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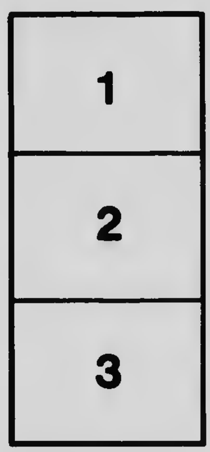
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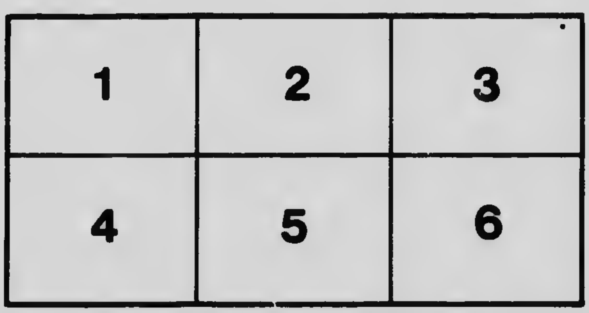
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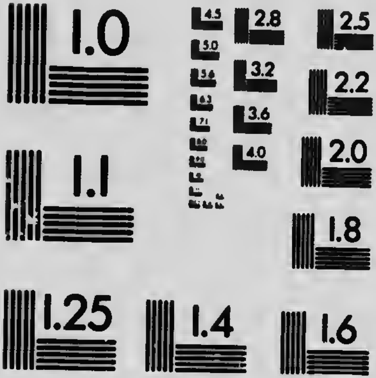

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The Progress of Science

AN OPENING ADDRESS

FOR THE

UNIVERSITY OF MANITOBA

Delivered Thursday, October 17th, 1912

By

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JANUARY, 1913

The Progress of Science

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The Progress of Science.

The Functions of a University.

A University has three functions—teaching, examining, and research. Teaching involves the conservation of knowledge, the spreading of that which is already known. Examining is the giving of certificates of merit to students for the work that they do. Research is the extension of the bounds of human knowledge, the plombing of the depths of the unknown, the discovery and investigation in detail of new intellectual lands and continents.

So far as the teaching function in our own University is concerned, I have little to say here. However, I am optimistic with regard to its extension, and look forward with confidence to the future. The time will come, I feel sure, when our University sapling will have developed into a strong and stately University tree, with all its main branches of knowledge fully developed and spreading out in all directions, and bearing fruit—fruit as choice as that borne on any University tree in any part of the world.

What kind of fruit should our University bring forth? What kind of men should it produce?

It seems to me that when a student's course has been finished, when he has at last left the University to enter on his life's work, he should have learned the art of learning. He should have become broad-minded and self-reliant, yet not prone to dogmatism, but able to recognize humbly the limits of his own acquirements. He should be master, or on his way to be master, of one subject in particular, and should know sufficient of many others to prevent himself from living in a groove without knowing it and to enable him to take a wide and lively interest in the welfare of his fellow-men. He should be able to perceive the beautiful, not only in poetry and literature, but also in the wonderful mechanism of the physical world around him. Above all, he should have acquired a real love of truth for its own sake, in whatever form it may present itself, and whithersoever it may lead. In short, on account of his training, in his *alma mater*, he should have become a high-minded and an effective citizen.

We have heard so much, and hear so much about examinations, that it is almost needless to say anything about them on this occasion. However, I may remark that although examinations are useful, in that they permit students to find out what progress they are making, and facilitate the granting of degrees, they may be, and often are, thought too much of. Students should realize that they come to a University, not merely to pass certain examinations, but to become educated. There are persons who have obtained the B.A. degree and yet who really and truly are ignoramuses, who have memorized a certain number of facts and written them down in their examinations, but who have acquired practically nothing of that knowledge which is of real value. Learning facts and figures is not the same thing as the formation of personality, the acquirement of a receptive attitude of mind, and the development of correct and broad habits of thought.

The research function has largely been neglected in our University, yet to some of us who have had opportunity to observe the life of other Universities, its encouragement seems to be of the highest importance. Up to the present, however, the University of Manitoba has done nothing to promote research. There is no lack of speech at the meetings of the University Council, yet during two years when I was one of the representatives of the University Faculty, I do not think the word "research" was ever mentioned once. In 1909, during the meeting of the British Association for the Advancement of Science which was held in Winnipeg in that year, Sir Joseph Thompson, the President of the Association and one of the greatest living physicists, addressed the University Club, and advised the University to encourage its teaching staff to engage in research. [illegible] of the members of the Council, on proposing a vote of thanks, practically told Sir Joseph that his 30 years of experience of University life could teach us nothing, and that our University Professors ought to be quite well satisfied if they devoted all their time to teaching! I could not help but feel that the prestige of our University had been lowered in the estimation of a number of scientific men of world-wide renown who had been invited to the University Club luncheon as guests.

Those of us who have carried on investigation have done so in silence. A scientific man, however, knows that his audience today is not limited to the students who sit in his class room, or who experiment in his laboratory, and to his colleagues and fellow-citizens with whom he comes in contact, but may extend round the whole globe. Any fact of importance, any true addition to our knowledge, thanks to the printing-press and the rapidity of modern transportation, is quickly communicated to every seat of the Higher Learning; and sometimes a man has more influence in other Universities than in his own. A University professor or lecturer may become a king, and turn his chair into a throne to which intellectual subjects may bow from every University in the world.

There are some men who are born investigators with the hardy pioneering spirit which no obstacle can daunt. In such cases the stimulus for research comes chiefly from within. But there are others who only acquire the research habit by being taught, by being trained and encouraged to think independently and to face the unknown in a resolute manner.

In Germany, training in the methods of research is one of the chief features of University education. The German University degree is the Ph.D. The most serious difficulty in obtaining it, is the writing of a thesis containing the results of original investigation. When one has presented one's thesis, one has to undergo a *viva voce* examination. To this one goes in a dress-suit, immaculate white gloves, and a top hat. The examination lasts but three hours at most and often less, and its result is announced immediately at its conclusion. On the other hand, the work for the thesis usually takes about two years and sometimes longer, and the thesis itself has to be approved of by the Professor under whom the work has been done. The result of the German system is that her Universities are all the while training a large army of investigators. When once the research habit has been acquired, it is likely to remain as a life-long possession. I feel sure that Germany's position today, especially in the realms of science and industry, is largely due to the fact that everywhere research is encouraged by the University system.

No University can live to itself alone. Other Universities are all the while watching us, expecting that we too shall teach them something in exchange for what they give us. It would indeed be shameful, if we were content to acquire all our knowledge second-hand and to contribute nothing new. When a University adds nothing to the world's stock of intellectual wealth, its prestige is small. The best students seek out leaders of thought, not those merely content to be led. It is quite certain that, as a rule, the best teaching is done in an atmosphere of research. This is readily explicable, for a man engaged in research must be all the while thinking new thoughts, reading fresh literature, making original experiments, mastering opposing difficulties, in short, avoiding routine. By such work, he keeps himself fresh in mind and avoids falling into an ever-deepening groove. Such habits act most potently on students by example. Students catch the enthusiasm of their masters and become imbued with their high standards of endeavour. Many a great discoverer can point to a single man whose personal influence exercised in a University laboratory, gave him the inspiration for his life's work. A University's best moments are just those in which it is rousing into activity the latent energy of the men and women who are to become the world's leaders.

I do not wish to lay down any absolutely hard and fast rule about research by University teachers, for here and there, there are some teachers who may help their University best by their powers of exposition, their organizing and administrative ability, their social gifts, or by applying their expert knowledge to the solution of the immediate practical problems of the community. Nevertheless, my opinion is that the majority of those holding teaching appointments should be engaged in one way or another in research. Some original work should be constantly going on in every scientific laboratory. Professorial appointments should only be granted to those who have contributed something of value to the world's stock of knowledge.

To give a man time for research, he should not be overburdened with teaching. About half his day should be entirely free from class work. Unless a man is free from the cares of giving instruction during at any rate several hours each working day, he will be deprived of acquiring that tranquillity of mind and that broad outlook upon scientific matters which are necessary for success in attacking the larger problems of science.

The Uses of Scientific Research.

There are those who ask what after all is the good of research in pure science? What practical value can the vast majority of investigations in Universities have?

In a new country like this, where material prosperity is advancing by leaps and bounds, it is sometimes apt to be forgotten that railway shares, timber limits, city lots, and the almighty dollar, do not constitute the only forms of wealth. It is intellectual wealth and moral wealth which do most to make the greatness of any country or any people. The University stands pre-eminently for intellectual enlightenment, for intellectual progress and prosperity: one of the means of obtaining these things is the discovery of new truths by patient research. Research, therefore, apart from its practical bearings, is valuable in that it adds to our intellectual wealth, it extends our mental horizons and increases that distance which already separates us so far from the brute world.

Many new truths found out by research do not appear to have any immediate practical value. But it often happens that apparently useless knowledge becomes suddenly useful. We need Pure Science before we can have Applied Science. It is the investigator who makes the inventor possible. Many of the most important advances in the arts of life have been preceded by a long series of investigations which were carried out without the least thought of their ever having any practical application. A few examples will illustrate what I mean.

It had long been said by an old school of philosophers that *Nature abhors a vacuum.* Torricelli set to work to investigate the cause of a vaccum. This was a piece of research in Pure Science. He found that Nature's so-called abhorrence of a vacuum was due to the pressure of the atmosphere. He took a strong glass tube about 3 feet long, closed at one end. This tube he completely filled with mercury. Having stopped up the mouth of the tube with his thumb, he inverted it, and plunged its mouth beneath the surface of some mercury contained in a basin before removing his thumb. When the thumb was removed from the tube, the mercury immediately descended until it stood at about 30 inches above the level of the mercury in the basin. Torricelli argued that the column of mercury was sustained by the pressure of the atmosphere. He remarked certain variations in the height of the column of mercury and he attributed these to the variations in the atmospheric pressure—a view which was soon proved by noting that at the top of a mountain, the mercury column is not nearly so high as at its base.

Torricelli's glass tube containing mercury has been made use of as our barometer, so that his piece of pure research which was undertaken without any thought of its practical application, has provided us with an instrument of far-reaching importance in our daily life.

The next step in the study of a vacuum was to contrive an apparatus by which a vacuum could be readily produced. After repeated trials and failures, Otto von Guericke invented the air-pump. This first air-pump was naturally somewhat crude; and since Guericke's time a large number of new air-pumps have been devised. With the invention of the air-pump, however, it became possible to obtain a high vacuum, *i.e.*, a very highly exhausted chamber containing but a minute quantity of air. A few decades ago, Sir William Crookes began the study of high vacua. He took a wide glass vessel from which he exhausted the air with an air-pump until comparatively few molecules of air were left. Then he sent electric sparks through the tube from one end to the other, and found that a curious glow was produced. Crookes' discharge tubes were long looked upon as the playthings of the physical laboratories. Röntgen then took up the study of Crookes' tubes, which, up to this time, had been of no practical importance, and thereby discovered the X or Röntgen rays. And now these rays are used in the saving of human pain and suffering in every well-organized general hospital in the world. The practical man has a vast respect for the work of Röntgen, because the uses of the rays that he has discovered are so obvious. But there could not have been any Röntgen rays had it not been for the patient labours of Torricelli, von Guericke, Crookes, and many other researchers in Pure Science who preceded Röntgen and made his great discovery possible.

Now let us take a second illustration. The discovery of the magnifying power of the lens led to the construction of the microscope which for more than a hundred years was of no practical use. But with the microscope, scientific men, desirous of extending the bounds of human knowledge, discovered a vast number of different kinds of microscopic animals and plants in pond water and other fluids. In 1683, Leeuwenhoek, using a microscope, discovered bacteria or microbes, the smallest of all plants, in the food particles which he had taken from between the teeth of his own movth. Nearly two hundred years later, thanks to the researches of Koch and Pasteur, it was proved that bacteria are the causes of infectious diseases. The invention of lenses and the perfection of them by opticians, which has enabled scientific men to discover bacteria, to trace their life histories, and to find out their relations to human beings and other animals, has led to a system of scientific hygiene which affects us all, and which is one of the best products of civilization. Koch and Pasteur's elucidation of the causes of infectious diseases naturally suggested a renewed study of malaria fever. It was shown that malaria is caused by a microscopic parasitic animal, known as *Plasmodium malariae* which is carried by mosquitoes. This discovery, which has taught us that to get rid of malaria, it is only necessary to destroy mosquitoes, is destined to render habitable many parts of the globe where Europeans formerly could not live. By following up the clue given by the study of malaria, it has been found more recently that the parasite of yellow fever is also carried by a mosquito. This knowledge has enabled the United States government to protect its 80,000 workmen in the Panama zone from Yellow Fever. During the few years that the French, under the great engineer, De Lesseps, were attempting to build the canal, 50,000 lives were lost through disease; but now the death rate of workers is less than that in most large towns. Thus, the discovery of bacteria by Leeuwenhoek, followed by a long series of purely scientific investigations into the life histories of microscopic organisms and of mosquitoes, is permitting the Panama Canal to be built without any danger to the life and health of a vast army of workers, with a proportionate economic saving, both in time and money, to the United States government.

Gregor Mendel, some forty years ago, studied the laws of inheritance in Garden Peas and Bees. As a result of his discoveries, a department of biological investigation known as Mendelism has come into existence which is destined to be of great importance to every agricultural country such as this. You are doubtless aware that Rust is one of the most deadly diseases which affects the wheat crop in this country. Mr. John Love, a former president of the Winnipeg Grain Exchange, said a few years ago, "I think that it is within the mark to say that Rust cost this country $20,000,000 in the year 1904." This sum, lost in one year, would be sufficient to found, equip, and maintain a first-class University. In Australia, according to McAlpine, losses from Rust, in a bad season, amount to from ten to fifteen million dollars. Similar heavy losses are constantly being suffered in India, England, France, Germany, Russia and every other wheat-growing country. Applying Mendel's laws of heredity to the problem of breeding new cereals, Professor Biffin of Cambridge has been able to produce a rust-resisting wheat which has already been grown successfully upon thousands of acres in England. As a result of Mendel's work—a piece of pure research, done in the quiet of a cloister—one may hope that some day we shall have both rustless and smutless varieties of wheat grown everywhere on our broad prairies. The farmers of this province and of the whole West should take notice of this development, and it should give them courage to support those institutions in which the higher learning is cultivated.

The practical man ought to realize how enormous has been the value to the world of those who have been in the front rank of scientific investigators. Huxley, in an address given in 1877, said, "I weigh my words when I say, that if the nation could purchase a potential Watt or Davy or Faraday at the cost of £100,000, he would be dirt cheap at the money. It is a mere common-place and every-day piece of knowledge that what these three men did, has produced untold millions of wealth in the narrowest economical sense of the word." I trust that some day original scientific investigators of equal economic importance will be produced by this University. But to secure this end, we must encourage research in a broad and enlightened manner.

Developments in Modern Science.

The growth of modern science is astounding, and as a result, it has been found necessary to revise many great generalizations which only a few decades ago were thought to be permanently established. Thus, the atom which was formerly considered to be indivisable is now regarded as consisting of smaller parts, some of which are known as electrons. Mass which was supposed to be an unalterable function of matter, has been shown by the experiments of Kauffman to be capable of an appreciable variation under different conditions. A constant force acting upon a moving body is not now believed under all circumstances to produce a constant acceleration. And Darwin's Natural Selection Theory, explaining the origin of species in the course of evolution, has been replaced in many minds by the Mutation Theory.

What has happened with these greater theories has happened also to lesser ones: they have in many cases been modified so as to make them of truer and deeper significance. The true scientist cannot be dogmatic: he must possess a mind open to new light and ready to act in accordance with it. A dogmatic scientist is a contradiction in terms and does not exist.

But every increase in knowledge, every modification of our generalizations of facts, only goes to increase our sense of wonder at the infinite complexity and beauty of the Universe. The mystery of the world ever grows greater as we know more about it. We are as the little child whom Emerson describes, looking up through the maple branches:

> "Over his head were the maple buds,
> And over the tree was the moon,
> And over the moon were the starry studs
> That drop from the Angels' shoon."

Physical Chemistry.

The two basal physical sciences are chemistry and physics. In each of these remarkable progress has been made in the last few years. A new and important connecting science known as *physical chemistry* has come into existence which deals with the nature of solutions, osmotic pressure, electrolysis, change of state, etc., a branch of knowledge of great importance to physiologists. Many Universities now have lecturers on this subject, and I presume ours will also have one before long. One of the leading minds in physical chemistry is Professor Ostwald, of Leipsig. Some years ago, Professor Ostwald appealed to the Saxon government for money to build a laboratory for physical chemistry. The Socialists in the Saxon parliament voted for the grant to a man. Would that such splendid support were always forthcoming for scientific institutions in Canada! The faith which the German people have in science has been fully justified. By supporting their Universities, they have reaped enormous industrial rewards.

Chemistry.

There has been a wonderful advance in synthetic chemistry during the past few decades. More than 150,000 organic chemical substances have been synthesised. A very large number of chemical experiments have been made for the purpose of finding out how atoms may be united into more or less complex molecul. The simple organic molecules may be regarded as chemical bricks. Now when some natural chemical substance, such as indigo, camphor, or rubber, has been found and analyzed, it is possible for chemists to set about a synthesis by which these substances can be made artificially. The knowledge slowly acquired of how to make chemical bricks, enables the modern chemist sooner or later to build up substances with the most complicated chemical structure. Brick can be added to brick until hundreds have been placed together to make up a unit of the most complex kind. Chemists can be looked upon as architects and builders. The more complex molecules that they build up, correspond in a way to the skyscraper and public buildings of our city. The enormous growth in skill of the chemical builders in the last few decades can but excite our wonder.

The first organic substance to be synthesised chemically was *urea*, which was put together by Friedrich Wöhler in 1828. This was a great triumph, for it was thereby shown that the chemical substances which come into existence in our bodies and the living substrata of plants and animals, are amenable to the same laws as those which govern the construction of inorganic substances like common salt, potassium nitrate, and water.

There are three classes of substances which predominate in living plants and animals—fats, carbohydrates, and proteins. Fats were synthesised two generations ago by M. Berthelot in Paris. The first synthetical carbohydrates, glucose (the sugar of diabetes), fructose, etc., were first made artificially in Wurzburg in 1890 by Professor Emil Fischer. The methods for building up proteins, i.e., substances like the white of egg, have also been devised by Professor Fischer, although so far no naturally occurring protein has been synthesised. This important work was done in Berlin. In 1910, Professer Fischer* gave a lecture on Modern Achievements in Chemistry, at Berlin, before the Emperor and many of Germany's most distinguished men. On that occasion, in referring to the synthesis of proteins, he showed them a specimen which he had built up. I will write the name on the board. "Laevoleucyltriglycyllaevoleucyltriglycyllaevoleucyloctaglycylglycine." The raw materials for building up this substance cost $250, and the labour in putting these compounds together must have cost considerably more.

Fats, carbohydrates and proteins are our chief food substances. It is to me of extraordinary interest that chemists should have learned the art of building them up in the laboratory. Possibly one day, a large part of man's food may be synthesised in chemical laboratories instead of being obtained from agriculture: but that is a problem for the remote future.

The discovery of how to build up organic compounds has brought chemistry into immediate contact with biological science. Much light has been shed on metabolism—the constructive and destructive chemical changes constantly going on in living organ-

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**Vide*—Chemical Research and National Welfare. Romance of Science Series, 1912.

isms. Chemists and physiologists have taken hands in the development of a new branch of science known as *bio-chemistry*.

One of the marks of civilization is the substitution of artificial for naturally occurring substances. In this field, the chemist during the last few decades, has been remarkably successful. Some of these artificial substances may here be mentioned. Artificial silk, made from cellulose, is now sold in large quantities, and people buy it under the impression that it is the genuine article of animal origin. It seems quite likely in the course of time that chemists will entirely replace the silkworm in the provision of delicate fabrics. Artificial dyes, made by most ingenious methods from such an unpromising looking material as coal-tar, have now practically replaced colouring matters which were formerly obtained from plants. Hundreds of synthetic dyes are now being manufactured: Alizarine now takes the place of the madder which used to be extensively grown in France and India, and artificial indigo has caused a diminution of the cultivation of the indigo plant in India to about one-sixth of its former extent. An Englishman, Sir William Perkin, in 1856, prepared the *first* of the great series of coal-tar dyes, namely *mauvine*, which was used for some time to colour penny postage stamps. Unfortunately, owing to the lack of recognition by industry in England of the value of science, Sir William Perkin's factory, at Greenford, was closed down, and the entire dye-stuff industry was removed to Germany, where at the present day the value of the dye-stuffs yearly produced approximates to some $75,000,000. Among other substances now made artificially are resin, artificial amber used for pipes, artificial odours, such as the scent of violets and attar of roses: the artificial sweet substance saccharine which is some 500 times sweeter than cane-sugar; artificial camphor, with the production of which the monopoly held by the Japanese for the sale of camphor was broken down; artificial quinine which is so valuable in combatting malarial fever; veronal which is an anaesthetic; antipyrene which is used for reducing temperatures in fever; adrenalin, a product of our suprarenal glands, which has an important effect in regulating our blood pressure; and caffein, the active principal of tea and coffee which, after alcohol, is perhaps the most widely employed stimulant. Professor Fischer has expressed the opinion that chemists will some day succeed in synthetically reproducing the aroma of tea and coffee, and then it will be quite easy to synthesise these beverages and perhaps to improve on them. The yearly consumption of naturally occurring india rubber is now enormous, and it is valued at about $250,000,000. This rubber is obtained from the latex of trees which grow in the tropics and sub-tropics. In 1892, Sir William Tilden prepared artificial india rubber from a substance known as Isoprene. The work has been followed up in Germany by Fritz Hoffman and Duisberg, and the latter has already employed synthetic rubber prepared by the firm of Baeyer & Co. successfully for the tyres of his own automobile.* A large company has recently been started in England, whose aim is to produce artificial rubber on a commercial scale. Should it prove a commercial success, we may expect in the course of time that artificial rubber will replace natural rubber, and that the whole india rubber industry will be revolutionized.

Physics.

We must now pass from chemistry to physics. One of the most famous and striking discoveries in recent years is that of the Röntgen rays. Sir William Crookes first of all investigated the discharge of electricity through high vacua. He sent electric sparks through glass tubes from one end to the other, and found that if he gradually exhausted the air, the cathode or wire terminal by which the electricity departs, began to glow over its surface, that with the progress of exhaustion, as the vacuum became greater and greater, a dark space, Crookes' dark space, appeared before the cathode, and that this dark space increased with further exhaustion until it filled the whole tube. At this stage, a green phosphorescence appeared on the anode and the glass opposite the cathode. This green phosphorescence, it has been proved, is due to the bombardment of the anode and glass by the so-called cathode rays. These cathode rays, it has been

*Congress of Applied Chemistry, Sept. 9th, 1912. Carl Duisberg. Lecture on the Latest Achievements and Problems of Chemical Industry.

found, are really solid particles charged with negative electricity, which are shot out in straight lines in a continuous stream with enormous velocity from the cathode. These cathode rays possess energy and can be made to turn a windmill. When the particles strike the anode or glass they set up several disturbances in them, and one of them is the emission of greenish phosphorescent light.

Professor Röntgen, of Munich, then took up the study of the cathode rays and the green phosphorescence, and, in the year 1895, made the sensational discovery of the Röntgen rays. This discovery is sometimes said to have been accidental, but accidents such as this one only occur to men of genius. Röntgen noticed that photographic plates which had been kept under cover in the neighbourhood of a highly exhausted tube through which electric discharges were passing, became fogged, just as they would do if exposed to light. On investigation, he found that the fogging was due, not to the cathode rays themselves, but to a new type of radiation produced by the glass or anode of the glass tube. When the cathode particles bombard the anode end of the tube, they not only produce waves of light which appear as green phosphorescence, but cause the glass to send out the waves which Röntgen called X-rays, but which are frequently called Röntgen rays. These waves, like light waves, are believed to be electromagnetic in nature, and they have the remarkable property of being able to penetrate many substances opaque to ordinary light. Röntgen. soon after this discovery, photographed the coins in his purse and the bones in his hand.

The discovery of X-rays by Röntgen very quickly found application in surgery, and now no large hospital is lacking in X-ray facilities. Those who are not associated with hospitals, scarcely know the numerous and important uses of the X-rays at the present day. It may, therefore, be of interest to mention that at St. Bartholomew's Hospital in London, about 4,000 X-ray plates are used each year, and in the London Hospital about 6,000. Large hospitals like these have their special X-ray departments, each provided with a special staff of experts. The rays are used for locating foreign bodies such as needles and bullets imbedded in the flesh, and for finding the exact state of dislocations and broken bones. Then they are used in disease, for detecting consumptive spots in the lungs, cancer in the stomach, and especially stones in the kidneys. Every day hundreds of stone cases are investigated. The X-rays are used for the cure of ring-worm—one of the troublesome diseases of children. A child's head is exposed to X-rays for about half an hour. There is no apparent immediate effect. However, three weeks later, the hair begins to fall out, and with it the fungus which is in the roots of the hair. In the course of another week the child becomes as bald as a bladder of lard. Two months after the child has become bald, the hair begins to grow again. In the course of a short time the child regains his normal appearance and can return to school.

Other diseases which can be treated with or cured by X-rays are lupus, acne vulgaris, chronic exema, rodent ulcer, and in certain blood diseases, the blood can be brought back to the normal. Hundreds of cases of external cancer are treated every day, with great benefit to the patients who are sometimes cured. One of the most recent applications is in the cure of excessive local perspiration—an application due to Dr. Pirie, of the Royal Victorian Hospital, Montreal.

The enormous benefit of X-rays in relieving suffering is due in the first place to pure science, to the patient investigations of a University Professor. Here we have a splendid object lesson in the uses of research. Could such a brilliant discovery be made in the University of Manitoba, what a splendid inspiration it would be to every one belonging to it. Let us see to it, that our staff and any of the students who wish, shall have such facilities as they require for carrying out investigations.

We must return once more to the cathode rays. The cathode rays have been extremely carefully investigated by Sir Joseph Thompson of the Cavendish Laboratory at Cambridge, and from these investigations, conclusions of the most far-reaching importance concerning the nature of the atom have been reached. It was found that the stream of particles, the cathode rays, can be deflected in their course by a magnet. From this fact and others, Sir Joseph has found it possible to calculate the mass of the particles which are now most generally known as electrons. These electrons have a mass only about one seventeen-hundredth of that of an atom of hydrogen. In the experiments of Sir Joseph Thompson and his school in connection with the negative particle of the cathode rays, one result seems to be clear, and that is that the atoms can give off at least one small part of themselves and therefore no longer can be considered indivisible.

The atom has been the foundation stone of chemists since the day of Dalton for a hundred years—the ultimate unit in our conception of matter. Now our conceptions have undergone a vast change: the atom still remains, but no longer is it something incapable of further analysis. There are about a hundred different kinds of chemical elements. It is now believed by many scientists that all of them have their atoms made up of the same fundamental stuff—the electron. The dream that some fundamental substance is present in the make-up of all the known elements, now appears to be a fair approximation to the truth, although we are still far from an exact proof of this generalization.

Another extremely important discovery in physics is that of the phenomenon of radio-activity, an entirely new property of matter, culminating in the isolation of radium, the conversion of one element into another, and the discovery of an enormous quantity of hitherto unsuspected energy stored up in the atom.

In the year 1896, Henri Becquerel discovered that compounds of uranium affected a photographic plate through an opaque covering of black paper. Compounds of thorium were found to possess similar properties. In 1898, M. and Mme. Curie, of Paris, made a systematic search for these effects in a great number of chemical substances. They found that several minerals containing uranium were even more active than uranium itself. Pitchblende which is chiefly an oxide of uranium containing impurities, was found to be especially active. Pitchblende, from an Austrian mine, was found to be three or four times as active as a corresponding quantity of uranium. It therefore seemed clear that there was something in the pitchblende which was more active than uranium. An analysis of the pitchblende was made and three previously unknown elements, radium, polonium, and actinium, all radio-active, were separated by different observers. The most active of the three is the substance radium which was discovered by the Curies. The amount of radium in good pitchblende is about one part in 10,000,000; or ten tons of pitchblende contain about one gram of pure radium. All the radium prepared does not exceed thirty grams, and so precious is the substance that an institution has been founded in Paris called the Radium Bank.

Radium is constantly radio-active: it gives out light and it emits three kinds of rays—α, β, γ. The α-rays are of atomic mass; they are, in fact, made up of atoms of the gas helium, carrying a charge of electricity. The β-rays are like the cathode rays—a stream of electrons, and the γ-rays are like the X-rays which come from a Crookes' tube.

One of the most extraordinary of the properties of radium is that of continuously giving out heat. In a single hour a piece of radium generates sufficient heat to raise the temperature of its own weight of water from the freezing point to the boiling point. Year after year a piece of radium continues to give out its stream of energy. The property of continually evolving energy is an essential part of the nature of radium. One cannot stop the flow of energy or increase it. It is not affected by heating to redness, by the cold of liquid air, or by chemical changes.

The cause of the activity of radium and its heat emission is the successive break-down of the atoms of radium itself. Pure radium placed in a glass tube can be shown to produce continually a gas known as *radium emanation* or *niton*, and at the same time,it liberates α particles which, as we have seen, are atoms of the gas helium; that is to say, it has been definitely proved that an atom of radium breaks up into an atom of the gas niton, and an atom of the gas helium. Niton itself breaks down in turn into a succession of solid substances, the sixth of which is the element polonium—one of the original radio-active elements discovered by Mme. Curie. In the course of these changes three more atoms of helium are emitted and numerous electrons. There is now strong evidence to show that polonium by the emission of another atom of helium produces the common element lead.

It has been estimated that the average life of radium is only 2,500 years. But historical records go back much further than this. Whence therefore, has the radium come? It is found that radium occurs in minerals containing uranium, itself a radio-active substance. It has now been proved by Soddy that a uranium preparation entirely free from radium, subsequently produces radium. The radio-active substances can be arranged in a set of family trees. Uranium gives rise to ionium, ionium to radium, radium to radium emanation, and this in all probability to the common metal lead. This transformation of the elements one into another, is not a thing that we can make to occur at will. All we can do is to observe the changes. The conversion of one element into another, the old dream of the alchemists has thus, through the wonderful skill for investigation displayed by our modern wizards, become a matter of observation; but we cannot control the changes, we cannot hasten them or retard them. Perhaps some day we shall learn how at will we may transmute one element into another, but that end does not at present appear to be in sight.

One of the most extraordinary consequences of the discovery that the atom contains electrons and of the fact of radio-activity, is that our eyes have been opened for the first time to the existence of a vast store of unsuspected energy—energy stored up in the atom which had been, until recently, entirely overlooked. Helium has been discovered in the sun by means of the spectroscope, and there seems every reason to believe that its parent radium is there too, i.e., that there are radio-active substances in the sun. For long it was believed that the sun's heat was only kept up by the shrinkage of its materials into smaller volume. But even shrinkage could not keep the sun's temperature constant for very long. Now geologists believe that the sun's heat has remained about the same for at least one hundred million years, and possibly much longer, and also that the earth's surface has remained in its present condition for this vast period.

According to modern views the maintenance of the sun's heat is due to radio-active substances which it contains. Atoms of different kinds in the sun are constantly undergoing spontaneous disintegration with the result that vast stores of energy are being liberated. It is this energy—energy of atomic source—which keeps our great sun, so to speak, alive, and prevents it from rapidly growing cold.

It used to be believed that our earth, not so very long ago geologically speaking, was too hot to support life. As one descends into the earth, the temperature rises, and the temperature gradient has been measured. From a knowledge of the temperature gradient, it could be calculated how long a period of time must have elapsed since the surface of the earth was too hot to sustain life. The calculation made by Lord Kelvin was about 40,000,000 years; but with this estimate geologists were not satisfied. They said that for the accumulation of the stratified rocks they could not do with a day less than 100,000,000 years. Now it has been found that the earth-crust contains a vast amount of radio-active substances: these are all the while giving out heat. The cooling of the earth, if it were ever once molten, must have been lengthened by the presence of these substances. There is no physical reason why the earth should not be many hundreds of millions of years old. Indeed, it has been suggested by Professor Joly that the earth may actually be getting hotter instead of colder; and analyses of radio-active minerals, made by Strutt, point very strongly to the conclusion that the solid earth has been in existence for at least 750,000,000 years.

The world—every kind of world—is kept going by energy. The discovery of atomic energy is a marvelous thing owing to its immense amount, and its vast importance to the history of our earth, our sun and all the heavenly bodies. At present, as Soddy has called it, this is the "Age of Coal." We are using up the forgotten sunshine of past ages, collected during millions of years, at a great pace—spending our capital of energy to a large extent careless of the future. But in the course of a few generations the day of reckoning for what has been called "our black and nervous civilization" must come. When coal is exhausted, unless some new source of energy is found, great cities like Birmingham and London, Paris and Berlin, New York and Montreal, and the city of Winnipeg, will not be able to exist. At present there is a race between the rate of exhaustion of the capital of the world's energy and the advance of science which may enable us to discover the means of obtaining a permanent income from some new source of energy. It seems very doubtful whether the wind and the waves and the sun can ever be so harnessed, or the internal heat of the earth ever be so used, or the growth of vegetation so increased, as to provide sufficient energy to carry on the work necessary to be done to keep in existence the world's teeming millions. Could we, however, tap the greatest source of energy, that residing in the atom, could we learn to cause atoms to disintegrate at will, then we should be placed in a secure position; every physical need humanity could ever have, so far as amount of energy is concerned, could be supplied. Science alone can avert an extraordinary disaster which is pending within the next few centuries. May this University, through the energy of its Physics and Chemistry and Engineering Departments, do great things towards the solution of one of the most important scientific and practical problems which men have ever had to face.

Biology.

In the last few decades, Biology, which includes all the sciences which deal with living organisms, has made quite as much progress as Chemistry and Physics.

Innumerable researches have been made upon the structure and functions of large numbers of living plants and animals. Palaeontologists and Palaeobotanists have brought to light thousands of species of fossil plants and animals, through the study of which it has been possible to reconstruct floras and faunas which existed millions of years ago in remote geological ages. The physiologist has developed the sub-science known as pharmacology which is devoted to the investigation of the action of drugs, and which is now rapidly placing the art of giving medicine upon a truly scientific basis. It has been discovered that many medicines, such for instance, as sarsaparilla and tincture of arnica, which hitherto have been used in enormous quantities, are entirely ineffectual remedies. The whole trend of pharmacology is in the direction of very markedly diminishing the drugging of patients. In the study of the action of drugs there is still an enormously wide field for the researches of the physiologists; and I trust that some of our medical students, sooner or later, will, by their own original investigations, contribute something to our knowledge within this important field. The growth in the literature of Physiology, like that of Botany and Zoology, has been enormous; and as an illustration of this I may mention that my colleague, Professor Swale Vincent, in a masterly work which he has just published on Internal Secretion, includes in his Bibliography some 3,000 references to original works and papers. The study of disease, through the efforts of the pathologist, is all the while making rapid strides. The means which have been devised to combat the specific parasitic microbes and the protozoa, which are the cause of our infectious diseases, in their ingenuity and thoroughness are among the greatest triumphs of the human intellect.

The anthropologist has recently brought to light, more especially in England, France and Germany, a number of new skeletal remains of prehistoric man, of men who lived during the great Ice Age. The most important recent discovery is that of a jawbone found in 1907 in the Mauer sands near Heidelberg, buried to a depth of 80 feet, and associated with the bones of extinct species of horse, rhinoceros and elephant. There is now every reason to suppose that man has existed upon this planet for several hundreds of thousands of years. Some authorities who have studied the mode of occurrence of the skeletons, and the rocks in which they have been buried, have estimated the age of the most ancient remains at about 500,000 years.

The most important of all biological generalizations is that of evolution, for nothing else has brought so many apparently diverse phenomena under a common point of view, or has accomplished so much for the unification of knowledge. Since the publication of that momentous work, the *Origin of Species,* in 1859, large numbers of searchers after natural knowledge have been busily engaged in collecting facts concerning living and dead organisms. And of all the innumerable facts thus gathered by the botanist, the zoologist, the anthropologist and the geologist, in the last half century, not one, so far as I know, is out of harmony with the idea of evolution. On the other hand, the theory of evolution has become immeasurably strengthened by the increase of knowledge. Indeed, we should not any longer think of evolution as being a theory but as being a fact. It may safely be said that at the present day there is not a single biologist of repute who has any doubt that evolution has taken place. Evolution to the biologist at least is a living conviction. He looks upon evolution as as certain a historical fact as the Norman Conquest of England, or the landing of the Pilgrim Fathers on the shore of Massachusetts Bay: and any system of philosophy or theology which is unable to assimilate the great out-standing fact of evolution seems to him to have its foundations laid upon the sand.

One of the best proofs that organic evolution is now universally regarded as a fundamental fact, a foundation stone of modern Biology, is the great celebration which took place in 1909 at Cambridge, at which I had the honour to be present as representing this University. Several hundred of the world's most famous men, leaders of thought in Science, Philosophy and Religion, assembled to do honour to the great name of Charles Darwin, on the occasion of the centenary of his birth and the fiftieth anniversary of the publication of the "*Origin of Species.*" Anyone who wishes to understand the profound influence upon modern thought of the establishment of the fact of organic evolution could not do better than read the fine volume issued by the Cambridge University Press, called *Darwin and Modern Science,* which contains 29 articles, each by a writer of world-wide eminence, dealing with the modern aspects of the great theory.

The most important recent advances in Biology seem to me to be those which have taken place as a natural consequence of the establishment of the fact of evolution. Darwin's theory to explain the fact of evolution was that new species arise from old ones by the summation through natural selection of certain characters in particular directions very gradually, in the course of a long series of generations. This theory, however, as a result of new observations and experiments, has been replaced in many minds by the Mutation Theory, according to which new species arise from old ones by jumps—in the course of a single generation. The parent species occasionally gives rise to filial descendants which have new and definite fixed characters and which constitute a new species. The chief work in connection with the Mutation Theory has been that done by de Vries, a Dutch botanist, who published the results of his twenty years' labour in two volumes in 1901 and 1903.

One of the chief factors in Evolution is Heredity. To Gregor Mendel is due the credit of throwing a new light upon this most important subject. He was born in 1822, of Austro-Silesian parents, and at an early age entered the monastery of Brünn. There, in the seclusion of the cloister garden, he carried out a series of experiments with the common pea which have since become famous. He published the results of his work which had taken eight years, in the *Proceedings of the Natural History Society of Brünn.* His brief paper of only some forty pages, upon inheritance in peas, has now become one of the classics in Biological literature. By a strange accident, Mendel's paper remained unknown for thirty-five years. At length, in 1900, it was discovered almost simultaneously by three distinguished Botanists who at once perceived its extraordinary importance. The result was that it was soon re-published in several languages. It is a great pity that the original paper did not fall into the hands of Charles Darwin, for had it done so no doubt its rare merit would have been early recognized. Before Mendel's time, Biologists had made laborious experiments in crossing different races of animals and plants, but they had always looked upon the individual as the unit. Their investigations led them to believe that mongrels or hybrids are usually intermediate between the parents, so that they resemble one in some features and the other in others: but they failed to discover any definite laws of inheritance.

Mendel, however, noticed that each variety of pea has a number of differentiating characteristics or unit characters. As examples of such unit characters, one may mention seed-colour, seeds being either yellow as in some varieties, or green as in others. In some varieties the seeds are round and smooth; in others, they are wrinkled. In some, the flowers are purple; in others, white. In some the plants are tall, 6 or 7 feet high; in others, dwarf, 1½ to 2 feet high. Mendel, instead of regarding whole plants as units, selected certain pairs of these unit characters and investigated their inheritance by themselves. Thus, for instance, he fixed his attention on tallness and dwarfness. He crossed tall and dwarf varieties of peas. He found that the next, or hybrid, generation, consisted of plants all of which were tall. He said, therefore, that tallness was *dominant*, while shortness which had apparently disappeared, he called *recessive*. He then collected the seeds from these hybrid tall plants which had been allowed to fertilize themselves, and found that out of every hundred about 75 developed into tall plants and 25 into short plants. He thus obtained an important numerical relation, namely, that dominant and recessive characters appear in the third generation in the proportion of 3 to 1. From this and many other similar experiments which were carried on through several successive plant generations, he drew some important theoretical conclusions. One of them is known as the principle of dominance, and another as the segregation of unit characters in the gametes or sex-cells. It is impossible to explain these principles in detail in the limits of this address, but their profound importance for understanding inheritance is now universally recognized. These principles are being applied on an extensive scale at the present moment in the breeding of new and useful varieties of animals and plants. Mendel's principles of inheritance have also been applied successfully in explaining the inheritance of certain characters in man, such for instance as eye colour, an abnormality known as brachydactyly, and a defect known as night-blindness. Light from the same source has been thrown upon the transmission of a number of human diseases.

Eugenics.

During the last few years, a new science known as Eugenics has been founded. The word "Eugenics" was invented by the late Sir Francs Galton, and he defined it as "the study of agencies under social control that may improve or impair the racial qualities of future generations either physically or mentally." Eugenics, as thus defined, includes the study of all agencies which have racial importance, i.e., both those concerned with nature and those concerned with nurture. The natural agencies are those which have to do with the qualities and gifts implanted in man-kind by heredity; while the agencies which have to do with nurture are those of the environment which lead to the development or suppression of natural qualities or gifts by the outward circumstances of life. Eugenics is therefore the study of the influence upon race, both of heredity and environment.

However, Biologists are beginning to feel that heredity is far more powerful than environment in the improvement and impairment of racial qualities. And it has therefore come about that Eugenics is concerned chiefly, though not exclusively, with the study of heredity and its relation to social problems.

During the past summer there was held in London the first International Eugenics Congress which was attended by representatives from all the great civilized countries, under the presidential leadership of Major Leonard Darwin, one of the able sons of Charles Darwin. At this Congress which I had the privilege of attending, many interesting papers were read, dealing with inheritance of feeble-mindedness, epilepsy, alcoholism, insanity, fecundity, and so forth. At present we require more knowledge, and the application of this knowledge will have to be made with great caution. Yet the end which the Eugenists have in view is a noble one—the improvement of the racial qualities of future generations. In the course of time we shall utilize all the knowledge we have acquired by studying the process of evolution in the past, to promote the moral and physical progress of Man in the future. Sooner or later every nation will have to undertake this work. It is possible, as Major Darwin said, that the twentieth century will be known in the future as a century when the Eugenic ideals were accepted as part of the creed of civilization.

Telepathy.

In conclusion, I wish to refer to the subject of Telepathy. There is a school which ought to go once more to school and learn the lesson, alas! too often forgotten, the lesson of an open mind. Great steps in progress often meet with violent opposition. Prometheus was bound for bringing the gift of fire to men, but in that heroic age it was a jealous god who chained him to the rock. As the world grew older it was his fellow-man who oppressed the discoverer of a new and illuminating truth. Galileo suffered for placing our earth in its right position in the starry heavens. Charles Lyell was treated with suspicion and coldness for having taught us the great antiquity of our planet. Darwin was preached against for having shown us that man has had but a lowly ancestry and that his extraordinary physical, mental, moral and spiritual characteristics have only reached their present state after millions of years of evolution. Elliotson and Esdaile were persecuted by the medical profession for introducing hypnotism as a rational method for treating certain mental diseases by means of suggestion. And, in these days, I have heard such men as the late F. W. H. Myers, Sir William Crookes and Sir Oliver Lodge scoffed at and derided for having spent years of labour, and for having published their views upon certain supernormal mental phenomena which scientific men had previously neglected.

One of these phenomena is that of Telepathy, the communication of one mind with another without the use of the ordinary organs of sense. In my opinion, Telepathy by means of overwhelming evidence has been established as a fact. For me, Telepathy is just as natural an occurrence as the falling of meteorites from space to this earth, or as the Aurora Borealis whose mysterious glow so often lights up our northern sky at night. I regard the establishment of the fact of Telepathy as enormously important, for here we have a phenomenon in connection with human beings which, it seems to me, cannot be explained by either the chemist or the physicist. Telepathy teaches us how little we yet know of our own minds and how much there is yet to be discovered of human personality.

Ladies and Gentlemen, this brings me to the end of my Address. The review which we have taken of the Progress of Modern Science, although of necessity very brief and incomplete, has, I think, been sufficient to show us how vast has been the increase of our knowledge during the last few decades, an increase which has been due to patient and never-ceasing research, to the successful exercise of what I trust you will join with me in considering to be one of the chief functions of a properly organized University.