was brought up to self reliant and thoughtful handicraft, and by his surroundings and the very necessities of the case was trained to be resourceful, inventive and alert in overcoming unprecedented surroundings and meeting unexpected emergencies. The American boy was a good carpenter, especially with the primitive tools, the jackknife, the ax and the hammer. He was a fair blacksmith, a capable harness maker and tailor, a good moccasin and shoe maker and a competent mason. Such characteristic resourcefulness was so universal an inheritance that almost every young American carried this early equipment into any technical occupation in which he found himself.

The mastery of nature by man's ingenuity in every other department of the applied sciences is abundantly allowed to America by the silent witnesses of the patent office. The activity of invention and achievement in every other applied art could not fail to stimulate a similar activity in the application of the science of surgery. The young American was surrounded with associates in chemistry, physics, engineering and manufacture who were meeting new problems and mastering them with the same unprecedented resourcefulness and enthusiasm which he felt within himself.

Unlike the European practitioner, the American surgeon found himself in a community in which there was practically a single standard of life; all Americans lived well, and social barriers were low, and the bond of sympathy between the doctor and his patient was high; the responsibility of the physician was increased by the sympathy of the man and neighbor. Each patient was a member of his family a little way removed, and called upon him for the most exacting, unselfish and resourceful assistance. In no other country is the patient's personality so large a factor with the physician as in America. Other countries may have a more learned profession; other countries may have a profession more highly remunerated or more materially recognized by organized society or by the government; but no country has a profession in such sympathy with the people as the great body of American doctors from colonial days to the present. This homogeneousness of American practice has been one of the greatest stimuli to surgical adventure and achievement.

The conditions of medical and surgical practice have been until a recent time almost entirely unrestrained by legal enactment or common law restrictions. The confidence of the people in the medical profession has been so great that the greatest professional liberty has been enjoyed. The courts, feeling this same confidence and sympathy, have always protected the adventures of surgeons, assuming the humane and benignant motives which prompted them.

The great isolation which surrounded many practitioners, the unusual accidents which befell a pioneer people, and the early experience of all pioneers in meeting unprecedented emergencies with unheard-of resources, have contributed their part to the achievements of Americans in this dramatic and tragic art. The life of the pioneer was risky, eventful and untrammeled, and his surgeon naturally became a pioneer in his art and undertook rational though drastic remedies inconceivable to his erudite but somewhat effeminated European teacher.

The accidental presence of the negro slave and the peculiar relation between the planter's surgeon and his bond labor encouraged a peculiar surgical art.

The art of surgery, however, is but a single and inseparable part of a medical culture which is itself contemporaneous and co-extensive with a general culture. The settlement of America was coincident with a revival of the arts and learning and with the appearance of rational industries, the opening of a world market, and the establishment of world wide unity in every department of science and the arts. Harvey's discovery of the circulation of the blood, with all its far reaching significance, Van Boerhaave's discovery of a new world of anatomy through his compound microscope, and a host of discoveries bearing the names of investigators with this new instrument, Malpighi, Steno, Wirsung, Rudbeck, Bartholinis, Glisson, Warton, Schneider, Peyer, Bruner, Bellini, Sylvius, Willis, Highmore, Graaf, fired the imaginations of the medical world and even lighted up the practice of surgery in the recently discovered and sparsely settled new world. For a hundred years or more the physicians of America were educated in the medical schools of Scotland, England, France and Germany, where these discoveries were taught first hand and with a vitality and energy which the printed page rarely carries.

It is impossible to even mention in an article of this sort all the achievements and advances in surgery to which America can reasonably lay a claim. Much more difficult is it then to credit the achievements of American surgery to the satisfaction of all claimants, and no attempt will be made to do so. Disputes exist over priorities between America and Europe and between different sections or cities in America, not to mention the differences between surgeons in the same community, over claims to almost every important advancement or device. It is interesting if not remarkable that when the psychological moment was ripe for it a simultaneous operation or performance, or a similar or identical invention or contrivance, was accomplished by distant and unrelated surgeons. Each decade, therefore, advanced the borderland of surgery into the unknown and untried along definite and limited fields. At a particular period in the early nineteenth century the impulse of Peré's great invention caused unusual attention to be given to the ligature of arteries, and as opportunity presented itself the ligation of each of the larger arterial trunks was hailed as an adventure and a distinct achievement. Passing from a cruel stolidity to a culture of greater refinement, the barbarous methods of treating fractures and dislocations were rapidly advanced and modified until the system of Hamilton, based partly upon theoretical grounds and partly upon anatomical study, assumed its scientific position. The study of the geographical and contemporaneous appearance of inventions could be beautifully illustrated by the discovery of general anesthesia, by the achievements in gynecological surgery, and by the methods, devices and achievements of intestinal surgery, and by the practice of appendicectomy.

The three epoch making achievements in surgery are hemostasis, anesthesia and antisepsis,—the arrest of hemorrhage, the abolition of pain, and the prevention of infection. Of these three great achievements America can indisputably claim but one, and upon this one all the possibilities of surgery indubitably depend. It is almost inconceivable that it took more than a quarter of a century for the ligature of Peré to displace the cautery of the ancients, and remove from the operating room the tragic forge and the actual cautery. The usefulness of the silken hemostatic was still limited by the agony of the cut. Surgery had been robbed of one of its greatest dangers, hemorrhage, but the knife and pain were still inseparable. Only when cosmetic dentistry and the higher standards of modern American life made surgery a common inheritance, were the materials of anesthesia, which Davey (1799) and Faraday (1818) had discovered almost half a century before, brought to their highest use.

Horace Wells was a practitioner of dentistry in Hartford, Connecticut. On the 10th of December, 1844, he saw an exhibition in which Dr. G. Hugh Colton used laughing gas, or nitrous oxide gas, upon a certain Mr. Cooley, who during the performance sustained a severe injury of the leg, the evident and necessary pain of which he never recognized. The next day Dr. Wells inhaled the gas and had a large molar tooth pulled and suffered no pain from it. He used the gas repeatedly in extracting teeth. Early in 1845 he attempted to demonstrate this anesthetic before a class at Harvard medical school, but either through the idiosyncrasy of the patient or the embarassment of the surroundings and inadequate administration, the anesthesia was incomplete, and the students cruelly hooted him out of the arena as a fakir. This seems to have broken Dr. Wells's nerve and spirit. He died by his own hand a few years later.

Just at this time the dentists of the United States were organized as a special class of medical practitioners, and great improvements were made, especially in the use, application and manufacture of false teeth and plates containing a number of teeth. One of Horace Wells's students or associates, William Thomas Green Morton, who had studied dentistry at Baltimore and medicine with Dr. Charles T. Jackson in Boston, made such improvements in plates of false teeth as relieved them of many of their undesirable appearances, but required the removal of any underlying roots. The use of his invention, then, was hindered by the pain which attended the extraction of these roots. To obviate the pain he tried various local applications, and incidentally observed that ether, which had been recommended by Dr. Charles T. Jackson, when used locally and in sufficient quantities to evaporate and to be inhaled produced a general narcosis. He extracted many roots with great success under an anesthesia produced by the inhalation of ether vapor. The ether had been manufactured and rendered pure, robbed of the deleterious effects of the original product by a method which had been invented by Dr. Jackson. After a series of experiments on animals and its use in the extraction of teeth, Dr. John Collins Warren was induced to operate upon a patient in the Massachusetts general hospital on October 16, 1846, with the patient anesthetized by Dr. Morton with ether produced by Dr. Jackson's method. At the close of this operation Dr. Warren, probably in memory of Dr. Wells's failure a year and a half before, announced to the astonished class "Gentlemen, this is no humbug." The success of this operation was quickly carried to all parts of the world, and on December 19th the first ether was administered in England, and a few days later in France. It developed at once that many other experimenters had obtained greater or less success in the use of general anesthetics. Dr. Crawford W. Long, of Danielsville, Georgia, had removed a small tumor from a negro's neck under a general anesthetic in 1842, but had failed to publish his achievement. The medical profession in Boston gave the credit of discovering a general anesthesia to Dr. Jackson. Dr. Morton had offended his colleagues and violated the almost universal practice of the American medical profession by securing a patent on his invention. The French academy investigated the subject and divided the Montyon prize, giving Dr. Jackson two thousand five hundred francs for the invention of etherization and Dr. Morton two thousand five hundred francs for the application of the discovery to surgical operation. The mature judgment of the profession is, however, expressed by Sir James Paget in the Nineteenth Century, December, 1879, as follows: "While Long waited and Wells turned back and Jackson was thinking, and those to whom they had talked were neither acting nor thinking, Morton, the practical man, went to work and worked resolutely. He gave ether successfully in severe surgical operations; he loudly proclaimed his deeds, and he compelled mankind to hear him." Whatever disputes there may be between Wells, Jackson, Long and Morton, the discovery and application of ether anesthesia is an American achievement. The demonstration of the action of nitrous oxide is not generally looked upon as the discovery of general anesthesia, though in Hartford, Connecticut, a monument erected to Wells is inscribed:—

> "HORACE WELLS. WHO DISCOVERED ANESTHESIA, DECEMBER 10, 1844."

In Mount Auburn cemetery, near Boston, is a monument bearing the inscription:—

> "WILLIAM T. G. MORTON. INVENTOR AND REVEALER OF ANESTHETIC INHALATION. BY WHOM PAIN IN SURGERY WAS AVERTED AND ANNULLED. BEFORE WHOM IN ALL TIME SURGERY WAS AGONY. SINCE WHOM SCIENCE HAS CONTROL OF PAIN."

The use of ether in midwifery was begun and advocated by Dr. James Y. Simpson, of Scotland, who afterwards used chloroform in its stead, and advocated the use of chloroform in surgery. Many other general anesthetics have been used, and mixtures of two or more; but none of them has held place against ether. The use of nitrous oxide gas as an anesthetic fell into oblivion until 1867, when Cooley reported 20,000 administrations for the extraction of teeth. Since that time it has maintained a narrow field of usefulness for short anesthesias in the offices of dentists. But during the past few years it has come into more general use for protracted anesthesias especially when mixed with oxygen or ether vapor.

Probably not one in a hundred thousand who have been anesthetized for a surgical operation has ever heard the name of Morton. He never profited by his invention financially, and little public recognition of this great achievement has ever been granted. Congress repeatedly refused to honor him; the trustees of the Massachusetts general hospital tardily and reluctantly presented him one thousand dollars. The French academy of sciences divided his honors with Dr. Jackson. When the golden jubilee of his discovery was celebrated in 1896 in almost every operating room and clinic in the world, the significance of his contribution first received anything like a public and general recognition.

One of the earliest achievements in American surgery was the method of reducing dislocations by manipulation, invented, practiced and taught by Nathan Smith, of New Hampshire (1762-1839). This can hardly be appreciated as a great achievement unless we look at the methods previously in vogue. The torture which patients endured with dislocated joints in pre-anesthetic days with wheel, block and tackle, can only be conceived of by a perusal of ancient literature and a study of the illustrations of these procedures. The method by manipulation is one which has grown into a complete science and has lately been extended even to the treatment of congenital dislocation of the hip. He also taught and practiced trephination for suppuration within the skull and founded Dartmouth medical college. He was a great leader of all medical thought.

Ephraim McDowell, of Danville, Kentucky (1771-1830), first performed rational ovariotomy with a favorable result. He was originally from Virginia, and studied in Edinburgh, Scotland (1793-94). He practiced in the neighborhood of Danville, and acquired an enviable reputation as a surgeon. In December, 1809, he performed an ovariotomy upon a Mrs.

Crawford, who was then about 60 years old, and in her own house removed a large ovarian tumor. She recovered and died in her 91st year, enjoying good health most of the time after the operation. McDowell thought so little of his achievement that he neglected to publish it until eight years later, when he reported three successful cases, and afterwards performed at least ten similar operations. For one of these he had agreed to operate for five hundred dollars, but the husband of the patient on the morning of his departure gave him a check upon one of the banks in Nashville, which McDowell supposed to be for the stipulated sum. On presenting it he discovered that it was drawn for fifteen hundred dollars. Presuming that a mistake had been made, he immediately dispatched his servant to the gentleman, who replied that no mistake had occurred, and that the services he had received from Dr. McDowell more than counterbalanced the sum he had paid him.

Ovariotomy as a procedure was rapidly established, and with the assistance of anesthesia and antiseptic methods it has become a safe and everyday procedure. The first ovariotomy was performed in Germany in 1819, in England in 1836, and in France in 1844. Many operators have reported a thousand cases with a death rate of only three or four cases, and the mammoth ovarian tumor of sixty to a hundred and fifty pounds is now practically unknown in civilized countries. Incidentally ovariotomy may be looked upon as the beginning of abdominal surgery and of all of that pathology which has been discovered in the course of abdominal section. The knowledge of the living abdominal viscera in conditions of health and disease became patent when ovariotomy had taught the surgeon the possibilities of abdominal section.

John Collins Warren (1778-1856), of Boston, who first operated under ether narcosis, and in 1820, designed and practiced the suture of harelip and cleft palate and made the existence of an unfortunate class less miserable. He successfully performed the first aspiration of the pericardial cavity.

Reuben Dimond Mussey (1780-1866), professor of surgery in Miami medical college, performed the first extirpation of the whole upper extremity with the scapula and clavicle and tied the carotid artery for the first time, for osteosarcoma.

Amos Twitchell (1781-1850), of Keene, New Hampshire, first tied the common carotid for secondary hemorrhage in 1807, and had a favorable result.

Valentine Mott (1785-1865), tied the innominate artery for the first time in 1818, but his patient died, as we know now, of sepsis. In 1827 he successfully ligated the common iliac artery.

Benjamin Winslow Dudley (1785-1870), of Lexington, Kentucky, performed more than one hundred lithotomies without a death, and reported 207 lithotomies with only six deaths. He first trephined successfully for epilepsy (1819). He afterwards reported six successful cases.

Jacob Randolph (1796-1848), of Philadelphia, first performed lithotripsy, or the crushing of a stone within the bladder, in 1831. His operations were bloodless and almost uniformly successful.

Nathan Ryno Smith, the son of Nathan Smith, of New Hampshire, invented special instruments for lithotomy, which he performed more than two hundred and fifty times successfully. He invented and taught special methods of treating fractures of the lower extremities.

Joseph Pancoast (1805-1882), of Philadelphia, first successfully operated for extrophy of the bladder, and published an account of the same in 1859. He was the author of a treatise on operative surgery which went through a number of editions and possessed great orignality.

Joseph C. Nott (1804-1873), of Mobile, Alabama, first removed the coccyx (1832) for coccydynia.

Samuel D. Gross (1805-1884), is not to be overlooked in this enumeration, although he is less known for his special achievement than for the general advance along the whole borderland of surgery made in his hands and under his direction. His surgery was influential in this country and widely read abroad. Following the suggestion of his preceptor, Joseph K. Swift, of Easton, Pennsylvania, he first used extension apparatus in the treatment of fractures.

Paul Fitzsimmons Eve (1806-1877), of Nashville, Tenn., was a remarkably successful lithotomist. He used tendon of the deer as ligatures.

John Watson (1807-1862), of New York, advanced the borderland of surgery, and especially first successfully performed esophagotomy for the removal of a foreign body in the gullet.

Frank Hastings Hamilton (1813-1886), first suggested and practiced skin grafting and invented and introduced many new methods of treating fractures and dislocations, and published a monumental and practical work upon this subject which went through many editions in English and was translated into every European and some Asiatic languages.

James Rushmore Wood (1816-1882), of New York, first made a total resection of the under jaw (1856) for phosphorous necrosis, and secured the complete regeneration of the jaw from the periosteum.

John Murray Carnochan (1817-1887), of New York, first ligated the femoral artery for elephantiasis, and in 1850 resected the second branch of the facial nerve for neuralgia, and made a complete resection of the ulna in 1853. He ligated both carotid arteries for hypertrophy of the tongue, and was known as Valentine Mott's most distinguished pupil.

Daniel Brainard (1812-1866), of Chicago, first performed subcutaneous osteotomy for ankylosis (1854) and secured union in ununited fractures by the use of bone nails.

William Detmold (1808-1895), of New York, first practiced subcutaneous tenotomy, and in 1850 opened a brain abscess located in the region of the speech center.

Lewis A. Sayre (1820), of New York, was the first advocate of the plaster of Paris jacket and cast in immobolizing the body and affected limb in cases of tuberculous disease of the vertebra and other bones or joints. His diagnosis was based upon novel features and tests, and the early treatment which it secured has saved thousands and established the method throughout the world. His work is probably as well recognized and credited as that of any American surgeon.

J. Marion Sims (1813-1883), of South Carolina, was the founder and practically the inventor of modern gynecology. He first succeeded in closing a vesico-vaginal fistula, which had been looked upon as an incurable condition, in 1849, and from this time on made many conquests in gynecological procedures, even going so far as to extirpate the uterus for beginning malignant disease. He invented and introduced many instruments, established a hospital for the study and treatment of the diseases of women, and practically forced upon the world an organization of the department of surgery known as gynecology.

Henry O. Marcy, of Boston, introduced the buried absorbable suture in the special form of the tendon of animals.

Rupture of the urinary bladder, which has become ss common an accident with the prevalence of heavy machinery and railway freight handling, was first successfully treated by suture by Dr. Walter, of Pittsburgh, Pennsylvania, in 1863. He closed a two inch rupture and the patient, a young man of twenty years, recovered.

Americans have done much to perfect the surgery of the kidney and ureter. M. L. Harris, of Chicago, devised an instrument to separate the urine from the two kidneys and Howard Kelly, of Baltimore, introduced the ureteral catheters; Christian Fenger of Chicago, and Weller Van Hook added much to surgery of the ureter.

The stimulus which ovariotomy gave to abdominal surgery led many American investigators to more or less valuable achievements. The work of these investigators is frequently so mixed and divided that it is difficult to give credit to individual achievement. Charles T. Parks, of Chicago (1842-1891), experimented in 1882 and 1884 on gunshot and other penetrating wounds of the intestine, and successfully practiced intestinal suture in his clinic. Nicholas Senn, of Milwaukee, repeated these experiments in the Milwaukee hospital. M. E. Connell, observing the protracted operation necessary to secure imperfect union of the bowel by the Czerny-Lembert method, even in the hands of so skillful an operator, conceived of a lateral anastomosis, using for that purpose lead plates fastened together by through and through sutures. These plates were afterwards improved upon by Senn, who put forth his decalcified bone plates. J. B. Murphy, of Chicago, modified this method of apposition by the use of the button, which he invented and which he advised for lateral, end to end, and other forms of opening one viscus into another. While these particular devices may have a limited and transient usefulness, they have given an impetus to abdominal surgery which cannot be overestimated, and they have been followed by simpler methods of more general and permanent application. The whole field of intestinal surgery has been explored and conquered by American surgeons.

The first successful suture of a perforated intestine occurring in the course of typhoid fever was accomplished by Dr. Weller Van Hook, of Chicago, in 1891.

John Stough Bobbs (1809-1870), of Indianapolis, Indiana, first performed cholecystotomy June 15, 1867. He opened the gall bladder, removed a clear fluid and stones; the wound closed in four weeks, and the patient was still living and well in 1893. From this small beginning a great army of American surgeons, toward whom it is not prejudicial to especially mention James McFadden Gaston (1824-1903), of Atlanta, Georgia, Christian Fenger (1840-1901), of Chicago, and William J. Mayo, of Rochester, Minnesota, have kept the advance in surgery of the biliary tracts well up to the standard of surgery elsewhere in the body.

The surgery of the ear and eye has been greatly advanced by American operators, but these advances have attracted little general public interest.

The early history of disease of the appendix (1759-1808), beginning with the classic case of Mestivier, belongs exclusively to France.

In 1812 Parkinson, of London, published a case in which he recognized at the autopsy that perforation of the appendix was the cause of death.

In 1827 Melier, a French surgeon, reported five cases of this disease. In a footnote he says: "If it were possible, indeed, to establish the diagnosis of these affections in a certain and positive manner, and to show that they are always entirely circumscribed, the possibility of an operation might be conceived; some day, perhaps, this result will be reached."

From 1830 to 1860 great advancement was made in Germany in this disease, especially along the line of its symptomatology.

Willard Parker, of New York, in 1867 reported four successful operations for abscesses in the right iliac fossa arising from the appendix, the earliest of which was performed in 1847. In one of these cases the abdomen was opened before fluctuation was detected.

In 1886 Reginald Fitz, of Boston, a medical man, cleared up the entire subject of typhlitis and perityphlitis and called the disease for the first time appendicitis. He gave the indications for treatment and turned the disease over for the consideration of surgeons. He fought hard for early surgical interference in this disease and holds that surgeons are justified in operating before the third day.

Thomas G. Morton, of Philadelphia, was the first to operate successfully for the removal of the appendix after making a diagnosis of disease in this organ. (April 27, 1887, and published in the same year.)

Treves, of England, in 1888, suggested the first improvement in the technique of excision of the appendix or appendicectomy, which was followed in the same year by an able paper on this subject by Nicholas Senn, of Milwaukee.

C. McBurney, of New York, in 1889, published an article on appendicitis which is considered a classic in the surgical history of America. He first described and accurately located the point of greatest sensitiveness to pressure in this disease, which point has since been known as McBurney's point. The abdomen was now being opened under the most rigid antiseptic precautions, and appendicectomy was now becoming recognized as the only rational treatment of appendicitis. McBurney, to combat the old idea of waiting for an abscess to arise, or to wait because the symptoms were not sufficiently urgent, etc., closes his paper with the following words:

"I hope that I may never again go every day to visit a threatening case, waiting bashfully for the authority of a clearly defined peritonitis before I dare take action. . . . If it can be shown by future experience with improved methods of operation, and with more perfect antiseptic precautions, that the exploratory incision for inspection of the diseased appendix is much more free from danger than the expectant treatment, then there could be but one answer to the question: What is the best treatment?"

As pioneers in this work in America must also be mentioned Weir, Sands, Worcester, Marcy, Fowler, Mynter and Richardson.

It is not alone in priority of operations and procedures that American surgeons have made their greatest achievements, but in the methods of early diagnosis of surgical disease, the prompt, rational and early removal of the sources of danger by an operation of short duration under the briefest anesthesia and with a minimum incision and laceration of tissue. The need of ligating large blood vessels, the opportunity of removing large ovarian tumors or calcified extrauterine fetuses, the occasion for terrible plastic operations, are superseded by early, trifling, common operations following early diagnosis and rational intervention. No other country possesses a larger body of more capable, conscientious and reliable surgeons whose every day achievements compare favorably with those of any similar body in Europe.

PROGRESS OF DENTISTRY IN AMERICA.

BY TRUMAN W. BROPHY.

[Truman William Brophy, dentist; born Cook county, Ill., April 12, 1848; educated in the public schools, and Elgin, Illinois academy; graduated from Pennsylvania college of dental surgery, D. D. S., Rush medical college, M. D.; President of and professor of oral surgery in Chicago college of dental surgery, associate professor of surgery in medical department of the University of Chicago, president for the United States of the fourteenth International Medical congress held at Madrid, Spain, 1903.]

In order to consider this subject intelligently, we must take a brief glance at the conditions which prevailed in our country in the early part of the nineteenth century. From about the year 1785 to 1830, the method of dental practice was almost entirely itinerant; but few of the larger cities could boast a resident dentist. The following is an extract from a letter written by Dr. E. Parmly to Dr. J. Brockway, Sr.: "In 1817 from Philadelphia to New Orleans, I met with no person who even called himself a dentist, and I practiced in the principal towns going west between these places." And Dr. Brockway himself, states that during the year 1822, while in practice in Vermont, he was the only dentist known, from Canada to Albany, and from the Rocky to the White mountains.

It is almost impossible for any one familiar with the present methods of practice in dentistry, and with the finely furnished and equipped offices of the practitioner, to realize that it has been so short a time since the very beginning of dentistry. During this earlier period, dentistry was not looked upon as a profession, but simply as a branch of mechanics, and its followers were wholly dependent upon their own resources. They had to manufacture all of the instruments which they used, and they had to prepare their own materials for use in filling teeth; and it is remarkable that such a high degree of success was attained by so many of these pioneers of the profession.

Dentistry was without a history. There was no such a thing as dental literature, but there were a few capable, earnest men, whose prophetic eye could see great things in the development of the profession in the future. In about 1839, a few of these earnest followers of this calling felt that the time was ripe for placing it among the scientific professions, and their earnestness found expression in the organization of the first dental college. This occurred in the city of Baltimore, and the Baltimore college of dental surgery was the first college of dentistry the world had seen. Speaking of this birth of the profession, Dr. Shepard says, "Let us not forget to hold in the highest honor the devoted men who assisted at this great birth. They are not the fathers of scientific dentistry. The primal causes date further back; but their care, over-sight and official administrations in guiding and assisting in the culmination of evolutionary changes, at its critical period, was most creditable. Like the great physician, they thought less of self than of humanity. They brought into the world the good evangel of dentistry, for previous to that time, knowledge and skill were guarded and sold as private property, while that day heralds the advent of good tidings to every man in search of knowledge for the good of men. The dental aspirant before that time, found every avenue to knowledge carefully defended. Knowledge could only be obtained in the private office of a dentist, and the ambitious student was obliged to buy it, frequently at fabulous prices, prohibitive to the majority."

To Drs. Chapin A. Harris and Horace H. Hayden, and their associates in the organization of this first college of dentistry, the highest honor belongs. Here we have the beginning of systematic dental education, and from this progress has been rapid. The course of instruction during the first session of this first dental college, covered the following subjects: Theory and practice of dental surgery, theory and practice of dental mechanism, dental pathology and therapeutics, anatomy and physiology. The student was required to attend two courses of lectures of four months each before being considered a candidate for graduation. Five years in dental practice, or graduation in medicine, was considered the equivelant of one course of lectures. In comparing these requirements for graduation with those of dental colleges of to-day, one is duly impressed with the great progress which has been made. The educational qualifications of the candidate, for admission to this first school of dentistry, were not considered. The simple desire to become a dentist was all that was necessary. The student could take up the course of instruction regardless of his previous training. The great benefits accruing to the dentist from this meager course of instruction were so manifest that the organization of other dental colleges followed rapidly, and for many years thereafter various colleges worked along independent lines. But although much good work was being done, there was a lack of harmony among the schools and a great difference in their course of instruction, and some rivalry between them, which was detrimental to the best interests of the student, and it was not until the year 1884, when the organization of the national association of dental college faculties was perfected, that dental education was placed upon the sound foundation and given the systematic method of instruction which has prevailed since that time.

The course of instruction in our dental colleges to-day embraces the following theoretical subjects: Anatomy, including the dissection of the entire body; physiology, almost as complete a course as that given in the first class medical colleges; bacteriology, including the laboratory course of practical experiments; chemistry, pathology and surgical pathology; physiology, diagnosis, materia medica and therapeutics, oral surgery and orthodontia, while the subjects of operative and prosthetic dentistry, of course, receive the most attention. The method of teaching has become so fully systematized that a student who has received one course of instruction in one college can with but little difficulty continue the work in some other school.

Where mechanics enter so largely into the work of the professional man as in dentistry, it will be readily seen that the course of instruction must be specially directed towards the training of the hand and the eye, and the development of skill in the use of instruments. In order to bring about the best development along this line, the colleges of the association organized a special school of dental technics, and by consultation and exchange of ideas, developed a course of instruction in which the first year student in a dental college spends almost one half of his time in the making of instruments, the operating upon and the studying of human teeth, carving from blocks of ivory, following the models assigned, and practically performing all of the operations required of a dentist, but using as their patients models upon which are mounted either human teeth which have been extracted, or ivory teeth which they have carved. During the first year, the student not only studies the forms of teeth and the characteristics of the different classes, but also the pathological conditions involving the root canals of the teeth, and is instructed in the various methods of treatment.

From a college course of two sessions of four months each, without any preliminary educational requirements, to a course of three sessions of eight months each and with a requirement of the completion of the first two years of a recognized high school course for admission, it will readily be seen that the graduate dentist of to-day has had opportunities for perfecting himself for the work of his profession far beyond the dreams of those who organized the first college of dentistry.

But there have been other influences which have had a great deal to do with the advancement of American dentistry. While perhaps the college has been the principal influence in its development, the organizing of dental societies and the rapid growth of dental literature have also had great influence for good. The first dental association was known as the American society of dental surgeons, organized in New York city on the 18th of August 1840, and among its officials we have the names of Horace Hayden, M. D., and Chapin A. Harris, M. D., who were also the founders of the first dental college. The organizing of this society was followed by the first state society, known as the Virginia society of surgeon dentists, organized in 1842. In 1844 the Mississippi valley society of dental surgeons was organized, and in 1845 the Pennsylvania society of dental surgeons. Then comes the society of dental surgeons of New York, organized in 1847. The first alumni association of dental colleges was organized in 1849 and was known as the alumni society of Baltimore college. From this time on, the organization of state and district dental societies was very rapid, and there is no doubt but that the quick development of American dentistry is very largely due to the meeting together of the various members of the profession in these societies, and the exchanging of ideas, demonstrating methods for operations, etc., thus giving to all the benefit of the superior knowledge and experiments of the few.

American dentists are liberal professional men. There is no disposition on the part of the American dentist to retain for his own exclusive benefit any particular discovery or method. The gathering together in these dental societies makes it possible for a frequent exchange of ideas.

The growth of dental literature has been parallel to that of the dental societies. The American Journal of Dental Science was the first dental journal in our country. It was first issued in June, 1839, by Drs. Parmly and Harris, of Baltimore. Thus we see that Dr. Harris not only organized the first dental college and the first dental association in the world, but also the first dental journal. Truly, the American dentist owes a great debt of gratitude to Dr. Harris.

Stockton's Dental Intelligence was the second dental journal issued. It was published in 1844, and was followed by the New York Dental Recorder in 1846; in 1847 by the Dental Register of the West; and in the same year the Dental News Letter. This was published as the Dental News Letter until 1859, when it was changed to the Dental Cosmos, under which title it is still published. The Dental Times and Advertiser was issued in 1851; Brown's Advertiser in 1854; the Dental Monitor in 1854; the Dental Obturator in 1855; the American Dental Review in 1857.

Thus, we see that during the first half of the nineteenth century, the development of dental periodicals was rapid and parallel with that of associations and colleges. While all dentists could not belong to an association by reason of their location, it was possible for them to get the benefit of the meetings of their various associations by reading of their proceedings as published in the dental journals of that period, thus keeping in touch with the progress which was being made in their profession.

Thus far we have considered those influences which have directed the progress of dental education. It is well for us to refer also to the advancement which has been made in the purely mechanical department of the subject and to refer to the improvements in the matter of materials and methods used by the profession. The pioneers in dentistry did not have access to large dental depots, in which they could secure almost any instrument desired, or the modern artificial crowns and teeth. In the earlier years human teeth, which had been extracted, were used, and then only the crowns which were attached to teeth the crowns of which had been lost by decay or accident. The method of making this attachment was varied. In some cases wire was used, or ligatures combining them to the roots. In other instances the roots were filled with pieces of wood, through which could be driven wire which had been previously attached. Animal teeth, such as those of sheep and cattle, were used, as well as the tusks of the teeth of the hippopotamus, and also crowns made from the ivory of the elephant, and in some instances from pieces of bone. The use of porcelain, or mineral teeth, was not introduced into this country until 1817, and of course the first teeth were very crude, but the value of porcelain was instantly recognized and it was experimented with so much that improvement in the quality of texture and color was very rapid.

In making plates for artificial teeth, the first substances used were ivory and bone. The work of carving an ivory base plate properly for the jaw must have sorely taxed the skill of early operators, and one can imagine that the wearing of such a plate must have been a great source of annoyance to the patient.

The use of metals for base plates followed this, and must have been a great relief to the profession, as well as to the patient. We find that gold, silver and platinum were all used. Rubber and gutta-percha were not common until about the middle of the nineteenth century.

There has not been so much change in the materials used for filling teeth as in the making of artificial teeth. We find that metals were used in filling teeth almost since dentistry was thought of. Lead was the first metal used, in the form of a leaf, pieces of which were rolled between the fingers as a ball, sufficiently large to more than fill the cavity. This ball would be put in the cavity and crushed into place.

Gold, however, has always been one of the principal materials used in the preservation of the teeth, and the only improvement in it has been in the method of preparing and lining it in the cavity. The earlier dentists had to prepare their own gold, which was done by beating a coin very fine, or taking it to a regular gold beater.

Another factor in the advancement of American dentistry which should not be overlooked, is dental legislation. During the earlier periods of American history there were no legal restrictions placed upon the practice of dentistry and any one could take up work as a dentist if he desired to do so, but the establishment of dental schools and the publication of dental periodicals, together with the growth of the more liberal ideas in the profession, gradually changed the state of affairs in dentistry. A dentist holding a diploma from one of the earlier colleges, and carrying with it a college degree, was given more recognition on the part of the public, and held in higher esteem than the irregular practitioner who had preceded him.

The first state legislature to enact the law regarding the practice of dental surgery, and regulating it, was that of the state of Alabama. This law was passed in December, 1841, and provided that from and after its enactment, all who desired to practice dental surgery in that state should be examined by one of the medical boards, and that a regular qualified dentist should be elected as a member of said board. In this way we see the dentist recognized in the professional world and given a legal status. Legislatures of other states were very slow in following the example of Alabama. Legal recognition by state legislation was not common until about twenty years had elapsed, but between the years 1860 and 1868 laws regulating the practice of dentistry were made part of the code of many states. During more recent years, the organization of the various state boards of dental examiners into a national board has been a great factor in improvement and advancement, and in establishing more firmly the professional status of the dentist. The profession at large is to be congratulated that in the harmonious working together of the association of dental college faculties, the national board of dental examiners and the national dental association—three of the strongest influences are being used for the betterment of the profession.

In dental materia medica and therapeutics the progress has been most marked. During the earlier years in the history of dentistry the idea of healing and correcting received very little consideration. The surgical part of the profession was the most important, and the thought of the dentist was to remove the diseased tooth or tissue; that of the modern dentist is to heal; and the course of instruction in our modern dental colleges is so very complete in dental medicine and therapeutics, and the remedies so numerous and efficient, that by far the major portion of the modern practitioner's time is taken up by the work of healing and preserving rather than in surgical methods.

The public has recognized this great advancement and has given to the modern dentist the position and credit to which he is justly entitled, while the earlier dentist was classed with the barber or even as a traveling tinker. The graduate dentist of to-day is recognized as a member of a noble profession, and one to whom is given the privilege of relieving pain and bringing comfort, making possible greater happiness, longer life and added health to men. Where for many years the members of the medical profession looked down upon dentistry as a purely mechanical calling, they recognize in the dentist of to-day a fellow worker in the great cause of health, and the service and advice of the dentist are often called upon by the medical practitioner.

It would be impossible to name the men who have given the best years of their lives and their best energies to the development of college, association, or legislation. The faculties of the earlier dental colleges could almost be taken as a roll of honor. Looking at dentistry from our own view point, we can readily see that these pioneers planted better than they knew, and that the great profession of to-day is the outgrowth of the seeds of instruction so carefully planted, and the shoot from which was so earnestly nurtured. The standing of the American dentist, and the value of the American diploma can have no better testimonial than the fact that the dentists of foreign countries are so anxious to be known as American dentists that for several years they have made it profitable for a number of disreputable men to deal in American diplomas. And it is only during recent years that the united action of the faculties' association and the dental societies and state boards has succeeded in suppressing the diploma mills.