

purpose, and, contrary to usual custom in American elevated roads, they are built on the ground underneath the railway. Every station has one entrance and one exit. An electric bell sounds automatically as a train from either end approaches within 500 ft. of the station, indicating the direction in which it is going.

wood to the west. Trains will be run at very short intervals, and the fare be 5 cents. The equipment will be similar in general design to that on the New York and Brooklyn elevated roads, with many improvements suggested by their experience, and they will be constructed and furnished in the best possible manner to

mounted on a fixed frame and arranged one alongside the other.

Each bicycle is at its rear wheel in frictional contact with a pulley connected with and actuating a transmitting device operating a pointer on a dial facing the riders.

The two pointers of the two bicycles indicate on the same dial and move independent of each other, and according to the speed given to the wheels by the riders ; the faster moving pointer signaling the victor.

The transmission is so proportioned that a full revolution of either pointer corresponds to a ride of a mile. —*T. G. H.*

THE MAN OF SCIENCE—HIS METHODS AND HIS WORK.*

By R. H. THURSTON.

INTRODUCTION.

Ladies and Gentlemen and Members of the Sigma Xi :

In appearing before a society of men of science, and especially before an association having such grand purpose and noble aims, the first duty of your orator is to acknowledge the compliment paid him in the invitation extended him on this occasion to present his best thoughts to so intellectual an audience, and to make an apology for their inadequacy to the occasion. The first may be made most heartily and unhesitatingly; the second would seem to demand a better reason than that which alone must be allowed: the brief time available for preparation, the very great pressure of work, and the unintermitted succession of duties compressed into the closing weeks of the college year.

But while I am sure that you cannot fully realize this gratification, and the appreciation of the honor which is its source, that my words would, if possible, indicate I am sure, also, that you will receive with friendly criticism and all charity what must represent my best endeavor under such exceptional and unusually unfavorable circumstances. That what I have to say is not fully up to the standard that I am sure we should all desire to see maintained at these annual meetings of members of a society pre-eminently devoted to high thinking, and peculiarly appreciative of great and fruitful thought and work, must be attributed to these adverse conditions, as well as to the fact that your chosen orator is neither philosopher, scholar, nor rhetorician. Frankness and honesty must make amends for all.

A word as to the character and aims of Sigma Xi. As I understand the formulated platform of our order, it declares our purpose to be the building up of a fraternity of the lovers of scientific truth, lovers of all the knowledge coming to us out of nature ; an association of students, of investigators, by exact and scientific methods of research, of all the phenomena of the seen universe. It seeks, at the same time, to furnish a nucleus about which to gather lovers of science for the sake of science and its works ; to give testimony of appreciation of good work performed by young men and women, devotees of science ; to establish a brotherhood—which, grammatically and naturally, embraces a sisterhood—of all engaged fruitfully in a common task and having a common purpose ; to encourage original research ; to promote the scientific spirit, scientific knowledge, scientific investigation in all known fields. We aim at, and hope to achieve, the foundation of a great fraternity that shall grow in numbers, strength, power for good, leading, in this country, at least, perhaps in all the world, the grandest scientific movements of coming times. The acorn is planted ; its first tender sprays are coming into view ; our successors, as we all hope, and with confidence, shall see a mightier oak of this variety than ever yet grew.

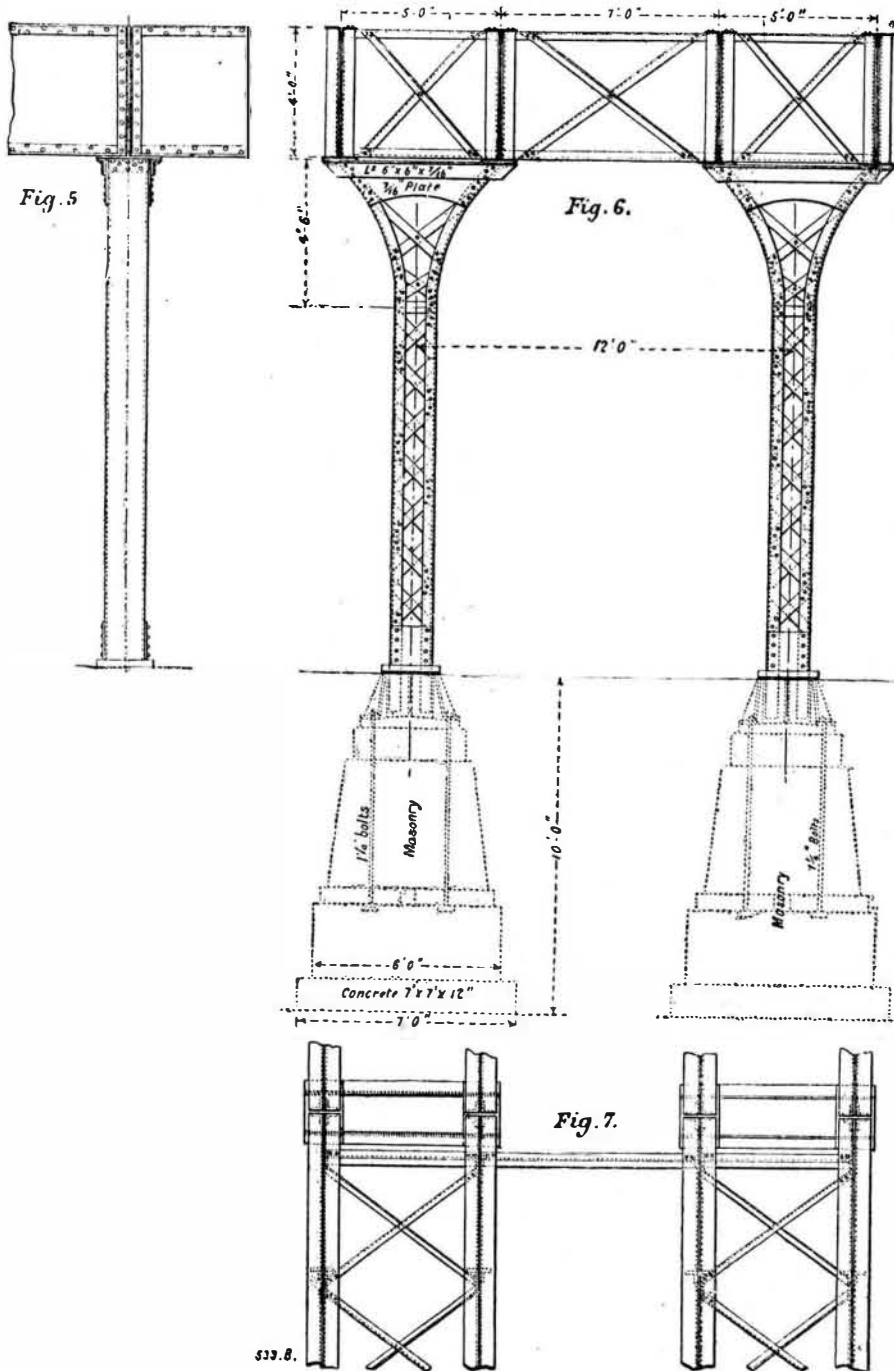
Such being the character and the purpose of our fraternity, I am sure I shall be justified in the selection of my theme; the methods and the work of our ideal type and representative, the true man of science.

In this discussion I desire to restrict myself mainly to the man with whom we are most familiar, while fully recognizing the fact that the man of science, in a true and liberal sense, is to be found far outside the range of our own special field. We do not *admit*, we *claim*, that Sir William Hamilton, the logician, Sir William Hamilton, the mathematician, was doubly a man of science, that Lord Bacon was as much a man of science as was Newton; that the framer of a code of law or of philosophy may be as much a man of science as the seeker among the stars; that we have among us the scientific lawyer, the scientific engineer, the scientific student of Fichte and Hegel and Compeute and of Kant, as well as of Descartes, of Darwin, or of Spencer or of Herschel. He is a man of science who loves truth for truth's sake, and who also seeks to know and to learn all the facts and principles that are recognizable by the human faculties in whatever realm of the seen or the unseen, the known, the unknown, or the possibly knowable, they may exist. Absolute integrity of intellect and judgment, combined with an inextinguishable desire to know the right by right ways, are the characteristics of all this class. They are found living, and working, and seeking knowledge in every department of human activity and of natural existence. To all such men we owe equal respect and equal honor. The seeker of truths, whether in the fields, or in the mine, in the pulpit, or on the bench, whether following Aristotle or Bacon, or Newton or Darwin, or the minutest or the grandest lights of the human mind, may be a man of science, and *will* be one, if true to himself and the right.

THE MAN OF SCIENCE—HIS METHODS AND HIS WORK.

The characteristics of the man of science, as I would define them, are to be found in the emotional and the moral, as well as in the intellectual aspects of his personality. He is distinguished by a love of nature and all her works, a love of learning for its own sake, a love of scientific methods and scientific work in research as intrinsically attractive, as well as a means to an end. He is characterized, in the ideal type at least, by an absolute conscientiousness, infinite courage, and invincible persistence, with a perfect faith in the complete accordance of all truths, and entire indifference as to what truths shall prove to be, so they be truths. His intellectual and specific qualities are

* An address before the fraternity of the Sigma Xi, Alpha Chapter, Cornell University, June 14, 1891.



THE CHICAGO ELEVATED RAILROAD.

Passengers having already obtained their tickets in the waiting room, deposit them at the foot of one of the stairs leading to the platforms above, one for the north, and the other for the south, bound trains.

The platforms, which are ample, being no less than 200 ft. in length by 8 ft. wide, will accommodate a train of six cars. These platforms are on the outside of either track, and will be illuminated at night with arc lights. The distance between stations varies from three to six blocks, according to the population and importance of the cross streets.

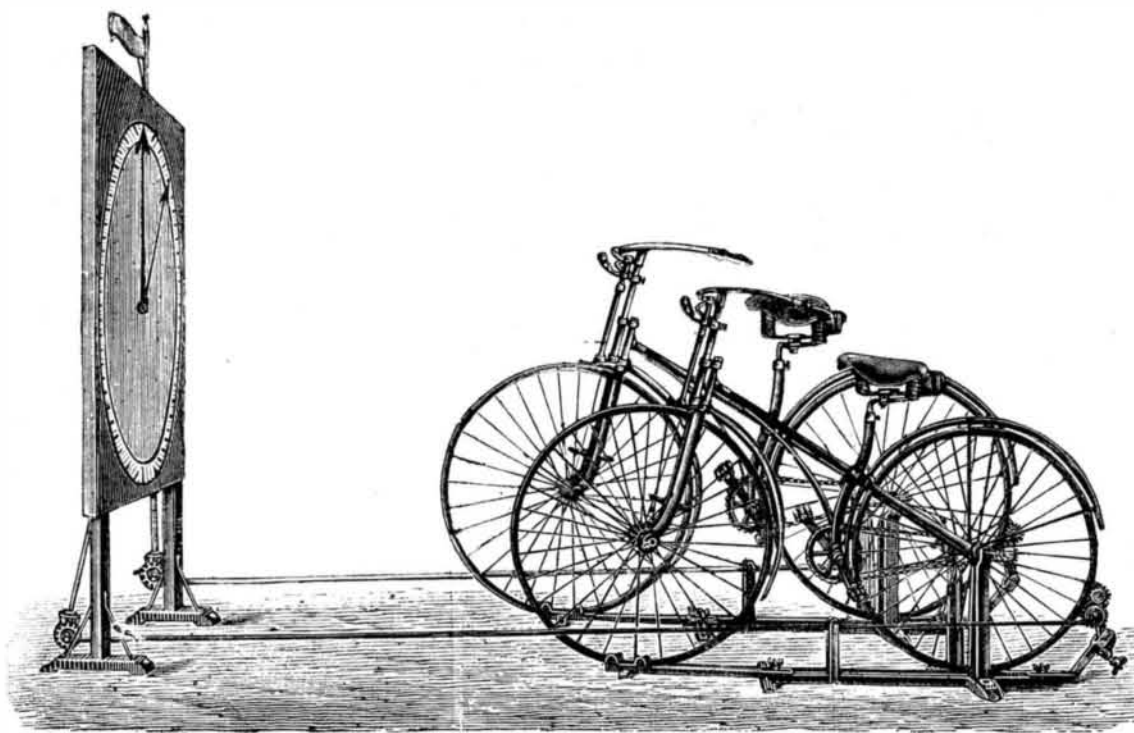
The road is a continuous straight line without exception from end to end; it will soon be extended four miles further south, branching to the World's Fair on the east, and to the rapidly increasing district of Engle-

avoid unnecessary noise, and secure comfort and convenience to passengers.

On Colonel C. Goddard, of Chicago, has rested the entire management and direction of the work connected with this railroad, Mr. R. J. Sloan assisting him as chief engineer.—*Engineering*.

BICYCLE RACING ARRANGEMENT.

THE annexed cut illustrates a stationary racing machine manufactured by Ernst Strecker and Dame in Magdeburg, Germany, and designed to accommodate bicyclists bent on racing in unfavorable weather. The machine is provided with two training bicycles



BICYCLE RACING ARRANGEMENT.

prompt and certain recognition of facts and principles; ready perception of the relations of facts to law, and of laws to sciences; a genius and an inventive talent for planning researches leading to the discovery of new truths through a knowledge of the facts and laws which comprehend old ones; power of production of purposeful plans, and of steady, never-discouraged, systematic work in carrying them into effect; ability to direct every available means to the one exactly conceived and formulated plan; turning to his own purposes every resource of contemporary knowledge and art. Any one of these classes of talent, whether moral, intellectual or emotional, being non-existent or lost, the man of science fails of perfect development.

Who but an Agassiz, loving nature as he loved his God, affected by the sight of an Alpine peak, of a river of ice, of the swelling waves of the ocean, loving his task as the boy loves his sports, but with a graver and steadier love, as the love of a patriarch for the gray haired companion of his life exceeds the love of the boy for his chosen partner, loving the pursuit of knowledge as the dearest task the world could assign him—what man but such as he could ever truly typify the scientific man? Who but a Bruno, loving truth more than life, trusting to nature more than to dogma, dying at the stake for man's knowledge, as opposed to man's beliefs, for God's law in opposition to the commands of the church, could represent the lover of knowledge, the real scientific spirit? Who but a Faraday, absorbed in the pursuit of the great truths revealed only to such an indefatigable investigator, devoting time, thought, life, and all his powers to a defined research, could have earned the fame that his work in electro-magnetism gained for the most modest of men, even though the inspiration of a Davy should exert its noblest influence upon him? Who but the loving seekers of truth for truth's own sake, amorous of her every charm, yet ascetic to the last degree, all-loving, self-giving, ready to die, as did many a man in earlier days, for her sake—who but such as these could stand as our ideal of the scientific man, with an emotional soul as his primary characteristic?

What were science, or the scientific man, without the moral qualities? What without conscientiousness, courage, faith, confidence on the part of the man would be the state or the standing of science. Had not every now famous member of this most royal of castes possessed the attributes so well stated by Clerk Maxwell, "Concentration of effort in seeking to identify the apparently different forces of nature, far-sightedness in selecting subjects for investigation, persistence in working out the results of his discoveries, and accuracy and completeness in making his final statement of the laws of the phenomenon?" had he not possessed all these qualities, what possible claim could he have earned to memory and fame? These characteristics of the scientific spirit must mark, and must permeate, every minutest portion of his work.

Without absolute conscientiousness, how could the chemist analyze the organic compounds? Without invincible courage, how could a Davy, or a Stephenson, devise and prove a safety lamp? Without a perfect confidence in the ultimate justification of law by apparently conflicting laws, how could astronomer or geologist proclaim the true motion of the spheres, or the measureless life of a slowly forming universe? How could any man of science, without inextinguishable belief in the ultimate reconciliation of all truths, stand before the mysteries and the wonders of the universe, and retain religious faith, intellectual poise, or even sanity? Without entire indifference as to the form that the outcome of his work shall ultimately take, so it be right, how could any investigator carry on his work without wavering or quailing?

The absolute sincerity and absolute truth of the scientific man is his grandest and bravest characteristic. "Speak what you think, now, in hard words, and to-morrow what to-morrow thinks in hard words again, though it contradict everything you said to-day." When a man seeks truth, with all his soul, consistency may be trusted to take care of herself. Without this quality no devout astronomer could pursue his calling, facing a thousand possible contradictions of his creed; lacking this, no intelligent geologist could read the Scriptures and continue his study of the growth of primary, secondary, tertiary and quaternary worlds. Failing here, the work of a Darwin, the researches of a Spencer, the investigations of a Tyndall or of a Huggins must all fail of their highest ends. The one and only question that the really scientific mind allows itself to seriously consider, first and above all else, is: What are the facts? And it is in the endeavor to learn exact truths that the laws enunciated and proved by a Newton are made to reveal the structure of solar and stellar systems; that the spectroscopist learns to read the constitution of the farthest stars; that the geologist seeks to ascertain the history and the chronology of the worlds; that the chemist tears apart the molecules and the atoms and recombines them in a thousand forms to find the secret of the Great Builder of the seen universe; that the physicist seeks the sources of light without heat and of heat without light, and of the electric forces, in every corner of the vast, the infinite arcanum, in animate as in inanimate nature, and looks to glow-worm, fire fly, gymnotus and torpedo, and fossil gum, and even invades the sacred precincts of the human body in his search for new facts.

Again, "the restraining grace of common sense is the mark of all the valid minds—of Æsop, Aristotle, Alfred, Luther, Shakespeare, Cervantes, Franklin."

Self-poise and a good judgment, with keenness of perception, breadth of view, and promptness of decision, all essentials of a real "common sense," are as much the characteristics of the scientific investigator and of the philosopher searching out the ways of the Maker, as of the man of business or of the thrifty housekeeper. This is the ballast required in any vocation, as in every over-sea voyaging craft. Without it the brightest minds may yaw and jibe, and drift far off the course, and may even fail to reach a haven at all. Goethe, in his early days, was taught this lesson, or we should never have known the grandeur and the might of his powers; Shakespeare, before Sir Thomas Lucy, made to plead for mercy, learned this lesson, or we should never have learned the noblest lessons of scientific construction of the drama, of deepest insight into human life and human passion. Franklin, alike great in science of nature, in science of the arts, in science of government, was the very concentration and essence

of common sense. Washington, scientific engineer, scientific strategist and soldier, scientific in the execution of his highest trust, exhibited the steadiness, the absolute reliability, every day of his life, that comes first and most of common sense. All modern work in science, whatever its department, stands upon a foundation of common sense method and of simple, straightforward application of previously acquired knowledge. Such is the man of science and such his ways, if he be really of our guild; such must be our ways if we be worthy of his comradeship.

"Teach me your mood, O patient stars!
Who climb, each night, the ancient sky."

His is the mood of the stars: "*Ohne hast, ohne rast, wie die Sterne*," he moves on steadily, quietly, confidently, toward an end and aim which he has distinctly and carefully determined, accomplishing his self-appointed task by the constant application of all these essential qualities of the conqueror of a mightier world than Alexander dreamed of. He does not know, nor does he concern himself, whether dangers, difficulties, herculean labors, lie in his way; over all and through all his patient, persistent, determined course is laid, and the great purpose is consummated, as is that of the sailor crossing fitful seas, despite calms, gales, fogs, rains, snows, icebergs, or reefs, dangers of wreck from earth, air, sea, or fire. If he goes by his chart, steers by his compass, takes regular observations, and makes exact computations of latitude and longitude, he will surely reach his port. The moods of the man of science are strong and steady, his ways are charted with sure insight and foresight; his methods are those of strategist, logician, and statistician; and his spirit is as determined as that of the followers of Cortez, as truth-loving as that of a Savonarola, as aspiring and as self-denying as that of a Livingstone; in all respects as worthy of divinity as human powers permit. Such, at least, is our ideal and our type, and to this we may all aspire and all incline; however far short of attainment we may finally reach. This is an ideal to which we may all and always cling.

Next in order, we ask, What is the work of the man of science? What is he to do; and, in the past, what has he done?

"What has he done? is the divine question which searches men and transpierces every false reputation." If what he has done proves him to "know the laws of nature better than other men, his nation cannot spare him." If he "inhabits a higher sphere of thought, into which other men rise with labor and difficulty," and has but to open his eyes to see things in a true light, and in large relations, he is a great man, but he is great because of what is in him:

"Deep in the man sits fast his fate,
To mould his fortunes, mean or great."

And as of the individual, so of the class of which he is a member.

What, we would now ask, is the work of the scientific man as we conceive him? What is his aim? What is his final reward?

The work of the man of science, as I understand it, and I now restrict myself to the modern and narrower, and, to us, more personal sense of the word—the work of the scientific man dealing with the natural sciences, so called, is, in grandest outline, the revelation of the facts, laws, operations of nature, of the plan of the universe, so far as the universe is composed of matter and moved by the forces affecting that matter, and still more, the construction of the formulas which constitute the code of that natural law. This, perhaps, more accurately speaking, is the work of scientific men. The work of the individual is either to discover and record new facts, to reveal new laws, to collate and build upon the discoveries of earlier workers, combining the products of separated and perhaps of discontinuous sections into smoothly connected areas, or to find new and useful applications of known facts and principles for the benefit of his fellows. The aim of science is twofold: To produce a pantology, as an intellectual and noble achievement, glorious in itself; and to make knowledge useful and helpful to the race. The early Greeks glorified the worker in the first of these fields; the modern world gives tribute and pays honor to both.

This work is his because he loves it. Says Ruskin: "Fix this in your mind as the guiding principle of all right, practical labor, and course of all healthful energy: That your art is to be the praise of something that you love. It may be the praise of a shell or a stone; it may be the praise of a hero; it may be the praise of God; your rank as a living creature is determined by the height and breadth of your love."

If we are scientific men, "all that we do, we do in kingly fashion; we let tongues wag as they will; what we see to be the right thing, that thing we do." But we do it after the methods of the art which is ours. We observe "the difference between similar and same;" we not only love, we labor; we not only labor, we wait, if needs be. Our love for our art impels us to seek, with righteous curiosity, the solution of a problem in the mystery of existence of which we are a part. Our science and the spirit which it promotes impels the seeker to move as a great strategist moves in war time. We are first to make sure of our base; looking far and near for certainty of our ground; then we plan the advance, carefully, completely, leaving no possible visible line unexplored; we study alternatives as the chess player traces out the threads and teaches himself to follow the intertwined net of advance and retreat, in his most masterly of the games of peace and leisure. The plan complete—always, as in any other serious campaign, subject to revision in the light of later knowledge and more complete information—we proceed to our exploration of the hitherto unknown field.

The method of the man of science, therefore, is: First, to study the "state of the art," in the department chosen for exploration. He reads the accounts of earlier work by those who have preceded him, in chronological order preferably, and verifies their statements and repeats their processes if necessary. In this he follows Gautier's advice, who says:

"Always go to the source. Take no man's authority, least of all mine. Verify every reference; keep an exact record of everything that you observe. Compare every statement that you find in your books with the original authorities. Be content to hold your judgment in suspense if you have no original source upon

which you can base an opinion; and remember that the original source is in all cases the court of last appeal."

This process of historical investigation, precedent to his own entrance into the field in research, gives the student a knowledge of already discovered facts, enables him to avoid the expenditure of time, patience, labor, in repetition, uselessly, of earlier investigations, and permits him to see clearly just where his own work must begin. It gives him a basis on which to build, teaches him what uncertainties of past completed work remain to be removed by further examination before attempting to advance; what dangers of insecure lines of communication behind him must be removed; what line may be safely and conveniently occupied in organizing for his forward march.

Secondly, the purpose and direction of the advance is to be considered. The objective point may be obvious and visible and may only require to be connected with conquered territory by well settled lines, and then free communication secured; or it may be that certain lines have been traced to a known point and their convergence may evidently lead to some unquestionably important but undefined grand center of natural phenomena, a ganglion in the nervous system of the universe, or, again, a boundary may have been reached and a desert may seem to give no promise and offer no potentiality of further gain by extension of our lines. But in either case, eternal curiosity, no less than eternal sense of the duty of leaving no known limit permanent, no hitherto unknown field unexplored, no possibility uninvestigated, allows no cessation of the self-imposed task. The visible point must be connected by exact and sure triangulation and by continuous lines with the area about us; the segmental sections and their untraced lines must be made complete; and the seemingly unfruitful desert must be explored and passed, that every undiscovered treasure, if such be existent, may be acquired.

Finally, the territories conquered from the unknown are to be minutely studied in every minutest part, mapped, reduced to measure, and permanently placed in the list of the accessible and actually known.

The simplest illustrations of the methods and processes of science are seen, perhaps, in the field of physical investigation, both in the construction of the science and in the minor work of detail in investigation. By the methods just outlined, in partial metonymy, the physicist, seeking the "light of a future," searches the records of the past, finds scattered facts and laws bearing upon his problem, sums up the state of the art to his own time, arranges facts and laws into as nearly a complete and consistent scheme as possible, finds that much has been done, that the general outline of a science has been constructed, that the processes involved in transfer of light, as of heat, are well known, but that the ways and means of transportation of energy into light, into heat, into any specified form of ether vibration, have not yet been all discovered. His own problem is identified and enunciated at once. It is for him to seek ways of compelling ether vibration of certain exactly stated rate and amplitude. Next he discovers that this is certainly possible; every jet of alcohol flame in his laboratory, every firefly circling over his lawn in a summer evening, proves the fact. Now he calls every resource of spectroscopy, of chemistry, of physiology even, to his aid, and seeks the road to the visible but hitherto inaccessible point. His historical research precedes the construction of his plan of physical investigation; his scheme comprehends all that can be compelled to illuminate his path, to give a clew to secret ways, or to indicate previously unsuspected applications of scientific principles to this case. Sooner or later, he is sure to reach his goal. Such are the methods of science, and such their applications. It is thus that the world has been enlightened, that a vastly greater progress has been made in a few recent centuries than in ages before.

Glance over the field and note how completely the knowledge of our own time, the positive knowledge—which mainly comprises the fruit of scientific investigation—has come of the work of two centuries. Read the chronologies and observe how the records of science, literature, and art gradually come in to displace the minor notes of rise and fall of dynasties, of births and deaths of kings, as we pass onward from the beginning of the seventeenth century; how the date of publication of a great author's works comes to supersede the record of political and diplomatic follies; how the inventor and the man of science assume nobler and nobler proportions, as benefactors of mankind, as we approach the nineteenth century. This, being interpreted, means simply that scientific methods and scientific work, unknown in earlier times, as was the product of their exercise, have gradually come into the world to perform their grand task of renovation, reconstruction, erection of new worlds on the decayed structures of the middle ages.

In the sixteenth century we find Spenser's Faerie Queen and Lord Bacon's Essays—not one scientific treatise other than philosophic; but even one work is a finger post pointing out all modern ways. Many works of faith, numberless editions of the Scriptures; but not a treatise of fact, no great treatise on science, no science created.

The seventeenth century opens with the martyrdom of that great representative of our guild, Giordano Bruno. The event constitutes an exclamation point, the mark of an historic, of a catastrophic event in the life of the race. The very same year, 1600, saw the publication of that classic, Gilbert's *De Magnete*. Chapman's Homer and Bacon's Advancement of Learning came in together in 1603-5, and the *Novum Organum* later. Galileo and Shakespeare closed their lives and did their work in this century—facts of mightier import than the death of Queen Elizabeth, by far. Tycho Brahe and Fabricius lived then; Kepler made his computations of the orbits, Harvey discovered the cycles of blood circulation; Boyle published his in some respects most remarkable, perhaps, of all works on physics; Milton lived, pleaded for another education and died, famous for his great poem, but even more entitled to honor for his vision of a modern method of scientific education in the arts as well as in the humanities.

Cromwell was born and the Taj Mahal was built; but the brightness of the day which saw Harvard College founded, or that which gave opportunity to observe for the first time the transit of Venus, far eclipsed even

those notable dates. Racine died, but Descartes and Newton were born; Richelieu died, but Pascal lived; and William Penn and Leibnitz were his contemporaries. Holland was wasted by the sea; but Von Guericke invented the air pump and Huyghens discovered a satellite of Saturn, the *Journal des Savants* was issued, and the Royal Society was founded. The peace of Westphalia was signalized in the year 1648, but Pascal demonstrated the fact of the pressure of an atmosphere in the same year, thus made vastly more notable. The patent for Carolina was given in 1663; but the year is famous as that in which Worcester invented his steam engine, in which coins were first made in England, in which the Academy of Inscriptions was founded in Paris. Only a year later, Newton announced the binomial theorem, a grander event than the signing of the treaty of peace between the French and the Pope. Rembrandt died in 1669; but Brandt discovered phosphorus, and Newton invented the reflecting telescope.

In this century Roemer marked the velocity of light, and Greenwich Observatory, the mightiest implement of modern astronomy, was organized; Leibnitz invented the calculus; Locke's Essay and the *Dictionnaire de l'Academie* were printed. The seventeenth century may indeed be considered as the date of the birth of modern science, after an embryonic period extending indefinitely into the earlier past. The death of Bruno marked the entrance into visible life of this modern Hercules, and the rapidity of growth of his mighty and wondrous powers may well startle and amaze the world.

In the eighteenth century, the child, supposed mature at its opening, if not Minerva-like in its entrance upon the scene, gives some idea of its capabilities, of its even now inconceivable powers and mission. The century was crowded with great events, in the presence of which wars and rumors of war, political changes, lives and deaths of princes, sink into insignificance. Frederick the Great and Louis XIV., Czar Peter and Napoleon, made the world uneasy; the French and the American revolutions marked grandest political movements; Charles XII. invaded Russia, and campaigns, sieges, and naval battles were never-failing causes of interruption of the greater works of peace. But it was in this century that Bosovich was born, and Buffon, Euler, Haller, D'Alembert, Adam Smith, Priestley, Lagrange, Watt, Galvani, Lavoisier, Volta, Laplace, Dalton, Fichte, Humboldt, Hegel, Ricardo, Davy and Gay Lussac, Oersted and Berzelius, George Stephenson, Fulton, and Evans and Stevens. Marvelous list of "honor men."

This same century gave us the voltaic pile, and Newcomen's steam engine, the first real heat engine, properly so called. Newton wrote his Optics and discovered the composite character of light. Franklin was born and Linnæus gave us his "philosophic botany" while the American sage was proving the identity of electricity with lightning. The patent law was established, and invention began her noble, beneficent, and wonder-working career. Dolland made the achromatic objective; Watt began his numberless improvements on the steam engine, giving the world its mightiest servant and most docile slave. Carbonic acid and oxygen, and hydrogen, were discovered. The outer planets were brought into view; the balloon became a new source of danger; while Jenner began his work of saving millions of human beings by vaccination. The germ of the telegraph was found; the hydraulic press was invented; the lithograph produced. The century was fittingly closed by the publication of Laplace's *Mécanique Céleste* and of Count Rumford's proof of identity of heat and dynamic energy.

In the seventeenth century, the seed began to germinate; in the eighteenth, it began to flower; in the nineteenth, we have seen a harvest reaped that we may well believe will prove the least and earliest of many, and constantly growing, centennial fruitages. What a list of marvels have been seen by our parents and ourselves! My father was born in the year 1800. When a child at his mother's knee the science of chemistry, given a new life and purpose by Lavoisier, was supplied with form and furnished foundations by the announcement of the atomic theory by Dalton (1803); a school boy of eleven years, he read of the completion of the Bell Rock lighthouse, the beacon directing later engineers, and the foundation of Stevenson's fame; at twelve he read of the discovery of iodine and its related elements; a year later, of Sir Humphry Davy's discovery of the electric arc and his correctness of Rumford's thermodynamic discovery, and a little later of the invention of the Davy and Stephenson safety lamps. At seven he shared the wonder of his parents when told of the voyage of Fulton's Clermont from New York to Albany, without wind or sail to aid, at the wonderful speed of five miles an hour, and was astonished to learn, on pursuing his inquiries, that, for twenty years, inventors had been more or less successfully striving with the problem of reducing the steam giant to service on the water, as Watt and his contemporaries had on land. At fourteen, the boy learned that George Stephenson had succeeded where, five years earlier, Trevithick had failed, and had made a steam carriage capable of drawing wagons and carriages filled with passengers on the long existing railways or tramways of the North of England, and he watched with breathless interest the progress of that grand invention until he saw its final success assured by the Rainhill competition of 1829.

At nineteen, he was interested in Macadam's plan of converting roads of dust and mud into good surfaces for vehicles to traverse; but he was roused to highest enthusiasm by the reports of Oersted's discovery of that—strange as it may seem—still mysterious phenomenon, electro-magnetism. In 1821, he built his first steam engine, with hammer and chisel, and a rude foot lathe, without a planer, and utilizing the water power of the home farm stream. A little later, he built a "sectional," or "safety" water tube boiler, following exactly the principles first enunciated so precisely by John Stevens, twenty years before, and then heartily wished that he might secure the services of Babbage and his marvelous, more than human, calculating engine (1822), in making his various professional computations. It was about this date that he made, with a brother equally interested and enthusiastic over the possibilities of steam power, one of the earliest steamboat voyages through Long Island Sound, from Newport to New York, only to find that Fulton and

Stevens, and Livingston, and the Vanderbilts, were gathering in the lines of commerce and fortune that they had dreamed were free to them. In the three quarters of a century that he lived and worked—for he fought the good fight and did his appointed work from early boyhood to the day which brought his last illness—in a single lifetime, this man saw the grandest development of modern times. He saw the growth of the whole system of textile manufactures, of the applications of steam to all its myriad labors, the building of the steamship, the invention of the locomotive, the introduction of the telegraph, the supplanting of iron by steel, the marvelous inventions and growth of photographic art, the discovery of Neptune and the synthesis of madder, the putting of a girdle of electric wire about the earth, traversed by thought in the twinkling of an eye, and saw the introduction of the modern iron-clad, the torpedo, the submarine boat, and the self-propelling and dirigible air ship. He saw nations grow in deserts, state policies controlled by the work of the reaping machine, the issues of peace and war decided in the banking houses of New York, London, Paris, and Frankfurt; Massachusetts and Minnesota, Maine and California, exchanging products to mutual advantage and profit; colonies organized by civilized races in India, South Africa, and throughout Australasia; continents and oceans traversed in days, the world circumscribed in weeks, months of work concentrated in a warship, or a transatlantic steamer, and a locomotive built in less time than he gave to his first little toy engine, two generations ago.

At sixty, this man of the century had read Darwin's Origin of Species, seen the invention of Bunsen and Kirchhoff making of the discoveries of Fraunhofer and the work of Huggins and Miller a bridge to the stars, and he learned through that dazzling light the composition of the sun and the nebulae. He had seen 'the famous men-of-war of 1812, and taken pride in their achievements, but saw them cast into shade by the modern war vessel which his hands aided in building during our own civil war, and by the iron-clad "monitors" that the genius of Ericsson and Timby gave us in our time of peril. He saw slavery abolished by the arts and manufactures of the North, the gift to the nation of men of his own sort. Commerce was turned into new channels by the Suez Canal, the work of his colleague in engineering, De Lesseps; and the opening of the Pacific Railway, and the grand enterprise of Sibley and his lieutenants, the transcontinental telegraph, made the country of his birth safe against meridianal dismemberment. Then he was ready to cry, "Now, Lord, let thy servant depart in peace."

Could this man, born in the first year of the century, have lived to the last, what might he not have seen of further progress? We are ourselves asking: What remains for us to do? Where do we stand in this path without visible end? What has been accomplished in the promotion of the work of the man of science? What may we regard as practicable and possible in further advancement of research, and in the discovery of other of nature's unrevealed secrets? We are in the midst of the bustle of many partial developments. Where may we best seek our opportunities? We have seen the biologicals reduced to formal science; the mathematics carried into space of the fourth dimension, and directed to the formulation of the motions of the sun, the moon, and the stars of the most distant universe; to the detection of new planets, the computation of the orbits and periodic times of the invisible elements of double stars. The law of evolution has been made to comprehend every department in which living force, whether vital or other, is carrying on the work of the Creator, including in its marvelous and continually extending field the development of protoplasm into man, nebulae into solar and stellar systems, barbarism into civilization, families into nations, paganism into Christianity.

Chemistry has learned to analyze every compound, and is beginning to make syntheses of most complicated compositions, to guide us in reducing the metals from their ores, to produce dyes from basest wastes, to make an odoriferous or a tasteful extract in exact copy of those of nature, to give the world innumerable new and useful gifts. Physics offers us the electric light, and turns darkness and crime to day and peace, and, by this same singular energy, as the handmaid of steam, reaches out along our streets and drives, through its slender wire, hundreds of cars, with rapid pace, exerting the power of a thousand horses. Or it sends its thought-conveying vibrations along the line from New York to Chicago, from Boston to San Francisco, across the oceans; and the telephone speaks to us in the voice of our friend beyond the sunrise, or the telegraph brings us his thought from over seas, and the phonograph and the graphophone make it eternal. This most impressive of the sciences, most brilliant of the departments of natural phenomena, does more. It gives us measurement of the temperature of the moon, the heat of the sun, the extent and velocities of motion of those solar cyclones which cover a hundred thousand miles in a fraction of a second; it tells us the composition of all the heavenly bodies, the state of matter in distant sun and nebula, marks the direction and times the movements of the fixed or the falling star, gives us a clew to the laws governing the transformation of every form of energy into every other, and guides us in our search for the coming substitutes for the heat engines.

Geology teaches us the history of the worlds, the story of the days of creation, the method of development, and the construction of our own terrestrial home. It points out the hidden vein of precious metal, the location of the diamond, the site of ancient forests, now more precious than the carbon crystal, and of deposits of ores of iron, the most precious of all the metals, shows where to seek the subterranean streams that may irrigate and make blossom the most barren soils or the broadest deserts, the reservoirs from which to gather mineral oils for fuel and light, and to be converted into lovely dyes and to give comfort and life to thousands. It shows us how to secure, from the buried relics of a life in prehistoric seas, fruition of the gardens of the florist of the metropolis, the wheat fields of the West, the cotton fields of the South, and the acres of oats and rye in the East and the North, transferring the energies of the sunlight of the earliest days of creation to do the work of the world to-day. What is left to the man of science now? Needless to ask the question of him. A thousand new problems confront him and the old remain largely unsolved.

All life and movement, whether of man, animals, vegetation, seasons, suns and planets, arts, commerce, civilization, intellectual, moral or physical worlds, depend upon transformations of pre-existing energy. All studies, all work in the domain of the physical, the natural sciences, relate to transformations of energies and their mutual interactions and modifications. A century or two is small space in which to reduce all to weight and measure. We have learned to compute the velocity, to determine the methods of refraction and reflection of light; but we still know little of its exact character as motion of molecules. We know the related form, heat energy, in its sensible effects; but we are still unable to differentiate the one from the other. We can produce and utilize electricity in many ways, but we, as yet, do not even know what it is or how its transformations from other energies are effected. We work with these three forms of power, they are the amusement of the ignorant, the wonder of the sage, the slaves of humanity; but we do not even know what is the nature of the substance through which they act to produce their beautiful, their marvelous, their world-impelling effects. The ether is still to us an enigma, unsolved by the wisest, a riddle to the most expert investigator.

The chemist knows much of the composition of "compounds," but he has never seen, felt, or identified an "atom," and still vaguely dreams of a single first element into which all shall be resolved. He counts with unseeing eyes the number of atoms in a "molecule," but has never yet learned their form or grouping. Even with the aid of the physicist he loses track of their transformations in the furnace of the sun and the stars, and finds in the spectroscopic lines a strange language of which he lacks the key. He can isolate and weigh the phosphorus in a gramme of steel, but he cannot give us the phosphorescent fuel, the source of light of the firefly. He can reduce the muscle, fat, and nerve matter of the human system into their elements, but he cannot produce the storage batteries of brain and spine or the gymnotus' cells.

The astronomer weighs and measures the sun, the moon, the planets, and the nearer stars; but he stands aghast and amazed by that flying sphinx, "1830 Groombridge," the "run-away star," flying 200 miles a second, faster than it could fall from infinite space, and its origin, course, destiny are to him questions for the oracles. He has, as yet, no solution. He is lost amid the depths of space, he knows not where to look for a limit, or how to prove its non-existence. He asks with the believing and the unbelieving among the simple, How and when shall the "Heavens melt with fervent heat?" and, How long shall this wandering handful of worlds traverse the infinite safely and without that conflagrating collision with other systems or other worlds that, as seems possible now and then, at intervals of years or of centuries, causes a star to blaze out in the midst of darkness with a brilliancy incomparably greater than that of the sun? His little span of life is too short to permit him to follow the evolution of the worlds from their initial nebulae, too brief to give him access to the secrets of their Maker.

The geologist tells us of the past history of all that lives, and of this spinning globe on which it has found foothold, falling into life from unknown space, and time, and depths, but he cannot tell us whence came all life, whence all spirits, all human and divine souls now constituting its living freight, as it wanders with unguessed mission through an unmeasured universe. He roughly traces its superficial changes from the days of mist, through the ages of creation and growth of all that has come into life; but he and the physicist and the astronomer are alike uncertain whether it shall endure a thousand million of years or a single day. The physicist predicts a limit of a few million years, the geologist believes many millions, but no man knows when life shall perish from the face of the earth.

The biologist can give microscopic measures and microphotographic pictures of the tissues, and can trace a nerve to its minutest ramifications; but we have yet to learn the secrets of the source of life, of method of production and application of energies, of those transformations that give form, structure, life, and power to the organism of monad or man. He exhibits the mechanism of the fish, but finds not the secret of separation of oxygen from the medium in which he lives, and cannot produce a submarine vessel. He knows the shape and movement of the bird, but flight remains to him a mystery. He measures the heat of the animal body, but biologist, chemist, physicist, and engineer, all together, give us no hint of the method of its production. They know, to an ounce, the power per cubic inch or per pound of the muscle, but neither one nor all can say how that power is originated, how transferred or how exerted by the transmitting threads of working muscle.

The engineer has, for a century, made steady progress in the adaptation of machinery to every purpose of modern life. He converts the potential energy of the vegetable life of a myriad earlier ages into steam power, and applies it to the impulsion of railway carriage, of steamship, and of mill; but, in the process, he wastes four-fifths or nine-tenths of it, and pays out principal where he might, perhaps, pay only interest. He turns the elastic force of expanding steam into an electric current, and sends it out to relieve the burden of the overworked horse; but he allows as much to slip from his grasp, often, as he usefully applies to his proposed work. He diverts the energy of combustion or of falling water into the new form, and the electric light, through his genius, gives illumination to street, and dwelling, and hall; but every light ray goes forth to its task carrying with it a sheaf of heat rays; and the glowworm shames the man, producing light without heat, and heat apart from light, and the researches of a Langley or a Hertz only exhibit our ignorance and comparative inefficiency. He measures the speed and power of the albatross, the eagle, and the swallow; but he only marvels the more at their beautiful movements and rapid flight. He captures the dolphin and overcomes the whale when they traverse the surface of the ocean, but he knows not how to follow them into the depths of the sea. He crowds his fellows into mills and factories, but sees no way of giving each an individual life and work, comfort and health in equal and fair quantity. The man of science, whatever his chosen task, whatever his field of labor, however high his attainments and whatever the magnitude of his accom-

plishments, finds acquisition of learning, gain in knowledge of the ways of nature, increasing appreciation of, and familiarity with, God's ways, only bring to his dazed eyes greater and more novel marvels, grander and wider sweep of opportunity, mightier and mightier mysteries, all challenging him to nobler aspirations, more earnest labor, higher aims. Every step toward higher, better, brighter life gives him reason for greater humility, larger faith, and stronger sense of the infinitude of duty and opportunity.

The work of the man of science is present still, and is never-ending. But, glancing at the past, he sees that he has no reason for discouragement; every reason for enthusiastic ambition. He sees a wonderful, a glorious, a fruitful work just begun, and his privilege of taking part in it. His work is the basis of present highest human existence, the potential foundation of still nobler life. Great problems have been solved; greater and grander remain, which shall certainly be solved by him. His is the task of showing the way to make all the powers of nature genial aiding man; of giving comforts of every kind to his fellow, and powers of accomplishment of great work for public good; pointing out the way to give widely distributed enjoyment of life, leisure for moral development, for intellectual growth, opportunity for study of the universes, the attainment of highest physical, intellectual, moral ideals. He will yet penetrate the secrets of the living machine, learn how to evade the law of Carnot, to produce and apply the energies of chemical combination to the generation of heat without light, light without heat, power without waste; to transform thermal from chemical energy, without combustion at high temperature, as does the meanest animal; to convert it into mechanical power without the thermodynamic loss inherent in our heat engines, as does beast, bird, and worm; to obtain its full equivalent of electric energy, as does the nervous system of every living creature; to intelligently select and sort out the radiant energies into luminous, thermal, or other etheric forms, at his will, as does the unconscious bit of hardly living jelly floating in the spume of the wave crest of every tropical sea.

Chemist, physicist, naturalist, engineer—every member of our noble guild has his task and his opportunity. Could highest ambition and grandest aspiration ask more? The worker in pure science is finding his way to greater works, to higher ends in the promotion of the good of his fellows and the race; the man of applied science reduces to practice the principles thus revealed, and directly gives them their place and use. Many Lavoisiers and many Newtons are still to rise into fame; fields are opening for new Boyles, and later Foucaults and coming Faradays. Agassiz, Linnaeus, Harvey, and Herschel have their legitimate successors; James Watt, Samuel Morse, George Stephenson, Robert Fulton, and our great contemporary discoverers and inventors are but the pioneers in a never-ending exploration of all the as yet unknown worlds of science. The coming men of genius are arising daily among the unobserved youthful disciples of these immortals. Their future and their fame should be no less glorious. What young man, entering these paths to-day, may not do so with ambition, hope, assurance of ample reward for such good work as he may do? What youth of honest spirit, persistent habit, steady aim, may not aspire to accomplish some one of these remaining tasks, and to become known to future generations, even though he may die, as often happens, unknown to contemporary fame? Who among us all can fritter away life, powers, opportunities, when such work lies open to all? What, in all the seen universe, can be offered of higher worth to the members of our latest of the fraternities?

And the way to the mountain peaks of science lies through the course which we have seen to be that invariably taken by the true lover of science. It comes of high aims, carefully laid plans, thorough preparation by preliminary investigation of the earlier progress of the pioneers, exact and full acquisition of existent related knowledge and equally accurate and persistent work in its advancement. The modern man of science is known by his works, and by this method of work. Where is worthier purpose sustained by worthier methods? His principles and those of nature are the same, and are eternal, for

"Nature ever faithful is
To such as trust her faithfulness,"

and science, of all pursuits of the intellect, best permits him to rise

"And carry learning to its height
Of untried powers and sane delight."

Natural science takes man nearest God; its field is the Maker's actual handiwork; it most nearly brings Creator and creature into actual touch;

"Without halting, without rest,
Lifting better up to best."

And we may well feel assured that,

"Future or past, no richer secret folds,
O friendless present! than thy bosom holds."

THE KNEE FEMINE.

THE difference of weight in the brains of men and women has long been a source of deep interest to all who discourse of equality and rights. Those extra ounces remain more or less a stumbling block to the unwary. Metaphysical justice refuses to regard them other than iniquitous. Yet certain structural differences escape such close scrutiny, notably that of the knee.

The structure of the knee feminine constitutes in itself a permanent disability for many masculine pursuits. The knee joint in women is a sexual characteristic, as Dr. Ely Van de Warker long ago pointed out. Viewed in front and extended, the joint in but slight degree intercepts the gradual taper into the leg. Viewed in a semiflexed position, the joint forms a smooth, ovate spheroid. The reason of this lies in the smallness of the patella in front and the narrowness of the articular surfaces of the tibia and femur, and which in man form the lateral prominences, and this is much more perfect as part of a sustaining column. Muscles designed to keep the body fixed upon the thighs in an erect position labor under the disadvan-

tage of shortness of purchase, owing to the short distance—compared to that of man—between the crest of the ilium and the great trochanter. A man has a much longer purchase in the leverage existing between the trunk and extremities than a woman. The feminine foot, comparatively speaking, is less able to sustain weight than that of man, owing to its shortness and the more delicate structure of the tarsus and the metatarsus.

Women are not well constructed to stand many hours consecutively and every day. It is safe to affirm that they have instinctively avoided certain fields of skilled labor on purely anatomical grounds, in which the smaller quantity of brain substance proves less an adverse factor than the shallow pelvis, the peculiarity of the knee, and the delicate nature of the foot. These, as parts of a sustaining column, undeniably leave something to be desired. Even the right to vote would not confer on womankind the right to be soldiers. Equality, it appears, is quite as much an affair of the knee as of brains.—*Medical Record*.

WHAT CONSTITUTES A FILTH DISEASE.

Dr. S. W. ABBOTT, Boston, Mass.

THE doctrine that filth plays an important part in the causation of disease lies at the foundation of very much of the sanitary administration of cities and towns throughout all civilized countries. The popular impression, however—and undoubtedly the belief among a very large part of the medical profession, as well as among many of the officials who have charge of sanitary administration—is that filth in the ordinary sense of the word is itself the active cause of disease, and that little else is essential to the production of certain infectious diseases than to deposit a certain amount of filth, or to allow such filth to accumulate within the premises occupied by a given population, in order to generate a pestilence. Hence the activity of sanitary bureaus in sweeping out filth, in cleansing foul spots, in removing garbage, in depositing tons of disinfectants in cess-pools, catch basins, and sewers. This activity in the cleansing of towns, the removal of filth, the sanitation of houses, cellars, and yards, is commendable so long as the true role of filth in the causation of disease is not lost sight of, and the entire energy of sanitary organizations is not expended in this one direction.

Undoubtedly each and all of the so-called filth diseases may find victims in houses that are absolutely faultless, provided that conditions otherwise favorable exist in such houses, the prime condition being the presence of human beings. A child sick with diphtheria in any house whatever constitutes a menace to every one who lives in the house, and especially to the younger portion of the household. This again is but one of the essential conditions to the propagation of infectious disease.

The results of the experimental researches of recent years, in regard to the natural history of infectious diseases, appear to show that what the older observers were wont to call causes were conditions only, and that overcrowding or density of population, faulty ventilation, and the presence of filth are simply the favorable and unfavorable conditions in the propagation of disease, and not in any sense its cause.

Analogy would teach us that the actual cause of an infectious disease is the disease itself—that is to say, a previous case—and the more we learn of the origin of the epidemics, as well as of so-called sporadic cases, the more we are inclined to look for previous cases as the true cause of origin. Nor does the fact that we do not find the previous case prove its non-existence.

By some authorities small-pox is called a filth disease, and experience has shown that the liability to its occurrence is increased by the presence of filth. About one-half of the local outbreaks in Massachusetts in the last ten years have occurred in paper mill towns and in the families of persons engaged in sorting rags, and in nearly every instance it was found that the rags had been collected in some large town in which small-pox had recently prevailed. In this case the presumption is very strong that the filth or the dust of the rags was simply the medium of contagion, the bales having probably contained rags which had had direct connection with the persons suffering with small-pox.

In the same category may be placed *anthrax*, a disease rare in the United States, but occasionally introduced into factories engaged in the sorting and preparation of foreign horse hair. The presence of the *materies morbi* in the dust of these factories is not to be wondered at, when it is known that such hair is sometimes shorn from animals which have died of anthrax.

Another disease which recent inquiries show conclusively to be propagated through the medium of dust-laden atmosphere is that most destructive of all diseases, *phthisis*. The danger which exists in the distribution of the dried sputa of phthisical subjects cannot be overestimated.

The liability of infection by *scarlet fever* is undoubtedly increased by the presence of dust; since the contagious principle of this disease, so far as can be learned, exists largely in the particles of dried epithelial scales which, falling from the body, mingle with dust of apartments, and thus spread the infection from the sick to the well.

In the same category may be placed *typhoid fever*. In fact, this disease may fairly be styled the chief of filth diseases, and although it may not be possible to trace the typhoid bacillus *en route* from the ileum of the sick to the oesophagus of the well by the medium of any drink in which milk or water is used, the evidence as to its transmission in this manner is conclusive. Lieberman says of the disease: "Daily observation is sufficient to show that the decomposition of organic substances, and of excrementitious substances, is not of itself sufficient to produce typhoid fever. There are multitudes of houses in which the effluvia of the privies can be smelled through all the rooms, and in which the inhabitants are constantly inhaling sewer gas; and neither the temporary nor permanent residents are attacked with typhoid fever." We are, therefore, forced to the conclusion that the poison of typhoid fever does not originate in filth or decomposing substances, but simply finds in them favorable conditions for its spread.

The evidence that both *cholera* and *yellow fever* are propagated by sewage—polluted water supply—is very

strong. In both cases the introduction of the disease from without appears to be essential to its propagation. Filth is simply a medium favorable to its spread.

The relation of *diphtheria* to filth is not so clear as in some of the infectious diseases, and it is often claimed that sewer gas is the common cause of the disease. That such filth may be a proper soil for the cultivation of the disease, when once introduced, I have no doubt, but the claim that the disease originates in it is open to question.

The point which I desire to emphasize is not that the removal of filth should be discouraged, but that when it is done it should be done intelligently, and with this principle in view: that filth is a condition rather than a cause; that it is the soil for the culture and transmission of the infection, and not the infection itself.—*Tennessee State Board of Health Bulletin*.

SOME RECENT ADVANCES IN SOLAR SPECTROSCOPY.

By Prof. C. A. YOUNG.

WITHIN the last three or four years our knowledge of the solar spectrum and of the phenomena which are studied by means of the spectroscopic observation of the sun has made substantial progress. In the present article we propose to enumerate the principal advances, and to call attention to such as are specially interesting or important.

Our limits permit only a passing reference to the recent work of the veteran Janssen, who, though no longer physically fit for mountain climbing, had himself carried to the summit of Mt. Blanc by a force of porters in order to study the debated question whether the great oxygen lines in the red region of the solar spectrum might not be, partly at least, of solar origin, notwithstanding the undoubted fact that they are mainly telluric. His observations on the mountain, taken in connection with those he made upon the electric light on the Eiffel tower as seen from Meudon, have settled the question in the negative.

We must content ourselves also with little more than a mere mention of the great map of the solar spectrum published last year by the Nice observatory; the work of Thollen, who however did not live to see it finished. It extends from the red to the green, and is on a larger scale and more full of detail than any other yet issued; it is specially valuable for the manner in which it brings out the distinction between the telluric lines, originating in the atmosphere of the earth, and those which are truly solar, but on the other hand its scale is purely arbitrary, and this greatly limits its utility. On the whole the new edition of Rowland's photographic map, which now covers the whole of the spectrum except a small region at the extreme red end, is comparably more satisfactory; it represents the ordinary appearance of the spectrum with the minutest accuracy, and bears an absolutely trustworthy scale of wave lengths. Its only drawback is that when the sun is near the horizon it ceases to correspond to the appearance presented: the telluric lines become so numerous and intense as to transform entirely the whole aspect of certain regions of the spectrum, and the observer then is driven to Thollen's map as the only one of much use under the circumstances. A new map of the spectrum, also photographic, is announced for early issue by Mr. Higgs, of Liverpool, who has already produced plates exceeding in beauty and clearness of definition even the best of Rowland's; but his work has been done with a Rowland grating, so that our American physicist can still claim a generous share of the credit for its excellence. In fact, the same may be said with reference to every piece of spectroscopic work we shall have occasion to speak of.

Duner, in Sweden, has recently repeated the investigation of the sun's rotation as measured by the displacement of the lines of the spectrum at the eastern and western edges of the sun's disk. His results confirm those of previous observers, extend them to higher latitudes, and are far more precise. Incidentally he confirms an old observation of the writer's in regard to the structure of sun spot spectra, finding them to be made up of fine, closely packed, dark lines, and not produced by a mere continuous absorption. This fact is of importance in its bearings upon the theory of the spots, but for some reason has remained without verification until now.

The most important piece of recent work in the line of solar spectroscopy is unquestionably Rowland's comparison of the solar spectrum with the spectra of the various chemical elements. It is, of course, to some extent only a repetition of work already done by others, but the new investigation is so much more thorough, and made with instruments of so much greater power, that its results are incomparably more trustworthy. The work is not yet entirely finished, but it has already greatly extended our knowledge, both by increasing the number of the elements recognized as present in the sun and also in increasing the number of the lines identified as belonging to the spectra of the elements previously known. A large majority of the lines of the solar spectrum are now thus identified, and no less than thirty-six of the terrestrial elements are recognized with certainty in the sun, while eight remain doubtful, and fifteen fail to give any evidence of their presence after the most careful search; ten remained to be tried at the time when the preliminary results were published last spring. Of the sixteen elements added by this investigation to our former list, the most important are carbon, silicon, silver and zinc: the detection in the sun of the newly discovered and rare metal germanium is also interesting; gallium as yet remains in the list of the untried. The most conspicuous of the "absentees" are nitrogen, sulphur, phosphorus, mercury, antimony and bismuth, while among those not yet examined are oxygen, bromine, chlorine, iodine and fluorine.

Hardly less interesting is the recent work of Hale, of Chicago, and Deslandres, of Paris, upon the ultra-violet spectrum of the chromosphere and prominences as studied by means of photography. It has long been known that the two wide, dark bands known as H and K at the violet end of the solar spectrum are "reversed" in the spectrum of the chromosphere and in the neighborhood of sun spots in the same manner as the hydrogen lines; indeed, this fact, in connection with some other circumstances, led some to suppose that these