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THE ORIGINS OF ENGINEERING[1]

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IT is a romance—the story which relates the gradual unfolding of scientific discovery and invention and their influence on the rise of social organization. It is a romance, and yet it is real. The romance embraces the transfer of physical labor from human shoulders onto machines and the increase of emphasis on human intelligence in contrast with brutality; which is the tale of the origins and growth of engineering.

The story wanders from quarter of the globe to quarter of the globe—from Mesopotamia and Egypt to China, Persia, Arabia, Phoenicia, Greece, Rome, Britain, the European continent, Africa, North America, South America—from race to race, from peoples to peoples, from the latter part of the Paleolithic age of man to the present time. In early ages even slight contacts by means of pilgrims and adventurous traders resulted in the retailing and circulation of romantic stories of conveniences in the possession of distant alien peoples. Thus one area crudely copied and then perhaps improved upon the deeds of other areas. Where two distantly alien peoples grew in organization simultaneously but without contact, the urge for convenience sometimes resulted in simultaneous inventions of equivalent natures. Ambition and craving for convenience seem to sow the atmosphere with ideas which simultaneously may be reached after in different quarters of the world.

Instinct alone was sufficient to inspire the prehistoric man to choose a cave for his abode in temperate zones or to arrange a grass-and-leaf shelter in tropical areas. Those things are done by the dumb beasts through the exercise of instinct. Perhaps to instinct may be ascribed the first use of fire by prehistoric man. It possibly did not require creative intellect for the cave man to build a fire in the cave and to roast

[1] Address as vice-president and chairman of Section M, American Association for the Advancement of Science, Boston, December 30, 1933.

meat, after the heat of a lightning-set forest fire had exhibited itself to him and the flavor of fawn accidentally roasted in that fire had been tasted. However, further changes in the modes of living came to pass with the development of simple man-made structures and machines that required creative spirit. Here was the birth of engineering in its earliest simple embodiments. This birth was an outcome of the lives of a creative-minded few living in the prehistoric days. The period apparently was tens of thousands of years ago, and records of those days are lacking; but we can hypothetically reproduce the conditions with considerable convincingness, utilizing for background a combination of archeological data and human psychology.

Tropical plains watered by great or small rivers are and have been subject to overflows that culminate in great floods in recurrent rainy seasons. It may be surmised that tropical dwellers in grass-and-fern-leaf shelters found their shelters periodically swept away in the waters, while they, themselves, fled for safety to higher ground in company with the jungle beasts. However, some dweller, more active-minded and physically indolent than his fellows, became discontented at the inconvenience of periodically restoring his shelter and slaving to replace whatever other movables he had possessed. The sharpness of this discontent finally caused him to use his mind and observe that the flood had never submerged a near-by rise in ground. Here was the first hydrographic survey. He built his new shelter on the rise.

After further floods, his slower-witted fellows followed the example and a community or village of shelters grew up. Thus early, loose community relations were formed. Such communities of grass houses can still be observed on high ground of the plains of Indo-China and Siam, of course with many ameliorations of conditions compared with the earliest communities. It is likely that the village-community tendency chronologically succeeded the individual engineering observation and the resulting improvement. This chronological relation is important to note.

The cave-men's problem was different. We may picture it as a problem of fire instead of water. Smoke from the fire built in a cave dwelling disturbed the proprietor's relaxation and sleep. Expostulations, however strong, with the fire-tenders (the women and children) were fruitless. Finally one male cave-dweller, more active-minded than his fellows, was so annoyed at his own continued inconvenience that he undertook to modify the situation. This resulted, through cut and try, in a fireplace structure at the mouth of the cave made of flat stones and partly protecting the fire from wind and weather.

The slower-witted cave-dwellers gradually came to more or less copy the first successful structure, and thus some of these dwellers secured relief from inconvenience as a consequence of the invention of their fellow man. The stone huts of the aboriginal Kabiles, who now dwell in the mountains of Algeria, which huts are windowless and have ingress and egress through a hole in the roof that also serves as a smoke outlet, may be a development that grew out of the idea of this first crude fireplace structure. If this inference is correct, it is another illustration of the chronological relation of the village community tendency to engineering observation and improvement.

Tools and also simple weapons are evidences of artisanship. We must seek for the trail of structures and machines, as distinguished from artisanship, in order that we may trace the development of engineering through its origins. I have referred to possible examples of rudimentary steps in the development of structures. The development of machines apparently lagged. The effort required for combining mechanical elements into machines demands a deeper intellectual exertion than was required to make rudimentary surveys and plan rudimentary structures. The archeologists' deciphered records of machines only go back for periods of some thousands of years. The advantage of differentiating between implements of like kind according to their intended use, by making variants for different kinds of use, seems to have been recognized very early. An example is a variant of arrows provided with stone heads in the stone age, which it is inferred from what data exist were so arranged that war arrows left the head in the wound when the shaft was withdrawn and hunting arrows could be withdrawn intact from the stricken animal. The creative quality required for invention of machines, however, is too abstruse to become stirred until the friction of inconveniences in living has created much mental warmth.

The wheel, an extraordinary contribution to muscular relief which we now take for granted as though it were a part of original genesis, is a work of man that comes as a tool to us moderns from the musty ages of unrecorded history. If, as ethnologists tell us, human intelligence has not changed in qualitative character over long ages measured in ten-thousands of years, we can reliably picture the mode of development of the wheel and its application to vehicles. One conceivable path for the invention is easily traced in the light of our present modes of mental reaction. Nomadic habits began very early, either for families, clans or tribes, and we can picture the discontent of the most mentally active men, even in a crude and unformed race, as they season by season faced the inconveniences and wear and tear of family movings across country. The physically indolent but mentally keenest of the men became wearied of dragging individual belongings or having them half carried by draft animals, or of transporting them on the backs of women and children or of loading the personal riding horses with goods. The delays pertaining to such transport naturally added to the annoyance. The weariness from time to time must have sunk to the soul of some such man, desire for release from the deadly annoyance must have fired his mind, and inventions followed as time progressed. Sleds are known to have been utilized in the early ages. Loose rollers were also utilized. Then controlled rollers may have been tried and other such expedients. Finally, two sections sawed off the end of a roller, mounted at the ends of a wooden trunk, gave the wheels-and-axle structure, and the two-wheeled cart was on the way. Dr. George Grant MacCurdy says the wheel is a Neolithic invention. Its introduction into use was slow until recent millennia, because hunting and fishing probably were the principal sources of food for men in the Neolithic age, formal agriculture and domestication of animals not then being generally practised, and tribal nomadism not yet established.

In a developed brain like that of early Neolithic man, the ability for invention may have existed, but sufficiently sharp recognition of keen inconvenience may not yet have chanced to arise in such a manner as to cause its exercise on complex improvements. Beginning with the latter part of the Stone Age when the numbers of people were considerable in various parts of the world and hand weapons had become effective, the insecurity of life and property was appalling, according to our standards. However, with each step forward in progress by inventions, the tendency toward community living accompanied by a growing respect for mutual interests seems to have become greater. It was only after the stimulus for making inventions had resulted in an easier life with respect to food and shelter and had released more time for cultivating physical ease that growing ethical relations between man and man and tribe and tribe became evident and community living became smoother. The speculative philosophers sing an intellectually interesting story which describes the fabric of civilization, but it is the inductive scientists and inventors on whom the unfolding of the fabric has depended and continues to depend. It is from the work of the latter that the origins of engineering have been derived, and additional origins will become disclosed as long as their work continues.

It seems rather well established that man enslaved fire and converted it to his service in the Pleistocene Age of geology, some hundreds of thousands of years ago. It also seems well indicated that *Homo sapiens* did not rise up and start upon his career of great inventions until some tens of thousands of years ago. *Homo sapiens* apparently began his special career by the domestication of animals and crudely establishing the cultivation of agricultural crops. Man already was distinguished as the user of crude tools and weapons made of stone and bone. As far as speaking for its conditions of life is concerned, the far past is as silent as a basket of clams, but it has left its records nevertheless.

The development of agriculture came in the Neolithic Age, possibly some 10,000 years before the Christian era. It may have been keenly practised first in Egypt some 6,000 to 10,000 years ago, but perhaps was actively practised earlier in Mesopotamia or some other favorable region of the world. Agriculture led to the production of machines to aid in the cultivation and in the preparation of its products.

A simple beginning of such machines might be machines for winnowing and grinding grain—very rude ones at first, but gradually taking improved and more complex forms. It may be presumed that winnowing was originally carried on by the manual process of tossing the grain and chaff of the threshing floor into the air and allowing the natural breeze to make the separation. This process still may be seen in many parts of the world, as for example in Algeria, where it may be observed in practise alongside of the operation of modern combine harvesters. The winnowing van is known to have been used in China in very early times, and perhaps also in Japan where it still may be seen in elementary forms used in the rice fields along with hand fans.

Crude plows drawn by bullocks are known to have been in use some two thousand years earlier than the period when (as Byron puts it) "The Assyrian came down like a wolf on the fold" at Jerusalem some 700 years before the Christian era.

The shadoof or hand-operated well-sweep was used in Egypt more than 3,500 years ago. Ropes and pulleys were used for raising waters from wells before the date of historical records. Perhaps animals such as bullocks were applied as motive power where agricultural irrigation was the purpose, much in the manner still widely used in India. Apparently the treadwheel applied to raising water for use on the land (which is still to be seen in China) also was used in prehistoric times. The treadwheel seems to have been followed by the noria in which the flowing stream impinging on peripheral paddles caused the rotation of the wheel instead of using man or beast on the treadwheel. The so-called Persian wheel, also of great antiquity, is apparently an improved offshoot of the noria. The picotah, on which a man or beast traveled on the tilting lever, made an advance on the shadoof where continuous operation was a need. The chain of buckets for raising water from a well also apparently comes down from primitive man, and likewise the simple chain pump.

Raising water for irrigation purposes from wells was a highly important act in many regions occupied by man even in prehistoric time and also in the early periods of history, as it is now in some regions, such as our own southern California and in India. How far into antiquity the atmospheric or suction-pump goes is obscure, but apparently the qualities of the siphon were known as far back as 1,500 years before Christ. Out of the water situation may have grown other devices. For example, syringes perhaps grew out of efforts to adapt bellows (possibly of a plunger type) to use with water. The plunger churn, the origin of which goes very far back, may have similar roots.

It is to be borne in mind that in the earlier days of the Paleolithic period esthetics, art and creative endeavor had not stirred appreciably in the intellect of man. The efforts for securing shelter and bare subsistence were sufficiently exacting to occupy fully the intellectual possibilities of mankind. Whatever effort of invention was forthcoming was to abate nuisance, reduce required muscular effort or conduce to safety.

The profound influence which a developing agriculture had on the life of prehistoric man probably is indicated by the usage of many existing primitive races, who name the natural seasons of the year in accordance with their relations to the normal weather and to planting and harvesting times. With the change from primary reliance for food on hunting and fishing, through a food supplement from agriculture, to primary reliance on agriculture for food, the influence of the agricultural life became gradually entrenched, even though the agricultural population itself might be seasonally nomadic. A suitable territory is capable of supporting a larger population of followers of agriculture than of hunters and fishers. Mutuality becomes more useful and the family unit becomes more integrated and ultimately the clan, the tribe, the community and the nation are successively recognized as units in the course of increasing population density. The opportunities for and the utility of inventions become larger with the increasing density of population. Thus engineering derives a steadily increasing influence.

Civilization means an advanced state of material and social well-being, and its foundations were laid with the domestication of animals and the practise of agriculture. Therefore we engineers as well as other citizens are in debt to agriculture. Let us see what engineers have done in this country and these modern times to discharge our ancient debt to agriculture. The present generation plays its parts with three major branches of applied science—agriculture, medicine and engineering. As we know them in their present states they are all founded on modern scientific discoveries but with the roots of their establishment reaching back to primitive man. Agriculture has not come forward commensuratively with preventive medicine and the engineering industries. But with the automobile, the tractor, manufactured nitrates, diversified cropping, hard-surfaced roads, electrical power in the rural communities all established as they bid fair generally to be, agriculture may rival its brothers in wonders, provided wisdom prevails in guiding the movement. Already many as yet uncorrected faults have been disclosed in the train of a general change from subsistence farming to commodity farming, and wisdom seems lacking for the correction of these faults as well as for fending against causes of additional faults.

The engineers have a responsibility in this. The problem of diversified cropping, I take it, is the farmers' own. It is old as history and the farmer apparently is slow to associate the tenets of modern science with the teachings of ancestral experience. For the automobiles (whether for passengers or goods), the tractor, manufactured nitrates, hard-surfaced roads and electric power the farmer is compelled to look to engineers and the engineering industries. This is true also even for farm sanitation. Thus engineering has contributed much to the convenience of farm life, but the farmers have adopted the improvements rather unrestrainedly and are suffering in consequence.

For example, is the farmer being misled by the many times repeated statement that our tremendous expenditures for hard-surfaced highways are being made for his benefit; and, even if it is good "politics" now, is it ethically right to spend from ten thousand to thirty thousand dollars a mile for secondary highway networks when half the money might serve the particular purpose and any money for the purpose has to be raised by difficult taxation? Until we engineers as individuals and as civic groups can correctly answer these and many similar questions which are essentially of engineering applications that influence convenience of life in the rural areas and profoundly affect the economic condition of the residents of these areas, we will not have discharged our oldtime debt to agriculture.

If our inventions available for contributing to convenience and welfare in the rural regions are misused, engineers may deny responsibility and liability; but if we should take that attitude we would be fixing on ourselves the purely secondary place of surveyors of physical possibilities in machines and structures, and of designers and constructors, and we would be leaving to others the primary place of authority for determining whether such machines or structures shall be produced and used in any particular situation. I do not believe that we are satisfied to occupy the secondary place solely, and we will therefore cultivate a fuller understanding of the relations held by engineering machines and structures to human relations and progress, in order that we may not only plan, design and build but may also hold a proper part in determining the objectives for doing so. In taking this attitude we must acknowledge that many of the origins of the future engineering, such for instance as relate to further agricultural development, are as yet to be established, notwithstanding that fifty centuries of continuing origination and development have been devoted to engineering as it now exists.

The community of interest which arises from integration of groups of people develops the qualities of civilization. Civilization takes on new aspects as the integration of communities follows in the wake of the great inventions which either make personal relations important for comfort and convenience or make such relations easier to secure and at the same time lift burden from individual muscles. The material and physical aspects of the civilization (which aspects we call political economy or economics) are in constant flux as scientific discoveries increase the possibilities of physically comfortable living, because of the increasing emphasis laid on mental activity *versus* man's muscular activity. The intellectual aspect of civilization, which we call culture, also widens as civilization widens. The shift of conditions in each human age has made preparation for the next age, so that it is often difficult to distinguish the relative importance of impressively influential inventions of successive ages. For example, was the eye-pierced needle capable of being used with cotton thread or the saw-like cotton-gin the greater invention?

We may thus observe that up to this generation we have not uncovered all the primary origins of engineering as they are likely to become disclosed by the farther progress of agriculture. Moreover, this is true notwithstanding the many tens of centuries since primitive man discovered the mechanical elements and his successors found convenience from applying them to the homely problems of raising water for irrigation, of winnowing grain and other now well-recognized agricultural processes. Therefore, as engineers, we have strong cause for giving thoughtful consideration to improvements of social organization and economic conditions in the agricultural regions.

It is now appropriate to seek the origins of engineering which have arisen and are arising through trade and transportation. Sailing and rowing ships are of great antiquity. Archeological remains indicate that there were ships on the Tigris and Euphrates 4,000 years before the Christian Era. Development of harbors was a gradual outcome of commercial trade carried on by water. It is impossible to say when formal highways (as distinguished from mere trails) were first constructed and maintained, but the date apparently should be assigned to lesser antiquity than hydraulic works. Bridges naturally followed with formally constructed roads. Indeed in some instances the bridges have been more permanent than the roads, as is illustrated by certain ancient examples in China. A modern instance where sound economic reasoning leads to like results is to be observed in Turkey, where permanent bridges are being established over some of the rivers, although the money is not yet available to convert the old part-year cart roads into satisfactory automobile highways. This is for the purpose of making the present roads available for traffic in certain seasons when rivers are in spate and still have adequate bridges in place when the roads have been rebuilt.

The seeds of civilization were sown when men who possessed like objectives first purposefully gathered together in communities. Those seeds germinated and the tree of civilization flourished and grew in influence as engineering expanded in scope and competent means for intercontact between the communities increased. However, as long as the horse continued to be the most serviceable message-runner, burden-bearer and draft animal, moderns had but little advantage over the ancients. Differences between specific earth roads and differences between strains of horses were but moderate differences between likes. Water-borne trade provided a difference in kind which profoundly affected ancient peoples. Heat-power motive devices equally profoundly distinguish our period from the conditions of a few centuries ago. While the invention of the wheel is lost in the dark of prehistoric time and the runner and courier as messengers of communication go back as far as we know, our own methods of transportation by heat-power on land and water and in the air and our methods of communication by electricity are recent revolutions and have introduced extraordinary economic changes. Stationary steam power and formally established factories alone would not have done so.

Ethnologists tell us that a common language is not necessary for family life and relations. This may be true; each one can find out by trying it on her husband or his wife; but, broadly speaking, a common language is needed for relations in a community of many individuals. The need is also particularly felt in the casual contacts of individuals made for commercial trade. Out of this need the spoken languages of the world doubtless were developed. Organized language must have greatly facilitated and increased trade, and thus the germs of ship engineering, harbor engineering and production engineering were fertilized to farther growth by those who felt advantage for themselves to be derivable from the growth of trade. Community concentration also became more notable as a consequence of the trade growth.

An emphatic demand for engineering structures and machines followed in the wake of community concentration. A convenient water supply for man and beast came into demand. Removal of offal became a demanded sanitary convenience. Better roadways were demanded so as to meet the convenience of the many citizens. Surveys of land boundaries were contributory to preserving order. Engineering experience and skill came under constant requisition and were enlarged by practise. The results of improved engineering skill made concentrated populations less uncomfortable, with a reflex result that urban populations continued to concentrate. City planning seems to be a rather old profession. It goes back at least 3,000 years in the East, and it still is adding new facets because of new discoveries in science and political economy in the West.

Thus we see that in each activity of life where structures or machines could be made serviceable for gaining convenience, they were given early attention. The dexterity of man from ages back is illustrated from the remark in the Book of Judges that, of a chosen 700 left-handed men, "every one could sling stones at an hair-breadth and not miss." Dexterity being established, the mental effort required to avoid physical inconvenience led to invention.

Inventions of structures or machines arise from applications of the mind to conceiving measures for modifying an existing situation or creating a new one. The practise of invention therefore is subsequent in time to the development of reasoning powers in man and coordinate with the application of mind to social organization. Social organization proceeds hand in hand with scientific discovery and invention, although the former may at times seem less lively in its forward steps than the latter. Invention also involves experimentation by which the conception is built up into a physical embodiment. Moreover, it involves the intellectual courage required to try again when a first embodiment has failed, and to try still again and again if need be after thoroughly reviewing and verifying the reasonableness of the conception. With the main stem of the human race reaching back a quarter of a million years, and brain volume as large as modern man's going back at least several tens of thousands of years, as anthropologists seem to have convincingly shown, there has been a long time for the more mentally active men who hated inconvenience to exert themselves in invention, but the early steps were founded on little experience and were crude. Full stride has only been reached in modern centuries. But through it all, the inventors of these improvements used intelligence to save exertion of muscles.

The very early period in which the urge of convenience affected at least a few of the human race is seen in a few flint implements or tools of a thousand centuries ago which were chipped to fit the using hand, although the proportion of early tools so fitted proves to be small. In contrast, a very modern illustration of man's propensity to shift muscular labor onto the machines comes from our American use of the automobile. Before the citizens of rural regions became addicted to automobiles, the rough-surfaced and rutted roads wound around the hills with curves and grades over which draft animals picked their way without much exertion of physical effort being required of their leisurely or somnolent drivers. Driving an automobile over those roads required continuous exertion of muscular effort. With the advent of automobiles as a rural transportation agency a demand widely arose for the abatement of this muscular effort. Therefore by the intervention of steam shovels, scrapers and steam rollers the hills have been cut through, the routes straightened and the surfaces made smooth so that drivers may tool along at ease.

Division of manual labor in the sense that Adam Smith used the term "division of labor" was not new in his generation but had existed over a long period of time. He brought it formally to the intellectual consciousness of scholars. Division of labor still exists and presumably will exist as long as man is called upon to do either manual or mental labor. The thing that is new in our day is *adaptation of labor* to the conditions wherein machines are used to shift the heavy labor from the muscles of individual men. Along with this adaptation goes a greater emphasis on intellectual power, and hence the origination of still further features of engineering. With the increasing emphasis of intellectual power there also has arisen a joy of achievement available to each individual which transcends the simple grubbing after food and other keep.

In war, necessity perhaps is the mother of invention, with the object of self-protection, as in the production of weapons or planning fortifications; but in pacific life the craving for relief for the muscles and for leisure free from heavy labor has been the stimulus for active-minded men to make the revolutionary, basic inventions. It was not necessity that drove Watt's engineering mind to the steam-engine, or George Stephenson's to the steam railroad, or Fulton's to the steamboat, and so on for the series of primary inventions. Even the easiest, and therefore ranked as best, methods of hunting and fishing probably were invented by relatively active-minded men anxious to secure their food with greater ease.

Since the middle of the nineteenth century, for the first time in the world's history, we of the Western world have been in command of knowledge, skill and natural resources sufficient to produce comfort and satisfaction for every one. Our deficiency is lack of effectiveness in our applications of knowledge and skill. This is a conjoint problem of political economy with engineering and opens up possibilities of new threads for engineering. Indeed, every newly discovered fact in science or political economy may disclose the origin of a new thread in the fabric of engineering. That aspect of engineering which primarily arises from a recognition that the dignity and power of the human mind makes it appropriate to relieve man-labor by machine-labor in drudge work is only now crossing the threshold of its origin. This aspect requires for its correct development all the facts that can be discovered in political economy, just as the older aspects of engineering have needed and have utilized all the facts available from the discoveries in natural sciences.

The solution of the conjoint problem of engineering and political economy which is required to provide for men the craved advantages of convenience and leisure can only be secured by applying the same exacting, unremitting and critical research as has characterized the unfolding of physical science. Much reflection on the question as to where such research can be established, with firm expectation that results suitable to the conditions in this country may be realized, leads me to the answer that certain of the engineering faculties of the educational institutions of the country will have to be relied on. If we in this country are to enlarge and more uniformly distribute our comforts and conveniences, we must rely on ourselves for developing sound tenets of political economy, extending scientific research, encouraging invention, and improving conditions for the production and also the distribution of industrial and agricultural commodities.

We treat our machines with the same lack of consideration and manners as we exhibit toward fellow men. Millennia of experience with domestic animals have taught the human race that considerate use of such animals contributes to their safe serviceableness for their masters and avoids injury to neighbors; but bulky and elaborate machines are relatively new to human generations, and experience has not yet borne in upon man the most economical and fruitful manner of using his machine creatures. Some guiding restraints are needed here, so as to avoid certain social disadvantages. The use of machinery obviously has forced a degree of mitigation of the *laissez-faire* philosophy of Adam Smith, Ricardo and John Stuart Mill, with its bitter "hire-and-fire" policy, but this is not sufficient to meet all the needs. We can not afford to retard the further development of engineering; but the results of untamed scientific discovery and invention must not be allowed to bear with cruelty on individuals or communities. The nation now seems conscious of the latter truth, but it will require some legislative procedure before the desirable end can be secured, and this procedure needs guidance by ripened intelligences of those who are experienced with the control of machines and structures.

The growth of civilization goes hand in hand with adventure of the mind, just as advance of science is a child of the spirit of inquiry. Thus civilization and science have a bond of romance, and engineering is an agent by which civilization profits from science. Civilization connotes harmonious cooperation of many human beings, and also mutually sympathetic, helpful and elevated relationships. Civilization expands with the engineering arts because the latter enable groups of people to become closely associated without sacrificing either convenience or major comforts. Only preventive medicine can vie with engineering in importance to civilization; but medicine is a later flower borne on the branches, rather than a root of civilization.

Like a banyan tree, civilization profits from additional roots as it becomes more and more effectively spread, and the origins of new aspects of engineering are continually arising from the new roots. The primary engineering inventions of great influence on civilization which have originated in the last century and a half include no less a series than adaptation of steam power to general use, steam-power transportation by land and water, automobiles associated with hard-surfaced roads, electric power generation and distribution, artificial lighting by electricity, electric communication by telegraph and telephone, air navigation, chemical production on factory scale, adaptation of mineral fuels to general use. These by no means exhaust the possibilities, and new origins of engineering may reside in each new discovery in natural science and almost surely will be found to reside in each new proved tenet of political economy.

Inventions of tens of centuries back were, for their day, of corresponding influence on the then civilization as the inventions of our day on our civilization. Witness the Roman roads which tied Western Europe together by one transportation network. Modern automobiles and associated hard-surfaced roads, while similar in some aspects, are so different in conception from anything within the reflections of a Roman leader that this modern development must be ascribed to its own modern origin. The outcome of some of the modern origins of engineering is nowhere seen more strikingly than in household affairs. Instead of skinning (by the exertion of main strength aided with crude tools made of chipped stone) the wild boar brought in on the back of her brute of a man, and burning the laboriously recovered meat over the open fire at the mouth of her cave, the woman of the dwelling now preserves her cherished rugs by passes of the vacuum cleaner, supervises the electric sewing machine, the electric washing machine, the electric mangle, and sets the temperature regulator for the oven of the gas or electric cooking-range. Thus, the practicable life of the house-woman has been revolutionized as an outcome of scientific discovery and invention and become one of light but highly skilled labor associated with physical and mental freedom and available time for reflection, recreation and not uncommonly for special service to society. Another homely but graphical example which serves to illustrate changes in only fifty years that have resulted from engineering of modern origins is the group of automobiles quiescently awaiting their worshipping masters around the country churches of a Sunday, where horses (with their buggies) formerly stood in fly-pestered impatience.

It is my hope that the foregoing sketch has convinced you that the origins of engineering lie in man's knowledge of the forces of nature and their application to man's convenience. Each fact discovered regarding those natural forces carries its own possibilities of useful application, and as the facts have been detected and identified with the course of time the scope of engineering has been correspondingly widened until it now possesses a very comprehensive influence on human life.

Man wishes to secure protection from the weather (that is, shelter and clothing), plenty of satisfactory food, safety for his person, sociable contact with his kind, and comfort in all his affairs. Engineering contributes to satisfying all these desires. It is worthy of the fullest development for the purpose of enlarging this influence. As science discloses the facts, engineering is able more fully to meet these desires in substantial degree for every one. Engineering is thus an inextricable thread in the fabric of the civilized world's social organization. Natural phenomena are not all understood; the facts have not yet all been observed and new ones are detected from day to day. Out of each one of these may spring new origins for engineering processes, and the scope of engineering may be expected to expand as long as man remains mentally of investigative character and corporally with a fondness for convenience.

SCIENTIFIC EVENTS

THE SOIL EROSION SERVICE

AMONG the numerous activities of those now enrolled under the Civil Works employment plan, it is reported from north-central Missouri that a group of 163 men are building rock dams across destructive gullies and mining limestone to correct soil acidity. These men are employed on a 200,000-acre erosion control project being carried out in the rolling part of the Missouri-Iowa corn belt by the Soil Erosion Service of the Department of the Interior.

The continuing destructive effects of soil washing in this extensive region of highly productive corn land has already largely stripped off the fertile topsoil from four and a half million acres. Nearly half a million acres have been essentially destroyed by gullying. These lands were all cultivated at one time, producing in good years around 75 bushels of corn per acre. Now much of this eroded land will not yield more than 15 or 20 bushels per acre, and in dry years the yields dwindle to nothing.

It has been shown at the soil erosion experiment station in this region that land sloping about eight feet in a hundred loses every year in the neighborhood of 85 tons of soil an acre, where continuously planted to corn. According to measured results 35 per cent. of all the rain runs off into the streams under this unwise system of land use. Where alfalfa is grown, on the other hand, the soil losses from the same kind of land are less than two fifths of a ton per annum, and the runoff of rainfall amounts to only 2 per cent. of the total precipitation. Clover and timothy are also effective in controlling erosion and runoff in this region.

In order to produce a good crop of clover or alfalfa it is necessary to "sweeten" the soil by applying ground limestone rock. The crushed rock will be scattered over the steeper sloping areas, which are to be planted with clover, alfalfa and various grasses. Erosion-control treatment will be applied to every acre of land over the 200,000-acre watershed in accordance with its particular needs.

Part of the Civil Works force now engaged on this project is making use of rocks and brush to close up the gullies which have been steadily cutting to pieces the sloping lands. The specialists of the service assert that men could not be put to more useful work, for the reason that, regardless of crop surpluses, the nation can not afford to lose any more of its high-