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INVENTIONS IN THE CENTURY

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Содержание

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CHAPTER I.
INTRODUCTORY – INVENTIONS AND DISCOVERIES – THEIR DEVELOPMENT

In treating of the subject of Inventions it is proper to distinguish them from their scientific kindred – Discoveries.

The history of inventions is the history of new and useful contrivances made by man for practical purposes. The history of scientific discoveries is the record of new things found in Nature, its laws, forces, or materials, and brought to light, as they exist, either singly, or in relation, or in combination.

Thus Galileo invented the telescope, and Newton discovered the law of gravitation. The practical use of the invention when turned to the heavenly bodies served to confirm the truth of the discovery.

Discovery and invention may be, and often are, united as the soul is to the body. The union of the two produces one or more inventions. Thus the invented electro-telegraph consists of the combination of discoveries of certain laws of electricity with an apparatus, by which signs are communicated to distances by electrical influence.

Inventions and discoveries do not precede or follow each other in order. The instrument may be made before the laws which govern its operation are discovered. The discovery may long precede its adaptation in physical form, and both the discovery and adaptation may occur together.

Among the great *inventions* of the past are alphabetical writing, Arabic notation, the mariner's compass, the telescope, the printing-press, and the steam-engine. Among the great *discoveries* of the past are the attraction of gravitation, the laws of planetary motion, the circulation of the blood, and velocity of light. Among the great inventions of the nineteenth century are the spectroscope, the electric telegraph, the telephone, the phonograph, the railways, and the steam-ships. Among the great discoveries of this century are the correlation and conservation of forces, anæsthetics, laws of electrical energy, the germ theory of disease, the molecular theory of gases, the periodic law of Mendeljeff in chemistry, antiseptic surgery, and the vortex theory of matter. This short enumeration will serve to indicate the different roads along which inventions and the discoveries of science progress.

By many it is thought that the inventions and discoveries of the nineteenth century exceed in number and importance all the achievements of the kind in all the ages of the past.

So marvellous have been these developments of this century that, not content with sober definitions, men have defined *invent*, even when speaking only of mechanical productions, as "creating what had not before existed;" and this period has been described as an age of new creations. The far-off cry of the Royal Preacher, "There is no new thing under the sun: Is there anything whereof it may be said, see this is new, it hath been already of old time which was before us," is regarded as a cry of satiety and despair, finding no responsive echo in the array of inventions of this bright age.

But in one sense the Preacher's words are ever profoundly true. The forces and materials of Nature always exist, awaiting man's discovery, and at best he can but vary their relations, re-direct their course, or change their forms. In a still narrower sense the truth of the Preacher's declaration is apparent: —

In an address before the Anthropological Society of Washington in 1885, the late Prof. F. A. Seely, of the United States Patent Office, set forth that it was one of the established laws of Invention, that,

"Every human invention has sprung from some prior invention, or from some prior known expedient."

Inventions, he said, do not, like their protectress, Pallas Athene, spring forth full grown from the heads of their authors; that both as to modern inventions and as to those whose history is unrecorded, each exhibits in itself the evidence of a similar sub-structure; and that, "in the process of elimination we go back and back and find no resting place till we reach the rude set of expedients, the original endowment of men and brutes alike."

Inventions, then, are not creations, but the evolution of man-made contrivances.

It may be remarked, however, as was once said by William H. Seward: "The exercise of the inventive faculty is the nearest akin to that of the Creator of any faculty possessed by the human mind; for while it does not create in the same sense that the Creator did, yet it is the nearest approach to it of anything known to man."

There is no history, rock-record, or other evidence of his existence as man, which discloses a period when he was not an inventor.

Invention is that divine spark which drove, and still drives him to the production of means to meet his wants, while it illuminates his way. From that inward spark must have soon followed the invention of that outer fire to warm and cheer him, and to melt and mould the earth to his desires. Formed for society, the necessity of communication with his fellows developed the power of speech. Speech developed written characters and alphabets. Common communication developed concert of action, and from concert of action sprung the arts of society.

But the evolution of invention has not been uniform. Long periods of slowness and stagnation have alternated with shorter or longer periods of prolific growth, and these with seasons of slumber and repression.

Thus, Prof. Langley has said that man was thousands of years, and possibly millions, in evolving a cutting edge by rubbing one stone on another; but only a few thousand years to next develop bronze tools, and a still shorter period tools of iron.

We cannot say how long the period was from the age of iron tools to the building of the pyramids, but we know that before those stupendous structures arose, the six elementary mechanical powers, the lever, the wheel, the pulley, the inclined plane, the wedge and the screw, were invented. And without those powers, what mechanical tool or machine has since been developed? The age of inventions in the times of the ancients rested mainly upon simple applications of these mechanical powers. The middle ages slumbered, but on the coming of the fifteenth and sixteenth centuries, the inventions of the ancients were revived, new ones added, and their growth and development extended with ever-increasing speed to the present time.

The inventions of the nineteenth century, wonderful and innumerable as they are, and marvellous in results produced, are but the fruit of the seed sown in the past, and the blossom of the buds grown upon the stalks of former generations. The early crude stone hatchet has become the keen finished metal implement of to-day, and the latter involves in itself the culmination of a long series of processes for converting the rough ore into the hard and glistening steel.

The crooked and pointed stick with which the Egyptian turned the sands of the Nile has slowly grown to be the finished plough that is now driven through the sod by steam.

The steam-operated toys of Hero of Alexandria were revived in principle and incorporated in the engines of Papin and the Marquis of Worcester in the seventeenth century; and the better engines of Savery, Newcomen, and more especially of James Watt in the eighteenth century, left the improvements in steam-engines of the nineteenth century – great as they are – inventions only in matter of detail.

It has been said that electrical science began with the labours of Dr. Gilbert, published in 1600. These, with the electrical discoveries and inventions of Gray, Franklin, Galvani, and others in the next century, terminating with the invention of his battery by Volta in 1800, constituted the framework on which was built that world of flashing light and earth-circling messages in which we now live.

The study of inventions in any one or all eras cannot proceed intelligently unless account is taken not only of their mode of construction, and of their evolution one from another, but of the evolution of distinct arts, their relation, their interdependence in growth, and their mutual progress.

The principles adopted by the ancients in weaving and spinning by hand are those still in force; but so great was the advance of inventions from hand-operated mechanisms to machines in these and other arts, and especially in steam, in the last half of the eighteenth century, that it has been claimed that the age of machine production or invention then for the first time really began.

When the humble lift became the completed elevator of to-day, the "sky-scraper" buildings appeared; but these buildings waited upon the invention of their steel skeletons, and the steel was the child of the Bessemer process.

The harp with which David stirred the dead soul of Saul was the prototype of the sweet clavichord, the romantic virginal, the tinkling harpsichord, and the grand piano. The thrumming of the chords by the fingers was succeeded by the striking keys; and the more perfect rendition of tones awaited the application of new discoveries in the realm of musical sounds. The keys and the levers in the art of musical instruments were transferred to the art of printing, and are found to-day striking a more homely music on the type-writer and on those other and more wonderful printing instruments that mould, and set, and distribute the type. But these results of later days did not reach their perfected operations and forms until many other arts had been discovered and developed, by which to treat and improve the wood, and the wire, and all the other materials of which those early instruments were composed, and by which the underlying principles of their operations became known.

Admitting that man possesses the faculty of invention, what are the motives that induce its exercise? Why so prolific in inventions now? And will they continue to increase in number and importance, or decrease?

An interesting treatise of bulky dimensions might be written in answer to these queries, and the answers might not then be wholly satisfactory. Space permits the submission of but a few observations and suggestions on these points: —

Necessity is still the mother of inventions, but not of all of them. The pressing needs of man in fighting nakedness and hunger, wild beasts and storms, may have driven him to the production of most of his early contrivances; but as time went on and his wants of every kind multiplied, other factors than mere necessity entered into the problem, and now it is required to account for the multiplicity of inventions under the general head of *Wants*.

To-day it is the want of the luxuries, as well as of the necessities of life, the want of riches, distinction, power, and place, the wants of philanthropy and the wants of selfishness, and that restless, inherent, unsatisfied, indescribable want which is ever pushing man onward on the road of progress, that must be regarded as the springs of invention.

Accident is thought to be the fruitful source of great inventions. It is a factor that cannot be ignored. But accidents are only occasional helps, rarely occurring, – flashes of light suddenly revealing the end of the path along which the inventor has been painfully toiling, and unnoticed except by him alone. They are sudden discoveries which for the most part simply shorten his journey. The rare complete contrivance revealed by accident is not an invention at all, but a discovery.

The greatest incentive in modern times to the production of inventions is governmental protection.

When governments began to recognize the right of property in inventions, and to devise and enforce means by which their author should hold and enjoy the same, as he holds his land, his house, or his horse, then inventions sprung forth as from a great unsealed fountain.

This principle first found recognition in England in 1623, when parliament, stung by the abuse of the royal prerogative in the grant of exclusive personal privileges that served to crush the growth of inventions and not to multiply them, by its celebrated Statute of Monopolies, abolished all such privileges, but excepted from its provisions the grant of patents "for the sole working or making of any manner of new manufactures within this realm to the true and first inventor" thereof.

This statute had little force, however, in encouraging and protecting inventors until the next century, and until after the great inventions of Arkwright in spinning and James Watt in steam-engines had been invaded, and the attention of the courts called more seriously thereby to the property rights of inventors, and to the necessity of a liberal exposition of the law and its proper enforcement.

Then followed in 1789 the incorporation of that famous provision in the Constitution of the United States, declaring that Congress shall have the power "To promote the progress of science and useful arts by securing for limited times to authors and inventors the exclusive right to their respective writings and discoveries."

In 1791 followed the law of the National Assembly of France for the protection of new inventions, setting forth in the preamble, among other things, "that not to regard an industrial invention as the property of its author would be to attack the essential rights of man."

These fundamental principles have since been adopted and incorporated in their laws by all the nations of the earth.

Inventions in their nature being for the good of all men and for all time, it has been deemed wise by all nations in their legislation not to permit the inventor to lock up his property in secret, or confine it to his own use; and hence the universal practice is to enact laws giving him, his heirs, and assigns, exclusive ownership to this species of his property for a limited time only, adjudged sufficient to reward him for his efforts in its production, and to encourage others in like productions; while he, in consideration for this protection, is to fully make known his invention, so that the public may be enabled to freely make and use it after its exclusive ownership shall have expired.

In addition to the motives and incentives mentioned inducing this modern mighty outflow of inventions, regard must be had to the conditions of personal, political and intellectual freedom, and of education. There is no class of inventors where the mass of men are slaves; and when dense ignorance abounds, invention sleeps.

In the days of the greatest intellectual freedom of Greece, Archimedes, Euclid, and Hero, its great inventors, flourished; but when its political *status* had reduced the mass of citizens to slaves, when the work of the artisan and the inventor was not appreciated beyond the gift of an occasional crown of laurel, when manual labour and the labourer were scorned, inventions were not born, or, if born, found no nourishment to prolong their lives.

In Rome, the labourer found little respect beyond the beasts of burden whose burdens he shared, and the inventor found no provision of fostering care or protection in her mighty jurisprudence. The middle ages carefully repressed the minds of men, and hid away in dark recesses the instruments of learning. When men at length awoke to claim their birthright of freedom, they invented the printing-press and rediscovered gunpowder, with which to destroy the tyranny of both priests and kings. Then arose the modern inventor, and with him came the freedom and the arts of civilisation which we now enjoy.

What the exercise of free and protected invention has brought to this century is thus summarised by Macaulay:

"It has lengthened life; it has mitigated pain; has extinguished diseases; has increased the fertility of the soil; given new security to the mariner; furnished new arms to the warrior; spanned great rivers and estuaries with bridges of form unknown to our fathers; it has guided the thunderbolt innocuously from heaven to earth; it has lighted up the night with splendour of the day; it has extended the range of human vision; it has multiplied the power of the human muscles; it has accelerated motion; it has annihilated distance; it has facilitated intercourse, correspondence, all friendly offices, all despatch of business; it has enabled man to descend to the depths of the sea, to soar into the air, to penetrate securely into the noxious recesses of the earth; to traverse the land in carts which whirl along without horses; to cross the ocean in ships which run many knots an hour against the wind. Those are but a part of its fruits, and of its first fruits, for it is a philosophy which never rests, which is never perfect. Its law is progress. A point which yesterday was invisible is its goal to-day, and will be its starting point to-morrow."

The onward flow of inventions may be interrupted, if not materially stayed, by the cessation of some of the causes and incentives which now give them life. When comfort for all and rest for all, and a suitable division of labour, and an equal distribution of its fruits are reached, in that state of society which is pictured in the visions of the social philosopher, or as fast as such conditions are reached, so soon will cease the pricking of those spurs of invention, – individual rewards, the glorious strife of competition, the harrowing necessities, and the ambitions for place and power. If all are to co-operate and share alike, what need of exclusive protection and fierce and individual struggle? Why not sit down now and break the loaf and share it, and pour the wine, and enjoy things as they are, without a thought for the morrow?

The same results as to inventions may be reached in different but less pleasant ways: When all the industries are absorbed by huge combinations of capital the strife of competition among individuals, and the making of individual inventions to meet such competition, will greatly disappear. Or, the same results may be effected by stringent laws of labour organisations, in restricting or repressing all individual independent effort, prescribing what shall be done or what shall not be done along certain lines of manufacture or employment. So that the progress of future inventions depends on the outcome of the great economic, industrial, and social battles which are now looming on the pathway of the future.

But what the inventions of the nineteenth century were and what they have done for Humanity, is a chapter that must be read by all those now living or to come who wish to learn the history of their race. It is a story which gathers up all the threads of previous centuries and weaves them into a fabric which must be used in all the coming ages in the attainment of their comforts, their adornments, and their civilisations.

To enumerate all the inventions of the century would be like calling up a vast army of men and proclaiming the name of each. The best that can be done is to divide the wide field into chapters, and in these chapters give as best one may an idea of the leading inventions that have produced the greatest industries of the World.

CHAPTER II. AGRICULTURE AND ITS IMPLEMENTS

The Egyptians were the earliest and greatest agriculturists, and from them the art was learned by the Greeks. Greece in the days of her glory greatly improved the art, and some of her ablest men wrote valuable treatises on its different topics. Its farmers thoroughly ploughed and fertilised the soil, used various implements for its cultivation, paid great attention to the raising of fruits, – the apple, pear, cherry, plum, quince, peach, lemon, fig and many other varieties suitable to their climate, and improved the breeds of cattle, horse and sheep. When, however, social pride and luxurious city life became the dominant passions, agriculture was left to menials, and the art gradually faded with the State. Rome in her best days placed farming in high regard. Her best writers wrote voluminously on agricultural subjects, a tract of land was allotted to every citizen, which was carefully cultivated, and these citizen farmers were her worthiest and most honoured sons. The condition and needs of the soil were studied, its strength replenished by careful fertilisation, and it was worked with care. There were ploughs which were made heavy or light as the different soils required, and there were a variety of farm implements, such as spades, hoes, harrows and rakes. Grains, such as wheat, barley, rye and oats, were raised, a variety of fruits and vegetables, and great attention paid to the breeding of stock. Cato and Varro, Virgil and Columella, Pliny and Palladius delighted to instruct the farmer and praise his occupation.

But as the Roman Empire grew, its armies absorbed its intelligent farmers, the tilling of the soil was left to the menial and the slave, and the Empire and agriculture declined together.

Then came the hordes of northern barbarians pouring in waves over the southern countries and burying from sight their arts and civilisation. The gloom of the middle ages then closed down upon the European world. Whatever good may have been accomplished in other directions by the crusades, agriculture reached its lowest ebb, save in those instances where the culture of the soil received attention from monastic institutions.

The sixteenth century has been fixed upon as the time when Europe awoke from its long slumber. Then it was after the invention of the printing press had become well established that publications on agriculture began to appear. The *Boke of Husbandrie*, in 1523, by Sir Anthony Fitzherbert; Thomas Tusser's *Five Hundred Points of Good Husbandry*; Barnaby Googe's *The Whole Art of Husbandry*; *The Jewel House of Art and Nature*, by Sir Hugh Platt; the *English Improver* of Walter Blithe, and the writings of Sir Richard Weston on the husbandry of Brabant and Flanders, were the principal torches by which the light on this subject was handed down through the sixteenth and seventeenth centuries. Further awakening was had in the eighteenth century, the chief part of which was given by Jethro Tull, an English agriculturist, who lived, and wrote, and laboured in the cause between 1680 and 1740. Tull's leading idea was the thorough pulverisation of the soil, his doctrines being that plants derived their nourishment from minute particles of soil, hence the need of its pulverisation. He invented and introduced a horse hoe, a grain drill, and a threshing machine.

Next appeared Arthur Young, of England, born in 1741, whose life was extended into the 19th century, and to whom the world was greatly indebted for the spread of agricultural knowledge. He devoted frequent and long journeys to obtaining information on agricultural subjects, and his writings attracted the attention and assistance of the learned everywhere. His chief work was the making known widely of the beneficial effects of ammonia and ammoniacal compounds on vegetation. Many other useful branches of the subject, clearly treated by him, are found in his *Annals of Agriculture*. It was this same Arthur Young with whom Washington corresponded from his quiet retreat at Mount Vernon. After the close of the War of Independence in 1783 and before the adoption of the Constitution in 1789 and his elevation to the Presidency in that year, Washington devoted very much of his time to the cultivation of his large estate in Virginia. He took great interest in every improvement in agriculture and its implements. He invented a plough and a rotary seed drill, improved his harrows and mills, and made many inquiries relative to the efficacy of ploughs and threshing machines made in England and other parts of Europe. It was during this period that he opened an interesting correspondence with Young on improvements in agriculture, which was carried on even while he was President, and he availed himself of the proffer of Young's services to fill an order for seeds and two ploughs from a London merchant. He also wrote to Robert Cary & Co., merchants in London, concerning an engine he had heard of as being constructed in Switzerland, for pulling up trees and their stumps by the roots, and ordered one to be sent him if the machine were efficient.

Jefferson, Washington's great contemporaneous statesman and Virginia planter, and to whom has been ascribed the chief glory of the American patent system, himself also an inventor, enriched his country by the full scientific knowledge he had gained from all Europe of agricultural pursuits and improvements.

The progress of the art, in a fundamental sense, that is in a knowledge of the constituents, properties, and needs of the soil, commenced with the investigations of Sir Humphry Davy at the close of the 18th century, resulting in his celebrated lectures before the Board of Agriculture from 1802 to 1812, and his practical experiments in the growth of plants and the nature of fertilisers. Agricultural societies and boards were a characteristic product of the eighteenth century in Europe and America. But this birth, or revival of agricultural studies, the enthusiastic interest taken therein by its great and learned men, and all its valuable publications and discoveries, bore comparatively little fruit in that century. The ignorance and prejudice of the great mass of farmers led to a determined, and in many instances violent resistance to the introduction of labour-saving machinery and the practical application of what they called "book-farming." A fear of driving people out of employment led them to make war upon new agricultural machines and their inventors, as they had upon weaving and spinning inventions. This war was more marked in England than elsewhere, because there more of the new machines were first introduced, and the number of labourers in those fields was the greatest. In America the ignorance took the milder shape of contempt and prejudice. Farmers refused, for instance, to use cast-iron ploughs as it was feared they would poison the soil.

So slow was the invention and introduction of new devices, that if Ruth had revisited the earth at the beginning of the nineteenth century, she might have seen again in the fields of the husbandmen everywhere the sickle of the reapers behind whom she gleaned in the fields of Boaz, heard again the beating on the threshing floor, and felt the old familiar rush of the winnowing wind. Cincinnatus returning then would have recognised the plough in common use as about the same in form as that which he once abandoned on his farm beyond the Tiber.

But with the spread of publications, the extension of learning, the protection now at last obtained and enforced for inventions, and with the foundations laid and the guide-posts erected in nearly every art and science by previous discoverers, inventors and writers, the century was now ready to start on that career of inventions which has rendered it so glorious.

As the turning over and loosening of the sod and the soil for the reception of seed was, and still is the first step in the art of agriculture, the plough is the first implement to be considered in this review.

A plough possesses five essential features, – a frame or beam to which the horses are attached and which is provided with handles by which the operator guides the plough, a share to sever the bottom of a slice of land – the furrow – from the land beneath, a mould board following the share to turn the furrow over to one side, and a landside, the side opposite the mould board and which presses against the unploughed ground and steadies the plough. To these have been commonly added a device called the coulter, which is a knife or sharp disk fastened to the frame in advance of the share and adapted to cut the sod or soil so that the furrow may be more easily turned, an adjustable gauge wheel secured to the beam in advance of the coulter, and which runs upon the surface of the soil to determine by the distance between the perimeter of the wheel at the bottom and the bottom of the plough share the depth of the furrow, and a clevis, which is an adjustable metal strap attached to the end of the beam to which the draught is secured, and by which the pitch of the beam and the depth and width of the furrow are regulated. The general features, the beam, handles, and share, have existed in ploughs from the earliest ages in history. A plough with a metal share was referred to by the prophecy of Isaiah seven centuries before Christ, "They shall beat their swords into plough-shares;" and such a plough with the coulter and gauge wheel added is found in the Caylus collection of Greek antiquities. The inventions of centuries in ploughs have proceeded along the lines of the elements above enumerated.

The leading features of the modern plough with a share and mould board constructed to run in a certain track and turn its furrows one over against the other, appear to have originated in Holland in the 18th century, and from there were made known to England. James Small of Scotland wrote of and made ploughs having a cast-iron mould board and cast and wrought iron shares in 1784-85.

In America, about the same time, Thos. Jefferson studied and wrote upon the proper shape to be given to the mould board.

Charles Newbold in 1797 took out the first patent in the United States for a plough – all parts cast in one piece of solid iron except the beam and handles.

It is a favourite idea with some writers and with more talkers, that when the necessity really arises for an invention the natural inventive genius of man will at once supply it. Nothing was more needed and sought after for thirty centuries among tillers of the soil than a good plough, and what finally supplied it was not necessity alone, but improved brains. Long were the continued efforts, stimulated no doubt in part by necessity, but stimulated also by other motives, to which allusion has already been made, and among which are the love of progress, the hope of gain, and legislative protection in the possession of inventive property.

The best plans of writers and inventors of the eighteenth century were not fully developed until the nineteenth, and it can be safely said that within the last one hundred years a better plough has been produced than in all of the thousands of years before. The defects which the nineteenth century's improvements in ploughs were designed to remedy can best be understood by first realising what was the condition of ploughs in common use when the century opened.

Different parts of the plough, such as the share and coulter, were constructed of iron, but the general practice among farmers was to make the beam and frame, handles and mould board of strong and heavy timber. The beam was straight, long, and heavy, and that and the mould generally hewed from a tree. The mould board on both sides to prevent its wearing out too rapidly was covered with more or less thick plates of iron. The handles were made from crooked branches of trees. "The beam," it is said, "was set at any pitch that fancy might dictate, with the handles fastened on almost at right angles with it, thus leaving the ploughman little control over his implement which did its work in a very slow and imperfect manner." It was some such plough that Lord Kames complained about in the *Gentleman Farmer* in 1768, as being used in Scotland – two horses and two oxen were necessary to pull it, "the ridges in the fields were high and broad, in fact enormous masses of accumulated earth, that could not admit of cross ploughing or cultivation; shallow ploughing universal; ribbing, by which half the land was left untilled, a general practice over the greater part of Scotland; a continual struggle between the corn and weeds for superiority." As late as 1820 an American writer was making the same complaint. "Your furrows," he said, "stand up like the ribs of a lean horse in the month of March. A lazy ploughman may sit on the beam and count every bout of his day's work; besides the greatest objection to all these ploughs is that they do not perform the work well and the expense is enormous for blacksmith work." It was complained by another that it took eight or ten oxen to draw it, a man to ride upon the beam to keep it on the ground, and a man followed the plough with a heavy iron hoe to dig up the "baulks."

The improvements made in the plough during the century have had for their object to lessen the great friction between the wide, heavy, ill-formed share and mould board, and the ground, which has been accomplished by giving to the share a sharp clean tapering form, and to the mould board a shape best calculated to turn the furrow slice; to improve the line of draught so that the pull of the team may be most advantageously employed, which has been effected after long trials, study and experiment in the arrangement of beam, clevis and draft rod, setting the coulter at a proper angle and giving the landside a plane and parallel surface; to increase the wear and lessen the weight of the parts, which has been accomplished by ingenious processes in treating the metal of which the parts are composed, and lessening the number of parts; to render the plough easily repairable by casting the parts in sets and numbering them, by which any part may be replaced by the manufacturer without resort to the blacksmith. In short there is no part of the plough but what has received the most careful attention of the inventor. This has been evidenced by the fact that in the United States alone nearly eleven thousand patents on ploughs were issued during the nineteenth century. When it is considered that all the applications for these patents were examined as to their novelty, before the grant of the patent, the enormous amount of study and invention expended on this article can be appreciated. Among the century's improvements in this line is the use of disks in place of the old shovel blades to penetrate the earth and revolve in contact therewith. Cutting disks are harnessed to steam motors and are adapted to break up at one operation a wide strip of ground. The long-studied problem of employing a gang of ploughs to plough back and forth and successfully operated by steam has been solved, and electricity is now being introduced as a motor in place of steam. Thus millions of broad acres which never would have been otherwise turned are now cultivated. The tired muscle-strained ploughman who homeward plodded his weary way at night may now comfortably ride at his ease upon the plough, while at the same time the beasts that pull it have a lighter load than ever before.

Next to the plough among the implements for breaking, clearing and otherwise preparing the soil for the reception of seed, comes the *harrow*. From time immemorial it has been customary to arm some sort of a frame with wooden or iron spikes to scratch the earth after the ploughing. But this century has greatly improved the old constructions. Harrows are now found everywhere made in sections to give flexibility to the frame; collected in gangs to increase the extent of operation; made with disks instead of spikes, with which to cut the roots of weeds and separate the soil, instead of merely scratching them. A still later invention, curved spring teeth, has been found far superior to spikes or disks in throwing up, separating and pulverising the soil. A harrow comprising two ranks of oppositely curved trailing teeth is especially popular in some countries. These three distinct classes of harrows, the disk type, the curved spring tooth type, and gangs of sections of concavo-convex disks, particularly distinguish this class of implements from the old forms of previous ages.

CHAPTER III.
AGRICULTURAL IMPLEMENTS

It is wonderful for how many generations men were contented to throw grain into the air as the Parable relates:

"Behold, a sower went forth to sow, and when he sowed some seeds fell by the way side, and the fowls came and devoured them up: some fell on stony places where they had not much earth, and forthwith they sprung up, because they had no deepness of earth; and when the sun was up they were scorched; and because they had no root they withered away. And some fell among thorns and the thorns sprung up and choked them. But others fell into good ground and brought forth fruit, some a hundredfold, some sixtyfold, and some thirtyfold."

Here are indicated the defects in depositing the seed that only the inventions of the century have fully corrected. The equal distribution of the seed and not its wide scattering, its sowing in regular drills or planting at intervals, at certain and uniform depths, the adaptation of devices to meet the variations in the land to be planted, and in short the substitution of quick, certain, positive mechanisms for the slow, uncertain, variable hand of man. Not only has the increase an hundredfold been obtained, but with the machines of to-day the sowing and planting of a hundredfold more land has been made possible, the employment of armies of men where idleness would have reigned, and the feeding of millions of people among whom hunger would otherwise have prevailed. Not only did this machinery not exist at the beginning of the century, but the agricultural machines and devices in this line of the character existing fifty years ago are now discarded as useless and worthless.

It is true that, as in the case of the ploughs, attempts had been made through the centuries to invent and improve seeding implements. The Assyrians 500 years B. C. had in use a rude plough in which behind the sharp wooden plough point was fixed a bowl-shaped hopper through which seed was dropped into the furrow, and was covered by the falling back of the furrow upon it. The Chinese, probably before that time, had a wheelbarrow arrangement with a seed hopper and separate seed spouts. In India a drilling hopper had been attached to a plough. Italy claims the honour among European nations of first introducing a machine for sowing grain. It was invented about the beginning of the seventeenth century and is described by Zanon in his *Work on Agriculture* printed at Venice in 1764. It was a machine mounted on two wheels, that had a seed box in the bottom of which was a series of holes opening into a corresponding number of metal tubes or funnels. At their front these tubes at their lower ends were sharpened to make small furrows into which the seed dropped.

Similar single machines were in the course of the seventeenth and eighteenth centuries devised in Austria and England. The one in Austria was invented by a Spaniard, one Don Joseph de Lescatello, tested in Luxembourg in 1662. The inventor was rewarded by the Emperor, recommended to the King of Spain, and in 1663 and 1664 his machines were made and sold at Madrid. The knowledge of this Spaniard's invention was made known in England in 1699 by the Earl of Sandwich and John Evelyn. Jethro Tull in England shortly after invented and introduced a combined system of drilling, ploughing and cultivating. He sowed different seeds from the same machine, and arranged that they might be covered at different depths. Tull's machines were much improved by James Cooke, a clergyman of Lancashire, England; and also in the last decade of the eighteenth century by Baldwin and Wells of Norfolk, England.

Washington and others in America had also commenced to invent and experiment with seeding machines. But as before intimated, the nineteenth century found the great mass of farmers everywhere sowing their wheat and other grains by throwing them into the air by hand, to be met by the gusts of wind and blown into hollows and on ridges, on stones and thorny places,—requiring often a second and third repetition of the same tedious process.

In 1878 Mr. Coffin, a distinguished journalist of Boston, in an address before the Patent Committee of the U. S. Senate, set forth the advantages obtained by the modern improvements in seeders as follows:

"The seeder covers the soil to a uniform depth. It sows evenly, and sows a specific quantity. You may graduate it so that, after a little experience, you can determine the amount per acre even to a quart of wheat. They sow all kinds of grain, – wheat, clover, and superphosphate, if need be, at once. They harrow at the same time. They make the crop more certain. It is the united testimony of manufacturers and farmers alike that the crop is increased from one-eighth to one-fourth, especially in the winter wheat. Winter wheat, you are aware, in the freezing and thawing season, is apt to heave out. It is desirable to bury the seed a uniform and proper depth and to throw over the young plant such an amount of soil that it shall not heave with the freezing and thawing. Of the 360,000,000 bushels of wheat raised last year I suppose more than 300,000,000 was winter wheat. One-eighth of this is 37,700,000 bushels."

It would seem to many that after the adoption of a seed hopper, and spouts with sharpened ends that cut the drill rows in the furrows and deposited the seed therein, that little was left to be done in this class of inventions; but a great many improvements were necessary. Gravity alone could not be depended upon for feeding the seed. Means had to be devised for a continuous and regular discharge from each grain tube; for varying the quantity of the seed fed by varying the escape openings, or by positive mechanical movements variable in speed; for fixing accurately the quantity of seed discharged; for changing the apparatus to feed coarse or fine seed; and for rendering the apparatus efficient on different surfaces – steep hillsides, level plains, irregular lands.

An important step was the substitution of what is called the "force feed" for the gravity feed. There is a variety of devices for this purpose, the principle of one of them being a revolving feed wheel located beneath the hopper, and above each spout, the two casings between which the feed wheel revolves forming the outer walls of a complete measuring channel, or throat, through which the grain is carried by the rotary motion of the wheel, thus providing the means of measuring the seed with as much accuracy as could be done by a small measure. The quantity sown per acre is governed by simply increasing or diminishing the speed of the feed wheel. In one form of device this change of speed is altered by a system of cone gearing. A graduated flow of the seed has also been effected by the employment of a cylinder having a smooth and fluted part working in a cup beneath the hopper with provision for adjustment of the smooth part towards and from the fluted part to cut off or increase the flow.

To avoid the use of a separate apparatus for separate sizes of grain and other seed, the seed holder has been divided into parts – one part for containing wheat, barley and other medium-sized grains, and another for corn, peas and the larger seeds. And as these parts are used on separate occasions, the respective apertures are opened or closed by a sliding bottom and by a single movement of the hand.

Rubber tubes for conducting the seed through the hollow holes were introduced in place of the metal spouts that answered both as a spout and a hoe.

In place of the common hoe drill of a form used in the early part of the century, the hoes being forced into the soil by the use of levers and weights, what are known as "shoe drills" have largely succeeded. A series of shoes are pivoted to the frame, extend beneath the seed box, and are provided with springs for depressing or raising them.

All kinds of seeds and fertilisers, separately or together, may be now sown, and the broadcast sowing of a larger area than that covered by the throw of the hand can now be given by machinery.

Corn and cotton seed are thus also planted, mixed or unmixed with the fertilising material.

Not only have light ploughs been combined with small seed boxes and one or more seed tubes, for easy work in gardens, but the arrangements varied and graded for different uses until is reached that great machine run by steam power, in which is assembled a gang of heavy harrows in front to loosen and pulverise the soil, then the seed and fertilising drill of capacious width for sowing the grain in rows, followed by a lighter broad harrow to cover the seed, and all so arranged that the steam lifts the heavy frames on turning, and all controlled easily by the man who rides upon the machine.

In planting at intervals or in hills, as corn and potatoes, and other like larger seeds, no longer is the farmer required to trudge across the wide field carrying a heavy load in bag or box, or compel his boys or women folk to drop the seed while he follows on laboriously with the hoe. He may now ride, if he so choose, and the machine which carries him furnishes the motive power for operating the supply and cut-off of the grain at intervals.

The object of the farmer in planting corn is to plant it in straight lines about four feet apart each way, putting from three to five grains into each spot in a scattered and not huddled condition. These objects are together nicely accomplished by a variety of modern machines.

The planting of great fields of potatoes has been greatly facilitated by machinery that first slices them and then sows the slices continuously in a row, or drops them in separate spots or hills, as may be desired. The finest seeds, such as grass and clover, onion and turnip seed, and delicate seed like rice, are handled and sown by machines without crushing or bruising, and with the utmost exactness. Just what seed is necessary to be supplied to the machine for a given area is decided upon, and the machine distributes the same with the same nicety that a doctor distributes the proper dose of pellets upon the palm of his patient.

Transplanters as well as planters have been devised. These transplanters will dig the plant trench, distribute the fertiliser, set the plant, pack the earth and water the plant, automatically.

The class of machines known as cultivators are those only, properly speaking, which are employed to cultivate the plant after the crop is above the ground. The duties which they perform are to loosen the earth, destroy the weeds, and throw the loosened earth around the growing plant.

Here again the laborious hoe has been succeeded by the labour-saving machine.

Cultivators have names which indicate their construction and the crop with which they are adapted to be used. Thus there are "corn cultivators," "cotton cultivators," "sugar-cane cultivators," etc. Riding cultivators are known as "sulky cultivators" where they are provided with two wheels and a seat for the driver.

If worked between two rows they are termed single, and when between three rows, double cultivators. A riding cultivator adapted to work three rows has an arched axle to pass over the rows of the growing plants and cultivate both sides of the plants in each row. Double cultivators are constructed so that their outside teeth may be adjusted in and out from the centre of the machine to meet the width of the rows between which they operate. A "walking cultivator" is when the operator walks and guides the machine with the hands as with ploughs. Ordinary ploughs are converted into cultivators by supplying them with double adjustable mould boards. Ingenious arrangements generally exist for widening or narrowing the cultivator and for throwing the soil from the centre of the furrow to opposite sides and against the plant. The depth to which the shares or cultivator blades work in the ground may be adjusted by a gauge wheel upon the draught beam, or a roller on the back of the frame.

Disk cultivators are those in which disk blades instead of ploughs are used with which to disturb the soil already broken. As with ploughs, so with cultivators, steam-engines are employed to draw a gang of cultivating teeth or blades, their framework, and the operator seated thereon, to and fro across the field between two or more rows, turning and running the machine at the end of the rows.

Millet's recent celebrated painting represents a brutal, primitive type of a man leaning heavily on a hoe as ancient and woful in character as the man himself. It is a picture of hopeless drudgery and blank ignorance. Markham, the poet, has seized upon this picture, dwelt eloquently on its horrors, and apostrophised it as if it were a condition now existing. He exclaims,

> "O masters, lords and rulers in all lands
> How will the future reckon with this man?"

The present has already reckoned with him, and he and his awkward implement of drudgery nowhere exist, except as left-over specimens of ancient and pre-historic misery occasionally found in some benighted region of the world.

The plough and the hoe are the chief implements with which man has subdued the earth. Their use has not been confined to the drudge and the slave, but men, the leaders and ornaments of their race, have stood behind them adding to themselves graces, and crowning labor with dignity. Cincinnatus is only one of a long line of public men in ancient and modern times who have served their country in the ploughfield as well as on the field of battle and in the halls of Legislation. We hear the song of the poet rising with that of the lark as he turns the sod. Burns, lamenting that his share uptears the bed of the "wee modest crimson-tipped flower" and sorrowing that he has turned the "Mousie" from its "bit o' leaves and stibble" by the cruel coulter. The finest natures, tuned too fine to meet the rude blasts of the world, have shrunk like Cowper to rural scenes, and sought with the hoe among flowers and plants for that balm and strength unfound in crowded marts.

But the dignity imparted to the profession of Agriculture by a few has now by the genius of invention become the heritage of all.

While prophets have lamented, and artists have painted, and poets sorrowed over the drudgeries of the tillers of the soil, the tillers have steadily and quietly and with infinite patience and toil worked out their own salvation. They no longer find themselves "plundered and profaned and disinherited," but they have yoked the forces of nature to their service, and the cultivation of the earth, the sowing of the seed, the nourishment of the plant, have become to them things of pleasurable labour.

With the aid of these inventions which have been turned into their hands by the prolific developments of the century they are, so far as the soil is concerned, no longer "brothers of the ox," but king of kings and lord of lords.

CHAPTER IV.
AGRICULTURAL INVENTIONS

If the farmer, toward the close of the 18th century, tired with the sickle and the scythe for cutting his grass and grain, had looked about for more expeditious means, he would have found nothing better for cutting his grass; and for harvesting his grain he would have been referred to a machine that had existed since the beginning of the Christian era. This machine was described by Pliny, writing about A. D. 60, who says that it was used on the plains of Rhætia. The same machine was described by Palladius in the fourth century. That machine is substantially the machine that is used to-day for cutting and gathering clover heads to obtain the seed. It is now called a header.

A machine that has been in use for eighteen centuries deserves to be described, and its inventor remembered; but the name of the inventor has been lost in oblivion. The description of Palladius is as follows:

"In the plains of Gaul, they use this quick way of reaping, and without reapers cut large fields with an ox in one day. For this purpose a machine is made carried upon two wheels; the square surface has boards erected at the side, which, sloping outward, make a wider space above. The board on the fore part is lower than the others. Upon it there are a great many small teeth, wide set in a row, answering to the height of the ears of corn (wheat), and turned upward at the ends. On the back part of the machine two short shafts are fixed like the poles of a litter; to these an ox is yoked, with his head to the machine, and the yoke and traces likewise turned the contrary way. When the machine is pushed through the standing corn all the ears are comprehended by the teeth and cut off by them from the straw and drop into the machine. The driver sets it higher or lower as he finds it necessary. By a few goings and returnings the whole field is reaped. This machine does very well in plain and smooth fields."

As late as 1786 improvements were being attempted in England on this old Gallic machine. At that time Pitt, in that country, arranged a cylinder with combs or ripples which tore off the heads of the grain-stalks and discharged them into a box on the machine. From that date until 1800 followed attempts to make a cutting apparatus consisting of blades on a revolving cylinder rotated by the rotary motion of the wheels on which the machine was carried.

In 1794, a Scotchman invented the grain cradle. Above the blade of a scythe were arranged a set of fingers projecting from a post in the scythe snath. This was considered a wonderful implement. A report of a Scottish Highland Agricultural Society about that time said of this new machine:

"With a common sickle, seven men in ten hours reaped one and one-half acres of wheat, – about one-quarter of an acre each. With the new machine a man can cut one and one-half acres in ten hours, to be raked, bound, and stacked by two others."

It was with such crude and imperfect inventions that the farmers faced the grain and grass fields of the nineteenth century.

The Seven Wonders of the ancient world have often been compared with the wonders of invention of this present day.

Senator Platt in an address at the Patent Centennial Celebration in Washington, in 1891, made such a contrast:

"The old wonders of the world were the Pyramids, the Hanging Gardens of Babylon, the Phidian statue of Jupiter, the Mausoleum, the Temple of Diana at Ephesus, the Colossus of Rhodes, and the Pharos of Alexandria. Two were tombs of kings, one was the playground of a petted queen, one was the habitat of the world's darkest superstition, one the shrine of a heathen god, another was a crude attempt to produce a work of art solely to excite wonder, and one only, the lighthouse at Alexandria, was of the slightest benefit to mankind. They were created mainly by tyrants; most of them by the unrequited toil of degraded and enslaved labourers. In them was neither improvement nor advancement for the people." With some excess of patriotic pride, he contrasts these with what he calls "the seven wonders of American invention." They were the cotton-gin; the adaptation of steam to methods of transportation; the application of electricity to business pursuits; the harvester; the modern printing-press; the ocean cable; and the sewing machine. "How wonderful," he adds, "in conception, in construction, in purpose, these great inventions are; how they dwarf the Pyramids and all the wonders of antiquity; what a train of blessings each brought with its entrance into social life; how wide, direct and far-reaching their benefits. Each was the herald of a social revolution; each was a human benefactor; each was a new Goddess of Liberty; each was a great Emancipator of man from the bondage of labour; each was a new teacher come upon earth; each was a moral force."

Of these seven wonders, the harvester and the cotton-gin will only be described in this chapter. "Harvester" has sometimes been used as a broad term to cover both mowers and reapers. In a recent and more restricted sense, it is applied to a machine that cuts grain, separates it into gavels, and binds it.

The difficulty that confronted the invention of mowers was the construction, location and operation of the cutting part. To convert the scythe or the sickle, or some other sharp blade into a fast reciprocating cutter, to hang such cutter low so that it would cut near the ground, to protect it from contact with stones by a proper guard, to actuate it by the wheels of the vehicle, to hinge the cutter-bar to the frame so that its outer end might be raised, and to arrange a seat on the machine so that the driver could control the operating parts by means of a lever, or handles, were the main problems to be solved.

In 1799, Boyce, of England, had a vertical shaft with six rotating scythes beneath the frame of the implement. This died with the century.

In 1800, Meares, his countryman, tried to adapt shears. He was followed there, in 1805, by Plucknett, who introduced a horizontal, rotating, circular blade. Others, subsequently, adopted this idea, both in England and America. It had been customary, as in olden times, to push the apparatus forward by a horse or horses hitched behind. But, in 1806, Gladstone had patented a front draft machine, with a revolving wheel armed with knife-blades cutting at one side of the machine and a segment-bar with fingers which gathered the grain and held the straw while the knife cut it.

Then, in 1807, Salonen introduced vibrating knifes over stationary blades, fingers to gather grain to the cutters, and a rake to carry the grain off to one side.

In 1822, Ogle, also of England, was the first to invent the *reciprocating* knife-bar. This is the movement that has been given in all the successful machines since. Ogle's was a crude machine, but it furnished the ideas of projecting the cutter-bar at the side of a reel to gather the grain to the cutter and of a grain platform which was tilted to drop the sheaf.

The world is indebted also to the Rev. Patrick Bell, of Scotland, who had invented and built as early as 1823-26, a machine which would cut an acre of grain in an hour, and is thus described by Knight:

"The machine had a square frame on two wheels which ran loose on the axle, except when clutched thereto to give motion to the cutters. The cutter-bar had fixed triangular cutters between each of which was a movable vibrating cutter, which made a shear cut against the edge of the stationary cutter, on each side. It had a reel with twelve vanes to press the grain toward the cutters, and cause it to fall upon a travelling apron which carried away cut grain and deposited it at the side of the machine. The reel was driven by bevel-gearing."

It was used but a few years and then revived again at the World's Fair in London, in 1851.

In the United States, inventions in mowers and reapers began to make their appearance about 1820. In 1822, Bailey was the first to patent a mowing machine. It was a circular revolving scythe on a vertical axis, rotated by gearing from the main axle, and so that the scythe was self-sharpened by passing under a whet-stone fixed on an axis and revolving with the scythe and was pulled by a horse in front. In 1828, Lane, of Maine, combined the reaper and thresher. In 1831, Manning had a row of fingers and a reciprocating knife, and in 1833, Schnebly introduced the idea of a horizontal endless apron on which the grain fell, constructed to travel intermittently so as to divide the grain into separate parts or gavels, and deliver the gavels at one side. Hussey, of Maryland, in 1833, produced the most useful harvester up to that time. It had open guard fingers, a knife made of triangular sections, reciprocating in the guard, and a cutter-bar on a hinged frame.

Then came the celebrated reaper of McCormick, of Virginia, in 1834, and his improvements of 1845-1847, and by 1850 he had built hundreds of his machines. Other inventors, too numerous to mention, from that time pushed forward with their improvements. Then came many public trials and contests between rival manufacturers and inventors.

One of the earliest and most notable was the contest at the World's Fair, in London, in 1851. This exhibition, the first of the kind the world had seen, giving to the nations taking part such an astonishing revelation of each other's productions, and stimulating in each such a surprising growth in all the industrial and fine arts, revealed nothing more gratifying to the lover of his kind than those inventions of the preceding half-century that had so greatly lifted the farm labourer from his furrow of drudgery.

Among the most conspicuous of such inventions were the harvesters. Bell's machine, previously described, and Hussey's and McCormick's were the principal contesting machines. They were set to work in fields of grain, and to McCormick was finally awarded the medal of honour.

This contest also opened the eyes of the world to the fact that vast tracts of idle land, exceeding in extent the areas of many states and countries, could now be sown and reaped – a fact impossible with the scythe and the sickle. It was the herald of the admission into the family of nations of new territories and states, which, without these machines, would unto this day be still wild wildernesses and trackless deserts.

This great trial also was followed by many others, State and International. In 1852, there was in the United States a general trial of reapers and mowers at Geneva, New York; in 1855, at the French Exposition, at Paris, where again McCormick met with a triumph; in 1857, at Syracuse, New York, and subsequently at all the great State and International Expositions. These contests served to bring out the failures, and the still-existing wants in this line of machinery. The earlier machines were clumsy. They were generally one-wheeled machines, lacked flexibility of parts and were costly. They cut, indeed, vast tracts of grain and grass, but the machines had to be followed by an army of men to bind and gather the fallen grain. This army demanded high wages and materially increased the cost of reaping the crop, and sadly diminished the profits.

When the Vienna Exposition, in 1873, was held, a great advance was shown in this and all other classes of agricultural machinery. Reapers and mowers were lighter in construction, and far less in cost, and stronger and more effective in every way. The old original machines of McCormick on which he had worked for twenty years prior to the 1851 triumph, had been succeeded by another of his machines, on which an additional twenty years of study, experiment and improvement had been expended. An endless number of inventors had in the meantime entered the lists. The frame, the motive gearing, the hinged cutter-bar and knives, the driver's seat, the reel, the divider, for separating the swath of grain to be cut from the uncut, the raising and depressing lever, the self-raker, and the material of which all the parts were composed had all received the greatest attention, and now was awaiting the coming of a perfect mechanical binder that would roll the grain on the machine into a bundle, automatically bind it, and drop the bound bundles on the ground. The latter addition came in an incomplete shape to Vienna. The best form was a crude wire binder. In 1876 at the Centennial Exhibition at Philadelphia, the mowers and reapers blossomed still more fully, but not into full fruition; for it was not until two or three years thereafter that the celebrated *twine* binders, which superseded the wire, were fully developed.

Think of the almost miraculous exercise of invention in making a machine to automatically cut the grain, elevate it to a platform, separate and roll it into sheaves, seize a stout cord from a reel, wrap it about the sheaf, tie a knot that no sailor could untie, cut the cord, and throw the bound sheaf to one side upon the ground!

So great became the demand for this binders' twine that great corporations engaged in its manufacture, and they in turn formed a great trust to control the world's supply. This one item of twine, alone, amounted to millions of dollars every year, and from its manufacture arose economic questions considered by legislators, and serious litigation requiring the attention of the courts.

At this Centennial Exhibition, besides twenty or more great manufacturing firms of the United States who exhibited reapers and mowers, Canada, far-away Australia, and Russia brought each a fine machine of this wonderful class. And not only these countries, but nearly all of Europe sent agricultural machines and implements in such numbers and superior construction that they surpassed the wildest dreams of the farmer of a quarter of a century before.

Up to this time, about eleven thousand patents have been granted in the United States, all presumably on separate improvements in mowers and reapers alone. This number includes, of course, many patents issued to inventors of other countries.

Before leaving this branch of the subject the lawn-mower should not be overlooked, with its spiral blades on a revolving cylinder, a hand lever by which it can be pushed over a lawn and the grass cut as smooth as the green rug upon a lady's chamber.

It is the law of inventions that one invention necessitates and generates another. Thus the vastly increased facilities for cutting grass necessitated new means for taking care of it when cut. And these new means were the hay tedder to stir it, the horse hay-rake, the great hay-forks to load, and the hay-stackers. Harvesters for grass and grain have been supplemented by Corn, Cotton, Potato and Flax Harvesters.

The threshing-floor still resounds to the flail as the grain is beaten from the heads of the stalks. Men and horses still tread it out, the wooden drag and the heavy wain with its gang of wheels, and all the old methods of threshing familiar to the Egyptians and later among the Romans may still be found in use in different portions of the world.

Menzies of Scotland, about the middle of the eighteenth century, was the first to invent a threshing machine. It was unsuccessful. Then came Leckie, of Stirlingshire, who improved it. But the type of the modern threshing machine was the invention of a Scotchman, one Meikle, of Tyningham, East Lothian, in 1786. Meikle threw the grain on to an inclined board, from whence it was fed between two fluted rollers to a cylinder armed with blades which beat it, thence to a second beating cylinder operating over a concave grating through which the loosened grain fell to a receptacle beneath; thence the straw was carried over a third beating cylinder which loosened the straw and shook out the remaining grain to the same receptacle, and the beaten straw was then carried out of the machine. Meikle added many improvements, among which was a fan-mill by which the grain was separated and cleaned from both straw and chaff. This machine, completed and perfected about the year 1800, has seen no departure in principle in England, and in the United States the principal change has been the substitution of a spiked drum running at a higher speed for Meikle's beater drum armed with blades.

In countries like California, says the U.S. Commissioner of Patents in his report for 1895, "Where the climate is dry and the grain is ready for threshing as soon as it is cut, there is in general use a type of machine known as a combined harvester and thresher in which a thresher and a harvester machine of the header type are mounted on a single platform, and the heads of grain are carried directly from the harvester by elevators into the threshing machine, from which the threshed grain is delivered into bags and is then ready for shipment. Some of these machines are drawn by horses and some have a portable engine mounted on the same truck with the harvester propelling the machine, while furnishing power to drive the mechanism at the same time. Combined harvesters and threshers have been known since 1836, but they have been much improved and are now built on a much larger scale."

Flax-threshers for beating the grain from the bolls of the cured flax plant, removing the bolls, releasing and cleaning the seed, are also a modern invention.

Flax and Hemp Brakes, machines by which the woody and cellular portion of the flax is separated from the fibrous portion, produced in practical shape in the century, and flanked by the improved pullers, cutters, threshers, scutchers, hackles, carders, and rovers, have supplanted Egyptian methods of 3,000 years' standing, for preparing the flax for spinning, as well as the crude improvements of the 18th century.

After the foundation of cotton manufacture had been laid "as one of the greatest of the world's industries," in the 18th century by those five great English inventors, Kay, who invented the fly-shuttle, Hargreaves, the "Spinning Jenny," Arkwright, the water-frame, Crompton, the spinning-mule, and Cartwright, the power-loom, came Eli Whitney in 1793, a young school teacher from Massachusetts located in Georgia, who invented the *cotton-gin*. His crude machine, worked by a single person, could clean more cotton in a single day than could be done by a man in several months, by hand.

The enormous importance of such a machine began to be appreciated at the beginning of the century, and it set cotton up as a King whose dominion has extended across the seas.

Prior to 1871, inventions in this art were mainly directed to perfecting the structure of this primary gin. By that machine only the long staple fibre was secured, leaving the cotton seed covered with a short fibre, which with the seed was regarded as a waste product. To reclaim this short fibre and secure the seed in condition for use, have been the endeavours of many inventors during the last twenty years. These objects have been attained by a machine known as the *delinter*, one of the first practical forms of which appeared about 1883.

In a bulletin published by the U.S. Department of Agriculture in 1895, entitled, "Production and Price of Cotton for One Hundred Years," the period commences with the introduction of Whitney's saw gin, and ends with the year mentioned and with the production in that year of the largest crop the world had ever seen. No other agricultural crop commands such universal attention. Millions of people are employed in its production and manufacture. How insignificant compared with the wonder wrought by this one machine seems indeed any of the old seven wonders of the world! Although the displacement of labour occasioned by the introduction of the cotton-gin was not severely felt, as it was slave labour, yet that invention affords a good illustration of the fact that labour-saving machines increase the supply of the article, the increased supply lowers its price, the lower price increases the demand, the increased demand gives rise to more machines and develops other inventions and arts, all of which results in the employment of ten thousand people to every one thousand at work on the product originally.

CHAPTER V. AGRICULTURAL INVENTIONS (*continued*)

When the harvest is ended and the golden stores of grains and fruits are gathered, then the question arises what shall be next done to prepare them for food and for shipment to the distant consumer.

If the cleaning of the grain and separating it from the chaff and dirt are not had in the threshing process, separate machines are employed for fanning and screening.

It was only during the 18th century that fanning mills were introduced; and it is related by Sir Walter Scott in one of his novels that some of his countrymen considered it their religious duty to wait for a natural wind to separate the chaff from the wheat; that they were greatly shocked by an invention which would raise a whirlwind in calm weather, and that they looked upon the use of such a machine as rebellion against God.

As to the grinding of the grain, the rudimentary means still exist, and are still used by rudimentary peoples, and to meet exceptional necessities; these are the primeval hollowed stone and mortar and pestle, and they too were "the mills of the Gods" in Egyptian, Hebrew and Early Greek days: the *quern*– that is, the upper running stone and the lower stationary grooved one –

was a later Roman invention and can be found described only a century or two before the Christian era.

Crude as these means were they were the chief ones used in milling until within a century and a quarter ago.

In a very recent bright work published in London, by Richard Bennett and John Elton, on Corn Mills, etc., they say on this point: "The mill of the last century, that, by which, despite its imperfections, the production of flour rose from one of the smallest to one of the greatest and most valuable industries of the world, was essentially a structure of few parts, whether driven by water or wind, and its processes were exceedingly simple. The wheat was cleaned by a rude machine consisting of a couple of cylinders and screens, and an air blast passed through a pair of mill-stones, running very close together, in order that the greatest amount of flour might be produced at one grinding. The meal was then bolted, and the tailings, consisting of bran, middlings and adherent flour, again sifted and re-ground. It seems probable that the miller of the time had a fair notion of the high grade of flour ground from middlings, but no systematic method of procedure for its production was adopted."

The upper and the nether mill-stone is still a most useful device. The "dress," which consists of the grooves which are formed in the meeting faces of the stones, has been changed in many ways to meet the requirements in producing flour in varying degrees of fineness. Machines have been invented to make such grooves. A Swiss machine for this purpose consists of two disks carrying diamonds in their peripheries, which, being put in rapid revolution, cut parallel grooves in the face of the stone.

A great advance in milling was made both in America and Europe by the inventions of Oliver Evans. Evans was born in the State of Delaware, U.S., in 1755, and died in 1819. He was a poor boy and an apprentice to a wheelwright, and while thus engaged his inventive powers were developed. He had an idea of a land carriage propelled without animal power. At the age of 22 he invented a machine for making card teeth, which superseded the old method of making them by hand. Later he invented steam-engines and steam-boats, to which attention will hereafter be called. Entering into business with his brothers within the period extending from 1785 to 1800, he produced those inventions in milling which by the opening of the 19th century had revolutionised the art. A description of the most important of these inventions was published by him in 1795 in a book entitled *The Young Millwright and Miller's Grist*. Patents were granted Evans by the States of Delaware, Maryland and Pennsylvania in 1787, and by the U.S. Government in 1790 and 1808.

As these inventions formed the basis of the most important subsequent devices of the century, a brief statement of his system is proper:

From the time the grain was emptied from the waggon to the final production of the finest flour at the close of the process, all manual labour was dispensed with. The grain was first emptied into a box hung on a scale beam where it was weighed, then run into an elevator which raised it to a chamber over cleaning machines through which it was passed, and reclaimed by the same means if desired; then it was run down into a chamber over the hoppers of the mill-stones; when ground it fell from the mill-stones into conveyors and as carried along subjected to the heated air of a kiln drier; then carried into a meal elevator to be raised and dropped on to a cooling floor where it was met by what is called a hopper boy, consisting of a central round upright shaft revolving on a pivot, and provided with horizontal arms and sweeps adapted to be raised and lowered and turned, by which means the meal was continually stirred around, lifted and turned on the floor and then gathered on to the bolting hoppers, the bolts being cylindrical sieves of varying degrees of fineness to separate the flour from its coarser impurities, and when not bolted sufficiently, carried by a conveyor called a drill to an elevator to be dumped again into the bolting hoppers and be re-bolted. When not sufficiently ground the same drill was used to carry the meal to the grind stones. It was the design of the process to keep the meal in constant motion from first to last so as to thoroughly dry and cool it, to heat it further in the meantime, and to run the machines so slowly as to prevent the rise and waste of the flour in the form of dust.

The Evans system, with minor modifications and improvements, was the prevailing one for three-quarters of a century. New mills, when erected, were provided with this system, and many mills in their quiet retreats everywhere awoke from their drowsy methods and were equipped with the new one.

But the whole system of milling has undergone another great change within the last thirty years:

During that time it has been learned that the coarser portion or kernel of wheat which lies next to the skin of the berry and between the skin and the heart is the most valuable and nutritious part, as it consists largely of gluten, while the interior consists of starch, which when dry becomes a pearly powder. Under the old systems this coarser part, known as middlings, was eliminated, and ground for feed for cattle, or into what was regarded as an inferior grade of flour from which to make coarse bread. It was customary, therefore, under the old method to set the grinding surfaces very close with keen sharp burrs, so that this coarser part was cut off and mixed with the small particles of bran, fine fuzz and other foreign substances, which was separated from the finer part of the kernel by the bolting.

The new process consists of removing the outer skin and adherent impurities from the middlings, then separating the middlings from the central finer part and then regrinding the middlings into flour.

This middlings flour being superior, as stated, to what was called straight grade, it became desirable to obtain as much middlings as possible, and to this end it was necessary to set the grinding surfaces further apart so as to grind *high*, hence the *high* milling process as distinguished from *low* milling. For the better performance of the high rolling process, roller mills were invented. It was found that the cracking process by which the kernel could be cracked and the gluten middlings separated from the starchy heart could best be had by the employment of rollers or cylinders in place of face stones, and at the same time the heating of the product, which injures it, be avoided.

The rollers operate in sets, and successive crackings are obtained by passing and repassing, if necessary, the grain through these rollers, set at different distances apart. The operation on grains of different qualities, whether hard or soft, or containing more or less of the gluten middlings, or starchy parts, and their minute and graded separation, thus are obtained with the greatest nicety.

The Hungarians, the Germans, the Austrians, the Swiss, the English and the Americans have all invented useful forms of these rollers.

This process was accompanied by the invention of new forms of middlings separators and purifiers, in which upward drafts of air are made to pass up through flat, graded shaking bolts, in an enclosed case, by which the bran specks and fuzz are lifted and conveyed away from the shaken material. In some countries, such as the great wheat state of Minnesota, U.S., where the wheat had before been of inferior market value owing to the poorer grade of flour obtained by the old processes, that same wheat was made to produce the most superior flour under the new processes, thus increasing the yearly value of the crops by many millions of dollars.

Disastrous flour dust explosions in some of the great mills at Minneapolis, in 1877-78, developed the invention of dust collectors, by which the suspended particles of flour dust are withdrawn from the machinery and the mill, and the air is cleared for respiration and for the production of the finest flour, while the mill is kept closed and comfortable in cold seasons. One of the latest forms of such a collector has for its essential principle the vertical or rotatory air current, which it is claimed moves and precipitates the finest particles.

The inventions in the class of mills have so multiplied in these latter days, that nearly every known article that needs to be cleaned and hulled, or ground, or cracked or pulverized, has its own specially designed machine. Wind and water as motive powers have been supplanted by steam and electricity. It would be impossible in one volume to describe this great variety. Knight, in his Mechanical Dictionary, gives a list under "Mills," of more than a hundred distinct machines and processes relating to grinding, hulling, crushing, pulverising and mixing products.

Vegetable Cutters.– Modern ingenuity has not neglected those more humble devices which save the drudgery of hand work in the preparation of vegetables and roots for food for man and beasts, and for use especially when large quantities are to be prepared. Thus, we find machines armed with blades and worked by springs and a lever, for chopping, others for cutting stalks, other machines for paring and slicing, such as apple and potato parers and slicers, others for grating and pulping, others for seeding fruits, such as cherries and raisins, and an entire range of mechanisms, from those which handle delicately the tenderest pod and smallest seed, to the ponderous machines for cutting and crushing the cane in sugar making.

Pressing and Baling.– The want of pressing loose materials and packing bulky ones, like hay, wool, cotton, hops, etc, and other coarser products, into small, compact bales and bodies, to facilitate their transportation, was immediately felt on the great increase of such products in the century.

From this arose pressing and baling machines of a great variety, until nearly every agricultural product that can be pressed, packed or baled has its special machine for that operation. Besides those above indicated relating to agricultural products, we have cane presses, cheese presses, butter presses, cigar and tobacco presses, cork presses, and flour packers, fruit and lard presses, peat presses, sugar presses and others. Leading mechanical principles in presses are also indicated by name, as screw presses, toggle presses, beater press, revolving press, hydraulic press, rack and pinion press, and rolling pressure press and so on.

There are the presses also that are used in compressing cotton. When it is remembered that cotton is raised in about twenty different countries, and that the cotton crop of the United States of 1897-98 was 10,897,857 bales, of about 500 lbs. each; of

India, (estimated) for the same period, 2,844,000, of 400 lbs each; of China about 1,320,000, of 500 lbs each, and between two and three million bales in the other countries, it is interesting to consider how the world's production of this enormous mass of elastic fibre, amounting to seventeen or eighteen million bales, of four and five hundred pounds each, is compressed and bound.

The screw press was the earliest form of machine used, and then came the hydraulic press. Later it has been customary to press the cotton by screw presses or small hydraulic presses at the plantation, bind it with ropes or metal bands and then transport it to some central or seaboard station where an immense establishment exists, provided with a great steam-operated press, in which the bale from the country is placed and reduced to one-fourth or one-third its size, and while under pressure new metallic bands applied, when the bale is ready for shipment. This was a gain of a remarkable amount of room on shipboard and on cars, and solved a commercial problem. But now this process, and the commercial rectangular bale, seem destined to be supplanted by roller presses set up near the plantations themselves, into which the cotton is fed directly from the gin, rolled upon itself between the rollers and compressed into round bales of greater density than the square bale, thus saving a great amount of cost in dispensing with the steam and hydraulic plants, with great additional advantages in convenience of handling and cost of transportation.

It is so arranged also that the cotton may be rolled into clean, uniform dense layers, so that the same may be unwound at the mill and directly applied to the machines for its manufacture into fabrics, without the usual tedious and expensive preliminary operations of combing and re-rolling.

It has also remained for the developed machine of the century to convert hay into an export commodity to distant countries by the baling process. Bale ties themselves have received great attention from inventors, and the most successful have won fortunes for their owners.

Most ingenious machines have been devised for picking cotton in the fields, but none have yet reached that stage of perfection sufficient to supplant the human fingers.

Fruits and Foods.– To prepare and transport fruits in their natural state to far distant points, while preserving them from decay for long times, is, in the large way demanded by the world's great appetites, altogether a success of modern invention.

To gather the fruit without bruising by mechanical pickers, and then to place the fruit, oranges for instance, in the hands of an intelligent machine which will automatically, but delicately and effectually, wrap the same in a paper covering, and discharge them without harm, are among the recent inventive wonders. In the United States alone 67 patents had been granted up to 1895 for fruit wrapping machines.

Inventions relating to drying and evaporating fruit, and having for their main object to preserve as much as possible the natural taste and colour of the fruit, have been numerous. Spreading the fruit in the air and letting the sun and air do the rest is now a crude process.

These are the general types of drying and evaporating machines:

First, those in which trays of fruit are placed upon stationary ledges within a heated chamber; second, those in which the trays are raised and lowered by mechanical means toward or farther from the source of heat as the drying progresses; third, those in which the fruit is placed in imperforate steam jacketed pans. Many improvements, of course, have been made in detail of form, in ventilation, the supplying and regulating of heat and the moving of trays.

The hermetically sealed glass or earthenware fruit jar, the lids of which can be screwed or locked down upon a rubber band, after the jar is filled and the small remainder of air drawn out by a convenient steam heater, now used by the million, is an illustration of the many useful modern contrivances in this line.

Sterilisation.– In preserving, the desirability of preventing disease and keeping foods in a pure state has developed in the last quarter of a century many devices by which the food is subjected to a steam heat in chambers, and, by devices operated from the outside, the cans or bottles are opened and shut while still within the steam-filled chamber.

Diastase.– By heating starchy matters with substances containing diastase, a partial transformation is effected, which will materially shorten and aid its digestion, and this fact has been largely made use of in the preparation of soluble foods, especially those designed for infants and invalids, such as malted milk and lactated food.

Milkers.– Invention has not only been exercised in the preservation and transportation of milk, but in the task of milking itself. Since 1860 inventors have been seeking patents for milkers, some having tubes operated by air-pumps, others on the same principle in which the vacuum is made to increase and decrease or pulsate, and others for machines in which the tubes are mechanically contracted by pressure plates.

Slaughtering.– Great improvements have been made in the slaughtering of animals, by which a great amount of its repulsiveness and the unhealthfulness of its surroundings have been removed. These improvements relate to the construction of proper buildings and appliances for the handling of the animals, the means for slaughtering, and modes of taking care of the meat and transporting the same. Villages, towns, and even many cities, are now relieved of the formerly unsavoury slaughter-houses, and the work is done from great centres of supply, where meats in every shape are prepared for food and shipment.

It would be impossible in a bulky volume, much less in a single chapter, to satisfactorily enumerate those thousands of inventions which, taking hold of the food products of the earth, have spread them as a feast before the tribes of men.

Tobacco.– Some of the best inventive genius of the century has been exercised in providing for man's comfort, not a food, but what he believes to be a solace.

> "Sublime Tobacco! which from East to West
> Cheers the tar's labour or the Turkman's rest."

In the United States alone, in the year 1885, there were 752,520 acres of land devoted to the production of tobacco, the amount in pounds grown being 562,736,000, and the value of which was estimated as $43,265,598. These amounts have been somewhat less in years since then, but the appetite continues, and any deficiency in the supply is made up by enormous importation. Thus, in 1896, there were imported into the United States, 32,924,966 pounds of tobacco, of various kinds, valued at $16,503,130. There are no reliable statistics showing that, man for man, the people of that country are greater lovers of the weed than the people of other countries, but the annual value of tobacco raised and imported by them being thus about $60,000,000, it indicates the strength of the habit and the interest in the nurture of the plant throughout the world. Neither the "Counterblaste to Tobacco" of King James I., and the condemnations of kings, popes, priests and sultans, that followed its early introduction into Europe, served to choke the weed in its infancy or check its after growth. Now it is attended from the day of its planting until it reaches the lips of the consumer by contrivances of consummate skill to fit it for its destined purpose. Besides the ploughs, the cultivators and the weeders of especial forms used to cultivate the plant, there are, after the grown plant is cut in the field, houses of various designs for drying it, machines for rolling the leaves out smoothly in sheets; machines for removing the stems from the leaves and for crushing the stem; machines for pressing it into shape, and for pressing it, whether solid or in granular form, into boxes, tubs and bags; machines for granulating it and for grinding it into snuff; machines for twisting it into cords; machines for flavouring the leaf with saccharine and other matters; machines for making cigars, and machines of a great variety and of the most ingenious construction for making cigarettes and putting them in packages.

Samples of pipes made by different ages and by different peoples would form a collection of wonderful art and ingenuity, second only to an exhibition of the means and methods of making them.

CHAPTER VI.
CHEMISTRY, MEDICINES, SURGERY, DENTISTRY

Chemistry, having for its field the properties and changes of matter, has excited more or less attention ever since men had the power to observe, to think, and to experiment.

Some knowledge of chemistry must have existed among the ancients to have enabled the Egyptians to smelt ores and work metals, to dye their cloths, to make glass, and to preserve their dead from decomposition; so, too, to this extent among the Phœnicians, the Israelites, the Greeks and the Romans; and perhaps to a greater extent among the Chinese, who added powder to the above named and other chemical products. Aristotle speculated, and the alchemists of the middle ages busied themselves in magic and guess-work. It reached the dignity of a science in the seventeenth and eighteenth centuries, by the labours of such men, in the former century, as Libavius, Van Helmont, Glauber, Tachenius, Boyle, Lémery and Becher; Stahl, Boerhaave and Hamberg in both; and of Black, Cavendish, Lavoisier, Priestley and others in the eighteenth.

But so great have been the discoveries and inventions in this science during the nineteenth century that any chemist of any previous age, if permitted to look forward upon them, would have felt

> "Like some watcher of the skies
> When a new planet swims into his ken."

Indeed, the chemistry of this century is a new world, of which all the previous discoveries in that line were but floating nebulæ.

So vast and astonishingly fast has been the growth and development of this science that before the century was two-thirds through its course Watts published his *Dictionary of Chemistry* in five volumes, averaging a thousand closely printed pages, followed soon by a thousand-page supplement; and it would have required such a volume every year since to adequately report the progress of the science. Nomenclatures, formulas, apparatuses and processes have all changed. It was deemed necessary to publish works on *The New Chemistry*, and Professor J. P. Cooke is the author of an admirable volume under that title.

We can, therefore, in this chapter only step from one to another of some of the peaks that rise above the vast surrounding country, and note some of the lesser objects as they appear in the vales below.

The leading discoveries of the century which have done so much to aid Chemistry in its giant strides are the atomic and molecular theories, the mechanics of light, heat, and electricity, the correlation and conservation of forces, their invariable quantity, and their indestructibility, spectrum analysis and the laws of chemical changes.

John Dalton, that humble child of English north-country Quaker stock, self-taught and a teacher all his life, in 1803 gave to the world his atomic theory of chemistry, whereby the existence of matter in ultimate atoms was removed from the region of the speculation of certain ancient philosophers, and established on a sure foundation.

The question asked and answered by Dalton was, what is the relative weight of the atoms composing the elementary bodies?

He discovered that one chemical element or compound can combine with another chemical element, to form a new compound, in two different proportions by weight, which stand to each other in the simple ratio of one to two; and at the same time he published a table of the *Relative weight of the ultimate particles of Gaseous and other Bodies*. Although the details of this table have since been changed, the principles of his discovery remain unchanged. Says Professor Roscoe:

> "Chemistry could hardly be said to exist as a science before the establishment of the laws of combination in multiple proportions, and the subsequent progress of chemical science materially depended upon the determination of these combined proportions or atomic weights of the elements first set up by Dalton. So that among the founders of our science, next to the name of the great French Philosopher, Lavoisier, will stand in future ages the name of John Dalton, of Manchester."

Less conspicuous but still eminently useful were his discoveries and labours in other directions, in the expansion of gases, evaporation, steam, etc.

Wollaston and Gay-Lussac, both great chemists, applied Dalton's discovery to wide and most important fields in the chemical arts.

Also contemporaneous with Dalton was the great German chemist, Berzelius, who confirmed and extended the discoveries of Dalton. More than this, it has been said of Berzelius:

> "In him were united all the different impulses which have advanced the science since the beginning of the present epoch. The fruit of his labors is scattered throughout the entire domain of the science. Hardly a substance exists to the knowledge of which he has not in some way contributed. A direct descendant of the school of his countryman, Bergman, he was especially renowned as an analyst. No chemist has determined by direct experiment the composition of a greater number of substances. No one has exerted a greater influence in extending the field of analytical chemistry."

As to light, the great Huygens, the astronomer and mathematician, the improver of differential calculus and of telescopes, the inventor of the pendulum clock, chronometers, and the balance wheel to the watch, and discoverer of the laws of the double refraction of light and of polarisation, had in the 17th century clearly advanced the idea that light was propagated from luminous bodies, not as a stream of particles through the air but in waves or vibrations of ether, which is a universal medium extending through all space and into all bodies. This fundamental principle now enters into the explanation of all the phenomena of light.

Newton in the next century, with the prism, decomposed light, and in a darkened chamber reproduced all the colours and tints of the rainbow. But there were dark lines in that beam of broken sunlight which Newton did not notice.

It was left to Joseph von Fraunhofer, a German optician, and to the 19th century, and nearly one hundred years after Newton's experiments with the prism, to discover, with finer prisms that he had made, some 590 of these black lines crossing the solar spectrum. What they were he did not know, but conjectured that they were caused by something which existed in the sun and stars and not in our air. But from that time they were called Fraunhofer's dark lines.

From the vantage ground of these developments we are now enabled to step to that mountain peak of discovery from which the sun and stars were looked into, their elements portrayed, their very motions determined, and their brotherhood with the earth, in substance, ascertained.

The great discovery of the cause of Fraunhofer's dark bands in the broken sunlight was made by Gustave Robert Kirchoff, a German physician, in his laboratory in Heidelberg, in 1860, in conjunction with his fellow worker, Robert Bunsen.

Kirchoff happened to let a solar ray pass through a flame coloured with sodium, and through a prism, so that the spectrum of the sun and the flame fell one upon another. It was expected that the well known yellow line of sodium would come out in the solar spectrum, but it was just the opposite that took place. Where the bright yellow line should have fallen appeared a dark line.

With this observation was coupled the reflection that heat passes from a body of a higher temperature to one of a lower, and not inversely. Experiments followed: iron, sodium, copper, etc., were heated to incandescence and their colours prismatically separated. These were transversed with the same colours of other heated bodies, and the latter were absorbed and rendered black. Kirchoff then announced his law that all bodies absorb chiefly those colours which they themselves emit. Therefore these vapours of the sun which were rendered in black lines were so produced by crossing terrestrial vapors of the same nature.

Thus by the prism and the blowpipe were the same substances found in the sun, the stars, and the earth. The elements of every substance submitted to the process were analysed, and many secrets in the universe of matter were revealed.

Young, of America, invented a splendid combination of spectroscope and telescope, and Huggins of England was the first to establish by spectrum analysis the approach and retreat of the stars.

It was prior to this time that those wonderful discoveries and labours were made which developed the true nature of heat, which demonstrated the kinship and correlation of the forces of Nature, their conservation, or property of being converted one into another, and the indestructibility of matter, of which force is but another name.

The first demonstrations as to the nature of heat were given by the American Count Rumford, and then by Sir Humphry Davy, just at the close of the 18th century, and then followed in this the brilliant labours and discoveries of Mayer and Helmholtz of Germany, Colding of Denmark, and Joule, Grove, Faraday, Sir William Thomson of England, of Henry, Le Conte and Martin of America, as to the correlation and convertibility of all the forces.

The French revolution, and the Napoleonic wars, isolating France and exhausting its resources, its chemists were appealed to devote their genius and researches to practical things; to the munitions of war, the rejuvenation of the soil, the growing of new crops, like the sugar beet, and new manufacturing products.

Lavoisier had laid deep and broad in France the foundations of chemistry, and given the science nomenclature that lasted a century. So that the succeeding great teachers, Berthollet, Guyton, Fourcroy and their associates, and the institutions of instruction in the sciences fostered by them, and inspired in that direction by Napoleon, bent their energies in material directions, and a tremendous impulse was thus given to the practical application of chemistry to the arts and manufactures of the century.

The same spirit, to a less extent, however, manifested itself in England, and as early as 1802 we find Sir Humphry Davy beginning his celebrated lectures on the *Elements of Agricultural Chemistry* before a board of agriculture, a work that has passed through many editions in almost every modern language.

When the fact is recalled that agricultural chemistry embraces the entire natural science of vegetable and animal production, and includes, besides, much of physics, meteorology and geology, the extent and importance of the subject may be appreciated; and yet such appreciation was not manifested in a practical manner until the 19th century. It was only toward the end of the 18th century that the vague and ancient notions that air, water, oil and salt formed the nutrition of plants, began to be modified. Davy recognized and explained the beneficial fertilizing effects of ammonia, and analysed and explained numerous fertilizers, including guano. It is due to his discoveries and publications, combined with those of the eminent men on the continent, above referred to, that agricultural chemistry arose to the dignity of a science. The most brilliant, eloquent and devoted apostle of that science who followed Davy was Justus von Liebig of Germany, who was born in Darmstadt in 1803, the year after Davy commenced his lectures in England. It was in response to the British Association for the Advancement of Science that he gave to the world his great publications on *Chemistry in its application to Agriculture, Commerce, Physiology, and Pathology*, from which great practical good resulted the world over. One of his favorite subjects was that of fermentation, and this calls up the exceedingly interesting discoveries in the nature of alcohol, yeast, mould – aging malt, wines and beer – and their accompanying beneficial results.

In one of Huxley's charming lectures – such as he delighted to give before a popular audience – delivered in 1871, at Manchester, on the subject of "Yeast," he tells how any liquid containing sugar, such as a mixture of honey and water, if left to itself undergoes the peculiar change we know as fermentation, and in the process the scum, or thicker muddy part that forms on top, becomes yeast, carbonic acid gas escapes in bubbles from the liquid, and the liquid itself becomes spirits of wine or alcohol. "Alcohol" was a term used until the 17th century to designate a very fine subtle powder, and then became the name of the subtle spirit arising from fermentation. It was Leeuwenhoek of Holland who, two hundred years ago, by the use of a fine microscope he invented, first discovered that the muddy scum was a substance made up of an enormous multitude of very minute grains floating separately, and in lumps and in heaps, in the liquid. Then, in the next century the Frenchman, Cagniard de la Tour, discovered that these bodies grew to a certain size and then budded, and from the buds the plant multiplied; and thus that this yeast was a mass of living plants, which received in science the name of "torula," that the yeast plant was a kind of fungus or mould, growing and multiplying. Then came Fabroni, the French chemist, at the end of the 18th century, who discovered that the yeast plant was of bag-like form, or a cell of woody matter, and that the cell contained a substance composed of carbon, hydrogen, oxygen and nitrogen. This was a vegeto-animal substance, having peculiarities of "animal products."

Then came the great chemists of the 19th century, with their delicate methods of analysis, and decided that this plant in its chief part was identical with that element which forms the chief part of our own blood. That it was protein, a substance which forms the foundation of every animal organism. All agreed that it was the yeast plant that fermented or broke up the sugar element, and produced the alcohol. Helmholtz demonstrated that it was the minute particles of the solid part of the plant that produced the fermentation, and that such particles must be growing or alive, to produce it. From whence sprang this wonderful plant – part vegetable, part animal? By a long series of experiments it was found that if substances which could be fermented were kept entirely closed to the outer air, no plant would form and no fermentation take place. It was concluded then, and so ascertained, that the torulae in the plant proceeded from the torulae in the atmosphere, from "gay motes that people the sunbeams." Concerning just how the torulae broke up or fermented the sugar, great chemists have differed.

After the discovery that the yeast was a plant having cells formed of the pure matter of wood, and containing a semi-fluid mass identical with the composition which constitutes the flesh of animals, came the further discovery that all plants, high and low, are made up of the same kind of cells, and their contents.

Then this remarkable result came out, that however much a plant may otherwise differ from an animal, yet, in essential constituents the cellular constructure of animal and plant is the same. To this substance of energy and life, common in the minute plant cell and the animal cell, the German botanist, Hugo von Mohl, about fifty years ago gave the name "protoplasm." Then came this astounding conclusion, that this *protoplasm* being common to both plant and animal life, the essential difference consisted only in the manner in which the cells are built up and are modified in the building.

And from that part of these great discoveries which revealed the fact that the sugary element was infected, as it were, from the germs of the air, producing fermentation and its results, arose that remarkable theory of many diseases known as the "germ theory." And, as it was found in the yeast plant that only the solid part or particle of the plant germinated fermentation and reaction, so, too, it has been found by the germ theory that only the solid particle of the contagious matter can germinate or grow the disease.

In this unfolding of the wonders of chemistry in the nineteenth century, the old empirical walls between forces and organisms, and organic and inorganic chemistry, are breaking down, and celestial and terrestrial bodies and vapours, living beings, and growing plants are discovered to be the evolution of one all-pervading essence and force. One is reminded of the lines of Tennyson:

"Large elements in order brought
And tracts of calm from tempest made,
And world fluctuation swayed
In vassal tides that followed thought.

One God, one law, one element,
And one far-off divine event
To which the whole creation moves."

In the class of alcohol and in the field of yeast, the work of Pasteur, begun in France, has been followed by improvements in methods for selecting proper ferments and excluding improper ones, and in improved processes for aging and preserving alcoholic liquors by destroying deleterious ferments. Takamine, in using as ferment, koji, motu and moyashi, different forms of mould, and proposing to do entirely away with malt in the manufacture of beer and whiskey, has made a noteworthy departure. Manufacturing of malt by the pneumatic process, and stirring malt during germination, are among the improvements.

Carbonating.– The injecting of carbonic acid gas into various waters to render them wholesome, and also into beers and wines during fermentation, and to save delay and prevent impurities, are decided improvements.

The immense improvements and discoveries in the character of soils and fertilisers have already been alluded to. Hundreds of instruments have been invented for measuring, analysing, weighing, separating, volatilising and otherwise applying chemical processes to practical purposes.

To the chemistry of the century the world is indebted for those devices and processes for the utilisation and manufacture of many useful products from the liquids and oils, sugar from cane and beets, revivifying bone-black, centrifugal machinery for refining sugar, in defecating it by chemicals and heat, in evaporating it in pans, in separating starch and converting it into glucose, etc.

Oils and Fats.– Up to within this century the vast amount of cotton seed produced with that crop was a waste. Then by the process, first of steaming the seed and expressing the oil, now by the process of extraction by the aid of volatile solvents, and casting off the solvents by distillation, an immensely valuable product has been obtained.

The utilising of oils in the manufacture of oilcloth and linoleum and rubber, has become of great commercial value. Formerly sulphur was the vulcanising agent, now chloride of sulphur has been substituted for pure sulphur.

Steam and the distillation processes have been applied with great success to the making of glycerine from fat and from soap underlye and in extracting fat from various waste products.

Bleaching and Dyeing.– Of course these arts are very old, but the old methods would not be recognised in the modern processes; and those who lived before the century knew nothing of the magnificent colours, and certain essences, and sweet savours that can be obtained from the black, hand-soiling pieces of coal. In the making of illuminating gas, itself a finished chemical product of the century, a vast amount of once wasted products, especially coal tar, are now extensively used; and from coal tar and the residuum of petroleum oils, now come those splendid aniline dyes which have produced such a revolution in the world of colours. The saturation of sand by a dye and its application to fabrics by an air blast; the circulation of the fluid colors, or of fluids for bleaching or drying, or oxidising, through perforated cylinders or cops on which the cloths are wound; devices for the running of skeins through dyes, the great improvements in carbon dyes and kindred colours, the processes of making the colours on the fibre, and the perfumes made by the synthetic processes, are among the inventions in this field.

The space that a list of the new chemical products of this age and their description would fill, has already been indicated by reference to the great dictionary of Watts. Some of the electro-chemical products will be hereinafter referred to in the Chapter on Electricity, and the chemistry of Metallurgy will be treated under the latter topic.

Electro-chemical Methods.– Space will only permit it to be said that these methods are now employed in the production of a large number of elements, by means of which very many of them which were before mere laboratory specimens, have now become cheap and useful servants of mankind in a hundred different ways; such as aluminium, that light and non-corrosive metal, reduced from many dollars an ounce a generation ago, to 30 and 40 cents a pound now; carborundum, largely superseding emery and diamond dust as an abradant; artificial diamonds; calcium carbide, from which the new illuminating acetylene gas is made; disinfectants of many kinds; pigments, chromium, manganese, and chlorates by the thousand tons. The most useful new chemical processes are those used in purifying water sewage and milk, in electroplating metals and other substances, in the application of chemicals to the fine arts, in extracting grease from wool, and the making of many useful products from the waste materials of the dumps and garbage banks.

Medicines and Surgery.– One hundred years ago, the practice of medicine was, in the main, empirical. Certain effects were known to usually follow the giving of certain drugs, or the application of certain measures, but why or how these effects were produced, was unknown. The great steps forward have been made upon the true scientific foundation established by the discoveries and inventions in the fields of physics, chemistry and biology. The discovery of anaesthetics and their application in surgery and the practice of medicine, no doubt constitutes the leading invention of the century in this field.

Sir Humphry Davy suggested it in 1800, and Dr. W. T. Morton was the first to apply an anaesthetic to relieve pain in a surgical operation, which he did in a hospital in Boston in 1846. Both its original suggestion and application were also claimed by others.

Not only relief from intense pain to the patient during the operation, but immense advantages are gained by the long and careful examination afforded of injured or diseased parts, otherwise difficult or impossible in a conscious patient.

The exquisite pain and suffering endured previous to the use of anaesthetics often caused death by exhaustion. Many delicate operations can now be performed for the relief of long-continued diseases which before would have been hazardous or impossible. How many before suffered unto death long-drawn-out pain and disease rather than submit to the torture of the knife! How many lives have been saved, and how far advanced has become the knowledge of the human body and its painful diseases, by this beneficent remedy!

Inventions in the field of medicine consist chiefly in those innumerable compositions and compounds which have resulted from chemical discoveries. Gelatine capsules used to conceal unpalatable remedies may be mentioned as a most acceptable modern invention in this class. Inventions and discoveries in the field of surgery relate not only to instrumentalities but processes. The antiseptic treatment of wounds, by which the long and exhausting suppuration is avoided, is among the most notable of the latter. In instruments vast improvements have been made; special forms adapted for operation in every form of injury; in syringes, especially hypodermic, those used for subcutaneous injections of liquid remedies; inhalers for applying medicated vapours and devices for applying volatile anaesthetics, and devices for atomising and spraying liquids. In the United States alone about four thousand patents have been granted for inventions in surgical instruments.

Dentistry.– This art has been revolutionised during the century. Even in the time of Herodotus, one special set of physicians had the treatment of teeth; and artificial teeth have been known and used for many ages, but all seems crude and barbarous until these later days. In addition to the use of anaesthetics, improvements have been made in nearly every form of dental instruments, such as forceps, dental engines, pluggers, drills, hammers, etc., and in the means and materials for making teeth. Later leading inventions have reference to utilising the roots of destroyed teeth as supports on which to form bridges to which artificial teeth are secured, and to crowns for decayed teeth that still have a solid base.

There exists no longer the dread of the dentist's chair unless the patient has neglected too long the visit. Pain cannot be all avoided, but it is ameliorated; and the new results in workmanship in the saving and in the making of teeth are vast improvements over the former methods.

CHAPTER VII.
STEAM AND STEAM ENGINES

"Soon shall thy arm, unconquered steam! afar
Drag the slow barge, or drive the rapid car;
Or in wide waving wings expanded bear
The flying chariot through the field of air."

Thus sang the poet prophet, the good Dr. Darwin of Lichfield, in the eighteenth century. Newcomen and Watt had not then demonstrated that steam was not unconquerable, but the hitching it to the slow barge and the rapid car was yet to come. It has come, and although the prophecy is yet to be rounded into fulfilment by the driving of the "flying chariot through the field of air," that too is to come.

The prophecy of the doctor poet was as suggestive of the practical means of carrying it into effect as were all the means proposed during the first seventeen centuries of the Christian Era for conquering steam and harnessing it as a useful servant to man.

Toys, speculations, dreams, observations, startling experiments, these often constitute the framework on which is hung the title of Inventor; but the nineteenth century has demanded a better support for that proud title. He alone who first transforms his ideas into actual work and useful service in some field of man's labor, or clearly teaches others to do so, is now recognised as the true inventor. Tested by this rule there was scarcely an inventor in the field of steam in all the long stretches of time preceding the seventeenth century. And if there were, they had no recording scribes to embalm their efforts in history.

We shall never know how early man learned the wonderful power of the spirit that springs from heated water. It was doubtless from some sad experience in ignorantly attempting to put fetters on it.

The history of steam as a motor generally commences with reference to that toy called the aeolipile, described by Hero of Alexandria in a treatise on pneumatics about two centuries before Christ, and which was the invention of either himself or Ctesibius, his teacher.

This toy consisted of a globe pivoted on two supports, one of which was a communicating pipe leading into a heated cauldron of water beneath. The globe was provided with two escape pipes on diametrically opposite sides and bent so as to discharge in opposite directions. Steam admitted into the globe from the cauldron escaped through the side pipes, and its pressure on these pipes caused the globe to rotate.

Hero thus demonstrated that water can be converted into steam and steam into work.

Since that ancient day Hero's apparatus has been frequently reinvented by men ignorant of the early effort, and the principle of the invention as well as substantially the same form have been put into many practical uses. Hero in his celebrated treatise described other devices, curious siphons and pumps. Many of them are supposed to have been used in the performance of some of the startling religious rites at the altars of the Greek priests.

From Hero's day the record drops down to the middle ages, and still it finds progress in this art confined to a few observations and speculations. William of Malmesbury in 1150 wrote something on the subject and called attention to some crude experiments he had heard of in Germany. Passing from the slumber of the middle ages, we are assured by some Spanish historians that one Blasco de Garay, in 1543, propelled a ship having paddle wheels by steam at Barcelona. But the publication was long after the alleged event, and is regarded as apocryphal.

Observations became more acute in the sixteenth and seventeenth centuries, experiments more frequent, and publications more full and numerous.

Cardan Ramelli and Leonardo da Vinci, learned Italians, and the accomplished Prof. Jacob Besson of Orleans, France, all did much by their writings to make known theoretically the wonderful powers of steam, and to suggest modes of its practical operation, in the latter part of the sixteenth century.

Giambattista della Porta, a gentleman of Naples, possessing high and varied accomplishments in all the sciences as they were known at that day, 1601, and who invented the magic-lantern and *camera obscura*, in a work called *Spiritalia*, described how steam pressure could be employed to raise a column of water, how a vacuum was produced by the condensation of steam in a closed vessel, and how the condensing vessel should be separated from the boiler. Revault in France showed in 1605 how a bombshell might be exploded by steam.

Salomon de Caus, engineer and architect to Louis XIII, in 1615 described how water might be raised by the expansion of steam.

In 1629 the Italian, Branco, published at Rome an account of the application of a steam jet upon the vanes of a small wheel to run it, and told how in other ways Hero's engine might be employed for useful purposes.

The first English publication describing a way of applying steam appeared in 1630 in a patent granted to David Ramseye, for a mode of raising water thereby. This was followed by patents to Grant in 1632 and to one Ford in 1640. During that century these crude machines were called "fire engines." It seems to have been common in some parts of Europe during the seventeenth century to use a blast of steam to improve the draft of chimneys and of blast furnaces. This application of steam to smoke and smelting has been frequently revived by modern inventors with much flourish of originality.

It is with a certain feeling of delight and relief, after a prolonged search through the centuries for some evidence of harnessing this mighty agent to man's use, that we come to the efforts of the good Marquis of Worcester – Edward Somerset. He it was who in 1655 wrote of the *Inventions of the Sixteenth*

Century. He afterwards amplified this title by calling his book *A Century of Names and Scantlings of such Inventions as at present I call to mind to have tried and perfected*, etc.

There are about one hundred of these "Scantlings," and his descriptions of them are very brief but interesting. Some, if revived now and put to use, would throw proposed flying machines into the background, as they involved perpetual motion.

But to his honor be it said that he was the first steam-engine builder. A patent was issued to him in 1663. It was about 1668 that he built and put in successful operation at Raglan Castle at Vauxhall, near London, a steam engine to force water upward. He made separate boilers, which he worked alternately, and conveyed the steam from them to a vessel in which its pressure operated to force the water up. Unfortunately he did not leave a description of his inventions sufficiently full to enable later mechanics to make and use them. He strove in vain to get capital interested and a company formed to manufacture his engines. The age of fear and speculation as to steam ceased when the Marquis set his engine to pumping water, and from that time inventors went on to put the arm of steam to work.

In 1683 Sir Samuel Morland commenced the construction of the Worcester engines for use and sale; Hautefeuille of France taught the use of gas, described how gas as well as steam engines might be constructed, and was the first to propose the use of the piston. The learned writings of the great Dutch scientist and inventor, Huygens, on heat and light steam and gas, also then came forth, and his assistant, the French physicist and doctor, Denis Papin, in 1690, proposed steam as a universal motive power, invented a steam engine having a piston and a safety valve, and even a crude paddle steamer, which it is said was tried in 1707 on the river Fulda. Then in 1698 came Thomas Savery, who patented a steam engine that was used in draining mines.

The eighteenth century thus commenced with a practical knowledge of the power of steam and of means for controlling and working it.

Then followed the combined invention of Newcomen, Cawley and Savery, in 1705, of the most successful pumping engine up to that time. In this engine a cylinder was employed for receiving the steam from a separate boiler. There was a piston in the cylinder driven up by the steam admitted below it, aided by a counterpoise at one end of an engine beam. The steam was then cut off from the boiler and condensed by the introduction beneath the piston of a jet of water, and the condensed steam and water drawn off by a pipe. Atmospheric pressure forced the piston down. The piston and pump rods were connected to the opposite ends of a working beam of a pumping engine, as in some modern engines. Gauge cocks to indicate the height of water, and a safety valve to regulate the pressure of steam, were employed. Then came the ingenious improvement of the boy Humphrey Potter, connecting the valve gear with the engine beam by cords, so as to do automatically what he was set to do by hand, and the improvement on that of the Beighton plug rod. Still further improved by others, the Newcomen engine came into use through out Europe.

Jonathan Hulls patented in England in 1736 a marine steam engine, and in 1737 published a description of a Newcomen engine applied to his system for towing ships. William Henry, of Pennsylvania, tried a model steamboat on the Conestoga river in 1763.

This was practically the state of the art, in 1763, when James Watt entered the field. His brilliant inventions harnessed steam to more than pumping engines, made it a universal servant in manifold industries, and started it on a career which has revolutionized the trade and manufactures of the world.

To understand what the nineteenth century has done in steam motive power we must first know what Watt did in the eighteenth century, as he then laid the foundation on which the later inventions have all been built.

Taking up the crude but successful working engine of Newcomen, a model of which had been sent to him for repairs, he began an exhaustive study of the properties of steam and of the means for producing and controlling it. He found it necessary to devise a new system.

Watt saw that the alternate heating and cooling of the cylinder made the engine work slowly and caused an excessive consumption of steam. He concluded that "the cylinder should always be as hot as the steam that entered it." He therefore closed the cylinder and provided a separate condensing vessel into which the steam was led after it raised the piston. He provided an air-tight jacket for the cylinder, to maintain its heat. He added a tight packing in the cylinder-head for the piston-rod to move through, and a steam-tight stuffing-box on the top of the cylinder. He caused the steam to alternately enter below and above the piston and be alternately condensed to drive the piston down as well as up, and this made the engine double-acting, increasing its power and speed. He converted the reciprocating motion of the piston into a rotary motion by the adoption of the crank, and introduced the well-known parallel motion, and many other improvements. In short, he demonstrated for the first time by a practical and efficient engine that the expansive force of steam could be used to drive all ordinary machinery. He then secured his inventions by patents against piracy, and sustained them successfully in many a hard-fought battle. It had taken him the last quarter of the 18th century to do all these things.

Watt was the proper precursor of the nineteenth century inventions, as in him were combined the power and attainments of a great scientist and the genius of a great mechanic. The last eighteen years of his life were passed in the 19th century, and he was thus enabled to see his inventions brought within its threshold and applied to those arts which have made this age so glorious in mechanical achievements.

Watt so fitly represents the class of modern great inventors in his character and attainments that the description of him by Sir

Walter Scott is here pertinent as a tribute to that class, and as a delineation of the general character of those benefactors of his race of which he was so conspicuous an example: —

Says Sir Walter: —

> "Amidst this company stood Mr. Watt, the man whose genius discovered the means of multiplying our national resources to a degree, perhaps, even beyond his own stupendous powers of calculation and combination; bringing the treasures of the abyss to the summit of the earth – giving to the feeble arm of man the momentum of an Afrite – commanding manufactures to rise – affording means of dispensing with that time and tide which wait for no man – and of sailing without that wind which defied the commands and threats of Xerxes himself. This potent commander of the elements – this abridger of time and space – this magician, whose cloudy machinery has produced a change in the world, the effects of which, extraordinary as they are, are perhaps only beginning to be felt – was not only the most profound man of science, the most successful combiner of powers and calculator of numbers, as adapted to practical purposes, was not only one of the most generally well-informed, but one of the best and kindest of human beings."

The first practical application of steam as a working force was to pumping, as has been stated. After Watt's system was devised, suggestions and experiments as to road locomotives and carriages were made, and other applications came thick and fast. A French officer, Cugnot, in 1769 and 1770, was the first to try the road carriage engine. Other prominent Frenchmen made encouraging experiments on small steamboats – followed in 1784-86 by James Rumsey and John Fitch in America in the same line. Watt patented a road engine in 1784. About the same time his assistant, Murdock, completed and tried a model locomotive driven by a "grasshopper" engine. Oliver Evans, the great American contemporary of Watt, had in 1779 devised a high-pressure non-condensing steam engine in a form still used. In 1786-7 he obtained in Pennsylvania and Maryland patents for applying steam to driving flour mills and propelling waggons. Also about this time, Symington, the Scotchman, constructed a working model of a steam carriage, which is still preserved in the museum at South Kensington, London. Symington and his fellow Scotchmen, Miller and Taylor, in 1788-89 also constructed working steamboats. In 1796 Richard Trevithick, a Cornish marine captain, was producing a road locomotive. The century thus opened with activity in steam motive power. The "scantlings" of the Marquis of Worcester were now being converted into complete structures. And so great was the activity and the number of inventors that he is a daring man who would now decide priority between them. The earliest applications in this century of steam power were in the line of road engines.

On Christmas eve of 1801, Trevithick made the initial trip with the first successful steam road locomotive through the streets of Camborne in Cornwall, carrying passengers. In one of his trips he passed into the country roads and came to a tollgate through which a frightened keeper hastily passed him without toll, hailing him as the devil.

Persistent efforts continued to be made to introduce a practical steam road carriage in England until 1827. After Trevithick followed Blenkinsop, who made a locomotive which ran ten miles an hour. Then came Julius Griffith, in 1821, of Brompton, who patented a steam carriage which was built by Joseph Bramah, one of the ablest mechanics of his time. Gordon, Brunton and Gurney attempted a curious and amusing steam carriage, resembling a horse in action – having jointed legs and feet, but this animal was not successful. Walter Hancock, in 1827, was one of the most persistent and successful inventors in this line; but bad roads and an unsympathetic public discouraged inventors in their efforts to introduce steam road carriages, and their attention was turned to the locomotive to run on rails or tracks especially prepared for them. Wooden and iron rails had been introduced a century before for heavy cars and wagons in pulling loads from mines and elsewhere, but when at the beginning of the century it had been found that the engines of Watt could be used to drag such loads, it was deemed necessary to make a rail having its top surface roughened with ridges and the wheels of the engine and cars provided with teeth or cogs to prevent anticipated slipping.

In England, Blackett and George Stephenson discovered that the adhesion of smooth wheels to smooth rails was sufficient.

Without overlooking the fact that William Hendley built and operated a locomotive called the *Puffing Billy* in 1803, and Hackworth one a little later, yet to the genius of Stephenson is due chiefly the successful introduction of the modern locomotive. His labours and inventions continued from 1812 for twenty years, and culminated at two great trials: the first one on the Liverpool and Manchester Railway in 1829, when he competed with Hackworth and Braithwaite and Ericsson, and with the *Rocket* won the race; and the second at the opening of the same road in 1830, when with the *Northumbrian*, at the head of seven other locomotives and a long train of twenty-eight carriages, in which were seated six hundred passengers, he ran the train successfully between the two towns.

On this occasion Mr. Huskisson, Home Secretary in the British Cabinet, while the cars were stopping to water the engines, and he was out on the track talking with the Duke of Wellington, was knocked down by one of the engines and had one of his legs crushed. Placed on board of the *Northumbrian*, it was driven at the rate of thirty-six miles an hour by Stephenson to Eccles. Mr. Huskisson died there that night. This was its first victim, and the greatest speed yet attained by a locomotive.

The year 1829 therefore can be regarded as the commencement of the life of the locomotive for transportation of passengers. The steam blast thrown into the smokestack by Hackworth, the tubular boiler of Seguin and the link motion of Stephenson were then, as they now are, the essential features of locomotives.

In the meantime America had not been idle. The James Watt of America, Oliver Evans, in 1804 completed a flat-bottomed boat to be used in dredging at the Philadelphia docks, and mounting it on wheels drove it by its own steam engine through the streets to the river bank. Launching the craft, he propelled it down the river by using the same engine to drive the paddle wheels. He gave to this engine the strange name of *Oruktor Amphibolos*.

John C. Stevens of New Jersey was, in 1812, urging the legislature of the State of New York to build railways, and asserting that he could see nothing to hinder a steam carriage from moving with a velocity of one hundred miles an hour. In 1829 George Stephenson in England had made for American parties a locomotive called *The Stourbridge Lion*, which in that year was brought to America and used on the Delaware and Hudson R. R. by Horatio Allen. Peter Cooper in the same year constructed a locomotive for short curves, for the Baltimore and Ohio Railroad.

Returning now to steam navigation: – Symington again entered the field in 1801-2 and constructed for Lord Dundas a steamboat, named after his wife, the *Charlotte Dundas*, for towing on a canal, which was successfully operated.

Robert Fulton, an American artist, and subsequently a civil engineer, built a steamboat on the Seine in 1803, assisted by R. Livingston, then American Minister to France. Then in 1806

Fulton, having returned to the United States, commenced to build another steamboat, in which he was again assisted by Livingston, and in which he placed machinery made by Boulton and Watt in England. This steamboat, named the *Clermont*, was 130 ft. long, 18 ft. beam, 7 ft. depth and 160 tons burden. It made its first trip on the Hudson, from New York to Albany and return, in August, 1807, and subsequently made regular trips. It was the first commercially successful steamboat ever made, as George Stephenson's was the first commercially successful locomotive. In the meantime Col. John Stevens of New Jersey was also at work on a steamboat, and had in 1804 built such a boat at his shops, having a screw propeller and a flue boiler. Almost simultaneously with Fulton he brought out the *Phœnix*, a side-wheel steamer having hollow water lines and provided with feathering paddle wheels, and as Fulton and Livingston had a monopoly of the Hudson, Stevens took his boat by sea from New York around to Delaware bay and up the Delaware river. This was in 1808, and was the first sea voyage ever made by a steam vessel.

Transatlantic steamship navigation was started in 1819. A Mr. Scarborough of Savannah, Ga., in 1818 purchased a ship of about three hundred and fifty tons burden, which was named the *Savannah*. Equipped with engine and machinery it steamed out of New York Harbour on the 27th day of March, 1819, and successfully reached Savannah, Georgia. On the 20th of May in the same year she left Savannah for Liverpool, making the trip in

22 days. From Liverpool she went to Copenhagen, Stockholm, St. Petersburg, Cronstadt and Arundel, and from the latter port returned to Savannah, making the passage in twenty-five days.

But Scottish waters, and the waters around other coasts of the British Islands, had been traversed by steamboats before this celebrated trip of the *Savannah*. Bell's steamboat between Glasgow and Greenock in 1812 was followed by five others in 1814; and seven steamboats plied on the Thames in 1817.

So the locomotives and the steamboats and steamships continued to multiply, and when the first forty years of the century had been reached the Iron Horse was fairly installed on the fields of Europe and America, and the rivers and the oceans were ploughed by its sisters, the steam vessels.

It was in 1840 that the famous Cunard line of transatlantic steamers was established, soon followed by the Collins line and others.

A few years before, John C. Stevens in America and John Ericsson in England had brought forward the screw propeller; and Ericsson was the first to couple the engine to the propeller shaft. It succeeded the successful paddle wheels of Fulton in America and Bell in England.

The nineteenth century is the age of kinetic energy: the energy of either solid, liquid, gaseous or electrical matter transformed into useful work.

It has been stated by that eminent specialist in steam engineering, Prof. R. H. Thurston, that "the steam engine is a machine which is especially designed to transform energy originally dormant or potential into active and useful available kinetic energy;" and that the great problem in this branch of science is "to construct a machine which shall in the most perfect manner possible convert the kinetic energy of heat into mechanical power, the heat being derived from the combustion of fuel, and steam being the receiver and conveyor of that heat."

Watt and his contemporaries regarded heat as a material substance called "Phlogiston." The modern kinetic theory of heat was a subsequent discovery, as elsewhere explained.

The inventors of the last part of the eighteenth century and of the nineteenth century have directed their best labours to construct an engine as above defined by Thurston.

First as to the boiler: Efforts were made first to get away from the little old spherical boiler of Hero. In the 18th century Smeaton devised the horizontal lengthened cylindrical boiler traversed by a flue. Oliver Evans followed with two longitudinal flues. Nathan Read of Salem, Massachusetts, in 1791, invented a tubular boiler in which the flues and gases are conducted through tubes passing through the boiler into the smokestack. Such boilers are adapted for portable stationary engines, locomotives, fire and marine engines, and the fire is built within the boiler frame. Then in the 19th century came the use of sectional boilers – a combination of small vessels instead of a large common one, increasing the strength while diminishing capacity – to obtain high pressure of steam. Then came improved weighted and other safety valves to regulate and control this pressure. The compound or double cylinder high-pressure engine of Hornblower of England, in 1781, and the high-pressure non-condensing steam engine devised by Evans in 1779, were reconstructed and improved in the early part of the century.

To give perfect motion and the slightest friction to the piston; to regulate the supply of steam to the engine by proper valves; to determine such supply by many varieties of governors and thus control the speed; to devise valve gear which distributes the steam through its cycles of motion by which to admit the steam alternately to each end of the steam cylinder as the piston moves backward and forward, and exhaust valves to open and close the parts through which the steam escapes; to automatically operate such valves; to condense the escaping steam and to remove the water of condensation; to devise powerful steam brakes – these are some of the important details on which inventors have exercised their keenest wits. Then again the extensive inventions of the century have given rise to a great classification to designate their forms or their uses: condensing and non-condensing, high-pressure or low-pressure – the former term being applied to engines supplied with steam of 50 lbs. pressure to the square inch and upward, and the latter to engines working under 40 lbs. pressure – and the low pressure are nearly always the condensing and the high pressure the non-condensing; reciprocating and rotary – the latter having a piston attached to a shaft and revolving within a cylinder of which the axis is parallel with the axis of rotation of the piston.

Direct acting, where the piston rod acts directly upon the connecting rod and through it upon the crank, without the intervention of a beam or lever; oscillating, in which the piston rods are attached directly to the crank pin and as the crank revolves the cylinder oscillates upon trunnions, one on each side of it, through which the steam enters and leaves the steam chest.

Then as to their use, engines are known as stationary, pumping, portable, locomotive or marine.

The best-known engine of the stationary kind is the Corliss, which is very extensively used in the United States and Europe.

Among other later improvements is the duplex pumping engine, in which one engine controls the valve of the other; compensating devices for steam pumping, by which power is accumulated by making the first half of the stroke of the steam piston assist in moving the piston the other half of the stroke during the expansion of steam; steam or air hand hammers on which the piston is the hammer and strikes a tool projecting through the head into the cylinder; rock drilling, in which the movement of the valves is operated by the piston at any portion of its stroke; shaft governors, in which the eccentric for operating the engine valves is moved around or across the main or auxiliary shaft; multiple cylinders, in which several cylinders, either single or double, are arranged to co-operate with a common shaft; impact rotary, known as steam turbines, a revival in some respects of Hero's engine. And then, finally, the delicate and ingenious bicycle and automobile steam engines.

Then there are steam sanding devices for locomotives by which sand is automatically fed to the rails at the same time the air brake is applied.

Starting valves used for starting compound locomotives on ascending steep grades, in which both low and high pressure cylinders are supplied with live steam, and when the steam, exhausted from either high or low pressure cylinders into the receivers, has reached a predetermined pressure, the engine works on the compound principle. Single acting compound engines, in which two or more cylinders are arranged tandem, the steam acting only in one direction, and the exhaust steam of one acting upon the piston in the cylinder next of the series, are arranged in pairs, so that while one is acting downward the other is acting upward.

Throttle valves automatically closed upon the bursting of a pipe, or the breaking of machinery, are operated by electricity, automatically, or by hand at a distance.

Napoleon, upon his disastrous retreat from Moscow, anxious to reach Paris as soon as possible, left his army on the way, provided himself with a travelling and sleeping carriage, and with relays of fresh horses at different points managed, by extraordinary strenuous efforts day and night, to travel from Smorgoni to Paris, a distance of 1000 miles, between the 5th and 10th of December, 1812. This was at the average rate of about two hundred miles a day, or eight or nine miles an hour. It was a most remarkable ride for any age by horse conveyance.

Within the span of a man's life after that event any one could take a trip of that distance in twenty-four hours, with great ease and comfort, eating and sleeping on the car, and with convenient telegraph and telephone stations along the route by which to comunicate by pen, or word of mouth, with distant friends at either end of the journey.

If Napoleon had deemed it best to have continued his journey across the Atlantic to America he would have been compelled to pass several weeks on an uncomfortable sailing vessel. Now, a floating palace would await him which would carry him across in less than six days.

Should mankind be seized with a sudden desire to replace all the locomotives in the world by horse power it would be utterly impossible to do it. It was recently estimated that there were one hundred and fifty thousand locomotives in use on the railroads of the world; and as a fair average would give them five hundred horse power each, it will be seen that they are the equivalent of seventy-five million horses.

Space and time will not admit of minute descriptions, or hardly a mention, of the almost innumerable improvements of the century in steam. Having seen the principles on which these inventions have been constructed, enumerated the leading ones and glanced at the most prominent facts in their history, we must refer the seeker for more particulars to those publications of modern patent offices, in which each regiment and company of this vast army is embalmed in its own especial and ponderous volume.

A survey of the field will call to mind, however, the eloquent words of Daniel Webster: —

"And, last of all, with inimitable power, and with a 'whirlwind sound' comes the potent agency of steam. In comparison with the past, what centuries of improvement has this single agent compressed in the short compass of fifty years! Everywhere practicable, everywhere efficient, it has an arm a thousand times stronger than that of Hercules, and to which human ingenuity is capable of fitting a thousand times as many hands as belonged to Briareus. Steam is found triumphant in operation on the seas; and under the influence of its strong propulsion, the gallant ship,

> 'Against the wind, against the tide
> Still steadies with an upright keel.'

It is on the rivers, and the boatman may repose upon his oars; it is on highways, and exerts itself along the courses of land conveyances; it is at the bottom of mines, a thousand feet below the earth's surface; it is in the mills and in the workshops of the trades. It rows, it pumps, it excavates, it carries, it draws, it lifts, it hammers, it spins, it weaves, it prints. It seems to say to men, at least to the class of artisans: 'Leave off your manual labour, give up your bodily toil; bestow but your skill and reason to the directing of my power and I will bear the toil, with no muscle to grow weary, no nerve to relax, no breast to feel faintness!' What further improvement may still be made in the use of this astonishing power it is impossible to know, and it were vain to conjecture. What we do know is that it has most essentially altered the face of affairs, and that no visible limit yet appears beyond which its progress is seen to be impossible."

CHAPTER VIII. ENGINEERING AND TRANSPORTATION

The field of service of a civil engineer has thus been eloquently stated by a recent writer in *Chambers's Journal*:

"His duties call upon him to devise the means for surmounting obstacles of the most formidable kind. He has to work in the water, over the water, and under the water; to cause streams to flow; to check them from overflowing; to raise water to a great height; to build docks and walls that will bear the dashing of waves; to convert dry land into harbours, and low water shores into dry land; to construct lighthouses on lonely rocks; to build lofty aqueducts for the conveyance of water, and viaducts, for the conveyance of railway trains; to burrow into the bowels of the earth with tunnels, shafts, pits and mines; to span torrents and ravines with bridges; to construct chimneys that rival the loftiest spires and pyramids in height; to climb mountains with roads and railways; to sink wells to vast depths in search of water. By untiring patience, skill, energy and invention, he produces in these several ways works which certainly rank among the marvels of human power."

The pyramids of Egypt, the roads, bridges and aqueducts built by the Chinese and by Rome; the great bridges of the

Middle Ages, and especially those built by that strange fraternal order known as the "Brothers of the Bridge"; the ocean-defying lighthouses of a later period – these, and more than these, attest the fact that there were great engineers before the nineteenth century.

But the engineering of to-day is the hand-maid of all the Sciences; and as they each have advanced during the century beyond all that was imagined, or dreamed of as possible in former times, so have the labours of engineering correspondingly multiplied. No longer are such labours classified and grouped in one field, called Civil Engineering, but they have been necessarily divided into great additional new and independent fields, known as Steam Engineering, Mining Engineering, Hydraulic Engineering, Electrical Engineering and Marine Engineering. Within each of these fields are assembled innumerable appliances which are the offspring of the inventive genius of the century just closed.

We have seen how one discovery, or the development of a certain art, brings in its train and often necessitates other inventions and discoveries. The development and dedication of the steam engine to the transportation of goods and men called for improvements in the roads and rails on which the engine and its load were to travel, and this demand brought forth those modern railway bridges which are the finest examples in the art of bridge making that the world has ever seen.

The greatest bridges of former ages were built of stone and solid masonry. Now iron and steel have been substituted, and these light but substantial frameworks span wide rivers and deep ravines with almost the same speed and gracefulness that the spider spins his silken web from limb to limb. These, too, waited for their construction on that next turn in the wheel of evolution, which brought better processes in the making of iron and steel, and better tools and appliances for working metals, and in handling vast and heavy bodies.

The first arched iron bridge was over the Severn at Coalbrookdale, England, erected by Abraham Darby in 1777. In 1793 one was erected by Telford at Buildwas, and in the same year Burden completed an arch across the weir at Sunderland. The most prominent classes of bridges in which the highest inventive and constructive genius of the engineers of the century are illustrated are known as the *suspension*, the *tubular* and the *tubular arch*, the *truss and cantilever*.

Suspension bridges consisting of twisted vines, of iron chains, or of bamboo, or cane, or of ropes, have been known in different parts of the world from time immemorial, but they bear only a primitive and suggestive resemblance to the great iron cable bridges of the nineteenth century. The first notable structure of this kind was constructed by Sir Samuel Brown, across the Tweed at Berwick, England, in 1819. Brown was born in London in 1776 and died in 1852. He entered the navy at the age of 18, was made commander in 1811, and retired as captain in 1842. We have alluded to the spider's web, and Smiles, in his *Self*

Help, relates as an example of intelligent observation that while Capt Brown was occupied in studying the character of bridges with the view of constructing one of a cheap description to be thrown across the Tweed, near which he lived, he was walking in his garden one dewy autumn morning when he saw a tiny spider's web suspended across his path. The idea immediately occurred to him of a bridge of iron wires. In 1829 Brown also was the engineer for suspension bridges built over the Esk at Montrose and over the Thames at Hammersmith. Before that time, a span in a bridge of 100 feet was considered remarkably long. Suspension bridges are best adapted for long spans, and have been constructed with spans more than twice as long as any other form. Sir Samuel Brown's bridge had a span of 449 feet. This class of bridges is usually constructed with chains or cables passing over towers, with the roadway suspended beneath. The ends of the chains or cables are securely anchored. The cables are then passed over towers, on which they are supported in movable saddles, so that the towers are not overthrown by the strain on the cables. Nice calculations have to be made as to the tension to be placed on the cables, the allowance for deflection, and the equal distribution of weight. The floor-way in the earlier bridges of this type was supported by means of a series of equidistant vertical rods, and was lacking stiffness, but this was remedied by trussing the road bed, using inclined stays extending from the towers and partially supporting the roadway for some distance out from the tower.

The next finest suspension bridge was constructed by Thomas Telford and finished in 1826, across the Menai Strait to connect the island of Anglesea with the mainland of Wales. Telford was born in Dumfriesshire, Scotland, in 1757, and died in Westminster in 1834. Beginning life as a stone mason, he rose by his own industry to be a master among architects and a prince among builders of iron bridges, aqueducts, canals, tunnels, harbours and docks.

The Menai bridge was composed of chains or wire ropes, each nearly a third of a mile in length, and which descended 60 feet into sloping pits or drifts, where they were screwed to cast-iron frames embedded in the rocks. The span of the suspended central arch was 560 feet, and the platform was 100 feet above high water. Seven stone arches of 52½ feet span make up the rest of the bridge.

But a suspension bridge was completed in 1834 by M. Challey of Lyon over the Saane at Fribourg, Switzerland, which greatly surpassed the Menai bridge. The span is 880 feet from pier to pier, and the roadway is 167 feet above the river. It is supported by four iron wire cables, each consisting of 1056 wires. It was tested by placing 15 pieces of artillery, drawn by 50 horses and accompanied by 300 men crowded together as closely as possible, first at the centre, and then at each extreme, causing a depression of 39½ inches, but no sensible oscillation was experienced.

Isambard K. Brunel was another great engineer, who constructed a suspension bridge at the Isle of Bourbon in 1823, and the Charing Cross over the Thames at Hungerford in 1845, which was a footbridge, having a span of 675 feet, the longest span of any bridge in England. Then followed finer and larger suspension bridges in other parts of the world. It was across the Niagara in front of the great falls that in 1855 British America and the United States were joined by a magnificent suspension bridge, one of the finest in the world, and the two English speaking countries were then physically and commercially united. At the opening of the bridge, one portion of which was for a railway, the shriek of the locomotive and the roar of the train mingled with the roar of the wild torrent 250 feet below. The bridge, 800 feet long, is a single span, supported by four enormous cables of wire stretching from the Canadian cliff to the opposite United States cliff. The cables pass over the tops of lofty stone towers arising from these cliffs, and each cable consists of no less than 4,000 distinct wires. The roadway hangs from these cables, suspended by 624 vertical rods.

The engineer of this bridge was John A. Roebling, a native of Prussia, born there in 1806, and who died in New York in 1869. He was educated at the Polytechnic School in Berlin, and emigrated to America at the age of 25. His labors were first as a canal and railway engineer, then he became the inventor and manufacturer of a new form of wire rope, and then turned his attention to the construction of aqueducts and suspension bridges. After the Niagara bridge, above described, he commenced another bridge of greater dimensions over the same river, which was finished within two or three years. His next work was the splendid suspension bridge at Cincinnati, Ohio, which has a clear span of 1057 feet. In 1869, in connection with his son, Washington A. Roebling, he commenced that magnificent suspension bridge to unite the great cities of New York and Brooklyn, and which, by its completion, resulted in the consolidation of those cities as Greater New York. The Roeblings, father and son, were to the engineering of America what George Stephenson and his son Robert were to the locomotive and railway and bridge engineering of Great Britain.

The Brooklyn bridge, known also as the East River bridge, was formally opened to the public on the 24th of May 1883. Most enormous and unexpected technical difficulties were met and overcome in its construction. Its total length is nearly 6,000 feet. The length of the suspended structure from anchorage to anchorage is 3,454 feet. A statement of the general features of this bridge indicates the nature of the construction of such bridges as a class, and distinguishes them from the comparatively simple forms of past ages. This structure is supported by two enormous towers, having a height of 276 feet above the surface of the water, carrying at their tops the saddles which support the cables, and having a span between them of 1,595 feet. The towers are each pierced by two archways, 31½ feet wide, and 120½ feet high, through which openings passes the floor of the bridge at the height of 118 feet above high water mark.

There are four supporting cables, each 16 inches in diameter, and each composed of about 5,000 single wires. The wire is one-eighth size; 278 single wires are grouped into a rope, and 19 ropes bunched to form a cable. The iron saddles at the top of the lofty towers, and on which the cables rest, are made movable to permit its expansion and compression – and they glide through minute distances on iron rollers in saddle plates embedded and anchored in the towers, in response to strains and changes of temperature. The enormous cables pass from the towers shoreward to their anchorages 930 feet away, and which are solid masses of masonry, each 132 x 119 feet at base and top, 89 feet high, and weighing 60,000 tons. The bridge is divided into five avenues: one central one for foot passengers, two outer ones for vehicles, and the others for the street cars. The cost of the bridge was nearly $15,000,000.

Twenty fatal and many disabling accidents occurred during the construction of the bridge. The great engineer Roebling was the first victim to an accident. He had his foot crushed while laying the foundation of one of the stone piers, and died of lockjaw.

It was necessary to build up the great piers by the aid of caissons, which are water-tight casings built of timber and metal and sunk to the river bed and sometimes far below it, within which are built the foundations of piers or towers, and into which air is pumped for the workmen. A fire in one of the caissons, which necessitated its flooding by water, and to which the son, Washington Roebling, was exposed, resulted in prostrating him with a peculiar form of caisson disease, which destroyed the nerves of motion without impairing his intellectual faculties. But, although disabled from active work, Mr. Roebling continued to superintend the vast project through the constant mediation of his wife.

Tubular Bridges.– These are bridges formed by a great tube or hollow beam through the center of which a roadway or railway passes. The name would indicate that the bridge was cylindrical in form, and this was the first idea. But it was concluded after experiment that a rectangular form was the best, as it is more rigid than either a cylindrical or elliptical tube. The adoption of this form was due to Fairbairn, the celebrated English inventor and engineer of iron structures. The Menai tubular railway bridge, adjacent to the suspension bridge of Telford across the same strait, and already described, was the first example of this type of bridge. Robert Stephenson was the engineer of this great structure, aided by the suggestions of Fairbairn and other eminent engineers. This bridge was opened for railway traffic in March, 1850. It was built on three towers and shore abutments. The width of the strait is divided by these towers into four spans – two of 460 feet each, and two of 230 feet. In appearance, the bridge looked like one huge, long, narrow iron box, but it consisted really of four bridges, each made of a pair of rectangular tubes, and through one set of tubes the trains passed in going in one direction, and through the other set in going the opposite direction. These ponderous tubes were composed of wrought-iron plates, from three-eighths to three-fourths of an inch thick, the largest 12 feet in length, riveted together and stiffened by angle irons. They varied in height – the central ones being the highest and those nearest the shore the lowest. The central ones are 30 feet high, and the inner ones about 22 feet. Their width was about 14 feet. They were built upon platforms on the Caernarvon shore, and the great problem was how to lift them and put them in place, especially the central ones, which were 460 feet in length. Each tube weighed 1,800 pounds, and they were to be raised 192 feet. This operation has been described as "the grandest lift ever effected in engineering." It was accomplished by means of powerful hydraulic presses. Another and still grander example of this style of bridge is the Victoria at Montreal, Canada. This also was designed by Robert Stephenson and built under his direction by James Hodges of Montreal. Work was commenced in 1854 and it was completed in December, 1859, and opened for travel in 1860. It consists of 24 piers, 242 feet apart, except the centre one, from which the span is 330 feet. The tube is in sections and quadrangular in form. Every plate and piece of iron was made and punched in England and brought across the Atlantic. In Canada little remained to be done but to put the parts together and in position. This, however, was in itself a Herculean task. The enormous structure was to be placed sixty feet above the swift current of the broad St. Lawrence, and wherein huge masses of ice, each block from three to five feet in thickness, accumulated every winter. The work was accomplished by the erection of a vast rigid stage of timber, on which the tubes were built up plate by plate. When all was completed the great staging was removed, and the mighty tube rested alone and secure upon its massive wedge-faced piers rising from the bedrock of the flood below.

The Tubular Arch Bridge.– This differs from the tubular bridge proper, in that the former consists of a bridge the body of which is supported by a tubular archway of iron and steel, whereas in the latter the body of the bridge itself is a tube. The tubular arch is also properly classed as a girder bridge because the great tube which covers the span is simply an immense beam or girder, which supports the superstructure on which the floor of the bridge is laid. A fine illustration of this style of bridge is seen in what is known as the aqueduct bridge over Rock Creek at Washington, D. C., in which the arch consists of two cast-iron jointed pipes, supporting a double carriage and a double street car way, and through which pipes all the water for the supply of the City of Washington passes. General M. C. Meigs was the engineer.

Another far grander illustration of such a structure, in combination with the truss system, is that of the Illinois and St. Louis bridge, across the Mississippi, of which Captain James B. Eads was the engineer. There are three great spans, the central one of which has a length of about 520 feet, and the others a few feet less. Four arches form each span, each arch consisting of an upper and lower curved member or rib, extending from pier to pier, and each member composed of two parallel steel tubes.

Truss and truss arched bridges.– These, for the most part, are those quite modern forms of iron or wooden bridges in which a supplementary frame work, consisting of iron rods placed obliquely, vertically or diagonally, and cemented together, and with the main horizontal beams either above or below the same, to produce a stiff and rigid structure, calculated to resist strain from all directions.

Previous to the 19th century, the greatest bridges being constructed mostly of solid masonry piers and arches, no demand for a bridge of this kind existed; but after the use of wrought iron and steel became extensive in bridge making, and as these apparently light and airy frames may be extended, piece by piece across the widest rivers, straits, and arms of the sea, a substitute for the great, expensive, and frequent supporting piers became a want, and was supplied by the system of trusses and truss arches. The truss system has also been applied to the construction of vast modern bridges in places where timber is accessible and cheap. Each different system invented bears the name of its inventor. Thus, we have the Rider, the Fink, the Bollman, the Whipple, the Howe, the Jones, the Linville, the McCallum, Towne's lattice and other systems.

What is called the cantilever system has of late years to a great extent superseded the suspension construction. This consists of beams or girders extending out from the opposite piers at an upward diagonal angle, and meeting at the centre over the span, and there solidly connected together, or to horizontal girders, in such manner that the compression load is thrown on to the supporting piers, upward strains received at the centre, and side deflections provided against. It is supposed that greater rigidity is obtained by this means than by the suspension, and, like the suspension, great widths may be spanned without an under supporting frame work. Two fine examples of this type are found, one in a bridge across the Niagara adjacent to the suspension bridge above described and one across the river Forth at Queens Ferry in Scotland. The Niagara Bridge is a combination of cast steel and iron. It was designed by C. C. Schneider and Edmund Hayes. It was built for a double-track railroad. The total length of the bridge is 910 feet between the centres of the anchorage piers. The cantilevers rest on two gigantic steel towers, standing on massive stone piers 39 feet high. The clear span between the towers is 470 feet, and the height of the bridge, from the mad rush of waters to the car track is 239 feet.

Messrs Fowler and Baker were the engineers of the Forth railway bridge. It was begun in 1883 and finished in 1890. It is built nearly all of steel, and is one of the most stupendous works of the kind. It crosses two channels formed by the island of Inchgarvie, and each of the channel spans is 1710 feet in the clear and a clear headway of 150 feet under the bridge. Three balanced cantilevers are employed, poised on four gigantic steel tube legs supported on four huge masonry piers. The height of the bridge above the piers is 330 feet. The cantilever portion has the appearance of a vast elongated diamond. Steel lattice work of girders, forms the upper side of the cantilever, while the under side consists of a hollow curve approaching in form a quadrant of a circle drawn from the base of the legs or struts to the ends of the cantilever.

Such is the growth of these great bridges with their tremendous spans across which man is spinning his iron webs, that when seen at night with a fiery engine pulling its thundering train across in the darkness, one is reminded of Milton's description, "over the dark abyss whose boiling gulf tamely endured a bridge of wondrous length, from Hell continued, reaching the utmost orb of this frail world."

The *lighthouses* of the century, in masonry, do not greatly excel in general principles those of preceding ones, as at Eddystone, designed by Smeaton. Nicholas Douglass, however, invented a new system of dovetailing, and great improvements have been made in the system of illuminating.

Lighthouses are also distinguished from those of preceding centuries by the substitution of iron and cast steel for masonry. The first cast-iron lighthouse was put up at Point Morant, Jamaica, in 1842. Since then they have taken the form of iron skeleton towers.

One of the latest and most picturesque of lighthouses is that of Bartholdi's statue of Liberty enlightening the world, the gift of the French government to the United States, framed by M. Eiffel, the great French engineer, and set up by the United States at Bedloe's Island in New York harbor. It consists of copper plates on a network of iron. Although the statue is larger than any in the world of such composite construction, its success as a lighthouse is not as notable as many farther seaward.

In *excavating*, *dredging* and *draining*, the inventions of the century have been very numerous, but, like numerous advances in the arts, such inventions, so far as great works are concerned, have developed from and are closely related to steam engineering.

The making of roads, railroads, canals and tunnels has called forth thousands of ingenious mechanisms for their accomplishment. A half dozen men with a steam-power excavator or dredger can in one day perform a greater extent of work than could a thousand men and a thousand horses in a single day a few generations ago.

An excavating machine consisting of steel knives to cut the earth, iron scoops, buckets and dippers to scoop it up, endless chains or cranes to lift them, actuated by steam, and operated by a single engineer, will excavate cubic yards of earth by the minute and at a cost of but a few dollars a day.

Dredging machines of a great variety have been constructed. Drags and scoops for elevating, and buckets, scrapers and shovels, and rotating knives to first loosen the earth, suction pumps and pipes, which will suck great quantities of the loosened earth through pipes to places to be filled – these and kindred devices are now constantly employed to dig and excavate, to deepen and widen rivers, to drain lands, to dig canals, to make harbours, to fill up the waste places and to make courses for water in desert lands.

Inventions for the excavating of clay, piling and burning it in a crude state for ballast for railways, are important, especially for those railways which traverse areas where clay is plentiful, and stones and gravel are lacking.

Sinking shafts through quicksands by artificially freezing the sand, so as to form a firm frozen wall immediately around the area where the shaft is to be sunk, is a recent new idea.

Modern countries especially are waking up to the necessity of good roads, not only as a necessary means of transportation, but as a pre-requisite to decent civilisation in all respects. And, therefore, great activity has been had in the last third of a century in invention of machines for finishing and repairing roads.

In the matter of sewer construction, regarded now so necessary in all civilised cities and thickly-settled communities as one of the means of proper sanitation, great improvements have been made in deep sewerage, in which the work is largely performed below the surface and with little obstruction to street traffic.

In connection with excavating and dredging machines, mention should be made of those great works in the construction of which they bore such important parts, as drainage and land reclamation, such as is seen in the modern extensions of land reclamation in Holland, in the Haarlem lake district in the North part of England, the swamps of Florida and the drainage of the London district; in modern tunnels such as the Hoosac in America and the three great ones through the Alps: the Mont Cenis, St. Gothard, and Arlberg, the work in which developed an entirely new system of engineering, by the application of newly-discovered explosives for blasting, new rock-drilling machinery, new air-compressing machines for driving the drill machines and ventilating the works, and new hydraulic and pumping machinery for sinking shafts and pumping out the water.

The great canals, especially the Suez, developed a new system of canal engineering. Thus by modern inventions of devices for digging and blasting, dredging and draining and attendant operations, some of the greatest works of man on earth have been produced, and evinced the exercise of his highest inventive genius.

If one wishes an ocular demonstration of the wonders wrought in the 19th century in the several domains of engineering, let him take a Pullman train across the continent from New York to San Francisco. The distance is 3,000 miles and the time is four days and four nights. The car in which the passenger finds himself is a marvel of woodwork and upholstery – a description of the machinery and processes for producing which belongs to other arts. The railroad tracks upon which the vehicle moves are in themselves the results of many inventions. There is the width of the track, and it was only after a long and expensive contest that countries and corporations settled upon a uniform gauge. The common gauge of the leading countries and roads is now 4 feet 8½ inches. A greater width is known as a broad gauge, a less width as a narrow gauge. Then as to the rail: first the wooden, then the iron and now the steel, and all of many shapes and weights. The T-rail invented by Birkensaw in 1820, having two flanges at the top to form a wide berth for the wheels of the rolling stock, the vertical portion gripped by chairs which are spiked to the ties, is the best known. Then the frogs, a V-shaped device by which the wheels are guided from one line of rails to another, when they form angles with each other; the car wheel made with a flange or flanges to fit the rail, and the railway gates, ingenious contrivances that guard railway crossings and are operated automatically by the passing trains, but more commonly by watchmen. The car may be lighted with electricity, and as the train dashes along at the rate of 30 to 80 miles an hour, it may be stopped in less than a minute by the touch of the engineer on an air brake. Is it midwinter and are mountains of snow encountered? They disappear before the railway snow-plough more quickly than they came. It passes over bridges, through tunnels, across viaducts, around the edges of mountain peaks, every mile revealing the wondrous work of man's inventive genius for encompassing the earth with speed, safety and comfort. Over one-half million miles of these railway tracks are on the earth's surface to-day!

Not only has the railway superseded horse power in the matter of transportation to a vast extent, but other modes of transportation are taking the place of that useful animal. The old-fashioned stage coach, and then the omnibus, were successively succeeded by the street car drawn by horses, and then about twenty years ago the horse began to be withdrawn from that work and the cable substituted.

Cable transportation developed from the art of making iron wire and steel wire ropes or cables. And endless cables placed underground, conveyed over rollers and supported on suitable yokes, and driven from a great central power house, came into use, and to which the cars were connected by ingeniously contrived lever grips – operated by the driver on the car. These great cable constructions, expensive as they were, were found more economical than horse power. In fact, there is no modernly discovered practical motive power but what has been found less expensive both as to time and money than horse power. But the cable for this purpose is now in turn everywhere yielding to electricity, the great motor next to steam. The overhead cable system for the transportation of materials of various descriptions in carriers, also run by a central motor, is still very extensively used. The cable plan has also been tried with some success in the propelling of canal boats.

Canals, themselves, although finding a most serious and in some localities an entirely destructive rival in the railroad, have grown in size and importance, and in appliances that have been substituted for the old-style locks. The latest form of this device is what is known as the pneumatic balance lock system.

It has been said by Octave Chanute that "Progress in civilisation may fairly be said to be dependent upon the facilities for men to get about, upon their intercourse with other men and nations, not only in order to supply their mutual needs cheaply, but to learn from each other their wants, their discoveries and their inventions." Next to the power and means for moving people, come the immense and wonderful inventions for lifting and loading, such as cranes and derricks, means for coaling ships and steamers, for handling and storing the great agricultural products, grain and hay, and that modern wonder, the *grain elevator*, that dots the coasts of rivers, lakes and seas, receives the vast stores of golden grain from thousands of steam cars that come to it laden from distant plains and discharges it swiftly in mountain loads into vessels and steamers to be carried to the multitudes across the seas, and to satisfy that ever-continuing cry, "Give us this day our daily bread."

CHAPTER IX.
ELECTRICITY

In 1900 the real nature of electricity appears to be as unknown as it was in 1800.

Franklin in the eighteenth century defined electricity as consisting of particles of matter incomparably more subtle than air, and which pervaded all bodies. At the close of the nineteenth century electricity defined as "simply a form of energy which imparts to material substances a peculiar state or condition, and that all such substances partake more or less of this condition."

These theories and the late discovery of Hertz that electrical energy manifests itself in the form of waves, oscillations or vibrations, similar to light, but not so rapid as the vibrations of light, constitute about all that is known about the nature of this force.

Franklin believed it was a single fluid, but others taught that there were two kinds of electricity, positive and negative, that the like kinds were repulsive and the unlike kinds attractive, and that when generated it flowed in currents.

Such terms are not now regarded as representing actual varieties of this force, but are retained as convenient modes of expression, for want of better ones, as expressing the conditions or states of electricity when produced.

Electricity produced by friction, that is, developed upon the surface of a body by rubbing it with a dissimilar body, and called frictional or static electricity, was the only kind produced artificially in the days of Franklin. What is known as galvanism, or animal electricity, also takes its date in the 18th century, to which further reference will be made. Since 1799 there have been discovered additional sources, among which are voltaic electricity, or electricity produced by chemical action, such as is manifested when two dissimilar metals are brought near each other or together, and electrical manifestations produced by a decomposing action, one upon the other through a suitable medium; inductive electricity, or electricity developed or induced in one body by its proximity to another body through which a current is flowing; magnetic electricity, the conversion of the power of a magnet into electric force, and the reverse of this, the production of magnetic force by a current of electricity; and thermal electricity, or that generated by heat. Electricity developed by these, or other means in contra-distinction to that produced by friction, has been called dynamic; but all electric force is now regarded as dynamic, in the sense that forces are always in motion and never at rest.

Many of the manifestations and experiments in later day fields which, by reason of their production by different means, have been given the names of discovery and invention, had become known to Franklin and others, by means of the old methods in frictional electricity. They are all, however, but different routes leading to the same goal. In the midst of the brilliant discoveries of modern times confronting us on every side we should not forget the honourable efforts of the fathers of the science.

We need not dwell on what the ancients produced in this line. It was a single fact only: – The Greeks discovered that amber, a resinous substance, when rubbed would attract lighter bodies to it.

In 1600 appeared the father of modern electricity – Dr. Gilbert of Colchester, physician to Queen Elizabeth. He revived the one experiment of antiquity, and added to it the further fact that many substances besides amber, when rubbed, would manifest the same electric condition, such as sulphur, sapphire, wax, glass and other bodies. And thus he opened the field of electrodes. He was the first to use the terms, electricity, electric and electrode, which he derived from the word *elektron*, the Greek name for amber. He observed the actions of magnets, and conjectured the fundamental identity of magnetism and electricity. He arranged an electrometer, consisting of an iron needle poised on a pivot, by which to note the action of the magnet. This was about the time that Otto von Guericke of Magdeburg, Germany, was born. He became a "natural" philosopher, and for thirty-five years was burgomaster of his native town. He invented the air-pump, and he it was who illustrated the force of atmospheric pressure by fitting together two hollow brass hemispheres which, after the air within them had been exhausted, could not be pulled apart. He also invented a barometer, and as an astronomer suggested that the return of comets might be calculated. He invented and constructed the first machine for generating electricity. It consisted of a ball of sulphur rotated on an axis, and which was electrified by friction of the hand, the ball receiving negative electricity while the positive flowed through the person to the earth. With this machine "he heard the first sound and saw the first light in artificially excited electricity." The machine was improved by Sir Isaac Newton and others, and before the close of that century was put into substantially its present form of a round glass plate rotated between insulated leather cushions coated with an amalgam of tin and zinc, the positive or vitreous electricity thus developed being accumulated on two large hollow brass cylinders with globular ends, supported on glass pillars. Gray in 1729 discovered the conductive power of certain substances, and that the electrical influence could be conveyed to a distance by means of an insulated wire. This was the first step towards the electric telegraph.

Dufay, the French philosopher and author, who in 1733-1737 wrote the *Memoirs of the French Academy*, was, it seems, the first to observe electrical attractions and repulsions; that electrified resinous substances repelled like substances while they attracted bodies electrified by contact with glass; and he, therefore, to the latter applied the term *vitreous* electricity and to the former the term *resinous* electricity. In 1745 Prof. Muschenbroeck of Leyden University developed the celebrated Leyden jar. This is a glass jar coated both inside and outside with tinfoil for about four-fifths of its height. Its mouth is closed with a cork through which is passed a metallic rod, terminating above in a knob and connected below with the inner coating by a chain or a piece of tinfoil. If the inner coating be connected with an electrical machine and the outer coating with the earth, a current of electricity is established, and the inner coating receives what is called a positive and the outer coating a negative charge. On connecting the two surfaces by means of a metallic discharger having a non-conducting handle a spark is obtained. Thus the Leyden jar is both a collector and a condenser of electricity. On arranging a series of such jars and joining their outer and inner surfaces, and connecting the series with an electrical machine, a battery is obtained of greater or less power according to the number of jars employed and the extent of supply from the machine.

The principle of the Leyden jar was discovered by accident. Cuneus, a pupil of Muschenbroeck, was one day trying to charge some water in a glass bottle with electricity by connecting it with a chain to the sparking knob of an electrical machine. Holding the bottle in one hand he arranged the chain with the other, and received a violent shock. His teacher then tried the experiment himself, with a still livelier and more convincing result, whereupon he declared that he would not repeat the trial for the whole Kingdom of France.

When the science of static electricity was thus far developed, with a machine for generating it and a collector to receive it, many experiments followed. Charles Morrison in 1753, in the *Scots Magazine*, proposed a telegraph system of insulated wires with a corresponding number of characters to be signalled between two stations. Other schemes were proposed at different times down to the close of the century.

Franklin records among several other experiments with frictional electricity accumulated by the Leyden jar battery the following results, produced chiefly by himself: The existence of an attractive and a repulsive action of electricity; the restoration of the equilibrium of electrical force between electrified and non-electrified bodies, or between bodies differently supplied with the force; the electroscope, a body charged with electricity and used to indicate the presence and condition of electricity in another body; the production of work, as the turning of wheels, by which it was proposed a spit for roasting meat might be formed, and the ringing of chimes by a wheel, which was done; the firing of gunpowder, the firing of wood, resin and spirits; the drawing off a charge from electrified bodies at a near distance by pointed rods; the heating and melting of metals; the production of light; the magnetising of needles and of bars of iron, giving rise to the analogy of magnetism and electricity.

Franklin, who had gone thus far, and who also had drawn the lightning from the clouds, identified it as electricity, and taught the mode of its subjection, felt chagrined that more had not been done with this subtle agent in the service of man. He believed, however, that the day-spring of science was opening, and he seemed to have caught some reflection of its coming light. Observing the return to life and activity of some flies long imprisoned in a bottle of Madeira wine and which he restored by exposure to the sun and air, he wrote that he should like to be immersed at death with a few friends in a cask of Madeira, to be recalled to life a hundred years thence to observe the state of his country. It would not have been necessary for him to have been embalmed that length of time to have witnessed some great developments of his favorite science. He died in 1790, and it has been said that there was more real progress in this science in the first decade of the nineteenth century than in all previous centuries put together.

Before opening the door of the 19th century, let us glance at one more experiment in the 18th:

While the aged Franklin was dying, Dr Luigi Galvani of Bologna, an Italian physician, medical lecturer, and learned author, was preparing for publication his celebrated work, *De viribus Electricitatis in Motu Musculari Commentarius*, in which he described his discovery made a few years before of the action of the electric current on the legs and spinal column of a frog hung on a copper nail. This discovery at once excited the attention of scientists, but in the absence of any immediate practical results the multitude dubbed him the "frog philosopher." He proceeded with his experiments on animals and animal matter, and developed the doctrine and theories of what is known as animal or galvanic electricity. His fellow countryman and contemporary, Prof. Volta of Pavia, took decided issue with Galvani and maintained that the pretended animal electricity was nothing but electricity developed by the contact of two different metals. Subsequent investigations and discoveries have established the fact that both theories have truth for their basis, and that electricity is developed both by muscular and nervous energy as well as by chemical action. In 1799 Volta invented his celebrated pile, consisting of alternate disks of copper and zinc separated by a cloth moistened with a dilute acid; and soon after an arrangement of cups – each containing a dilute acid and a copper and a zinc plate placed a little distance apart, and thus dispensing with the cloth. In both instances he connected the end plate of one kind with the opposite end plate of the other kind by a wire, and in both arrangements produced a current of electricity. To the discoveries, experiments, and disputes of Galvani and Volta and to those of their respective adherents, the way was opened to the splendid electrical inventions of the century, and the discovery of a new world of light, heat, speech and power. The discoveries of Galvani and Volta at once set leading scientists at work. Fabroni of Florence, and Sir Humphry Davy and Wollaston of England, commenced interesting experiments, showing that rapid oxidation and chemical decomposition of the metals took place in the voltaic pile.

Конец ознакомительного фрагмента.