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CONTENTS:

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*RESEARCH IN STATE UNIVERSITIES.**

THE word research, as used by scientific men, signifies study systematically carried on for the purpose of discovering that which is unknown. It is the seeking for new facts, new forces, new laws and new ideas without direct reference to their utility.

The word *re*-search has been chosen to express this high aim, rather than the same root without the prefix, because in most instances explorations have to be repeated, experiments performed again and again, and the advances made in any direction scrutinized from many points of view before the conclusions reached are deemed worthy of acceptance.

The field of research is not restricted to the laboratory or the library, but is as wide as the universe. It includes the study of man as well as his environment. It is essential alike to the growth of industries and the development of philosophies.

Research, then, is the painstaking endeavor to increase the world's store of knowledge in any department of human thought.

The Scope of Research.—One of the most important results of the modern development of industries is the recognition of the fact that discovery is the mainspring of progress. This conclusion, although self-evident, does not seem to have received the recognition it deserves. The creed which needs to be repeated over and over again in the hearing of every intelligent human

* Read before the Research Club of the University of Michigan, January 20, 1904.

being, in order that still greater achievements may be accomplished, is that all man has gained which makes him the superior of the beasts of the fields, has come as a reward for increasing his knowledge of the cosmos in which his lot is cast. The fact that progress depends on and is an outcome of human exertion, should stimulate and encourage all mankind to strive to reach a higher plane. The end in view is the attainment of all possible knowledge, and the application of that knowledge to the increase of man's happiness, the lessening of his burdens, and the decrease of his sufferings. The goal, on reaching which man can say: The bounds of the knowable have been attained, and all possible wisdom is mine! is not in sight. So vast and intricate are the laws and processes of nature and of mind, that the Ultima Thule of human endeavor will never be reached. But to approach and make nearer and nearer approximations to the magnificent ideal, like the alpine climber who seeks to scale some cloud-encompassed peak, we need no other guide than the assurance that all ascending paths lead toward it.

The uplifting of man by providing him with additional powers through research may, as just suggested, be illustrated by the tasks that mountaineers set for themselves. It is true that on a mountain's side all ascending paths lead toward its summit, but some are impassable, others beset with extreme difficulties, and only one perhaps is practicable. The discovery of that way is the mountaineer's hope. Many fruitless efforts must be made, but at last some one climber, more skilled, steadier of nerve, or stronger and more enduring than his companions, discovers the right way and others follow, guided and encouraged by his example and counsel. The foremost mountaineer is an explorer. Following in his foot-steps but improving the path he has made and discovering side excursions from it, others gain glorious alpine gardens, and traverse shimmering snow-fields never before pressed by human foot. In a similar manner, among those who strive to make advances into the realm of the unknown in other directions, some one investigator gifted beyond his fellows, inspired by a new idea, or discovering a new meaning in some well-known fact, like the successful mountaineer, leads the way. When such an advance is made, others are encouraged to follow and a new and wider view of nature is obtained. The all-important fact is that some one shall lead. Leaders in research have appeared from time to time and in increasing numbers as the importance of their services to mankind has become more and more appreciated and the demand for an increase of knowledge more general. Some of the pioneers in research have been greater than others, but all alike have assisted in the great work of extending the boundaries of the known. The recognition of the fundamental importance of research has been slow, and resulted from the observed increase with its advance in material gains, enhanced comforts, greater effectiveness of labor, better health and greater average length of life. As these and other similar results have been recognized, the demand for more knowledge, in order that still other forces might be utilized, has steadily increased, and never before in the world's history has this demand been greater than now.

In a large view of human advancement research work in pure philosophy, from which but little direct aid to industry is perhaps furnished, must be reckoned fully as important as the discoveries of the chemist, the physicist and others, which are widely utilized in enhancing man's material welfare. The discoveries in relation to the flow of electricity, or the studies which furnished a knowledge of the properties of steam, great as have been the re-

sults of their application, it is safe to say, have been no more beneficial to the human race than the researches which made known the mode of development of plants and animals. Electricity and steam have furnished power for the moving of ponderous matter, but *evolution* has given a mental force which has profoundly modified the philosophies of all civilized peoples, and as there is no doubt will be a means of discovering many new truths in the future. Advance in philosophy, ethics, etc., is no less dependent on research than is the growth of manufacture or commerce. But no separation of purely intellectual and purely industrial development is permissible, since, as there is abundant evidence for proving, progress in any department of human activity is followed by gains at other points along the frontier of the domain of the known.

The Bounds of the Knowable not yet Reached.—The incentive which leads men to devote their time and energy to research is an unquenchable thirst for knowledge. The unknown has fascinations which in all ages have awakened a response in the human breast. In the earlier stages of intellectual development, the mountains, the ocean, the caverns and other but little-known portions of the earth were peopled in imagination with gods, genii and fairies, both genial and malign. When reason supplants fancy and experiment undermines credulity, the voices from the unknown become still more alluring. They lead the astronomer to explore distant space where he finds no limit; the geologist to trace backward the history of the earth without discovering a beginning; the chemist and physicist to scrutinize the laws governing matter and force without untangling all of their complexities; the archeologist, the historian, the philosopher, the socialist and others to investigate man's estate and development, only to find the records failing before the beginning of thought is discernible; the biologist to describe and classify the manifold ways in which life is encased and study the functions of bone, muscle and nerve, only to learn that the longed-for insight as to what life really is recedes farther and farther as he advances. Along these and many other tributaries of the river of knowledge explanations have been carried without reaching their sources. On every hand and at no great distance, as shown by the explorations that have been made, the known merges with the unknown.

This same conclusion can be indicated in another way: The rate and character of a change that is taking place are frequently indicated by means of a curved line, which shows graphically, perhaps an increase, a culmination and a decline. By this means the rate at which human knowledge has increased might be plotted, but the curve would fail to indicate a maximum and give no suggestion of a decline. The nineteenth century has been termed the 'wonderful century,' and why? Because during that century scientific discovery, followed by invention, was carried on more systematically, more enthusiastically and by a larger number of skilled investigators than during any previous century. The tide of discovery and invention which made itself prominent during the century recently closed, and increased in force as the years of that century increased in number, is still advancing and, as it seems, with continuous acceleration. The intellectual tide-gauges of the world give no suggestion that the nineteenth-century wave of discovery has culminated. On the contrary, there is abundant evidence to show that the rate of intellectual development is still on the increase, and that yet more important conquests in the domain of the unknown than have illuminated the past will be made in the future. On our

graphic illustration of the world's progress, each year extends the curve upward.

The conclusion that the known is but a small fraction in comparison with the unknown is perhaps startling, yet in view of the recency of numerous discoveries and the increasing rate of the returns from more and more careful investigation, such seems to be the ratio of the sum total of man's knowledge to the possible discoveries of the future. To demonstrate this broad proposition, which if true is most stimulating to human endeavor, facts might be presented from any department of knowledge. We are saved the trouble of compilation in this connection, however, by the timely appearance of 'Year Book' No. 1 of the Carnegie Institution.

The officers of the Carnegie Institution, in seeking to learn how they might best apply the money placed at their disposal, obtained assistance from various advisory committees, consisting of from one to six scientific experts, and in several instances the committees themselves sought counsel from other leaders in research both in the United States and in foreign countries. The reports of the committees referred to cover 284 octavo pages, and deal in a broad way with the problems awaiting investigation in several but by no means all departments of learning. Some of the directions in which, in the opinion of the members of the committees, profitable research work can be done, are enumerated below, but it is not practical to review the entire category at this time, and, besides, in several important divisions the precise questions to be asked of nature are not formulated.

From the reports mentioned, we learn that botanists are desirous of broadening their science in at least two directions:

The first pertains to the relation of vegetation to environment in the United States. In this connection, studies are suggested as to the function and effect of the forest in humid regions in reference to the influence of trees on atmospheric moisture, precipitation and run-off, and the converse effect on the forest; and also similar studies respecting the plants of arid regions, for which purpose the establishment and maintenance of a desert botanical laboratory are advocated.

The second recommendation of the advisory committee on botany is in reference to the carrying on of extensive botanical explorations in Central America and the West Indies, for which outline plans are presented.

These are the only ways in which the committee seems to have thought it expedient to recommend the undertaking of research work by the Carnegie Institution, but even a novice in the science of plants can readily see that there are promising lines of work in many other directions.

The advisory committee on physics outlines a broad plan for establishing a well equipped physical laboratory to be devoted to research work in pure physics, with a corps of investigators, together with recommendations in reference to grants of money to be made to persons, societies, etc., engaged in physical research, but does not outline the problems to be attacked.

In reference to investigations pertaining to the earth, which are of mutual interest to both physicists and geologists, the advisory committee on geophysics outlines some of the more prominent problems which demand immediate attention.

Among the salient questions pertaining to the earth's gaseous envelope, or the *atmosphere*, are those of its origin, its mass, its mass-limitations, and its mass-distribution, the potential atmosphere absorbed in the ocean and in the body of the earth, its sources of depletion and enrichment, its function as a thermal blanket over the sea and land, the possible changes in its diathermacy and the relations of these to

great climatic changes, together with many related problems that enter profoundly into the interpretation of the earth's past, and seem to have immense importance to the future of the human race.

In reference to the waters of the earth, or the *hydrosphere,* the geophysicists desire an opportunity to investigate its origin, mass and mass distribution; the constancy or variations in the volume of the ocean and changes in its level in relation to the land; the part which the water-mass plays in the changes of the form of the earth; the origin, constancy, or variation of the ocean's salinity, and many other questions.

Concerning the rigid outer portion of the earth, or the *lithosphere,* the geophysicists would seek for information relating to the origin and maintenance of the continental platforms with their superposed mountains and plateaus, and of the oceanic basins, involving questions of rigidity, distribution of pressures, etc.; the agencies and conditions that make possible the prolonged periods of crustal quiescence recorded on the earth's surface by extensive plains produced by erosion; the nature and causes of the movements in the earth's crust which have produced crumplings and breaks or faults, and upraised mountains and plateaus, and are indicated also in a large way by continents and oceanic basins; the breaking, shearing and folding of the rocks leading on to the general problems of rock metamorphism, and a great group of intricate questions of a chemical and chemico-physical nature, including the flow of rocks, the destruction and genesis of minerals, the functions of included water and gases, the flow of material within the earth, the origin of ore deposits, the evolution and absorption of heat, and other phenomena that involve the effects of temperature, pressure, tension and resultant distortion on chemical changes and mineralogical aggregations.

Within the earth's outer crust lies what is termed the *centrosphere,* concerning which the advisory committee on geophysics states its desires as follows: The themes here are the kinds and distribution of the lithic and metallic materials in the deep interior; the states of the matter; the distribution of mass and of density and the consequent distribution of pressure; the origin and distribution of heat; the conductivities of the interior material under the pressure and heat to which it is subjected; the heat possibilities arising from supposed original gaseous condensation, or alternately from initial impact of aggregation; the heat of subsequent attractional condensation; the secular redistribution of heat within the earth, and its loss from the surface; the possible relations of redistribution of internal heat to volcanism and to deformation, and similar profound problems.

Long as the above category of as yet unsolved problems may seem, it by no means exhausts the lines of earth study suggested to the Carnegie Institution as awaiting elucidation. Laboratory experiments are outlined in reference to the effect of pressure on the melting point of rocks carried on at high temperatures and pressures, and through a wide range of material; the effect of temperature and pressure on thermal conductivity and on elasticity, with reference especially to the transmission through the earth of seismic tremors. Nor is this all; geophysical questions in reference to the relation of the earth to other bodies in the solar system, such as the deformation of the earth owing to the attraction of the sun and moon, thus furnishing a means for testing its rigidity, the history of oceanic tides and their influence on the earth's rotation. These and other questions lead to still greater problems such as the origin of the solar system and even the genesis of the stars.

It is not desirable to weary my readers with a more extended exposition of our ignorance concerning the earth on which we live, as outlined in the 'Year Book' from which citations have just been made, but I may perhaps be pardoned for mentioning that following the presentation of the larger problems referred to, comes a list of sixteen extensive groups of specific questions which demand for their solution the establishment and maintenance for a series of years of an extensive and well-equipped geophysical laboratory.

The immediate lesson illustrated by this catalogue of wants is: great as are the results of the geological studies already made, several chapters of the earth's history have yet to be written and nearly all of the chapters already in print need thorough revision.

In the 'Year Book' cited above, the desire for further knowledge on the part of geographers, meteorologists, chemists, paleontologists, zoologists, psychologists, anthropologists, bibliographers, engineers, physiologists, historians, mathematicians, etc., are outlined, and in each department the importance of pressing on with discovery is clearly and earnestly expressed.

It will perhaps be a surprise to many persons, that in the recommendations for research work made to the Carnegie Institution, astronomy occupies more space than is assigned to any other science. Seventy-three pages are devoted to outline plans of some of the ways in which the study of the heavens can be continued with the promise of valuable returns. If the oldest of the sciences has such hopes for the future, surely the outer boundary of the knowable is far distant.

There is another point of view by which the magnitude of the research work brought to the attention of the trustees of the Carnegie Institution may be estimated. About one half of the plans suggested by advisory committees are accompanied by estimates of cost. This category—including estimates in several instances for laboratories, observatories, biological stations, endowments, etc., and running expenses for a period of five years—calls for an expenditure of about $16,000,000. The expense of all the investigations outlined for a period of five years may safely be placed at $30,000,000, or three times the present capital of the Carnegie Institution. In this connection it is to be remembered that the institution does not propose to undertake any research already provided for by individuals, universities, societies, etc., but to supplement such work or cooperate in carrying it on. The plans to which attention has been directed are for investigations over and above those already initiated or likely to be made without the aid of the Carnegie Institution. And again, to some extent the work outlined is circumscribed by political limits and pertains to the United States.

This brief showing of the problem already in view will, I think, serve to sustain the statement made above, in reference to the vastness of the realm of the unknown which surrounds us on every side. To extend the limits of the known in all the directions in which scientific men are looking would certainly require the resources of many Carnegie institutions, and the time and energy of many generations of investigators.

Increasing Difficulty of Research.—In considering the aims of research and the means available for its encouragement, the increasing difficulties in the way of discovery as knowledge increases, should be clearly recognized. Not only this, but the tendency to feel that enough has been accomplished, or in other words, self-satisfaction, needs to be combated. Contentment is not the motto of the enquiring mind.

The close scrutiny, the hard and long-

continued work and the careful mental training required to continue making discoveries in an old field, are seemingly self-evident. In geographical explorations, the discoverer of a new land has a virgin field before him, concerning which the most trivial notes are of value. As exploration progresses, however, and more and more is known concerning a newly discovered land, the problems to be attacked become more and more difficult, require deeper thought, better equipment and broader preparation on the part of the would-be discoverer. But old fields yield rich returns, even to the geographer, as is shown by the conspicuous advances made in physiographic studies in the older portion of America during the past decade.

The increased difficulties of discovery as advances are made might be emphatically illustrated by any one of the older sciences. In astronomy, for example, as every one knows, greater precision has demanded better instruments. While the moon yielded abundant returns when observed with the small telescope of Galileo; to resolve the distant nebulæ, measure the motions of double stars and map the heavens, requires instruments of vastly greater power. To the work of observing and measuring, the astronomer has added the study of the physical condition and chemical composition of the matter composing the heavenly bodies, measurements of the heat emitted by the stars, etc., and in several divisions of his task assistance is had from photography. The increased accuracy demanded and the broadening of the scope of astronomy, particularly by the addition to it of spectroscopic work, has vastly augmented the expense of equipping and maintaining observatories, and also demanded greater and more varied preparation on the part of the men who explore the realm of distant space.

The increase in the size and excellence of the instruments required by astronomers is well known. The great observatories are in sight and open to the public. The beauty and costliness of the modern telescope, so complex with its many attachments that it might well be termed an astronomical engine, are apparent even to the casual observer. Both the interesting methods of observation and the startling results of astronomical study are described from time to time in newspapers and popular magazines. From these and other sources the growing needs of the astronomer as his work progresses are at least recognized, and to a great extent appreciated by the public, and broad-minded citizens have in many instances contributed money freely for the betterment of the tools with which he works.

The increase in size and in costliness of astronomical instruments and the broadening of the scope of astronomy, are but an illustration of what has taken place and is increasing from day to day, in every department of human thought. The chemist, physicist, biologist, meteorologist, geologist and explorers who are following other paths of learning are meeting with greater and greater difficulties and are demanding better facilities, in the way of laboratories, collections, libraries, etc., as their work advances. These demands, although in many instances less obvious to the public than those of the astronomer, are none the less pressing, and fully as important. In each of these departments of research and, as has been stated, in all branches of knowledge, as advances have been made, greater and greater skill and more and more thorough preparation are necessary on the part of the persons engaged in the work. To continue research and place in the hands of inventors, manufacturers, teachers and others still more efficient means for conducting their tasks, it is evident that communities, in order to reap still greater har-

vests, must supply better and more expensive equipment, and furnish still more efficient means for the training of the persons who do research work for them.

Recognition of the Importance of Research.—In America three important steps in the recognition of research are marked by enduring movements. These are: the *American Journal of Science,* the first volume of which appeared in 1818, and which has continued to be a record of investigation to the present day; the Smithsonian Institution, organized in 1846, which has for its motto, 'The increase and diffusion of knowledge among men'; and the Carnegie Institution, established in 1902, which, in the words of its generous founder, has for its aim 'the securing for the United States leadership in the domain of discovery and the utilization of new forces for the benefit of man.'

These three monuments mark not only the road of scientific but of industrial advance in America, since the latter follows in the footsteps of the former. The aims of the Carnegie Institution, in particular, should arrest the attention of every so-called practical man, since they recognize a principle that is invading and revolutionizing industry in all of its many branches, namely, the substitution of precise or scientific methods in place of 'rule of thumb,' and the seeking for legitimate gains by the application of original studies to the arts. In brief, it is becoming noised abroad that there is money in research.

In reference to the growing appreciation of the value of research, a few illustrations may not be amiss.

The recognition of the importance of research to the farmer is indicated by the work carried on at public expense by the Department of Agriculture at Washington. Although the so-called practical application of discoveries already available, is the avowed aim of this well-organized department by the government, yet many contributions to pure science have been made in its eighteen sub-departments or bureaus, and at the fifty-six experiment stations under its general supervision and located in nearly every state of the union. Research in pure science is a part of the work of the Weather Bureau, and of the Divisions of Chemistry, Entomology, Botany, Biology, Forestry, Soils, Public Roads, Animal Industry, etc., of the Department of Agriculture and supplemented by experiments in agriculture by nearly 700 men in the many agricultural experiment stations. The results of the investigations carried on in these many related fields of study, not only furnish direct aid to farmers throughout our broad land, but establish safeguards and quarantines about their pursuits, the money value of which can only be reckoned in millions of dollars annually.

The term 'chemical industries' applied to a large group of manufactures such as beet sugar, soda ash, Portland cement, etc., is a recognition of the fact that they are based on the research work of the chemical laboratory. But capitalists are no longer content to await returns from the investigator who may chance to devote his time and energies to the special field in which their money is invested, but establish laboratories of their own and employ research workers who can point out ways of improving processes and enlarging factories. So great is this demand that our universities are being called upon to supply trained men by the score, who are able to originate new methods as well as superintend work already in process. The recognition of the value of research in the factory is even more pronounced in Germany than on this side of the Atlantic, as is indicated by the fact that in that country a single chemical establishment employs continuously more than thirty doctors of science, the best the universities there can turn out, who devote

their entire time to original investigations. As is frankly conceded in England and other countries which are the industrial rivals of Germany, the marked enlargement of her manufacturing industries in the past decade is directly due, as may be said for the sake of emphasis, to her including brains among the raw materials used.

Research in pure physics, as is well known, has led to the mobilization and training of industrial armies, which have built railroads, telegraph and telephone lines, laid ocean cables, and erected wireless telegraphy stations, and in numerous other ways aided transportation and intercommunication, and enhanced the comforts and conveniences of every-day life.

The direct economic value of research work in geology is shown by the fact that nearly every civilized country, and many states and provinces within the limits of larger political organizations, carry on geological surveys. The principal object of such surveys is to furnish assistance in the discovery of materials of economic importance such as building stone, coal, petroleum, iron, etc., but while this is largely routine work and the application of knowledge already acquired, research work is necessary at almost every step. To discover mineral substances of commercial value the far-reaching laws governing the many ways in which such substances have been concentrated, recrystallized, etc., so as to be available for man's use, have to be investigated. In recognition of the fact that the geologist has but entered on the exploration of the treasures of the earth, every national and state geological survey favors research work in a high degree.

A moment's thought will suffice to show that the few instances just mentioned in which research is fostered, do not stand alone. In medicine, hygiene, engineering, economics and many other broad fields of activity the direct utility of seeking for more knowledge is apparent and widely recognized.

These brief statements in reference to the growing recognition of the value of scientific discoveries have been selected from a great number that might be presented, with the hope of making it clear that there is a *demand for research men.* Men are wanted who can not only conduct industries on long established methods, but who have the ability to originate new methods and discover and apply new principles, particularly in the way of doing cheaper and better that which is now being done and of utilizing that which is now being wasted.

Never before in the history of the world has the demand for intellectual leaders of industry been greater than at present. The direct material benefits to be derived from the application of the forces of nature to human ends are now more widely appreciated than ever before. With this appreciation go a demand for fresh explorations and a thirst for the results of research that are most stimulating and encouraging. To persons engaged in the business of education, these considerations must awaken the enquiry: How is this great and growing demand to be met?

Preparation for Research Work.—To a large extent, the men who have enlarged human knowledge have been men of genius —with a mental grasp stronger than their fellows. Thousands of people saw apples fall to the ground before Newton formulated the law of gravity, but lacked the ability to deduct the cause from the effect. So in all branches of learning some one man, more gifted than his contemporaries, has led the way into the unknown. Although genius is all important, even the man of genius must have training for his work, in order to make the best use of his exceptional endowments. Just what training is necessary is a difficult question to decide, especially for one who is not a

genius, and not a specialist in the line of work for which a student is to be prepared. To a large extent the specially qualified or exceptional man must decide for himself as to the mental equipment required for his individual work. The education of the exceptional man is a delicate task. Too much training in the methods others have followed may make him an imitator instead of a leader; too little training, and he may fail to acquire the mental tools necessary in his particular line of work. The best that can be done by universities desirous of encouraging their sons and daughters of exceptional ability to make the most of their mental gifts is, seemingly, to furnish them with opportunities to develop; to endeavor to train the body as well as the mind, to educate the hand as well as the head, to supply libraries, laboratories and gymnasiums, to all who may be inclined to cultivate and develop the higher strains of inheritance or the special variations latent in them. From the thousands who present themselves for this arduous work it is the duty of the university to select the few of exceptional ability and encourage them to devote their lives to the task of carrying on research in the direction in which they are especially qualified.

Once the exceptional man is discovered, the purely economic interests of the community, if no higher principle, demand that he be assisted in every practicable way in carrying on his great work. Here again the encouragement of genius is a delicate task. Discovery means close application and long continued and painstaking work. The discoverer, as previously suggested, may be likened to a mountain climber. He must put forth his best efforts, deny himself many of the pleasures of life, and toil on for the most part alone, so far as intellectual companionship is concerned. He is but a man, however, and lavish emoluments may lure him to walk in the customary paths leading through bowers of pleasure, to the neglect of the more rugged ways tending upward; too little aid may leave his task so difficult that a great part of his energy will be consumed in overcoming the difficulties of mere existence.

Both in the education of the thousands in order that the exceptional man may be found, and in the assistance the university may in its own interest extend to him as a research worker, the persons best qualified to act as trustees for the community are the men with sufficiently wide training, and at least an appreciation of the higher and more ennobling aims of discovery, who are interested in similar lines of work. Such men are to a great extent included in the faculties of the higher institutions of learning. Committees from several such faculties, it is to be presumed, would be best able to decide as to what extent the men with new ideas or of exceptional ability should receive financial assistance.

The Place of Research in the University.—In view of the several considerations touched upon in the preceding pages—namely, the catholic aims of research; the narrow bounds of the known; the fact that discovery is the all important initial step in applying the materials and forces of nature to man's use; the convincing evidence as to the general and widely spread awakening among the leaders of industry in reference to the economic importance of fresh discoveries; and the growing recognition of the fact that not only skill, but originality, pays—the question presents itself: What should be the attitude of communities and institutions of learning toward research? In this connection communities and institutions of learning may be considered together, since many schools, colleges and universities are supported by public taxation.

Public schools, state colleges and state universities, so far as is declared in the

laws creating them, are maintained for two principal reasons: first, because education tends in a conspicuous manner to promote integrity, refinement and all that speaks for good citizenship; and, second, to train students in various arts and professions in such a way that they will be enabled to serve efficiently the communities in which they live.

The recognized method of attaining these ends, to use a part of the motto of the Smithsonian Institution, is to *diffuse knowledge among men.* The frequently quoted ordinance passed by the Confederate Congress, in 1787, which records the planting of the seed from which the public school system of the United States has grown, reads:

"Religion, morality and knowledge being necessary to good government and the happiness of mankind, schools and the means of education shall forever be encouraged."

In this and, so far as I have been able to learn, in all subsequent legislation bearing on public education, there is no direct recognition of the fundamental principle expressed in the first clause of the Smithsonian's motto, namely, *the increase of knowledge,* and found in the first of the declared aims of the Carnegie Institution, which reads, *To promote original research, paying great attention thereto as one of the most important of all departments.*

The proclaimed purpose of education has been and to a paramount degree still is, the transmission of knowledge, without endeavoring to add to the assets of the bank on which drafts are made, or striving to train the student to discover new truths for himself. Teachers and professors in state schools, colleges and universities, so far as indicated by their contracts with the institutions they serve, are simply conveyors of knowledge previously gained. In a few universities in America, it is true, chairs of research have been endowed by individuals, and in two notable instances, namely, Johns Hopkins University and Clark University, institutions having research as their primary aim, have been founded by broad-minded citizens. In the main and almost entirely, however, such additions as have been made to the world's store of knowledge by teachers and professors are due to their individual zeal and industry during hours not occupied by routine work in the lecture room or the laboratory.

Admitting the argument sometimes advanced in justification of the neglect of research in state universities, namely, that the duties of such institutions are purely educational, and that they are not supported for the purpose of fostering research, the fact still remains that research is in itself a method of mental training of a high order and demands a place in our institutions of learning on account of its exceptional educational value. As stated by Sir Norman Lockyer in his recent presidential address before the British Association for the Advancement of Science, *research is now generally acknowledged to be the most powerful engine of education that we possess.* The inquiry into the secrets of the unknown necessitates not only rigid mental discipline on the part of its votaries, but is an incentive to exertion to a degree that no other phase of education presents. Not even the desire for technical training in order that pecuniary returns may be had awakens such an earnest desire to know, or stimulates the student to such untiring diligence as exploration in a chosen field. And, besides, in the present stage of the growth of knowledge in order to make fresh conquests, the investigator must become familiar with that which has already been accomplished along the path he is to follow, and at least have a working knowledge of the languages in which the results reached by his predecessors are re-

corded, as well as some understanding of the departments of learning closely related to his specialty. The lesson to be read between the lines in these statements is that research does not supplant other means of education, but supplements them and gives them vitality.

If the primary object of public education is the development of character and the making of good citizens, research must from this point of view also be given a higher place than the mere following in the footsteps of others, since its sole aim is the discovery of truth. The inquiry for truth implies painstaking accuracy, the searching criticism of one's own work and the seeking of criticism from others, the dissipation of false hypotheses, the cultivation of logical methods, fearless abandonment of long established prejudices, the acceptance of conclusions based on oft-repeated experiments no matter how disturbing to former opinions, the discounting of mere authority, and other ennobling attributes of the mind.

In the several particulars just mentioned and more besides, the superior educational value of research over the mere acquiring of knowledge already formulated and recorded in books seems self-evident.

From the considerations briefly and inadequately presented on the preceding pages, at least two important conclusions may be drawn: one is that research furnishes the only means man has of increasing his control over nature; and the other, that in thus enlarging his sway he cultivates his own powers and enchances his chances of still greater advancement. Or stated in other words: an increase in knowledge adds to man's economic resources and at the same time is an educational exercise which develops the higher faculties of the mind.

The attitude that the state should hold toward research is thus twofold; first, to secure for her citizens a knowledge of the materials and forces of nature which can be utilized for increasing their comforts and enhancing their happiness; and second, to supply her students with an efficient means for developing their mental powers and awakening in them a consuming desire for the truth.

This claim for the educational value of research, as already stated, does not imply the abandonment of present methods of education, but simply the adoption of another means of attaining the desired end. While observation should be encouraged at all stages of school and college life, owing to the broad preparation necessary for true research, it can not be expected that the student, unless a genius, will be able to make independent investigations before completing his college studies. The place for definite and final training in research must necessarily be in the university. Such training furnishes the keystone which completes the arch of public education and finishes the structure begun in the grade schools, and must of necessity be fashioned and put in place in the university. It is not until this is done that the university ceases to be a high school of larger growth. In each college of a university a few students are usually graduated each year who desire to continue their studies and earn a master's and later a doctor's degree. These few, by a process akin to natural selection or the survival of the fittest, form a class by themselves and in general, owing to exceptional mental endowments, or more than ordinary diligence, are best qualified of all the sons and daughters of a university to become contributors to the world's store of knowledge, to enter the ranks of teachers, or to assume the duties of the learned professions. It is to the lives of these few that the university looks for her greatest share of reflected honor, and the state for her highest grade of professional men. It is for the encouragement and

advancement of these exceptional students, who are to be intellectual leaders in after life, that the university may reasonably be asked to extend special consideration and assistance during the continuance of their graduate studies.

This would seem to be the highest function of the university, not only because it encourages her best students to strive to attain the higher walks of intellectual life, but because in the process of discovering the man or woman of exceptional ability all her sons and daughters are encouraged to advance to the highest plane their mental endowments permit them to reach.

The place for research work in the university is, then, at the close of the courses of study pursued in her several colleges; that is, in the graduate school, to which only those students who have successfully passed their final college examinations and received the bachelor's degree are admitted. The graduate school might well be named and made in fact the *school of research*. Without such a school a group of colleges should not be classed as a university. As expressed by Hon. Seth Low, in an article on 'Higher Education in the United States,' published in the *Educational Review*, 'The work of the college is to teach that which is already known—the work of the university is, in addition to this, to enquire, to ascertain what lies beyond the line that marks the limit of the known.' In the school of research, the leading idea being the development of originality, it is evident that the professors should be chosen from the ranks of those who have won distinction on account of their original contributions to the branch of knowledge in which they presume to serve as guides. In the school of research, also, professor and student should be coworkers and mutually assist each other. From such comradeship, that intangible something which is transmitted from person to person by association and contact, but can not be written or spoken—we may term it inspiration, or personal magnetism, or perhaps the radium of the soul—is acquired by the student in a greater degree than at any previous time in his life after leaving the caressing arms of his mother. In the school of research professor and student should have the time and facilities their work demands. From such schools, as may reasonably be expected, will come in the future the best trained men and women and the greatest contributions to human knowledge.

Seemingly, all college-bred men must recognize the demands of higher education, every captain of industry appreciate the commercial benefits flowing from an increase in knowledge, and every citizen see that the search for truth is the best method of enhancing morality and integrity and of elevating the human race. The interests of all branches of society are thus primarily centered on research. There is a *demand* that progress be made and that the utmost attainable bounds of the knowable be reached.

Demands of men trained in the law, in medicine, in engineering, etc., have led the trustees and regents of universities to establish and maintain professional schools, and not only the number of men entering the learned professions, but their efficiency, has been increased thereby. As I have endeavored to make clear, there is also a demand which is urgent and pressing, for men who can carry on research work in pure science, and who are qualified to discover new facts, new laws and new forces to be utilized in industry. This demand also deserves to be met by our state universities, in order that the best possible returns may be made to the citizens of a state who, by taxing themselves, support such institutions. While the direct economic returns to be expected from the es-

tablishment and adequate maintenance of research schools at public expense would amply justify such a course, such promises do not stand alone, as research, to use the words of Lockyer quoted above, is the most powerful engine of education known.

The undertakings of communities, as is well understood, are formulated and guided by a comparatively few individuals who see not only the immediate and tangible ends to be gained, but the far-reaching influences that follow. It is from these few informally appointed directors of communities that I venture to ask for due recognition of the fundamental importance of research, both as a means for securing greater returns from commercial pursuits and higher educational training in our universities. When these truths are fully appreciated and clearly expressed by the leaders of communities, the keystone will be placed in the educational arches states have erected, and the continued advance of our country and the attainment of a still greater degree of human happiness be assured.

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SCIENTIFIC BOOKS.

Grundlinien der anorganischen Chemie. Von Wilhelm Ostwald. Zweite, verbesserte Auflage. Leipzig, W. Engelmann. 1904. Pp. xx + 808.

The first edition of this book appeared in 1900, and in the course of three years the entire edition of four thousand copies was exhausted. In addition, translations into English and Russian have appeared which have also had a large sale. A translation into French is in course of preparation.

The second edition differs but very slightly from the first. The first half of the first chapter has been rearranged somewhat to secure a clearer presentation of general fundamental conceptions; but aside from this, practically nothing has been done except to correct minor errors appearing in the first edition.

The general plan of arrangement and treatment of the subject matter of this book was sufficiently elucidated in the pages of Science when the first edition appeared. The new departure represented by this treatise consists in an attempt to incorporate systematically the conception of mass action, the phase rule and, in general, the hitherto much neglected influence of temperature, pressure and concentration, as vital factors in determining the progress of chemical reactions. This feature of the treatise together with the constant endeavor of the author to develop ideas inductively and to connect with the substances studied their various important physical and physiological as well as chemical properties, constitutes the valuable, if not the epoch-making part of the book and justifies the remarkable sale of the first edition, which clearly indicates that chemists generally have gladly embraced the opportunity afforded to become acquainted with this new method of presenting elementary chemistry.

On the other hand, the introduction of the 'ions' as a purely chemical conception is unfortunate. While there might possibly have been a justification to thus introduce this conception at the time the first edition was written, the unqualified retention of this notion in the second edition can not be justified; for, since the appearance of the first edition, it has been demonstrated that instantaneous chemical reactions occur in the best of insulators exactly as they do in electrolytes. The use of the term ion in the 'purely chemical' sense as it appears in this book must now be considered merely as a mode of speaking, the term signifying only what has hitherto been expressed by the word radical.

The descriptive part of this book is not unlike that of other books of similar scope, except for an additional remark here and there about ions of this or that kind. Indeed, in most instances Ostwald writes reactions as they have always been written, without using the ionic notation; in so doing he virtually admits that it is not feasible to apply the ionic conceptions logically in most cases. Such an attempt would, indeed, often lead to grotesque distortions rather than to a simple mode of expression which every one could understand.