The principal question now in dispute is the relation of the Iowan to the Illinoian drift. Chamberlin and Leverett in recent years have referred it tentatively to the same glacial stage as the Illinoian drift. But Kay and his associates on the Iowa Geological Survey and Alden of the U. S. Geological Survey hold to an early idea that it is the product of a distinct glacial stage standing between the Illinoian and the Wisconsin. They grant, however, that there does not seem to be any equivalent of the Iowan drift in the district east of the Mississippi valley. They thus restrict the Illinoian drift to the Labrador part of the Laurentide field of glaciation, and the Iowan to the Keewatin part, which seems a very doubtful and unnatural restriction.

The reference of the Iowan drift to a later glacial stage than the Illinoian is based by these students on the lack of a gumbotil deposit on its surface, such as is found on neighboring parts of the Illinoian drift. They also maintain that the erosion and weathering and especially the leaching of lime is less on the Iowan drift. Recently Kay has announced the presence of a loess deposit on the Illinoian drift that seems to him to correlate with a loess that underlies the Iowan drift. The absence of gumbotil on the Iowan drift seems to be due to a lack of favorable conditions for its development rather than to a lack of time. It is hoped that further field study may clear up the remaining points of difference.

CONCLUSION

From what has been outlined it will be seen that there are problems of various kinds awaiting solution. These problems call for training in various lines. There will be work for students of various degrees of ability. But, as remarked by one of my associates, it will require native ability, thorough training and a steady scientific aim to clarify the main problems of glacial geology.

A NEW SCIENCE[1]

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The most ancient art—and still an art—emerges into the most modern science, one that began to develop with the "Machine Age" and never will be completed.

We need science in education, and much more of it than we now have, not primarily to train technicians for the industries which demand them, though that may be important, but much more to give everybody a little glimpse of the scientific mode of approach to life's problems.—R. A. MILLIKAN.

"NECESSITY—thou best of peacemakers, as well as surest prompter of invention," said Sir Walter Scott. Necessity has often been described as the mother of invention, but there have been other parents such as desire and even accident. Whatever the economic urge behind invention may have been, it is clear that to-day science is the father of both discovery and invention so far as method is concerned. What have been the forces which have propelled individuals toward new goals? The search for the beginning of an idea usually leads far back of the date of the invention, and it is difficult to place a historical finger on the individual who originated an idea. National urges and movements are much easier to trace and in the long run are as important in measuring the causes of and steps in discovery and the resulting influences on the social organism.

Just what was the motive force five thousand years ago in the Nile Valley? A desire for a form of immortality led to the construction of the tombs and pyramids of Egypt. The temples of Thebes, Amenra, Edfu, Luxor, Memphis, Baalbeck and others were erected to perpetuate a cult. They represent a national skill, but not a national culture, as the erection of such monuments was by the decree of a despot and at the expense of thousands of slaves.

Greece was a democracy, and the national search for beauty gave us the Parthenon and the attendant philosophy of Plato. Not less impressive were certain scientific gifts contributed by Greek culture of which much less is said.

Religious zeal also gave us the Gothic period, which was the first architectural style to emphasize the vertical line. The cathedrals of Bourges, Chartres, Amiens, Rheims, Notre Dame, Salisbury, Wells, York, Lincoln, Cologne and Milan represent a wide-flung culture and a reborn skill.

Whatever have been the incentives to progress and whatever scale of intelligence may have been reached, there have been limitations to the skill or productivity of nations, and the most obvious has been the tools which they used. The implements of primitive man were the product of hunger, fear, love and his environment, but the later national advances were limited by the tools available, and tools have been a product of science as the latter has fabricated new materials and

[1] Address of the retiring vice-president of Section M—Engineering, American Association for the Advancement of Science, Des Moines, December, 1929.

discovered new principles. The greater the advancement of a nation, the more it is dependent on the contributions of science.

The tools of the Egyptian period from 4000 to 1000 B. C. were of bronze and included straight and circular saws, solid and core drills, chisels, hammers and axes for dressing timber and stone. Their skill as workers in stone was limited by the materials and tools which they possessed. The Greeks attained even finer expression with tools of the same materials, and their craftsmanship as designers and sculptors was acquired and perfected in a comparatively short period of national history.

Invention could offer very little improvement in tools and skill until long after the Christian era began. Roman ruins reveal bronze as the metal most frequently used, and the best Roman art was transplanted from Greece.

Roman aqueducts are monuments to the ability of early engineers who worked with simple tools. Aqueducts and roads were among the earliest utilities constructed for public benefit. Egypt had its irrigation canals and pyramids; Greece had supplied water to Athens by gravity, but Rome was conspicuous for its early engineering works which were constructed in the face of great obstacles. Such knowledge as there was of column, beam and arch was empirical—the product of experience rather than of science. The first circular arch of which we have knowledge is Egyptian and dates from about 1550 B. C. It was formed of four courses of brick totaling four feet in thickness and was eleven feet in span. The dome belongs to a later period, about 440 B. C., and was probably of Etruscan origin.

For a thousand years, skill remained at or below the Greek level. Few inventions were made, and inventions are ideas at work.

Let us trace a few of the most impressive inventions and discoveries of a scientific character and their influence on knowledge and skill in the use of it.

Astronomy began with the earliest civilization. The Egyptians, during their most productive period, had a calendar and a system of simple surveying, and they located the axes of some of their temples by stellar or solar observations.

But the Greeks left much more to admire. Pythagoras pronounced the earth round. Anaxagoras first stated the theory that the sun, moon, stars and meteors were of a common substance from a common source—"one of the most marvelous feats of human intelligence," says Henry Smith Williams in his "History of Science."

Ptolemy was a transplanted Greek who first discovered the solar system as such, though in error in locating the earth as the center. Little was possible in geography or navigation until the truth about the solar system was discovered.

Archimedes, the inventor of the screw pump, may be called the father of the science of mechanics. Previous to his time (the third century B. C.) water was raised by buckets operated by hand for irrigation and domestic use. His was an important contribution as it involved an analysis of the screw. He first formulated the principle of buoyancy and determined the relation between a sphere and a circumscribing cylinder by experiment and analysis.

There followed over ten centuries fallow in the field of mechanics. Galileo then corrected the theories of Aristotle on falling bodies, announced the principle of forces in equilibrium, of inertia, studied the telescope, the earth's motion and the pendulum. Newton followed immediately with his well-known principles.

The birth of the science of mechanics dates from Archimedes, but its adolescence lasted over fifteen hundred years. Its renaissance was accompanied by a galaxy of contributors, chief of whom were Kepler, Huyghens, Descartes, Maxwell, Rankine.

The study of anatomy, no doubt, began in prehistoric times, but it is not until the time of Pythagoras and Aesculapius that the science began to emerge. The function of heart, veins, arteries and the brain were contemplated, and "the four elements, fire, water, earth and air, were made the basis of all organisms," then little progress was made for two thousand years, until Harvey discovered the circulation of the blood, oxygen was studied by Priestley about 1774 and, beginning with Pasteur in the last century, came the rise of biology. The Greeks considered the atom, but this field of science was closed to them and to their successors until the microscope was produced.

Aristarchus and Hipparchus made real studies of the size of the sun, moon and earth, but their apparatus was inaccurate. Hipparchus is credited with the first pronouncement of the precession of the equinoxes, although the fact of such a movement must have been known to the Egyptians. Ptolemy followed Hipparchus but failed to accept the sun as the center of our solar system.

There was experimental knowledge at an early date of the effect of heat on air, but Hero, of Alexandria, was the first, so far as we have record, to use heat to do work. His inventions were toys rather than devices for relieving men of labor, and to them perhaps too much importance has been attached. Nevertheless, tremendous significance must be assigned to the Greek contributions to early science.

The Romans contributed to geography, medicine and law but left no such impress on science as the Greeks.

During the ten centuries following the opening of the Christian era a few contributions to science were made by Arabic and Roman scholars, but the period is comparatively sterile. Science was throttled; skill was limited. The rotundity of the earth was not accepted and a true concept of the solar system was not vigorously sponsored, though it had been suggested by both Greek and Alexandrian searchers.

In the thirteenth century, advances were made in medicine. Universities were founded in Italy, France, England and Germany. Roger Bacon reviewed the learning of certain Arabians and pronounced in favor of a scientific search for truth.

It was not until the fifteenth century that master minds emerged from the dark ages. Columbus, Leonardo da Vinci and Copernicus were born in this period. Columbus proved what Ptolemy and his followers had pronounced, that the earth was round. Leonardo added to the proof that the earth moved and the sun did not. He experimented with steam much as Hero had done, but made no material advance. He observed many facts of nature and formulated a few principles which marked an advance in the field of geology and optics. His accomplishments as an engineer, military genius and artist are much more impressive than his contributions to science.

Copernicus was a German who studied in Vienna and Rome. He taught mathematics and for thirty or more years considered the Ptolemaic theory. He did not publish his famous book addressed to the pope until about the time of his death.

Tycho Brahe contributed to the advance of astronomy but rejected a part of the Copernican theory.

Kepler, a sixteenth century observer, successfully defended the theory of Copernicus and announced his three laws concerning the variation in speed and in the distance of the planets from the sun as they traveled their elliptic orbits.

At about this same time, the first systematic studies of magnetism were made by William Gilbert in England. Galileo believed in him, and later Priestley called Gilbert the father of modern electricity. He coined the phrases, "north and south poles," "electric force" and "electric attraction." He distinguished between magnetism and electricity and made numerous experiments.

Alchemy and astrology had existed from the beginning, handmaids of ignorance, superstition and evil. They throve until about the time of Elizabeth, when advances in the search for facts began to cast grave doubts on them. Progress in anatomy was made by a considerable number of investigators leading up to Harvey, who first understood the blood circulation and the action of the heart. Closely following came the discovery of bacteria by Leeuwenhoek, in 1683.

These two discoveries laid the foundation for a science of medicine which, however, grew very slowly. The scientific method was applied by a few, such as Descartes and Leibnitz.

Boyle, Hook, Huygens, all added to the refinement of physics. Newton formulated his laws of motion and of gravitation, studied the spectrum of light, the nature of color, refraction and reflection.

A very large number of investigators followed Gilbert and contributed something to our knowledge of static electricity. It was, in fact, applied in medicine as early as 1743. William Watson, of England, appears to have described his experiments, and his descriptions were read by Benjamin Franklin. He and his coworkers began a long series of very productive experiments, first with the Leyden jar, from which he constructed a battery. Several had suspected the identity of electricity and lightning, but Franklin was the first to prove it.

A scientific basis for the development of an electrical science was laid by Faraday, Henry and others in the next half century, and close on its heels came one of the most spectacular changes in industry and society.

James Watt condensed steam in a more efficient way and his successors improved the art. Rankine, Carnot, Joule and others developed the science of heat energy and showed that heat *is* energy. Without this science our present social organization would be impossible.

May I emphasize that in nearly all fields the development of a science has been followed quickly by applications which have had great significance?

We have developed the science of the infinitesimal, of the infinite and of nearly every phenomenon in the earth beneath, the waters thereof and the heavens above so far as they relate to matter, force and motion. The changes resulting from this new knowledge have transformed the environment of man though they may have influenced his character but little. We find ourselves in the midst of an industrial civilization which has removed physical limitations and reduced manual burdens. This age of men and machines is hailed as a savior and condemned as a destroyer. Obviously, the machine itself is guiltless. If it serves, then the designer, inventor, manager are to be commended. If the machine is a curse, then it seems that the person or persons responsible for the abuse are guilty. The machine can do no wrong, can break no laws. Laws may abolish certain tools or machines because they are to be used for evil purposes just as men are removed from society because they are dangerous.

The science which has developed the materials and instruments of this age of power has been followed by applications which were impossible before. The art has followed the science rapidly. The skill of men has been equal to the materials and tools provided.

Science has developed a law of action for nearly every force known to man, but there has been no accepted science of man-power, no science to serve as a guide to the management of men. Numerous principles have been proposed commencing with the Biblical injunction to "Do unto your neighbor as ye would that he should do unto you." The psychologist has studied intelligence, nerve action, inhibitions and complexes. The economist has studied trade, wealth and cycles of various kinds. The social scientist has dealt with masses, movements and legal restraints. None of these has attempted to develop either a theory or a practice of industrial operations, *i.e.*, a science of management.

The earliest important contribution to a science of directing and using human energy was by Frederick Taylor, who applied the scientific method of measurement to tasks and approached the problem of wages and incentives in the same manner. Gantt, Barth, Emerson, the Gilbreths and many others have contributed to this scientific achievement of the twentieth century. It has been summarized and formulated by Mr. L. P. Alford in a paper presented to the American Society of Mechanical Engineers in 1926, in which principles are laid down for handling materials, the product and men. The laws of leadership are capable of broad application even to colleges and universities. The law of responsibility, the law of exceptions, the law of task and wage incentives, the law of productivity, the law of acquiring skill are fundamental precepts, the recognition of which lays a firmer foundation on which to build administrative skill.

In engineering education recently nothing has attracted more attention than instruction in the field of human relations and industrial proficiency. The personality of the student as well as scholarship is being considered, and the approach to industry is becoming rationalized. Sentimentalism is being replaced by facts and preparation. The induction process begins in college and continues well into industry. Systematic study is replacing a *laissez faire* attitude, and something of the scientific approach is being made. Enlightened management is no less an art but more of a science, and so far as it is a science we may not ignore it entirely in our engineering instruction. The methods employed may differ widely but the purpose is to make the young man more familiar with some of the elementary principles.

OBITUARY

DEXTER DWIGHT MAYNE

DEXTER DWIGHT MAYNE, for twenty-six years principal of the School of Agriculture, University Farm, St. Paul, Minnesota, died at Gulfport, Mississippi, on Saturday, December 14, and was buried at Platteville, Wisconsin, on Friday, December 20.

Professor Mayne was born at Beetown, Wisconsin, May 14, 1863, the son of Nicholas and Mary (Treloar) Mayne. He was graduated from the State Normal School at Platteville in 1883. He was principal of schools at Fennimore, Wis., from 1883 to 1884; Elkhorn, 1884 to 1889; Fort Atkinson, 1889 to 1893; superintendent and principal of schools, Janesville, Wisconsin, 1893 to 1901, and superintendent of schools, Ishpeming, Michigan, 1901 to 1902. From the last-named place he went to the School of Agriculture of the University of Minnesota, a technical school giving a course of three years, of six months each year, and open to pupils who had had only grammar-school preparation, on the same campus but separate from the College of Agriculture of the University of Minnesota. In this position he continued until his death.

Under Professor Mayne the School of Agriculture of the University of Minnesota had a remarkable growth, the attendance at one time approaching or exceeding one thousand. Its success was so marked that it attracted attention throughout the country and led to the establishment of two similar schools, one at Crookston and one at Morris, Minnesota, within a few years after Professor Mayne assumed the headship of the school at University Farm. Three years ago a third school of the kind was opened at Grand Rapids. The establishment of these outlying schools, with the introduction of agriculture into the curriculums of high schools of Minnesota, led to a falling off in the attendance at the school at University Farm, but the school has continued throughout to attract large numbers of students interested in training themselves for leadership in farm and rural home life.

Professor Mayne was a man of alert mind and prompt and sure decisions, of persuasive friendliness and of resolute will. He was quick to decide and quick to act, and persistent in following through any project undertaken for the development of his students. He gave much time to intimate personal contact with the young men and young women under him, and his students were swift to respond. Their confidence, once won, never weakened. He had the extraordinary gift of imparting inspiration and