The Sciences and the Arts

OF THE

NINETEENTH CENTURY.

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BY

Rev. John M. Gregory, D. D.,

OF CHICAGO.

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When Victor Hugo was closing his brilliant description of the battle of Waterloo,—that battle which ended a dynasty and opened a new era,—he consoled his French chagrin at the result by saying, "The great *man* must disappear that the great *century* may come in." Hugo was right. The great century was already in the gateway,—the century whose grandeur would not brook the presence of a mere conquering warrior however great. The man of blood must yield to the men of brains. The victories of muskets and cannon must give way to the mightier victories of microscopes and crucibles. The mastery of fighting armies over trampled territories, was to be followed by the grander mastery of mind over matter, over nature, over the universe.

The two great factors in the problems of history are the brain and the world. Given a human brain and a world, the question arises, what will the *brain* do with the *world?*

Tell me, at any epoch, where the human brain is tending, and I will tell you where all the phenomena and forces of history will follow. Just as the great tidal waves of the ocean follow the attractive power of the moon, so will the great tidal movements in human affairs follow where the preponderant brain power of the age shall lead.

In the olden time, the ruling brains of the world made military glory their object, and political power their end; and so the earth was a battle field and a capital city, around which all human thoughts mustered and revolved.

In our age the best brains are in the laboratories and schools, or in the mills and fields, in the service of those gigantic, world-sustaining and world-transforming arts and sciences which are making the globe a school and a workshop, over which senates must watch, and around which the moral and political power of the world revolve. If we inquire for the great chieftains,—the strongest, boldest, all-daring, all-conquering minds,—such as in antiquity and in the middle ages were the leaders of armies and of senates, we now find them at the head of the great corporations of trade and transportation, wielding powers before which monarchs cringe, and whole populations grow pale with disquietude and dread; and leagued with these, as prime ministers and cabinet chiefs, are the great inventors and scholars,—the students, interpreters and masters of nature. In place of marshaling armies of soldiers, and leading campaigns for the bloody conquest of States, they marshal the great forces of labor and life, and organize experiments for the mastery of new realms of nature and of truth, and for the conquest of new fields of science and of art. The centuries of brawn have passed away. The centuries of brain are ushered in. And that we may the better forecast what these centuries are to be and to do, we question this nineteenth century,—the first born of the new era,—the *great century*, as Victor Hugo has named it.

But in our questioning, let us not be misled by the accidents of our position. nor deluded by the vanity of our time.

Every age counts itself peculiar. Every age *is* peculiar and grand to its own children. Each century has its own marvels of history, and its own strides of progress. We must try our century by other tests than that of our own feelings to determine its real greatness, or to detect its peculiarities and promise.

It has frequently been called the century of progress. There is a fever for progress. The movement of events is so rapid that all eyes turn instinctively forward any watch to catch the new scenes which arise as the swift train of history sweeps on. The current talk of the street is loaded with twe words which imply advance movement. And the epithets of deepest condemnation which the age stamps upon those out of harmony with its spirit, are words which describe the hesitating, halting,

slow-going conservative lover of the old, and the timid, shrinking, distrustful opponent of the untried and new.

This cry of progress, wild as it sometimes is, is but the articulate voice of the century, forcing itself on the tongues of men. We may deny its truth, decry its wisdom, denounce or deplore it as we will; it bursts afresh from the lips of mankind with every new discovery in science, every new achievement in art. To the common mind, the past is a grave; the future hides in it homes and life and joys. The past is an exhausted field; the future is a mine of gold, a field full of buried treasures. The past is night, a time of darkness, or at best of twilight, of moonshine, of shadows and ignorance. The future is broad daylight advancing to high noontime,—of clear vision, of facts and truths unveiled. Let every one answer for himself if such is not the real gospel of his most secret and cherished creed. It is the *modern* "Psalm of Life" that sings, "Let the dead past bury its dead."

The Russian Nihilist, the latest expounder of the popular feeling which fills the struggling masses, shouts "annihilate all that has come from the past; make of old things *nihil;* let all things be new; or rather let only new things be." Sad folly; miserable and mistaken reading of the grand significance of the progress of this century; but testimony, nevertheless, to the wonderful and even startling character and power of the century itself.

Progress is a result not a cause; it is motion, not force. We must look behind the movement to ascertain the forces which shape the century. We must penetrate the progress to discover the power which produces and guides it. Thus looking and thus penetrating, we reach the secret. It stands revealed in the one word—SCIENCE. The nineteenth century is pre-eminently the century of science. In this lies the secret of its power and progress. Darkness imprisons. Ignorance is a more terrible darkness. Science like light liberates, and the science of this century has liberated the powers of man from the thraldom which made progress slow and toilsome.

There were sciences so-called in other and older centuries. And there were arts of a character so grand and splendid that we still bow before their monumental remains with wonder and

admiration. But the sciences and arts of the past were not the chief features of their times; nor were they comparable in the truths imbodied, and in the powers involved, with those of this century.

Let us do other centuries full justice. Or rather let justice be done to our common humanity. Man has always been true to his divinely ordered instincts,—to his love for knowledge, for liberty, and for advancement towards higher ideals, and a fuller development. But he has often missed his way, and stumbled in the darkness he could not dissipate. Yet even in the twilight, he has wrought wonders of blind strength. No structures excel in massiveness the pyramids of Egypt, nor in grandeur the rock temples of India. The monolithic obelisks of the Nile are still sought to ornament the capitals of Christendom; and the very fragments of the Parthenon are treasured as remains of an architecture which to this hour stands unrivaled. The sculptures of Phidias, Polycletus, Myron, and Praxiteles give law to modern art, and Homer's great epic is still studied as the masterpiece of poetry. Emerson pointed to the works of Plato as the forerunners, if not the fountains, of all modern thought; and even science loves to quote Democritus and Aristotle as the early seers of positive learning. In eloquence, statecraft and war, the age of Pericles equaled the age of Pitt; and the classic literature of antiquity still runs like a line of golden light through the best fields of modern learning.

Nor were the middle ages without their triumphs. The night-time of the centuries was not all night and darkness. Great planetary lights blazed in the midnight skies, and constellations of genius illumined the gloom. Great thinkers, scholars and statesmen, such as Anselm and Abelard, Becket and Friar Bacon, Beda and Erigina, were found among the much derided school-men,—men whose thought and work made modern light and modern liberty possible.

But after visiting, with due reverence, all the great shrines of the past, we return to gaze with increased wonder and admiration on the mighty and marvelous achievements of the present age. The wonder grows that with all the splendor of ancient genius, so much was left for modern science to discover.

As the heir of older ages, it is natural that ours should excel; but it is not in the inherited wealth of the past that the nineteenth century challenges attention. It is by its own grand achievements in knowledge, its own wonderful discoveries in science, and its own mighty triumphs in arts, that it claims our reverence.

But now a question of deep import arises. The greatness of this century admitted, and the source and character of that greatness established, as consisting in the immense increase of human knowledge, and in the sweep and certainty of modern science; in the very spirit of the century, we ask the causes of phenomena so unprecedented and surprising.

First, then, we answer, they come from no increase in the powers of the human intelligence nor from any augmentation in man's desire or need for knowledge. Humanity in the nineteenth century is not certainly superior to the humanity of the first, fifth or fifteenth century. Nor is its need or greed for knowledge greater. Something may be allowed for the laws of evolution and environment. This mighty century-plant, after ages of struggling growth, has suddenly effloresced into this splendor of brightness and power. But passing the minuter steps of variation which we call growth, let us seek the larger causes by which this great crisis of human history has been urged on, the causes which have made this the age of science.

These causes are few, but grand. They are themselves among the discoveries, and their enumeration will be the best proofs we can offer of the real greatness of the age. Effects indeed of previous causes, they are effects which, turned to causes, account for all that follows.

Without pausing to determine the order of precedence among forces which are all acting together, and aiding each other by a thousand subtile reactions, let us note them as they rise.

1. The settled belief in the universality and uniformity of natural law. This fruitful belief has fallen like a sunburst of revelation into the fields of modern thought. To the ancients, the great domain of nature was invaded, and more or less controlled, by supernatural beings and forces, benign or malignant, who interfered to bring storms or sunshine, or to scatter blight-

ing or blessing over fields and cities, over families and empires. Even till late in modern times, this belief was not wholly dissipated. It was an immense stride forward, when science recognized that the universe is under the dominion of universal laws, and hence open to scientific research. All nature passed into the realm of science the moment this great fact was established. In any age this belief would have revolutionized human thought. In our age, it has put the key of the universe into the hand of science, and bid it go wherever it will.

2. The *reverence for facts* is another of the forces working for modern thought. Since law is universal, it follows that every fact is the outcome and expression of some law. In the olden time, facts were mere chance happenings, curious or otherwise, mere freaks of nature or of some meddlesome power over nature; and though not wholly insignificant as demonstrating some theory, yet if they disagreed with the theory, so much the worse for the facts. Now every fact is recognized as the effect of some adequate cause; a result to be accounted for. Each fact is significant in every part of it. Its finger points steadily to some unseen power whose messenger it is, and whose nature it reveals. Modern science is fact-learning. The nineteenth century worships facts, as the voice of nature and of God. Refusing all other answers to its inquiries, it steadily demands the facts, and by these advances along the pathway of its certain and assured progress.

3. The modern *method by verification* completes the trinity of interior or spiritual forces—the thought agencies—which have built modern science to its high proportions. The ancient scholar, trusting to the power of his syllogism, observed and theorized; but his theory once formed, he dismissed his senses and sent forth his discursive thoughts to complete his work. The modern scholar also observes and theorizes, as did his ancient brother,—no better, no worse. All science must begin in an observed fact, and a theory or explanation of that fact. Ancient science ended with the theory; modern science counts its work but just begun here. The theory must be verified. Verification is the very secret of our success. With us, the theory formed, observation begins afresh. Under every possible case, the hypothesis is submitted to the test, and the work only ends when theory

corrected, reformed and demonstrated, stands forth no longer a theory, but a proven truth,—a great law of nature answering to all the facts coming under it. Each truth gained and verified thus, becomes the vantage ground of a swifter and surer advancement.

Thus the scholarship of this great century recognizes at last the greatness and the authority of nature, and turns reverently to its pages as to another word of God. Discarding speculation as no source of truth, the modern scholar listens to the long neglected voice of facts,—facts which have been waiting for ages to be read and understood. Facts, he says, are God's thoughts. Theories are the thoughts of men. When these disagree, the thought of man must be dismissed, or renewed and re-shaped till it perfectly answers to, and is verified by, the fact. Verification has been to science the divine seal to its truth. The fact speaks, but in an unknown tongue; verification translates its speech into the vernacular. It is the silent "yea and amen" of nature to man's prayer for light.

4. Passing from the forces within to the forces without the man, we meet first the instruments of precision which have given him, as it were, new and keener senses, and sharpened a thousand fold his power of observation. To his eye, limited in range and feeble in penetration, the microscope lends its million magnifying power, peopling the rain-drop with myriads of living forms, and tracking organic life and force to their hiding place amid the atoms and molecules of matter. The telescope fills, for him, the endless sweep of space with mighty families of worlds—star-peopled empires, marching in the endless mazes and migrations of an eternal history. The spectroscope with its spectre-summoning power, carries chemistry into the skies, and makes it the companion and servant of the heaven-scaling astronomy. The chemical balance, whose poised beam turns at the touch of the lightest hair, has added for man the sense of a finer feeling; and a hundred instruments of strange construction and names stand as so many sharper, stronger senses added to the human organism—senses so keen, so penetrating and far-reaching that neither in the heights nor in the depths, in the magnificent nor in the minute, can nature hide her secrets from the scholar's quest. The silences become voiceful; emptiness

is found to be peopled; darkness is full of light; death is only another mode of life; repose is but the dead-lock of immeasurable forces; and "things are not what they seem." In the bible story of the young man whose eyes were opened at the prophet's prayer, the cleared vision saw the mountains full of horses and chariots of fire. To the eye aided by science and its instruments the universe itself is full of God's chariots and horses of real fire—fire hidden in coal-beds and rocks, in icebergs as in suns, in all things living or dead,—the fire-energy working out the purposes of creation under every form of movement and of being.

5. Along with the instruments of precision mest be counted the mathematics, that instrument of mental power and precision which one has justly called the "great iron key that unlocks the universe." Science must have stopped half way in its course without this aid, but with this mightier weapon it enters the infinite and limits the unknown. Had all these instruments been in the hands of Aristotle, the history of the world would have been changed.

6. But our count of the causes of the greatness of modern science is not yet complete. We must take in the wide spread of popular and public education. This has reinforced the thinking brains of the world with an innumerable host of observers, students and workers. In place of the scattered skirmishers once invading the domains of nature and science, it has moved forward the grand divisions—the great army-corps of educated peoples—to dissipate ignorance and superstition, and to hold and occupy the conquered territories of truth. Genius works now with a double zeal, in the presence of appreciative and applauding populations. Astronomy no longer steals away to the astrologer's garret to hide its star-gazing from the fear and hate of a superstitious mob; and chemistry is not forced to creep into the darkened caves of the alchemist to escape the vengeance visited upon those suspected of dealing with the powers of evil. In the midst of admiring millions, the astronomer now turns his telescope to the starry heavens; and chemistry builds its palatial laboratories by the side of the great manufactories which wait to turn its discoveries to profitable use.

7. Shall we count it as another, or as a part of the same line of causes—the emergence of the people from the low and brutish condition of the middle and older ages, into the recognized manhood, the political supremacy, the social aspiration, the all-embracing, all-inspiring freedom of thought and work and worship of these latter days? Not the wars of great monarchs, but the daily wants of the greater millions, now dictate to science its problems; and its rewards come, not from the stinted bounty of kings and nobles, but from the rich fruitage of the million-handed arts which it serves. The coronation of the people was the enfranchisement of learning. The age of the people is by natural sequence also the age of science. The skilled hand and the educated brain are no longer separated by the whole diameter of the social world, but they stand linked in vital union, and are driven by the pulse-beat of the same mighty heart.

We close this enumeration of causes with the obvious remark that any one of them, set at work in any age or among any people, would change the currents of life and thought. Let them all work together as in this nineteenth century, and how can we longer wonder at the results attained, or put a limit to our hopes of the future?

If now from the pathway of its advance, and the instruments of its progress,—from the causes, which are also prophecies, we turn our gaze to the grand outcome and fulfilment,—to the Titanic array of the sciences of the nineteenth century,—what a galaxy of light blazes before us! The mere roll-call of these sciences would consume the hour and weary our patience. To pass them in full review, we must employ a library instead of a lecture. A glance at two or three of the grand divisions may show us not only how they differ from the sciences of antiquity, but how great they are in themselves.

As we have said, there were seers and scholars in ancient time, but as compared with the students and scientists of today, those older scholars did but walk around the great temple of nature, and catch partial and distorted glimpses of its inner glories through its shutters and keyholes. To us the doors are ajar; and if not yet admitted to its highest altar places and more sacred arcana, we stand in the vestibule and send our eager

glances along the far-stretching aisles. There were star-gazers on the plains of Shinar, and astronomy left its records on the baked tablets of Chaldea, and on the temple walls of Egypt; but how meager the seven planets supported by their crystalline spheres compared with the astronomy of Newton and Laplace, of Herschel and Proctor. The mathematics of Pythagoras and Euclid and Archimedes were but as babies' fingers compared with the world-grasping calculus of infinitesimals. The old alchemy with its puerile problems of love philters, elixirs of life, and philosophers' stones, was but as a farthing dip in contrast with the chemistry which summons every element of matter to throw off its disguises and tell the story of its loves and hates; which chases life to its hiding places in its ultimate germ cells, and forces the sun's ray to reveal through the spectrum the fuel which feeds its enormous and all-consuming fires; which stores up lightning in condensers and peddles it by the foot-pound in the market, and which lends to the ear the photophone and bids us listen to the song of the colors as to the voice of Memnon awakened by the sunrise.

If we compare the territory visited by ancient research with that traversed by modern science, the contrast will be still more surprising. In a few narrow fields, like small islands in the great oceans, *they* studied the mere surfaces and most common phenomena of matter, while the great wastes of unknown seas rolled around them impassable and dark. To-day all facts are scientific; all fields are filled with truth; all phenomena are over-written with nature's open secrets; and the material universe is reverberant with the messages of knowledge. No inch of space, no push of force, no form of matter, no flash of light, no mode of life, but furnishes a field for science. The pebble picked from the roadway is claimed at once by half a dozen sciences which seek to read its riddles. Chemistry recognizes it as one of her compounds; physics takes note of its form, color, density, weight, and physical properties; dynamic geology asks after its travels and history; lithology questions it of its place in the families of rocks; mineralogy seeks to know its anatomy and bodily structure; and geometry takes account of its form and content. To modern scholarship nothing is out of the reach and range of science. The universe is one great lab-

oratory in which all the sciences are at work, repeating in endless rounds their experiments, and proving the truth and force of their laws.

But we must still narrow our view. Let us summon from the ranks a single one of these sciences. Nay, let us limit our view to a single theory of one of these sciences, that we may the better comprehend the grandeur of them all. We choose for this survey the theory of *force*, that unknown something which produces all motion of matter, molar or molecular. We give the theory as now understood.

It is an old truth that no effort of man, however aided, can create or destroy a single particle of matter. All that ever has been, now is. Through all changes, growths, or decays, every particle of substance abides. Playing its part in a million bodies, plant and animal, the atom survives the destruction of them all, and still answers to the roll-call of the all-marshalling gravitation.

It is a later and, if possible, more wonderful truth that force too is eternal,—that no effort of man can create or destroy a single impulse of it. The force with which I lift my hand, or utter these words, was in existence in the morning of time. It has played in sunbeams, rocked in earthquakes, thundered in tornadoes, worked silently in the building up of plants, or in the tissue growths of animals, marched with great armies, roamed the desert with wild beasts, flitted in the air, swum in the seas, slept in the coal beds, sung in cathedrals, spoken in the senates, toiled at the plough, the anvil and the loom, rocked the cradle, carried the coffin, flashed in lightnings, glowed in sunsets, played all parts in the great drama of history and survived them all; and now, having served my present use, it has gone out into the universe to play new parts long after my voice is silent and my tongue is stilled, gone to exert its unwasting power till the endless end.

Let us illustrate. In winding my watch I use a certain amount of force. This force enters into the mainspring which its coils, and in the slow uncoiling runs the watch through the twenty-four hours. The spring had no force of its own; it has simply given out the identical force which passed into it from my hand,—no less, no more. And the force which passed from

the mainspring into the wheels was not lost or consumed, but went on into new conditions, possibly hard to follow, but certainly not lost.

Let me expend the force of a hundred pounds in lifting a weight from the floor to this table. A month may pass,—a year, a century, a thousand centuries, and if the weight and table still remain unchanged, the weight in falling to the floor will exert the same hundred pounds of force which I used in lifting it. Connect this weight while on the table with an equal one, by cord and pulley, taking now no account of friction, and the fall of the one will lift the other; and the force originally in my arm will pass to the second weight and so on, through any number of similar weights.

But now let us track it backward to its source in my arm. It was hidden there in the organized molecules of muscle and nerve matter, each one of these, like the mainspring of the watch, having a certain amount of force locked up in it by the vital processes of its growth. These organized molecules gave up their organic force, and became unorganized matter, in lifting my arm with the weight. A certain large number of such efforts would exhaust all the energy of my body,—would waste particle by particle all the muscles, and leave me a skinny skeleton, or dead. We have all seen how the fat horse is made lean by hard driving. It is the force which was stored up in his muscles and nerves which drags the heavy cart, or whirls our carriage along the avenue. His flesh disappears not because it is worn away by the friction, but because particle by particle it yields up the force which held these particles in organization.

Following backward still the force which I have traced from weight to muscle, I find it coming from the food which fed the muscle. It has the force which lay coiled in the bread and beef of my breakfast. My digestive organs did but uncoil one set of springs to coil another. The identical force which was in my food went into my muscles, as that from one of my weights was transferred to the other. Another step tracks the force from the food to the powers of nature which made the wheat to grow, and fattened the beef; and still another step and we reach the sunshine which energizes all nature, stimulating all growths, and filling the earth with force and life. And here it eludes

our search only by hiding itself in that ocean of fire and flame, —that immense reservoir of force—which rolls above our heads.

But our science of force does not end here. More properly it does but begin here. Our illustration has led us into the presence of another law of force discovered by modern science. It is that of the transformation of forces, the correlation of forces, as science terms it.

The force we began with was lifting power, the strength which moves masses of matter. It fled before us till it hid itself in the sunshine. But how does the sunlight hold force? Science replies that heat and light are only other forms of energy. It shows us that wherever there is heat there is always force. Steam power is nothing but the heat which pushes apart the particles of the water and turns it into vapor. The energy which the sunshine of other ages stored in the coal,was released in the fire, and passing thence into the water, sent the swift particles of the steam driving against the piston, and whirling the great wheels, and so it drove forward the heavy locomotives, and dragged on the ponderous train. It is the fire, the heat force, and not the water, which whirls us forward forty or fifty miles an hour. What was fire in the furnace became pushing power in the piston, and swift motion in the wheels. In the heated axles it is often turned back to fire again.

The electric light shows another of these strange transformations. A steam engine whirls the coil in a Gramme machine, and the energy of the fire, passing successively through the steam, the moving engine, the magnet and the electric currents, leaps between the points of the Jablakoff candle, or around the horse-shoe bend of Edison's lamp, and flashes out into brilliant electric light. Substitute a common battery for your engine and Gramme machine, and you have the chemic forces of acid and zinc changing to electric currents, and again to the dazzling arc.

Nature's great household is a magnificent masquerade, in which, under myriad forms, energy is filling the scene with perpetual surprises, the silent sunshine falling soft and warm, on land and sea, works with a force that none can measure, masking itself in the chemistry of soil and plant, lifting the browh earth into green growths, tossing into the sky millions of

tons of the heavy waters, and wearing them there as fleecy plumes, or driving them as mighty water carts over the thirsty earth. Sleeping in the snowflakes or burning in volcanic fires, flushing the cheek of beauty, cr flashing in the lurid lightning, building the delicate grass blade or energizing the strong arm of labor,—it is everywhere and under all disguises, the self-same, undiminished, unresting, indestructible force.

We do not pause here. Our science or force does not end with these marvelous transformations. It has another chapter of wonders more marvelous still,—or two of them rather,—the chapter which tells of its modes of existence—the molecular motions seemingly inseparable from it; and that other chapter which describes its universal prevalence, and its almost inconceivable power. Science reports that the forms of energy are modes of molecular motion, motion whose range is so short that no eye armed with the most powerful glasses can see it. Thought alone can compute it.

Heat this bar of iron, and each molecule in it is put in motion,—but the motion though swifter than the lightning does not disturb the solidity of the metal. This motion reveals itself only in the burning touch which blisters our hand. Heat it more and the red light tells us, says our science, that the motions number four hundred and fifty millions in a second, and that forty-seven millions of these wavelets would reach only an inch in space. Heat it still higher and the motions multiply; the white light, or white heat, as we call it, comes. The atoms now move more than five hundred and fifty billions of times in the swinging of the pendulum. Quicken the movements a few billions more per second, and the solidity gives way and your solid iron becomes a dazzling liquid mass. Fling it into water and the motion which produced all these changes ceases in the iron but turns the water into steam. The motion has been transferred from the molecules of iron to the molecules of the water. The iron pauses and grows cold; the water rushes into violent vapor and intense heat.

Everywhere, where force in any of its disguises, as heat, light, color, chemical affinity, magnetism or electricity, appears, there molecular motion is found, and the changes in the rate of

movement are followed by transformations in the forms or kinds of energy.

And here lies an inconceivable wonder. Through the same space at the self-same moment, all these motions are passing without apparent interference or difficulty.

The atmosphere of this hall bears to your ears the waves of my voice and of all the sounds which come to you from whatever direction. Each various word and note sends its own sound-waves through the entire space; but these waves, though of inconceivable minuteness, are large and coarse in comparison with others which stir this air. The warmth of every living body, and the heat from every source from which this atmosphere gets its present temperature, send their myriad molecular wavelets in every direction, in tidal currents which the most delicate thermometer could not always detect, and which leave no smallest point of this space unshaken with their motion. But further still, from every luminous and light-reflecting point the infinitesimal light-waves sweep circling out, swift as vision, and counting by hundreds of billions in each second; each separate hue and color having its own fixed number, and all filling at once every place and spot where the pupil of an eye could be placed to take them in, in its act of vision. To lift the wonder higher, around every atom and molecule of the silent atmosphere, and of the solid forms which it incloses, play the vibrant chemical forces, various and mingled as the chemical properties they produce or represent. What a mystery of motion! How utterly inconceivable to the quickest and keenest thought? and yet through the solid earth and vast universe, no single particle of matter ever lies still, no single inch of peopled space but is constantly swept with waves and wavelets more numerous than all that can be found upon the bosom of the broadest ocean counted from shore to shore.

Now finally comes the crowning chapter in this volume of wonders, the inconceivable might,—the practical omnipotence of these molecular forces. Compared with the grandest of the molar forces,—with the torrent, the tornado, the earthquake, the volcano, or the avalanche these molecular forces are as steel cables to the spider's thread, or as the push of a fly to the rush of a whale. No credulity would believe the story were it not

attested by facts of every day observation. All have heard how a little water thrown on the tense rope lifted the mighty obelisk to its place. The molecules of freezing water, struggling to take their places in the forming crystals push the stoutest pitcher to pieces, and would burst a cannon if it should attempt to confine them. The burning of a little powder hurls the five hundred pound shot five miles away, or lifts the ponderous ship of war out of the water. The combustion of a few bushels of coal drives the monster steamship weighing thousands of tons against storm and mountain waves; and daily we see the great iron horse, fed by a little burning coal or wood, dragging its enormous load with the swiftness of the wind.

Such in brief is one of the nineteenth century sciences—such the product of its studies in a single field of investigation. We might have chosen others as full of wonderful facts and truths. Chemistry and biology would tell us even greater marvels; while the star-written astronomy would make our story seem as a child's tale. History and archæology, ethnology and philology and the great twin sciences of physiology and psychology, would all answer to the roll-call with facts so novel and so grand as to cover the century, each with its separate glory.

I dare not detain you for more than a passing glance at that other great field of nineteeth century power—the field of *modern arts*, which in the eyes of many, at least, are the crowning proofs of our science, and the topmost achievements of the eentury, the sublimest fruitage of man's mastery over his environment and over nature.

If we were to confine our glance to the four great classes of the useful arts necessary to life and known to all ages of history, the food-producing, the cloth-making, the house-building, and the tool-making arts,—we should find ample proofs of the greatness of our century.

In agriculture one hesitates which most to admire, the productive or the plastic power of modern agricultural art,—the vast abundance or the vast variety of our farm products. The savage gleans a scanty and precarious supply for one person from a thousand acres of fertile soil. Modern agriculture knows how to force from a single acre the abundant support of a man. The tables of the Cæsars, loaded with the products of the con-

tinent, knew not half the forms of vegetable and animal food which feed us. The soil quickened and reinforced by fertilizing matter, yields to mankind harvests of wealth beyond the wildest dream of ancient art.

In the fabrics of the loom we may not surpass the fine muslins of India, the hand-work of Cashmere, or the embroideries of the gorgeous Orient, but in the variety and volume of our clothmaking, this century outdoes all others. It is no longer true that those who wear soft raiment dwell only in king's houses. The rustle of silk is heard in cottages, and purple and fine linen clothe peasants as well as princes. Our looms imitate deftly the cunningest embroideries. Our aniline dyes surpass in beauty the Tyrian purple, and the millions upon millions of yards of cloths of all materials, and textures issuing from our mills daily would have crazed the monarchs of Mesopotamia and the world-robbers of Rome.

Modern *Architectural Art* builds no parthenons, but neither the Parthenon nor the palace of the Cæsars showed such combinations of utility and taste, such richness and abundance, suce palaces of trade and such homes for the millions as deck the continent and crowd the magical cities of these modern times. And the modern constructive art is as much superior in its power as in its variety. Whole populations in harness dragged to tneir places the stones for the pyramids and temples; today a single engineer with his steam-nerved iron arm lifts into position the mightiest masses needed for the grandest structures.

In the tool-making arts the modern genius revels as in a field all its own. Having trapped the secret forces of nature, it has contrived, invented and combined, till its machinery, as multiplied in power as it is multitudinous in form and purpous, threatens to displace human brains as well as sinews from their wonted fields of work. The trick of invention has been learned, and it is reduced almost to a trade. Given clearly the thing to be done, and given the promise "it will pay," and you may have your machine invented to order. Would you see the wonders of modern tools, bring your microscope to count on the one side their fineness of work, and your grandest dyanmometer to test on the other their terribleness of power. You will need the one to see

the delicate screws of the watch, and the other to measure the force of the eighty ton steam hammer, and the hundred tons of heated iron pounded on its anvil.

But while the old arts have been thus pushed to new heights, whole families of new arts have been summoned into existence by modern science, arts of which the fathers never dreamed.

Around the electric battery a score or more of rich and productive industries have already gathered, and almost yearly new ones are added to the group. Telephony with its wires—the slender railroads of fire-driven speech—stretching through the air and under the seas, rivals the great postal service which it threatens largely to displace. Telegraphy makes of our cities great whispering galleries, or halls of audience, and across the breadth of these cities men hold confidential conferences and discuss bargains and business. Electroplating fills our homes with the sheen of silver, and consumes annually millions of the precious metals in its fabrics. The electro-metallurgic arts daily assume new forms and larger dimensions. Electric lighting has achieved its place, and must soon become the street light if not also the home light of the world. Electro-motors drive street cars. They may soon drive railroad trains and ocean ships. Photographic arts now work in a hundred fields. They aid astronomy and the engineer, the naturalist and the physician, the engraver and the artist. Chemistry has also its family of useful industries, and their fabrics fill a hundred shops and shelves. No catalogue can keep pace with the triumphs of nineteenth century learning and labor.

Out of this mere sketch and brief survey of this great century emerge in the final thought two great truths of passing sublimity and power.

1. On the high summit of his ever-lifting and expanding sciences stands MAN—the science-maker. The *thinker* is always greater than his *thought.* The grand reflex of every discovery is the greatness of the soul capable of making such discoveries. The reason reveals its own power in every fresh grasp it gains of truth, every triumph it wins over nature.

The problem of our humanity—of man's nature and destiny—instead of being nearly solved, grows constantly grander

and more difficult. Every step that he takes in science, in civilization, in his mastery over things, widens the gulf that lies between him and the instinct-guided animals below him. Mind remains forever the last, the insoluble problem of science, since every new solution brings to light new forces to be studied and accounted for—a higher mind standing above, and gazing down upon the problem solved. It is the thinker standing above his thought.

No age is really great which does not both reveal and increase the greatness of Man, and of Society. Of what avail is it to *know*—to know grandly even, and with scientific certainty and precision—if this knowledge does not lift the cognizant soul into loftier faith in itself, and into grander thinkings of duty and destiny, into a life of greater purity and power. And here also our century is great; great in its estimate and care for man as man.

2. The second truth is of still grander proportions and import. On the outer rim of our expanding knowledge presses forever, in grander extent, the *unknown*—not the unknown *nothingness*, but the unknown *somethingness*—the primal, eternal, all-sufficient force and intelligence which devout men name God. And why not God? If the progressive discoveries of science enlarge the known area of second causes, do they not thereby make grander and more necessary the power and wisdom of the great First Cause? Just as every new stretch in the diameter of a circle adds three times as much of border line to feel the touch of outer things, so the expanding circle of science multiplies in a much larger proportion the demands upon the all-embracing wisdom and power of the Creator. What if it is by a series of tremendous negatives, we arrive at our conception of the divine Creator, the truth of His existence remains none the less certain. It is the logical sweep of a grand and awful *reductio ad absurdum*, which shuts us up to this conclusion. As in the studies of Elijah, not in the mighty rushing wind, nor yet in the earthquake, the play of the giant cosmic forces; not even in the all-energizing fire force of the universe, have we found God, but in the still, small, authoritative voice of the eternal Reason, the whisper of the Soul, He is perpetually proclaimed. Why rob Science of its grandest need—its

last and highest conclusion? Deep calls unto deep in the profundities of knowledge, in its quest for the infinite reason and Creator of all, and instead of an "unnecessary hypothesis," God is the one postulate which, being granted, makes rational and clear all the rest.

As the last problem of Science is Man, so the last conclusion of all true Science must be God. The century will forfeit all its real grandeur with right thinking men, if its splendors of knowledge and power shall lead to any conclusion less fitting and benign.