NTION

The Master-Key to Progress

Rear-Admiral BRADLEY A. FISKE, LL.D.


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INVENTION, THE MASTER-KEY TO PROGRESS

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BY

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PREFACE

TO show that inventors have accomplished more than most persons realize, not only in bringing forth new mechanisms, but in doing creative work in many walks of life, is, in part, the object of this book. To suggest what they may do, if properly encouraged, is its main intention. For, since it is to inventors mainly that we owe all that civilization is, it is to inventors mainly that we must look for all that civilization can be made to be.

The mind of man cannot even conceive what wonders of beneficence inventors may accomplish: for *the resources of invention are infinite.*

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CHAPTER I

INVENTION IN PRIMEVAL TIMES

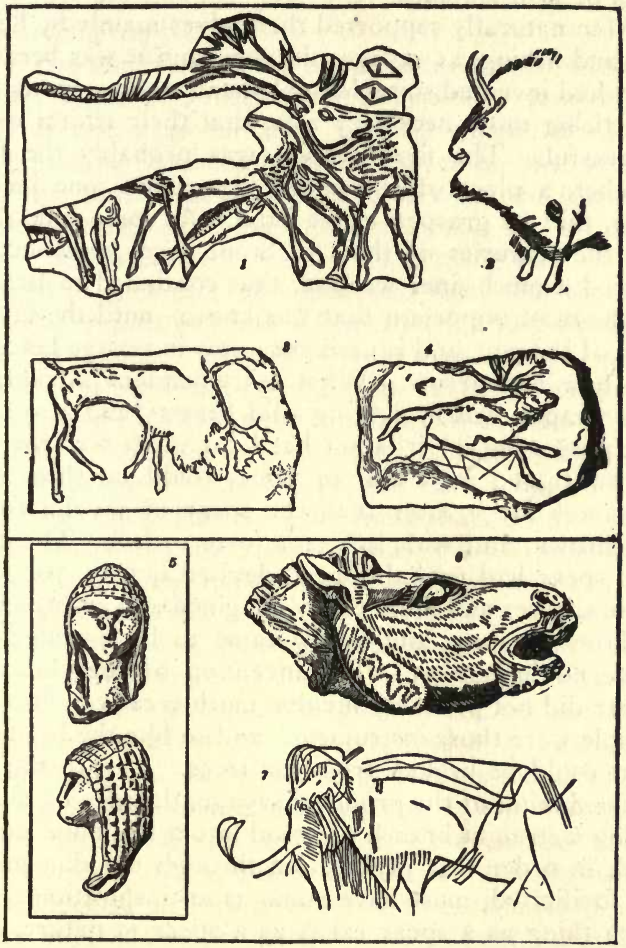
OUR original ancestors dwelt in caves and wildernesses; had no sewed or fabricated clothing of any kind; subsisted on roots and nuts and berries; possessed no arts of any sort; were ignorant to a degree that we cannot imagine, and were little above the brutes in their mode of living. Today, a considerable fraction of the people who dwell upon the earth enjoy a civilization so fine that it seems to have no connection with the brutish conditions of primeval life. Yet, as these pages show, a perfectly plain series of inventions can be seen, starting from the old conditions and building up the new.

The progress of man during the countless ages of prehistoric times is hidden from our knowledge, except in so far as it has been revealed to us by ruins of ancient cities, by prehistoric utensils of many kinds, and by inscriptions carved on monuments and tablets. The sharp dividing line between prehistoric times and historic times, seems to be that made by the art of writing; for this epochal invention rendered possible the recording of events, and the consequent beginning of history.

Of prehistoric times we have, of course, no written record; and we have but the most general means of estimating how many millenniums ago man first had his being. Geological considerations indicate a beginning so indefinitely and exceedingly remote that the imagination may lose itself in speculations as to his mode of living during those forever-hidden centuries that dragged along, before man had advanced so far in his progress toward civilization as to make and use the rude utensils which the researches of antiquarians have revealed.

Inasmuch as the most important employment of man from his first breath until his last has always been the struggle to preserve his life; inasmuch as the endeavor of primeval man to defend himself against wild beasts must have been extremely bitter (for many were larger and stronger than he), and inasmuch as man eventually achieved the mastery over them, one seems forced to conclude that man overcame wild beasts by employing some means to assist his bodily strength, and that probably his first invention was a weapon.

The first evidences of man's achievements that we have are rude implements of stone and flint, evidently shaped by some force guided by some intelligence;—doubtless the force of human hands, guided by the intelligence of human minds. Many such have been found in caves and gravel-beds over all the world. They were rough and crude, and indicate a rough and crude but nevertheless actual stage of civilization. Some call this the Old Stone Age and others call it the Early Stone Age. Besides stone and flint, bones, horns and tusks were used. Among the implements made were daggers, fish-hooks, needles, awls and heads of arrows and harpoons. One of the most interesting revelations of those rude and immeasurably ancient implements is the fact that man, even in those times, possessed the artistic sense; for on some of them can be



Carvings in Ivory (1 and 3-7) and in Stone of Cavern Walls (2), made by the Hunters of the Middle Stone Age seen rough but clear engravings of natural objects, and even of wild animals.

Men naturally supported themselves mainly by hunting and fishing, as savages do now; and it was because they had invented suitable implements and weapons for practicing those necessary arts, that their efforts were successful. The first weapon was probably the fist-hatchet, a piece of sharpened flint about nine inches long, that he grasped in his hand. At some time during the centuries of the Old Stone Age, someone invented a much finer weapon, that continued to be one of the most important that was known, until the invention of the gun, and is used even now in savage lands—the bow and arrow. What a tremendous advantage this weapon was in fighting wild beasts (and also men not possessing it) it is not hard for us to see; for the arrow tipped with flint or bone, could be shot over distances far greater than the spear or javelin could be thrown, and with sufficient force to kill. The club and spear had probably been devised before, for they were simpler and more easily imagined and constructed.

How the bow and arrow came to be invented we have no intimation. The invention of the club and spear did not probably involve much creative effort, so simple were those instruments, and so like the branches that could be broken from the trees. Yet, to the untrained mind of the primeval savage, the idea of sharpening a straight branch of wood into a fine point at the end, in order that penetration through the skin might be facilitated, must have come as an inspiration. No such thing as a spear exists as a spear in nature, and therefore the making of a spear was a creative act. To us, the use of the spear as a projectile may not seem to have required the inventive faculty—unless the hurling of stones may also be supposed to have required it. It may be, however, that with the dull mind of primeval men, even the idea of using stones or javelins as projectiles was the result of a distinct, and perhaps startling inspiration.

The invention of the bow and arrow was one of the first order of brilliancy, and would be so even now. It is not easy to think of any simple accident as accounting for the invention; because the bow and arrow consists of three entirely independent parts—the straight bar of wood, the string, and the arrow; for the bow was not a bow until the string had been fastened to each end, and drawn so tight that the bar of wood was forced into a bent shape, and held there at great tension. When one realizes this, and realizes in addition the countless centuries during which the bow and arrow held its sway, the millions of men who have used it, and the important effect it has had in the overcoming of wild beasts, and the deciding of many of the critical battles of the world, he can hardly escape the conclusion that the invention of the bow and arrow was one of the most important occurrences in the history of mankind.

A still more important occurrence was the invention of making fire. Probably less inventive effort was needed for this than for the bow and arrow; for fire could be seen in the lightning and in trees struck by lightning, and in the sparks that came forth when two hard stones were struck together. The discovery of fire may have been made by accident; but this does not mean that no invention was needed for devising and producing the means whereby fire could be produced at will. To note the fact of a phenomenon, say the production of fire when stones are accidentally struck together, or the falling of an apple from a tree, requires no special effort, and of itself brings forth no benefit; but to reason from the appearance of the sparks to the production of an apparatus for making fire at will; or to reason from the falling of an apple to the enunciation of Newton's Law of Gravitation, is the kind of successful mental effort that has produced the effects which it is the endeavor of this humble book to indicate. These effects have combined as progress has advanced, to put civilized man in a position relatively to his natural surroundings very different from that held by primeval man, and very different from that held by the brutes, both in primeval days and now. Evidently, the effects have been made possible by some faculty possessed by man and not by brutes. This faculty is usually called reason, and is held to be a faculty by means of which man can infer cause from effect, and effect from cause, and can remember events and facts to a degree sufficient to enable him to hold them in his mind, while reasoning about them.

But it seems impossible to explain the advent of even the oldest and simplest inventions by the possession of reason only, using the word reason in its ordinary sense; for it is obvious that no matter how clearly a man could reason as between cause and effect, no matter how great a student of all phenomena he might be, no matter how good a memory he might have, he might nevertheless live for many years and never invent anything. In fact, we see men at the present day who possess great knowledge, splendid energy, keen powers of analysis, high courage, and even great administrative talent, and yet who are obviously deficient in originality, who seem to possess the constructive faculty in only a small degree, and who seem incapable of taking any step forward except on paths that have been plainly trod before.

Countless instances can be cited of the persistence of men, even in civilized lands, in following a certain practice for long periods, until someone possessing the inventive faculty has devised a better one. For the sake of brevity, only two cases, and those well known, will be mentioned as illustrative. One was the invention of movable type, and the other that of pointing the wood screw. Man had continued for centuries to make blocks of wood or other material on which words and phrases were engraved or cut, and then to print from them. Suddenly a man in Germany (usually said to be John Guttenberg) made the change, so slight in appearance and yet so tremendous in results, of cutting only one letter on a block, and arranging and securing the blocks in such a way as to enable him to print any word or words desired. This did not occur until about the year 1434 A. D. Why had not someone done this in all the long centuries? Surely it was not because men of great reasoning faculties had not lived; for in the long interval the civilization of Egypt, Assyria, Babylon, Persia, Greece and Rome had flourished; and Plato, Aristotle, Cæsar and the great inventor Archimedes had lived! Similarly, men continued to use in wood the same flat pointed screw that they used in metals, boring the hole first in the wood with a gimlet, and then entering the flat point of the screw into the hole. Suddenly (but not until the nineteenth century A. D.) an inventor made and patented a screw which came to a sharp point like a gimlet, which could be forced into wood just as the gimlet was, and then screwed into the wood without further ado. How can we explain the curious fact that countless men of reason, intelligence and mechanical skill had continued century after century to bore into wood with gimlets, and then follow the gimlet with flat-pointed screws?

The explanation seems to be expressed in the phrase, "the idea had not occurred to them." Why had it not occurred to them? This question cannot, of course, be answered convincingly; but it may be pointed out that there is a small class of men to whom original ideas seem to come of their own accord. The inventor of mechanical appliances is in this class, and is perhaps its most conspicuous exemplar.

It may be pointed out, however, that the inventors of mechanical appliances are not the only men to whom original conceptions come; for original conceptions evidently come to the poets, the novelists, the musical composers, the artists, the strategists, the explorers, the statesmen, the philosophers, the founders of religions and the initiators of all enterprises great and small. It may be pointed out also that their mental processes are similar, and that they are best described by the greatest of all poets in the lines—

"The poet's eye in a fine frenzy rolling,
Glances from heaven to earth, from earth to heaven;
And as imagination bodies forth
The forms of things unknown, the poet's pen
Turns them to shapes, and gives to airy nothing
A local habitation and a name."

These lines suggest that the first step in invention is made almost without effort; that a picture, confused and dim but actual, is made by the imagination on the mental retina; and that, after that, the constructive faculties arrange the elements of the picture in such wise as to produce a clear and definite entity.

Regarded in this way, the inventor of mechanical appliances suddenly sees a confused and dim picture of an instrument or a mechanism (or a part of it) that he has never seen with his bodily eyes; the musical composer hears imperfectly and vaguely a new musical composition; the sculptor sees a statue, the painter sees a new combination of objects and colors producing a new effect, and the poet feels the stirring in him of vague, but beautiful, or powerful or inspiring thoughts.

If now the picture is allowed to fade, or if the constructive faculty is not able to make it into an actuality, or if the picture has not in itself the elements which the state of civilization then prevailing make it possible to embody in an entity, no invention of a mechanical appliance is made, no plan of campaign, no musical composition, no statue, no painting, no poem is produced.

If, however, the constructive effort develops successfully the conception that the imagination made, and if the circumstances of time and place are all propitious, then the art of making fire at will is born, or Bonaparte's suggestion at Toulon is made, or the strains of Beethoven's music inspire the world, or the statue of Moses is carved, or the Immaculate Conception is pointed, or Hamlet is written, or the electric telegraph binds the peoples of the earth together.

The inventor in mechanics, the sculptor, the painter, the novelist and the poet embody their creations in material forms that are enduring and definite, and constitute evidences of their work, which sometimes endure throughout long periods. The architect and the constructing engineer are able similarly to produce lasting and useful monuments to their skill; but it can hardly be declared that their work is characterized by quite so much of originality and invention, because of the restrictions by which the practice of their arts is bound. It is, in fact, hard to conceive of a bridge very different in principle or design from bridges that had been built before; and while it is not difficult to conceive of an engine different in principle and design from previous ones, yet we realize that the points of novelty in such an engine would be attributable more to invention than to engineering. This is because the arts of engineering and architecture rest on principles that have long since been proved to be correct, and on practices that are the results of long experience; whereas one of the main characteristics of invention is novelty.

It is true that many of the most important inventions have been made by engineers; but this has been because some engineers, like Ericsson, have been inventors also. But it is also true that only a small proportion of the engineers have made original inventions; and it is equally true that many inventions have failed—or have been slow in achieving success—because of lack of engineering skill in construction or design. These facts show that the work of the inventor is very different from that of the engineer, and that the inventor and the engineer are very different people, though an engineer and an inventor sometimes live together inside of the same skin. In fact, it is by a combination of inventive genius and engineering talent in one man that the greatest results in invention have been achieved; though great results have often followed the intimate cooperation of an inventor and an engineer, the two being separate men.

It is in the latter way that important advances have usually been made; and it is somewhat analogous to the way in which authors and publishers, actors and managers, promoters and capitalists cooperate.

But while the individuals whose inventions have taken the form of new creations, such as novel machines and books and paintings, have received the clearest recognition as men of genius, may not the inventive faculty be needed in other fields and be required in other kinds of work? If an instrument is produced by the joint exercise of imagination and constructive talent, is not every puzzle worked out, and every problem solved, and every constructive work accomplished by the similar exercise of those same faculties?

It may seem obvious that this question should be answered in the negative, and so it unquestionably should be. But there always has been much cloudiness as to what constitutes invention in our own minds; and it must be admitted that the dividing line is not immediately obvious between invention and the art of meeting difficulties with resourcefulness, or between invention and the act of solving any of the perplexing riddles of our daily lives.

It may be declared with confidence, however, that the difference between invention and any one of these other acts is that, while invention ends in performing such acts, it begins with an exercise of the imagination. A man who designs an engine to fulfil a stated purpose, who solves any problem whatever that is presented to him from outside, simply accomplishes a task that is given to him to accomplish; whereas, while the inventor accomplishes a similar task, he does it as a second step in a task that was not given him to accomplish, but that he himself had pictured to himself. The act of inventing consists of three separate acts—the act of conceiving, the act of developing, and the act of producing. Of these three acts, that of conceiving is obviously not only the first, but also the most important, distinctive and unusual.

For every real invention, there have been countless constructive acts. In the invention of the bow and arrow, the conception was probably instantaneous and unbidden. The subsequent work of developing the conception into material and practical shape was probably one of long duration, consisting of many acts, accompanied with many difficulties and disappointments, and accomplished finally in the face of much active and passive opposition.

The Old Stone Age gradually developed into the New Stone Age at different times in different localities, as successive improvements in implements were made. The New Stone Age was distinguished from its predecessor mainly by the fact that the principal weapons and utensils were formed into regular shapes, polished into smoothness, and in many cases ground to sharp points and keen cutting edges. These improvements made the implements more effective both as weapons and as utensils, by facilitating not only cutting but penetration.

How much invention was needed to make these improvements, it is not easy to decide; but probably only a little was required, and that of an order not very original or high; for the improvements were rather in detail than principle. Perhaps their character can be best indicated by saying that they were improvements, rather than inventions of a basic kind.

It may here be pointed out that the act of improving upon an invention already existing may be almost wholly a constructive act, performed on a visible and tangible material object, and not on a picture made by the imagination on the mind. In such a case, the act of improving belongs rather in the category of engineering than of invention, for the reason that it involves only a slight use of the imagination. It may also be pointed out, however, that a mere improvement may be, and sometimes has been an invention of the highest order. As a rule, of course, basic inventions have been the most brilliant and also the most important.

But it was not only by polished instruments of stone and bone that the New Stone Age was characterized; for we find in the records which our ancestors unintentionally left us, many evidences that they had invented the arts of making pottery, of spinning and weaving, and of constructing houses of a simple kind. This Age was characterized by many improvements besides those relating to articles of stone, and was a period far in advance of its predecessor on the march to civilization. It was marked by the domestication of animals and plants, the tilling of the soil, and a gradual change from a purely savage and nomadic mode of life. This change was first to a pastoral life, in which men lived in fixed habitations and tended their flocks; thence to an agricultural life, in which men cultivated the ground over large areas and grew crops of cereals and vegetables; and then to a still more settled existence, in which men congregated in villages and towns. Certainly, the race had taken the first steps, and had started on the path which it has since pursued.

In order to make the start and to proceed afterwards in the line begun, many physical, mental and spiritual attributes were needed and employed, that mere brutes did not possess, and because of which the civilization of the Old Stone Age had been begun and gradually developed. Of these faculties, those principally characteristic seem to have been mental; and among those faculties, invention, reason, construction and memory seem to have been the most important. It would be unreasonable to declare any one of those faculties to have been more important than the others; but it can hardly be denied that the first steps in the march of progress should be credited to invention. Clearly, it was the weapons and utensils of the Old Stone Age that made possible the subduing and subsequent domestication of certain animals, such as the horse, the cow, the dog, the sheep and the goat.

It may be pointed out, in passing, that many animals have not been domesticated even at this late day—such as the tiger, the eagle and the bear. But, equally, certain tribes of men have not been domesticated. It may be that in both the undomesticated men and the undomesticated brutes, the mind is of such a character that it cannot assimilate even the first grains of knowledge, or make any effort whatever of an inventive character.

There was one invention that was probably made in the Old Stone Age, which must have needed considerable inventiveness to be developed as highly as it was developed during the Old and New Stone Ages, and that was language. The origin of language is, of course, hidden in the impenetrable mystery of the childhood of the race; and it may be that language was an original attribute of man. If we reason, however, that the development of language must have been a continuing act from the first, inferring it from the fact that it has been a continuing act from the dawn of recorded history until now, and if we suppose that it had a rise and a growth like those of other arts, we may reasonably conclude that some man invented the plan of making his wants known by the use of vocal sounds, uttered in accordance with a preconcerted code; that the invention was only partially successful at first, and that it was afterwards improved. That language was not a natural gift, but rather the result of an invention and subsequent development, is suggested by the fact that a child has to be taught to speak, but does not have to be taught to exercise his natural functions, such as breathing, eating, drinking, walking, etc.

Which was the first invention ever made by man, there is, of course, no means of ascertaining; but it seems obvious that that of language must have been among the first. The invention of weapons we may easily imagine to have been actually the first, called for by the necessity of defense against wild beasts and other men. Following the defense by individual men of their individual lives, it seems logical to suppose that a man and his wife, a man and his brother, and then groups of men, banded together in their common defense against common foes. To further their joint action, what would be more valuable than a language consisting of vocal sounds, arranged in accordance with a simple code, as a means of conveying information, issuing warnings, and giving signals in emergencies, to insure concerted action?

That language should later be used for manifold other purposes would be most natural; for many other arts have been invented primarily to further man's first aim, the preservation of his life, and have afterwards been employed for other purposes. The uses of clothing, houses, knives, guns and of nearly all weapons are cases in point.

The New Stone Age seems to have passed gradually into the Age of Copper, because doubtless of a more or less accidental discovery when native copper was seen upon the ground, or when some copper ore was subjected to fire. The metal, by reason of its great durability, ductility, elasticity and strength, came to be used for many purposes—the first use being probably in weapons; for weapons were the main dependence of the people in their struggle against beasts.

A great advance was made when bronze was discovered, with which weapons and tools of many kinds could be made that were harder than those of copper. Then the Age of Bronze succeeded the Age of Copper. One can hardly imagine that bronze was really invented; for it is difficult to see how, knowing the softness of copper and tin, any primeval man could have imagined a metal made from them much harder than either, and then proceeded to make it by mixing about seven parts of copper with one part of tin. The gradual improvement made in bronze implements, and the different kinds of bronze that later appeared (made by altering the proportions of tin and copper) were doubtless due more to constructive and engineering methods than to pure invention; but nevertheless a considerable amount of inventing must have been required; for one can rarely effect any important improvement in any weapon, instrument or tool, without first imagining the improvement, and then endeavoring to effect it.

In fact, an overwhelming majority of the "inventions" for which patents are issued by our Patent Office, are for mere improvements over existing apparatus; and the bald fact that the thing accomplished is only such an improvement, instead of the creation of something different from everything else whatever, like the telephone or phonograph, does not debar the achievement from being classed as an invention. The pointed screw was merely an improvement over previous forms of screw, and yet it was an invention of high originality, novelty and importance. Obviously, improvements occupy various positions not only in importance and scope, but also in the relative degrees in which invention and construction were employed to bring them into being.

It is held by some that no purely human act can possibly create anything really new, that "there is nothing new under the sun," and that therefore every so-called invention made by a man must be merely a novel arrangement of already existing objects.

Of course, no man "creates" anything, in the sense that he makes anything whatever out of nothing; but it is a well-known fact that he has created many things in the sense that he has made many entities to exist that had not existed before as such entities; for instance, man made the speaking telephone to exist. The speaking telephone did not exist before Bell invented it, and it did exist after he invented it. To say that Bell did or did not create the telephone conveys a meaning dependent wholly on the meaning in which the word "create" is used. Men ordinarily use the word with such a meaning that it is correct to say that Bell created the speaking telephone; it being understood as a matter of common sense that Bell did not create the metals and other material parts which he put together to make the telephone.

Used in this sense, primeval man (or more correctly some primeval men, and probably a very few) created certain weapons, implements and utensils, that gave the men who used them such mastery over wild beasts and over men who did not use them, that the steps since taken toward civilization were made possible.

Our whole civilization can be traced back to those inventions, and can be shown to proceed from them and be based upon them. *No other basis that civilization could have proceeded from can even be imagined; for the actual progress of events was the outcome of the actual nature of man, and the actual nature of his environment.*

We seem forced to conclude, therefore, that we owe our civilization primarily to the invention of certain primeval implements and weapons, the art of making fire, etc., and therefore to the inventors who made the inventions. This does not mean that we do not owe it to other things besides inventions, and to other men besides inventors; for it is obvious that we owe it to all the facts of our history, and to such of our ancestors as did anything to advance it. We owe it in part, for instance, to the men who framed the laws that made living in villages and cities possible, to the men who executed the laws, and to all the men and women who observed the laws and gave examples of righteous living. For it is obvious that, no matter what inventions were made, the march of civilization could not have even started, unless there had been a sufficient number of good and intelligent men and women to keep the human procession in good order from the first.

It may be pointed out here that, although every human being has much of evil in his nature, yet even the most depraved person desires other people to be good. Even thieves see the advantage to themselves resulting from the fact that most men do not steal; murderers have no inclination toward being themselves murdered, and human beings as a class see the benefits of morality and good living throughout society as a whole. For this reason, and for the still more important reason that most individuals are not very different in their characteristics and abilities from the average of all individuals, the tendency of society is to reduce men to a common level; so that we see only a small fraction who are extremely good or extremely bad, extremely brilliant or extremely stupid, extremely large or extremely small, etc. Similarly, there is only a small fraction of the people who have done much good individually or much harm, or who have exercised individually any noticeable influence of any kind.

We may reasonably conclude, therefore, that there were only a few men in primeval days who performed any acts that entitle them to individual recognition; and as the only records that have come down to us indicate that the most important acts were the inventing of certain implements, we seem forced to conclude that most of the recognition accorded to individuals of primeval days may be limited to a very small number, and they inventors.

Who they were, and where and when they lived, is not known and probably never will be. For countless centuries their names and personalities have been forgotten as wholly as those of many beasts. But maybe other achievements like those that have exposed the history of certain Oriental kings and wise men to our knowledge, will some day tell us who were the inventors who started the march of human progress, and pointed out the road that it should follow.

Yet, if we infer the probable conditions of the remote past from the conditions of the present and recent past, we shall have to conclude that, while the names and deeds of prehistoric rulers may some day become known to us, and even the names of authors, poets and song singers, the names of the original inventors will be forever hid. For inventors have ever been depreciated in their day; even at the present time, despite the known facts as to what inventions and inventors have done for every one of us, the inventor as an inventor is lightly regarded, and so are his inventions. So are his inventions until they have ceased to be regarded as inventions, and have been accepted as constituent parts of the machine of civilization. By that time the inventor has often been forgotten.

The Age of Iron succeeded the Age of Bronze in the countries from which we have inherited our civilization; but in Africa bronze does not seem to have been discovered until after iron was. Iron being an element like copper, and not an alloy of two metals like bronze, it seems probable that its discovery, like that of copper, followed the act of heating stones with fire. The coming of iron seems due therefore to discovery rather than to invention; but yet the mere discovery that a very hard substance had been accidentally produced would of itself have brought forth no fruit. One is almost forced to infer from probability that the fact must have become known to many men, but only as a plain and uninteresting fact. Finally, some man realized that that hard substance was superior to bronze for making weapons, and then set to work to ascertain exactly what kinds of stone it could be gotten from, and exactly what process gave the best results.

To us who have been carefully taught the facts known at the present day, and whose minds have been trained by logic and mathematics to reason from effect to cause, and to construct frameworks of cause where-from to gain effects, it seems that anyone who noted that the hard substance which we call iron came from heating certain stones, would immediately invent a process for making iron in quantities. But prehistoric man had no knowledge whatever save that coming from his own observation and the oral teachings of the wise men; mathematics and logic did not exist; and the only training given him was in those simple arts of hunting, fishing, field tilling, etc., by which he earned his livelihood. For a mind so untrained and ignorant to leap from the simple noting of the accidental production of the metal to a realization of its value, then to a correct inference as to the possibility of producing it at will, then to a correct inference as to the method of producing it, and then to devising the method and actually producing iron at will, suggests a reasoning intelligence of an order exceedingly high.

Nevertheless, the art of making iron may have originated not so much from effort as from inspiration; the process may have been less one of reasoning than one of imagination, less one of construction than one of invention. In fact, when we realize that imagination is almost wholly a pure gift (like beauty, or artistic genius or a singing voice) while the reasoning and constructive faculties require long education, we may reasonably conclude that the production of iron and of all the metals and processes in prehistoric times, was probably attributable mainly to invention.

The crowning invention of prehistoric man was that of writing; for it lifted him out of his dependence on oral teachings, with their liability to error and forgetfulness, into a condition in which the facts and experiences of life, and the reasons for failure or success, could be put into permanent form, and supply sure bases from which to start on any line of progress in the future.

The production of the art of writing seems to have been a pure invention, and it has always been so regarded. Nothing resembling writing is to be found in nature; *nowhere do we see in nature any effort to preserve any records of any kind.* How man, or a man, was led to invent writing we can only imagine, for we cannot ascertain. When we realize, however, how entirely novel an undertaking the production of writing was, and that there is no process of mere reasoning by which a man could arrive at a decision to produce it, we seem forced to conclude that it must have been caused by one of those inexplicable conceptions that imagination puts into the mind, and that constitute an inspiration, coming from the Great Outside and its ruler, the Almighty.

In fact, if one ponders the history and teachings of the Christian religion (in truth of all religions), and notes that the revelations on which they are believed to have been founded seem to have come unbidden to certain men as inspirations from On High, he must realize how similar are the conceptions that come to inventors in a field less spiritual, but yet actual. For in the case of each basic invention, an idea seems to have come unbidden to the mind, and grown and developed there.

The first writing was what we call picture writing, in which representations in outline of well-known objects were scratched with a hard point on some softer substance. This form of writing probably began in the Old Stone Age. It continued for different lengths of time among different peoples, as have all other characteristics of any stage of civilization; and it is practiced in some degree by some peoples even now. In fact, one might with reasonableness declare that many of the illustrations used in books and magazines and papers, many of the paintings and drawings that adorn our walls, and many of the moving pictures in our places of amusement convey messages by means of pictures, and are therefore forms of picture writing.

As the intelligence of man increased, and his consequent need for better means of expressing himself in writing increased, the idea occurred to someone to use conventional drawings to represent vocal sounds, instead of pictures of visible objects. The first writing of this kind, called phonetic writing, used characters that represented spoken words, and therefore required many characters and necessitated long and tedious study to master it. It was gradually replaced among most peoples by an improved phonetic system, in which each character represented a syllable instead of a word; though the Chinese have never wholly abandoned it. The syllabic system needed, of course, fewer characters, and was much more easily learned, much more flexible and generally satisfactory. The syllabic system was finally replaced among the more progressive peoples by the alphabetical system, in which each character represents a separate vocal sound. As the number of separate vocal sounds is few, only a few characters are needed. In most alphabets, the number of characters varies between twenty-two and thirty-six.

We of the present day plume ourselves greatly on our achievements in invention, and point to the tens of thousands of scientific appliances, books and works of art with which we have enriched our civilization. To most of us, prehistoric man was an uncouth creature, living in caves and uncleanly huts, and so far removed from us that in our hearts we class him as little higher than the beasts. Yet to prehistoric man we owe all that we are and all that we have. The gift of life itself came to us through him; and so did not only our physical faculties, but our mental, moral and spiritual faculties as well. It was prehistoric man who invented the appliances without which the wild beasts would not have been overcome, and the man, wilder than himself, been kept at bay; by means of which the soil was tilled, and boats were made to move upon the water, and villages and towns were built. It was prehistoric man who invented spoken language and the arts of drawing, painting, architecture, weaving and writing. It was prehistoric man who started the race on its forward march, and pointed it in the direction in which it has ever since advanced. It was prehistoric man who made the inventions on which all succeeding inventions have been based. The prehistoric inventor exercised an influence on progress greater than that of any other man.

CHAPTER II

INVENTION IN THE ORIENT

THE first countries to pass into the stage of recorded history were Egypt and Babylonia. Excavations made near the sites of their ancient cities have brought to light many inscriptions which, being deciphered and translated, give us clear knowledge of the conditions under which they lived, and therefore of the degree of the civilization that they had attained.

As we note the progress that the inscriptions show us to have been made beyond the stage reached by prehistoric man, it becomes clear to us that much—if not most—of that progress could not have been made without the aid of writing. One cannot conceive of the invention and development of Astronomy, for instance, without some means of recording observations that had been made.

In developing the art of writing itself, much progress was effected in both countries, and many improvements were made in the art itself that must have been due to that lower order of invention which consists in improving on things already existing. In addition, invention was employed in devising and arranging means for preserving the writings in an enduring form. In Babylonia, this was done by making the writing on soft tablets of clay about an inch in thickness, that were afterwards baked to hardness. In the case of records of unusual importance, the precaution was sometimes taken of covering the baked inscription with a thin layer of clay, making a duplicate inscription on this layer, and then baking it also. If afterwards, from any cause, the outside inscription was defaced, it could be removed and the inside inscription exposed to view.

In Egypt, the writing was done on sheets of papyrus, made from a reed that grew in the marshes. To devise and make both the baked clay tablets and the papyrus, it is clear that invention had to be employed; for nothing exactly like them existed in nature. Thus the invention of the art of writing was supplemented by the invention of the art of preserving the records that writing made. The act of writing would have been useful, even if no means had been invented for preserving the things written; even if the things written had perished in a day. But the importance of the invention of writing was increased ten thousand fold by the invention of the means for preserving the things written; because without that means it would have been impossible by any process of continual copying of tablets to keep at hand for reference that library of records of the past on which all progress has been based, and from which every act of progress has started, since some inventor of Babylonia invented baked clay tablets and some inventor of Egypt invented papyrus.

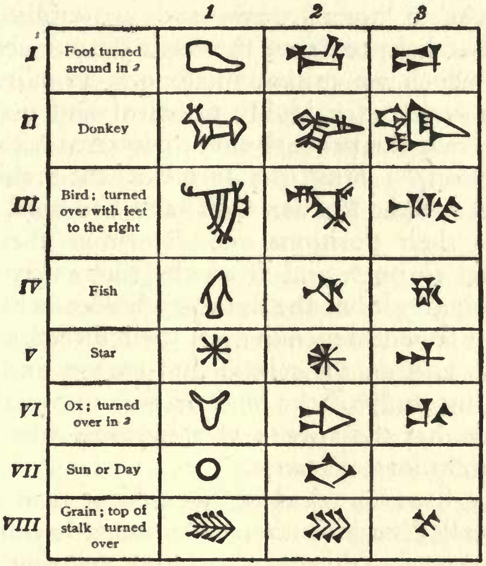
It may be objected that there is no reason for assuming that any one man invented either; that each invention may have been the joint work of two men, or of several men. This, of course, is true; but it does not minimize the importance of either invention, or the credit due to the inventors. It simply divides the credit of each invention among several men, instead of giving it all to one. It is a notable fact, however, that, although some inventions have been made by the joint work of two men, and although some books have been written, and some music has been composed by two men working in cooperation, yet such instances have been rare.

Many men combine to do constructive work of many kinds, and millions combine to work and fight together in armies; and it is an interesting fact that the working together of many men has been made possible by inventions, such as writing and printing. Yet there is hardly any other kind of work that is so wholly a "one man job" as inventing. The fact that only one man, as a rule, makes a certain invention, or writes a certain book, or composes a certain musical piece, or does any other inventional work, seems to spring naturally from the original fact that an invention begins with a picture made by imagination on a mind. Now a picture so made is an individual picture in an individual mind. If the picture is allowed to fade, or if from any cause the mind that received it does not form it into a definite entity, no invention is made. If, on the contrary, the mind develops the dim picture into a definite entity of some kind, that mind alone has made that invention; even if other minds improve it later by super-posing other inventions on it.

It is true that sometimes a man who receives from his imagination a mental picture of some possible invention will communicate it to another man, and that other man will contribute some constructive work, and make the dim picture into a reality; so that the complete invention resulting will be the joint product of two men. It seems to be a fact, however, that these dim pictures have rarely been disclosed while in the formless period, and that almost every invention of which we know the history, was made by one man only.

It need hardly be interjected here that we are discussing inventions only, and not the acts of making inventions practicable in the sense of making them useful or commercially successful. At the present day, there are few inventions indeed, which even after having been completed as inventions, need no modification at the hands of the engineer and the manufacturer, before they are suitable to be put to practical use.

That the Babylonians realized the importance of their invention is proved by the fact that their baked tablets were carefully preserved, and that in some cities



Early Babylonian Signs, Showing Their Pictorial Origin

large libraries were built in which they were kept, as books are kept in our libraries at the present day. When the expedition of the University of Pennsylvania made its excavations near the site of the ancient city of Nippur, in the southern part of Babylonia near the city of Babylon, a library was discovered that contained more than thirty thousand tablets.

The writing of the Babylonians, while phonetic, was a development of picture writing, each character expressing a syllable, and was made of wedge-shaped characters. From the shape of the characters the adjective *cuneiform* has been applied to the writing, the word coming from the Latin word, *cuneus,* a wedge. Syllabic writing was in use for probably three thousand years among the peoples of western Asia.

The Babylonians utilized their ingenuity and inventiveness in divers ways, and accomplished many things that help to form the basis of our civilization, without which we cannot imagine it to exist. Their creations were of a highly practical and useful kind, and illustrate the proverb that "necessity is the mother of invention." From the fact that their ships sailed the waters of the Persian Gulf, and had need of means to locate their positions and determine their courses from port to port, and from the fact easily noted by their navigators that the heavenly bodies held positions in the firmament depending on their direction from an observer, and on the month and season and the time of day, the study of the heavens was undertaken; with the result that the science of astronomy was conceived and brought into existence.

It may here be asked if this achievement can properly be called an invention. One must hesitate a little before answering this question either negatively or positively; because such an achievement is not usually called an invention, and yet it cannot truthfully be denied that there is nothing in Nature like the science of astronomy, and that therefore it must have been created by man. It cannot reasonably be denied, also, that after the science had at last been formulated, it was as clearly a distinct entity as a bow and arrow or a telephone. Furthermore, it does not seem unreasonable to suppose that, before any of the principles of astronomy were laid down, before anyone even attempted to lay them down, before anyone even attempted to ascertain the laws that seemed to govern the movements of the heavenly bodies, the idea must have occurred to someone that those heavenly bodies were all moving in obedience to some law; and a more or less confused and yet real image must have been made upon his mind of a great celestial machine. He must actually have imagined such a machine. This first act would be quite like that of the inventor of a mechanical device. The next act would be to observe and record all the phenomena observable in connection with the movements of the celestial bodies, then to analyze and classify them. This series of acts would not, of course, be inventive or even constructive. They would rather be like those studies of any art, without which no man could be an inventor in that art.

The analysis having been completed, the positions of the heavenly bodies at various times having been ascertained and tabulated, the next step would seem to be to construct a supposititious machine of which each part would represent a heavenly body, and in which those various parts would move according to laws induced tentatively from the actual motions of certain heavenly bodies. If it were afterwards found that all positions of each part, predicted in advance by applying the laws tentatively induced, corresponded to the actual positions of the heavenly body that it represented, then the supposititious machine could be truthfully declared to be a correct imitation of the great celestial machine. That is, the machine could be declared to be successful.

The science of astronomy is, in effect, such a machine. Its parts are representations of the sun, moon and other heavenly bodies, that move according to laws that are illustrated in the diagrams, and expressed precisely in the formulas.

The first act of the originator of the science of astronomy being one of the imagination in conceiving a picture of a celestial machine, and being like that of the inventor in conceiving a picture of an earthly machine; and his second act being also like that of the inventor in developing the picture, a justification for speaking of the "invention" of the science of astronomy may perhaps be reasonably claimed.

(We must bear in mind, of course, that no invention is complete until the third act has been performed, and the thing invented has been actually produced.)

To speak of invention in connection with bringing forth novel creations is far from new, for the phrases "construct a theory," "invent a science," "invent a religion," etc., are in almost daily use; and it may seem unnecessary to some persons, therefore, to discuss it at such length. But most people seem to regard such phrases as merely figurative; while the author wishes to make it plain that they are not figurative but exact.

As this modest treatise does not pretend to be a learned one, and as the author is not a professional scholar, no further attempt will be made to claim the production of the science of astronomy as an invention. To pursue the subject further would be merely to enter a discussion as to the meaning, both original and derived, of the word invention. The author, however, cannot escape the conclusion that, no matter what may be the literally correct meaning of the word, the mental acts performed by the originators of the science of astronomy were like the mental acts performed by the inventors of mechanical appliances, and exerted a similar influence on history. That is, he believes that the men who brought into being the science of astronomy and the men who brought into being the bow and arrow, first saw pictures on the mental retina of some things actual yet vague and formless, and then constructed entities from them. He believes also that the creation of the bow and arrow, and the creation of the science of astronomy constituted actual and similar stepping-stones on which the race rose toward a higher civilization.

In default of any definition of the word invention, which precludes its application to the origination of a science, theory, religion or formulated school of thought, the author begs permission so to use it, in indicating the influence on history of the novel creations which, according to this meaning of the word, have been inventions.

The influence on history of the invention of the science of astronomy has been so great that we cannot estimate its greatness. On it the whole science of navigation rests. Without it, the science and the art of navigation could not exist, no ships could cross the ocean from one port to another, except by accident, and the lands that are separated by the ocean would still rest in complete ignorance of each other. This world would not be a world, but only a widely separated number of barbarian countries; most of them as ignorant of even the existence of the others as in the days before Columbus.

Following the invention of astronomy, or as it was first called, Astrology, the imaginative and practically constructive intellects of the Babylonians naturally led them to invent the sun-dial for indicating the time during the day, and the water-clock for indicating it during the night.

Another invention, doubtless brought into being by the study of the movements of the heavenly bodies, was the duodecimal system of notation, of which the base was twelve. In accordance with this system, the Babylonians divided the Zodiac into twelve equal parts or "signs"; divided the year into nearly equal months, that corresponded approximately to the length of a lunar month; divided a day and a night into twelve equal parts or hours; divided an hour in sixty (12 x 5) equal parts or minutes, and divided a minute into sixty (12 x 5) equal parts or seconds.

The duodecimal system of notation has been supplanted for many purposes by the more convenient decimal system, the invention of which is attributed by some to the Arabs; but the duodecimal divisions of time are still with us, and the duodecimal divisions of the circle are still used in most countries.

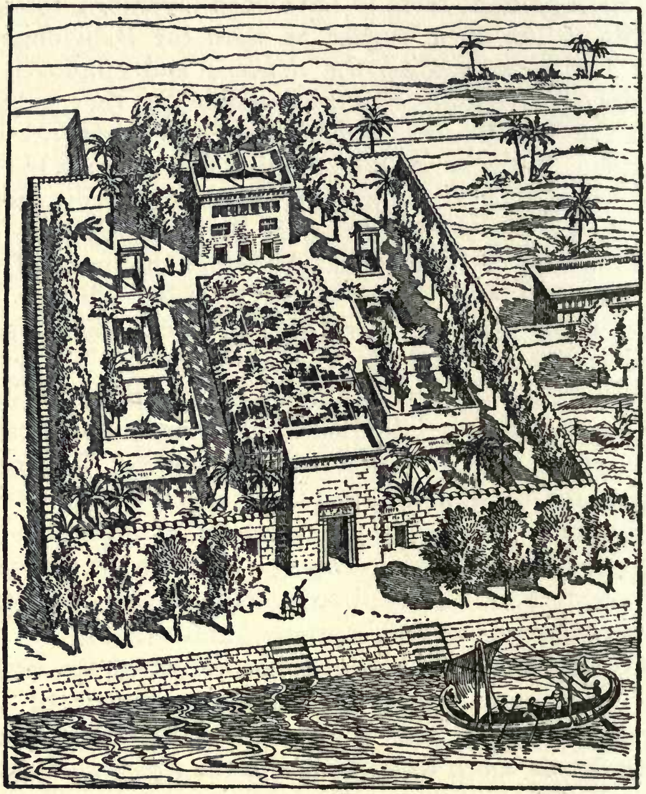
The duodecimal system of notation seems to have been the earliest system of notation invented; and it was an invention so important that we cannot imagine civilization without it and the decimal system, possibly its offspring. The influence of these two inventions on history has been so great that the mind is incapable of realizing its greatness, even approximately.

Who were the inventors, we do not know. It is almost certain that none of our generation ever will know, and it is far from probable that any one of any generation will ever know. If any knowledge on this subject is ever given to the world, it will be knowledge of names only—only names. Yet some human beings, forgotten now and probably obscure even in their lifetimes, invented those systems, and contributed more to the real progress of the race than many of the great statesmen and warriors of history.

The Babylonians invented measures of length, capacity and weight, also; and it is from those measures that all the later measures have been directly or indirectly derived. To have invented systems by which time, angle, distance, space, weight and volume were lifted out of the realm of the vague and formless into the realm of the definite and actual, was an achievement that almost suggests that noted in the first chapter of Genesis, in the words, "And God said 'Let there be light,' and there was light"; for what a clearing up of mental darkness followed, when the science of measurement turned its rays on the mysteries that beset the path of early man!

The Egyptians seem to have been inventors, though hardly to the same degree as were the Babylonians. The Egyptians studied the heavens and employed a science of astronomy; and it is possible that they, rather than the Babylonians, should be credited with its invention. But it is not the intention of this book to decide points in dispute in history, or even to discuss them. Its intention is merely to study the influence that inventions and inventors had. Whether the name of an inventor was John Smith or Archimedes, whether he lived in the year 1000 or 1100, or which one of two rival claimants should be credited with the honor of any invention, is often an interesting question; but it is not one that is especially important to us, unless it casts light on the main suggestion of our inquiry. The only reason for mentioning names and dates and countries in this book is to show the sequence of inventions as correctly as practicable. In order to show the influence of invention on history it seems best to give the treatment of the subject an historical character.

Possibly the most important invention of the Egyptians was papyrus, which was the precursor of the paper of today. The clay tablets of the Babylonians were clearly much less adapted to the making of many records than was papyrus. One cannot readily imagine an edition of 300,000 newspapers like the *New York Times,* made out of clay tablets an inch in thickness, and sold on the streets by newsboys. Clearly the invention of papyrus was one so important that we cannot declare any invention as more important, except on the basis that (other factors being equal) the earlier an invention was the more important it was. To



Villa of an Egyptian Noble

assume such a basis would, of course, be eminently reasonable; because the earlier invention must have supplied the basis in part for the making of the later. The invention of writing, for instance, was more important than the invention of papyrus.

A curious invention of the Egyptians was the art of embalming the bodies of the dead, an art still practiced in civilized countries. It was prompted by their belief that the preservation of the body was necessary, in order to secure the welfare of the soul in the future life. This belief resulted further in building sepulchres of elaborate design, filling them with multitudes of objects of many kinds, decorating the walls with paintings, sculptures and inscriptions, and placing important manuscripts in the coffins with the mummies or embalmed bodies. The sepulchres of the kings were, of course, the largest and most elaborate of all; and of these sepulchres the grandest were the pyramids. By reason of the great care and labor lavished on tombs and sepulchres and pyramids, and by reason also of the dryness of the air in Egypt, and the consequent durability of works of stone, it has been from the tombs that many of the clearest items of information have come to us about old Egyptian times.

The Egyptians excelled in architecture, and the greatest of their buildings were the pyramids. As to whether or not there was much invention devoted to those works, it is virtually impossible now to know. The probability seems to be that they could not have been produced without the promptings of the inventor, but that the progress was a slow and gradual march. It seems that there was a long series of many small inventions that made short steps, and not a few basic inventions that proceeded by great leaps.

The Egyptians seem to have been the inventors of arithmetic and geometry. What men in particular should most be credited with inventing them, we do not know; but that some men were the original inventors the probabilities seem to intimate. For these sciences were creations just as actual as the steam engine, and could hardly have been produced save by similar procedures.

The suggestion may here be made that whatever we do is the result (or ought to be) of a decision to do it,

The Pyramids of Gizeh

that follows a mental process not very different from that invented by the German General Staff for solving military problems. By this process one writes down—

1. The mission—the thing which it is desired to accomplish.

2. The difficulties in the way of accomplishing it.

3. The facilities available for accomplishing it.

4. The decision—that is, how to employ the facilities to overcome the difficulties and accomplish the mission.

In solving a military problem (or in solving many of the problems of daily life) it is often a matter of great difficulty to arrive at a clear understanding of what the mission actually is, what one really wishes to accomplish. In the majority of ordinary cases, however, the mission stands out as a clear picture in the mind. Such a case would be one in which an enemy were making a direct attack; for the mission would be simply to repel it. Another case would be one in which the mission was stated by the terms of a problem itself; for instance, to build a steam engine to develop 1000 horse power. In the case of the inventor, the mission seems to be sent to him as a mental picture; he suddenly sees a dim picture in his mind of something that he must make.

Perhaps, many centuries ago, some man who had been laying out plots of ground in Egypt, of different shapes and sizes, and making computations for each one, suddenly saw a phantom picture in which all the lines and figures appeared grouped in a few classes, and arranged in conformity to a few fixed rules. The mission was given to him free, but it devolved on him to formulate the rules. As soon as he had formulated and proved the rules, the science of Geometry existed.

It is interesting to note that the conception of the idea required no labor on the part of the conceiver. He was virtually a passive receiver. His labor came afterwards, when he had to do the constructive work of "giving to airy nothing a local habitation and a name."

The Egyptians seem to have learned the use of many drugs, though they can hardly be said to have invented a system or a science of medicine. They did, however, invent a system of characters for indicating the weights of drugs. Those characters are used by apothecaries still.

The first means of cure were incantations that evidently influenced the mind. It is interesting to note that modern systems tend to decrease the use of drugs and increase that of mental suggestion.

Both the Babylonians and the Egyptians held religious beliefs; but it is doubtful if the religious beliefs of either were so definite and formulated that they could be correctly called religions, according to our ideas of what constitutes a religion. An interesting fact is the wide difference between the beliefs of the two peoples, in view of the similarity of many of the other features of their civilizations. The beliefs of neither can be called highly spiritual; but of the two, the Egyptian seems to have been the more so. The Egyptians believed that the souls of those who had lived good lives would be rewarded; while the Babylonian belief did not include even a judgment of the dead.

One of the most important inventions made in Babylonia was that of a code of laws. It is usually ascribed to a king named Hammurabi; but whether he was the real inventor or not, we have no means of knowing. We do know, however, that the first code of laws of which there is any record was invented in his reign, and that it was the prototype of all that have followed since.

The influence on history of the invention and carrying into effect of a formulated code of laws, we cannot exactly gauge; but we may assert with confidence that modern civilization would not have been possible without codes of laws, and that the first code must have been more important than any code that followed, because it led the way.

Both the Babylonians and the Egyptians seem to have made most of their inventions in the period of their youth, and to have become conservative as they grew older. The Babylonians were a great people until about the year 1250 B. C., when a subject city, Assur, in the north, threw off its allegiance and formed an independent state, Assyria. The decline of Babylonia continued until the fall of Assyria and the destruction of Nineveh, its capital, about the year 606 B. C., when the new Babylonian, or Chaldean Empire, came into existence. It enjoyed a period of splendid but brief prosperity until it was captured by Cyrus, king of Persia, in the year 538 B. C.

Egypt's career continued until a later day; but it was never glorious in statesmanship, war or invention, after her youth had passed.

A nation possibly as old as the Babylonian or Egyptian was the Chinese; but of their history, less is known. It is well established, however, that they possessed a system of picture writing in which each word was represented by a symbol. The system was much more cumbrous, of course, than the syllabic or alphabetical; but its invention was a performance, nevertheless, of the utmost brilliancy and importance, viewed from the light of what the world was then. There is little doubt also that the Chinese were the original inventors of the magnetic compass and of printing from blocks, two of those essential inventions, without which civilization could not have been brought about. Another of China's inventions was gunpowder; though it is not clear that the Chinese ever used it to propel projectiles out of guns.

Achievements equally great, and maybe greater, were the creations of religions—Confucianism and Taoism, invented in China, and Buddhism, invented in India. These religions may seem to us very crude and commonplace and earthy; but we should not shut our eyes to the fact that they have probably influenced a greater number of human beings toward right living than any other three religions that we know of.

Like Babylonia and Egypt, China became conservative as she grew older. At the present day, her name stands almost as the symbol of everything non-progressive and non-inventive.

Assyria was able to capture Babylon about the year 1250 B. C., and to maintain the position of the dominant power in western Asia for about 600 years. A progressive and ambitious people, they accomplished an original and important step in the art of government by organizing conquered peoples into provinces under governors appointed by the king. It does not seem to be a great straining of the word to declare that this achievement was so novel, so concrete and so useful as to possess the essential features of an invention. For if we realize that during all the times that had gone by, conquered peoples had remained simply conquered peoples, paying tribute but not forming parts of the conquering state, we can see that the idea of actually incorporating them into the state, thereby increasing the population of the state by the number of people incorporated, and making the state stronger in that proportion, we can hardly fail to realize that the conception of doing this was of the highest order of brilliancy. To work out afterwards the details of developing the conception in such a way as to render possible the production of an actual and workable machine of government was a constructive act. When the machine was actually produced a new thing had been created. In other words, the institution of this new scheme in government seems to have followed the same three stages as the invention of a mechanical device; that is, conception, development and production.

The likeness between this process and that of conception, gestation and birth is obvious.

The Assyrians were evidently a very practical and constructive people, somewhat such people as the Romans later were. They devoted themselves to the practical side of life, and to this end they developed the governmental and the military arts. They were great warriors. The period of their greatest greatness was in the seventh and eighth centuries B. C., when the conquerors Sargon II and Sennacherib were kings. The splendor of the empire afterwards was conspicuous but not long lived; for after unifying the great nations of the Orient under Assyrian rule, and carrying on wars marked with the utmost of cruelty and oppression, they finally entered on a rapid decline in morals, and consequently in national prosperity and strength. The end came in 606 B. C., when a combined force of Medes and Babylonians captured and sacked the hated Nineveh, the capital. The intensity of the hatred against the Assyrians may be gauged by the completion of the destruction visited on Nineveh. When Xenophon saw its ruins only two centuries afterwards, he could not even ascertain what city those ruins marked.

The Assyrians have left us clearer records of their achievements in the invention of weapons than has any other ancient nation. It is impossible to declare with certainty that all the seemingly novel weapons and armor which the ancient Assyrians possessed and used were invented by themselves, and not by the Egyptians or the Babylonians; but the mere facts that the Assyrians were the most military nation of the three, and that the specimens of those weapons which have come down to us have been mostly Assyrian, give probability to that supposition.

The Assyrian soldier was finely equipped and armed as far back as the thirteenth century B. C.; and Assyrian bas-reliefs show that they actually used war-chariots then, drawn by horses and operated by armed warriors. The infantry soldiers wore defensive armor consisting of helmets, corslets made of skin or some woven stuff on which plates of metal were sewn, and sometimes coats of steel mail; with leggings to protect the legs. They carried shields, and were armed with lances, swords, slings and bows and arrows. The Assyrians employed cavalry, the horsemen wearing mail armor, and carrying shields and swords and lances. They employed archers also; the archers being sometimes mounted.

The use of war-chariots, with all the mechanical equipment that was necessary, in order to make them operate effectively, shows a state of civilization much higher than many people realize. It shows also that a great deal of inventiveness and constructiveness must have been employed, and must have been skilfully directed;—for it is a very long road—a very long road indeed—from the bow and arrow to the war-chariot. In order to produce the war-chariot, several inventions must have previously been made. The most important of these was one of the most important inventions ever made,—the wheel.

Who invented the wheel, and when and where did he invent it?

This is one of the unanswered questions of history. The war-chariot suddenly appears on the stage, without any preliminary announcement, and without any knowledge on our part that even the wheel on which it moved had been invented.

It is true that the records of prehistoric man show us that in fashioning pottery he used a disc that he revolved on a spindle and applied to the surface of the urn or vase; and it is also true that a revolving disc is a kind of wheel. But a disc revolving on a stationary spindle is in its intent and use a very different implement from a wheel placed on a chariot, and turned by the forward movement of the chariot itself, for the important purpose of reducing its resistance to being drawn along the ground.

It is true also that invention was needed to produce the revolving disc, the forerunner of all the polishing and turning machines on the earth today. But the wheel was a different invention, probably a later one, and certainly a more important one. There are things sometimes seen in nature that look a little like revolving discs; for instance, swirls of dust or water. In fact, almost anything put in rotation looks like one, if the rotation is rapid enough; for instance, the sling that a primeval slinger revolved around his head. But what do we know of in nature that looks like a wheel, or that is used for a similar purpose? Nothing. This being the case, the mind may lose itself in speculation as to what could have led to the conception of such an appliance in the mind of the original inventor of the wheel.

The suggestion may be hazarded that the invention was preceded by an accidental recognition of the fact that it was easier to drag something along the ground, if it rested on round logs, than if it did not so rest; and by noting also that the logs were passed over and left behind continually. From this point to the mental conception of a roller that would not be left behind, but would be secured to the thing dragged by a round shaft on which it revolved, there was probably a single mental jump. Someone saw such a contrivance with his mental eye. It looked dim and unreal—but he saw it. To make the picture clear, and then to develop the thing pictured, constructiveness was used. In other words, conception and development accomplished their successive but cooperating tasks. The invention was complete when a wheel was actually produced.

To realize the importance of the wheel, we have but to ask ourselves (or our neighbors) how history could possibly have been even approximately what it has been if the wheel had not been invented.

Another important invention probably made by the

Assyrians was the catapult; another one, somewhat similar, was the balista. The catapult was used for hurling stones, balls, etc.; the balista for shooting arrows with greater force than an archer could exert. Another was the battering ram for making breaches in the walls of fortresses.

The Assyrians used these inventions in their wars against the contiguous nations of the East, and with their aid achieved the mastery, and unified the Orient.

Assyrians Flaying Prisoners Alive. (From a bas-relief.)

That the Assyrian rule was harsh and cruel should not be denied; but, on the principle that any kind of government is better than no government, it cannot reasonably be supposed that the central and efficient administration of Assyria was not better than the condition of continual petty wars and quarrels that had existed among the numerous tribes and nations, with their enormous possibilities for suffering of all kinds.

It may be pointed out here that the cruelties and injustices committed by any powerful government against great numbers of persons attract immeasurably more notice and condemnation by historians and others than do the numberless atrocities of all kinds that lie hidden in the darkness of anarchy, or the confusion of petty wars. In the endeavor to preserve order over widely separated and barbarous peoples, when means of transportation and communication were inadequate, stern measures seem always to have been required. That they have often been too stern, and that great cruelty has often been exercised, the wail of the ages testifies. But human nature is very imperfect; and no really good government, no government free from the faults of man, has ever been established. Yet every government has been better than anarchy.

The Assyrians, despite their cruel treatment of their conquered peoples, did a direct service to mankind and gave a powerful stimulus to the march of progress. For the great empire which they established, and the great cities which grew up, and the system of provinces which they instituted, formed a pattern for similar work by later nations; while the civilization which they spread throughout the more backward countries under their rule, especially in Greece, started the later culture which Greece developed, and which is the basis of all that is most beautiful in the civilization of today.

The influence of the weapons which the Assyrians invented was toward this end.

Between Egypt on the west and Babylonia and Assyria on the east lay Syria; a territory not very large, of which the part that played the most prominent part in history bordered the eastern coast of the Mediterranean Sea. Two important peoples dwelt in Syria, the Hebrews and the Phœnicians. Both belonged to the Semitic race, and neither was distinctly warlike; though the Hebrews during a brief period achieved considerable military strength and skill, under their great king David.

The main gift of the Hebrews to the world was the Jewish religion, a more spiritual religion than any that had preceded it, and based on a conception of one God, a holy God. The ideas held of immortality and of judgment after death for the deeds done in this life were not entirely new, but the conception of a holy and beneficent Deity was new; and it was so inspiring and stimulating a conception that it lifted the Jews at once to a moral and spiritual plane higher than any people had ever lived on before. It constituted a step also directly toward the Christian religion—which also was born in Syria; in Palestine.

That the conception and establishment of the Jewish religion was an invention may not be admitted by some; but the author respectfully asks attention to the sense in which he uses the word invention in this book, and points out that they constituted an invention in that sense.

That it was a beneficent invention, and that it helped the human race spiritually in a way analogous to that in which the invention of many mechanical devices helped it materially, does not seem hard to realize. For in both cases the race was transported away from savagery and toward high civilization; and in both cases there was first a conception of something desirable, then a constructive effort to develop it, and finally its production.

The Phœnicians lived just north of the Jews, and possessed a territory smaller than that of any other people who ever exercised an equal influence on history; for it embraced merely a little strip of land hardly longer than a hundred and twenty miles from north to south, or wider on the average than twelve miles from east to west. It bordered on the eastern edge of the Mediterranean Sea, and was shut off by the mountains of Lebanon from Syria, that lay due east.

The Phœnicians were a people of extraordinary enterprise and initiative. Inventors are men of extraordinary enterprise and initiative. How much the Phœnicians are to be credited with the invention of sailing vessels, we have no means of knowing; but we do know that (with the possible exception of the Egyptians) the

Phœnicians were more identified with early navigation by sailing vessels and by vessels pulled by oars than any other people. It is even known that Phœnician vessels were navigating the Eastern Mediterranean, both under sails and under oars, as long ago as 1500 B. C. So, while we should not be justified in asserting positively that the Phœnicians were the inventors and developers of sailing vessels and of vessels pulled by banks of oars and steered by rudders, we may declare with ample reason that probably they were.

For the purposes of this book, however, the identity of the inventors is not important. What is important is the fact that the invention of those vessels had immediate fruit in a commerce by which the products of eastern civilization were taken westward to Greece and other countries, while tin and other raw material were brought east from Spain and even Britain; and that it had later fruit in gradually building up a western civilization. It had other fruit as well, in demonstrating the possibilities and the value of ocean commerce, and forming the basis of the world-wide navigation of today.

Few inventions have had a greater influence on history than that of the sailing ship. To some of us it may seem that no invention was involved; that to use sails was an obvious thing to think of and accomplish. But if any one of us will close his eyes a moment and imagine an absence of most of the great scientific and mechanical knowledge of today, and imagine also the absence of nearly all the present acquaintance with the laws of weather, flotation, resistance to propulsion, metacentric height, etc., he may realize what a feat was the invention of the sailing ship and even of the ship pulled with oars and steered with a rudder. It is true that we have no reason to assume that either vessel was conceived by one leap of the imagination and developed by one act, while we have many reasons to think that each was the result of a series of short steps; but this does not invalidate the invention of the ships, or depreciate its influence.

By two other achievements, also, the Phœnicians showed the kinship between the inventor and the man of enterprise and initiative; the invention of the Tyrian dyes and of an alphabetical system of writing that forms the basis of the systems of today. Here again it is necessary to remind ourselves that possibly the Phœnicians were not the sole and original inventors of the alphabet, and that they may have merely improved upon a system invented by, say, the Cretans; and again it may be helpful to point out that the important fact is not the personality of the inventors but the birth of the invention, and the influence of the invention on history. Certain it is, however, that it was the Phœnicians who brought alphabetical writing to the practical stage and who not only used it themselves, but carried it in their ships all over the Mediterranean, where it bore abundant fruit. It bore fruit especially in Greece.

Phœnicia is an instructive illustration of the fact that a country (like a man) may make inventions of lasting usefulness to mankind, and yet not hold a position of power or splendor in the world. Phœnicia was nearly always a vassal, paying tribute to one great monarchy or another.

In striking contrast with Phœnicia was the empire of Persia, which, though it gave to the world of that day the best government it had ever known, contributed nothing in the nature of an actual new stepping-stone to civilization.

Persia conquered Lydia, which is credited with the important invention of coinage. The coins first issued by the Lydians were of electrum, an alloy of gold and silver. King Crœsus later issued coins of pure gold and pure silver.

Directly east of Syria was Phrygia. It was in Phrygia that the flute, the first real musical instrument, is supposed to have been invented, in about the sixteenth century B. C.

The brief résumé just given of the inventions made in prehistoric times, and also in historic times in China, Egypt and western Asia, shows that before Greece had attained any civilization whatever the most important inventions for the betterment of mankind had been already made. These inventions were not only mechanical appliances and such arts as spinning, weaving, pottery making, etc., that were intended for safety and material benefit generally; for they included systems of government and codes of laws and even religions that aimed to elevate man, and that did elevate him mentally, morally and spiritually.

At the present day, when inventions follow each other with such rapidity that even students and experts cannot keep themselves informed about them, except in certain specialties, it is natural for us to feel that no inventing of any consequence was ever done before. In fact, the present age is called "The Age of Invention." Yet all the inventions of the last century added together have not had so great influence on mankind as the invention of writing, or of the bow and arrow, or the wheel—or almost any of the inventions we have noted. Not only are they not so important,—they were not so novel, they did not constitute steps so long, they did not mark such epochs, and probably resulted from less brilliant pictures on the mind. Can anyone think that the telephone was as novel or as important as the wheel? Can anyone suppose that the steam engine, or the electric telegraph, or the powder-gun took us as long a step upward to civilization as did papyrus? Will anyone declare that the railroad ushered in as great an epoch as the sailing ship? Is it probable that the first conception of the phonograph made quite so startling a picture on the accustomed brain of the habitual inventor as that of the art of making fire did on the virgin mentality of the savage?

The last contribution of western Asia to the betterment of the world was Christianity. It was not made until after Greece had reached the prime of her civilization and passed beyond it; and some may consider it a sacrilege to call it an invention. It was an inspiration from On High. But dare anyone assert that the wonderful conceptions that have come unbidden to the minds of the great inventors were not, in their degree, also inspirations from On High? Whence did they come? That they came there can be no doubt. Whence did they come? Our religion teaches us that God directs our paths, that He puts good thoughts into our minds. It also teaches us that He inspired the men who wrote the Bible. In the ordinary meaning of the word "inspired," Some One inspired every noble and novel and beneficent achievement that was ever made. Who?

Without insisting tediously on the meaning of the word invention, one may point out that the word is used continually to mean a mental act by which something heretofore non-existent is created. The expertest of all word users, in any language, cried:

"Oh, for a muse that would ascend the highest heaven of invention"; expressing almost exactly what the present author is trying to express, and indicating invention as the highest effort of the mind.

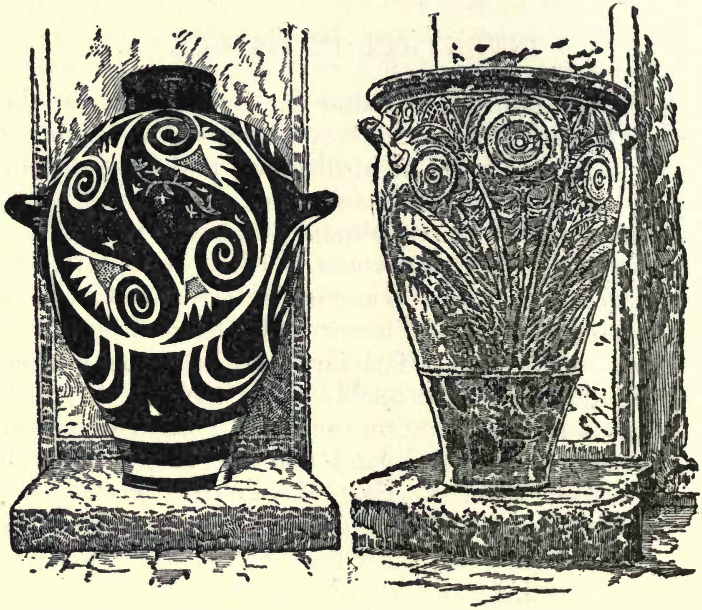
In this sense, may I reverently claim the Christian Religion as an invention, one of the greatest inventions ever made?

CHAPTER III

INVENTION IN GREECE

OUR brief survey has thus far carried us over the lands of Egypt, China and western Asia; lands so far removed from us in distance, and inhabited by people so far removed from us in time and character, that they seem to belong almost to another world. But we now are coming to a country which, though its history goes back many centuries before the Christian era, was a country of Europe and inhabited by a people who seem near. The Greeks who overran what we now call Greece, probably about 1500 B. C., took possession of a civilization exceedingly high, which the inhabitants of the mainland and the Ægean Islands had received from the East, through the Phœnicians, who brought it in their ships. This civilization the Ægean islanders, especially the Cretans, had developed and improved, particularly in creations of beauty and works of art. The Greeks created a still higher civilization, and transmitted it to us. The influence of Greek civilization we see on every hand:—in our language, in our daily life, and especially in our ideas of art, literature and philosophy.

That a civilization so high and beautiful should have been attained, could hardly have been brought about without the presence of great imagination among the Greeks, and the exercise of considerable invention. The presence of both imagination and invention are evidenced in every page of the early history of Greece, in the stirring stories of her heroes, and in the conception and development of her government. Compared with the stories of ancient Greece, the stories of the childhood of every other country seem unimaginative and tame. The stories of early Greece still live and



Two Cretan Vases

still have the power to charm. The Iliad and Odyssey are in the first rank of the great poems even now; and the story of Helen and the siege of Troy is as full of life and color as any that we know.

An interesting legend characteristic of the inventiveness of the ancient Greeks was that of the large wooden horse in which a hundred brave warriors concealed themselves, and were drawn within the walls of Troy by the Trojans themselves, who had been induced to do this by an ingenious story, invented to deceive them.

Whether the legend is true or not does not affect the fact that invention was needed and employed to create the legend in the one case, or to cause the incident in the other case.

The prehistoric age of Greece was filled with myths of so much beauty, interest and originality, that the Greek mythology is more read, even now, than any other. It formed also the basis of the later mythology of the Romans.

It may be noted here that mere imagination is not a quality of very high importance, unless it be associated with constructiveness. In fact, imagination is evidenced more by savage and barbarous peoples than by the civilized; as it is also by children and women than by men. Imagination by itself, untrained and undirected, while it is unquestionably an attribute of the mind, is not one of reason, in the sense that it does not necessarily employ the reasoning faculties. In fact, the imagination, unless trained and well-directed, may lead us to the absurdest performances, in defiance of the suggestions of reason. Using the word imagination in this sense, Shakespeare said—

> "The lunatic, the lover and the poet
> Are of imagination all compact."

It is only when imagination has been assisted by reason, it is only when conception has been followed by construction, that practical inventions have resulted.

The myths invented by the Greeks in their prehistoric period were the products of not only imagination but construction. Each myth was a perfectly connected story, complete in all necessary detail, admirably put together, and told in charming language. The story of Jason's Argonautic Expedition in search of the Golden Fleece cannot be surpassed in any of the elements that make a story good; Penelope is still the model of conjugal devotion, and Achilles the ideal warrior; Poseidon, or his Roman successor, Neptune, still rules the waves; Aphrodite, or Venus, calls up more vividly before our minds than any other name the vision of feminine beauty even to this day. Hercules exemplifies muscular strength, and Apollo still typifies that which is most beautiful in manliness.

The influence of the Grecian myths, "pure inventions" as they were, in the sense that they were fictitious and not true, has been explained and demonstrated at great length and with abundant enthusiasm by poets and scholars for many centuries. They have been generally regarded as inventions, but nevertheless as quite different from such inventions as the steam-engine or the printing press. The present author wishes to point out that the mental processes by which both myths and engines were created were alike, and that the inventions differed mainly in the uses to which they were put.

Even the uses to which they were put were similar in the end; for the use of the myths and of the steam engine was to improve the conditions of man's existence. There is only one way in which to do this, and that is by improving the impressions made on his mind. The myths did this by making beautiful pictures for his mind to gaze at, and by using them to induce him to follow a certain (good) line of conduct, rather than the contrary. The steam engine did it by making the conditions of living more comfortable, by rendering transportation more safe and rapid, and by rendering possible the procuring of many of the pleasant things of life from distant places.

The invention of a myth may be said to be the invention of an immaterial thing; the invention of a steam engine to be of a material thing. These two lines of effort, invention has followed since long before the dawn of history. Of the two, the invention of myths and stories probably succeeded the other.

Probably also it has been the more important in affecting our actual degree of happiness; affecting it beneficently in the main. For, while some myths and stories have filled men with dread and horror, a very large majority have had the opposite effect; and while many mechanical inventions have contributed to our material ease and comfort, it is not clear that they have much increased our actual happiness. Men accommodate themselves easily to changes in their material surroundings; what is a luxury today will be a necessity tomorrow; and very many of the material inventions have tended to artificial and unhealthful modes of living, with consequent physical deterioration and its accompanying loss of happiness.

As to influence on history, however, the influence of the material inventions has probably been the greater. Immaterial inventions might have been made in enormous numbers without of themselves affecting history greatly; but the material inventions have brought about most of the events that history describes; and without one material invention, that of writing, history could not exist at all. History is rather a narrative of men's deeds than of their thoughts; and their deeds have been directed largely by the implements which they had to do deeds with.

We must realize, of course, that the Greeks were much indebted to the Ægeans; for discoveries about the shores and islands of the Ægean Sea show that long before the advent of the Greeks they used tools and weapons of rough and then of polished stone, and later of copper and tin and bronze; that they lived on farms and in villages and cities, and were governed by monarchs who dwelt in palaces adorned with paintings and fine carvings, and filled with court gentlemen and ladies who wore jewelry and fine clothing. Exquisite pottery was used, decorated with taste and skill; ivory was carved and gems were engraved, and articles were made of silver and bronze and gold.

As early as the sixth century B. C., the Greeks made things more beautiful than had ever been made before. One almost feels like saying that the Greeks invented beauty. Such a declaration would be absurd of course: but it seems to be a fact that the Greeks had a conception of beauty that was wholly original with them, and that was not only finer than that which any other people had ever had before, but finer than any other people have had since. And not only did they have the conception, they had the ability to embody the conception in material forms that possessed a beauty higher than had ever been produced before, and higher (at least on the average) than have ever been produced in any other country since.

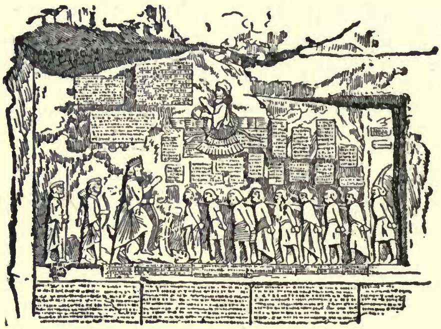
Looked at in this way, the production of a new and beautiful statue, painting or temple, seems to be an act of invention much like the formulation of a myth or the writing of a poem. In this sense, the Greeks were inventors, inventors of works of beauty that have existed as concrete material creations for centuries, and have exercised an enduring influence on the minds of men.

The influence of paintings, statues and temples is not so clear as that of material inventions, but more clear than that of myths and poems. They may be said to form a class midway between inventions of material appliances and inventions of immaterial thoughts and fancies. A beautiful painting or statue is a material object in the same sense as that in which a steam engine is; but its office is to stimulate the mind, as a poem does.

The first inventor of mechanical appliances, mentioned by name as such, was Dædalus of Athens. He was probably a mythical person. He was reputed to be the son or the grandson of Erectheus, a probably mythical king. He is credited with the invention of the saw, the gimlet, the plumb-line, the axe, the wedge, the lever, masts and sails and even of flying;—for he is said to have escaped from Crete to Sicily with artificial wings. The story of Dædalus, like that of many other mythological personages, is both interesting and irritating from the mixture of the very probable, the highly improbable, and the entirely impossible, in a jumble. But the story of Dædalus seems to make it probable that all the things which he is reported to have invented (except flying) were in use in Greece in prehistoric times.

As no records show to us that the inventions just enumerated (except masts and sails) had been invented elsewhere, we may feel justified in inferring that they were invented in Greece by Dædalus, or by some other man bearing a different name,—or by some other men. The name borne by the man is not important to us now; but it is important to realize that such brilliant and original inventions were made so long ago by a primeval people; especially since they were of a character somewhat different from those invented in Egypt and Asia which we have already noted. The invention of the gimlet seems the most brilliant and original of those just spoken of; and one marvels that it should have been invented at such a time; for the action of the gimlet was a little more complicated than that of even the balista or the catapult. It is true that the number of parts was less, that in fact there was only one part. But that part turned around in one plane, and advanced in another; it was less like anything that existed before than the catapult was like the sling, or the balista was like the cross-bow. There was no immediate forerunner of the gimlet. In other words, the mental jump needed to invent the gimlet was from a base of nothing that we can exactly specify.

A possible suggestion for the gimlet was the succession of inclined planes by which one mounted to the top of an Assyrian or Chaldean palace; these planes rising gradually on each of the four sides, so as to form together what might be called a square spiral. It is possible that a circular spiral may have been traced



Insurgent Captives Brought Before Darius

later around some cylindrical shaft or column, and given the first suggestion for the screw or gimlet. Of course, a gimlet is a kind of screw.

The Greeks do not seem to have applied their inventiveness after the time of Dædalus to mechanical appliances, but to works of art and systems of religion and philosophy. One of their most important inventions may be said to be mid-way between: it consisted in adding vowels to the Phœnician alphabet and producing the basis of the Latin and succeeding alphabets. The Greeks were not naturally of a warlike disposition, and their peculiarly jealous temperament prevented the various states and cities from combining and forming a great nation. Their energetic character and great intellectuality saved them, however, when Darius, King of Persia, invaded Greece in 490 B. C.

By that time the Greeks had raised and trained an army of great excellence. No especial inventiveness seems to have been exercised, but the equipments of the men, their organization, their armor, their weapons and their discipline had been brought to a standard exceedingly high. All these advantages were needed; for the Persians were a warlike people, their King Darius was an ambitious and successful conqueror, and the number of Persians that invaded Greece was far greater than the number that Greece could raise to fight them.

Had the Greeks been destitute of invention they would have followed the most obvious course, that of shutting themselves up inside the protection of the walls of Athens. Had they done this, the Persians would have surrounded the city, shut them off from supplies from outside, and slowly but surely forced them to surrender.

But, on the insistent advice of Miltiades, the Greeks advanced to meet the Persians, leaving the shelter of their walls behind them. It may not seem to some that Miltiades made any invention in planning the campaign which he urged against much resistance, and which the Athenians finally carried out. Yet his mental action was one allied to that of making an invention; for his mind conceived a plan as a purely mental picture, then developed into a workable project, and then presented it as a concrete proposition. Later, when the hostile forces met on the low plain of Marathon, Miltiades rejected the obvious plan that an uninventive mind would have adopted. Instead of it, he invented the plan of weakening his center, strengthening his flanks, and departing from the usual custom of advancing slowly against the enemy, in favor of advancing on the run. The plan (invention) worked perfectly. The unsuspecting Persians broke through the center and pursued the fleeing Athenians to a rough ground;—only to be caught between the two flanks, like a nut in a nut-cracker, and crushed to pieces.

It can hardly be seriously questioned that in this plan Miltiades showed the abilities of the inventor, and in a highly brilliant and highly important way. Had he fought the battle in the obvious way, the great numerical superiority of the Persians could hardly have failed to gain the victory, despite a really considerable superiority of the Athenians in training and equipment. But the Persians were the victims of a new and unexpected kind of attack. A new weapon suddenly brought to bear on them would have had a similar effect.

This is the first illustration in recorded history of the influence of invention on the deciding of a war. Its influence was enormous in this case; for the battle of Marathon was one of the most decisive and one of the most important battles ever fought. If it had been decided contrariwise, Grecian civilization would have been stamped out, or so completely stifled that it would never have risen to the heights it afterwards attained; freedom of thought and government would have been smothered, and the world would be immeasurably different now from what it really is.

The defeat of the Persians was so decisive that they withdrew to their own country, but with the determination of returning, and in overwhelming force. By reason of a variety of circumstances, including the death of the king, the invasion did not take place until ten years later. Then, in the year 480 B. C., King Xerxes set out on a punitive expedition against Greece with an enormous military and naval force.

Again Greece was saved from Persia by pure brain power, that of Themistocles. Like Miltiades, he rejected the obvious. Discerning, as no one else discerned, that the weakest point in the Persian forces was the line of communication across the Ægean Sea, because the ships of those days were fragile, and an invading army needed to get supplies continually from Persia, he pointed out that although it was the Persian army that would do the actual damage in Greece, yet nevertheless, the major effort of the Athenians should not be spent on their army but on their navy.

The difficulties he met in making the Athenians see the truth may easily be imagined, from experiences in our own day. He succeeded at last, however; so that by the time the Persians reached Greece, Greece had a fleet that was very good, though not nearly so large as the Persian. The fleets came near to each other in the vicinity of Athens. The majority of the Athenian leaders advised that the Athenian fleet should retreat toward the south and west, to the isthmus of Corinth, and await the Persians there; because, if defeated, a safe retreat could be effected. But Themistocles opposed this plan with all the force and eloquence he could bring to bear; pointing out that the aim of the Athenians should not be to find a safe line of retreat, but to win a battle; and that the Bay of Salamis was the best place, for two reasons. One reason was that the Persians would have to enter the bay in column, because the entrance was narrow, and the Persian ships, as they successively passed into the bay, would therefore be at a great disadvantage against the combined attack of the Athenian ships, waiting for them there; the other reason was that the bay was so small that the great numbers and size of the Persian ships would be a disadvantage, instead of an advantage. Themistocles (not without the use of considerable diplomacy and even subterfuge) finally secured the assent of the other Athenian leaders. The result was exactly what he predicted that it would be. The Persian fleet was wholly defeated, and Greece again was saved.

The great victory of the Greeks over the Persians wrought a powerful stimulation among all the people, especially in Athens, and was followed by the most extraordinary intellectual movement in the history of the world. It lasted about a century and a half; and in no other country, and at no other period, has so much intellectual achievement been accomplished by so few people in so short a time.

Before the Persian wars, the Greeks had already shown an extraordinary originality in art and literature; especially in architecture, sculpture and poetry. Naturally these peaceful arts languished during the wars; but after the Persian invaders had been finally ejected, they rose with renewed vigor, stimulated by the patriotic enthusiasm of the nation as a whole.

It was in Athens, and among the Athenians that most of the movement was carried on. The principal state in Greece besides Athens then was Sparta. The Spartans devoted themselves mainly to warlike and allied arts, while the Athenians devoted themselves mainly to the beautification of Athens; though they were careful to guard it adequately by maintaining an excellent navy, surrounding the city with high walls, and building two long parallel walls from Athens to Piræus, its seaport.

It would be out of place in a book like this to attempt any description or discussion of the various phases of the intellectual activities that rose with such startling quickness, and developed into such important movements, during the century and a half that followed the Persian wars; especially as this has already been done by many scholars, in many languages, and at many times. A very brief and elementary statement may, however, be made, for the purpose of illustrating the influence of invention on history.

The main characteristic of the movement as a whole and of every one of the various channels which it followed, was originality. No such perception of beauty had ever been evidenced before; no such conceptions of logic, philosophy or science.

Accompanying these was a conception of free government equally original. Whether the government of Athens was the cause of the intellectual rise, or the intellectual rise was the cause of the government, may safely be left to scholars to debate; for the purposes of the present discussion, it seems sufficient that they coexisted and had together a powerful influence on history.

The greatest genius that guided the intellectual forces of the Athenians in the matter of government was that of Pericles, who ruled their minds by pure force of argument and persuasion, from about 445 to 431 B. C. Athens and her subject cities formed a virtual empire, small in extent, but powerful in influence; though in form it was a democracy. In some ways it was the most perfect democracy that ever has existed even to this day; for not only was every citizen available for office, but he was expected to take active part in deciding public measures, and to be really qualified to hold office.

This idea was put into practical operation by a careful system of payment for every public service; to the end that even the poorest citizen should be enabled to hold office, and a wealthy office-holding caste prevented from existing. To so great an extent was this carried out that, by the time that the Age of Pericles ceased and the Peloponnesian War began, almost every citizen was in the pay of the state. The perfect equality of all the citizens, and their community of interests and privileges, was recognized by supplying them at times with free tickets to places of amusement, and by banqueting the people on great occasions at the expense of the state. To distribute widely the powers and duties of citizenship, exceedingly large juries were established for the trials of all cases. There was no king or president or prime minister. The source of authority was the Assembly which included every citizen over eighteen years of age, and held forty meetings a year. Cooperating, as a sort of committee, was a Council of Five Hundred, whose members were chosen by lot each year from citizens over thirty years of age.

The success of the Athenian democracy has had a powerful influence ever since on history; because it has supplied not only a precedent but an encouragement to every people to try to escape from the individual restrictions that monarchies and all "strong governments" tend to impose. But it had another though less powerful influence also, which continued for a long while, but now has ceased, in supplying a precedent for slavery. For while the citizens of Athens were free, only the sons of Athenian fathers and Athenian mothers could be citizens; many thousand workers and merchants of all kinds could take no part in the government, and there were besides an enormous number of slaves. It was to a great degree the fact of slavery that made possible the success of the so-called Athenian democracy; for it liberated the citizens in very great measure from the drudgery of life, and gave them leisure to devote themselves to the study of government and the arts.

In addition, Athens acquired great wealth from the spoils of its wars and the tribute of its subject states. This wealth was expended largely in the beautifying of Athens, and in the consequent encouragement and opportunity to artists of all kinds. Naturally, the art most immediately encouraged was that of architecture; and that the encouragement met with ready and great success the most beautiful ruins in the world superbly testify. The directing genius in this work and in all the others was Pericles, who stimulated the Athenians with his conception and description of a city worthy to symbolize the power and glory of the empire. The twin arts of architecture and sculpture worked together and in harmony; and a city more beautiful than ever known before, or ever known since, testified to the soundness and brilliancy of the conception and to the constructive ability of the Athenians to embody it in material form.

The poets and scholars kept pace with the statesmen and the architects and the sculptors; but the philosophers surpassed them all. For, while the successful democracy of Athens is a model still, and while the Parthenon and the statue of Apollo are models still, yet an integral part of the system of government (slavery) has been abjured by the civilized world, and the temples and the statues have been for the pleasure of but a few; while the teachings of the philosophers have been the basis on which has rested ever since much of the intellectual progress of mankind.

It may be noted here that, as men have progressed up the steep road to civilization, the only guides they have had have been men who have not themselves passed over the road before, and whose only qualification as guides has lain in some attribute of the mind that enabled them to survey the road a little farther ahead than the others could, and to point out the paths to take, and the obstructions to avoid. Man's physical instincts guide him considerably as to the methods to preserve his physical existence; but they help him not at all to lift himself above his physical self, and in many ways they hinder him. It seems to be the office of the mind both to discern the upward paths and to stimulate the will to overcome the difficulties and dangers in the way.

Of the great pointers of the way, Socrates, Plato, Aristotle and others, it might be deemed presumptuous of the present author to do more than speak; and of the great stimulators, Æschuylus, Sophocles, Euripedes, Herodotus, Thucydides, Xenophon, and, above all, Demosthenes as well. But because it is pertinent to our subject it is instructive for us to note that the main distinctive feature of the work of each was originality. It is true that it is the completed work in the case of each that meets our gaze; it is true that the superficial impression would be the same, even if each work had been a copy of some work that had gone before; in the same way that, superficially, many a copy of an oil painting is as good as the original. But from the standpoint of influence on the future, it is the originator rather than the copyist who wields the influence; just as it is the basic inventor of a mechanical appliance rather than the man who improves upon it.

The Athenians and Spartans became involved in the Peloponnesian War, that lasted from 431 to 404 B. C., and ended with the capture of Athens. The Spartans thereupon became dominant in Greece, but only to be mastered by the Thebans in 371 B. C. The little jealous states of Greece were never able to agree together long, and no one state was ever able to unite them. But the half-barbarian people of Macedonia, under Philip their king, after developing their army, according to a novel system invented by him, overcame and then united under their sway the highly cultured but now military weak states that had despised them.

Possibly, it would somewhat strain the meaning of the word invention, to declare that Philip made a radically new invention, when he improved on the Theban phalanx, and devised his system of military training; for kings and other leaders had trained armies long before Philip lived, and Philip departed only in what some might call detail from the methods that had been used before. But, at the same time, it was an act, or a series of acts, betokening great initiative and originality, for a man ruling a weak collection of tribes such as dwelt in Macedon, to create out of such crude material as he began with, such an extraordinary army as he ultimately was able to lead to battle. To accomplish this it was necessary for him to conceive the idea of doing it, then to embody his conception in a formulated plan, and then bring forth the finished product. The thought of doing it must have come to him:—how else could he get it? An idea comes from outside through the mental eye to the mind; as a ray of light comes from outside through the physical eye to the retina.

The picture made on Philip's mind must have impressed him profoundly, for he spent the rest of his life in giving it "a local habitation and a name." To accomplish it cost him years of continual effort of many kinds, but he did accomplish it. He did, as a result, produce a machine, as truly a machine as Stephenson ever produced, but made up of many more parts; each part independent of any other, and yet dependent on every other, and all working together, for a common purpose.

Let us remind ourselves again that a machine composed of inanimate parts only is only one kind of machine; for a machine may be composed of animate parts, or inanimate parts, or of parts of which some are animate and some inanimate. Clearly, it makes no difference, so far as the act of invention goes, whether a man uses animate or inanimate parts; the essential of invention is the creation of a new thing. If a man merely puts two pieces of wood and a piece of string into a pile, or if he merely collects a number of men together, no invention is made and nothing is created. But if he so combines the two pieces of wood and the string as to make a bow and arrow; or if he combines a modified Theban phalanx with masses of cavalry and catapults in a novel and effective way as Philip did, invention is exercised and something is created.

Before Philip's time a phalanx was used to bear the brunt of the battle, and to overwhelm the enemy by mere strength and force; as the Thebans did at Leuctra and Mantinea. But Philip conceived the idea of merely holding the enemy with his phalanx assisted by the catapults, and hurling his cavalry against their flanks. Philip's army, as Philip used it, was a machine and a very powerful one:—each part independent of every other, yet dependent on every other—all the parts working together for a common purpose. Philip conceived the idea of making this machine, and afterwards made it; just as Ericsson more than two thousand years later conceived the idea of making a *"Monitor"* and afterwards made it.

By means of his machine Philip defeated the Greeks at Cheronea in the year 338 B. C., just as Ericsson by means of his machine defeated the *Merrimac* at Newport News in the year 1862 A. D., exactly twenty-two centuries later. The two machines differed, it is true. Yet they did not differ so much as one might unthinkingly suppose; for each machine was made up of parts, of which some were animate and some were not; and in each machine every part, animate or inanimate, cooperated with all the others; and all cooperated together, to carry out the inventor's purpose, the destruction of the enemy.

The influence of Philip's invention began before Philip died, and it continues to this day. For after

Philip's death, his son Alexander put it to work at once on the task of subduing thoroughly all of Greece, and then subduing Asia.

The influence of the machine in subduing even Greece alone must not be regarded lightly; not so much because Greece was subdued, as because the various little states were by that means brought together; and because it illustrates the fact that without a machine, no great number of people can work together. It *was because of the absence of any machine* that the Grecian states acted separately and antagonistically, instead of in cooperation.

After subduing Greece, Alexander took his machine across the Hellespont, in the year 334 B. C., to try it on the Persian troops in Asia Minor. The machine worked so successfully at a battle on the Granicus that Alexander took it south, and with its aid was able to conquer all of Asia Minor in about a year.

It may be objected that it is not correct to attribute all of Alexander's success to the excellence of his machine; and this objection would have great force and receive the approval of most people, for the reason that, in most histories, the main credit is given to the energy of Alexander and the courage of his troops;—though the excellence of the training and organization bequeathed by Philip is admitted.

To this hypothetical objection the answer may be made that the ultimate result was due to both the machine and the excellence with which it was operated; that is, to the product of what the machine could do if it were used with perfect skill and the percentage of skill with which it was actually used. This statement is, of course, true of all machines and instruments, as the author has often pointed out, in articles and addresses.

In the case of Alexander and his army, the percentage of skill, of course, was high; but Alexander and each one of his soldiers was only a part of the machine; and even their skill was part of the machine in the sense that it was a characteristic included in the original design of Philip. In other words, we should not fall into the error of dissociating the skill of Alexander and his soldiers from the machine itself; because it was part of Philip's invention that the training should produce that skill. The system of training was part of the invention.

It is true, however, and exceedingly important, that the degree of skill which Alexander brought to bear personally was far in excess of what any system of training could possibly produce. When we read of the amazing victories that Alexander made over superior forces of highly trained warriors, we see that Philip of Macedon should not be given all the credit; that the genius of Philip of Macedon was not the only genius contributing to the result. We see that genius of some kind directed the decisions of Alexander. What were the characteristics of that genius?

Courage? Yes; history tells of no one possessing higher courage, both physical and moral, than Alexander. Not only was he physically brave, not only did he dare physical danger of many kinds, and on many occasions, but he was morally brave; he did not shirk responsibility; he did not fear to take enormous risks; he did not hesitate to reject advice, even the advice of his most experienced and able generals; he was willing to stake everything, sometimes, on the success of some wholly untried expedient of his own devising.

But does mere courage, even of so many kinds—and even if it be added to trained skill and the possession of an admirable machine—do they all together explain the amazing successes of Alexander? No. What does explain them?

Genius? Yes, but the word genius is only a word, and explains nothing; for the reason that no one knows what the word genius means. It is merely a label that we attach to a man who is able to do things that other men cannot do. But granting that the possession of "genius" is an explanation of Alexander's being able to accomplish what he did, in what way did that genius operate? in what way did it help him to win so many victories and extricate himself from so many perilous situations?

By inventing methods and devising schemes and improvising plans that an uninventive man would not have thought of. The story of the Gordian knot may or may not be true; but it seems credible, because it was exactly the kind of a thing that Alexander might have been expected to do in such an emergency. Posing as a great conqueror, he was (according to the legend) suddenly confronted with the untying of a knot, the successful accomplishment of which would make him master of Asia. He realized that he could not untie it. Any man but a man like Alexander would have tried it and acknowledged failure, or have declined to try it: placing himself in a defensive position in either case. But Alexander draws his sword and cuts the knot in two, thereby accomplishing whatever the untying of the knot would have accomplished, but in an unexpected way. Alexander's victories and escapes from perilous positions were largely accomplished by unexpected measures.

But Alexander showed his inventive ability before he invaded Persia; in his very first campaign undertaken to subdue a revolt in Thessaly immediately after he ascended to the throne. The Thessalians opposed him in a narrow defile. An ordinary man would have thought, as the Thessalians did, that he was checkmated. But Alexander conceived and executed the ingenious scheme of cutting a new road up the steep side of the mountain, leading his army along that road, and suddenly threatening the Thessalians in their helpless rear. Shortly afterward in Thrace he reached a defile in the mountains which it was necessary for him to pass, but which he found defended by a force that had stationed a number of war-chariots at the top, to be rolled down on the Macedonians. Alexander immediately ordered his infantry to advance up the path and to open their ranks whenever possible to let the chariots rush through; but when that could not be done to fall on their knees and hold their shields together as a sort of roof on which the chariots would slide, and from which they would roll off. This amazing story is supposed to be true; and it is said to have succeeded perfectly.

Not long afterward Alexander had to cross the Danube with his army and all their equipments and attack a force of barbarians on the farther bank. This he saw he could not do by the use of any means available of an ordinary kind. Nothing daunted, he conceived and executed the scheme of floating his equipments across at night in floats made of tent skins, filled with hay.

The next clear example that we find of Alexander's inventiveness was when he undertook the siege of Tyre. Tyre stood on an island of Phœnicia in the extreme eastern end of the Mediterranean Sea. It was surrounded with a wall, very thick and very high, and was separated from the shore by half a mile of deep water. To capture such a place was no small undertaking for a man who had no ships. But Alexander conceived and executed a scheme that worked successfully. In accordance with that scheme, he built a causeway that extended from the shore out toward the island on which Tyre stood. Naturally, the Tyrians obstructed his efforts by sending fireships against him and firing projectiles; and these tactics became more and more effective as the causeway approached the city. Then Alexander visited some of the jealous neighbors of Tyre that had submitted to him, and secured a fleet of some eighty ships; and these he led, as the admiral commanding, against the Tyrian harbor.

By this time, the causeway was well protected with catapults and war-engines of various kinds, and had been carried close up to the island. Yet little actual damage could be done to Tyre, because of the height and thickness of the walls, and because Alexander's galleys that he had equipped with war-engines could not get close enough, by reason of large boulders under water. Alexander then equipped certain galleys with windlasses to root up the boulders, the galleys being fitted with chain cables to prevent divers from cutting them. Tyre was soon afterwards reduced to a purely passive defense and consequent surrender.

The story of the siege of Tyre, if read in the light of the conditions of the comparative barbarism of the world in those days, is a record of inventiveness, on the part of Alexander, so convincing and complete, as to entitle Alexander to a place in the first rank among the inventors of our race.

Shortly afterward Alexander reached the town of Gaza, the great stronghold of the Philistines. It stood on high ground, and was more than two miles from the sea. Alexander's engineers reported to him that, as the fleet could not assist them, and as the walls were themselves very high and stood on a high hill, the walls could never be stormed. Things looked serious. They were serious; and failure would then have come to any man, except a man like Alexander. He cut the Gordian knot by ordering that ramparts be thrown up as high as the top of the walls, and war engines placed on the ramparts. This was done, and the city was taken.

Alexander's campaigns in Egypt, and afterward in western Asia, were characterized by the same quickness and daring, both in conception and in execution, that had marked his opening campaigns in Greece. Later, when advancing toward Persia, he encountered a tribe of hillsmen in the Uxian Pass, who, like the Thessalians and the Thracians, thought they had blocked his passage by opposing him in so narrow a defile. Alexander literally "circumvented" them by making a night march over a difficult mountain pass, and astonishing them by an attack on their rear the following morning. Shortly afterward a like situation presented itself, when an army opposed him in a narrow defile called the Persian Gates, that was fortified with a wall. Alexander soon realized that the position of his enemy was impregnable. He learned, however, that there was a path that led around the pass, though it was exceedingly dangerous, particularly to men in armor and to horses, and especially at that time, when snow and ice were on the ground. He again utilized his former invention (circumvention) and with his former success; though the conditions under which it was accomplished were much more difficult.

The four examples just given of literally circumventing an uninventive enemy illustrate in the simplest form the influence of invention on military history.

After it became clear to Alexander that his invasion of Asia would be successful from a military point of view, his active imagination presented to his mind a picture of a grand and noble empire, embracing the whole world, but dominated and inspired by the spirit of the civilization of Greece. To develop this conception into an actual reality, became at once the object of his efforts. To develop it, he decided to adopt in some measure the characteristics and dress of the people in whatever province he might be, and to take such steps in organizing provinces, founding cities and establishing systems, as to weld all into one empire, under himself, as ruler. One can hardly credit the authoritative account he reads of Alexander's bewildering success. He seems not only to have won battles, and built cities, and organized provinces, but actually to have super-posed Greek civilization on Persian civilization!

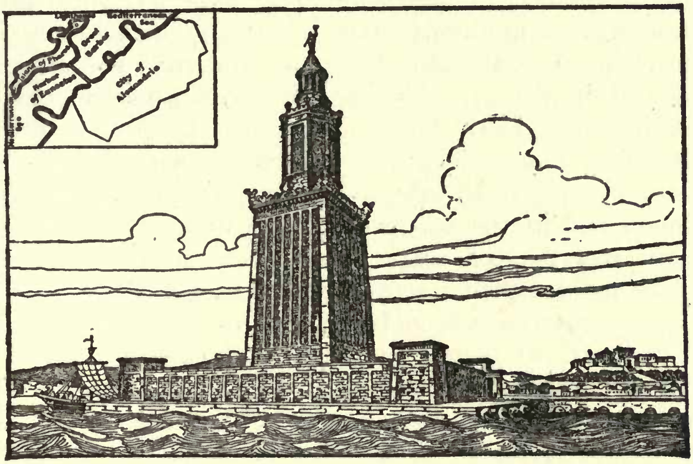
In one of his most important later battles, Alexander again utilized his inventiveness. If he had not done so, he would assuredly have lost the battle. It was against King Porus in northwestern India. Alexander found the forces of Porus encamped on the opposite side of the Hydaspes River, with the evident intention of preventing him from crossing. As the army of Porus in men alone was evidently equal to his own, and as it was reinforced with a multitude of elephants, Alexander was apparently confronted with a problem impossible of solution. It would have been impossible to anyone but a man like Alexander. He, however, by means of various feints and ingenious stratagems, managed to get across at night about sixteen miles up the river, using boats that he had constructed, and floats of skin stuffed with straw. Porus took up a position on the opposite shore and made ready to receive attack, his front preceded by war chariots and elephants. Alexander had neither; but he did have brains and originality. So he simply held the enemy with his infantry, and then made a determined attack with cavalry and archers on the enemy's left flank, and especially on the elephants. The elephants soon got beyond control; and the rest of the battle was a fight between a highly trained Macedonian phalanx, assisted by cavalry, and an Oriental mob.

Alexander died in Babylon when not quite thirty-three years old. In actual and immediate achievement he surpassed perhaps every other man who has ever lived. He founded an empire which he himself had conceived and developed, which covered nearly all the then known world, and which, though it was composed mainly of barbarous and semi-barbarous people, was dominated by Greek thought. It is true that the empire fell apart almost immediately after Alexander died. But it did not fall into anarchy, or revert to its previous state: it was divided into four parts, each of which was distinct, self-governing and well organized. The two larger parts, the kingdom of the Seleucidæ, which occupied approximately the territory of Persia, and the kingdom of the Ptolomies, or Egypt, continued as torch-bearers to civilization for many centuries thereafter.

Of the two, the former was the larger and was probably the better, from an administrative point of view; but Egypt represented the finer civilization; for Alexandria, with its library and its wonderful museum, became the seat of learning and the resort of the scholars of the world, and the centre of the Hellenistic civilization that followed that of Greece.

This Hellenistic civilization, it may here be pointed out, was in some respects as fine as that of Greece, and in some respects was finer, because it was more mature. But (perhaps for the reason that it was more mature) it lacked much of the element that was the highest in the Greek, the element that gave Greek civilization greater influence on history than any other civilization ever had—the creative element. The creative period of Greece ceased when her political liberty was lost. Furthermore, the immense amount of wealth that poured into the Grecian cities and the Græco-Oriental world, by reason of the putting into circulation of gold that had been stored away in Oriental palaces, as well as by the commercial exploitation of the riches of the East, brought about a general effeminizing of all classes of society, and the consequent dulling of their minds.

Nevertheless, there was great intellectual activity in the Græco-Oriental world, and a certain measure of



The Lighthouse of the Harbor of Alexandria in the Hellenistic Age

invention, though little was of a basic kind. Euclid improved the science of geometry, and put it in virtually the same shape as that in which it has been taught since, even to this day. Aristarchus, the astronomer, announced the doctrine that the earth revolves around the sun and rotates on its own axis; and Hipparchus invented the plan of fixing the positions of places on the earth by their latitudes north and south of the Equator and their longitude east or west of a designated meridian. Hippocrates and Galen conceived and developed the foundations of the science of medicine of the present day. Eratosthenes estimated with extraordinary accuracy the circumference of the earth, and founded the science of geography.

But the greatest of all of the original workers of that time was Archimedes, who lived at Syracuse in Sicily, and was killed by mistake when Syracuse was captured in the year 212 B. C., while engaged in drawing a geometrical figure on the sand. His principal fame is as a mathematician; but as a great inventor of mechanical appliances, he is the first man recognized as such in history. The invention with which his name is most frequently linked is that of the Archimedean screw. This consisted of a tube, wound spirally around an inclined axle, and so disposed that when the lower end of the tube was dipped into water and the axle was rotated water would rise in the tube—as shavings do when a screw is screwed down into wood. It constituted a very convenient pump and was so used. This was, of course, a mechanical invention of the utmost originality and value, and forms one of the clearly defined stepping-stones to civilization.

There seems to be a belief in the minds of some that Archimedes was the inventor of the lever. The lever was, of course, invented long before he lived; but the laws of its operation and the principle that the weight on each side of the fulcrum, multiplied by its distance from the fulcrum, is equal to the weight on the other side, multiplied by its distance (when the lever is in equilibrium), seems to have been established by him.

Many stories are told of his exploits when Syracuse was besieged by the Romans, but they are rather vague. The best known story is that he arranged a great many mirrors in such a way that he concentrated so many rays of sunlight on some Roman ships that they took fire. Whether this is true or not is not definitely known; but many centuries later Buffon, the French scientist, made an arrangement of plane mirrors with which he set fire to wood 200 feet away.

The greatest single exploit of Archimedes was his discovery and demonstration of the hydrostatic principle that the weight of liquid displaced by a body floating in it is equal to that of the body. The story is that the king gave him the apparently impossible task of determining the quantity of gold and the quantity of silver in a certain gold coin, in making which the king suspected the workmen of stealing part of the gold and substituting silver. Pondering this subject later while lying in his bath, Archimedes suddenly realized that his body displaced a bulk of water equal to that part of his body that was immersed, and conceived the consequent law; and the conception was so startling and so vivid that he rushed unclad out into the street crying, "I have found it, I have found it."

The story as a story may not be exactly true; but if Archimedes had realized the full purport and the never-ending result of his conception, he would probably have done something even more eccentric than he did.

Archimedes esteemed mechanical inventions as greatly inferior in value to those speculations and demonstrations that convince the mind, and considered that his chief single work was discovering the mathematical relation between a sphere and a cylinder just containing it.

Whether this discovery and the discovery of the hydrostatic principle just mentioned were inventions or not, depends, of course, on the meaning of the word invention. Within the meaning of the word as employed heretofore in this book, both seem to have been inventions. Each made a definite creation and each caused something to exist, the like of which had never existed before. Furthermore, the mental processes followed resemble very closely the conception and formulation of a religion or a theory, the conception and composing of a new piece of music, story or poem, the conception and developing of any new plan or scheme; the conception and embodying in material form of any mechanical device.

It is not asserted, of course, that all inventions are on a dead level of equality, simply because they are inventions. Evidently there are degrees of excellence among inventions as among all other things.

CHAPTER IV

INVENTION IN ROME: ITS RISE AND FALL

WE have noted, up to a time approximately that of Archimedes, a continual succession of inventions of many kinds, that formed stepping-stones to civilization so large and plain, that we can see them even from this distance.

We now come to a period lasting more than a thousand years, in the first half of which there was a gradually decreasing lack of inventiveness shown, and in the latter half a cessation almost complete.

The nation that followed Greece as the dominant nation of the world was Rome. She became more truly a dominant nation than Greece ever was; but her civilization was built on that of Greece, and her success even in war and government was due largely to following where Greece had led. That Rome in her early days should have followed the methods of Greece was natural of course; for the two countries were close together, and the methods of Greece had brought success. The early religion of Rome was so like that of Greece that even to this day the conceptions of most of us regarding Zeus and Jupiter, Poseidon and Neptune, Aphrodite and Venus are apt to become confused.

Like the Greeks, the Romans first were gathered in city-states that were governed by kings; and as with the Greeks, more republican forms were adopted later. In one important particular, the Roman practice diverged from the Greek, and that was in incorporating conquered states into the parent state, and granting their inhabitants the privileges of citizenship; instead of keeping them in the condition of mere subject states. The Roman system was somewhat like the system of provinces established by the Assyrians. It forms the basis of the "municipal system" of the free states of the present day, in which local self-government is carried on, under the paramount authority of the state.

It may be pointed out here that the conception of such an idea and its successful development into an effective machine of government by the Romans constituted an invention; though in view of what had been done before by Assyria and Greece, it cannot be called a basic invention.

The early Romans were very different in their mental characteristics from the Greeks; for they were stern, warlike, intensely practical, and possessed of an extraordinary talent for what we now call "team work." As a nation they were not so inventive as the Greeks; but the Roman, Cæsar, was the greatest military inventor who ever lived.

As might be expected, their early endeavors pertained to war, and their first improvements were in warlike things. One improvement that was marked by considerable inventiveness was in changing the phalanx into the legion. The phalanx, the historian Botsford tells us, was "invented by the Spartans, probably in the eighth century B. C.," and consisted of an unbroken line of warriors, several ranks deep. The Thebans improved on this; and from the Theban, Philip developed the Macedonian phalanx with which Alexander fought his way through Asia. The Romans under Servius Tullius developed this into the Roman phalanx, which was different only in detail. The essential characteristic of the phalanx was strength. This was gained by the close support given by each man to his neighbor, the personal strength of each man and the trained cooperation of all. A tremendous blow was given to an enemy's line when a phalanx struck it.

In the early wars among the hills of Italy, the Romans found the phalanx too rigid for such uneven country; and it was in endeavoring to invent a substitute that they finally developed the legion. This machine was much more flexible, the individual soldiers had more room for their movements, and yet the machine seemed to possess the necessary rigidity when the shock of impact came. The heavy infantry was in three lines, and each line was divided into ten companies, or "maniples." The burden of the first attack was borne by the first line. If unsuccessful, the first line withdrew through gaps in the second line, and the second line took up the task;—and then the third, composed of the most seasoned troops. The attack usually began with the hurling of javelins, and was followed at once by an assault with the Roman strong short swords.

Now the legion was just as truly an invented machine as a steam engine is; and it had a greater influence on history than the steam engine has ever had thus far. It was by means of their legions that the Romans passed outside of the walls of Rome, and conquered all of Italy. It was by means of their legions that the Romans conquered all the coast peoples that bordered the Mediterranean Sea, subdued Gaul, Europe and Egypt and Asia, and became the greatest masters of the world that the world has ever seen.

The first war of the Romans that history calls great was their war against the splendid and wealthy city of Carthage, situated on the opposite side of the Mediterranean, inhabited by descendants of the Phœnicians. They were an aggressive and energetic people, but only commercially. They were not of the warlike cast, and delegated the work of national defense to hired soldiers and sailors. They had one great advantage over the Romans in the possession of an excellent navy.

The Romans resolved to create a navy. With characteristic energy and practical ability, they devoted themselves at once to both the acquisition of the personnel and the material, and the adequate training of the crews. It is stated that within two months from the time of starting, Rome possessed a hundred quinqueremes, the largest galleys of those days, having five tiers of rowers; though they had had none when the war broke out. The first naval battle took place near the promontory of Mylæ. Naturally, the Romans were at a great disadvantage as compared with the experienced officers and sailors in the Carthaginian fleet; for though the Roman soldier was far better than the Carthaginian, the Roman sailor was inexperienced and unskilful. To remedy the difficulty, the Romans made a simple but brilliant invention. They provided each quinquereme with a *"corvus,"* that consisted essentially of a drawbridge that could be lowered quickly, and that carried a sharp spike at its outer end; and then arranged a plan whereby each quinquereme should get alongside of a Carthaginian, drop the drawbridge at such a time that the spike would hold the outer end of the drawbridge in place on the Carthaginian deck, and Roman soldiers should then rush across the drawbridge and attack the inferior Carthaginian soldiers.

Few more brilliant inventions have ever been made; few have been more successful and effective. The battle ended in a perfect victory for the Romans, and constituted the initial step in the subjugation of Carthage by Rome.

There were three wars in all, called Punic Wars. The great Carthaginian General, Hannibal, invaded Italy by land in the Second War, and after a campaign marked with a high order of daring and ability, threatened Rome herself after a brilliant victory near Lake Trasimene. Another victory followed at Cannæ, but a decisive disaster later on the Metaurus River. So the Second War was won by Rome. But Carthage still existed, and menaced the commercial, naval and military dominance of Rome. Therefore war was brought about at last by Rome, and Carthage destroyed completely.

The conduct of Rome toward Carthage cannot be justified on any grounds of any system of morality accepted at the present day; and yet it cannot reasonably be denied that it was better for human progress that Rome should prevail than Carthage. The Romans, harsh and ruthless as they were, were less so than the Carthaginians; and they had an element of strong manliness and a comprehensive grasp of things beyond mere commerce and money-getting and ease and comfort that the Semitic Carthaginians wholly lacked. The effect of the conquest of Carthage by Rome was a little like that of the conquest of Persia by Alexander.

During the same year (146 B. C.) when Rome destroyed Carthage, she also destroyed Corinth in Greece, and brought Greece and Macedonia under her sway. She had previously (190 B. C.) defeated Antiochus the Great, and taken from him nearly all his territory in Asia Minor.

By the year 58 B. C., Rome had become the most powerful nation in the world and still preserved a republican form of government. In that year, 58 B. C., the man who probably is the most generally regarded as the greatest man who has ever lived, appeared upon the stage of history. His name was Julius Cæsar.

He appeared in that year, because he went then from

Rome to Gaul, and started on those brilliant and in many respects unprecedented campaigns which have had so profound an effect on history, and which for originality in conception and execution have had no rivals since.

At this time, Italy and the lands of Africa and Asia on which Alexander had impressed the civilization of Greece, were prosperous and well-governed; but beyond those countries only barbarous customs prevailed, and only a primitive civilization reigned. The lands that lay north and northwest of Italy, throughout all Gaul, were inhabited by savage tribes that were in a state of continual war with each other. In the southern and middle parts the effects of Roman civilization might be dimly seen; but in the southwestern part, and in the north, especially among the German tribes on the Rhine, and the Belgæ near the North Sea, a condition of virtually pure savagery prevailed.

Into such a country Cæsar marched, at the head of a body of men wholly inferior in numbers to those they were to meet, not superior to them in courage or physical strength, but considerably superior to them in discipline, and vastly superior in the weapons and methods that had gradually been invented, with the progress of civilization. Thus, while the Roman machine was superior as a machine to any that the Gauls could bring to bear, it was smaller; so that the question to be decided was whether the superior excellence of the Roman machine was great enough to balance its inferiority in size. Looking back from our vantage ground on the history of the campaigns that followed, we feel inclined to answer the question in the negative, unless we consider Cæsar himself a part of the machine. It is true that the campaigns were decided in favor of the Roman machine; but there seems little ground for doubting that they would not have been so decided, if the genius of Cæsar had not managed the Roman machine and made improvements from time to time.

Cæsar had had little experience as a soldier, but his habits of life and traits of character were of the military kind. As the campaigns progressed, his courage, equanimity and rapidity of thought and action were continually displayed;—yet not to such a degree as to put him in a higher class than many other generals of history, or to account wholly for his marvellous successes. One peculiar ability, however, he possessed and exercised in a degree greater than any other general of history: and it was by the exercise of that ability that his most extraordinary victories were achieved, and his generalship especially distinguished from the generalship of others. That ability was inventiveness.

His first contact was with the Swiss (Helvetii), who were about to leave the barrenness of their mountain lands, and march west to the fertile lands beyond. As this would take them through Roman territory and tend to drive the Gauls into Italy, open Switzerland to occupation by the Germans, and point a road thence for them also into Italy, Cæsar hastened to the Rhône River, destroyed the bridge which they would naturally go over, and forbade the Swiss to attempt to cross the river. The Swiss pleaded with Cæsar to permit them to cross. As Cæsar realized that the Swiss were too greatly superior in force to be kept back, unless he could strengthen himself in some way, he asked time for reflection, and told them to return in two weeks. When the Swiss returned at the end of that time, their astonished eyes disclosed to them the fact that Cæsar had constructed walls and trenches and forts at every point where a passage could reasonably be attempted.

It may be objected that walls and trenches and forts were not new, and that therefore Cæsar invented nothing. This may be admitted as an academic proposition; but nevertheless, it was clearly the ingenious and wholly unexpected construction of certain appliances by Cæsar that opposed the barbarous Swiss with barriers which they could not pass. It may even be argued with much reason that the conception and successful execution of Cæsar's plan as a whole constituted an invention, even though the material used was old. Certain it is that a situation was created which did not exist before, and that it was the creation of this situation, and not the exercise of strength or courage, that was *the determining factor* in stopping the Swiss. Froude says of Cæsar, "He was never greater than in unlooked-for difficulties. He never rested. He was always inventing some new contrivance."

Cæsar realized fully the value in war of mechanical appliances, and took careful measures before he left Italy to supply his army adequately with them, and also with men trained to use them. Besides the fighting men strictly considered, Cæsar took a considerable number of engineers with him, and expert men for building bridges, and doing mechanical work of many kinds. The ingenious and frequent use that Cæsar made of these men and of mechanical appliances was the most powerful single factor that contributed to his success.

The Swiss departing from Switzerland by another route, Cæsar pursued them, and defeated a fourth of them in a battle on the banks of a river which the other three-fourths had crossed. He then built a bridge over the river and sent his army across. This feat alarmed the Swiss more than their defeat; because Cæsar had built the bridge and sent his army across in one day, whereas they had consumed twenty days in merely crossing. The Swiss pleaded to be allowed to proceed; but Cæsar was obdurate. A battle followed, in which the Swiss, though greatly superior in numbers and reinforced by 15,000 allies, were decisively beaten; not because of inferior courage or warlike skill, but by reason of inferior equipments, mechanical appliances and weapons.

Cæsar's next battle was with the Germans. It was won, if not precisely with inventiveness, at least with "brains." He learned that the German matrons had declared, after certain occult proceedings, that Heaven forbade them to fight before the new moon. Apprehending his opportunity, he advanced his forces right up to the German camp, thereby forcing them as valiant soldiers to come out and fight. Fight they did, but under an obvious psychological disadvantage, and with the natural result.

In this battle, as in others between the Romans and the barbarians, it was noticeable that although their first onslaught was fine, the barbarians seemed to be at a loss afterwards,—especially if anything unexpected occurred, or if any reverse was sustained; whereas the Romans—and especially Cæsar himself—never behaved so well as when threatened with disaster. This may be expressed by saying that the barbarians, as compared with the Romans, were wholly inferior in the inventiveness needed to devise a new plan quickly.

Not long afterward, Cæsar advanced against the town of Noviodunum. He soon saw that he could not take it by storm; and so he brought forward his mechanical siege appliances. The psychological effect of these on the barbarians was so tremendous that they at once pleaded for terms of surrender.

After a battle with the Nervii, in which Cæsar defeated them disastrously, largely because of his resourcefulness in emergency and their lack of it, he advanced against a great barbarian stronghold that looked down on steep rocks on three sides, and was protected by a thick, high double wall on the fourth side. Cæsar made a fortified rampart around the town, pushed his mantlets (large shields on wheels protected on the sides and top) close up to the wall, and built a tower. The barbarians laughed at this tower; seeing it so far away that, they thought, no darts thrown from it could reach them. But when they saw the tower actually moving toward them they were struck with terror and began at once to sue for peace.

During the following winter the Veneti, a large tribe on the northwestern coast, the most skilful seamen and navigators of Gaul, stirred up a revolt that quickly and widely spread. The situation at once became serious for Cæsar, for the reason that the Veneti could not be subdued, except on the sea; and neither the Roman sailors nor the Roman vessels were as good as were those of the Veneti. Nevertheless, Cæsar ordered war-vessels to be built on the Loire River, and seamen and rowers to be drafted from the Roman Province.

When the improvised fleet of the Romans and the thoroughly prepared fleet of the Veneti came together, the latter was superior even in numbers. Furthermore, the Romans were at a great disadvantage in the matter of throwing projectiles, from the fact that the Veneti's decks were higher than theirs.

But Cæsar had prepared a scheme that gave him victory. In accordance with it, the Roman galleys rowed smartly against the Veneti ships, and Roman sailors raised long poles on which were sharp hooks which they put over the halliards that held up the sails. Then each Roman galley rowed rapidly away, the halliards were cut, and down came the sails. The Veneti ships became helpless at once and were immediately boarded; with the result that, of all the number, only a few made their escape.

Somewhat later, Cæsar decided to cross the Rhine into the country of the Sueves, and to impress them with the power of Rome by building a bridge and marching his army across. This bridge and the quickness and thoroughness with which it was built are still models for engineers; for in ten days after he had decided to build it, at which time the material was still standing in the forest, a bridge 40 feet wide had been constructed. Across this Cæsar at once marched his legions. The effect on the barbarous Germans can be imagined. It made them realize that the Romans were a race superior to themselves in ways that they could not measure or even understand; and it impressed them with that fear which is the most depressing of all fears, the fear of the unknown.

Did Cæsar make an invention? This depends on the meaning of the word invention. Cæsar did not invent the bridge; but he did conceive and carry into execution a highly original, concrete and successful scheme. By it he accomplished as much as a victorious campaign would have accomplished, and without shedding any blood. *He devised means which created a state of thought in the minds of his enemies that destroyed their will to fight.* Therein lay his invention.

Cæsar then conceived the idea of going across the water to the island of Britain, about which little was known. After having a survey made of the coast, he took his legions across in about eighty vessels. He had to fight to make a landing, of course; but he succeeded, and then formed his camp. A Roman camp, we may now remind ourselves, was so distinctly a Roman conception, and so distinctly a part of the Roman system of conducting war, that it almost constituted an invention. Whenever a Roman army halted, even for one night, they intrenched themselves within a square enclosure, surrounded with a ditch and a palisade of stakes, and made a temporary little city, laid with streets. In such a camp they were reasonably safe against any attack that barbarians could make.

But a storm arose that drove some of Cæsar's ships ashore and some out to sea. In this emergency, Cæsar's resourcefulness and energy directed the work of recovery and repair, and enabled the Romans to collect and put into good condition nearly all their ships. Cæsar returned shortly afterward to Gaul; arrived there, he gave directions for building and equipping another and larger fleet.

In the following July (54 B. C.), he started again for Britain. This time he took five legions and some cavalry and had about 800 vessels. He landed and formed his camp, and then advanced inland;—but another storm arose that scattered his ships. He returned at once to the coast, and instituted such prompt and resourceful measures that in ten days he was able to resume his march. On this march, which took him far inland, he was able to overcome all opposition; largely because, after the first onset, the barbarians seemed to be without any plan of action, while Cæsar was at his best.

Cæsar had the ability to invent under circumstances of the utmost danger and excitement.

Cæsar's remaining campaigns in Gaul were marked with the same resourcefulness and originality on his part, and the same lack of resourcefulness and originality on the part of the barbarians. Cæsar would continually do something that the barbarians had not expected him to do. True, they gradually learned some of his schemes and methods from him; but only to find that he had then some newer schemes and methods.

Cæsar at one time remarked that wise men anticipate possible difficulties, and decide beforehand what they will do, if certain possible occasions arise. Does not this process involve invention, in cases where the possible occasions are not of the ordinary and expectable kind? In such cases, does it not require imagination to foresee the possible occasions, and form a correct picture on the mind of the resulting situations? This being done, does it not require the exercise of the constructive faculty afterwards, to make a concrete and effective plan to meet them?

If it be so, then we may reasonably declare that, of all the factors that contributed to the successes in Gaul of Cæsar, the most powerful single factor was his inventiveness.

The final crisis came when Cæsar besieged Alesia, and Vercingetorix, who had taken refuge in it, sent out a call for succor, that was eagerly and promptly responded to; for it was plain to the barbarians that Cæsar, being held in position fronting a fortress that he could not successfully storm, would be in a precarious condition if attacked vigorously in his rear. Attacked vigorously he was; for the barbarians came in his rear with about 250,000 men; Cæsar having only 50,000, and the enemy in front having 80,000.

But it required somewhat more than a month for the barbarians to unite and reach Alesia. With his wonted energy and resourcefulness, Cæsar had by this time cast up siege works all around the fortress, placed camps at strategic points, and constructed twenty-three block-houses. He dug a trench twenty feet deep around the place, and back of this began his other siege works. These included two parallel trenches fifteen feet broad and fifteen feet deep. Behind these he built a palisade twelve feet high, and to this he added a breast-work of pointed stakes; while at intervals of eighty feet he constructed turrets. In addition, he had branches cut from trees and sharpened on the ends; and these he fastened at the bottom of the trenches, so that the points projected just above the ground. In front of these he dug shallow pits, into which tapering stakes hardened in the fire were driven, projecting four inches above the ground. These pits were hidden with twigs and brushwood. Eight rows of these pits were dug, three feet apart; and in front of all stakes with iron hooks were buried in the ground at irregular intervals. When all this had been done on the side toward the fortress, Cæsar constructed parallel entrenchments of the same kind, to protect his rear; the two sets being so arranged with respect to each other that the same men could man both. Having constructed all these material appliances, he instituted a comprehensive system of drills, so that his men would know exactly how to utilize them under all probable contingencies.

In the battle that followed the barbarians showed their wonted courage and dash; but an unexpected situation arose when Cæsar attacked a separated part in their rear. Then they were seized with panic, and the natural rout and disaster followed.

This battle decided the fate of Gaul; though its actual subduing, especially in the southwestern part was not accomplished immediately. The last major act was taking a strong fortress. This was accomplished by cutting a tunnel, by which the spring was tapped that supplied the garrison with water. As Vercingetorix said, the Romans won their victories, not by superior courage, but by superior science.

Cæsar's later passage across the Rubicon, the flight of the Senate, and his later operations by land and sea against Marseilles (Massilia) and hostile forces in northern Spain, are well known, and were characterized by the same high order of inventiveness. His later operations against Pompey, and later still against Pharnaces and Scipio, were conducted under conditions that gave him less opportunity to utilize the quality of inventiveness in such clear ways; but they were marked with the kindred qualities of foresight, skilful adaptation of means to ends, and presence of mind in emergencies.

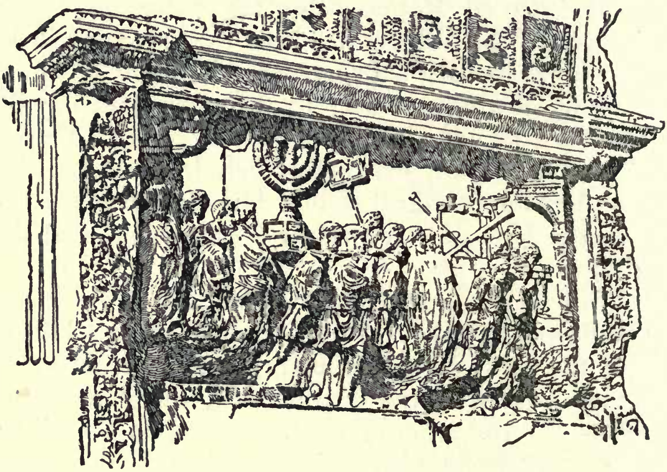
In the minds of some, Cæsar's greatest influence on history has been due to his improvement of the Calendar, and especially his reforms of the public morals and the laws of Rome, after his campaign against Pharnaces. This subject has been the theme of jurists and scholars to such a degree that it might seem presumptuous in a navy officer to do more than mention it. At the same time it may be pointed out that Cæsar's work was not in any matters of detail, or in contributing any legal or juridical skill or knowledge, but in conceiving the idea of creating the *Leges Juliæ,* and then creating them.

Julius Cæsar was murdered in the year 44 B. C. He was followed in power by his grandnephew Octavius, one of the most fortunate occurrences in history; for Octavius possessed the ability and the character to carry on the constructive work that Julius Cæsar had begun. Under Octavius and his successors, the Roman Empire became increasingly large and strong, until the reign of Trajan in the second century, A. D., when it acquired its greatest territorial extent.

During the time when Rome was increasing in extent and power, the wealth of cities and of individuals increased also, and enormous public works of all kinds were constructed, many of which are still the admiration of the world. Material prosperity reached its highest point.

But the creative period had passed. Youth, with its dreams and vigor of doing had gone, and maturity, with the luxury of prosperity and the consequent dulling of the imagination, had assumed its place. Senescence followed in due course. Then the empire was divided into two parts, the Empire of the West and the Empire of the East. Finally, in 476 A. D., Rome died and with it the Empire of the West.

But the Eastern Empire stood, and Constantinople was its capital. And it stood, alone and unassisted, as the sole bulwark of Christianity and civilization for



Triumphal Procession from the Arch of Titus

nearly 1000 years, until it finally fell before the Ottoman Turks in 1543. It could not have done this, if in the latter part of the seventh century when it was beleaguered by a Turkish fleet, much greater than its own, it had not suddenly received unexpected aid in the shape of a new invention. This was "Greek fire," which seems to have been a pasty mixture of sulphur, nitre, pitch, and other substances, which when squirted against wood set it on fire with a flame that water could not quench. In the very first attack, the Turks were so demoralized by the Greek fire that they fled in panic. They never learned the secret and were never able to stand up against it. On one occasion, fifteen Christian ships, using Greek fire, actually put to rout a Turkish fleet numbering several hundred.

During all the countless centuries before the dawn of recorded history, and during the approximately forty centuries that elapsed from the beginning of recorded history until the fall of Rome, we have observed the coming of many inventions of both material and immaterial kinds, and noted the influence of those inventions in causing civilization, and therefore in directing the line that history has followed.

It may be objected that a perfectly natural inference from what has been written would be that the only thing which had influenced the direction of movement of history was invention. To this, the answer may very reasonably be made that this book does not pretend to be a history, or to point out what have been the greatest factors that have influenced its line of movement; it attempts merely to emphasize the influence of one factor, invention, and to suggest that maybe its influence has not hitherto been estimated at its proper value.

Another objection like that just indicated might be made to the effect that all the progress of the world up to the fall of Rome is attributed in this book to inventors only; that all the work of statesmen, scientists, generals, admirals, explorers, jurists, men of business, etc., etc., is ignored.

Such an objection would be natural and reasonable; but to it an answer like the previous one may be made, to the effect that the purpose of this book is not to compare the benefits conferred by any one class of men with those conferred by any other, but merely to point out, in a very general way, what inventors have done.

Nevertheless, it does seem clear that inventors did more to map out the direction of the progress just traced than any other single class of men. If we will fix our attention on any one invention about which we know enough—say, the water-clock—we can see that the original inventor of the water-clock (no matter who he was) had more influence on the history of the clock than any other man has had; and that the inventors of clocks who followed him had more influence on the clock than any other equal number of men had. This does not mean that the men who risked their money in making novel clocks did not influence the history of the clock materially; and it does not mean that the men who made good materials for them did not influence the history of the clock greatly; and it does not mean that the engineers and mechanics who operated them successfully did not influence its history. It would be absurd to pretend that each one of these men did not influence the history of the clock; for without them there would have been no successful clock. Nevertheless, in the nature of things, the original inventors must be credited with influencing the history of the clock more than any other equal number of men did, just as a father must be credited with influencing the history of his children more than any other man can, from the mere fact of his having caused them to be born. The inventors of clocks were the fathers of the clocks that they invented, and also the forefathers of all the inventions that proceed directly or indirectly from them.

What has been said about the clock applies with equal force to every other invented thing. Therefore, it can hardly be gainsaid that, so far as invented things are concerned, their inventors have had more influence on the history that has resulted from them than any other men have had.

If anyone will glance through any book of ancient history, he will realize that it is mainly a record of wars; the political changes caused by wars, or rendered possible by their means; the growth of nations and other organizations; the invention of certain mechanisms, arts and sciences; and the construction of certain structures such as temples, palaces and ships. All these agencies influenced ancient history, of course; but it is clear that the agency that influenced it the most obviously and immediately was the wars.

Yet let us remind ourselves that the real effect on history of any war was not exerted by the war itself, so much as by the result of the war. Let us also remind ourselves that the result of any war was because of the material forces engaged and the skill with which they were handled.

Now the material forces put onto the field of battle on each side in any of the wars were the product of the material resources of the country, of its wealth, its ability to manufacture weapons and transport troops; that is, of its utilization of invented mechanisms, processes and methods. The skill with which they were handled—(especially when supreme skill was exerted, as in the cases of Alexander and Cæsar)—was the outcome not of mere laborious training, not of mere knowledge, or courage, or carefully detailed arrangement, but of plans so conceived, developed and produced (invented) as to confront the enemy with unexpected situations that they were not prepared to meet. So the influence of even the wars seems to have been due fundamentally to invention.

As to the other agencies that influenced the course of ancient history, they seem to owe their influence even more obviously to invention than war does. Every department of ancient civilization seems traceable back to some invention or inventions. The whole of ancient civilization seems to rest primarily on inventions.

As inventions were made by inventors, we seem forced to the conclusion that inventors influenced ancient history more than any other one class did. This does not mean that the inventor of a child's toy influenced history more than did any one of the millions of wise and good men in each generation who helped to keep the machine of civilization working smoothly; for it refers to inventors as a class, and not to inventors as individuals.

CHAPTER V

THE INVENTION OF THE GUN AND OF PRINTING

THE period from the fall of Rome to the beginning of the fourteenth century was almost destitute in the matter of inventions that can be distinctly named: though the conception and carrying into effect of Mohammedanism in the seventh century, the campaigns and governmental systems of Charlemagne in the ninth century, the invasion of England by William of Normandy in the eleventh century, and the Crusades in the eleventh, twelfth and thirteenth centuries, as well as all the numerous wars and campaigns that succeeded each other so rapidly, indicate a mental and nervous restlessness which sought relief in action, and which received guidance in seeking that relief from the suggestions of invention.

During the interval, paper is supposed by some to have been invented, or at least the art of making it from rags. Paper itself, however, had been invented long before in China.

The early part of the twelfth century opened a new era in Europe with the introduction of one of the most important inventions ever made, the gun. It is often said that gunpowder was invented then. Gunpowder, of course, had been invented or discovered many centuries before.

There is much obscurity about the invention of gunpowder. It is usually supposed to have been invented in China, and to have crept its way first to the western

Asian nations, and afterwards to Europe by way of the Mediterranean. There can be little doubt that gunpowder was known to the Romans in the days of the empire; and some accounts of Alexander's campaigns declare that he used mines to destroy the walls of Gaza.

It is supposed by many that the Chinese had cannon, from certain embrasures in some of their ancient walls; but there seems to be no absolute proof of this. It seems fairly well established that the Moors used artillery in Spain in the twelfth century; though some writers hold that what were called firearms in Europe before the fourteenth century were only engines which threw fire into besieged places.

It seems probable that the gun was invented as the result of an accident that occurred while some man was pounding the (gunpowder) mixture of charcoal, saltpetre and sulphur in a receptacle of some kind. According to one story, the mixture exploded and threw the pestle violently out of the mortar. From this incident, the man who was handling the pestle, or a bystander, is supposed to have conceived the idea that the powder could be used intentionally to throw projectiles, and he is supposed also to have actually proved that it could be done at will, and to have produced a concrete appliance for doing it. From the history of the case, it would seem that the first gun was what we still call a "mortar."

It may occur to some that (conceding the story to be true, which it possibly is, in essentials) the gun was not an invention so much as a discovery. It may be pointed out, however, that while the fact that gunpowder would blow a pestle out of a mortar might be truly called a discovery, yet the conception of utilizing the discovery by making a weapon, and the subsequent making of the weapon constituted an invention of the most clean-cut kind.

Let us realize the extreme improbability that the phenomenon of the expulsive force of gunpowder was then noted for the first time. It seems probable that accidental ignition of the mixture had often occurred before, and missiles hurled in all directions in consequence. But, as happens in the vast majority of all incidents, no one imagined any possible utilization of the facts disclosed by the incident; and if the man who invented the gun, after witnessing the expulsion of the pestle from the mortar, had not been endowed with both imagination and constructiveness, he would have treated it as most of us treat an incident—merely as an incident. But the imagination of this man must at once have conceived a picture of what we now call a mortar, which should be designed and constructed so that projectiles could be expelled from it at will, in whatever direction the mortar were pointing; and then his constructive faculty must have taken up the task that imagination had suggested, and developed the conception into a concrete thing.

Into the long, elaborate and exciting history of the development of the gun, that has been carried on with enormous energy ever since, it is not necessary at this point to enter. Since the sixteenth century, its history is accurately known, and many large books are filled with descriptions and diagrams and mathematical tables and formulæ that recount its progress in detail; while the histories of all the nations blaze with stories of the battles in which guns have been employed. Of all the inventions ever made, it is doubtful if the development and improvement of any other has enlisted the services of a greater number of men and of more important men, than the gun. It is more than doubtful if a greater amount of money has been expended on any other invention, if a greater number of experiments have been made, or if more mental and physical energy has been expended. Certain it is that no other invention has had so direct and powerful an effect on human beings; for the number of men it has killed and wounded must be expressed in terms of millions.

This phase of the influence of the gun on history is clearly marked. Not so clearly marked, but really more important, has been its influence in deciding wars; for the ways in which wars have been decided have been the turning points in the march of history. The issue of Alexander's wars, for instance, had decided that Greek civilization should not perish, but survive; the issue of Cæsar's wars in Gaul had decided that Roman civilization should extend north over Europe, and that the western incursion of the savage Germans should be stopped; the issue of the wars between the vigorous Goths and degenerate Rome had decided that Rome must die; and so forth, and so forth. So, after the invention of the gun, the issue of every succeeding war supplied a new turning point for history to follow. Naturally, those nations that took the most skilful, prompt and thorough advantage of the power, range and accuracy of the new invention gained in almost every case the victory over their opponents.

So long as no weapons existed, struggles between men had to be decided by physical strength and cunning and quickness only. When the first flint fist-hammer was invented, a man who was sagacious enough and industrious enough and skilful enough to make one, could gain the victory over many another man of greater physical strength and quickness, but who had not the sagacity, industry and skill to provide himself with a flint fist-hammer.

Supposing the flint fist-hammer to be the first invention ever made, as many think it was, we see here the first instance of the influence of invention on history; because this first invention influenced the course of history in favor of men possessing sagacity, industry and skill, as against men not possessing those qualities. By doing this, it not only decided that such men (and tribes composed of such men) should prevail, but did even more to influence history; *it induced men and tribes to make and develop and utilize inventions.* This resulted in what we call civilization.

As each improved weapon followed its predecessor, a new demand was made;—not only for a new kind of skill on the part of the man making the weapon and on the part of the soldiers using it, but also for foresight on the part of the tribe or nation that would supply the weapon to its troops. It is easily realized that, if there were two contiguous tribes about to go to war against each other, one of which was ruled by a sagacious, energetic and far-seeing chief, while the other was ruled by a dull, slothful and short-sighted chief, the former chief would probably provide his warriors with the newest weapon (say, the bow and arrow) and train them in its use; whereas the other would ignore it and go to battle with clubs and javelins only. As between two tribes otherwise equally matched, the result would be obvious; and doubtless it was exceedingly obvious in hundreds of tribal battles, before the dawn of history.

It is a characteristic of evolution, as has been pointed out by wise men, that complexity eventually evolves from simplicity. In no one department of man's endeavor does this truth stand out more clearly than in the evolution of weapons. For the oldest weapon that we know of was probably a stone, or a stick used as a club; and each succeeding weapon has been more complicated than its predecessor,—needing additional parts with which to secure the additional results achieved. This increased complexity has entailed increased liability to derangement, because the failure of any one part has entailed the failure or the decreased effectiveness of the weapon as a whole. This increased liability to derangement has entailed a demand for not only increased care and skill in fabricating the weapon, but for increased knowledge, diligence and skill in caring for it, and using it.

The superiority of the gun over all previously existing weapons was quickly recognized, and every civilized nation soon adopted it as its major implement of war. As the gun was a piece of mechanism, it possessed the attribute which seems to give to pieces of mechanism an element of superiority over every other thing in the universe, the attribute of continual improvability. Human beings do not possess this attribute, nor does any other thing in nature, so far as we know. Every human being begins where his father did—and so does everything else on the earth; though human invention has recently made it possible for certain plants to be improved. No new invention ever dies as a man does, even if the material parts or immaterial parts that compose it are destroyed. On the contrary, it lives, in the sense that it exists as a definite usable entity, and also in the sense that it continues to propagate. And the things that it propagates do not begin as helpless and useless babies, but as mature creations. The first completed gun is still the model for the guns that men make now, and will continue to be the model for all guns in the future. The man who made the first gun has been succeeded by other men, as the first gun has been succeeded by other guns; but the human successors have been no improvement on the inventor of the first gun, while the guns that have succeeded the first gun have been improvements on it to a degree that it is difficult—in fact, impossible, to realize.

The relations of the gun to civilization are reciprocal, and are therefore in accord with most of the other phenomena of our lives; for just as the gun furthered the improvement of civilization, civilization furthered the improvement of the gun. Nearly every step taken in the physical sciences, and afterward in engineering and general mechanics, has had a direct effect in improving the gun. The gun began as an exceedingly rough, awkward and crude appliance; the gun today is one of the most highly specialized and perfect appliances that the world possesses.

But it is not only the gun itself that has been improved; the powder has also been improved, and to a degree almost equal, if not quite. When we realize that modern gunnery is so exact that if a gun is fired in any direction and at any angle of elevation, the projectiles will fall so close to a designated spot that all considerable variations in the points of fall from that spot are usually attributed to other causes than imperfection in the powder; and if we realize also that a variation of one per cent. in the initial velocity imparted to a projectile by its powder would result in a variation (practically speaking) of one per cent. in the range attained, we then may realize how perfectly understood the laws of the combustion of powder and the development of powder gas have become, and how perfect are the methods of manufacturing, storing and using it. Books upon books have been written on the subject of making and using gunpowder; and as high a grade of experimental ability has been employed as on the development of any other art.

It is not quite clear whether stationary cannon or small guns carried by soldiers were the first to be used; but the probability seems to be that cannon were the first. It soon became desirable to devise and to make appliances for holding the cannon in position, elevating them to predetermined angles, and transporting them from place to place. To accomplish these things, gun-carriages were invented. These appliances have kept pace with guns and gunpowder in the march of improvement; countless minor inventions have been made; countless experiments have been conducted; countless books and articles have been written; countless millions of money have been expended. That the field has been large can readily be realized, when we remind ourselves of the numberless situations that gun-carriages have had to be adapted to, on the level plains of Central Europe, in the mountains, on the sands of the desert,—in cold and heat and wet; and on the ocean also, in small vessels and great battleships, to handle cannon great and small, on the uneasy surface of the sea. But it will not be enough for us to realize that it has been necessary to construct gun-carriages so ingeniously that guns can be handled on them under all these circumstances; for we will fall short of a realization of what must be attained, unless we realize that the guns must be handled with safety, and (which is more difficult of attainment) with precision and yet with quickness.

Now to bring the gun and its accessories to the high standard they have now reached, the resources of virtually all the physical sciences have been required and utilized; so that, while modern civilization was made possible by the gun, and could not have been made possible without it, the modern gun has been made possible by civilization, and could not have been made possible without it.

This mutuality between civilization and the gun is evident in the relations between civilization and every other great invention. It is very clearly evident in the case of material mechanism; for it has been plainly impossible for any material invention to exist without directly and indirectly contributing to the improvement, and even to the birth, of others. Any improvement in the process of making any metal or any compound has always been of assistance to every mechanism using that metal or that compound; and it seems impossible to name any mechanism or process whose invention has not helped some other mechanism or process. In the matter of the invention of immaterial things, the effect may not be quite so obvious; and yet it is plain that most of those inventions have contributed to the safety, intelligence and stabilization of peoples, and therefore to a condition of mentality and of tranquillity that permitted and often encouraged the improvement of existing appliances, and the invention of new ones. Of one class of immaterial invention, such as new books on the physical and engineering sciences, the influence on material inventions is, of course, as obvious as it is profound.

The boom of the gun may be said, by a not forced figure of speech, to have ushered in the new civilization that rose from the mental lethargy of the Middle Ages; for it was the first great invention of all in the long line that have followed since. As it was the first, and because without it the others would have been impossible, we can hardly avoid the conclusion that it was the most important.

The mutual reactions between the gun and civilization have resulted, and are still resulting, in widening the distance between the civilized and the uncivilized, placing more and more power in the hands of the civilized, and putting the uncivilized more and more into subjection by the civilized. The process that began with the invention of the fist-hammer, and was continued through the centuries by all the improvements in weapons that followed, was brought to a halt when Rome fell, and not revived until the gun came into general use in the fourteenth century. During the interval of nearly nine hundred years, civilization indeed went backward with the advance of the barbarians into Europe, checked but not wholly stopped by Charles Martel at the Battle of Tours in 732, and later by Charlemagne, his grandson, in numerous campaigns. But the gun, being adopted and improved by peoples having the mentality needed to discern its usefulness, stabilized the conditions of living afterward by keeping in check the barbarians, especially east of Europe. Its greatest single usefulness followed from this by making possible the development and utilization of the next great invention. This invention was next to the gun in point of time. It was next to the gun in influence on history also; and some people think it has had even more influence than the gun. This invention is usually called the invention of printing.

Of course, printing had been invented centuries before, probably in China, and had been practiced during all the intervening centuries, in China, Egypt, Babylonia, Assyria, Greece, Rome, the Hellenistic countries and Italy. But the printing had been done from blocks on which were cut or carved many characters, that expressed whole words or sentences. Naturally, printing done from them was not adaptable to the recording of discussions, the making of connected narratives, or the publishing of books.

Suddenly, about the year 1434, John Gutenberg, who lives at Mayence, conceives the idea of cutting only one letter on each block, putting the blocks in forms so arranged that the blocks can be put in such sequence as may be desired for spelling words, and all the blocks secured firmly in position. In other words, he invented movable type.

Objection may be made to this statement, and the declaration urged that movable type were used in China before the Christian era. Possibly they were; some declarations have been made to that effect. But even if they were, we cannot see that their invention there had any considerable influence on history. China was separated from western Asia and from Africa and Europe by the long stretch of the dry lands of Central Asia, across which little communication passed. It is more nearly certain than most things are in ancient history, that the civilized peoples of western Asia, Africa and Europe, including Gutenberg himself, did not know of movable type until Gutenberg invented them.

It is absolutely certain that virtually the whole of the influence that printing by movable type has exercised on history sprang from the invention of Gutenberg. It started almost immediately; and it increased with a rapidity and a certainty that are amazing. No invention made before, not even the gun, was seized upon with such avidity. The world wanted it. The world seemed to have been waiting for it, though unconsciously.

It may be well at this point to impress upon our minds the fact that no invention has ever been recognized as an invention, unless it has been put into a concrete form. The U. S. Patent Office, for instance, will not award a patent for any invention unless it is described and illustrated so clearly that "any one skilled in the art can make and use it." It is an axiom that a man "cannot patent an idea." In many countries a patentee is required to "work" his invention, to make apparatus embodying it, and to put the apparatus to use. The underlying idea of the patent laws of all countries is that the good of the public is the end in view, and not the good of the inventor; that rewards are held out to the inventor, merely to induce him to put devices of practical value into the hands of the people. From this point of view, which seems to be the correct one, the mere fact that a man conceives of a device, even if he afterward develops his device to the degree that he illustrates it and describes it to someone in such a way that a person skilled in the art can make and use it, does not entitle him to any reward. He must use "due diligence" in communicating full knowledge of his invention to the public, through the Patent Office, ask for a patent, and pay to the Government the prescribed fee.

Now, Gutenberg "worked" his invention so energetically that, with the assistance of Faust, Schaeffer and others, an exceedingly efficient system of printing books was in practical operation as early as 1455. The types were of metal, and were cast from a matrix that had been stamped out by a steel punch, and could therefore be so accurately fashioned that the type had a beautiful sharpness and finish. In addition, certain mechanical apparatus of a simple kind (printing presses) were invented, whereby the type could be satisfactorily handled, and impressions could be taken from them with accuracy and quickness.

News of the invention spread so rapidly that before the year 1500 printing presses were at work in every country of Europe. The first books printed were, of course, the works of the ancient authors, beginning with three editions of Donatus. These were multiplied in great numbers, and gave the first effective impulse to the spread of civilization from the Græco-Oriental countries, where it had been sleeping, to the hungry intellects of Europe.

The new birth of civilization (usually called the Renaissance) began in Italy, where civilization had never quite died out, at some time during the fourteenth century, and took the form at first of the study of classical literature. This led naturally to a search for old manuscripts; and so ardent did this search become that the libraries of cathedrals and monasteries in all the civilized countries were ransacked. Many new libraries were founded, especially in Italy, to hold the old manuscripts that were discovered. A great impetus was given to the movement by the exodus of scholars from Constantinople, and their migration west to Italy, during the half century between the year

The Printing of Books

1400 and the fall of Constantinople before the Ottoman Turks in 1453.

Therefore, when the news of the invention of Gutenberg reached the scholars of Italy and other lands, they seized upon it as an undreamed-of blessing for bringing about that widespread study of the classical authors which they had been struggling under so many difficulties to accomplish.

To narrate and describe the progress made since then in the art of printing would be to rewrite what has been written from time to time in books and magazines and papers. To describe and point out the other arts that have sprung directly from the art of printing, such as the manufacture of printing presses and allied machinery, would require an enormous book of a wholly technical nature; to describe and point out the arts that have been made necessary, and the arts that have been made possible, by the invention of printing would entail a history of most of the industrial arts of the present day; while to mention and adequately describe the measures that have resulted from the invention of printing, and those made necessary and possible by it, would entail a history of all the civilization that has come into being since printing was invented.

The effects of the invention of printing are most of them so obvious that it would be unnecessary to call attention to them. No other one art seems to be so directly and clearly to be credited with the progress of civilization. In the minds of many people, perhaps of most people, printing is considered the most important invention ever made. Maybe it is; but let us remind ourselves that the gun came before the printing-press, and that the civilization contributed to by the printing press would not have been possible without the gun. It may be answered that, nevertheless, the printing press contributed more than the gun; in the same way that a bank contributes more to the welfare of a city than does the policeman who guards the bank.

Such an argument would have much to commend it, and it may be based on the correct view of the situation. But to the author, the gun seems to constitute the foundation of modern civilization, and the printing press to be part of the structure built upon it; for the fundamental enemy to civilization has always been the barbarian, be he a savage under Attila or a Bolshevik in New York. It is true that civilization may be considered as more important than the means that makes it possible, but even this seems to be discussible; but that the gun constitutes more distinctly the preservative influence of modern civilization than any other one thing constitutes civilization itself seems hardly to be discussible. The whole system of defense of all the nations against foes outside and anarchy inside has rested on the gun ever since it was invented; whereas, not even the printing press can be said to be the only element, or even the main element, in modern civilization.

This brief discussion is perhaps not very important; but it does not wholly lack importance, for the reason that it brings into clear relief the fact that we cannot reasonably discuss civilization without realizing the dangers that confront it, and have always confronted it, and will continue to confront it. *Civilization is an artificial product,* that some people think has more evil in it than good for the majority of mankind, and that certainly has been forced on mankind by a very small minority. The foundation on which the force has rested for four hundred years has been the gun.

But whatever the comparative amount of influence of the gun and the printing press, there can be no doubt that they have worked together hand in hand: that one guarded, and the other assisted, the first tottering steps of the Renaissance movement, and that both have continued to guard and assist the grand march that soon began, and that is still advancing.

As the circumstances surrounding the invention of both the gun and the art of printing are sufficiently well known to warrant the belief that each was made, not by a king or any other man of high position, but by a man relatively obscure, and that the surroundings and early life of both were not those of courts or palaces, but those of a humble kind, it may be well to note how enormous are the results that have flowed from causes that seem to be very small. We have been told that "great oaks from little acorns grow"; but the consequences that have grown from the conception of the idea of printing are larger than any oak; and an acorn is probably much larger than the part of the brain in which an idea is conceived.

As a matter of interest, let us realize the strong resemblance between the impression we receive from a material object actually seen by the eye and the memory of that impression afterwards. Let us then realize the strong resemblance between it and another impression of that same object seen mentally but not physically; for instance, let us realize the strong resemblance between the impression made on us by actually seeing some friend and the impression received by *imagining* him receiving a letter which we are now writing to him. The first picture was an image of the external object that was physically made on the retina, as a picture or image is made by a camera on a screen; but that picture on the retina must have been seen by the brain, or we would not have known of it. The other pictures were not made physically on the retina, so far as we know. Yet we all realize that we can make pictures on our minds the more readily if we close our eyes. The fact of our eyes being open seems to operate adversely to our receiving a clear mental picture.

Now it is a matter of fact that an object (for instance, a pole) can be seen by a person with normal eyesight, if it subtends an angle as great as one minute; that a pole a foot thick can be seen clearly from a distance of 3600 feet, at which distance it subtends that angle. The rays of light pass through the crystalline lens of the eye and are focussed on the retina, as they pass through the lens of the camera, and are focussed on the sensitized paper. Assuming the distance from the crystalline lens to the retina to be about three-quarters of an inch, the pole would be represented on the retina by an image $\frac{3}{4 \times 3600}$ or less than 1/4000 of an inch wide. During daylight our retinas are continually receiving images of which all lines as wide as 1/4000 of an inch (and much narrower) are very clearly apprehended by the mind.

But very few of those images are noticed by us. It is only when some incident calls them to our attention, or when the mind voluntarily seizes on them, that any conscious impression is made upon the brain. Similarly, images of physical objects unseen by the physical eye are continually made on the mind: we are continually thinking of our friends and of past incidents and possible future incidents; and our thoughts of these things take the form of pictures. We see the man with whom we had a conversation yesterday, and we see him with a clearness that is proportional to the interest taken by the mind in the conversation and the circumstances surrounding it. If our conversation was uninteresting and the circumstances tame, we see him dimly. But if our conversation was angry and the circumstances were exciting, we see him and the surroundings very vividly—so vividly that our anger is again aroused; perhaps to as high degree as on the day before, or even higher.

This image-making is, of course, voluntary sometimes; but most images come without volition on our part, and require no effort that we are conscious of. To call up an image voluntarily requires conscious effort; and to keep it in position while we gaze upon it requires effort that is great in proportion to the time during which it is exerted. Psychologists speak of this act of keeping an image in position as one of giving attention, or paying attention.

To perform this act requires the exercise of will, unless the act gives pleasure, or the image suggests danger; in each of these cases, of course, the act is almost involuntary.

A man who is observant notes consciously the incidents that are passing around him: he seizes on certain of the millions of pictures passing before him, concentrates their images on his retina, and gazes on each one for a while. Similarly, a man who is contemplative, seizes on certain of the vague mental pictures passing through his mind, concentrates his attention on them, and gazes at each one for a while. We call the former an observant man and the other a thoughtful man. Sometimes an observant man learns a great deal from what he sees, in the same way that sometimes a studious man learns a great deal from what he studies; but the learning of course cannot be accomplished without the assistance of the memory. One is often surprised to see how little some observant and studious men have remembered. Many impressions have been received, but few retained.

The thoughtful man, of course, cannot in the nature of things receive so many conscious impressions as the merely observant or studious man; for the reason that he continually seizes on one and then another, and holds each for a time, while he fixes his attention on it. Usually, however, the thoughtful man memorizes his observations or his studies for some specific purpose; he moves the various images about in his mind, and arranges them in classes: for otherwise, the various images would form merely an aggregation of apparently unrelated facts. The value of such aggregations is, of course, enormous; they compose what we call data, and include such things as tables of dates, etc.

But data, even tables of dates, have no value in themselves; it is only from their relations to other things that they have value. There would be no value, for instance, in knowing that William of Normandy invaded England in 1066, unless we knew who William was, and what England was, and what the effect of his invading it was. Now the thoughtful man, like the man who arranges a card-catalogue in such a way that it will be useful, not only notes isolated facts, but puts them into juxtaposition with each other, and sees what their relations are. The mental pictures that he finally fixes in his mind are of related things, seen in their correct perspective. They are like the pictures which are made on the mind of anyone by—say, a landscape: whereas the mental pictures made by an unthoughtful man are such as little children probably receive from nature; pictures in which the trees and hills and valleys of a landscape do not appear as such, but merely as a great aggregation of numberless separate images, confused and meaningless like the colored pieces of a kaleidoscope.

To the thoughtful man, therefore, life seems not quite so meaningless as to his neighbor; though even the most thoughtful can fix very few complete and extensive pictures in his mind. If his thoughtfulness takes him no further than simply forming pictures that enable him to see things as they are, and in their correct relations to each other, he becomes "a man of good judgment," a man valuable in any community, especially for filling positions in which the ability to make correct deductions is required.

Such a man, however, no matter how correctly he may estimate any situation, no matter how clearly he may see all the factors in it, no matter how accurately he may gauge their relative values and positions, may be unable to suggest any way for utilizing its possible benefits, or warding off its possible dangers. That is, he may lack constructiveness. He is like a man who possesses any desirable thing or dangerous thing, and who understands all there is to understand about it, but *does not know what to do with it.* The various factors are in his (mental) hands, but he can make nothing of them.

The constructive man can construct concrete entities out of what are apparently wholly individual factors having no relation to each other; he can, for instance, take two pieces of wood and a piece of string, and make a weapon with which he can kill living animals at a considerable distance. With neither the pieces of wood nor the string could he do that; and he could not do it with all three, unless he were able to construct them into a bow and arrow. That is, he could make the weapon if he had ever seen it made before. If he were only constructive and not inventive, he could not make it unless he had seen it done before, or knew it had been done.

Men of purely constructive ability have not of themselves taken very conspicuous parts on the stage of history; and yet the things that they have constructed comprise nearly all that we can see and hear and touch in the world of civilization. Thus history, while it is a narrative of things that have been done, is not a narrative of all the things that have been done, but only of the new and striking things. It is a narrative of wars, of the rise and fall of nations, of the founding of cities, of the establishment of religions and theories, of the writing of books, of the invention of mechanisms, of the painting of pictures, of the carving of statues; in general, of the creative work that man has done.

The merely constructive man, unless he has been inventive also, has never constructed anything of a really novel kind. It is a matter of everyday experience that nearly all the things that are constructed are according to former patterns and the lessons of experience. All the constructive and engineering arts and sciences are studied and practiced for the purpose of enabling men to build bridges and houses and locomotives, etc., in such ways, as experience has shown to be good. Nearly all our acts, nearly all our utterances, nearly all our thoughts, are of stereotyped and conventional forms.

This condition of affairs possesses so many advantages that we cannot even imagine any other to exist. It enables a man to act nearly automatically in most of the situations of life. The main reason for drilling a soldier is that when confronted with the conditions of battle, he shall fire his musket and do his other acts automatically, undisturbed by the danger and excitement. Similarly, all our experience in life tends to automaticity. It is a very comfortable condition, for it demands the minimum amount of mental and nervous energy. The conductor demands your fare, and you pay it almost automatically. That a condition of automaticity prevails in nature, as we see it, one is tempted to suppose: for the seasons succeed each other with a regularity suggestive of it.

But even if the machine of nature and the machine of civilization are automatic now, we have no reason for believing that they always were so. Even the most perfect automatic engine had to be started at some time, and it had to be invented before it could be started; and it had also to go through a long process of development. Similarly, a man reads a paper almost automatically; but it required years of time to develop his ability to do so.

Now it has happened from time to time in history that some invention has broken in on the smoothly running machine of civilization and introduced a change. The gun did this, and so did the printing press. In every such case, a few men have welcomed the invention, but the majority have resented the change: some of them because their interests were threatened by it; others because of the instinctive but powerful influence of dislike of change.

The purely constructive man does not cause any such jolt. His work proceeds smoothly, uniformly, and usually with approval. But the inventive man, "his eye in a fine frenzy rolling," is visited with some vision which he cannot or will not dismiss, and which compels him to try to embody it in some form, and to continue to try until he succeeds in doing so, or gives up, confessing failure. The inventive man, having seen the vision, becomes a constructive man, and (in case he succeeds) *puts the vision which he sees into such form that other people can see it also.*

It is obvious therefore that two kinds of ability are needed to produce a really good invention of any kind, inventive ability and constructive ability; and it is also obvious that they are separate, though they cooperate. Many an invention of a quality that was mediocre or even inferior in originality, novelty and scope, has been quite acceptable by reason of the excellent constructive work that was done upon it: many a book and many an essay has succeeded almost wholly because of the skilful construction of the sentences; many a picture because of the accuracy of the perspective and the mixing of the colors; many a new mechanical device because of the excellent workmanship bestowed upon it. Conversely, many a grand and beautiful conception has failed of recognition because of the poor constructive work that was done on it. But occasionally a Shakespeare has given to the world an enduring masterpiece, the joint work of the highest order of invention and the highest order of constructive skill; occasionally a Raphael has painted a picture similarly conceived and executed; and occasionally an Edison has given the world a mechanical invention, comparably wonderful and perfect.

In all such cases, the start of the work was a picture on the mental retina; an image of something that was not, but might be made to be. A physical picture is actually made on the physical retina, but it cannot be recognized by the owner of the retina, unless a healthy optic nerve transmits it to his brain. Every mental picture must also be transmitted to the brain; and some mental pictures are very bright and clear. In some forms of insanity, the mental pictures are so clear that the patient cannot be persuaded that they are not physical; the patient sees a man approaching him, when there is no man approaching him; but the impression made on the patient's mind is the same as if there were.

The thought of the enormousness of the consequences that have followed the appearing of some visions to men (the vision of the gun, for instance) is almost stunning, if we try to realize the small area of the brain that the vision must have covered. If a line 1/4000 of an inch wide made on the physical retina and afterwards transmitted to the brain is seen with perfect clearness by the mind, what a small area of the brain must have been covered by the original vision of the gun! Yet how vast have been its consequences!

The fact that the inventor sees a vision, and then mentally arranges and rearranges the various material elements available in order to embody his vision in a painting, a project, a machine, a poem or a sonata, indicates that the essential processes of invention are wholly mental. This truth is illustrated by the work of every inventor, great or small. Possibly, the most convincing illustration is that given by the deaf Beethoven, who conceived and composed some of his grandest works when he could not physically hear a note.

Reference to the work of Roger Bacon has not been made, because of the doubts surrounding it.

CHAPTER VI

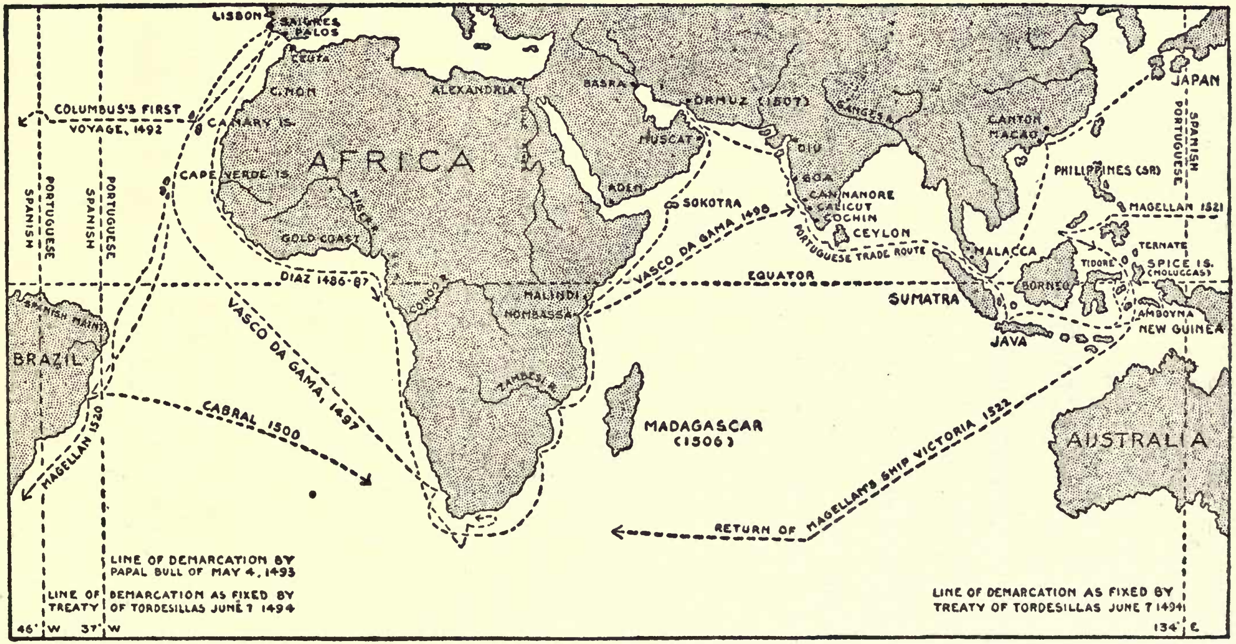
COLUMBUS, COPERNICUS, GALILEO AND OTHERS

LONG before the Christian era the Chinese used pivoted magnetic needles to indicate absolute direction to them; but that they possessed or had invented the mariner's compass, there is considerable doubt. The history of the invention of the mariner's compass has not yet been written. It is not known when, or where, or by whom it was invented.

It is well-known, however, that the mariner's compass was in use in the Mediterranean Sea in the early part of the fifteenth century A. D. Guided by it, the navigators of that day pushed far out from land.

The first great navigational feat that followed the invention of the compass was that performed by the Portuguese, Bartholomew Dias, who conceived the idea of reaching India by going around Africa, and sailed down the west coast of Africa as far as its southern end, later called the Cape of Good Hope. It was a tremendous undertaking, and it had tremendous results; for it demonstrated the possibilities of great ocean voyages, proved that the road to India was very long, and led to the expedition of Columbus, six years later. It was also a great invention, both in brilliancy of conception and excellence of execution, although Dias did not reach India.

The second great navigational feat was performed by Christopher Columbus in 1492. Before that time it was conceded by most men of learning and reflection



Portuguese Voyages and Possessions

that the earth was spherical; and it was realized that, if it was spherical, it might be possible by sailing to the westward to reach India, the goal of all commercial expeditions in that day. Columbus is not to be credited with the first conception of that possibility.

But that conception rested undeveloped in the minds of only a few men. Had it not been for Columbus, or some man like him, it would have remained undeveloped and borne no fruit. The Savior in his parable tells us of the sower who went forth to sow, and tells us also that most of the grain fell on stony ground. So it is with most of the opportunities that are offered to us every day; and so it is even with most of the visions that are placed before our minds. But the Savior tells us also of other grains that fell on good ground and bore abundant fruit. Such are the conceptions that the great inventors have embodied; such was the conception that fell on the good ground of the mind of Christopher Columbus.

The conception that came to him was not of the possibility that someone could sail west and eventually reach India, but of preparing a suitable expedition himself and actually sailing west and reaching India. The conception must have been wonderfully powerful and clear, for it dominated all his life thereafter. But he could not make others see the vision that he saw. For many years he went from place to place, trying to get the means wherewith to prepare his expedition. He made only a few converts, but he did make a few. Some of these exerted their influence on Queen Isabella of Spain. She, together with her husband Ferdinand, then supplied the money and other necessaries for the expedition.

The invention of the gun was followed by the invention of printing in 1434, and this by the discovery of America in 1492. These three epochal occurrences started the new civilization with a tremendous impetus. This impetus was immediately reinforced by the voyage of the Portuguese Admiral, Vasco de Gama, around the Cape of Good Hope to India in 1497-1498, and the circumnavigation of the globe by Ferdinand Magellan in 1519-1522.

The immediate practical influence of da Gama's feat was almost to kill the commerce of the cities of Italy and Alexandria with India by way of the Red Sea and the Indian Ocean, and to transfer the center of the sea-commerce of the world to the west coast of Europe, especially Portugal. Near the west coast it has rested ever since; though but little of it stayed long with Portugal.

While Magellan's voyage was not quite so important as the discovery of America, it was not immeasurably less so; for it set at rest forever the most important question in geography,—was the earth round or not? The voyage of Columbus had not answered it, because he returned by the same route as that by which he went. But Magellan started in a southwesterly course, and one of his ships again reached home, coming from the east. The Victoria had circumnavigated the globe! Only eighteen men and one ship returned. The other ships and the other men had perished. Magellan himself had been buried in the Philippines.

The news of Magellan's great exploit and the stories that came to Europe of the riches beyond the sea, resulted soon in an idea coming to the mind of Hernando Cortez, the development of that idea into a concrete plan, and the making of a complete invention. This was a plan by which he should head an expedition to a certain part of the New World, and "convert" the heathen dwelling there; doing whatever killing and impoverishing and general maltreatment might be found to be convenient or desirable. The invention worked perfectly; some half-savage Indians of what we now call Mexico were "converted," many were killed, and untold treasure was forcibly obtained.

The success of this invention was so great that Francisco Pizarro was inspired to copy it, and to try it on some Indians in a country that now we call Peru. Whether Pizarro improved on Cortez's scheme, or whether the conditions of success were better need not concern us now: the main fact seems to be that Pizarro was able to convert and kill and impoverish and generally ruin more effectively than Cortez.

Following Cortez and Pizarro, many expeditions sailed from Spain to the West Indies, Central America and South America, and carried out similar programs. The two principal results were that those parts of the world were soon dominated by Spain, and that the people of Spain received large amounts of gold and treasure. The main result to them was that they succumbed under the enervating influence of the artificial prosperity produced, and rapidly deteriorated. By the end of the hundred years' period after Columbus discovered America, Spain was clearly following the downward path, and at high speed.

One of the early results of the invention of printing was an increased ability of people separated by considerable distances to interchange their views; and a still greater though allied result was an increased ability of men of thought and courage to impress their thoughts upon great numbers of people. At the time when printing was invented, the Church of Rome had ceased to dominate European nations as wholly as it had done before; but it exercised a vast power in each country. This was because of its prestige, its hold on the clergy and the Church property, and its authority in many questions connected with marriage, wills, appointments, etc. This was resented, but impotently, by the various sovereigns.

It was realized also (and it came to be realized with increasing clearness toward the end of the fifteenth century) that there were many grave evils and scandals in the Church, even in the highest quarters. The printing-press lent itself admirably to the dissemination of views on this matter: so that there gradually grew up a strong and widespread feeling of discontent. But despite considerable friction as to the limits of their respective functions, the Church and the State were so intimately allied in every country, and each realized so clearly its dependence on the other, that no movement of any magnitude against even the acknowledged evils had been able to gain ground. No man appeared who was able to conceive and execute a plan that could successfully effect reform.

But such a man appeared in the year 1517, whose name was Martin Luther. He was a poor monk; but a knowledge of virtually all there was to know lived in his mind, coupled with imagination to conceive, constructiveness to plan, and courage to perform. In that fateful year, 1517, the Pope sent agents through the world to sell "indulgences," which remitted certain temporal punishments for sin, in return for gifts of money. The agent who was commissioned for Germany carried out his work with so little tact and moderation, that he made the granting of indulgences seem even a more scandalous procedure than it really was. Luther had been preaching the doctrine of a simple following of the teachings of the Savior, and deprecating a too close adherence to mere forms and ritual. He now seems to have conceived a clean-cut plan of effective action; for on the evening before the indulgences were to be offered on All Saints Day, in the Church of Wittemberg, Luther nails on the door his celebrated ninety-five theses against the sale. The printing-press reproduced copies of these in great numbers throughout Germany. A definite sentiment antagonistic to the indulgences developed rapidly, and a general movement toward the reform of the abuses in the Church took shape. Luther was threatened with excommunication by the Pope in 1520, but he burned a copy of the "papal bull" in a public place on December 10 of that year.

The emperor of Germany convened a meeting of the Diet at Worms in 1521, at which he exerted all his powers to make Luther retract: but in vain. So great a following did Luther now have that, though the emperor put him under ban, and all persons were forbidden to feed or give him shelter, he was cared for secretly by men in high position, until he voluntarily came out of hiding, and appeared in Wittemberg. The emperor called a meeting of the Diet at Spires in 1526, and another meeting in 1529. Both meetings had for their object the suppression of the movement begun by Luther. It was against a decree made by the second Diet that certain high officials and others made the famous protest, that caused the name to be affixed to them of Protestants. This name has been perpetuated to this day.

As is well known, the movement resulted, after nearly a hundred years of disturbed conditions, in a series of wars, called "The Thirty Years' War" that began in 1618, and ended with the Peace of Westphalia in 1648. This Peace marked the end of the Reformation period, and resulted in establishing Protestantism in North Germany, Denmark, Norway, Sweden, England and Scotland.

The influence of Luther's conception with its subsequent development was thus definite, widespread and profound, even if regarded from a merely religious point of view: but the influence it had on religion was only a part of its total influence. In words, the protest was against certain abuses in the Roman Church; but in fact it was against a domination exercised over the minds and souls of men. Luther's influence was in reforming not only the Roman Catholic Church and the practice of the Christian religion throughout Europe, but also the conditions under which men were allowed to use their minds.

While the inventions in mechanism, religion, etc., which we have just noted were going on during the fifteenth and sixteenth centuries, others were going on in the realm of science. The movement was begun about 1507 by a young man named Nicolas Copernicus, who was executing the dissimilar functions of canon, physician and mathematician in the little town of Frauenberg in Poland. Copernicus at this time was thirty-four years old, but he had even then devoted the major activities of his mind to astronomy for several years. Naturally, his efforts had been devoted to mastering whatever of the science then existed. The efforts of most people in dealing with any subject end when they have gone thus far—and very few go even thus far. But Copernicus noted that, while the Ptolemaic System (suggested, though probably not invented by the Egyptian king) was the one generally accepted, it did not account for many of the phenomena observed; that none of the other systems that had been suggested afterward explained matters more satisfactorily, and that no one of the systems was in harmony with any other.

Thereupon this daring young man conceives the idea of inventing a system of astronomy himself, in which all the movements of the heavenly bodies should be shown to be in accordance with a simple and harmonious law. Seizing on this idea, he proceeds at once to develop it; and he works on it until death takes him from his labors in 1543 at the age of seventy.

The whole civilized world had virtually accepted the Ptolemaic Theory,—at least, the part of it which assumed that the earth was the center of the universe, the sun and stars and planets revolving around it. Copernicus invented the theory that the sun was the center, that the earth and the other planets revolved around it, and that the earth revolved on its own axis once in twenty-four hours. So great was the insistence of the religious bodies in adhering to the Ptolemaic Theory, so set were the minds of all men of high position on it, that though Copernicus wrote a book expounding his own theory, he did not think it wise to publish it. He seems to have completed the book in about 1530. He did not publish it till 1543. Just before its printing was finished, Copernicus was taken ill. The first volume was held before him. He touched it and seemed to realize dimly what it was. Then he relapsed into torpor almost immediately, and soon died.

It is interesting to note that Copernicus was not the first to conceive the idea that the earth turns on its own axis, or that the earth revolves around the sun, any more than Bell was the first to conceive the idea that speech could be transmitted by a suitable arrangement of magnet, diaphragm and electric circuit. But Copernicus was the first to invent a system of astronomy that was like a machine. It was a usable thing. It could be made to explain astronomical phenomena and predict astronomical events correctly.

It may be well to remind ourselves again that no application for patent will be granted by our Patent Office unless the invention is described and illustrated so clearly and correctly that "a person skilled in the art can make and use it," and to realize that this admirable phraseology may be utilized to distinguish any other novel endeavor of man entitled to be called an invention from any other not so entitled; for no system, no theory, no religion, no scheme of government, regardless of how attractive it may be, is entitled to be called an invention, unless, like the Copernican System, "a person skilled in the art can make and use it."

Shortly after Copernicus, came Johann Kepler, who was born in Württemburg in 1571, and died in 1630. He had been a pupil of Tycho Brahe, who did not succeed in making any great invention or discovery, but who did collect a great amount of data. Utilizing these, Kepler devoted many years to the study of Copernicus, and tried to invent a system which would explain some facts of astronomy that the system of Copernicus did not explain, notably the non-uniform speed of the planets. The main result of his labors was the famous Kepler's Laws, which were

"1.. The orbits of the planets are ellipses having the sun at one focus.

"2. The area swept over per hour by the radius joining sun and planet is the same in all parts of the planet's orbit.

"3. The squares of the periodic times of the planets are proportional to the cubes of their mean distances from the sun."

These three discoveries, enunciated in three interdependent, concrete laws, constituted an invention which, while it was merely an improvement on Copernicus's, was so great an improvement as almost to make the difference between impracticability and practicability. Without this improvement, astronomy would not be what it is, navigation would not be what it is, the regulation of time throughout the world would not be what it is, and the present highly intricate but smoothly running machine of civilization could not exist at all, except in a vastly inferior form. The machine of civilization is dependent for its successful operation on the good quality and correct design of every other part. So is every other machine; for instance, a steam-engine.

The Copernican System was not recognized for more than a century. It was, in fact, definitely rejected, and people were subjected to punishment and even torture for declaring their belief in it.

One of the amazing facts surrounding Copernicus's invention was that he carried on his observations with exceedingly crude appliances. *The telescope had not yet been invented.*

Who invented the telescope is not definitely known; but it is probable that both the telescope and the microscope (compound microscope) were invented by Jansen, a humble spectacle-maker in Holland. Both inventions were made about the year 1590, and were of the highest order of merit from the three main points of view,—originality, completeness and usefulness. Few inventions more perfectly possessing the attributes of a great invention can be specified. The originality of the conception of each seems unquestionable; the beautiful completeness of the embodied form of each was such that only improvements in detail were needed afterward; and, as to their usefulness, can we even imagine modern civilization without them both?

The interesting fact may now be called to mind that, although many men who lived in Jansen's time were loaded with honors and fame and wealth and glory, the inventor of the telescope and the microscope received no reward of any kind that we know of; and his fame has come to us so imperfectly that we are not even sure that Jansen was his name.

The man usually credited with the invention of the telescope is Galileo, though Galileo himself never pretended that he invented it, and though historical statements are clear that he heard that such an instrument had been invented, and then designed and constructed one himself in a day. It would be interesting to know just how much information Galileo received. It seems that his information was very vague. If so, a considerable amount of inventiveness may have been required, besides a high order of constructiveness. But the mere fact that Galileo knew that such an instrument had been invented caused his mental processes to start from an image put into his mind by an outside agency and not from his own imagination. Galileo's work did not begin with conception, and therefore it was not an invention.

Galileo was one of the foremost and most ardent supporters of the Copernican Theory; and it was on his skilful and industrious use of the telescope in making observations confirming the theory that his fame mainly rests. As late as 1632, nearly a century after Copernicus's doctrine had become known, Galileo was compelled by threat of torture to recant, and was condemned to imprisonment for life.

The influence of inventions on history has been greater and more beneficial than that of any other single endeavor of man. Yet most inventions have been resisted. *The invention of Copernicus was resisted for more than a century by the organization commanding the greatest talent and character and learning that the world contained.*

The extraordinary access of mental energy in Europe about the beginning of the seventeenth century is illustrated by another invention virtually contemporaneous with those of Copernicus and Jansen, and also in the line of mathematical research. This was the invention by Baron John Napier of logarithms.

It was a curious invention—an invention the like of which one cannot easily specify; for the thing invented was not a material mechanism, or a theory, or anything exactly like anything else. It is difficult to classify a logarithm except as a logarithm: — yet Napier did create something; he did make something exist that had not existed before; he did conceive an idea and embody that idea in a concrete machine. That machine, in the hands of a man who understood it, could supply extraordinary assistance in making mathematical calculations, especially calculations involving many operations and many figures, as in astronomy. It has been in continual use since Napier invented it, and is used still. In order to indicate the simplicity and the value of Napier's invention, it may assist those who have forgotten what a logarithm is, or who have been so fortunate as never to have been compelled to study about them, to state that logarithms are numbers so adapted to numbers to be multiplied, divided, or raised to any power, that one simply adds their logarithm, subtracts one logarithm from the other or multiplies or divides a logarithm by the number representing the power, and then notes in a table the number resulting, instead of going through the long process of multiplying, dividing, squaring, etc. Of course, in the case of small numbers, the use of logarithms is not only unnecessary but undesirable; but in the case of the long numbers used in astronomy, and even in navigation, logarithms are inexpressibly helpful and time-saving. The mental feat of Napier consisted in conceiving the idea of accomplishing what he subsequently did accomplish, and then constructing and producing the "logarithmic tables" that made it possible.

Another indication of the new intellectual movement in Europe was the experiments, deductions and inventions of William Gilbert, an English physician, who lived from 1540 till 1603. According to the use of the word invention followed in this book, only two actual inventions can be credited to Gilbert, that of the electroscope and that of magnetization. Gilbert's work was valuable in the highest degree, more valuable than that of most inventors; and yet it was more inductive and deductive than inventional. It is not the purpose of this book to suggest that invention has been the only kind of work that men have done which has had an influence on history; and the work of Gilbert gives the author an opportunity to emphasize the value of certain work which is not inventional. At the same time, the author cannot resist the temptation of pointing out that Gilbert's work was original and constructive, that it hovered around the borders of invention, and that it did more to assist the inventors of the electric and electro-magnetic appliances that were soon to follow, than the work of almost any other one man.

The full influence of Gilbert's work was not apparent for many years; not, in fact, until the discoveries and inventions of Volta, Galvani and Faraday showed the possibilities of utilizing electricity for practical purposes. Then the facts which Gilbert had established, and the discoveries built upon them afterward, were the basis of much of the work of those great men, and of the vast science of electrical engineering that resulted.

The inventions made before the opening of the seventeenth century A. D., wonderful as they were, were quite widely separated in time, and seem to have been wholly the outcome of individual genius, and not the result or the indication of any widespread intellectual movement. But soon after it opened, the influence of printing in spreading knowledge became increasingly felt, and inventions began to succeed each other with rapidity, and to appear in places far apart.

In the beginning of the seventeenth century, certain writings appeared in England that took great hold on the minds of thinking men, not only in England, but throughout Europe. The name of the author was Francis Bacon.

It would not be within the scope of this book even to attempt to analyze the philosophy of Bacon, to differentiate between it and the philosophy of Aristotle or any other of the great thinkers of the world, or to try to trace directly the influence of Bacon's philosophy on his own time and on future times. It is obvious, however, that Bacon invented a system of inductive reasoning that assisted enormously to give precision to the thoughts of men in his own day, by convincing them of the necessity of first ascertaining exact facts, and then inferring correct conclusions from those facts. This seems to us an easy thing to do, looking at the matter in the light of our civilization. But it was not easy, though Bacon's high position gave him a prestige exceptional for a philosopher to possess; and this smoothed his way considerably. Men had not yet learned to think exactly. The efforts of even the great minds were of a groping character; and fanciful pictures made by the imagination seem to have intertwined themselves with facts, in such a way that correct inferences (except in mathematical operations) were hardly to be expected. Bacon insisted that every start on an intellectual expedition should be made from absolutely indisputable facts.

The first effect of such teaching was to make men seek for facts. Not long afterward, we find that many men were making it the main business of their lives to seek for facts from Nature herself. This does not mean that men had not sought for facts before from Nature, or that Bacon alone is to be credited with the wonderful increase in the work of research and investigation that soon began.

Bacon's principal book was published in 1620, and called the "Novum Organum," or "the new instrument." It was obviously an invention, for it was a definite creation of a wholly new thing, that originated in a definite conception, and was developed into a concrete instrument. That Bacon so regarded it is evident from the title that he gave it. Furthermore, he described it as "the science of a better and more perfect use of reason in the investigation of things and of the true aids of the understanding." Bacon was a patient of Dr. Harvey, who discovered the circulation of the blood; and it would be strange indeed if Bacon's philosophy did not give to Harvey a great deal of guidance and suggestion that furthered his experiments.

William Harvey discovered the fact that the blood circulates in the bodies of living animals. This declaration stated by itself would convey to the minds of some the idea that Harvey discovered it, somewhat as a boy might discover a penny lying on the ground. The first definition of the word discover in the *Standard Dictionary* is "to get first sight or knowledge of"; so that the mere announcement that an investigator has "discovered" something gives to many people an incorrect idea of his achievement. Harvey discovered the fact of the circulation of the blood after years of experimentation and research on living animals, and by work of a most laborious kind. His conclusions were not accepted by many for a very considerable period; but he was fortunate, like Bacon, in holding a position of such influence and prestige, that he escaped most of the violent opposition that inventors usually meet.

Harvey's discovery did not of itself constitute an invention; but the embodiment of that discovery in a concrete theory, so explained "that persons skilled in the art could make and use it," did constitute an invention of the most definite kind. The whole influence of that invention on history, only a highly equipped physician could describe; but, nevertheless, one may feel amply justified in stating that its influence on the science and practice of surgery and medicine, and on the resulting health of all the civilized nations of the world, has been so great as to be incalculable.

A contemporary and acquaintance of Harvey was Robert Boyle, one of the most important of the early scientific investigators, who was an avowed disciple of Bacon, and followed his methods with conscientious care. His work covered a large field, but it was concerned mostly with the action of gases. He is best known by "Boyle's Law," which is usually expressed as follows: "When the volume of a mass of gas is changed, keeping the temperature constant, the pressure varies inversely as the volume; or the product of the pressure by the volume remains constant." While it has been found that this law is not absolutely true with all gases at all temperatures and pressures, its departure from accuracy are very small, and these are now definitely known. With certain tabulated corrections, this law is the basis on which most of the calculations for steam engines, air engines and gas engines are made. It is usually expressed by the formula

$$p\,v = p'\,v' = \text{constant}.$$

Boyle is said to have "discovered" this law, and Harvey is said to have "discovered" the circulation of the blood. Doubtless they did: but if they had done no more than "discover" these things, no one else would have been the wiser, and the world would have been no richer. What these two men did that made us wiser and the world richer, was to make inventions of definite character, and give them to the world in such manageable forms, that "persons skilled in the art can make and use them."

In 1620, the spirit thermometer, as we know it now, was invented by Drebel. It is by some ascribed to Galileo. An interesting controversy has been waged as to which was actually the inventor. The facts seem to be that Galileo did invent a thermometer in which the height of water in a glass tube indicated approximately the temperature. The tube was long and ended in a bulb at the top. The bulb being warmed with the hand of Galileo, and the open lower end of the tube being immersed in water, and then the warmth of the hand removed, water rose in the tube to a height depending on the warmth of the air in the bulb. The height of the water therefore varied *inversely* as the temperature. The defect of the instrument was that it was a barometer as much as it was a thermometer; because the varying pressure of the atmosphere caused the water to rise and fall accordingly, and thus falsify the thermal indications. Drebel realized this, and closed both ends of the tube.

Thus Galileo came very near to inventing both the thermometer and the barometer, but yet invented neither! It seems incredible that he should have failed to invent the barometer, having come so near it; for he had been engaged for a long period in investigating the weight of air, and finally had succeeded in ascertaining it. The barometer was invented or rather discovered by Galileo's successor, Torricelli, in 1645. Torricelli, in investigating the action of suction pumps, constructed what now we call a barometer; but it was not until *after* he had constructed it that he realized that the height of mercury in his tube indicated the pressure of the air outside. Seventy-five years later, Fahrenheit made a great improvement in the thermometer by substituting mercury for spirits.

Meanwhile, Otto von Guericke, following in the footsteps of Galileo and Torricelli, had invented the air-pump, by means of which he succeeded in getting a fairly perfect vacuum in a glass receiver. This seems to have been an invention of the most clear-cut kind, resulting from an idea that occurred to Guericke that he seized upon promptly and put to work to serve mankind. Its influence in giving impetus to the science and art of pneumatics, and the influence of pneumatics on the progress of civilization, are too obvious to need more than to be pointed out. The invention of Guericke is a simple and clear illustration of the "power of an idea"; an illustration of seed falling on good ground and bringing forth fruit an hundred fold.

One of the greatest inventors that ever lived was Isaac Newton, who lived from 1642 till 1728. Even as a child he busied himself with contriving and constructing mechanical appliances, mostly toys. As a young man he occupied himself mostly with studies in mathematics and experiments in physics, especially optics. In 1671 he invented a special form of the reflecting telescope, called after him the Newtonian telescope. He made many experiments in optics, in consequence of which he discovered and announced that white light consists of seven colors, having different degrees of refrangibility. The influence of this discovery on the advancement of learning since that time, it is unnecessary to point out; but we cannot realize too clearly that without it much of the most important progress in optics since that time would have been impossible.

The invention by reason of which Newton is most generally known is his theory or law of gravitation, which he announced in his *Principia,* published in 1686. In 1609, Kepler had announced his famous laws, that reads:

"1. The orbits of planets are ellipses having the sun at one focus.

"2. The area swept over per hour by the radius joining sun and planet is the same in all parts of the planet's orbit.

"3. The squares of the periodic times of the planets are proportional to the cubes of their mean distances from the sun."

Newton showed from the laws of mechanics which he had discovered that, assuming the first two laws of Kepler to be true, each planet must always be subject to a force directing it toward the sun, that varies inversely as the square of its distance from the sun: otherwise, it would fly away from the sun or toward it. From this, Newton inferred that all masses, great and small, attract each other with a force proportional to their masses, and inversely proportional to the square of the distance between them, and invented what is now called the law of universal gravitation.

Another invention of possibly equal value, also published in his *Principia,* but not so generally known, is his three laws of motion. These are

"1. Every body continues in its state of rest, or of moving with constant velocity in a straight line, unless acted upon by some external force.

"2. Change of momentum is proportional to the force and to the time during which it acts, and is in the same direction as the force.

"3. To every action there is an equal and contrary re-action."

It is probably impossible for any human mind to conceive any invention of a higher order of originality than either of these two, or to construct any invention more concrete and useful. Certainly no more brilliant inventions have ever yet been made. These two wonderful products of Newton's genius underlie the whole structure of modern astronomy and modern mechanics. The sciences of modern astronomy and modern mechanics could not exist without them, and would not now exist unless Newton (or someone else) had invented them.

It may be pointed out that Newton's conception of our solar system is that of a machine in rapid motion, of which the sun and the planets are the principal parts.

Another important invention ascribed to Newton is that of the sextant, a small and easily handled instrument, used ever since in ships for purposes of navigation; but whether he should receive the entire credit for this invention seems quite doubtful; for another astronomer, Robert Hooke, is credited by some with the original suggestion, and John Hadley, still another astronomer, with having adapted it to practical sea use. Numerous other scientific inventions, however, that have formed the basis of much of the scientific work of later experimenters and inventors are clearly to be credited to Newton. Among these, his formula for the velocity of a wave of compression, his color-wheel, and his simple apparatus known as "Newton's rings," by which can be measured the wave lengths of light of different colors, are possibly the most important.

In approximate coincidence with the Renaissance movement and the accompanying awakening of the intellect of Europe, there began a conflict between the sovereigns and the Pope. The Popes had gradually acquired great power, because of their prestige as the successors of St. Peter, to whom it was declared our Savior had given the keys of heaven. Coincidentally, the multitudinous barons had gradually built up the Feudal System. This was a loose-jointed contrivance, under which Europe was virtually divided into little geographical sections, ruled over by hereditary feudal lords, who in each country owed allegiance to a sovereign. By reason of the slowness and uncertainty of transportation and communication, the various feudal lords were extremely independent, and each one did substantially as he willed in his little domain.

The situation was a miserable one for every person, except the Pope, the sovereigns, the feudal lords and their hangers-on; not only because of the various petty tyrannies, but because of the continual little wars and the general absence of good government. Gradually, the sovereigns got more and more power (except in England) and the conditions improved so much that the people realized that it was better to be ruled by one king, or emperor, than by a multitude of barons. The sovereigns finally acquired so much power that they dared to oppose the Pope in many of his aggressions; but no very important situations were developed until the Reformation caused the existence of protestant or heretic sovereigns, and the occasional excommunication of one of them by the Pope, with its attendant exhortation to his subjects to take up arms against him. To meet this situation, the theory of the Divine Right of Kings was invented.

This was a very important invention; for it offset the Divine authority of the Pope as Pope, and gave a theme for the bishops and priests in their discourses to the people, and a slogan for the soldiers. It was extremely successful for three centuries, and its influence was in the main beneficent. It worked for the establishment of stable governments and great nations, tended to prevent the excessive domination of a religious organization, and, by recognizing the fact that every sovereign's power comes from the Almighty, it suggested the sovereign's responsibility to Him. At first this suggestion evidently bore little fruit; for the seventeenth and eighteenth centuries were characterized by general oppression of the people, and filled with dynastic wars, waged merely in behalf of monarchical ambitions. But gradually the kings and the peoples came to realize the duties of sovereigns, as well as their privileges and powers. Gradually then, the view came to be held that kings were bound to exercise their power for the benefit of their people.

Even the doctrine of the Divine Right of Kings, now condemned and obsolete, had a great influence and a good influence during the time it was in vogue; and it supplies a clear illustration of the power of a good idea, skillfully developed, to fulfill a given purpose, so long as its existence is necessary.

Most men have a considerable amount of energy, but do not know what to do with it. Children are in the same category, except that toys have been invented for them, and parents give these toys to their children. Without toys, children find the days very long, and parents find their children very trying. The usefulness of toys seems to be mainly, not so much in giving children pleasure directly, as in supplying an outlet for their energies, both physical and mental. For what greater pleasure is there than in expending one's natural energies under pleasant conditions?

Possibly, all the work that men have done in building up civilization is like the work that children have done with building blocks. Certainly there are many points of similarity. The mental efforts are similar; and, so far as we can see, the results are similar also. Toy temples have been built of building blocks, and then have been destroyed. Civilizations also have been built and then destroyed. And in the case of both the building blocks and the civilizations, the pleasure seems to come, not from the result achieved, but from an enjoyable expenditure of energy in achieving it. In both cases it has been the inventors who have pointed out the ways in which to expend the energy, and achieve the results.

CHAPTER VII

THE RISE OF ELECTRICITY, STEAM AND CHEMISTRY

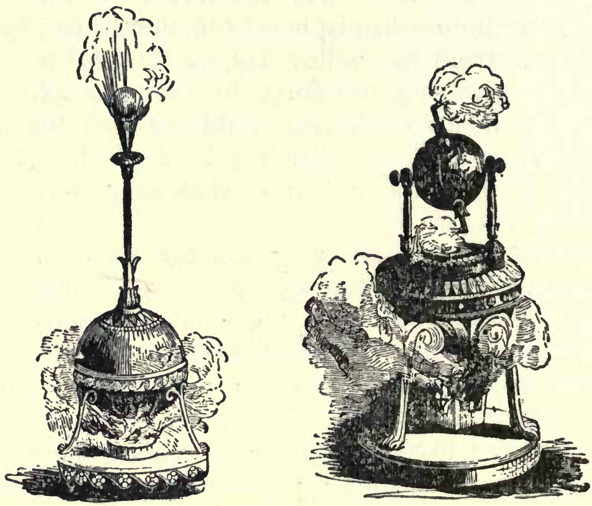
THE invention of the first electrical machine was made by Otto Von Guericke, of Magdeburg, about 1670. It consisted of a sulphur ball, a stick with a point, and a linen thread "an ell or more long," hanging from the stick. The lower end of the thread being made to hang "a thumb breadth distance" from some other body, and the sulphur ball rubbed and brought near the point of the stick, the lower end of the thread moved up to the body. The ball being removed, the lower end of the thread would drop away from the body; so that by moving the ball back and forth, the lower end of the thread would be made to move back and forth simultaneously.

It may be objected that Guericke made no invention, because he did not conceive the idea of making a machine or instrument and did not, in fact, produce one: that he merely made a discovery. The author admits that such an objection would have great reasonableness, and that Guericke's feat is a little hard to class. It is classed by many as an invention, however, and the present author is inclined to class it so; because there seems no reason to doubt that Guericke first conceived the idea of doing what he did do, and that he did produce a device whereby an actual motion of a rubbed ball at one place caused actual motion at another place, through the medium of a current of electricity that traversed a conductor joining the two places. The device is sometimes spoken of as the first telegraph instrument.

Guericke (like Gilbert) was more distinctly an experimenter than an inventor,—and (like Gilbert) his work was not only in electricity, but in most of the other branches of science. Of the two, Guericke seems to have covered a wider field, and to have been more distinctly an inventor. His celebrated experiment of holding two hollow hemispheres together, then exhausting the air from the hollow sphere thus formed, and then demonstrating the force of the atmosphere by showing that sixteen horses could not pull the hemispheres apart, indicates just the kind of clear apprehension of the laws of Nature that characterizes the inventor.

By some, Guericke is esteemed the inventor of the first electric light, because by rubbing a sulphur ball in a dark room he produced a feeble electric illumination. Of Guericke's discoveries and inventions, the only one that has survived as a concrete apparatus is the air pump; but it is doubtful if the direct influence on history of the air pump, great as it has been, has actually been any greater than the indirect influence of his less widely known discoveries and experiments.

One of the early influences of the art of printing was to bring to the notice of some restless minds the writings of Hero and Archimedes. In Hero's *Pneumatics,* published more than 120 years before Christ, he gives such a clear account of an invention of his own, in which the expansive force of steam was used to give and maintain motion, as to establish thoroughly his right to the basic invention of the steam engine. He described three apparatus that he devised. In one, the currents of air and aqueous vapor rising through a tube from a hollow sphere, containing water, under which a fire is burning, support a ball placed immediately above the tube, and make it seem to dance. In another apparatus, a hollow sphere into which steam has arisen from what we now call a boiler, is supported on a horizontal or vertical axis, and provided with tubes that protrude from the sphere, and are bent at right angles to the radius and also to the pivot. The inner ends of these tubes lie within the sphere, so that the steam



Hero's Engines

passes from the sphere through the tubes. As soon as this happens, the sphere takes up a rapid rotation, that continue so long as the steam continues to escape from the nozzles of the tubes, which point rearwardly. A third apparatus was merely an elaboration of the second, in that the sphere was connected with an altar which supported a large drum on which were figures representing human beings. The fire being lighted, the sphere would soon begin to revolve, and with it the drum; and the figures on it would seem to dance around, above the altar. The invention was probably to impress the people with the idea that the priests were exerting supernatural power.

Hero's wonderful invention remained unused and unappreciated for nearly 2,000 years. About 1601, an Italian named Della Porta, published a book that seems

Hero's Altar Engine

to show acquaintance with it, also with the fact that if water be heated it is converted into a gas that can raise water to a height. In 1615, a Frenchman named de Caus published a book in which he showed a hollow sphere into which water could be introduced through an orifice that could then be closed; the sphere carrying a vertical tube that dipped into the water at its lower end, and ending in a small nozzle at its upper end. When a fire was started under the sphere, the air in the upper part expanded, and forced down the water that occupied the lower part, so that a jet of water would soon issue from the upper end of the tube. Of course, this was really less than Hero had done, because the appliance described did not constitute a machine, in any real sense of the word.

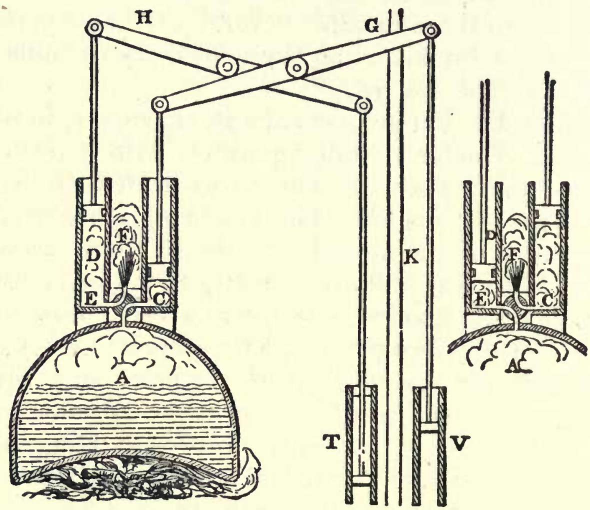
In 1629, an Italian named Branca carried Hero's invention a step further, by inventing a simple apparatus whereby the revolution of Hero's hollow sphere was communicated to a series of pestles in mortars, and put to the useful work of compounding drugs. Branca seems entitled to the basic invention of the steam engine as an industrial machine.

About 1663, the Marquis of Worcester invented a steam engine that exerted about two horse-power, and was employed to raise water from the Thames River, and supply it to the town of Vauxhall. Six years later (1669) Captain Thomas Savery erected a steam engine about twenty-five feet above the water in a mine, and successfully drew water out. This was a very important feat, because the difficulties surrounding the problem of freeing the mines from water were extremely great, and the desirability of overcoming them was equally so. In Savery's engine, there were two boilers in which steam was raised, and two receivers communicating with them. Steam being admitted to one receiver, the connection with the boiler was shut off by a valve, and a cold jet was then suddenly thrown on the receiver, condensing the steam and forming a partial vacuum. This vacuum the water below immediately rushed up to overcome. Connection with the pipe leading down was then shut off, and steam introduced to the receiver. This steam forced out the water from the receiver into a pipe, which discharged it above. This operation was then performed by the other boiler and receiver; so that, by their continued and alternate action, a fairly continuous stream of discharged water was maintained.

This invention was quickly followed by Captain Savery with another, by means of which the discharge stream was made to fall on a mill-wheel, as though from a natural waterfall. Several of these machines were erected for actuating the machinery of mills and factories in the district.

In 1690, Dr. Papin invented a steam engine, in which he used a cylinder containing water, with a piston so arranged that, when the water was heated, the steam would raise the piston. The fire being then removed the pressure of the atmosphere would force down the piston. This was followed shortly by an invention of Newcomer and Cawley, which was a very considerable advance on previous engines. It comprised a separate boiler and furnace, a separate cylinder and piston, means for condensing the steam in the cylinder by injecting water into it, and a system of self-acting valves that were opened and closed by a long beam that was moved by the piston. Furthermore, this beam communicated motion to a pump that pumped the water up directly. This engine was so efficient and so practically useful, that it was very generally introduced into service for draining mines throughout England. About 1775, Smeaton built an engine carefully designed on these lines, of which the cylinder was 72 inches in diameter, and the length of stroke was 10 feet and 6 inches.

In 1725, Jacob Leupold invented an engine, in which the work was done by steam alone, instead of by the atmosphere, as in the engines that immediately preceded it. Leupold used two cylinders. They were open at the top to the atmosphere as in the others, but he used higher pressures of steam, and arranged a four-way cock between the bottoms of the two cylinders in such a way that the bottom of each cylinder, in its turn, was connected to the boiler or to the open air. Each cylinder actuated directly a separate vibrating beam, which in turn actuated the piston of a pump; the two



Leupold's Engine

pistons acting reciprocally, each drawing up water in its turn.

In 1765, James Watt made the very great improvement of providing a condenser separate from the cylinder of the engine, so that the great loss of heat caused by cooling the cylinder and then heating it at each stroke was wholly avoided. He covered the cylinder entirely, and surrounded it with an external cylinder kept always full of steam, that maintained the cylinder at a high temperature. The steam, instead of being condensed within the cylinder, after it had done its work, was allowed to escape into the condenser. To facilitate this action, the condenser was fitted with an air-pump that maintained a good vacuum in it.

In 1769, Watt invented an improvement that consisted mainly of means whereby the supply of steam to the cylinder could be shut off at any desired part of the stroke, and the steam allowed to complete the rest of the stroke by virtue of its expansive force. This invention increased tremendously the efficiency of the engine: that is, the amount of work done with a given amount of steam.

During all this time, Watt had realized that virtually all the work was done on the down stroke, and none on the up stroke, and also realized that it would be highly desirable to devise an apparatus whereby the reciprocating motion of the piston could be converted into a rotary motion. Watt was able to accomplish both feats, and to connect the bottom and top of the cylinder alternately with the condenser and boiler by a simple mechanism driven by a wheel rotated by the engine. The result was the reciprocating steam engine in its main features, as it exists today.

The influence of Hero's invention on history is not direct, because his engine has never been employed for any industrial purpose. But Hero's engine has had an enormous influence on history, nevertheless, because it supplied the basis on which the steam engine of the last two centuries has rested. The influence of Hero's invention was not realized until two thousand years after he had died, and until after all those men had died whose names have just been mentioned. It is inconceivable that any of those men could really have expected that their work was to have even a small fraction of the influence on mankind that it actually has had. The influence of Watt's work became visible to some degree before he died, and became clearly visible not very long after he had died; so clearly visible that by many men Watt is credited with the invention of the steam engine. But his good work was built on the good work of his predecessors, whose main work was in making Watt's work possible. The successive feats of all, like the successive layers in the foundations of any building, were to support, in time, the whole superstructure of the great and beneficent science of steam engineering.

But the work done by these men was not all the work that had to be done, to make Watt's steam engine the efficient machine it was. These men were the men who are directly to be credited, but they were not the only men engaged. Neither did they belong to the only class of men engaged. There was another class of men whose labors were equally arduous, and equally important, though not so clearly in evidence—the physicists, as we now call them. It was by the knowledge which they gleaned regarding the properties of steam and air and water and iron, regarding the laws of motion and heat and work and force and weight and mass, that the inventors' experiments were guided. It is true that the science of physics was then in its infancy, as we realize with the knowledge of the science today; but Aristotle in the days of Greece, and Archimedes and Hero later, and Galileo and many others in Italy—as well as Guericke in Germany, Newton and Gilbert in England, and others of less note, had evolved a good deal of order out of what had been chaos, and had given inventors a great deal of firm ground on which to stand themselves and raise their structures. And reciprocally, the inventors found themselves confronted with problems of a kind that gave opportunities for the physicists to show their skill and knowledge.

Thus were opened up promising avenues of investigation, and not only of investigation, but of invention also. For it is obvious that, while investigation and experimentation can hardly fail to secure data, they may secure nothing else, and usually do. But mere data are mere facts; and, valuable as they are if suitably classified, they are not valuable unless they are classified; and even after data are classified, they are not useful until some use is found for them. The data in card-indexes are mere unrelated facts, and are almost useless, until they have been classified and arranged in boxes alphabetically labeled. Then they are useful whenever any use is found; when, for instance, some one is seeking information on a certain subject. In this condition, data are like material substances, in that they are available for use,—in fact, data are often spoken of by writers as "material"; a certain series of incidents, for instance, supply "material" for a story. Now, just as pieces of iron and brass supply material with which an inventor can create a new machine, so classified facts, or data, supply material with which an inventive investigator can create a new theory, or formulate a new law.

Our books on physics are full of accounts of experiments and investigations conducted by such men as Hero, Archimedes, Gilbert, Galileo and many others, the consequent discoveries that they made, and the consequent laws that they enunciated; but those books could not possibly describe all the investigations that have ever been made. Those which they describe are those that ended in some definite creations, such as the hydrostatic law enunciated by Archimedes. Most investigations, experiments and researches have ended in nothing definite:—most of them, in all probability, have not even established facts. The investigations that we studied about when boys were such as those of Archimedes, that presented us with inventions, in the form of useful and usable laws. No appreciable difference is apparent between the mental operations of Archimedes in inventing these laws and his mental operations in inventing his screw: for in both cases the mental operations consisted mainly in conceiving an idea and then embodying it. The Archimedean screw was a machine of an entirely new kind that, in the hands of a man understanding its use, would enable the man to do something he could not do before—or enable him to do a thing he could do before, but do it better. So were his laws. The laws have been utilized ever since, as definite and concrete devices; and to a much greater extent than the special form of screw that he invented.

In a like way, all the laws that investigators have put into concrete and usable form, have been used by other investigators as bases for further investigations, and by inventors as bases for future inventions. Even the inventor of the fist-hammer had to know something about the material which he employed; he had to know that it was hard and heavy, for instance, and that it could be hammered so as to have a point and a sharp edge. He had to know also something about the flesh of a man: he had to know that if his flesh was struck with a sharp hard instrument, it would be bruised, and the man injured, and maybe killed. Similarly, the inventor of the gun, and the inventor of printing, and the inventors of steam engines, had to know a good deal about the materials which they employed, and about the uses to which their appliances could be put. Naturally, they had to know much more than did the inventor of the fist-hammer. But the inventor of today has to know still more, because there is still more to know. An inventor of the present day who knew no more about physical science than Galileo did would not be able to go far.

A like remark may be made about any man in any vocation, as compared with his predecessor in Galileo's time. The machine of civilization is so vast and so complex, that the amount of knowledge which anyone of us needs in mere daily life is almost incredible. Let anyone try to enumerate all the facts he knows! The attempt will convince him quickly.

It may be pointed out here that, while modern civilization differs from ancient civilization in many ways, it differs more in complexity than in any other one way. Some of the factors of ancient civilization were as good as those of today; such things, for instance as temples and pyramids and stationary objects in general. But the ancients did not understand motion clearly, especially irregular motion; and they had no fast vehicles of any kind. Their knowledge of statics must have been fairly complete, or they could not have built their temples and pyramids; but their records show little understanding of dynamics.

Now the basis of dynamics is mathematics. Dynamics is the result of the application of mathematics to the observed effects of force on bodies, in producing motion. Dynamics is a branch of the science of mechanics, and a most difficult branch. It is built on the observations, calculations and conclusions of Newton and a host of experimenters and mathematicians of lesser mentality, and it could not have come into being without them.

But dynamics has not been the only physical science involved in making the machine of civilization. All the physical sciences have taken part; and each one has taken a part which was essential to the final result, and without which the final result could not have been attained. The science of light made possible the solution of our problems of illumination and the development of inventions for producing it; the science of acoustics made possible the solution of our problems of sound, including music, and the invention of acoustic and musical instruments; the science of heat made possible the invention of all the complex and powerful steam and gas engines that have revolutionized society; the science of electricity (including magnetism) has made possible the invention of those electric and electro-magnetic machines that have supplemented the work of the steam engine; and the science of pneumatics has made possible the invention of those "flying machines" of many kinds, that promise to complicate civilization further still.

But let us realize clearly that no one of these sciences by itself has been able to perform any of the feats just mentioned. Each one was virtually dependent on every other one; and all were dependent on mathematics. In order to make the steam engine work efficiently, it was not enough that heat should expand water into steam: the mathematical laws which showed how much water was needed to secure a certain amount of steam, for instance, and how a certain desired pressure of steam could be secured, had first to be comprehended and then to be followed. In order to have boilers and engines so designed as to prevent disastrous explosions, the laws governing the strength of materials had to be known and followed. In order that a projectile could be so fired from a gun as to reach a certain predetermined spot, the laws of heat, pneumatics, chemistry and dynamics had all to be understood and followed with exactness.

But it was not only the machines and instruments that needed the assistance of those sciences, it was the sciences themselves; because it was only after eliminating phenomena caused by one agency from those caused by another, that accuracy in any conclusions whatever could be secured; and in order that the phenomena caused by one agency could be kept separate from the phenomena caused by another agency, the laws underlying both had to be understood. The science of light could not be developed until the action of heat was fairly well understood; dynamics had to wait on statics; Newton could not have contributed what he did to astronomy, unless the science of light (including optics) was sufficiently understood; and the laws of pneumatics could not have been developed, unless the laws of heat had been developed, etc. And not one of the physical sciences could have gone beyond the state of infancy, if the science of mathematics had not been invented and made into a workable machine.

The paragraph above may be put into a different form, and made to state that all the physical sciences have been brought up to their present stage, by subjecting the phenomena studied by each science to quantitative investigation. It was by making these quantitative investigations that Newton and the others were able to ascertain the exact facts from which to start in their endeavor to discover the laws of nature; and it was from the laws of nature thus induced that later investigators were able to start on still further expeditions of discovery into the unknown. As the common basis of all quantitative work is mathematics, the common basis of all the physical sciences is mathematics. This makes all the physical sciences interdependent, despite the fact that each is independent of the others. Each one of the physical sciences has contributed its part to building the machine of civilization; the part that each has specially contributed can be clearly specified; and yet, since the machine is the result of the combination of what all have contributed, their contributions are interdependent. This remark applies to the various parts of all machines. The piston of a steam engine, for instance, and the valve that admits steam to the cylinder are entirely separate from each other; but from the mere fact that they both work together, each one must be designed and operated with reference to the other; so that both in their construction and their operation, they are interdependent.

Francis Bacon, in the sixteenth century, may be said to have inaugurated the system on which the whole of modern progress has been based, and Newton in the seventeenth century to have taken up Bacon's work and carried it further on. Following Newton, only a few great investigators can be seen in the seventeenth century; but in the eighteenth, began that intense and brilliant movement of investigation, discovery and invention, that has been adding more and more to the machine of civilization—and still is adding more.

One of the earliest and most important contributions was an apparatus for measuring time accurately. Who was the inventor is not precisely known. It seems fairly well established, however, that Galileo was the first to call attention to the fact that the vibrations of a pendulum were nearly isochronous, and could be used to measure the lapse of time; and that Galileo's son (as well as Dr. Hooke, Huygens and a London mechanic named Harris, in the early part of the seventeenth century) made clocks based on that principle. It is fairly well established also that Huygens was the first one to make a mathematical investigation of the properties of the pendulum, and to enumerate the laws since utilized for making accurate clocks and watches.

Most of the investigators of the eighteenth century occupied themselves with studies indirectly or directly caused by the invention of the steam engine, that is with studies relating to heat and light; but, by reason of the interdependence of all the physical sciences, their investigations led them automatically into the allied fields of acoustics and electricity. Their investigations led even further; they led to the establishment, on the ruins of the illusions of alchemy, of a wholly new and supremely important science, chemistry.

One of the most important inventions of a purely scientific character made during the period was one that has never been known by any other name than "Atwood's machine." It is an interesting illustration of the addition of invention to investigation, in that its end was—merely investigation; and it reminds us of a fact that many people are prone to forget, that invention may be applied to almost any purpose whatever, and that even a "machine" may be devoted to a purpose not utilitarian.

Atwood's machine was the outcome of studies into the relations between force and a body to which force may be applied. Galileo had shown that a body subjected to a constant force, like that of gravity, will gradually acquire a velocity and at a constant rate; and also that this rate, or acceleration, is proportional to the force (leaving out the effect of air resistance). Atwood's machine consisted merely of an upright with a pulley at its upper end over which passed a cord, to both ends of which weights could be attached. In any given experiment, a weight was attached to one end and allowed to fall free; but another weight could automatically be attached to the other end by a simple device, when the first weight had fallen through any predetermined distance. If the added weight were equal to the first weight, the velocity of movement became uniform at once; while if it were less, the velocity approached uniformity to a degree depending on the approach to equality of the two weights. While this machine did not establish any new law, or prove anything that Newton had not proved before, it supplied a very valuable device for conducting quantitative experiments with actual weights, and for instructing students.

The first important improvement in the art of printing was made by a Scotch goldsmith named William Ged, about the year 1725. It is now called stereotyping, and it seems to have been successful from the first, from a technical point of view. It was far from successful from a financial point of view, however, mainly because of the opposition from the type-founders; so that Ged died without realizing that he had accomplished anything. Ged's invention was not put to practical use for nearly fifty years after his death; but after that, its employment extended rapidly over the civilized world. Ged's experience was bitter, but no more so than that of many other discoverers, inventors and benefactors. He did not profit in the least by his invention; in fact, it must have brought him little but exasperation and discouragement. But can we even imagine civilization to exist as it exists today, if stereotyping had not been invented?

An invention of a highly original kind was made some time in the middle of this century which is attributed by some to Daniel Bernoulli, one of the eight extraordinary investigators and scholars of that family. According to this theory, the pressure of any gas is due to the impact of its molecules against the walls of the vessel containing it. Naturally, the greater the density of the gas, and the greater the velocity of the molecules, the greater is the pressure. This theory has greatly assisted the study of gases, and contributed to the investigation of electric discharges in gases and partial vacua, and therefore to the modern science of radio-activity.

In the year 1640 there came to the little throne of the Margravate of Brandenburg a coarse and violent man, who conceived a principle of government that seems to have been wholly novel at that time, the principle of efficiency. Having conceived this idea clearly in his mind, he proceeded to develop it into a system of administration, in spite of opposition of all kinds, especially inertia. He ruled till 1688. He found Brandenburg unimportant, disordered and poor; he left Brandenburg comparatively rich, with a good army, an excellent corps of administrators, a very efficient government, and a recognized standing before the world. For his contribution to the cause of good government, he is known in history as The Great Elector. He might be called, with much reasonableness, the inventor of governmental efficiency, if Julius Cæsar had not in some degree forestalled him.

He was followed by his son, who contributed nothing to this cause or to any other, but who was able to take advantage of his father's work and be crowned as King of Prussia. He was followed by his son, King Frederick William I, who was a man like the Great Elector, his grandfather, in the essential points of character, both good and bad.

He was somewhat like Philip of Macedon also; for he conceived the idea of making his army according to a certain pattern, novel at that time, though considerably like the pattern that Philip had employed. The likeness was in so organizing and training the soldiers that a regiment or division could be handled like a coherent and even rigid thing, directed accurately and quickly at a pre-determined point, and made to hit an enemy at that point with a force somewhat like the blow of an enormous club. He succeeded during his reign of twenty-seven years in developing his conception into such a perfect and concrete reality, that he was able on his death in 1740 to bequeath to his son a veritable military machine—the first since the days of Rome.

These two Frederick Williams were inventors in the broad sense of the word, and made inventions that have had an influence on history since they died, as great as that of almost any other contemporary inventions that can be specified. Their immediate influence was to make it possible for the son of King Frederick William, Frederick the Great, to put Prussia in the first rank among the nations, and to lay the foundations of the German Empire.

It may be objected that the ultimate result was not extremely great, after all, because the German Empire fell in 1918. To this possible objection, it may be answered that, nevertheless, the doings of Prussia and the German Empire have had an enormous influence up to the present time; and that, though the empire itself has ceased, the influence of its policies and doctrines, of its military system, and, above all, of its doctrine of efficiency in government has not ceased, and shows no signs of ceasing. Besides, *history still is young.*

Frederick the Great made no inventions in improving the military machine bequeathed him; but he did operate it with inventiveness, daring and success. He showed these qualities in his actual operations in the field; but he showed inventiveness in an equal degree before those operations took place, in the plans which he prepared. As a tactician, Frederick could hardly help being good, in view of the training he had received and the military atmosphere in which he had been born and bred. But no amount of training could have given Frederick the brilliant and yet correct imagination that enabled him to see entire situations clearly and accurately with his mental eye; that enabled him to form a correct picture of the mission in each case, the difficulties in the way of accomplishing it, and the facilities available for his use. And, equally, no amount of training or knowledge or experience could of themselves have given him the constructive ability necessary to build up such plans as he built up, for accomplishing the mission with the facilities available and in spite of the difficulties.

Frederick's first invention was his successful invasion of Silesia. This may be called by some "an invention of the devil," and perhaps it was inspired by him. But even if Frederick's conception came straight from the devil, it was a brilliant conception, nevertheless, as the conceptions of the devil himself are popularly supposed to be. So original in conception and so perfect in development was Frederick's invented plan, that he had seized the capital of Silesia before Austria had taken any real defensive measures of any kind.

During the first half of Frederick's reign, or twenty-three years (from 1740 to 1763), he was engaged continually in war or preparation for war; and in both activities he had to plan to fight against odds that often seemed overwhelming. They would have overwhelmed any man, except a man like Frederick. It is true that Frederick had two advantages, the best trained army, and the fact that all his forces, military and political, were united under one head—his own. But it is the verdict of history that even these advantages were far from sufficient to explain his victories; that his victories cannot be explained except on the ground that Frederick showed a generalship superior to that of his foes. In what did its superiority consist? A careful study of his campaigns, even if it be not in detail, shows that Frederick was able to invent better plans than his adversaries, to invent them more quickly, and to carry them into effect more promptly. If he had been born under other stars, he might have exercised his inventiveness in such ways as men like Guericke, for instance, did; as is shown by his gathering around him, in the peaceful period of the latter half of his reign, a company selected from the most eminent philosophers and scientists of the age; and as is shown with equal clearness by his admirably conceived and executed measures for the better government of his country.

The middle of the eighteenth century is especially distinguished by the success of some extraordinary and brilliant experiments with electrical apparatus. One of the most important in results occurred about 1746, in the town of Leyden, where Muschenbroek invented a device that made possible the accumulating and preserving of charges of electricity. This appliance consisted of merely a glass jar, coated on the outside and the inside with tin foil. It was a most important invention, and it is still in general use, and called the Leyden jar.

The Leyden jar was soon put to practical work in electrical investigations, notably by the Royal Society in London; and many valuable demonstrations were made with it. Among these were the firing of gunpowder by the electric spark that passed when both surfaces of tin foil were connected by an external conductor; and the transfer of the spark over a distance of two miles, by using one discharging conductor or wire two miles long, the earth acting as the return conductor.

But the greatest results came from the investigations of Benjamin Franklin, who proved that there was only one kind of electricity, that the two coatings of tin foil were both charged with it, that one had more than its ordinary quantity, while the other had less, and that the spark was caused by the transfer of electricity from one coating to the other. These discoveries were as much as any one discoverer might reasonably be expected to contribute; but Franklin soon followed them by his discovery of the power of points to collect and discharge electricity. He then pointed out with extraordinary clearness the fact that all the phenomena which had been produced by electricity were like those produced by lightning; and made the suggestion that lightning and electricity were identical.

This was an interesting suggestion, but a suggestion only. To make it into a theory, or prove it as a law, an invention was required. Franklin made the invention. He conceived the idea of bringing down the electricity, with which he imagined that a storm-cloud was charged, by means of a long conductor, and of drawing off a spark from the lower end of the conductor as from an electrical machine. The long conductor he had in mind was a high spire that was about to be erected in Philadelphia. The erection of the spire being delayed, his imagination presented to his mind the picture of a kite flying near the cloud, and the charge flowing down the cord, made into a conductor by the accompanying rain. Forthwith, he embodied his conception in definite form by preparing a kite to which was connected a long cord, that ended with a piece of non-conducting silk, that was to be held in the hand, and kept dry if possible, and a key that was secured to the junction of the conducting cord and the non-conducting silk. The expectation was that the key would receive the charge from the cloud and give it out as a spark, if Franklin applied to it the knuckle of his disengaged hand. The invention was a perfect success in every way; sparks were given off, a Leyden jar was charged, and subsequent discharges of the Leyden jar were made to perform the same electrical feats as jars charged from ordinary electrical machines. (June, 1752.)

The courage shown by Franklin in performing this experiment may here be pointed out. To the eye of a casual observer, he must have been trying to get struck by lightning.

This brilliant invention caused Franklin to conceive another brilliant invention, the utilization of the discovery he had just made in combination with his previous discovery of the power of points to collect electricity. He embodied his conception in what we now call "lightning rods," by erecting on the highest points of houses thin metal rods or conductors, the lower ends of which were buried in the earth, while their upper ends were sharpened to points, and made to project upward, above the houses. Franklin's theory was that the points would collect the electricity from the clouds and allow it to pass harmlessly through the conductors into the ground. The invention worked perfectly, and has been utilized everywhere ever since.

Naturally, Franklin's epochal discoveries stirred the scientific world in Europe, and gave a great impetus to the study of electricity and the other physical sciences. One of the earliest important discoveries that followed (made by Mr. Cavendish) was that the electrical spark could decompose water and atmospheric air, and make water by exploding mixtures of oxygen and hydrogen. An epochal discovery was made by Mr. Cavendish about 1787, when he exploded a mixture of oxygen and nitrogen and obtained nitric acid.

In 1790 Galvani discovered that, if two dissimilar metals were placed in contact at one end of each, and if the free ends are put into contact with the main nerve of a frog's hind leg and the thigh muscle respectively, spasmodic muscular movements would ensue. In investigating the cause of this phenomenon, Volta discovered that if the lower ends of two dissimilar metals were immersed in a liquid they would assume opposite electrical states; so that if their outer ends were joined by a conducting wire, electricity would pass along it. This led him at once to the invention of the Voltaic cell. The enormous value of the Voltaic cell in building up the science of electricity need hardly be pointed out. It is still used in electric telegraphy as a source of current.

During the eighteenth century, the relations between chemistry and heat were very ill defined; but they were cleared up gradually by the researches of such men as Black in Scotland, Priestley and Cavendish in England, and Lavoisier in France. Black's work was mainly in making investigations of the phenomena of heat. In the course of them he discovered the important fact that different substances require different amounts of heat to be applied to a given mass to raise its temperature 1°. From this discovery arose the science of calorimetry, which deals with the specific heats of all substances, solid, liquid and gaseous, and which is necessary to the present science of heat and the arts that depend upon it. About 1774 Dr. Priestley discovered oxygen.

Lavoisier prosecuted rigorous researches in heat and chemistry, and finally made a discovery that cleared up a great fog of doubt as to the nature of oxidation, by proving that it consisted in an actual attack on a metal by oxygen, and that the increased weight resulting from oxidation was that of the oxygen that became associated with the metal in the form of rust. He therefore disproved the theory formerly loosely held that the increase in weight was due to the escape of a spirituous substance which the chemists of that day imagined to depart from the metal, and called by the name phlogiston. An analogous and equally valuable contribution by Lavoisier was that of introducing the use of exact measurements into the study of chemistry. The result of his labors was to put the science of chemistry on a new basis and to separate it from physics entirely.

It might be supposed that Lavoisier would live and die in great honor. He lived in comparative obscurity, and was publicly guillotined on a false accusation. He requested a brief respite, in order to complete an important experiment, and was told in answer that "the Republic has no need of philosophers." This was France's reward for one of the most useful lives that has ever been lived.

One of the most important industrial inventions ever produced and one of the first of the long list of inventions for making things by machinery that had formerly been made by hand, was the spinning machine, that was invented by Dr. Paul in England about 1738. Spinning is an exceedingly ancient art, and consists in forming continuous lengths of thread by drawing out and twisting together filaments of such material as wool, cotton, flax, etc. This art was practiced in many of the ancient countries; and it seems to have been practiced in essentially the same way in England in the eighteenth century A. D., as in Egypt and Assyria long before the eighteenth century B. C. About 1738 Dr. Lewis Paul invented and patented a simple mechanism that anyone with imagination could have invented at any time during the two or three thousand years before, in which the filaments were drawn between rollers. The invention seems to have been moderately successful from the start; for it is stated that in 1742 a spinning mill was in operation in Birmingham in which ten girls were employed, and in which the motive power was supplied by two asses. Paul's invention was improved by a weaver named Hargreaves, who invented the "spinning Jenny"; and it was later brought to a high state of efficiency and value by an invention of a poor and wholly uneducated barber, named Richard Arkwright. The spinning machines of the present day are of the highest order of intricacy, efficiency and usefulness; but they are all based directly on the invention of Arkwright, and his was based on the previous inventions of Paul and Hargreaves. Few persons have contributed so much as these three men of humble station to the comfort and well-being of the race.

On July 3, 1775, George Washington arrived at Cambridge, near Boston, and took command of an army of about 17,000 men that faced a British army occupying Boston. Washington devoted his energies to organizing and training his motley force during the ensuing fall and winter, the enemy making no decided move to drive him off. Finally, on March 4, 1776, having conceived a plan that promised success to him, he suddenly seized and fortified Dorchester Heights, about two miles south of Boston, from which he could command the whole of Boston and the channel south of it, by means of guns which he had ordered to be dragged through the snow from Ticonderoga. His plan worked perfectly; for the British General Howe, after a vain attempt to drive Washington away, evacuated Boston himself, and took his army to Halifax.

This was Washington's opening move in our War of the Revolution. It was the execution of a plan admirably conceived. There may seem little of originality or brilliancy in it to us now, looking at a map of Boston in the quiet and safety of a library, but there must have been a great deal of merit and originality in it; for it took a British major-general completely by surprise, and compelled him to evacuate an important stronghold with a precipitancy that must have been distinctly galling to British pride. Few neater feats of strategy can be found in military history.

Washington's next feat was in extricating his force from a distinctly perilous position in Brooklyn in front of a superior British force, retreating across the East River to New York, and landing near what is now called Fulton Street. This was on August 30, 1776. The next three months were spent in maneuvers that showed great clearness in conception and great energy in execution on Washington's part, and ended with his occupying Trenton, and Howe occupying New York with the bulk of his forces. Washington had only a little more than 4,000 men, while Howe had 30,000. Washington's troops were discouraged, half-ragged, underfed and untrained; Howe's were elated, well clad, well fed and thoroughly trained. Washington was in as dangerous a plight as can easily be imagined. He extricated himself by conceiving and carrying into execution the brilliant plan of crossing the Delaware River on Christmas night, forcing his way through floating ice, and falling on the amazed camp of the Hessians on the other side. His invention worked perfectly, and effected almost a complete reversal in the relative conditions of the opposing forces; for it put the British on the defensive, and made them withdraw all their forces from New Jersey.

Thenceforward, Washington, by the exercise of imagination, constructiveness and sheet force of will, fought a continual fight against forces that were superior in material and training, but inferior in mentality. Finally, in August, 1781, the crisis came. The British were occupying New York, and Washington was in front of it, threatening to attack it, but knowing that he could not do so with success. About August 14 he received a letter written in July by Admiral Comte de Grasse, then in the West Indies, saying that he would start with his fleet and a force of troops for Chesapeake Bay on August 13. Washington knew that the British General Cornwallis was entrenched at Yorktown, near the mouth of the Chesapeake, with a force considerably inferior to his own. He instantly proceeded to embody in action an idea that he had already conceived—that of leaving the vicinity of New York secretly, and marching with the utmost possible despatch to Yorktown, and calling on de Grasse to assist him to capture Yorktown, and if posible Cornwallis. No invention ever succeeded better. Its influence on history was to precipitate the collapse of the entire British program of hostilities, and cause the establishment of the United States.

The balloon was invented about 1783. Mr. Cavendish had found that hydrogen was about seven times lighter than air, and Dr. Black had forthwith delivered a lecture in which he pointed out that a thin light vessel inflated with hydrogen should be able to rise and float in the air. He conceived the idea of the balloon, but made no invention. The Italian philosopher, Cavallo, about 1782, inflated soap-bubbles with hydrogen gas, but went no further. The subject of making balloons filled with hydrogen was widely discussed; but the first balloon really to rise was the hot-air balloon invented by Joseph and Stephen Montgolfier. This balloon made a successful ascent on June 5, 1783, carrying the two brothers, flew about ten minutes, and alighted safe, after a trip of about a mile and a half. This was followed on August 27 by a flight of a balloon filled with hydrogen gas, the design of which was made by the physicist Charles, and the cost of which was met by a popular subscription. The flight was followed shortly by many others. The first employment of balloons in practical work was in making observations of the enemy by the French army in 1794.

An important invention for utilizing mechanical power in place of hand-power was the power-loom invented in 1785 by Edmund Cartwright. This was an invention of the most clean-cut kind, originating in the conception by the Rev. Dr. Cartwright of the possibility of doing much more weaving by mechanical power than by hand, then constructing the machine to accomplish it, and then accomplishing it. An interesting fact in the early development of looms for weaving was the determined and angry opposition of weavers to each improvement in succession.

Another invention also utilizing external power, made near the end of the eighteenth century, was the hydrostatic press. It consisted of a vertical cylinder, fitted with a piston prevented by suitable means from rising, except against great pressures; the piston resting on a liquid in the bottom of the cylinder, which was connected by a small pipe with a small pump, by which more liquid could be forced in. When the pump was operated the pressure per square inch on the piston of the pump was communicated to each square inch of the large piston in the press, and a force exerted equal to that pressure multiplied by the difference in area of the two pistons. This is the model on which hydraulic jacks and many other hydraulic mechanisms are constructed; and it has taken a prominent part in the development of the science of hydraulics ever since it was invented.

Because of the gradual recognition of the value of sea-commerce in the British Isles, and the fact that the stormy seas adjacent necessitated the construction of ships at once sturdy and yet capable of speed, much study and experimentation were carried on during the eighteenth century, especially in England. In these experiments, the invention by Archimedes of the hydrostatic principle of buoyancy supplied the starting-point, and gave an excellent illustration of the influence of invention on history: for from experiments and investigations on floating bodies carried on in England, based on the invention of Archimedes, and followed by others of English origin, sprang England's merchant marine and England's navy and England's domination over a quarter of the land on the surface of the earth.

The eighteenth century closed with the invention of two very important mechanisms that reinforced the power of the human hand with power drawn from external sources: these were the threshing machine and the cotton gin; the former invented by Andrew Meikle in 1788, and the latter by Eli Whitney in 1793. It would be hard to decide with knowledge as to which has had the greater influence in constructing the machine of civilization; but it is not at all hard to realize that the machine of civilization could not have attained its present stage without the assistance of both.

One of the last important inventions of the century was that of an art entirely new, as distinguished from inventions like the cotton gin, that merely increased the value of an art already in existence. This was the invention of lithography, or printing from stone, made by Alois Senefelder in 1796. The first thing printed by him was a piece of music. While this invention was more brilliant than those of Meikle and Whitney, it was hardly so important. Nevertheless, it was important in a high degree and made a valuable addition to civilization.

An invention of a kind different from either Whitney's or Senefelder's was made on October 15, 1793, by Napoleon Bonaparte. He was at that time a young and ill-clad captain of artillery, attending a Council of War in Toulon. An idea for driving out the English had been conceived and embodied in a complete plan by a celebrated engineer, and it had been approved by the Committee on Fortifications. The youthful and prestigeless captain opposed this plan with a vehemence and convincingness that came to be familiarly known a few years later, and proposed in place of it a plan that he had himself conceived and embodied in a concrete form. His plan consisted in the main merely in mounting some guns on a point of land that he designated, from which they could command the British war-ships in the harbor; and it was so much simpler and in every way better, that, despite his obscurity and youth, it was adopted, and he himself was charged with carrying it into operation. This he did; and with such constructive skill and energy, that the British ships were driven from the harbor and the entire vicinity, and without doing any damage to the town. The British soldiers, then unsupported, immediately withdrew.

What was the determining difference between Napoleon's plan and that of the great engineer? *The idea conceived.*

CHAPTER VIII

THE AGE OF STEAM, NAPOLEON AND NELSON

IN the early part of the nineteenth century began what has been called the Age of Steam; but before it ended, it was supplanted by the Age of Electricity. When the century opened, the steam engine of Watt existed in a practical and useful form, and the numberless experiments of the physicists in the preceding century had laid bare the main laws governing the force and the expansion of steam and air, and of gases and vapors in general. The laws of the expansion of solids and liquids were also understood in their main features, and the various inventions mentioned in the last chapter were in operation. Seizing on the facilities thus supplied, and noting the worldly success that certain discoverers and inventors had achieved, the inventors of the nineteenth century got speedily to work. The result was that the civilized world at the end of the nineteenth century was vastly different from the civilized world at the end of the eighteenth century.

In general terms, it may be declared that during the first half of the nineteenth century, the principal inventions were in the utilization of heat, especially in the form of steam engines; while during the latter half, the principal inventions were electrical:—though some very important electrical inventions were made before 1850. In this brief résumé, no attempt will be made to describe or even mention all the inventions made, or even all the important ones; for such an attempt would be impossible to carry out. Only a few super-important ones will be mentioned.

The first important successful application of the steam engine was embodied in the steamboat *Charlotte Dundas* that was produced in Scotland in 1801. Other steamboats had appeared before, but they had not been successful. The first was tried on the Soane River in France in 1781. Later, Fitch and Ramsay made some unsuccessful attempts in the United States. Then, in 1788, Patrick Miller, with the assistance of an engineer named William Symington, had constructed a steam vessel that attained a speed of five knots on a lake in Scotland. In the next year, Mr. Miller and Mr. Symington had put another steamboat on the water that developed a speed of nearly seven knots. None of these experiments could be called successful of itself; but the experience gained by them induced Lord Dundas to build the *Charlotte Dundas* and name it after his daughter. The *Charlotte Dundas* was a practical success from the start; for, in March, 1802, it towed two vessels of 70 tons each a distance of 19½ miles in six hours, while such a strong wind was blowing from ahead that no other vessel on the canal tried to move to windward.

Whether or not this constituted an actual invention the present author will not attempt to determine, even in his own mind. It is clear, however, that it was the direct issue of several inventions, and that it was the first embodiment in a concrete form of the successful and practical application of steam power to transportation on the water.

The next successful application was made by Robert Fulton, who built the *Clermont* in 1807. This vessel went into regular service in 1808, plying between New York and Albany, on the Hudson River.

The first steamboat to venture on the ocean was the

Phœnix, that made the trip from New York to Delaware Bay by sea in 1808. It was built by Mr. R. L. Stevens, an engineer of Hoboken. If it accomplished nothing else, it supplied a precedent and gave encouragement to inventors everywhere. It made "le premier pas qui coute."

Meanwhile, in June, 1802, Mr. Thomas Wedgewood had published "An Account of a Method of Copying Paintings upon Glass, and of making Profiles by the Agency of Light upon Nitrate of Silver," with observations by Sir Humphry Davy. In the course of his paper, he declared that he had secured profiles of paintings made on glass by throwing the shadows of those paintings on paper covered with a solution of the nitrate; the paper showing the objects delineated in tones that were dark or light inversely as they were in the painting. He also took profiles of natural objects by throwing their shadows on the prepared paper: the parts of the paper covered by the shadows being white, while the parts outside the shadows became dark.

This seems to have been an actual invention, in that it followed a discovery made by Wedgewood that sunlight acted on nitrate of silver, and was the embodiment of an idea, then conceived by him, to utilize his discovery in making profile pictures. His invention was far from perfect, however; the greatest imperfection being the fact that the pictures could not be fixed; because, unless the paper was ever afterward kept away from the light, its whole surface would become dark, and the picture therefore cease to exist. In consequence, it aroused almost no interest whatever at the time. In 1814, M. Niepce invented a process that he called "heliography," by which he made pictures on silvered copper covered with a thin solution of asphaltum. In 1829, Daguerre and Niepce entered into a copartnership for developing heliography, and instituted experiments that led Daguerre to inventing the daguerreotype, made by a process quite new in detail, but based on the earlier inventions of both Wedgwood and Niepce. The daguerreotype was followed in 1850 by the present "photograph."

The invention of electroplating was made by Brugnatelli in Italy in 1803. The fact that electric currents could decompose certain liquids had been known since 1800, and also the further fact that oxygen and hydrogen, acids and alkalies, appeared at the positive and negative poles respectively of the wires in contact with the liquid. But Brugnatelli seems to have been the first to conceive the idea of utilizing these facts in a device whereby he could deposit metals at will at the negative end of a solution. In the embodiment of his conception, pieces (say of silver) were hung on rods in connection with the positive pole of the battery supplying the electric current, while the articles to be plated with silver were hung on rods connected with the negative pole. The value of this invention and its extensive use in the electrodeposition of metals at the present day are well known.

In the following year, Sir Humphry Davy, working along the general line of electrical decomposition of liquids, made a number of super-brilliant investigations. Possibly the most important result was his discovery of a new metal, to which he gave the name Potassium, formed at the negative pole by the electrical decomposition of moistened caustic potash. He followed this by decomposing caustic soda and discovering another new metal, that he named Sodium.

During the course of his experiments, Davy noted that when the two terminal wires from a large Voltaic battery were touched together and then drawn apart, not only did a spark pass, but a continuous discharge of great brilliancy, that did not cease until the wires were separated by a considerable distance. The extent of this distance was found later to be dependent on the number of cells in the battery. He noted also that the discharge did not follow a straight line, but was bent into an arc; and for this reason he gave it the name, "Voltaic arc." This light is still known by the name "arc light." Its importance does not seem to have been realized until after the dynamo-machine had been invented, and means thereby supplied for providing a greater amount of electric current, and at less expense than Voltaic cells were capable of delivering.

Davy's last great invention was his miner's safety lamp, made in 1816. There had been frequent explosions in the collieries, attended with great loss of life, and Davy was requested to try to ascertain how they could be prevented. After visiting the mines, he had samples of the gas that was found in them sent to him for investigation. He went about the work with scientific thoroughness and system, and ascertained that the gas would not explode if it were mixed with less than six times or more than fourteen times its volume of air; that air rendered impure by the combustion of a candle would not explode the gas; that, if a candle were burnt in a closed vessel, with small openings near the flame, no explosion would take place, even if the vessel were introduced into an explosive mixture; and that the gas from the mines would not explode inside a tube less than ⅛ inch in diameter. These data being secured, Davy conceived the idea of making a lamp in which a small oil light should be fixed and surrounded with a cylinder of wire gauze. He then embodied his conception in a concrete form, and the "Miners' Safety Lamp" resulted.

This was an invention of the first order; original, concrete and highly useful. After meeting the customary chorus of prejudice and opposition, it justified its existence by a quickly established record of effectiveness, and took its place among the useful adjuncts of the machine of civilization.

Meanwhile, several other adjuncts had appeared. Among these was the steel pen, a process of making malleable iron castings, the planing machine, a fire-proof safe, the knitting machine and the band wood-saw.

In 1726 Dr. Hales had announced that a gas capable of burning, and giving light while burning, could be distilled from coal. This announcement created great interest, and led to a long series of scientific investigations as to the possibility of utilizing it for house and street illumination, especially by a Mr. Murdock in the latter decade of the century. In 1802 Mr. Murdock made a public display of the result of his labors, by illuminating a factory with gas. In the year 1803-1804 the Lyceum Theatre in London was so lighted, and a year later some extensive cotton mills in Manchester. Public interest was so roused that investigations on a larger scale ensued, which resulted in lighting Westminster Bridge with gas in 1813, and the town of Westminster the following year. In 1816 street lighting by gas was common in London. The lighting of houses by gas followed later, but very slowly.

It is a little difficult to see that there was much invention of an original or brilliant kind involved in the gradual development of the art of illuminating by gas; but it cannot reasonably be denied that a considerable amount of invention must have been done in the aggregate, for the reason that a wholly novel art was created. If it was not invented, how was it brought into being? The best answer probably is that the art was not the result of one brilliant invention followed by others that improved upon it, but was rather the aggregate work of a number of minor inventions, each one of which carried the art forward, but by only one short step.

Other minor inventions produced the locomotive and the railroad. The first steam engines were stationary; but portable engines, now called locomotives, gradually came into being. They were engines mounted on platforms resting on wheels that, in turn, rested on the ground; the revolutions of the engines turning the wheels, and causing the advancement of the whole. In 1807 a wagon-way was laid down on which cars were run to and from a colliery, and this wagon-way passed close in front of a house in which lived a poor family named Stephenson, a member of which was a boy whose Christian name was George. In the following year, the wooden parts were taken up and replaced by a single line of iron rails with sidings. In 1811 a portable engine was constructed for running on these rails, and this was followed by another in the following year. George Stephenson made a locomotive for running on rails in 1814, and followed it by another in 1816, both for hauling coal.

It was now so obvious that locomotives could haul other things than coal, that a railroad was laid down between Manchester and Liverpool, and a prize of £500 was offered for the best engine. On October 6, 1829, the competition was held, though only three engines appeared. The prize was won by Stephenson's locomotive, the *Rocket,* which attained a speed of 29 miles per hour.

With the locomotive, as with illuminating gas, it is impossible to see any one original or brilliant invention. We do see, however, the result of the superposition on one brilliant invention (that of Hero's steam engine) of a number of minor inventions, and much constructive ingenuity and initiative.

An invention of a higher order had signalized the latter part of the eighteenth century, in the form of a printing press in which the speed of printing was greatly increased by the use of revolving cylinders; one holding the type on its outer surface, and the other covered with leather, the paper passing between, and receiving the printed impression by the pressure exerted between the two cylinders. In order that the type should fit on the curved surface of the cylinder, they were made narrower toward the bottom. The machine was invented by an Englishman named Nicholson. It was never put into practical use; but a machine embodying the revolving cylinder for receiving the force of the impression communicated to the paper, was invented and put into successful use later by a German named König. The type, however, was not put on a cylinder in this machine, but on a flat plate that passed back and forth under the revolving impression cylinder. Two of König's presses were bought for the *London Times;* and on November 28, 1814, one made 1,100 impressions per hour, a marvelous advance over speeds previously attained. From the standpoint of pure invention, it was not so admirable as Nicholson's; but being a later product, and being based on Nicholson's principle, it was naturally an improvement in construction and mode of operation.

In 1814 Sir David Brewster, while experimenting on the polarization of light, made an invention of the most original and concrete type, which required a high grade of scientific knowledge for its conception and development, but which was not intended for any utilitarian purpose, and yet was of too serious a character to be called a scientific toy. This was his famous kaleidoscope; an instrument described accurately by its name, for it enabled one to see beautiful things. It was very simple in construction and principle, and seems to have fallen short of greatness in only one element, that of usefulness. By a careful adjustment of two prisms at a definite angle to each other, Sir David showed that geometrical images of the utmost beauty and variety could be made of objects placed between the mirrors, especially if those objects were small objects, and if they were of different colors, like bits of colored glass. Knowledge of this escaping, thousands of kaleidoscopes were soon put on the market, and sold in all the principal cities, before Sir David had had time to get a patent. Though the instruments were unscientifically made, they gave beautiful pictures nevertheless; but the result was that the kaleidoscope was not appreciated at its full value. The inventor improved the instrument greatly, and developed it into one of the most beauty-producing appliances known, and one of the most extraordinary and unique. The most remarkable fact connected with it is that no real usefulness for it has ever yet been found. The present author ventures to predict that a clear field of usefulness will some day be found by some fortunate inventor.

Meanwhile, the ill-clad captain of artillery who had invented the plan by which the British were pushed out of Toulon with so much neatness and despatch, had nearly turned the civilized world upside down. No man save Alexander ever accomplished so much of that kind of work in so short a time. His work consisted of a number of acts performed by him, each of which was like his act at Toulon, in that it began with the conception of a brilliant idea, proceeded with the embodiment of the idea in a concrete plan, and ended with the carrying into operation of that plan. Napoleon was great in each of these lines of work. He had a brilliant and yet correct imagination, that enabled him to conceive ideas of extraordinary brilliancy, and also to select from them the ideas that were the most susceptible of being made into concrete plans of the kind that could be carried out successfully. He possessed great constructiveness, that enabled him to construct mentally a plan in which all the means available for his use were seized upon and put to their special tasks. He possessed finally great ardor, industry and courage, that enabled him to start his plan to going very quickly, and keep it going very rapidly, until it had performed its task. It would be idle to discuss at which of these three stages of the work he was the greatest, or to try to decide which stage of the three was the most important; because the three were links in a continual chain, and the chain depended on each equally for its strength:—as any chain does on its links.

It may be interesting, however, to realize that mere imagination is possibly the most elementary activity of the mind; mere imagination is evidenced by savages, for instance, and by children, more than by highly educated men. Constructiveness, on the other hand, is little to be found in savages or children, and is a product of education, and a result of the training of the reasoning faculties. Courage and impulsive energy again are elemental faculties, and are observable more in savages than in the civilized. It seems to be the effect of civilization, therefore, to develop the reasoning faculties, at the expense of both imagination and courage. In fact, it is clearly the effect of civilization to develop a cold and calculating materialism. Men are rare therefore, and have been rare in every age, who combine the three qualities of imagination, constructiveness and courage. Napoleon combined all three in harmonious proportions; and he possessed each one in its most perfect form.

His performance at Toulon was so spectacular that it attracted attention at once, and caused his promotion to the command of the artillery in Italy. Here he was able to suggest projects that received approval and brought successes. One plan conceived and developed by him, however, was disapproved. It consisted essentially of dividing the Piedmontese and Austrians, crushing the Piedmontese, and then driving the Austrians out of Italy into Austria and following them thither. Later, this plan was approved, and he himself was put in command in Italy. It was this plan, executed by the Bonaparte of those days, that began the career of the Napoleon of history. So original and brilliant had been the conception, so mathematically correct and practically feasible had been the plan which Bonaparte developed from it, and so furiously energetic were his operations in carrying out the plan, that the sluggish Piedmontese were defeated before they quite realized that war had been begun. A like catastrophe happened to the equally mentally and physically sluggish Austrians; then another catastrophe, and then another, and then still others; and in such rapid and bewildering succession, that in a year and a month after his arrival in Italy he had driven the Austrians out completely, formed the Cisalpine and Ligurian republics in the north of Italy, and signed the armistice of Leoben with the Austrians, within fifty miles of Vienna.

Napoleon's next invention was a project for ruining England by attacking her East Indian possessions by a campaign beginning with an invasion of Egypt. Everything proceeded in substantial accordance with the plan developed, until August 1, 1798. In the evening of that day the whole project was destroyed by Horatio Nelson.

It was destroyed in a battle near the mouth of the river Nile, that was decided in fifteen minutes, though it was not wholly concluded until it had been raging for nearly four hours. In fifteen minutes, the French fleet on which depended Bonaparte's communications with Europe, had been so severely damaged that the failure of Bonaparte's project was decided.

Nelson was a man like Bonaparte in certain qualities; in the qualities that are essential to great leadership, imagination, constructiveness and executiveness. The first clear evidence of these qualities he had displayed startlingly at the battle of Cape St. Vincent on February 14, 1797;—when, swiftly realizing that two separated parts of the hostile Spanish fleet were about to join, he suddenly conceived the idea of preventing the junction by committing an act that — unless it brought success—would probably cost him his commission and perhaps his life. Now, the mere conception of an idea so revolting to professional ethics would not occur to an unimaginative man: and still less would it be retained. But it did occur to Nelson; and Nelson retained it and looked it squarely in the face. To embody his idea in a practicable plan was a simple matter to his active and trained intelligence, while to execute the plan was an act so natural as to be almost automatic. Much to the amazement of the Commander of the fleet and all the officers and men in both the fleets, the little division commanded by Commodore Nelson was seen actually to leave the line of battle! Nelson had taken his life, his fortune and his sacred honor in his hand, and staked all on an endeavor to get between the two separated parts of the Spanish fleet. The British Commander quickly realized what his daring subordinate had in mind, and speedily came to his relief. A brilliant, though not materially decisive, victory was won. The already distinguished Commander-in-Chief was then made Earl St. Vincent, and the hitherto obscure Horatio Nelson brought into the forefront of naval heroes, with the rank of rear-admiral, a gold medal and a knighthood.

Now, Nelson had not appeared at the mouth of the

Nile because of any accident, or any chain of fortuitous circumstances; he did not fight the epochal battle there because of any accidental occurrences or conditions, and he did not gain the victory because of any similar causes. Nelson appeared at the mouth of the Nile in accordance with a plan that he had conceived as soon as he heard of Bonaparte's departure from Toulon on a destination carefully kept secret, but which Nelson divined as Egypt. He so divined it, by imagining himself in Bonaparte's place, and imagining for what purpose he, Nelson, would have left Toulon under the conditions prevailing then in France. He engaged the French fleet when he did, and he fought the French fleet in the way he did, in accordance with a plan that he had conceived long before. No men were ever more cautious, more solicitous about the future, more painstaking, more prudent, more insistent against taking undue risks, than those reputedly reckless devil-may-cares, Napoleon Bonaparte and Horatio Nelson.

Napoleon realized at once that his brilliant scheme had been shattered; but he could not now even take his army home, because the British fleet was in the way. Finally, he succeeded in making the trip himself, with only a few of his staff. Events ran rapidly then; and on the sixth of May, 1800, we see Napoleon leaving Paris to undertake a campaign in northern Italy, in accordance with a plan embodied to carry out an idea conceived in his fertile mind, of taking his army through the great St. Bernard pass, dragging his cannon with him through the snow. This plan (like most of his plans) was so brilliantly conceived, so skillfully planned, and so energetically executed, that when Napoleon suddenly appeared with his army in the North of Italy, the Austrian general was bewildered with amazement. The natural result developed quickly, and the Austrians retired beyond the Mincio River.

By this time affairs in Europe were vastly complicated, because of the fact that the maritime enemies of France (which meant virtually all the other maritime countries of Europe) became exasperated at one of their number, Great Britain, in consequence of what they considered her unreasonable insistence on certain doctrines concerning maritime affairs. A League of Armed Neutrality against her was finally formed, that soon assumed menacing proportions. This league was completely broken by the same Horatio Nelson in a naval battle off Copenhagen on April 2, 1801. This battle was the direct result of a plan conceived by Nelson, that was so original and so daring that for a long time he could not secure the consent of his Commander-in-Chief to its execution. The battle resulted in a victory that was brilliant in the highest degree; but it was brilliant only because the original idea was brilliant, and because it was developed into a plan that was constructively correct and skillfully carried out.

Meanwhile, a brief campaign had been going on between the French and the Austrians in Austria. It was carried on with great brilliancy of conception and skill of execution by Moreau, and ended with the battle of Hohenlinden and the disastrous defeat of the Austrians. The treaty of Lunéville followed in February, 1801, and left Great Britain as France's only antagonist.

The victory of Copenhagen having broken the strength of the Confederacy of Neutrals, and Napoleon seeing the folly of attempting further to ruin British commerce then, the Treaty of Amiens between Great Britain and France followed in March, 1802.

As part of this treaty, Great Britain agreed to give up Malta. For various reasons that do not concern this discussion, Great Britain did not do so, and war followed in May, 1803.

Before that time, Napoleon had realized that his principal enemy was England. He now conceived the project of sending an invading army across the English Channel, knowing that if he could accomplish that, he could march to London, and dictate his own terms of peace. But how could he get across the channel, in the face of the British fleet? From the numberless pictures conjured up in his brilliant imagination, Napoleon selected the one which showed a French fleet threatening British possessions in the West Indies, a British fleet rushing to the West Indies to save them, the French fleet returning and joining with another French fleet waiting for it, then the combined fleets securing the mastery of the English Channel from the depleted British fleet remaining, then a French flotilla of transports with an invading army forthwith starting across the channel, then a landing against an opposition easily overcome, then a march to London, then a capture of London: and finally, he, Napoleon, riding in triumph through London streets and sleeping in the palace at London—as he had slept in other palaces on the Continent.

It was a beautiful vision;—a beautiful series of moving pictures presented to his imagination. To embody all these pictures in realities became the pre-occupation of his waking and his sleeping hours. By dint of herculean exertions, he finally collected near Boulogne about 200,000 troops and 1,500 transports. At the proper time, Villeneuve, with a powerful fleet, was sent to the West Indies to threaten the British possessions there.

But the same man who had spoiled his India project by the battle of the Nile, and who had spoiled his project of ruining British commerce by the battle of Copenhagen, spoiled his present project: the same man, Horatio Nelson. Nelson had some imagination himself; and he imagined (correctly as usual) that Villeneuve had sailed for the West Indies—and away he went in pursuit. Arriving there, and finding that Villeneuve had been in the West Indies but had left, Nelson left also. He imagined that Villeneuve had sailed for Europe; and so Nelson sailed for Europe also, sending a fast frigate to inform the Admiralty of all that he had learned, and of all that he inferred. The frigate made such speed, and the First Lord of the Admiralty, Admiral Lord Barham, acted with such sailor-like energy and skill, that a large British fleet intercepted Villeneuve on his return, brought him to action near the coast of Spain, and handled him so roughly that he went for repairs to Cadiz. He arrived there on August 20.

The news of this, reaching Napoleon, wiped all the beautiful pictures out of his mind. But he had other pictures in the background. These he put promptly into the foreground, and started off with incredible swiftness toward Austria. On October 19, he brought the Austrians to battle near Ulm, and achieved one of the most decisive victories of his career. The victory was mainly due to the clearness and correctness of Napoleon's conceived idea, and the amazing speed and certainty of his movements in carrying it into execution. The Austrian General Mack was so wholly taken by surprise that he found his army was completely surrounded before he had had time to take any preventive measures.

Napoleon had correctly judged the import of Villeneuve's interception by the British fleet, and realized that it would be mere folly afterward to attempt to cross the channel then. Still, the situation was not wholly bad for him, and the victory at Ulm made it beautiful. For, though England was still greater on the sea than France, France was also great, and was still a powerful weapon which he could wield against England, with all the power of genius. But, two days after the victory of Ulm, came the disaster near Cape Trafalgar, when Nelson defeated the combined French and Spanish fleets, and thereby secured for England a superiority at sea, vastly more pronounced than it had been before. This victory, by making Napoleon helpless at sea against Great Britain, ruined all Napoleon's chances of dominion, except upon the Continent.

Napoleon made two brilliant campaigns after this, that brought him to the summit of his career. Had he been content to stop there, had he not tried to climb still higher, his descendants might now sit on the throne of France. But the intoxicating fumes of success seem to have clouded that brilliant mind, and to have prevented those clear and correct pictures from forming there that had formed before. The result was that he embarked on a new project for ruining England that began with an invasion of Portugal and Spain, which brought on a war with Austria. It is true that, by a brilliant campaign, Napoleon worsted Austria and made an advantageous treaty with her, and then married the daughter of the emperor: but the continuance of the policy that underlay the war with Austria, brought on later a war with Russia that sent Napoleon to Elba, an exile.

We see the key to Napoleon's successes in the quality of his mind at the time of those successes, and we see the key to his failures in a lowering of the quality of that mind. Military writers tell us that his mind was not of the same quality when he planned his Russian campaign as it had been when he planned his early campaigns. Now the reasoning faculties do not grow dull when one approaches middle age; but the imaginative faculties do—(in most people). It is an old saying that "one cannot teach an old dog new tricks." Clearly, this cannot be because of any failing of memory, though memory fails with age; because the memory is not involved, save slightly. It must be therefore because of failing impressionability and receptivity. We all speak of the "receptive years," meaning the years of childhood and then of youth; and it is a common saying that young people are more receptive than old people. Of what are they receptive? Clearly, of mental impressions. Parents and teachers are warned not to forget that the minds of young people are very impressionable, and to be careful that their minds receive good impressions only, so far as they can compass it. Napoleon, when he made his Russian campaign, was only 43 years old in years; but he had lived a life that was far from normal or hygienic physically, and extremely abnormal and unhygienic mentally.

The intention of the last sentence is to point out that mental health cannot be long preserved amid surroundings mentally unhealthful, any more than physical health can be long preserved amid surroundings physically unhealthful; and that the highest qualities of our nature are the most difficult to maintain and therefore are the first to fail, under unhealthful surroundings. The spiritual faculties fail first, then the moral, then the mental and lastly the physical. Now the imagination, while a mental quality, rather than a moral one, partakes in a measure of the spiritual, and is one of the highest of the mental attributes. For this reason imagination is one of the first to be impaired.

The especial picture of the imagination that becomes faulty under certain conditions, is the picture of one's self. Under conditions such as Napoleon had lived under for several years, the picture of himself in his mind had become unduly magnified in relation to the pictures of other men. Now is there any one thing more dangerous to a man than to carry in his mind an incorrect picture of himself?

In Napoleon's case, it led him to the unforgivable military crime; that of underestimating the enemy. His imagination, by presenting a magnified image of himself, presented relatively dwarfed images of his antagonists. The very faculty (imagination) which started Napoleon on his great successes, started him now on his great reverses. The actual beginning of these was in his carelessly planned campaign in Russia. His invention seems to have failed him both in planning the campaign and in meeting situations afterwards; because his imagination failed to picture each situation to him exactly as it was.

But the Russian campaign did not wholly ruin him. Even after that, even after Elba, situations were sometimes presented to him, such that (although Trafalgar had prevented him from achieving European domination), yet, if he had been able to see them as clearly as he had seen situations in his unspoiled days, he might at least have saved himself from ruin. But his imagination had become impaired and therefore his powers of invention also.

Napoleon as general, and Nelson as admiral were what we may term "opportunistic inventors," who made inventions for meeting transient situations with success, as distinguished from inventors like Newton and Watt, who made permanent contributions to the welfare of mankind. Napoleon as statesman, however, made contributions of a permanent character.

A supremely valuable contribution of this kind was the stethoscope, which was invented about 1819 by Dr. Laennec in Paris, and by means of which the science and art of diagnosis were given an amazing impetus almost instantly. Possibly one cannot find in the whole history of modern invention any instrument so small and so inexpensive that has been so widely and definitely useful. A painful interest hangs to it in the fact that by means of his own invention, Laennec discovered that he himself was dying of tuberculosis of the lungs.

In July, 1820, a discovery of a vastly different character was made by Oersted in Copenhagen; the discovery that if a current of electricity be passed over or under a magnetic needle, the needle will be deflected in a direction and to a degree depending on the strength and direction of the current and the position of the conducting wire relatively to the needle. Now Laennec invented a simple and little instrument that began virtually perfect, and that exists today substantially as it started. Oersted did something equally important, that ultimately initiated intricate inventions of many kinds, and yet he did not really invent anything whatever. The importance of his discovery was recognized at once; so quickly, in fact, and by so many experimenters and inventors, that Oersted soon found himself in the extraordinary position of being left behind, in an art to which himself had almost unknowingly given birth! That some relation existed between magnetism and electricity had long been evident to physicists; but what that relation was they did not know until Oersted told them. They seized on his information with avidity, with results that the whole world knows now.

The first man heard from was Ampère, who communicated the results of his experiments in the new art to the Institute of France as early as September 18th. Almost immediately afterward, Arago discovered that, if a conducting wire were wrapped around iron wires, those iron wires became magnets and remained magnets as long as the electric current continued to pass. Thereupon, Arago made and announced his epoch-making invention, the electro-magnet. The influence of this invention on the subsequent history of the machine of civilization, it is hardly needful to point out.

The experiments of Oersted gave rise at once to much speculation as to the nature of the action between electric currents and magnets, and also to considerable experimental and mathematical research. As had been the case for many thousand years in other endeavors, speculation accomplished little, but experimental research accomplished much. By this time mathematics had been highly developed, not only as an abstract science but also as an aid to physical and chemical research. The man who attacked the problem in the most scientific manner was Ampère, who in consequence solved it in the following year, after a series of mathematically conducted experiments of the utmost originality and inductiveness. As a result in 1820, he showed that all the actions and reactions of magnets could be performed by coils of wire through which electric currents were passing, even if there was no iron within the coils: — but that they were more powerful, if iron were within. From this and kindred facts, which he developed by experiment — (especially the fact that electric currents act and react on each other as magnets do), he established a new science to which he gave the name electro-dynamics. In recognition of his contributions to electricity, the name given many years later to the unit of electric current was ampère.

In the following years, while pursuing a series of investigations into the new science, Faraday invented the first electro-magnetic machines. In the first machine, a magnet floating in mercury was made to revolve continuously around a central conducting wire through which an electric current was passing; in the second a conductor was made to revolve continuously around a fixed magnet; in a third machine, a magnet so mounted on a longitudinal axis that an electric current could be made to pass from one pole half way to the other pole, and then out, would revolve continuously as long as the electric current was made to pass. Faraday invented the first machines that converted the energy of the electric current into mechanical motion; though Oersted was the first who merely effected the conversion. It can hardly be said that Oersted invented a machine; but Faraday certainly did.

The first utilization of Oersted's discovery in a concrete and practically usable device was the galavanometer, invented by Schweigger in 1820. It was a brilliant invention, and solved perfectly the important problem of measuring accurately the strength of an electric current. The apparatus consisted merely of a means of multiplying the effect of the deflecting current by winding the conductor into a coil, the magnetic needle being within the coil. The galvanometer (named after Galvani) was an invention of the utmost value, and it is in use to this day, though in many modified forms. When one realizes how obvious a utilization of Oersted's discovery the galvanometer was, and that Schweigger did not invent it until two years later, he wonders why Oersted himself did not invent it. But the history of invention is full of such cases and of cases still more amazing. Why did the world wait several thousand years before Wise invented the metal pen? Why are we not now inventing a great many more things than we are? Nature is holding out suggestions for inventions to us by the million, but we do not see them.

In the year before Schweigger's invention, in 1821, the important discovery had been made by Seebeck in Berlin, that if two different metals are joined at their ends, and one junction be raised to a higher temperature than the other, a current of electricity will be generated, the strength of which will vary with the metals employed and the difference in temperature of the junctions. The discovery was soon utilized in

Nobili's invention of the thermopile in which the current was increased by employing several layers of dissimilar metals (say antimony and bismuth) in series with each other. The main use of the thermopile has been in scientific investigations, especially in the science of heat.

One of the results of the increased use of mathematics, especially arithmetic, was the invention of Babbage's calculating machine in 1822. The usefulness of this invention was so apparent that it was not long in coming into use, or long in causing the invention of improvements on it of many kinds. The calculating machine was a distinct contribution to civilization.

Another contribution, but of quite a different kind, was made by Faraday in the following year (1823) when, after a series of experiments, he announced that he had succeeded in liquefying many of the gases then known by the combined action of cold and pressure. The possibility of doing this had long been suspected by physicists reasoning from known phenomena; but the actual accomplishment of the liquefaction of gas was none the less a feat of a high order of brilliancy and usefulness. In experiments subsequently made, Dewar received the gases in a vessel of his invention which had double walls, the space between which he had exhausted of air, and thus made a vacuum—which is a non-conductor of heat. The "thermos bottle" of today was invented by the great chemist Dewar, and is not therefore a new invention.

Meanwhile, the steam engine had been undergoing rapid development, though the use of locomotives for drawing passenger trains does not seem to have come into regular use until the Liverpool and Manchester Railroad was opened in 1830. In 1828, the Delaware and Hudson Canal Company constructed a short railroad, and sent an agent to England to buy the necessary locomotives and rails. In the four years following twelve railroad companies were incorporated. The Baltimore and Susquehanna began actual operations in 1831.

The inventions of Hero, Branca, Worcester, Savery, Papin and Leupold, brought to practicality by Watt, had now come to full fruition, and entered upon that career of world-wide usefulness that has advanced civilization so tremendously and still continues to advance it.

But the most decisive triumph of the steam engine had come more than a decade before, when in 1819 the American steamship *Savannah* crossed the Atlantic ocean in 26 days, going from the United States to Liverpool.

CHAPTER IX

INVENTIONS IN STEAM, ELECTRICITY AND CHEMISTRY CREATE A NEW ERA

WHEN the nineteenth century opened, George III was King of England, Napoleon was First Consul of France, Francis II was Emperor of Germany, Frederick William III was King of Prussia, Alexander was Czar of Russia (beginning 1801), and John Adams was President of the United States.

By this time the influence of the inventions of the few centuries immediately preceding, especially the invention of the gun and that of printing, was clearly in evidence. The Feudal System had entirely vanished, the sway of great and powerful sovereigns had taken the place in Europe of the arbitrary rule of petty dukes and barons, the value of the natural sciences was appreciated, and a fine literature had developed in all the countries.

A terrible war was raging, however, that was not to end for fifteen years and that involved, directly or indirectly, nearly every European nation. The war had started in France, where the tremendous intellectual movement had aroused the excitable people of that land to a realization of the oppression of the nobility and a determination to make it cease.

The wars that ensued were not so different from the wars of the Egyptians and other ancient nations as one might carelessly suppose, because the weapons were not very different. The only weapon that was very novel was the gun; and the gun of the year 1800 was a contrivance so vastly inferior to the gun that exists today as not to be immeasurably superior to the bow and arrow. It had to be loaded slowly at the muzzle; and the powder was so non-uniform and in other ways inferior, that the gun's range was short and its accuracy slight. Even the artillery that Bonaparte used so skillfully was crude and ineffective, according to the standards of today. The cavalry was not very different from the cavalry of the Assyrians, and the military engineers performed few feats greater than that of Cæsar's, in building the bridge across the Rhine. There were no railroads, no steamships, no telegraphs, no telephones. There was less difference between the armies of 1800 A. D. and those of 1800 B. C., than between the armies of 1800 A. D. and those of 1900 A. D.

The same remark applies to virtually all the material conditions of living. There was less difference, for instance, between the fine buildings of 1800 B. C. and 1800 A. D. than between the fine buildings of 1800 and 1900 A. D. The influence of the new inventions on the material conditions of living was only beginning to be felt; for the twin agencies of steam and electricity, that were later to make the difference, had not yet got to work. It was the power of steam that was to transport men and materials across vast oceans and across great continents at high speed, and place in the hands of every people the natural fruits and the foods and the raw materials and the manufactured appliances of other lands; it was the subtle influence of electricity that was to give every people instant communication with every other. It was the co-working of steam and electricity that was to make possible the British navy and the British merchant marine, and the relatively smaller merchant marines and navies of other countries, and to bring all the world under the dominance of Great Britain and of the other countries that were civilized.

The opening of the nineteenth century, therefore, marks the opening of a new era. In 1800 the steam engine was already an effective appliance, but it was not yet in general use. Electricity was a little behind steam; and though Franklin and the others had proved that it possessed vast possibilities of many kinds, and also that it could be harnessed and put to work by man for the benefit of man, electricity had as yet accomplished little of real value.

Under the stimulating influence of the quick communication given by the art of printing, literature had blossomed especially in Great Britain, France, Germany and Italy; but in 1800 one has to notice the same fact as in previous years—literature had not improved. The literature of 1800 A. D. was no better than the literature of Greece or Elizabethan England—to state the truth politely; and no such poet lived as Homer, Shakespeare or John Milton. It seems to be a characteristic of literature, and of all the fine arts as well, that each great product is solely a product of one human mind, and not the product of the combined work of many minds. To the invention of Watt's steam engine, numberless obscure investigators and inventors had contributed, besides those whose great names everybody knows: but how can two men write a poem or any work of fiction, or paint a picture or carve a statue? It is true that each of these feats has been performed; but rarely and not with great success.

For this reason, it is not clear that mere literature as literature, or that any of the fine arts as such can exert much influence on history, and it is not clear that any of them have done so. That they have had great influence in conducing to the pleasure of individuals there can be no question; but the influence seems to have been transient. History is a record of such of the doings of men as have had influence at the time, or in the future. Of these doings, the agency that has had the most obvious influence is war, and next to war is invention. War, next after disease, has caused the most suffering the world knows of; but out of the suffering have emerged the great nations without which modern civilization could not exist. The influence of invention is not so obvious, but it is perhaps as great, or nearly so; the main reason being that invention has been the agency which has enabled those nations to emerge that have emerged. Without the appliances that invention has supplied, the civilized man could not have triumphed over the savage.

Now literature and painting and sculpture and music, while they have made life easier and pleasanter, have contributed little to this work, and in many ways have rather prevented it from going further by softening people, physically and mentally. This statement must not be accepted without reservations of course; for the reason that some poems, some works of fiction, and some paintings and (especially) some musical compositions have tended to strengthen character, and even to stimulate the martial spirit. But a careful inspection of most works of pure literature and fine art must lead a candid person to admit that the major part of their effect has been to please,—to gratify the appetite of the mind rather than to inspire it to action.

The author here requests any possible reader of these pages, not to infer that he has any objection to being pleased himself, or to having others pleased; or that he regards the influence of literature and the fine arts as being detrimental to the race. On the contrary, he regards them as being valuable in the highest degree. He is merely trying to point out the difference between the influence of inventions in the useful arts and those in the fine arts.

A like remark may be made concerning inventors and other men; the word inventors being here supposed to mean the men who make inventions of all kinds. These men seem to have been those who have brought into existence those machines and books and projects of all kinds that have determined the kind of machine of civilization that has now been produced. These men are very few, compared with the great bulk of humanity; but it seems to be they who have given direction to the line along which the machine has been developed.

This does not mean, of course, that these men have been more estimable themselves than the men who kept the machine in smooth and regular motion, and made the repairs, and supplied the oil and fuel; but it does mean that they had more influence in making its improvements. Naturally, their work in making improvements would have been of no avail, if other men had not exerted industry and carefulness and intelligence and courage, in the countless tasks entailed in maintaining the machine in good repair, in keeping it running smoothly, and in receiving with open minds and helping hands each new improvement as it came along. And it was not only in welcoming real improvements, but in keeping out novelties which seemed to be improvements but were not improvements that the work of what may be called the operators, as distinguished from the inventors, was beneficent. Nothing could be more injurious to the machine than to permit the incorporation in it of parts that would not improve it. There has been little danger to fear from this source, however; for the inertia of men is such that it is only rarely that one sees any new device accepted, until it has proved its value definitely and unmistakably in practical work.

Possibly the greatest single impetus given to progress about the year 1800 was that given by Lavoisier shortly before, which started the science of chemistry on the glorious career it has since pursued. As a separate branch of science, chemistry then began, though it had been the subject of investigation for many centuries, beginning in Egypt and the other ancient countries of the East. In the Middle Ages, it was known in Europe by the name Alchemy. Originally, and in all the long ages of its infancy, the investigations of the experimenters were carried on mainly to discover new remedies in medicine, or to learn methods to transmute base metals into precious metals; though there was a considerable degree also of pursuit of knowledge for its own sake. As a result of the investigations, many startling facts were developed, and many discoveries were made; but, for the reason that the investigations were not conducted on the mathematical or quantitative lines that had led to so much success in developing physics, alchemy or chemistry did not rest on any sure basis, and therefore had no fixed place to start from. It was in the same vague status that some subjects of thoughtful speculation are in today, such as telepathy, which may (or may not) be put on a basis of fact some day, and started forward thence, as chemistry was started.

What gave chemistry its basis was the methods introduced by Lavoisier who was a practiced physicist. He introduced the balance into the study of chemistry, and raised it instantly from a collection of speculations to an exact science, capable of progressing confidently and assuredly thereafter, instead of wandering in a maze. Lavoisier gave chemistry a mathematical basis to start from, and sure beacon lights to guide it; and though many changes in its theory have been made from time to time, they have been due only to increase of knowledge and not to departure from fundamental principles. Finding that a substance was not an element, but was a compound of two elements, or more than two, did not require any rejection of accepted principles, but merely a readjustment.

We now see that it was impossible because of the exact nature of the way in which the various elements combine, that chemistry could have become a science until the balance had been used to weigh the substances investigated; and we also see that it was impossible that the balance could have been so used until physics had been developed to the point permitting it, and men skilled in exact measurements had been brought up by practice in physical researches. Lavoisier himself had served a long apprenticeship, and his earliest claim to fame was his mathematical researches on heat, embodied in an essay, written in connection with Laplace, and published in 1784. Even after an enormous mass of facts had been collected and announced, chemistry could not take her place by the side of physics, and Bacon's teachings could not be followed, until those facts had been mathematically investigated, and their mathematical relations to each other had been established. This Lavoisier and his followers did.

No better illustration of the influence of invention on history can be found than the fact that chemistry hovered in the dim twilight of speculation, guess-work and even superstition, until Lavoisier brought to bear the various inventions made in physics. Then, presto, the science of chemistry was born.

We must not let the fact escape us, however, that Lavoisier would have left mankind none the wiser, if he had merely brought mathematical research to bear and discovered what he did, and then stopped. If he had stopped then, his knowledge would have remained locked inside of his own mind, useless. The good work that Lavoisier actually did was in actually producing an invention; in conceiving a certain definite method of chemical research, then embodying it in such a concrete form that "persons skilled in the art could make and use it," and then giving it to the world.

The first important effect of Lavoisier's work was the announcement by Dalton about 1808 of his Atomic Theory, which has been the basis of most of the work of chemistry ever since. Dalton's earlier work had been in physics, and its principal result had been "Dalton's Laws" in regard to the evaporation and expansion of gases, announced by him about 1801. These investigations led his mind to the consideration of the various speculations that had been entertained concerning the nature of matter itself, as distinguished from the actions and reactions between material objects that physics studies; and they brought him to the conclusion that there are certain substances or elements which combine together to form compounds that are wholly different from each of the elements (oxygen and hydrogen, for instance, combining to form water); and that those elements are made up of units absolutely indivisible, which combine with each other in absolutely exact proportions. The units he called atoms. He built up a theory wonderfully convincing and coherent, that explained virtually all the chemical phenomena then known, and supplied a stepping-stone following Lavoisier's, from which chemists could advance still further. Dalton classified certain substances as elements which we now know are not elements, because they have been found since to be compounds of two or more elements; but this in itself does not disprove his theory, because he himself pointed out that means might be found later to decompose certain materials that seemed then to be elements, because no means had then been found to decompose them.

It may be instructive to note here that Dalton was not the first to imagine that certain forms of matter were elemental, or that matter was indivisible beyond a certain point, or that substances entered into combination with each other in definite proportions. Speculation on all these points had been rife for many years, but it had not produced the invention of any workable law or even theory. Similarly, many men later speculated on the possibility of devising an electrical instrument that would transform the mechanical energy of sound waves into electrical energy, transfer the electrical energy over a wire, and re-convert it into sound; but no one succeeded in producing such an instrument, until Bell invented the telephone in 1876.

History is a record of acts, and not of dreams. And yet the greatest acts were dreamed of before they were performed. Every process, no matter how small or how great, seems to proceed by three stages—conception, development and production. Most of our acts are almost automatic, and the three stages succeed each other so quickly that only the final stage itself is noted. But the greatest acts, from which great results have followed, have begun with the conception of a picture not of an ordinary kind, such as a great campaign, a new machine, a novel theory, a book, painting, statue or edifice: — then a long process of development, during which the conception is gradually embodied in some concrete form, as, for instance, a statue, a painting or an instrument;—and then production. *Finis opus coronat, the end crowns the work;* but the work is not crowned until it is finished, and a concrete entity has been brought forth.

Lavoisier finished his work. Not only did he dream a dream, but he embodied his dream in a definite form, and gave it to mankind to use. Dalton did similarly. This does not mean that their work was not improved upon thereafter, or that they invented the chemistry of today. They merely laid the foundation of chemistry, and placed the first two stones.

A remarkable exemplar of the meaning of this declaration was Benjamin Thomson, who was an American by birth, but who entered the Austrian Army after the War of the Revolution, and made an unprecedented record in the application of physical and chemical science to the relief of the distressed and ignorant and poor, especially the mendicant classes. For his services he was made Count Rumford. His researches were mostly in the line of saving heat and light, and therefore saving food and fuel. He ascertained by experiments of the utmost ingenuity and thoroughness that the warmth of clothing was because of the air entangled in its fibers; he investigated the radiation, conduction and convection of heat, analyzed the ways in which heat could be economized, and invented a calorimeter for testing the heat-giving value of different fuels. In 1798 he had noted the fact that heat was developed when cannon were being bored. He immediately conceived the idea that the heat developed was related to the amount of work expended driving the boring tool, and invented a means of measuring it. This consisted simply of a blunt boring tool that pressed into a socket in a metal block that was immersed in water, of which the temperature could be taken. To get a basis for his investigations into the problem of lighting economically the dwellings of the poor, Rumford invented a photometer for measuring illumination. No man in history shows more clearly the co-working of a high order of imagination, and a careful and accurate constructiveness; and no man ever secured more intensely practical and beneficent results. In the hospital at Verona he reduced the consumption of fuel to one-eighth.

In 1827 a valuable improvement was made to the machine of civilization by Ohm, who announced the now famous Ohm's Law, that the strength of an electric current in any circuit is equal to the difference in potential of the ends of the circuit, divided by its resistance. This is usually expressed by writing $C = \frac{E}{R}$.

Can anything be less inspiring than $C = \frac{E}{R}$? Yes: —few things have been more inspiring. Few things have inspired more zeal for work than that simple formula. That simple formula evolved order out of chaos in the little but super-important world, in which physicists and chemists were trying to solve the riddles that the utilization of electric currents presented. It gave them a basis from which to start, and a definite rule to work by. No oration of Demosthenes, Cicero or Webster has imparted more inspiration, or supplied a greater stimulus to high effort, or done more for human kind than $C = \frac{E}{R}$

In 1827 Walker in the United States invented friction matches. It seems strange that someone had not invented matches before. The usual way of getting light was with the flint and steel and tinder-box,—a most inconvenient contrivance. It was quite well known that certain substances would ignite when rubbed, and yet men waited until 1827 to utilize the fact in matches!

In the following year Wöhler succeeded in reducing aluminum, thus contributing a valuable new factor to human knowledge and a valuable new metal to human needs. In the same year Neilson took out a patent in England for "an improved application of air to produce heat in fires, forges and furnaces," in which he proposed to pass a current of heated air through the burning fuel. His invention met with opposition of all kinds, but eventually proved its usefulness. Another invention produced in the same year was Woodworth's machine for planing wood. Still another, was the tubular boiler for locomotives.

In 1829 the first steam locomotive was put into use in the United States. No especial invention seems to have been expended on this device; but there was considerable invention of the kind that I have ventured to call "opportunistic" involved in conceiving the idea of getting the locomotive, and then in actually getting it, and then putting it to work. In the following year Braithwaite and Ericsson in London brought out the first portable fire-engine. There was a great deal of invention of the practical kind involved in the design, construction, production and successful employment of this novel device; and an important step was taken in the means of protecting life and the material products of civilization from destruction by fire.

In 1831 Faraday in London made one of the most important discoveries in physical science ever made, the discovery that if a current of electricity is changed in strength, or if a conductor carrying a current be moved, an instantaneous magnetic effect is felt in the vicinity; and that this magnetic effect will cause an instantaneous current in any closed conducting circuit that may be near. Faraday also discovered that a similar instantaneous current will be set up in a closed circuit if a magnet be moved in its vicinity. This discovery is usually spoken of as the discovery of electro-magnetic induction; and the instantaneous currents are said to be "induced."

About the same time Professor Henry in Princeton discovered that an electric circuit will act not only on other circuits in its vicinity, but on itself; that the fact of being increased or decreased will set up instantaneous currents that tend to oppose the increase or decrease. Thus, while Faraday is credited with the discovery of electro-magnetic induction, Henry is credited with the discovery of self-induction. It has been claimed by some that Henry discovered electro-magnetic induction before Faraday did. This question is of great interest but it is outside the scope of this modest volume.

While both discoveries were of prime importance, and were also analogous, that of electro-magnetic induction has played the more conspicuous part. With it began the endeavor to develop electric currents by the relative motion of coils of wire and magnets, that resulted in the invention of the dynamo, and the later invention of electric lights and motors.

In the same year the discovery (or was it the invention?) of chloroform was made by Guthrie in America, Soubeiran in France and Liebig in Germany. A curious fact connected with the early history of chloroform is that, although its anæsthetic properties were known in general, and although the idea of using gases and vapors and medicines to deaden pain was many centuries old yet nevertheless, chloroform was not put to practical use until about 1846 when Dr. Morton, a dentist, of Boston, adopted it as an anæsthetic. Of all the single inventions ever made, chloroform has unquestionably done more than any other, invented till that time, to give relief from agony.

In 1832 the electric telegraph was invented by Morse, though he did not patent it until 1837. The influence of the electric telegraph on subsequent history has been so great that the influence of no contemporary invention can reasonably be declared to be greater. As with many other inventions, one is tempted to wonder why it had not been invented before; for the fact that electricity could be sent along a conductor and made to cause motion at the other end had been known since Guericke had demonstrated the fact in the closing years of the seventeenth century. The original invention of the electric telegraph is claimed by some for Henry, who had a wire run between his house and his laboratory at Princeton, over which he sent messages, by opening and closing the circuit and thereby actuating an electro-magnet at the receiving end.

The first machine to put Faraday's discovery of magneto-electric induction to practical use was invented by Pixii in France in 1832, and exhibited before the Academy of Sciences. It consisted of a powerful magnet that was made to revolve with great rapidity before a bar of soft iron that had wrapped around it a coil of insulated wire about 3,000 feet long. The north and south poles taking position in succession in front of the coil, currents were induced that alternated in direction, twice in each revolution. If a man grasped two wires in the circuit he received a series of sharp electric shocks; but such effects as decomposing water that were produced by the continuous currents of Voltaic batteries could not be produced by these alternating currents. To secure such effects, Siemens and others made machines in which the magnet in the form of a U was stationary, two coils of wire revolved in front of the poles, and a two-part "commutator" was used. When this was placed on the axle, and the axle was revolved, the change in direction of the current was obviated, though a smooth and uniform current was not produced. The reason was that the current fell to zero twice in each revolution.

The magneto-electric machine, as it was called, remained virtually in this form for many years. It was not sufficiently effective or efficient to be of much practical usefulness in any art, and was considered more of a scientific toy than a machine of serious importance.

Still, the probability was realized by many investigators that a new discovery or invention might be made at any moment, that would put it in the forefront of the useful inventions of the age. (The invention was not made till 1862; it was made by Pacinnotti in Italy and will be mentioned later.)

The influence of the magneto-electric machine, therefore was not direct, but indirect. It was a basic invention; and like many basic inventions, it formed the hidden foundation on which a conspicuous superstructure was later to be reared. One of the lessons of history is that it is the men and the methods and the other things which are in evidence when some important occurrence happens, that are identified with it in the minds of people not only at the time, but afterward. An invention that may have cost its creator the toil and struggle of a lifetime may not gain success simply because of some existing unfavorable conditions of some kind. Suddenly the conditions become favorable. John Doe takes advantage of all the work that other men have done, adds some slight improvement, achieves "success" and dons the laurel wreath.

We see at this time (1832) very clear signs of an increasing number of inventions per year, an increasing speed of invention. We see an acceleration in invention which we cannot help associating in our minds with the acceleration which any material object gets, when continuously subjected to a uniform force, like that of gravity. One almost feels that there must be a continuous force impelling men to invent; so clear is the increase of the speed of inventing.

Following the magneto-machine in 1832 came the invention of a rotary electric motor by Sturgeon, the discovery of chloral-hydrate by Liebig, the production of the first large American locomotive by Baldwin and the invention of link motion by Sir Henry James. The last was an exceedingly important and ingenious contribution to the steam engine, especially in locomotives and ships; for it gave a very quick and sure means of reversing its direction of motion, and of regulating the travel of the valve and the degree of expansion of the steam. In the following year came Stephenson's steam whistle; and in the year following (1834) came the McCormick reaper. Few inventions have had a greater or a more immediate effect on the trend of modern progress, which is to influence men to live in large communities. For the McCormick reaper could do so much more work, and so much better work, than men could do without it, that the cultivation of extensive areas of land could be undertaken with the assurance that large crops of grain could be secured. This not only secured more grain for the country, but liberated many men from toil on farms, and permitted them to migrate to the cities.

The author does not wish to be understood as meaning that migration to cities is wholly desirable; for he is familiar with its disadvantages and dangers. But whether it be desirable or not is beyond the scope of this book. This book is merely a modest attempt to point out the influence of invention in making the world what it is today. Perhaps it would have been better if men had had no invention and had remained in a state of savagery. Some men say so sometimes; but even those men (or most of them) like to sit by a warm fire in a cozy room when it is cold outdoors. The consensus of opinion seems to be that civilization in the main has been a blessing to men, though not an unmixed blessing, and though men must keep on their guard against certain manifest dangers which civilization entails.

In the same year, 1834, Jacobi invented an electric motor and Runge made the important discovery of carbolic acid. In 1835 Burden invented a horse-shoe machine. In 1836 four important inventions added four important parts to our rapidly growing Machine.

The first was the "constant battery" invented by Daniell. Before this time a Voltaic cell, or battery, soon lost its strength, because of various chemical actions inside the cell which need not be detailed here. Daniell overcame this difficulty almost wholly by inventing a battery, in which there were two liquids instead of one, and the two liquids were in two separate compartments but separated only by porous material. This invention was successful from the start, and immediately increased the usefulness of Voltaic batteries and the means of utilizing electric currents.

The second great invention in 1836 was that of acetylene gas made by Edmund Davy. It is still the most brilliant illuminating gas we have, and is rivaled by the electric arc-light only. The third invention was that of the revolver, made by Samuel Colt.

It may be objected by some that the revolver did not contribute anything valuable to the Machine of Civilization because it was merely an improvement on the pistol, and enabled one to kill more men in a given time than he could before. Such an objection would have much to justify it; but it may be pointed out that the Machine must be made self-protective as far as possible; and that anything which increases the power of civilized man as against the savage, or barbarous, or semi-barbarous increases its power of self-protection. It is true that a savage can use a revolver, if he be instructed; but the more complicated a weapon is the more difficult it is for a savage, as compared with a civilized man, to use it effectively. This is not an argument in favor of complication for its own sake; but it is an argument in favor of accepting complication in a weapon, if the complication renders greater effectiveness possible.

The last invention was the most important of the four, the application of the screw propeller to navigation made by John Ericsson. The author is aware of the fact that this invention was claimed by others, and is claimed for others now. The weight of testimony, however seems to be on the side of Ericsson; and as has been pointed out before, the question of the identity of the inventor is not important to our discussion. The first ocean steamship to be propelled by a screw was the *Stockton*, which was built in England under Ericsson and fitted with his screw. The first war-ship to be fitted with a screw was the U. S. S. *Princeton* in 1841. Its screw was designed by Ericsson.

In 1837 Crawford invented a process for "galvanizing" iron; for electro-plating it with a non-oxidizable metal. The value of this invention in preserving iron wire and iron articles in general needs not to be pointed out; it was a contribution to the permanency of the Machine. In the same year, Cooke and Wheatstone in England invented their famous "Needle Telegraph," in which a magnetic needle was made to deflect quickly to the right or left when one of two keys was pressed by an operator and letters thereby signaled. This invention was a valuable contribution; but it was eventually superseded by Morse's telegraph, after that system had established itself in the United States and on the Continent.

In 1839 Babbitt invented his celebrated Babbitt metal, which has been successfully used ever since in the bearings of engines and in moving machinery generally, for reducing friction; and in the same year Goodyear made an invention even more important, the art of hardening, or "vulcanizing," rubber by means of sulphur. This invention was a great boon to mankind, but not to Goodyear; for the jackals who lie in wait for great inventions eager to wrest unearned profit for themselves from the men who have truly earned it, made Goodyear's life miserable for many years. Before he died, however, his wrongs were righted at least in part. In the same year Jacobi, in Germany, propelled a boat by electricity using an electric motor of his own invention.

But the great contributions made in 1839 were to the art of what we now call photography. About 1834 Talbot had succeeded in taking pictures in a camera by the agency of light on paper washed with nitrate of silver and also in fixing them. Later, he was able to obtain many copies, or "proofs," from one picture or negative. It seems that he did not publicly announce his invention till 1839. To it was given the name "calotype." In May of that year Mr. Mungo Ponton announced that he had been able to copy pictures of engravings and of dried plants on paper that he had soaked in bichromate of potash. A number of other investigators forthwith announced similar feats, using various chemical solutions.

In 1840 Draper published the result of certain important experiments made by him in photographing celestial bodies. In 1841 pneumatic caissons were invented by Triger in France. In 1842 Long discovered the usefulness of ether as an anæsthetic, and Seytre invented the automatically played piano. In the same year, Selligne discovered a method of utilizing water-gas, made by decomposing water and producing a new illuminating agent that could be used by itself or in combination with coal gas. In the same year James Nasmyth in Scotland invented the steam hammer—a simple appliance by means of which steam was able to make a hammer give blows much heavier than the human arm could give. This invention belongs to the class in which the human muscles are assisted in doing work which the brain directs them to do, but which they are not strong enough to do effectively.

The self-playing piano belongs in a class closely allied, in which the machine invented merely assists the muscles: the assistance in this class being not in supplying power in order to do more work, however, but in supplying what may be called auxiliary physical agencies. In the player piano, the fingers are replaced by little mechanical hammers; in the steam hammer the arm is replaced by a piston actuated by steam. One secures quickness, the other secures force.

But the self-playing piano and the steam hammer are in very different classes, when viewed from the standpoint of their influence on history. The influence of the piano is scarcely discernible, while the influence of the steam hammer stands out in enormous letters of steel. The piano seems to be in the same category as are literature and poetry and music in general: it serves to please. The steam-hammer, on the other hand, has had so great an influence on history subsequent to its invention, that we know that subsequent history could not have been as it has been, if the steam hammer had not been invented.

It has been the steam hammer and the ensuing modifications of it that have made possible the making of large forgings of iron and steel. It has been the large forgings of iron and steel that have made possible the use of large solid masses of those metals in the construction of engines, guns, shells, houses, bridges and ships. It is the ability to use large and solid masses of iron and steel, free from holes and seams, that has enabled constructors and engineers to produce the tremendous engineering structures that characterize today. *The main element in the progress of the race has been its triumph over the forces of material Nature.* This triumph has been gained by inventors, who conceived of certain methods and devices (clothing, for instance) by means of which materials provided by Nature could be utilized by man to protect himself against her attacks upon him—attacks by cold, for instance. Inventions of the useful kind have had a history of their own, as definite as the history of any other thing or things, in which it is shown that every useful instrument or method has been succeeded by another and better; so that the history of useful inventions may be compared to a picture of men mounting a flight of stairs toward civilization, the steps of the stairs being the successive useful inventions of different kinds.

The paragraph just written is not intended to mean that inventions which please have no value, but merely to point out the difference between what are aptly called the fine arts and the useful arts. There would be little happiness given to man by toilsomely climbing the stairway to civilization, unless he were occasionally cheered on the way by a strain of music, or a beautiful painting, or a poem, or a brisk walk in northwest weather, or a gladdening glass of wine. It may be argued that these are the things that really give happiness; it may be claimed that these things go direct to the seat of happiness in the brain, but that steam hammers merely provide a material civilization, which continuously promises to make men happier some day, but never makes them happier.

Verily, verily, the way to happiness is not so clearly marked, that anyone can walk in it all the time, or even for five minutes, except on rare occasions. The consensus of opinion seems to be, however, that the civilized man is, on the whole, happier than the savage; that civilization is preferable to savagery. It is the purpose of this book, moreover, merely to point out that that structure of civilization has become so complicated and is moving so fast that it is now a veritable machine and to indicate the part that invention has taken in building it.

Not only is it a veritable machine, it is the largest, the most powerful, the most intricate machine we know of—except the solar system and the greater systems beyond it. And not only is it powerful and intricate—it is, like all powerful and intricate machines, extremely delicate. Extreme delicacy is a characteristic of all machines; it is inherent in every machine, simply because the good working of every part is dependent on the good working of every other part. An organism is a machine of the highest order, and therefore possesses this characteristic of inter-dependability in its highest form. A club is not an organism, or even a machine, and does not possess it. If a man injures one end of a club the other end is just as good as before; but if a club injures one end of a man, the other end is injured also. A severe blow on the head will prevent the effective use of the foot, and a severe blow on the foot will prevent the effective use of the head.

Similarly, in this great Machine of Civilization, a war between any two nations affects every other nation in the realm of civilization, though it may not affect appreciably the savages of Australia. A strike in the coal mines affects every person in the United States;—and even a threat to strike by the railway employees affects not only the whole United States, but, to some degree, all Europe.

This brings us to realize that, while the Machine of Civilization itself has improved tremendously, it is only as a machine, and only because it is a machine. It should make us realize also that the mere fact that a machine is good or useful is no bar to its being destroyed. It should make us realize besides that the finer a machine is the greater danger there is of its being injured and even destroyed, by careless or ignorant handling. These facts are clearly realized by all engineering companies of all kinds; and the result has been that highly competent engineers have been trained to care for and handle their engines. There are no more highly competent men in any callings than are the engineers in every civilized country. One might declare without much exaggeration that, of all the men in business or professions, the engineers are the most competent for their especial tasks; and the reasonableness of the declaration might be pointed out on the ground that the very nature of the engineering profession (unlike that of most other professions) makes it impossible for an engineer to be incompetent, and yet maintain his standing.

But the Machine of Civilization is composed not only of material parts, such as come within the province of the engineer, but also of immaterial parts; in fact, the principal parts are men, and especially the minds of men. It is the office of the Machine of Government to handle the men. It is also its office to direct their minds; because unless those minds view things correctly, the Machine of Government cannot work with smoothness. Now, men are inferior to machines in one important way: — men, as men, cannot be improved. It therefore devolves on Government continuously to instruct and train men to handle the Machine of Civilization skillfully, because the machine is being made more and more complicated, and more and more in need of intelligent care, with every passing day.

Is this fact realized? I fear not. No sign is visible to the author of these pages that the people in any country realize or even suspect that there is any need for looking out for the integrity of the Machine as a whole. The closest approximation to it is a belated realization that the Bolsheviki are a danger to "society." The people do not seem even to realize the necessity of having competent experts at the head of governmental affairs.

The Machine of Civilization had been developed to a very high stage when Trajan ruled the world about the year 100 A. D. For three-quarters of a century afterward, it continued to run with smoothness, under intelligent care; but in the year 180 A. D. Commodus came to the throne, and soon after began to abuse it. For two hundred years thereafter, the Machine suffered from such abuse and neglect, that by the year 395, it had become so unwieldy, that it was divided into two parts, one administered from Rome and the other from Constantinople. The two parts soon became two separate Machines, the Roman Machine being at first the better, but gradually becoming more and more ineffective under the unfavorable conditions of abuse and neglect. In 476, the Roman Machine broke down completely, and the barbarian chief, Odoacer, sat himself on the throne of Octavius Cæsar.

A ruin more complete, it would be hard to realize. The vast structure of Roman civilization, built on the civilization of Greece and Assyria and Babylonia and Egypt, was hurled to the ground; and its fine and beautiful parts were scattered to the winds by barbarians who hated civilization because they were barbarians. The progress of science and literature and art stopped. The marvelous inventions of the past were forgotten and disused. A condition of semi-barbarism passed into Europe, and continued for a period of five hundred years, to which the name Dark Ages has been aptly given. A feeble light began to glow about 800 A. D. as a result of the activities of Charlemagne, but it almost expired when he did. It began again when the Crusaders came back from the Orient with knowledge of the civilization that still persisted there;

and shortly after came the first effort of the Renaissance. Then followed the invention of the gun, and then the invention of printing:—and presto—the making of another Machine of Civilization is begun.

Now let us realize three facts: one fact is that the Machine of Modern Civilization, though bigger and more complicated than the one of Trajan's time is not nearly so strong; another fact is that the Roman Machine was destroyed because it had become ineffective through carelessness and abuse; the third fact is that because in a measure, "history repeats itself," the Modern Machine may be destroyed, as the Roman was.

The Machine of today is vastly weaker than Trajan's. Trajan's Machine was operated by a powerful empire that controlled the whole world absolutely. No rival of Rome existed. The structure of society was simple, homogeneous and strong. It was almost wholly military. It rested on force; but that force rested on reason, moderation, skill and patriotism. Rome had many foes; but they were so weak compared with Rome, that she had naught to fear from them—so long as she kept her Machine in order.

The Machine of today is not only more complicated than that of Trajan, and therefore more liable to derangement from that cause alone—but it is supported by no government that dominates the world. On the contrary, the control is divided among a number of different nations that have diverse interests. The influence of this condition can be clearly seen in the fact that every great war has set back the progress of civilization for a while in all civilized countries, even though in some ways it has advanced it. The World War just finished, for instance, shook the very foundations of society; and we do not yet know that it did not impair them seriously. Certainly the Machine has not yet begun to run smoothly again. Certainly, the Bolsheviki are threatening it as seriously as the barbarians began to threaten Rome not long after Trajan's time. The Romans did not regard the barbarians then any more seriously than we regard the Bolsheviki now.

The barbarians finally succeeded in destroying the Roman Machine, but not for the reason that they had become any stronger. They had not become any stronger, but the Roman Machine had become weaker. It had become weaker for the reason that the men in charge of it had not taken the proper care of it. They failed to take proper care of it, for the reason that they were not the proper kind of men to have charge of that kind of machine. The reason for this was that the Roman people did not see to it that they put the proper kind of men in charge of their Machine.

Someone may say that Rome was an autocracy, and that there are no autocracies now. True, but republics have been inefficient, just as often, and in as great a degree as autocracies have. The United States under President Buchanan, for instance, was excessively inefficient; while the Roman autocracy under Octavius was exceedingly efficient. But whether a government is autocratic or democratic, the degree of civilization must depend in the main on the people themselves. Even the power and genius of Charlemagne could not at once make Europe civilized; and even the power and bestiality of Commodus could not at once make Rome uncivilized. In every nation, the rulers and the people re-act upon each other, and each makes the other in a measure what they are. A people that are strong and worthy will not long be governed by men who are weak and unworthy. If a nation continues to have weak and unworthy rulers, it is because the people themselves are weak and unworthy.

Therefore, it is an insufficient explanation of the breaking down of the Roman Machine to declare that the Roman emperors were what they were. The Roman emperors reflected the Roman people, or they would not have remained Roman emperors. If the Roman people had been as strong individually and collectively as they were in the days of Octavius and Trajan, no such emperors as later sat on the throne would have been possible. But the Roman people gradually deteriorated, morally, mentally, and even physically; and inefficient government was one of the results.

What caused the deterioration of the Roman people? The same thing that has caused the deterioration of every other great people that have deteriorated—the softening influence of wealth and ease.

Thus, Rome did not fall because of the barbarians, but because of herself. She fell because her people allowed the Machine which she had built up, in spite of the barbarians outside, at so much cost of labor and blood, to become so weak that it could no longer protect itself. Can this happen to our Machine? Yes, and it will happen as surely as effect follows after cause, unless means be taken to see that men are trained to care for the Machine more carefully than they are trained now. *In no country is there any serious effort made to train men to operate the Machine of Government,* except those parts of the Machine that are called the army and the navy:—though some tremendous efforts are made in private life to train men to handle corporations and business enterprises, and to learn all that can be learned in medicine, engineering, the Law and all the "learned professions." And even the efforts made to train officers to handle armies and navies are in great part neutralized by placing men at the head of those armies and navies who are not trained in the slightest.

The Roman Machine fell with a crash that was proportional to the magnitude of the Machine. The Machine of today is much larger and heavier than the Roman. If it falls, as it may, the crash will be proportionally greater. What will follow, the mind recoils from contemplating.

CHAPTER X

CERTAIN IMPORTANT CREATIONS OF INVENTION, AND THEIR BENEFICENT INFLUENCE

IN 1843 Charles Thurber invented the typewriter. Few inventions are more typical. In 1843, the conditions of life were such that the first stage in inventing the typewriter must have been the conception of an extremely brilliant and original idea. After that, the difficulties of embodying the idea in a concrete form must have been very great; for it was not until about 1875 that instruments of practical usefulness were in general use. Since then, typewriters have penetrated into virtually every office in the civilized world.

Though the typewriter is a very simple apparatus in both principle and construction, yet few machines stand out more clearly as great inventions. Few inventions also have exerted a greater influence—though the influence of the typewriter has been auxiliary, rather than dominant; it has merely enabled a greater amount of business to be transacted than could be transacted before. If anyone will go into any business office whatever, and note the amount of work performed in that office by means of one typewriter that could not be performed without it, and will then multiply that amount by the number of typewriters in the world, he will come to a confused but startling realization of the amount of executive work that is being done in a single day through the agency of the typewriter, that otherwise would not be done. If he will then go a step further, and multiply the number of days that have gone by since the typewriter was first employed, by one-half, or even one-tenth, of the amount accomplished by means of all the typewriters in a single day, he may then be able to appreciate in a measure the enormous influence on progress which the invention of the typewriter has already had. One would not make an exaggerated statement if he should declare that if the typewriter had not been invented, every great business organization in the world today would be much smaller than it is; the great industries would not exist in their present vastness; and all the arts of manufacture, transportation and navigation would be far behind the stage they now have reached.

The electric telegraph was patented by Morse in 1837, but the first telegram was not sent till 1844, along a wire stretched from Washington to Baltimore. It is said that the first official message was "What hath God wrought!" This message shows a realization of a fact which some people fail to realize: the people who say, "God made the country, but man made the city." The message showed a realization that God inspires the thoughts of men, as truly as He provides them with things to eat. It is inconceivable that it was intended to call attention to the fact that God wrought the wire along which the message ran, or the wooden poles that carried the wire, or the material zinc and copper of the battery. The only new thing evidenced in the telegraph so far as anyone could know, was the invention itself. God had wrought that through the agency of Morse. It is a known fact that no human mind, no matter how fine it may be, or how brilliant and correct its imagination, can have any images or ideas that are not based in some way on the evidence of the senses. We can imagine things, and even create things, that have never existed before; but those things must be composed of parts whose existence we know of through the evidence of our senses. So Morse, although he invented a thing that was wholly new, although he created something—did not create any of the parts that composed it. He used such well-known things as wire, iron, zinc and copper. Even in the creation of man, the Almighty himself used common materials: "And the Lord God formed man of the dust of the ground, and breathed into his nostrils the breath of life: and man became a living soul." (Genesis, Chapter II.)

If the Lord God breathed the breath of life into Adam, He inspired him according to the original meaning of the word inspire. If He inspired Morse with the conception of the electric telegraph, He inspired him according to the modern meaning of the word, which is not very different from the original meaning, and which is not at all different from the meaning according to which He is said to have inspired the prophets of old.

To bring before us clearly the whole influence of the telegraph on history would require a book devoted to no other subject; yet the telegraph belongs in the same class with the typewriter, in the sense that its main office is to assist the transaction of business. The telegraph does not of itself produce results. It is not in the class with the fist hammer, or the weaving machine, or the gun, or the steam engine, or the electric light, or chloroform, or the telescope, or the discovery of America. It owes its reputation largely to the spectacular way in which it first appeared, and to the seeming wonderfulness of its success. Yet the telegraph seems no more wonderful than the typewriter, to a person who knows even a little of electricity; and the task of making it practicable was much easier. A very simple and crude apparatus sufficed for the telegraph: but a highly perfect mechanism was needed for the typewriter.

It is probably true, however, that the telegraph has had a greater influence on history than the typewriter, though modern civilization would not be even approximately what it is, if either had not been invented. And if by any combination of circumstances, either one should now be taken from us, the whole Machine would be thrown into inextricable confusion.

It may be objected that if Morse had not invented the telegraph, or if any inventor whoever had not invented whatever thing he did invent, some other man would have done so; and that therefore those inventors do not deserve to be placed in any especial niche of honor. There would be considerable reasonableness in such an objection, as is evidenced by the fact that in many cases two or more men have invented the same thing at about the same time. It may be pointed out, however, that while this has often happened in regard to improvements on basic inventions, it has not happened very often in regard to the basic inventions themselves; and also that, even if we include all the inventors the world has ever heard of, we find that there have been surprisingly few. Therefore, it really makes little difference to the race as a whole whether Smith or Jones made a certain invention, or whether Smith would have made it, if Jones had not made it. "The man who delivers the goods," receives, and as a rule deservedly, the recognition of mankind. Furthermore, this book, as has been stated, is not concerned mainly with inventors, but with inventions.

In 1844, the use of nitrous oxide gas (laughing gas) as an anæsthetic was introduced by Dr. Wells. It cannot be said that this invention has had any direct influence on history itself, though it has had a great deal of influence on the history of some individuals. It contributed a new and distinct part to the Machine, however, and certainly helped to ameliorate the conditions of living. Besides, it seems to be one of the lessons of history that most new and distinct creations, even if no use has been found for them for a long while, have ultimately found a field of usefulness. Furthermore, every new and useful thing, like nitrous oxide gas, attracts the attention of men to the advantages that the study of physical sciences and the prosecution of invention offer, and gives inspiration for further study and endeavor.

In the same year, Léon Foucault invented the first practical electric arc-light. Davy had made the basic invention of the Voltaic arc in 1808; but his invention was in the class just spoken of, in that it was not utilized for many years. Even the arc-light that Foucault produced in 1844 was not utilized then. In both cases, the cause of slowness of utilization did not rest so much in the invention as in the stage of civilization at the time. The world was not yet ready for the arc-light. In fact, it did not become ready, and it could not become ready, to use the arc-light in real service, until a cheaper means of producing electric current had been invented. This did not happen until the dynamo-electric machine had been invented and had been brought to such a point of practical development that it could supply electric current, not only adequately and economically, but reliably. A necessary step toward the utilization of the arc-light was made in 1845, however, by Thomas Wright, who invented a means whereby the carbons could be kept automatically at the correct distance apart for maintaining a continuous and uniform light.

In 1845, Robert Hoe made an important contribution in his double-cylinder printing press. In the same year, R. W. Thompson invented the pneumatic tire. This invention belongs distinctly in the class just spoken of, for the pneumatic tire did not come into general use until the bicycle did, about 1890. It may be asked if there is any use in inventing appliances long before they are needed. So far as the inventor is then concerned—no: so far as the public is eventually concerned, yes. All inventions made and patented are described and illustrated in the Patent Office Gazette; and many of them are described and illustrated in magazines and newspapers, even if they are not used in actual practice. These records form part of the general knowledge of mankind, just as much as do the facts of geography and history and arithmetic; and they can be drawn upon by investigators and inventors, and made to assist them in their work.

In 1846, an invention was made by Elias Howe, that does not belong at all in the same category as that of the pneumatic tire, because it was utilized almost immediately. This is usually spoken of as the sewing-machine; but the essence of the invention was not a machine, but merely an instrument; for it consisted of a needle in which the eye was near the point, instead of at the other end, as in existing needles. The machine afterwards produced was merely an obvious means for using the new kind of needle.

The invention of the sewing-machine was one rich in influence on subsequent progress; and all the story connected with it is interesting in many ways. But the most wonderful fact connected with the invention is that it was not made before! Many inventions have not been made because the conditions at the time did not demand them, or make their successful utilization possible: and yet some inventions, like the Voltaic arc, were made despite the unfavorable conditions. But what conditions were unfavorable to the utilization of

Howe's sewing-machine, even as far back in history as the days when the pyramids were built? The Howe sewing-machine was not so complicated an apparatus as the ballista, or the chariot, used by the Assyrians and the other nations in the "fertile crescent," that curved from Alexandria to Babylon; and it was much easier and cheaper to make. Its construction required immeasurably less scientific knowledge and carefulness than the printing press, the gun, the telescope and the microscope, and a score of appliances that had preceded it by several centuries. Why was the sewing-machine not invented before? Why, why? This question continually presents itself to the mind, when certain simple inventions appear, that (so far as we can see) could have been invented and ought to have been invented, long before.

In 1846, the printing-telegraph was invented by House. No such question as that just discussed is presented to our minds by this invention, because we realize that it could not have been invented before some means of generating continuous electric currents had been invented. The printing-telegraph was not an invention of the same order of influence as the sewing-machine; but it has assisted the work of the telegraph in supplying news, especially in reports of stock fluctuations.

In the same year, De Lesseps started his project of building the Suez Canal, and joining the Mediterranean to the Red Sea; so that ships could proceed to India from Europe by a direct route. Many centuries before, a canal had been cut and generally used that ran from the Nile River to the Red Sea. The canal that De Lesseps proposed was to be larger, and the engineering difficulties greater. The vast enterprise was finally carried out, at a cost of about $100,000,000. It seems to have passed through the three successive stages of conception, development and production. The idea of building a canal did not originate in 1846, or in the brain of De Lesseps; for the idea was very old, probably older than recorded history. But the only man who formed the mental picture in his mind and afterwards developed it into a concrete plan was De Lesseps. He did this; and his plan was so complete and coherent, and so evidently practical, that he finally succeeded in convincing engineers and capitalists of the fact, and forming a large company. The execution of the concrete plan was not begun until 1859, and it was De Lesseps who began it. Thus De Lesseps, though he did not conceive the basic idea, conceived and combined the various ideas necessary to embody the basic idea in a concrete plan, then constructed the concrete plan, and then produced the actual instrument.

This instrument (the canal) was a very useful instrument. An instrument, according to the *Standard Dictionary,* is "a means by which work is done." By means of the Suez Canal, the work of direct water transportation between the Far East and Europe was done; and it could not have been done, except by means of that instrument. It has been done by that instrument ever since, and at an increasing rate. The canal was completed in 1869, and widened and deepened in 1886. It has shortened the water distance between England and India by about 7600 miles, and has had a tremendous influence on history, especially on Great Britain's history. One of the largest stockholders is the British Government; three-fourths of the ships passing through it have been British; and though the whole world has benefited, the greatest single beneficiary has been Great Britain.

Yet De Lesseps was a Frenchman! This calls to our minds the fact that although some of the greatest names in History are French, yet the French nation, as a nation, has never shown the same concerted national purpose as the British. In this respect, the French seem to have borne somewhat the same relation to the British, as the Greeks did to the Romans: and yet the French are more nearly allied by blood and language to the Romans than are the British. The Greeks and the French aimed to make life pleasant, by the aid of the fine arts and a general utilization of all that is delightful; while the Romans and the British, early in their careers, conceived the idea of dominion, embodied the idea in a concrete plan, and proceeded to carry the plan into execution. The plan was continually accommodated to the changing conditions of the times, and the means of execution were continually accommodated also. The result has been that Greece and France never, as nations, acquired dominion even approximately; while Rome did completely, and Great Britain did, approximately.

The author does not wish to be understood as approving of the idea of acquiring dominion, or as failing to realize the sordidness of such an ambition, and the evil that men and nations have done, in order to achieve it. He begs leave to point out, however, that the Machine could not have been built, except under the stable conditions that large nations permit better than small nations do; and that it has been the endeavor to achieve dominion by aspiring tribes and nations, and the consequent endeavor to gain strength in order to prevent it, by other aspiring tribes and nations, which have caused the gradual building up of the great nations of today, with the comfort, security and culture that their existence permits.

In the same year, 1846, artificial limbs were invented, and so was the electric cautery. Neither of these inventions had a profound influence; but each was a new creation, and each formed a useful and distinct addition to the Machine. But another invention was made in 1846, that has had great influence.

This was the invention of gun-cotton, made by Schonbein in Germany by the action of nitric and sulphuric acids on cotton, or some other form of cellulose. It was the first practical explosive that depended for its usefulness on the decomposition of a chemical compound, and not on the combustion of a mechanical mixture, like gunpowder. The explosive power of gun-cotton was declared by the chemist Abel to be fifty times that of an equal weight of the gunpowder of that day; but this does not mean that it possessed fifty times the energy. The action of gun-cotton is very much more sudden than that of gunpowder; and for that reason, it exerts a much greater force for an instant, and has much greater efficacy for such purposes as breaking into structures, bursting shells, etc. On the other hand, the very fact that its energy is developed with such suddenness, causes its force to fall to zero very soon, and makes it useless for such purposes as gunpowder fulfils in firing projectiles from guns. In a gun, especially in a long gun, the endeavor is made to keep down the pressure of the gas and prolong its continuance; so that the projectile will receive a comparatively gentle but prolonged push, that will start it gradually from its seat, and will continue to push it, and therefore to increase its velocity, all the way to the muzzle.

Gun-cotton does not belong in the class with the typewriter and the telegraph, that merely assist men to transact business: gun-cotton transacts business "on its own account." Gun-cotton belongs in the class with the gun; and its main influence has been to increase the self-protectivity of the Machine. It has done this mainly by increasing the power of the submarine torpedo against the hulls of warships. It may be objected that both sides in a war between civilized nations would use torpedoes, that no persons except organizations controlled by civilized nations (such as those in warships) would use torpedoes, and that therefore, whatever effect the torpedo might have on the Machine is neutralized by the fact that two civilized bodies use it against each other. True; but the fact that the torpedo and the gun-cotton in it require a high degree of civilization in the people who use it, gives civilized people an immediate and tremendous advantage over uncivilized people; and furthermore, the fact that the torpedo and the gun-cotton in it depend for their ultimate effect not only on their being used, but on the degree of knowledge and skill with which they are used, gives an advantage to which every nation in any war is willing and able to utilize the most knowledge and exert the most skill. That is, the torpedo and the gun-cotton in it combine to give the advantage to the nations possessing the highest degree of civilization and will-power. They enable the Machine of the most highly civilized nation to protect itself if it will against the Machines of less highly civilized nations.

In the year following the invention of gun-cotton, came Sobrero's invention of nitro-glycerin, made by the action of nitric acid on glycerin (1847). The new explosive was more powerful than gun-cotton, but much more dangerous to handle. By reason of its extreme sensitiveness and the consequent danger of handling it, the use of pure nitro-glycerin has never been great.

In the same year, 1847, the time-lock was invented by Savage. This invention was in the class with the gun and gun-cotton, in the sense that it enhanced the self-protectiveness of the Machine. It did not enhance its self-protectiveness against a few great, open, external foes, however, but against a myriad of small, secret, internal foes. The Machine is very expensive to maintain in operation, and so is every one of the little mechanisms of which it is composed. And each one of these little mechanisms, each bank, its business corporation, each company, each department store, each little shop, requires that its money be kept safe from the burglar and the pilferer. Inasmuch as the time-lock assists in doing this, the time-lock has been a valuable contribution to the Machine, and has exerted a good influence on history since it was invented.

In the same year, 1847, R. M. Hoe invented his great printing press, that could make 20,000 impressions per hour. As it was a long step forward in the improvement of printing, this invention deserved the applause which it received; and the inventor deserved the financial reward which he received.

In 1848, Dennison invented a machine for making matches. This was a most useful contribution; but one is inclined to wonder why twenty years elapsed between the invention of matches and the invention of a machine for making them. Inventing was not going ahead so fast then as it is now. Surely, no such interval is allowed to pass unutilized, in the present inventing days.

In 1849, the "interrupted-thread" screw, for use in closing the breeches of guns was invented. Many men have claimed the honor of this invention. Regardless of who the particular inventor was, the invention itself must be regarded as one of a very high order, from the standpoints of originality, constructiveness and usefulness. Though the screw itself was a very old contrivance, the idea of cutting a long slot lengthwise, so that the screw could be pushed forward quickly without the slow process of continuously turning it around, yet so arranged that the screw could be turned when near the end of its travel, and the force-gaining power of the screw-thread thus secured, seems to have been entirely new. Certainly the idea was original and brilliant and useful. To develop the idea into a concrete plan was not difficult, and neither was it difficult to carry the concrete plan into execution. This invention falls into the happy class of which the stethoscope is typical, in which the idea originally conceived was so perfect, that little else was needed. The main use of this invention has been that for which it was first intended, to close the breeches of guns. It is used in most of the navies and armies. Its principal rival is the famous sliding breech-block of Krupp.

In 1849, came an invention in the gun class, the magazine gun, made by Walter Hunt. This invention also seems to fulfil all the requirements of a real invention, in originality of conception, constructiveness of development and ultimate usefulness. But in this case, the original idea can hardly be declared as brilliant and spectacular as that of the "interrupted thread"; and certainly the labor of developing it was incomparably greater. The author feels the temptation of declaring that the more brilliant and valuable a conception is, the less will be the difficulty of developing it. He refuses to declare it, however, realizing that it would not be wholly true; and yet he wishes to point out that if a conception be wholly erroneous, it cannot be developed into any concrete plan whatever; and that many of the most brilliant conceptions, such as the fist-hammer, the flute, the telescope, the telegraph and the telephone were very easily developed into forms sufficiently concrete to make them practically usable. An idea itself is an extremely simple thing, even if it be developed ultimately into a highly complex machine. The idea of the steam engine, for instance, the idea which Hero conceived was, of itself, extremely simple; but see into what complex forms it has been developed! The original idea of Hero was easily developed into "Hero's engine." The improvements that have been made upon it have been the developments of separate ideas that were conceived later. Not one of these ideas has been nearly so brilliant as Hero's, and few of them have been so easily developed.

In 1849, Bourdon invented the steam pressure gauge that still bears his name, and made a contribution of distinct and permanent value, by which ability to keep track of the steam pressure in boilers was increased, and safety from explosion increased proportionately. In the same year, Sir David Brewster invented his lenticular stereoscope. In this beautiful instrument two separate pictures of the same object are put on one card, one picture showing the object as it would look to the left eye from a given distance, and the other picture showing the object as it would look to the right eye. The two eyes of an observer look at the two pictures through the two halves of two convex lenses, that are so shaped that the two pictures are seen as one picture, but so superposed as to represent the object in relief, as the actual object appears to the two eyes. Like the kaleidoscope, this later product of Sir David Brewster's brilliant imagination has had little influence thus far, except possibly to lead the way toward stereophotography and the stereopticon: but it seems hardly probable that an important field will not be found some day for an invention so suggestive.

In the same year, Hibbert made an important improvement on the knitting machine, and Corliss invented his famous engine cut-off, which vastly economized fuel. Neither invention was especially novel or brilliant, but both were highly practical and useful contributions to the improvement of the Machine. In the same year also came Worm's improvement on the printing press, that concerned the making of "turtles" which held type in a curved shape, so that they could be secured to the cylinder of the press.

In 1850, Scott Archer succeeded in using collodion to fix silver salts on the surface of glass plates in photography. He cannot be credited with the basic invention, because the idea of doing this had been suggested long before. The invention made an important contribution to the growing art of photography, mainly by supplying a stepping stone for further advances. In the same year, an important improvement was made in watch-making by inventing a watch-making machine. This was one of the first of those distinctly American inventions, by which machine-work replaced hand-work, with great increase in speed of production and lessening of cost, but without decrease in accuracy of workmanship.

The influence of this invention has escaped the notice of many of us, for the reason that it has spread so gradually, and has been of such a character as to fail to strike the imagination from its lack of spectacularity. But the idea of what we now call "quantity production" has spread to all the fields of the manufacturing world, and is the basis of much of the enormous industrial progress of the last half century. It is rendered possible mainly by making the machinery automatic, or nearly so. Without such exaggeration, America may justly claim the contribution of automaticity to the Machine of Civilization.

In 1851, Dr. Charles G. Page produced the first electric locomotive. Like many pioneers, it did not achieve practical success itself, but it supplied a stepping stone to further progress. In the same year, Seymour produced his self-rakers for harvesters, and Gorrie invented the ice-making machine. Two more important inventions were the ophthalmoscope, invented by Helmholtz, and the "Ruhmkorff coil," invented by the man whose name still clings to it.

The ophthalmoscope reminds one of the stethoscope; so simple it is, so perfect and so useful. It consists merely of a small concave mirror with a hole in it, a lamp and a small convex lens: the mirror being held so that one eye of a physician can look through it, and the lens being placed conveniently by the physician near the eye of a patient. The mirror reflects light from the lamp towards the patient's eye, and the convex lens concentrates them on whatever is to be examined—usually the interior of an eye. This instrument belongs in the small class of inventions already spoken of, in which the original conception was so perfect, that the acts of developing it into a concrete instrument and then producing the instrument were easily performed.

The Ruhmkorff coil is in the same class; for it consists merely of two coils of wire; one "primary" coil being of coarse wire and connected with a source of electric current, and the other "secondary" coil of fine wire placed around the coil of coarse wire. If the current in the primary coil be made or broken or changed in force or direction, currents are "induced" in the secondary coil; the strength of the two currents varying relatively according to the sizes and lengths of the wires in the two coils. This invention has an interest apart from its usefulness, in the fact that Ruhmkorff invented it for purposes of scientific study, and that no utilization of it for everyday life occurred until nearly half a century later. Then Ruhmkorff coils were made into "transformers" for use in "stepping down" the small high voltage currents needed for transmitting electric currents over long distances, into the larger but lower voltage currents needed for actuating electric lights and motors.

In the following year, 1852, Channing and Farmer invented the fire-alarm telegraph, an important contribution to the safety of the Machine, though it did not come into general use for several years. In the same year, Fox Talbot made another of his epochal contributions to photography, by inventing a process by which photographic half-tones could be produced. In the following year, a process was invented for making from wood a pulp that was very valuable as the basis of making paper,—and Faraday made three important discoveries. These were the laws of electromagnetic induction, the relations of the dielectric to the conducting bodies in electro-static induction, and the laws of electrolysis.

These discoveries of Faraday were all inventions, in the sense in which the word invention is used in this book. Each one was the outcome of a series of careful and mathematically guided experiments, and the outgrowth of an idea. In the following year, Melhuish invented photographic roll films, and Herman invented the rock drill. The latter invention has been of the utmost practical value in blasting operations of all kinds, and must be regarded as a very distinct addition to the Machine.

In the same year, appeared the Smith & Wesson revolver; not a great invention, but an improvement in many ways over Colt's; Mr. A. B. Wilson brought out his four-motion feed for sewing-machines, and R. A. Tilghman invented his process for decomposing fats by hot steam. In the following year (1855), Lundstrom made the highly important invention of safety matches. When one reflects (as every one must at times) how great and absolutely irretrievable are the losses caused by fire each year, how the amount of possible destruction grows each year exactly as fast as the Machine grows, and realizes how large a fire many a small match has caused, he feels inclined to give a mental salute to Mr. Lundstrom of Sweden.

In the same year, iron-clad floating batteries were used in the Crimean War. This was not the first time that iron-clad vessels had been employed, for vessels protected on the sides with sheets of iron and copper had been used by the Coreans in their victorious war against the Japanese about three hundred years before; but it was the first time that such vessels had appeared in Europe. Cocaine was invented the same year, and one of the most valuable anæsthetics yet known was then produced.

But the most valuable contribution to the Machine in 1855 was Henry Bessemer's epochal invention of making steel by blowing air through molten cast iron, until enough of the carbon had been burnt off to leave a steel of whatever quality was desired. This invention reduced the cost of making steel, and the time required, in so great a degree as to place the manufacture of steel on a basis entirely new, and to extend its field of employment greatly. And, as with many previous great inventions, this one paved the way for still other inventions, by indicating the possibility of still wider fields. The Bessemer process is not in the class with the typewriter or the telegraph, but in the class with the gun; for it does things itself. It would be difficult to specify any invention (except one produced at a much earlier time) that has had more influence, and more good influence, on history than Bessemer's. No one can look out of his window in any town or city, without seeing some of the innumerable products of Bessemer's idea.

Our record has now brought us to the middle of the nineteenth century. The conditions of living in 1850 were greatly different from those of 1800. In fifty years, the physical conditions of living and of carrying on business of all kinds, had improved more than in the century between 1700 and 1800, more than in the two centuries preceding 1700, and more than in the ten centuries from 500 and 1500. Rapid transportation over the land in railroad trains for both passengers and freight had largely replaced the slow transportation methods of 1800; and, in an almost equal degree, steam transportation at sea had replaced transportation by sails. The printing press had been developed from a crude and slow contrivance, worked by a hand, to a magnificent mechanism worked by steam: the electric battery had been improved into an appliance of the utmost reliability and usefulness; telegraph lines stretched over the continents, and messages were sent surely and instantaneously over hundreds of miles of land; and the science of chemistry had arisen from the ashes of alchemy. As a result of this, the science of photography had been born, and had already begun its work, so varied and so useful. Physics had grown so surely and so greatly, that it had been divided into the separate but allied sciences of heat, light and electricity—including magnetism: the science of engineering had expanded so widely, that it also had been divided into other sciences—civil engineering, mechanical engineering, hydraulic engineering and electrical engineering: the science of medicine, because of the advances in chemistry and physics, had advanced at an equal rate: the gun had been so greatly improved, and gunpowder also, that such a degree of precision and range had been attained as to make the gun of 1800 seem crude indeed; and the improvement had been inevitably caused by the greater knowledge placed at the disposal of ordnance officers, by the advances in chemistry, heat, light, electricity, magnetism and the various engineering arts. The introduction of illuminating gas, the improvements in forging, casting and turning metals, had made possible the building of edifices, and the fabrication of better and cheaper utensils of every kind: improvements in the means and methods of spinning, knitting and weaving had bettered the materials that people wore upon their persons: improvements in rubber manufacture had made possible the use of waterproof garments; crops could be gathered more quickly and surely: safety from fire had been increased: methods of heating houses had been vastly improved: and the discovery of anæsthetics had relieved civilized man in great degree from his most distressing single enemy. As a result, the people of every civilized country lived under conditions of comfort far greater than had ever been known before in similar climates.

The facts and conditions detailed above relate almost wholly to the material conditions of living, and show that, for most people, they had been enormously improved: though it is noteworthy that for the very poor, they had not improved in many cases, and had been altered for the worse in other cases. The unfavorable changes were mainly those produced by "factory life" which in 1850 must have been worse than country life for the same class of people. These cases were so greatly in the minority, however, as not to affect the main proposition that the advance in civilization from 1800 to 1850, caused by new inventions, had improved the material conditions of living for the great majority of the people affected by them.

That it was desirable that these conditions should be improved, some people may be disposed to deny; pointing out that the improvement tended to develop "luxury, thou cursed of Heaven's decree." One of the effects of increasing material prosperity is undoubtedly a tendency toward luxury. But the number of people thus affected was so very small in the period from 1800 to 1850, and the degree of luxury attained then was so slight, that this question need hardly be discussed, at this point.

But the mental condition of the people had changed as greatly as the physical conditions of their environment. The immediate cause of this change was, of course, the printing press, which disseminated the thoughts of thinking men broadcast, and told of events that were occurring not only in places near, but also in places distant. This gave an enormous stimulation to the minds of the people by exciting their interest: and it also gave to their minds both "food for thought" and almost unlimited opportunity for exercise. Before this period, only a small part of the population had a wide range of knowledge, or a large number of subjects to think about. Their lives were exceedingly monotonous, and would have been exceedingly dull, had it not been for the continuous necessity of combating the inconveniences of every-day life by continual toil of one kind or another. There were very few subjects of conversation.

But the printing-press told the people of other things besides the events that were taking place; it told them also of new discoveries and inventions that were being made, and of the effects they would produce. The news of a great discovery or invention must have created more excitement in 1831 when the discovery of chloroform was announced, than almost any discovery would now, because we are so accustomed to new discoveries as almost to be sated. We know what excitement the first successful railway trips created. The coming of these new discoveries and inventions gave mental exercise in four ways:—first by stimulating the imagination with a picture it had never seen before, and whose possibilities reached no one could guess how far; second by stimulating the logical powers to reason out and understand the principles underlying each discovery or invention; third by stimulating the memory to engrave upon its tablets certain new and important facts; and fourth, by stimulating the inventive faculties, to carry inventions further.

Thus, the influence of new inventions was to change a man's environment, both physical and mental. Now every man is said to be the product of his environment and his heredity; so that the influence of these new inventions was to change men to a degree proportional to the degree by which they changed their environment. This does not mean that inventions have changed man biologically, or even changed him so much that he will act very differently from a savage, under abnormal conditions. It does mean, however, that they have caused men so to adapt themselves to the new environment which inventions have created, that, while in that environment, they will for all practical purposes, be very different from savages. It means that under nearly all the conditions of living, a gentleman in civilized society will be a gentleman—courteous, refined, law-abiding and moral. It does not mean that he will be perfect, but that he will be very much more courteous, refined, law-abiding and moral than a savage; and it means, in consequence that the society of civilized people in general will possess these characteristics much more than any society of savages does.

Not only, however, have these inventions changed the environment of civilized man, they have changed his heredity also; because they had previously changed the environment of his parents, grandparents and other ancestors. The graduate of Oxford of 1850, the son of an Oxford graduate who was also the son of an Oxford graduate, though he was biologically the same as his barbarian ancestors of ten thousand years before, was nevertheless a much more refined, intelligent and courteous gentleman. Under certain abnormal conditions, such as intense thirst, hunger, jealousy, passion or unlooked-for temptation he might act as badly as a savage:—in fact such men sometimes do. But nevertheless, the fact that in 99% of the conditions under which he lives he acts as a gentleman and not as a savage makes him 99% a gentleman, and only 1% a savage, during his mortal life.

Thus inventions, while originating (or seeming to originate) in the minds of men, change the environment of men, and this changes the men. Of the two changes, it would be easy to say that the change made in the men is the more important; but would it be truthful to say so? We have already noted the curious fact that inventions have the faculty of self-improvement to a degree far greater than men have it; for the reason that each new man must begin where his last ancestor began, whereas each new invention begins where his last ancestor finished. This suggests that the changes produced in environment are more profound than the changes produced in men; that in fact the changes in environment are very profound, and the changes in men quite superficial. That this is really the case is indicated by the very long time needed to build up the environments of civilization, and the very short time needed for men to adapt themselves to those environments, or to any changed conditions. The fact has often been noted (sometimes with chagrin) that highly refined gentlemen adapt themselves with extreme facility to the often primitive environments of hunting or campaigning, and history shows in many instances how quickly barbarians have adapted themselves to civilization.

This leads us to suspect that the Machine which inventions have built up may not be of so much permanence as we are prone to think, and makes us realize that it is not a natural production but one wholly artificial. Now nothing that is wholly artificial can reasonably be expected to be permanent, unless adequate and timely measures are taken to insure it.

CHAPTER XI

INVENTION AND GROWTH OF LIBERAL GOVERNMENT. AMERICAN CIVIL WAR

WHILE the period from 1800 to 1850 was alive with inventions of many sorts, it was alive also with the economic changes which the inventions caused and with political changes also. It was in the United States of America that the greatest changes of all kinds came. This was to be expected from the fact that before 1800 the United States were considerably behind the countries of Europe from which their own civilization had been derived; whereas in 1850, they had been able to get abreast of them, by reason of the quickness of transportation and communication that ocean steamers gave, and the energy and enterprise of the new American nation. During the period from 1800 till 1850, the United States went through three successful wars; one with Great Britain, one with Algiers and one with Mexico. They expanded also over a considerably greater territory, acquired a much greater population, added new states, and showed such aptitude in scientific discovery and invention as to achieve a place in the first rank of nations in this particular.

The Constitution of the United States may be characterized as a great invention, in the meaning of the word which is used in this book; and until 1850, it had worked with a success that surprised many of the statesmen and scholars of Europe. The problems placed before the nation had been many, various and difficult;

but all had been solved with a sufficient degree of success for practical purposes; and the resulting situations had, on the whole, been met with courage, energy and intelligence. The Monroe Doctrine had been treated with respect, if not with entire acquiescence; the conduct of the Navy in the War of 1812 had demonstrated to Europe the fighting ability of our people; our scientific men, such as Franklin and Henry, ranked as high as any who had ever lived in any country; certain of our statesmen such as Franklin, held equal rank with statesmen anywhere; and the invention and first use of the electric telegraph had put America ahead of every other country in inventions of a basic kind.

When we realize the rapid growth of the United States in the half century 1800-1850, and realize also that it was a growth almost *ab initio,* and note that the engineering materials of all kinds and all the knowledge of science in the country had come from Europe, we must admit that it is to the influence of invention, more than to any other one thing, that we owe the rapid progress of our country. As is the case with individuals, nations are prone to extol their own successes, and to take the entire credit for them. Americans are apt to thank themselves only for their amazing progress; but, in fairness, they should admit that without the inventions made in Europe and by Europeans, they would have had no means for even starting. The first locomotive used in the United States was brought from England.

In Great Britain, the wars with France were under full headway in 1800, and her statesmen knew that she was faced with a danger so great that only the most strenuous exertions, and the utmost naval and military skill could overcome it. This danger was not overcome till the Battle of Waterloo in 1815. Thereafter, the progress of the nation was fairly quiet and assured, the main difficulties centering in the deplorable condition of the working classes, serious disturbances in Ireland and the mutiny in India.

In few matters has the influence of invention been greater than in the relations between Great Britain and India. In 1564 a company called the Merchant Adventurers had been formed for competing with the merchants of Spain, Venice, Holland and other countries. A company coming into existence shortly afterward was the East India Company, formed for trading with India, Persia, Arabia and the islands in the Indian Ocean. The company was chartered by the Crown and had a monopoly of a certain territory. The object was that the company should not only make money for itself, but promote the welfare of Great Britain and her subjects, by taking out manufactured goods, and bringing back raw materials and coin. During the seventeenth century, naval wars took place with Holland, and in the eighteenth century with France; both originating in commercial and colonial rivalry—especially in regard to India. Both wars were won by Great Britain. The Seven Years' War in particular ended to the advantage of Great Britain, as regards India; for France was left with only a few trading stations. By 1773, the East India Company was in virtual control of India; but in 1784 William Pitt secured political control of it by the Government. Napoleon realized the importance of India and sent an army there to recover control, but without success. The Crimean War that began in 1853 between Russia and Turkey was joined by Great Britain in 1854 because she feared that Russia would flank the British route to India through the projected Suez Canal. This war ended to the advantage of Great Britain, and the danger to India was removed.

Now the whole area of the United Kingdom of

Great Britain and Ireland is only about 121,000 square miles, while that of India is about 1,803,000, nearly fifteen times as great. The population of the United Kingdom in 1917 was about 45,370,000, while that of India was about 315,156,000, or nearly seven times as great. Yet Great Britain has secured the complete mastery of India! How has she been able to do it? The easiest answer would be that the British are a "superior" people. Even if they are, such an answer would explain nothing, unless the means be indicated by which the superiority was made effective in conquering India. The superiority evidently did not consist in courage or physical strength, which were obvious factors in achieving the victories in the field that were necessary, for those qualities were shown equally by the Indians. But if we should answer that the British succeeded for the reason that they could bring to bear superior weapons, equipments, means of transportation, means of communication, methods of organization and methods of operation, we evidently would explain what happened adequately and convincingly Now all these facilities the British had available; they had been invented and were ready.

One of the important influences of invention on history therefore, has been to give Great Britain control of India.

In France, the changes in economic and political conditions rivaled the changes that one sees take place in Sir David Brewster's kaleidoscope. In 1800 Napoleon had been First Consul, in 1804 emperor, in 1814 an emperor and then an exile, in 1815 an emperor and then an exile. France was a kingdom from then until 1848, and then a republic till 1852, when she again became an empire, under Napoleon III. The virtual anarchy following the Revolution had been crushed out and replaced with order; and the menace to republican institutions had been removed by the genius of Napoleon I, who then established an autocracy of a kind that, though arbitrary, was so wise and broad-viewed as to be beneficent on the whole. The result of all was that in 1850, France was in a condition of civilization and prosperity that was amazing to one who remembered the conditions of 1800.

When we analyze the causes of the evolution of order and prosperity out of the conditions of 1793, and the later conditions of 1800, we can hardly fail to realize the greatest single cause was the same cause as that of Napoleon's victories. It was the mind that conceived and developed and brought forth; the mind that invented so amazingly.

That many other causes may be named need hardly be pointed out. In the complex affairs of human life, every result is the resultant of many causes; but in most of those affairs, most of those causes are always present; so that we have to find an unusual cause to explain an unusual condition or event. It would be easy to say that the cause of France's return to a condition of law and order was that the condition of anarchy was abnormal; and that France simply returned to her normal state, as a wave does after it has risen above or fallen below the level of the sea. But would this be true? Is the condition of anarchy more abnormal than the condition of law and order? Which was the condition of primitive man? Which is an artificial product of man's invention? Is it not logical to conclude from the record of invention's influence that it was man's inventions that brought into existence the artificial condition of law and order which existed in France prior to 1793, and that it was also man's inventions that restored it afterward? Three ideas were conceived in France and developed into the Revolution: these ideas were the principles of equality, of the sovereignty of the people and of nationality. After the overthrow of Napoleon, the Congress of Vienna met to readjust the affairs of Europe. The Congress seems to have conceived the idea of preventing the carrying out of those principles as their first starting point, and to have developed that idea with fixed determination. The Commissioners endeavored to restore everything to its condition before the Revolution, and to discredit the principles conceived and developed in France. They succeeded in accomplishing their intent, so far as remaking political boundaries, etc., was concerned; but they did not succeed in discrediting the principles. A great picture had been made in the minds of men, and the Commissioners could not wipe it out. As a result, three revolutions took place in 1820, 1830 and 1848, of which the second was more important than the first, and the third was more important than the second.

Shortly after the fall of Napoleon, the Czar Alexander, with the emperor of Austria and the king of Prussia, invented the Holy Alliance. It was in pretense an alliance to advance the cause of religion, and to reduce to practice in political affairs the teachings of Christ; but it was in intention a league against the spread of the ideas embodied in the French Revolution. The League was not successful in the end, for the picture of liberty made in the minds of men was too brilliant and too deeply printed to be wiped out. One of the results of the Holy Alliance was the invention by the United States of the Monroe Doctrine which was made to prevent that intervention in affairs on the American continent which the proceedings of the Alliance foreshadowed.

Italy was very harshly treated by the Congress of Vienna, two of her largest provinces in the north being given to Austria, who forthwith proceeded then to try to control the entire peninsula. In 1820, a revolution broke out in Italy, but it was soon suppressed. Another broke out in 1830, simultaneous with that in France; and this was also suppressed. The third, in 1848, met a similar fate. But the revolutions in France were successful; the one of 1848 resulting in the formation of a republic. At the same time, a sympathetic revolution in Germany was in a measure successful also.

In Germany, the formation of the German Confederation in 1815 by the Congress of Vienna was the formation of a kind of political body that has never lasted long; for no political body has ever lasted long, except an actual and definite nation. The various components of the German Confederation were too loosely bound together. This invention, like others of mechanical machines, was not a practical invention because the machine invented was too easily thrown out of adjustment. The Customs Union was invented in 1828 to supply the necessary element of coherency. It was hardly adequate for its task, at the time; but it made the people think of national union; an idea that was finally developed in 1871.

In Russia, considerable progress was made from 1800 to 1850, though not so much as in the countries farther west. An adequate reason would seem to be that there were too few minds, in proportion to the entire population, that were able to conceive and develop the ideas that are needed to make progress.

During this half-century, while the names of many men stand out as having done constructive work in invention and discovery, and while many great statesmen existed, the names of three statesmen stand out more brightly than the rest: Pitt, Talleyrand and Metternich. Each had the mind to conceive, develop and produce; and each did conceive, develop and produce. Of the three, William Pitt was, according to almost any accepted standard by far the greatest, and Talleyrand was second. Without the force and guidance of such a mind as Pitt possessed and utilized, it is hard to estimate what would have been the rôle of England in the Napoleonic wars, and what would have been her fate. In the actual course of events, it was England that announced the "mate in four moves" to Napoleon at Trafalgar, and that finally checkmated him at Waterloo. True, Pitt died long before Waterloo; but the policy which he conceived and developed was the policy which was followed; and the influence of his mind lived in almost unabated strength after his poor, frail body had ceased to live.

Talleyrand seems to have been what I have asked permission to call an "opportunistic inventor"; quick to conceive, develop and produce plans for meeting difficult situations as they arose, but without any ultimate objective, or any moral or other principles of any kind. Metternich, on the other hand, though lacking the brilliancy of Talleyrand, exerted his talents devotedly to the interests of his country, as he saw them. But he failed to realize how deep the ideas of the French Revolution had been engraved in the minds of men, and finally saw the Machine of the Austrian Government almost destroyed in 1848. He himself was forced to flee; and the Emperor was forced to abdicate in favor of his nephew, who granted the people a Constitution, in order to save the Machine. In Prussia, affairs went almost as far as in Austria, though not nearly so far as in France. The Machine in Prussia was saved by the promise of the granting of a constitution.

The main ultimate political result of the agitations of all kinds during the half century 1800 to 1850, was the granting to greater numbers of people of a part in directing the affairs of State. In France, the whole Machine of Civilization had been menaced with destruction in the years just previous to 1800; but destruction had not resulted, and actual improvement had been begun by 1800, though in an experimental and tentative way. During the fifty years now under consideration, the idea conceived and developed in France spread to all other civilized countries; and in all those countries it exercised its benignant influence, especially in the new nation across the Atlantic, the United States of America. Reciprocally, the news of the formation of that republic, and the adoption of its Constitution in 1787, had exercised considerable influence in giving support to the idea of the people of France, although the United States of America was very far away indeed, and her experiment in government was as yet untried. Then, as the years went by, between 1800 and 1850, and as the American experiment became increasingly successful, and as the ocean steamships brought prompt and adequate information about all of its developments, the American idea joined with the French idea, to advance the cause of government by the people.

It may be pointed out here that the discoveries in the physical sciences and the utilization of those discoveries in the invention of material instruments and mechanisms were more fruitful in creations of a permanent and definite character than were the achievements of statesmen, generals, admirals and "opportunistic inventors" in general. The same remark is true of discoveries and inventions in systems of government, ethics and religion. These also have developed monuments of extraordinary permanency; witness, for instance, the inventions of the kingdom, of democracy and of the Buddhist, Shinto, Taoist, Jewish, Christian and Mohammedan religions. The distinctive feature in securing permanency seems to have been the intent to secure it. The sudden conception, development and production of a campaign, political maneuvre or business enterprise, seems to have produced a creature that was merely a temporary expedient, adapted only to meet emergencies that themselves were temporary.

This does not mean that the influence of these temporary expedients has not sometimes been great: it does not mean, for instance, that the influence of the victory at Salamis was not great. It does not mean to deny the plain fact that it has been the succession of the results of temporary expedients that has brought affairs to the condition in which they are today. It does mean, however, that the actual pieces of the existing Machine of Civilization are the permanent inventions which have been made; while the opportunistic inventions have in some cases prevented, and in other cases have furthered, the making of those inventions, and the incorporation of them in the Machine. The invention of printing, for instance, produced an actual part of the Machine; while the successful wars waged by civilized nations with the gun against savages, barbarians and peoples of a lower order of civilization, made possible the further development of printing, and its continual use in upbuilding the Machine. The use of the opportunistic inventions seems to have been in assisting the inventors of permanent creations and in directing the efforts of the operators of the Machine.

An analogue can be found in the case of the invention, development and operation of the smaller machines of every-day life: the inventor of each machine merely invents that machine; when he has done this his work is virtually finished. When his machine is put to work (say, an electric railroad) the operators carry on the various routine tasks; just as the president of a bank operates his bank, or the president of a nation administers the affairs of the nation. But there arise occasions when something goes wrong, when something besides supplying coal and oil and electricity is necessary for the successful running of the railroad, when something more than routine administration is required of the president of the bank, or the president of the nation. Then the ingenious and bright mechanic or electrician invents a practical scheme for circumventing the difficulty with the railroad; or Napoleon invents a campaign to save the French Republic.

In 1855 Taupenot made the important invention of dry-plate photography, by which dry plates can be prepared and kept ready for use when needed, and Michaux invented the bicycle. Both of these were fairly important contributions of a practical kind; so was Woodruff's invention of the sleeping-car, and so was Perkins's discovery of aniline dyes, both of which came in 1856. None of these was a brilliant invention, though each was a useful one. But they were immediately followed by one of a high order of brilliancy and usefulness, Siemens's regenerative furnace, in which the waste heat of the combustion gases was utilized to heat the air or gas just entering. In the same year, Kingsland invented a refining engine for use in making paper pulp. In the following year the first ocean-going iron-clad ship of war, *La Gloire,* appeared, and in 1858 the first cable car, invented by E. A. Gardner.

In the same year Giffard invented his famous injector, which performs the feat (seemingly impossible at first thought) of using steam at a certain pressure in a boiler to force water into that same boiler against its own pressure! The explanation of course is that the area of the stream of water that enters the boiler is less than the area of the stream of steam that leaves the boiler. This invention was one of a very high order of brilliancy of conception, excellence of construction and usefulness of final product. It was a valuable contribution to the Machine.

In the same year Cyrus Field of New York succeeded in laying the first Atlantic cable between Ireland and Newfoundland. It is difficult to declare whether this achievement constituted an invention or not, and it may not be so classed by many people. Nevertheless, it created something that had not existed before, and it progressed by the same three stages of conception, development and production by which all inventions progress. It was a contribution of enormous value to the Machine, moreover; for though the first cable was not a practical success, and though the second cable broke while being laid in 1865, it was recovered and re-laid and afterward operated successfully. Since that time, submarine cables have been multiplied to such an extent that there were more than 1800 in operation in 1917, and they formed a network under all the seas. Such important parts of the Machine of Civilization have these submarine cables become that the Machine as it is could not exist without them. That is, it could not have existed before the wireless telegraph came. The wireless telegraph has made the Machine less dependent on submarine cables than it was before, and yet not wholly independent.

In 1858 the *Great Eastern* was launched, the largest steamship built up to that time. The case of the *Great Eastern* is interesting from the fact that she was too large to fit in the Machine as it then existed, and that by the time that the Machine had grown large enough the *Great Eastern* was obsolete!

About 1859, Kirchhoff and Bunsen invented the spectroscope, an optical instrument for forming and analyzing the spectra of the rays emitted by bodies and substances. In 1860 Gaston Planté invented his famous "secondary battery," formed by passing an electric current through a cell composed of two sheets of lead immersed in dilute sulphuric acid, the two sheets separated by non-conducting strips of felt. The acid being decomposed, hydrogen formed on one plate, while oxygen attacked the other plate and formed peroxide of lead. There being now two dissimilar metals in an acid solution, a Voltaic battery had been created, that gave a current which passed through the liquid in a direction the reverse of the current ("charging current") that had caused the change. Planté's secondary battery was an important and practical contribution to the Machine; but the credit for the basic invention does not belong to Planté, but to Sir William Grove, who had invented the "Grove's gas battery." In this battery, two plates of platinum were immersed in dilute acid, and submitted to a charging current that decomposed the liquid and formed an actual though practically ineffective "secondary battery"; the two elements being oxygen and hydrogen.

In the next year Philip Reis invented the singing telephone, by which he could transmit *musical tones* over considerable distances. Whether or not Philip Reis invented the speaking telephone has been a much controverted question, for the reason that speech was occasionally transmitted over Reis's telephone,—though not by intention. The invention that Reis conceived, developed and produced was a singing telephone only; the apparatus by which he sometimes transmitted speech was his singing telephone, slightly disadjusted. That Reis should have failed to invent the telephone is amazing, in the same sense that it is amazing that Galileo did not invent the thermometer and the barometer; and the fact is extremely instructive in enabling us to see distinctly what constitutes invention. To make an invention, a man must himself create a thing that is new, and produce it in a concrete form, such that "persons skilled in the art can make and use it." Reis did not do this: and yet

Philip Reis's telephone could be made to speak in a few seconds, by simply turning a little thumb-screw! Reis did not know this, and consequently could not give the information to "persons skilled in the art." Reis did not invent the speaking telephone, for the fundamental reason that his original conception, although correct for his singing telephone, was wholly incorrect for a speaking telephone; because the speaking telephone requires a continuous current, while Reis's conception included an intermittent current.

Apologies are tendered for going into what may seem a technicality at such great length; but the author wishes to utilize this example to emphasize the importance of the original conception, the image pictured on the mind by the imagination. This original conception is of paramount importance in making inventions, not only of material mechanisms, but of all other things that can be invented, such as religions, laws, systems of government, campaigns, books, paintings, etc., etc. The final product cannot be better than the original conception, except by chance; for even if the development be absolutely perfect, the invention finally brought forth can be only equal to the original conception. It is obvious that the simpler the invention is the more easily it can be made equal to the original conception, and vice versâ. For this reason the stethoscope is a more efficient embodiment of the original conception than is that very inefficient product—the steam engine.

The fact that the final product cannot be better than the original conception (except by chance) is the bottom reason for placing men of fine minds at the head of important organizations. It is the ideas conceived by the man at the head in any walk of life, that are developed by his assistants: at least, this is the intention, in all organizations, and the only efficient procedure. We see an analogue in the actual life of every individual. Now the conception is the work of the imagination, and not of the reasoning faculties: the reasoning faculties develop and construct what the imagination conceives. It is because of this that men of fine mentality sometimes devote their talents to evil ends: their imaginations have conceived evil pictures. Sometimes this is the result of a bad environment in childhood. The environment of Talleyrand's childhood, for instance, caused the conception in his imagination of evil aims.

In 1860 Carré made the important invention of the manufacture of ice with the use of ammonia. In 1861 Craske improved stereotyping by making it possible to reproduce curved printing plates from flat forms of type. Green invented the driven-well in the same year, and McKay invented the shoe-sewing machine.

The most important event of 1861 was the outbreak of the Civil War in America, when the invention of the American Constitution was put to its severest test. It had been known ever since the adoption of the Constitution that the instrument was faulty in not defining clearly the relative rights of the Federal Government and the separate states; but it had been found impossible to secure the assent of a sufficiently large body of citizens to any proposition that defined them clearly; and so the machine of Government had operated for nearly three-quarters of a century, with the disquieting knowledge in the minds of its operators that conditions might put it to a test that would break it down, and perhaps destroy it totally. The most dangerous condition was seen to be the one associated with the question of slavery in the Southern States. This question, and the consequent condition of antagonism between the North and the South, became rapidly worse during the period from 1846 to 1861, when war between them finally broke out.

The war was ultimately decided in favor of the North, despite the fact that the South was much the better prepared; in fact, that the North was wholly unprepared. The main weakness in the Confederate situation was the fact that cotton was virtually the only product with which she could raise money for feeding and equipping her army, that she had to get the equipments from Europe, and that the line of communication to Europe was across the Atlantic Ocean, 3000 miles wide. The weakness seemed, during a period of about twenty-four hours, to be removed by the invention of the iron-clad *Merrimac;* for the *Merrimac* destroyed the *Cumberland* and *Congress,* two of the finest warships on the Union side, without the slightest difficulty in one forenoon, and threatened the destruction of all the other Union ships. The Union ships having been destroyed or made to flee to port, complete freedom from blockade of the Confederate coast would follow immediately. The *Monitor* had been invented years before; but no steps had been taken to build her, despite the insistence of the great inventing engineer, John Ericsson. News of the work of constructing the *Merrimac* had reached the North, however, and stimulated the northern imagination to the extent that it was able to see in the *Monitor* a savior (and the only savior) from the *Merrimac.* By the exercise of amazing engineering skill, Ericsson constructed his invention with such speed and precision that the *Monitor* was able to meet and defeat the *Merrimac* the very day after she had destroyed the Union ships.

The result was an immediate and absolute reversal of conditions. It was the North now that controlled the sea and the South that was to be blockaded. And not only this; for the fact that the North possessed a warship that was not only the most formidable in the world, but was of such simple construction that many of them could be launched in a very short time, showed to those European powers who were deliberating as to whether or not they should recognize the Confederacy, the futility of their attempting to carry into effect on the American coast any naval policy of a character unfriendly to the United States. The victory of the *Monitor* was the announcement of the "mate in four moves." Victory for the South became immediately impossible, no matter how long the final checkmate might be delayed. We know, of course, that checkmate was delayed until April 9, 1865, when Lee surrendered to Grant at Appomattox.

In few cases has the influence of invention on history shone more clearly than in the case of the *Monitor*. The *Monitor* was the deciding factor in the Civil War. This does not mean that the *Monitor* alone won the Civil War. No one event or person or maneuver won the Civil War: for the Civil War was won by the resultant effect of many events, persons and maneuvers. It does mean, however, that the victory of the *Monitor* made it virtually impossible for the issue to be otherwise than it eventually was; provided, of course, that a course of conduct not wholly unreasonable was pursued by the North. All the other factors in the war were what might be called usual: the *Monitor* alone was unusual. The *Monitor's battle was the only battle in which the light of genius shone, on either side.*

The *Monitor's* victory emphasizes a truth previously pointed out in this book: the truth that the influence of invention has been to advance the cause of civilization, by giving victory in wars, as a rule, to the side possessing the higher civilization. This was clearly the case in our Civil War; for the South was far more an agricultural and primitive community than the North. It was for this reason that Ericsson lived in the North. We can hardly imagine Ericsson coming from England and going to live in the South; for the simple reason that Ericsson, the dynamic, inventive Ericsson, could not possibly have lived a life even approximately satisfying to him in the South. There was no opportunity in the South for him to exercise his powers. It has been said sometimes that the *Monitor* might have been produced by the South, and the *Merrimac* by the North. Of course, anything is possible that is not wholly impossible; but history shows that inventions have, as a rule, been produced by people like those of the North, and not by people like those of the South.

The influence of invention on history has been to bring about such victories as that of the *Monitor* over the *Merrimac;* and the influence of those victories has been to enhance the advantages possessed by the more highly civilized. Furthermore, the victory of the more civilized has given civilization greater assurance in its struggle to go still higher, just as defeat has made it pause and sometimes retreat. The issue of the Civil War, for instance, was more than a victory over slavery and the tendency to dissipation of energy by a division into two parts of the forces of the country; for it removed permanently a highly injurious obstruction and started the rejuvenated republic along that career of progress which it has followed since so valiantly.

In 1861 E. G. Otis invented the passenger elevator. Possibly this was not an invention of the first order of brilliancy, but certainly it was an invention of the first order of utility. Can anyone imagine the New York of today without passenger elevators? The Otis elevator has not made it possible to grow two blades of grass where one blade grew before; but it has made it possible to operate hotels and office buildings of more than twice as many stories as could be operated before.

Few inventions have had more immediate influence on contemporary history than the passenger elevator.

In the same year was invented the barbed-wire fence. The production of carbide of calcium followed in 1862, and also the invention of the Gatling gun. This was the first successful machine gun, and an invention of a high order of brilliancy of conception, excellence of construction and practical usefulness. Few inventions have been more wholly unique than this machine: so beautiful and harmonious and simple in principle—though devoted superficially merely to the killing and wounding of men. Like all inventions in the gun class, it contributed to the self-protectiveness of the Machine.

An invention in a similar class, smokeless gunpowder was invented by Schultze in 1863, for use as a sporting powder. Being based on the action of nitric acid on cellulose, it was somewhat like gun-cotton, and therefore a chemical compound; rather than a mechanical mixture like the old gunpowder. It gave out but little smoke when fired. Smokelessness would be such an obvious advantage in military operations, that the study of this powder was prosecuted carefully, with a view to obtaining a smokeless powder suitable for military purposes. This was accomplished in 1886 by Vieille in France. The invention of smokeless powder was not one of a high order of brilliancy for the reason that it was the result of a long series of painstaking investigations and not of any luminous idea. It was nevertheless a contribution of the highest usefulness to the self-protectiveness of the Machine, and therefore to Civilization.

In 1864 Behel invented the automatic grain binder, an invention of the same class of practical and concrete usefulness as McCormick's reaper, and a distinct contribution to the Machine. It expedited the binding of grain, tended to insure accuracy and efficiency, and stimulated the agricultural classes to a study of mechanism, and therefore of physics and the arts depending on it. In other words, this invention performed the double service that many other inventions have performed, of contributing to the material necessities of men, and inspiring their intellects as well. In the following year, Martin invented his process for improving the manufacture of fine steel.

In the same year (1865) Lister brought out his method of antiseptic surgery. It would be difficult to specify any invention which has contributed more in half a century to the direct welfare of mankind. It has effected such a change in surgery as to make the surgery before Lister's time seem almost barbarous. It made a greater change in surgery than any change ever made before: one is tempted to declare that it has brought about a greater change in surgery than all the previous changes put together. Now, it is interesting to realize that all these changes, extending over all the civilized world, and affecting countless human beings, were caused by "a mere idea." They were caused by a picture made by the imagination of Lister on his mental retina, that must have covered a very small area of his brain. It is interesting also to realize that if that part of his brain had become impaired from any cause, the picture could not have been imprinted there. And was his brain always in condition to receive such a picture, or only seldom? Knowing as we do that even the most brilliant minds are brilliant only rarely, may we not infer that conditions of the brain permitting such pictures as this of Lister occur but rarely?

It was also in 1865 that Bullock invented his web-feeding printing press, and Dodge invented the automatic shell-ejector for firearms. In 1866 Siemens and Martin invented the open-hearth process for steel making, Burleigh the compressed air rock-drill, and Whitehead the automobile torpedo.

The Whitehead torpedo was an invention of the highest order of brilliancy of conception; but, unlike many other inventions of this class, it has been a matter of the utmost difficulty to develop it. The possible usefulness suggested was so great that the principal European nations, especially the Germans and English, went about its development at once; but the practical difficulties encountered were so many and so great, and the opportunities of testing out its usefulness in actual warfare were so few, that it was not until after its successful and important use in the war between Russia and Japan in 1904-1905, that the torpedo was accepted as a major weapon. This invention is one of the most important contributions ever made to the self-protectivity of the Machine of Civilization; not only because of its immediate usefulness in war, but because its complexity necessitates such skill and knowledge in the operators, and its cost is so great, that only the most wealthy and highly civilized nations are able to use it successfully. As has been pointed out repeatedly in this book, one of the influences of invention on history has been to urge nations to a high degree of civilization, under pain of greater or less subjection to nations more highly civilized.

In 1866 Wilde in England and Siemens in Germany invented dynamo electric machines, in which the magnetic field was made, not by permanent steel magnets, but by electro-magnets of soft iron that were energized by the current which the machine itself produced. This was an invention of the utmost practical value; but who was the actual inventor does not seem to be exactly known. Its main value is in its ability to produce a much more powerful current than could be produced when using permanent magnets; caused by the fact that electro-magnets can create a "magnetic field" much stronger than steel magnets can.

In 1867 Tilghman invented his sulphite process for pulp making, and in 1868, Moncrief invented his famous disappearing gun-carriage. This was an invention requiring a high order of conception and constructiveness; it resulted in a considerable improvement in the art of sea-coast defense, and therefore in the self-protectiveness of the Machine, by keeping the guns safe behind fortifications except when actually being fired. Moncrief's carriage, although originally very good, has been improved upon from time to time; whenever the progress of the mechanic arts has made it possible, and some inventor has realized the fact.

Attention is here requested to the last clause in the last sentence. As civilization has progressed and various inventions have been made, the whole field of possible future invention has been narrowed, but a field of clear though limited opportunity has been mapped out. Each invention narrows the field by removing the opportunities for making that especial invention: after the printing press had been invented, for instance, the number of possible inventions was reduced by one; but see what a field for future invention was mapped out, and what immeasurable opportunities were suggested! Nevertheless, opportunity does not produce inventions, it merely invites them; and we have occasionally noted in this book that the opportunity to make a certain invention had existed for ages before it was realized: for instance, the sewing machine and the little stethoscope.

In 1868 Sholes invented what is usually considered the first practical typewriting machine. The machine that Thurber had invented in 1843 had never been developed to a practical stage, and, consequently, it was not itself a direct contribution to the Machine.

Whether it paved the way for Sholes's is a debatable point; if it did, it was an indirect contribution, like Hero's engine. Not for several years after 1868 did the typewriter take its place in the Machine: but now it plays an exceedingly useful, if not conspicuous, part in making it operate day after day.

In the same year Nobel contributed another of his notable inventions, and called it dynamite. It was the development of an exceedingly brilliant and original idea; and, as often happens with conceptions of that kind, it was easily developed into a concrete, usable and useful thing. It consisted merely in mixing nitro-glycerin with about an equal quantity of very finely divided earth. The resulting mixture was much less sensitive to shock and therefore much safer to handle than nitro-glycerin. It supplied the factor needed to render the utilization of nitro-glycerin possible, and therefore it was a valuable contribution to the Machine. In the same year, Mege invented oleomargarine, a comparatively inexpensive substitute for butter, and therefore an important factor in furthering the health and comfort of the poorer classes and a considerable forward step.

Shortly after 1866, Mrs. Eddy declared to many people that she had made a discovery which enabled her to cure the sick with Divine aid, and without the use of drugs. She healed many people and gradually gathered followers. In a few years, she developed a religion that is now called Christian Science; and in 1875 she published a book called "Science and Health, with Key to the Scriptures." Since then, the number of her followers has increased enormously, and Christian Science Churches have been erected in all the civilized countries of the world. Though the doctrines of Christian Science have not been accepted by many Christians, the great opposition directed toward them at first has now been largely overcome; and it is admitted by most fair-minded people that Christian Science seems to have made an important contribution to the spiritual, mental and physical welfare of mankind.

In 1868, Westinghouse made his epochal invention, the railway air-brake. It was the result of a brilliant mental conception that was put into practical form without very serious difficulty. At first sight, this invention might not be considered of very great importance, because one might assume that its only office was to prevent collisions and consequent loss of life and property. Doubtless that was its only direct effect; but its indirect effect was to increase the confidence of the people in the safety of railway travel, consequently the number of people who traveled, consequently the prosperity of the railway companies, consequently the faith of people in railway investments, consequently the number and magnitude of railway projects, consequently the number and length of railways, consequently the speed and general excellence of transportation and communication over the land in every civilized country, and consequently the coherency and operativeness of the entire Machine.

CHAPTER XII

INVENTION OF THE MODERN MILITARY MACHINE, TELEPHONE, PHONOGRAPH, AND PREVENTIVE MEDICINE

IN 1866, one of the most important inventions of history was put to test, in a war between Austria and Prussia. The invention was the Prussian Military Machine, of which the inventor was von Moltke, the Chief of Staff of the Prussian Army. Moltke was not the original inventor of the Military Machine, any more than Watt was the original inventor of the steam engine; but he was the inventor of the modern Military Machine, just as Watt was the inventor of the modern reciprocating steam-engine.

Moltke had been made Chief of Staff in 1858, and had proceeded at once to embody an idea that his mind had conceived some years before. This idea was to utilize all the new inventions of every kind that had been made, especially in weapons, transportation and communication; and to continue to utilize all new inventions as each reached the useful stage, in such a way that the Prussian Army would be an actual weapon, which could be handled with all the quickness and precision that the products of modern civilization could impart to it. Philip of Macedon, Julius Cæsar, and Frederick William of Prussia evidently had had similar ideas; but no one after them, save Moltke, seems to have realized fully that armies and navies must utilize all the new methods and appliances that can be made to assist their operations, if those armies and navies are to attain their maximum effectiveness. It is true that no very great changes in arms or in methods of transportation and communication had recently taken place, at the time when Napoleon went to war; but this only emphasizes the new conditions with which Moltke was confronted, and the courage and resourcefulness with which he met them.

Moltke's Machine was, of course, much more comprehensive and detailed than the paragraph above would indicate; but almost every machine, after it has been perfected, is comprehensive and detailed, even if the original idea was simple. It is true also that the direct means which Moltke employed to perfect his Machine was to train officers to solve independently certain problems in strategy and tactics, just as children at school were taught to solve problems in arithmetic. It is true also that more attention has usually been fixed on Moltke's system of training than on his utilization of inventions, and it may be true that Moltke himself fixed more attention on it. But the idea of training officers as he did, seems also to have been original with Moltke; and it is certain that Moltke was the first to develop such a system, and therefore, that he was the inventor of that system.

We see, therefore, that Moltke made two separate inventions, and combined both in his machine. Both inventions were condemned and ridiculed, but both succeeded. The result was that, when war was declared in 1866 between Prussia and Austria, a reputedly greater nation, the Prussian machine started smoothly but quickly when the button was pressed, advanced into Austria without the slightest delay or jar, collided at once with the Austrian machine, and smashed it in one encounter. This encounter was near Sadowa and Königgrätz, and took place only seventeen days after war began. The most important single invention that

Moltke had utilized was the breech-loading "needle gun," a weapon far better than the Austrians had, not only in speed of loading, but in accuracy. The two armies were not very different in point of numbers: so that, even if von Moltke's other measures had not been taken, the superiority of the Prussian musket over the Austrian must of itself have caused the winning of the war, though not so quickly as actually was the case.

But in the war with France, Moltke's machine demonstrated its effectiveness even more completely, because its task was harder. For France was esteemed the greatest military nation in the world; it was the France of Napoleon the Great, then ruled by his nephew Napoleon III. In the usual sense of the word, the French were a more "military" people than the Prussians. The Empire of Napoleon III was much more splendid than the poor little Kingdom of Prussia, the army was more in evidence, there were more military pageants, the people were more ardent. But the military leaders of the French included no such inventor as von Moltke, there was no one who conceived any such ideas as were pictured in Moltke's imaginative brain; and consequently it never occurred to anyone to utilize strenuously all the new inventions, or to train officers like school boys, in the practical problems of war. The result was that Moltke's machine got into France before the French machine had been even put together. The pieces of the French machine had not been got together even when the war ended. When war was declared by France, her military machine was in three parts. Two of them got together fairly quickly, so that the French machine was soon divided into only two parts; one under Marshal Bazaine, and the other under Marshal McMahon. But Moltke's machine was together at the start, and it stayed together throughout the war. This does not mean that all its parts stood in the same spot; but it does mean that the parts were always in supporting distance of each other. The two parts of the French machine were not in supporting distance of each other, and the German machine prevented them from uniting. When McMahon and Bazaine tried to unite, McMahon was defeated at Wörth, and Bazaine at Gravelotte. McMahon was forced to surrender his entire force, including the emperor at Sedan; and Bazaine was shut up in Metz. Paris was then besieged. Bazaine was soon forced to surrender and Paris to capitulate.

The main immediate result was the establishment of the German Empire. A later result was the establishment of what is sometimes called militarism. Of the two, the latter was probably the more important in future consequences; for the influence of Moltke's conception of military preparedness has been to make all civilized nations keep up enormous and highly organized military and naval establishments, under pain of being caught unprepared for war and beaten to subjection.

The German Empire has vanished, but militarism has not vanished. There seem to be no signs that it will soon vanish, for it is simply part of a general preparedness movement that embraces many fields of life, that is necessitated by the existence of this cumbrous Machine of Civilization, and that is advanced by the realization that everyone must cultivate foresight. The physicians tell us, the financiers tell us, the lawyers tell us, the clergymen tell us, even the business men of every day and the housewives tell us that we must continually look ahead and continually prepare to meet what may be coming. Now this is what Militarism urges as applied to the coming of war. Militarism is the doctrine of preparedness for war; it holds the same relation to national health that preventive medicine does to individual health. It would make us do many unpleasant things, and refrain from doing many pleasant things. But to do many unpleasant things and to refrain from doing many pleasant things is necessary, in order to lead even a moderately virtuous and prudent life. Militarism may be pushed to an undue extreme; but so may any course of conduct.

It may be interesting to note that Moltke was not an "opportunistic inventor," like most men of action typified by Napoleon, but that Bismarck was. Moltke made inventions of a permanent nature, but Bismarck did not. Yet Moltke was a soldier and Bismarck was a statesman. Bismarck's German Empire has already passed away, but Moltke's method of preparedness is with us still, and is gathering more and more prestige as the years go by. Judged by the standard of permanent achievement, Moltke was a greater man than Bismarck; though a belief to the contrary was held during their lifetimes, and is generally held by most men now.

In 1870, Gramme invented the famous Gramme dynamo-electric machine, which was so excellent a machine for producing a smooth and unidirectional electric current, that it gave the start to that wonderful succession of electrical inventions which established the Age of Electricity. The main part of Gramme's machine was a modification of the Pacinnoti ring, invented by Pacinnoti in 1862, which seems never to have been put to practical use, and never to have been heard of by Gramme. The Pacinnoti ring consisted of a ring around which a continuous coil of wire was wound. This ring being rotated in a magnetic field, the various parts of the wire at any instant lay at different angles to the lines of force, instead of at the same angle to them, as was the case with the flat coil of previous dynamo machines. The result was that some coil was always cutting the magnetic lines-of-force at the maximum speed, while others were cutting them at varying speeds, down to zero; so that the aggregate of all was approximately the same at all instants. The result was that the current was nearly uniform in strength. The influence of this invention on subsequent history need hardly be pointed out; for it is impressed on us every day and every night, in every part of the civilized world.

In the same epochal year that ushered in the Franco-Prussian War and the Gramme machine, the Hyatts invented celluloid. The invention was of the simplest character, involving mainly the compression of camphorated gun-cotton by hydraulic or other force. This was not a great invention, but a useful one; making it possible to fabricate many useful articles at low cost.

In the following year of 1871, Goodyear invented his welt shoe-sewing machine and Maddox made his epochal discovery. This was that when nitrate of silver was added to a solution of gelatine in water containing a soluble bromide, silver bromide was formed, which did not subside even after long standing; that the emulsion could be made quickly and in large quantities, and that by thus substituting gelatine for collodion on the surface of glass plates used in photography, greater sensitiveness, and therefore, greater speed could be obtained. This led to an important improvement, and paved the way to others, and thus became the basis of rapid photography.

By 1871 the work of several inventors had produced a press that printed an endless sheet of paper on both sides and folded it automatically. In the same year Ingersoll invented his compressed air rock drill. In 1872, Lyall invented his positive-motion weaving loom, and Clerk Maxwell propounded his electro-magnetic theory of light. According to this theory, luminous and electric disturbances are the same in kind, the same medium transmits both, and light is an electro-magnetic phenomenon. This was a most important invention in the field of physical science, and is now accepted by the majority of scientists. It is not so applicable to the needs of men at the present moment as the weaving loom; but in the future, it may be more so.

In the same year, Westinghouse invented an improvement on his original air-brake that made it automatic under some conditions, and in the following year Janney invented the automatic car-coupler. Both of these were brilliant inventions, though not nearly so brilliant as Clerk Maxwell's. They were immeasurably more important, however, from the standpoint of material contributions to the Machine. One result was that the inventors were immeasurably more rewarded in a material way than was that great mathematical physicist, Clerk Maxwell.

In the same year of Our Lord, 1873, Willis invented his platinotype photographic process, in which finely divided platinum forms an image virtually permanent, and Edison invented his duplex telegraph. This was the first of those wonderful inventions that made Edison famous; and it embodied possibly as brilliant an idea as he ever conceived. The principle was exceedingly simple, and consisted merely in using currents that increased in strength as the key was pressed to actuate an ordinary electro-magnet for one message, and using currents whose direction was reversed when the key was pressed, to actuate a polarized relay for another message. By combining this scheme with one long before proposed, of putting the receiving instruments across the arms of a Wheatstone Bridge, the entire system could be duplicated, and two messages sent at the same time in each direction. This, of course, constituted quadruplex telegraphy.

In the same year, Gorham invented the twine-binder for harvesters, Bennett improved the gelatine-bromide process of Maddox; and Locke and Wood invented the self-binding reaper. In 1874, Glidden and Vaughan invented a machine for making barbed wire, and Sir William Thomson invented his super-excellent siphon-recorder for receiving messages over the Atlantic cable. This invention combined the three elements that constitute a great invention; brilliancy of conception, excellence of construction and concrete product. It was of immediate usefulness also, which a great invention may not necessarily be. But Sir William Thomson was a "canny Scot," a good mechanic, and a man of the world, as well as a mathematical physicist of the highest order; with the result that even on his loftiest flights, he held tight to a string that connected him to the earth, and that kept his flights within the regions of the practical and immediate. His siphon-recorder was very much more sensitive to electric currents than any recorder ever invented before; a quality which made feebler currents utilizable, decreased induction and therefore increased speed. Coming when it did, and coming because Sir William Thomson saw a need for it, it was a great and important contribution to submarine telegraphy, and therefore to the Machine; for the Machine has now become very large and complicated, and needed the best possible communication among its various parts. Some of these parts were far distant from each other.

In the following year, 1875, Brown invented his cash-carrier. This was not so brilliant or important an invention as Sir William Thomson's; but it can hardly be doubted that a hundred thousand times as many cash-carriers and their children, cash-registers, have been made as siphon-recorders. In the same year, Lowe invented his illuminating water-gas; Wegmann his roller flour mills; Smith his middlings purifier for flour; and Pictet his ice-machine. The last four inventions were of that distinctly practical kind that contribute directly to the operativeness of the Machine, by facilitating the conditions of living in large communities, and make great cities possible. Of the four, the invention of Pictet was the most brilliant and scientific, and the least directly useful.

In 1876, Bell made an invention that is usually conceded to be the most important of modern times, and that was also of the highest order of brilliancy of conception, excellence of construction and concreteness of result. The invention was that of the speaking telephone.

The telephone is not in the class with the actual doers of things, like the weaving machine and the gun, but rather in the class with the telegraph and the typewriter, in being an assistant to the doers of things: that is, it is an instrument rather than a machine. This does not mean that a machine is more important than an instrument, though possibly machines have done more work directly in furthering civilization than instruments have. A machine does something itself; an instrument is a means or agency or implement with which men do something. As a class, machines have probably been more directly useful than instruments; but this does not mean, of course, that any machine that one may name has been more useful than any instrument. A machine (generally speaking) does only one class of work; the sewing-machine, for instance, does no work save sewing; while such an instrument as the telephone is an aid to men in directing the work of thousands of machines.

It may be pointed out here that, in the broad meaning of the word instrument, every machine that does actual work is an instrument in the hands of men for doing that work; but that every instrument is not necessarily a machine. A machine, by definition, is composed of various parts that work together to a common end, and it carries with it the ideas of movement and of power. An instrument, on the other hand, need not be composed of more than one part; it may of itself be incapable of moving or exerting power; and yet, in the hands of men and women, it may be the means of doing the most useful work. A familiar illustration among many is the needle.

Now the telephone can hardly be called a machine: it can of itself do nothing. It is not like an engine that can do work hour after hour, without external interposition, supervision or assistance. Yet, for the reason that the only value of a machine lies in the fact that it is an instrument whereby men can get results, an instrument is not necessarily in a lower class than a machine.

The essential value of the telephone seems to lie in the fact that the Machine has become so complicated, and composed of so many separate parts, that, without the telephone, those parts would not be adequately linked together. The telephone, like the telegraph, acts in the Machine of Civilization as do the nerves in the human organism. The human organism could not be an organism without the nervous system; and the present Machine could not exist in its present form without the telegraph and the telephone. These two instruments have so greatly improved the Machine as to raise it toward the dignity of an organism. They have not made it an organism, because they have not endowed it with life. They have, however, raised it to the dignity of an automatic machine, by supplying such a ready and sure means of conveying information and instructions, that a blow to the Machine anywhere is felt everywhere, and assistance to the part attacked can be summoned from everywhere.

Illustrations of this can be seen the most clearly in our large cities, in which information concerning a fire, or a riot, or an accident is transmitted instantly to all parts of the city; and fire engines, police or ambulances are sent in response thereto. Illustrations covering wider fields come to mind at once; but they are of the same character, whether the fields comprise single states or continents or seas, or the whole surface of the earth. Possibly the best single illustration is that supplied by the events of the recent World War, in which the nerves of civilization in every land were kept on the tingle by the news continually received from the fighting fronts, and measures were continually taken to meet each situation as it occurred. Australia and New Zealand and America and Canada and South Africa assisted France to repel the invader from her soil.

The influence of the telephone on history has been so great that history would not be at all as it has been, if the telephone had not been born. Has this influence been beneficent? Probably, because it has tied the parts of the Machine together, and made it more coherent. But it may be well to realize that this very fact has had the effect of permitting other additions to the Machine; with the result that the Machine is perhaps no more coherent now than it was when the telephone was added to it. Furthermore, we must not forget that, although the influence of each new invention is usually to assist civilization rather than to assist its enemies, yet we cannot assume that 100% is exerted on that side, for a considerable percentage is always exerted on the other side. For instance, the printing press is used to disseminate harmful teachings as well as beneficent teachings, the telephone is used for bad purposes as well as good ones, etc.

We must not restrict our appreciation of the influence of the telephone by ignoring the stimulation which it has given to study and experiment, especially in the physical sciences. People of the present day do not realize the amazement and excitement caused throughout the world by the sudden realization of the fact that human speech could be transmitted. Coming as it did so soon after the invention of the Gramme dynamo, it waked the minds of men with a sudden start, and opened a dazzling avenue of anticipation of discoveries and inventions yet to come. Young men, and especially young men of fine ambition, saw ahead a clear line of useful and brilliant work; and the colleges and technical schools were soon thronged with eager youth. A new epoch—the electric epoch—was at hand.

The most generally noticed herald of the new epoch was not the telephone, however, but the "electric candle" invented by Jablochkoff in 1876, which soon afterward came into use in Paris. This candle consisted of two parallel sticks of carbon separated by an insulating substance, made of some refractory material, that fuzed as the carbons gradually burned away. The two carbons were connected to an electric circuit that passed from the tip of one carbon to the tip of the other, causing a brilliant electric arc. To prevent one carbon wasting away more rapidly than the other, an alternating current was employed. This great invention is now almost forgotten, because it was soon supplanted by the present arc-light that is better in many ways. Nevertheless, to Jablochkoff must be accorded the distinction of being the first to make electric lighting on a large scale practicable, and to demonstrate the fact.

In the same year, an invention of more than doubtful beneficence was made, a machine for continuously making cigarettes; but this was balanced in the same year by the inventions of the steam saw-mill and of Portland cement.

In the following year came an invention fully as brilliant as the telephone, though not so useful, the phonograph. It is usually considered as more brilliant; certainly it was more unexpected. The idea of transmitting speech was very old, many men had worked on it, and many were working on it at the time when Bell accomplished it; but the idea of recording speech was almost undreamed of. Up to the present moment, it can hardly be said that the phonograph has had great influence on history; for its main work has been in giving pleasure by the music it has rendered. We can easily imagine the present Machine, without the phonograph, but not without the telephone.

And we cannot imagine the present Machine to exist without the gas engine, invented the same year by Dr. Otto, that made possible the use of large units of mechanical power, without the need of boilers or condensers or other external appliances; for the combustion of the fuel was carried on inside the engine itself. This invention has been followed by many others during the forty-five years that have since gone by, in which oil has taken the place of gas. Petrol or gasolene has been the oil (or spirit) most used; but engines of the Deisel type, employing heavy oils, have now come into being in large numbers.

It is easy to underestimate the influence of the gas-engine, or oil-engine (usually called the internal combustion engine), as is proved by the fact that most people do so; despite the evidence of its importance on all sides, in the shape of submarine vessels, automobiles and similar vehicles. Its most important single effect has been to make possible the aeroplane, and all the science and art of aviation, and the consequent conquest of the air.

In the same year of 1877, Edison made his great invention, the carbon telephone transmitter, which increased enormously the effect of the voice in varying the resistance of a telephone circuit, and thereby increased the loudness of telephone speech. In the same year, Berliner invented the induction transmitter, which consisted of a primary coil of small resistance in circuit with the transmitter and the secondary coil connected to the outside circuit. These two inventions, added to Bell's original invention, made the telephone of today—in its essential features.

In 1878, Edison produced his incandescent lamp, in which a carbon filament, enclosed in a bulb exhausted of air, was heated to incandescence by an electric current. The importance of this invention need hardly be even mentioned. As to the originality of the conception, there are many opinions; for several experimenters had been working in this field, and many brilliant results had been achieved. Important as this invention was, we can imagine the Machine to exist without it, though not in quite so perfect and complete a form. Its main use is its obvious use; though there can be no doubt that the improvement it wrought in the conditions of comfortable living, and the attractions it offered to ambitious youths enlisted a large army in the study of the physical sciences, gave impetus to all the mechanic arts, and assisted in many important ways the upbuilding of the Machine.

In 1879, Appleby invented the automatic grain-binder, and Sir William Crookes made his epochal discovery of cathode rays. This discovery, like many others of a highly scientific character, was not of immediate practical value; consisting as it did in the fact that if the poles of the secondary circuit of a Rhumkorff coil were connected to the two ends of a glass tube from which nearly all the air (or other gas) had been exhausted, a stream of electrified particles was projected from the cathode, or negative pole. These particles were evidently projected with great violence; for if they struck the side of the tube, they produced a brilliant illumination there; while if they struck a piece of metal they developed heat. If the metal were sufficiently thin, it was melted. Later study of these cathode rays developed the fact that the stream of charged particles could be deflected by magnetic and electric fields, thus showing that they had actual physical mass; and still later studies resulted in that mass being determined, and also the amount of the electric charges on them. To an individual particle the name electron was given; and the interesting fact developed that the mass of an electron is only about one-thousandth that of an atom of hydrogen.

This is not very exciting news to men whose time is consumed in the engrossing occupation of earning a living; but scientific facts have a curious habit of lurking in the background, sometimes a long while, and then suddenly stepping up to the footlights in the form of facts or inventions of a kind that are exceedingly important,—even from the standpoint of making a living, or at least of enduring the conditions of living. The study of electrons, for instance led the way to the discovery of the beneficent X-rays, made in 1895 by Röntgen.

The first electric railways, like the first railways of any kind, were laid in mines; for the superiority of electricity over steam for use in the unventilated spaces of mines was obviously greater than in the open spaces on the surface. The first one was in the mines at Zankerode in Germany and was constructed by the famous Siemens Brothers. The first electric surface railway was built at Berlin in 1879. It was about three hundred and fifty yards in length, and laid upon wooden sleepers; an auxiliary rail being fixed midway between the two main rails. The auxiliary rail carried the electric current, which was taken off by a brush connected to the electric motor on the car, from which it went to the rails that acted as the "return." The similarity between this system and that now used in all our cities is striking, and shows how practically and scientifically good the first electric railway was.

To estimate correctly the influence of the invention of the electric railway would be, of course, impossible, especially on partially developed countries; for the electric railway assisted greatly in developing them. It seems possible, however, that the electric railway may be of not very long life, for the reason that the internal-combustion-engine possesses the same great advantage of smokelessness that the electric motor does and makes possible the use of a much simpler system than electric railways necessitate. The fact that any invention is displaced by a later one does not, of course, detract from the merit of the invention displaced, in having supplied the needed stepping-stone for the other one to rise from.

In the same year, Foy invented the steam plow, and Lee invented his magazine rifle. In the following year (1880) Blake invented his telephone transmitter, an improvement of a practical character over preceding ones, Greener invented his hammerless gun, and Faure invented his electric storage battery.

The Faure storage battery was a very important invention, but not nearly so important a one as was at first supposed. It was an improvement on Planté's battery, and consisted mainly in applying red lead and litharge directly to the positive and negative lead plates, before sending any charging current through the liquid; thus expediting the making of the battery very greatly. The invention was hailed with extravagant rejoicings, even Sir William Thomson being carried away from his habitual equanimity; but serious practical difficulties soon developed that are familiar to most of us, and that have never yet been overcome.

In 1880, Koch and Eberth isolated the typhoid bacillus, and Sternberg the pneumonia bacillus. The importance of these two discoveries is not usually appreciated by any but physicians and those who have suffered from these diseases and been cured. Even those who have been saved from having them, especially those in armies who have been saved from having typhoid fever, fail to realize their debt. But the almost perfect immunity from typhoid fever enjoyed by all the enormous armies of the vast World War, compared with the frightful distress and mortality caused by typhoid fever in previous wars, bears eloquent witness to the influence of the great discoveries of those tireless investigators.

It may be pointed out here that of all the inventions and discoveries ever made, those made in medical and surgical science, especially in preventive measures, have had more direct and immediate influence on history than contemporary inventions in any other field, save possibly religion. For what is history but the life-story of the human race; and what greater influence can be had than influence upon the health of its component members? The discoveries and inventions made in the field of bacteriology especially, by gaining knowledge concerning the unseen and unheard foes that attack us from within, have lifted civilized man up to a condition of cleanliness and purity, in comparison with which the conditions under which our forefathers lived seem almost repulsive.

It is true that many of these conditions were outcomes of civilization itself, and that for some of them medicine has merely found the antidotes. Yet the fact that medicine has found antidotes shows that medicine has been keeping pace with progress and has invented measures for preventing the Machine from poisoning itself by a sort of auto-intoxication. That the Machine is in danger of disruption by outside and inside forces has been suggested frequently in this book; so that what seems to be indicated as desirable is a series of discoveries and inventions that will prevent it. But, in attempting this, we must not forget that each new discovery or invention adds another part, that safety devices are sometimes so intricate as to increase the danger element rather than lessen or prevent it, and that safety appliances themselves are apt to get out of order, and thus lead to a false sense of security. These reflections force on our attention the fallibility of the human, the necessity for continuous study of all situations as they successively develop, and the solemn fact that progress is not beneficial of itself; for it may be in the wrong direction.

One obvious fact that we have always realized, startles each one of us occasionally; the fact that "people do not know what is good for them." The appetites and instincts of undomesticated brutes are said to be much more trustworthy as guides than those of domesticated brutes and human beings. We, by cultivating our imaginations and reasoning powers, and the brutes by being given food and shelter that they themselves do not have to get, seem to have lost a considerable part of the instinctive abilities with which we were originally blessed. With human beings, many objects that most of us aim for are extremely artificial, and some of them are extremely harmful. An illustration is the craving for much food and little physical labor,—

a craving that is gratified almost at once by most people suddenly achieving wealth, with consequences that are always deplorable and are frequently distressing.

Of course this comes from excessive yielding to our appetites; but the brutes seem to feel no temptation to excessive yielding; an undomesticated brute seems to know when he has had enough. We not only yield, we go further and force our appetites. Possibly this is only an illustration of the fact that our minds have a sort of inertia, comparable to the inertia of physical objects; so that when we move in any direction, we are apt to go too far. That it is a tendency of human nature to go too far in any line of conduct, when once it is entered on, the facts of daily life continually testify. What reformer in public or private life ever knew when to stop; what money maker ever realized that he had enough money and ceased his efforts to get more? A small percentage have, but only a small percentage.

For this reason and others, the human machine and the Machine of Civilization do not get along together as harmoniously as might be wished. Though many inventions, especially the basic ones, have been actually uncontrollable acts of self-expression, many others have been inspired by motives largely selfish, such as the wish to gain fame, or power or money (or fame *and* power *and* money); and the result is a Machine that contributes more to man's material well-being than to his moral, mental or spiritual well-being, and a consequent civilization that is necessarily artificial. The net effect, however (unless all our standards are wrong), has been beneficial; for it cannot truthfully be denied that physically, mentally, morally and spiritually, the civilized man is better than the savage, and to a degree commensurate with the degree to which he is civilized.

Probably most civilized men would agree to this proposition. Probably most of them would also agree that civilization brings its evil influences as well as its good influences, that the Machine has been found vulnerable to destructive influences in the past, that the ultimate effect must be judged from its influences on human beings, and that the most beneficent inventions and discoveries have been those that tend to the safety of the Machine itself and the spiritual, moral, mental and physical health of the individual humans who comprise its principal parts. They will therefore applaud such discoveries as those of Eberth, Koch and Sternberg of 1880, and also another one of Koch and one of Pasteur two years later. Both of these benefactors then isolated deadly microbes of disease: Koch the bacillus of tuberculosis, and Pasteur that of hydrophobia.

In 1881, Reece invented a button-hole machine and Schmid a hand photographic camera. Both of these were useful inventions if not brilliant. It would be interesting to know the amounts of money realized by their inventors, compared with the amounts received by Koch, Pasteur and Sternberg. In 1884, by the way, Koch made another epoch-making and beneficent discovery, and isolated the bacillus of cholera. Loeffler did the same thing, in the same year for diphtheria, and Nicolaier for lockjaw; while Kuno produced antipyrene.

In reflecting on what these great men accomplished, it is interesting to point out to ourselves that the consensus of opinion seems to be that, for most people, "the pursuit of happiness" is the main business of life. Whether this ought to be or not, should not distract our attention from the fact that it really is. To most of us—at least to those of us who are young—happiness seems to lie in the thing pursued, provided the pursuit succeeds. We all seek the crock of gold at the end of the rainbow, and imagine that if we get it, we shall get the *summum bonum* of everything — happiness. Yet all one has to do is to remember how happy he was one day when he was feeling well physically, morally, mentally and spiritually (as we all have at rare intervals), to realize that happiness is merely a condition,— and that it is a condition that depends more on *the condition of his own machine than on all other things put together.* When one observes the action of a fine trotting horse, the smooth and noiseless motion of a large steam-engine, or the majestic setting of the sun; or when he hears the harmonies of some great musical composer, or the grander harmonies of the ocean-breakers on the beach; or when he ponders on the inconceivably swift but God-like regularity of the stars and planets, he may get a faint and brief conception of what it means for a machine to be in order. Our human machines are rarely in this condition: but sometimes, without any assignable cause whatever, one takes a deep, full breath, and says, "It is good to live."

The men just spoken of, and the great teachers of truth in all ages, in even a higher degree, admonish us to keep our machines in order, and tell us how to do it.

How not to do it, the world and the flesh and the devil tell us unceasingly; beguiling us, as the serpent beguiled Eve, to eat; to gratify one and all the appetites of the senses, regardless of the effect on the machine inside. For we know those senses ought to guard our intake valves, but do not.

Why cannot some one invent a device that will automatically regulate our intake valves? Such an invention would prevent us from eating too much, drinking too much, and smoking too much, and also from eating, drinking and smoking things detrimental to the machine, and injurious to our happiness; and even from taking in sights and sounds and thoughts of an unhealthful kind. This might be followed by another invention that would regulate our outgo valves, and put a brake on our speech, our ambition, our acquisitiveness, etc. But would not these take from us our God-granted free will? Yes, in great measure. But such is the effect of the Machine of Civilization. The primeval savage lived—(and the primeval savage still lives) in a condition of almost perfect liberty, as do the beasts that perish: but in the vast Machine of Civilization, we are only tiny parts. Each of us, it is true, has a little freedom of motion; but it is like the "lost motion" of a loose part in a crude or ill-constructed engine; and it seems to be growing smaller and smaller, as the Machine grows larger and improves.

CHAPTER XIII

THE CONQUEST OF THE ETHER—MOVING PICTURES—RISE OF JAPAN AND THE UNITED STATES

IN 1884, Mergenthaler invented the linotype machine, in which matrixes for casting different type were moved successively into line, by pressing the corresponding alphabetically marked keys on a keyboard, and the whole line then moved to the casting mechanism and cast. This was an invention of the most clean-cut and perfect character; following clearly the processes of conception, development and production, and resulting in an improvement in the art of printing of a most important kind. Few inventions embody such a brilliant and original conception, such excellent constructiveness and such a useful product. So perfect was the result, and so clear was the conception that preceded it, that one marvels that some one had not invented it before. Why make matrixes for type, then cast the type, then space the type individually one after the other in line, and then stereotype them as they stand in line, when it is so much easier simply to place the matrixes in line and then stereotype the matrixes? The influence of this invention is of the same kind as the influence of the invention of the art of printing from movable type, because it is an improvement in that art. All over the world this invention, or inventions suggested by it, are used by the newspaper and book publishers, with the result that the quickness and accuracy of printing are much enhanced, and the work of co-operating the parts of the Machine thereby facilitated.

In the same year Marble increased the safety of the bicycle by his invention of the rear-driven chain, and Schultz invented his chrome process of tanning leather. Both of these were important in their way; but in 1885 Cowles made a more important invention, that of reducing (and thereby producing) the metal aluminum from its oxide, called alumina, the chief constituent of clay. The usefulness of aluminum lies largely in its extreme lightness, and in the fact that when combined with certain metals, notably copper, it forms important alloys.

During the same year, Welsbach invented his gas mantle, a valuable contribution to gas-lighting, and Bowers invented his hydraulic dredge, in which the act of dredging a channel or harbor was accomplished by hydraulic power. In the same year, Van Depoele invented a practical contact appliance for use in taking off the current from the overhead wires of electric railways. In 1886, Bell and Tainter invented the graphophone, an important improvement on the phonograph, and Elihu Thompson invented electric welding. This was an epochal invention, inaugurating as it did an entirely new art, and contributing enormously not only to the quickness of welding, but to its accuracy and strength. Many improvements have been made on this invention during the past few years, that have increased its scope and value. Many articles are now made in one piece that is really solid, though composed of several parts: for those parts are so firmly welded together that the joints cannot be seen and are as strong as any other parts.

In the same year, Matteson invented his combined harvester and thresher. In the following year, Prescott invented his band wood saw, and McArthur and

Forrest invented their process of extracting metals (especially gold and silver) from ores by the use of a solution of potassium cyanide, and greatly cheapened the work. In the same year, Tesla invented his system of multi-phase electric currents, which rendered possible the economical transmission of power over long distances, of which the first use was made in transmitting power derived from Niagara Falls. This was another invention of the first order of merit in brilliancy and originality of conception, excellence of constructiveness and usefulness of result. Its value has been only dimly appreciated by most men, because the invention does not stand continually before our eyes, like the telephone and electric light; for it cannot be seen at all. It is not a machine or instrument (in the common use of those words) but a system, actually invisible of itself, that governs the method of design, construction and operation of the visible dynamos, motors and conductors. Like the germ of life, we see not it, but only its manifestations.

In the same year, Welsbach brought out an improvement on his incandescent gas-mantle that was valuable for cases in which a brilliant illumination was desired, that leaped almost immediately into public favor. In the following year of 1888, Sprague made the first installation of street electric railways in the United States, and the first in the world in which the conditions of operating were difficult. The success of Sprague's system was largely due to the excellence of Sprague's electric motor, which had the curious property of being designed on principles which the scientific men of those days declared to be wholly wrong. Sprague's reputation rests mainly on his electric railway; but, from the standpoint of the inventor, Sprague's invention of his electric motor was of a higher order than that of his electric railway.

In 1888, Harvey invented his process of making armor-plate. In the same year, Eastman and Walker invented the kodak camera, in which the novelty consisted mainly of a continuous roll of sensitized film, on which photographs could be successively made; and De Chardonnet invented his process of manufacturing artificial silk from threads that were made by forcing collodion through very small holes. These were important in fact; but in comparison with the discoveries in the realm of the actual ether made in the same year by Hertz, they were quite trifling.

These discoveries resulted from experiments with electric apparatus of the simplest and most inexpensive character, in a space near which sparks were passing between the two terminals of a Rhumkorff coil. It had been known before that each spark accompanied and therefore represented an establishment of equilibrium between the two oppositely charged terminals, and that each discharge was of an oscillatory character—as any readjustment of equilibrium always is. By means of a mere single wire, curved into a circle, except that the two ends were not quite joined, Hertz discovered that the space was filled with electric waves that were propagated in straight lines from the source (as light is) and accompanied with vibrations at right angles to the direction of propagation (also as light is); and also that the electric rays were refracted, reflected and polarized, as light rays are. Subsequent experiments with modified apparatus measured the velocity of the propagation of electric waves, and found that it was virtually the same as that of light.

To some, this may not seem a very important discovery, "from a practical standpoint"; and doubtless it is not, from the "practical standpoint" of some people, because it does not affect the amount of their worldly possessions, or their ease, comfort and pleasure. It was hailed with delight by scientific men, however; because not only did it support the electromagnetic theory of light, but the course of Hertz's work had demonstrated the suspected fact that the "receiver" of electric waves must harmonize in its electric dimensions with the transmitter, in order that the greatest amount of electric energy may be developed in the receiver; and it had thus given assistance to investigations then in progress on what we now call "wireless telegraphy."

Many investigators were now in the field, among whom was the humble author of these pages. Little real progress was made until, in 1891, when Branly announced his amazing discovery and utilized it in his amazing invention, called the "coherer." His discovery was that, if a tube containing metal filings be placed in the "field" of the spark of an electric machine, Leyden jar, or Rhumkorff coil, it (the filings) will become a conductor of electricity when hit by the electric waves; and that it will revert to its normal state as a non-conductor, if smartly tapped: the effect of the waves being to cause the separate particles to co-here and form a continuous metal conductor; while the effect of the tapping was to jar the particles apart. The first use of this coherer was in place of the ring that Hertz had used; but its value as an instrument of practical usefulness in achieving electric communication without wires was almost immediately perceived—and demonstrated.

The career of the wireless telegraph since Branly's great discovery has been as rapid, widespread and important as any other new agency has ever enjoyed, and possibly more so. That wireless telegraphy was a distinct invention may perhaps be questioned. If it was, who was the inventor? It is true that an invention does not have to be associated with any one inventor in order to have the right to be characterized as an invention; but in the case of the wireless telegraph, it seems safe to say that, although some of the separate steps toward its achievement were inventions, the final step was merely the adding together of these separate steps in a way that was perfectly obvious, and that several men accomplished almost simultaneously. As soon as Branly produced his coherer, the problem was thereby automatically solved. Every experimenter realized that it was merely necessary to use Branly's coherer, in place of any receiver previously used, and to "tune" the transmitting and receiving circuits into harmony.

The first man to make a practical wireless installation seems to have been Marconi, in 1896. As is well known, the distances over which messages can be sent has been increasing rapidly ever since, and so has been the number and the importance of the organizations using it, of which the largest are the various national governments themselves. The vast influence of wireless (or radio) telegraphy on the history of the great World War is too recent to need detailing, but possibly it may be well to call to mind the fact that the ocean cables were virtually all under the control of the Allies, and that "the wireless" was almost the only means that Germany had for receiving information quickly and sending instructions quickly beyond her own coast line. It was used by the Allies, however, almost continually in the controlling of their multitudinous naval units on the sea, and among those units themselves; and it made possible that prompt and harmonious action among numerous widely separated groups, that distinguished this war from all preceding wars. It would be difficult to determine whether the wireless lengthened the war by the assistance it gave to Germany, or shortened it by the assistance it rendered the Allies. In the early part of the war, when Germany was directing ships that were far away, it helped Germany more than it helped the Allies; but in the last years, when the Allies were fighting the submarines in the Mediterranean and North Seas, it helped the Allies more. In the main, it probably shortened the war considerably, by accelerating the operations.

This reminds us of the fact that the general effect of invention has been to make wars more terrible but more brief; and that the abbreviating effect is especially noticeable in inventions that increase the speed and safety of transportation and communication. Another effect of invention has been to make wars more widespread; for the reason that it links some nations together and creates antagonism between other nations, even if they are far apart. Larger and larger organizations are thus brought into being, not only as nations but as allies and confederates. In this way, Japan fought in Asia, in co-operation with her allies in France.

On the supposition that the Machine is going to continue to increase in size and strength and excellence, on the further supposition that the more highly civilized nations will continue to control the less civilized nations increasingly, the time may not be many generations distant when all the nations of the world will be divided into a very few groups, each dominated by one great nation; as the Middle Europe nations were dominated by Germany in the last war. As all the known world was once divided into two groups headed by Assyria and Babylon; at another time by Assyria and Persia; at another time by Greece and Persia; at another by Rome and Carthage, etc., and as at various times Europe also has been divided into two opposing groups of nations, so the whole known world may again be divided into two opposing groups of nations: —possibly the white and the yellow nations.

The clash of the fighting machines of two such vast organizations, perfected in power and speed as they doubtless will be as the years go by and inventions succeed each other, will surpass in grandeur anything yet dreamed of. It may never occur. *Never?* It may never occur; but something approximating it will occur, if history is to be as much like past history as history usually has been.

In 1889, Schneider invented his process of making nickel steel, and thereby effected an improvement in steel that was first utilized in making armor, and afterward in making other articles of many kinds. Hall invented a process of making aluminum during the same year. In the following year, Stephens invented his electric plough, and Mergenthaler made an improvement on his linotype machine. About the same time, pneumatic tires were attached to bicycles; and an invention of a most important kind, that had lain dormant for many years, was put to work at last. The inventor had long since died. Does he know that his invention is now used all over the civilized world? If so, does the knowledge give him pleasure?

One of the most unsatisfactory parts of an inventor's experience is the difficulty he has in making other men see the value of his inventions, combined with the fact that when the invention is finally adopted, his part in it is often forgotten, and sometimes intentionally ignored. This applies especially to inventions of a high order of originality, that are a little in advance of the requirements and knowledge of most men at the time, and that are looked upon as visionary and do not come into use for a considerable while. Many an inventor has endured a purgatory while trying to get a hearing for his invention, and yet been wholly forgotten when it was finally adopted. To make the matter worse, he has often been branded for life as a visionary, and remained so branded, even after the invention had been adopted because of which he had been branded. In other cases, manufacturers have stolen his invention and denied his claims, knowing that he was too poor to fight against them with all of their resources. In other cases, business men and lawyers have combined to induce him to sign papers of a highly advantageous character to the business men, but contrariwise to the inventor. In all of these cases, the matter has usually been the worse for the inventor in proportion to the high order of the invention: for the real inventor, like the real artist, is usually so absorbed in his thoughts that he cares but little (too little) for material gain. The case of the inventor who makes a business of inventing is somewhat different. He usually confines his efforts to making inventions that will bring in money, becomes an expert on nice points in patent law, discerns chances for circumventing existing patents while utilizing their basic principles, perceives opportunities for making the little improvements in detail that promote practicability, and becomes the kind of inventor who owns a limousine.

In 1890, Krag-Jorgensen invented the famous rifle of that name. In the following year, Branly invented the coherer mentioned on page 305, and Parsons invented his rotary steam turbine. The steam turbine was an improvement over the reciprocating steam engine for many classes of work, great and small. The first steam engine invented by Hero was a rotary engine, but it was of course, most uneconomical of steam. The first steam engine that was really efficient was the reciprocating engine produced by Watt. The greatest single defect of rotary engines has always been the loss of steam in going by the rotating parts without doing any work, a defect existing in only a small degree with the closely fitting pistons of reciprocating engines. In the turbines invented by Parsons and others about the same time, wastage of steam was prevented by various means that need not be detailed here, and smooth motion of the rotary engine at the same time secured. The greatest benefit accrued probably to ocean steamships, in which the absence of vibration, and the saving in weight, space and number of attendants required were features of great practical importance.

About 1890, Edison invented the kinetograph and kinetoscope, after a long series of investigations and experiments. These followed the experiments made by Dr. Muybridge some years before, in which he had taken many successive pictures of horses at very short intervals, by means of as many separate cameras, (twelve pictures in one stride for instance), and afterwards reproduced them in such a way as to show horses in rapid motion. They came also after Eastman's kodak, in which pictures could be taken successively, on a traveling film. In the kinetograph, only one object glass was used; and the film was drawn along behind it in such a way that, at predetermined intervals, the film was stopped and a shutter behind the object glass or lens was moved away, and a picture taken. The moving mechanism (at first the human hand) continuing in motion, the shutter was closed and the film was moved along a short distance, so as to bring another part behind the object glass. Then the same operation was repeated—and so on. In the kinetoscope, the operation was reversed, in the sense that the pictures taken were presented successively to the eye of the observer. In the first form, the observer looked at them through a peep-hole: but in the latter forms, the pictures have been thrown upon a screen—somewhat as from a magic lantern, and become the "movie" of today.

Here, again, we see an invention of the highest order in each of the three essentials—conception, development and production. No invention exists of a higher order. As to their use and usefulness, we are most familiar with them in moving pictures. Whether it is for the public good to produce so many shows for idly disposed men and women to spend their time in looking at, is perhaps a possible subject for enlightening discussion. But the moving picture is used for many purposes, especially for purposes of education and research, besides that of mere amusement, and will unquestionably be so used, more and more as time goes on. One of its most obvious spheres of usefulness is in making photographs of movements that are very rapid, and then analyzing and inspecting those photographs when presented very slowly, and when stopped. Another is in taking photographs of successive situations that have occurred at considerable intervals of time, and then presenting the pictures quickly, and thus showing a connected story. By dealing in this way with historical incidents, we can get a realization of the interdependence of those incidents that we cannot get in any other way, and see how cause has produced effects, and effects have come from causes. Similarly, the work of building any large structure can be shown by presenting rapidly a series of photographs taken at different stages; and so can the growth of a plant or animal, and almost any kind of progress.

Let us impress on our minds the fact that if we read any book, or witness any occurrence, or listen to any argument, or receive any instruction of any kind, the only value comes to us from the pictures made on our mental retinas and the permanence and clearness of the records impressed. Thus, any means that can impress us quickly with the most important pictures must be of the highest practical value, both in prosecuting studies of events, and in gathering conclusions from them. In fact, the kinetograph and the kinetoscope are simply Edison's imitation of the operations carried on inside the skull of each of us; for we are continually taking moving pictures of what we see and hear and read and feel; recording them on our own moving sensitized films, and bringing them before our mental gaze at our own volition and sometimes in spite of it.

In 1890, the author of this book patented "A Method of Pointing Guns at Sea" that has been adopted in all the great navies, under the name "Gun Director System." In 1891 he patented a modification under the name "Telescopic Sight for Ships Guns." These two inventions are used in every navy in the world, have increased the effectiveness of naval gunnery immeasurably, and have, therefore, been important contributions to the self-protectiveness of the Machine.

In 1893, Acheson invented his process for making carborundum, a compound of carbon and silicon, made in the electric furnace, and used for abrasive purposes; and in the same year Willson made carbide of calcium from carbon and quick-lime, also in the electric furnace. In 1895, Linde invented his process of liquefying air, and the first installation of great electric locomotives was effected: this was in the Baltimore and Ohio tunnel. In the same year, Röntgen made the epochal discovery of what he called by the significant name "X-rays," a name that still clings to them.

They were discovered by Röntgen in the course of his researches with cathode rays. His discovery was in effect that electric rays emanated from the part of the tube struck by the cathode rays. They were not cathode rays, though produced by them, and had the amazing property of penetrating certain insulating substances, such as ebonite, paper, etc., while not penetrating metals, except through short distances. Unlike the cathode rays, they were not deflected by magnets; and neither did they seem to be reflected or refracted similarly. Their most important property was that of acting photographically on sensitized plates, even when in closed slides, and wrapped carefully in black paper.

The greatest usefulness of the X-rays thus far made has been in photographing internal parts of the human body; for the rays pass through certain parts less readily than through other parts; through bones for instance, less readily than through soft parts. Fractures or displacements of bones can therefore be readily detected. So also can the formation of pus in cavities, and the appearance of abnormal products of many kinds. To this discovery we must give a rank as high as almost any other that we have noted in this book, though we cannot tell, of course, how long it will hold it. With mechanical and scientific inventions, as with books and poems and inventions of other kinds, the question of permanence of value or of usefulness cannot be decided until after many years.

One of the curious properties of X-rays is that of rendering the air through which they pass a conductor of electricity. So far as the author is aware, no invention of practical usefulness has yet been made, based upon this property.

In 1896, Marconi brought out the first practically successful system of wireless telegraphy, Finsen demonstrated the usefulness of certain rays of the spectrum for treating certain skin diseases, and Becquerel discovered what have since been called the Becquerel rays. In experimenting with X-ray photography, he found that a sensitized plate, though covered with black paper, was acted on not only by X-rays, but also by the metal uranium and certain of its salts; and he also found that the mere presence of uranium made the contiguous air a conductor, as did the X- or Röntgen rays. The amazement caused by the discovery of such undreamed-of properties, especially in so commonplace a substance as uranium had been supposed to be, can easily be imagined; and it is plain why strenuous efforts were made at once by scientific people, to see if other substances did not possess those properties also. As a result, it was soon found that other bodies did possess them. To those bodies that seem to possess the quality of radiating activities of certain kinds, the adjective *radio-active* has been applied. The most important radio-active elements are uranium, thorium and radium, of which the last is immeasurably the most active and important. Radium was discovered in 1898 by M. and Madame Curie and M. Bémont, while experimenting with the uranium mineral pitchblende. It seemed to some people at the time to challenge the theory of the conservation of energy, and to threaten the destruction of the whole science of Physics, by emanating energy without loss to itself. It has since been found, of course, that radium does give up part of its substance; that it disintegrates in fact, as a result of its emanations.

How great an influence the discovery of radium is going to exert, it is now impossible to predict with confidence; but it is manifest that the three successive and allied discoveries of cathode rays, X-rays and radium have introduced a new and growing science into the Machine; and it is seemingly possible that that science may, soon or tardily, ascertain the nature of the atom, and even teach us to divide it. It seems that an atom of radium does actually disintegrate, and by disintegrating give out energy. The energy it gives out is so enormous in proportion to the mass which gives it out, as to suggest to us an almost infinite source of available power, if other substances can be made to disintegrate. It is said that one gramme of radium can emit a quantity of heat of about 100 calories per hour; that is enough heat to raise 100 grammes of water a 1° centigrade in temperature, *by simply existing.* It is true that radium is the most expensive article in the world; but that is only because of the difficulties of obtaining it at present. Now if radium is so potentially powerful and disintegrates so easily, it seems possible that other substances less easily disintegrable could emit greater energy, if (or when) a means is discovered for disintegrating them.

The interesting question now suggests itself of what would happen if some man should some day discover accidentally a means of disintegrating—say carbon—and should unintentionally disintegrate a few tons of coal in Wall Street. We know what has happened at times when piles of explosives have been accidentally detonated. But explosives are merely chemical compounds, and, compared to atoms of radium are relatively microscopic in the energy developed when broken up. We remember the story of the commotion caused by the monk's experiment in making powder, when the mixture exploded and hurled the pestle out of the mortar and across the room. Imagine a few tons of carbon atoms exploding.

Sounds dangerous To me. Seems like someone could make an "A"-Bomb or Something.

In 1894 a war, long presaged, broke out between China and Japan. In 1854, when Commodore Perry went to Japan, and gave a virtual ultimatum that resulted in Japan's opening her seaports to the commerce of the world, China and Japan were on the same plane of civilization, though China was many times greater in area and population. But the people of Japan were different from those of China in the essential mental characteristic of imagination,—at least their rulers were. For those rulers, noting the superior power of the foreign war-ships as compared with theirs, and reasoning from this to the conditions of the countries that produced those war-ships, and that produced also the implements of war on board that were so much superior to the Japanese, made a mental picture of what would happen to Japan some day, when those war-ships should come to Japan and demand submission. To make such a picture did not require much imagination, maybe; but the fact seems to be that no other Asiatic nation, and no African nation, made it. Then the Japanese made another picture, that required imagination of a brilliant kind; and that was a picture of Japan learning the arts of the foreign devil, and then utilizing those arts to keep the foreign devil himself at bay.

To us, looking back on the perfectly clear record of performance that Japan has made since then, that performance may seem not very difficult either to attempt or to achieve. But no other nation in the history of the world has ever paralleled it, or even approximated it. To appreciate it, one must exert all the imagination of which he is capable, and see himself in Japan as Japan was in 1854, amid all the influences of the history and environment then prevailing, with all their accompaniments of ignorance, prejudice, inertia and racial pride. It is the consensus of opinion throughout the world that the performance of Japan since 1854 has been amazing. It is part of the humble effort of this book to show that, in all great achievements, the result should be attributed mainly to the estimate originally formed of the situation, and the decision (invention) made to meet it. "C'est le *premier* pas qui coute": the rest follow as results.

The war between China and Japan, and in greater degree the result of that war, give clear and impressive demonstrations of the influence of invention on history; because the victors were victors simply because they had taken advantage of the inventions made in Europe and America. There was no marked difference physically in favor of the Japanese. Whether there was morally, we have no means of judging. Was there a difference mentally? We have an excellent means of judging this,—the fact that the Japanese had made a correct estimate of the situation and come to a correct decision, while the Chinese had not.

In the war that occurred ten years later, between Japan and Russia, the influence of invention was even more clear and striking, for the reason that Japan was a virtually semi-barbarous country in 1854, while Russia was one of the five great powers of civilization and Christendom; and yet in exactly fifty years, Japan demonstrated her equality with Russia in the decisive court of war on land, and beat her ignominiously in the equally decisive court of war on sea.

Why? Because during that fifty years Japan had availed herself of the aid of invention more than Russia had done; with the result that when they went before the supreme tribunal, Japan had better methods, better equipment, better plans, better soldiers, better ships, better *tout ensemble.* The most important single item was the naval telescope sight invented by the author. That was the cause of the immeasurably superior gunnery of the Japanese at the decisive naval battle of Tsushima.

Concerning Japan's war with China in 1894, the same truths may be uttered, though not with quite so much emphasis; for the results had not been so startling. Both wars demonstrate the same principles, though in unequal degrees of convincingness. Both wars show that the influence of invention has been to build up a Machine which is powerful not only for peace but for war; to assist those nations the most that avail themselves of it with the greatest skill and energy, and therefore to spur ambitious and far-seeing people to the study of whatever knowledge the world affords. The study most clearly indicated is that of the resources of physics and chemistry, and the experiences recorded in history.

In 1897, Henry A. Wise Wood invented the autoplate, a machine for making printing plates previously made by hand, which multiplied fourfold the reproduction of the type page in printing plates. This invention facilitated and cheapened the cost of printing, and was therefore a valuable addition to the Machine.

In 1898 a war, giving us lessons similar to those of the Japanese wars, broke out between the United States and Spain. The disproportion of material resources was great, and was in favor of the United States. Yet in the early part of the sixteenth century, Spain had been esteemed by many to be the greatest of all the powers, while the territory later held by the United States was the wild domain of savages. Why had Spain fallen so far below a country so new, living three thousand miles away from the civilization of Europe? Because she had lost her vision; because she had become infected with the disease of sordidness which quickly-gotten wealth, especially ill-gotten wealth, has often brought to nations; because she had ceased to encourage such bright visions as she had encouraged in the days of Columbus and Magellan, and settled down in the torpor of unimaginativeness. The United States, on the other hand, had been seeing such visions and following them to learn what lay beyond; and had been embodying all that could be embodied in practical projects and machines and methods and instrumentalities of all kinds. The United States had been taking all possible advantage of the potentialities of invention, but Spain had not.

An important result of this war was the proof, and its utilization on a large scale in Cuba and other Spanish-American countries, that the mosquito is a carrier of the infections of yellow fever and many other diseases.

Hardly had this war finished, when a war broke out in 1899 between Great Britain and the Boer Republic in South Africa. It is an evidence of the important influence of invention that it was possible for Great Britain to wage effective war so far away, and finally to triumph. She triumphed mainly because of the superior power of her military machine; but she had been able to construct and to improve it continually by her persistent utilization of the possibilities of invention. The possibilities that she had utilized became especially conspicuous when the necessity came for transporting the necessary troops and guns and munitions and supplies over the vast ocean spaces intervening, and for handling them on a foreign soil; under conditions very novel, and against a wary and yet skilfull and aggressive foe.

This war had not closed when the Boxer rebellion broke out in China, and a lesson even more clearly marked was given to the world. For the Chinese Government was perhaps the oldest in the world and the Chinese nation the most numerous. The revolt grew out of a series of aggressions by certain European powers, especially Great Britain, Germany, France and Russia, that consisted in virtually appropriating under various pretexts, certain important positions and valuable pieces of territory in China. Because of the fact that China had lost her vision, and had not even been stimulated to realizing facts by the example of Japan, China was at this time an incoherent aggregation of separate states and organizations; though she was supposed to be a coherent nation, under the emperor in Pekin. Because of a lack of such a nervous system as was given to each civilized nation by its railways, mails, newspapers, telegraphs and telephones, China was a soft and almost amorphous mass; with no definite purpose and no strength, either external or internal. China was not a machine in any proper sense of the word, and was therefore incapable of any action of an effective kind. The result was that, although the cause of the Boxers was not only just but laudable, the whole movement resulted in a series of pitiful atrocities committed by the Boxers in Pekin, followed by a forced entry into that ancient capital by a few thousand troops from the principal civilized nations, and a quick and complete suppression of the entire revolt.

There, in Pekin, in the closing days of the year 1900, could be seen, in two contrasting groups, peoples representing the highly organized and effective Machine of Civilization on one side and its crude and ineffective predecessor on the other side. What was the cause of the enormous difference between the groups? In physical strength and size and courage, little difference if any was observable;—yet one went down before the other, like tenpins before a bowling ball. Some may say that the difference was due to the difference in race. Yet the Japanese were of the same race as the Chinese, and the Japanese troops were as markedly superior to the Chinese as were the troops of any other nation: in fact, it was the consensus of opinion that the Japanese troops were superior to all the others, except the German. Some may say it was because of the difference in religions. Yet the Japanese were of virtually the same religion as the Chinese. Of course, the paramount difference was in the degree of civilization. What was this difference in civilization due to? Clearly, it was due to numberless causes; but there seem to be two causes more important than the others: a difference in attitude toward the possibilities of invention, and a difference in what has been called "the fighting spirit."

But the fighting spirit and a receptive attitude toward invention are usually found together, though the fighting spirit may sometimes lie dormant in inventive and enterprising people; may lie dormant, even for considerable periods, when conditions are peaceful, and prosperity prevails. But Achilles—(so the legend runs)—dwelt at one time in hiding, dressed in woman's garb, quiet and unsuspected. Yet when suddenly the bugle rang, he grasped the sword and shield. So, in 1914, and for some years before, Great Britain, the United States and France slumbered under the narcotic spell of pacifism; yet when suddenly the German War Machine advanced upon them, each nation and all three nations together rose in quick and yet majestic armed reply, and proved their fighting spirit was not dead, although it had been sleeping.

CHAPTER XIV

THE FRUITION OF INVENTION

THE twentieth century was the fruition of all that invention had achieved during the ages of the past. When it opened, the world was a world far different from what it had been, even in times not long gone by. It was far different from the world of 1850, or even 1875; for many inventions had been made and utilized during the passing years.

The last quarter of the nineteenth century, the interval between 1875 and 1900, has been called the "industrial age," because of the great advances made in all industrial appliances, and the consequent advance made in the size and wealth and power of industrial organizations of all kinds. In especial, the organizations dealing with systems of transportation and communication, and with manufacturing the many appliances needed by them had expanded greatly. Other organizations had expanded also; for the improvement and extension of the means of transportation and communication rendered possible the existence and successful operation of organization in many branches of effort, to a degree impossible before. Cities grew in area and population; the buildings in size and especially in height; railroads increased in number, length of route and speed of travel; locomotives and cars grew commensurately; colleges, hospitals, churches, clubs, scientific bodies, benevolent societies—all seemed to take a start about 1875 and to grow at increasing speed, as year succeeded year. But the greatest single advance was made in ocean transportation; for the sea, by the year 1900, had become a plane across which steamers moved with a speed and a certainty and a safety, rivaling that of railway trains on land.

The factors most immediately and importantly to be credited with all these advances were the improvements in the steam engine, the electric telegraph, and the manufacture of steel; also the invention of the dynamo-electric machine, the electric light and the telephone. These factors had given such power and certainty and speed to the Machine of Civilization that the nations which joined it and became contributory parts of it, advanced rapidly in prosperity and wealth, both actually and also relatively, as compared with nations that did not.

In the year 1900, the great nations of the world were Great Britain, France, Germany, the United States and Japan. Of these Japan had advanced the most in civilization during the preceding half century, then the United States, then Germany, then Great Britain, and then France. The nation that had increased the most in territorial extent was Great Britain. In 1900, the British Empire, including India, covered about one-fourth of the whole surface of the earth. It comprised, besides Great Britain and Ireland, five self-governing colonies, the Dominion of Canada, the Commonwealth of Australia, the Union of South Africa, New Foundland and New Zealand, in addition to the 1,800,000 square miles of British India and her three hundred million people. France had "expanded" in both Africa and Asia; that is, she had conquered territory in those partially civilized continents. Germany had done similarly; and Russia had subjugated the nomadic and semi-nomadic tribes of Central Asia. The United States had taken only a little territory, that included in the Philippines and Porto Rico; for she had expanded her constructive energy and skill in developing the vast and fertile area within her own boundaries. Japan had expanded only slightly in actual territory; the exercise of her constructive talents being urgently required at home.

It may be declared that invention should not be credited with any of this expansion, for the reasons that to increase one's possessions is an instinct of human nature, and that the colonization of savage and barbarous lands has been a favorite activity with great nations always. True: but the inventions enumerated in this book, and the agencies which they supplied for going quickly, surely and safely to places far away; of taking to those places certain tools of conquest, such as guns and powder; and of supplying afterward to the conquered people finer conveniences of living, juster laws and better government of every kind, have been the effective means to an end that could not have been attained without them.

It may be objected that the principal factors in all of these achievements have been omitted, the commercial enterprise of the merchants, the farseeing wisdom of the statesmen, the valor and skill of the strategists, and (back of all) the courage and enterprise of the original explorers. That these have been omitted, is true; for the reason that this discussion is intended to point out only what invention has done. It is obvious that the main incentive of colonization has been commercial gain, and that the initiators of colonization schemes have usually been merchants. It is equally obvious that the statesmen are to be credited with the framing and execution of the measures needed to make any colonization scheme effective; and it is equally obvious that strategists and explorers did work without which no expansion whatever would have been possible. Nevertheless, it must be clear that the essential difference between the conquerors and the conquered, by reason of which the uncivilized were conquered by the civilized, lay in the aids which civilization had supplied to the civilized. Colonization and conquest have been going on ever since the beginning of recorded history and before; but from the days of Thutmose III in ancient Egypt until now, the conqueror and the colonizer have in almost every case been more civilized than were their victims. It is true also that savages have sometimes overrun civilized countries, and even conquered them, for Alaric captured even Rome: but up to the present time, the fruits of such conquests have not been permanent, whereas the fruits of colonization have been.

In 1900, then, the Machine of Civilization was in operation in all parts of the world; in the dark continent of Africa, the deserts of Asia, the wild regions of Australia, and even on the ocean. In fact, it was on the ocean that the Machine was operating with the most efficiency and effectiveness; for nowhere else are the power and the harmony of machinery of all kinds, inert and human, seen in such perfection as in great steamships on the sea.

We seem safe in concluding, therefore, that while invention was only one of many factors in bringing about the world-wide conditions that prevailed in 1900, invention was the initiating factor. It was invention that suggested to the explorer that he explore; to the merchant that he launch his enterprise; to the statesman that he encourage the merchant and assist him with wise laws; to the strategist that he make such and such plans, to meet the emergencies that arose. Finally, it was invention that made possible the actual transportation of explorers and merchants and troops to designated spots, and made successful the operations which ensued there.

But the Machine still continued growing. In 1900 Hewitt invented his beautiful mercury-vapor electric light, and in 1901 Santos-Dumont invented his air-ship and demonstrated its practicability by going around the Eiffel Tower in Paris in it and returning to the spot from which he started. This feat began that great succession of feats with dirigible balloons with which we are so familiar now, and which promise to be succeeded by a condition of world-wide transportation through the air.

In 1900, the author of this book patented the method of controlling the movements of vessels, which consists in using radio telegraphy. This invention has recently been brought to the stage of practicality by the United States Navy. It was utilized in July, 1921, for steering the Iowa when bombed by airplanes.

In 1903 came the first successful flight by areoplane, which was made by the brothers Orville and Wilbur Wright at Kitty Hawk, North Carolina. This was an epochal adventure; it inaugurated an age which is already called the Aerial Age, and which will bring about changes so vast that our imagination cannot picture them.

An interesting and instructive fact connected with this flight, and with the aeroplane in general, is that the aeroplane was not practicable and could not be made practicable before the internal-combustion engine had been invented and developed; because all preceding engines had been too heavy. This illustrates the fact occasionally adverted to in this book, that one of the most important factors in the influence of invention is that each new invention facilitates later inventions. *The influence of invention is cumulative.*

In 1905, Elmer Sperry invented his gyroscopic compass which is unaffected by terrestrial magnetism and points to the true north. In 1907, he invented his gyroscopic stabilizer which reduces greatly the rolling of ships, aeroplanes, etc.

Meanwhile, the endeavor to accomplish photography in color had been receiving persistent attention from many scientific experimenters, but without much practical success. The achievements of Becquerel, Lippman, Joly, Lumière, Finlay and others have doubtless laid the initial stepping stones; for color-photography by their efforts has been made an accomplished fact. As yet, however, the art is still in its infancy, and has not, therefore, reached the stage of maturity that enables us to estimate what importance it will eventually assume.

In 1908 Goldschmidt invented the thermit process of welding; thermit being a mixture of aluminum with some metallic oxide such as oxide of iron. When this mixture is ignited, the oxygen leaves the iron and unites with the aluminum, causing an enormous rise of temperature, and the consequent formation of molten iron. This molten mass being poured around the ends of two pieces or iron, welds them together at once. In the following year, Hiram Maxim invented his silencer for fire arms, by means of which the noise resulting from firing a gun is greatly lessened. How valuable a contribution this will be to the Machine, it is impossible at the moment to predict with confidence.

In 1910, Henry A. Wise Wood invented his printing press that more than doubled the speed of printing, produced a thousand newspapers of the largest size per minute, and directly enhanced the solidarity of the Machine.

In 1911 Glenn Curtiss produced his epochal flying-boat, Just and Hanaman invented the tungsten electric light, and Drager his pulmotor, for reviving persons who have been asphyxiated or partially drowned, by forcing oxygen into their lungs. The pulmotor has come into use to a surprising degree, and has already been established as a part of the Machine with a recognized value. It belongs in the class of remedial agents, about which nobody questions the beneficence, and for which everyone recognizes the debt of gratitude owed by mankind to the inventors.

In 1912, the author of this book invented the torpedoplane, a simple combination of the automobile-torpedo with the aeroplane, so designed that an aeroplane can carry a torpedo to a predetermined point near an enemy's ship and then drop it, while simultaneously operating the torpedo's starting mechanism: so that the torpedo will fall into the water, and then continue under its own power toward its victim. As the torpedo-plane combines the most powerful weapon with the swiftest means of transportation, many Navy officers think it an invention of the first rank of importance, that threatens to wipe all surface fighting vessels off the seas. During the World War, it played only a subordinate part, though it was used effectively by the British and the Germans. Our Navy did not use it at all, as Secretary Daniels rejected it. The British Navy has already adopted it as a major instrument of war, and constructed two especially designed fast vessels, each of which carries twenty torpedoplanes. It seems obvious that such a ship, if sufficiently fast to keep out of the range of a battleship's guns, could sink her without much trouble.

In the same year Flexner discovered his antitoxin for cerebro-spinal meningitis, and Edison invented the kinetophone, a combination of the phonograph and the kinetoscope. As yet, this has not been made to work with such complete success as to warrant its introduction into use. The probabilities seem to be that someone will eventually supply the link that is evidently necessary, and make the voice and the picture on the screen cooperate in unison as they should. Two years later, Flexner isolated the bacillus of infantile paralysis and Plotz that of typhus fever.

The World War that broke out in August, 1914, was marked with far greater utilization of new inventions than had marked any war before, and foreshadowed even greater utilization of new inventions in the next war.

The first evidence of any new appliance was a rain of heavy projectiles on the tops of the Belgian forts; the forts having been designed to resist projectiles on their sides. The projectiles, it was discovered later, came from mortars of a kind the existence of which had not been suspected. Soon after, the German submarines showed qualities of endurance and radius of action that bespoke new appliances; and then came attacks on the Allied troops with poison-gas that almost were successful. The Allies replied with new inventions, especially in wireless telegraphy and telephony, mines, "depth-bombs" and "listening devices;" the latter being employed under water to detect the movements of submarines. Many other inventions were almost on the point of practicality when the Armistice was signed, but were not quite ready; showing what had often been shown before, that inventions for use in war, like all other preparations for war, should be complete ready for use, before the war begins.

As soon as the war broke out in Europe, the present author began to urge that the United States develop naval and military aeronautics to the utmost; in order that, when we should finally enter into the war, we should have available a large force of bombing aeroplanes and torpedo-planes. When we finally entered into the war, in April, 1917, he urged continually that we develop a great aeronautical force and send it to

Europe to prevent the exit of German submarines from their bases, to destroy those bases and to sink the ships of the German fleet. These suggestions were rejected by Secretary Daniels as impracticable; but subsequent developments have proved that they were thoroughly practicable; in fact, an expedition was organized in England to carry them out, when the Armistice was signed.

It is interesting to consider what would have been the effect on the war (and, therefore, on all subsequent history) if the United States had sent a large force of bombing aeroplanes and torpedoplanes to Europe shortly after we entered the war in the Spring of 1917. This we easily could have done, if we had started to get them ready, when the suggestion was first made; or even at a considerable time thereafter. Certainly, the war would have been greatly shortened, and much suffering averted.

The inventions and discoveries made since the Great War began, though some are evidently important, are so recent that we cannot state with any confidence what their effect will be; and for this reason the author craves permission to close his brief story at this point.

* * * * *

A noteworthy fact observable in the history of invention is that it has been confined almost wholly to Egypt, Assyria, Babylon, China, Persia, Greece, Italy, Germany, France, Great Britain, and the United States, and to a few men in those countries. Now it is in those countries that the highest degree of civilization has been developed, and *it is from them that other nations have drawn theirs.* The almost total absence of invention in women is more noteworthy still; for Mrs. Eddy and Madame Curie seem to be the only women who have contributed really original and important work.

Another noteworthy fact is that the idea-germs from which all inventions have been developed have been very few and very tiny. But what a numerous and important progeny has been brought forth; and how wholly impossible civilization would be now, had it not been for a few basic inventions and certain improvements made upon them! We can realize this, if we try to imagine the effect of removing a single one of the basic inventions (and even of certain derived inventions) from the Machine of Civilization.

Try to imagine what would happen if the invented art of—say writing—for instance were suddenly lost. Would not the whole civilized world be thrown into chaos as soon as the fact were realized? A like disorder would be occasioned, though possibly not so quickly, if men should suddenly forget how to print, or even how to use the telegraph, telephone or the comparatively unimportant typewriter. Try to imagine what would happen in even one city,—say New York —if the typewriter were suddenly to be withdrawn! Would not all the business of New York be paralyzed in a single day? Or fancy that all the machines for making and utilizing electricity for supplying light and power should suddenly become inoperative. Would there not be a panic within twenty-four hours or less? Fancy that all the elevators should have to stop. Imagine what would happen if the steam engine should suddenly cease to operate, and all the steamships and railroad trains should stop, and the countless wheels of industry that are turned directly or indirectly by steam should cease to turn. Imagine that gunpowder should cease to function, and that savages could meet modern armies on equal terms.

Some one may declare that this line of argument does not prove as much as it seems to prove regarding the influence of invention, for the reason that it includes a sudden change, and that every sudden change produces results which are caused merely by the suddenness of the change. So let us grant this, and then imagine that the changes suggested would not take place suddenly, but very slowly. Imagine, for instance, that we should discover that the various inventions noted in this book were gradually to cease to operate, but that they would not cease altogether for twenty years, or even forty. *Is it not certain that the human race would revert to savagery, after those inventions had ceased to operate?*

CHAPTER XV

THE MACHINE OF CIVILIZATION, AND THE DANGEROUS IGNORANCE CONCERNING IT, SHOWN BY STATESMEN

THE originating work of inventors of all kinds, and the assistance rendered by countless wise and good men and women, have built up a Machine of Civilization that is surpassingly wonderful and fine.

To keep the great Machine in order and to handle it, large numbers of men have been educated in specialties pertaining to its various parts. The first men were probably the warriors, who defended whatever little Machines the various tribes had built up, in their little villages and towns. Next, probably, came the kings or rulers who commanded the warriors; and then, the priests who inculcated in the people the various virtues, such as loyalty, courage, honesty, etc., that tended toward the discipline of the individual and the consequent solidarity of the tribe. Probably agriculturists came next, who tilled the soil; and then came the inventors, who assisted the warriors and the agriculturalists by devising implements to help them do their work. It seems probable that the artisans came next; and that it was by the co-operative working of them with the inventors, that the conceptions of the inventors were embodied in implements of practical usefulness and value. As time went on, and implements were produced that consisted of two or more parts, the activities of the artisans were enlarged, so as to take care of those implements and keep them in adjustment. The bow and arrow, for instance, would not work well, unless the cord were maintained at the correct degree of tension, the feathers on the arrows were kept straight, the ends of the cords properly secured to the bow, etc. Similarly, the mechanisms made for spinning and weaving and fabricating pottery had to be kept in proper condition and adjustment; and if we could realize the small amount of mechanical knowledge extant in primeval days, we would probably also realize that the difficulties of keeping these crude appliances in good working order were as great as are the like difficulties now, with the most complicated printing-press.

Furthermore, it was not only for keeping mechanisms in good condition that artisans were needed: a higher degree of skill was needed for operating them. We are forced to the conclusion that, as soon as mechanisms were produced, the need of artisans trained to operate them was felt. Not only this: the fact that the mechanisms were operated, the facts that flax was spun and textures were woven, and pottery was fashioned and baked, and that bows and arrows were used in battle, prove that operators were actually trained to skill in the various arts. This means that, as soon as the Machine of Civilization was begun, operators skilled in the kinds of work which that Machine required were trained in their various parts, and did their appointed work.

It was not only machines of brass and iron and wood, moreover, that required skilled operators: the individual human machines were continually getting out of order, and men were trained in whatever knowledge the world contained, to keep them in good order. Hence the physician came into being.

The merchant must have been developed shortly after the agriculturist and the artisan, to act as the agent for placing the products of the soil and the products of the mechanisms in the possession of the consumers.

As a tribe or nation increased in size, laws had to be formed to regulate the mode of living of its members, decide disputes, punish offences, and regulate conduct in general. Hence the lawyer was gradually developed.

It seems probable, therefore, that even in prehistoric times, warriors, rulers, priests, physicians, agriculturists, inventors, artisans, merchants, and lawyers were at work, and that the activities of men were divided mainly among those classes.

The activities of men are similarly divided now. In fact, it is by these separate activities that the separate parts of the Machine are handled. That these *separate parts* are handled well, the progress made in those parts convincingly testifies.

Despite this fact, however, no book on invention would be complete which did not point out that the Machine, *as a whole,* is not being handled well.

The Machine in each country is, of course, handled by the ruler and his assistants. Originally the ruler handled it alone; but, as it increased in complexity and size, the task became too great for one man, and advisers and ministers were appointed to assist him. Men fulfilling such tasks and allied tasks we now call statesmen.

Now it is to the hands of the statesmen of each country that the actual management of the Machine of Civilization is committed. Yet it is a well-known fact that although there are but few men in the world so wise and learned that they know much about the Machine or any of its parts, yet it is not from the wise and learned class that the great officials of governments are selected!

The truth of this statement cannot reasonably be denied. That the whole safety of the Machine of Civilization is in the hands of men untrained in statesmanship is incontrovertible. In fact, the whole status of statesmanship is disconcertingly vague; for in all the grand progress of mankind, no science of statesmanship seems to have developed, or any system of training to practice it. There seem to be no fixed principles of statesmanship, no literature except of an historical kind, and little activity save of an opportunistic sort. No special education seems to be thought necessary in a statesman, or any record of achievement; for in all countries, irrespective of their form of government, men are placed in positions carrying the utmost of human power for good and for evil, with little previous experience or training, and without having to pass any examinations of any kind!

This fact demands attention. Of what avail is it to train men to handle the separate parts of the Machine, if the Machine as a whole is to be handled by untrained men? Of what avail is it to train engineers, warriors, priests, physicians, lawyers and merchants to handle their several parts, if the Machine as a whole is to be handled by statesmen who have not been trained to handle it? It must be obvious that no men can handle the Machine as a whole, unless they comprehend the Machine as a whole, and also understand all its parts enough to realize their relation to the whole. *No man can well handle any machine, be it large, or be it small, without such knowledge.* No man can be a good captain of a battleship, for instance, until he has spent many years mastering the necessary knowledge. Ignorance of the parts and the whole of a battleship is not permitted in a captain of a battleship. Why is ignorance of the parts and the whole of their respective responsibilities permitted in officials occupying higher places in the governments?

That there are few men in the world who understand enough of all the various parts of the Machine to understand the Machine as a whole is certainly unfortunate; that almost none of these few men are selected to fill the positions of statesmen is dangerous to the last degree. For the Machine has grown to be extremely complicated; and it has the quality, which all machines have in common, that an injury to any part affects the whole. This quality is highly valuable, in fact it is essential; but it carries with it a menace to the entire machine, if it is operated by unskilled men. The Machine of Civilization came very near to being smashed in the World War; because the statesmen of France and Great Britain were so inefficient in the most important part of their work (that of guarding the Machine as a whole) that they permitted Germany to catch them unprepared.

The longer this condition continues to prevail, the greater the danger to the Machine of Civilization will become. The resources of invention are infinite. The resources of invention are almost untouched. Every new discovery or invention prepares the road for a multitude of others. These inventions and discoveries improve and enlarge the Machine; but they complicate it more and more, and demand greater knowledge in statesmen; just as increase in complexity of ships demands greater knowledge in captains.

It can be mathematically proved by the Theory of Probabilities that, if there be any chance that a certain accident may occur, it will surely occur some day if the predisposing causes are suffered to continue; and that therefore, any machine committed to unskilful handling will be wrecked some day, if the unskilful handling is suffered to continue. This establishes the probability that our Machine of Civilization will be wrecked some day, unless statesmen be trained to handle it.

An invention seems to be needed that will insure adequate knowledge in high officials in governments. But such an invention is not really needed, because it is merely necessary to utilize an invention made and used in Greece many centuries ago. This invention consisted in conceiving, developing and producing a system whereby every candidate for any office was required to show adequate knowledge of matters coming within the jurisdiction of that office, by passing a rigid examination.

Such a system may be deemed impracticable in modern representative governments. *Why?* It is followed in all civilized armies and navies.

If it be really impracticable, then it is impracticable to assure that wise and able men shall manage the complex Machine of Civilization. This means, if history has any lessons for us, that sooner or later, it will again go down in ruin;—as it has gone down at different periods of the past, in Egypt and Assyria and Babylon and Rome.

That influences are already at work which impair the functioning of the Machine in the present and threaten its continuance in the future, cannot reasonably be denied. Of these, the two most powerful may be classed under the general heading "bolshevistic" and "pacifistic." At the bottom of the bolshevistic movement is, of course, the thirst for wealth and power; the thirst for opportunities for handling and using the Machine and its various parts, by men who have done no work in designing, or building, or caring for it. At the bottom of the pacifistic movement is effeminacy: a desire for mere ease and luxury and softness, a shirking of responsibility and discipline and sacrifice.

These two influences, unlike though they are, combine to threaten the Machine; the bolshevistic by assault, the pacifistic by insuring weakness of resistance to assault. Of these, the pacifistic is the more dangerous, because the more insidious; for the same reason that a disease hidden inside is more dangerous than an attack made openly outside. The most potent cause of pacifism is the effeminacy caused by the combination of prosperity and long-continued peace, with its resulting division of a population into a vulgarly ostentatious rich minority and a more or less envious poor majority. When a division like this has come to pass, hostile conflict has usually ensued. Such a conflict produced the French Revolution, and almost wrecked the Machine in France. Such a conflict is now in progress in Russia, and threatens some parts of Europe.

Unfortunately, the progress of invention, by enlarging the scope and speed of communication and facilitating the acquiring of superficial knowledge, has put into the hands of men possessing merely the natural gift of eloquence the power to influence large numbers of people, without possessing knowledge or skill in statesmanship. It has facilitated demagoguery:—and herein lies the root of the danger to the Machine; for without the demagogue, the bolshevist and the pacifist would be unable to get their civilization-destroying doctrines presented attractively to the people.

Fortunately, the Great War, though it caused tremendous suffering, broke up many visionary notions that were crystallizing into beliefs, and brought the world face to face again with realities. And although the violent disturbance of society's always unstable equilibrium is still evident in the world-wide unrest among the poorer classes, yet the unrest seems gradually to be dying down, with the realization that better conditions of living will be theirs in future.

And as every nation that is not wholly degenerate, possesses the power within itself to save itself, and as the great nations of the earth are very far indeed from being degenerate, we are warranted in assuming that each nation will take the necessary steps, not only to guard the Machine of Civilization, but to increase its power and excellence.

CHAPTER XVI

THE FUTURE

THE fact that invention has not only been increasing during the past one hundred years, but that its speed of increase has been increasing and is still increasing, is well recognized. There seems to be a constant force behind invention that imparts to it an acceleration, comparable to that of gravity in accelerating the descent of a falling stone. Such a phenomenon would be thoroughly conformable to modern theories; and that there is a force, impelling people to invent, must be a fact; for otherwise, they would not invent. If that force be constant, the acceleration imparted to invention will be constant. If the force be variable, the acceleration imparted to invention will be variable. In other words, the future speed of invention, like that of every moving body, must be governed by the force behind it and the resistances opposed.

At the present moment, the resistance to invention is being gradually lessened because the benefits coming from invention are being realized. Simultaneously, the facilities for inventing are being increased.

These facilities are mainly in instruments of measurements and research. So many of these are there now, that it would only complicate matters to enumerate them and describe their spheres. Two of the most important are the spectroscope and the photographic camera. By means of the spectroscope, the astronomer can ascertain the chemical elements of far distant stars, the temperature and pressure under which they exist, the stage of progress of the star, and its speed and direction of movement, whether toward us or away. By means of the photographic camera, not only can records be made of stars so far away and faint that light-waves from them cannot be noted by the eye, even with the assistance of the most powerful telescope,—but a virtually unlimited number of permanent records can be made.

All fields of research now feel the assistance imparted by new instruments and methods. Even the chemist realizes the aid of instruments invented by the physicist; while every physicist welcomes the aid that comes to him from chemists. The chemists and the physicist are now working together in harmony and with enthusiasm, engaged in a friendly rivalry as to which shall help the other most. And, as discovery succeeds discovery, and invention succeeds invention, they find themselves—although the domain of each is widening—not drifting farther apart, but drawing closer together. For it seems to be coming more and more assured that the Laws of Nature are simpler than we thought, that chemistry and physics are more alike than we supposed. Many startling generalizations have been suggested, with much reason; such as, that matter and energy are one, that space and time are one, and that even the mind of man may be subjected to physical methods and analysis. In fact, some of the greatest advances made during the past twenty-five years have been in psychology, and achieved largely by the use of physical apparatus. Many subjects, formerly included with alchemy and astrology in the class of occult if not deceitful arts, are now being developed apparently toward more or less exact sciences; as alchemy was developed into chemistry, and astrology into astronomy. Efforts are even being made to communicate with distant planets and with the spirits of the dead.

That much is being attempted that may not be realized is true. But if we realize that the universe is now supposed to be many millions of years old, it seems only yesterday that the phenomena of electrical and magnetic attraction and repulsion were confusing the minds of even the wisest: and now electricity and magnetism are harnessed together, and working together in perfect harmony and marvelous effectiveness, for the good of man.

That the future of invention is to be as brilliant as its past, every omen indicates. In what direction will it proceed? Probably in all directions. But the line of direction that will occur the first to many, is probably in aerial flight. Doubtless it is in aerial flight that the greatest advance has been made since flight was first successfully accomplished in 1903; and doubtless it is in that line that the greatest progress is being made now. The enormous speeds already achieved; the growing size of both aeroplanes and dirigibles; their increasing speed, safety and convenience; the fact that roads are not needed for aerial transportation as they are for carriages and railway trains, or deep water channels as for water craft; and the comparative cheapness with which people and light packages can be carried swiftly and far, all point to a vast increase in aerial transportation, and a great modification in all our modes of living in consequence.

Akin to transportation is communication:—but in communication, one may reasonably feel that we have arrived almost at the boundary line, not only of the possible but even the desirable. For we have almost instantaneous communication all over the surface of the earth and under almost all the ocean, by the telegraph and telephone, using wires and cables; and nearly equally good communication by radio telegraph, using no material connection whatever. The wireless telephone is following fast on the heels of the wireless telegraph; and by it we can already telephone hundreds of miles between stations on land and sea, and carry on conversation for several miles between fast moving aeroplanes.

But progress is going on rapidly also in the older fields of invention. The ocean steamship, especially the battleship, is growing in size, speed and safety; so is the locomotive, so is the automobile. Because of the progress in all the useful arts and sciences, buildings of all kinds are being constructed higher and larger, and more commodious and safe; civil engineering works of all description—roads, canals, bridges and tunnels are setting their durable marks of progress all over the earth; the uses of electricity are growing, and showing every indication that they will continue so to do; and so are the uses of chemistry and light and heat. And through all the industrial world, in manufactures of every kind, we see the same unmistakable signs of progress, increasing progress and increasing rate of progress.

In the field of pure science, we note the same signs of progress, increasing progress, and increasing speed of progress. Naturally, however, it is far more difficult to predict with confidence the direction which future progress will take in this field than in the field of the practical application of pure science, in which invention usually bestirs itself. The fact, however, that any actual advance has begun in any new science gives the best possible reason for expecting that the advance is going to continue. Therefore, we may expect continuing progress in all branches of pure science: for the near future, for instance, in biology, psychology and what is loosely called "psychics," which seems to be a virtual excursion of psychology into the hazy realms of telepathy, clairvoyance, spiritualism, and so forth.

That invention and research are concerning themselves more and more with immaterial subjects is a fact that is not only noticeable but of vital importance to us, for signs are not lacking that man's material comfort is already sufficiently well-assured; in fact, that perhaps he is already too comfortable for his physical well-being. Already we see that labor saving and comfort-producing appliances are impairing the physical strength of men and women, and to such a degree that artificial exercises are prescribed by doctors. Inasmuch as "the mind is its own place, and in itself can make a heaven of hell, a hell of heaven," it seems probable that the direction of effort in which the greatest real benefit can be attained is in research and consequent invention concerning the mind itself. But, for the reason that this is probably the most difficult road, it seems probable that success in it may come the latest. It seems probable also that even in that road, progress will be achieved by means analogous to those by which it has been achieved in other roads; that is by the use of physical and chemical instruments and methods. Much has been done already by their aid in psychology, and much more is promised in the not distant future.

The idea of influencing the mind directly to states of happiness, and guarding it from unhappiness, is far from new; for what were the epicureans, stoics, and others trying to do but that? Such attempts, many systems of philosophy and many mystic sects distinctly made. Of these sects, one of the most interesting was that of the omphalopsychites, who were able to raise themselves to high states of happiness by the simple and inexpensive process of gazing at their navels. Some advantages of their system are obvious. Certainly it was less costly than other means of gaining happiness, such as wearing narrow-toed shoes, chewing tobacco, smoking cigarettes and drinking whiskey; and there is no evidence that it ever caused ingrowing toe-nails, delirium tremens, or Bright's disease.

That invention and progress have produced and may be relied upon to continue to produce prosperity, may reasonably be predicted. But will they together produce happiness?

The author respectfully begs to be excused from answering this question. He requests attention, however, to the manifest facts that invention is a natural gift, that the impetus to invention has always been the desire to achieve prosperity of some kind, and that to employ our natural gifts to satisfy our natural instincts can reasonably be expected to further our happiness; unless, indeed, we suspect Nature of playing tricks upon us.

That Nature sometimes seems to do this, and that it is dangerous to follow our instincts blindly is of course a fact. But it seems to be a fact also that the danger in following our instincts seems to come only when we follow them blindly; and that, though there may be danger sometimes in following them even under the guidance of our reason, yet the only way in which we have ever progressed at all has been by following our instincts under reason's guidance, and invention's inspiration.

And since the civilized world is in virtual agreement that civilization is a happier state than savagery, and since we have been impelled toward civilization by invention mainly, there seems no escape from the conclusion that it is to invention mainly that we must look for increase of happiness in the future.

It may be, of course, that happiness does not come so much from a condition or state attained as from the act of striving to attain it. It may be suggested also by some one that life is merely a game, and that happiness comes from playing the game and not from winning it, just as children delight more in constructing a toy building with their blocks than in the building when completed: for they no sooner complete the building than they knock it down, and begin to build it up again. But, even from this point of view, the desirability of fostering invention would be apparent; because it would continually supply us with new games to play, and new toys with which to play them.

But that any thoughtful person could really think life a game is an impossibility. No man with a mind to reason and a soul to feel can contemplate the awful suffering that has always existed in the world, and think life a mere game. No man can think life a mere game, who with an eye to see and an imagination to conceive, gazes upon the infinite sea of stars visible to his unaided vision, realizes how many thousands upon thousands of stars there are besides, that the photographic camera records, and realizes also that, though light travels even through air at a rate exceeding 186,000 miles per second, yet that some stars are so distant that the light now reaching us from them started ages before the dawn of history. And no man who is able to follow the teachings of science, even superficially, can note the enormous development of civilization during the last few thousand years, and realize that a development similar though infinitely grander, must have been going on in all the universe for countless centuries, without realizing also that "through the ages an increasing purpose runs." He may even note a likeness between it and the development on an infinitely smaller scale, of the conception of a merely human inventor. Possibly, his fancy may even soar still higher: possibly he may even wonder if all this great creation may not be in effect a great invention, and God its Great Creator, because its Great Inventor.

So, whether we fix our thought on what the scientists tell us of the probable course of development of the universe during the countless ages of the past, or consider merely the development of man since the dawn of recorded history, we seem to find as the initiating cause of both—invention.

Let us therefore utilize all means possible to develop this Godgiven faculty, the chiefest of the talents committed to our keeping. That way lie progress, prosperity and happiness. How far and how high it may lead us, God only knows; for the resources of invention are infinite.

The End.

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