Princeton Lectures

Published by PRINCETON UNIVERSITY Princeton, N. J.

April 3, 1920

Announcement

To the Alumni of Princeton:—

Enclosed is a document which we believe every Princeton man will find of extraordinary interest.

It is not only an intensely interesting lecture by one of the most distinguished members of the Princeton faculty, it is also the first step in a plan to make every one of the 11,000 alumni of Princeton once again Princeton students and continuously active participants in the work of the university.

It embodies the beginnings of an effort on the part of the university to take Princeton to her alumni; to do something for them and not merely to be asking them to do something for Princeton.

* * *

The average alumnus in the past, after his four delightful and memorable years at Princeton, has received his diploma, and gone out into the world.

Thereafter there was no definite and continuous relationship between him and his alma mater. He kept in touch with the University through reading the Alumni Weekly; at times he returned to take part in University functions or alumni reunions, he attended commencement baseball games or the annual football contests with Yale and Harvard.

Meanwhile he has known little or nothing of the progressive life of the University and of the contributions members of the faculty were making to the growing thought of the world.

Princeton's mission is not merely to inform and train the undergraduate mind, but to make significant contributions to the rapidly developing world of knowledge.

Professors at Princeton are constantly plowing new intellectual ground, but there has been no effective means whereby

Princeton might share her intellectual and spiritual life and growth with the great body of her alumni.

It would indeed be a happy consummation if it were possible to make every man feel that once he matriculated at Princeton he became a Princeton student in a life-long course.

It is therefore our purpose to endeavor to carry to the alumni body, as far as possible, the most interesting and striking products of the living thought of Princeton of today, hoping that some new idea thus gained will prove a stimulus to the intellectual life of the sons of Princeton.

* * *

This is the proposed plan of operation:

Stenographic reports will be taken of the most interesting lectures delivered during the year to the undergraduates by members of the Princeton faculty. Only such lectures will be selected as embody new ideas or the results of recent research having direct relationship with current events or problems of high present interest.

The transcripts of the lecture will be carefully edited with a view of making them of the greatest possible interest and use to the alumni.

They will then be printed in a form easily read, and distributed at frequent intervals to Princeton alumni, in no matter what part of the world the individual alumnus may be.

The printed lectures will be accompanied in each case by a brief biographical sketch of the member of the faculty delivering them. At the end of each lecture there will be a short bibliography indicating the more important recent books which could profitably be read as shedding light upon the subject matter of the lecture.

Many alumni have written from time to time to the university asking for guidance in the conduct of their reading. It is to be hoped that these bibliographies will be of real value in that direction.

* * *

This plan is not University Extension in the usual sense. The scheme is addressed to those who have actually been in attendance in the classrooms of Princeton.

Each field of university activity will be covered in these lectures. We wish the alumni to have a more personal knowledge of the members of the faculty through this intimate contact with their thoughts and the results of their learning and research.

* * *

The development of this plan, we hope, will mark a new era in the relations between Princeton and her alumni, and possibly, in the maintenance of such relations, contribute something of value to the cause of university education in general.

President

Princeton University
April 3, 1920

Number One

Princeton Lectures

Published by PRINCETON UNIVERSITY Princeton, N. J.

APRIL 3, 1920

NOTE

These pages contain the first of the lectures by members of the Princeton faculty, which are to be distributed to the University Alumni.

This lecture, "Has Human Evolution Come To An End?" embodies results of recent scientific researches and reflections upon a topic of universal interest.

The lecture comes from the Biological Department of Princeton at the head of which is Prof. E. G. Conklin, of whom a biographical note follows:

CONKLIN, EDWIN GRANT, Professor of Biology, Princeton University, was born in Ohio in 1863. He has the degrees of B.S., A.B. and A.M. from the Ohio-Wesleyan University, Ph.D from Johns Hopkins, honorary ScD. from the University of Pennsylvania. From 1891-94 he was professor of biology at Ohio-Wesleyan University; 1894-96 professor of zoology at Northwestern University; 1896-1908 professor of zoology at University of Pennsylvania, since which time he has occupied the Chair of Biology at Princeton University. He is a trustee of the Marine Biological Laboratory at Woods Hole, Mass. A member of the Advisory Board of the Wistar Institute at Philadelphia. Associate Editor of the Journal of Morphology, the Biological Bulletin and the Journal of Experimental Zoology. He is a member of the National Academy of Sciences; American Society of Zoologists (President 1899); American Society of Naturalists (President 1912); Fellow of the American Association for the Advancement of Science (Vice-President 1907); American Philosophical Society (Secretary 1901-08); Academy of Natural Sciences of Philadelphia (Vice-President since 1901). Honorary member of K. K. Acad. Wissenschaften Prog.; Societe Royale Zoologique de Belgique; Societe Royale de Sciences; Medicals et Naturelles da Bruxelles. The author of about 100 contributions to our knowledge in Heredity, Development and Evolution.

Published semi-monthly. Application pending for second class mail privilege.

Has Human Evolution Come to An End?

A LECTURE

By EDWIN GRANT CONKLIN

Professor of Biology in Princeton University

The doctrine of special creation taught that man was perfect when he issued from the hands of the Creator, but that his disobedience brought upon him imperfection, degeneracy and death.

The doctrine of evolution teaches that man has come up from animal ancestors, that he is the culmination of this stupendous work of time, and that he is becoming more and more perfect. Indeed many evolutionists assume that there are no limits to the possible evolution of man, that we began in primordial protoplasm and will go on to

> "Some far off divine event,
> To which the whole Creation moves."

The recent cataclysm which has overwhelmed the world, the present perils of civilization, the threatenings of revolution, the widespread recrudescence of emotionalism and irrationalism have awakened us from this roseate dream.

Let us consider the present position and the future prospects of the human race from the rational rather than the emotional, from the scientific rather than the poetic points of view.

I

The Principles of Evolution

There is no longer any doubt among scientists that man is descended from the animals, that he is a vertebrate, a mammal, a primate.

Even non-scientific persons generally recognize this animal relationship although John Fiske used to tell of a man who became very indignant when he was told that he was a mammal and replied "I am not a mammal nor the son of a mammal." He added that he had probably been brought up on a bottle.

There is no longer any doubt among leading anthropologists and biologists that not only the body but also the mind and society of man are the products of evolution and there is no reason to doubt that the great principles of evolution which have operated in the past will continue to act in the future.

* * *

What are these principles?

1. Evolution is trans-formation and not new-formation; it consists of new combinations of the elements of which organisms are composed, whether those elements be organs or characters, hereditary units or the molecules of which such units are composed and it does not consist in the creation *de novo* of molecules, units, characters, organs or functions.

2. Evolution can take place only by means of changes in the germplasm—the material basis of heredity. The only living bond between successive generations is found in the germ cells which extend back from us without a break to our earliest progenitors.

* * *

The body is mortal, it develops and dies in each generation, but the germ cells are at least potentially immortal.

Changes in heredity are due to changes in the immortal germplasm rather than in mortal bodies and evolution consists primarily in the evolution of germplasm rather than of developed organisms.

In spite of much controversy, due largely to lack of clear thinking, it is now practically certain that "acquired characters" of the mortal body are not inherited, that is are not transmitted to the germplasm and evolutionary changes are not first wrought in developed bodies but in germplasm. The "New Hope of Hereditary and Evolution" based upon the supposed inheritance of acquired characters has led only to new disappointments.

The Results of Evolution

3. The results of evolution may be summarized in three words—Diversity, Adaptation, Progress.

Diversity is seen in the innumerable variations, mutations and species of the living world. Most of these are no more complex or perfect than the stocks from which they sprung and some of them are degenerate descendants of more perfect ancestors. Diversity in short is mere change, whether progressive or retrogressive, whether useful, indifferent or harmful.

Adaptive evolution is increasing perfection of adjustment to conditions of life. The only scientific explanation of such adjustment or fitness is Darwin's principle of natural selection of the fit and elimination of the unfit and it is eloquent testimony to the greatness of Darwin that more and more this great principle is being recognized as the only mechanistic explanation of adaptation.

Progressive evolution is the advance in organization from the simplest to the most complex organisms, from amoeba to man. Biological progress means increasing complexity of structures and functions, increasing specialization and co-operation of the parts and activities of organisms, and human progress, whether physical, intellectual or social, means no more and no less than this.

The Limits of Progressive Evolution

4. The limits of progress are fixed by its very nature. No single animal or plant, however complex it may be, can combine within itself all the complexities of all organisms. Specialization or differentiation means limitations in certain directions in order to advance in others.

If a creature have wings it cannot also have hands (except in art where angels are given an extra pair of appendages and hair and feathers are mixed regardless of zoological classification); if its limbs are differentiated for running they cannot also be specialized for swimming; if it have enormous strength it cannot also have great delicacy of movement.

Thus while certain animals are specialized in one direction and others in another no one animal can be differentiated in all directions.

Furthermore increasing specialization leads to lack of adaptability; peculiar fitness for any special condition of life means unfitness for other and different conditions.

When differentiations in any one direction go so far that they unfit the organism for any condition of life except a single and special one the chances for survival are greatly reduced and sooner or later this highly differentiated organism becomes extinct or returns to a more generalized type.

* * *

Paleontology is in the main the science of organisms that were too highly differentiated to adjust themselves to the new conditions that came upon them and which therefore became extinct. The death of species like the death of individuals is the price that is paid for differentiation.

One-celled organisms and all germ cells are potentially immortal, but the highly differentiated bodies of animals and plants and their highly differentiated muscle, nerve and tissue cells are mortal, probably because they are too highly specialized to adjust themselves to all the changing conditions of existence.

Similarly species that are not highly specialized are highly adaptable, and have great powers of survival while those that are highly specialized have little adaptability and consequently are more likely to become extinct.

For this reason new paths of evolution usually start from generalized rather than from highly specialized types.

* * *

The Paths of Progress

5. Millions of diversities exist among organisms and they are appearing continually; thousands of adaptations have arisen during the course of evolution and are still arising; but different lines of progress have been relatively few. The most important paths of progress throughout all past ages have been in the direction of:

> (*a*) *bodily complexity* or the multiplication and differentiation of cells, tissues, organs and systems;
>
> (*b*) *society* or the differentiations and integrations of individuals or persons whether among ants, bees or men;
>
> (*c*) *intelligence* or the capacity of profiting by experience which comes with increasing organization of the nervous system.

* * *

a. In all these paths of evolution progress is most rapid at first and it then slows down until it stops.

One-celled organisms reached their utmost limits of complexity millions of years ago; since then they have shown many diversities, many adaptations, but little if any progress.

Many-celled animals and plants long ago reached the limits of their possible progress in almost every line.

Many new species have evolved and are still appearing, there has been diversification and adaptation almost without limit, but progress in the sense of increasing complexity of organization has practically come to an end.

b. Animal societies represent the highest grade of organization which has yet appeared on earth.

Here the differentiations and integrations of individuals make possible this higher degree of organization. The evolution of animal societies may be traced from a condition in which every member is much like every other and the bond of connection between individuals is a very loose one up to societies of ants, bees and termites in which the specialization and co-operation of individuals is extraordinarily developed.

Already differentiation among ants and termites has gone so far that the three principal functions of life, namely nutrition, reproduction and defense, are no longer found in the same individuals; "workers" are unable to reproduce or to defend the colony, males and females are unable to get food or to defend themselves, "soldiers" are unable to reproduce or even to feed themselves. At the same time co-operation within a colony is practically perfect.

It is difficult to imagine how differentiation and integration can go farther than this, and unless it does go farther progress in this direction has come to an end.

The Last Stage of Evolution

c. Intellectual evolution is the last and, from the human point of view, the most important path of progress which has ever been discovered by organisms. In lower animals intellect is either lacking or is but little developed, and behavior is guided entirely by rigid instincts; in higher animals it is more fully developed but instinct is still the rule of life; in man only has intellect become to a certain extent the master of instinct.

For thousands of years man has endeavored to improve by selective breeding certain qualities of domestic animals, and among these the intelligence of dogs and horses especially. Undoubtedly much improvement has been made but in intelligence as in other qualities a limit to improvement is sooner or later reached beyond which it is not possible to go.

There is no evidence that intellectual progress, as distinguished from diversity, is still going on among animals and that they will ultimately graduate into man's class.

* * *

In bodily complexity, social organization and intellectual capacity progressive evolution has virtually come to an end among organisms below man; further progress, if it occurs, must be in new paths and from generalized rather than highly specialized types.

Has progressive evolution come to an end in the case of man also?

II

The Successive Steps in Human Evolution

Through unnumbered millions of years evolution has moved on from the lowest form of life to the highest, from amoeba to man.

> About half a million years ago the immediate progenitors of man appeared on the earth.
>
> The earliest man-like fossil so far discoverd is the Ape-man, *Pithecanthropus erectus*, of Java.
>
> About 100,000 years ago the Neanderthal man appeared, a member of the genus *Homo* but an extinct species, *neanderthalensis*.
>
> Then came, about 25,000 years ago, certain races of the existing species, *Homo sapiens*, such as the *Cro-Magnon* and the *Grimaldi* races.

Finally at the beginning of the historic era, say about 10,000 years ago, we find the white, yellow and black races of man, with the subdivisions of each of these, much as they are today.

1. Physical Evolution of Man

Since the beginnings of recorded history there have been very few and wholly minor evolutionary changes in the body of man. Chief among these are the decreasing size of the little toe and perhaps a corresponding increase in the size of the great toe; decreasing size and value of the wisdom teeth; and probably a general lowering of the perfection of sense organs.

These changes are in the main degenerative ones due to the less rigid elimination of physical imperfections under conditions of civilization than in a state of barbarism or savagery. Such changes are insignificant as compared with the enormous changes which led to the evolution of man from pre-human ancestors.

* * *

Individual variations due to new hereditary combinations or to environmental influences are always present but they have little or no evolutionary value.

By hybridization of various races and stocks there has come to be a complicated intermixture of racial characters, but new characters have not been evolved by hybridization; by changes in environment modifications have been produced in development but not in heredity, these are *fluctuations* and not *mutations*.

For at least 10,000 years there has been no notable progress in the evolution of the human body. The limits of physical evolution have apparently been reached in the most perfect specimens of mankind.

There is no prospect that the hand, the eye or the brain of man will ever be much more complex or perfect than at present.

By selective breeding the general level may be improved, just as it has been in domestic animals, but there are no indications that future man will be much more perfect in body than the most perfect individuals of today.

Intellectual Evolution

But if man is not growing more perfect physically surely, it will be said, he is growing more perfect intellectually. Let us examine somewhat critically this claim.

We certainly know more things than the ancients did and we are proud to think that "The minds of men are widened by the process of the suns." But it is most important to distinguish between knowledge and intellect, between things known and the capacity for knowing.

By means of language, tradition, writing the experiences of past generations can be handed on to present and future ones and thus each generation may receive the knowledge accumulated throughout the past. In this sense we are "the heirs of all the ages."

Knowledge is certainly growing, but is intellectual capacity increasing?

Does anyone think that in the past 2,000 or 3,000 years there has been any increase in human intellect comparable with the increase in knowledge? Do the best minds of today excel the minds of Socrates and Plato and Aristotle?

On the contrary it is the opinion of those who have studied the subject most that no modern race of men is the equal intellectually of the ancient Greek race.

> In the two centuries between 500 and 300 B. C. the small and relatively barren country of Attica, with an area and total population about equal to that of the present State of Rhode Island, but with less than one-fifth as many free persons, produced at least 25 illustrious men.
>
> In this small country in the space of two centuries there appeared such a galaxy of illustrious men as has never been found on the whole earth in any two centuries, perhaps not in all the centuries, since that time.
>
> Galton concludes that the average ability of the Athenian race of that period was, on the lowest estimate, as much greater than that of the English race of the present day as the latter is above that of the African negro.

There has been no progress in the intellectual capacity of man in the past two or three thousand years, and it seems probable that the limits of intellectual evolution have been reached in the greatest minds of the race.

Increasing size of brain and complexity of nervous organization leads to mental and physical instability and disharmony, and the great increase in nervous and mental diseases in modern life warns us that there is a limit to intellectual evolution.

Even in the most distant future there may never appear greater geniuses than Socrates, Plato, Aristotle, Shakespeare, Newton, Darwin.

Undoubtedly eugenics and education can do much to raise the intellectual level of the general mass, but it cannot create a new order of intellect.

Social Evolution

But if the evolution of the human individual has come to an end certainly the evolution of human society has not. In social evolution a new path of progress has been found the end of which no one can forsee.

Evolution has progressed from one-celled organisms to many-celled, from small and simple organisms to larger and more complex ones. By the union of many individuals into a society a still larger and more complex unit of organization was formed with possibilities of almost endless progress.

Society lasts from age to age, while individuals come and go; society preserves the experiences, acquirements, wisdom of the past and hands it on to the future so that each age builds upon the preceding ones; thus society has advanced from savagery to barbarism and then to civilization and the end is not yet.

At present social evolution is proceeding at a rate which is amazing if not alarming.

All kinds of variations and mutations of the social organization are occurring and, if only we have the wisdom to preserve the good and eliminate the bad, progress will be certain and rapid.

Evolution has progressed from amoeba to man; from reflexes to instincts, intelligence and reason; from the solitary individual to the family, the tribe, the modern state, and in spite of narrow-minded politicians and reactionary senators we or our descendants will yet see the whole human race brought together into a Society of Nations.

Man's Conquest of Nature

The evolution of man is no longer limited to his body or mind nor even to society, but by adding to his own powers the forces of nature man has entered upon a new path of progress.

The differentiations of various members of a colony of ants or bees are limited to their bodies and are fixed and irreversible; but in human society differentiations are no longer confined to the bodies of individuals but have become, as it were, extra-corporeal.

By his control over nature man has taken into his evolution the whole of his environment.

Although he is not as strong as the elephant nor as deft as the spider nor as swift as the antelope nor as powerful in the water as the whale or in the air as the eagle, yet by his control of the forces of nature outside of his body he can excel all animals in strength and delicacy of movement, in speed and power on land, in water and in air.

This new path of progress is in all respects the most important which has ever been discovered by organisms and *no one can foresee the end of this process of annexing to our own powers the illimitable forces of the universe.*

III

What of the Future?

There is no probability that a higher animal than man will ever appear on the earth.

The only reason for surmising that other species of the genus Homo may appear in the future is the fact that there have been species in the past which do not exist at present. These prehistoric species have everywhere been replaced by the existing species probably because they were intellectually inferior.

It is possible, of course, that similar causes may lead to the elimination of the present species but this does not seem probable for the following reasons:

(1) All races of man may and do interbreed owing to fertility *inter se* and to the lack of geographical isolation; consequently there is a growing tendency to the breaking down of racial isolation and to the hybridization of existing races.

> This is clearly shown in all countries where races, even the most distinct, have been brought together, as in North and South America, the West Indies, Australasia, Polynesia, Asia and Africa.
>
> Such hybridization may possibly lead to the production of new types or mutants, but these would probably be "swamped" and lost unless they were isolated.

All present signs point to an intimate commingling of all existing human types within the next two or three thousand years at most.

Even if new races may be developed by psychological or social selection there is no likelihood that new species will thus arise which will supplant the existing species.

* * *

(2) The development of moral and social ideals of equal justice for all people will prevent the extermination of inferior races, and the democratic ideals of self-government and majority rule will necessarily prevent even the merciful elimination of all except the most perfect types.

The majority cannot be expected to decree its own effacement; the most that can be expected is that the majority will eliminate from reproduction only the most inferior and defective individuals. By this means the standards of the race may be preserved at the present level but they cannot be greatly advanced.

No great improvement in domesticated animals or plants would be possible if breeders were able to eliminate only the most inferior individuals, and the same will certainly be true of human breeds.

Even if the dreams of eugenicists should come true the most that could be expected would be that the standards of the race as a whole would more nearly approach the most perfect specimens of humanity which now exist.

No Likelihood of New Species

There is little likelihood therefore that a new and higher species of man will develop on the earth.

And there is no probability that some other genus or class or phylum may give rise to an animal physically, intellectually and socially superior to man.

It is possible but not probable that the entire human species may become extinct, but even if this should happen from what other source could a superior animal arise?

No other animal approaches man in intellectual capacity, upon which depends the rational organization of society and the conquest of all nature.

However imperfect, irrational and anti-social mankind may be; however much we may at times sympathize with Mark Twain's comments on "the damned human race," we may feel confident that in the long ages of future evolution no greatly superior species will appear upon this planet.

IV

Conclusion

The human race has come up through physical, intellectual and social evolution to its present condition. In body and mind the most perfect individuals of the race have probably reached the limits of possible progress.

In the rational organization of society and in the conquest of nature no one can foresee the end.

This is now the main path of human progress, the great goal toward which the human race must continue to move for ages to come. By rational co-operation man is now able to direct and hasten his own evolution.

The powers and emotions and intellects of men are centered in the three greatest institutions of human society, namely the State, the Church, the University.

These institutions must more and more devote themselves to the furthering of human evolution, and to us as individuals is given the opportunity of aiding in all this work of time.

What other aim is so worthy of high endeavor and great endowment? In the spirit of Ulysses let us set forth on this new path of evolution:

> "Death closes all; but something ere the end,
> Some work of noble note, may yet be done,
>
> 'Tis not too late to seek a newer world.
> Push off, and sitting well in order smite
> The sounding furrows; for my purpose holds
> To sail beyond the sunset, and the baths
> Of all the western stars, until I die."

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Number Two

Princeton Lectures

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MAY 1, 1920

THE LECTURER

HENRY NORRIS RUSSELL, Professor of Astronomy, Princeton University, was born in Oyster Bay, N. Y., October 25, 1877. He has the degrees of A.B., Princeton, 1897, *insigni cum laude* and Ph. D., Princeton, 1900, *summa cum laude*. He was Advanced Student, Kings College, Cambridge University, England, 1902-03; Research Assistant of the Carnegie Institution of Washington; stationed at the Cambridge Observatory, England, 1903-05; Instructor in Astronomy, Princeton, 1905-08; Assistant Professor in Astronomy, Princeton, 1908-11; Professor of Astronomy, Princeton, 1911—; Director of the Observatory, 1912—. His war service, 1918-19, was as civilian engineer, Bureau of Aircraft Production, engaged in development and testing of military and aeronautical apparatus in the course of which he did considerable flying as an observer. He is also Foreign Associate of Royal Astronomical Society of London; Member of National Academy of Sciences, American Astronomical Society, American Physical Society and other learned societies. Author of many papers on astronomical topics published in technical journals in this country and England.

Published semi-monthly. Application pending for second class mail privilege.

Modifying Our Ideas of Nature

THE EINSTEIN THEORY OF RELATIVITY

NOTE

This is the second lecture of the series by members of the Princeton faculty, to be distributed to the University Alumni.

This lecture embodies an explanation of the elements of the theory of relativity and tells how our conceptions of Nature have been modified by it.

Dr. Albert Einstein, whose scientific discoveries are described as the most remarkable and important since Newton's theory of gravitation was promulgated and as propounding a new theory of the Universe, is a Swiss Jew, 45 years of age. He was, for some time, a professor in mathematical physics at Polytechnic at Zurich, and later professor at Prague. Afterward, he was nominated a member of the Kaiser Wilhelm Academy for Research in Berlin, with a salary of eighteen thousand marks per annum, and no duties so that he should be able to devote himself entirely to research work.

It was approximately fifteen years ago when Dr. Einstein first made known his "theory of relativity."

The present revival of interest in the theory is due to the remarkable confirmation which it received in the reports of observation made during the sun's eclipse last May, to determine whether rays of light passing close to the sun are deflected from their course.

The actual deflection of the rays, it was discovered by the astronomers, was exactly what had been predicted theoretically by Einstein many years since.

Dr. Einstein is a physicist, and not an astronomer. He developed his theory by a mathematical formula. Confirmation of it came from the astronomers. As he himself says, the crucial test was supplied by the last total solar eclipse.

Observation then proved that the rays of fixed stars, having to pass close to the sun to reach the earth were deflected by the exact amount demanded by Einstein's formula. The deflection was also in the direction predicted by him.

Asked one time to express the difference between his conception and the law of gravitation in terms understandable to the layman, Dr. Einstein stated:

"Please imagine the earth removed, and in its place suspended a box as big as a room, or a whole house, and inside a man naturally floating in the center, there being no force whatever pulling him.

"Imagine, further, this box being, by a rope or other contrivance, suddenly jerked to one side, which is scientifically termed 'accelerated motion'. The person would then naturally reach bottom on the opposite side.

"The result would consequently be the same as if he obeyed Newton's Law of Gravitation, while in fact, there is no gravitation exerted whatever, which proves that 'accelerated motion' will in every case produce the same effects as gravitation.

"I have applied this new idea to every kind of 'accelerated motion'; and have thus developed mathematical formulas which I am convinced give more precise results than those based on Newton's Theory. Newton's formulas, however, are such close approximations that it was difficult to find by observation any obvious disagreement with experiments."

* * *

Bibliography

The literature of Relativity is already extensive, but most of the publications are of a highly technical character, and intelligible only to experts. Perhaps the best discussion of a semi-popular character is to be found in the Monthly Notices of the Royal Astronomical Society, of London, for December, 1919, which contains an account of a meeting of this society at which the theory was discussed by Professors Eddington, Varmor, and others.

Modifying Our Ideas of Nature

A LECTURE

By Henry Norris Russell
Professor of Astronomy in Princeton University

I

It is probably a long time since there has been any occasion on which a matter so definitely belonging to pure science as the "theory of Einstein" has excited so much popular interest.

Although the statements in the newspapers concerning "the overthrow of Newton's Laws" and similar "scare heads" have gone beyond the more sober statements of scientific authorities, it is nevertheless true that the theory of relativity, of which the recent work of Einstein forms an extension, has modified our conceptions of Nature in a very remarkable fashion.

Einstein's reported statement that there were not more than twelve men in the world who could read and fully understand his book was probably quite within the facts. But the elementary ideas on which the theory of relativity is based do not involve any difficult mathematics, and the only obstacle to grasping or holding them is their remarkable novelty. We can understand them easily enough, or at least understand what they are about, if only we begin at the beginning.

* * *

It probably has not occurred to all of you that while I was speaking the last sentence we traveled several hundred miles. Yet, of course, we did. If we had not, the earth would have left us behind it somewhere in empty space.

In fact, we are undergoing a very complicated series of motions, carried around with the rotating earth and swinging along much more rapidly and in a much vaster curve with its orbital motion.

But of this fact we are blissfully unconscious. Why? Because the motion is perfectly smooth, without jar or shock, and in particular because not merely we ourselves, but all the objects that constitute our environment, are moving together.

Motion and Distance Ordinarily Measured by "Tying Up" to Definite Objects

So we come to one of the main conceptions of the theory of relativity, the *moving frame of reference.*

We ordinarily refer our measurements and indeed our notions of distance and of motion to some *frame*, what the mathematician would call some system of coordinates, which, so to speak, is "tied" to some definite objects—ordinarily to that portion of the earth's surface on which we may have set ourselves or over which we may be traveling at the moment.

Though we and all our well-informed ancestors for two centuries have known very well that this frame of reference is not at rest but is in rapid and intricate motion, we are, nevertheless, still accustomed to referring our motions to this moving frame and saying that a thing has not budged when its position with respect to the ground has not altered.

And in doing this we not only follow the promptings of common sense, but find a practical and working basis for the scientific description of almost all terrestrial affairs.

But the moment we begin to look off the earth into space things are different. It then becomes obvious that the earth is not at rest but moving, both on its own axis and about the sun.

I say "obvious"; but it is worth remembering that these facts—at present so familiar even to the man in the street—aroused, when their truth was first advocated, the most violent disbelief and agitation, and that it took a century or more of controversy to displace the old innate belief in the fixity of the earth, that is, of our frame of reference, and substitute the belief that it was in motion.

Necessity of Finding Other Means of Measuring Motion and Distance

So far as our solar system goes we may comfortably treat the Sun as being at rest and attach our frame of reference to it. But when we come to look still farther afield at the stars we find them in motion and later detect a drifting tendency among them which indicates beyond question that our Sun itself is moving.

So next we hitch our frame of reference on to a sort of average position of all the stars visible to the naked eye, and find that with respect to this new frame of reference the Sun and planets are moving at the rate of about twelve miles per second in a definitely known direction.

We were content with this until within the last decade, when observations upon the nebulae, which we know now to be enormously farther off than the naked eye stars, revealed extremely rapid motions.

If we try now to hang a frame of reference, so to speak, to the average of these nebulae, it begins to look as if our Solar System was moving, compared with this, at a speed of something like four hundred miles per second, which motion of course the system of stars visible to the naked eye must substantially share.

But now, which of all these systems is really moving?

Are the stars at rest and the nebulae moving, or are the nebulae at rest and the stars moving, or are they both moving past each other in different directions, and is there anything at rest? Can we really find anything anywhere in the material universe upon which we can really set the feet of our imagination and say "J'y suis, j'y reste" with the conviction that we are at last upon the firm rock of the Absolutely Motionless?

* * *

It is from a search for an answer to this question that the theory of relativity grew.

The first great contribution was made by Newton. An immediate consequence of his fundamental principles of physical science is that if we have a number of objects moving together in space, which we may call a system, acting upon one another in any fashion, however complicated, but free from outside influence, then the relative motions of the bodies in that system will not depend at all upon the rate at which the system as a whole is moving through space, or the direction of its motion, but only upon the mutual interaction of its parts.

Simple uniform motion in a straight line, what we technically call a "motion of translation," does not influence the things that happen in the system at all, even to the minutest degree. Therefore an observer within the system cannot hope to detect it unless he has something outside to observe. It is on account of this great dynamic principle that we are unconscious of the motion of the Earth about the Sun.

In our proposed search, then, for "absolute motion" we must use some other means, and our most efficient tools are likely to be the waves of light. We know that light spreads out from any hot body into space in all directions and at the great speed of 186,000 miles a second.

Taking the Ether as a Basis in the Search for Absolute Motion

Despite this enormous velocity, *something real* actually travels outward, because it carries with it energy which is, to the modern physicist, one of the most fundamental of all realities.

This energy may still be perceptible to our eyes or apparatus when reaching us from the stars after a journey which has consumed many thousands of years.

We know, too, that this energy, while it is on its way, travels in a manner strikingly similar to the propagation of waves, so much so that we feel justified in describing light as consisting of waves of definite lengths and properties.

Now how does this energy travel through apparently empty space with these singular wave properties? The natural answer, almost the intuitive answer, is to say that it travels through a medium, and so we invent the "ether," simply as the medium which carries the light.

But if there is such a medium in space, and light travels through it in every direction at the same speed, it would seem as if here, at last, in this undisturbed ether, we had our frame of reference which we could use as our basis for the measurement of all other motions.

Detection and Measurement of Motion by Light Signals Through the Ether

If this be true, we can detect whether this world of ours is moving through the ether or not by sending light signals through equal distances in different directions and seeing whether they come back to us at the same interval of time.

To see how the thing works, let us suppose first that we have an observer at rest with respect to the ether and surrounded by a circle of mirrors set in various directions from him but all at a distance of 186,000 miles.

If he then produces a flash of light at his own position this light will travel out and in one second will reach all the mirrors simultaneously, will be reflected at each and at the end of another second will come back to him simultaneously from all the mirrors. (If this hypothetical apparatus appears to you inconveniently large, you can just as well imagine one a million times smaller, which would make the radius of the circle about a thousand feet, and count your time in millionths of a second instead of whole seconds.)

So far so good. But now suppose that the observer and his whole circle of mirrors, big or small, are not at rest but are all moving together uniformly at a speed of half the velocity of light.

Now let the observer send out a light signal and wait for its reflection from that mirror which is directly on the line of his track and in the direction toward which he is moving.

The light traveling out toward this mirror would itself move 186,000 miles a second but would have a "stern chase," since the mirror is receding half as fast as it is traveling, and it is easy to see that it would take two whole seconds to reach the mirror.

On the return journey the observer will be advancing to meet it with half the speed of light, and this part of the process will take only two-thirds of a second. The elapsed time for the round trip of the light will be two and two-thirds seconds, considerably longer than if the observer was at rest.

Consider next a ray of light which gets reflected in the mirror whose direction from the observer is at right angles to the first.

It will not have the long stern chase which the first ray has, but nevertheless it will lose something, because in order to reach the moving mirror it will have to travel "on the bias," so to speak, through space, so that it will reach not the point where the mirror was when the light started, but the point where it will be when it gets there, and something quite similar will happen on the return journey.

When this is calculated it is found that the round trip will in this case take about two and one-third seconds. (The exact amount involves calculating a square root that we need not bother with here.)

The important point is that in this case, where the observer and mirrors are moving through the ether, the ray of light which has traveled up and down the direction of motion will take a longer time for the round trip than the ray which has traveled cross-wise to the motion over a path of exactly the same length.

We should, therefore, in this way be able to detect motion of our own system through the ether, and if our measurements were sufficiently accurate, determine its direction and rate.

Failure of Early Experiments

This was attempted in the famous Michelson-Morley experiment. The distance of the round trip was in this case only a few feet, and the difference in time over the two paths only something like a millionth part of one billionth of a second.

But this minute interval could be measured by splitting a ray of light into two parts by letting part of it be reflected sidewise from a transparent mirror and the rest go through, and reuniting the parts after their trip.

If one had gained on the other by even a fraction of the time of vibration of a single light wave the fact could be detected, and the waves which we ordinarily call light vibrate at the rate of about six hundred thousand billion per second.

Michelson and Morley tried their experiment, and in place of the easily measurable result which they anticipated, they got nothing. The light waves came back over the two paths in exactly the same interval of time.

They tried it again and again at different times of the year when the earth was moving in different directions around the sun, so that even though the earth might have been at rest in space on some one of these days it certainly was not at rest on all of them. But they always met the same negative result.

II

Einstein's Assumption that only Relative Motion is Possible of Study

Other optical experiments of a more intricate nature and even greater delicacy were attempted with the same object of detecting the motion of the earth through the ether and they all failed.

After it became clear that the trouble was not in the apparatus or the experiment, it was evidently necessary to account for the absence of the predicted effect.

After various minor hypotheses had been tried, Einstein started in with the bold assumption that these experiments had unveiled a new law of nature, viz., that the universe was so constructed that it was not possible by any physical experiment, optical or otherwise, to detect the existence of absolute, uniform, straight-ahead motion, or indeed to determine whether the observer's frame of reference was at rest or in such uniform translational motion.

If this is true, it follows that it is only the RELATIVE motions of material bodies in the universe which we can study at all.

Hence the name of the "Principle of Relativity."

A second principle following naturally from the experiments which led to the first is that the velocity of light in empty space will always come out the same, whether measured by an observer moving, with his apparatus, in one direction at one rate or by one similarly moving in another direction and at a different rate.

Novel Consequences of Einstein's Hypothesis

This principle sounds harmless enough, but the consequences which follow from it are so different from our old pre-conceived opinions that they often appear to us grotesque to a degree.

Take one of the simplest ones. Let us go back to the observer with a ring of mirrors surrounding him, from all of which the reflections of his flash of light reach him at the same instant. If he thinks that he is at rest in space he will say that these mirrors are distributed around a perfect circle with his own position as center.

Now suppose he chooses a different frame of reference, in uniform motion compared with his original one. That is, suppose that he thinks that he and the mirrors together are moving uniformly in some particular direction and at a high velocity.

He will now say, "If these mirrors were really on a circle the light would take longer to reach me from those which were in the direction of my path than from those at right angles. Since the light returns simultaneously from all, the mirrors are not arranged on a circle but on an ellipse, which is longer at right angles to the direction of my motion than it is the other way."

If, as in the case previously discussed, he supposes himself to be moving with half the speed of light, he will conclude that the longer diameter of this ellipse is about fifteen per cent greater than the shorter diameter. If he estimates his own velocity higher, he will regard it as differing still more from a circle.

But although the mirrors in this case are not all at equal distances from him, he cannot find this out by measuring the distance with a measuring rod. In fact, if he does so, their distances will all appear to be exactly the same, if the principle of relativity is true. For, otherwise, by combining an optical experiment and a direct measurement he would have a method by which he could distinguish between rest and uniform motion; and this is, by the very hypothesis, impossible.

Hence nature must be so constituted that his measuring rod would automatically change in length when turned from a position parallel to his motion to one at right angles to it.

This sounds strange enough, but something of the sort is entirely necessary in order to explain the Michelson-Morley experiment. The assumption that material bodies, when moving through space, contract slightly in the direction of motion was made by Lorentz in order to explain this experiment before the more general theory had been developed. At such speeds as are actually reached by the planets in their orbits, the contraction is less than one part in one hundred million and beyond detection by anything except the most refined investigations.

* * *

We have now seen that, according to the principle of relativity, the answer to the question whether two material rods laid on the table at right angles to one another are of the same length or of different lengths depends on whether we choose to think that we and the room in which the apparatus is situated and the rest of the world, are at rest in space or are moving in different directions with high uniform speeds.

The fact that when the two rods are laid side by side they are obviously exactly equal does not prove that they are the same length when we turn them so that they make an angle with one another.

So much for the measuring of distances and the measuring of the lengths of things.

Measurement of Time Also only Relative

Now how about measuring times?

Let us go back to our observer with his mirror and call him A, and suppose that at the mirror there is a second observer whom we will call B, and that both observers have clocks which run with perfect accuracy, and are able to observe the time of anything with the aid of their clocks as precisely as you please.

Now let us suppose that exactly at twelve noon A sends a flash of light out toward B. B perceives it at the instant when it is reflected by his mirror and notes the time as exactly one second past twelve o'clock. A observes the reflected signal at two seconds past twelve o'clock.

Repetitions of this signal on successive days give exactly the same result. A and B will conclude that the distance between them does not change, since it always takes light the same time to make the round trip, and that their clocks are running at the same rate.

Now suppose that A and B regard themselves as at rest. They will then agree that the distance between them is 186,000 miles, since it takes light one second to go each way, and they will also agree that their clocks are not merely running at the same rate but are exactly synchronized, because the light must have reached B just one second after it left A.

But now suppose that A and B agree in the belief that they are moving through space with half the speed of light, so that they are following the same track with B preceding A.

Using the same principle of the stern chase of which we have spoken before, they will now figure out their distance apart is not 186,000 miles, but just three-fourths as much, or 139,500 miles, and also that the light in going outward over this distance from A to B on the stern chase took one and a half seconds, whereas in coming back it occupied only one-half second.

This change in the distance amounts to exactly the same thing which we described a few moments ago; but there will be a second interesting change with respect to their measurement of time. For since they now believe that the light took one and a half seconds to go out, the time when it reached B was one and a half seconds past noon by A's clock and only one second past noon by B's clock.

Hence they will agree that B's clock is half a second fast.

On the other hand, it is easy to see that, if they had supposed themselves to be going along the same line, and at the same rate of speed, but in the opposite direction, they would have concluded that B's clock was half a second slow.

We reach, therefore, the still more picturesque conclusion that the question whether or not two events which take place at different points of space are simultaneous or occur at different times cannot be answered until we have defined the uniformly moving frame of reference with respect to which we are to make our measurements and reasoning.

With the distance that we have assumed the difference between the two clocks would be only a fraction of a second even if the assumed speed was very great. But if we had taken a distance such as that between the remoter stars, whose light takes thousands of years to travel, then, according to our choice of a frame of reference, we might have been led to the conclusion that A's clock was either in agreement with B's or fast or slow by several centuries.

Once again, the possible difference between the results of different assumptions are immeasurably small for such observations as could be made upon our tiny and slowly moving earth. But for such distances as separate the stars and for greater assumed speeds they may become extremely large.

I might go on to describe what happens if we imagine two observers, A and B, receding from one another with half the speed of light and exchanging signals by a reflection back and forward from mirrors carried by both. As I have not a blackboard, I will spare you the details, which are not hard for anyone to work out who takes a pencil and piece of paper.

New Conclusions About Space and Time

I will simply state the result that, given a certain set of definitely observed facts upon which both observers are entirely and perfectly agreed, it is possible that A, if he considers himself at rest, will say that B is receding from him with half the velocity of light and carrying a clock which is running at exactly the same rate as his own; while B, who naturally may prefer to think of himself as at rest and the other fellow moving, will believe that A is receding from him with half the speed of light, but will insist that his clock and A's are not keeping together but are running at different rates.

The root of this extraordinary discrepancy between their opinions will lie in the fact that they divide up the round trip time interval for the reflected light waves in different manners on account of their different assumptions as to whether the reflecting mirrors are at rest or being chased by the light, thereby introducing a difference into their methods of comparing one another's clocks which continually increases as the distance between them increases, and the round trip time for the light with it.

I have certainly gone far enough now to show you how we are led, if we stick to these apparently simple and harmless principles of relativity, into the most extraordinary conclusions with respect to space and time.

As someone has well put it, "when-ness" and "where-ness" are all mixed up together. You can't say just when a thing happened without saying where it happened, and also with respect to what frame of reference you define both when and where.

All these spectacular changes, however, reach perceptible amounts only for objects which are moving with at least a moderate fraction of the velocity of light; and the actual motion of the planets is so much slower than this that no perceptible differences will be introduced by our choosing frames of reference which are attached to the earth, the sun, the planets, or the stars.

III

Recent Astronomical Experiments Confirm Einstein's Hypothesis

Not content with these remarkable results, Einstein proceeded a few years ago to generalize his theory further, in imagining another type of question which did not come within even the wide view of the older relativity theory.

To make this idea clear let us imagine two observers, each with his measuring instruments, means of subsistence, et cetera, in a large and perfectly impervious box, which forms his "closed system."

> The first observer, with his box and its contents, alone in space, very remote from all gravitating bodies and entirely at rest.
>
> The second observer, with his box and its contents, is, it may be imagined, near the earth or the sun or some star and falling freely under the influence of its gravitation.
>
> To be more precise, we imagine him in what is called a "uniform gravitational field," where the gravitational force is exerted on all objects in exactly the same direction and is not converging toward the center of the attracting body, where it is always of exactly the same amount, and there is nothing to interfere with an indefinitely long fall.
>
> This second box and its contents, including the observer, will then fall under the gravitational force, that is, get up an ever increasing speed, but at exactly the same rate, so that there will be no tendency for their relative positions to be altered.

According to Newton's principles, this will make not the slightest difference in motions of the physical objects comprising the system or their attractions on one another, so that no dynamical experiment can distinguish between the condition of the freely falling observer in the second box and the observer at rest in the first.

But once more the question arises, what could be done by an optical experiment?

According to the beliefs which have been held from the time of Maxwell, who first developed the electro-magnetic theory of light, until the present, it has generally been believed that gravitation, however powerful, has no effect whatever upon light, and that light would therefore travel in a straight line through a field of gravitational attraction exactly as it would through empty space.

Einstein Concluded Light Does Not Travel in a Straight Line

Einstein, on the other hand, assumed, just for the fun of seeing what would come of it, that the principle of relativity still applied in this case, so that it would be impossible to distinguish between the conditions of the observers in the two boxes by any optical experiment.

It can easily be seen that it follows from this new generalized relativity of Einstein that light cannot travel in a straight line in a gravitational field.

> Imagine that the first observer sets up three slits, all in a straight line, at considerable distances apart. A ray of light which passes through the first and second will obviously pass exactly through the third.
>
> Suppose the observer in the freely falling system attempts the same experiment,

placing the line of his three slits at right angles to the direction in which he is falling and having them equally spaced.

The ray of light which has passed the first slit, must, in order to get through the second, move not toward the point where that slit was when it emerged from the first, but toward the point where the second slit will be when the light reaches it.

It will, therefore, be moving not at right angles to the direction in which the system is falling, but at a slant, so that during the interval in which it has traveled laterally from the first slit to the second, it will have moved downward by a certain fixed amount, namely by the amount through which the system fell in that interval.

In moving from the second to the third slit, the light will occupy the same interval of time, and, if it moves in a straight line, will go downward by the same amount as before.

But since the system is falling ever faster and faster, it will during this time interval have dropped farther than it did in the preceding time interval, and carried the third slit with it.

Hence the ray of light will strike above the third slit and fail to go through it, provided it travel in a straight line in space.

But on Einstein's assumption it must go through the third slit, since the two conditions are indistinguishable.

In consequence, the path of the light in space must be curved and not straight when gravitation is present, and the ray of light must bend downward, that is, in the direction of the gravitational force.

Deflection of Light Effected by Gravitation

This deduction from Einstein's new principle may thus be reached in a very simple fashion, but the further following out of the principle, and the exact calculation of its consequences is far too intricate a matter for me to speak of here.

The results, however, are not difficult to understand. The principal ones are these:

1. A ray of light passing near a gravitating body like the sun will not travel in a straight line, but will be deflected slightly downward toward the gravitating body, much as a very rapidly moving projectile would be deviated.

Calculation shows that the amount of deviation would be quite too small to measure for a ray of light that has passed near the moon or planets, but that for light that has passed near the sun the deviation reaches nearly two seconds of arc, which the modern astronomer, accustomed to accurate measurements, considers a large and very easily measurable quantity.

2. Newton's law of gravitation, on Einstein's principle, appears to be only an approximation to the true law, but an exceedingly good approximation—so much so that among all the intricate motions of the planets there is but a single case in which the introduction of the new law instead of Newton's principle produces perceptibly different consequences.

* * *

We all know the planets are moving in elliptical orbits about the sun and that the line joining the sun to the nearest point of the orbit has a certain definite position.

On Newton's theory this line would remain permanently fixed in space—always in the same direction—if it were not for the fact that the orbits of the planets are slightly but continually modified by their mutual attraction. These influences, or so-called perturbations, can, however, be accurately calculated and allowed for, so that they need not worry us here.

On the Einstein hypothesis this line to the nearest point in the orbit, or the perihelion, should not remain fixed, but should move slowly forward in the direction in which the planet is moving around the sun. The rate of its motion can be calculated from the theory when the distance and period of the planet are known. To this effect are added the influences of the attraction of the other planets as before.

It has been known for some thirty or forty years that the perihelion of the planet Mercury, after allowance had been made for the perturbations due to the attraction of the other planets, was actually moving slowly forward in a manner which was very difficult to explain. Attempts to account for it have failed.

For example, the attraction of an unknown planet between Mercury and the sun would do the trick, but observations made during eclipses of the sun show that there is no planet there. Nor can there be a great number of small bodies whose combined attraction would do it, for these would reflect so much sunlight as to produce a bright region in the sky, which again would have been observed during eclipses.

The discrepancy remained very puzzling until Einstein's theory appeared—and this theory predicts not only the fact and the direction of the discrepancy, but its exact amount, bringing observation and calculation into beautiful accordance.

The similar effects for the other planets are so small that they are at the very limit of measurement, but even so, the Einstein theory appears to fit the facts better than the old theory.

Results of Recent Experiments of Astronomers

This remarkable success deeply impressed astronomers, and set everyone waiting with keen interest the result of the observations made to determine whether rays of light passing near the Sun were deflected.

To settle this question it is necessary to photograph stars in the immediate neighborhood of the Sun, and this can be done only at the time of a total eclipse, when the Moon completely hides the Sun and enables us to observe the stars on a nearly dark sky.

Fortunately, the eclipse of May, 1919, afforded a very favorable opportunity for such observations. The Sun was eclipsed for more than four minutes and was situated at the time in a region of the heavens remarkably full of stars bright enough to be easily photographed.

In spite of the short interval since the conclusion of the war English astronomers rose to the occasion and sent two expeditions, one to Brazil and the other to an island off the African coast, equipped with photographic instruments of high power and especially suited for the work. By extraordinary good fortune the weather was clear enough at both stations to allow the obtaining of valuable results.

Every precaution was taken to secure accuracy. For example, after the eclipse the telescope was left in place for nearly two months so that the same stars might be photographed upon a dark sky, after the Sun had moved out of the way, to obtain plates showing their ordinary positions to use for comparison with the eclipse plates.

The photographs were brought to England and measured with the greatest care, and the result indicates that the apparent shift of the stars due to the deviation of the light is unquestionably present and is of very nearly, if not exactly, the amount predicted by Einstein, the difference between the observed and calculated amounts being hardly greater than the very small error which is still inherent even in these precise observations.

The observers, Professor Eddington of Cambridge and Dr. Crommelin of the Greenwich Observatory, are men of the highest standing, and their results prove beyond a doubt the reality of the predicted effect.

IV

New Theory Based on Positive Results

The older form of the theory of relativity was based upon the result of very precise observations, but upon *negative* results—upon the failure to find things which ought to have been found, and easily found, provided that the older theories had been correct.

But the new extension of the theory is based upon *positive* results—the presence of an effect, in the case of the planet Mercury, which though long known baffled all explanation, and in the case of the eclipse observations, upon the presence of an unquestionable and very remarkable influence whose existence no one anticipated or imagined until it was predicted by the theory.

It therefore appears to be very strongly established.

It is true that the original form of Einstein's theory also predicted that the position of the lines of any element, such as iron, in the solar spectrum should be slightly different from those produced by the same element in the laboratory. At the present time it is very hard to say whether this effect has been observed or not.

The positions of the lines in the spectrum can indeed be measured very accurately. But there are a variety of influences at work on the Sun's surface which may shift the positions of these lines, such as the pressure in the Sun's atmosphere, actual motion of this atmosphere, and possibly a host of other things, so that different lines of the same element are shifted by different amounts and in spite of years of investigation of this exceedingly complex problem it is not possible yet to explain all the things that have been observed.

It is, therefore, still uncertain whether, after these other causes are allowed for, it would be found that the lines in the Sun's spectrum were shifted or not. It seems probable, however, that Einstein's theory could be modified in such a manner as to account for the other effects already observed without demanding the existence of this one. Hence this can hardly be called at the present time a failure of the Einstein theory.

The mathematical expression of this last portion of Einstein's theory is the part which is so intricate and difficult.

Mathematicians whose minds are saturated with conceptions with which the layman is utterly unfamiliar find that these mathematical expressions may be (to them at least) most simply described in terms of space of four dimensions, or even of five dimensions in certain cases.

This side of the subject, although deeply interesting to the mathematician, and also to the philosopher, is not a matter of practical concern, principally for the reason that it does not deal with the facts of nature themselves, but entirely with the mathematical language which we employ in describing them.

Fundamentals of Einstein's Theory Summarized

The fundamental physical facts concerning nature which have developed in connection with the theory of relativity may be briefly and somewhat crudely stated in this fashion:

1. Our methods of measuring space and time are tied up with our assumption as to whether and in what direction we are moving in a manner which, if we assume our motion to be very rapid, greatly modifies the results of these measurements, but which, for motions which are not more rapid than those of the planets or most of the stars, produce no difference in these measurements which could be detected except by the most delicate and refined methods of observation, and usually not even a difference great enough to be so detected.
2. The new conceptions are, therefore, of very little or no importance to the practical man, but are of very great interest to the philosopher, since they indicate that the old traditional conceptions of space and time are not the only conceptions of this sort which the human mind is capable of forming, and, what is more, that when the comparison is made very precise these newer and apparently bizarre conceptions of space and time fit the facts of nature more closely than the simple common sense ones.
3. It has more recently been shown that the previous assumption that gravitation and the motion of material bodies on the one hand, and electricity, magnetism and light on the other, formed two separate sides of nature, not connected with one another, is incorrect. These two great complexes of natural phenomena and forces are actually parts of one still greater whole, although the connection between them is of such a character that it produces measurable results in only a very few cases.

The theory of relativity does not supersede the older scientific conceptions or destroy them, but leaves them as very close and very useful approximations to the facts of nature. As is usually the case with great scientific advances, it leaves us with a view of nature which is more complex and harder to understand and to work with than our previous conceptions, but which at the same time reduces what previously appeared to be disconnected things to manifestations of a single underlying unity of principle.

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NOTE

This is the third lecture in the series by members of the Princeton faculty to be distributed to the University Alumni. It is especially timely and interesting in view of the present efforts of both the railroad and the government to meet the problem of supplying the country's necessary transportation facilities.

THE LECTURER

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Private Ownership on Trial

SOME PROBLEMS FACING THE RAILROADS

A LECTURE

By FRANK HAIGH DIXON
Professor of Economics in Princeton University

On March 1st last the Federal Government relinquished its control of the railways of the country and returned them to the possession of their owners. This step was taken in response to an unmistakable mandate of the American people, who for the present at least have no desire for a continuation of government operation.

This step was taken in conformity with the so-called Federal Control Act, under which the roads were originally nationalized. This act limited the period of federal control to twenty-one months after "the date of the proclamation by the President of the exchange of ratifications of the treaty of peace." This limitation would apparently have permitted an indefinite continuation of federal operation, but the law also provides that the President may relinquish control at any time that he shall deem such action needful or desirable.

With the recovery of physical possession of their properties, the railroads become the recipients of a sheaf of unsolved problems, some of which have sprung inevitably from the transfer to private control, some of which have been passed on to them by the Federal Administration, which had no enthusiasm for the solution of new problems during its declining days, and which properly felt that any decisions on its part might only prove an embarrassment and obstruction later.

Threefold Aspect of the Railroad Problem

I

Credit

Without entering into all of the details of these various problems that now face the railroads, it may be possible to summarize the present situation by considering it in three of its aspects: namely, the financial problem, the labor problem, and the problem of public service.

Bulking large in the mind of every railroad executive is the problem of credit—when and how to secure the funds immediately necessary at rates of interest that will justify investment.

That the need for investment funds is insistent, none would deny who has given more than a superficial examination to the present situation. This can be most readily demonstrated by a statistical survey of the physical development of the railroads over the past few years, which will bring out their present capacity or lack of capacity for handling present business.

Steady Increase in Traffic

Let us look first at the traffic situation.

The striking fact in this regard is that traffic, both passenger and freight, has, in spite of the war, kept up its steady increase. In the face of all the discouragements set up by increased rates and inferior service, passenger travel has steadily grown and in 1919 exceeded all former records.

To be sure, the troop movement was in part responsible, but this had largely disappeared by the end of the summer of 1919; yet passenger traffic has continued in a volume wholly unprecedented since that time.

> The total passenger miles of service during 1919 will reach 46,200,000,000, which is 35 % in excess of the highest figure before the war.
>
> Freight traffic is more directly subject to industrial influences, and hence does not show so continuous a trend, yet its progress is unmistakable. The highest record reached before the war for the country as a whole was about 300,000,000,000 ton miles in 1913.
>
> The total exceeded 400 billions in 1918, and would have reached or have passed this figure in 1919 but for the serious interruptions to traffic due to labor and weather conditions. Reports for January and February of this year indicate the heaviest traffic for these months in the history of the country.

It has been the policy of railroad executives in the past to accept this steady increase as an axiom, and to plan as far ahead as financial conditions would permit to meet the "costs of progress." The programme of the more prosperous roads has been always to have a surplus capacity available.

Investment Not Equal to Traffic Requirements

But this program has been for some years an unrealized ideal. For several years before the war, investment had not kept pace with traffic requirements, or at any rate had not kept a safe distance ahead. Many reasons are given for this—some of them the subject of considerable controversy. Unquestionably the increasing demands for capital in other and more attractive fields created a competition that railroads found it difficult to meet.

It is charged that the Commission had not sufficiently recognized the public need and had been niggardly in its favors. Doubtless the meager results that the railways have obtained from their more important recent requests for rate increases created an uncertainty concerning the future value of railroad securities among investors, and made the securing of capital more difficult.

But whatever the cause, the fact is undisputed that during the period preceding the war there was a decided falling off in the generosity of provision for future needs, accompanied by and doubtless in part caused by a decline in the rate of return upon the railway investment. Railroad managements were already aware, before the war, of the declining support of the investment market.

During the abnormal war period, new investment was cut to the bone. Capital and labor were needed primarily for war purposes and only such additions to capital investment were undertaken as were imperatively necessary.

Even this programme was further restricted by the delay of Congress in passing the necessary appropriations in March, 1919, and by the decision of the Administration, later in the year, to turn the roads back to their owners, which made impracticable the undertaking of any long time policy of capital investment by the Government.

Need 2,000 Miles More Yearly

The results of this policy of semi-starvation are evident, and may be best shown statistically. In the ten-year period from 1905 to 1915, there were constructed annually an average of 3,500 miles of line, and in the previous five years an average of nearly 5,000 miles per year.

The figures for recent years are as follows:

MILES OF LINE CONSTRUCTED IN THE UNITED STATES:

Year	*Mileage*
1914	1532
1915	933
1916	1098
1917	979
1918	722
1919	686

No other such low record as the last five years disclose can be found in our statistics since 1864. Of course war conditions are immediately responsible. Moreover, we should of course expect a declining amount of new mileage as the country grows up to itself; but we have not yet reached the point for the country as a whole when railway building can stop.

Experts declare that we should build for many years to come at an average of 2,000 miles a year.

Equipment Situation Extremely Acute

Let us turn now to equipment. The extraordinary development of passenger travel has already been referred to.

> During the ten-year period 1905-1915 passenger traffic increased 48 %, and while the increase in passenger equipment was not in proportion, a sharp decline having set in during the latter part of the period, yet the increase in cars was 35 % for that decade, 26,800 new cars being added. The average number of passengers per car was about 15 during this period.
>
> Since June, 1915, passenger traffic has increased 43 %, and equipment 2½%. During the last two years of federal administration there were virtually no additions to passenger or sleeping car equipment, and the number of passengers per car, influenced in part by the troop movement, jumped from 15 to 21.
>
> Since 1915 the additions to equipment have not been sufficient to cover the minimum requirements of a sound retirement policy.

A similar situation, more acute because of its greater importance industrially, is the condition in respect to freight cars. Car shortages have been a common phenomenon since 1916.

The only factor that has saved the situation from a complete breakdown during the last two years has been the unified handling of equipment under the direction of the Car Service Bureau of the Federal Railroad Administration, which has introduced such measures as the "permit system," the zoning of certain kinds of traffic, the liberal use of the embargo, the disregard of corporate ownership in the routing of freight and the like.

> Freight traffic increased during the decade 1905 to 1915 by 61% and freight cars by 36%.
>
> From 1915 to 1918 traffic increased 45% and cars in service 1.6%.

Even assuming an increase in capacity of cars, this situation is alarming. Had retirements taken place during this war period as rapidly as in normal times, there would have been an actual decline in the freight carrying capacity of the railroads.

Locomotive figures tell the same story. A steady increase not only in number of locomotives but in tractive power is necessary to meet the increased density of railroad traffic.

One expert has estimated that with the retirement of locomotives long overdue there will be required to meet the traffic needs of the next three years an addition of over 13,000 locomotives of modern design. This in face of the fact that for the ten years 1905–1915 the average increase was less than 2,000 per year.

But these figures concerning rolling stock by no means tell the whole story. Every operating man appreciates that in most cases the terminal facilities constitute the "neck of the bottle," and that it is of little use to increase trackage and equipment if there is not adequate yardage for efficient handling. The cost of securing the terminal facilities needed right now is anyone's guess, but the sum is enormous.

And then there are demands which have awaited the return of normal conditions and which now press for solution, such as grade revision, elimination of curves, cut-offs, engine houses and shops, and the installation of improved shop equipment. There is the whole problem of signalling, in which only a beginning has been made; there is the work of electrification, which will in many cases repay handsomely the investment, but for which the initial capital must be found. To attempt to express the aggregate in exact figures would be idle for our purposes.

Capital Requirement of $6,000,000,000 in Next 3 Years

This much, however, might be said. As far back as 1907 Mr. James J. Hill estimated that the capital needs of the railways demanded an investment of a billion dollars a year for five years. No such additions have been made during the intervening years. In fact, the railroads have fallen far short of this figure.

The Railroad Administration reports capital expenditures during the two years of federal control of $1,200,000,000. Executives disagree as to the total needed at present; in fact few have ventured any estimate.

The expert investigators on the staff of the *Railway Age* have estimated the capital needs of the railroads for the next three years, omitting new terminal facilities and electrification, at over six billions of dollars.

Then there is the much discussed question of deferred maintenance. Due to the shortage of labor, during the early part of the war, while the railroads were still in private hands, there was unquestionably a falling off in the standards of maintenance of track and equipment. Director General Hines insists that the Federal Administration "has closely approximated compliance with its contract obligations to return the properties in substantially as good condition as when received."

Railroad executives take direct issue with this statement. Professor Cunningham, who was connected with the Operating Division of the Railroad Administration during the war, and whose opportunities of observation were therefore unusual, is of the opinion that the claims of the railroads against the government for undermaintenance may amount to $100,000,000.

This claim, if allowed, will eventually reach the railroad treasuries, but the demands of track and equipment maintenance cannot wait upon the snail-speed of a government settlement. Funds are needed at once.

* * * * *

Sources of Capital Funds

This rough picture shows why the railroads need capital. What are their sources of funds?

There is first the open market.

Two of the largest railroads of the country with unquestioned credit have just placed issues of securities on the market, the Pennsylvania and the New York Central. Both issues are attractive in their terms, short time, the one being a collateral trust issue backed by mortgage bonds, the other an equipment trust. Both had to offer 7% to command par.

Under such conditions there is little hope for the smaller or less prosperous road. Moreover it is to be noted in this connection that this unprecedented rate for bonds means that the floating of stock is probably impossible.

Already the amount of funded debt outstanding in the hands of the public is over 60% of the total net capitalization, and on many roads it is far in excess of this figure.

The financial standing of railroads in the investment market should be such as to permit them to maintain a sound relationship between stock and bond capitalization. At present the inevitable tendency is in the wrong direction.

Another source of capital funds is to be found in the provision of the recent transportation act under which $300,000,000 is appropriated as a revolving fund, to be used for the purpose of making loans to railroads during the transition period following the termination of federal control.

But in the face of the enormous capital needs, this sum is a miserable pittance. Moreover, it will doubtless be conserved in the interest of those roads whose credit is so doubtful that they can obtain capital nowhere else.

No Alternative to Increased Rates

This leaves but one further source of capital funds, and that is surplus earnings. What is the probability that there will be surplus earnings from railroad operation?

At present rates, none at all. The government operating the railroad system as a unit, putting into use many methods of economy not available under private operation, and paring down maintenance expenditures to a point not justified as a continuous policy in time of peace, has ended its stewardship with an operating deficit of $903,000,000, which should probably be increased to about a billion dollars by adding claims for under-maintenance.

This deplorable state of affairs was in little if any degree the fault of the Railroad Administration. The situation cannot be analyzed here in detail. Suffice it to say that it is the outcome of increased wage, fuel and material costs, combined with an insufficient increase in rates. Increases in wages alone were over a billion dollars a year, in excess by over $100,000,000 of the total guarantee of net return to the railroads by the government.

This situation the railroads have inherited.

> There is not the slightest chance that their expenses will decline; on the contrary they are likely to increase.
>
> There is a strong probability that they will be forced to concede a considerable increase in wages all along the line.
>
> Fuel costs will go up rather than down; there is no immediate likelihood of a fall in the prices of other needed materials.
>
> Maintenance accounts need to be fattened up rather than skinned.

There seems to be no alternative to an increase in freight rates, and an increase of very considerable amount. Yet even this is not likely to bring directly the funds needed for capital investment; the public would hardly stand for the rates required to meet the operating expense situation, and a surplus for betterments.

All that can be hoped for, or properly asked for, are rates sufficient to reëstablish the credit of the railroads, as a result of which they may secure funds in the open market properly distributed between stock and funded debt.

To establish such credit it is necessary that rates be sufficiently high to guarantee a revenue that will cover operating expenses, including generous maintenance, and a reasonable return on a fair value of the property. Such net return should be adequate to pay a fair dividend on a conservative stock capitalization, and leave some surplus as a safety fund against revenue fluctuations.

New Transportation Act Intended to Restore Confidence

What aid does the new law give toward restoring the confidence of the investor?

The Commission is instructed to prescribe rates so that the carriers as a whole in such groups as the Commission may designate, "will under honest, efficient, and economical management and reasonable expenditures for maintenance of way, structures and equipment, earn an aggregate annual net railway operating income equal as nearly as may be to a fair return upon the aggregate value of the railway property of such carriers held for and used in the service of transportation."

For the first two years, this rate of return is to be 5½%, with an additional ½% at the discretion of the Commission for improvements and betterments. One-half of the excess of the earnings of any individual carrier above 6% are to be paid over to the government, and deposited in a general railroad contingent fund to be used as a revolving fund. From it loans may be made to carriers, or equipment may be purchased by the government and leased to the carriers.

The other half of the excess over 6% is to be carried by the individual railroad to a reserve fund for interest and dividends until it amounts to 5% of the value of its property; thereafter the railroad may use any further surplus "for any lawful purpose."

So much depends upon the method of grouping adopted by the Commission, and the basis upon which the value of railroad property is to be determined, that it is impossible to predict at this time whether these provisions of law will prove adequate to restore railroad credit, and to carry the railroads safely through the next year or two of financial difficulty. At present it is a matter of opinion.

My own opinion is that the aid of the government will prove insufficient, and that unless the government comes more whole-heartedly to the support of the railroads, it may have them on its hands again.

II

Labor

So much for the problem of credit; the other two questions may be more speedily disposed of.

In the solution of the labor problem in its broader aspects, the public must take a hand. The growing power of organized labor on railroads, and the public necessity for uninterrupted transportation, have taken the question out of the category of private disputes between capital and labor. The utter dependence of the public upon the product of this industry makes it impossible for the public to confine itself to assuring the contestants a free field and fair play.

This was recognized in the Senate bill which forbade employees to enter into a combination, with the intent to hinder or prevent the operation of trains or the movement of commodities in interstate commerce. This went a long way and a little too rapidly, and when the bill emerged from conference, the anti-strike provision had disappeared, and a permanent Arbitration Board set up, with no power to enforce its findings except the power of public opinion.

I doubt very much whether the American people are yet ready to endorse the drastic plan of the Senate Committee. There is much force in the argument that a public service should be uninterrupted, and that both capital and labor should accept service in this type of industry subject to this limitation.

But it is quite a different thing to incorporate this principle suddenly into law, and impose it upon a group of employees just emerging from the restrictions of government employment into which they were drafted for war purposes—a group of men which has long been in service, has acquired many valuable seniority rights, and is in considerable degree unfitted by age and service to seek an alternative employment.

We should work toward the ideal of the settlement of disputes in public industries by arbitration, but we must accomplish it without doing violence to the rights of labor.

Organization and Discipline the Immediate Problem

The immediate problem of the railroads is one of organization and discipline.

There is little doubt that the morale of railroad labor is at a low ebb. The main reason for this is to be found in the centralizing and standardizing policy of the Federal Railroad Administration. Standardization was rapidly extended during the war, until now the individual employee to an almost complete extent is receiving the same pay for the same type of work everywhere throughout the country, irrespective of local conditions and cost of living.

This boon has come from Washington. Organization has been rapidly extended into sections of the country and on to railroads heretofore not unionized, and groups of employees not before organized have created national unions.

This has given labor an immense increase in its strategic power. But more than all else, the habit of disregarding local machinery for settlement of disputes, and looking to Washington, which began with the passage of the Adamson Act in 1916, has increased to an extraordinary degree, and has correspondingly weakened the power of the manager of the individual railroad.

Executives fully realize the seriousness of the situation, and are bending all their efforts to a restoration of morale and the building up of an efficient working organization.

The size of the task is indicated by the present strike, which, however much it may be due to radical propaganda—and I think this influence has been exaggerated—and however much it may be due to the exasperating deliberation of the Federal Administration in responding to the requests of the employees for a hearing on their demands for wage increases, nevertheless reveals not only a breakdown in the operating organization of the railroads, but a serious disorganization within the ranks of railroad unionism, upon the orderly working of which efficient railroading to a large degree depends.

III

Service

The problem of credit having been solved and the funds secured with which the needed capital expenditures may be made, and the labor force of the railroads having been once more developed into an efficient working organization, there remains for the railroads to provide the public with the most efficient service possible.

This problem has no terrors for the railroad executive if the other two conditions are fulfilled.

It demands on the part of the public wholehearted support in assuring to the carriers revenue adequate for its accomplishment.

It demands on the part of railroad management—and I have in mind here particularly financial management—a policy that shall subordinate everything to the one object of giving the public the service it requires. Beyond a reasonable return upon the investment, railroad capital is entitled to nothing.

It should have no melons, no opportunity for speculative gains.

It is entitled to that reward, and that only, which will obtain the capital necessary to assure the service.

The problem is critical in this sense, that if private management fails in this undertaking, government ownership is inevitable.

The public has put private railroad operation on trial.

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Bolshevism in Literature

SOME ASPECTS OF MODERN POETRY

NOTE

This is the Fourth Lecture in the series by members of the Princeton faculty distributed to the University alumni.

THE LECTURER

ALFRED NOYES, poet and critic, and Visiting Professor of English at Princeton, was born in the county of Staffordshire in England not quite forty years ago. Just twenty-seven years later, he married a very charming American wife, Miss Garnett Daniels, a daughter of Col. B. G. Daniels of the United States Army. In 1913 Mr. Noyes, already widely known in this country by his poetry, came to America as lecturer on the famous Lowell Foundation at Boston. During this visit, he also lectured at various universities and colleges, including Princeton. He was given the honorary degree of Litt.D. by Yale. In the following year he was made Visiting Professor at Princeton. The Oxford man has already become a loyal Princetonian; and the Englishman seems quite content to spend half of every year in an American college town.

During the war, Mr. Noyes, unable because of defective eyes to get into military service, worked untiringly for his country with his pen and on the lecture platform. In 1916 he was attached to the Foreign Office of the British government; and in 1918 the value of his work was recognized by the great honor of an appointment as Commander of the Order of the British Empire.

Mr. Noyes's first book of verse, *The Loom of Years*, was published in 1902; other volumes succeeded it in 1903 and 1904. In 1908 appeared the epic, *Drake*, and a critical study of William Morris in the English Men of Letters Series. In 1910 was published the first collected edition of his poems in two volumes. Among his more recent works may be mentioned *A Salute from the Fleet*, 1915, and *The New Morning*, published in 1919. This includes his poem on Princeton, and other American poems.

In his poetry and his criticism Mr. Noyes is a loyal adherent to the great tradition of English poetry. For the anarchy of form and of thought which calls itself "free verse" he has small sympathy. He has still less patience with the attitude of contemptuous condescension assumed by a certain school of present-day critics toward everything Victorian. He confidently asserts the enduring greatness of the Victorian laureate, Alfred Tennyson.

R. K. R.

Entered as second class matter at the post office, Princeton, N. J.

Bolshevism in Literature

Some Aspects of Modern Poetry

A LECTURE

By Alfred Noyes
Visiting Professor of English in Princeton University

I

Tendencies Toward Lower Intellectual Standards

One of the results of the vast broadening of the field of thought in the beginning of the twentieth century was the increasing tendency among modern writers to lose their hold on any central and unifying principle; to treat all kinds of complex matters as if they were quite simple, and where a hundred factors were involved, to treat a problem as if it involved the consideration of only two or three.

Literature tended more and more to enunciate what might be called the gospel of the half-truth.

Jaunty solutions of problems involving the whole of civilization were obtained by the very simple process of considering only one or two factors, sometimes only one or two individuals who, more often than not, were obviously super-individuals, made in the image of the author himself.

Paradox began to lose the real value which it once had as an occasional weapon in the hands of truth, for it became the rule rather than the exception.

The fiery rebellion of a Shelley against those conventions, those rules of the road (which, accepted more practically by the average man, have at any rate saved our traffic from chaos hitherto), that occasionally splendid rebellion, having been observed to be splendid by a thousand critics, became a kind of artistic convention for use on all occasions.

We were confronted by the strange spectacle of something like ten thousand lonely literary rebels, each chained to his most comfortable peak and all chanting in perfect union a perennial song of hate against all institutions. The strangest part of the spectacle was that the world was practically unanimous in applauding them.

Each believed that he was entirely original and "thinking for himself," though their sublime defiance of what they called the early Victorian period had long been the established convention of every popular magazine and every girls' school in the country.

* * *

If, then, the name of rebel was to be given to each member of this unanimous multitude, it was quite obvious that the whole ground had shifted and that the name no longer meant what it did in Shelley's day. Names are not exempt from that change which has been described as the pulse of life.

The real rebel of to-day in the Shelleyan sense is not to be found in those serried ranks; he is to be found standing by the merely unpopular truth, which of course is no longer called 'truth', for the mere name has become popular. To-day the real truth is called 'commonplace' or 'platitude', but it is still the property of a very small minority.

The real rebel, the follower of the real truth, will be found obeying or trying to obey those laws of life, thought, art, in which there may be no more originality (in the fashionable sense) than in the laws that govern the courses of the sun. Yet, in their service still, to-day as yesterday and forever, we enter into our perfect freedom.

Intellectual Bolshevism a Cause of the Great War

I suppose we are all very grateful, if we ever have time to think about it, that the sun shows little tendency to originality or eccentricity. It would be more than a little disturbing, if, instead of rising at its appointed time to-morrow, it were to repudiate its "early Victorian" methods and rise at noon in three sections of a livid green.

Yet that is what has been happening in the world of literature and art, and it may be said with the utmost seriousness that the intellectual Bolshevism which has been prevalent during the last quarter of a century has been more responsible both for the Great War and for the present peril of civilization than has yet been properly realized.

You cannot treat all the laws that keep us from chaos, even the law of individual honor, as if they were scraps of paper to be altered at the caprice of the individual, without a terrible reckoning. Yet this is what a great number of the so-called intellectuals of Europe have been doing for half a century in their novels, and plays, and poems.

There has been a lowering of the standards everywhere; I am not speaking merely of moral standards, for I do not profess to be a moralist, but of intellectual and æsthetic standards also. Their downfall has led us to the brink of greater dangers than our practical men seemed to realize until they were confronted by this incomprehensible spectre which they call Bolshevism.

But our European art and literature, and latterly, certain sections of American literature, have been increasingly Bolshevistic during the last thirty years.

Whatever may be the subtle reservations in the following passage from one of the most widely read rebels of the present day, there is no question whatever that nine-tenths of his readers would believe it to mean neither more nor less than what Lenin and Trotsky mean:

> "Self-worship is the last step in the evolution of the conception of duty. . . . The evangelist of this last step must therefore preach the repudiation of duty. This, to the unprepared of his generation, is indeed the wanton masterpiece of paradox. What! After all that has been said by men of noble life as to the secret of all right conduct being only 'Duty, duty, duty,' is he to be told now that duty is the primal curse from which we must redeem ourselves before we can advance another step along the road which, as we imagine—having forgotten the repudiations made by our fathers—duty and duty alone has brought us thus far? But why not? God was once the most sacred of our conceptions; and he had to be denied. Then Reason became the Infallible Pope, only to be deposed in turn. Is Duty more sacred than God or Reason?"

Spread of False Literary and Artistic Standards

It must not be supposed that the spirit of this evil, which in the political world has been called Bolshevism, is an isolated phenomenon. It is active everywhere, and nowhere more active than in our art and literature, where it has gone far toward viciously perverting the whole reading public.

This aspect of the matter has not been regarded seriously enough by those practical men who think that ideas and intellectual conditions are of no account. Practical men thought the same of the destructive ideas that has gone were born before the Reign of Terror in Russia.

It has become the fashion to praise these manifestations of the merely destructive spirit in the literary columns of the news papers whose political editors are desperately striving to fight it. The fashion has established absolutely false artistic and literary standards amongst us, and it has become difficult at the present time for any mere man of letters to maintain the true standards.

It is as much as any critic's reputation is worth, for instance, to assert that there is any merit whatsoever in the finest artist in verse in the last century. You know who he is, and I know who he is, but we must not say so, because it is alleged that once upon a time he shook hands with Her late Majesty Queen Victoria.

Let us not deceive ourselves about the present position. The intellectual world of to-day is almost completely in the dark with regard to fundamental principles of any kind.

The nations that won the war were saved from the intellectual ruin of Germany partly because of their instinctive cleaving to certain traditional codes of honour, but in the almost complete agnosticism of intellectual Europe how long can we trust to customs and conventions, already in process of rapid disintegration?

How long can we hope that the truth shall be maintained by those who have retained one sentence and one alone from all that used to echo in their temples, and even that single sentence only an echo of Pilate—what is truth?

Losing Our Sense of World Unity

The reply has been left to specialists, who, as Professor Caird said, have lost their sense of totality, the sense of the value of their particular studies in relation to the whole.

The old completeness of view, the old single-hearted synthesis which saw the complex world in its essential unity, saw it steadily and saw it whole, man as a soul and body, life and death as a march to immortality, all that white light of vision has been broken up into a thousand prismatic and shifting reflections. We are in danger of losing the white light, not because it is not there, but because the age has grown so vast that we cannot co-ordinate its multi-colored rays.

Analysis has gone so far that we are in danger of intellectual disintegration. It is time to make some synthesis, or we shall find ourselves wandering through a world without meaning. We are already in such a position that our eagerness to accept new and often doubtful gains makes us drop our old certainties out of both hands. Some of the arts have grown so wealthy that we think we can afford to accept the latest freak of fashion and reject the old immortals. . . .

In every age there has always been a tendency to belittle the work of its immediate forerunners.

But quite apart from the perhaps natural desire to seize the torch from the hands of our predecessors and to belabour them about the head with it, there is a tendency to throw away the torch altogether, into a hay-rick, or a fine inflammable old library for preference, and to go on our way tossing up coloured Chinese crackers; to throw the torch of Wordsworth into the gutter and proceed with a meaningless splutter of epigrammatic squibs whose charm is in the unexpectedness of such explosions as even their holders cannot foretell or direct; to throw away the torch of Turner and dance down to posterity in a blaze of post-impressionist Bengal lights.

Certainly, we want our new little discoveries; but we do not want to kick away the ladder, nay, kick away the whole world from under our feet, as soon as our fingers have touched the new toy. There are certain possessions of ours, certain heirlooms which we must accept from the past, or perish through a universal aphasia.

Our reactions and our rushes after novelty (for it is the novelty-hunter who is really the reactionary) did not matter very much so long as we accepted that essential heritage. There are perhaps not very many truths, but there are certainly some which must be regarded as axiomatic.

So-called Intellectuals Rejecting Fundamentals of Civilization

There are certain postulates of our civilizations, indeed, of our very existence, the basic elements of life, thought, art, literature, and religion, for all time.

These basic elements, these postulates, a large section of our recent literature has been in the habit of accepting tacitly for the purpose of making books which could not otherwise be made at all, and at the same time, rejecting them and forgetting them in its rush after novelties, which, unless they could be brought into harmony with those broad primary postulates, it was the business of literature to wave aside as chimerical and false. By this simultaneous acceptance and rejection, certain modern works of superficial brilliancy are turned into complex examples of logical fallacy.*

See what play some of our modern pessimistic writers have made with the pain and suffering of the world, how they will affirm at one moment, especially if they are dealing with some pet political theory, that human life has some divine meaning of its own; and how, in the very next chapter, they will adduce some disaster on this planet as proof that the whole world is a meaningless bubble, and the power behind it is an eyeless, blundering experimentalist; showing us again and again that they believe the whole to be considerably less than that very small part of the Universe which writes pessimistic novels.

* Even in their technical theories, they are often a mass of contradictions. In a volume on "new" tendencies of poetry, a recent author praised a "new" poet for his complete disregard of what were quite erroneously supposed to be the traditional methods of scansion; and, on a subsequent page, mildly criticized him for mispronouncing a certain word. The proof of the mispronunciation was given by applying the very methods (false in themselves) which the "new" poet was supposed to have overthrown.

It is not enough that in the next chapter they should again contradict themselves, and, at the sight of a sunset, or some triumphant human accomplishment, or at a mere phrase, like the progress of democracy (progress admittedly only until the death of the sun) break out into ecstasies and say something else.

Our so-called intellectuals have not the courage to accept all the facts simultaneously. They have lost their hold on any central and unifying principle.

In the most literal sense they have become eccentrics, for again, to quote Professor Caird, "to see that we are ruled from the centre, not from the circumference," to find and maintain our hold on some central principle of unity is the whole salvation of man. All social work, all material progress, all science, all art, all literature are vain unless they be inspired and directed from thence.

II

Faith in the Order and Harmony of the Universe the Basis of All Art

In all great literature, in all great poetry, in all great art, we do obtain that central position and that white light of vision whereby we may see this vast and complicated modern universe in its essential unity and harmony as clearly as ever Thomas á Kempis could see all things in one. Are we to abandon that great literary heritage?

Let me remind you of those remarkable words of Matthew Arnold, perhaps the most remarkable in the whole history of criticism when one remembers the very precise and temperate mind of their author:

> "The future of poetry," he said, "is immense, because in poetry, where it is worthy of its high destinies, our race will come to find a surer and ever-surer stay."

The reasons he gave for that remarkable utterance were the subject of great controversy in his own day, but at the present time they have come to be regarded almost as platitudes, and this should surely give an additional interest to that remarkable piece of literary prophecy:

> "There is not a creed which is not shaken, nor an accredited dogma which is not shown to be questionable, not a received tradition which does not threaten to dissolve. Our religion has materialized itself in the fact, and now the fact is failing it. But for poetry the idea is everything, poetry attaches its emotion to the idea, the idea *is* the fact. The rest is a world of illusion. The strongest part of our religion to-day is its unconscious poetry."

Kipling and Darwin on the Foundations of Poetry

But we may go further to-day than Matthew Arnold could foresee. Materialistic science itself has been confronted with its own old question, what is truth? To-day there is not an accredited dogma of materialism which is not shown to be questionable, not a received tradition of the kind of rationalism that we were told was to destroy poetry, that does not threaten to dissolve.

Mr. Rudyard Kipling has summed up the whole position of conventional materialism and conventional religion in four lines:

> "We have learned to whittle the Eden tree to
> the shape of a surplice peg,
> We have learned to bottle our parents twain
> in the yolk of an addled egg,
> We know that the tail must wag the dog, for
> the horse is drawn by the cart,
> But the Devil whoops, as he whooped of old:
> It's clever, but is it Art?"

* * *

Materialism of all kinds, we may say, has placed its faith in the fact, and now the fact is failing it. Wherever men of science thought they had a fundamental fact, a material basis for their systems of thought, they have to-day on every side an immeasurable and incomprehensible miracle.

On every side, more silently than in temples made with hands, all true men of science are bowing the head before that grand sequence of events which, as Darwin himself said, definitely and emphatically, our minds refuse to accept as the result of blind chance.

> "The understanding," he wrote in the "Descent of Man," "revolts from such a conclusion."

The understanding revolts! In that short, sharp summary of the attitude of Darwin toward the blind chance systems of the modern sciolists, we have the testimony of one of the greatest men of science to the reality of what may be called the foundations of poetry.

The understanding revolts from doubt of what must be the basis of all creative art, a condition of all thought, namely, an unhesitating assumption of the ultimate order and harmony of the universe, a faith as implicit as our much less logical certainty that the sun will rise to-morrow.

All Great Poetry Based on Harmony of the Universe

That basis of the universe in an ultimate harmony is the first postulate of all thought, all science, all art, all literature. Without it there is nothing left to us that has the slightest meaning. And indeed, a large part of our recent literature does seem to have reached that final stage of negation. It has reduced the world to dust and ashes and left it there. It has turned from the world in its completeness, turned from the world that contains love and faith, and insisted on pointing us to the dust and ashes in which it says these things end.

In other words, it has turned from the things which we do know about the greatness of human life, those great factors which can only be referred to something greater than themselves, some divine power at the heart of the universe, and has declared that all these things are illusion; while, in the name of realism, it has occupied itself with the dust of which we know nothing, except that, under the scrutiny of science, it does indeed become an insubstantial pageant.

* * *

So in the name of reality many of our writers have been indulging in a most shadowy kind of make-believe, and have dropped the substance of beauty for the shadow of a mud pie.

Some of the most notable figures in contemporary literature have been telling us the world is an accident. For such writers as these the secret of great poetry, the poetry in which Matthew Arnold could affirm that our race would come to find a surer and surer stay, would seem to be lost.

And what is that secret? It is simply this—that all great poetry, all great art, brings us into communion with that ultimate harmony of the Universe.

Art's Business to Relate the Isolated Incident to the Whole

The business of art is to take the isolated incident and relate it to the whole, to set the temporal fact in relation to the eternal. Poetry is the strongest part of our religion to-day, because, in the very simplest and noblest sense, poetry is religion.

The greatest of American poets—Emerson—has said:

> "It is a secret which every intellectual man quickly learns, that, beyond the energy of his possessed and conscious intellect, he is capable of a new energy (as of an intellect doubled on itself), by abandonment to the nature of things; that, beside his privacy of power on which he can draw, by unlocking, at all risks, his human doors, and suffering the ethereal tides to roll and circulate through him: then he is caught up into the life of the Universe, his speech is thunder, his thought is law, and his words are universally intelligible as the plants and animals.
>
> "The poet knows that he speaks adequately, then, only when he speaks somewhat wildly, or 'with the flower of the mind,' not with the intellect used as an organ but with the intellect released from all service, and suffered to take its direction from its celestial life; or, as the ancients were wont to express themselves, not with the intellect alone, but with the intellect inebriated by nectar.
>
> "As the traveler who has lost his way throws his reins on his horse's neck and trusts to the instinct of the animal to find his road, so must we do with the divine animal who carries us through this world. For if in any manner we can stimulate this instinct, new passages are opened for us into nature, the mind flows into and through things hardest and highest, and the metamorphosis is possible."

This way of stating it, of course, will not please many modern critics, for at first sight it may seem to narrow the field of poetry and prevent some of our moderns, for instance, from dealing with their favorite unpleasant subjects. But a little reflection will show that this theory of poetry affords the only possible justification for their claim that all subjects may be treated by the artist.

They may. A broken boot or an old tree stump is subject enough, but only on the condition that the artist can relate it to the eternal harmonies.

Most of the very greatest poems, of course, are tragic in substance; but what is tragedy? It is not a declaration of universal futility. It is the casting off of the temporal for the eternal. All great tragedy surveys the world under the "eternal aspect." Or, take one of the very slightest snatches of song in a certain Elizabethan comedy. You remember the scene where Toby Belch and Andrew Aguecheek call on the Fool to give them a song, and the Fool suddenly lifts above their half-witted and half-drunken mirth one of the most exquisite of all the brief songs of youth and love in the whole range of literature,

> "O Mistress mine, where are you roaming,
> O stay and hear. Your true love's coming,
> That can sing both high and low,
> Trip no further, pretty sweeting,
> Journeys end in lovers meeting,
> Every wise man's son doth know."

Poetry's Undertone of Music

"Journeys end in lovers meeting." The poet is not speaking here of the kind of journey to which some of our realistic novelists would devote their art.

There is a deep undertone of music which conveys more than the superficial meaning. It is an instance of how the poet can take three sounds and make of them, not a fourth sound, but a star. He is dealing with that land beyond our world, the land where all roads meet. It has a profound metaphysical meaning, though it is touched in as lightly by the hand of the master as a butterfly settles on a flower.

It is this undertone of music that differentiates this poem from the mere drawing-room ballad, and exalts it to the realms of great art, and it is this undertone of music that the destructive influences in modern literature have never been able to create, to understand, or even to hear.

This music almost vanished from our literature during that other age of scepticism, the eighteenth century, when poets like Falconer implored the help of the Muses so that in a world of teacups and clouded canes they might

> "In unrivaled strains deplore
> The impervious horrors of a leeward shore."

But it has been well said that one of the most dramatic moments of our literature is marked by the sudden transition from the last of the poems that were written before the French Revolution to the first of those that were written after it.

> "Ye banks and braes of bonny Doon,
> How can ye bloom sae fair?"

Religion and poetry during the eighteenth century had been buried in narrow forms and conventions, and the great awakening that followed the thunder-peal of the French Revolution, the Renascence of Wonder, as it has been called, was nothing less than the resurrection of poetry and religion in one, a movement as wide and unfettered as the resurrection of the spring.

It was the rediscovery of the real world (which has never been the world of the sceptics and the superficial realists), and it was the rediscovery of the living God.

The Faith of Shelley, Wordsworth and Browning

Shelley was expelled from Oxford for atheism by the orthodoxy of the age of scepticism. He was expelled from a community in which faith was dead, only to make one of the most triumphant declarations of faith that ever rang from the lips of man; faith, not in any narrow, pietistic system, but in

> "That Light whose smile kindles the universe,
> That beauty in which all things live and move."

It was the same faith that was enunciated by Wordsworth in poem after poem, equally free from the shackles of mere pietism, indeed, it was Wordsworth that first struck the note of that neo-paganism which developed later into the religion of beauty of Swinburne and his fellow pre-Raphaelites.

He summed it all up in one of those great little masterpieces in sonnet form:

> "The world is too much with us, late and soon
> Getting and spending, we lay waste our powers.
> Little we see in Nature that is ours,
> We have given our hearts away, a sordid boon.
> The sea that bares her bosom to the Moon,
> The winds that will be howling at all hours
> And are upgathered now like sleeping flowers,
> For this, for everything, we are out of tune.
> It moves us not. Great God, I'd rather be
> A pagan suckled in a creed outworn,
> So might I, standing on this pleasant lea,
> Have glimpses that would make me less forlorn,
> Have sight of Proteus rising from the sea,
> Or hear old Triton blow his wreathèd horn."

The torch was caught from the hands of Wordsworth by that greatest artist of the nineteenth century (whose name we must not mention) and in *In Memoriam* he gave us the greatest elegy, not only in the English language but in any language.

It is the greatest because there is no other to compare with it in range of thought, in the exquisite delicacy of its craftsmanship, and the unfailing pulse of that profound music which flows from the source of all great poetry:

> "O yet we trust that somehow good
> Will be the final goal of ill,
> To pangs of nature, sins of will,
> Defects of doubt, and taints of blood;
>
> That nothing walks with aimless feet;
> That not one life shall be destroy'd,
> Or cast as rubbish to the void,
> When God hath made the pile complete;
>
> That not a worm is cloven in vain;
> That not a moth with vain desire
> Is shrivell'd in a fruitless fire.
> Or but subserves another's gain."

The same spirit manifested itself in Browning. He dealt with the theory of his art in poem after poem, affirming that "the rest may reason and welcome, 'Tis we musicians know"; and illustrating it most significantly perhaps in his most famous lyric, where the little Italian silk-weaver, passing a house that has been the scene of a foul crime, is made to sing:

"The year's at the spring,
The day's at the morn,
Morning's at seven,
The hillside's dew pearled;
The lark's on the wing,
The snail's on the thorn,
God's in His Heaven,
All's right with the world."

A good deal of scorn has been poured on the last two lines of this poem by those who have forgotten or never known that it had any context.

* * *

And this spirit continued to manifest itself in English poetry in ever new ways right down to the present moment. One of the most remarkable aspects of this manifestation is the fact that the same writer will often in his poetical works express this spirit while in his prose he will sometimes apparently deny it completely.

An example of this is to be found in the case of Robert Louis Stevenson, that most typical of modern artists, who in his *Pulvis et Umbra*, enunciates (very nobly, of course), what might be called a philosophy of despair, while in a wonderful little prose-poem to be found in a letter to W. E. Henley, he sums up the whole philosophy of art and reaches the same conclusion as Browning and Tennyson,

"*Sursum corda!*
Heave ahead;
Here's luck!
Art, and blue Heaven,
April and God's larks,
Green reeds and the sky-scattering river,
A stately music
Enter God."

"Ah, but you know," he continued, "until a man can write that 'Enter God' he has made no art, none! Come, let us take counsel together and make some."

* * *

There have been moments, even in English poetry, of decadence, moments when it has seemed to be the poet's chief aim to display the mud upon his garments as evidence that he has fallen from Heaven. But even there the important thing has been the fall which the poet desired to prove.

There have always been great voices to sound the rallying cry of major poetry and to carry on the torch. Swinburne, using the sea as an image of the eternal; Francis Thompson, inspired by the great ritual of a historic religion, and crying,

"Not where the wheeling systems darken,
And our benumbed conceiving soars,
The drift of pinions would ye harken
Beats at our own clay-shuttered doors.

The angels keep their ancient places.
Stir but a stone, and start a wing
'Tis ye, 'tis your estrangéd faces
That hide the many-splendored thing."

* * *

A still more recent poet has shown us how even our modern machinery lends itself to the uses of poetry, how indeed it may be treated as a kind of micro-cosmic symbol of the universal processes.

As in McAndrew's hymn:

"They're all awa', full power, true beat, the clangin' chorus goes
Clear to the tunnel where they sit, my purrin' dynamos,
Interdependence absolute, foreseen, ordained, decreed,
To work, ye'll note, at any tilt' an' every rate of speed.
Fra sky-light-lift to furnace-bars, backed, bolted, braced and stayed,
And singing like the Mornin' Stars for joy that they are made,
While, out o' touch o' vanity, the sweatin' thrust-block says,
'Not unto us the praise, or man—not unto us the praise'.
Now a' together, hear them lift their lesson—theirs and mine—
Law, order, duty and restraint, obedience, discipline."

Even more to the point is that most beautiful of all his lyrics, *To the True Romance*, where he describes various functions of poetry and romance in life, and comes to precisely the same conclusion,

> "O, charity, all patiently
>   Abiding wrack and scaith;
> O, faith that meets ten thousand cheats,
>   Yet drops no jot of faith.
> Devil and brute thou dost transmute,
>   To higher, lordlier show;
> Who art, in sooth, that lovely truth
>   The careless angels know."

Again and again, during the course of the war, a still later generation of poets has proved the truth of Matthew Arnold's assertion that the strongest part of our religion to-day is its unconscious poetry.

III

Valuable Heritage of the Past vs. a Mess of Bolshevistic Pottage

We have come now to the parting of the ways. At this moment the world is beginning to discover (even some of the realistic novelists have begun to discover), that unless it can regain that white light of vision which hitherto our poetry has never lost, our civilization itself is in deadly peril.

Is it too much to hope that those who are concerned to guard the true fire of literature will be very careful in the days before us, not only to welcome every true attempt to give us new manifestations of the spirit of poetry, but also to set their faces absolutely against every attempt to destroy what is good in the heritage of the past?

Those who, even in poetry, are attempting to destroy this are attempting the wildest of all paradoxes; for the literal meaning of poetry is "creation"; and we shall not build our new towers more efficiently if we waste energy in attempting to destroy what was really valuable in our heritage from the past.

Even in poetry, here and there, we see the signs of an ignorant Bolshevism, often—as one of its exponents has confessed—crudely ungrammatical, taking upon itself to dismiss not only all former English metrical poetry, but the metrical poetry of all the ages from Homer and Sophocles down to the present day, on the ground that those who cannot spell or master the elementary technique of their art have nevertheless attained to a subtler truth of expression.

Again and again it is affirmed by superficial critics that the crude language of a drunkard in a pot-house is a more vital and subtle means of expression than the English language as used by masters like Tennyson, with their exquisitely delicate shades of meaning.

Nobody wants mere repetition of the old; but the true advance is along the lines of development, not along those of destruction, and the foolish attempt to begin again from the beginning.

It is only one more symptom of the Bolshevistic conceit, a conceit so overwhelming as to amount to insanity, that has been displayed in all the arts during the last few years; but the crudest amateurs have been encouraged to believe their five-finger exercises better than the symphonies of the masters.

College Men Must Meet New Literary Barbarism

And unless democracy is to fulfil the worst prophecy of the pessimists and submerge all the finer shades of thought, all the subtler tones of beauty, in the general flood of half-educated mediocrity, tyrannously ruled by little Soviets of the various Bolshevistic and pseudo-literary coteries, it behoves all our college men to meet this new threat of barbarism, and to carry on the torch of the true traditions of literature and art.

It behoves the editors of the journals that deal with books to do their utmost to counteract the tendency of the publishers to swamp good literature in the rubbish that they delight to boom; those novelties for novelty's sake that are issued to catch the more gullible members of women's clubs; novelties that are advertised in terms that would make Tennyson turn "in his marble slumbers" and would be exaggerated if they were applied to Dante or Shakespeare.

If this threat to good literature is not met, we shall soon be in the thick of a chaos where any "bluff" will succeed. I have read very carefully some of the manifestoes of "new schools" that succeeded temporarily, but already are beginning to be found out by their victims; and it is quite certain that in nine cases out of ten the theorists do not even understand their own theories, and have only the most elementary acquaintance with the art which they profess.

Is the America of Emerson, her subtlest poet, going to surrender her glorious birthright for a mess of Bolshevistic literary pottage?

It is to be hoped that the colleges, at least, will answer "NO!"

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Princeton Lectures

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NOTE

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THE LECTURER

PROFESSOR FRANK FROST ABBOTT was called to Princeton as Kennedy Professor of Latin in 1908, being at the time Professor in the University of Chicago. He was graduated from Yale in 1882 with distinguished honors, and after pursuing graduate studies there was appointed Tutor in Latin in 1884.

In 1891, when President W. R. Harper, until then a Professor at Yale, was organizing the new University of Chicago, the first scholar whom he summoned to his faculty was Professor Abbott.

During his connection of seventeen years with the University of Chicago, Professor Abbott not only revealed unusual gifts as an administrative officer, but also won a commanding place among scholars. His interests led him to devote especial attention to Roman History and Political Institutions—a field which he has emphasized since his connection with Princeton. It is safe to say that he has sent out more Doctors of Philosophy in Roman History than any other American scholar; and his pupils fill a very large number of the most important chairs in the country.

He has been a very prolific writer. All scholars know his *History of Rome*, his *History and Description of Roman Political Institutions*, and his *Handbook for the Study of Roman History;* and his literary essays, which have appeared in the magazines, have brought the results of his studies on Roman society and politics to a wide circle of general readers.

Special mention should be made of the two volumes, published by Scribner's, which appeared soon after he came to Princeton—*Society and Politics in Ancient Rome* (1909) and *The Common People of Ancient Rome* (1911).

Professor Abbott has been the recipient of many honors, among which may be mentioned the Presidency of the American Philological Association in 1918. He is also a Trustee of the American Academy in Rome.

Local Government vs. Paternalism

MUNICIPAL GOVERNMENT AND FINANCE IN THE ROMAN EMPIRE

A LECTURE

By FRANK FROST ABBOTT
Professor of Latin Language and Literature in Princeton University

The history of the cities under the Roman Empire furnishes us perhaps with the longest experiment in municipal government under one sovereign power which the world has ever known. It should have an intrinsic historic interest therefore. It is essentially a struggle between local self-government and a central authority.

During these years of stress through which we have lately gone, when, under the exigencies of war we have willingly allowed the central government to reach down into our everyday life in Princeton and Trenton and tell us what we may eat and drink and wear, what we may make or build, the experience of another people under similar conditions may be suggestive and even helpful, unless the pessimistic remark which some one has lately made be true, "that the only thing which we learn from history is that no one learns anything from history." Let us hope that even the Modern School will not make that statement a reality for many of us.

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I

Development and Characteristics of Roman City Governments

In thinking over the history of ancient times, I have sometimes felt that our conception of the Roman world as a vast empire extending from the Sahara to the Rhine, from the Euphrates to the Atlantic, has prevented us from appreciating fully some of the most characteristic features of life in the ancient world. It is true that Roman arms and Roman governors maintained order, and Roman law was observed, and the Latin language was spoken throughout this great stretch of territory.

But the average Roman subject, the Sicilian or the African, for instance, was little concerned with Rome or the Empire. Even the province of Sicily or Africa meant little to him. He enjoyed his rights and privileges, not because he was a Sicilian or an African, but because he was a citizen of Syracuse or Carthage, and the taxes assessed upon him he paid as a resident of Syracuse or Carthage.

Independence of City-states

His native city had been in existence long before the Romans had arrived, and the coming of the Romans had made little change in the course of his daily life, except in the way of ensuring him better protection for his life and property. His religion, his business, his everyday life, his amusements, were untouched, and even the city government under which he lived and the old practices which had come down from time immemorial were left intact. The city had led a life of its own —it had been self-sufficient—for generations.

It continued to be so. His sentiment of patriotism went out, not to Rome or the Empire, but to this city. We need to think only of the devotion of the Florentine or the Venetian to his native city in the period of the Renaissance to understand his feelings. It is not hard to explain this sentiment. The city-state stands against the world.

It must fight for its privileges, its liberty, and its life. All of its citizens are known to one another, and all that they have and are is present before their eyes in their temples or churches, in their fora or marketplaces, and the sense of unity, the feeling that they stand or fall by themselves is brought home to them by the presence of other city-states ten or twenty miles away, their natural rivals, and possibly their enemies. These are some of the reasons that account for the intensity of the feeling which the people of Rome and other communities felt for their native cities.

Rome Followed "Divide and Rule" Policy

It was to the advantage of the Romans during the early stages of their occupation of a new territory to foster this feeling, to keep the cities of the Empire from coming into closer relations with one another, and not to obliterate their characteristic features. This same policy of "divide and rule" Rome had carried out consistently and with great success in her early history, in dealing with the cities of Italy. She now carried it into the provinces.

The truth is also that the Roman shrank from the intellectual labor of thinking out a new system in its entirety at home or abroad. He found it easier to keep up the old institutions, modifying them only when a change in the situation forced him to do so. In this way the cities in the conquered civilized regions kept their individuality, and the old life went on in them without serious change.

I wish to say a few words here about some of the characteristic features of that life. The feeling of independence and self-sufficiency which we have found in these cities, is brought out in no more convincing way than in the bitter rivalries and hostility which we see springing up between them, and no small part of the duty of a Roman governor lay in composing these differences. It is the same situation which we find in the Italian cities in the Renaissance.

Both inscriptions and ancient literature have preserved to us the stories of these quarrels and of their settlement by Roman Commissioners.

These incidents point to the strong feeling of individuality which the cities had and to the civic pride of their citizens.

A greater degree of uniformity, however, prevailed in the government of the cities than we should expect. Most of them had executive officers and a senate, or common council, as we should call it. Our fullest information about their municipal system has come to us in recent years, through the three municipal charters discovered on bronze tablets in Spain.

The two most famous of these tables were found not *in situ*, nor buried by the earth which had settled upon them in the course of the centuries, but carefully deposited in the ground, encased in tiles for protection, and I like to think of the burgesses of Salpensa and Malaca as hiding their charters from some autocratic Roman governor, just as my ancestors in Connecticut are said to have hid their charter in the old oak near Hartford, to protect it from the intolerant Governor Andrus.

Comparison of Political Customs

From these charters it is clear that most cities in the West had a board of two or four magistrates, so that the Roman system was somewhat like our lately developed commission method of city government. The magistrates were chosen by popular ballot, as long as the popular assembly existed, and must be free-born citizens of at least twenty-five years of age. No political conventions were called for the purpose of nominating them, but candidates presented their own names to the voters, just as candidates for the House of Commons do.

We get a clear idea of Roman electioneering methods from certain extant corrupt-practices acts, from the pamphlet "On Running for the Consulship," which Quintus Cicero addressed to his brother, Marcus, and from the political posters at Pompeii. The absence of compact party organizations in the Roman political system deprived candidates of the organized support which aspirants for office enjoy to-day. For the same reason political platforms were unknown.

Many of our present day methods of securing votes were, however, in vogue. In Rome itself the candidates and their supporters made political speeches, and posters were freely used. The most effective support, however, in Rome, at least was to be had from the permanently organized political clubs, of which we hear a great deal in Quintus' pamphlet.

These clubs were brought to a high state of efficiency, as you will remember, by Cicero's political enemy, Clodius, and by Cicero's friend, Milo. They served practically as guards of honor and as bands to protect friendly political meetings, and to break up the meetings held in the interest of the opposition candidate. Of course in the smaller cities politics had not developed to as high a point of perfection as they had in Rome or Alexandria.

The most noteworthy difference between the ancient and modern political poster is the absence on the Roman placard of any reference to political issues. No candidate promises cleaner streets, better police protection, more elaborate games in the circus, and none of them agrees "to turn the rascals out." Even experience in the management of public affairs is not mentioned. An upright life and honesty in business are the only qualifications spoken of. One man, we are told in a poster, furnishes his customers with good bread.

Municipal Officers Paid for Election in Public Benefactions

Instead of receiving a salary municipal officials were actually out of pocket for the privilege of holding office. One of the municipal charters of which we were speaking a moment ago reads:

> "All duoviri shall . . . celebrate a gladiatorial show or dramatic spectacles to Jupiter, Juno, and Minerva, and to the gods and goddesses, or such part of the said shows as shall be possible, during four days, for the greater part of each day, and on the said spectacles and the said shows each of the same persons shall expend of his own money not less than 2,000 sesterces."[1]

The law fixed the minimum amount which the newly elected magistrate was called on to spend, but memorial tablets in towns all over the Empire show us that sums far in excess of 2,000 sesterces were spent by grateful officials on their supporters at the polls. On the epitaph of a chief magistrate of Pompeii we read: "He gave 10,000 sesterces to public causes in return for the duumvirate,"[2] and of a magistrate in the village of Turris Libisonis in Sardinia we hear that

> "Besides the promised sum of 35,000 sesterces, or $1,400, which he contributed to the city in cash in return for the quinquennial office conferred upon him, he constructed a reservoir and brought in the water at his own expense."[3]

I have mentioned these post-election contributions, not simply for the purpose of noting a difference between our political practices and those of the Romans, but because this custom helps us to understand what would otherwise be a puzzling characteristic of the ancient city. It is clear that a very large number of the public structures in these cities were not put up at public expense, but they were built from the gifts made by generations of newly elected magistrates and of ambitious or patriotic private citizens.

The form which the munificence of the donors in these cases often took is surprising. We can understand the satisfaction which a public spirited citizen of Princeton might take in erecting a fountain on Nassau street with a suitable inscription on it to the giver, but it strains the imagination to think of him as giving a large sum to pave Mercer street or lay a water main on Bayard lane, but gifts for such purposes as these were not at all uncommon in the cities of the Empire.

But the pleasure-loving citizen of the ancient world could not content himself with such matter-of-fact gifts, and the successful candidate understood his fellow-townsmen. He had to remember their love of amusement and of the good things of this world. This weakness a citizen of Sinuessa had in mind when he left this record:

> "Lucius Papius Pollio, the mayor, to his father, Lucius Papius. Cakes and mead to all citizens of Sinuessa and Caedici; gladiatorial games and a dinner for the people of Sinuessa and the Papians; a monument at a cost of 12,000 sesterces."[1]

The distinction of being a magistrate was so much coveted that a citizen was rarely lucky enough to hold it more than once. When he did, he had to open his purse very wide. This good fortune came to a certain Aulus Clodius Flaccus in Pompeii. What he did to show his appreciation of the honors heaped upon him is recorded in an inscription found in that city.[2]

All these benefactions contributed to the comfort and pleasure of the citizens, and relieved them from the payment of taxes, but the practice of making such gifts brought disaster in the end to the givers, and was fatal to the integrity of town life, as we shall have occasion to notice in a moment.

Items in a Roman City Budget

This method of meeting part of the cost of public improvements and amusements, which was so characteristic of the ancient world, naturally leads us to ask what charges there

[1] *C. I. L.* II. 5439.
[2] *C. I. L.* X. 1074.
[3] *C. I. L.* X. 7954.

[1] Wilmanns, *Exempla Inscriptionum Latinarum*, 2037.
[2] Wilmanns, No. 1917

actually were on the public budget, and how the ancient city budget was made up. Unfortunately no city ledgers of the ancient world have come down to us, but painstaking students have brought together from literature and the inscriptions so many items bearing on the subject that we have a fair idea of ancient municipal finance.

A modern city gets its income by taxing its citizens. The residents in an ancient city, as a rule, paid no taxes at all. Some of our heaviest expenses are for the payment of the salaries of city officials, for the police and fire departments, for lighting the streets, for schools, asylums and hospitals. No one of these items would appear in the expense account of the average city in the Roman Empire.

Earliest Form of Single Tax

On the receipt side of the ledger for an ancient city we should find such donations from newly elected officials and wealthy private citizens as we were discussing a few minutes ago; we should find interest set down from invested funds which had come to the city from legacies. Another large item would be the rental from lands which the city owned outside its walls.

The colonies always had land assigned to them for the support of the communal life, and other cities had acquired theirs by conquest or private gift. You might call this last item the single tax in its earliest form of development.

Sometimes this *territorium* was close to the city, but not always. Cicero in one of his letters[1] speaks of the district which his native town, Arpinum in central Italy, owned in Cisalpine Gaul—almost as far away as Connecticut's *territorium*, the Western Reserve, was. The city of Nîmes, or Nemausus, in Gaul owned twenty-four outlying villages which paid tribute to it.

The other two important items of income were fines and receipts from the *octroi*. We can't say how generally *octroi* were collected, but we know of several cases, and the list of dutiable articles in the case of two cities, Palmyra and Zaraï in Northern Africa, have come down to us. The Palmyra list includes mainly, as do the lists in European cities today, articles of food. The Zaraï list of dutiable articles covers not only food but animals, and certain raw materials and manufactured wares, like sponges, skins and clothing.

Ancient Municipal Expenses

The expense side of an ancient municipal budget had in common with a modern one items to cover the cost of paving the streets, laying drains, and supplying water. Very few cities outside of Rome had a police or fire department. Even the streets in Rome were not lighted, and Antioch held the unique position of "a city in which the bright lights throughout the night call to mind the brilliance of the day."

If the style of architecture at Pompeii, where the houses have few openings on the street, and the shop fronts close, was characteristic of the Empire, walking on the streets of an ancient city at night where there were no lights and little if any police protection must have been a hazardous enterprise. The rich man might return at night from a late supper, carried safely through the streets in his sedan chair, preceded by torch bearers and protected by clients or slaves, but the shopkeeper or artisan, with a few sesterces in his purse, would avoid many of the streets after nightfall.

A Roman city needed no street-cleaning department, because this work, as well as the care of the public buildings, was taken charge of by the slaves which it owned. The absence of any public charge for such institutions as schools, asylums, and hospitals is characteristic of the ancient world.

The cities rarely assumed any responsibility for education, and generally no provision was made by them for the sick and the needy.

[1]Cicero, Epistulae ad Familiares, 13.7.

Perhaps this latter fact accounts in part for the terrible devastation which plagues and epidemics made in the later centuries. In a few cases there were physicians paid out of the public treasury, but such cases were rare. Indeed public charity would seem to have come in with Christianity.

Little Spent for Education and Charity

If none of these items which bulk so large in a modern municipal budget found a place in the expense account of a Roman city, for what objects did it spend its money? For the maintenance of public baths, temples, theatres and the city walls, for drainage and a water supply, for the care of roads leading to the city, for festivals, dramatic entertainments, gladiatorial contests and games in the circus, and for delegations to Rome and the provincial assembly.

We may leave this hasty comparison of an ancient and a modern municipal budget with one or two general reflections. One of the points which I have in mind will already have occurred to you—I mean the striking difference which one notices between the objects for which ancient and modern cities make appropriations.

Leaving out of account such practical matters as paving the streets and providing a water supply, the Roman city gave little if anything to education and charity, but spent immense sums on those things which appeal to the æsthetic taste and to the pleasures of the senses—to porticoes, fountains, baths, temples, theatres, to religious festivals, to dramatic and gladiatorial contests.

We had occasion to notice a few minutes ago the intense civic patriotism which developed in the municipalities of the Empire. The beautiful public buildings which they constructed in the early centuries of our era are at the same time a tribute to it and a result of it. The citizens of Antioch or Lugudunum felt the same strong desire to make their city the most beautiful place in the world which the city-states of Florence and Siena felt at a later date.

The heavy charges which were put on the budget for popular amusement need not surprise us when we recall the large sums which are paid out by continental cities every year for the theatre, the opera, and public music. Many of our own cities are yielding to the same popular demand, by establishing public playgrounds and municipal golf courses, and by furnishing music in the parks.

Public Improvements Depended Largely on Private Benevolence

It is clear also that cities in the ancient world depended much more largely upon private benefactions to meet their running expenses and the cost of permanent improvements than modern cities do. This method of meeting municipal charges worked well in times of prosperity and civic patriotism, but it had great elements of danger in it, if these conditions should change. And if private benevolence should die out, no system of financing could be found to take its place.

Local taxation could not be introduced, because in the ancient world the tax was a sign of servitude. Rome could exact taxes because she was mistress of the world, but for citizens to pay taxes to governments which they themselves had established was not in harmony with the ancient way of thinking. Fortunately the Early Empire was a period of unexampled prosperity.

You will recall Gibbon's famous tribute to it in the third chapter of his history:

> "If a man were called to fix the period in the history of the world, during which the condition of the human race was most happy and prosperous, he would, without hesitation, name that which elapsed from the death of Domitian to the accession of Commodus,"

that is from the close of the first to the close of the second century of our era. This eulogy of Gibbon's was an unconscious echo of the confession which the Christian writer, Tertullian, was forced to make in the early years of the third century,[1] and toward the end of his long study of Roman history and institutions, Mommsen in contemplating this period writes:[2]

> "If an angel of the Lord were to strike the balance whether the domain ruled by Severus Antoninus was governed with the greater intelligence and the greater humanity at that time or in the present day, whether civilization and national prosperity generally have since that time advanced or retrograded, it is very doubtful whether the decision would prove in favor of the present."

It may be noted in passing that Mommsen speaks not only of the prosperity of the world under the Early Empire, but also of the wisdom with which it was governed. This wisdom showed itself above all in the practice which the Early Empire followed of allowing the cities a large measure of autonomy and in permitting them to lead their own lives. This wise policy is reflected in the extant municipal charters, in literature, and in official documents, and was the source from which municipal life drew its vigor.

II

Loss of Independence and Economic Decline Causes of Ancient Municipal Failures

When and why the amazing prosperity which aroused the enthusiasm of Tertullian, Gibbon, and Mommsen declined is a matter of high dispute.

Perhaps we may find one explanation of the decline in the civil wars and the raids of the barbarians throughout the third century which left no part of the Empire, except Africa and the islands, untouched. We may find it in the natural exhaustion of the soil, in the spread of malaria, in the prevalence of plagues and epidemics, and the consequent decrease in the size of the population.

Effect of Imperial Interference

Farms were being abandoned, and farmers were flocking into the cities to live, partly for protection, but more especially to enjoy the pleasures, the society, and the comforts which the city could offer. In fact there was the same movement away from the land which we deplore to-day. The cities themselves began to suffer from the heavy debts which they had incurred for temples, theatres, aqueducts and stadia.

The imperial government was by no means blameless. It introduced a vicious system of taxation, and an expensive bureaucracy, and it tried to meet the situation by debasing the coinage. But perhaps after all, these were only symptoms of a more deep-seated trouble. When a civilization has reached its highest point the upper, intellectual classes suffer nervous exhaustion, and the reins drop from their trembling hands.

This high point Rome had reached, and from it she fell. It is not essential to our purpose to analyze the causes of the decline, but only to record the fact and to note the symptoms with a view to observe briefly some of the effects which the downfall brought in its train on municipal life and municipal finance.

In particular I would invite your attention to two questions.

How did it come about that these cities, many of which had gloried in a long tradition and a large measure of self-government, lost almost all control over their own affairs?

What made the title of duovir and decurion, or Common Councillor, a hissing and byname and these positions penalties?

We shall find a sufficient answer to both questions, I think, in two movements which were at work at the same time—the benevolent interference of the imperial government in

[1] *De Anima*, 30.
[2] Roman Provinces, vol. I. Introd. 5.

local affairs, and the economic decline of the Empire.

Under almost every emperor of the first and second centuries we hear of measures of relief in time of disaster, and probably an imperial commission was sent out to each of the unfortunate cities to examine the local situation and restore normal conditions. This was a philanthropic step to take and it was the only way in which the suffering could be relieved, but it set an unfortunate precedent.

Imperial Supervision of Municipal Finances

If the central government was to bring relief and assume some control of local affairs when the property of a city had been lost in a fire or through an earthquake, why shouldn't it take some responsibility for the finances of a city which had become bankrupt by building expensive theatres or aqueducts?

Still better, why shouldn't it anticipate the evil by interfering to prevent the local officials from putting too much money into elaborate stadia or improperly constructed aqueducts?

This was the question which confronted kind-hearted Pliny when he was governor of Bithynia in the early part of the second century. In one of his letters to Trajan he writes anxiously that the people of Nicæa have spent 10,000,000 sesterces on a theatre, and that the walls have already begun to crack. Shall it be completed, abandoned, or pulled down? An immense gymnasium is being built, but the plan is so confused that the money is likely to be wasted.[1]

The next step forward toward imperial supervision of municipal finances was to have a city ask permission of the Emperor before undertaking the construction of any important public work. This the people of Prusa did before restoring their public baths.[2]

The same fatherly motive which had influenced Pliny in the case of Prusa, led him to propose to the people of Apamea the inspection of their financial accounts. Their reply is instructive. They expressed a desire to have him scrutinize their accounts, but their books had never been submitted to a proconsul before, since they had enjoyed the privilege from time immemorial of managing their own affairs.

Here the dilemma presents itself in its naked form. It is centralized efficiency versus lax self-government.

But financial questions are inextricably related to all sorts of administrative questions. One source of income in many cities was the initiation fee required of members of the local senate. It is a matter of dispute in certain Bithynian towns whether this fee shall be required of all members of the Common Council. The question, which involves the interpretation of the provincial charter, is referred to the proconsul for adjudication.

And so it goes from one local question to another, until, in one of his latest letters, Pliny writes Trajan:

> "Those who put on the *toga virilis* or celebrate a wedding, or take up a magistracy, or dedicate a public work, usually invite the whole senate and no small part of the plebeians, and give each a present of one or two *denarii*. I beg you to write me how far this practice should be allowed to go." [1]

Paternal Attitude of Central Government

I have followed the policy of Pliny in some detail because the development of it illustrates the paternal motives which actuated the imperial government. Under the Republic the central government and the provincial governor cared little for the welfare of the cities. They were objects of taxation for the government and sources of profit for the capitalist. In the management of their affairs they were allowed to go their own way.

But with the coming of the Empire a new spirit of sympathy, of helpfulness, and brotherhood comes in, a spirit which in the end finds its fit expression in the edict of Caracalla

[1] *Epistulae ad Traianum*, 39

[2] Pliny, No. 23.

[1] Pliny, No. 116.

granting citizenship to all freemen in the Empire. It was this spirit of kindness which killed the cities.

The reorganization of the imperial system, especially under such efficient emperors as Trajan and Hadrian in the second century of our era, made the carrying out of imperial reforms in the cities feasible. Probably even our late Teutonic enemies did not develop so elaborate and complete a bureaucratic system as grew up in the Roman Empire. The machinery provided, for instance, even for the settlement at Rome of so trivial a question as the covering of an open drain in the remote city of Amastris in Asia Minor.[1]

Oriental Influences On the Empire

I have often thought also that this imperial desire to have a larger share in directing affairs in the cities may well reflect the Orientalizing tendencies of many of the Emperors. Under the Oriental theory a kingdom was a domain, the land belonged to the king, and the king could deal directly with each subject. This theory was in direct opposition to that on which the *civitas* or city rested.

Incidentally the transplanting in Italy and other parts of Europe of theories of government which the Romans had found in Egypt and the Orient furnishes an interesting illustration of the political and social influence which a conquered people may in course of time exert on their conquerors.

The Oriental theory was exemplified in the government of the large imperial estates which come into existence from the first century on. On these domains there is no city organization, but the Emperor governs directly through his appointed representatives. The land belongs to the crown, and the residents are tenants upon it. These autocratically governed communities alongside the self-governing cities must have exerted a baneful influence on the latter and must have hastened their downfall.

[1] Pliny, No. 98.

Cities Gradually Lost Financial and Judicial Powers

We observed a few minutes ago the benevolent efforts of provincial governors to improve financial conditions in the cities. This movement to control municipal finances was given a systematic form from the time of Trajan by the establishment of a new imperial office, that of curator.

The official who held this position was responsible, not to the citizens of the town to which he was sent, but to the governor of the province, and took entire charge of all the land and other property belonging to the city, and paid all the public charges. In this way municipal officials lost their financial powers. When later the right of citizens to appeal to the governor from the decisions of local magistrates was freely recognized, the city officials lost their judicial functions also, and their offices became meaningless.

* * *

In speaking of the decay of self-government in Roman cities, we noticed that a second influence at work was the economic decline of the Roman world.

We have seen that one important source of municipal revenue consisted in private benefactions and in the contributions made by newly elected officials. As soon as financial conditions became bad, gifts from private citizens ceased and residents in the cities were less eager to hold the offices. There are premonitions of both these conditions under the Early Empire.

Pliny in one of his letters[1] hints at the failure of certain citizens of Nicaea to make donations which they had promised, and in illustration of the second point there is a strange and amusing provision in the charter of Malaca,[2] of 81-84 A.D., to the effect that if there are not candidates enough for the offices the magistrate who is to preside at the election may on his own authority post the names of eligible citizens, who can only escape office by nominating somebody else.

[1] No. 39. [2] *C. I. L.*, II, 1964, Chap. 51.

Loss of Sources of Revenue

Outside the walls of each city, as we noticed, there was usually a large district owned by it. This outlying region contributed largely to the payment of the imperial taxes. As the soil became exhausted, the country devastated by civil war and by the barbarians, farm after farm was abandoned, and this source of taxation dried up.

Now it had become the practice of the central government not to collect taxes from the individual, but to exact a lump sum from a community, and it was a very natural thing for it to hold the *curiales*, that is the members of the local senate and those eligible to it, responsible for the payment of the amount fixed for the city. The burden became intolerable, as conditions grew worse, and those whose property rendered them eligible to a magistracy, or to the local senate, made frantic efforts to escape the honor thrust upon them.

Public Office Shunned

The two codes of Justinian and Theodosius furnish us with amusing yet pathetic records of the struggle between them and the government. It is like a game of chess with clever moves by the citizen checkmated by the government. I wish the time at my disposal would allow me to read some of the pertinent titles from the Theodosian Code, but I must content myself with mentioning a few of the regulations to show the means to which men had recourse to avoid municipal office.

Some men gave up their residence in a city, or moved into another province, but they were brought back. When they transferred their property to someone else, so as to become ineligible, the recipient of the property was held for the office. Some married slave women, so as to lose their legal status, or became monks in the desert, but the government pursued them inexorably. Even enlistment in the army and the taking of holy orders was no protection.

Entrance into orders caused the state great difficulty. At first bishops were granted exemption, but later by a statute of 399 A.D. even they had to provide substitutes. The only bit of sarcasm which I have happened on anywhere in the Theodosian Code has to do with those who avoid service in the *curia* by taking up the ministry.

Title XII. I. 104 of 383 A.D. reads:

> "If the *curiales* who prefer to serve the church rather than the *curia* wish to be what they pretend to be, let them show their contempt for those worldly goods which they take along with them."

The only social group to whom exemption was granted was made up of fathers of thirteen children. This exemption in itself testifies to a threatening decline in the birth rate and an effort to check it, which finds parallels in contemporary legislation.

Municipal government had fallen. The well meant efforts of the imperial government to remedy its evils had robbed the magistracies and the senates of their importance and the people of their independence, and the economic decline of the Roman world had brought down in ruins a system of municipal finance which rested on an unstable basis.

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THE LECTURER

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Influence of Geography on History

A LECTURE

By WILLIAM B. SCOTT
Professor of Geology and Palæontology in Princeton University

My dear old friend, Dr. Hill whom some of you possibly remember, was very fond of saying that this is a weary, wicked world and few of us get out of it alive.

Inasmuch as we have to live our lives here, we are necessarily under the conditions of terrestrial existence. That is, of course, a high-sounding platitude. And yet it is impossible even now to take into our minds fully just what that means because there are involved in it a large number of unsolved problems—problems of the earth and problems of man, man simply as a living creature, without any regard to him as a human being.

For example, there is the unsolved biological problem which is constantly cropping up, as to whether characteristics acquired in the lifetime of the parent are transmissible to the offspring.

We know, as a result of observation, that the peoples who live in hot climates have dark colored skins, dark hair, and dark eyes. The question is, is that due to the influence of the climate directly acting upon generation after generation of men? A great many of the natives of India, dark as any negro, are just as direct in descent from white stock as we are.

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Thus we have the question whether this is a direct effect of the hot climate or whether it is indirect, namely, whether the people of light complexion are at a disadvantage and therefore are slowly eliminated, weeded out. The result would be the same in either case. But the method by which that result is obtained would be totally different in the two cases, and we cannot determine which is the correct explanation of the undoubted fact. There are many other things just like that, concerning which we simply can say that the result is so and so, but how it is reached, we are still unable to prove.

No Racial Difference of Importance

Another matter: The everlasting question of race and race superiority. We need not enter into the disputable questions of relative quality of the colored races, the brown man and the black man and the yellow man; but confining our attention altogether to the white man, I think there is no racial difference that amounts to anything. I think in his case it is pretty definitely proved that his environment, including his language, his historical tradition, his religion, and the thousand and one things that go to make up what we call his environment, is vastly more important than his race: Many have always talked as though race was "the whole thing." The Frenchman, Gobineau, and Houston Stewart Chamberlain are in part responsible for this pernicious idea of race supremacy among white men. In fact, there is no pure race in existence. All are mixed. But, that again is a question which leaves open a good many unsolved problems.

Then, too, the question arises as to how men are affected by their external environment. One set of writers would have you believe that a man is very much like a lump of clay or a piece of putty, moulded by external circumstances, without any will or any exertion on his part. That is one extreme. Another set of writers would have you believe that all that counts for nothing, that the human will is the only factor of any importance in the world, and especially in history.

You have in another form the same problem in the question of "great" men. According to Carlyle, history is simply a biography of great men. They were the leaders; the herd merely followed meekly in their footsteps.

At the other extreme is Tolstoi, and plenty of others with him, who argue that there are no great men; the greatness of humanity is a contradiction in terms; there are no real differences among men. Tolstoi in particular says, in that wonderful book of his, "War and Peace," that the great Napoleon was simply a bubble on the surface of the stream of events, showing its direction of flow, but having no control over its movement. How is one to pick out among these conflicting views the moderate, sane, sober statements which are susceptible of proof?

From one point of view the topic that I have taken, "The Relation of Geography and History," would be the whole history of mankind with reference to the geographical surroundings of each country in which men dwell. Needless to say, that cannot be done in an hour's talk. All that is possible is to pick out a very few illustrative examples of the way in which men are controlled and their affairs necessarily determined by their geographical environment.

Effect of Geography on Military Operations

Let us consider the effect of geography on military operations. It is no paradox to say that the events of the great war, through which we have just come, were determined by things that happened millions of years ago. Go over the south of England and the north of France and Belgium. If certain rocks had not been formed in a certain way in a certain order, some in fresh water and some on the bottom of the sea, if these rocks had not been upheaved at a certain time, if certain particular climatic events had not come in, if certain rivers had not been established where they are, these and countless other items that I might go on to catalogue—if these had not happened in just the way they did the events of the war would have been altogether different. East of Paris, France is traversed by north and south lines of cliff, caused by the coming to the surface of hard beds of limestone. Of those scarps, there are five, but they all descend gradually northward and die away in the Belgian plain.

The battle of the Marne was a very complicated thing. It took six days to settle and extended over an active fighting front of two hundred miles, and it would take more than one lecture to take up the various elements of geography which determined the victory. But I want to call your attention to one fact: what saved France was not only the skill of French generals and the valor of the French troops in that first onrush of the Germans, but the fortifications which nature placed there. If the Germans had been able to carry the Grand Couronnée, a natural scarp at Nancy—just to the north of Nancy is a high line of cliffs which the Germans assaulted in great force—if they had broken this, the battle of the Marne would have been a German victory. But they could not break through. Although the French were greatly outnumbered, the strength of that position was such that one to three could hold it, and they did hold it.

It is a commonplace of military science that topography determines strategy. The whole strategy of the Germans was completely conditioned by the existence of the natural defenses on the eastern portion of France, between the frontier and Paris, and also by the fact that by going through Belgium they turned the flank of all those defenses and had a clear road to Paris.

Climate a Geographical Fact of Great Importance

Let us turn from that to certain other matters. There is no geographical fact of greater importance than climate. This is shown by the fact that civilization has arisen and has been maintained almost exclusively in the north temperate zone. There is not and never has been an indigenous tropical civilization. And what civilization there is in the tropics, save in Southern India, is due to men from the north temperate zone who pushed their way a little into the tropics, but who have rarely been able to maintain themselves there.

Latitude a Factor in Making Climate

Among the factors which make climate is, of course, latitude. But we are wont to attribute a great deal too much importance to latitude, because, as a matter of fact, the prevailing system of winds is almost as important as latitude in determining climate. For example, you know that in the south of England there is an extraordinarily mild climate. The south coast of England has many plants that do not occur again until you get down to the Mediterranean. The southwest corner of England doesn't know anything about frost or snow. The islands just off the coast of Cornwall raise flowers for the London market all the year round, and if you go there in January or December you will find fields of daffodils and narcissi and tulips and hyacinths in full bloom.

Continue the latitude of that southern coast of England across the Atlantic—you land in Laborador, one of the very bleakest places of the earth, with a climate so severe that even the Eskimos are hardly able to live in the interior. Similarly, if you go from New York to San Francisco you are on the same parallel of latitude, and you go up the Pacific coast to Sitka in Alaska, and you find there a climate like that of London, with a winter which is far milder that the average New York winter, and a cooler summer.

What is the reason for these enormous differences? The reason is in the system of prevailing winds; because in the temperate zone in both the north and south hemispheres the wind blows three-fourths of the time from some western quarter. If you take a record of the way the wind blows here, it will swing from southwest around to northwest, and about three-fourths of the time it is blowing from some western quarter. That means that here on the Atlantic coast our winds come over the land. And land winds in summer are hot winds and in winter are cold winds, because the land gets far colder than the sea ever does. The open sea doesn't freeze except in the polar regions, and until it freezes you can't have a temperature below 28 degrees Fahrenheit, whereas you can have the temperature of the land 50 degrees below zero. Every one here knows that cold waves in the wintertime come invariably with a northwest wind, because that means a vast volume of air from the direction of Minnesota and the Dakotas.

But in Europe they get their west winds off the water. Consequently the climate is mild. The summers are cool, the winters are relatively warm. Here in Princeton the annual range of temperature may be as much as 120 degrees. We have all seen it here 100 degrees, and we have also seen it 14 degrees or 15 degrees below zero—not often, but we sometimes do. You never see anything like that in the west of Europe, in western France or Scotland, nothing in the least approaching that. The range of temperature there is seldom more than 60 degrees or 70 degrees. This difference is due entirely to the prevailing winds, in one case coming off the land and in the other off the water.

Mild Climate Found on Western Shores

That means, of course, that the western shore of a continent is one of mild climate and small temperature variation. The eastern shore is one of a severe climate and a great variation, because the eastern shore, like ours here, is the shore of land winds. The western shore is the shore of sea winds.

Suppose, for example, that the European settlers, instead of coming to America on the Atlantic side, where they found a low plain of rich land, forming the Southern States, and a compact little plain of New England, all of that Atlantic coast region, none of it high, all of it furnished with an abundance of navigable streams—suppose they had come in on the Pacific coast. The whole course of our history would have been changed. There would have been the colonization of a small coastal strip, not far inland these colonists would have been confronted by a gigantic rocky mountain wall fourteen or fifteen thousand feet high, covered with eternal snow and ice. When they had surmounted that they would have found themselves with five hundred miles of desert before they could find any arable land which might be cultivated without irrigation and very extensive resources.

Effects of Colonizing Atlantic Coast First

In short, the whole past, present and future, the whole development, the whole of our existing conditions are due to the fact that the colonization of the country took place on the Atlantic side and not on the Pacific side. The arrangement of mountains with reference to the coasts and of the desert with reference to the coasts is such that the coastal strip only could have been populated, could have been cultivated, could have been settled, for a very long time after the discovery of the country.

The three elements that go to make up climate, then, are temperature, moisture, and prevailing winds.

Why is it that the white man doesn't thrive in the tropics? In the first place, there are the insect-borne diseases, such as yellow fever, tropical malaria, tropical dysentery, sleeping sickness—not the sort of thing the doctors have been talking of lately, but the real article. Those are all due to insect bites. The parasites that produce these diseases live in the insect and are transmitted to the human blood by the bite. This whole thing has been traced through the complete cycle of development, the yellow fever parasite, the typhus fever parasite—typhus is transmitted by a louse—the bubonic plague or black death, which devastated Europe in the fourteenth century, and which is due to the bite of the rat flea. And the number of diseases which are due to the bite of insects is steadily increasing; or rather, our knowledge of them is increasing.

When I went down to Panama during the construction of the Canal, I hardly saw a mosquito. I remember one night just outside the city of Panama, Colonel Gorgas, Chief Sanitary Officer, had come to return my call, and we were chatting about sanitation. He said:

"I received a letter the other day from a lady, announcing in terms of great indignation that she had seen a mosquito here in the Tivoli Hotel, and expected me to take immediate steps about it. I did, but there was not much to do." The sanitation of twelve hundred acres, that was all, a little over two square miles, cost $570,000 a year to keep the mosquito down.

Quarantine as Control for Yellow Fever

Yellow fever could be controlled by quarantine, and there had not been a case of yellow fever on the Isthmus since 1910, except a few that have come in on ships. These were protected from mosquitoes, and no new cases arose. In the last eleven years there has not been a single case of yellow fever in a country where from that disease the French died like flies.

I don't think the world will ever do justice to the French engineers who faced those horrible conditions of yellow fever in 1889–96. A conductor on the Panama Railroad said to me one day—I had asked him what he thought of all this sanitation and expected to hear him laugh at it, talk about it as highfalutin' nonsense—"I used to run the De Lesseps Special on this road. I never ran a train without the baggage car full of Frenchmen dead from yellow fever. Sometimes we would have to lay them out in rows along the street. There were not wagons enough to carry them."

And when you think that the French never faltered once in all that horrible time, I think their record is magnificent!

Why the French Failed to Build the Canal

They failed because of two things. In the first place, nothing was known then about the causes of those tropical diseases or how to control them or what to do for them. And in the second place, they failed because of the horrible corruption with which the whole enterprise was dealt with in Paris. In those conditions, of course failure was inevitable.

But my point is that despite that sanitation, despite that enormous expenditure, despite the strictness of a military administration—because you must always remember that Panama was under strict military law and controlled just as much as any fort, and things were done under those conditions which would not have been possible under an ordinary civil administration—what was the result? People used to laugh and say that the Isthmus was now a health resort. You never saw a finer looking crowd of children, healthier looking women, than the American women and children in the Isthmus. Yet in spite of the fact that it was a picked population, and in addition to the large numbers who were attacked by malaria and had to come home, there was a very large number of people who went to the Isthmus and had no particular disease, malaria, yellow fever or typhoid, yet they simply could not stand the climate and had to go home. It was the constant pressure of that monotonous heat, not very severe,—I never saw a day in Panama anything like what we often have here in August—but it is the unrelenting pressure of it. After six months or a year you feel that you would give anything you possess to see a snowflake. And so the Canal Commission used to send the employees home every year on furlough, paid their expenses, that they might get the benefit of a bracing climate. That is why there has been no great permanent civilization in the tropics.

Greatest Civilization of World Is of the Temperate Zone

But the point I want to make is this, that the greatest civilization of the world is the civilization of the temperate zone. And of course one can see why it should be so. There can be no civilization in the polar regions, where a man's whole time and energy have to be spent in getting his day's dinner. He has not got much leisure for the investigation of natural phenomena or for anything else. He is a hunter, and is compelled to spend his whole time on the trail of the polar bear or the runways of the seal or in fishing. Beyond that, of course nothing is possible.

In the tropics the white man does not thrive. Whether he may learn to do so in the future is another question. I think it is very rash and very foolish to attempt to put bounds to the possibilities of scientific discoveries, but certainly so far, the great civilization of the world is a civilization of the temperate zone, and especially of the north temperate zone.

For many thousands of years the civilization of the world was concentrated around the Mediterranean. All the great nations of antiquity, China excepted—Babylonia, Assyria, Phoenicia, Egypt, Greece, Rome—were Mediterranean powers. And all commerce and navigation was Mediterranean navigation.

What drove the Europeans out to the Atlantic? Just two things. In the fifteenth century there came the completion of the conquest of the Eastern Empire with the fall of Constantinople. The Turk had gradually taken possession of that region, bit by bit. First he took the Asiatic side, and then he had gone over into Europe and taken possession of Greece, Bulgaria, Servia, and the greater part of Hungary. In 1453 the last remnant of the Eastern Roman Empire fell with the capture of Constantinople.

This shut the East off from Europe. The great Eastern traffic had moved through the Red Sea into Egypt and by caravan across Persia up to the Mediterranean coast, and had for thousands of years brought that rich commerce to and from the East, from India, China, and Japan, and from the great Asiatic Islands.

It is difficult for us to appreciate what a tremendous part in the life of the Middle Ages is played by spice—spice of all kinds. They valued spice in a way we do not understand. Shut off by the Turkish conquest, some commerce still came through, and so cities like Venice and Genoa were able to keep up a semblance of the old commerce and to keep alive. As a result, the Italian cities had very little interest in the discovery of another route to the East, but the rest of Europe deliberately set themselves to find a way to India. The Portuguese spent forty years in creeping down the west coast of Africa before they got into the Pacific Ocean. In 1498 Vasco da Gama got up the east coast of Africa and was able to take advantage of the southwest monsoon and reach Calcutta. That was the first time any European had ever been there.

That opened one route. The other was opened by Columbus. Columbus started westward with the idea that he was to find the spice islands that way. Neither he nor anyone else had any notion there was a great continental mass interposed between Europe and Asia on that side, but his voyage, of course, led to the discovery of America.

Early Exploration by Italian Mariners

Columbus's venture was immediately followed up by other nations. It is very curious, I think, to see that while the Italians as a corporate body (the republics of Genoa and Venice were the great commercial republics) took no part whatever in these discoveries, the captains in the service of the Portuguese and Spanish, of the English and the French, were all Italians. There is Columbus, the two Cabots, who worked for England under Henry VII, and a number of Italians who worked for Prince Henry of Portugal, because they were the men who had had the widest experience in difficult navigation. And so these Italian seamen made these great discoveries. Those who were not Italians were Portuguese. But having once had the roads opened, all the other nations took part.

What happened? The French, the English, the Spanish, and the Portuguese immediately began to colonize and establish possessions on the mainland of the Americas.

By a curious fact, the French came in north of the British, and in the year 1538 Jacques Cartier discovered the St. Lawrence River, sailed up to where Montreal and Quebec now stand. The French colonized Canada, and leaving the New England coast between Nova Scotia and Florida to the English, "turned" or got beyond the great inland obstacle which kept the British colonists on the Atlantic coast for over two hundred and fifty years, namely, the Appalachian Mountains. These mountains run down only a couple of hundred miles inland, or less, but until the middle of the eighteenth century the British colonists could not get over that barrier. Partly, of course, that was due to the hostile Indians.

French Pioneers' Outposts Cut Continent in Two

So, the British colonists, being blocked off from the interior, made compact agricultural settlements, while the French scattered out far to the west. They could not stand the temptation. Long before the end of the seventeenth century La Salle had discovered the Mississippi and had gone down to its mouth and established the colony of Louisiana. In this way the French cut the continent right in two, and they established military posts at streams which flowed into the Mississippi.

Where Pittsburgh is was Fort Duquesne, and there were other forts, like Fort Necessity. They set up in a great chain. Detroit and St. Louis were French outposts. They held the country in the hollow of their hands, and had the French government given adequate support to the admirable work done by the settlers, more particularly by soldiers like Montcalm, France would have been the dominant power in this continent to-day. But they didn't. They were too absorbed with their European affairs, and they let Canada shift for itself, so that ultimately the French had to submit. They were outnumbered at the time, but by the aid of the navigable rivers the French still held the interior of the continent.

Rapids Bar Navigation of Rivers of Africa

For two reasons the exploration of the interior of Africa was not accomplished till the latter part of the nineteenth century. In the first place, Africa has practically no navigable rivers. All South Africa has not one, not even enough to float an Indian birch bark canoe, which was the great French method of exploration. The French had passed from lake to river, from river to lake. They would make a portage from one stream to another, and it was usually a very easy carry. But even with a birch bark canoe, in a great part of South Africa, you cannot go anywhere.

I recall my sensations when I reached the Zambesi and saw all that water running to waste. It was dreadful. Even the Zambesi is not navigable, it is so broken up by rapids.

If you go up the Congo, a magnificent river, for a few hundred miles you get into a series of falls and rapids. The exploration of the interior of Africa was impossible in a boat, by which the French had in less than two hundred years carried themselves all over North America.

Another obstacle is the deadly insects of Central Africa, especially the tse-tse fly. It looks much like an innocent horsefly. You know at once from his looks that he is a bloodsucker, but he does two things. There are several species of him, and each one has a different kind of parasite which he transmits to the blood of his victim. He is the cause of the real and deadly sleeping sickness. When the British established the colony of Uganda in Central Africa they were forced to withdraw the natives because, among them, there had been a hundred thousand deaths from sleeping sickness alone. White men could protect themselves better, but, even so, a great many white men fell victims. A great many had been victims in the Belgian Congo, too.

In Africa is another species of the fly which attacks animals, horses, oxen, goats, sheep, anything. And this parasite is immediately fatal to the animal, so that a horse, for example, will die within twenty-four hours. Consequently the exploration of Africa had to be done on foot. That is the most costly and ineffective method of doing it, because when you get a man to carry his own food for three months that is about all he can do.

Industrial Revolution of the Eighteenth Century

Of course you understand that I have just picked the things here and there out of an enormously big subject. But, finally, there is just one other consideration that I want to mention. And that is the industrial revolution, the industrial revolution of the eighteenth century.

Have you ever realized that our own grandfathers—mine, I know, I can remember very well—were less removed from the conditions of Julius Caesar's time than they were from those of to-day in all matters of the exterior and material side of civilization? The methods of travel and manufacture, of distribution of goods, of transportation, were those of the Romans down to the industrial revolution of the latter eighteenth century and early nineteenth.

That industrial revolution resulted in the main from the substitution of the steam engine for human and animal power. And so the industrial revolution was conditioned by coal. The time is going to come to a certainty when the coal will be exhausted. And here let me say in parenthesis that there is no more pernicious word in the English vocabulary than "inexhaustible." When I was a boy I was taught in my geography that Pilot Knob was an inexhaustible source of iron ore, which would supply the whole world for many centuries to come. Pilot Knob and Iron Mountain have been exhausted for forty years.

Fallacy that Nature Holds Inexhaustible Supplies

There isn't enough ore there to pay to take it, and so it is for everything else. Nothing is inexhaustible. And remember that every kind of thing you get from the earth, ores, natural gas or petroleum, all are exhaustible, and we are living on capital, and the time will come when these things will be gone. Yet civilization need not go, because substitutes can be found. But the point here is that the industrial revolution is a revolution of coal, and the great industrial nations are the nations like Germany, Great Britain, the United States, which have abundant supplies of good quality and easily accessible coal.

Coal is a temporary thing. A few thousand years, at most, and it will be gone. Then in particular will be the time when the importance of the tropics to the white man will become vital, because when it is no longer possible to keep warm in our winters, when fuel is prohibitory in price or not to be had at any price, we must migrate to the tropics. In the meantime we have got to learn how to live there.

Number Seven

Princeton Lectures

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Development of Organic Chemistry

A LECTURE

By LAUDER WILLIAM JONES
Hepburn Professor of Organic Chemistry at Princeton University

NOTE

This is the Seventh Lecture in the series by members of the Princeton faculty to be distributed to the University alumni.

THE LECTURER

LAUDER WILLIAM JONES was graduated at Williams College with the degree of A.B. in 1892, and earned the degree of Ph.D. at the University of Chicago five years later. He was on the staff of the Chicago institution for the following ten years, and in 1907 went to the University of Cincinnati as Professor and head of the Department of Chemistry and Chemical Engineering.

In the spring of 1918, Dr. Jones was elected Dean of the School of Chemistry at the University of Minnesota, but before beginning active administration of the School he was called to Washington to take charge of research work in gas warfare. About two hundred chemists were employed in the investigations under his direction, and Princeton, Yale, Columbia and Johns Hopkins were among the institutions that maintained branch laboratories as a part of his organization. The Armistice brought this work to a close.

Dr. Jones assumed his active connection with the University of Minnesota in January, 1919, and six months later he was asked to undertake also the direction of the College of Engineering and Architecture. He became Hepburn Professor of Organic Chemistry at Princeton in September, 1920.

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Chemistry, as a science, emerged from Alchemy toward the close of the eighteenth century, less than one hundred and fifty years ago; but, even to this day, there are many persons who believe that it still retains much of the mystery as well as the earmarks of its ancestry.

Perhaps the chief factor responsible at that time for the birth of modern chemistry is to be found in the conviction held by Lavoisier and others that it was of the utmost importance to study the *quantitative* relations, which can be measured during the course of chemical reactions, a method in striking contrast to the one previously employed, which required mainly the observation of the *qualitative* changes in the physical properties of substances during these same reactions.

These two points of view differ so widely that it is not easy for us now to turn back the tide of time and place ourselves once more in the position of the alchemist. To him the transmutation of some base metal into gold was not only a fascinating venture, but, at the same time, a highly practical industrial problem.

Even in these days, it might seem to the uninitiated a much simpler task to transmute lead into gold than to convert a sample of black, viscous, evil-smelling coal-tar into perfumes of Araby, indigo of the Orient, dyes of every color of the rainbow, and drugs as potent and more specific than those known to the ancients. Since the alchemist placed his emphasis chiefly upon variations in physical properties or qualities, there was nothing inconsistent in his belief that lead might be mixed with other substances, fortunately chosen, to confer upon it all of the characteristic qualities of gold, and that gold itself would result.

On the other hand, the consideration of quantitative values, proposed by the new school, soon led to the discovery that gold could be obtained from a very limited number of substances. Furthermore, that gold, itself, was an elementary substance; that no reaction, however drastic it might be, ever separated it into two or more substances. If it suffered any change whatsoever, it was observed that the new materials produced always weighed more than the gold originally taken for the experiment. In other words, gold "compounds" were formed.

Distinction Between Elementary and Compound Substances Fundamental

This distinction between elementary substances and compound substances, as determined by a balance and weights, was fundamental; the achievements of modern chemistry are the logical consequences and fruitage of this conception. Patterson Muir draws an interesting comparison when he says: "Today it is possible to recognize a certain likeness between the saying of Stephanus of Alexandria (about 620 A.D.), that 'it is necessary to deprive matter of its properties to draw out its soul,' and the statement of Lavoisier (1789) that 'the object of chemistry is to decompose the different natural materials and to examine separately the different substances which enter into their composition.' "

One of the most interesting episodes of these early days concerned organic chemistry and the unique position which it occupied at the beginning of the nineteenth century. To give some insight into the historical setting, I must go back to the year 1675, when Nicholas Lemery, a professor of Medicine in the University of Paris, published a textbook of chemistry. This book must have been one of the "best sellers" of its day, for, during the lifetime of its author, it passed through thirteen editions and was translated into Latin, English, German, Italian and Spanish. It was in use as late as 1750.

In this text Lemery divided the realm of chemistry into three provinces: Mineral Chemistry, Animal Chemistry and Vegetable Chemistry. In other words, material substances were classified according to their origins. In time, however, it was discovered that some of the materials extracted from plants were identical with some which could be obtained from animals. This led to the proposal of a new classification into Mineral or Inorganic Chemistry and Organic Chemistry, the chemistry of substances obtained from organisms.

Difference Between Mineral and Organic Compounds Baffling Mystery at First

During the early part of the nineteenth century it was observed that all typical organic compounds contained the element carbon, combined in various proportions with other elements. But there seemed to be a remarkable difference between mineral compounds and organic compounds. While many of the substances called "mineral" had been made in the laboratory by the direct union of elementary substances, no chemist had succeeded in causing carbon to unite with other elements to produce a single one of the many organic compounds extracted from plants or animals. There must be some baffling mystery here. How could this be explained?

A theory was proposed which held that organisms possessed a subtle principle called "vital force," under the influence of which the elements were assembled to form organic compounds. It was even predicted that the chemist never would be able to prepare these compounds directly from carbon, hydrogen, oxygen and other elementary substances.

But a few years prior to the middle of the last century the supposedly impossible was performed. For, without the intervention of "vital force," the synthesis of several familiar organic compounds, such as urea, acetic acid, and alcohol, had been accomplished, to the great surprise of the dogmatic school of chemists.

Even then the necessity of holding firmly to a theory, however threadbare it may have become, caused some of the more sceptical chemists to propose this question, "How do you know that all of the carbon on the surface of the globe may not have been a part of a plant or an animal at some time in the past; and, on that account, may still retain a remnant of 'vital force,' sufficient at least to account for the successful synthesis for which chemists have claimed the credit?" This was too absurd to be given serious consideration, and the debate ended.

In the glorious days which followed, the organic chemist, rejoicing in his newly acquired control over nature, set about feverishly to prepare the materials formerly coaxed from plants and animals. His efforts were crowned with success, which even the imagination could not have foretold. Once in possession of the magic word, he seemed to hold a wishing-wand by which the most marvellous transformations could be brought to pass. Every realm of plant and animal substance was invaded. The plant acids, such as oxalic, tartaric, citric and malic, were made from mere carbon and the other necessary elements. He made perfumes of many flowers, such as the rose, the violet and the pink; subtle essences; indigo, alizarin, and other dyes which, for untold ages, had been taken from cultivated plants; active principles of the alkaloids and medicinal remedies of ancient times; sugars, such as grape sugar, fruit sugar, and others; camphor; rubber; and hundreds of other substances.

150,000 Compounds of Carbon Prepared and Classified

Although these accomplishments were often of great practical importance in themselves, the discovery that the chemist could not only imitate but could also create added fat to the fire and stimulated investigation to such an extent that now, less than one hundred years since his emancipation, the organic chemist has prepared, described and classified upwards of 150,000 pure compounds of carbon, of which a relatively small number has ever been obtained from the tissues of plants or animals. For the most part they are new creations, and, so far as we know, are not present in any known form of living matter.

Molecules Not Merely Aggregate of Atoms

Throughout the entire period of these accomplishments, the minds of chemists were busy formulating hypotheses, theories, and laws by means of which to correlate the vast store of facts. With the atomic theory of Dalton as a starting point, chemists conceived the idea that molecules are not merely aggregates of atoms jumbled together, as peanuts in a sack, but that each compound is composed of molecules, all alike, in which the atoms are arranged in a perfectly definite structure, or as the chemist expresses it, are "linked together." By means of symbols, the chemist constructed formulas which sought to represent the arrangement of atoms in molecules. These formulas are distinctly esoteric, and mean little to the uninitiated, but to the organic chemist they are plans which have a meaning as definite as that of a set of blueprints to an architect.

It is difficult to make this point clear to an audience unfamiliar with the chemist's problems, but it is so fundamental to organic chemistry that I must venture to offer some explanations of it by the use of a very crude analogy. Suppose a castle built of colored blocks were placed before a child of some ingenuity, and we should ask him to take it apart and reconstruct it again in its original form. If he observed very carefully the order in which the blocks, or groups of blocks, were removed, the task of reproducing the castle would be a comparatively easy one.

Billions of Molecules in Every Sample

Now, the organic chemist's problem is much less concrete, because every sample of matter which he investigates contains billions on billions of molecules. But, if he subjects known weights of a compound to various chemical changes, and determines the identity of and the relative weights of the substances produced during these reactions, he can easily translate his results, true for billions of molecules, so that they apply no less rigorously to a single molecule.

The simpler parts or products obtained from the more complex substance during chemical changes bear a relation to the complex molecule similar to that which the blocks or groups of blocks bear to the castle. If the chemist has observed carefully and has reasoned accurately as he takes his compound apart, he can proceed at once to build, or synthesize, the molecules he has just dismantled.

Two illustrations may serve to indicate how the chemist finds and solves his problem: In ancient India and Egypt, as far back as historic records go, madder was cultivated to yield a valuable dye which, with various mordants, produced a great variety of colors upon cloth. Mummy cloths, dyed with madder, have been found in the older tombs of Egypt. When sea traffic to the Orient was established, the cultivation of madder appeared in Italy, and in the eighteenth century in Holland and France vast tracts of land were given over to its cultivation.

Isolation of Chief Active Dye Principle of Madder

It was natural that a plant substance so important as this dye should arouse interest concerning its chemical nature. However, the chief active dye principle of madder was not isolated until 1826. It was called "alizarin" because of the Oriental name of madder, alizari. In 1848 a complete analysis of alizarin showed that it was composed of the elements carbon, hydrogen, and oxygen.

Because of the limited number of reactions which had been studied, its relation to other known compounds had not been established with sufficient accuracy, so that all attempts to synthesize it were failures. But, in 1868, two chemists, Graebe and Liebermann, conceived the idea that the oxygen which alizarin contained might be removed, if alizarin was distilled with zinc dust.

This method had been employed in other similar cases with success. When the experiment was performed they obtained a compound composed exclusively of carbon and hydrogen, but, to their great surprise, this material was a well-known substance, anthracene, which is present in large quantities in the higher boiling fractions of coal tar.

Artificial Alizarin Produced

Here was the necessary clue. Alizarin was a derivative of anthracene, a compound of known structure. A careful analysis of alizarin revealed the fact that to convert anthracene into alizarin it would be necessary to remove two hydrogen atoms and introduce four oxygen atoms in exactly the right position within the structure. In a short time this was accomplished, and artificial alizarin made its bow to the world.

Graebe and Liebermann, in the article which announced their discovery, say, "The enormous consumption of madder, the large tracts of fertile soil required for its cultivation, clearly bespeak the importance which would be obtained by a new branch of industry based upon the artificial preparation of alizarin from anthracene, a common constituent of coal tar."

In 1868 the world's production of madder amounted to five hundred thousand tons. During the ten years which followed, the production of artificial alizarin, chiefly by German industries, had made such inroads that the total recorded production of madder amounted to only five hundred tons.

Iodine Compounds in Thyroid Gland

Goiter, exopthalmic goiter, and cretinism have been scourges of mankind for ages. Modern medicine discovered that an intimate relation exists between hypertrophy of the thyroid gland and these pathological conditions. Careful investigation of the substances which make up this gland revealed the presence of iodine compounds. Iodine is not localized in any other part of the human body in any such amounts.

This singular quality of the thyroid substances suggested that the deficiency which leads to disease might be supplied by some iodine compound in this gland. So the thyroid glands of animals were saved and dried in certain large packing-houses. When they were powdered and administered to patients, it was discovered that they acted in a remedial manner.

A short time ago Dr. E. C. Kendall, connected with the Mayo Foundation of the University of Minnesota, succeeded in extracting the pure active principle of the thyroid gland. It is an organic compound which contains iodine. This principle, free from all extraneous substances which make up the chief part of the powdered thyroid, is many fold more active and may be injected directly into the blood circulation. Its use in the clinics of the Mayo Brothers at Rochester, Minnesota, has met with remarkable success.

But Doctor Kendall was not satisfied with the extraction of the principle. He has investigated the chemical nature of the substance and has succeeded in unravelling the secret of its structure to such an extent that he has already brought together the parts necessary to produce synthetic thyroxin, as the principle has been called. It is probable that in the near future the synthetic product may replace that obtained from the thyroid glands of animals.

Synthetic Chemistry Has Unlimited Possibilities

These two illustrations, one chosen from the field of plant products and the other from that of animal substances, may serve to give you an insight into the meaning of the term "Synthetic Chemistry." I have already mentioned the fact that most of the known organic compounds do not occur in plants and animals. Synthetic chemistry, therefore, has unlimited possibilities, and it is probable that the attainments of the past are merely child's play when compared with the accomplishments which await us in the future.

Early in the nineteenth century it became obvious that many of the results of pure science might be put to practical application in industry. The discovery of the wealth of substances which could be obtained from coal tar by distillation contributed in large measure to the enormous development of synthetic organic chemistry of the past eighty years. Such substances as benzene, toluene, xylene, phenol, naphthalene, anthracene and others in the hands of research chemists yielded hundreds of intermediates, from which by logical experiment the countless coal-tar derivatives—dyes, medicines, perfumes, essences, explosives, poison gases—have been derived.

Germany Becomes Master of Coal Tar Dye Industry

The first synthetic coal tar dye, mauve, was discovered in England by Perkin in 1856. During the years which followed immediately upon this discovery it seemed that England would supply the world with synthetic chemical products. But Germany, with envious eye, saw her opportunity to become master of this great industry. The story of her success has been related so often during the World War that it needs no repetition here.

By the combined efforts of the German universities, the leading banking interests, and large industries, an intricate system of chemical industry, associated in "cartels" or syndicates and subsidized by the Government, was constructed. The marketing problems were attacked with equal vigor, not always in as straightforward a manner as might be desired, until the whole world was in a large measure dependent upon Germany for dyes, intermediates, synthetic drugs, and fine organic chemicals.

When the World War began, the United States was woefully lacking in chemical industries to supply even the most necessary things. It seemed for a time as if many large industries dependent upon regular supplies of chemicals would be prostrated. But during these trying years hundreds of millions of dollars have been invested in plants and equipment, so that to-day the United States may point with pride to what has been accomplished.

Chemists' Contribution to Industrial Success

Chemists of this country have contributed in no small measure to the success which has been attained. Before the war most of the industries dependent upon chemistry looked upon research chemists as visionaries who could contribute little to the successful carrying on of their business. One of the most interesting changes to be observed in the present attitude of these same industries is their desire to seek counsel from men of pure science; and it not infrequently happens that professors who have held important chairs in universities are called by these industries to come into their service, not in the capacity of menials, but with the opportunity of dreaming dreams for them.

Many chairs in universities and colleges, formerly held by professors of chemistry, now stand idle because of inducements which industry has offered to those who formerly held them. It is not only the large financial compensation which has induced these men to relinquish their positions, but the industries are now organizing research laboratories equipped with every possible facility for carrying on investigation, and this inducement, more than the money value of the position, has probably led to the desertion of posts in universities by these chemists.

This is so important a matter for the consideration of universities that I feel that more emphasis should be placed upon it. In modern universities the encouragement of research in science is oftentimes neglected, and facilities in the way of laboratories, equipment, and leisure for the pursuit of this aim are oftentimes not furnished to those who have ability for this service. Unless the universities come to a realization of this fact, it is probable that it will be more difficult in the future to fill the vacancies which now exist than it has been in the past.

Number Eight

Princeton Lectures

Princeton University, Princeton, N. J.

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NOTE

This is the Eighth Lecture in the series by members of the Princeton faculty to be distributed to the University alumni.

THE LECTURER

HAROLD H. BENDER, Professor of Indo-Germanic Philology in Princeton University, was born in Martinsburg, W. Va., April 20, 1882. He is a graduate of Lafayette College, A.B., 1903, and of Johns Hopkins University, Ph.D., 1907; in 1906-1907 he was fellow in Sanskrit and comparative philology under Bloomfield at Johns Hopkins. The following year he continued his philological studies with Pischel and Schulze at the University of Berlin. From 1909 to 1912 he was instructor in modern languages at Princeton University; 1912-1918, assistant professor, preceptor in modern languages; 1918-——, professor of Indo-Germanic philology. He is a member of the American Oriental Society, American Philological Association, Modern Language Association of America, Modern Humanities Research Association, Gesellschaft für deutsche Philologie in Berlin, Lithuanian Society of Science (Kovno), and the Oriental Club of Philadelphia. He is the author of *The Suffixes mant and vant in Sanskrit and Avestan, The Lithuanian Word-Stock as Indo-European Material* (in *Studies in Honor of Maurice Bloomfield*), *A Lithuanian Etymological Index,* and editor of *German Short Stories.* He has also published, in American and European philological journals, various articles on the grammar, syntax, accent, and etymology of divers Indo-European languages.

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"Extraordinary advances have been made in recent years in the scientific investigation of prehistoric times. In the lecture below, Professor Bender illustrates how large a part the science of philology plays in the study of the past of the human race."

The Aryan Question

Did the Languages of Europe Come From Asia?

A LECTURE

By Harold H. Bender

Professor of Indo-Germanic Philology in Princeton University

In the Later Stone Age there lived somewhere a people or a group of peoples who spoke a tongue from which were descended the languages of the Hindus and the Persians, the Greeks and the Romans, the Slavs, the Celts, and the Teutons, including the Scandinavians and the English, that is, *the present speech of perhaps a quarter of a billion people in Asia and of most of the inhabitants of Europe and of North and South America.*

Comparative study of these various languages has reconstructed to a considerable extent not only the speech but also the daily life, the government, and the religion of that Neolithic people, known as Aryan, Indo-Germanic, or Indo-European, which had split into groups and wandered apart before the dawn of recorded history.

Language an Insufficient Test of Race

Linguistic relationship is not in itself sufficient proof of racial relationship. The conquered may adopt the language of the

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conquerors, or the conquerors that of the conquered, or there may be peaceful mingling in irregular proportions of race and language.

Max Müller's oft-quoted words have become almost an article of philological faith: "To me an ethnologist who speaks of Aryan race, Aryan blood, Aryan eyes and hair, is as great a sinner as a linguist who speaks of a dolichocephalic (long-headed) dictionary or a brachycephalic (round-headed) grammar."

When we speak of the Indo-Europeans we mean merely the people, whoever they were, that spoke Indo-European, and we imply nothing whatever as to race or racial characteristics. As a matter of cold fact and despite many opinions on the subject, we know very little racially about the ancient Indo-Europeans; we do not even know whether they were one race or a mixture of types.

But language is the best evidence of *community of life and culture,* and we can at least assume that at some time and in some more or less definite territory there dwelt a people or a group of peoples, racially pure or racially mixed, who lived, to a large extent, a common life and who spoke a tongue which was the common ancestor of the languages now spoken by the majority of the civilized peoples of the earth.

Indo-European Civilization

By the processes of linguistic paleontology, by the comparative study of the fossils of language, we know that this people constructed houses and fortified-places; that they domesticated animals, bred cattle, and raised grain and wool; that they knew how to spin and weave; that they used wheeled vehicles. They had developed a patriarchal organization of family and clan, and political government under some kind of a king. They distinguished between the mortal body and the soul, and worshipped the gods with reverence. The *Dyáuṣ pitár-* of the Hindus, the Ζεὺς πατήρ of the Greeks, and the *Jup-piter* of the Romans show a common name and a common concept of a father-god of the shining sky. Their religion was fundamentally a mere nature-worship, but they had distinctly ethical and spiritual ideas. Much of the exalted connotation of our ecclesiastical word *credo* has come down to us with the word itself from Indo-European times.

But where did this ancient people live? That is the so-called "Aryan Question," which after nearly a century of philological investigation remains still a question, although it is perhaps in process of solution.

Tradition that the Home of the Indo-Europeans was in Asia

It has not been much more than a hundred years since it was generally assumed that all the languages of the earth were descended, through the Tower of Babel, from the Hebrew, just as it was believed, even by such scholars as Sir William Jones, the brilliant pioneer of Sanskrit studies in the Occident, that all people and peoples were descended, through the three sons of Noah, from the first parents, who lived in the earthly paradise of Semitic tradition, in the Garden of Eden, in the land of the Tigris and Euphrates.

Tyre and Sidon, Babylon and Nineveh were more ancient than Athens and Rome. Not only Judaism and Christianity, but all the other great ethical religions had sprung from Oriental sources. Asia was obviously "the cradle of the human race." Only in recent times has it been realized that reasoning man, *Homo sapiens,* not to mention *Pithecanthropus erectus,* appeared on earth long before 4004 B. C., and that there is no evidence of a primeval universal language of mankind.

With the beginnings of the science of comparative philology early in the nineteenth century came the knowledge that Sanskrit was the oldest of the Indo-European languages—if not the mother of them all, at least their eldest sister. Philologists concluded that the home of the Hindus must also have been the home of the Indo-Europeans, and this common home they visualized on the banks of India's most sacred stream, the Ganges. The study of the Veda soon showed, however, that the Vedic people did not know the Ganges, but lived in northwest India; so the primitive home of the Indo-Europeans was moved from the banks of the Ganges to the banks of the Indus, to the country of the "Five Rivers," the Punjab.

Later it was shown that Indian and Iranian, the languages of the Hindus and the Persians, were closely related, and the home of the Indo-Europeans was moved once more, this time into the Iranian region east of the Caspian Sea.

Now the philologians, who were following the Veda into wider fields, and the theologians, who were following the traditional interpretation of the Bible, met, for different reasons, on common ground for the location of our ancestral home. That common ground was southwestern Asia. It was heresy from the religious point of view, and lunacy from the scientific, to propose any other region.

The Duodecimal Argument

Formerly the Asiatic hypothesis was little more than a baseless tradition, but in the nineteenth century many and varied arguments were offered in its behalf. One of the most recent, and perhaps the most widely accepted, of these arguments rests upon the assumption of close contact between early Indo-European and Semitic civilizations. The evidence consists mainly of a mingling in prehistoric times of the Indo-European decimal system and the Babylonian duodecimal or sexagesimal system of numerals. Thus, early English had a "long hundred" of 120; Gothic numerals above 60 were formed differently from 60 and below; our own words for 12 and below are distinguished in form from the -teens; duodecimal or sexagesimal are our concepts of dozen and gross, our 60 minutes to the hour, 24 hours to the day, 12 months to the year, 360 degrees to the circle. Such elements are widespread in Indo-European speech. The claim is that these facts tend to prove that the Indo-Europeans once lived in or near Babylonian territory and colored their decimal system with its duodecimal system.

It is certain that the Indo-European system of numerals was originally, and in all essentials still is, decimal; and it is very probable indeed that the duodecimal admixture is in some way of Babylonian origin. But it is not necessary to assume therefore that the Indo-Europeans must have lived near Babylonia. Babylonian influence extended over much of southern and western Asia, over Egypt, and around the Mediterranean; the mercantile traffic of Babylon early reached as far as Greece on the west and India on the east, and there is no better carrier of numerals than commerce.

Indeed, if the Indo-Europeans had ever lived near Mesopotamia, in immediate contact with so highly developed and so vigorous a material civilization as the Babylonian, we should expect vastly more Semitic influence upon Indo-European than could possibly be indicated by the rather casual evidences that have been preserved.

Furthermore, duodecimal notation appears also in the speech of a non-Indo-European, Finno-Ugrian people in northern Europe and among the Chinese in eastern Asia. That the Chinese or the Finns ever lived near Babylon is unthinkable.

The duodecimal argument is a general one, but many scholars have presented claims in behalf of rather particular localities in Asia. Some have laid the home of the Indo-Europeans north of Afghanistan between the Oxus and the Jaxartes rivers, or between the Oxus and the Hindu-Kush Mountains; others have argued for the plateau of Pamir, "the Roof of the World"; others for Armenia; others for the region north and south of the Caucasus; and still others for the Aralo-Caspian steppe. Most of these special claims have been either disproved or rendered exceedingly improbable.

Methods used in Approaching the Problem

Modern philological research attacks the problem by somewhat different methods from those that were used in the past. First, it reaches a degree of detachment by showing that the Asiatic hypothesis rests upon mere tradition and upon a number of more or less scientific arguments, most of which have faded away in the light of scholarly investigation. Next, it adopts as a principle of method the process of elimination. Many earlier writers erred:

(a) In arguing *ab initio* and with special pleading for this or that restricted area, without sufficient regard to the various probabilities of the other parts of the Indo-European field;

(b) In basing final conclusions upon one or two quite specific and isolated pieces of evidence.

In all likelihood the case never will be decided on the testimony of a single witness or the presentation of a single fact, however material it may be, but a conclusion can, it seems now, be made exceedingly probable through the *preponderance of evidence.* Preponderance of evidence is best obtained by starting, not with a point, but with the entire Indo-European territory, eliminating the parts from which the Indo-Europeans could not possibly have come, and then searching for the balance of probability in an effort to limit still further their original home.

A Land Flowing with . . . Honey

We can begin by striking off all of India. The Rig-Veda itself offers part of the quite convincing evidence that the ancestors of the Vedic Hindus had come from the north through the passes of the Hindu-Kush Mountains into the Punjab and there subjected and dispersed the dark-skinned, non-Indo-European aborigines.

The Hindu (Indian) and Iranian (Persian) peoples had formerly lived together as one people, probably in the territory of the upper Oxus (Amu) and Jaxartes (Syr) rivers, in the region corresponding to ancient Sogdiana and Bactria, and to modern Samarkand, Bokhara, and northern Afghanistan. This terrain has been claimed by more than one modern investigator as the original home of the Indo-Europeans, but against this claim there are several general considerations and at least one bit of specific evidence.

That almost every Indo-European language shares with its cognates a common word for honey or for an intoxicating drink made from honey is shown by two simple and irreproachable etymologies. The first stem, Indo-European **melit,* is not represented in Indo-Iranian nor in Balto-Slavic, but it is widespread elsewhere: Latin *mel* 'honey'; Greek *μέλι* 'honey', *μέλισσα* 'bee'; Albanian *mjal* 'honey'; Gothic *miliþ* 'honey'; *Anglo-Saxon milisc* 'honey-sweet', *mildēaw* 'mildew' (literally, 'honey-dew'); Cornish *mel* 'honey'; Old Irish *mil* 'honey'; Armenian *metr* 'honey'.

The second stem, Indo-European **medhu,* is distributed over practically the entire field: Sanskrit *mádhu* 'honey, mead', *madhúkas* 'bee'; Avestan *maδu* 'mead, wine'; Old Bulgarian *medŭ* 'honey'; Lithuanian *medùs* 'honey', *midùs* 'mead'; Lettish *medus* 'honey, mead'; Old Prussian *meddo* 'honey'; Greek *μέθυ* 'intoxicating drink', *μέθη* 'intoxication'; Old High German *meto* 'mead'; Old Icelandic *mio̧đr* 'mead'; Dutch *mede* 'mead'; Welsh *medd* 'mead'; Old Irish *mid* 'mead'; Anglo-Saxon *medu* 'mead'; English *mead.*

It is clear that the primitive home of the Indo-Europeans must have been a honey-land, a land where the honey-bee abounded.

Now it seems to have been proved that the bee did not exist in the land of the Oxus and Jaxartes, in fact, that it is native in Asia only within a narrow strip which runs through Asia Minor, Syria, northern Arabia, Persia, Afghanistan, the Himalayas, Tibet, and China. In Turkestan it did not exist. Indeed, *not one of the Asiatic sites that have been seriously considered by modern philologists as the possible home of the Indo-Europeans falls within the bee-belt,* although one or two of them border on it. In Europe, on the other hand, the bee is indigenous almost everywhere.

Evidence of Floral and Faunal Names

We can not cut off all of Asia by showing that the Indo-Europeans must have lived in the temperate zone and not even in the southern part of that zone, but we can tend to eliminate much of southwestern Asia, the only part of that continent which offers the slightest *prima facie* claim.

There are no common Indo-European words for elephant, camel, lion, tiger, monkey, crocodile, parrot, banyan, palm, but there are common words, more or less widely spread over Indo-European territory, for snow and freezing cold, for oak, beech, pine, birch, willow, bear, wolf, otter, beaver, polecat, marten, weasel, deer, rabbit, mouse, horse, ox, sheep, goat, pig, dog, eagle, hawk, owl, jay, wild goose, wild duck, partridge or pheasant, snake, tortoise, crab, ant, bee, etc.

However, such evidence must be weakened by several, not mutually exclusive, considerations:

(a) Absence of proof that the Indo-Europeans had a name for a thing does not necessarily imply that they did not have the thing.

There is no uniform, widespread word for milk: the name changes almost from language to language. And yet the Indo-Europeans were a cattle-raising people, and they themselves were mammals.

(b) Some of the examples just mentioned are preserved in only two or three languages and are insufficiently authenticated as universal Indo-European.

The word for tortoise appears only in Greek and Slavic. It may be a special development in those languages in the sense of 'the green one' (from an Indo-European word for green), or it may be borrowed from a pre-Indo-European language.

(c) Even if a word is old and widespread we cannot always be certain as to what it meant to the primitive Indo-Europeans.

The names of trees are especially subject to variation in meaning. Related stems signify 'beech' in Latin and the Germanic languages, but 'oak' in Greek, 'elder' in Slavic, and 'elm' in Kurdish.

(d) A migrating people sometimes applies an old name in a new region to a new, or at least a different, plant or animal.

The word *gopher* is appended to a squirrel in Wisconsin, to a rat in Missouri, to a snake in Georgia, and to a turtle in Florida.

(e) A word may be widespread and have the same meaning in many Indo-European languages, and the word still not be originally Indo-European.

The word *tobacco* is almost universal and the plant is cultivated in many countries, but it would be folly to assume therefore that the prehistoric Indo-Europeans were ardent nicotians.

(f) Some of the plants and animals included in the list just given are not sufficiently restricted geographically to furnish climatic evidence for the original home.

With the exception of a few islands, snakes are found almost everywhere between the arctic and antarctic circles.

(g) A people or a group of peoples may import a product from a distant clime and with the product borrow its native name.

The word *potato* (English, Spanish, Italian, dialectic German, etc.) was borrowed with the vegetable from the Carribean Indians.

(h) The vocabulary of a language transcends actual experience.

Most of us have never seen a dodo, a great auk, a hippogrif, an aardvark, or even a European bison.

Evidence of Vocabulary Cumulative Rather than Specific

It has become fashionable in late years to discount efforts to restore Indo-European prehistory through the evidence of common Indo-European vocabulary, and too much weight has been given by recent writers to some of the considerations that have just been mentioned.

These considerations are precautions and qualifications rather than objections. Any one of them may apply, to be sure, in any given case, but none of them has more than occasional application. The names of familiar things are usually well preserved. The *argumentum ex silentio* can be ruled out of court as a fallacy only when it is applied to the absence of single words; nothing less than a race-wide conspiracy could kill *all* the words of a prominent group (the Germans tried it with their French loan-words during the war), and if Indo-European *milk* has perished, *cow, udder,* and *cottage-cheese* (Tacitus's *lac concretum*) have survived.

A word found in only two or three Indo-European languages is likely to be original Indo-European if those languages are widely separated geographically. The majority of borrowings can be traced and checked by historical, cultural, or purely phonetic criteria. The giving of an old name to a new thing is not a common process. Even with modern transportation the number of imported products is always small in proportion to the number of native products. And the language of Neolithic man was, for the most part, restricted to the physical world immediately about him.

Such evidence as that drawn from vocabulary is cumulative. If a number of Indo-European languages had a word derived in each case from the same stem, and if the literature of each languge indicated that the word in that language signified, for example, the same, or approximately the same, animal as in the other languages, and if the animal were familiar enough to make borrowing unlikely, then it would be absurd to deny the probability that the ancient Indo-Europeans knew that animal.

And if the floral and faunal words that are more or less common Indo-European property are predominantly those of the temperate rather than the torrid zone, it is only reasonable to suppose that the Indo-Europeans came from the temperate zone. And certainly the flora and fauna of the Indo-Europeans indicate Europe rather than Asia as their original home.

If it be objected that the European members of the family might have inherited names for tropical or subtropical plants and animals and abandoned them when there was no longer need for them, the answer is that the Indo-Iranian names for those plants and animals are, for the most part, obviously secondary in origin and, from the Indo-European point of view, late and local in formation.

Other Arguments in Behalf of the European Hypothesis

Other arguments for Europe have varied considerably in value. More than once the thesis has been advanced that the early habitat of the Indo-Europeans should be sought in Europe because it is there and not in Asia that the languages of the family cover the greater area and show the more variety.

It is true that most of the Indo-European languages have been European and not Asiatic since prehistoric times, but if that thesis had universal application the early habitat of the English should be sought in the United States and that of the Spanish should have its focus in Central America.

The absurd argument for Asia that "human migration is always westward" has long since been rejected, and no actual sign of prehistoric Indo-European migration from Asia to Europe has been discovered, unless such an indication be furnished by the Iranian nomads whom the Greeks called Scythians and who lived in historical times north of the Black Sea. On the other hand, we can glimpse several early tribal or national movements in the other direction, from Europe to Asia.

The best contemporary opinion agrees with the Greek tradition that the Phrygians of Anatolia and other peoples whom we know to have been Indo-European crossed the Hellespont into Asia Minor from Europe, especially from Thrace, at about the dawn of history; Herodotus was probably not in error when he assigned the same provenience to the Armenians. Indeed, of the Indo-European peoples in Asia there is none whose known past specifically indicates Asiatic origin, whereas several of them point to Europe as their original home.

A Recently Discovered Language—Tocharian

According to their treatment of certain original consonants, the various Indo-European languages are divided into two great groups, called respectively *centum* and *satem*, after the Latin and Avestan words for hundred, which illustrate the variation. The *centum* group is, with the exception of one minor language, western and entirely European; to it belong Greek, Latin, Celtic, and Germanic. The *satem* group lies, with one, geographically slight, exception, the Albanian, to the east of the *centum* group, and its largest part is situated in Asia; it includes Indo-Iranian, Balto-Slavic, Armenian, and Albanian.

If, as is now well established, the Tocharian, an Indo-European language recently discovered in East or Chinese Turkestan, is a *centum* language, that fact alone would seem to be an indication of European ancestry, for wherever the Indo-Europeans originated it is clear that the European languages are preeminently the *centum* languages. It is, on the face of it, not so plausible that all the *centum* languages of Europe came from this limited Tocharian territory (it is probably the only *centum* language in Asia), as that the Tocharians came by secondary migration from Europe, where and where only *centum* speech is thoroughly at home.

The Tocharian has quite recently been used as the *pièce de résistance* in a collection of arguments intended to prove the Asiatic origin of the Indo-Europeans. None of the manuscripts to which we owe our still incomplete knowledge of Tocharian bear dates; they seem, however, to belong to the latter half of the first millennium after Christ. Certainly we have no record of the language that is older than 500 A. D.

Chronologically, the Tocharian that has been preserved to us is but a tottering guidepost to the Indo-European of three thousand years before. Moreover, the language itself indicates that the Tocharians were relatively late, Italo-Celtic emigrants from western Europe.—Incidentally, one wonders if there has ever been a longer tribal migration: from, say, the upper Danube to within the shadow of the Great Wall of China, almost quarter-way around the globe.

Testimony of Anthropology and Archeology

Anthropology and archeology may in time throw a revealing light upon the culture and the geographical location of the Indo-Europeans of the Stone Age, although it will always be difficult to determine from the examination of a skull or a stone ax what language their owner spoke in life. If the skulls or the axes of the Indo-Europeans differed in form from those of other Neolithic peoples, we do not yet know in what way. Here lies the great gulf between comparative philology and her two sister sciences, a gulf that will not be completely bridged *until we can identify the Indo-Europeans racially, ascribe to them definite archeological remains, and designate those remains by their Indo-European names.*

Meanwhile, however, we have the valuable archeological testimony that the proethnic Indo-European civilization of Europe is impenetrable, and that central European implements indicate indigenous origin and continuous development. With almost every advance of Continental archeology the European prehistory of the Indo-Europeans retreats into remoter antiquity.

Attempt to Delimit the European Home

If it be granted that the original home of the Indo-Europeans probably was in Europe, it is possible, by process of elimination, still further to restrict the place of origin. We can at once cut off the south, the west, and the north of Europe, because these regions were earlier inhabited by non-Indo-European peoples.

Whoever the ancient Pelasgians may have been, it is certain that the Mycenaean and Minoan civilizations of pre-Hellenic Greece were not Indo-European. Italy was inhabited by the Etruscans and perhaps other non-Indo-European peoples.

The Iberians preceded the Indo-Europeans in Spain and a part of France. Whatever the Picts were, Britain was peopled, before the Celtic invasions, by non-Indo-Europeans.

The Finno-Ugrians held northern and eastern Europe at least as far south and west as the Volga, although Finland itself was not colonized by the Finns before the Christian era.

This leaves us, in general, southern Sweden, Denmark, the Netherlands, part of France, Germany, Austria, Hungary, Czecho-Slovakia, the Ukraine, Poland, Lithuania, the Balkan countries, and southwestern Russia.

Now we can take a further step and cut off all of Europe that borders on the sea; despite opinion to the contrary, there is sufficient evidence that the Indo-Europeans were not familiar with the great ocean.

The various ethnological and archeological arguments for Germany and Scandinavia seem to have failed. The Teutonic languages of the Netherlands, Scandinavia, Germany, and Austria have drifted, in their fundamental treatment of consonants (Grimm's Law) and in the decay of their inflections, so far away from the mother-tongue as represented by the other Indo-European languages that it is difficult to conceive of the primitive home as lying within originally Teutonic territory.

The geographical distribution of the *centum* and *satem* languages speaks against France and southern and western Germany, separated as they were by the Celts and the Germans on the east from the nearest *satem* peoples. The historical division of Indo-European into *satem* on the east and *centum* on the west is too clean-cut to permit us to ascribe it to anything else than an equally clean-cut geographic division in prehistoric times.

Just before their separation the Indo-Europeans were, almost certainly, still a more or less nomadic, cattle-grazing people, widely spread geographically, and inhabiting vast plains. These conditions are poorly met by the territory south of the Carpathian Mountains—Czecho-Slovakia, Hungary, and the Balkan peninsula.

We have left, finally, the great plain of central and southeastern Europe which embraces, roughly, the present Poland, Lithuania, Ukraine, and Russia south and west of the Volga; toward this region the balance of probability seems to lean. Almost every condition is satisfied by the conception of the Indo-Europeans as inhabiting some part of this plain as late as 3000 or 2500 B. C. (they knew at least one metal before the dispersion, certainly copper), early differentiated linguistically into distinct groups and covering a vast territory, a pastoral people just at the beginning of agriculture, but still nomadic enough to change their habitat freely under changing economic or political conditions.

The Antiquity of Lithuanian

Geographically this central European plain lies in the very heart of Indo-European territory as we now know it, between the *centum* and *satem* groups, and adjacent to the Finno-Ugrian, with which Indo-European must early have come in contact.

Nor can we ignore the notable fact that right here we find the Lithuanian, which has preserved into modern living speech more of the Indo-European past than any other language on earth. Not a scintilla of evideuce, historic or linguistic, has been produced to indicate that the Lithuanians have ever stirred from their present dwelling-place since they separated from the other Indo-European-speaking peoples. Indeed, it has been made very probable, on the grounds of linguistics, natural science, and history, that the Lithuanian stock has dwelt in its present location for at least five thousand years, which would approximate the duration of the Indo-European period, so far as it is known. There is probably no other part of Indo-European territory for which there is so much evidence against autochthonous, non-Indo-European predecessors.

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THE LECTURER

HENRY JONES FORD, Professor of Politics in Princeton University, was born in Baltimore, Md., Aug. 25, 1851, and was educated in the public schools of that city. He entered journalism and held a series of editorial positions, serving on the staff of the Baltimore *American*, Baltimore *Sun*, New York *Sun*, and Pittsburgh *Gazette*. In 1906 he entered university work as lecturer at Johns Hopkins University, and was called to Princeton in 1908. He is the author of *The Rise and Growth of American Politics, The Scotch-Irish in America, The Cost of our National Government, Washington and His Colleagues, The Cleveland Era, Alexander Hamilton,* and other political, historical and biographical works. He has also been engaged in public service, among the posts held by him being that of Banking and Insurance Commissioner of New Jersey, and that of member of the Interstate Commerce Commission at Washington.

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What Is Socialism?

A LECTURE

By HENRY JONES FORD

Professor of Politics in Princeton University

"Socialism" is a very flexible term. Its primary meaning is simply that of association or companionship. But association is a condition of all human life unless one lives like Robinson Crusoe before he met man Friday. Therefore Socialism means nothing in particular until some indication is given of the actual conditions proposed.

There is great variance of opinion among Socialists just what those conditions should be and opposing views are maintained with bitterness and animosity exceeding what is usual in political controversy. Hence the use of the term "Socialism" does not ordinarily imply any policy save that public ownership of the implements of associated industry should supersede private ownership. If a man shapes a stick into a cane or a fishing rod by his own labor, it is exclusively his own product and hence is his very own. But if he works in a factory that turns out canes or fishing rods the factory and its products should be under collective ownership.

There are extremists who demur to this distinction on the ground that if the existence of any right of private property is conceded logical consequences might have to be admitted that would be fatal to the whole scheme. The cogency of this objec-

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tion appears as soon as one enters into calm examination of details. Why should not the individual labor applied to shaping a business create an individual property right as well as the individual labor applied to shaping a stick into a cane? It is therefore argued that the man who made a stick into a cane by his own unaided exertions does not thereby create an individual property right in his cane, for he himself is a social product and is really dependent upon society for the opportunity to get his stick and make his cane, so that after all there is no just basis for any individual property rights, although in ordinary practice personal belongings would be reserved to individual use by customs enjoying social sanction without positive legal right.

Logical difficulties in the application of Socialist principles can therefore be best avoided by strict adherence to the doctrine laid down by Proudhon[1] that in its very essence "property is theft." This was at one time a widely accepted tenet of Socialism but it does not hold that position now, and in a practical consideration of the movement as a political force in these times it would be a mistake to regard Socialism as the champion of this doctrine as an universal principle. The contention of modern Socialism is not that there should be no property rights at all, but that collective ownership should be substituted for capitalistic control of social production. The man who shaped modern Socialism is on all hands admitted to be Karl Marx,[2] and he declared its purpose to be "collective ownership of all the means of production brought about by the expropriation of the usurping capitalists."

Anarchism

But any sort of positive right to property, whether collective or individual, implies law and its restraints. Divergence at this point has produced a deep split in the revolutionary movement, dividing the Anarchists from the Socialists. It is a common error to ignore this distinction and lump them all together as a set of anarchists. As a matter of fact anarchy and modern Socialism are irreconcilable in their principles, discordant in their aims and hostile in their activities. The Socialists want to take possession of public authority; the Anarchists want to abolish public authority. Socialists favor political candidacy and participation in government; Anarchists reject and denounce all such activities. In 1864 Marx founded the International Workingmen's Association, and issued his famous call: "Proletarians of all countries, unite!" The Anarchists, under the lead of Bakoun-

[1] Pierre Joseph Proudhon (1809-1865) was born in humble circumstances and learned the printer's trade in his native town, Besancon, France. In 1837 he won a scholarship granted in aid of poor young men who wished to devote themselves to a literary or scientific career. He pursued his studies in Paris and acquired ideas which he expressed in a number of works devoted to social problems. His principal treatise is *The System of Economic Contradictions or the Philosophy of Misery* (1846). Eventually he shifted from Socialism to Anarchism, opposing all interference with the free initiative of the people, a position which involved him in controversy with Socialist leaders. Participation in the revolutionary movement of 1848 landed him in prison where he wrote his *Confessions of a Revolutionary.* After his release he escaped further imprisonment by fleeing to Belgium. He was eventually pardoned and returned to France in 1863, but lived only about two years longer.

[2] Karl Marx (1818-1883) was born at Trier, Germany, the son of a Jewish lawyer who had embraced Christianity. He studied at Bonn and later at Berlin, where he took his doctor's degree. He became a journalist and edited the *Rhenish Gazette* until it was suppressed in 1843. Marx took refuge in Paris where his revolutionary activities got him into difficulties from which he fled to Belgium. He returned to Germany in 1848 but the following year again went into exile settling in London where he remained until his death.

in,[3] organized in opposition to the Marxian Socialists and the conventions which the International held nearly every year became noisy battle grounds for the factions.

At the convention held at the Hague in 1872, Bakounin and his adherents were expelled and since then the Anarchists have worked through their own organizations, apart from and opposed to the Socialists. John Most, at one time a Socialist member of the German Reichstag, went over to Anarchism, and he introduced its organization in this country in 1882. It spread so rapidly, championed by his incessant activity as speaker and writer, that for a time it almost wiped out the Socialist organization, absorbing its membership so that ever since Socialism has been confused with Anarchism in the minds of the American public. Not until the Haymarket tragedy of May 4, 1886 had caused a reaction against Anarchism did the Socialist party make any important gains in the United States.

It should be observed that Anarchism does not necessarily imply violence or even disorder. It means literally absence of government by law, no ruler of any sort. There is a school of philosophic Anarchism that is in sympathetic touch with Pacifism and condemns any use of physical force as a violation of individual liberty. It holds that with all legal restraints removed social harmony would naturally grow out of human intercourse. Emerson and Thoreau have been claimed to be Anarchists of this type, by reason of views as to government expressed in their writings, which probably in their own intention did not amount to more than rhetorical emphasis on the rights of the individual.

The bad odor which clings to the term Anarchism is the work of the terrorist section of the Anarchists, inspired and promoted by Bakounin. "Our task," he declared, "is terrible, total, inexorable and universal destruction." Not until every vestige of existing institutions had been swept from the earth, could "Anarchy, that is to say, the complete manifestation of unchained popular life," be made secure. He held that for practical revolutionists all speculations about the future are "criminal, because they hinder pure destruction and trammel the march of the revolution." Such views and such tactics were not at all to Marx's liking and a vigorous pamphlet warfare took place in which each denounced the other. The antagonism between Socialism and Anarchism has ever since continued to be active and bitter.

Utopian Socialism

In considering modern Socialism as a political force it is scarcely necessary to go back very far in time. Socialists themselves distinguish modern Socialism from its precursors by designating the old Socialism as Utopian and modern Socialism as Scientific. This must not be taken to mean that modern Socialism rejects the ideas and principles of Utopian Socialism. On the contrary, Frederick Engels,[4] who first made the distinc-

[3] Michael Bakounin (1814-1876) belonged to the old nobility of Russia and he was well educated. He became an officer in the army but in 1834 renounced his military career and gave himself up to the study of philosophy from which he deduced anarchistic principles which got him into such trouble that he went into exile. In 1849 he took an active part in an uprising in Germany and was sentenced to death but was eventually handed over to the Russian government. His sentence was commuted into a term of imprisonment after which he was banished to Siberia. Through the efforts of his influential relatives he was allowed such freedom of movement that he was able to go to Japan, thence returning to Europe where he spent the rest of his life in promoting terrorist methods which frankly included assassination.

[4] Friedrich Engels (1820-1895) was born in Prussia of well-to-do people who obtained for him a business opening in Manchester, England, where he settled. He became acquainted with Marx while a youth, imbibed his theories and

tion and stated its terms, credits some of the Utopians—such as Owen[5] in England, Saint Simon[6] and Fourier[7] in France,—with almost all the ideas of present day Socialism that are not strictly economic. Engels held that the Liberal institutions propagated by the French Revolution were, despite their fine pretences, a huge swindle of the poor. He observed that when the French philosophers of the eighteenth century substituted reason for moral obligation as the basis of government this rule of reason was in reality nothing more than "the idealized understanding of the Eighteenth century citizen, just then evolving into the bourgeois." By introducing this rational society and government the Liberalism of the Nineteenth century merely established the rule of business interests.

> "The antagonism between rich and poor, instead of dissolving into general prosperity, had become intensified by the removal of the guild and other privileges, which had to some extent bridged it over, and by the removal of the charitable institutions of the Church. The 'freedom of property' from feudal fetters, now veritably accomplished, turned out to be for the small capitalists and small proprietors, the freedom to sell their small property, crushed under the overwhelming competition of the large capitalists and landlords, to these great lords, and thus, as far as the small capitalists and peasant proprietors were concerned, become 'freedom from property.' The development of industry on a capitalistic basis made poverty and misery of the working masses conditions of existence of society."

Owen, Saint Simon and Fourier are credited with having done work of inestimable value in exposing the fraud of Liberalism and in showing that "the social and political institutions born of the 'triumph of reason' were bitterly disappointing caricatures." But the working masses were then so lacking in political opportunity that only partial and inadequate solutions of the social problem were then available. They

became his close friend and active associate. After Marx's death he got out complete editions of Marx's writings. His own literary activity, which was considerable, was as an exponent and interpreter of Marxian views.

[5] Robert Owen (1771-1858) became manager of a large cotton mill in England when only nineteen years of age, and he introduced marked improvements in cotton spinning. He bought a large mill at New Lanark, Scotland and effected such improvements in living conditions there that New Lanark was regarded as a model community. He held that education combined with cooperation would remove social ills and his plans were received with great favor and commanded influential support but as his agitation proceeded his business success declined and his position became that of the head of vigorous propaganda of Socialism and Secularism in which he dissipated his fortune. He went to the United States and established a number of communistic societies none of which had more than temporary success.

[6] Claude Henri, Count de Saint Simon (1760-1825) served with the French troops in this country during the Yorktown campaign. On his return to France he was promoted to the rank of colonel but in 1785 he resigned his commission. In the Revolution of 1789 he voted to abolish titles, but he was not otherwise active in the Revolution. After order had been restored Saint Simon devoted himself to literary labors and published a series of works in which he proposed plans for the reorganization of the institutions of religion, family and property on Socialist principles.

[7] Francois Marie Charles Fourier (1772-1837) was educated in the college of his native city, Besancon. He inherited a fortune from his father but lost it during the Reign of Terror. He was imprisoned and obtained release only by enlisting. Discharged from the army in 1795 on account of ill-health he got commercial employment at small pay and gave all his spare time to producing treatises which he published himself as fast as he could scrape together sufficient funds. He began publishing in 1808 but his views attracted no attention until 1831. The distinctive feature of his scheme of social reorganization was the phalanstery, in which 1800 people were to work and enjoy life together. His ideas gained some disciples who were able to secure considerable vogue for them, particularly in the United States, but this was not until after his death.

sought "to discover new and more perfect systems of social order and to impose them upon society from without by propaganda, and wherever it was possible, by the example of model experiments. These new social systems were foredoomed as Utopian; the more completely they were worked out in detail, the more they could not avoid drifting off into pure phantasies."

Although Robert Owen began the example of model experiments in England, with brilliant temporary results, the principal scene for them soon became the United States, where Owen started a number of communistic colonies. This Utopian Socialism aroused great enthusiasm and secured many eminent adherents. The Brook Farm community, one of the experiments of this nature, has become famous in our literary history. Nathaniel Hawthorne was one of its members and an imaginative portrayal of it is given in his "Blithedale Romance." Numerous communistic experiments were made in this country from about 1824 to 1849 with results that vindicate the accuracy of Engels' statement.

Scientific Socialism

The year 1859 is regarded as an epoch in the history of Socialism, as it was then that what is characterized as Scientific Socialism made its appearance. Its founder was Marx, who in that year published his *"Contributions to the Criticism of Political Economy"* in which work he formulated the ideas which subsequently he developed in his elaborate treatise on *Capital,* published eight years later. Darwin's[8] *Origin of Species* was also published in 1859. The naturalistic view of human origins suggested by that work was promptly appropriated by Marx and this coalescence of Socialist dialectic with natural history has been exhibited as complete justification of the claim made by modern Socialism that it possesses genuine scientific character;—that it is no longer merely an emotional movement sustained by the benevolent considerations to which the Utopian Socialists appealed, but it now rests upon premises established by strict scientific induction from economic history. Important departures from Marx's theories have taken place among Socialists but one must have some notion of Marx's teachings before one can understand what is going on.

Marxian Doctrine

The fundamental principle laid down by Marx is what he termed "the Materialist Conception of History," for which in ordinary discussion the term "economic determinism" is commonly substituted as a briefer expression of the same idea, which is that all institutions,—religious, political, juridical, or social,—take their characteristic shape from economic conditions. This law of economic determinism as stated by Marx was this:

> "In the social production of their everyday existence, men enter into definite relations that are at once necessary and independent of their own volition—relations of production that correspond to a definite stage of the material powers of production. The totality of these relations of production constitutes the economic structure of society—the

[8] Charles Darwin (1809-1882). His activities were purely scientific and the use which the Socialists made of his theories surprised and somewhat amused him. Although his writings profoundly affected the thought of his times, he wrote purely as a naturalist, without any attempt to develop the philosophical or political implications of his theories. Further research along the lines he indicated has discredited the factors he instanced as accounting for the formation of species, although his fundamental idea that in some way they originate from antecedent types by transformation is still generally held among naturalists. The view that appears to be now ascendent is that the transformation appears by abrupt mutation so that the process assumes a creative aspect.

> real basis on which is erected the legal and political edifice and to which there correspond definite forms of social, political and mental evolution in general."

Marx held his theory to be the extension and completion of Darwinism. He held that whereas Darwin showed that material conditions explain the structure of plants and animals, and the form of their organs, it was equally true that the material conditions explain the structure of society and the form of social organs. From this standpoint Marx examined economic history. His analysis of the changes that have taken place in material conditions shows much acute criticism and he displayed marked intellectual power in working out the details of his thesis. His great treatise on *Capital* is copious in statistical data and is highly technical in character, but it is philosophical in tone, full of abstract reasoning often presented in mathematical form, and it is decidedly tough reading. It is a remarkable circumstance that such a ponderous work has become so renowned and influential among the masses, but this has been due not so much to the direct effect of his writings as to the diffusion of his views by literary adherents and interpreters just as Darwin's views have been spread abroad by innumerable popular treatises and essays so that they have reached multitudes of people who would never have cared to tackle Darwin's own writings.

The conclusions at which Marx arrived were in brief as follows: The overthrow of feudalism, the rise of nationality, the Reformation, the destruction of guild industry, the spread of the wage system, the growth of factory production, and the capitalistic system of industrial management, have transformed labor from a social function into a commodity and made pauperism the lot of the working classes. Indidentally, however, the capitalist system has promoted invention, improved technique, economized industrial process, and has expanded commerce until the whole world has been enclosed in its net. But just as material conditions generated the capitalistic system, so too the material conditions produced by that system will eventually supersede it.

Marx's huge treatise is nothing more than a detailed exposition of the thesis that modern capitalist society must needs bring forth as its natural result the socialistic order of society.

The principal doctrines laid down by Marx have ever since been of cardinal importance in Socialist discussion and in surveying modern Socialism some mention must be made of them. They are:

1. *The Surplus Value Theory.* Although all wealth is produced by labor labor gets in wages only a portion of the wealth produced by it, leaving a surplus value which, according to Marx, is "a value acquired without compensation, the product of the unremunerated labor of others." The accumulation of this surplus value forms capital, which by its nature continually seeks further accumulation of surplus value through the exploitation of labor. An inevitable incident of the capitalistic system is therefore.

2. *Progressive Pauperization.* The more the share of the worker in the value he creates is reduced the greater becomes the surplus value appropriated by capital. The system therefore tends to depress wages to the level of bare subsistence. Hence there is "an accumulation of misery corresponding to the accumulation of capital," and pauperism develops much faster than population and wealth.

3. *Concentration of Capital.* Since capital is derived from exploitation, it operates against the small capitalist as well as against the workers, and thus tends to concentrate in fewer hands. "One capitalist kills a good many others." Industries on a large scale keep ousting industries con-

ducted on a small scale. The means of production are monopolized more and more in the hands of a few great capitalists. This internecine struggle naturally produces

4. *Collapse and Crisis.* In stimulating production the capitalistic system subjects itself to a fierce need for markets, and a struggle for them rages among capitalists culminating "on the average every tenth year in an economic crisis which convulses society to its very foundations." Overproduction results in business failures and compulsory liquidation producing further accumulation of capital in the hands of the few and further decrease of small proprietors, the goal to which the process naturally tends being the concentration of wealth in a few hands while the masses of the people are absorbed into the ranks of the proletariate, whom meanwhile the system accustoms to associated effort. Marx remarks that while capitalism is really anarchic in its activities, bending law and institutions to its purposes, within the workshops and factories production approaches more and more to socialist organization. A new order is maturing which will be established by

5. *The Proletarian Revolution.* Marx gave this account of the process:

> "Along with the diminishing number of the magnates of capital . . . grows the mass of misery, oppression, slavery, degradation, exploitation; but with this too grows the revolt of the working class, a class always increasing its numbers, and disciplined, united, organized, by the very mechanism of the process of capitalistic production itself. The monopoly of capital becomes a fetter on the mode of production, which has sprung up and flourished under it. Centralization of the means of production and socialization of labor at last reach a point where they become incompatible with their capitalist integument. This integument is burst asunder. The knell of capitalist private property sounds. The expropriators are expropriated."

This account of the Proletarian Revolution it will be noted is rather vague, and the point is now much discussed whether Marx would have approved such a revolution as has taken place in Russia. His account of the state of things that would ensue from the Proletarian Revolution is also rather vague. He distinguishes two periods or phases in

6. *The Socialist Commonwealth.* In the first period of communist society, when it is but newly hatched from the egg of capitalist society, and still bears traces of the old shell, labor-time must serve as a basis of distribution. The individual labor-time of each producer is the part of the social working day furnished by him; it constitutes his share. The society will give him a certificate that he has furnished a certain quantity of labor-time, and by presenting his certificate he may draw from the society's stores goods or provisions, of equivalent value as computed in labor-time. But when human nature has received the full impress of the new social order, every one may be allowed to take from the common store whatever he needs, without any medium of exchange. Here is Marx's own account of this profound change in the nature and habits of mankind:

> "In a higher phase of communist society, after the slavish subordination of the individual under the divisions of labor, and consequently the opposition between mental and bodily work, has disappeared; after labor has ceased to be merely the means of sustaining life, but has become an urgent desire; after the individual has become more perfect in every respect, increasing thereby also the productive forces and giving full play to the fountains of cooperative wealth—then only can the narrow barriers of right and justice be demolished and society inscribe upon its banner: *From each according to his abilities, to each according to his needs.*

This remarkable passage should be borne in mind in considering the prospects of Socialism. It is a frank admission that it can not fulfill its ideals without a revolution in human nature. Great confidence was at one time expressed by Socialist writers that this would surely result from communism once it was fully installed. The English poet and artist, William Morris,[9] was so sure of it that in his *News From Nowhere,* in which he portrays life in the Socialist Commonwealth, he insisted that the main difficulty with which society would then have to contend would be "a work famine," —not enough work to do to fully satisfy the urgent desire for work that would then exist. But among Socialists themselves the question has at times been raised whether this expectation is not Utopian rather than scientific.

Socialist Criticism of Marxian Dogma

At one period practically all Socialists, as distinguished from Anarchists, were Marxists, just as all evolutionists were Darwinians, but as discussion proceeded and more information became available modification of views and variance of opinion took place among Marxists resulting in different schools that clash among themselves. Every one of the dogmas on which the Marxian system rests has been shaken by criticism. His labor theory of value when subjected to analysis at once brings forward the question, just what is meant by the term "labor"? Does it mean merely the physical effort of the workers, exclusive of the management that directs their activities? If so, then how can it be claimed that it is the source of all wealth, and that the share of the value of the product taken by the management is a surplus labor value that really belongs to the workers? If ten shoemakers can make ten pair of shoes a day by their labor, and if their labor is supplemented by factory appliances and management so that the same amount of labor produces one hundred pairs of shoes, is the extra ninety pair thus obtained due to the labor or to the direction given to that labor by skilful management?

Confronted by such difficulties, the term labor is sometimes broadened by Socialists so as to include effort expended in direction and management, a view which in fine makes the term labor equivalent to human capacity. But in that case the share of the product taken by the management is not surplus value but is an actual value resting upon a basis of distinct creation. Logical difficulty of this order is to some extent avoided by the averment that as an incident of the evolutionary process which Marx described technique will be so generally diffused and methods be so standardized that the element of direction and management will dwindle in importance and eventually disappear as an important factor in production. But this view, however stoutly maintained, has yet to be brought into agreement with well known facts. Everybody who gives any attention to facts knows that the success of every enterprise in which men work together depends upon the ability of the management.

Some Marxian dogmas are admitted to have fared badly under the test of actual experience. His theory of progressive pauperization was completely refuted by the solid statistics collected by the precise methods of German income tax returns and charitable relief. So too was his theory of

[9] William Morris (1834-1896) produced much charming narrative in prose and verse, designed furniture, tapestry and wall-paper patterns, set up a printing press, devised new type faces, and turned out books that are beautiful artistic products. He abominated ordinary factory products and threw himself into the Socialist movement with characteristic energy and vehemence in order to demolish the social order that had such inartistic results. In the ideal society he described in his *News From Nowhere* he swept away most of the present public buildings of London and although he spared the houses of Parliament it was only as a convenient place to store manure for Socialist gardening operations.

the concentration of capital. Statistics showed that the growth of big concentrations of capital instead of wiping out small capitalists made more of them. If their number declined in some lines they increased in other lines, the conditions introduced by large capital opening new opportunities for small capital.

The ten year period assigned by Marx for industrial crises has become obsolete with improvement in banking methods. With correction of Marx's views on those points the premises from which he deduced the proletarian revolution were removed and it no longer appeared to be a necessary consequence of modern industrial conditions, as Marx had contended.

The movement of Socialist thought has also been affected by the change that has taken place in the intellectual climate. The scientific world has emerged from the Darwinian period. Materialism is no longer in fashion among philosophers. The new theories of physics, which display the atom as a very complex structure, have played havoc with the so-called law of evolution, one of whose tenets was that its process was from the homogeneous to the heterogeneous.

Probably the most marked characteristic of applied science and modern business system is now the general tendency towards standardization, making homogeneous what had been heterogeneous. About all that is left of the philosophical theory so influential in Marx's time is the truism that events have their antecedents and their consequences, but it is now generally recognized that it makes an immense difference how events are treated and what direction is given to their influence. The scientific data on which Marx relied in framing his theory of economic determinism are now either discarded or are so extensively modified that they no longer prop his doctrines.

Socialist Schism

This process of criticism eventually caused a split in the Socialist camp. It was the work of one who had himself been a recognized official exponent of orthodox Marxism. Edward Bernstein was the editor of the Zurich *Social Democrat*, the official organ of the German Socialist organization during the period of Bismarck's anti-Socialist laws. With the cessation of Bismarck's attempts to crush Socialism by law, Bernstein returned to Germany and continued his discussion of the movement by a series of articles in the *Neue Zeit*, a Socialist party organ.

In 1897 he published a compilation of his articles under the title "Socialist Problems." The book made a great stir among the Socialists for in it he admitted that doctrines propounded by Marx had been so impaired by criticism that it was necessary to revise Socialist principles. In the hot controversy that followed, Bernstein and his adherents were dubbed the Revisionists, and the issue thus raised between Revisionists and orthodox Marxists extended all over Europe, producing a voluminous literature.

The Revisionists hold that while Marx's labors should always be honored, the Socialist movement must not be bound by his theories. "Socialism," declared Bernstein, "has outlived many a superstition; it will also outlive the superstition that its future depends on the concentration of property, or, if you prefer. on the absorption of surplus value by a diminishing number of capitalist mammoths."

The Revisionist split has been followed by other factional groupings among European Socialists. Revisionism is the dominant school of opinion but among Revisionists differences exist as to party policy and these differences keep constantly tending to produce factions.

Christian Socialism

Marxian Socialism in general has been strongly anti-religionist. But the term Socialism is so plastic that there is no logical difficulty in the way of giving it a Christian complexion. It is merely a matter of appropriate definition. Important movements bearing that name took place in England and France, but as an organization which is a distinct factor in European politics Christian Socialism owes its origin to Ketteler,[10] whose public activity dates from 1848, the year of revolutions. With his active support and effective guidance Christian Socialist societies were founded which hold annual conventions to consider ways and means of solving social problems.

The movement is quite practical in its activities. It promotes cooperative enterprises and operates cooperative stores; it founds banks and building associations; it maintains inns and clubs; it provides legal assistance for its members; it champions legislative measures the details of which are worked out with skill and prudence. It has produced many treatises displaying ability that commands attention and inspires discussion, and it sustains a flourishing periodical press securing publicity for its aims and activities. Similar methods of organization had extended into Belgium, France, Switzerland and Austria before the war, and they now appear to be penetrating Italy and Spain, but no exact statistics are available as to conditions since the war. Christian Socialism agrees with much that Socialist writers in general say against the capitalistic system but it holds that the remedy is not to destroy individual property rights but to humanize their exercise by enforcing moral, religious and legal obligations.

[10] William Emanuel, Baron von Ketteler (1811-1877) came of a wealthy and noble family. He studied law and in 1834 entered public administration but in 1838 he resigned his post to take up the study of theology and he was ordained in 1844. During the revolutionary year of 1848 he attracted general attention by a series of sermons on "The Great Social Questions of the Day." In 1850 he was appointed Archbishop of Mayence. During the long period of his episcopate he never ceased his fruitful activity in the interests of the working classes. His endeavors always had a practical cast and his great administrative abilities were evinced in the organization of "associations of production in the soil of Christianity." The institutions he founded have perpetuated the movement which he originated.

Present State of Socialism

Party alignments were much disturbed by the recent war and by the Russian Revolution, which has produced lines of cleavage on the whole correspondent to the old differences between orthodox Marxists and Revisionists, but which have brought new political labels into use, such as revolutionary Socialists, moderate Socialists, evolutionary Socialists, Guild Socialists, Possibilists, etc.

In general, political ascendency is with the moderate Socialists, whose leaders both in Germany and France now dominate the administration of public affairs, acting with promptness and energy in repressing revolutionary outbreaks.

The Spartacan uprising in Germany was an attempt to bring on the proletarian revolution as predicted by Marx, but it was crushed by the Socialist administration.

The question whether or not the Bolshevist regime in Russia is an exhibition of Marxism in actual practice is a matter of controversy, but it is of record that Marx held that "we must finally have recourse to violence" and the "the revolution must be universal."

So far as one can judge the character of the present Russian government from its literature it appears to be an unflinching attempt to give effect to Marxian principles. At present Bolshevism and Socialism are pitted against one another in European politics as furious enemies. Hence the term "Socialist" has ceased to suggest revolutionary activity and it appears to be getting to be as vague and generally acceptable a term as "democratic," which in the early days of our republic was a term of opprobrium. In some countries the political leaders of our times all seem to have turned Socialists, each with his own recipe for producing the genuine article. There is now a marked tendency in Europe among old-fashioned Socialists to describe themselves as Communists and no longer as Socialists, since that title has lost its original revolutionary significance and has become an ordinary party label.

In the United States Socialism was never more than a minor party, split into two irreconcilable factions, each of which at elections cumbered the ballot with its own distinct list of candidates.

The Revisionist movement in Germany did not have any noticeable effect on the character of the American movement. The Russian Revolution has, however, split the American Socialists into wrangling factions, and rhetoric that used to be concentrated on the bourgeoisie now blazes for or against Bolshevism. The row has had a marked effect in checking Socialist propaganda in this country. *The Appeal To Reason,* the Socialist organ of largest circulation, in its issue of September 10, 1921, declared: "For the first time since its inception in this country, the Socialist movement is failing to function. . . . All admit that the Socialist movement not only fails to meet present needs, but it is less effective than it was a decade ago. We have not only failed to go forward, but we have gone backward."

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THE LECTURER

KARL TAYLOR COMPTON graduated at the College of Wooster in 1908, received the degree of M.S. from Wooster in 1909 and the degree of Ph.D. from Princeton in 1912. He taught chemistry in Wooster in 1908-1909, was head of the department of physics of Reed College from 1913-1915, and has been in the physics department of Princeton since 1915, where he came as an assistant professor and has been professor since 1919. During the war he was Associate Scientific Attaché to the Embassy in Paris and an officer of the Research Information Service, which was the clearing-house for interchange of scientific war information between the allied governments and armies.

Professor Compton is a Fellow and member of the Council of the American Physical Society, Fellow of the A. A. A. S., a member of the Optical Society of America, and an associate editor of the *Journal of the American Optical Society*. Reports of his researches on problems relating to atomic stability, interaction of electrons and radiation, and allied topics have been published in *The Physical Review, The Philosophical Magazine, The Astrophysical Journal* and *Science*.

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Note: Owing to the very recent and rapid developments in this field, no comprehensive treatment of the subject has been published. The nearest approach is the book by Sommerfeld. In reading the older references, it must be remembered that some of the suggestions have been later disproved.

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Recent Discoveries and Theories Relating to the Structure of Matter

A LECTURE

By KARL TAYLOR COMPTON

Professor of Physics in Princeton University

Molecules of matter are sometimes defined as the smallest sub-divisions which have the properties of the matter which they compose. Their existence has long been accepted because of the satisfactory explanation which they give of elastic, thermal and other properties of matter, particularly in the gaseous state. More recently, the existence of such particles, in rapid random motion, has been made almost visible in that we can accurately explain, by the bombardment of such molecules, the erratic jerky movements made by a small particle immersed in a gas or liquid and observed through a microscope.

Atoms are sometimes defined as the smallest particles which take part in chemical reactions, and a chemical reaction is simply a change from one to another kind of grouping made by atoms of the same or of different kinds. Any characteristic grouping of atoms constitutes a molecule. The existence of atoms was first suggested to explain the fact of chemical combination of substances in definite proportions.

Within the last twenty-five years, and chiefly within the last ten years, definite proof of the existence of atoms and mole-

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cules has been found, and methods have been developed to count and weight them *individually,* with very significant results. More important still, it has been shown that all atoms are themselves built out of still smaller and more fundamental units of matter, electrically charged, called positive electrons and negative electrons. There is very decisive evidence of the existence of these two fundamental types of matter, and of the number of each type in any given kind of atom. To this extent, the "electron theory of matter" is no longer to be considered as a theory, but as a fact. But when we attempt to explain *all* the physical and chemical properties of matter as due to these electrons and the electromagnetic forces between them, we encounter some surprising and unexpected facts regarding the behavior of electrons when influenced by other electrons or by radiation, so that this is still a field of hypothesis and experimentation.

Negative and Positive Electrons

Properties of the Negative Electron. When an electric discharge at several thousand volts is passed between two metallic electrodes sealed into a glass vessel from which most of the air, or other gas, has been pumped, the remaining gas and the walls of the glass vessel become luminous. This luminosity is of different sorts in different parts of the vessel, and can easily be shown to be due to two different agents. One of these consists of something shooting out from the cathode, or negative electrode, and producing luminosity in everything in its path. The other consists of something shooting out from the anode and moving toward the cathode, also producing luminosity of gas molecules or other objects in its path, but luminosity of a different color from that produced by the stream from the cathode.

The so-called cathode rays are found to consist of a stream of negatively charged particles, as is proved by the fact that their paths are bent if placed in an electric or magnetic field, or by the fact that, if they are caught in a metallic cup, this cup receives a charge of negative electricity. From the amount of bending in electric and magnetic fields of known strength, which may be seen by the luminous trace of the path of the stream along a properly placed fluorescent plate, it is possible to calculate the speed of the particles and the ratio of their charge to their mass, denoted by e/m. The speed of the particles depends upon the voltage applied to the discharge tube, but the value of e/m does not depend on the voltage or the kind of gas in the vessel or the material of the electrodes. It is a definite constant about 1846 times larger than the ratio of the charge to the mass of hydrogen ions liberated by electrolysis. Thus if the charge on one of these particles is equal to the charge on a hydrogen ion (as we shall see is the case), then these particles must be 1846 times lighter than hydrogen atoms. These particles, which constitute the cathode rays, are the negative electrons. They may be driven out of metals by raising the temperature, or by exposing to ultraviolet light or X-rays, or by intense bombardment, or by chemical actions, etc. Their properties, as regards mass and charge, are the same however they are liberated, and they must be considered as one of the fundamental units of which matter is composed.

The anode rays are also deflected by magnetic and electric fields, in a direction showing that they are positively charged particles and by an amount showing that the ratio of their charge to mass is characteristic of atoms or molecules of the gas in the tube. In other words, they are the residues of the gas atoms or molecules which remain after electrons have been driven out. Knowing their charges, the bending of their paths in magnetic and electric fields enables their masses to be determined. It is in this manner that atoms and molecules have been *individually* weighed with high precision.

In order to find the mass m from the above values of e/m, it is necessary to know the charge e of a negative electron. This has been measured with the greatest accuracy by Professor Millikan about eight years ago. The most sensitive instrument for measurement of electric charges is the electroscope, which consists, essentially, of a strip of gold leaf suspended between two oppositely charged metal plates. When the gold leaf is charged, it is attracted by one plate and repelled by the other, and the size of its charge may be measured by observing the distance which it moves from its uncharged position. But this instrument is not sensitive enough to measure the charge of an electron. Professor Millikan substituted for the gold leaf a tiny droplet of oil from the spray of an atomizer. Because of its weight it tended to fall through the air, slowly because of its small size and the viscous resistance offered by the air. But if this droplet were electrically charged, it could be drawn upward, in opposition to gravity, by an electric field between the two horizontal metal plates between which the droplet moved. By observing, through a telescope, the rate at which the drop fell in the absence of an electric field and the rate at which it rose in the field, data were obtained permitting a calculation of the amount of electric charge on the drop. It was found that all charges were simple multiples of a fundamental unit charge, which is the charge of an electron. Thus the negative electron is not only a fundamental unit of matter, but also a fundamental unit of electricity.

By such experiments it is found that the mass of a negative electron is $8.97(10)^{-28}$ grams and its charge is $4.774(10)^{-10}$ electrostatic units. The mass of a hydrogen atom is $1.65(10)^{-24}$ grams.

Positive Electrons. When the positively charged residue of an atom, the part left after the loss of an electron, is weighed by measuring the bending of its path in an electric and magnetic field, two very significant results are obtained. In the first place, the weight of every atom, except hydrogen, is an exact integral multiple of the weight of a fundamental unit. This unit is one-fourth the weight of a helium atom, or one-twelfth that of a carbon atom, or one-sixteenth that of an oxygen atom, etc. The unit has *almost* the weight of a hydrogen atom, but is less by 0.77°/°. This discrepancy is accounted for by the fact, discussed later, that when electrically charged particles are grouped together, their combined mass differs slightly from the sum of their separate masses. We may conclude, therefore, that all atoms are built up of hydrogen atoms. We shall see later that the hydrogen atom itself consists of one *negative* electron and the part that remains, which is called the *positive* electron. The positive electron carries an electric charge equal to that of a negative electron, but of opposite sign, and is 1846 times heavier. Thus we go a step further, and conclude that all atoms are built up of positive and negative electrons.

Why was not this simple integral relationship between atomic weights discovered long ago, since chemists have accurately known atomic weights for many years? Simply because chemical methods of determining atomic weights measure only the *average* weight of a great number of atoms. But the method described above measures the weights of *individual* atoms. In the case of the element chlorine, for instance, the chemical determinations give the weight equal to 35.46 times our unit; but the deflection method shows that there are three different kinds of chlorine atoms, of weights exactly 35, 37 and 39, which are chemically inseparable and which are present in such relative proportions as to make the average atomic weight 35.46. These different kinds of chemically similar atoms, with different masses, are called *isotopes.* It has been found that isotopes exist in a large number of the chemical elements, but that the weight of every individual atom or isotope is an exact multiple of that of the fundamental unit.

If positive electrons, or the massive part of hydrogen atoms, are parts of the structure of all atoms, we might expect to be able to break up heavier atoms into hydrogen. This has actually been done by Professor Rutherford in the case of nitrogen, aluminium and a number of other elements.

How Electrons are Arranged in Atoms

Thus we have both direct and indirect evidence that atoms are structures built out of positive and negative electrons. The next question is, "How are these electrons arranged in the various atoms?" A good deal is known about this arrangement, as I shall proceed to indicate, but there is much more which is still unknown.

The Nuclear Structure of Atoms. Radium and the other radio-active elements owe their unusual properties to the fact that they emit positively and negatively charged particles, called α and β particles, respectively, with tremendous velocities. By the bending of their paths in electric and magnetic fields, or by other methods, it is found that the β particles are negative electrons which have velocities as large as ninety-seven per cent of the velocity of light, or about 180,000 miles per second. Similarly, the α particles are atoms of helium which have lost two negative electrons and which consist, therefore, of four positive and two negative electrons, forming a very compact and stable group. These have velocities as large as about one-tenth that of light. The β particles set up oscillations of negative electrons in neighboring atoms which they strike, and these oscillations produce radiation called γ radiation or wave motion in the aether. The atoms of radium do not "explode" in this manner frequently. In fact the occurrence is so rare that the chances are even that any given atom will or will not explode within a time of 2000 years. When it does explode, there remains not an atom of radium (atomic weight 226), but an atom of radium emanation (atomic weight 222) and an α particle (helium, atomic weight 4).

In spite of their smaller velocity, the α particles possess much greater kinetic energy than do the β particles, being nearly 7400 times heavier. It was by means of bombardment of nitrogen and other atoms by these α particles that Professor Rutherford has effected their atomic disintegration, yielding hydrogen as a product.

When the α particles shoot out through a gas, such as air, their paths may be seen and photographed, provided the air is saturated with water vapor and suddenly cooled by expansion. The air molecules in the path of the α particles have negative electrons forced out of them by the action of the positively charged α particle as it comes very close. These positively and negatively charged residues of the air molecules serve as nuclei for the condensation of water vapor. Thus the path of the α particle is visible as a thin line of water droplets. In air at atmospherice pressure, these paths may be as long as 11 centimeters.

Now the diameters of air molecules are known to be about $3(10)^{-8}$ cm., and there are about $2.7(10)^{19}$ of them in each cubic centimeter. An α particle, in traversing 11 cm. of air, would pass through about 200,000 molecules. Yet many α particles go this entire distance without changing the direction of their motion, and most of them go at least several centimeters without swerving from their course. This can only mean that *an α particle may pass right through thousands of atoms without colliding with that part of an atom in which practically all of its mass is situated.* We must, therefore, think of all of the positive electrons (and possibly some of the negative electrons) of an atom as grouped within a region which is excessively small as compared with the size of the atom. Around this compact group, or "nucleus" the remaining negative electrons are situated at relatively large distances,—distances comparable with the atomic radius.

With all the heavy positive electrons and only some of the negative electrons constituting this nucleus, it is evidently positively charged. An α particle is also positively charged, with a known charge. Professor Rutherford suggested that a collision between them, indicated by a sharp bend in the path of the α particle as it passes through the air, may be due simply to the effect of the repulsive force between these two charges when they come very near together. Darwin calculated, on this hypothesis, the fraction of all the observed deflections of α particles, shooting through air or any other substance, which should be within any specified angular limits. When this calculation was compared with the experimental measurements of deflections through various angles, it was found that there was exact agreement only provided the force between the α particle and the nucleus is taken to vary inversely as the square of the distance between them, and provided the charge of the nucleus of the atom is taken equal (in electronic units) to its *atomic number.* The atomic number of an element is its order in the periodic table, i.e., 1 for hydrogen, 2 for helium, 3 for lithium, etc.

This conclusion was verified by an entirely independent method. When a beam of X-rays passes through substances, some of its energy is abstracted and sent out in all directions. The amount, character and ditribution of this scattered radiation have been exactly accounted for by ascribing the scattering to the action of the electrons outside the nuclei of the atoms. These electrons are accelerated by the electric forces in the X-ray beam, and, as a result of their acceleration, give rise to the scattered radiation. Sir J. J. Thomson calculated the proportion of the energy of an X-ray beam scattered by each negative electron in its path. Dividing the observed amount of scattering by this gives the number of negative electrons taking part in the scattering. Dividing this by the number of atoms gives the number of scattering electrons per atom, which is found equal to its atomic number. But the number of scattering electrons (electrons outside the nucleus) must obviously equal the positive charge of the nucleus, in electronic units, thus verifying the previous conclusion regarding the nuclear charges of atoms.

Finally, a relation between the atomic number of an element and the vibration frequency of the radiation constituting its X-ray spectrum was discovered by Moseley. It can be expressed rather accurately by saying that the square root of the frequency of any particular type of X-radiation is directly proportional to the atomic number of the radiating element. This has been satisfactorily accounted for only by supposing that the atomic number of an element is equal to the electronic charge on its nucleus, i.e., to the excess of positive over negative electrons in its nucleus.

Atomic Constituents. The foregoing evidence, and much additional evidence, leads to the conclusion that the various chemical elements have atoms constituted as shown in the following table, which contains only a few examples. Those elements bracketed together are isotopes.

Element	Atomic Number	Atomic Weight	+ Electrons in Nucleus	− Electrons in Nucleus	− Electrons outside Nucleus
hydrogen	1	1.007	1	0	1
helium	2	4	4	2	2
lithium	3	6	6	3	3
		7	7	4	3
boron	5	10	10	5	5
		11	11	6	5
carbon	6	12	12	6	6
nitrogen	7	14.01	14	7	7
oxygen	8	16	16	8	8
neon	10	20	20	10	10
		21	21	11	10
		22	22	12	10
mercury	80	197	197	117	80
		198	198	118	80
		199	199	119	80
		200	200	120	80
		202	202	122	80
		204	204	124	80

Thus far we may go with considerable certainty in our picture of atomic structure. When we endeavor to learn *how these electrons are arranged,* both within and without the nucleus, we must base our conclusions on such evidence as we can get from the nature of the chemical (electro-magnetic) forces between atoms, from the ways in which the atoms may be broken up or their parts set into vibration, producing light or other radiation, from their behavior in electric and magnetic fields, etc. To understand the structure fully, we should know all about the forces which hold the parts together. In this direction some progress has been made but certain phases of the problem are very perplexing.

Electrons and Radiation

Quantum Theory. Electromagnetic theory leads to the conclusion that radiation is produced when an electric charge is accelerated, and this conclusion has been amply verified. Yet it appears that, under some conditions, electrons are accelerated without producing radiation. Ordinary dynamical theory leads us to expect that a negative electron, rotating or oscillating about a center of force, might rotate in an orbit of any radius or oscillate with any amplitude under appropriate conditions. Yet it appears that only certain particular stable motions are possible, those which satisfy the condition $\int p\, dq = hs$, where p is the momentum of the electron, q is its distance from some reference point in its path, s is any integer such as 1, 2, 3, etc., and h is a universal constant, known as Planck's constant. We naturally think of radiant energy as being emitted continuously from its source and being absorbed continuously by material in its path, these emitting and absorbing agents being known to be electrons. Yet there is evidence that radiant energy is absorbed or emitted as if in discrete units equal to hn, where n is the frequency of vibration of the radiation.

Such considerations have given rise to the *Quantum Theory,* which has been remarkably successful as a statement of the conditions under which an electron will or will not radiate and of the conditions under which it may be in equilibrium in an atom. Little progress has, however, been made in explaining the quantum laws, and, until this is done, it will probably be impossible fully to understand the forces which hold the parts of atoms together.

Spectral Series. In the apparently complicated spectra of chemical elements, some of which contain hundreds of bright lines in the visible spectrum alone, there have been discovered remarkable relationships between the frequencies of vibration of the different spectral lines of an element and between corresponding lines of different elements. These relationships may be expressed by *series formulae,* of which the following formula for the vibration frequencies of the various kinds of light, or spectral lines, due to hydrogen atoms is an example:

$$n = N\left(\frac{1}{r^2} - \frac{1}{m^2}\right)$$

Here n is the number of vibrations per second, N is a universal constant $3.29025(10)^{15}$ and r and m are integers which may have any value between 1 and infinity. Thus, if $r = 1$ and $m = 2, 3, 4, \ldots$, each value of m gives a frequency corresponding to a spectral line in the extreme ultraviolet. These lines constitute a spectral series. Similarly if $r = 2$ and $m = 3, 4, 5$, etc., we get a series of lines in the visible and near ultraviolet spectrum. If $r = 3$ and $m = 4, 5, 6$, etc., we get a series of lines in the infra red. The frequencies of these lines agree with the measured frequencies with an accuracy of about one part in a hundred thousand.

For elements other than hydrogen, there are added to r and m certain constants characteristic of the element, but r and m still take various integral values.

A study of the absorption or refraction of light by a medium leads to the possibility of calculating the number of atoms in the absorbing substance which are, at any given instant, capable of emitting light of any given frequency. By such methods we learn that only a small fraction of the atoms are, at any instant, taking part in the emission of light and that *the atoms emitting one line in the spectrum are different from those emitting any other line.* Thus an atom, when it emits radiation, emits only one frequency of radiation at a time.

Zeeman Effect. Mention only can be made of the discovery by Zeeman in 1896 that, when a source of light is placed in a strong magnetic field, its spectral lines are split up into several components. The nature of this effect leads to the conclusion that light is emitted by negative electrons which, during emission, are moving in orbits which are usually circular, but sometimes elliptical. As a matter of fact it was the study of the Zeeman effect which first led to the discovery of the negative electron and to a determination of the ratio of its charge to its mass.

Radiation and Atomic Structure. A consistent correlation of the facts of radiation is obtained by supposing that there are only certain definite conditions in which a negative electron may exist in stable equilibrium in an atom, each of these conditions being characterized by a certain total energy (kinetic plus potential). In the case of hydrogen, for example, the energies of all these states are given by $-Nh/s^2$, where s may have any *integral* value and each such value specifies the energy of an electron in a particular state. When, for any reason, an electron passes from any state of energy W_m to a state of less energy W_r, the difference between the energies is sent out as radiant energy. Thus the energy radiated is $W_m - W_r = Nh\left(\frac{1}{r^2} - \frac{1}{m^2}\right)$. Combining this with the quantum law in the form $W_m - W_r = hn$, we have, for the frequency of the resulting radiation,

$$n = N\left(\frac{1}{r^2} - \frac{1}{m^2}\right),$$

which is the ordinary series formula for hydrogen. Similarly, for any element, we interpret the series formula, for any two integral values of r and m, as proportional to the difference between the energies of an electron in the two corresponding states, and take h to be the constant of proportionality. An electron may pass from any state to any other state. If the integer characterizing the second state is less than that characterizing the first, energy is radiated. If the second integer is greater than the first, energy is absorbed by the electron, from whatever agency produces the displacement.

This, in very bald outline, is the theory of spectral radiation and of those features of atomic structure which determine the nature of its radiation. When we attempt to account for or describe these particular stable states (which really involves accounting for the quantum laws) by any dynamical model of an atom, our steps become more uncertain, although some notable advances have been made.

Atomic Models

The Bohr Theory. Bohr, followed by Sommerfeld and Silberstein, has formed atomic models which have been remarkably successful in accounting for the phenomena of radiation and ionization (or breaking up) of systems consisting of a positive nucleus and a single outer negative electron, but which have not been developed successfully to account for these phenomena in more complicated systems, nor for the magnetic properties of atoms.

For the simplest case, a relatively heavy nucleus of positive charge E and a negative electron of charge e and mass m rotating n' times per second about the nucleus in a circular orbit of radius a, we have equilibrium if the electric attraction is just balanced by the centrifugal force, or

$$\frac{eE}{a^2} = (2\pi n')^2 ma.$$

The total energy, kinetic plus potential, is easily shown to be

$$W = -\frac{1}{2}\frac{eE}{a}.$$

By the quantum law $\int p\, dq = hs$ it is found that the only possible values of W are those for which $W = -\tfrac{1}{2}\, s\, h\, n'$, where s is any integer. By solving these three equations simultaneously we find the various possible energies and radii of the atom to be given by substituting the various integral values of s in the equations

$$W = -\frac{2\pi^2 me^2E^2}{s^2h^2},\ a = \frac{s^2h^2}{4\pi^2 m\, e\, E}.$$

Since the difference of energy in any two states equals hn, the various possible radiation frequencies are given by $n = (W_m - W_r)/h$, or

$$n = \frac{2\pi^2 me^2E^2}{h^3}\left(\frac{1}{r^2} - \frac{1}{m^2}\right),$$

where r and m are any two integral values of s. E is simply the atomic number of the element times the electronic charge e.

These three equations are in exact accord with all experimental evidence available. The spectral tests of the latter equation are particularly severe and convincing, since substitution of the known values of the constants makes the term outside the parenthesis exactly equal to the observed Rydberg constant N, so that the equation is identical with the spectral series formula.

This theory has been extended to take account of the small motion of the nucleus as the electron revolves, of possible elliptic as well as circular orbits, of the variation of the mass of an electron with its speed and of the effect of placing the atom in a strong electric field. In every case the theory leads to results in *exact* accord with the facts. When dealing with systems with several negative electrons outside the nucleus, the problem of the way in which they and their orbits are distributed in space must be considered. Models with coplanar, parallel and crossed orbits have been considered, with the latter giving, on the whole, the best results. But the computations are very complicated, and but little progress has been made with such systems or with molecules.

The Lewis-Langmuir Theory. In marked contrast with the preceding *dynamical* model of an atom, Professor Lewis and Dr. Langmuir have developed a *static* theory of atomic structure to account, primarily, for the chemical valencies of atoms and the periodic recurrence of their properties when they are arranged in the order of their atomic numbers. In this theory the electrons outside the nucleus are arranged as symmetrically as possible in positions on the surfaces of imaginary concentric "shells." The maximum possible numbers of electrons in these are 2 in the inmost shell, 8 in the next, 8 in the next, 18 in the next, 18 in the next, etc. No shell can contain any electrons unless all the shells inside it contain their full quota of electrons. The number of electrons to be thus distributed in the case of any given atom is equal to the atomic number of the atom. Chemical combinations of atoms are supposed to be due to the "sharing" of electrons in common by different atoms in such a way as to give the outer shells of all the atoms as nearly as possible their full quota of electrons. This theory of chemical combination, which we have, of necessity, treated very inadequately, is in more complete accord with the facts of combination than any other yet proposed.

Discussion. The chief weaknesses of the Bohr theory are its failure to account easily for certain chemical properties and the uncertainties regarding its proper method of application to any but the simplest atoms. The weakness of the Lewis-Langmuir theory, on the other hand, lies in its qualitative rather than quantitative nature and its disregard of all questions of structural stability, radiation and phenomena due to any part of the atom except the electrons in the outer shell. Yet the striking successes of both theories in particular fields suggests that both contain elements of truth. The present endeavor is, therefore, to reconcile the two viewpoints, and some progress in this line has been achieved.

Matter, Electricity and Energy

Whenever an electrically charged body is set in motion a magnetic field is set up in the region surrounding the body. But a magnetic field cannot be produced without expending energy, and it is possible to calculate how much work must be done to set up any given magnetic field. Obviously, therefore, more work must be done to impart a given speed to a body when charged than if it were uncharged. In other words, the presence of the charge increases the inertia, or mass, of the body. The question immediately suggests itself, therefore, "Is *all* mass due simply to the electric charges of the positive and negative electrons of which matter is composed?" Certain experiments on the variation of the mass of a negative electron with its speed, at speeds approaching the velocity of light, indicate that *the mass of a negative electron is entirely due to its charge,* so that it has no material mass as distinguished from electromagnetic mass. Therefore we consider a negative electron to be not a particle of matter bearing an electric charge, but simply a particle or unit of negative electricity.

It has not been possible to make similar experiments with positive electrons, but all we know about them points toward the conclusion that they, also, are simply units of positive electricity. It is believed, therefore, that matter, in its ordinary sense, is simply an aggregate of positive and negative electric charges.

Furthermore, the electromagnetic mass of any electric charge can be shown to be always proportional to the energy of the electric field to which it gives rise. It is unnecessary, therefore, to distinguish between mass and energy. Whenever the total electrical energy of a group of electrons changes, by a change of their relative positions, the mass of the group also changes in a definite proportion. Theoretically, therefore, all chemical combinations should result in a change of total mass. But the energy changes in chemical reactions correspond to mass changes which are too small for detection by the most sensitive instruments. In cases of atomic disintegration such as in radioactivity, however, the energy changes are very large in comparison with the energy changes in chemical reaction, and suggest the possibility of detecting the corresponding mass changes. Sir Oliver Lodge has stated, as an example of radioactive energy, that, if the total energy liberated during the disintegration of one gram of radium could be utilized for the purpose, it would suffice to lift the entire British navy several thousand feet. These energy changes are large enough to suggest the possibility of showing that the mass of radium is greater than the total mass of the elements into which it splits up. Such measurements have not as yet been made, since radium splits up so slowly. We therefore combine two fundamental laws, the principle of the conservation of mass and the principle of the conservation of energy into a single principle—that of the conservation of energy.

In this connection attention should be called to the probable reason for the slight excess in the atomic weight of hydrogen over that of the least common multiple of the other atoms. In the heavier atoms, positive and negative electrons are packed together in the nucleus, so that their electric fields partially neutralize each other, thus diminishing the total energy and hence the total mass. If we suppose the universe to have been originally formed by the grouping together of positive and negative electrons, the energy liberated as they combine to diminish the total mass in the observed ratio, 0.77°/°, is sufficient to have accounted for the heat of the sun and stars for about a million million million years—an ample period to satisfy the most exacting geological and evolutionary theories.

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