PRESIDENT'S ADDRESS.

By C. A. Waldo.

INTRODUCTION.

Of the seven volumes of Proceedings published by the Academy or under its direction, it has been my fortune to be more or less intimately connected with the editorial work upon six of them. The general work of the Academy has, therefore, come under my notice in a peculiar way. This fact has led me to attempt a slight departure from the excellent models set by my able predecessors, and to premise the usual discussion expected at this time by a brief resumé of the scientific work recently done in the State, especially during the year 1898.

We may congratulate Indiana upon the amount, the character and the importance of the scientific activity within her borders. In attempting to select a few things for mention we must beforehand pray indulgence. Pardon is asked for sins of omission and commission—these will be because of ignorance or imperfect vision, and for no other reason.

In the following mention, the order of our program for this year is followed.

The mathematicians of the State are showing a commendable zeal in the prosecution of pure and applied mathematics in the higher ranges of the subject, and are building up several centers in which the work done is incomparably beyond that of a generation ago.

Our physicists have been busy investigating electrical, optical and acoustic phenomena and extending our knowledge of these subjects. The year has seen completed within the State a great car-testing plant, the invention of an integrating dynamometer, the completion of investigations on train resistance on straight and curved tracks, and large contributions to engineering literature. Two of our engineering instructors have been honored with important assignments on committees of international importance.

Our chemists have been establishing the value of our coal deposits, have enlarged our knowledge of toxicology, have made special examination of alkaloids and have contributed towards the investigation of food supplies, the exhaustion and restoration of soils.

The year has witnessed, with the co-operation of the Academy, the completion of a treatise on the Phanerogamic Flora of the State, giving the range of nearly 1,500 species, together with specific studies of forests, weeds, and unutilized vegetable resources; this now is awaiting publication.

The year has also seen the culmination of extensive investigations upon beet sugar as a possible Indiana product and the determination of large areas—practically the whole of the northern part of the State—where under existing conditions the sugar beet can be cultivated with profit. Plant disease, like the San José scale on fruit trees or smut on cereals, have received much attention, and valuable results have been obtained. Valuable conclusions have been reached in the use of specific fertilizers for specific plants, and upon the relative merits of surface and sub-irrigation.

Yeast investigations have been continued and further conclusions reached of prime importance to every household.

Additions have been made to our knowledge of cell life and cell modification in plants, as affecting various theories of heredity, and much systematic work has been prosecuted in various parts of the State tending to perfect our knowledge of the State flora. Our denuded lands and their possible reforestration have received scientific attention.

In zoölogy the greatest event of the year has been the issuance from the State Geologist's office of a monograph upon the birds of Indiana. This work is thoroughly up to date and is not a mere catalogue. It gives attention to the economic side of bird life, and enables the farmer to recognize his friends and enemies. No recent extensive scientific publication in the State has created such a widespread interest. An edition of 8,000 has been already exhausted and the demand is for more.

An event of almost equal importance is the removal of the Summer Biological Laboratory from Turkey to Eagle Lake. At the former location many Indiana teachers and scientific workers have been trained in laboratory methods; many more will find their way to the new location and through its influence will enter the ranks of trained specialists. In addition to this, much light is being thrown upon the problem of variation as bearing on the origin of species. During the year there must be credited to Indiana some first-class work on cave fauna which is receiving national attention, and which must have a large bearing upon the problem of the influence of environment.

Animal diseases have been investigated with varying degrees of success, and studies made of food for various forms of live stock.

In the geological work of the year in Indiana, the influence of the new scientific spirit abroad in our midst is especially manifest. Besides the report on birds already referred to, we find in the volume for 1897, recently distributed, a timely revision of Indiana paleontology, and further prosecution of county geological surveys. On the economic side, the clay industries have been well and exhaustively set forth, while the conflicting interests of oil and gas production have received able attention. It will be found eventually that the fearless conservation of our gas deposits will have paid a thousandfold the expense to the State of our geological department. It is refreshing, too, and characteristic of the true scientific spirit, to note how the truth and the whole truth is told of our disappearing gas supply. No permanent prosperity founded on deceit and misrepresentation can come to our commonwealth. Rigorous, unadulterated scientific truth is, however, a sure basis for wealth, honor, morality and happiness.

Naturally flowing out of gas belt indications comes the work of this year—a prospectus of which is given in the volume of 1897.

A thorough investigation and report upon the vast coal deposits of the State is at this time especially opportune. As this investigation has already shown deposits equal to all demands upon it for two hundred years to come, the result of the work can only be to establish us in a confident reliance upon the industrial future of Indiana.

This review would not be at all complete without some notices of a general character. In sociological matters the State is making splendid progress. Along this line there is only time to mention the new pathological laboratory at the Hospital for the Insane, the establishment of the Indiana Reformatory at Jeffersonville, leading to the rational treatment of criminals, the introduction of the Bertillon measurements in four of our cities, and the increased activity in our Board of State Charities. Sanitation in our centers of population, in our public schools and homes and public buildings, is receiving great attention. The agitation for pure food will probably soon lead to advanced legislation on this important subject.

Educationally, nothing perhaps has occurred comparable to the widespread influence resulting from the general dissemination throughout the

State of twenty-five nature study leaflets conspicuously adapted to the wants of our great rural population.

In our educational centers we note with pleasure the extension of laboratories, the growth of cabinets and library facilities. Attention is also called to the gratifying fact that recently the office of State Entomologist has been created and worthily filled.

An event of unusual significance to those who have occasion from time to time to consult the scientific publications in the State Library is the fact that during the year '98 the large and growing science accumulations of the Academy of Science and of the Brookville Natural Science Club have been made available to the general public by being placed upon the shelves of the State Library.

Two thoughts are suggested here as a conclusion:

1. Such valuable results as we are now securing in works like the birds and the phanerogams of the State, its clays and coals, have been reached only by the organization of our scientists, and through their increase and their development of ideas and enthusiasm, resulting certainly in a marked degree from the thirteen years' influence of the Academy of Science.

2. The official relation which we sustain to the State has brought the feet of our scientists to the ground and the economic aspects of their studies are being emphasized as never before.

At best this is but an imperfect and rapidly dissolving view of the teeming and multiplying scientific progress within Indiana's borders. A wise choice of topics would perhaps have given the whole time of this address to a review of progress in Indiana since 1885, but I must leave that inspiring theme to some future historian.

To-night, fellow-workers, I greet you and congratulate you upon work worthily done. Fame may not always follow endeavor, but, whether public recognition of work attempted and results accomplished ever comes or not, the true scientist knows that his highest compensation is in the opportunity for service, and he is at peace with his environment.

Services of Mathematics.

Of the twelve gentlemen who have preceded me in addressing the Indiana Academy of Science on occasions similar to the present, three might have interested you with a mathematical topic, but they did not.

One, famous for his vigorous championship of Christian thought, chose a subject in which he used mathematical methods in theological reasoning. The other two, though splendidly equipped in mathematics, preferred to present phases of physics. Our program shows six subdivisions of science, among which mathematics has always held a secure place, but up to the present time no one has had the inclination or the courage to attempt to discuss in a popular manner the oldest science and the one second to none in its services to mankind and in the zeal with which it is to-day cultivated and enlarged. It is, I confess, with misgivings that I break this thirteen years' silence, for the range of the subject has now become so vast that no one person can longer hope for an intimate acquaintance with all of it, and any writer must rely more or less on testimony for many results and their bearings upon progress. And yet when we consider the extent to which the science of mathematics is cultivated among educated people, the large part that it plays in all our lives, are we not justified in an occasional attempt to call attention to prominent facts concerning it as they appear to some of us who have spent fifteen years or more in trying to disseminate its truths?

In the British Association there have been at least three notable presentations of the claims of mathematics by three of its most famous exponents. One of these is little less than an inspired plea for his loved discipline, by one of its prophets; a second shows how higher ranges of the subject have been suggested by other sciences; a third is a classic argument for the unrestricted development of mathematics along systematic lines both for its own sake and for its possible future utility in fields now undreamed of. In the American Association there has been a tendency to make mathematical lectures more technical and therefore less interesting to the general public than in the British. One essayist made a notable attempt to explain modern algebra to the uninitiated, a second spoke upon the evolution of algebra, while a third gave a historical disquisition upon the origin of our methods with imaginaries. A fourth was an exception to these in that he argued for reform in the choice of subjects in college curricula and in the manner of presenting them.

The essential difficulty in discussing a mathematical topic is the fact that this science possesses the most highly developed symbolism and an almost perfect technical language. Both these attributes condense our reasoning to a minimum and make it unintelligible to the uninitiated. In trying to popularize, we are in danger of becoming puerile. Most mathematicians of our time have abandoned the former attempt, and therefore speak a language absolutely without meaning to the average man. Often the use of symbols and technical terms is not even a matter of choice. It is a necessity, for the ideas sought to be conveyed can be expressed in no other language. The mathematician, therefore, often labors on with no understanding or appreciation of his work or its results on the part of the general public. His subject is dumped into the same class with the dead languages. Latin, Greek and mathematics must form an unnatural alliance in a fight for recognition. Too frequently the mathematician is grudgingly given but a tithe of what he claims, and even then he is asked why he should cumber the ground and impede the way to higher and more useful pursuits. Before Latin had a literature, mathematics *was*. Now, when the conviction is rapidly gaining ground and in all progressive institutions being put into practice, that a smattering of Greek and Latin soon forgotten are not essentials in education, mathematics have entered new fields and conquered new territory. Their cultivation has gone forward in the last generation in leaps and bounds, their advance has kept pace with and in a large measure conditioned, both on the material and intellectual side, the tremendous and unexampled progress of civilization in that period.

There are three general aspects in which mathematics can be viewed:

First. As a disciplinary study.
Second. As a cult.
Third. As a tool.

These three general grounds for consuming time and effort in cultivating this science are not mutually exclusive. Their territory frequently overlaps and the determination of the stronger incentive often depends upon the point of view of the individual or his environment.

As a disciplinary study, mathematics are present in some form in all the curricula of colleges, high schools and the grades. In the grades, however, we must recognize as the principal reason for time and effort, the thorough mastery of number and the development through drawing of the form perception for the practical every-day business of life's activities. At this point it has seemed to me that a serious error is quite commonly committed. Too often instructors imbued with that philosophy of education which unduly idealizes every subject taught, make a premature attempt to develop logical processes at the expense of an intimate knowledge of number combinations and of a practical facility in their rapid and accurate manipulation. Very properly in the high school the disciplinary idea predominates, but even here it is a question whether the time is not near at hand when some of the older mathematical subjects taught should be in a measure set aside and other newer ones substituted which are of equal disciplinary value, but whose knowledge content is greater.

In the earlier portion of the college course the disciplinary idea still strongly predominates, but if mathematical study is continued through the last two years and into graduate work it becomes a cult or a profession or a necessary adjunct to a profession.

In its development we may roughly divide mathematics into three general subjects:

Arithmetic.
Geometry.
Algebra.

Yet again these, especially in their higher ranges, continually overlap each other. The theory of numbers seems to belong to arithmetic, yet some of the problems like that of prime numbers, which were among the earliest propounded, demand now for their approximate solution, after twenty-five centuries of development, the highest powers of analysis. In analytics, geometry and algebra melt into each other, while in the modern group theory the three which in their earlier manifestations seem so diverse in spirit and purpose form one grand generalization.

As a discipline these studies need no apology. Their influence in the development of the reasoning powers is unquestioned. They exercise the muscles and sharpen the teeth of the logical faculty. They furnish the growing mind with exercise in useful knowledge with reference to which it can have absolutely no prejudice and, while leading to certain truth, generate confidence in intellectual powers. They develop the inventive faculty by sharpening the powers of comparison, by diversifying and enriching the powers of attack, by developing the power of long continued attention and concentration.

As a cult, pursued for its own sake, it furnishes one of the highest occupations of the intellect. The mind revels in the realm of pure thought, and each triumph must bring the thinker closer to that all-pervading intelligence whose very existence and activity entirely removed from chance and imperfect knowledge must be conditioned by mathematical necessity.

The chemist often pursues his investigations into the constitution of matter without any thought of any possible utility in his results. He pursues the science for the sake of science, that man may grow in knowledge whether or not he can turn that knowledge to practical account in the manufacture of steel or the dyeing of silk or the synthesis of nitrogenous compounds.

Yet not seldom in his case, as in the history of pure mathematics, has it transpired that a truth sought for truth's sake has become the necessary foundation for splendid material achievement. One need but recall the labors of an Archimedes or a Newton to note how a searcher for higher mathematical truth for its own sake may become an epoch-maker in human progress.

It is not my purpose, however, to dwell upon this part of my subject, and I conclude with two quotations from Sylvester. In recommending the high living of the mathematician and nature's provision for his evolution he says: "The mathematician lives long and lives young; the wings of his soul do not early drop off, nor do his pores become clogged with the earthy particles blown from the dusty highways of vulgar life." And again: "Space is the Grand Continuum from which, as from an inexhaustible reservoir, all the fertilizing ideas of modern analysis are derived, and as Brindley, the engineer, once allowed before a parliamentary committee that, in his opinion, rivers were made to feed navigable canals, I feel almost tempted to say that one principal reason for the existence of space, or at least one principal function which it discharges, is that of feeding mathematical invention."

Passing, then, with this cursory mention, a theme so inspiring and fruitful as the consideration of mathematics from the ground of discipline and culture, let us confine our attention to the question of utility alone. What has mathematics done that it should commend itself to the great, struggling masses of humanity who are busily engaged in adding to the surplus products of the race, who are breaking the virgin sod or swinging the artisan's hammer or directing the world's exchanges? Has mathematics any right to stand with physics, chemistry, botany, zoölogy, geology, whose cultivation has revolutionized civilized life?

Can a science which begins with assumptions never in perfect accord with fact and which ends with conclusions impossible of exact application ever get its feet on the ground sufficiently to secure a leverage for pushing along the car of progress?

In considering the services of mathematics from this purely utilitarian point of view we shall find it convenient to speak of

GEOMETRY AND ANALYSIS.

The American people are unusually intelligent, but is it not true that no more than one per cent. of them ever have any adequate conception of the innumerable ways in which geometry enters into their every-day life?

Houses of all kinds, from the humble cottage to the Manufacturers' Building of the White City, from the backwoods meeting house to the vaulted cathedral, first grow on paper under the magic of geometry. Bridges and everything that rolls over them, shops and every manufactured product that comes out of them, grow into being in the same way.

Only a Michael Angelo can hew out a statue without model or drawing, but Raphael himself must resort to mathematical perspective for depth and sky. Not of Euclid do the towering buildings and the diversified industries of a teeming city attest, so much as they do of the Frenchman Monge, upon whose discoveries and researches are based our systems of industrial drawing now so rapidly and deservedly gaining ground. The time, I believe, is not remote when descriptive geometry in some of its phases will find a more open way into the high school and will insist on recognition whatever else may suffer. The heart of the shop is the draughting room, a room without which the trunk line, the ocean steamship and a thousand and one things necessary to our complex civilization can not exist.

The educational revolt of a generation ago against fossilized methods then widely practiced arose from a conviction that we had outgrown monastic institutions. The training suitable for a state of society where all education was in the hands of the church and all educated men became priests was found to be no longer adequate to the needs of a country which was rapidly developing into the most powerful nation on the earth through the industry, inventive genius and mechanical skill of its people.

The learning of the college was laughed to scorn. Then came science and elective courses, but this was not enough. Technology was transplanted from Russia and Germany. It took quick root and has had a marvelous growth in American soil.

Throughout the world what an expansion! till to-day, through the influence of their technical institutions of all classes, the civilized nations are battling for the industrial supremacy of the earth.

So essential is modern geometry to technology that it is safe to say the latter can not exist without the former. Through geometry the controlling mind translates the creative idea to the willing worker, and what was only a dream of beauty or utility now stands clothed in material form under the eye of the world for its edification, elevation and use. The artist whose masterpieces adorn our walls, first groups his figures as he wishes them to appear, then he calls geometry to his assistance to make them seem to be where he wishes them.

We mistake, however, if we confine the services of geometry to technology. Nature is continually inviting the observant mind to geometric study. The beautiful crystalline forms which abound in the rocks of the globe, in the snow and the ice speak of unity in infinite diversity. Under the microscope the thinnest plate of shapeless rock, the very particles of dust at our feet, tell through shape alone a story of origin and character interesting and valuable alike to the physicist, the geologist, and the chemist. The latter, interested in the ultimate forms of matter, finds suggestions for valuable theories upon atomic forms, and constructs geometric molecules in which a dissimilar position of a characteristic atom will in a measure explain such curiosities in nature as right and left-handed sugar, which, though having different properties, still are made of precisely the same constituents in the same proportions.

Analytic geometry occupies the border land between geometry and the higher analysis. The elements of this subject so far as the construction of loci is concerned are rapidly becoming the possession of the reading public. The variations of temperature, of humidity, of productivity, of commerce, of population, of crime and of the price of wheat, from hour to hour, or from day to day, or from season to season, are immediately expressed to the eye by curves in which portions of time are the horizontal measurements and the various values of the function are the vertical. In science the natural way to express one series of facts dependent on another is through a curve. Passing on from loci, which are so full of meaning and so suggestive of causal relations, it is customary to discuss in detail the circle, the parabola, the ellipse and the hyperbola. The laws of gravity lead to these curves, and they are the fundamental orbits of the bodies of the universe. In terrestrial matters they lie at the basis of the laws governing stresses and strains, the study of optics, the propagation of impulses in homogeneous media, and a thousand practical things. As we rise higher and approach analysis we trace the lines along which stresses are propagated and materialize these in the beautiful iron bridge, with its parts nicely shaped and adjusted to the load it is to carry. Advancing further, our lines become in the strain diagram a veritable graphical calculus, through which we discover the stress with which any load, fixed or moving, strains a structure, and therefore through it find a ready means of designing our creations to resist safely the stresses to which they will be subjected.

But this brings us to the question of analysis—the other side of our subject. I shall not dwell upon algebra as we usually understand that term in high school and elementary college work. I need only speak of it as generalized arithmetic to recall to you how it gathers up the rules of the lower subject and condenses and generalizes them, and how, by introducing the result sought at the beginning of a series of operations, we easily carry to a conclusion logical sequences, otherwise exceedingly difficult to follow, and ascertain whether or not the problem proposed is capable of solution.

It must be confessed, however, that algebra in the ordinary school sense is very largely a discipline, little used in the ordinary affairs of life and finding its principal utility in the studies which lie beyond. Yet to pursue these with ease and success, a knowledge of ordinary algebraic methods and facility in algebraic manipulation, including the analysis of the angle, is a prime requisite. I come now to speak of the higher analysis in the sense in which it is ordinarily applied—that is, the infinitesimal calculus and its developments and allied subjects—the invention of which marks an epoch in human progress second, I believe, to no other scientific event.

It is curious, when we think back over human advancement, that some of the things now most patent to our senses escaped recognition so long. The alchemist stumbled through centuries without learning the nature of air and water. The most puerile ideas regarding the earth's structure prevailed down to the American Revolution and later. And so, while arithmetic, Euclid, Diophantine analysis and trigonometry are highly artificial, calculus brings us back to nature. Space and time were continually thrusting themselves upon the attention of man, motion in the former, rate in the latter, as exemplified by every moving thing and changing substance, and were perpetually inviting attention to an arithmetic that took hold upon continuous number and rate of change. Yet for centuries without result. The method of exhaustions came very near to the invention of the calculus, yet Grecian civilization, with its brilliant record, flourished and died without any knowledge of it. A Scotch professor in Dalhousie University was accustomed to say that with the calculus the Greeks would easily have outstripped us in invention. In depth and clearness of thought, in majesty, beauty and originality of ideas and ideals, in strength and suppleness of limb and delicacy of touch, they were clearly our masters. They could geometrize amazingly, but they had no science of continuous number; therefore modern civilization is passing theirs with giant strides.

When the Reformation occurred in Germany, its spirit was abroad everywhere. Had Luther not come to the leadership at that time, who will say that another champion would not have arisen to espouse the new ideas and stake his life upon their success?

So, in the intellectual progress of the seventeenth century, new notions had permeated the mathematical world. The idea of the dependent and the independent variable had gained such ground that the then new science, analytic geometry, was the necessary result. This new subject lent itself readily to the graphic representation of mathematical interdependence and thus furnished in mathematical form a generalized expression and representation for a thing changing in obedience to law. The rate of change necessarily followed soon after, and isolated cases of its use in determining the tangent to a curve show that it was in the air. Newton and Leibnitz immortalized themselves by noting the mathematical drift, seizing the new methods and constructing from them the new discipline.

Thus man came into possession of an instrument adapted to discover and establish the laws and processes of nature because it is constructed on nature's model. Trees do not increase instantly a foot in height and then rest for a period before the next jump. Rivers are not at one instant a swelling, muddy flood, and at the next a clear, tranquil stream. The Knickerbocker Express does not go by jerks and instantaneous leaps from point to point as it passes over the space between Indianapolis and New York. But everything from external nature to the innermost soul of man connect various times, seasons and conditions by continuous number. The tree, the animal grows, the flood abates, the train progresses, mind matures, life expands, love deepens and broadens.

> "Chance and change are busy ever,
> Man decays and ages move."

God alone changeth not.

But everything we see, all else we can think of, is in a state of flux. The rate of these changes is matter of common observation and comment, and it is nothing but the first differential coefficient. Tait says every one uses the ideas of the calculus if he is not a fool. I doubt whether any of us, without we consciously give ourselves to reflection upon the subject, begin to see the clearness, the depth, the breadth, the comprehensiveness, of Newton's philosophic vision when he gave to the world the words *fluent* and *fluxion* in connection with his new culture.

As calculus was the first master-word spoken to the very soul of nature, so it has wrested from her first this secret then that, until man with this powerful ally is rapidly enslaving all her powers to work out his own will.

The calculus rewarded its discoverer by giving him the demonstration of the invisible chains binding the moon to the earth and then by delivering into his hand the secret of the system of the world. Who will estimate the services to civilization of these cosmical studies? Old superstitions disappeared forever. A man's horoscope became only a poetic fancy. Men no longer prayed to be delivered from the flesh, the devil and the comet. But our solar system was reduced to order and beauty, while mathematical analysis reached out with her long, delicate, quivering fingers and snatched from the depths of space a new planet never seen by the unaided eye of man—to enrich the retinue of our sun, and to demonstrate the divinity of the human intellect.

This was the first great conquest of the calculus. But when it was turned upon things terrestrial, it exerted an influence less dazzling perhaps, but no less profound. It laid the foundations, more perhaps than any other one thing, for our age of brilliant invention and startling discovery. Great generalizations have sprung from active imagination and patient accumulation of facts. But these usually have a far richer content than their first announcers dream of. The calculus analyzes these great thoughts, recombines them and produces results the most unexpected and important.

Much of our polite learning has been in the possession of the world for two thousand years or more, but the peculiarity of our present civilization is the general diffusion of knowledge and the triumphs of engineering skill. Invention and machinery have multiplied man-power by twenty. And below it all lies the calculus. The successful engineer who would be anything but a mere slavish copyist must have a mind well founded in mathematics.

Let us refer briefly to some of the things which calculus has done or helped to do in engineering. We may say with little danger of contradiction that the engineering of to-day is a question of minimum causes and maximum effects—a question of the first differential coefficient.

A Tay bridge disaster reveals a crime against humanity. We wonder at the pyramids and temples of Egypt, but when we think of the lives sacrificed like flies in these colossal but useless works, where the means employed were vastly out of proportion to the ends sought, here, too, was a crime against humanity.

It is equally beneath the dignity of the disciplined man to put too much or too little into a structure to serve its designed purpose in use and beauty.

In hydraulics, calculus investigates water pressure on a submerged surface and center of pressure for same, thus determining the size and form of retaining walls of all kinds, and solving the first problem of a water supply. It also investigates the quantity of discharge through orifices, notches and overweirs, determines the most economical sections of conduits and canals, the time of emptying or filling locks or other vessels under a varying head; the maximum range of jets from a given inclination determines empirical formulae from experimental data by the aid of least squares; discusses non-uniform flow in rivers and back water curve above dams; discusses the maximum work derived from moving vanes, such as stationary water wheels, wheels of steam boats, and screws of propellers.

Fifty years ago an excellent engineer by the name of Uriah Boyden spent weeks in designing the buckets of a water wheel. He obtained correct forms, but by the aid of the calculus a man no more talented naturally may to-day do the same work in two or three hours.

In machinery and structures it investigates the work absorbed by friction of pivots and the like; moments of inertia and centers of gravity leading to transverse strength of beams, their deflections, slopes and elastic curves; it establishes the strength of thick hollow cylinders and spheres upon which is based the design of fire-arms and ordnance; computes suspension bridges; determines stresses in arched ribs of iron, steel, or timber, or in stone arches.

It gives the mathematical theory of maps, derives formulae for computing geographical co-ordinates and for map projection; adjusts observations in triangulation and determines the probable error.

It analyzes and improves the steam engine; it studies the effects of reciprocating parts, studies the balance wheel, the shaft, rods, and cranks: it enters the steam box and discusses steam pressure, horse power, and efficiency. It measures the contents of irregularly shaped vessels.

It may sometimes seem that the problems along these lines have been worked out and embodied in the shape of formulae and that there is no more use to study the method further for these purposes. That, however, is not true. A man should always be master of the tools he is using if he wishes the best results. The man who can derive a formula understands best its applications and limitations. Moreover, occasionally new and important questions arise which can not be answered at all unless one is versed in the use of the calculus.

It has largely developed the dynamo and has given us Fourier's series upon which the theory of this machine rests.

Klein once said to a former pupil of his:

"You know that I have been too busy with theoretical matters to keep up with the practical things; what is the greatest recent discovery in the application of electricity to the arts?" The pupil replied: "The greatest recent discovery in electrical engineering is a method by which a current may leave a long circuit at a higher potential than it entered it." This is the well-known principle by which Niagara Falls, for example, becomes available many miles away from the fall itself, as a source of power. Klein said: "Wait. That," he presently exclaimed, "depends on the second differential coefficient."

Problems such as I have thus far alluded to are the problems of civilization. Light, heat, power, architecture, water supply and distribution, dissemination of news, transportation—did you ever think how closely these things affect us? Chemistry and mathematics have done their best in providing for our locomotive a rail that would resist the strain of a

40-ton car and an 80-ton engine. The 40-ton car is the ship of the plains. Without it millions of acres now dotted by happy homes would have been unavailable for settlement.

Up to this time but a small per cent. even of our educated people have been imbued with the spirit of the calculus and have appreciated its power. Indications point to a large expansion in the near future in the number of those who will cultivate it for the power that it will give.

A popular German treatise upon this subject has recently been written expressly for chemists.

The object of this treatise is easily deduced from a remark in it quoted from Jahn in his elements of electro-chemistry. He says: "Chemists must gradually accustom themselves to the thought that theoretical chemistry without the mastery of the elements of the higher analysis will remain for them a sealed book. For the chemist the differential or integral sign must cease to be a senseless hieroglyphic if he will avoid the danger of losing all comprehension of the theory of his subject, for it is fruitless labor to attempt to make clear in many weary pages what an equation says to the initiated in a single line."

By the higher analysis Guldberg and Waage have obtained formulae for studying the course and end of a chemical reaction. Neither in the application of analysis to chemistry are mathematical difficulties seriously in the way. The inner nature of the physical or chemical process is represented as truly by the method and working of the higher analysis as an object is represented by its photograph.

The power of the analysis in nature lies largely in its ability to deduce instantly from one set of laws another set equally important which at first sight do not seem to be closely related to it. For example, knowing the law of motion in space, we deduce velocity at any instant; knowing the chemical reaction as a whole, we deduce its intensity at any moment; from the weight of air and the law of gases we deduce its pressure at any height.

To the chemist we must look for the solution of many problems, whether of theory or practice. Perhaps the greatest of these is *the* philosophic question of the ages—*the nature of matter*. If this question is ever definitely settled it will be by the chemist, with the aid of the calculus.

The higher analysis in its services to mankind is not confined to the exact sciences.

Those who cultivate the natural sciences, so called, have been making and sifting vast accumulations of important facts with an enthusiasm, energy, patience and self-devotion which form an impressive illustration of the self-denial, the intelligent consecration of self to the race, the sublime purpose in life of the educated man of to-day. Where in history will you find finer examples of chivalric self-renunciation than are occurring among these men and women every day? Natural history has had its profound generalization. From the nature of the scientific laws of the origin of species, and from their fancied bearing upon religion as well as science, every foot of ground has been bitterly contested. Even to-day Darwinianism has many confident enemies. The controversy has reached that stage, however, where something akin to mathematical demonstration is needed if the theory would make further serious advance. To this last chapter Indiana is worthily making its contribution; but when an attempt is made to discuss observations and establish results upon higher ground, the calculus again comes into requisition. Indeed, so should it be, as the problem here presented is simply this: Can small accidental variation be integrated into specific differences?

Geology in its dynamical aspects, in its discussions of the earth's interior, and in questions of time necessary for the deposition of strata under varying conditions must sooner or later resort to the infinitesimal analysis.

To these will be added surface problems similar perhaps to the one suggested by a geologist. He asked that the calculus should be applied to determine the way in which varying temperatures apart from rain or frost may round off angular fragments of rock.

As political economy grows in certainty and increases in exactness, it is found that it becomes a proper field for the higher analysis. Economists, in fact, who desire to get the full content from the material which they try to interpret and generalize are coming to the calculus for an essential part of their equipment. In 1838 Augustin Carnot wrote upon the mathematical principles of the theory of wealth. Recently this has been translated in America, and a Yale professor has published a little work on the calculus to enable those to understand it who are untrained in higher mathematics. In all products which may freely invite competition there are certain ascertainable relations among quantity, demand, price and profit. These are expressible in analytic form, can be operated upon by the methods of the higher analysis and the result can be reduced to rational laws for the control of trade.

When the diversified interests of our country have been thus subjected for a period of years to statistical investigation and these results again have been formulated into equations of condition which in turn may be operated upon by the prolific methods of the mathematician; when finally the laws thus deduced have been published, read and understood, we may hope that commerce may be something besides a shrewd guess and that its shores will not be strewed with the wrecks of the hopes of 95 per cent. of those who embark upon its uncertain tides.

In 1815, Elkanah Watson, the well-known promoter of the Erie Canal, made his famous prophecy concerning the rapidity of the settlement of the United States. Some will remember how marvelously accurate this prophecy was fulfilled up to the sixth decade. But, beginning with the census for 1870, a wide divergence set in. At first the large deficiency in the observed population of 1870 was naturally attributed to the influence of the civil war. The mathematicians, however, soon began to analyze the returns and they discovered that the havoc and distress of our great conflict was quite inadequate to account for the change in rate of increase. As a result of these purely mathematical investigations, our sociologists began to search for the new conditions which were so profoundly affecting American life. They found them in the increase of luxury, in the more expensive habits of living then introduced, which tended to check the size of American families. So, analysis applied to sociological questions can not report on more forces than have been entrusted to it, but it may call attention to the fact that new and unknown causes have entered into problems under discussion and show where they first made their appearance. Thus it may lead the way to discoveries of vast moment in the sum total of human knowledge.

To what is our analysis leading us? Who can tell? It is certainly gradually arming us with powers comparable to those of the fabled Martians of recent Cosmopolitan fame.

Faraday was probably an abler man than Maxwell. The former developed many ideas which would not have occurred to the latter, but he was no mathematician. Maxwell took up the results furnished by his predecessor and worked out by the calculus the electro-magnetic theory of light, deducing many curious things which could never have occurred to Faraday.

Our warrior no longer wears mail and carries the cumbrous shield, spear, and battle ax, but we arm him with the Krag-Jorgensen and he strikes his blow from as far away as he can see his man.

Who will set the limits to our advance? As our knowledge becomes more exact, the application of our analysis will widen till it embraces man and nature in all their essence and relations.

Woollen's Garden of Birds and Botany. By W. W. Woollen.

Woollen's Garden of Birds and Botany is situated due northeast from the city of Indianapolis, on the south bank of Fall Creek, and is nine miles from the Indiana Soldiers' Monument, the center of the city, and four and a half miles from its corporate limit. It consists of forty-four acres of land, being four acres larger than Shaw's Garden, near the city of St. Louis. About twenty-nine acres of the garden is woodland, and the remaining fifteen acres are in cultivation.

It has a river front of one-third of a mile, and this is covered with timber and vines. The cultivated portion, most of which is rich bottom land, lies between the river front and the woodland. This is divided by strips of timber into three irregular parts and susceptible of being made very useful and attractive. In it, with little expense, two lagoons can easily be made for the growing of water plants. The river front can be admirably adapted to the same use.

The timber land consists of three hills, extending from the south to the north, the projections of which gracefully slope to the cultivated land, forming two perfect amphitheaters overlooking the cultivated land. These amphitheaters are exceedingly beautiful, the line of timber on them coming down to the very edge of the cultivated land and encircling it on the north with curved lines as true as could be drawn by a landscape gardener.

The hills are from one hundred to one hundred and twenty-five feet high, and divided by spring rivulets, which have rocky bottoms and beautiful meanderings. On one of these hills, in the very depths of the forest, is an immense bowlder, and on another a very considerable mound, which tradition says is the grave of an Indian chief. None of the hillsides are precipitous, and because of this, every inch of their surface is adapted to