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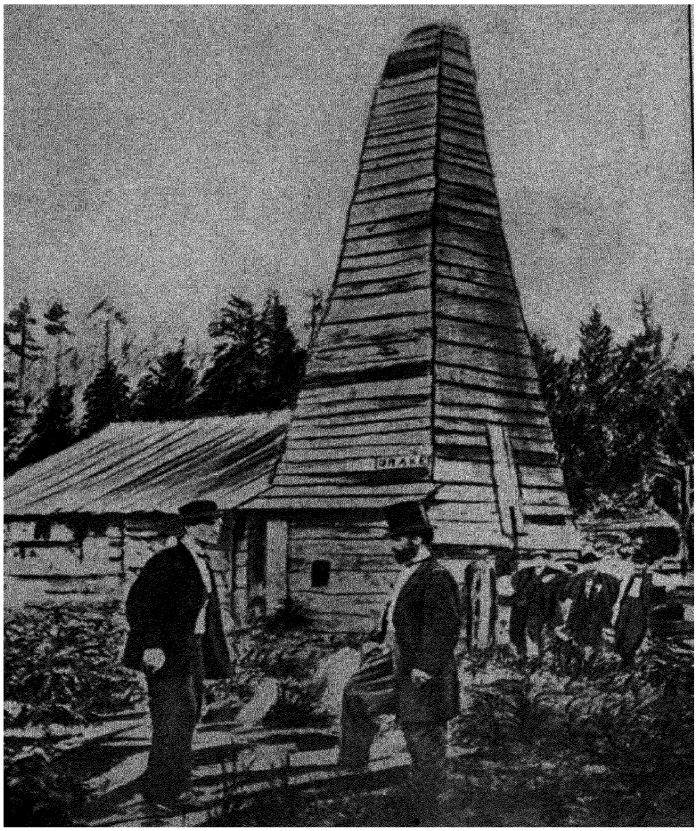
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SCIENCE REMAKING THE WORLD



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THE FIRST OIL WELL IN THE UNITED STATES

On Oil Creek in Pennsylvania. Col. E. L. Drake, shown in the picture with the high hat, began work on this well May 20, 1859, and on August 27 of the same year struck oil at a depth of 69½ feet. The well produced thirty barrels a day for a year

OTIS W. CALDWELL
Ph. D., Director of the Lincoln School of Teachers College, and Professor of Education, Columbia University

EDWIN E. SLOSSON
Ph. D., Editor, "Science Service"

SCIENCE REMAKING THE WORLD



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PREFACE

DURING the summer of 1922, nineteen men coöperated in presenting a course of lectures in Teachers College, Columbia University. The purpose of the course was primarily to provide interesting and engaging information about the achievements of modern science. It attempted to give students of all subjects an understanding of certain types of achievements of modern science, to suggest the meaning of science in various aspects of modern life and thought; to indicate the place of science in modern, social, and industrial relations. Before half of the lectures had been presented, hundreds of listeners had requested me, as organizer of the course, to assemble and publish part of the lectures and if possible, to find means for wide distribution of the resulting volume. In my desire that the volume, when published, might benefit from the unusual style and scientific clarity of Dr. E. E. Slosson, his assistance was successfully importuned in the venture. Then, a gracious and generous though anonymous benefactor agreed to finance the placement of a limited number of copies of the proposed volume in libraries of educational institutions. Finally, the publishers coöperated by providing at bare cost of production the first lot of copies for general distribution, depending upon later sales for their profits from the publication. The authors and the

editors have contributed their services without personal remuneration, and have done this as a welcome privilege in helping to extend the achievements and underlying truths of this most conspicuous field of modern thought. Not all the lectures which were given in the course are available; also changes which are advisable for publication have been made; and Dr. Kellogg and Dr. Williams have kindly added chapters upon topics of wide interest and importance.

Why give such a course of lectures, and why publish such a volume? Because the citizen of our day uses modern science at each turn of his day's work. If he is a thinking citizen, he is ambitious to benefit by what he understands as scientific procedure in using facts, principles, and occurrences. A manufacturer wants his operators to possess whatever knowledge of materials and processes science has produced for the improvement of quality and quantity of output. A lawyer or preacher desires factual illustrative material from the working world of science with which to make his case clear and convincing. If this citizen is a teacher of any subject or grade he deals with the biggest science need of all, for those whom he teaches belong to an age which science has made unlike any of its predecesssors. To men in industry, commerce, and the professions, it is of increasing importance that progressive workers shall have knowledge not only of accomplishments of science, but of the methods by which discoveries are made.

Some thirty years ago Louis Pasteur said:

In our century science is the soul of the prosperity of nations and the living source of all progress. Undoubtedly, the tiring daily

discussions of politics that seem to be our guide are empty appearances. What really leads us forward are a few scientific discoveries and their applications.

And the following is quoted from a recent statement by President James R. Angell:

Nothing can be more certain than that the character and rapidity of our national development in all matters which relate to industry, agriculture, public health and the preservation of the physical framework of our civilization will be dependent upon the quantity and quality of sound research which is carried on. The truth of this assertion becomes even more apparent when one recognizes the fact that every modern nation stands in relation of industrial and commercial competition with other nations, and, in the measure in which this is true, to fall behind the others in scientific development is to precipitate a trend of events which spells national depression and disaster. In other words, the price of a sound, comprehensive national life is, in these times, widespread and intelligent scientific research.

Men need and desire a genuine interpretation of modern science as it appears in the home, street, and factory. They want to know its meaning in public health, in industry, in social relations, and above all in the adjustment of their philosophy to the scientific truths of the modern world.

This volume is especially designed to assist the teacher of courses in general science or the special sciences by bringing textbooks up to date and suggesting possible occupations to young people who really need guidance in finding callings which appeal to them as fields of opportunity and usefulness.

It is expected also that the public will find this volume a convenient and engaging means of catching up with

the progress of modern science. Every intelligent person, whatever his professional interests, has a natural curiosity to know something about the new things in science, as well as in art, literature, drama, and world events. But it is not so easy to keep in touch with the advancement of science since comprehensible compendiums of recent researches are hard to find. At the end of each chapter there has been appended a list of several recent and reliable books and articles, both technical and popular, for the convenience of readers who seek further information.

The reader will notice that in almost every chapter there is given, besides an explanation of recent discoveries and applications, some account of the efforts that have led to them and of the personalities concerned in them. This unusual feature is due to a theory of the editors of the volume that more attention should be paid to scientific history and biography. They believe that one of the reasons why science is commonly regarded by the public as dry is that it has been too completely divested of its human interest. It is important for the public to understand that scientific progress is not a mere series of the lucky accidents and happy inspirations of a few favoured individuals, but a long and toilsome process of investigation, hypothecation, and verification on the part of many workers who often follow fallacious theories and turn into blind alleys from which they have to find their way back to the highway leading toward truth.

OTIS W. CALDWELL.

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SCIENCE REMAKING THE WORLD

SCIENCE REMAKING THE WORLD

ACHIEVEMENTS AND OBLIGATIONS OF MODERN SCIENCE

By Otis W. Caldwell, Ph.D.
Teachers College, Columbia University

A FEW years ago at a New York City luncheon, a business acquaintance expressed a keen desire to have a conference with a Chicago scientific friend of one of the luncheon guests. He said: "Will you not telephone him and see if he will meet me in New York to-morrow?" Thus, at 12:00 noon, the telephone connection with Chicago was made, a conversation held with the friend, and at 12:45 P.M. the Chicago scientist took his train. At 10 o'clock next day the conference was held in New York, and at 2:45 P.M. the man of science was on his return journey which placed him in Chicago next morning, ready for his regular day's work. What an age in which to live! A science man, almost a thousand miles away, is needed for a conference. The telephone permits a brief conversation with words so clear that the peculiarities of friends' voices are heard almost as in the speaker's

presence. A modern train transports the passenger while he eats, sleeps, and writes his plans for his meeting. The necessary conference is held next morning, and the following morning he is back at his regular post.

This ready and effective communication and dizzy speed of travel have become ordinary and slow, as modern science continues to work. By wireless we speak not merely from New York to Chicago or to San Francisco, but over the oceans—around the earth in a few relays. So rapidly is science improving communication that we hesitate to write of "wireless," knowing full well that what we say will be out of date, possibly, before the statements appear on the printed page. And what of human transportation? The Twentieth Century, the Broadway Limited, or the Transcontinental Express, apparently creeps along as the modern airplane above speeds on its way. A regular service route is proposed which will permit the passenger to dine in New York or Chicago, go to a theatre, then take his airplane sleeper, and breakfast in the other city. Even the erstwhile astounding feat of a non-stop flight in twenty-seven hours from New York to San Diego has ceased to give us its early thrill, so confident are we that modern science contains possibilities surpassing our wildest expectations. "Twenty thousand leagues under the sea" no longer seems fanciful. "You can no more do that than you can fly," is now meaningless. "Voices passing through the air," is now so true that even we as speak to one another there may be passing through the atmosphere about you unseen messages pertaining to peace and war, love

and hate, commerce, industry, government—every topic which holds men's minds—all being transmitted through a common medium, none necessarily interfering with any other. Surely the imagery of the past seems trivial when compared with the reality of to-day.

Science has successfully attacked many of the ills to which men succumb. We need not now have smallpox unless we prefer *not* to do the things which science has shown will prevent this disease. Typhoid, far less common than two decades ago, is so well understood and its transmission so definitely associated with uncleanliness that we shall soon see the day when it will be not only unfortunate but not respectable to have the disease. It would now be more indecent to have typhoid than it is to have the "itch," were each person as fully in control of his own personal environment for the one disease as for the other. Yellow fever, the awful plague of many countries, not only can be destroyed, but has actually been destroyed in certain of its worst centres. It is a picturesque campaign now being waged, one with a vision of service to the human race, to remove yellow fever from the earth. The most dreaded disease of all, perhaps, tuberculosis, is slowly but surely yielding. Though big tasks are ahead, enough is now known and proved in practice with tuberculosis patients to give abundant hope to hundreds of thousands of discouraged people who have this disease. It is but a brief time since a clear diagnosis of tuberculosis was all but a death warrant. Surely science is making the earth a better home for men.

In instruments of warfare science has produced an

antithesis not yet understood by men. In the World War the airplane dropped bombs within the range over which the airplane could fly. The dirigible balloon could carry heavier bombs over a longer range, but the gas which carried the dirigible aloft was highly inflammable, and a gun shot through the gas bag meant conflagration and a terrible death to those who were in the balloon. But a scientist studying the sun found helium in the sun's chromosphere. Of what use to us would the sun's helium be? Then helium was found in a mineral in the earth. Helium, lighter than air, was not inflammable, was not easily affected by electric currents—thus an ideal gas for dirigible balloons. Helium, supposedly very rare, could be secured only at a cost of something like $1,500 per cubic foot, and a large dirigible balloon requires a million or more cubic feet of the gas. Then another scientist discovered that helium may be secured from natural gas and the gas be improved for domestic use when the helium is removed. Later developments will permit men now to secure large quantities of helium at a cost of a few cents per cubic foot. Thus dirigible balloons may be floated on the air by a non-inflammable, non-electrifiable gas at heights and over distances hitherto thought impossible.

During this development, new discoveries regarding explosives have increased their efficiency, so that now it is said that a single ton of the highest explosive will, if advantageously placed, serve to destroy the largest existing battleship. Or if the bomb is loaded with the latest destructive gases, it will snuff out the life of all

the occupants of a modern city. Helium gas for use in balloons, other new substances for modern explosives and killing gases—these are instruments of destruction which will completely change warfare in its methods. Even modern battleships are now said to be obsolete, since none is protected against modern scientific bombs. Helium carried dirigibles may go anywhere and drop destructive gases hundreds, even thousands, of miles from the base of operations.

The achievements of science are very great both in their number and in the magnitude of their influences. Tremendously powerful for good and for ill as are the material advantages gained through modern science, it is possible that still greater advantages may be gained through certain attitudes of thinking, judging, and acting which modern science is patiently teaching to a slowly learning human race. It is but a little while, in the comparative history of men, since those who disagreed too loudly with generally accepted ideas were put to death. This was done presumably to show others the terrible results of permitting one's thinking processes to lead him to unconventional conclusions. If a daring honest mind led one to say that the earth is round, not flat, this thinker's life had to be taken, lest his heresy should be accepted by others. If a patriot questioned the divine rights of the king, this patriot was thought to be dangerous to the common good. If one claimed the right and accepted the responsibility of thinking through and acting according to his own conclusions regarding spiritual problems, his life was endangered because his thinking might undo the sys-

tems then in vogue. Even in a country to which our ancestors came in order to think freely, they themselves soon began to shackle, and occasionally destroy, those whose alleged freedom in thinking led to conclusions unacceptable to those in authority. In the present age of science and renewed belief in the power of truth, we see the old and inevitable strife between those who do and those who do not believe in the progressive nature of truth. Attempted legislation against truth merely increases the caution and obligation of inquiring minds, thus helps to refine the inquiry and make the results more secure. Certainly an attack upon a progressive thinker cannot kill progressive thought, but rather by antithesis creates one more spiritual monument in the name of truth seeking. Legislation against truthful, progressive thinking helps to advertise the issues involved, and to cause plastic minds to desire to know. Even if legislative walls could be erected, progressive truth would leak through, filter beneath, fly above, or, radium-like, would radiate by processes too elusive, too intangible, and too fundamental to be denied its logical advance. Did the persecution of Columbus keep the earth from being round, even though many of the ideas of Columbus's times have since been found to be faulty? Did the persecution of Harvey stop the complete circulation of human blood, even though later investigations have corrected many of Harvey's ideas? Could legislation stop biological development even though thousands of research workers are earnestly endeavouring to ascertain unknown truths about the processes involved?

During the unprecedented scientific development of the past half century, there have frequently arisen certain tendencies on the part of men of science which have caused many non-scientific persons to misunderstand the real nature of scientific truth. A scientific discovery is usually much involved in scientific terminology and is complicated by its intellectual associations with a field of special facts and theories. The public usually does not understand the terminology or the related facts and theories as does the scientific worker. Hence the public cannot fully comprehend the discovery or new line of thought. It is extremely difficult for the worker to explain, since his field and even his vocabulary are not sufficiently sensed to provide a common basis of understanding. So the worker in science too often belittles the "common man's" ability to understand and too often makes no effort to inform him. He does, however, more or less inconsistently expect the "common man" to accept his conclusions in so far as these scientific conclusions touch the fields in which this "common man" operates. The man who knows sometimes becomes intolerant toward the man who does not know, quite as the uninformed man becomes intolerant of the man who knows. Most men, most of the time at least, desire to do what is right, and will oppose or support an idea because their conclusions, or their prejudices which they think are their conclusions, seem right to them. The intolerance of scientific men toward a public which is more or less uninformed about science may easily become quite as objectionable intellectually, and perhaps as dangerous socially, as the

intolerance of a group which is uninformed regarding scientific matters.

Further, there is no monopoly of uninformedness. Those who do not know science often do know much of human nature or practical affairs, or of government, or of literature, art, and social relations; and some of these are equally essential in accomplishing the things which are really worth while. It usually helps to get the point of view of the other man, and also increases the light of vision and reduces the heat of friction.

One of the heaviest obligations on modern science requires that it shall organize and present many of its results so that these results may be seen and understood by intelligent but non-scientific persons. People will eventually follow the truth, but they cannot follow it unless they can amidst their confusion see its light at least often enough and clearly enough to enable them to keep the general direction in which truth is moving. In our day they cannot be expected to follow truth too constantly merely by the admonitions of someone whose evidences are known to him but unknown to them.

In the rapid development of science another serious social need has arisen among the science men themselves. The separate sectors or divisions of science have been so compelling in their interest, so gigantic in their possibilities, and so exacting upon the time and energy of specialists, that many specialists have lost perspective of the whole field of science, not to speak of the other necessary human interests mentioned above.

The specialist, however, like other people, guides his life by the stars which he sees, and his conclusions about affairs and people outside of his field are sometimes seriously and harmfully limited. One can and must, if he is a productive student, dig deep into a special subject. But deep wells, while suggestive of depth and height of vision, are not suggestive of broad and comprehensive views. The figure would better be changed to that of a "skyscraper mind," which rises to great heights and consequently may have broad and dependable views, since it stands upon foundations which are secure and since its structural materials are those which will endure under the seasonal and human exigencies of its working environment.

One of the greatest functions of our organizations of science men is the bringing together of scientists from various sectors of science and compelling them to learn enough of the elements, at least, of the other fields, to gain some understanding of the purposes, ambitions, and accomplishments of other science men. It would not be bad for science, nor for the public, if specialists were required to teach other specialists enough to enable all to take a reasonably elementary examination upon the special fields of one another.

There is another supremely important function to be served by means of a better public understanding of modern science and its uses. Science knowledge, scientific processes and appliances, have reached the stage where ignorance means danger, sometimes destruction. Far more people are killed at street crossings than before the gas motor became common property. The air-

plane which "won the war" has exacted the life of many of those who persisted in flying. Gasolene, which also "won the war," is just coming under reasonably safe control. To live in a scientific age, an age of rapidly accumulating knowledge, imposes heavy obligations upon education and upon the resultant social and industrial controls. In the presence of modern science those who do not know cannot long survive, else they must seek the primitive places of the earth where the more elemental practices may persist for a time. Even in these primitive places, science will soon catch up and there will again recur the old biological requirement to learn, to move, or to cease to exist.

But the hardest question is yet to come. Has the common appreciation of moral obligations developed to a point where it is socially safe for all science knowledge to become common property? Can the common moral sense be trusted? Does knowledge of those chemicals which will readily destroy human life ever result in an easier suicide or in the more ready destruction of one's human enemies? Poison gases and other war inventions are so terrible that it is not even safe to allow all citizens to know what a few inquisitive and trusted scientific men have discovered. If a biochemico-physicist were to discover just how to change electrical potentials over an area twenty miles square, so that the electrons of human protoplasm would instantly break down, it would not as yet be morally safe for the different nations to have possession of this secret. Since science deals with progressive truth, it should not omit its obligation toward better common

knowledge of useful scientific truth. It *dare* not omit its due share of the obligation to have modern society develop in moral ideals and controls so that constructive and not destructive use of science shall result.

It is surely a heavy burden that is imposed upon modern education. Exact knowledge and faithful interpretations of science in themselves provide large obligations. But the still larger one—without which modern science is dangerous—asks that intellectual and moral ideals and controls shall develop in harmony with growth in possession of scientific knowledge.

GASOLENE AS A WORLD POWER

By Edwin E. Slosson, Ph.D.
Director of Science Service, Washington

THE work of the world is done by sun power. Whether it be done by the muscular labour of horses or human beings, by the whirling of windmills or water wheels, by the burning of wood, coal, or oil, or by the swift and silent electric current, the energy comes directly or indirectly from the solar reservoir. "Give us this day our daily bread" is the same as saying "Give us this day our daily sunshine." But the sun does not shine every day and it cannot shine on all sides of the earth at once and it favours different zones at different times of the year.

So man in order to avoid the darkness of night and the cold of winter invented a way of using the sunshine of the past for present needs. According to the Greeks fire was a gift of that foresighted Titan Prometheus who stole fire from heaven and brought it down to man in a hollow reed. For this crime he was chained to the Caucasus and from his torn liver flowed a stream of black petroleum. The Greek mythologists differ as to whether Prometheus was ever released from his chains or not, and we cannot count Shelley as an authority, but the streams of petroleum have continued to flow in the Caucasus to this day. The Zoroastrians came to wor-

ship the Fountain of Everlasting Fire, rightly regarding it as somehow a gift from the sun, though how they could not tell, any more than can the modern geologists just how the energy of the solar rays came to be embodied in the blazing oil. Marco Polo, who passed through Baku on his way to Far Cathay, says that a hundred ships might be filled at a time from the lake of oil, and he notes, quite correctly, that it is not good to eat but good to burn and to cure the sore backs of camels.

To-day this same Caucasian oil, which was to the Persians the object of adoration and to the Greeks the subject of a grotesque story, is to the modern world a source of power and the desire of all nations. It is the only liquid asset of the Bolsheviki and their efforts to bargain it off to the highest bidder broke up the Genoa Conference and are holding up The Hague. From 1898 to 1901 a ten-mile square of the Baku district supplied nearly half the world's output of oil and it is still the greatest source of the Old World.

First Uses of American Oil.—But the United States has been favoured above all other nations in the endowment of oil, and it was here that it first became an important factor in civilization. It was from the earliest time used in Pennsylvania, as Marco Polo saw it used five hundred years before in the Caucasus, to cure the sore backs of beasts of burden. The Indians spread their blankets on the creeks that carried a film of oil and wrung them out. The product was sold to the Whites as "Seneca Oil" for man and beast at $2 a gallon. A little more than a century ago a well was being drilled for brine in Kentucky when there burst

out instead of salt water a stream of black oil that literally set the river on fire. The Kentuckians ascribed it to a different supernatural source from the Zoroastrians and called it "The Devil's Tar." Nowadays values are reversed and the driller who strikes brine instead of oil is disappointed.

In 1859 Drake of Titusville, Pennsylvania, put down a well and thereafter sold Rock Oil at the rate of thirty barrels a day. The value of the new fuel was now beginning to be perceived, and after the war the great oil boom set in and millions were gained and lost on paper while petroleum and its products found their varied uses. The great fortunes that are peculiar to our time had their origin in petroleum and it would be impossible to overestimate their influence in all fields of modern life.

Why petroleum is an unprecedented wealth producer and how it can be so readily monopolized by individuals or governments can be easily seen by reference to its geology and chemistry. In the first place petroleum comes in pockets and is therefore readily pocketable. It forms pools under pressure, pushed up from below by water and held down from above by a dome of impervious rock. The first man who drills through the rock gets the oil, not only the oil under his own claim but much of what seeps in from his neighbours' claims. Hence the race to get down the first well in a new field. But great haste means great waste. It is estimated that half the oil is lost through lack of system in drilling. Much of it runs off or is burned up before the well is brought under control. More of it is left in the ground through

the competitive drilling. At the other end of the process, the consumption, at least half of the product is wasted, either through burning the oil to make steam when it might be used in internal combustion engines, or by the careless use of the gasolene in automobiles. On the other hand the intermediate part of the process, the refining and transporting, being under unified management and chemical control is carried on with comparative efficiency and economy. Yet we hear little complaint over the irreparable loss of some three fourths of the world's supply in the drilling and the using while there is furious and incessant denunciation of those who carry on the distribution and distillation because they have made so much money out of it. We do not seem to care how much wealth is wasted but we care dreadfully if somebody gets more than we do.

Mineral oil therefore lends itself naturally to monopoly because it is found in but few places in the world and there concentrated in small space; it is also irreplaceable and indispensable. But why has petroleum such a close connection with wealth? Here the chemist can give the answer. Wealth is produced by the expenditure of energy, human, animal, or inanimate. The unprecedented accumulation of wealth within the last hundred and fifty years is due to the utilization of external inanimate energy, chiefly the heat of combustion of fossil fuel in the steam and gasolene engine. In America the greatest use has been made of such sources and therefore this country is the richest in the world. If measured in the ancient way in terms of man-power we would each of us on the average have a train of

twenty able-bodied slaves waiting on us day and night.

This increment of energy, that has given to all of us comfort and conveniences beyond the power of potentates in former times, comes mostly from two simple and similar chemical reactions, the union of hydrogen and of carbon with oxygen, or in common language, burning. The first reaction, the uniting of hydrogen with the oxygen to form water gives more heat than any other combination of elements. Hydrogen would, therefore, be the best possible fuel but for two reasons. In the first place it is too expensive. It is not found free in nature, except in natural gas, and this is rare and running out. To get the hydrogen out of water would require as much expenditure of energy as we should get out of it by burning it back again to water. Secondly, hydrogen is a gas and therefore not convenient to carry around. It would not be convenient to have a big gas bag hitched to your car like a captive balloon. It is true hydrogen can be liquefied but it does not stay so and it is then exceedingly cold.

Carbon is tolerably abundant in many countries in the form of coal. But carbon has less than one fourth the heating power per pound that hydrogen has. Carbon, being a solid, is handier to use than a gas like hydrogen, but not so handy as a liquid would be. A solid has to be shovelled. A liquid will flow. Coal has to be mined and hoisted up from the ground. Petroleum is so anxious to get out that it will blow off the rigging when its rock prison is tapped.

What, then, would be the ideal fuel if we could have

just what we wanted? It would be composed only of hydrogen and carbon. It should give on complete combustion only water and carbonic dioxide, innocuous final products, already in the air. It should contain no ash; leave no solid residue to foul the cylinder. It should contain just as much hydrogen and as little carbon as possible. It should be a liquid at ordinary temperatures but be easily converted to a gas for combustion. It must not rot on keeping or freeze on cooling. It should not contain water because that reduces the heating power. Preferably it should look nice and clear like water and not stain things. It must not have a disgusting odour like carbon disulfide, though we will not insist upon absolute odourlessness or a pleasant perfume.

Now all these requirements are found in gasolene and in that only. The compounds of carbon and hydrogen are constructed like a chain. Each link is composed of one carbon atom connected with two hydrogen atoms. The first of the series and the simplest possible is methane, CH_4, but that is a gas. So is the next, but when we get along to the fifth and sixth members of the methane series we get to liquids of the gasolene group.

JUST WHAT IS GASOLENE?—Gasolene is not a single and uniform substance. You who use it know that it varies in quality, especially in volatility. It is simply the lightest part of petroleum, the part that comes over at the lowest temperature when the distillation of petroleum begins. Next comes kerosene, and then the heavy lubricating oils, and later vaseline and paraffin, while asphalt is left behind in the still. Formerly, when

there was no demand for gasolene, as much of it was run into the next fraction, the kerosene, as it would stand without blowing up in the lamps. Each state had to have an oil inspector whose duty it was to see that no kerosene was sold that had an ignition point below the safety point of the lamps. There is now no difficulty on that score because the temptation is all the other way, to run the heavier kerosene fractions into the gasolene until it becomes too heavy to burn and the motor knocks. In the early days the gasolene, being injurious to the illuminating oil and not being much wanted anywhere, was allowed to run from the refineries into the streams, where it sometimes took fire. When the introduction of the automobile created a demand for gasolene the refiners awoke to the fact that they had been wasting one of the most valuable parts of the petroleum. Then they began to save and sell their lighter distillates which under ordinary conditions amounted to about 11 per cent. of the crude oil.

But with the multiplication of motors this did not suffice. It became necessary to break up the heavy oils into light oils, which meant breaking up the big molecules into little molecules. Nobody knows exactly how petroleum was formed in the first place, nor even what it was made out of. But presumably it was made from masses of vegetable matter subjected to heat and pressure. If, then, we could reproduce those conditions we could shatter this sorry scheme of things and remould it nearer to the heart's desire.

This was accomplished by W. W. Burton, president of the Standard Oil Company of Indiana, who worked

out a scheme of distillation under pressure which cracked up the heavy oils into lighter fractions. To-day the Standard Oil Company of Indiana has 800 pressure stills which can produce 2,000,000 gallons of gasolene a day. This makes possible the running of 2,000,000 motor cars. In recognition of this achievement the American Chemical Society bestowed upon Mr. Burton the medal that bears the name of Perkin, the discoverer of the first coal-tar dye. The profits of this process are so great that stock in the Standard of Indiana bought for $100 in 1911 would be worth $37,200 ten years later. Crude oil is now made to give on the average 28.5 per cent. of gasolene by cracking and this amounts to 54.4 per cent. of the value of its products.

Another new source of motor fuel is the saving of the gasolene vapours that are contained in natural gas. These used to be lost but are now condensed by cooling and provide about 8 per cent. of our present supply.

What the invention of the steam engine did for the world we can read about in any modern history. What the invention of the gasolene engine has done we can see for ourselves if we only look about us. The signing of the Declaration of Independence in 1776, which we yearly celebrate by going on a picnic, was a much less important event in the history of the world, even in our own history, then the contemporary discovery of the possibilities of steam power. Watt has had more influence over the current of human affairs than Washington.

The Age of Steam lasted a hundred years. In 1876, when we were celebrating our Centennial at Philadel-

phia, the rival and superior of the steam engine was born. Doctor Otto of Cologne, Germany, in that year made the first practicable engine run by the explosion of a mixture of gas and air instead of by the expansive force of steam. The steam engine was not thereby put out of business. It will continue in the service of mankind so long as the coal holds out and perhaps longer. But the internal-combustion engine is more powerful and compact, simpler and more economical, and it has already within the observation of all of us gone farther and come into our lives more intimately than the steam engine ever did. The agile auto climbs mountain trails where the railroad cannot go, and reaches communities that have never been awakened by the whistle of a locomotive. It has made engineers out of our boys and girls. No schools could teach mechanics as widely and practically as the auto has. Gasolene has given to man the wings he has always longed for but which he had despaired of getting until he got to heaven. It has enabled men to go down to the sea in ships on their more or less lawful occasions. It has multiplied the magnitude of man by giving him the power to contract all four of the dimensions within which his activities are confined, the three dimensions of space and the fourth dimension of time.

What is there about the gas engine that gives it this manifold power and adaptability? Wherein does it differ from the old steam engine? It is not merely in using a different kind of fuel, as some seem still to suppose. It is a different kind of motive power. In their fundamental principles, however, the two are alike.

What, to begin with, does man want of an engine? He wants it usually to turn a wheel. And right here man shows his superiority to all other animate beings, for none of them makes use of a wheel. Man has no wheels in his body, whatever he may have in his head. If he wants, say, to turn a grindstone, he must do it by a to-and-fro motion of his arm. But in the course of many thousand years man got tired of this and then it occurred to him to shift the work from his muscles to the molecules. Man is naturally a shifter; therein lies the secret of his progress. Where could man find a multitude of molecules which would be so manageable that he could make them work for him for nothing? He found them where Lenin and Trotzky found their docile Bolsheviki, in a state of anarchy. In any gas the molecules have lost all sense of solidarity and reached a state of complete freedom and independence such as man fortunately has never been able to attain. It is self-determination carried to the limit, for in any gas each molecule is at liberty to do what it likes without regard to what any other molecule may do. Every molecule therefore goes straight ahead in its own way until it runs up against some other molecule or a wall; then it gives the obstacle a kick and goes off in some other direction. The kick is light since the molecule is small, but if all the kicks could be combined and turned in one direction they would amount to something and could be used for something. Force directed by intelligence produces power, and power directed by intelligence produces progress. As soon as man acquired the intelligence he utilized the aimless force of the molecules knocking against

the prison walls of the containing vessel as a motive power for his own purposes. This was accomplished by the simple expedient of making one of the partitions movable. If a crowd of molecules are imprisoned in a steel cylinder they bump incessantly against all the sides equally as though trying to get out. If, now, one of the ends is a piston head, slipping easily in the cylinder, this gets shoved out by the constant pounding until finally the exhausted molecules make their escape into the open air.

WHAT HAPPENS IN AN ENGINE?—If the molecules are crowded into a prison half the size by shoving in the piston partition they naturally knock against it twice as often. This observation is so obvious that you will probably not appreciate it properly until you know that it is called "Boyle's Law." Then again if you shove in the piston head suddenly and crowd the molecules into smaller space they naturally get hot about it and do more knocking than ever. The hotter they get the harder they pound against the prison walls. This also is so easy to see that you will not get credit for it, even from yourself, unless you dignify it by calling it the "Law of Charles" and express it in such words as: "The pressure of a gas at constant volume is proportional to the absolute temperature."

Having now in mind the two laws that all anarchic molecules obey we can see how we can get the most work out of a given number of them. Obviously this will be, first, to confine them in the smallest space and force them to fight their way out to the largest possible space. Secondly, to get them as hot as possible and let them

cool off as completely by exhaustion. Or in other words, the efficiency of an engine depends upon getting the longest possible range of pressure and temperature between the beginning and the end. The automobile is run by two horses, heat and cold. The higher the heat and the lower the cold, the greater the power.

We can use any gas we like for our engine, for all gases behave about the same. Naturally steam was the first gas used in the cylinder. But steam has to be made separately in a boiler and then conducted into the cylinder. And a boiler is a bulky thing and occasionally blows up. To heat the boiler there must be a furnace and to the furnace there must be attached a tall chimney to create a draft. A pile of coal must be at hand and a stoker to shovel it in. If the engine is large and complicated there must be an engineer, duly licensed and a member of the union. There is inevitably tremendous waste of potential energy, for the steam has at best a small fall of temperature while it is doing its work in the cylinder. It is not nearly so hot as the furnace gases which are lost up the chimney.

If in some way we could combine the furnace and the boiler and burn the fuel in the cylinder itself, right where we want to do the work, we could take advantage of the high temperature to get high pressure and simplify the apparatus. This is just what is done in the gasolene engine. The cylinder is made the furnace. Fill it up, by a jerk of the piston rod, with air mingled with a little vaporized gasolene, set it afire with an electric spark. The carbon and the hydrogen of the gasolene unite with the oxygen of the air, forming car-

bon dioxide and steam. The heat of combustion raises both these gases to a high temperature and therefore to a high pressure and the piston is pushed out and turns the wheel, and there we are. We have done away with the big boiler, the tall smokestack, the fiery furnace, the pile of coal, the skilled engineer and the fireman. We can have a range of temperature two or three times as great in the gas engine as in the steam engine and so get two or three times the efficiency. That is, more than twice the percentage of the total energy in the fuel may be got out in the form of usable energy by the gasolene engine besides its advantages in compactness, cleanliness and convenience. No wonder then that it has transformed the conditions of modern life.

The steam engine and the gas engine passed from peaceful competition to armed conflict in 1914 and the newer motive power won the war. Senator Berenger of France said that the Germans expected to win because they had the advantage over France in coal. But the Allies won with the aid of oil. "It was a victory of the automobile over the railroad," he says. This is confirmed by Lord Curzon, who said: "The Allied cause was floated to victory on a wave of oil."

We first realized the possibilities of the new military machine in September, 1914, when we read that the taxicabs and omnibuses of Paris had been mobilized to carry Gallieni's army out from the capital to attack Von Kluck's invading forces in the rear and aid in driving them back from the Marne.

From that time on both parties relied more and more upon the mobility of the motor. Germany, having no

oil fields of her own, was forced to seek a supply in Poland and Roumania and so turned her attention from France and Belgium to the eastern front.

Thanks to the supply of American petroleum the steady line of camions was kept going into Verdun and so the enemy did not pass the cornerstone of the French frontier. But in December, 1917, the French petroleum trust notified their government that their stock would be exhausted by the following March and that they could not supply the army in time to meet the German spring attack. The monthly consumption of gasolene was 30,000 tons and the stock had fallen to 28,000 and soon would be reduced to nothing. Then Premier Clemenceau sent an urgent cablegram to President Wilson, personally requesting him to use his authority to bring the 100,000 tons of tankers from the Pacific to the Atlantic where they might replace those that the Germans had sunk. M. Clemenceau closed his appeal with the words: "If the Allies do not want to lose the war it is necessary that fighting France, in the hour of the supreme German shock, should possess the gasolene which is as necessary as blood in to-morrow's battle."

President Wilson complied, and the Petroleum War Board supplied the ships used to bring the motor fuel to France. Thanks to this prompt action Foch was able to send an auto army to fill the gaps next spring when the British gave way before the German drive toward Amiens.

It is not necessary for me to speak of the gasolene-driven submarines, for what they did and what they nearly did is all too fresh in the memory of us all. But

we should recall that the swift motor boats that guarded the coasts were also run by gasolene.

Nor can I stop to discuss what the new art of aviation meant in the war. Leonardo da Vinci designed a flying machine but it had to wait for five hundred years for a motor light and strong enough to carry it through the air. But aviation as yet plays little part in our everyday lives so let us turn to the automobile, whose influence we can observe for and on ourselves.

In 1896 there were only four gasolene cars in the United States. To-day there are 10,000,000. Of these four pioneer automobiles, one was built by Elwood Haynes of Kokomo, Indiana, one by Henry Ford of Detroit, one by C. E. Duryea of Pennsylvania, and one by Benz of Germany.

These early cars were called "horseless carriages" and that is what they looked like, as though the horses had been unhitched and the buggy left to run down hill alone. Many inventions come in this negative way; wireless telephones, fireless cookers, smokeless powder and the like. Something left out makes something new. This seems to be also nature's way, for biologists tell us that valuable mutations in plants and animals often arise from the omission of some single chromosome that has accidentally got lost in the shuffle.

Gradually, however, the motor car ceased to look like a mere mutilated vehicle and assumed a form and symmetry of its own. The horse, who had most reason to view with alarm the advent of his fiery rival, soon became oblivious to it. The machine, at first refused admittance to the highways, came in the course

of time to dominate them. Up to 1896 automobiles were prohibited from running on the English public roads faster than four miles an hour and even then the law required that a man should walk in front waving a red flag. This had a tendency to hamper the development of the automobile in England. Just so, a hundred years before, Parliament had refused to allow a thirty-mile railroad to be built on which Stephenson's engine could run from Manchester to the sea. Thomas Creevy, who was on the committee that killed the bill in 1825, writes in his diary:

> Well—this devil of a railway is strangled at last . . . this infernal nuisance—the loco-motive Monster, carrying *eighty tons* of goods, and navigated by a tail of smoke and sulphur, coming through every man's grounds between Manchester and Liverpool.

Now the situation is reversed and the auto has the upper hand. It is already proposed to prohibit the use of horses in New York City within a few years. Certainly anybody with a heart, who has seen the city in a snowstorm when the poor horses slip and fall on the icy pavement and have to be whipped to force them through the drifts with a light load, will rejoice when they have been displaced by the tireless and unfeeling truck. Suppose there had never been horses and livery stables in the city. What would happen to the man who tried to introduce them? The police, the health department, the humane societies and the street cleaners would unite to banish horses from the city, but they would have to work quickly to get ahead of the mob. In any innovation the majority of men see the disadvantages

before they see the advantages, while in regard to the things to which they are accustomed they ignore the faults and value the virtues.

THE GREATEST INVENTIONS.—Macaulay says: "Of all inventions, the alphabet and printing press alone excepted, those that have shortened distance have done the most for humanity." Then gasolene, which has given man a higher speed than he ever attained before, must rank among the most beneficial of human inventions. It has enabled man to travel in one hour 180 miles in an automobile and 220 miles in an airplane, and to rise to a height of 41,000 feet in the air, 2,000 feet higher than Mount Everest, which British explorers have been trying vainly to ascend.

Such records, though they may gratify man's ambition, do not benefit his life. The real advantages of rapid transit are that it gives him greater power to overcome the limitations of nature and lengthens his life as measured by his activities. For practical purposes distances are measured by the watch, not by the map. "Twenty minutes from Times Square" means something definite, if true. "Ten miles from Times Square" means nothing, for it varies widely according to direction.

The dimensions of cities, counties, states, and nations depend upon the rapidity of communication. The faster our vehicles the larger may be our political divisions. The smallest territorial unit of our country used to be the school district, which was measured by the length of the legs of the littlest children. This virtually ceases to have significance when the school 'bus

can collect the children from a county and bring them to a central school. The radius of a metropolitan area is determined by the average time taken out of the day in coming in to shop or office and going home again. The extent of territory reached by a newspaper or a store depends on the delay in delivery. Cutting the time in half means multiplying the tributary territory by four, for the area increases as the square of the radius. One may almost say that the area increases as the cube since we have by skyscrapers invaded the third dimension and are building cubical habitations.

Any new scheme of speedier intercommunication tends to expand the boundaries of political divisions. But it does more than that. It weakens the boundaries themselves. Statesmen may cut up continents into countries but science knows no nationality. Ideas will somehow leak through from one language to another. Print and pictures will penetrate anywhere. The map may be coloured like a crazy-quilt, but nobody can put up partitions in the ether. The frontier may be lined with soldiers, the radio will overreach them. The three-mile limit of the high seas has ceased to have meaning. The self-propelled projectile, the auto-airplane, carrying death in its bombs, has no limit to its range. No wall, trench, or barbed-wire fence can shut out the molecules of poison gas. The airplane soars over custom houses. The submarine dives under blockades. The automobile runs across tariff walls.

Science erases the artificial barriers that the politician erects. As the world comes under the sway of science political divisions will be impossible to maintain.

Commerce, the child of science, is doing more to promote the unification of the world than all the politicians. Politics is the art of managing men. It was therefore of supreme importance in the days when war and work were done by men. But as war and work come to be done by machinery the importance of the politician diminishes as the importance of the engineer increases.

The financial side of the automobile business is interesting but puzzling. The best estimate of the annual expenditure on motor cars in this country for 1921 makes the total out to be $7,783,000,000, distributed as follows:

New Cars	$1,448,000,000
Depreciation	1,800,000,000
Interest	295,000,000
Tires	450,000,000
Gasolene	823,000,000
Oil	175,000,000
Garage	552,000,000
Repairs and Supplies	1,000,000,000
Insurance	185,000,000
Taxes	275,000,000
Drivers' Salaries	600,000,000
Road Maintenance	180,000,000
	$7,783,000,000

That is to say, we are spending approximately eight billions of dollars a year on something that did not exist twenty-five years ago.

Where does the money come from? I am not complaining of extravagance. I am not saying that it is a cent too much. But it would be interesting to find out, if we could, from what sources this immense amount of

money has been derived. Here is a new channel of expenditure into which an enormous flood of funds has been suddenly turned. From what other channels has it been diverted? If we say it comes from the recent general increment of wealth or the fictitious increment due to inflation, then we can put the question in another way: For what would this eight billions of dollars be spent if there were no motor cars?

I do not know that the question can be answered statistically but perhaps you get an answer from individual observation or experience. When a man buys a car and spends say a thousand dollars a year on it in interest, depreciation and supplies, what does he economize on? Does he take it out of his savings or what he otherwise would have laid up for a rainy day? But savings and investments have also increased during this period. Does a family after it owns an auto spend less on clothing or food or theatres or books or summer resorts or golf? Or does it spend more? Is there a saving on shoe leather by using rubber tires? But more is spent on shoes and clothing than there used to be. So of almost everything else. The only field in which a definite falling off can be discerned and ascribed to the introduction of the auto is in carriages, city stables and the like, but this is little compared with what is spent on motor cars and motoring.

The building of railroad mileage has been virtually at a standstill for a number of years, though the population and business activity of the country have been increasing. It may be said, then, that a large part of the money spent for motor transportation would other-

wise have been put into spur-line railroads, electric railways or else, which is more probable, there would have been much less in the way of transportation facilities available and consequently less wealth created. The creation of rail lines covering the network of highways over which motor cars travel, would probably be prohibitive in cost.

A saving in the wages of farm workers has been another source of income for automobile investment. There has been a drift of farm population to the cities without as yet a noticeable diminution of the volume of farm products. The decrease in labour has been taken care of by farm machinery, including motor transportation, which has tremendously increased the amount of time at the individual farmer's disposal as compared with the horse-and-buggy days.

Another source of possible saving is in city rents by removal to the suburbs and country, which would leave the difference in rent available for motor transportation. But city rents have not perceptibly fallen and there is also the extension of city deliveries into the vicinity to balance this economy.

Besides the question of money expenditure there is the question of time expenditure, equally important and equally unanswerable. Leaving out of consideration the commercial use of motor cars there is an enormous amount of time spent in pleasure riding, in taking care of the machine and talking about it and in sitting around waiting for a new tire to be put on. How was this time spent formerly or how would it be spent now if there were no automobiles? Here we are not both-

ered by a change in the standard of measurement. The length of the day is one of the few things that the war has not altered. Has there been a decline in sleeping, reading, seeing motion pictures, playing cards, going to church or what? Unfortunately we have no census figures on how we spend our spare time although many less important queries are asked us by the Census Bureau.

I used to ask such questions as these of my students in the School of Journalism at Columbia and while the answers were not always valuable I am sure the questions were. The important thing is to get a realization of the innumerable and various ways in which any such invention affects all our lives. The same question would often bring opposite answers but I was not under the painful necessity of marking either one of them wrong. Take, for instance, this question of the effect of the automobile on church attendance. Some of my students would report that the congregations had fallen off, for the people went riding on sunny days while on rainy days they could not be expected to go to church. But students from other sections would say that church attendance had increased because the people could come from many miles around and it took less time. There would seem to be something in this because the churches have grown in membership during the automobile era and why should people join a church if they do not go to its meetings?

Another question bringing different answers was the effect of the automobile on the spirit of democracy. Students from New York City were apt to say that it

had intensified the tension between social classes because the poor pedestrian resented having to turn out of the road at the honk of the plutocrat and receive a whiff of scorched gasolene in return. On the other hand students from the West reported that the automobile was an agency for democracy for it had wiped out the distinction between classes. Formerly when the few had buggies and the rest had to ride to town in lumber wagons the former set looked down on the other but now that all had automobiles they were substantially on a level. This must be the case in such states as California, Iowa, South Dakota and Nebraska, which have one motor vehicle for each five and a fraction persons, that is, one for every family.

Once I asked my class to "specify the influence of the automobile in political, commercial, social, and martial affairs." I got unexpected answers, for some students seemed to have difficulty in reading my writing on the blackboard and mistook the "martial" for "marital." But I was glad of the misunderstanding for the answers were interesting. Some said that automobiles promoted marriages by providing courting parlours but others said they dissolved marriages for similar reasons. Here, as usually, the truth lies not in the mean but at the extremes. Two opposites may both be true but if we average them we may get nothing, or a falsehood. Many a fallacy has come into sociology through dealing with an average man who does not exist.

It was commonly assumed that the automobile would relieve the congestion of our cities and check what was called their "abnormal growth." The mental

conservatism of the masses of mankind leads them to call anything "abnormal" that is merely unprecedented. The expectation that there would be an exodus from the cities if opportunity were offered was based upon the unconscious assumption that people were more anxious to get out of the city than to get in. But it seems on the contrary that the pressure of population is from the rarer to the more densely inhabited districts: the reverse of the law of gases, for men do not always behave like molecules. Our cities continue to grow and the bigger they are the faster they grow. Autos are more used to bring countrymen into the town than townsmen out to the country. However the balance lies the net result is to bring about a greater mixing of rural and urban population. God made the country. Man made the city. Gasolene made the suburb.

CHANGES IN THE COUNTRY.—The roadside inn has been revived. Front rooms of farmhouses, formerly only opened for weddings and funerals, have been turned into tea houses. Apples and berries, sweet corn and melons, are set out on a box by the roadside in charge of a child as salesman and the passing autos take their pick of the produce as though it were a cafeteria. This brings the grower and eater directly together and omits the middle man or men. That the city dweller is led by a love of nature into the country is evidenced by his effort to bring the country back with him by filling his car with other people's flowering trees and bundles of flowers. But all men kill the thing they love. Before the end of the season there are few flowers left within the radius of the afternoon ride and next season there

may be none, unless some means may be found for adding brains to enthusiasm. A sylvan solitude loses its chief attraction when it becomes densely thronged.

The motor furniture van has facilitated the fondness of Americans for moving. All the contents of a seven-room flat in New York City may be stowed, without crating, in a van and set up in a house in Washington next day without breakage, loss, or delay. Already the motor truck is a close rival to the railroad car in tonnage carried. (In 1921, tonnage carried by truck, 1,430,000,000; by railroads, 1,641,000,000). In the number of passengers and the number of miles they were carried the motor cars have gone far beyond the trains. (In 1921, passengers carried in motor cars, 7,000,000; in railroad cars, 1,000,000. Passenger mileage: motor cars 71,000,000, railroads 37,000,000).

The spread of the automobile created a demand for new materials in large quantities, for something that would give a stouter skeleton and a softer tread. Metals like vanadium and molybdenum, names so unfamiliar to the people that they had to be taught in advertisements how to spell and pronounce them before they could ask for them, were needed to give steel a greater elasticity and strength, and these "rare elements" had to be provided by the thousands of tons. During the automobile races of 1905 in Florida a French machine went to smash. There happened to be hanging about, a man with an abnormal curiosity, Henry Ford. He picked up a fragment of the wrecked racer, a valve stem, and found it lighter and stronger than anything he could make. He had it analyzed and

found that it contained vanadium, a metal that American steel makers did not know how to use. Special furnaces had to be made for it since vanadium melts at 3,000 degrees Fahrenheit and the ordinary steel furnace could not run above 2,700 degrees. But vanadium steel is two and a half times as strong for equal weight as common steel and was therefore peculiarly fitted for a car that was to be light and tough, as well as cheap and simple.

THE BEGINNINGS OF RUBBER.—The boom in rubber had begun before, in the Bicycle Age, when an Irish horse doctor named Dunlop tied a rubber tube around the rim of his boy's velocipede, and blew it full of air. Brazilian forests could not supply the caoutchouc needed for pneumatic tires and electrical apparatus, so attention was turned to the Congo, where a reporter for the New York *Herald* named Stanley had established a Free State under the patronage of the leading European nations and the United States. The protecting powers, anxious to make the natives safe and happy and fearing that they might be exploited if put under one of the greater powers, picked out a benevolent looking old king with a long white beard and gave him a mandate for the Congo. King Leopold of Belgium was a high liver and a free spender in the promotion of the fine arts, especially drama and dancing, and was not content with the 300 to 800 per cent. income on the capital invested. So the Belgian officials in the Congo, to get their tale of rubber, drove the negroes deeper into the jungle. Men were murdered, women were flogged, children had their hands cut off. Finally the Congo

atrocities aroused the moral sense of the world and the Free State was rescued from the hands of Leopold.

In 1910 the price of Para rubber had risen to $2.00 or $3.00 a pound and the forests were being depleted of the trees. Then science came to the rescue and showed how an unlimited supply of the precious gum could be obtained without robbing the natives or ruining the trees. This was by cultivating the rubber tree. The foresighted British and Dutch set out rubber plantations and produced a better product than the wild rubber for 25 cents a pound or less. The United States consumes some 75 per cent. of the world's rubber but it is all foreign grown. Akron, Ohio, alone manufactures over a third of the world's rubber. We found what it meant to have neglected to cultivate our own garden when the war broke out and threatened to ruin the third largest of our industries by taking off our tires. We had to pay whatever the British and the Dutch cared to charge us, and they reaped a rich harvest from their providence, but in 1920, when the automobile business took a sudden slump, the price of rubber fell from 55 cents a pound to 13. Three per cent. of the rubber plantations of the world are now owned by American companies but none of them have been placed in our own tropical possessions. Dutch and British dependencies are evidently considered more dependable than ours. So we see that development of a new motive power affects international relations everywhere. The same thing may bring ruin to the Congo and prosperity to the Malay Peninsula. Recently the British have put an export tax on their rubber and we are beginning to

wake up to the desirability of having a few rubber trees in our own yard. So Congress has consented to appropriate $500,000 to see if we cannot grow rubber under the American flag in the Philippines or elsewhere.

Hardly had the automobile been born before it began to complain about the roads, especially in America. In Europe the roads were better than ours, thanks to the Romans who, whenever they conquered a country, made a good road through it leading straight to Rome and so solid that it lasts to this day. The French cars that we first imported groaned dreadfully over our rough roads, sometimes indeed balked at travelling in the dirt. So we resolved to mend our ways and have done wonders in a few years. In the period 1910–1921 over two and a half billion dollars were spent in road construction in the United States. The Federal Government has come to the aid of the states and at the end of 1921 there had been completed 12,900 miles of good roads, costing about $221,000,000, of which the Federal Government had contributed 46 per cent.

Although the improvement of highways is chiefly due to the demands of the motor car they ease the labour of the surviving horses. The automobiles wear out the roads more than horse-drawn vehicles but on the other hand they contribute heavily to the government revenues. New York City alone takes in $6,000,000 a year in motor fees—not counting fines. In 1921 the states received in registration and license fees and gasolene tax more than $132,000,000. Altogether it is estimated that motor vehicles paid into the treasuries, state, national and municipal, $341,300,000 in 1921.

Taking the locomotive off the rail and putting it on the road is in itself a revolution of wide-reaching influence. With a network of good roads covering the country and with vehicles that require no other track, our population has acquired a flexibility of movement that has amazing consequences. The jitney can shift its routes from day to day according to where the people want to go, while the tramcar must stick to its trolley and track regardless of traffic. A touring car can change its mind in a moment's caprice while the railroad train must follow the time-table. In England the rural districts are getting disturbed by the invasions of cockneys in the char-à-banc or motor lorry.

The transformation of the farm by motor fuel, striking as it seems, is only beginning. Agriculture has so far been comparatively little affected by the industrial revolution. This is because the revolutionary agent, the steam engine, has not found a place upon the farm as it has in the factory. Farm work is too varied and scattered to be run by a central power plant. Look into one of our big steel plants or machine shops and you will be struck by the scarcity of men. The building seems deserted when it is really most active. Here and there is a man moving about looking after things. Groups of three or four may be standing by a process and occasionally intervening. If you find a bunch of a dozen straining their muscles in lifting or pulling you may be sure that something has gone wrong with the machinery and they are fixing it up.

The human muscular labour that has been so largely eliminated from the factory is still the mainstay of

the farm. The horse aids man but does not supplant him. The gasolene motor may do for the farmer what the steam engine could not. The motor is small, light, portable, cheap and easily managed. The tractor is capable of doing the work of two or three teams of horses although it seems that the farmer must still keep a team or two. For the road haul and running to town the motor vehicle is rapidly displacing the old lumber wagon and buggy. There are about three million motor vehicles used on American farms. Of these 150,000 are trucks. The states having most cars on farms are Iowa, Illinois, and Ohio. The states having most trucks on farms are Pennsylvania, New York, and Iowa. In many places gasolene has knocked the picturesque milkmaid off her three-legged stool. A motor will milk a dozen cows at a time and never complain of the chores, and the mechanical milkmaid is more sanitary. The day of the open pail is passing. We may hope to see the man with the hoe supplanted by the man with the Ford. His brow will not slant so much, for the farmer of the future will have to be a high-brow to manage power machinery.

Where will the fuel come from to run all these new machines? The world's oil-tank is running dry and we are not yet in sight of a new supply. The United States, that was the best endowed, has been most extravagant. We have wasted the greater part of our oil and have sold to everybody that would buy. Now, like the foolish virgins, we must ask others for oil and are likely to get the same reply.

Nobody knows how much petroleum there is left in

the ground in various parts of the world, but it is evident that it is not enough to go around.

According to the estimate of the United States Geological Survey there is still underground in the United States some six billion barrels of oil. This seems like a lot, but we are burning over half a billion a year. Half a billion goes into six billion twelve times which would put the date of the practical exhaustion of American oil fields in 1934 at the present rate. But the rate of consumption is increasing. Between 1910 and 1921 the consumption of crude oil in the United States arose 68 per cent., while the domestic production increased only 56 per cent. Therefore our importations increased 600 per cent. for the same period. Last year we had to import more than 125,000,000 barrels of petroleum and we will have to import more and more every year hereafter —if we can get it.

What can take the place of gasolene for the motor? There are two present possibilities: shale oil and alcohol. Either will be more expensive and less satisfactory, so the transition will bring about a new sociological transformation.

I have shown how naturally the distribution and distillation of petroleum led to the concentration of great wealth in the hands of a few individuals. Many of those who "struck it rich" in the early days spent their money about as quickly as they got it on reckless personal extravagance. This had only a temporary effect on society and that altogether bad. But greater wealth has come into the hands of some who have spent it in carefully contrived means for public welfare.

Mr. Rockefeller's donations to education and welfare organizations amount to more than half a billion dollars. From this source about $10,000,000 a year is dispensed, largely for medical education and public sanitation. Last year two millions were promised to Harvard for a school of health, a million to Columbia, three and one half millions for rebuilding the medical schools of Brussels. A complete modern medical school has been established in Peking and twenty-five other medical centres in China have been helped. Consider what it means for the four hundred million people of China to have scientific research established there at this critical period in their history. Nineteen countries besides our southern states have been helped in unhooking the hookworm. Campaigns against yellow fever and malaria have been instigated the world over. How much does that mean for the increase of human health and energy? Notice that these donations, large as they are, do not compare with what the communities concerned will themselves spend in the work thus started. Who can estimate the influence of the University of Chicago and of the other universities which its founding has effected? Here are profound and far-reaching sociological effects resulting from the almost accidental accumulation of this wealth in the hands of one particular man. Any other man or group of men would have spent it differently, worse or more wisely, as you choose to think.

How Has Gasolene Affected Us?—I must not close without mention of the psychological effects of the introduction of gasolene, its influence on the mind of

man. The horseman realizes that he is dealing with an intelligent or a wilful, capricious, and perhaps vicious animal, whose conduct will be affected by his own temper. The chauffeur knows that he is handling a machine which cannot be punished or coaxed. Anger has no effect on an auto-engine. To display or even to feel any emotion toward it is simply silly. In Wells's Freudian novel, "The Secret Places of the Heart," the man who in a fit of fury smashes up his wife's dainty sedan betrays thereby his subconscious animosity toward the owner. The substitution of machinery for all slave and animal power and even in large part for personal service must in the long run have very profound effects on human character.

A professor of psychiatry tells me that he prescribes automobile driving for certain types of nervous patients, especially such as suffer from inability to concentrate their minds on anything outside of themselves or who are deficient in quick decision. The chauffeur who hesitates is lost. The automobile obviously cultivates celerity of decision on the part of the pedestrian as well as of the driver. When the automobile first came into use it was said that it was dividing the population into two classes: the quick and the dead. This has ceased to be a joke. More than twelve thousand persons are killed each year in the United States by automobiles. How many persons do you suppose were killed in Great Britain during the late war by all the shells and bombs from German ships and airplanes and zeppelins? Six hundred forty-two, or about 1 per cent. of our death rate from motor cars.

The acquisition of external energy, as in employment of gasolene, means an augmentation of the individual. The management of a machine gives one a sense of personal power, much like that of the consciousness of controlling other human beings but less harmful in its reflex effect on the possessor of the power. This sense of power is doubtless one of the chief reasons for the fondness for fast driving. The best expression of this feeling that I have found in literature is the following passage in Maurice Maeterlinck's essay on the automobile in "The Double Garden":

> The pace grows faster and faster, the delirious wheels cry aloud in their gladness. And at first the road comes moving towards me, like a bride waving palms, rhythmically keeping time to some joyous melody. But soon it grows frantic, springs forward, and throws itself madly upon me, rushing under the car like a furious torrent, whose foam lashes my face; it drowns me beneath its waves, it blinds me with its breath! . . . Now the road drops sheer into the abyss, and the magical carriage rushes ahead of it. The trees, that for so many slow-moving years have serenely dwelt on its borders, shrink back in dread of disaster. They seem to be hastening one to the other to approach their green heads, and in startled groups to debate how to bar the way of the strange apparition. But as this rushes onward, they take panic, and scatter and fly, each one seeking its own habitual place; and as I pass they bend tumultuously forward, and their myriad leaves, quick to the mad joy of the force that is chanting its hymn, murmur in my ears the voluble psalm of Space, acclaiming and greeting the enemy that hitherto has always been conquered but now at last triumphs: Speed. . . . Space and Time, its invisible brother, are perhaps the two great enemies of mankind. Could we conquer these, we should be as the gods.

When I told M. Maeterlinck how much I admired it he laughed heartily and said that the inspiration of the rhapsody was one of the primitive five-horse-power

machines of twenty years ago that got out of breath when it climbed a hill and occasionally broke down on a level. But I do not think he can write any better now that he has a modern racer.

The French seem to be quicker than we in perceiving the poetry in modern inventions. Maeterlinck's prose poem on the first automobile may be matched by Edmond Rostand's sonnet on the first airplane:

J'avais sur la montagne un grand jardin secret
Mais, ce soir, se levant du fond de la campagne,
Le long biplan que l'œil des bergers accompagne
Vint à ma solitude infliger un soufflet.
Car, doublant mon toit basque où, presque, il s'éraflait,
Le monstre pour lequel il n'est plus de montagne
Passa sur mon jardin comme le vent d'Espagne,
Et mon sable eut son ombre, et mon lac son reflet!
J'aurais dû t'en vouloir, Ô beau monstre de toile,
Moi qui n'ayant cherché que l'aigle et que l'étoile
Suis venu sur ce mont, loin du plaisir humain,
Pour avoir à moi seul un ciel qui se déploie!
Mais j'ai crié d'orgueil et j'ai pleuré de joie
Lorsque j'ai vu mon ciel devenir un chemin![1]

[1]For the benefit of those who do not read French my wife has put this poem into English verse:

A high and secret garden was my own.
This evening, rising from the low champaign,
While shepherds stood astare, the long biplane
Above my sheltered seat was swiftly blown,
And buzzed about my Basque roof with its drone!
The linen monster mountains bar in vain,
Passed o'er my garden like the wind from Spain;
A moment's shadow on my lake was thrown.
Fair monster! Should I not have wished you far;
I, who to seek the eagle and the star,
To claim a space of heaven for my abode,
Had climbed the height to human joy denied?
I wept with joy and shouted out with pride
To see this heaven of mine become a road!

Guide to Further Reading

"Discoveries and Inventions of the Twentieth Century," by Edward Cressy. (Dutton and Company.) Contains chapters on petroleum and gas engines.

"Chemical Discovery and Invention in the Twentieth Century," by Sir W. A. Tilden. (Dutton and Company.) 1916. Contains chapters on petroleum and rubber.

"America's Power Resources," by C. G. Gilbert and J. E. Pogue. (Century Company.) 1921. Shows the economic significance of coal, oil and water-power. See also the same authors' "Energy Resources of the United States," Bulletin 102, Smithsonian Institution, Washington.

"Gasoline and Other Motor Fuels," by Carleton Ellis and Joseph V. Meigs. (Van Nostrand Company.) 1922. Comprehensive volume on the manufacture of gasolene.

Reports of the United States Bureau of Mines for statistics of production of petroleum products.

Yearbook of the National Automobile Chamber of Commerce (N. Y.), and current motor magazines for figures on the development of the industry.

For the sociological effects of the introduction of the gasolene motor the reader will have to rely upon his own powers of observation and reasoning.

THE INFLUENCE OF COAL-TAR ON CIVILIZATION

By Edwin E. Slosson

WHAT were the most precious things in the ancient world? What would a king bring to a great king whose favour he sought? What would the great king offer to his god? When a daring trader had reached the Far East after untold hardships by land and sea for many months, what commodities would he pick out to purchase and take back, knowing that he must make his fortune out of what he could carry on a camel's back, or perhaps his own, through the torrid desert, beset by robbers, and over the icy mountains? You know what he could buy to take back if you know your Bible, or even if you know your Arabian Nights. You could inventory that cargo from such fragments of ancient verse or prose as linger in your memory. You know that when his pack of rare and precious goods was opened it would be found to be filled largely with what are now called coal-tar compounds. Not much else, except gold and gems. There would be dyes and drugs, perfumes, and preservatives; whatever amorous youth would choose to enhance the beauty of his lady love, and whatever pious youth would use to embalm the body of his father; whatever

would colour the curtains of the palace of the king or of the temple of the deity; whatever would serve to scent the banquet hall or ascend to heaven as incense from the altar.

Now these that were the gifts of kings, the prerogative of royalty, the acme of luxury, all these have, by the bounty of science, been put within the reach of all. To be born to the purple is no longer a distinction. It is the natural heritage of any American babe. King Solomon in all his glory was not arrayed like a lady who has all the aniline dyes at her disposal. The shop girl may rival the Queen of Sheba in her employment of perfume—and she often does.

But notice this—that perfumes and similar luxuries are not used so lavishly now when they are cheap as in the days when they were rarities. They are not abused by the many as they were by the privileged few. We may think that nowadays some people put too much scented unguent on their person, but we never see any one with so much of it as was used in the case of Aaron, where it soaked his head, ran down to the tip of his beard and went on to grease his garments to the skirt and doubtless formed a puddle on the floor. If we should see and smell anything like that to-day, there would indeed be reason for outcry against the growing extravagance of the age.

All of the comforts and conveniences of our ordinary life were on their introduction denounced by moralists as extravagant and demoralizing luxuries. Juvenal declared that Rome was in decadence because the rich used ice and white bread at their banquets. But now-

adays to live on white bread and iced water is not regarded as wicked indulgence. Nobody objects to it except those who think that brown bread and tepid water are better for the health.

This does not prove that Juvenal and such satirists were wrong. On the contrary they were doubtless right, for the aristocrat who ate white bread and drank cold drinks when nobody else in the city could afford them, did feel a selfish satisfaction at his superiority and so it was demoralizing to him. But when the roller mill and the refrigerating machine brought these table delicacies to the level of common life they became quite harmless.

The way to make a luxury innocuous is to make enough of it to go around. When it becomes cheap it ceases to be extravagant, and when it becomes common it ceases to be exclusive, and therefore it is no longer a menace to morality. Isaiah was doubtless justified in denouncing the daughters of Zion for their "changeable suits of apparel," but I do not think he would say the same now when a package of dye soap can be bought for ten cents. For the ladies who change the colour of their apparel by the use of such coal-tar products do not, I am sure, feel sinfully set up about it.

The coal-tar products form a new factor in our civilization. Not long ago, chemists celebrated the fiftieth anniversary of the day when a London schoolboy, washing up his glassware after an experiment that had failed, found that the black sticky stuff in his beaker kept colouring the wash water purplish. Like Columbus and Saul, young Perkin had failed to find what he was

looking for, but had hit upon something greater. He was after quinine, but he had accidentally entered the unknown field of aniline dyes and drugs, many of which are more valuable to the world than the knowledge of how to make quinine without the aid of Peruvian bark. He was working in a laboratory that he had fitted up for himself at home because the Royal College of Science was not open enough hours to satisfy him, and he was using impure chemicals. This was fortunate, for if his aniline had been pure he would have missed mauve.

The first coal-tar dye, mauve, was discovered in the Easter vacation of 1856. Note the date, I mean the time of year. It is significant. Not because it was Easter, although you may have a childhood association of aniline dyes with Easter eggs. But it was in vacation. It was made by a boy who played hooky from vacation, by a boy who had rather work than eat, so he spent his noon hour fussing with chemical apparatus. There are such boys even now in spite of the fact that they are persecuted by their classmates as grinds and are not always encouraged by their teacher. I don't know how William Henry was treated by his schoolmates, but he was encouraged by his teacher in the most effective fashion by being set at a discouraging task, in fact an impossible task to him, one that has not yet been accomplished—the synthesis of artificial quinine.

The English and the French at first entered with enthusiasm upon the preparation of new coal-tar compounds, but were ultimately distanced by the Germans,

who made the research laboratory a part of the factory and by thus putting their industries under scientific guidance had, before the war, obtained practically a world monopoly of the manufacture of synthetic organic chemicals.

The 1914 edition of Schultz and Julius Dyestuff Tables listed 925 coal-tar dyes as used in the trade, but the chemist knows of thousands of others that he might make if needed. We already have dyes for all kinds of material and for any desired colour and shade. Some are fast and some are fugitive. Some are glaring and some are dull. Some are cheap and some are dear. Some are poisonous and some are harmless. It is absurd to condemn or commend the coal-tar colours as a whole, because they differ in every possible respect.

That is, the dyer of to-day has a thousand pigments on his palette not counting shades and combinations. Before the discovery of mauve in 1856—you will remember that date if I repeat it often enough—there were barely a score of dyestuffs in general use, mostly barks and roots of uncertain composition. It is hard for us to realize what a different-looking world we are living in, thanks to coal-tar compounds, and still harder to express in words the difference in æsthetic effect.

Coal-tar has brought more colour into our dull lives, not only through our clothing but also through our food. Food and drink, appropriately tinted, become more attractive, and being more attractive become more appetizing, and being more appetizing become more digestible, and being more digestible become more nutritious, and being more nutritious become more strength-

ening. Each step in this Aristotelian sorites has, I believe, been experimentally demonstrated, so it seems to lead logically to the conclusion that the increasing use of aniline dyes in food products has added to the energy of the nation. I do not put entire faith in Aristotle's logic until it is confirmed by the calorimeter, so I will not press this argument, but content myself with the safe observation that the coal-tar colours add to popular pleasure, whether or not they increase the public efficiency That they are at least harmless is assured by the United States Department of Agriculture, which analyzes every batch of dyes used in edible products to see that they are not in themselves poisonous and do not contain accidental arsenic. No new dye is added to the allowed list until it has been put through a long series of tests, first on animals, then on man, to see that it is not injurious, even in much larger amounts than are to be used in edibles.

The use of artificial colours in foodstuffs is increasing rapidly. About 500,000 pounds of dyes are used every year in the United States for colouring foods and drinks. This is some four times greater than the quantity used a few years ago. The favourite colours in this field are the same as those which periodical publishers have ascertained to have the greatest selling value on the cover of a magazine, red and yellow. I leave it to the psychologist to explain this popular preference for the longer wavelengths of the spectrum. The red dyes go largely into frankfurters and the yellow into butter and rival spreads, while all the colours of the rainbow are in demand for cake and candy icings and ice cream, and for

the wide variety of soft drinks that are gradually weaning the American people away from hard liquor. Four billion pints of bottled soda are consumed annually in the United States, not counting what is sold from fountains.

Another indication of the popular trend toward a gayer taste is the use of chemical compounds with intent to increase the attractiveness of the naturally more attractive sex. The people of the United States are now spending about one hundred million dollars a year on perfumes and cosmetics. We are importing four times as much of these, measured by cost, as we were before the war and we are exporting ten times as much.

I will not attempt to apply here the syllogistic chain used above, for experimental evidence is almost altogether lacking. Since odours are known to have a profound influence upon the emotions, the effects of the wider use of perfumes and the introduction of new scents cannot be negligible, although they may be indeterminable.

In the manufacture of fine odours the chemist is rapidly catching up with the flowers; in fact has already surpassed them in some lines. Let not the reader stick up his nose at synthetic perfumes. We could not get along without them. In fact we are altogether dependent upon them for certain popular forms of perfumery, for many flowers do not give up their scent satisfactorily and so the perfumer has to imitate it as best he can. For instance, the perfumes sold under the names of arbutus, sweet peas, mayflower, cyclamen, magnolia, phlox, honeysuckle, lilac, and lily of the valley

are not produced from the flowers, but are put together by the perfumer from chemical compounds or other floral essences.

In the field of perfumes and flavours the benzene derivatives, natural or artificial, play a prominent part. This world would lose a large part of its delight if the "aromatics" should be deprived of the power of titillating our two chemical senses, taste and smell. These six-membered carbon rings enter into all sorts of combinations and serve us in various ways. For instance, anthranilic acid in divers forms gives us the odour of jasmine and orange blossoms, the flavour of the grape, and the colour of indigo.

Salicylic acid cures our corns and relieves our rheumatism and in combination with the deadly "wood alcohol" (now rechristened "methanol" to keep people from drinking it) gives us the wintergreen flavour for which we Americans inherit a taste from our New England ancestors. Saccharin, a coal-tar product, is several hundred times sweeter than sugar. It is altogether lacking in nutritive value, but a dietary experiment on the largest conceivable scale, namely its daily use by many millions of Europeans for several years during the sugar shortage in the late war, should remove the popular impression acquired during the pure food campaign, that it is injurious to health. This has been recently confirmed by M. Bonjean of the Superior Council of French Public Hygiene who made a series of physiological experiments of long duration with men and dogs in all doses practically possible and found no derangement of health or digestion.

The familiar phrase for anything particularly expensive or extravagant, "It costs like smoke," implies doubtless an unconscious realization of the fact that oxidation is the reversal of the synthetic reaction, the undoing of the constructive activity of animate nature. The plant builds. Man utilizes. Fire destroys. Now one of the most wasteful forms of smoke was that which poured uninterruptedly during the great part of the last century from the open tops of the beehive coke ovens. In fact one can yet see these prodigal flares on the Pennsylvania mountains as he looks out of his Pullman window in the night. This is not merely a waste of fossil fuel, which we already begin to realize will not last for ever, but there is also a loss of a variety of compounds that can be made very useful if properly worked up. If a ton of bituminous coal is heated in a closed retort instead of the open beehive, we may get besides the gas and the coke, a dozen pounds of ammonium sulfate and a dozen gallons of tar. The ammonium sulfate is valuable as a fertilizer, since it will feed nitrogen to the crops, and the tar on redistillation will yield a dozen products out of which some 200,000 distinct organic compounds may be made, some of which are extremely useful to mankind.

There is no use crying over lost coal-tar, but the time is coming when we must be more economical. I do not want to use language instigating violence, because that is against the law, so I will merely quote Admiral Dumas, Secretary of the British Royal Commission on Oil Fuel, who said not long ago:

"I would like to see a government official hanged on

every lamp-post where gas is burned, because benzol goes up with the flame." He had in mind particularly the impending shortage of gasolene, for which benzol, or benzene as we call it, is a suitable substitute as motor fuel.

Before the war the British were glad to sell their surplus tar at low price to the Germans who made out of it all sorts of dyes and drugs which they sold back to the British at high prices. The Germans also found the stuff useful for the manufacture of high explosives which however, they were not so anxious to sell abroad but preferred to keep at home for purposes best known to themselves.

We Americans, too, were neglectful of the explosive possibilities of the coal-tar products. Indeed, there was then a prevalent feeling that war was an anachronism and would gradually sink into innocuous desuetude. We Americans have a curious belief that anachronisms die out spontaneously if let alone, whereas history shows that they are very long-lived creatures and rarely die of old age but usually have to be killed off. In 1914 there were only enough by-product coke-ovens in the United States to turn out 700,000 pounds of toluene a month. Toluene is used in wartime for making trinitrotoluene, familiarly known as TNT, but there was not much demand for it then, so most of the coke makers let it burn. When America entered the war our Government persuaded them, more or less imperatively, to put in by-product coke-ovens, and by 1918 they could turn out 12,000,000 pounds of toluene a month.

The Great War differed from all former wars in the

use made of high explosives; that is, compounds that can be kept and carried with comparative safety but which explode with terrific violence on being set off by a percussion cap of the right sort. The Germans with the chemical factories and nitrate plants were better prepared with these new weapons of warfare and that is why they burst through the border with such alarming speed. The steel and concrete cupolas of the Belgian and French fortresses were shattered to pieces by single shells from the 42 centimetre guns. The British troops had to fall back rapidly before Von Kluck's army and even then narrowly escaped destruction. Lord Kitchener and the British general staff were slow to realize that the old means of defence and offence were useless against the coal-tar munitions, but finally word was got to the British people that the army in France must have high explosives or perish. They got them in time to make a stand after the first German drive had spent its initial force and so coal-tar products "won the war."

In considering coal-tar explosives we must not think that their usefulness is confined to settling the relative strength of nations in war. Explosives are simply compact packages of potential chemical energy put up in a form ready for quick release, and as such they are valuable in various ways. In 1921 the United States produced and used for industrial purposes 538,000,000 pounds of explosives. This does not include exports, but includes explosives not made from coal-tar, such as gunpowder and nitroglycerin.

Carbolic acid, which the chemist calls "phenol,"

comes directly from coal tar. If this is acted upon by nitric acid, picric acid is formed, which is a dye, a drug, and an explosive. Treat picric acid with chlorine and we get chlorpicrin, one of the poison gases first used in the late war. The mother substance of this group of aromatic compounds is benzene, a colourless liquid. Treated with nitric acid this becomes nitrobenzene, and this reduced by hydrogen gives aniline, from which the innumerable and variously coloured aniline dyes are made. Acting on aniline dye with acetic acid, the acid of vinegar, gives us acetanilid, a headache remedy, or, rather, relief. Toluene, the next member of the series to benzene, can be converted by similar treatment into dyes and drugs, explosives and sedatives, perfumes and poison gas. The benzene family is remarkably versatile. What is made for one purpose often serves for another. During the war the women munition workers in England were found to be using trinitrotoluene for dyeing their hair an auburn shade, and had to be warned against the dangerous practice by an official of the Explosives Department.

When we were children and played the "game of twenty questions" we always used to begin by asking "Is it animal, mineral, or vegetable?" We thought by that to corner the unknown object in one of the three kingdoms of nature, for it did not occur to us that any material thing could belong to more than one or lie outside of all three. But there are no lines in nature. What seem to us such are but merely the boundaries of our own ignorance. The synthetic products of chemical art, since they are built up from the primary elements

themselves, do not properly belong to any one of the traditional three kingdoms for they may be made from material found in any of them and the product is the same whatever the source. So with the substances that we are considering. They are commonly called coal-tar products because that is the ordinary source of the raw material, for tar is a by-product of the gas and coke industry, formerly thrown away and even yet often wasted. But it is necessary to understand that there is nothing exclusive or peculiar about coal-tar. It does not contain the various valuable things that are made from it. These are mostly composed of four elements, the commonest in the world: carbon, hydrogen, oxygen, and nitrogen. These four make up air and water, and out of air and water these compounds could be made, although it would be a difficult and expensive process.

In the chemistry books they are known either as the "aromatic compounds," because a good many of them have an aromatic odour, or the "benzene series" from the light colourless oil known as benzene which distils off when tar is heated, and which serves as the basic substance of those compounds. This benzene is composed of molecules consisting of six carbon atoms hooked up into a ring. But the benzene ring and similar structures are commonly found in vegetable and animal substances.

The reason why I call your attention to this is that there is a prevalent impression that the coal-tar products are some new invention of the chemists, perhaps instigated by the devil with whom chemists have always been accused of being too familiar. Many of the things

that are now made from coal-tar were formerly extracted from plants.

Indigo, for instance, has been prepared from the most ancient time out of the juice of a plant grown in India. The preparation of the dye was a toilsome process. The natives cut the plant by hand, squatting on the ground, and then beat it up in vats with paddles, standing up to their waists in the blue liquid. In 1896 there were more than a million and a half acres devoted to its culture in that country. Shortly after that the Germans invented a way of making artificial indigo—no, let us say more correctly, of making indigo artificially—from coal-tar, and then the land and natives of India were released for better employment. Since the war America makes her own indigo and has enough surplus to export. In 1920 there was produced in the United States more than 18,000,000 pounds of indigo, which is more than twice what we imported before the war.

Next to indigo the most popular of the old vegetable dyes was madder. This has been used for more than two thousand years. It is the ground root of an Asian plant and is known as "Turkey Red." Extensive fields were given over to its culture in France and the Netherlands until 1869 when two German chemists, Graebe and Liebermann, discovered how to make the pure dyestuff, alizarin, from a waste product of coal-tar, anthracene. The artificial alizarin is better and cheaper, and this early triumph of synthetic chemistry was, at the end of the first decade of its manufacture, saving the world $20,000,000 a year, and is now saving

much more than that. As Professor W. A. Noyes recently put it:

"It is scarcely an exaggeration to say that enough has been saved from this to pay for all the university laboratories in the world."

Let us consider another famous dye, the royal purple. You may recall what Browning says of it in the poem "Popularity."

> Who has not heard how Tyrian shells
> Enclosed the blue, that dye of dyes
> Whereof one drop worked miracles,
> And colored like Astarte's eyes
> Raw silk the merchant sells?

Now this same royal purple that used to be extracted drop by drop from the Mediterranean mollusc may be made by the ton from coal-tar. Why is it not? Because it is not good enough to satisfy modern taste. Some of the new aniline dyes are superior to it.

This idea that the coal-tar products are artificial and unnatural sometimes leads to amusing consequences. In the days when the newspapers were publishing scare stories about the poisonousness of benzoic acid, an over-zealous food inspector tried to confiscate a carful of cranberries because he found benzoic acid in them. But when he attempted to get at the person responsible for putting in the forbidden preservative so that He could be properly punished, He was found to be too high up and powerful for the police to reach, being no less a personage than the Creator of Heaven and Earth and all that in them is. He puts benzoic acid into cran-

berries whenever He makes them, whatever may be the law of the land.

A similar instance occurred recently. The leading manufacturer of grape juice was accused of adding another coal-tar preservative, namely anthranilic acid, to his bottled product. But this also turned out to be a case of "natural adulteration," so to speak, for all grapes of this species contain anthranilic acid; in fact, that is what gives them their pleasant flavour.

We could not rule the coal-tar products, these benzene compounds, out of our life if we wanted to, and we certainly do not want to, for they furnish a large part of the beauty and pleasure of the world, of the flavours of its fruits, the perfumes of its flowers, the colours of its plants. Yet you will now hear some foolish craftsman say that we ought to do away with aniline dyes and go back to such good old vegetable colouring matters as indigo and madder. But we can beat nature at making these same things, as well as make others even more beautiful that nature cannot make.

In the incessant warfare between man and microbe the human side received a powerful ally when coal-tar came to its aid, because then for the first time man could see his insidious foes. For thousands of years man had seen men and children, the strongest of the warriors and wisest of the elders, struck down by invisibles enemies against whom he had no weapons, for he did not know what they were nor whence they came. No wonder he thought such deaths were due to the unseen arrows of evil spirits. But by 1880 the bandage was lifted from the eyes of man, for about that time

Robert Koch and others began to use aniline dyes to stain the microscopic disease germs and to catch their pictures on the photographic plate, developed by coal-tar chemicals. From that time on, as he said, discoveries fell into the lap of the investigator like ripe fruit. In 1882 he discovered the bacillus of tuberculosis and in the following year the bacillus of Asiatic cholera.

The bacillus of typhoid fever was discovered in 1880 and in 1896 a serum was prepared to prevent it. What this has meant for public health we are all vaguely aware, but a few figures may fix our ideas. In our war with Spain where we had 107,973 men in encampments, 20,738 of them were taken down with typhoid and 1,580 of them died of it. But in 1912, when we had 12,801 men under similar conditions stationed on the Mexican border, only two cases developed, while in the Great War there were only 227 deaths from fever in all the American armies during two years. This microbe that had been the most formidable foe in previous wars has been finally conquered because we know where it lives and how it is carried and can even prepare the body in advance to resist it, if in spite of our precautions it gains entrace.

It is not a matter of chance that certain dyes have been found valuable as drugs. The same thing that makes them good dyes makes them good medicines; that is, their ability to attach themselves to some particular kind of animal or vegetable substance. Many of our most dangerous diseases are, as we now know, due to minute vegetable or animal parasites, bacteria or protozoa, that flourish in the blood and at our expense.

But these are hard to see on a microscope slide where they are mixed up with all sorts of similar cells and tissues and may be quite invisible. It was fortunately found that the aniline dyes were useful in bringing out the various substances, for some would be stained with a particular colour while other things on the slide were unaffected. Those of you who have tried home dyeing will have found that in a piece of cloth composed of mixed cotton and wool, the dye is apt to attach itself to one kind of thread and leave the other untinted.

One day Dr. Koch was being shown through the Breslau laboratories, and as he passed a table where a young student was busily engaged in staining microscope slides, he was told: "This is our little Ehrlich. He is a first-class stainer of tissues, but he will never pass his examinations." In fact, he never did, but his "staining of tissues" led to the new science of chemotherapy which has given remedies for diseases hitherto incurable. He found first that fuchsine, a familiar red dye, would stain the tubercle bacilli so that they could be seen on a miscroscope slide. Later he found that these stains would act even in the living cell. He discovered that methylene blue, a common colouring matter, would seek out and destroy the parasite that causes the quartan type of malarial fever. With this as a clue he set about making molecules that would not only search out and attach themselves to the pernicious parasite, but carry along a dose of poison. For instance salvarsan, otherwise known as "606," or as it has been rechristened in America since the war, arsphenamine, consists of two aniline rings with arsenic atoms attached.

The number shows the difficulty of this research, for it means that 605 failures preceded this success.

The only way to get a realizing sense of the influence of the introduction of these coal-tar compounds is to pick out one of them and consider what pleasure or pain it has brought into the world, how much suffering it has caused or cured.

For instance, did you ever have a headache that you relieved by aspirin or any of the other coal-tar remedies? If so, multiply your headache by as many million times as you think other people have been so relieved and by as many years as you think people will continue to have headaches.

Did you ever have a tooth pulled without, and another one with, the use of a local anesthetic? If so, you are in position to estimate in some degree the amount of human misery that has been eliminated by the invention of procaine (novocain) and similar pain-killers.

Did you ever see an epileptic fit? Then imagine that seizure and thousands like it prevented by the use of luminal.

Did you ever lose a friend from diphtheria? Then you can realize what it meant to the world that the bacterium of the disease was made visible by staining with methylene blue, so that physicians could identify it in any suspected case and administer an anti-toxic serum.

Statistics are meaningless to us unless we can translate them into concrete terms.

Who can estimate the increase in industrial efficiency

and individual happiness caused by the abolition of malarial mosquitoes in a community whose inhabitants have shaken for generations with "fever and ague?"

In many warm countries the energy of 80 per cent. of the population is being continually sapped by the hookworms which they carry about with them but which may be expelled by thymol, one of the benzene compounds. I quote a single minor incident in the anti-hookworm campaign from the 1921 Report of the Rockefeller Foundation:

> Three estates in Sumatra which, in spite of all recommendations, refused to adopt hookworm control measures, had in the course of two and one half years 4,657 admissions to the hospital. Three other estates with a laboring force of the same size which did adopt these measures had only 1,034 admissions—a difference of 78 per cent. One hospital admission represented on the average twenty-two days of treatment, which, reckoned at fifty cents a day, meant an aggregate loss of no less than 40,000 guilders during a period of only two and one half years.

A striking illustration of the possible importance of a coal-tar compound comes to hand as I am writing this. The Germans are talking of trading off Bayer 205 for their lost African colonies. Bayer 205 is a secret synthetic medicine, presumably a coal-tar derivative like the previously known remedies of the sort, which is supposed to be a sure cure for the sleeping sickness. It is said to be fatal to the trypanosomes, the minute creatures with whip-like tail and spiral movement, that invade the blood of men and cattle in tropical Africa and bring them to a stupor that ends in death. These microbes are conveyed and injected by the tsetse fly, as fevers are by mosquitoes. The opening up of trade

routes through Africa has carried the fly and the parasite into the heart of the dark continent and almost depopulated large areas. The white man has found his dearly bought possessions valueless because neither man nor beast could live there except under constant danger of the "pestilence that flieth by night." Various coal-tar products have been found effective against the trypanosomes. Ehrlich used trypan rose, an aniline dye, and Koch used atoxyl, an arsenic compound, but none proved a complete and permanent cure once the vicious little animals were in the blood.

We may question the right of the Germans to withhold knowledge of such a boon to humanity until they get their price for it, although the price demanded is hardly greater than the total profit that has been derived from other remedies and not by Germans alone. We may surmise, too, that the Germans could not keep the secret of Bayer 205 very long anyway, for if the drug comes into general use somebody will analyze it, whatever the promises under which it may be supplied. Or the pharmacologists of other countries would in time work out the formula for themselves since they already can give a shrewd guess at what sort of a substance it is.

But assuming that Bayer 205 is all that is claimed for it and will rid Africa of its plague and that Germans have a monopoly of it, then the British, French, and Belgians could well afford to trade off to Germany a large part of the immense territories they won by the war, for the value of the remainder would be immeasurably enhanced. It is not at all likely that such a bargain will be struck, but the mere fact that it has been

suggested shows that a single coal-tar compound might have a value that would make it a factor of importance in international relations.

It is unnecessary to expand upon their war-time importance, but I must call attention to two revolutionary changes that chemical warfare has made in the balance of power. First, it has already increased the superiority of the civilized man over the savage and of the scientific and industrial nation over the ignorant and primitive. There is no longer any danger that civilized nations will be overwhelmed by barbarians, as has often happened in the past, unless indeed we hatch our own barbarians in our midst. In ancient times, when martial prowess meant merely the muscular ability to wield a sword or spear and a fondness for fighting, the barbarian was likely to be more than a match for the civilian. But with the introduction of chemical warfare by the use of gunpowder in the 14th century, the balance turned in favour of the scientist against the savage, and the odds have increased ever since. Second, the recent development of chemical warfare in the way of high explosives and toxic gases has given the defence an advantage against the offensive and has made numbers less important than intelligence.

I picked out coal-tar as a topic because it is such unpromising material; black, smelly, sticky stuff, neither liquid nor solid but variably between, depending on the temperature, hard to handle because it could be neither poured like oil nor picked up like coal, combustible but not convenient for fuel, poisonous to fish if run into the water and offensive to folks if left on the land. It was

worse than a waste product: it was a nuisance. It clogged up the gas works in the old days and could hardly be given away.

When the chemist took this disagreeable stuff in hand he extracted from it, or rather prepared out of it, useful and beautiful things innumerable. Out of the strong came forth sweetness. The most dainty perfumes, the most brilliant colours, the most potent drugs, the most violent explosives, the means of destroying life and extending life, and making life more enjoyable. A good chemist, like a good cook, is one who can make best use of left-overs.

Yet coal-tar is not peculiar in its ability to contribute to man's needs. There are dozens of other forms of waste that might be made as valuable lying around loose. As I look out of the window for lack of an illustration, I see the ground covered with autumn leaves and dried weeds standing thick by the roadside. I wonder how many million tons of such vegetable matter containing all sorts of carbon compounds go to waste in the woods and wilds of the world every year without serving any other purpose than to refresh the humus of the soil. And then there is sawdust, and peanut shucks, oathulls, corncobs, straw, and the refuse from sugar factories, oil mills, and wood-pulp works; any of these and their like might well be worked up into all sorts of desirable commodities.

The production of coal-tar compounds is an important industry, and I have not tried to conceal its importance in these pages. But it is not a big business. It is one of the minor chemical industries as measured

by financial income or avoirdupois output. It does not compare in these respects with such chemical industries as steel-making, glass-making, sugar-making, or cement-making. The coal-tar dyes manufactured in the United States in 1921 were valued at $32,400,000, but the chewing gum manufactured was worth—or was sold for—much more ($51,240,000 in 1919).

But 1921 was an off year all around. Let us rather consider the famous year of 1920 when the United States manufactured 88,000,000 pounds of dyes valued at $95,000,000. This is nearly as much as we imported, chiefly from Germany, in 1914 when we did not have any dye industry to speak of. We exported American-made dyes in 1920 to the value of $30,000,000, which is a big advance over 1914 when we exported only $400,000 worth, and considerably higher than 1921, when we exported $6,270,000 worth. Still our home industry is not yet sufficient to satisfy our needs for all kinds of dyes, so in 1921 we imported about 4,000,000 pounds of dyes valued at $5,000,000, about nine tenths of which came from Germany and Switzerland. Besides dyes, the United States manufactured in 1920 coal-tar medicinals to the amount of 5,000,000 pounds and the value of $5,700,000, and perfumes and flavours to the amount of 100,000 pounds and the value of $300,000. Whether this infant industry will thrive or decline under the new tariff law remains to be seen and does not concern us here since we are considering only the influence of these products on the world at large. The figures and facts given are sufficient to show how rapidly a new industry, created out of a waste product, can assume in-

ternational importance and affect in various ways the lives of all of us.

The aesthetic and emotional effects of such new factors in our civilization are doubtless more important than the material but they are more apt to be underestimated because they cannot be figured in pounds or dollars. What, for instance, is the psychological influence of the varied tints that our chemists have recently introduced? On this point we should consult the sex that takes most delight in colour, or at least makes most use of it. So I quote without permission from a private letter I recently received from a professor of chemistry in one of the leading colleges for women:

> Our colours are so much more beautiful than those which we had formerly. I remember the first aniline dyes which were introduced when I was a little girl. "Crushed strawberry" and "raspberry" were fashionable. The colours improved greatly, but they have never since then been so beautiful as they are getting to be now. There is a whole range of colours developed by our chemists which are entirely new, all the shades of henna, of jade, Russian green, the rose colours, to mention only a few. They are much more suited to our climate, to our taste and to our fabrics than the German dyes which so often looked "dowdy." If a colour is pleasing, our chemists can introduce more varieties in it, just as has happened with henna. At first there was only one shade, now there are many more, delicate ones suited to summer skies and deeper ones for winter.
>
> The psychological effect of colour is beginning to be understood very much better now than formerly. The colours which our chemists have introduced are so much more refining and stimulating than the old ones. A lovely colour gives an aesthetic pleasure, oftentimes surpassing that of music, and sometimes makes the possessor of it aspire to something higher and finer. It brings freedom with it.

Coal-tar has also played a part in the development of our other aesthetic sense, the sense for sound.

Carbolic acid, or phenol, is most familiar to us as an antiseptic for it destroys those microscopic enemies of ours that are always hanging around ready to enter any breach in the wall of our bodily citadel. But there is another use of it, not less important but much less familiar: its use in making artificial resins. Phenol unites with formaldehyde, another well-known antiseptic, and by the union of the liquid and the gas there is produced a hard solid insoluble substance, looking like amber or jet. This is called by the various manufacturers "bakelite," "redmanol," and "condensite," and is extensively used, together with hard rubber, for the insulating parts of electrical apparatus, therefore contributing to electric light and power and to telephone and radio. It also is a factor in the phonograph.

Various kinds of tar, asphalts, and pitch are also employed in the manufacture of phonograph records; each manufacturing house has its own secret recipe. In the Edison record a thin coating of condensite on both sides of the disk receives the imprint of the spiral groove that carries the music. No synthetic phenol was made in this country before the war, and when we entered the conflict there came a sudden demand for an immense amount of it for making picric acid to be used in shells. Of course munitions came before music and the phonograph was robbed to make explosives. The price of phenol jumped from nine cents a pound to $1.50. Edison with his accustomed energy set up a factory for making phenol artificially and had it running within a month. Others followed suit and before the war was over there was plenty. In 1918, 106,800,000 pounds

of synthetic phenol was made in America. But it was, if you remember, some time before phonograph disks recovered their former reliability. We knew the world was out of tune because our records were.

In one of the numerous notebooks, in which Thomas A. Edison has recorded the ideas that flash through his fertile brain, is sketched under date of July 18, 1877, a crude cylinder with a handle and a trumpet, and this note written beneath:

> Just tried an experiment with diaphragm having an embossing point and held against paraffined paper moving rapidly. The speaking vibrations are indented nicely and there's no doubt that I shall be able to store up and reproduce automatically, at any future time, the human voice perfectly.

This was a momentous day in the history of the human race, for it was the first time that inanimate nature had answered, although man had been talking for more than a hundred thousand years. But when Mr. Edison said "Hello, hello!" back came the friendly hail "Hello, hello!" from the paraffined paper. It was the first time that a man had heard his own voice, except as an echoed syllable. It was the beginning of an era of preserved speech.

The invention naturally created a sensation and there was much speculation as to what would come of it. Edward Bellamy of "Looking Backward" was among the prophets and he, like most of them, saw in the phonograph the supplanter of print. It was commonly expected that our newspapers and books would be replaced by talking machines and that we should use our ears instead of our eyes in getting the news and perusing

novels. Not so much was said about the phonograph as a musical instrument. I asked Mr. Edison, when he showed me that page in his notebook, if he foresaw its musical possibilities at the beginning, and he said that he did not, that he thought of it as a dictating machine, but now, he said, "I am hoping to hear Beethoven's Ninth Symphony with an orchestra of seventy-five pieces perfectly reproduced before I die."

The so-called "talking machine" has had little talking to do except in office work. There is little call for the canned speeches of our statesmen and little demand for recitations except certain comic monologues. The phonograph newspaper and novel have yet to appear. We shall have to substitute some sort of continuous strip for the dinner plate to allow of sufficient length. The radio with aid of coal-tar compounds has now entered this field and has converted the continent into one vast auditorium.

In the field of music the phonograph has gone beyond the wildest anticipations of its early days. It is the mocking-bird of musical instruments. It can imitate all of them, some with such exactness as to defy detection, some inadequately and imperfectly but sufficiently well to recall to our minds the original music as we may have heard it and so to give us a pleasure that is partly memory, as a monochrome sketch will recall a beautiful painting. It is only in trying to record a chorus or large orchestra that the diaphragm gets rattled and makes a failure.

Whatever the defects and deficiencies of the phonograph as it is, it has served as a test of taste on a nation-

wide scale and a trainer of taste as well. It used to be said that only the few could appreciate the best music but we know that this is not true. For the greatest of composers are represented by some disks in the poorest collection. They may have been bought in the beginning for the looks of the thing and may at first be brought out only for high-brow visitors, but some of the family are likely in time to like them better than the flashy trashy tinkling tunes that first caught their fancy. This is the first time that good music has had an even chance in competition with poor music for popular appreciation. To rural communities, where formerly the only music to be heard was that of a painfully played cabinet organ or of a self-taught fiddler, the phonograph has brought at least a hint of the possibilities of all instruments and of the characteristics of various compositions and of the peculiarities of varied players.

With the phonograph has come into vogue its complement, the motion picture, and soon the two are likely to be made one. As the telescope brings to us happenings distant in space, so the phonograph and the motion picture bring to us happenings distant in time. The motion picture film is produced with coal-tar developers so this too as well as all photography might be included among the beneficiaries of benzene. In short there is no end to the ramifications of the influence of coal-tar compounds on our daily life.

Guide to Further Reading

"Chemical Discovery and Invention in the Twentieth Century," by Sir William A. Tilden. (Dutton.) Chapters XXI and XXII.

"Creative Chemistry," by Edwin E. Slosson. (Century.) Chapters IV and VII.

"Application of Dyestuffs," by J. Merritt Matthews. (Wiley.)

"Dyes Classified by Intermediates," by R. Norris Shreve. (Chemical Catalogue Co.)

"Dyes and Dyeing," by C. W. Pellew. (McBride.) Nontechnical.

"Manufacture of Dyes," by J. C. Cain. (Macmillan.)

"Dyes and Their Application to Textile Fabrics," by A. J. Hall. (Pitman.)

"The Story of Drugs," by H. C. Fuller. (Century.)

"The Future Independence and Progress of American Medicine in the Age of Chemistry." (American Chemical Society.)

"Origin and History of All the Pharmacopoeial Vegetable Drugs, Chemicals, and Preparations," by J. U. Lloyd. (American Drug Manufacturers' Association.)

Reports of the United States Department of Commerce and of the United States Tariff Commission.

ELECTRONS AND HOW WE USE THEM

By John Mills, M.A.
Educational Director, Western Electric Company

WHAT is the electron? It is to-day's ultimate element. What to-morrow's may be no one can say. In terms of it the scientist of to-day envisages all matter, all the stuff of which our universe is composed. The constant change and motion of matter, which appear as chemical or electrical or gravitational phenomena, are ascribed to another entity, called energy, which is the hidden motive power. A third entity is sometimes postulated to fill the broad spaces in which our tangible and ponderable matter forms mere specks. A vast ether is then assumed through which energy may be transmitted from one body to another, whether as light and heat from solar bodies or as so-called ether waves from a broadcasting radio station to the household receiving set.

Matter, energy, and a universal medium are the three entities in terms of which our present-day science is finding its explanations and extending its applications to human welfare. Of these the ether is the most debatable assumption. Perhaps energy is not transmitted in waves through a continuous ethereal medium but hurtles through empty space like a bullet. For this

there is much evidence—too much in fact for exposition within the limits of a single chapter.

Energy, the second unknown of modern science, is accepted by the physicist, not only because it is a necessary assumption in the eternal sequence of changes which occur within us and about us, but also because there is an unknown something which correlates exactly with all these changes and seems to be conserved throughout them. Whenever changes occur in the form, chemical composition, or location of bodies of matter the magnitude of the change is always definitely to be predetermined upon the assumption that this mysterious energy will be constant and unchanged in amount.

Its existence is an inference from the motions involved in the change. Only in this kinetic form is it to be detected and measured; and then, of course, only by the motions of ponderable matter. Between such occasions it masks its potentialities and appears as harmless as the explosive shell, the high-tension electric wires, or the reservoir of still water in the hills above the hydro-electric plant. But when released, the magnitude of the changes which occur shows that it has not been altered by quiescence.

In a science where the ether is a convenient postulate, and energy a formless unknown, the electron stands out in stark reality as a definite ponderable particle, the tiny material element of the universe.

Its identification in 1897 by Professor J. J. Thomson followed close upon the discoveries of radium and X-rays to which it now furnishes the mechanism for a valid explanation. The quarter of a century since his

definite experiments has been enriched by thousands of delicate researches and the verification of ingenious theories.

In the first place there has been proved the existence of a counterpart to the electron, a complementary particle, conveniently known to-day as the "proton." In the original literature the proton is called a positive electron, the term deriving from the earlier and arbitrary classification of electricity as positive or negative.

Of protons and electrons all known kinds of matter are composed. More than that, these elementary particles are the positive and negative electricities which were earlier assumed to explain electrical phenomena. So now we say that matter is granular in structure and electrical in nature, although we might equally well say that *electricity is granular and material.*

These positive and negative specks follow the well-known electrical laws: like particles repelling each other and unlike attracting. Their actions (manifestations of energy), appear as if they were the result of two urges for both of which a common satisfaction is only rarely attained. One is toward the assembling in any region of equal numbers of protons and electrons, that is, a tendency toward an unelectrified condition. Protons are attracted toward regions where there are more electrons than protons, and vice versa. Bodies composed of more protons than electrons are called positively charged; and similarly an excess of electrons is the state of a negatively charged body. The uncharged, or neutral, condition with equal numbers is the stable condition.

The other urge, instead of depending as does the first upon the mutual attraction of protons and electrons, depends upon the mutual repulsions which occur between two or more protons or between two or more electrons. In any grouping of several protons and electrons there are some amenities in the way of proper separations between mutually repellent members. Certain configurations, or arrangements of the particles in space, seem to be more stable than others and toward such configurations this second urge is effective.

One of the most stable groups comprises four protons and four electrons, satisfying thereby the more fundamental urge of equal numbers. All of these, except two electrons, are closely grouped into a tiny particle, known as an "alpha particle." Why and how four protons and two electrons should group so closely no one as yet knows. (Perhaps, at such infinitely small and subatomic distances, it has been suggested, the laws of attraction and repulsion do not follow the same mathematical relationship as they do for the larger distances at which they were determined.) The two remaining electrons disport themselves at some distance and presumably on opposite sides of the alpha particle, which attracts them because it has an excess of protons.

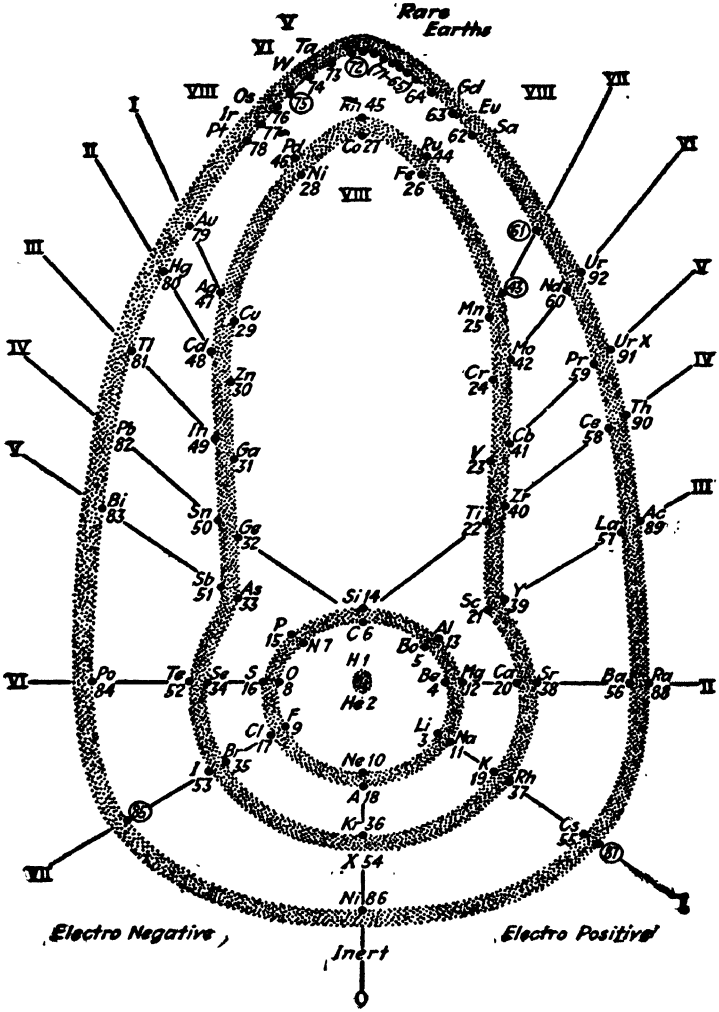
The entire group is known as an atom of helium, that inert gas which has been recommended for airships. In this grouping both urges find complete satisfaction. No greater satisfaction could be obtained by any arrangement; so there is no residual tendency to join with other protons and electrons to form a larger but more stable group.

In the helium atom we have the characteristic structure of all atomic systems. At the centre there is a nuclear particle composed of a close arrangement of protons and electrons but including more protons than electrons. In the region beyond there are electrons. The whole constitutes a miniature celestial system in which the nucleus is the central mass and the remaining electrons planetary satellites.

Atomic structure is more completely illustrated by the familar nitrogen of which we daily breathe about four times as much as we do of oxygen. Its nucleus contains seven more protons than electrons; in fact fourteen protons and seven electrons. About this nucleus are seven planetary electrons. Two of these apparently occupy positions on opposite sides like the satellites in the helium atom; and the remaining five, at a greater distance from the nucleus, are disposed as if on an imaginary sphere about the nuclear centre.

How much of this well-ordered picture is speculation? Relatively little. Admitting that the evidence is not direct but circumstantial and that the positions of the planetary electrons are not exactly known, the statement stands as made. The evidence, however, may well wait the presentation of further facts and some ideas as to the magnitudes involved.

Imagine this atom of nitrogen which consists of seven specks in space enclosing imperfectly a central speck, for the atom is mostly hole—imagine it magnified about one hundred thousand times. The specks would then be about as large as the unmagnified atom. Two such atoms of nitrogen, associated much like partners in



From "Within the Atom," by John Mills. Published by D. Van Nostrand Company]

Atomic systems at the periodic table. Place numbers correspond to atomic numbers. Systems similarly situated, as indicated by radial lines, have similar chemical properties

polite dancing, form a molecule of nitrogen. Of such molecules you inhale with each breath a few score billion, to say nothing about one fourth as many oxygen molecules each formed of two atoms. In the air around you all these molecules are moving at about one thousand miles an hour, in a haphazard way, for on the average each can travel less than one thousandth of an inch before it must dodge another. That means a change of front about fifty million times a second, and establishes a world's record in expediency.

Now imagine a cube of this air about three eighths of an inch on a side, a cubic centimeter. Let the cube and its contents grow until its edge would reach from New York to Cleveland. Then about every foot along the way there would be a molecule; but you could not expect to see one because it would be only a few tiny specks, each speck about one hundred thousandth of an inch.

Nitrogen has an excess of seven protons in each atomic nucleus. Helium has two. So far as concerns an excess of protons in the nucleus there are just ninety-two possible conditions, extending from a nucleus of one proton and no electrons to the condition of ninety-two more protons in the nucleus. Whether or not there ever were any nuclei with an excess of more than ninety-two no one knows. If there were in the early geologic ages, they have now disappeared, for nuclei with more than eighty-two excess protons spontaneously disintegrate. This is the secret of the radioactive elements of which radium is the widest known, but uranium and thorium are the unrelated parents.

Uranium, a chemical element of which the atomic nucleus has an excess of ninety-two protons, has a most unstable internal situation. Every little while some atom of uranium will yield to the strain and expel from its nucleus a whole group of protons and electrons,

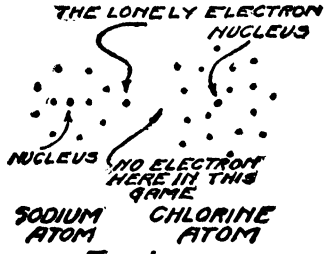


FIG. 1

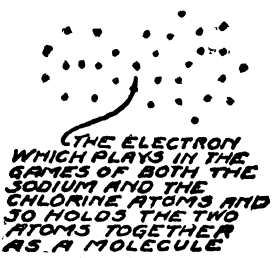


FIG. 2

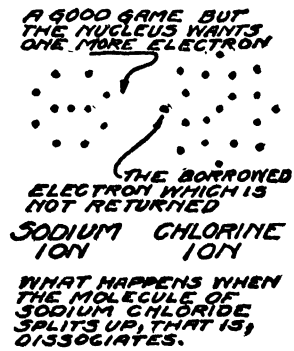


FIG. 3

From "Letters of a Radio-Engineer to His Son," by John Mills. Published by Harcourt, Brace and Company, Inc.

closely associated and forming the so-called alpha particle. When it has done so the nucleus contains four less protons and two less electrons, making a net excess of ninety. During the process the number of planetary electrons is reduced from ninety-two to ninety, to cor-

respond to the reduced attraction of the nucleus. The result is the formation of an atom of an entirely different chemical element with different chemical properties.

This process has continued for ages, gradually decreasing the supply of uranium. In its place are its disintegration products, uranium X^i, so-called, and helium because the emitted alpha particle soon finds two electrons to act as its planets and with them settles down to the uncompanionable existence of a helium atom.

The expulsion of an alpha particle from a uranium atom fails, however, to cure its internal troubles. Two electrons are therefore successively expelled from the nucleus of the newly formed uranium X_1. The excess of protons in the nucleus is increased from ninety to ninety-one and then to ninety-two. The expelled electrons shoot into space with enormous velocity, but their independent careers are not our present concern.

With their leaving, the nucleus returns to a condition of ninety-two excess protons. Thereafter it is a spendthrift, losing one alpha particle after another until it finally becomes identical with the nucleus of the lead atom, which has an excess of eighty-two. During its downward progress it serves for a time as the nucleus of the well-advertised radium atom.

The radioactive elements are responsible for much of our present-day knowledge of electronic physics. They gave away the inner secrets of a large group of atoms to such ingenious and persistent investigators as Professors Rutherford and Soddy. It was the former, for example, who proved that the alpha particle is really

the kernel of the helium atom. He used a glass tube with a deep dimple in one side. First he tested the atmosphere within the tube for the presence of helium and found none. Then in the dimple he placed a radioactive substance. Again he tested; and helium was then present. The enormous velocities of the alpha particles had carried them through the glass wall into the enclosed space, where they showed in the spectroscope the lines which are characteristic of helium.

More recently Professor Rutherford has let these alpha particles shoot through nitrogen gas. Imagine, if you care to, some enormously solid comet plunging into our solar system so rapidly as not to perturb our planet until the fatal moment when it collides with the sun. The violent impacts of alpha particles and nuclei of nitrogen were relatively infrequent since both are very tiny; but when they occurred the nitrogen atom was disrupted and some of the protons knocked out of its nucleus.

There is dove-tailing evidence enough on all these matters to require several graduate courses in physics for its exposition, so the reader whose time is limited must accept it on faith. He might justly ask, however, how these protons were recognized? By the distance they were knocked! And the reason is this: Alpha particles rushing from their former nuclear homes will penetrate a fairly definite distance in air before they are so slowed down that they will not produce little scintillations when they strike a properly prepared screen. If instead of air they rush through an atmosphere of hydrogen gas the effect is the same except that occa-

sional scintillations may be observed at a much greater distance from the radioactive material. Now, hydrogen has long been known to be an atom with a single proton for a nucleus and, of course, one planetary electron. These scintillations are due to these protons which, being lighter than the alpha particles, are thrown farther by the collision. When pure nitrogen is used there are occasional scintillations at that greater distance which corresponds to a single proton being projected forward by the collision.

In the radioactive atoms the nucleus is most expressive but in all atoms it is the real determining influence. Upon it depends the number of planetary electrons, for their number is normally equal to the excess of protons in the nucleus. Upon this number depends the configuration and that determines the chemical behaviour of the atom. In final analysis the nuclear content makes the atom what it is. For that reason it is convenient to classify on a purely numerical basis by the "atomic number" which states the excess of protons in the nucleus.

For purposes of visualizing the chemical behaviour of atoms it is simplest to deal with those of atomic numbers 11 and 17 which are sodium and chlorine, respectively. Now it happens that the atom of atomic number 10 is that of neon, an inert gas, much like helium except heavier, which is completely satisfied. The atomic number 18 denotes another satisfied structure, that of argon. Sodium and chlorine, however, were created without the complete satisfaction of both the urges which were mentioned earlier. Sodium has one

planetary electron too many for a really satisfactory configuration such as is represented by the planetary electrons in the neon atom. Chlorine on the other hand lacks one electron of the eighteen which would assume the stable arrangement of the argon atom.

A sodium atom is like a human being wrought upon by two conflicting emotions. If it should lose a planetary electron its remaining satellites would have a satisfied configuration, but the urge for an equal number of protons and electrons would then be effective and the atom would merely have changed the kind of its discontent. On the other hand, the chlorine atom would be better off with an additional electron in its planetary spheres, if it were not that, for it also, the urge of equality and electrical neutrality would then be dominant. One has an electron to lose: the other, one to gain. They meet apparently on the same plane of mutual profit as do buyer and seller in the ideal case of business transactions. An electron is transferred. But neither buyer nor seller dares balance his books thereafter. The only solution is to remain together so that for purposes of accountancy the transaction may be considered incomplete and yet both may have the satisfaction which is the profit. This seems to be the basis of the existence in combination of a sodium and a chlorine atom as a molecule of sodium chloride, the common salt of the table. In fact, in a crystal of salt the various atoms are arranged in orderly rows in such a manner as to make the accountancy surprisingly satisfactory to each atom. Above and below, in front and behind, to right and left of each sodium atom there is one of

chlorine; and the converse is true of each chlorine atom.

In the confusion, however, which occurs when salt is dissolved in water the necessity of balancing accounts is momentarily forgotten. The chlorine nucleus moves out into free space between the water molecules, taking with it as an extra satellite an electron from the sodium. The sodium nucleus starts off on its wanderings with one too few electrons. From that time on each is an "ion," an electrically charged particle, seeking a means of balancing its electronic accounts. In its wanderings it may meet with another and oppositely charged ion but the association and consequent satisfaction are only transient because the fluid milieu in which they find themselves encourages incompatibility. (Of course, if there is too little water crystallization occurs.)

If molecules of some other substance, which also dissociates into ions, have been dissolved in the same water these ions may afford satisfaction to the ions formed from the salt. A positive ion, that is one which has lost an electron, will always welcome a meeting with a negative ion for the latter has too many electrons.

Combinations into molecules occur between atomic systems, that is atoms or ions, either under the urge of attaining greater satisfaction of configuration for the planetary electrons or under the urge of becoming electrically neutral. (In the non-chemical phenomena of electricity it is the second urge which is responsible.) The unsatisfactions which lead to activities may involve more than one electron for each atom, instead of just one as in the simple case of sodium and chlorine. Complicated molecular unions may, therefore, be formed

comprised of many atoms, which as individuals may have had urges of different degrees of intensity.

The chlorine atom which serves for visualizing chemical activity will also illustrate one fact which remains to be expressed before the picture is complete. Chlorine is a substance well known to the chemist. In our modern terms it is the element of atomic number 17, that is, it contains in its nucleus seventeen more protons than electrons. Its atomic number states a difference; but what about the actual content of the nucleus?

In the first place we know the masses of the proton and electron. The proton is about eighteen hundred and fifty times greater in mass than the electron. It is, therefore, responsibile for the weight of discrete atoms and of their aggregations in such masses as we weigh on chemists' balances or coal-scales. The weight of a helium atom which contains four protons in its nucleus should then be practically four times that of the hydrogen atom which has a single proton for its nucleus. Oxygen, which is known to contain sixteen protons, is approximately sixteen times as heavy as the hydrogen atom.

The masses of various atoms have been found by an electrical method by Professor J. J. Thomson and more recently by Dr. F. W. Aston. The method involved ionizing the atoms, that is removing from them one or more electrons. Due to the resulting electrified condition the atom will respond to electrical attractions and repulsions. The amount of its motion may then be used as a measure of its mass just as you might measure masses by observing what motions you could give to

them with a definite muscular force. As to knocking electrons off from atoms, and thus ionizing, there are many ways but they are not our present concern.

The important point is that because of the electrical nature of the tiny particles which compose atoms it becomes possible not only to determine the masses of the atoms but also to separate atoms by weight.

The chemist has always separated atoms on the criterion of chemical behaviour, that is, unconsciously until recently, on the basis of atomic number. For atoms so separated there have long been available very accurate determinations of the relative weights of the atoms of different chemical elements. The results of the electronic physicist agree with these in those cases where the chemist had found for the atomic weight a whole number, when compared to the weight of the oxygen atom assumed as sixteen. The weights should be related as integers since the nucleus should contain whole numbers of protons.

The chemical method determined the average atomic weight of a large number of atoms of a chemically pure element. The physical method could be applied to a mixture of elements and would separate the atoms according to their weight. The chemical method applied to chlorine obtained an atomic weight of 35.45 on a scale where the oxygen atom was 16.00. The physical method applied to chlorine indicated a mixture of two distinct types of atoms, one with a weight of 35 and the other with a weight of 37. There were apparently in any sample of chemically pure chlorine about three times as many atoms with weights of 35

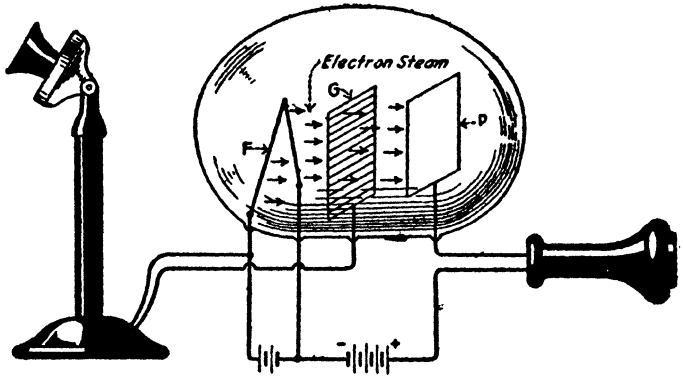
as there were with weights of 37. On the average such a mixture would then have the weight indicated by the chemical method.

Two kinds of atoms, differing in the total number of protons, were thus found to possess the characteristic behaviour of chlorine. They are called "isotopes" of each other because they occupy in the chemical tables the same position. The term was introduced by Professor Soddy who has met a similar phenomenon in his study of the chemistry of the radioactive elements. The case of uranium which was cited earlier will illustrate it. Uranium loses from its nucleus successively an alpha particle and two electrons. Thereby it has reduced its nuclear content by four protons and four electrons. The atomic number of the new element, uranium II, is the same as uranium; the chemical behaviour is the same although, of course, the radioactivity is different; but the atomic weight is reduced by four units. The new element is an isotope of the old, chemically identical, but with a lower atomic weight.

Such is a brief outline of the present ideas as to the matter of which our universe is composed. It is granular in structure and electrical in nature, being composed of definite specks. Upon the number and arrangement of these specks, protons and electrons, depend all the physical and chemical characteristics of matter.

Instead of classifying matter inexactly by the average behaviour of a number of atoms it is now possible to extend a rigorous and numerical classification to individ-

ual atoms. The key to the atom is its nuclear composition. Its weight depends upon the number of protons in its nucleus. Its normal possibilities of combination into molecular form, that is, its chemical properties, depend upon the excess of protons in the nucleus. That



From "Letters of a Radio-Engineer to His Son," by John Mills. Published by Harcourt, Brace and Company, Inc.

The Thermionic Vacuum Tube. Electrons emitted by a heated filament, F, are drawn across a highly evacuated space to a plate, P. The stream is very sensitive to changes in the electrical potential of the grid, G. The device is widely used in the Bell System as an amplifier of telephone currents

determines what is its normal complement of planetary electrons and their configuration.

In terms of excess protons in the nucleus, that is, the so-called atomic number, there are ninety-two classes, of which eighty-seven are known chemical elements. In each class, however, there may be required a further subdivision on the basis of total number of protons in the nucleus. In addition, although the point has not previously been developed, there may be a difference in nuclear history which predisposes a nucleus to one

course of degradation rather than another. This is true of certain of the radioactive elements, where atoms of the same atomic weight as well as of the same atomic number may follow different sequences of radioactive changes.

Whenever the number of planetary electrons about a nucleus does not correspond to the atomic number, then the atomic system is electrically charged, that is, "ionized." Its further activities are due to that charge and the atom is under the urge of restoring a state of electrical equilibrium. Of such activities there are too many for present mention. They accompany any derangement of the planetary electrons and to them are due many of the phenomena of light and X-rays.

A current of electricity exists whenever there is a stream of electrons from one point to another. In conduction through gases the gas must be ionized before it becomes conducting. Its molecules must be split apart in some manner which will result in the formation of ions, that is, atomic or molecular systems which have more or less than the normal number of electrons. Such ionization may be accomplished in a number of ways, by the action of ultra-violet light, by exposure of the gas to X-rays, by impacts with swiftly moving electrons or alpha particles from radioactive substances, or by collision with swiftly moving free electrons or ions however obtained. Under these conditions some of the gaseous molecules lose by impact planetary electrons and thus become positive ions. The freed electrons immediately take up their way toward the positive electrode and the positive ions take the opposite way

toward the negative electrode. Both may produce further ions from the normal molecules of gas with which they collide if the impacts are sufficiently violent.

Such, in general, is the phenomenon of conduction through gases. In solid bodies, like wires, conduction occurs by the motion of free electrons which wander this way and that through the intermolecular or interatomic spaces. The metals, the best conductors, are electropositive, that is, their atoms are systems with inconvenient electrons in excess of the simplest configurational requirement but not in excess of the number of protons in the atoms. It is these loosely held electrons, most probably, which serve to conduct electricity through solid conductors. Their haphazard wanderings are superseded by a definite drift when the terminals of the solid are connected to a battery.

This phenomenon of electron streams in wires conducting electricity is made to furnish the electrons which form the stream through the vacuum of an audion. The audion consists of an evacuated vessel with a filament through which a current of electricity may be passed. There is also a metal plate and between the plate and the filament a fine wire-grid.

A strong current of electricity through the filament is manifested by its rise in temperature and its luminescence. Both the heat and the light are due to the disturbances created among the atoms of the wire by the stream of electrons which constitutes the current. The individual electrons of the stream, which is being forced through the filament by an external battery, must dodge or jostle their way past the more fixed atomic systems

and the stay-at-home electrons. They move with considerable velocities and from time to time one is diverted from the straight path of the conductor and flies beyond the restricting influence of its protons to the free space surrounding the filament. The number that thus escape is very large, increasingly so at high temperatures of the filament.

Another battery is connected to the audion in such a manner as to make the plate positive with respect to the filament. The free electrons are then drawn across the vacuum from filament to plate. On the way, however, they pass through the meshes of the grid. The latter is strategically placed nearer the filament than the plate. Feeble electrical changes in the condition of the grid, therefore, produce pronounced changes in the stream of electrons which flows from filament to plate. Changes produced in this manner will be evident in the external portion of the electrical circuit which is formed by the second battery, the filament, the plate, and the intervening vacuum. The small inertia of these individual electrons and the delicacy with which the strategically placed grid controls their actions have resulted in the marvellous application of the audion to the electrical communication of speech by wire and by radio.

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AN INVESTIGATION ON EPIDEMIC INFLUENZA

By Peter K. Olitsky, M.D. and
Frederick L. Gates, M.D.
The Rockefeller Institute for Medical Research

EPIDEMICS of influenza have occurred at intervals for centuries, and may be recognized from contemporary descriptions though they were known under different names in different places and different times. The disease has had a wide or more restricted distribution according to various circumstances of the time, especially the rapidity and extent of the movements of men. Thus in earlier centuries human transport carried the pestilence slowly and over limited areas; in modern times, in a world knit closely together with frequent and rapid means of migration, the disease passes quickly from country to country and from continent to continent. During the World War it quickly exacted a death toll from the warring countries surpassing their losses under arms.

The place or places of origin of the epidemics are still under investigation, and it remains for future study to determine whether the spread takes place from a single source or from many. History traces the outbreaks of many epidemics to regions of eastern Russia and Turkestan; but indications are not wanting that in-

fluenza lurked in many centers preceding the pandemic of 1918. Which ever of these divergent places of origin proves to be the true one, certain essential conditions (as yet undiscovered) must be regarded as combining to convert smouldering inactivity into epidemic spread.

THE EPIDEMIC OF 1918.—The emergency created by the epidemic outburst of 1918, which was of unparalleled severity, coincided with the exigencies of the Great War so that the full weight and force of modern methods of clinical and bacteriological study could not quickly be brought to bear upon the disease. In many instances investigators were further handicapped through failure to distinguish influenza as a primary infection from the frequent pneumonias of common bacterial origin which were secondary to it; or were prejudiced in their views by the general acceptance of Pfeiffer's bacillus as the bacterial cause of influenza. This bacillus had been discovered by Richard Pfeiffer during the epidemic of 1889.

Early in the course of the epidemic, however, discordant findings cast doubt on the part played by Pfeiffer's bacillus as the cause of the disease and in many laboratories the search was started *de novo* for some hitherto unknown microbe whose distribution and character would more nearly fit the requirements of the case. The results of such an investigation at the Rockefeller Institute for Medical Research are described in this chapter.

DEFINITION OF EPIDEMIC INFLUENZA.—Epidemic influenza free from complications is usually a mild affection. On the fringes of an epidemic it is not always

easy to distinguish it from other indefinite ailments of the upper respiratory tract. In the midst of an epidemic, however, when many similar cases may be seen, its manifestations are more obvious and uniform. The attack is usually sudden with a chill, or chilly sensations, and fever. Headache, frontal or general, develops, with pains in the back, joints, and extremities. In the severer cases the prostration that accompanies these symptoms forces the patient to bed. The eyes become inflamed and painfully sensitive to light. The face is flushed; the throat swollen and raw, a thin irritating secretion flows from the nose, and the progress of the infection is denoted by hoarseness and a dry and distressing bronchial cough. Examination of the chest, however, reveals no certain signs of lung involvement. Other organs are not usually obviously affected. Pulse and respiration are only slightly accelerated. The temperature remains fairly constant, between 101.5 and 103° F. for two to four days and, then after a profuse perspiration, it falls rapidly to normal (about 98.5° F.) with the beginning of convalescence.

The duration of uncomplicated influenza is usually one to three days; in the severer cases four to six days. When symptoms persist beyond this period a secondary pneumonia or some other sequel is to be suspected.

Peculiar features of the disease are an early drop in the circulating white blood cells, a lowering of the resistance of the lungs to secondary infection by common bacteria, resulting in a high incidence of severe and fatal secondary pneumonias, and the persistence of a profound physical and mental depression during con-

valescence. Characteristic of an epidemic is the rapid spread, coupled with a high incidence of infection, so that more than half a population may be attacked in the first wave, and the recurrence of successive waves of diminishing extent and severity until, in the course of three or four years, the epidemic dies out.

EXPERIMENTAL INOCULATIONS.—In September, 1918, when it was decided to undertake a search for the infectious agent of epidemic influenza in the laboratories of the Rockefeller Institute for Medical Research, methods of transmitting the infection to animals were first considered, because an experimental infection in animals offers facilities for study not obtainable in human cases. For example, the transmission of a transient disease such as influenza through animals insures its indefinite propagation and affords material for study after human sources fail. An infection in laboratory animals can be interrupted at any time for necessary examinations of its progress and offers many avenues of approach which are closed to the investigator if he must depend wholly upon human cases for study.

Uncomplicated influenza, however, is a relatively mild disease in man and some of its prominent manifestations such as chills, headache, sore throat, and depression cannot be observed in animals. It was expected that the experimental disease, if successfully established in animals, would be mild as well, and might be missed unless some definite, measurable criteria could be employed to indicate the development of abnormal conditions similar to those observed in human cases. It was thought that among the characteristic

signs of the human infection, the typical changes in the blood might be used as an indication of successful transmission and it appeared probable that some local injury might be found in the lungs of the animals which would account for the characteristic defect in the resistance of the lungs following human influenza.

Influenza is transmitted from person to person by the secretions of the respiratory tract, so the first experiments were undertaken with washings from the noses and throats of human patients in the early hours of the disease. These washings of course contained many varieties of bacteria, but it was expected that in favourable instances the ordinary bacteria of the nose and throat would be suppressed through the natural resistance of the animal and that the specific effects of an extraordinary microbe might thereby be revealed.

In a short series of experiments monkeys were found to be unsuitable for use in the study of influenza both because of their scarcity and because of the frequent presence of pulmonary tuberculosis in the available monkeys. These preliminary experiments, however, gave a clue to a method of injecting the nasal washings which promised definite results. Injections of the washings into the nose and throat, the eyes, the blood, and under the skin produced no distinctive effects. But when the injections were made into the trachea, so that the material ran down into the lungs, the monkeys showed a decrease in the white cells of the blood, such as is characteristic of human influenza. This suggestive sign could not be correlated with local damage to the lungs, however, because of the frequency

of diseased conditions due to other causes. The rabbit was then chosen for further experiments.

The results of the first injections of nasal washings from human influenza patients into the lungs of rabbits showed that something in the washings was producing definite and characteristic effects. On the first or second day after injection the rabbits appeared ill, with ruffled fur, inflamed eyes and usually a degree or two of fever. The constant feature of their illness was a sudden drop in certain of the white cells of the blood which fell to half or a quarter of their normal number. These effects were transitory, and after two or three days the animals recovered. If the animals were killed for examination at the height of the attack, their lungs showed evidences of a definite type of injury and disorganization unlike that found in ordinary pneumonia but similar in many respects to the influenzal damage found in persons dying early in the disease. Usually no ordinary bacteria could be recovered from the injured rabbits' lungs and it appeared that the effects produced by the human nasal washings were independent of the presence of commonly recognized microbes.

By injecting into the lungs a suspension of ground lung tissue from a previously affected rabbit the typical effects just described could be induced successively in a series of animals. In one instance fifteen successive transmissions were obtained before the experiment was discontinued. The persistence of these characteristic results, in spite of the repeated dilution of the original material between transmissions, indicated the presence of a self-perpetuating agent; a living organism or virus.

The next step was to define the living agent more exactly and to attempt its cultivation in the laboratory. It was soon found to be so minute that it readily passed through earthenware filters impervious to ordinary bacteria. In this way it could be separated from other microbes in the human nasal washings or in affected rabbits' lungs. Filtered nasal washings from influenza patients and filtered lung suspensions produced the typical train of effects in rabbits and thus proved that ordinary bacteria were not involved in the process. The specific microbe, which as yet had not been seen but whose presence was clearly indicated by the animal experiments, was a "filter-passer." Now although very few filter-passing microbes have been identified, the group, in general, has certain well-known characteristics which this virus was found to share. For example, although it was readily killed by heat at 133–140° F., temperatures often used in pasteurization, it was resistant to drying or freezing and could withstand the action of 50 per cent. glycerine for periods up to nine months. When animal tissues containing it were contaminated by moulds or bacteria, the virus still survived.

Another noteworthy effect of this active agent early claimed attention. When unfiltered nasal washings from influenza patients were injected into rabbits' lungs, other microbic residents of the nose and throat were likewise deposited. Ordinarily such bacteria do not do any damage under these conditions but are overpowered by the active protective mechanisms of the body. But in the presence of the primary injury caused by the influenzal agent these bacteria were sometimes

able to multiply and cause severe pneumonias. The similarity of these accidental infections in the experimental animals to the secondary pneumonias in man led to a series of experiments to put this significant train of events to further test.

These experiments proved that a decrease in the resistance of the lungs to common bacteria was a characteristic result of infection with the filterable virus. After the lungs had been damaged by the influenzal agent the other organisms were injected into the trachea or into the blood stream, and from both sources the common bacteria invaded the injured lungs and there induced a typical pneumonia. To the normal lungs of healthy or "control" animals the same doses of these microbes were harmless.

The first object of the investigation had now been accomplished. An infectious agent, present only in the nasal washings of influenza patients in the early hours of the disease, had been transmitted to laboratory animals and could now be studied under experimental conditions. The presence of this virus induced changes in the blood that are typical of the blood changes in human influenza. And the lungs of the infected rabbits were found to be the site of typical injuries, which predisposed them to severe and fatal pneumonias.

Artificial Cultivation.—From the beginning of the investigation, while the first animal transmission experiments were in progress, attempts were made to isolate the active agent in artificial cultures outside the body. For this purpose the usual methods of cultivation were discarded in favour of the particular methods

developed by Doctor Noguchi, based on the early experiments of Doctor Theobald Smith. The Smith-Noguchi culture medium, which had proved successful in the cultivation of certain highly parasitic microbes, consists of dilute blood serum or tissue fluid with a small fragment of fresh sterile tissue—usually rabbit kidney—and is thus very different from the artificial broths and jellies commonly employed in bacteriology. Besides furnishing nutritive substances the tissue fragment creates an environment favourable to those peculiar "anaerobic" microörganisms which can live only in the absence of air. The choice of this medium for the cultivation of the active agent of the animal transmission experiments proved to be a fortunate one.

In November, 1918, certain extremely minute but characteristic spindle-shaped bodies were observed in strictly anaerobic cultures of the filtered nasal washings of an influenza patient in the early hours of the disease. In size they approached the limit of vision with the highest powers of the microscope so that the sparse growths in the early cultures were identified with the greatest difficulty. Soon, however, other cultures were obtained, both from the filtered nasal washings of other influenza patients and from the whole or filtered lung-tissue specimens of rabbits which had been typically affected by these secretions, as has been described.

As these minute microörganisms were carried through successive generations of culture, they became better adapted to artificial cultivation and multiplied more luxuriantly, so that the cultures could be used in animal experiments with unequivocal results. These experi-

ments proved beyond question the identity of the active agent obtained from influenza cases and the bodies obtained in culture. Both were derived from the same sources. Both were filterable. Both produced identical effects in rabbits, and from the pulmonary lesions produced by either, further animal passages, or cultures, could be obtained. Both, protected by bits of affected lung tissues, withstood 50 per cent. glycerine for periods of months. Both had that curious property of damaging the lung in such a way as to lower its resistance to secondary invasion with ordinary bacteria. It was from this character that the microbe, objectively, received its name. It was called *Bacterium pneumosintes*—a bacterium that injures the lung. Finally, conclusive evidence of the identity of *Bacterium pneumosintes* and the virus from the human nasal washings was furnished by a series of experiments which showed that a previous infection with either one of these pathogenic agents rendered an animal immune to attack by the other.

IMMUNITY.—In many infectious diseases, the immunity conferred by an attack is associated with the appearance in the blood of specific principles, or "antibodies," which can be demonstrated by serum tests. Efforts were therefore directed toward the observation of antibodies in the blood of experimentally infected rabbits, and of influenza patients, from which the strains of *Bacterium pneumosintes* ultimately had been derived. But it was found that cultures of *Bacterium pneumosintes* in the Smith-Noguchi medium were unsuitable for such experiments. The sparse growth of

the earlier generations was mixed with protein precipitate that interfered with the reactions and had properties that precluded its use. It was therefore necessary to devise special methods of cultivation, and before these methods became available the first opportunity was lost to test for antibodies in the blood of influenza patients and of affected rabbits.

It was found later that if the Smith-Noguchi medium was enclosed in a collodion sac, surrounded by distilled water or physiological salt solution, anaerobic conditions were shortly established throughout the system and the nutritive and growth-promoting substances of the medium diffused through the membrane in sufficient quantities to support a luxuriant growth in the surrounding liquid. The protein precipitate that collected around the tissue fragment was retained within the sac.

When it was possible to cultivate *Bacterium pneumosintes* by this method in quantities sufficient for use, rabbits were repeatedly injected with small doses of live cultures, or of heat-killed organisms. After a suitable interval, their blood serum was found to possess specific antibodies against *Bacterium pneumosintes*.

A significant feature of the immunity experiments and also of these serum tests was the fact that all the strains tested had similar properties and reacted identically with the specific antibodies produced by any one of them. This is what would be expected if they were all derived from a common source.

The experiments described above based on the epidemic of 1918–1919 and the recurrence of 1920, had extended over three years and the facts had been care-

fully controlled, and checked by repetition. They could not be further extended, however, without fresh material from influenza cases and for some time it was not possible to determine whether the blood of influenza patients contained specific protective substances against *Bacterium pneumosintes*, or whether protection might be afforded by subcutaneous injections of the killed organism—a method of prevention that has proved so efficacious against typhoid fever. An opportunity for further study was finally provided by a recurrence of epidemic influenza in New York City in January and February, 1922.

With material obtained from a number of early cases of influenza in this outbreak, all the essential steps in the former investigation were repeated so that this series of experiments served to check and confirm the results of the earlier work. Especially significant was the fact that the new and old strains reacted identically in specific serum tests and that rabbits immunized against the old strains were subsequently resistant to the new ones, thus proving the identity of the micro-organisms.

With the 1922 strains of *Bacterium pneumosintes* the experiments on the blood of recovered patients and on the protection afforded by vaccination with killed cultures could now be carried out. In the blood tests specimens of serum were studied from nineteen persons who had recovered from influenza from ten days to five months previously, and from twenty-two other persons who gave no history of influenza since 1920. The sera of the twenty-two controls were uniformly negative in the

tests. On the other hand, the serum specimens from seventeen of the nineteen persons who had influenza during the recurrence of 1922 reacted positively and thus afforded presumptive eivdence that they had recently been infected with *Bacterium pneumosintes*. One of the persons chosen as a control subsequently had influenza. It was interesting to find that his blood serum, previously negative, reacted positively with *Bacterium pneumosintes* when tested on the tenth and eighty-ninth days after recovery. In other instances demonstrable antibodies persisted in the blood for at least five months following an attack of influenza.

The second series of experiments that were made possible by the acquisition of new and pathogenic strains of *Bacterium pneumosintes* dealt with the immunizing effects in rabbits of subcutaneous injections of appropriate doses of the heat-killed organisms. When a number of rabbits had been prepared by three injections of the killed bacteria the protective effects of the vaccination were demonstrated in two ways. By examination of the blood serum it was found that eleven among fifteen vaccinated animals had developed specific antibodies against *Bacterium pneumosintes*. Their resistance was then tested to doses of the living organisms which were pathogenic for normal, unvaccinated animals. In all but two instances the protection was complete. Not only did the vaccinated rabbits fail to show the characteristic signs of infection with *Bacterium pneumosintes* but, with the two exceptions noted above, they were normally resistant to secondary infection with ordinary bacteria. Incidentally, it was observed

that the doses of vaccine were well borne and did not even temporarily reduce the rabbits' resistance to other infections. These experiments therefore pointed the way to a similar series of observations in man.

On the basis of these results the vaccine has been offered to several groups of men in the United States Army. A very wide and extended experience will be necessary, however, to determine its value, and at present nothing definite can be said as to its efficacy in the prevention of influenza.

CONCLUSIONS.—As the result of this investigation at the Rockefeller Institute a hitherto undiscovered organism, *Bacterium pneumosintes*, has been isolated from the nose and throat secretions of influenza patients in the early hours of the epidemic disease. It is filterable, anaerobic, resistant, and pathogenic for rabbits, in which it induces a typical infection seemingly identical with epidemic influenza in man. The significant features of this experimental infection are the changes in the blood cells and the production of a characteristic injury to the lungs associated with a defect in their resistance to secondary invasion with common pathogenic bacteria.

All the strains of *Bacterium pneumosintes* have similar properties, indicating a common source. Animals subjected to a primary infection, or injected with living or killed organisms, are immune to subsequent injection. The killed bacteria induce specific antibody formation even when injected subcutaneously in doses well tolerated by man. The blood serum of recovered influenza patients contains antibodies for *Bacterium*

pneumosintes, whereas that of normal persons does not.

These experimental observations, reported elsewhere in greater detail, especially in view of the source of the cultures, their effects in rabbits, their identity, and the presence of specific antibodies in the blood serum of recently recovered influenza patients, point to *Bacterium pneumosintes* as the bacterial incitant of epidemic influenza. Moreover, many of the essential facts brought out in this study have been confirmed by Loewe and Zeman, and by Baehr and Loewe in New York, by Gordon in England, and by Lister in South Africa. The significance of similar observations from such widely separated localities is obvious. But medical science is apparently at the threshold of knowledge of a group or class of minute microörganisms which the anaerobic Smith-Noguchi technique and more recently developed methods of cultivation have thrown open to exploitation. This new field of bacteriology invites further investigation. It has seemed wise merely to report the experimental facts so far obtained and to defer the final decision on the precise relation which *Bacterium pneumosintes* bears to epidemic influenza until further experience is obtained.

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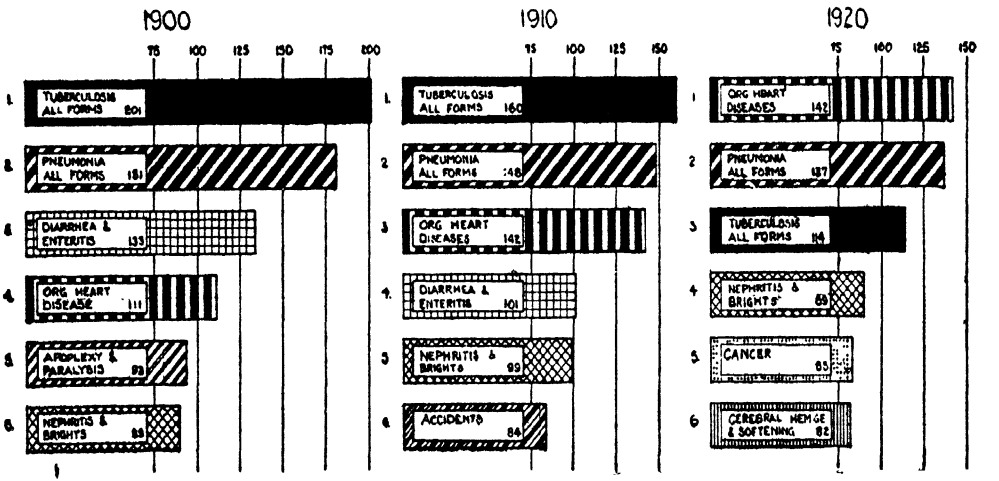
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OUR PRESENT KNOWLEDGE OF TUBERCULOSIS

By Linsly R. Williams, M.D.
Managing Director, The National Tuberculosis Association, New York City

DURING the 17th and 18th centuries the words "consumption" and "phthisis" were commonly used to designate various wasting diseases now known to be of many varied types. In the medical literature of this period there appears frequently the word "tubercle," but what the authors meant by this word was apparently nothing more than small nodules the size of a small pea or smaller which were found from time to time in bodies that were examined. Tubercle was first described definitely by Baillie in England in 1793, who, relying on naked-eye observations, differentiated tubercle from other tumors and commented upon its constant appearance in autopsies of persons dying of consumption. In 1810 Bayle in Paris attempted to classify the different types of these tubercles. A few years later (1819) Laennec, the inventor of the stethoscope, showed that in autopsies made of persons dying of consumption there were found in the lungs small tubercles, agglomerations of many tubercles. Also he found some tubercles which had undergone a partial degeneration; and found cavities in the walls of which small tubercles appeared. By means of

DEATH RATE PER 100,000 POPULATION FROM LEADING CAUSES
U. S. REGISTRATION AREA



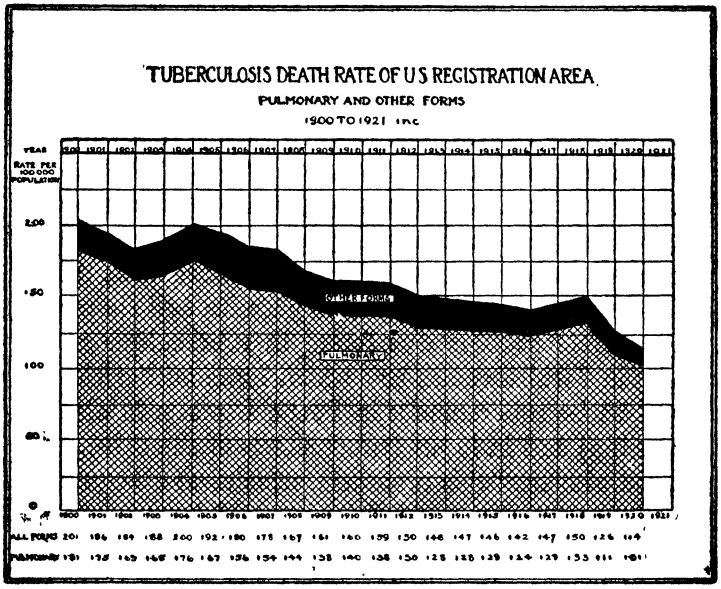
such studies of degeneration of lung tissue Laennec thus showed that consumption and tubercle were nothing more than parts of the same situation.

COMMUNICABILITY OF TUBERCULOSIS.—No one apparently believed in the possibility of tuberculosis being a communicable disease until the epoch-making studies of Villemin, who in 1862 demonstrated by carefully controlled animal experimentation that tuberculosis could be communicated from one animal to another, thus for the first time refuting the existing theory that tuberculosis was a hereditary disease.

THE TUBERCLE BACILLUS.—The causative agent of tuberculosis was not known until in 1882 Koch of Berlin described the tubercle bacillus. Not until 1884 did he fully describe the nature of this parasite and show that the tubercle bacillus was found in tuberculosis of the lungs; in "white swellings" which some authorities believed to be tuberculosis; in Pott's Disease; in diseases of the hip; and in lupus (tuberculosis of the skin). He showed also that this organism, which was always present in these various conditions, could be grown artificially in various media in pure culture; that the pure culture would show no parasitic life other than the tubercle bacillus; that when these tubercle bacilli were introduced into animals they reproduced a disease identical in its lesions to the disease known as tuberculosis; and finally that these same tubercle bacilli could be recovered from the organs of the animal which had been given the disease.

HOW DO THE BACILLI ENTER THE BODY?—As soon as Koch's epoch-making discoveries were made known

to the scientific world, numerous observers began to experiment in order to learn how the tubercle bacillus entered the body. There were those who believed that it entered the body through the respiratory passages; others who thought that it entered the body through the



digestive tract; others by way of the skin; and a few who still believed that the disease was hereditary and that the tubercle bacilli were transmitted directly from mother to infant. The researches of Cornet and others showed that in experimenting upon animals tuberculosis could readily be induced by permitting them to inhale moist air which was impregnated with tubercle bacilli. For a considerable time nearly all the methods for the

prevention of tuberculosis were based on the assumption that tuberculosis was caused by inhaling tubercle bacilli. Later researches, however, showed that experimental tuberculosis could also be produced in animals by means of the ingestion of food impregnated with tuberculous material or tubercle bacilli. When these animals were autopsied they showed not only tuberculosis of the intestinal tract, but also tuberculosis of the lungs. Also tubercles could commonly be found in the lymphatic ducts passing from the intestinal tract to the lymph glands of the lung. Von Behring in 1903 made a great contribution to our knowledge when similar experiments performed by him with very young animals showed that when the tubercle bacilli were ingested they might induce tuberculosis of the mesentary nodes or of the bronchial lymph nodes without causing any lesion in the intestinal tract. He stated as a hypothesis that tuberculous infection in man would commonly take place during childhood through the digestive tract and that the tubercle baccili would lie dormant in the bronchial lymph nodes for an indefinite period of time. Skin infection was also proved to be possible though rare.

Influence of the Bacilli on the Body.—The effect of the tubercle bacilli on the body, once having entered it, depends upon a number of factors. These factors are the initial number of tubercle bacilli, the virulence of the bacilli, and the capacity of the body to manufacture products which tend to wall off the bacilli or to kill them. If the number of bacilli be relatively small and the resistance of the individual good, the

bacilli will do little harm. This is true even if they are lodged in a number of places, for a reaction is induced which causes the growth of epithelial and interstitial cells which soon form a globular mass and completely surround the tubercle bacilli. The bacilli may remain alive and virulent but are walled off from the rest of the body. These small pin-head size masses of walled-off bacilli are not always readily detected. They are known as miliary tubercles.

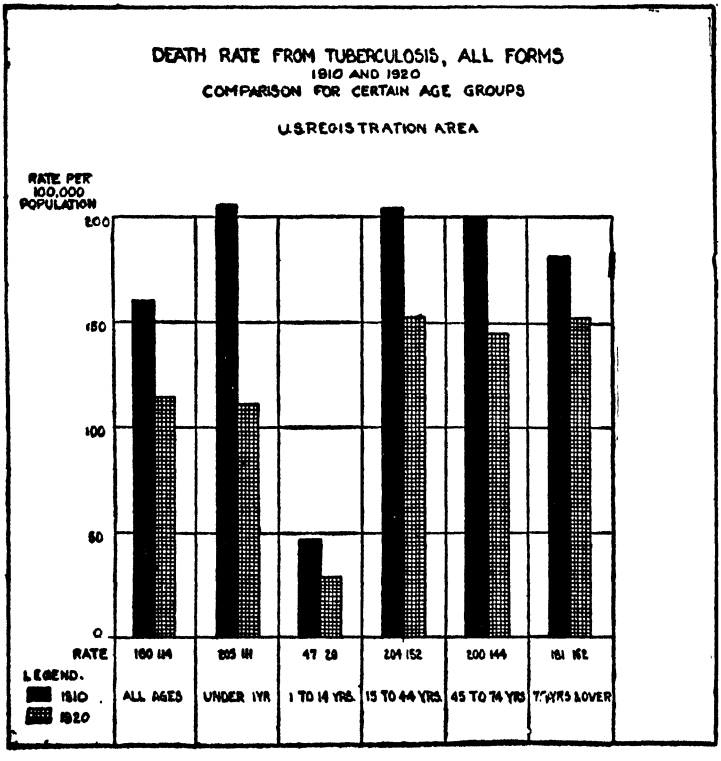
If, however, the conditions are favourable for the growth of the tubercle bacilli and they find satisfactory conditions for their nourishment within the body, the tissues adjacent to the bacilli are injured and although new cells are formed, these new cells in turn are killed and the area of dead tissue enlarges, so that we soon have an ulcerating sore in some part of the body. On the other hand, a series of small tubercles may be near together and may combine into one larger tubercle as big as a pea or larger. The tubercle bacilli encased within the wall or cells may not kill the cells which surround them, but may gradually cause the degeneration of these cells so that this larger globular tubercle becomes a soft granular mass. When these conditions develop, a variety of symptoms occur and the individual is then said to have tuberculosis.

In the vast majority of instances, when infection takes place the number of bacilli is limited and the process of walling them off from the rest of the body does not cause any disturbance. If, however, a considerable number of tubercles are being formed at the same time, the growth of the tubercle bacilli and the

effort of the body to wall off these bacilli produce a reaction as a result of the dissemination throughout the body of the products of the tubercle bacilli. This reaction is expressed in terms of symptoms which make the individual realize that something is wrong. In a comparatively small number of instances this tuberculous process becomes chronic, the tubercle bacilli continue to grow, the infected areas become larger and larger, and more and more of the organ in which they are seated becomes destroyed. More and more symptoms are produced and the efficiency of the body is reduced by the influence of the poisons distributed throughout the body in the circulating blood and by the destruction of part of some organ of the body. In rare instances a tubercle may grow in the wall at a small vein or in a small artery and eventually rupture into the vein, and the contents of the tubercle with many tubercle bacilli are thus discharged into the blood stream. When this takes place there is a rapid dissemination of bacilli throughout the body, causing a marked increase in the number of tubercles growing in the body. In such a case the condition known as miliary tuberculosis is produced.

HEREDITY.—As has been stated, until the time of Villemin the generally accepted theory was that tuberculosis was hereditary. It is now known that fetal infection may occur but that when such infection occurs, the mother is in the advanced stages of tuberculosis and tubercle bacilli are circulating in the blood which passes through the placenta into the fetus. This is a rare occurrence and in only a few instances have reports

been made of the presence of tuberculosis in a newly born child. The tubercle bacilli are rarely found in the circulating blood, and individuals or animals which are promptly removed from tuberculous parents do not



necessarily become diseased. It is also known that tuberculosis is extremely rare in foundling asylums and that in thousands of children autopsied during the first year of their life tuberculosis is hardly ever found

unless the child had been constantly exposed to an individual affected with advanced tuberculosis. It has been noted also amongst the thousands of infants placed out to board by the municipality of Paris that tuberculosis is rarely responsible for death during the first years of their life.

Evidence of the Presence of Tubercle Bacilli in Healthy Individuals.—Naegeli in 1900 reported that he had autopsied over 500 adults dying of all types of disease and found upon careful examination that tubercle was found in 97 per cent. of these autopsies. Many observations were made in the latter part of the 19th century on the autopsies of children which controverted the findings of Naegeli in adults. Loomis in New York in 1890 reported the autopsies of a large number of adults who had died as a result of traumatism and found in practically every instance that tubercles were present although the individual did not have the disease known as tuberculosis. Loomis removed the tubercles from the dead bodies of these healthy adults and injected them into rabbits and this injection almost invariably caused tuberculosis. So that prior to the discovery of tuberculin by Koch, it had been surmised if not generally accepted that the tubercle bacilli were pretty generally present amongst all adults and that it was extremely rare to find any evidence of the presence of tubercle bacilli in infants.

Tuberculin.—Tuberculin, a product of the tubercle bacilli, was discovered by Koch in 1894 and thought by him to have great curative value. Tuberculin when administered subcutaneously produces local, systemic,

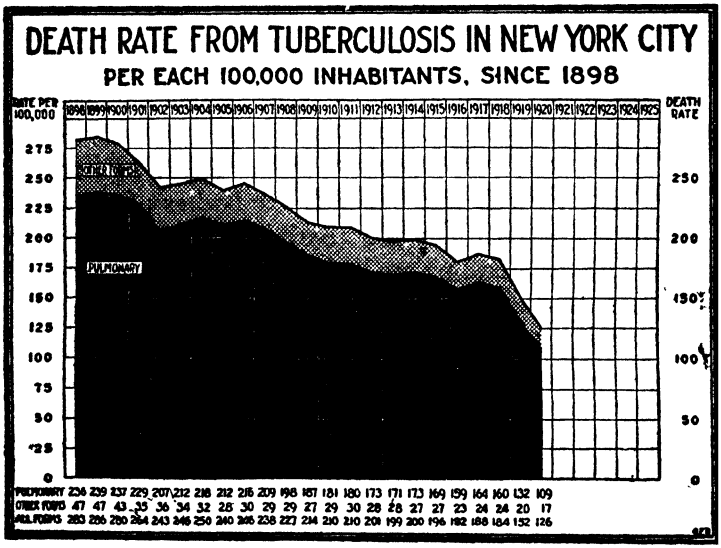
and focal reactions. A local inflammation is produced at the site of injection, a general reaction characterized by headache, backache, and fever, and a renewed or increased activity at the site of injection. This latter can readily be seen in lupus. Tuberculin was advocated by Koch as a curative agent, but it has been proven almost valueless and when not properly administered does more harm than good. Koch announced that the general reaction did not take place except in tuberculosis, but many observers soon found that healthy individuals reacted when larger doses were given. It was found that sometimes 50 per cent. of adults reacted, and even 90 per cent. at times, depending on the size of the dose. Its diagnostic value was therefore minimized. Calmette and Wolff-Eisner found that tuberculin dropped in the eye would produce a reaction. Moro rubbed it into the skin and finally Pirquet in 1907 found that if a very slight abrasion were made in the skin and a drop of tuberculin placed on the abrasion, a local reaction would take place in tuberculous persons, but without systemic or focal reaction. At first this test was thought to be of great diagnostic value, but as in the subcutaneous test it seemed that nearly every one healthy or tuberculous reacted, with the exception of very young children. Here was a phenomenon which was difficult at first to accept; but Naegeli had shown that 97 per cent. of adults autopsied showed an old tuberculous process and many others had shown that tuberculous lesions were rare in infants, but that as the child grew older the lesions were more frequently found. It is evident then that there was a marked difference

between tuberculous infection and tuberculous disease. Almost every child in civilized communities is exposed to tubercle bacilli and infection takes place either through the respiratory or digestive tract, so that by fifteen years of age, nearly every child has become infected. It is true that nearly all adults harbour tubercle bacilli in their bodies, but only when for some special reason these bacilli begin to grow or when additional large numbers of bacilli enter the body does the individual become affected with the disease tuberculosis.

Tuberculosis in Man and Animals.—The natural habitat of the tubercle bacilli is the bodies of men and domestic animals. In the aboriginal Negro, tuberculosis is rarely found unless he is brought in contact with civilization. Occasionally tuberculosis is found in wild animals but usually when they have become domesticated. Three special types of tubercle bacilli are known: the human, bovine, and avian. The human strain is most virulent to man, the bovine less virulent and the avian bacilli are a negligible factor in human tuberculosis. We have already seen that tubercle infection is almost ubiquitous among civilized people of the human race. This is also true of the bovine races, but in other animals it is far less common. The bacilli, however, will live for months outside of the body but are killed by sunlight. The disease tuberculosis, although occurring in but a small proportion of those infected, is one of the most serious of diseases.

During the past century one seventh of all deaths were the result of tuberculosis. During the year 1921

100,000 persons died of tuberculosis in the United States and from 86 per cent. to 90 per cent. of them died of pulmonary tuberculosis. Further, we know that for each person dead of tuberculosis, there are at least three seriously ill of tuberculosis and at least seven more who have symptoms from time to time. This



C. J. DROLET, Statistician
NEW YORK TUBERCULOSIS ASSOCIATION

means that at least a million persons in the United States will be either seriously ill or have symptoms of tuberculosis this year. A similar situation exists among all civilized races.

These enormous numbers of deaths and illnesses occur most frequently during early adult life and chiefly among the wage-earner group. When standards of

living are low or overcrowding or under-nourishment exists, the death rates are higher, and conversely among the wealthier class the amount of disease and death is low.

IMMUNITY FROM TUBERCULOSIS.—Practically no one is immune to infection, but many are immune to the disease. The exact reason for this immunity is not known. Immunity is racial, family, or individual. The Jews and the Italians are relatively immune while the Irish and the Negroes have very little immunity. Family immunity exists, for in many families no evidence of tuberculosis may exist for generations. Then sometimes one individual in a family may remain well when all other members become diseased even though apparently exposed to the same dangers. Individual immunity varies also, for the immunity is lowered by acute illness, pregnancy, childbirth, long hours of laborious work, and constant undernourishment.

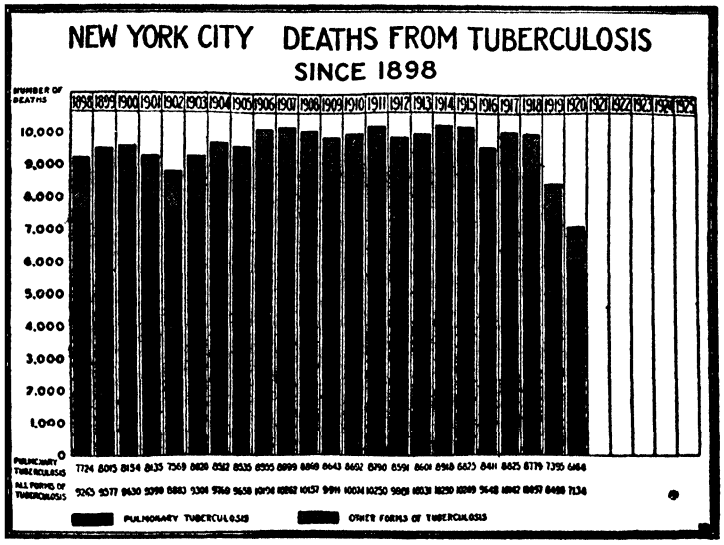
DANGERS OF INFECTION AND DISEASE.—The dangers are twofold. First, the risk of receiving at one time large quantities of tubercle bacilli from a case of advanced pulmonary tuberculosis or from the milk of a cow with tuberculosis of the udder. Second, having one's resistance lowered as a result of ill health or a poor standard of living. In many instances both factors play a part, as when a healthy woman cares for her tuberculous husband, the family income is lowered, the woman's work becomes more arduous and she is constantly exposed to infection. There is no considerable danger, however, from the brief exposure of healthy individuals to those affected with tuberculosis which

may occur daily in our crowded cities. Nurses, physicians, or employees in hospitals and sanatoria for tuberculosis are not thought to be in any considerable danger. In the latter case the patients are trained in the employment of sanitary precautions and tuberculosis is more rare in this class of hospital employees than in the same class outside of institutions. Consequently the presence of such an institution in a community is of no danger to its population. Milk from cows not proven to be free from tuberculosis is undoubtedly a source of danger, especially to young children whose intestinal wall will not always prevent the tubercle bacillus from entering the lymphatic system. Proper methods of pasteurization remove this danger.

SYMPTOMS OF PULMONARY TUBERCULOSIS.—The symptoms of pulmonary tuberculosis at the onset are cough with or without expectoration, loss of weight and strength, slight rise of temperature, and the spitting of blood. Any one or any group of these symptoms should arouse suspicion, and the patient merits a physical examination and an examination of the sputum, if there is any, for tubercle bacilli. If they are present it is a positive diagnosis. The examinations should be repeated if symptoms persist and an X-ray examination should be made also. The disease may be active, however, and detected by medical examination even when no symptoms exist. Fortunately this condition is relatively rare. Persistent cough and unexplained fever are danger signals and a pulmonary hemorrhage or hemoptysis is almost positively diagnostic. If the disease progresses, cough and expectoration, fever,

emaciation and night sweats are the prominent symptoms. Hemorrhages may occur and complications may arise in various parts of the body.

NON-PULMONARY TUBERCULOSIS.—If tuberculous disease develops elsewhere than in the lungs, it develops



a train of symptoms depending primarily on its location. If the meninges be affected, symptoms of meningitis; if the pleura or peritoneum, symptoms of pleurisy or peritonitis; if the intestines, symptoms of inflammation of the bowels; if glands, symptoms of inflammation resulting in a cold abscess; if bone or joint, symptoms of osteitis or arthritis.

TREATMENT OF TUBERCULOSIS.—Any chronic disease to be successfully treated requires two important fac-

tors—a skilled physician and a patient with character and an earnest desire to get well, come what may. There is no specific cure for tuberculosis though many cures have been heralded. Reliance must be placed upon rest, nourishment, and fresh air under the guidance of the physician. Sanatorium treatment is extremely valuable in training the patient to follow closely rules of conduct as to food, air, and rest, and the more skilled physicians are usually found in sanatoria or in resorts near them. Climate is a relatively unimportant factor, for recoveries take place in our crowded cities and in all climates. The disease was once supposed to be incurable. Not only are most cases curable, but thousands of persons who have been cured gladly give this testimony.

THE PREVENTION OF TUBERCULOSIS.—Preventive measures are primarily those which will prevent the bacilli from entering a healthy body by killing the bacilli as soon as they leave an infected body. If all bacilli coming from tuberculous individuals in the sputum or other discharges could be destroyed and all milk coming from tuberculous cows could be pasteurized, tuberculosis would soon disappear. Unfortunately, large masses of people do not know this and many persons have tuberculosis who do not know it, or even after they know it they endanger the lives of their families by careless habits. It is necessary, therefore, to educate the public in so far as is possible; to provide sanatoria for the care and cure of tuberculosis; to provide hospitals or special pavilions for the isolating of the more dangerous advanced cases; dispensaries to care for ambulatory or

moderately advanced cases, to supervise the chronic milder cases and to ascertain what facilities are available for institutional care; and finally public health or tuberculosis nurses to educate the other members of the patient's family and others to take the precautions necessary to prevent the disease.

Other general measures which improve the public health or the individual health are useful. Public health measures which provide pure water, sewage disposal, clean streets, sanitary housing, and measures which prevent other communicable diseases; general measures which improve the individual health by means of education of the care of the body; the Modern Health Crusade which not only teaches children the principles of health, but also trains them to acquire healthy habits; the playground, the summer camp, the fresh-air home, outdoor sports, proper habits of exercise and diet, rest and play and all measures which improve body health help in the prevention of tuberculosis.

Results of Prevention.—The death rate in the United States from tuberculosis has fallen from 201 to 99 per 100,000 during the past twenty years, which caused a saving of 100,000 lives in 1921. The value of these lives is almost beyond compute, as is also the cost of caring for such an army of sick persons. Suffering, death, and sorrows have diminished, but there still remains much to be done.

Work Still to Be Done.—More scientific research to determine many unknown factors on infection and immunity and the final perfection of a cure for tuberculosis which would be as effective as quinine is for malaria,

or a preventive as effective as vaccination for smallpox. Failing these, there is great need for increased education of the public, more health education for school children, better training for physicians and nurses from the scientific and social aspect. Most persons need not have tuberculosis unless they choose to do so by declining to do the things necessary for its prevention.

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LOUIS PASTEUR, AND LENGTHENED HUMAN LIFE

By Otis W. Caldwell, Ph.D.
Teachers College, Columbia University

WHEN Louis Pasteur was sixteen years old his father, anxious about his education, decided to send him from the home town of Arbois to Paris. The boy was to have the advantage of instruction in the École Normale, a school in which the father thought there would be an exceptionally good opportunity for his boy since the École Normale had been established to train men for college positions. This was in 1838, when schools were not generally as good in France as they are to-day. The elder Pasteur did not have the privilege of much schooling but had gained a fair education for his time by personal industry and efforts. Like many a father of recent times, or to-day for that matter, Louis' hardworking father decided that poverty should not deprive his son of a good education, and thus planned family sacrifices in the name of the boy's education. That parental sacrifice does not guarantee an education was as true of Louis Pasteur as it has proved to be of many another boy or girl. No sooner did the boy find himself at the school in Paris than an old and honourable malady befell the boy—homesickness. It is honourable and eminently respectable to

be homesick, even almost disgraceful not to be so on occasion; but succumbing to this worthy emotional illness is not so respectable.

Louis Pasteur's father was a tanner of hides, as had been his grandfather and great-grandfather. His home was near the malodorous tannery yard, and his childhood home street in Dôle before his family moved to Arbois, was known as the "street of the tanners." From his birth in 1822 until he was almost sixteen years of age, his life had been more or less associated with the tannery. And now, as a lonesome boy in a distant school, in a great city one hundred leagues from home, he longed so earnestly "for a whiff of the old tannery" that genuine illness would have been welcome if it could have secured his return to his home. Hours were days to the boy, and he soon decided he could stand it no longer. His work was poor, he was miserable, and so wrote to his father. The father, with much depression, went to Paris and took the boy back to his Arbois home.

The halo over the home and playground is sometimes more easily seen one hundred leagues away than close at hand. It was so with young Pasteur, for the halo evanesced and certain stern realities appeared. He soon announced his readiness to return to Paris, but the wise father replied that the schools of Arbois would suffice for the present. The boy became an outstanding pupil in drawing, so recognized by all. At night he went over all of his day's lessons with his father, not the lessons of the next day, as is so commonly done nowadays to make sure that pupils know their lessons; but the lessons of the preceding morning and afternoon, as

the father desired to learn those things with which the son was dealing, and Louis became truly his father's teacher. Two years in the schools of Arbois, then two years in the college at Besançon not far from Arbois, brought to Louis recognition as a successful student and as a tutor of his fellows. Then, at twenty years of age, in 1842, he returned to Paris as a student in the École Normale, soon to be widely recognized as a young man of industry, intellectual integrity, and earnest devotion to his studies.

In addition to other studies, Pasteur attended lectures at the Sorbonne and devoted much time to the study of the structure of crystals. He became widely known and highly respected as a student of chemistry, and on January 15, 1849, began an eight-year period of useful service as professor of chemistry at the University of Strassburg. A characteristic Pasteurism occurred in the early part of his stay at Strassburg. The rector of the University was most cordial to the newly arrived professor of chemistry and took him to his home, where Pasteur was introduced to the rector's wife and daughter. In two weeks Louis addressed a lengthy letter to the rector, serving notice that the elder Pasteur, according to the customs of the times, would soon appear and propose marriage between Louis and the daughter. In this letter Louis informed the rector that, "as to the future, unless my tastes should completely change, I shall give myself up entirely to chemical research." The father came, the proposal was made and duly accepted, the marriage occurred in three months.

At the close of 1854 Pasteur left Strassburg for a pro-

fessorship at the University of Lille, where he served for two years. Then he went back to Paris, which was the central location of his work for the rest of his life.

When Pasteur went to Lille he fully expected to continue his studies in chemical and physical problems relative to crystals. The brewers and wine makers about Lille were having great difficulty since they could not be certain to secure the kinds of fermentation specifically needed in different cases, in order to produce the different specific results they desired. The wine and beer "went wrong," fermentation could not be controlled, and the industry was suffering great financial losses, said to exceed $20,000,000 yearly in certain years. Pasteur was known as a chemist, and as a manipulator of the crude microscopes of that day. The manufacturers appealed to him to solve their problems, and he reluctantly agreed to the temporary diversion from his chosen studies, for he saw in this study great possibilities of new knowledge. Through the studies of famous German students, much had recently been learned about the yeasts which produce fermentation and about certain bacteria, but application of these studies had not been made in the brewing industries. There was still extended belief that the living organisms of fermentation came into existence spontaneously (spontaneous generation of life, as it was called), and that such organisms spring into existence in the wine and beer because of "a vital force of nature," and thus injure it. Pasteur, and others even more than Pasteur, proved that if nutritive liquids are sterilized and con-

stantly kept from contact with air and other unsterile substances, no organisms will develop within this nutritive liquid no matter how long the experiment is continued. There was recently exhibited in the United States (1922), a flask of beef broth which it is claimed, correctly no doubt, that Pasteur prepared over fifty years ago. The beef broth is still fresh-looking and clear, never having had the stopper removed from the glass flask in which the broth has been constantly kept. Small living things, like the larger ones which we readily see, come only from other living things of their own kind. The process of treating wines as recommended by Pasteur, known as pasteurization, has since been applied to milk in all civilized countries.

With previously gained facts in mind, Pasteur proceeded to separate single living yeast plants under his microscope, and then to grow pure cultures from these organisms thus separated. He not only found that they grew as pure culture, but that each kind of small organism produced its own peculiar kind of fermentative products in the nutritive liquids. He thus taught the brewers and wine manufacturers how to separate, grow, and use the particular kinds of living microscopic organisms which produce the kinds of wine and beer that they desired.

We are not keenly interested in the fact that such discoveries taught people how to save the alcoholic industries of France and Germany. What interests us most is that he isolated the microscopic organisms, grew them in pure cultures, and proved that microscopic living things, like the larger ones we readily see,

each produces its own peculiar results as product of its life and growth.

We need to recall that when Pasteur was studying fermentation the human race did not know the causes of human diseases. Causes had been suspected, but not proved. What we know to-day as the science of public health did not exist. The bacterial origin of diseases was merely suspected, and the idea generally ridiculed. If a person had been bold enough to assert as true even a small part of what we now know to be true, such a person would have been thought insane or foolish. It was then not uncommon to think that persons who became ill had been guilty of some gross wrong-doing, and that illness was sent upon them as punishment for their sins. Or it was sometimes said that the "humours of the body," of which the blood and the bile were two, in some way got into wrong proportions or became deranged and thus caused illness. It is now generally known that most, if not all, common diseases are caused by living microscopic organisms, either bacteria or small animal parasites. Though this knowledge is but a few decades old, it is so common that it is difficult to put ourselves back to the recent date when the human race did not possess this knowledge. It is of such untold importance that Louis Pasteur lived and accomplished what he did, that, as we read this chapter, we must imagine ourselves for a time moved back a little more than forty years in the history of man's desire and efforts to have better health. Then, as now, most people wished to live instead of to die, and while living wished to have the best possible health. Then, as now,

there were some benighted people who would not do the things necessary to produce good health, even if knowledge of how to do them were available.

When Pasteur's yeast and spontaneous generation studies were almost completed, he was urged to go to southern France to try to discover why the silk worms were sick. He tried to decline saying: "I have never touched a silk worm in my life." Why did people urge Pasteur to do this? Why didn't they call a bacteriologist or a student of insect diseases? At that time there were no bacteriologists because there was no bacteriology. Of course there were bacteria, but since no one then knew the laws of bacteria, there was no bacteriology. Likewise there was no science of insect diseases, or science of diseases of men as we now understand those terms.

For many years the silk industry of France had suffered. Often the worms became sick and died, or if they lived, they produced poor cocoons. Poor cocoons, or no cocoons, mean reduction or loss of the desired silk, which means poorer food for the people, poorer education for their children, and all the poorer things which accompany reduction or loss of a fundamental industry. So important was the silk industry in southern France, and so great the anxiety about the health of the silkworms, that one writer says the workers when meeting would salute one another by saying: "Good morning! How are the silkworms this morning?" What they desired was good healthy adult silk moths which laid good moth eggs; that these eggs should hatch into worms which might feed and grow healthily upon their

food, the mulberry leaves; that the full-grown worms might spin good cocoons from which the workers could unravel the desired silk; that enough good cocoons should be left to produce adult moths to continue production of new supplies of healthy eggs.

Pasteur began this study in 1865. He studied the eggs and found within some of them certain small bodies resembling the smallest animal cells. He called these bodies corpuscles, simply meaning "small bodies." He noted that when eggs which contained the corpuscles hatched, the worms were sickly and usually died. Using his crude microscope, he separated the eggs which contained no corpuscles and caused them to hatch. The worms thus produced seemed to be healthy, and after careful work, Pasteur announced that people could produce healthy worms and good cocoons by selecting eggs which contained no corpuscles. When this was tried and failed, Pasteur patiently returned to his microscopic studies and found another small organism, a bacterium, and immediately concluded that the silkworms had two diseases instead of one. One, *pebrine*, was caused by the animal corpuscles; and the other, *flacherie*, caused by bacteria. Through long and careful experiments he discovered that eggs selected so as to be free from corpuscles and bacteria would produce healthy worms; that such worms when grown upon fresh mulberry leaves would mature and produce good silk cocoons; but that even healthy worms when grown were likely to sicken and die. He thus concluded that the corpuscles and bacteria produce the diseases, and that diseases from sick worms may be transmitted to healthy

worms by contact with the food in which sick worms have fed. It is not so important that Pasteur taught France how to save her silk industry as it is that he proved that the small organisms produce the diseases; that transmission of the organisms may transmit the disease; and that prevention of transmission prevents disease. We are not likely to over-estimate the importance of these discoveries to modern public and individual health.

Meantime the cattle and sheep industry of France and of other countries was suffering from a disease known as anthrax. So deadly was anthrax to human beings that when once it was clear that a person had the disease, it was regarded almost as a death warrant. Fortunately and for reasons then unknown, the disease did not often attack human beings. Its destruction of cattle and sheep was enormous.

Other students had discovered the nature of the bacterium which causes anthrax and had definitely proved the causal relation of the organism. But since no preventive or cure had been discovered, people appealed publicly to Pasteur to attack the problem. No less than 3600 public officers and prominent citizens signed petitions to Pasteur to undertake to find a means of preventing the ravages of this dreaded disease. He responded and began the study. It is interesting and important to know that the so-called anthrax bacteria cause the disease anthrax; but if they cannot be kept from causing the disease what does the knowledge profit us? If cattle and sheep and men must die, there really isn't large comfort in mere knowledge of what

caused this wholesale death. That knowledge was essential for the beginning of Pasteur's study, but was merely the beginning.

After many efforts, too many and too intensive to be related in this connection, Pasteur recalled an important discovery made by the Englishman, Jenner, in 1798. Jenner, working in England, noted that persons who milked cows which were ill with cowpox contracted a disease resembling human smallpox, and that thereafter such persons would not contract smallpox from human beings ill with that disease. Jenner devised means, now improved and known to everyone, for giving human beings generally the infection or vaccination which protects against smallpox. In recalling this situation, Pasteur argued that smallpox was caused by a living organism; that the organism when it lived in cattle did not flourish, and that this organism when introduced from cattle into human beings was not vigorous enough to produce a bad case of smallpox; that the case produced was bad enough, however, to leave some kind of protection or immunity against an attack from organisms from persons who have a vigorous case of smallpox. This line of thought is most interesting when we recall that we do not yet possess satisfactory evidence as to just what kind of an organism causes smallpox.

Meantime Pasteur had been carrying on experiments with chicken cholera. He left cultures of chicken cholera germs in his laboratory, and went away for a short vacation. Upon his return he found that these old cultures would no longer produce chicken cholera when

some of the cultures were injected into fowls. Most important of all, he found that after the fowls had been treated with these old cultures they would not take chicken cholera even when injected with fresh and virulent germs. Therefore partly by chance came the discovery of the process of vaccinating poultry against cholera by use of depleted cholera germs or possibly by use of the dead products remaining in old cultures of these germs.

Thus Pasteur began his efforts to reduce the vigour of anthrax germs so that perchance they might not produce anthrax of usual destructiveness. Many highly illuminating experiments were performed. Finally, by growing anthrax bacteria in beef broth at high temperatures, it was found that they flourished for a time, then slowly died out. By using some of these cultures when the bacteria were much depleted, it was found that sheep could be given mild attacks of anthrax from which they recovered. After their recovery they were given fully active anthrax germs, from which the sheep promptly developed bad cases of anthrax and died. Pasteur then tried a first vaccination of depleted bacteria, and when the sheep had recovered, gave a second mild attack by use of bacteria much less depleted than those first used, but far from normal vigour. The sheep and cattle upon which this experiment was tried took successive mild attacks of anthrax. Thereafter, fully virulent anthrax bacteria failed to produce the disease, and Pasteur announced his triumph in producing progressive vaccination with successful results.

So important was this discovery that Pasteur was

challenged to make a public demonstration of his claims. The Agriculture Society at Melun, France, offered to provide sheep and cattle for the demonstration. Delegates were invited and came from many interested organizations and countries. Pasteur penned ten sheep to serve as controls to determine whether anthrax was in the food, air, or water given to them and to the other sheep and cattle. Twenty-five sheep and six cows were to be vaccinated, and twenty-three sheep, two goats, and four cows were not to be vaccinated but were to receive fully virulent anthrax bacteria at the same time as the vaccinated sheep and cattle. On May 5, 1881, the first vaccination was given to the twenty-five sheep and six cows. On May 17, 1881, the second vaccination was given to the same animals. On May 31, 1881, fully virulent anthrax germs were given to all vaccinated sheep and cows, to the four remaining cows, and to the twenty-three sheep and the goats. Pasteur told the delegates to return on June 2. This direction was unnecessary as most of them did not leave, so keenly did they appreciate the momentous importance of what was going on. Many were disbelievers and expected Pasteur's downfall. The results were triumphant. On the morning of June 2, all of the non-vaccinated sheep and cows and the goats were dead, dying, or severely ill. Not a vaccinated sheep or cow or a control sheep died as a result of the treatment they had received. Since that day the human race has known how to avoid anthrax, if only it will do what is known as good to do. More than this, the idea of successive vaccination was proved, and this has been the founda-

tion of many subsequent advances in prevention of diseases of several types.

Did Pasteur then retire from active labour, one man's gigantic work having been done? Did he remind his co-workers that since 1868 half-paralysis had made his work very difficult? No! Rather he reminded his closest friends that his part-paralysis which he suffered in 1868 enabled him to make more cautious and effective use of those parts of his body not affected by his malady—a malady for which the answer is not yet at hand. Instead he turned now to his last and most spectacular achievement. For many years the sympathies of this great founder of the science of bacteriology had been sorely tried because of the ravages of the awful disease rabies or hydrophobia. It is doubtless true that the cry of "mad dog" has created human panic since the times of primitive men. No sane person who has witnessed death from hydrophobia will willingly do so a second time, unless he is needed in ministrations of assistance or mercy. For years Pasteur had studied the dreaded disease and performed experiments with rabbits and other animals in efforts to locate the causal organism and to find a preventive or cure. It almost belittles this gigantic task to go directly to results, omitting description of many fruitless efforts, false hopes roused in the man whose heart as well as mind was now devoted to his supreme task. However, one day, after many failures to locate any guiding arrow, Pasteur used for inoculation in a rabbit a piece of old and dry spinal-cord tissue previously taken from a rabbit that had died of rabies. He had previously oftentimes

transmitted the disease by use of nerve tissue, but the diseases thus produced were violent and death-producing. This time, however, the desiccated nerve tissue produced a mild attack from which the rabbit recovered. Following this lead, a series of less and less dry nerve tissues were used to produce a cumulative series of mild attacks, after which the bite of a rabid animal failed to produce hydrophobia.

At this juncture one of the most striking events of all science occurred. Frau Meister, of Alsace, had a boy, Joseph, who two days before had been bitten by a rabid dog. Such an attack as that shown by the fourteen bites upon the unfortunate boy had been previously regarded as meaning almost certain death. The mother had heard of Pasteur, and at once started to Paris with her boy. The treatment had not been given to any human being; it was not known whether results would be similar to those obtained in lower animals; it was not known what series or gradation of treatments would be necessary for human beings; it had been proved that the treatment could be applied to animals after a rabid bite, and that protection could be secured. Frau Meister was obdurately insistent. Pasteur's advisers intimated that the boy's death would be upon Pasteur if he refused to treat him and the mother absolved him from responsibility if the treatment were given. Against advice from his friends, Pasteur began the experiment upon the boy, shortening the periods between treatments in efforts to secure cumulative protective results. The ignorant but beautiful confidence of the mother and boy permitted them to sleep and rest between

treatments; but the highly intelligent understanding and tremendous responsibility and hope of Pasteur made sleep and rest almost impossible for him until the crisis had passed, and he felt sure that the boy's life had been saved.

Soon Pasteur institutes appeared in available centres throughout the civilized world, and to-day it is very rarely that a human being need die from hydrophobia. Superstitious and ignorant fear of hydrophobia has given place to the intelligent guidance of modern science.

On Pasteur's seventieth birthday (1892, three years before his death) delegates from the scientific societies and public bodies of the civilized world met in France, in the great theatre room of the Sorbonne. The band of the Republican Guard of France played the triumphal march. The President of the Republic was the escort as down the aisle came one of the greatest heroes and benefactors in human history. Gounod directed a choir which sang his Ave Maria. Coquelin recited verses written by him especially for this occasion. The Minister of Public Instruction among other things said:

Who can now say how much human life owes to you and how much more it will owe you in the future? The day will come when another Lucretius will sing, in a new poem on Nature, the immortal Master whose genius engendered such benefits.

Joseph Lister, when called upon said:

Your researches upon fermentations have thrown a powerful light which has illuminated the baleful darkness of surgery and has changed the treatment of wounds from an uncertain and too often

disastrous empirical affair into a sure beneficent scientific art. Thanks to you, surgery has undergone a complete revolution which has robbed it of its terrors, and has enlarged almost without limit its efficacious power. Medicine owes not less than surgery to your profound and philosophical studies. You have lifted the veil which had covered infectious diseases during the centuries; you have discovered and demonstrated their microbial nature. Thanks to your initiative and, in many cases, to your own special work, there are already a large number of these pernicious maladies of which we now know the causes.

Then Pasteur rose and spoke quietly and feelingly of his hope that science would save men from their bodily ills; that men will be more useful when free from disease. Then turning to the delegates he said:

And you, delegates from other nations, bring me the deepest joy that can be felt by a man whose invincible belief is that Science and Peace will triumph over Ignorance and War, that nations will unite, not to destroy, but to build, and that the future will belong to those who will have done most for suffering humanity.

The foundations of the science which may remove from man all his bodily ills if only he will turn his mind to them long enough, with sufficient patience and unselfishness—that is the achievement of Louis Pasteur. Human life is now much lengthened because of the work of Pasteur, by the few others of his time, and by the many others since who have been stimulated and whose work has been made possible by him. Those who know and do what modern health science teaches are the ones whose lives are lengthened. It is they who are of most worth to the world. A man at forty has just learned how to work. To add ten or fifteen or twenty years to his life saves to the world a man who is equipped and ready. His added years may double his service to the

world. Surely in an age when great warriors are still extolled, it is supremely important for our young people to appreciate that true heroes help men to live and serve rather than teach them to vanquish and destroy their fellows.

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INTERNATIONAL PUBLIC HEALTH

By George E. Vincent, Ph.D.
President of the Rockefeller Foundation, New York City

IF THE hygienic control of the world were put in the hands of some superman with scientific knowledge and authoritative powers it is possible to imagine the way in which he would organize his forces and carry out his task. First of all he would not rest content with the scientific resources in his possession, but would provide for continuous investigation in order to re-examine constantly the knowledge already acquired and to add new information. He would fit up well-equipped and competently manned centres for investigation. These institutions he would place in strategic positions throughout the world in such a way as to bring the widest variety of diseases under constant scrutiny. He would further see to it that the staffs of these research centres were in constant communication so that duplication of effort would be avoided and the results secured in one place put quickly at the disposal of workers in all the other institutions. In this way he would organize medical research as a world activity, constantly recruiting his groups of investigators and producing steadily new knowledge about the nature, cure, and especially the prevention of the maladies which afflict mankind.

In the second place, this hygienic force would effect an administrative health organization throughout the world. Each country would be subdivided into sanitary districts, while the nations themselves would be brought into a unified administrative system under central control. Thus stationed throughout the world would be health officers with their technical experts and subordinates all organized into a hierarchy under single authoritative control. Under such a military régime sanitation, control of epidemics, regulation of individual conduct in the interests of health would be in force with all the efficiency which characterized the success of preventive measures in Cuba and the Panama Canal Zone.

In the third place, through such an organization as has been described, there would be centralization of vital statistics—accurate and trustworthy conclusions based upon the reports of competent diagnosticians performing their duties in an objective way uninfluenced by economic and social considerations. These statistics constantly gathered and interpreted by experts, would guide the organization and conduct of health campaigns in various parts of the world to meet situations as they were revealed by the statistical data. The appearance of an epidemic would be instantly reported to headquarters and orders would issue at once to apply measures which would insure the prompt control of the threatened outbreak. Outposts and barriers against epidemics would be established and held in readiness for emergencies. Gradually the foci of diseases would be circumscribed until finally these sources of danger would be eliminated.

In the fourth place, the guardian of the world's health would not rest content with the negative control of disease. He would regard sanitation and epidemiology as only the first steps toward a positive campaign to be carried out through control of the diet, housing, exercise, and recreation of the world's population. This benevolent autocrat would see to it that children were well born and nourished and from their earliest days trained to hygienic habits. In this way he would, through the perfect obedience of millions to the dictation of wisdom and benevolence, produce a vigorous and healthy race.

Of course, as fundamental to this entire programme the commanding officer would establish medical schools and training centres in which the officers and privates of his army of hygiene would be recruited and trained for their important tasks. Under his guidance medical schools would transfer their chief interest from the cure to the prevention of diseases. The stress would be laid upon early diagnosis and upon preventive treatment, upon frequent medical examinations, upon sound habits of living, upon the importance of mental serenity and a stimulating social life. From such schools of medicine and hygiene would go out men and women apostles of the doctrine of prevention determined to keep people well and regarding the occurrence of disease among those under their charge as a serious reflection upon the vigilance and resourcefulness of the members of the profession.

The description of an arbitrary control of this kind in itself sufficient to show how impossible and in-

tolerable such a régime would be. Local autonomy, nationalistic feeling, the absence of supermen, and human nature's resentment of control imposed from without are a few of the many obstacles which would make it utterly impossible to bring about the hygienic solidarity of the world. But the outlining of an imaginary unified system of control at least serves as a background against which to observe influences which have been going on for a long time in the world, but which of late have gained greatly in definiteness of organization. In some sense, every one of the things which have been suggested as a part of an imaginary world organization is being to a degree accomplished.

Thus there are more than 445 medical schools scattered throughout the world. They represent the influence of three systems of medicine: the British, the Latin, and the German. These systems have been distributed in accordance with well-organized principles of national influence. The British system has prestige throughout the Empire, subject to modification especially in Canada. French medicine prevails in the Latin countries of Europe and in Central and South America; while the German plan is largely followed in Scandinavia, Austria, eastern Europe, in the Balkan regions, and in Japan. In the United States a combination of British and German methods has been gradually developed with certain features which are not found in either of the two European systems. The three national types are yielding to internal influences which may be counted upon to produce, not uniformity, but a more cosmopolitan ideal than at present exists anywhere in the

world. In short, forces of intercourse and coöperation are approximating a world system more successfully than anything but the control by a superman could bring about.

Moreover, institutes for medical research are found in many parts of the world. Of these the best known are the Pasteur Institute of Paris, the Rockefeller Institute of New York, the London and Liverpool Schools of Tropical Medicine, the Hongkong School of Tropical Medicine. Many other centres exist throughout the world. These centres, through publications, migrations, and international congresses are kept in close communication so that knowledge of each other's work is quickly disseminated. In a very true sense there is an informal and effective world organization for prosecution of medical research. Many of the medical schools are an integral part of this system, making important contributions to what is a genuine international product.

In the collection of vital statistics definite progress toward world organization has been made. Through the *Office International d'Hygiène* in Paris, forty nations are regularly exchanging information with respect to vital statistics. Uniform methods of reporting deaths have been agreed upon and are to a considerable degree being successfully carried out. The areas from which trustworthy and acceptable reports are made in various countries are being gradually extended. It is true that only a beginning has been made but these beginnings have sketched a programme of international coöperation in the gathering and dis-

tribution of vital statistics which will inevitably be steadily elaborated during succeeding decades.

Growth of health organizations in different countries is constantly recorded. The leading nations of the world are giving increasing attention to health administration; administrative areas are being organized and trained sanitarians put in charge. Not only is this national organization going forward, but the nations are drawing closer together in their coöperation for world health. The first European conference to consider health problems was held in 1851. Twelve nations were represented. Concerted measures against cholera, plague, and yellow fever were adopted. Thereafter at intervals of a few years other congresses were called to insure better team-work in conformity with rapidly advancing knowledge of preventive medicine. In 1902 an International Sanitary Bureau was established in Washington by the Pan-American Union. Finally, in 1908, a permanent International Office of Hygiene, which has already been mentioned, was established in Paris.

The most significant development in this world movement is the recent creation under the League of Nations of a Health Organization which has the direct support of fifty-two nations and the sympathetic cooperation of the United States. The programme of the League's Health Organization includes the gathering of vital statistics, prompt notification of epidemics, a standardizing of vaccines and sera, international conferences and exchanges of health officers, securing of better health conditions for sailors on shipboard and in

ports, coöperation with League mandatories, with the Commission on Opium, and with the Labour Office.

The fact that great epidemic diseases disregard national boundaries forces upon nations the adoption of coöperative measures against the ravages of these diseases. The first congress in 1851 was called to consider ways of dealing with cholera, plague, and yellow fever. The most striking illustration of national coöperation was afforded in 1920 and 1921 by the special commission against typhus in eastern Europe. This campaign was organized under the auspices of the League of Nations and had the direct financial support of fourteen governments. A sanitary barrier was erected in eastern Europe and the march of the disease was halted. There is every reason to expect that cooperation of this sort will become more frequent and that diseases which heretofore have flourished because they encountered only unorganized resistance will now face the united front of a world sanitary army.

After public-health officers have done all that they can in the way of sanitation and control of contagious diseases, there remains a majority of diseases with which only the individual can deal. A large part of the problem of public health resolves itself into the question of personal hygiene. Only by changing the health habits of millions can the level of national and world efficiency be raised. In attempting this task certain traits of human nature must be reckoned with. All the resources of modern education, publicity, and suggestion must be employed. Especially must the habits of children be formed while they are still in a plastic stage.

Thus attempts in popular education in personal hygiene are being made in many countries and by various methods. The movement is still in the stage of experiment and demonstration. There are some signs of definite accomplishment in this field, but much remains to be done in the way of testing the material and methods of instruction before the campaign can be pushed with complete conviction and hope of permanent success. But this is inevitable unless control from without is to be substituted for mere self-direction. No one advocates the course of compulsion except with respect to well-established conditions of contagious disease which call for the exercise of the police power of the community in the interests of all.

The essential task of training health officers and the various technical experts who form the staff of a modern health organization is being put upon a professional basis. The School of Hygiene and Public Health of Johns Hopkins University, the new School of Public Health of Harvard University, the School for Nurses of Yale University, the training centres at the University of Toronto and at London, Ontario, the new School of Hygiene which is being established in London under the auspices of the British Government, the Institutes of Hygiene at Prague and Warsaw, and many other institutions of a similar sort are equipped to give a thorough professional training, both in the fundamental sciences which underlie modern hygiene and in the practical application of scientific knowledge to the problems of control and administration in the field. Through a system of interchange of health officers being carried

on by the Health Organization of the League of Nations, a spirit of international coöperation is being created in this individual and personal way; the knowledge of health procedures in one country is being put at the disposal of other nations.

The direct coöperation of governments is having an important bearing upon the growth of international hygiene. The leading governments furnish health officers in the ports of other countries so that valuable means of contact and coöperation are established. What amounts to the appointment of attachés of hygiene is being brought about so that it is possible to look forward to a time in the early future when every country will have its sanitary representatives in other lands. Such a system cannot fail to increase in many ways the effectiveness of organization and activity in behalf of world health.

Non-governmental health agencies are playing a significant part in the new hygienic movement. The international Red Cross has for many years concerned itself with the health conditions of prisoners of war. With the organization of the League of Red Cross Societies in 1919, a new international voluntary agency was set up. A programme of this society includes as an important feature the promotion of public health measures in the different countries where the Red Cross Society has been established. The Rockefeller Foundation, through its subsidiaries, the International Health Board, the China Medical Board, and the Division of Medical Education, is carrying on work which, during recent years, has included items of coöperation

and service in sixty of the governmental areas of the world. It has demonstrated on a large scale the possibilities of the control of hookworm disease and the use of such control measures as a means of educating whole populations in the matter of public health work. The International Health Board of the Foundation has also conducted a successful campaign which aims at the complete eradication of yellow fever. This has called for the coöperation of Mexico, Central America, and several South American countries. The outcome is a striking proof of what can be accomplished when nations work together with complete confidence and good-will.

Thus as we try to get a picture of what is going on today in the world in the interests of the health of all the nations, we see that there is something like an approximation to the ideal system which a superman might conceivably try to set up. As compared with what remains to be accomplished, only an insignificant start has been made, but looked at from the standpoint of a century ago, really striking progress has already been achieved. In the last half century the scientific resources of modern medicine have been enormously enriched. The causes of a great number of devastating diseases have been discovered; the methods of controlling them have been worked out; medical education has been put upon a higher level; a beginning has been made in the training of expert sanitarians and an entire hygienic personnel. Organization of health administration has been greatly increased in efficiency. The death rates in all the leading countries of the world have fallen

in a most gratifying fashion. Beginnings have been made in the education of the public in the laws of personal hygiene. International understandings and goodwill have been promoted. He would be hopeful indeed who should at the present time see anything like a millennium of human brotherhood; but at any rate it is obvious that the tendencies now to be seen in the world toward coöperation for health cannot fail to draw scientific men everywhere into closer comradeship. So much is clear gain. There is reason to hope that for a time at least the resources of science will be turned from the destruction of human life to the healing of the nations.

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EDUCATIONAL VALUE OF MODERN BOTANICAL GARDENS

By George T. Moore, Ph. D.
Director of the Missouri Botanical Garden, St. Louis, Mo.

THE cultivation of plants for their healing qualities by the monks of the middle ages appears to have been the beginning of the modern botanical garden, although these medieval gardens doubtless took their origin from others of greater antiquity.

A most ingenious theory concerning the origin of botanical gardens was put forward by a Frenchman who claimed that during the 16th century designers of embroidery and lace in France sought inspiration from blooming plants. To meet this demand an enterprising horticulturist opened a garden with conservatories in which he cultivated many strange and little-known varieties. Later this garden became crown property and medical students were admitted on condition that they would not interfere with the designers of textiles and laces. Although the aesthetic study of plants must have appealed to those who visited public gardens, and even at the present day designers and makers of artificial flowers get many ideas from studying nature, it seems quite certain that botanical gardens were primarily created for the students of *materia medica.*

The educational value of a botanical garden did not develop much, if at all, prior to the middle of the 17th century, when those at Bologna, Montpelier, Leyden, Paris, and Upsala became more or less noteworthy as aids to scientific teaching. The taste for ornamental and decorative plants had meanwhile been slowly growing and persons of wealth and influence, desiring to cultivate rare and unusual species, began to employ men skilled in botanical knowledge to take charge of their gardens. The world was searched for new and rare plants which were brought back for cultivation in the botanical gardens of Europe, and many handsomely illustrated volumes describing these plants were published by the rich patrons of botany. These older gardens were essentially private institutions, but gradually a few of the existing establishments and a number of new ones were opened more or less to the public.

Modern botanical gardens, therefore, have a number of functions which have not appeared simultaneously but have been a matter of gradual development. Beginning with the utilitarian idea, there have been added to this the aesthetic, the scientific, and the educational. Naturally these elements have been given different degrees of prominence depending upon local conditions; but whether a garden be essentially scientific or mainly utilitarian, or combine all of the essential functions of a garden, it is clear that the educational features are receiving more and more emphasis. Formerly a public garden was a mere museum of living plants; at best a place for recreation and pleasure. Nowadays the at-

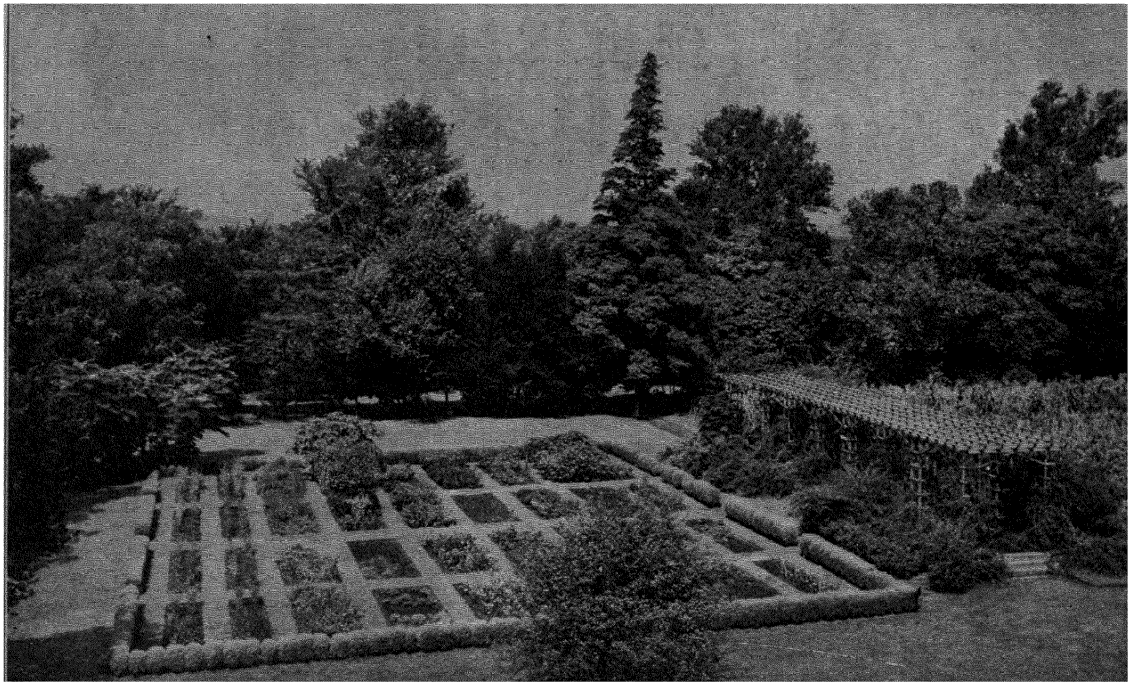
tempt is to have collections which, while appealing to the sense of the beautiful, will give definite information and instruction to the amateur as well as to the specialist.

The modern botanical garden fails to serve the community as it should if the school pupil as well as the advanced student is unable to learn much from it. Modern educators who are seeking to find improved methods of teaching are beginning to recognize the fact that gardens furnish some most important and unique opportunities for imparting knowledge. Formerly books and travel were the chief sources of information to the general public; in these days of the phonograph, the radio, and the moving picture, visual education is taking a larger and larger place. Exhibits of plants native to countries being studied in geography may give a better idea of conditions in that country than anything short of an actual visit could accomplish. The growing of tropical fruits, spice and perfume plants, rice, cotton, sugar cane, coffee, tobacco, peanuts, and other economic plants, particularly if their peculiarities are pointed out by one familiar with their various characteristics, forms a most helpful adjunct to modern educational practices. Nowhere can fundamental facts concerning heredity, selection, and breeding be so well demonstrated as in a garden; and an insight into physiology, morphology, and pathology may be easily gained when presented through the life of a plant. Most children are interested in gardens of one sort or another and through their desire to learn what to grow and how to grow it, as well as the kind of care which must be exercised in order to make a success, many important bits



Photo by Louis Buhle

Nearly 75,000 children are annually reached through the work of the Brooklyn Botanic Garden. Group teaching seen any day in the children's garden



A section of the Demonstration Garden, Missouri Botanical Garden

of real knowledge, as well as much general information may be imparted. For this reason a botanical garden as an educational institution may be a much more helpful feature in a community than a zoölogical park or a museum, since it comes so close to everyday life.

It is impossible to treat in detail the various kinds of exhibits and demonstrations prepared to impart knowledge to young persons. The ease with which this may be done coupled with its recreational and pleasure-giving qualities, makes it desirable for many communities to include in their educational systems a botanical garden of some kind. Not only should the rare "vegetable curiosities," consisting of a sort of botanical circus, be featured, but common things such as wild flowers, weeds, and farm crops must also be instructively displayed. Accurate labels giving the most important information about plants are a necessity, and by using different colours to indicate the country from which plants come or the uses to which they are put, definite facts and geographic interpretations are absorbed almost unconsciously. When to the educational function is added the great humanizing power of a garden, and the recreational service which it is able to render to the business man, the student and the plant lover, it becomes clear why so many thousands of citizens regularly visit gardens in cities which possess them.

Guide to Further Reading

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THE MEANING OF EVOLUTION

By John M. Coulter, Ph.D.
Professor of Botany, University of Chicago

THE meaning of evolution is probably more misunderstood than any doctrine of science. The reason for it is that it has been discussed very freely by those who are not informed, and in this way much misinformation has been propagated. The evolution of the material world, called inorganic evolution, aroused wonder but not apprehension; but when organic evolution came into prominence hostility was aroused, because such evolution seemed to involve man. The general meaning of organic evolution is that the plant and animal kingdoms have developed in a continuous, orderly way, under the guidance of natural laws, just as the solar system has evolved in obedience to natural laws. There are at least three important reasons why an understanding of the doctrine of evolution should be regarded as a necessary part of college training:

1. It has revolutionized modern thought. Every subject to-day is being attacked on the basis of its evolution. Not only are inorganic and organic evolution being considered, but also the evolution of language, of literature, of society, of government, of religion. In other words, it is a point of view which represents the atmosphere of modern investigation in every field.

2. It is persistently misunderstood. From the press, the lecture platform, and even the pulpit, one frequently receives amazing statements in reference to organic evolution. If it were made an essential feature of student training, there would be developed a propaganda of information instead of misinformation.

3. It has revolutionized agriculture. The practical handling of plants and animals in the way of improving old forms and securing new ones, was made possible and definite when the laws of inheritance began to be uncovered through experimental work in evolution.

In brief, the purpose of a course in organic evolution should be to give some appreciation of its meaning and methods, to furnish a check on rash and unfounded statements in reference to it, and to show how the study of evolution has led to enormously practical results.

Periods in the History of Evolution

There have been three distinct periods in the history of evolution, based upon the method of attack. These three methods may be spoken of in general as speculation, observation and inference, and experimentation.

1. Speculation.—The *idea* of organic evolution is as old as our record of men's thoughts, for all the old mythologies are full of it. No modern man, therefore, is responsible for the idea, although it is a common misconception to load this responsibility upon certain distinguished modern students of evolution. For example, the name of Darwin is so conspicuous in connection with evolution that many seem to think that Darwinism and evolution are synonymous. Until 1790,

however, organic evolution was a pure speculation, with no basis of scientific work. In other words, it was based upon meditation rather than investigation, and was to be regarded as a philosophy rather than a science. It should be emphasized that the idea of evolution has always been in the mind of men.

During the latter part of this period certain facts began to be observed that made some thinking men conclude that evolution might be a *fact*, and not merely a speculation. It will be helpful to note briefly, in historical succession, the kinds of facts that set these men to thinking, and that resulted in the second period in the history of evolution, when it became a science.

In classifying plants and animals, which was the initial phase of biology, men rigidly defined the different species, the thought being that the different kinds had descended in unbroken succession "from the beginning," whenever that may have been. When more extensive observations were made in the field, numerous intergrades began to be found. The species, as defined, seemed to intergrade freely. In other words, the pigeon-hole arrangement, with rigid partitions, did not express the facts. It became evident that species had been defined by man rather than by nature. Some were distinct enough, but many intergraded. It ought to be realized that a species is the conception of man, and fluctuates just as do human opinions. Biologists learned, therefore, that species are human inventions, and intergrading suggested that one species might come from another, the intergrades marking the trail.

The next observations suggesting that evolution

might be a fact had to do with what was called the "power of adaptation," which we now call "responses." It was observed that plants and animals respond to changes in environment, often in a striking way. I have seen what were regarded as two good species changed into one another by changing from a moist habitat to a dry one, or the reverse. This ability to respond to changing conditions seemed to indicate that species are not so rigid and invariable as had been supposed.

As technique developed, and the internal structures of plants and animals became known, it often happened that rudimentary structures were found, which never developed to a functioning stage, but which occurred fully developed in related forms. For example, it was found that in the developing parrot a set of embryo teeth begins, but never matures. The inference was natural that these structures had been functional in the ancestors, but had been abandoned by some of their descendants. In these days, it has become the habit to call these rudimentary structures "vestiges." Plants and animals are full of these vestiges. One illustration in the human body is the vermiform appendix. It seems safe to say that we are walking museums of antiquity. As technique developed still further, the embryology of plants and animals began to be studied in detail, the whole progress from egg to adult being observed. In very many cases, during this progress, glimpses of fleeting structures and resemblances were obtained, which had disappeared when the adult stage was reached, but which related the form to other species.

After this succession of facts, there came a revelation which convinced more men that evolution is a fact than any evidence which had preceded. The geologists had begun to uncover that wonderful succession of plants and animals from the earliest geological periods to the present time. They saw in the oldest periods forms unlike any now existing; they saw gradual changes with each succeeding horizon; they saw a steady approach to forms like those of to-day, until by insensible gradations the present flora and fauna were ushered in. This geological record, becoming continuously more detailed in its interpretation, set men to thinking seriously.

Finally, after all this evidence was in, men began to look around them and to realize what they had been doing for centuries in domesticating animals and plants. They had been bringing them from the wild state and changing them so much by the methods of culture that in many cases the wild originals could not be recognized. Most of our cultivated plants, if found in nature associating with their wild originals, would be regarded as extremely distinct species.

In the presence of such an array of facts, is it to be wondered at that certain men began the serious, scientific study of evolution? As a result, the second period in the history of evolution was ushered in, and evolution became a science.

2. Observation and Inference.—In time this period extends from 1790 to 1900. It is characterized by the appearance of a succession of explanations of evolution. It is important to remember that the men

who offered these explanations are not responsible for the *idea* of evolution, but merely attempted to explain the *fact* of evolution. They were explainers rather than authors. It is also important to realize the method used. It may be called the method of comparison and inference. Plant and animal forms were observed, and resemblances were assumed to indicate relationship through descent. It was not demonstration, but inference based on observation. Darwin carried the method to the limit of its possibilities, observing not a small range of forms, but observing through several years a world-wide range of forms, in connection with the famous voyage of the *Beagle*. His caution is also indicated by the fact that his observations were under consideration for some twenty years before his conclusions were published. His facts were so undoubted, and his case so well put, that his explanation of evolution attracted immediate attention and really fought the battle of evolution. This is what made his explanation an epoch in the history of biological science.

This period in the history of evolution, which may be thought of as the mediaeval period, is marked by the appearance of three conspicuous explanations. There is no need to define these explanations in detail. The explanation which ushered in the period was proposed simultaneously and independently by Goethe of Germany, St. Hilaire of France, and Erasmus Darwin of England, in 1790. Observations of responses to changed environment, led to the conclusion that environment is the direct cause of change, actually moulding forms. This evolutionary factor, therefore, is

entirely external to animal or plant. It was a natural first explanation, but it was too superficial, and environment as a *direct* cause of evolution soon passed into the historical background.

In 1801, Lamarck, in a series of lectures, announced his explanation, calling it the theory of "appetency." This was really the first explanation with a body of doctrine, and hence Lamarck has often been called the "founder of organic evolution." The term "appetency," however, has been abandoned, and its real meaning expressed by the "effect of use and disuse." With Lamarck, environment is not the direct *cause* of the change, but the *occasion* for the change. The cause is the striving, the effort to do something that had become necessary. Thus organs would become developed as a consequence of some change in environment calling them into use; and conversely, organs would become gradually aborted as a consequence of some change in environment that eliminated their use. This explanation rests absolutely upon the inheritance of acquired characters, meaning characters not inherited by the possessor, but acquired during the lifetime of the individual.

In 1858 the epoch-making explanation by Charles Darwin was announced, an explanation which was dominant for about fifty years. It is too familiar to need explanation, but I wish to call attention to the steps by which it developed in Darwin's mind. These steps have been spoken of as five facts and one inference, and the inference appeared so natural that there was no escaping it. The five facts in their logical sequence are the ratio

of increase, the equilibrium of species, variation, and artificial selection, from which natural selection was the inevitable inference. In brief, it claims that nature selects among variations, that the method of selection is competition, that the result is the destruction of the relatively unfit, or as Spencer put it, the "survival of the fittest." In brief, the theory is really an explanation of what is called adaptation.

As facts multiplied, the current explanations of evolution were found to be inadequate to explain some of them. This led to a general misunderstanding of the situation by the uninformed public. For example, more intensive study developed the fact that Darwin's explanation does not always explain. His name is so identified with evolution in public thought, that this criticism of the universal application of his conclusions by certain scientific men was taken to mean that the theory of evolution was being abandoned. The real situation is that every proposed explanation may prove inadequate, and yet the fact of evolution remains to be explained.

All of the explanations offered are partial explanations which simply means that no one of them applies to all the facts. We need them all and more besides. So far from being abandoned, evolution is the basis of all biological work to-day.

The method of comparison and inference continued until the beginning of the present century. Then came a new epoch in the history of evolution.

3. EXPERIMENTATION.—This may be called the modern period, in contrast with the mediaeval and

ancient periods. It was ushered in by the work of DeVries, who introduced the experimental study of evolution, and announced his explanation of evolution by means of mutation. The problem was to discover whether one species actually produces another one. It had been inferred that it does, but inference is not demonstration. By means of carefully controlled pedigree cultures, DeVries discovered a plant in the actual performance of producing occasionally a new form among its numerous progeny. This form bred true and preserved its distinctive characters; in other words, it was a new species, or at least a different species from its parent. Many such species have now been observed originating in this way, both in plants and animals. That one species can produce another one is no longer inferred, but demonstrated, and demonstrated repeatedly. There is no longer any doubt, therefore, that evolution is a fact. It is quite a different question whether the proposed explanations are adequate.

This outline of methods and results in one phase of one science is illustrative of all scientific investigation. It is uncovering facts by experimental demonstration, and is taking less account of inferences. In the field of evolution, when inferences were the only results, it was natural to extend inference to the evolution of the plant and animal kingdoms, and this involved the origin of man. In these days, there is no such attempt, for experimental demonstration of the evolution of the whole series of organic forms, culminating in man, is clearly impossible. Biologists, therefore, are no longer concerned with the whole story of evolution, but only

in discovering experimentally how one species may produce another one. The *fact* of evolution is established, but the whole story of evolution must remain an inference.

PRESENT STATUS OF EVOLUTION.—Only a very general statement is possible, since a full statement would involve an extensive discussion. The experimental study of evolution has led to the development of the field of genetics, a subject which has grown with remarkable rapidity. It is genetics which must uncover the machinery of evolution, which of course is fundamentally a matter of inheritance. The facts thus far uncovered indicate complexities which were not realized before, but which should have been anticipated, for inheritance with its resulting evolution represents the most complex biological situation imaginable.

The present status of evolution as a body of doctrine may be said to be in a state of flux, out of which the truth will emerge eventually. Any meeting of biologists at which evolution is discussed will disclose considerable diversity of opinion. It is evident, of course, that whatever produces variation furnishes a basis for evolution. But what produces variation? Environment is one factor, direct or indirect; sex is another factor, especially when strains are crossed; and still other factors might be cited. Any factor claimed to induce variation must stand the test of genetics, with its cytological background. Variations, however produced, are of two general kinds, as indicated by behavior, namely, the so-called continuous variation of

Darwin's explanation, and the so-called discontinuous variations of De Vries's explanation. The differences of opinion have to do with the method of variation production, that is, variation that may result in a new species.

After variation is secured, there is no question as to the function of selection. It is merely a statement of fact to say that some variations persist and some are eliminated. It is a very different matter to claim that only the "fit" persist. In some way the selection is made, and the selection factors may be quite variable. In general, it may be said that there is no serious difference of opinion that evolution is based on variation and subsequent selection. It is only a matter of detail to determine the exact factors.

There is a much more serious problem of evolution, however, which is still baffling. The variations observed, which result in new species, as tested by genetics, and for which the cytological machinery has been observed, produce species either laterally or retrogressively; that is, species of the same phylogenetic level, or of declining rank. There is as yet no adequate explanation of *progressive* evolution, the advance from one great phylum to another. Progressive evolution is a very evident fact, as shown by many an impressive series disclosed by the geological records, and also by our inferred lines of phylogeny. The theory of orthogenesis is often cited as an attempt to explain progressive evolution. Orthogenesis is not an explanation, but a statement of the fact of progressive evolution, which still awaits explanation. The multiplication of species

is within the reach of experimental study as to causes and methods, and the results are leading to conclusions that may vary with the investigator, but which will be checked up by further investigation. The phylogenetic advance of species, however, is still within the region of inference. It is something like the difference between the tracks in a switchyard and the main line. We have succeeded in investigating the switching, but the through trains are still baffling.

Practical Results

The experimental study of evolution, leading to the development of the science of genetics, resulting in increasing knowledge of the laws of inheritance, has led to practical results which the public in general do not appreciate. I wish to refer to two of these by way of illustration.

1. The Revolution in Agriculture.—It seems a far cry from speculations concerning evolution to a revolution in agriculture, but the continuity is unbroken. Speculation led to observation; observation led to experimentation; experimentation resulted in discovering the laws of inheritance; and the application of these laws has enabled us to handle plants and animals in a way that was never dreamed of before. It is a good illustration of the fact that there is no sharp dividing line between what is called pure science and applied science, for pure science may prove to be enormously practical.

A brief statement will illustrate the agricultural results in the application of our knowledge of inheritance.

It had become evident, for example, that for various reasons the ratio of increase in population was much greater than the ratio of increase in food production. The statement was made that during the ten years preceding the great war our population had increased 20 per cent. and our food production about 1 per cent. I cannot vouch for the accuracy of this statement, but it illustrates the situation. It was certainly an alarming outlook. Under these circumstances, plant crops began to be studied from the standpoint of genetics, and plant breeding became a science.

The lack of crop production arose chiefly from three causes, namely, lack of adaptation of crops to environment, destruction by drought, and destruction by disease. The same races were being cultivated everywhere, and only in certain places was the maximum result obtained. A study of races of crop plants throughout the world, and of the environment necessary for maximum yield, resulted in such an adjustment of crops to conditions that total food production was enormously increased. The problem of drought is being rapidly solved by the discovery or development of drought resistant races, not only insuring against loss from this cause, but also enormously increasing the possible area of cultivation. The problem of disease has been attacked in the same way, and disease resistant races of most of the important crops have been developed, insuring against this loss. As a result, food production is now beginning to overtake population, and we may thank the persistent study of evolution for the result.

2. THE DEVELOPMENT OF THE SCIENTIFIC SPIRIT.—This is a result of such fundamental importance that it must be considered, for it is revolutionizing the mental attitude of the human race. Its relation to the study of evolution may not be clear, but it was the study of evolution that revolutionized science and put it upon its present basis. The scientific spirit means a certain attitude of mind, which may be described best by speaking of some of its characteristics.

(1) *It is the spirit of inquiry.*—In our experience we encounter a vast body of established belief in reference to all important subjects, such as society, government, education, religion, etc. It is well if our encounter be only objective, for it is generally true, and a more dangerous fact, that we find ourselves cherishing a large body of belief, often called hereditary, but really the result of early association. Nothing seems more evident than that all this established belief which we encounter belongs to two categories: (1) the priceless result of generations of experience, and (2) heirloom rubbish. Unfortunately, the discovery of the latter has often resulted in weakening the hold of the former. The young inquirer, or the non-logical inquirer, is in danger of condemning all the conclusions of the past when one is found wanting.

Toward this whole body of established belief the scientific attitude of mind is one of unprejudiced inquiry. It is not the spirit of iconoclasm, as some would believe; but an examination of the foundations of belief. The spirit which resents inquiry into any belief, however cherished, is the narrow spirit of dogmatism; and

is as far removed from the true scientific attitude as the shallow-minded rejection of all established beliefs. The childhood of the race accumulated much which its manhood is compelled to lay aside, and the world needs a thorough going over of its stock in trade. Such work cannot be done all at once, or once for all, for it must be a gradual sloughing off as the spirit of inquiry becomes more generally diffused.

It must be evident that this spirit is diametrically opposed to intolerance, and that it can find no common ground with those who confidently affirm that the present organization of society is as good as it can be; that the present republics of the world represent the highest possible expression of man in reference to government; that the past has discovered all that is best in education; that the mission of religion is to conserve the past rather than to grow into the future. This is not the spirit of unrest, of discomfort, but the evidence of a mind whose every avenue is open to the approach of truth from every direction. Like the tree, it is rooted and grounded in all the eternal truths that the past has revealed, but is stretching out its branches and ever-renewed foliage to the air and sunshine, and taking into its life the forces of to-day.

In his essay on Intellect, Emerson says:

> God offers to every mind its choice between truth and repose. Take which you please, you can never have both. Between these as a pendulum, man oscillates. He in whom the love of repose predominates will accept the first creed, the first philosophy, the first political party he meets, most likely his father's. He gets rest, commodity, and reputation; but he shuts the door of truth. He in whom the love of truth predominates will keep himself aloof

from all moorings, and afloat. He will abstain from dogmatism, and recognize all the opposite negations between which, as walls, his being is swung. He submits to the inconvenience of suspense and imperfect opinion, but he is a candidate for truth, as the other is not, and respects the highest law of his being.

Dogmatism still finds many victims, for education has not yet touched the majority; but every day the possible victims are becoming fewer in number, and those who seek to lead opinion must presently abandon the method of bare assertion. The factors in this general intellectual progress are perhaps too subtle and interwoven to analyze with certainty, but conspicuous among them is certainly the development of scientific training. For fear of being misunderstood, I hasten to say that this beneficent result of scientific training does not come to all those who cultivate it, any more than is the Christ-like character developed in all those who profess Christianity. I regret to say that even some who bear great names in science have been as dogmatic as the most rampant theologian. But the dogmatic scientist and theologian are not to be taken as examples of the "peaceable fruits of righteousness," for the general ameliorating influence of religion and of science is none the less apparent.

(2) *The scientific spirit demands a real connection between an effect and its claimed cause.*—It is in the laboratory that one first really appreciates how many factors must be taken into the count in considering any result, and what an element of uncertainty an unknown factor introduces. In the very simplest cases, where we have approximated certainty in the manipulation of factors

to produce results, there is still lurking an element of chance, which simply means an unknown and hence uncontrolled factor. Even when the factors are well in hand and we can combine them with reasonable certainty that the result will appear, we may be entirely wrong in our conclusion as to what in the combination has produced the result.

For example, we have been changing the forms of certain plants at will by supplying in their nutrition varying combinations of certain substances. By manipulating the proportions of these substances we produce the expected result. It was perhaps natural to conclude that the chemical nature of these particular substances produce the result, and our prescription was narrowed down to certain substances. Now, however, it is discovered that the results are not due to the chemical nature of these substances, but to a particular physical condition which is developed by their combination, a condition which may be developed by the combination of other substances as well; so that our prescription is much enlarged. In this operation we are thus freed from slavery to particular substances, and must look only to the development of a particular physical condition.

It seems to me that there is a broad application here. In education, we are in danger of slavery to subjects. Having observed that certain ones may be used to produce certain results, we prescribe them as essential to the process, without taking into account the possibility that other subjects may produce similar results.

In religion, we are in danger of formulating some specific line of conduct as essential to the result, and of condemning those who do not adhere to it. This is the essence of formalism. That there may be many lines of approach to a given result, if that result be a general condition, is a hard lesson for mankind to learn.

If it is so difficult to get at the real factors of a simple result in the laboratory, and still more difficult to interpret the significance of factors when found, in what condition must we be in reference to the immensely more difficult and subtle problems which confront us in social organization, government, education, and religion; especially when it is added that the vast majority of those who have offered answers to these problems have had no conception of the difficulties involved in reaching absolute truth. It is evident that in the vast problems which concern human welfare in general, we are but groping our way, and that our answers as yet are largely empirical. The proper effect of such knowledge is not despair, but a receptive mind. In my judgment, therefore, the diffusion of the scientific spirit will make it more and more difficult for any one with a nostrum to get a hearing.

The prevailing belief among the untrained is that any result may be explained by some single factor operating as a cause. They seem to have no conception of the fact that the cause of every result is made up of a combination of interacting factors, often in numbers and combinations that are absolutely bewildering to contemplate. An enthusiast discovers some one thing which he regards, and which perhaps all unprejudiced

and right-thinking people regard as an evil in society or in government, and straightway this explains for him the whole of our present unhappy condition. This particular tare must be rooted up, and rooted up immediately without any thought as to the possible destruction of the plants we must cultivate. The abnormal tissue must be destroyed without reference to the fact that the method of destruction may debilitate the normal tissue.

This habit of considering only one factor, when perhaps scores are involved, indicates a very primitive and untrained condition of mind. In the youth of science it often threw its votaries into hostile camps, each proclaiming rival factors, when the problem really demanded all the factors they had and many more besides.

It is fortunate when the leaders of public sentiment have gotten hold of one real factor. They may overdo it, and work damage by insisting upon some special form of action on account of it, but so far as it goes it is the truth. It is more apt to be the case, however, that the factor claimed holds no relation whatever to the result. This is where political demagoguery gets in its most unrighteous work, and preys upon the gullibility of the untrained; and is the soil in which the noxious weeds of destructive radicalism, charlatanism, and religious cant flourish.

It is to such blindness that scientific training is bringing a little glimmer of light, and when the world one day really opens its eyes, and it is well if it open them gradually, the old things will have passed away.

(3) *The scientific spirit keeps one close to the facts.*— One of the hardest things in my teaching experience has been to check the tendency of many students to use one fact as a starting point for a flight of fancy that is simply prodigious. Such a tendency is corrected, of course, when the facts accumulate somewhat, and flight in one direction is checked by a pull in some other direction; but most of us have this tendency, and the majority are so unhampered by facts that flight is free. This exercise is beautiful and invigorating if it is recognized to be what it really is, a flight of fancy; but if it results in a system of belief it is a deception.

There seems to be abroad a notion that one may start with a single, well-attested fact, and by some logical machinery construct an elaborate system and reach an authentic conclusion; much as the world has imagined for more than a century that Cuvier could do if a single bone were furnished him. The result is bad, even though the fact have an unclouded title; but it too often happens that great superstructures have been reared on a fact which is claimed rather than demonstrated.

We are not called upon to construct a theory of the universe upon every well-attested fact, and the sooner this is learned the more time will be saved and the more functional will the observing powers remain. Facts are like stepping stones; so long as one can get a reasonably close series of them, he can make progress in a given direction; but when he steps beyond them he flounders. As one travels away from a fact, its significance in any conclusion becomes more and more attenuated, until presently the vanishing point is reached,

like the rays of light from a candle. A fact is really influential only in its own immediate vicinity; but the whole structure of many a system lies in the region beyond the vanishing point.

Such "vain imaginings" are delightfully seductive to many people, whose life and conduct are even shaped by them. I have been amazed at the large development of this phase of emotional insanity, commonly masquerading under the name of "subtle thinking." Perhaps the name is expressive enough, if it means thinking without any material for thought. One of the great dangers of our educational system is in laying special stress on training. There is danger of setting to work a mental machine without giving it suitable material upon which it may operate, and it reacts upon itself, resulting in a sort of mental chaos. An active mind turned in upon itself, without any valuable objective material, can never reach any very valuable results.

It may not be that science is the only agency, apart from common sense, which is correcting this tendency; but it certainly teaches most impressively, by object lessons which are concrete and hence easiest to grasp, that it is dangerous to stray very far from the facts, and that the farther one strays away the more dangerous it becomes, and almost inevitably leads to self-deception.

In conclusion, it may be said that the attitude of mind represented by the scientific spirit must bring independence in observation and conclusion, some idea as to what an exact statement is, and some conception of what constitutes proof.

Any field, whether religion or science, is to be estimated by its ideals, even though its occasional performance may be open to criticism. The ideals of science are (1) to understand nature, that the boundaries of human knowledge may be extended, and man may live in an ever-widening perspective; (2) to apply this knowledge to the service of man, that his life may be fuller of opportunity; and (3) to use the method of science in training man, so that he may solve his problems and not be their victim.

I find nothing more helpful to the student and leader of men than a clear appreciation of the working of evolution as exemplified in plants and animals. Evolution teaches that progress is gradual; that a better is progress toward the best; that sudden radical changes are not to be expected; that the future has its roots in the present. It teaches that revolutions may be very slow. It forbids unreasonable demands upon the individual or upon society, and discountenances the usual type of reformer. It shows that there have been no universal catastrophes and new creations, but that the present has gradually evolved from the past, and that the future will appear in the same gradual way. Furthermore, it shows that advance in a certain direction may not be uniform, for there are periods of apparent recession, as well as those of more rapid advance. The results are only apparent in the large view over long periods of time, when the tossing back and forth of surface waves disappears, and the steady advance of the slow-moving current becomes apparent.

Perhaps most important of all, it teaches that man

is a poor interpreter of individual events, and has no means of deciding whether they contribute to advance or not. Hence it must lead to cautious and charitable judgments; but at the same time it supplies a strong ground of confidence that there must be eventual progress. Some of the minor details of evolution may be useful to the pessimist, but its whole sweep justifies the broadest optimism.

Guide to Further Reading

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OUR FIGHT AGAINST INSECTS

By L. O. Howard, Ph.D.
Chief of the Bureau of Entomology,
U. S. Department of Agriculture

THE civilized part of the human race is just awakening to the fact that the future welfare and happiness of humanity depends to a considerable extent upon its success in the fight against the insects. They possess characteristics which permit them to live under all sorts of conditions and their work as a class brings them into direct conflict with the interests of humanity in multitudes of ways, many of which are entirely unsuspected by people in general and many others are still undoubtedly undiscovered. Their small size has often obscured their destructive powers, but in their very insignificance in size lies much of the danger.

Insects damage practically all of the farmer's crops, but it is not generally known that year after year at least a tenth part of all that is artificially grown is consumed by them. Not only do they eat the crops, but they eat clothing in city and country and they damage stored foods of all kinds; they burrow into the timbers of our buildings, they eat books, and wooden and leather implements. They accommodate themselves to new conditions as they arise. Telegraph lines, comparatively new in the history of human civilization have

come into the insects' view, and they eat the poles and even burrow into the insulating lead of the wire coils. A still later step in man's advance, the airplane, also involves a fight against the insects, for the wood which is used in their propellers is also damaged by certain species.

Most domestic animals suffer greatly from their attacks. Almost every kind of animal that is domesticated and used by human beings has its serious insect enemies, and man himself is far from immune. Aside from the species that sting him and annoy him, there are other forms that carry disease. The house fly carries at least thirty different kinds of disease and parasites. Mosquitoes of different kinds are responsible for distribution of malaria and yellow fever, dengue fever, and filariasis. The tsetse fly carries the sleeping sickness which has decimated large areas in Africa, the tick carries the germs of Rocky Mountain fever, and there are many other insects that carry various diseases, some doubtless unknown.

A few years ago we should have said that this was a fairly comprehensive summary of the possibilities of insect damage, but it has recently been discovered that they are responsible for the carriage of many of the most fatal diseases of cultivated plants just as they carry the diseases of animals and man. They are carriers of fatal diseases to many of the most important crops and to fight the diseases we must fight the insect carriers and control them.

Country after country has organized its entomological service, following the lead of the United States,

which was the first country to begin to study insects in a really competent way from the economic point of view. This action on the part of our own country is not in the least surprising, since as agriculture spread intensively over its hitherto uncultivated territory and the so-called balance of nature was upset in a rapid and most imperative manner, many native species took readily to the new food planted for them in enormous fields and multiplied to an incredible extent.

And in this development, with the bringing over of products of different kinds, including plants from the old countries, their insect enemies were brought with them, and finding themselves in a region where the summers or breeding seasons were longer and where the cultivation was upon a tremendous scale, the insects took cheerfully to the new environment and multiplied to an extent which had not been possible in the small fields and shorter summers of Europe.

Beginning in a small way and really not until after the completion of the Civil War, the good results reached by the labours of a few entomologists, notably Walsh and Le Baron in Illinois and Riley in Missouri, gained public attention. With the establishment of the state agricultural experiment stations in the late 'eighties, activity in the work against insects was multiplied in this country. From that time to the present the increases in the state and government appropriations have been rapid. Capable young men have studied in the universities and colleges of agriculture in increasing numbers until at the present time the Bureau of Entomology of the Department of Agriculture at

Washington has an annual budget amounting to more than a million and a half dollars and employs a small army of trained workers. Each state also has its corps of entomologists. In California there is a competent entomologist for each county of the State.

Other countries have followed, and France and Italy particularly have shown themselves to be keenly alive to the importance of this work. Although the entomological problems of the British Isles are comparatively less exacting than in the United States, Great Britain is developing many competent workers in her vast colonial possessions in many of which conditions are much like those in the United States. In London there is an Imperial Bureau of Entomology which is in constant touch with the official entomologists of the different dominions and colonies and assists them in many important ways.

While it must seem to many people that insects are more abundant and more injurious now than ever before, a large part of this opinion is due to our better appreciation of conditions and to the fact that as the population increases and the competition for existence grows keener the losses brought about by the insects are sooner noticed and more grievously realized. The entomologist, when attacking an insect problem, first attempts to learn all he can about the intimate life history of the destructive species which engages his attention. This is usually slow work and is usually prosecuted while the entomologist at the same time is learning the efficacy of spraying. Indeed, spraying is practical both with and without knowledge of its effects.

In other cases the cultural practices are changed in efforts to affect the life of injurious insects. Or, as in the case of the California white scale and the Australian ladybird, the entomologist attempts to use the natural enemies of insects in his warfare.

The importation of the Australian ladybird into California in the late 'eighties to kill off the white scale which threatened the extinction of the orange and lemon growing industries was a great accomplishment in itself and saved the country many millions of dollars. It is of especial significance, however, in that it pointed out the possibility of the utilization of the natural enemies of destructive insects, particularly those accidentally imported from one country into another, in such a way that it has been followed with other successes in this country and elsewhere.

We need only refer to the gipsy moth and the brown-tail moth to realize the importance of these kinds of investigation cited above. It has been possible to retard the spread of the gipsy moth for many years and practically to confine it to New England largely by the development of spraying methods which render possible the spraying of large forested areas. During a number of years parasites of different kinds were imported from all parts of Europe and from Japan. Several species of these parasites have become established in this country, and it is due largely to their work that the brown-tail moth has become greatly reduced in number and that the area over which it had spread has become greatly restricted. And it is also due to these parasites, at least in part, that in the Boston metropolitan dis-

trict and in other New England towns the gipsy moth has been so reduced in numbers that it is rather rarely to be seen. Moreover, the long and careful study of the gipsy moth has shown that with a certain kind of forest management its destructive work can largely be avoided; that is, by the gradual elimination of its preferred food plants, such as oak, from the mixed forests.

With the cotton boll-weevil, a species which is at the present time much in the public eye, the parasite method of control has been unsuccessful. Where the weevil has occupied a territory for some years, some of the native parasites of allied weevils have attacked it but never in competent numbers. The early studies of the life history and habits of the weevil which were made in Texas in the early part of the century soon indicated means by which the damage could be greatly lessened by certain farming methods, notably early planting, pushing the crop, picking it early, and destroying the old plants at as early a date as possible. These recommendations were repeatedly made, but the southern planters as a rule did not adopt them, and the weevil spread year after year until now practically the whole cotton belt is infested. In the meantime, however, a method of control has been found, in the way of dusting with calcium arsenate, which can be used with profit on good land, and another method has recently been announced by the Florida State Plant Board by which cotton can profitably be grown on poor land in that State, the Florida method being cheaper than the one just mentioned. The dusting process will be made simpler and

cheaper as time goes on, and there is a good chance that the airplane may be used in community dusting to great advantage.

The ravages of the pine bark-beetles in the far northwestern forests in past years have caused enormous loss. Some people have said that this loss has been as great as that from forest fires. These beetles have been carefully studied from all points of view by Dr. A. D. Hopkins and his associates, and it has resulted that when an epidemic of these beetles has gained a start it is now possible, by felling only a certain percentage of the infested trees, to arrest the plague, while the expense of the operation is largely borne by the value of the felled trees. This, however, has to be done at a certain time of the year, namely in the month of April, and the trees must be marked by trained scouts who explore the forests during the previous autumn and winter. A clean-up of this kind has just been made in southern Oregon and northern California by coöperative work of the Interior Department, the Forest Service, the Bureau of Entomology, and private owners, the operations being directed by a trained entomologist.

At the present time more than 140 distinct projects are being investigated by the federal bureau, and these projects involve possibly five hundred of the species of insects most injurious to crops, domestic animals, stored foods, forest products, shade trees, and ornamental plants. It is safe to say that some form of remedial treatment has been found for almost every markedly injurious insect in the United States; but continued

efforts are being made to find something more effective, or cheaper or simpler.

In addition to the large projects mentioned in preceding paragraphs, many striking things have been accomplished. The pear thrips, which at one time threatened the extinction of the fruit industry on the Pacific coast, is no longer feared; two serious pests of the clover seed crop can now be handled by slight variations in the cropping methods; sprays and spraying machinery have been developed which can be used successfully against practically all leaf-feeding species; the fumigation of nursery stock and of warehouses has been perfected; such injurious species as the onion thrips, the grape-berry moth, the alfalfa weevil, the tobacco horn worm, and many others of recent prominence can now be controlled.

The two outstanding problems at present before the country are the control of the European corn-borer, which at present exists in portions of New England, New York, and Ohio, and of the Japanese beetle which is at present confined to an area in New Jersey and Pennsylvania. Both of these insects bid fair to extend their range greatly and to damage the corn crop and, in the case of the Japanese beetle, to damage the orchards to an extent which cannot be predicted but which promises enormous loss. Pending the development of more satisfactory means of control, efforts are being made to prevent these insects from rapid spread.

The fight calls for many more trained entomologists and the expenditure of much larger sums than are at present available.

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INSECT SOCIOLOGY

By Vernon Kellogg, Ph.D.
Secretary of National Research Council, Washington, D. C.

WHAT may be called our personal relations to each other, resulting in various degrees and types of social organization, constitute a subject of particular interest to the students of man and his life. If insects could see each other as we see ourselves—maybe they can—the students among them would also have a lively interest in their own personal relationships. These insect relationships may even have some special interest to us, because they attain a peculiarly high degree of specialization, perhaps because there are so many more kinds of insects than there are of any other kind of animals—indeed, than there are of all other kinds of animals put together.

Because of these many insect kinds there is an especially keen competition and struggle for existence among them, and all kinds of adaptations and shifts for a living are carried to extremes. Social organization is but an adaptation for successful living. So the study of insect sociology is but a study of a biological phenomenon. That is also true, fundamentally, of human sociology.

There are individualists among insect kinds, insects that set up no special relations with other kinds except those of general competition for food and a place in the

sun, and whose individuals have no special social relations with other individuals of the same kind. The butterflies are good examples of these individualistic insects. Their specialized associations are more with the flowers than with other insects even of their same kind. However, there are a few species of gregarious butterflies whose individuals come together occasionally in large swarms for some reason not well understood. The familiar large reddish-brown monarch or milkweed butterfly (*anosia archippus*) is such a gregarious butterfly. I have seen tall Monterey Pine trees on Point Pinos near Monterey, California, simply covered by thousands of these conspicuous butterflies, hanging to the branches and to each other in long festoons. This butterfly species has, too, the habit of migrating occasionally in immense swarms.

Social Bees.—Such gregariousness is exhibited also by certain mining bees which sometimes make their nest-burrows, a single burrow for each mother bee, in large numbers close together in some clay bank. Other kinds of mining bees carry this nesting association a step farther, in that several mother bees will combine to dig a common vertical burrow and then each will build a short side tunnel branching off from the common entrance tunnel for its own eggs and the stored food for the larva which are to hatch from them later.

The next step in this progress of the bees toward a social life, at least a family social life, is shown by the bumble-bees. With all the bumble-bee species a few fertilized fertile females or "queens," produced in the autumn, go over the winter in concealment under

stones or in other convenient hiding places, and come out in the spring, each to found then a family colony or community. Finding a deserted field-mouse's nest or some natural small hole or crevice in the ground, the queen brings to it a small mass of flower pollen and nectar and lays a few eggs on this food mass. As the eggs hatch the issuing grubs (larvæ) begin eating the stored food and do this in such a way as to form for each a little irregular cell, in which, when finished with their feeding, they pupate and from which they finally issue as full-fledged worker (infertile female) bumble-bees.

These workers now bring more mixed pollen and nectar, the queen lays more eggs from which new workers are produced, and this process continues through the summer until there is a large colony (or family) of bees. In the autumn some males and females are produced, which fly out and find mates, the old queen and workers die, and the mated females (now "queens") hide themselves to pass over the winter and come out in the next spring to found new family communities.

This is the way also in which the social wasps, the hornets and yellowjackets, found their family communities which live in large wood-pulp paper nests in the ground or hanging from branches or the eaves of houses and out-buildings. Each queen wasp, coming out from her winter hiding place, makes a little paper "queen nest," composed of a few interior cells enclosed in one or two layers of wood-pulp paper which she makes by biting off and chewing up bits of old wood. In the cells of this queen nest eggs are laid by the queen from

which soon hatch wasp grubs that are fed by her with chewed-up insects until the grubs pupate. After a few days they issue as worker wasps (infertile females), which immediately enlarge the nest, and make more cells in which the queen lays more eggs. The grubs hatching from these eggs are fed by the workers, and by repeating this performance the family grows by the end of the summer into a community of many hundreds of active wasps. But in the autumn, after males and females have been produced to mate and provide fertilized females (queens) to start new families in the next spring, the old queen and workers die and the community breaks up.

The honey-bees take a great step forward, for their communities do not regularly break up each year, but go on continuously for an indefinite period occasionally budding off new communities ("swarming"). Each community, too, may, and in the course of time always does, contain individuals produced by different queens, for whenever new queens are produced, which happens each year, it is sometimes the old queen that goes out with the swarm, leaving the new queen to produce new individuals in the hive.

There is, too, in the honey-bee community much more differentiation as regards the work done in the communal home than in the social wasp and bumble-bee communities, and this work is much more varied in character. At any given time in the honey-bee community some workers will be acting as nurses for the larval bees, some as pollen and nectar gatherers, some as wax-makers and comb-builders, some as cleaners,

some as ventilators, and some as guards at the entrance of the hive. The queen, on the other hand, never does any work at all except to lay eggs. The drones simply act as consorts for the queens. The founding of a new community by the swarming away of a new (or the old) queen with several thousand workers is very different from the establishing of new wasp or bumblebee communities, in which an unaided queen does all the work necessary to get the community started, making a beginning nest herself and caring for the first brood of young.

There are two other kinds of communal insects, namely the termites, or "white ants," with a number of different species mostly limited to the tropics and semitropics, and the true ants, with a great many species, occurring abundantly all over the world. The true ants have often been called the most successful and, because of their high structural and economic specialization, the "highest" insects. Both the termites and the ants have more different "castes," or kinds of individuals, belonging to a species than the social wasps and bees, which have only three castes, that is, males (drones) fertile females (queens) and infertile females (workers).

The termites have usually two and sometimes three kinds of workers, namely, minim and major workers and soldiers, and they have, besides, both "complementary" or reserve males and females in addition to the regular males and queens. These complementary forms can replace the regular males and queens in cases of emergency.

The true ants also have varying numbers of castes and

exhibit an extraordinary degree of variety and specialization in economic organization. Some kinds are agriculturalists, and collect and store up seeds, some are hunters and marauders and travel about in large armies, some make slaves of other ants, some care for plant lice and scale-insects, which secrete honey dew—a favourite food of the ants—not only to the extent of protecting these helpless "ant cattle" from predaceous insect enemies but even to the extent of taking care of their eggs and putting the newly hatched young on proper plants for their nourishment.

There is a well-known little brown ant common in the cornfields of the Mississippi Valley which collects the eggs of the corn-root plant-louse, laid in the autumn in the soil, carries them into its nests and protects them through the winter. In the spring these plant-louse eggs hatch before the corn has been planted and there are no corn roots yet for the plant-lice to feed on, so the ants place the delicate little plant-louse babies on the roots of an early weed, called pigeon grass, that grows in the cornfields. Then when the corn is planted and the corn roots are developed the ants carry the plant-lice from the pigeon-grass roots to the corn roots.

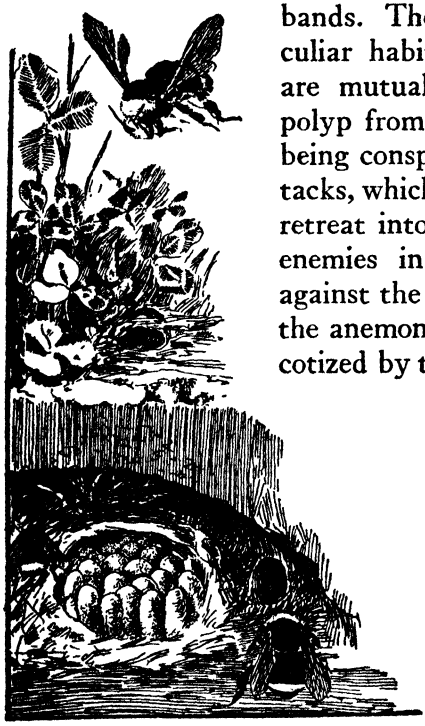
Why this interest on the part of the ants in the plant-lice? Because the plant-lice secrete, while they are sucking sap from the corn roots, a plentiful supply of that honey dew which is so favourite a food of the ants. Thus through this interesting social relation between the ants and the plant-lice, these latter get protected and cared for and the former get a welcome supply of

food. This is an excellent example of what the naturalists call helpful *symbiosis*, meaning the living together of two different kinds of animals (or plants, or of animals and plants) to the mutual advantage of both kinds.

There are many examples of this symbiotic association that are well-known to naturalists. Various species of hermit crabs always have a growth of hydroid polyps on the front upper part of the shell which serves them as a movable house. If these polyp colonies are removed the crabs do not rest until they have found other colonies which they dislodge from the rocks to which they are attached and plant on their shells. By this arrangement the polyps, ordinarily fixed in one place, are carried about by the crabs and in this way are aided in finding food. They probably get some of this food by seizing loose bits of the small animals seized and torn up by the crabs in their own feeding. The crabs, for their part, gain a certain protection from enemies by the presence of the polyps which have stinging tentacles that dangle down over the head of the crab, that make things uncomfortable for any moving sea animals looking for crab-meat.

Among the coral reefs of the South Seas there lives an enormous kind of sea anemone or polyp. Individuals of this great polyp measure two feet across the disk when fully expanded. In the interior, or stomach cavity, which communicates freely with the outside by means of the large mouth opening at the free end of the polyp, there may often be found a small fish (*Amphiprion percula*). That this fish is purposely in the gastral cavity of the polyp is proved by the fact that when

it is dislodged it invariably returns to its singular lodging place. The fish is brightly coloured, being of a brilliant vermilion hue with three broad white cross-bands. The discoverer of this peculiar habit suggests that there are mutual benefits to fish and polyp from this habit. The fish, being conspicuous, is liable to attacks, which it escapes by a rapid retreat into the sea anemone; its enemies in hot pursuit blunder against the outspread tentacles of the anemone and are at once narcotized by the "thread-cells" shot out in innumerable showers from the tentacles, and afterward drawn into the stomach of the anemone and digested.



Underground nest of the bumblebee

There are more than one thousand species of insects, including various cockroaches, beetles, flies, etc., that live in ants' nests in various kinds and degrees of symbiotic association with their ant hosts. In some cases this symbiosis takes on a very highly specialized form. For example Wheeler (the foremost student of ants and an entirely reliable observer) has worked out the follow-

ing extraordinary symbiotic relation between the red-brown ant, *Myrmica brevinodes*, and the smaller *Leptothorax emersoni*. The little *Leptothorax* ants live in the *Myrmica* nests, building one or more chambers with entrances from the *Myrmica* galleries, so narrow that the large *Myrmicas* cannot get through them. When needing food the *Leptothorax* workers come into the *Myrmica* galleries and chambers and, climbing on the backs of the *Myrmica* workers, proceed to lick the face and the back of the head of each host. A *Myrmica* thus treated, says Wheeler,

> paused, as if spellbound by this shampooing and occasionally folded its antennae as if in sensuous enjoyment. The *Leptothorax* after licking the *Myrmica's* pate, moved its head round to the side and began to lick the cheeks, mandibles, and labium of the *Myrmica*. Such ardent osculation was not bestowed in vain, for a minute drop of liquid—evidently some of the recently imbibed sugar-water—appeared on the *Myrmica's* lower lip and was promptly lapped up by the *Leptothorax*. The latter then dismounted, ran to another *Myrmica*, climbed on its back, and repeated the very same performance. Again it took toll and passed on to still another *Myrmica*. On looking about in the nest I observed that nearly all the *Leptothorax* workers were similarly employed.

Wheeler believes that the *Leptothorax* get food only in this way. They feed their queen and larvæ by regurgitation. The *Myrmicas* seem not to resent at all the presence of their *Leptothorax* guests, and indeed may derive some benefit from the constant cleansing licking of their bodies by the shampooers. But the *Leptothorax* workers are careful to keep their queen and young in a separate chamber, not accessible to their hosts. This is probably the part of wisdom, as the thoughtless

habit of eating any conveniently accessible pupae of another species is widespread among ants.

Finally there is another widespread type of social relationship in the life of insects, and that is the relationship of parasite to host, or parasitism. Thousands of insect kinds live exclusively as parasites on other insects, and in many cases a very high degree of specialization in this relation has been developed. One of the most familiar forms of this relation is shown by the many various ichneumon flies which lay their eggs on or in the bodies of the caterpillars (larvæ) of various moths and butterflies. When the ichneumon grubs hatch from these eggs they burrow about in the body of the caterpillar, feeding on its tissues but avoiding till the last the tissues and organs especially necessary for the life of the caterpillar. So the caterpillar moves about, feeding on the leaves of its food plant, while the ichneumon grubs grow and develop inside of it. By the time these grubs are full grown the caterpillar dies or may just be able to change into a chrysalid, from which issues, however, not a butterfly or moth but a number of ichneumon flies.

It is undoubtedly true that the most effective checks against the too terrible increase in numbers of various serious insect pests of our orchard and field crops are their natural insect parasites. A considerable number of our worst insect pests have come to this country by one means or another from other countries, and in many of these cases they have come unaccompanied by their parasites. Under these circumstances the insect pest has been able to increase so rapidly in this country as

to threaten to wipe out some important American wild or domesticated food plant or flower. In several such cases entomologists have visited the native country of the insect pest, found its natural parasites and brought them to this country, where they have been released among their hosts and have soon increased to such numbers as to be a remedy for the pest.

Thus we find among insects brilliant examples of a number of phases of social relationships which are



Honey-ants about three times natural size, taken from ground about the roots of pine trees

familiar to us in human life. These relationships are accompanied, in the insects, by a good deal of structural modification of individuals for the sake of accomplishing special functions which is a phenomenon that occurs in but slight degree among human beings. We devise and use different tools and machines to equip different individuals for different kinds of work. But the results are similar in the two groups.

Some of the phases of insect sociology have been developed and specialized far beyond the condition attained in human life. The communal life of the

honey-bee, for example, goes to an extreme hardly dreamed of yet by man as possible to him. If he did dream of it, it would be a bad dream. The worker honey-bees literally kill themselves working for the community. The summer foragers fly back and forth between hive and the flowers from which they bring pollen and nectar until they can fly no more. They often fall dead with their loads at the very entrance to the hive. They have no children of their own; the royal mother produces all the children; they take care of them. The males do nothing but act as royal consorts in the summer and then they die or are killed by the workers, as useless individuals, when winter comes on. The queen never works. She simply lays eggs. And so on. Not a kind of social organization we want, but a successful one, biologically.

The insects go in strongly for parasitism, also a biologically successful way of making a living. But we try to discourage it in human society. Some of the ants do nothing but fight and rob. They have even given up caring for their own young. They enslave other ants to act as nurses and to collect food for the whole community. Other ants convert some of their community members into living honey-jars, which stuff themselves with honey until their stomachs are so full and their bodies so swollen that they can hardly move and simply lie in a gallery or room in the ant nest ready to give up some of their honey by regurgitation to the active workers who come and tap them with their antennæ.

Insect sociology is interesting, but most of its teach-

ing to us is that, however successful biologically it may be for insects, it is not the kind of sociology we want for ourselves. Differentiation of labour and specialization of social relationships may be advisable for us up to a certain point; beyond that they are highly inadvisable. Let us not too literally follow the familiar injunction which instructs us to learn from the ant. To imitate his industry cannot lead us wrong; to imitate his extreme communism would be to make depersonalized and de-individualized automatons out of us.

Guide to Further Reading

"American Insects," by Vernon Kellogg. (Henry Holt & Co.) Second edition 1908. A comprehensive account of the insects of North America with classification, structure, general habits, and special adaptations.

"Ants, Their Structure, Development, and Behaviour," by William Morton Wheeler. (Lemcke.) 1910. The best book yet published about ants.

"The Life of the Bee," by Maurice Maeterlinck. (Dodd, Mead & Co., New York.) 1902. A poetical but fairly accurate account of the life of honey-bees.

"Social Life in he Insect World," by J. H. Fabre. (Century Co., New York.) 1912. This, together with other books by Fabre about insect life, are full of interesting observations and are delightfully written.

"The Psychic Life of Insects," by E. L. Bouvier (trans. by L. O. Howard). (Century Co.) 1922. A keenly analytic account of insect instincts.

HOW THE FORESTS FEED THE CLOUDS

By Raphael Zon, F. E.
Forest Economist, United States Forest Service

FOR a long time it has been accepted without any question that all the vapour that is condensed in the form of rain or snow over the land surface is furnished by the evaporation of water from the oceans. The part which vapour from the ocean plays in the precipitation over the land has been greatly exaggerated. A noted European meteorologist, Professor Bruckner, has computed the amount of water evaporated from the ocean surface and the land surface, and the amount of water which is returned to the ocean and the land in the form of precipitation. The balance sheet of the circulation of water on the earth's surface is shown in the accompanying illustration. The regions tributary to oceans are capable of supplying *seven ninths* of the precipitation by evaporation from their own areas. The moisture which is carried by the winds into the interior of vast continents, coming thousands of miles from the oceans, is almost exclusively due to continental vapours and not to evaporation from the ocean. Bruckner's figures for the entire earth's surface are corroborated also by study of specific drainage areas. The most interesting study in this direction is that by Professors Francis N. Nipher and George A. Lindsay on



Fig. 1. Clouds forming over forests as a result of large quantities of moisture given off by them into the air



Fig. 2. The clouds formed over the forests are driven by the prevailing winds into the interior of the continent

the rainfall of the State of Missouri and the discharge of the Mississippi River at St. Louis, Mo., and Carrollton, La.*

FOREST THE GREATEST EVAPORATOR OF WATER.—What are the sources from which the evaporation on land is the greatest? The evaporation from a moist bare soil is on the whole greater than from a water surface, especially during the warm season of the year when the surface of the soil is heated. A soil with a living vegetative cover loses moisture, both through direct evaporation and through absorption by its vegetation, much faster than bare, moist soil and still more than free water surface. The more developed the vegetative cover, the faster is moisture extracted from the soil and given off into the air. The forest in this respect is the greatest desiccator of water in the ground. Numerous experiments in Europe in the level and slightly hilly forest regions have shown that the forest, on account of its excessive transpiration, consumes more moisture, all other conditions being equal, than a similar area bare of vegetation or covered with some herbaceous vegetation. The amount of water consumed by forests is nearly equal to the total annual precipitation. In cold and humid regions it is somewhat below this amount and in warm and dry regions it is above it. The ground water table under forests was found invariably to be lower than in the adjoining open fields.

*Francis E. Nipher: "Report on Missouri Rainfall, with Averages for Ten Years ending December, 1887." *Transactions of the Academy of Science of St. Louis*, Vol. V, p. 383. Geo. A. Lindsay: "The Annual Rainfall and Temperature of the United States." *Transactions of the Academy of Science of St. Louis*, June, 1912.

This enormous amount of moisture given off into the air by the forest, which may be compared to clouds of exhaust steam thrown into the atmosphere, must play an important part in the economy of nature and deservedly earns for the forests the name of the "oceans of the continent."

WIND PERIODICITY AND PRECIPITATION.—In the eastern part of the North American continent east of the 100th meridian the winds during the winter and partly in the fall and in the early spring come from the west and northwest. These prevailing winds bring cold and comparatively dry air from the interior of the continent. In summer the prevailing winds are from the southeast in Texas, and farther north and east they come from the south and southwest. There is a most intimate relation between the prevailing southerly winds and precipitation in the eastern half of the United States. It is during the summer period, when the entire eastern half of the United States is under the influence of the southerly winds, that most of the precipitation falls over it. On the plains east of the Rocky Mountains the summer rainfall forms from three fourths to four fifths of that of the entire year. In winter, with the change in the direction of the wind, there is a radical change in precipitation.

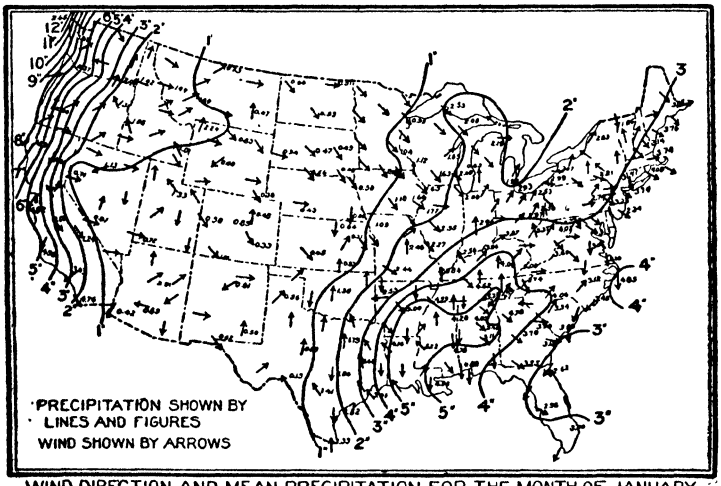
The periodicity of the wind direction and its relation to precipitation over the eastern half of the United States is well illustrated on the two maps. The arrows indicate the direction of the prevailing winds, and the lines and figures show the mean precipitation for the months of July and January. The map for the month

of July is typical for the summer period and the one for the month of January is typical for the winter period. The data represent more than twenty years of continuous records.

THE SIGNIFICANCE OF THE FACTS.—The three facts just discussed, namely, that vegetation from land contributes more to the precipitation over land than evaporation from the ocean, that forests evaporate more water than free water surface or any other vegetation, and that transpiration of the eastern half of the United States is intimately connected with the prevailing south wind, throw an entirely new light on the relationship between the forests of the coastal plain and the Southern Appalachians and the humidity of the central states and the prairie region.

The central portion of the United States is distinctly a continental region, particularly the prairie region, which suffers from lack of precipitation. On the other hand, large areas in the south and southeast because of large swamps, suffer from too much humidity, which is caused not only by excessive precipitation but also by deficient evaporation. We have, therefore, two extremes in the eastern half of the United States: (1) in the states adjoining the Atlantic Ocean and the Gulf of Mexico, there is an excess of moisture on the ground, both on account of excessive precipitation and slight evaporation; (2) in the vast interior of the Central United States, on the other hand, there is a deficiency of moisture both on account of scant precipitation and of the intense evaporation. Is there not some connection between these two extremes? Is it not possible

that changes which take place in one part of this vast region may exert some influence on the condition of the other? We have seen that in the central states in summer the prevailing westerly and northwesterly winds give way to southerly and southeasterly winds. In other words, in the summer the central states are under the influence of moist winds just at the time when

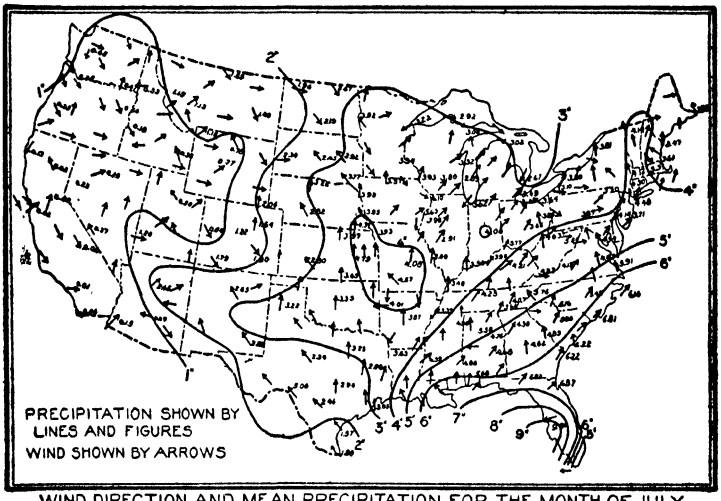


WIND DIRECTION AND MEAN PRECIPITATION FOR THE MONTH OF JANUARY

the evaporation is the greatest and the forest vegetation is especially active. It seems, therefore, that the amount of moisture evaporated within the more moist region of the United States can influence the conditions of humidity, not only in the states close to the ocean, but also in the region into which the prevailing moist winds flow. The more moisture there is evaporated from the ground in the southern and southeastern

portions of the United States, the moister must be the air in the central states and the more precipitation must fall there.

The central interior region of the United States is the battleground of two titanic forces, of which one is harmful and the other beneficial. The beneficial force takes its origin in the Gulf of Mexico and the adjoining



WIND DIRECTION AND MEAN PRECIPITATION FOR THE MONTH OF JULY

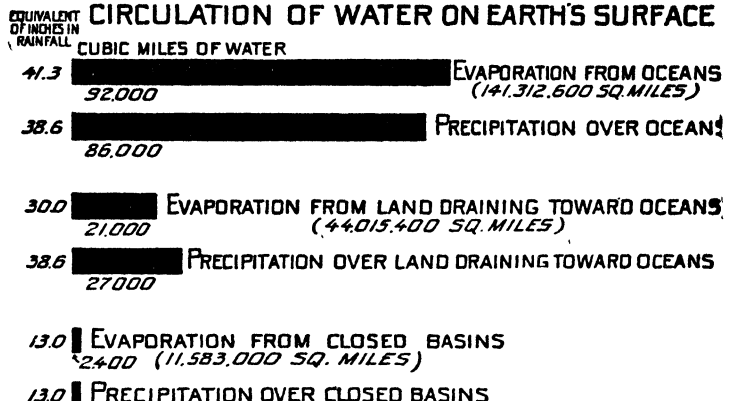
ocean, the harmful in the interior of the contintent and the Rocky Mountain region. The central states and the prairie region are geographically at the point where the battle between the two forces is fiercest and the victory is now on the one side and now on the other, being dependent on the cold and humid and the warm and dry climatic cycles as well as upon the seasons of the year. When the humid southerly winds extend their

influence far into the interior of the country and overpower the dry continental winds, the central states and prairie region, the granary of the United States, produce large crops. When the dry winds overpower the humid southerly winds there are drouths and crop failures.

The southerly winds on their way from the Gulf of Mexico do not meet any mechanical obstacles. Since the Appalachian Mountains, running in a northeasterly and southwesterly direction, do not hamper their passage, they are capable of penetrating far into the interior of the country and, therefore, determine the amount of precipitation even in such states as Minnesota, Nebraska, North Dakota, and South Dakota. The moisture-laden winds from the Gulf, as soon as they reach the land and encounter irregularities, are cooled and begin to lose part of their moisture in the form of precipitation. As long as the air currents are saturated with moisture the slightest cooling or irregularity of the land that causes them to rise will cause precipitation. But as they move inland and become drier, the remaining moisture is given off with difficulty and precipitation decreases. The sooner the humid air currents in the passage over land are drained of the moisture, the shorter is the distance from the ocean over which abundant precipitation falls; the longer the moisture is retained in the air currents, the farther into the interior will it be carried and the larger will be the area over which precipitation will be distributed.

If precipitation over land depended only on the amount of water directly brought by the prevailing

humid winds from the ocean, the land would be pretty arid and the rainfall would be confined to only a narrow belt close to the ocean. Fortunately, not all the water that is precipitated is lost from the air currents; a part runs off into the rivers or percolates into the ground, but a large part of it is again evaporated into the atmosphere. The moisture-laden currents, therefore,



upon entering land, at first lose the moisture which they obtain directly from the ocean, but in their farther movement into the interior they absorb the evaporation from the land. Hence, the farther from the ocean, the greater is the part of the air moisture contributed by evaporation from the land. At a certain distance from the ocean practically all of the moisture of the air must consist of moisture obtained by evaporation from the land. At least it must form a larger part than the water which was obtained directly by evaporation from the oceans.

The vapour brought by the prevailing winds from the ocean is many times turned over or reinvested before it is returned again to the ocean through the rivers. If we could reduce the surface run-off, and at its expense increase the evaporation from the land, we would thereby increase the moisture in the passing air currents and in this way contribute to the precipitation of that region into which the prevailing winds blow. This conclusion is almost axiomatic.

If the southerly and southeasterly winds in their passage toward the north, northwest, and northeast, in the spring and summer, did not encounter the vast forest areas bordering the shores of the Gulf of Mexico and the Atlantic Coast and those of the Southern Appalachian region and, therefore, were not enriched with enormous quantities of moisture given off by them, the precipitation in the central states and the prairie region would undoubtedly be much smaller than it is now.

If the present area occupied by forest in the Atlantic plain and the Appalachian region were instead occupied by a large body of water, no meteorologist would hesitate for a moment to admit that this water surface would have a perceptible influence upon the humidity of the central states and prairie region. Should not, therefore, the forests which give off into the atmosphere much larger quantities of moisture than free water surface have at least a similar influence upon the regions into which the prevailing air currents flow?

Direct proof of this climatic influence quantitatively expressed is still lacking. It will take many decades

before direct observations of such a character will be secured. If, however, the premises upon which the discussion rests—namely, that precipitation of the eastern half of the United States is intimately connected with the prevailing south winds, that evaporation from land contributes more to the precipitation over land than evaporation from the ocean, that forests evaporate more water than free water surface or any other vegetation—are correct, then forests in the path of prevailing winds must necessarily act as the distributors of precipitation over wide continents.

The moisture given off by the forests into the air is formed into clouds. These are carried by the prevailing southerly winds in the summer far into the interior of the country. There they settle as rain and enrich with moisture the fertile-agricultural lands. The central and prairie region—the granary of the United States—depends to a large extent for its rains on the moisture supplied by the forests of the southern and southeastern States.

Guide to Further Reading

"Forests and Water in the Light of Scientific Investigation," by Raphael Zon. Appendix V of the Final Report of the National Waterways Commission, Senate Document 469, Sixty-second Congress, Second Session. A non-technical summary of the entire subject of the relation of forests and waters.

"What the National Forests Mean to the Water User," by S. T. Dana, U. S. Department of Agriculture. A popular presentation of the dependence of the water supply in the West on the National Forests.

"Primer of Forestry." Farmers' Bulletins 173 and 358, U. S. Department of Agriculture. A popular discussion of the entire

field of forestry. The statistical material is somewhat out of date.

"Timber—Mine, or Crop?" 1922 Yearbook article. A comprehensive, non-technical presentation of the importance of growing timber as a crop treated from a national economic standpoint.

"Forests and Forestry in the United States." Report prepared by the U. S. Forest Service for the Brazilian Exposition Commission, 1923, Forest Service, Washington, D. C. A popular statement of the progress of forestry in the United States, with special reference to the National Forests.

THE MODERN POTATO PROBLEM

By Charles O. Appleman, Ph. D.
Dean of the Graduate School and Professor of Plant Physiology, University of Maryland

THE potato crop ranks next to the cereals as a food crop in the United States. It ranks third in the number of calories that can be grown on an acre of land, corn ranking first and sweet potatoes second. The average per capita annual consumption of potatoes for the past several years is 3.5 to 4 bushels. The 1922 acreage was more than 4,000,000 and the production nearly 400,000,000 bushels, or an average of about 100 bushels per acre. These are still far below the possibilities and are greatly exceeded in some other countries. Much scientific effort and education have been necessary to maintain even our present production and quality. The purpose of modern study of the potato is not only a greater average production per acre, but also a product of higher grade and quality that can be kept in good condition for consumption through the greater part of the year. Many years of investigation on some of the older and simpler problems have yielded such conclusive results that they are now simply awaiting more general application in practice. New potato problems are constantly arising. They are very diverse in character and their study is demand-

ing the combined efforts of many scientific specialists. What are a few of these problems and how are they being studied?

THE REST PERIOD.—In order to insure the continued vegetative propagation of the potato plant as a permanent inhabitant of the earth, nature has endowed the tubers with a rest or dormant period, so that the young plants will not immediately start to grow and then be killed by the coming winter cold. This is fine for the wild plant, but since man has tamed it and brought it under cultivation, the operation of the rest period does not always suit his requirements. Usually the potato tubers will not sprout for several weeks after they are harvested. The length of the rest period varies with different varieties, but is fairly constant for a given variety grown for a long time at the same place. The cause and control of this rest period is a subject of importance. Any practical means of eliminating or even abbreviating the rest period would be very valuable in growing a second crop in our southern states. It is also of equal importance to know how to extend the rest period of potatoes during storage. So far scientists have not been able fully to unravel nature's secret of dormancy in potatoes, but some clues have been obtained. By carefully removing the skins from the tubers and supplying them with plenty of moisture, air, and a certain amount of warmth, the young sprouts will start to grow in a comparatively short time. This seems to indicate that the skins keep out something necessary for growth or prevent the escape from the inside of the tuber of something holding growth back.

The former may be oxygen of the air and the latter the carbon dioxide produced by the tuber's respiration. Other methods that have been found effective in shortening the rest period, such as treating the tubers with certain gases, probably do so by rendering the skins more permeable to oxygen or carbon dioxide. However, this does not explain how the tubers finally come out of their rest period without help. Nature does not remove their jackets.

DEGENERATION OF POTATOES.—When we start with a potato plant grown from a seed and use the tubers for its propagation, each succeeding crop really represents an annual growth of our original plant. This may be made clearer by comparing the seedling potato plant with a young apple tree. Every summer the tree produces a large number of buds which remain dormant until the following spring, when they give rise to a new crop of shoots. The potato plant likewise produces dormant buds on the tubers, which are large fleshy underground shoots, or stems. By the annual death of the vines the tubers are separated from the parent plant whose life is perpetuated by the tubers. If we imagine each succeeding crop of tubers, like the apple shoots, becoming a permanent part of the parent plant, we would have a giant potato plant often many years old. Are these giant potato plants, known as varieties, immortal, or are they subjected to old age and final death the same as animals? At first thought this might seem an easy question to answer, but scientists still hold divergent views about it.

Degeneration of potatoes is a well-established fact.

Varieties are known to have progressively lost their vigour and entirely run out in certain regions. We know now that many cases of degeneracy are due to slow diseases and not to old age. Symptoms that were once attributed to senility are now recognized as typical symptoms of "Mosaic" and other virus diseases. An extreme view holds that a given variety would remain vigorous and live indefinitely if grown continuously under favourable conditions. According to this view any degeneracy of a variety not due to apparent disease simple means that it is unable to cope with the adversities of its environment. This is undoubtedly often the case because varieties have been grown for many years in some places without loss of vigour, but gradually degenerate in another region. Potatoes for the spring planting in the southern states are usually imported from the north, as these varieties degenerate when the seed stock is home-grown. Even in the more northern states it is often necessary to obtain the seed tubers of some varieties from other regions in order to maintain the normal vigour of the crop and certain desired characters of the tubers. Lack of adaptation to environment can be argued against any claims for an inherent tendency to old age in potato varieties, so we may still ask the question, does our giant potato plant naturally grow old?

Seed Stock.—Modern potato research is showing a very decided trend toward studies of the factors influencing the vitality of the seed stock and of practical methods for maintaining the normal vigour of the variety. The potato plant is grown from a specialized

vegetative portion of the parent plant, namely, the tuber. Therefore, if the daughter plant is to maintain full vigour the parent tuber, or fraction thereof, must possess and maintain this normal vegetative vigour until it is planted. The growing appreciation of the importance of good vigorous seed stock true to name is one of the most promising developments in modern potato culture. Many factors are now known to influence in varying degrees the vitality of seed tubers, as storage conditions, maturity, repeated sprouting, methods of preparation of tubers for planting, physiological and virus diseases, climatic conditions, where and when seed is grown, etc. Important researches concerning the vitality of seed stock have yielded information of great value to potato culture, but there is still need of much careful research.

The practice of seed inspection and certification is contributing greatly toward the improvement of seed stock. The growers of seed potatoes apply to state officials for inspection of their crop. The inspections are made two or three times while the crop is growing and once after harvest. If the crop comes up to certain standards in respect to freedom from diseases and weak plants, as well as true to type, it is certified. The grower pays a small fee for this service and commands a higher price for the certified product. The grower can afford to pay a higher price for he can then grow more and better potatoes.

If the tubers have begun to sprout before they are planted, as is frequently the case, the character of the sprout growth is a rough index of seed vitality in many

varieties. Good normal tubers, as a rule, will sprout first from the eyes on the terminal or seed end of the tuber. These sprouts, if not destroyed, or too much impeded in growth, will inhibit the growth of sprouts from the basal eyes. If the first sprouts lack the normal vigour of the variety they will not prevent the growth of sprouts from the more basal eyes, but sprouts will be scattered over the entire tuber. This lack of apical dominance in the first crop of sprouts is a sign of low tuber vitality, or in other words, its inability to produce vigorous plants with the proper number of stalks. Extreme cases of low vitality are manifested in the spindliness of the sprouts, but in many cases the sprouts are much below normal in growth vigour without showing the characteristic spindliness. It is in the latter case that lack of apical dominance is of service as a guide.

A great deal of the older potato research was concerned with methods of cutting the seed tubers and with the most profitable amount of seed to plant per acre. In regard to certain phases of this problem the results have been so uniform and conclusive that it is now largely a matter of education to get them more generally adopted in practice. It is generally conceded that no conditions will justify planting seed pieces weighing less than 1.5 to 2 ounces. With high fertility and cheap seed it is sometimes profitable in some localities to plant seed pieces weighing even more than 2 ounces. More recent research has shown that the low yields from small seed pieces is traceable to weak sprouts produced by the small pieces. After a mini-

mum size of seed piece is reached, the vigour of the sprouts becomes progressively less as the size of the seed piece is further reduced. This minimum size for many varieties has been found to be about 1.5 ounces. The cause of the weak growth of sprouts on pieces of tuber below a minimum size is not definitely known. There are some indications that the potato tuber contains a limited amount of an accessory growth-promoting material. This may or may not be analogous to the vitamine so essential to growth in animals. Experiments have shown that seed pieces large enough to contain an abundance of the usual nutrients for sprout growth still produce weak sprouts. These seed pieces lack something in sufficient amount to start growth off normally. The plants from these weak sprouts are correspondingly weak and the best of cultural conditions will not revive their normal vigour. During the recent war a prominent newspaper recommended the planting of peelings and saving the rest of the tuber for consumption. Valuable land and labour were wasted by this practice.

VARIETAL NOMENCLATURE.—The ever increasing number of so-called varieties has made the subject of nomenclature for potato varieties an important potato problem. More than five hundred names are reported for varieties that are supposed to be still grown in the United States. Much of the present confusion in varietal nomenclature has resulted from the propensity of seedmen to rename old varieties and to introduce new varieties indistinguishable from existing ones. This chaotic condition has been greatly improved by

arranging these names into typical groups, a very important but difficult task. The public and the potato industry should be protected by certain restrictions governing the introduction of new potato varieties. Encouraging efforts are being made in this direction.

POTATO IMPROVEMENT.—Variety testing has long been a favourite type of potato investigation. The results of this enormous amount of work have been of great local importance in discovering standard varieties best suited to particular climate and soil conditions, but they have been of very limited general application. Recent years have shown a marked decrease in the number of such investigations. Much of this effort is now being replaced by attempts to improve our standard varieties and to develop new varieties better suited to local condition.

The potato can be improved by application of modern knowledge of breeding and selection. The former method consists in the actual crossing of two varieties by artificially applying the pollen of one parent to the stigma of the other. This is the only means by which desirable characters of two parents can be combined in the offspring. It is frequently desirable to combine, in the offspring, immunity to disease of one parent with high yield or better cooking quality of the other parent, or high yield with more desirable tuber characters, as size, shape, shallow eyes, etc. Most of our present varieties have originated as seedlings, either by chance or artificial breeding. Unfortunately potato breeding is fraught with many difficulties. On account of long continued reproduction by tubers or for other

reasons, sterility in the flowers of potatoes is the rule rather than the exception—that is, potato seeds are rarely produced. The cause of this phenomena is being investigated with the view of bringing it under control in breeding work. Another difficulty is the fact that most varieties of potatoes are already hybrids possessing latent characteristics of their wild ancestors. These undesirable characters are liable to crop out and become dominant in the seedlings, so it is necessary to grow a large number of plants from which to select the ones desired. The increasing prevalence of diseases is also adding greatly to the almost insurmountable difficulties of the potato breeder. On account of difficulties involved and the expert technique required, to say nothing of the expense, potato breeding cannot be generally practised as a method of potato improvement. However, important improvements of potato varieties have been made by this method and the outlook is very promising for further improvements. Some attempts are being made to breed strains that will propagate themselves just as well by seeds as by tubers. If this can be accomplished, it will result in great saving in the price of seed and in the elimination of diseases that are carried in and on infected tubers.

The second method intended to improve existing varieties is by selection. The procedure is to propagate from a single tuber, or from desirable hills selected in the field. Selection methods have been extensively used and are still practised, although it has not been definitely proved that our existing varieties can be much improved by these methods. The chief benefits

derived from selection methods may be due entirely to the elimination from the seed stock of tubers produced by degenerate or diseased plants. From this viewpoint, hill selection must be an annual task. Bud sports or "mutants," do occasionally appear in the tubers. New varieties have arisen in this way, most of them differing from the parent variety merely in a modification of the colour of the skin or tissue and in the period of ripening. Bud sports are not usually considered of much importance in selection work on account of their infrequent occurrence.

At the present time great emphasis is being placed upon the importance of discovering strains of our standard commercial varieties that are more vigorous and productive than others.

SALT NUTRITION.—Different crops have different requirements regarding the nutrients supplied to the roots. All of them demand a group of essential elements, but these are utilized in different proportions by different crops. If the soil does not already contain these necessary elements in the proper amounts, they must be supplied in fertilizers. The importance of fertilizing the crop rather than the soil has led to extensive and carefully controlled experiments to discover the salt requirements peculiar to different crops. This applies not only to the proper proportions of the salts, but also to the kind of salts carrying the fertilizer elements. Modern methods of salt nutrition studies applied to the potato crop are now supplementing the older empirical fertilizer tests and the outlook indicates a more rational and economic fertilizer practice.

DISEASES.—Potatoes, like human beings, are subject to serious and destructive diseases. Some of these diseases frequently become epidemic in certain sections of the country, causing almost total loss of the crop. The potato plant may become afflicted with purely physiological troubles but the most destructive diseases are parasitic in origin. As in the case of animals, these pathogenic organisms are of several different types. Although fungous diseases are rare in animals they cause the largest group of potato diseases. Early blight (*Alternaria solani*) and late blight (*Phytophthora infestans*) especially the latter, head the list of destructive fungous diseases. Both are diseases of the foliage and stems but late blight also attacks the tubers, causing them to rot either in the field or under improper storage conditions. Fortunately, science has found a specific preventive for these parasites. Spraying the plants with Bordeaux mixture will check the ravages of both diseases. In 1885 Millardet, then professor at the University of Bordeaux, published the first directions for preparing Bordeaux mixture, which consisted of certain proportions of water, copper sulfate, and lime. This mixture has proved of inestimable value in the control of some of the most destructive diseases of our food crops.

The thread-like hyphae of the fungi causing the *Fusarium* and *Verticillium* wilts grow in the conducting vessels of the stems and thereby prevent the passage of water through the stems to the leaves. Wilting of the foliage and death of the plant follow. Although the wilts do not cause as much damage as the unchecked

blights, they are more difficult to control. Certain helpful measures have been found effective in checking these diseases, but absolute control is yet unknown.

One of the most dangerous of the European fungous diseases of the white potato is the potato wart. It is a disease of the tubers and from the standpoint of its seriousness and some of its characteristic manifestations it may be thought of as potato cancer, although it is unlike true animal cancer in that it is very infectious. In advanced stages the warty growths on the tubers may be as large as the tuber itself. In severe cases the fungous consumes nearly all of the stored food material in the tuber, reducing it to a soft mass. Realizing the possibility of this dread disease being introduced into the United States, an embargo went into effect in 1912 against potatoes from countries known to harbour wart. This legislation evidently came a little too late, for in 1918 the disease was discovered in gardens at Highland, Pa., a hamlet in the heart of the anthracite coal district. The alarming discovery of this malady in the United States at once led federal and state officials to launch an extensive campaign to discover the extent of its occurrence in this country. So far it has been found only in gardens, chiefly in restricted areas of the mining districts, in Pennsylvania, West Virginia, and Maryland. Strict quarantine has been placed on these districts and every effort is being made to prevent its spread. This virulent and dangerous disease has rather suddenly become one of the modern potato problems in this country. Immunity to disease in plants is beauti-

fully demonstrated in the case of potato wart. Experiments have shown that the susceptibility of the varieties tested varies within wide limits. A number of varieties were found to be absolutely immune. Included in this group are some of our leading commercial varieties, as the Irish Cobbler and Green Mountain. On the other hand it is unfortunate that some of our other leading varieties are so susceptible that they are practically destroyed when attacked by the wart disease. The growing of immune varieties has been found to be the only practical method of controlling this disease in several European countries.

There is a group of filamentous micro-organisms occupying an intermediate position between the moulds and the bacteria. To this group of parasites belong the *Actinomyces*. Certain species of this parasite cause serious suppurative affections in animals. Another species is the cause of one of the most common diseases of the potato tuber, the common scab. It is recognized by the rough pitting of the tubers, rendering them unsightly and greatly depreciating their market value. This disease is no longer a serious problem in potato culture aside from the expense and labour involved in its control. By careful selection and disinfection of the seed tubers, this source of the infection may be controlled. The most effective, as well as the cheapest, means of controlling the organisms in the soil are still problems that are being studied. This organism thrives best in soils of an alkaline reaction. The addition of sulphur to certain types of soil has recently been recommended as a means of controlling scab. The oxidation

of the sulphur produces the necessary acid reaction in the soil to check the growth of the scab organism.

Several years ago Dr. Erwin F. Smith ventured the statement that "there are in all probability as many bacterial diseases of plants as of animals." Time has more than borne out this statement. However, bacterial diseases of the potato crop are not at the present time a serious problem. The disease known as blackleg (*Bacillus phytophthorus, Appel*) which attacks both the vines and tubers, may, under certain climatic conditions, cause considerable damage. There seems to be no evidence that the causal organism can live over winter in the soil or in diseased tubers that may remain in the soil. Careful selection and disinfection of the seed tubers would appear then to be adequate prophylactic measures to control this bacterial disease of potatoes.

The two diseases known as "Leaf-roll" and "Mosaic" belong to the same category as measles and scarlet fever, being infectious diseases of unknown causation. Potato leaf-roll has been recognized only in recent years in this country. Mosaic is an old disease formerly known as leaf-curl or curly dwarf and thought to be associated with degeneration or senility of the variety. On account of the increasing prevalence of these diseases and the difficulties involved in their control they have become the chief potato disease problem in some sections of the country. Quanjer, a Dutch scientist, has shown by grafting diseased branches on healthy stocks that both diseases are contagious and that the virus is carried in the juice of the plant and tuber. He also showed that the virus from diseased

plants may pass through the soil to healthy plants as far as two or three yards away. More recently the transmission of leaf-roll from one plant to another by aphids, or plant-lice, has been demonstrated. Other means of transmission are yet unknown. Healthy growing plants that become infected with the virus of either of these diseases respond rather slowly to the infection, making it difficult to recognize the symptoms in the first crop. Since the virus is carried in the tuber these diseases are truly hereditary, and they become progressively more severe with each succeeding generation. The impossibility of reaching the virus by seed treatments coupled with the difficulty of recognizing the symptoms in their incipient stages, greatly add to the seriousness of the increasing prevalence of both the leaf-roll and mosaic diseases.

Of the physiological diseases of the potato, the so-called spindling sprout disease is probably the most important. However, to speak of a spindling sprout disease is misleading, since the weak spindling sprouts are merely a symptom which may have a variety of causes. The true spindling sprout diseases referred to here appears to be a response to unusually hot and possibly dry mid-summer conditions when the tubers are forming. The only reliable visible symptom of the disease in the tuber is the spindliness of the sprouts and the frequent appearance, in severe cases, of small tubers at the base of these sprouts. Studies on this disease have revealed some characteristic physiological and chemical conditions of the spindling sprout tubers, but it is impossible yet to say whether any one of these con-

ditions is the cause or result of the trouble. There are some indications that suggest a lack on these tubers of a sufficient amount of an accessory growth-promoting substance. It is possible by repeated sprouting to cause normal tubers to produce typical spindling sprouts even to the point when small tubers appear at the base of the sprouts, a characteristic of severe cases of the spindling sprout disease. Chemical analysis of the mother tubers showed that very small amounts of the usual food materials had been removed from the tubers when the sprouts began to show decided spindliness of growth. However, the tubers were exhausted of a substance necessary for normal growth.

In cool climates the spindling disease is rare, but it is very prevalent in our southern states. Experimentation in recent years has proved conclusively the superiority of northern seed over home-grown seed for the early crop in the more southern latitudes. The true character of this place-effect in the production of seed potatoes is certainly not definitely known, but it is believed that the spindling sprout disease is an important contributing factor.

During certain seasons the potato crop suffers much damage by the premature death of the tips and margins of the leaves, without evident parasitic causation. This condition, known as tip-burn, has usually been attributed to the loss of water from the leaves by transpiration at a more rapid rate than it can be supplied by the roots under the prevailing climatic conditions. This simple explanation of tip-burn has been recently contested, and its true cause has truly become a real mod-

ern potato problem. Entomologists have recently demonstrated an apparent close association of the insects known as leaf-hoppers with tip-burn and they have been inclined to carry this condition over into their domain and have renamed it hopper-burn. It has also been claimed that the secret of tip-burn on the potato foliage is to be found in the water pores, or hydathodes, which are grouped around the margin of the leaf on the upper side and masked toward its tip end. The death of the marginal vein is due to the loss of water from these pores which lie over it. This is followed by a browning of the entire region. Attention is particularly called to the fact that the plant can control the opening and closing of the stomata but that the hydathodes remain open permanently.

Modern potato disease research in common with research on plant diseases in general has assumed a much broader scope than formerly. In the past the pathologists devoted most of their studies to the parasite. This type of research is now being supplemented by physiological studies. The influence of environment on disease is being emphasized. Investigations are yielding results of tremendous practical importance. They are explaining the variability in the occurrence of certain diseases both in general and local areas. The factors influencing the susceptibility of the plant to various diseases and the physiological responses of the plant to the invading organisms are problems awaiting further research.

POTATO STORAGE.—The storage and transportation of plant food products is becoming a national problem,

ranking in importance with their production. The concentration of our population in the cities makes it necessary to draw on stored products in ever greater quantity and for longer periods of time. Great quantities of potatoes for future consumption and for seed are stored both at places of production and in terminal warehouses. The present losses due to unfavourable storage conditions are enormous. To store potatoes like household furniture, a method still practised, especially in terminal warehouses, is a costly procedure.

First of all we must bear in mind the fact that the potato is a living, breathing creature and must be treated as such. It is not endowed with natural long life, but is intended to perpetuate the life of the variety by giving rise to new plants. The practical problem of potato storage is to prolong the life of the tubers without impairment of their culinary or seed value. They must also be protected against decay caused by micro-organisms. Their tissues form an ideal medium for the growth of fungi and bacteria.

The necessity of specialized storage for potatoes is now generally recognized, but there is still much difference of opinion regarding the most favourable storage conditions. This situation is due in part to a lack of sufficient and accurate scientific information on the physiology of the potato tuber during the different periods of its storage life. Storage conditions that are most favourable or allowable for one period in the storage life of the potato may not be the best or even tolerated in a previous or succeeding period. Although the complete story of the physiology of the potato during

its storage life is yet to be written, sufficient information is now available to characterize certain fairly definite periods of importance in practical storage. During the early dormant period chemical changes due to ripening may continue, if the tubers have not fully ripened in the ground. These chemical changes consist mainly in the building up of complex food and structural materials from simpler substances. For example, nearly all of the sugar in unripe potatoes is converted into starch. Cork formation in the skins may continue for some time. Shrinkage of the tubers due to loss of water is unusually high during this period.

The latter part of the dormant period may be spoken of as the late dormant period. By this time the skins are well corked and the loss of water from the tubers by evaporation is very low unless the storage air is unusually dry. The building up and breaking down processes in the tubers now tend to equalize each other and at temperatures between 40° and 70° F. there is very little change in the percentage composition of the tubers. The potatoes are much less effected by storage condition than during any other period in their storage life.

The period that elapses between the time when potatoes come out of their rest period and will sprout under growing conditions, and the time when sprouting actually begins, may be thought of as the post-dormant period and is the critical period in the storage of potatoes. The breaking-down processes, or hydrolysis, tend to predominate, probably due to weakening with age of the constructive or synthetic processes. The tubers are liable to soften rapidly with unfavourable

storage conditions. The market demands a firm potato as it has better cooking qualities. The sprouting period is characterized by high destructive metabolism, resulting in loss from the tubers of starch and other solids. Loss of water through the sprouts may also be high. The final result of these processes is the extreme wilting of the tubers.

External conditions have a profound influence on the physiology of potatoes in storage. Undesirable changes in the tubers may be controlled or checked and their storage life prolonged by a proper combination of storage temperature, humidity, and ventilation. The most favourable combinations of these factors for the different periods in the storage life of the potato can be determined only when we possess accurate and controlled data on the individual effects of these storage factors.

When human beings are well the temperature of their bodies is practically constant regardless of the external temperature. Plants are not so fortunate, as the temperature in their tissues changes with that around them. This explains why temperature is so important in shaping the life activities of plants and in controlling their destiny.

The researches of Muller-Thurgau clearly demonstrated the relationship between storage temperature and the accumulation of sugar in the tubers. Potatoes attain their maximum sweetness after a few weeks' storage at a temperature of 32° F. and not as a result of freezing, which does not occur until the temperature falls to 28° or 26° F. Potatoes will accumulate a small amount of sugar at 42° F. but practically none

above this temperature. The maximum sugar content found in potatoes after storage at a given low temperature varies with time of year and with individual tubers, young tubers accumulating less sugar than older ones. Muller-Thurgau found that the sugar in potatoes after a period of storage at low temperature is changed again into starch when the tubers are exposed for from eight to ten days at ordinary room temperature. This discovery has been confirmed by other workers on a large number of different varieties and is a practical means of removing from potatoes their undesirable sweetness. More recent work has shown that the room temperature must not be too high because potatoes which have become sweet will not lose their sugar at temperatures as high as 80° to 85° F., but may continue for a time to accumulate more sugar.

Respiration is a vital process common to all living things. Breathing is just as essential to the life of a potato as it is to the life of man, although this fact is not generally appreciated. The intensity of respiration in potatoes varies with the storage temperature, the higher the temperature up to a maximum of about 110° F. the greater the respiratory rate. In the process of respiration, oxygen and carbohydrates, as sugar and starch, are consumed and carbon dioxide, water and heat are produced. The accumulation of these products in storage is injurious to potatoes, therefore ventilation is just as essential to the health of a potato as it is to the health of animals. In extreme cases of high temperature and poor ventilation, death of the internal tissues of potatoes by suffocation may occur, giving

rise to the condition known as "Black Heart." Dead tissue of a vegetable or fruit will decompose and spoil very quickly at ordinary temperature.

One of the most important discoveries in connection with respiration of potatoes is the fact that when they have been stored for a period at low temperature and then transferred to higher temperature their respiration for a few days is very high but gradually falls to the normal rate for the given temperature. This initial period of abnormally high respiration may, under certain conditions, become an important factor in the keeping qualities of cold-storage potatoes during their transportation and marketing. These potatoes must be supplied with very good ventilation, especially for the first week or two after they are taken from cold storage. For the same reason potatoes in late common storage must be well ventilated. Experiments are now in progress to discover, if possible, storage conditions that are generally satisfactory but that will not impose upon the tubers the initial abnormal rate of respiration when they are exposed to higher temperatures.

Storage temperature is the most important factor in controlling the growth of decay organisms as well as the growth of sprouts in late storage. At temperatures below 46° F. the damage due to rot organisms is very slight.

When all of the temperature effects are considered, the selection of the best storage temperature will be a compromise and will probably vary somewhat with the storage period. Temperatures ranging from 36° to 42° F. are now recommended for potatoes to be used

for food. Seed potatoes may be stored at temperatures as low as 33° F. without impairment of seed value if the storage period is not too long. It is probable that the age and condition of the tubers, when placed in storage, are important factors in determining the possible period of cold storage before they are damaged for seed.

Besides supplying oxygen to the potatoes and dissipating the products of respiration, ventilation is also a means of removing excessive moisture from the storage air and of controlling the temperature of common storage. The necessary amount of ventilation depends upon the temperature and the season of the year. It is quite generally agreed that the humidity in the storage air should not permit condensation of water on the tubers, but it should be high enough to prevent undue shrinkage and wilting of the tubers by evaporation of their water. The relative humidity would vary with the temperature; at 40° F. it would be about 80 per cent.

This discussion has included just a few of the important modern potato problems. Many others of equal importance are confronting the potato grower and the potato industry in general—such as the physiology of tuberization, immunity to disease, various cultural problems, marketing, utilization of culls and surplus crops, chemical composition, and cooking qualities of the tubers as effected by different conditions.

Many of the modern potato problems are typical of other food crops and rank with the most important problems confronting modern science as they are concerned with the world's food supply.

Guide to Further Reading

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CHEMISTRY AND ECONOMY OF FOOD

By Henry C. Sherman, Ph.D.
Professor of Food Chemistry and Executive Officer of the Department of Chemistry, Columbia University

"HALF of the struggle of life is a struggle for food" in the sense that a majority of the world's people must spend as much of their time or their earnings in providing themselves with adequate food as with all other necessities combined.

The Cost and the Functions of Food.—A family in comfortable circumstances may spend as much for rent, sometimes (too often perhaps) as much for clothing, as for food. The food is more nearly a fixed requirement than are the other items of the cost of living. When we consider the larger numbers of families who must live on smaller incomes we find that while the expenditures for food average somewhat less than in well-to-do families of the same size, yet in general it is not feasible to diminish the expenditure for food in the same proportion that the income is diminished. Thus the smaller the income the larger the proportion of it that goes for food. In the typical family of a labouring man or minor clerk half of the entire income is often spent for food and must be if the health and efficiency of the family are to be maintained. Or as one writer puts it:

"The less the worker gains the more he must invest in food, renouncing of necessity all other desires."

Why? What makes it necessary for the majority to renounce so much of what they rightly desire in other directions and spend such large fractions of their slender incomes upon food?

It is because the functions performed by our food are so urgently and fundamentally necessary not only to our comfort, efficiency, and health, but even to life itself. Very briefly stated the functions of food are: (1) to yield energy for carrying on the activities of the body; (2) to furnish the materials necessary for the growth and repair or upkeep of the body tissues; (3) to regulate conditions and processes in the body. The most prominent function of food, and the one in which nearly all articles of food take part, is to burn in the body and so yield the energy for the work which is always going on in every living organism even when it is, as we ordinarily speak, at rest. For every act and sign of life involves warmth, movement, or some other form of energy expenditure.

Fundamental as is the energy requirement or need for calories, yet food requirements cannot be met in terms of calories alone. Our wheat and corn crops alone would furnish each year enough calories for four times our population. But we could not thrive long on grains alone, for they are not entirely satisfactory in the fulfillment of the second and third functions of food. While we in America have an unparalleled food resource in our grain crops, we need other food crops also to make our food supply adequate as well as abundant.

FOOD CHEMISTRY.—Chemistry has already made and will surely continue to make many important contributions to the problems of food supply. Soil problems; fertilizer problems, including the fixation of atmospheric nitrogen and the utilization of the potash which would otherwise be lost in the cement industry or remain unclaimed in the desert lakes or in the sea; the problems of properly handling and preserving the food crops; the invention, development, and control of manufacturing operations in the food industries; as well as the inspection of their products in the interest of the consuming public—all these are problems largely for the chemist to solve and fields of work in which chemistry has already shown noteworthy achievements and must continue to play a leading part.

Perhaps the most important of all the services of food chemistry lies in the formulation of the requirements of human nutrition in explicit, scientific, and practical terms, and in determining the relative values of different foods in nutrition and the ways in which they supplement each other so that we may know how best to use our food supplies to the end that all people may be as well nourished as possible. For good nutrition is an even larger factor in health, happiness, and efficiency than we have previously supposed.

Until recently the application of chemistry to food problems, which has been uppermost in the public mind, has been in the use of chemical analysis to detect adulterations in food. There was justification for the charge sometimes brought against the food chemist that he "spends his time finding out what we shouldn't eat

instead of what we should." In those days, too, attempts to describe a good diet in purely chemical terms were hampered by the embarrassing fact that all efforts to raise animals upon mixtures of carefully purified food substances containing all the chemical compounds then known as essential to foods, had ended in failure; in fact, the purer the chemical substances making up the food mixture, the more certainly did it fail to support normal nutrition. Whether nutritive failure resulted from the need of other substances in addition to those then known as essential, or from faulty selection or combination of the nutrients entering into the artificial food mixture, remained obscure until about ten years ago when the work of Hopkins in England, and of Osborne and Mendel and McCollum and Davis in this country, made it clear that an adequate food supply must furnish certain substances which are absolutely essential but whose existence was previously unknown, and which we now know as the vitamins.

Although the vitamins have not yet been isolated in pure form, nor their chemical nature determined, yet we now know enough of their occurrence in foods and their functions in nutrition to include them in our study and discussion of food values, and we can now describe adequate food supply in chemical terms with confidence that we are taking account of all essential factors. Such a description requires the use of a small number of terms which a few years ago were regarded as technical but which have now become household words through the war-time discussions of food values and food conservation. An adequate food supply may be

described from the chemical point of view as one which furnishes: (1) sufficient amounts of digestible material to yield when burned in the body the necessary number of calories of energy; (2) enough protein of suitable sorts; (3) adequate amounts and suitable proportions of a number of mineral or inorganic elements (the ash constituents of the food); (4) enough of each of at least three kinds of vitamins.

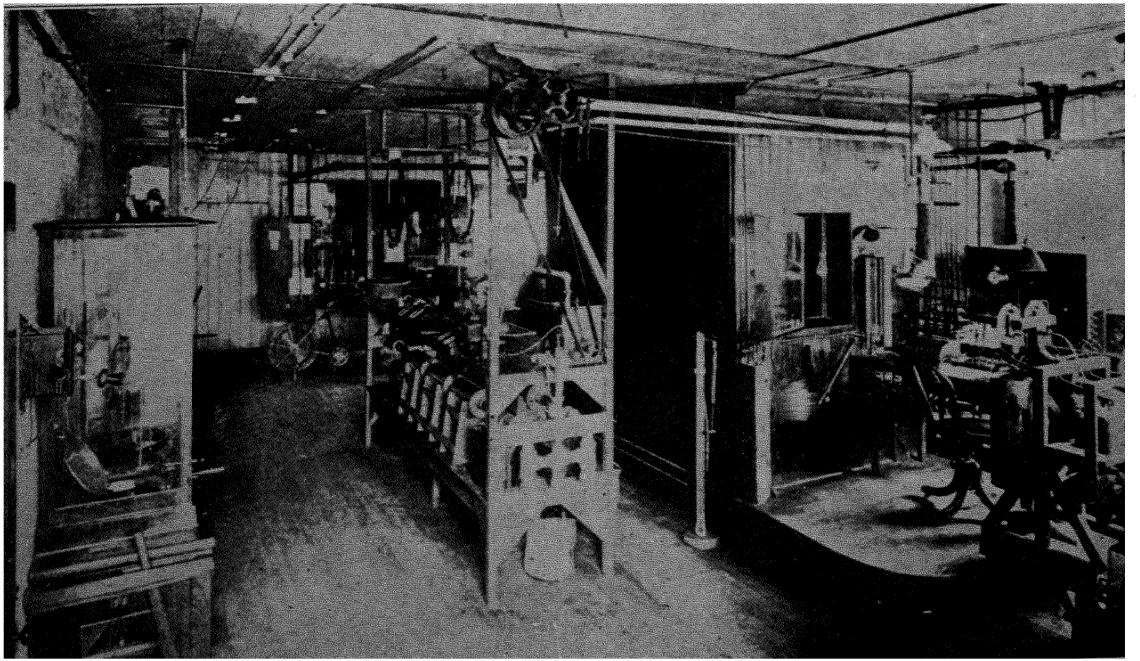
If a mechanical analogy helps, one may compare the body and its food to a gasolene engine and its requirements. The digestible organic foodstuffs such as fats, sugars, and starches correspond to the fuel for the engine; the proteins and some of the mineral matters to the materials of which the motor is made; other mineral matters to the lubricant; and the vitamins to the ignition sparks whose own energy is insignificant but without which the engine cannot run, however fine the materials of which it is built or however abundant and appropriate the supplies of fuel and of lubricant.

The efficiency with which economy in the use of food can be combined with entire adequacy of nutrition is chiefly dependent upon the extent to which we can state the various esssentials of an adequate diet in quantitative terms. Here in the most practical manner imaginable the exact science of the research laboratory in food chemistry comes directly into the service of human nutrition. How best to spend a dollar in the purchase of food for a family, or how best to divide the money which is to be spent for food—is a problem more often met than faced and one which may well serve to put into practical use whatever knowledge of food values and

food needs has been gained from the simplest food study of the elementary school or from the most advanced university course in the chemistry of food and nutrition.

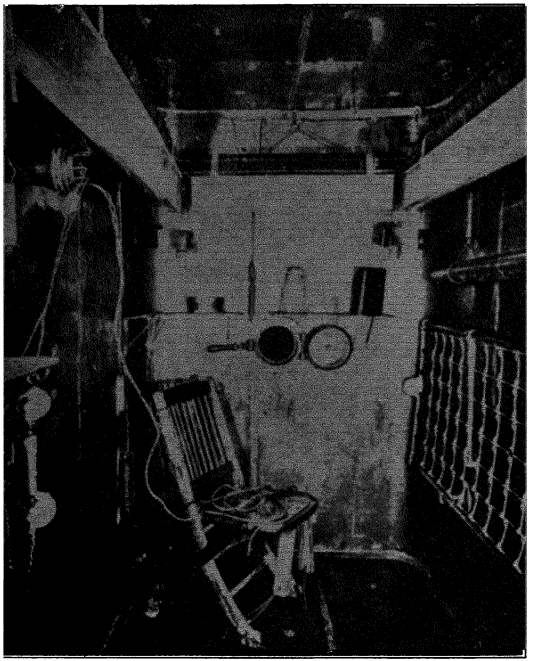
FUEL OR ENERGY VALUES OF FOOD—THE TOTAL FOOD REQUIREMENT.—The exact quantitative determination of human food requirements is chiefly the outgrowth of the nutrition investigations begun by means of a small appropriation made by Congress to the United States Department of Agriculture and expended under the direction of Dr. W. O. Atwater, late Professor of Chemistry in Wesleyan University. Professors Atwater, Rosa, and Benedict constructed in the basement of the chemical laboratory of Wesleyan University at Middletown, Connecticut, the first practically successful apparatus for the measurement of the energy exchanges in, and the energy needs of, the human body.

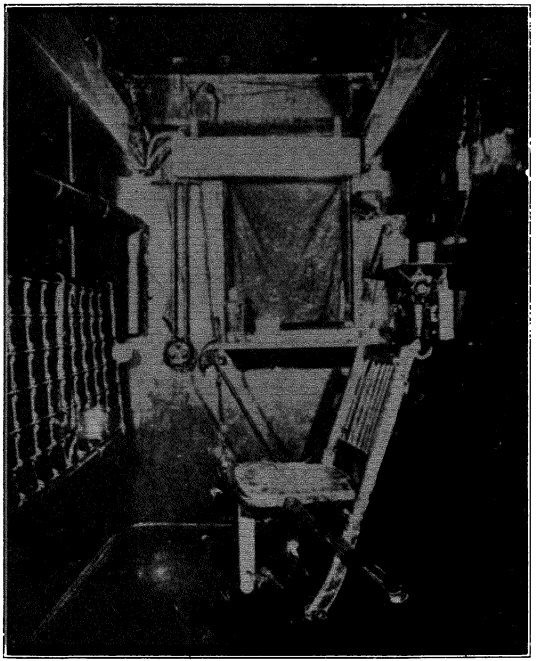
The outstanding achievement of Professor Atwater's work in this field was the development of a respiration calorimeter suited to direct experiments with men at rest and at work, and the perfection of this apparatus until it became truly an instrument of precision. This respiration calorimeter provided a copper room seven feet long, four feet wide, six and one-half feet high in which a man may live as many days as the particular experiment may require, and fitted with means for measuring accurately the amounts of energy used by the man under various conditions of activity and occupation. Figure 1 shows a general view of this apparatus as it was developed and used in the Atwater laboratory; Figures 2 and 3 show inside views of the living



Courtesy of Drs. Benedict and Langworthy and the United States Department of Agriculture

Fig. 1. General view of the respiration calorimeter laboratory





Courtesy of Drs. Benedict and Langworthy and the United States Department of Agriculture

Fig. 2. Interior of respiration chamber. View taken from the window

Fig. 3. Interior of respiration chamber. View taken from rear of the chamber

chamber. For explanation of the various parts reference must be made to fuller descriptions of the apparatus, *e. g.*, Bulletin 175 of the Office of Experiment Stations, United States Department of Agriculture, and Publication 123 of the Carnegie Institution of Washington.

When the experiments made by means of this original respiration calorimeter had given sufficient knowledge of the relative expenditures of energy at different times of the day and night and under different conditions of work and rest, it became possible to study particular problems by means of apparatus of smaller size and of particular design according to the nature of the problem to be investigated. Examples of such apparatus are the chair calorimeter and bed calorimeter (Figures 4 and 5) which are but two of the many improved calorimeters devised by Dr. F. G. Benedict, the Director of the Nutrition Laboratory of the Carnegie Institution of Washington and the leading experimenter in this field. Another important contribution made by Doctor Benedict to the methods of research upon energy requirements is the perfection of respiration apparatus by means of which the amount of oxidation taking place and of energy being used in the human body can be accurately determined by means of measurements of the oxygen consumed and the respiratory products given off, which measurements are now accomplished without necessitating the confinement of the man in the respiration calorimeter.

So fruitful did this line of study prove that notwithstanding the considerable expense involved in making

the experiments and the difficulty of securing funds for such work—since its more practical bearings could not be brought out in convincing fashion until the results of years of research could be brought together—it has been carried forward by the United States Department of Agriculture first under Professor Atwater and then under Dr. C. F. Langworthy, and also by the Carnegie Institution of Washington in its nutrition laboratory under Doctor Benedict, until now the energy requirements of the normal human body for different ages, sizes, and conditions of work and rest are fairly accurately known. The number of calories expended per hour by an average-sized man under various conditions of daily living, industrial occupation, and athletic exercise is shown in Table 1, taken from the author's "Chemistry of Food and Nutrition, Second Edition," in which may be found a fuller discussion of the achievements here sketched in bare outline.

TABLE I

Hourly expenditure of energy by average-sized man (70 kilograms or 154 pounds without clothing) under different conditions of activity. (Approximate averages only.)

	CALORIES
Sleeping	60-70
Awake, lying still	70-85
Sitting at rest	100
Standing at rest	115
Tailoring	135
Typewriting rapidly	140
Bookbinding	170
"Light exercise" (bicycle ergometer)	170
Shoemaking	180
Walking slowly (about 2¾ miles per hour)	200

	CALORIES
Carpentry	240
Metal working	240
Industrial painting	240
"Active exercise" (bicycle ergometer)	290
Walking actively (about 3¾ miles per hour)	300
Stoneworking	400
"Severe exercise" (bicycle ergometer)	450
Sawing wood	480
Running (about 5¼ miles per hour)	500
"Very severe exercise" (bicycle ergometer)	600

This exact quantitative knowledge of the energy values of foods and energy requirements in nutrition now forms the basis of all sound practical work in food chemistry and human nutrition—whether it be a problem of an individual or a family, a nation or a whole group of nations. During the World War the food crops and the food needs of America and the Allies were pooled and apportioned on the basis of calories; and every individual who wishes to purchase food economically begins his or her planning by deciding first upon the level of expenditure which is best expressed in terms of the number of calories which must be bought with a cent, or the number of cents which may be spent per 1000 calories of total food obtained.

THE NUTRITIVE EFFICIENCIES OF FOOD PROTEINS.—Protein has long occupied a prominent place in studies of food and nutrition and during the past decade much new interest has been attracted to this factor in food value by the discovery that the different proteins found in foods may, when taken separately, show very different efficiencies in nutrition.

Dr. Thomas B. Osborne of the Connecticut Agricul-

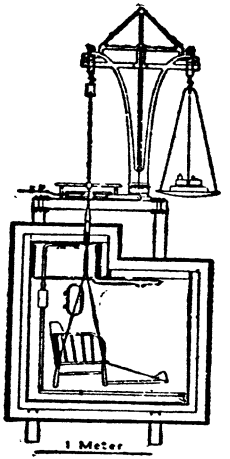


FIG. 4

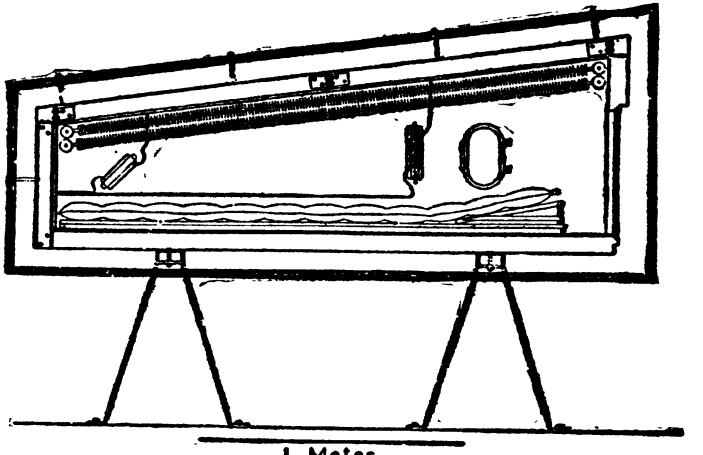


FIG. 5

Courtesy of Dr. F. G. Benedict and the Carnegie Institution of Washington

Fig. 4. Vertical cross-section of chair calorimeter from front to back, showing structural steel supporting calorimeter and the large balance above for weighing the subject inside the calorimeter. The chair, method of suspension, and apparatus for lowering and raising are shown. Part of the heat absorbers is shown, and their general direction. The ingoing and outgoing air-pipes and direction of ventilation are also indicated. The positions of the food-aperture and wire mat and asbestos support are seen. Surrounding the calorimeter are the asbestos outside and hair-felt lining

Fig. 5. Cross-section of bed calorimeter showing part of steel construction, also copper and zinc walls, food-aperture, and wall and air-resistance thermometers. Cross-section of opening, cross-section of panels of insulating asbestos, and supports of calorimeter itself are also indicated

tural Experiment Station and Professor Lafayette B. Mendel of Yale are the leaders in this field of science and their successful correlation of the chemical differences among proteins with their nutritive functions and efficiencies is one of the great achievements of modern science. Only a hint of it can be given here. When only one protein was fed at a time, along with mixtures of other foodstuffs known to be adequate to all other nutritive requirements, it was found that some proteins are adequate to support normal growth, others support maintenance but little if any growth, while still others always fail even to permit the animal to maintain his weight. A photograph of a rat whose growth had been practically suspended by feeding with a diet good in all other respects but containing gliadin as sole protein is shown in Figure 6 along with photographs, taken at the same focal distance, of normal rats, one of the same age, and another of the same weight, as the rat which had been thus stunted.

At first thought, therefore, it may seem surprising that the Inter-Allied Scientific Food Commission while setting standards for food needs in terms of calories declared it unnecessary to set standards for protein on the ground that a food supply of any ordinary character and sufficiently abundant to meet the calorie (energy) requirement can be trusted to furnish adequate protein without special planning. The justification for this view is found in two facts: (1) the quantities of protein actually required for healthy nutrition have been found by much careful research to be considerably smaller than formerly supposed; (2) the differences in nutritive

efficiency shown by certain individual proteins taken singly do not imply any great danger that the daily food will furnish inefficient protein, because the articles of food which we actually use contain many kinds of protein and these different proteins supplement each other. To explain this fully would require too long a discussion of the individual amino acids of which the proteins are composed.

THE MINERAL ELEMENTS AND VITAMINS OF FOODS.—Besides the five chemical elements of which simple proteins are composed, about a dozen more are now known to be essential to human nutrition; and besides the chemically known organic foodstuffs at least three other organic substances, vitamins A, B, and C, are also necessary. Space does not permit the discussion here of even the more important of our recent advances in the study of the mineral elements of food, and the vitamins need not be further discussed in this chapter since they are treated elsewhere in this volume by Doctor Eddy. It must, however, be emphasized that the recently developed knowledge of the nutritive importance of the mineral elements and vitamins and of the very uneven distribution of these dietary essentials among the different articles and types of foods has greatly clarified our ideas of food values. For progress in this line of study we are greatly indebted to McCollum and Simmonds, formerly of the University of Wisconsin and now of the Johns Hopkins University. It was formerly customary to speak as though dietaries could be "balanced" by a consideration of protein, fat, and carbohydrate, whereas we now see clearly that the mineral

elements and vitamins are at least equally important in this connection.

Taking account of energy values, protein content, mineral elements, and vitamins, we now group the chief articles and types of food according to their outstanding *nutritional* characteristics as follows:

1. *Grain products*—economical sources of energy and protein but not satisfactory in their mineral and vitamin content.

2. *Sugars and fats*—chiefly important from the nutritional standpoint as supplementary sources of energy, although some fats are also important as sources of the fat-soluble vitamin.

3. *Meats*, including fish and poultry—rich in protein or fat or both, but showing, in general, the same mineral and vitamin deficiencies as do the grains.

4. *Fruits and vegetables*—varying greatly in their protein and energy values but very important as sources of mineral elements and vitamins.

5. *Milk*—important as source of energy, protein, mineral elements, and vitamins; the most efficient of all foods in making good the deficiencies of the grains and in ensuring the all-round adequacy of the diet. (See Fig. 6.)

Fruits, vegetables, and milk are now seen to have much higher food values than were hitherto known, because they serve (as meats, sweets, and most fats do not) to make good the mineral and vitamin deficiencies of the breadstuffs and other grain products.

What we now call the newer knowledge of nutrition has been acquired within much less than a generation

and as yet its practical application has but barely begun. The economic and hygienic benefits which we may reasonably anticipate are incalculable. We must remember that the food crops produced by a country are not determined by nature (though writers often seem to imply this) but by the relative demands for the different things which any given farm can produce. The farmer in the long run will employ his land and labour and dispose of his crops in whatever way he finds most profitable and this in turn will depend upon what the consumer demands in the market and the relative prices which he (or she) is willing to pay. As fast as consumers come to understand that fruits and vegetables and milk are worth more and that meats and sweets are worth less than has been hitherto supposed, and show this knowledge by shifting the emphasis of their demands from meats and sweets to fruits, vegetables, and milk, just so fast will more fruits, vegetables, and milk be produced because they will thus become the crops that pay the farmer best.

For instance, when a normal American corn crop has been harvested and all the demands of human consumption, of industry, of seed for the next crop, and of feed for the farmers' draft animals have been met, there remain in the hands of the farmers of the United States over a billion bushels of grain to be turned into extra meat or into extra milk according to which "the market," that is, the consumer, makes it more profitable for the farmer to produce. Increase in the milk supply need not be entirely at the expense of a decreased meat production, but even if this were true the production of

milk could be doubled by decreasing the meat supply only one third. Two thirds of our present meat supply would give us a larger per-capita meat consumption than any European country, even Great Britain, has ever enjoyed in modern times—in all probability quite as much as is good for us; while to double the milk supply of the United States would undoubtedly mean a tremendous gain in the well-being of the people.

Even if our present milk supply be regarded as adequate, we now have evidence that a more liberal supply would be better.

ADEQUATE VERSUS OPTIMUM FOOD SUPPLY.—The space assigned for this paper being nearly exhausted, let us conclude it with a brief account of a current investigation demonstrating the fact that through our present knowledge of food chemistry, a food supply already adequate may still be capable of improvement with corresponding gain in health and vigour.

In developing and applying the newer knowledge of food chemistry in our work at Columbia University, we have not been satisfied to stop with adequacy of nutrition. We have sought to find and to show how a food supply which is already adequate may be made still better so that it will support a higher degree of health.

The Century Dictionary defines health as: "Soundness of body; that condition of a living organism and of its various parts and functions which conduces to efficient and prolonged life. . . . Health implies also, physiologically, the ability to produce offspring fitted to live long and perform efficiently the ordinary functions of their species."

We are somewhat accustomed to quantitative ratings of soundness and efficiency and much more so to data of growth rates, birth rates, and statistics of duration of life. In human experience so many factors may enter to influence health in the course of a lifetime that it is hard to separate and measure the effects of food alone. But this can be done with laboratory animals of rapid growth and early maturity like the rat, and in such experiments it is possible to determine under conditions uniform in all other respects the influence of food upon the various factors of health comprised in the definition just quoted.

Among the recent findings of nutrition experiments carried through successive generations of such laboratory animals the results of which are, I believe, directly and fully applicable to the problem of the attainment of the highest degree of human health, is the fact that starting with a diet already adequate we may by improvement of the diet induce a higher degree of health and vigour. This has been rather strikingly shown in experiments with rats in which different families from the same stock have been kept for successive generations upon two uniform food supplies: the first diet adequate as shown by the fact that it has supported healthy growth, development, and reproduction in some families for no less than six generations; the second diet differing from the first merely in that it contains a higher proportion of milk. These experiments are still in progress but certain results are already clear.

Among the evidences of a higher degree of health

which we find to result from increasing the proportion of milk in a diet already adequate are the following:

1. More rapid growth.
2. More efficient growth, i. e. a greater gain in weight for each 1000 calories of food consumed.
3. Somewhat larger average size at all ages, though the difference in size is not striking and probably not of great importance.
4. Greater vigour as indicated by earlier maturity, larger capacity for reproduction, and greater success in rearing the young.
5. The period of full vigour was prolonged and the proportion of families dying without issue was greatly reduced.
6. The weight of the mother was better maintained while suckling her young and the young grew and developed better during the suckling period.
7. Both infant mortality and the death rate after infancy were reduced, and this notwithstanding the fact that the females had borne and suckled more young.

There is no reason to doubt that all these findings, as thus stated in qualitative terms, will apply equally in human experience and that a higher degree of health will follow an improvement in the dietary of the individual or in the food supply of the community, such as an increase in the proportion of milk, even where the original dietary was already adequate according to all current standards.

This does *not* mean, as the sensationally minded would have it, that by the use of a "super-diet" we can produce a "super-race." It *does* mean that by the right use of our present knowledge and of our food supplies we can in future bring to a much larger percentage of our people that full measure of health and efficiency which only the more fortunate now enjoy.

May not such results of scientific investigation function somewhere in the curriculum of every school?

Guide to Further Reading

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OUR DAILY BREAD AND VITAMINS

By Walter H. Eddy, Ph.D.
Professor of Physiological Chemistry, Columbia University

ONE of the outstanding events in nutrition of the past decade has been the evolution of the vitamin hypothesis. Unfortunately the application of this hypothesis to the needs of the layman has provided the food and nostrum purveyors with material for advertising and exaggeration, and it is now essential that the cold facts in the case be presented to the public if we are to avoid the evils that have arisen from this quackery. In this chapter I wish to outline briefly the significant steps that have led to our knowledge of vitamins, the relation of this knowledge to our previous conceptions of right feeding, the methods which are used to evaluate the vitamin content of foodstuffs, and some simple rules for guidance in food selection in view of the new discovery.

Previous to 1906 the study of nutrition by laboratory methods has provided important basal principles for guidance in food selection. These principles are as fundamental and basic to-day as they were then, and the first fact to emphasize is that the vitamin discoveries have merely provided knowledge with which to supplement these facts, not to supersede or overthrow them.

The basal principles to which I refer may be summarized rather briefly.

First, food is fuel. Like coal the amount of energy that a given food will produce can be measured in heat units and that is all there is to the calorie evaluation idea. The calorie is simply a unit to measure with, like the inch or the centimetre. Thanks to accurate instruments and chemical analyses, it is now easily possible to determine on the one hand just how many calories of energy you or I need to run our human machine for twenty-four hours, and on the other hand just how much of the various kinds of foods we must consume to produce these calories.

But even though a foodstuff measures up to our calorie needs the body requires other qualities. To produce energy alone we can use starches, sugars, or fats, but to rebuild the living cellular matter (protoplasm) we require not only these foods but also others rich in nitrogen. The chemist calls starches and sugars, "carbohydrates." He calls the fatty substances, "lipins," and to the nitrogenous foodstuffs he has applied the term "protein." For all of these collectively he uses the term "organic nutrients." Chemical analyses easily give the proportions of carbohydrates, fats, and proteins in any foodstuff and this information is now available to the public in the form of tables issued by the Government and to be found in the many standardized texts on dietetics. If the ordinary individual will so select his foodstuffs as to provide fifty grams (about two ounces) of protein per day and to meet the calorie needs, he has satisfied most of what we

call the per diem nutrient needs of the human machine.

Aside from the organic nutrients present in a food, however, it has been found that the body also requires certain mineral salts. The manufacture of bone, for example, is a matter of lime deposition and we are learning that to deposit this lime as bone the body requires, not only lime salts, but a certain amount of phosphorus. Again the prevention of various bad conditions lumped collectively under the name of acidosis requires that our blood be kept nearly neutral in reaction and the carbonates and phosphates play an important part in this regulation. Mineral salts, then, constitute a fourth nutrient.

We are accustomed, then, to say that the *second principle* for guidance in food selection is to make sure that the foodstuffs contain the proper kinds and amounts of nutrients, including under this term carbohydrates, fats, proteins, and mineral salts.

The next discovery was the demonstration that proteins differ in nutritive value and that not only must the body have its fifty grams of protein per day, but it is extremely fussy as to the kind of protein it demands. As a result of the studies of many chemists working in this field we know that proteins are to be thought of as mosaics made up of separate chemical pieces and that there are some eighteen of these pieces, nearly all of which are absolutely necessary to make a body-satisfying protein. These pieces are known chemically as amino acids, but the principle involved is covered if we say that not only must we be sure of the amount of protein, but we must also assure ourselves as to its quality or make-up.

There are also foods which were originally despised because of their poor showing in the respects referred to above, which are now valued for another cause. The normal activity of our digestion demands a certain bulk to our food mixture, even though that bulk is secured by materials which are classed as indigestible. It is of course obvious that no matter how rich a food may be in the qualities outlined above, the nutrients must be of such a nature that the digestive juices can act upon them and so change them that they will pass freely from the digestive organs to the blood. If not they will fail to reach the muscle, nerve, skin, bone, and other structures they are intended to nourish. This property, then, demands that our foods be digestible, but if we attempted to feed a man on completely digestible mixtures his stomach and intestines would in time become atrophied. In other words we must have present a certain amount of indigestible matter to provide bulk and stimulation to the lining of the digestive tract. The cellulose which forms the coating of starch grains, the connective tissue that forms the indigestible portions of meats, etc., are examples of such substances. We speak of them as roughage and they are mechanical necessities of our food mixtures which must not be neglected if we are to avoid constipation and like ills. In general, then, while our foods must contain digestible nutrients they should also carry a certain amount of indigestible roughage.

Finally the form of the food offered is important. Eating is to a high extent a psychological affair. If the food is presented in an unpalatable form the body

can utilize it, but in time the mental antipathy reacts physiologically and the individual becomes badly affected thereby. It is worth-while always to pay attention to palatability.

Osborne's and Mendel's studies on the significance of protein quality were conducted between 1908 and 1911 and actually published in 1911. At that time the principles mentioned above were supposed to have *completely expressed* the basis for guidance in food selection. To illustrate these principles let us consider for a moment the composition of a foodstuff which is universally recognized as a perfect type of food, milk. In the following table are listed the chemical facts which are necessary to establish the standing of this foodstuff in the light of the knowledge of 1906–1911.

THE VALUE OF MILK AS A FOODSTUFF

(a) One quart of milk will produce about 700 calories of energy. If a baby's need were 700 calories per day one quart of milk would therefore meet this need without resource to other food. A man requiring 3,000 calories per day would, of course, need to consume a very large amount of liquid if he lived on milk alone and hence usually prefers to supplement milk with other less watery products.

(b) The nutrient content of ordinary cow's milk is as follows:

Protein of good quality	3.3%
Lipins	4.0%
Carbohydrates	5.0%
Mineral salts	0.7%
Water	87.0%
Wt. of one quart	34.4 oz. or 2.15 lbs.

Amino acid content—All the essential ones

It is also digestible and palatable.

Such tabulation as the above is perhaps sufficient index of how to test out any foodstuffs concerning which we have similar data.

In our introduction we called attention to one viewpoint which we wish to reëmphasize here. The vitamin hypothesis has not changed any of the basal principles by which we judge food value but merely requires us to supplement that knowledge by an additional criterion. How has this supplementary material been derived? What led to the vitamin hypothesis?

Briefly, two lines of investigation that at first may seem to have no relationship. First, the prevalence in certain parts of the world of a disease whose cause was unknown and whose toll of human lives justified scientific study. Second, the attempt of the nutrition students to prove that if we ate foods which met all the requirements cited above we would get normal growth, and the failure of the experiments to demonstrate this.

Since the word vitamin itself was coined as a result of pursuit of the first line of investigation we will consider that side of the story first. In the Orient, especially in East Asia, where the diet consisted largely of fish and white or polished rice, a peculiar disease often manifested itself to which was given the name beri-beri. This disease has been known for hundreds of years. Outside of the Orient the second greatest area was Brazil and the disease was also known, though less extensively, in many other districts of the world. The idea that this disease was of dietary origin seems to have first suggested itself about 1878–1880. In 1882 Takaki pro-

posed to change the diet of the Japanese Navy from rice diet and to add meat, bread, fruit, and vegetables. The result was an immediate reduction in cases of beri-beri. Rice then was early indicated as one of the offending articles of diet in the production of this disease. It would take too long to follow out all the investigations that were developed after the idea that beri-beri was due to a certain dietary deficiency first appeared. We will mention only a few of the most important. Of these, the investigations directed or personally conducted by Eijkman, a Dutch investigator in Java, deserve special attention. To him we owe two very important contributions. The following table collected by Vordermann at Eijkman's suggestion from Javanese prison cases shows how rice was first convicted of being a casual agent.

KINDS OF RICE IN DIETS	NO. OF PRISONERS FED THESE DIETS	NO. OF BERI-BERI CASES	RATIO OF BERI-BERI CASES
White rice	150,266	4,201	1:39
Rice with partial silver skin	35,082	85	1:416
Unpolished rice	96,530	9	1:10725

"A glance at this data shows how attention was focused not only on rice but on the polishing of rice, or "silver skin," as the carrier of protection against the disease. In 1896 Eijkman made a very important accidental discovery. He found that chickens fed upon the remains of foods used in a hospital for beri-beri died

of a disease which he called "polyneuritis gallinarum" and recognized as similar to human beri-beri. With chickens as experimental animals he was then able to supplement his medical investigations and to demonstrate that beri-beri was brought about in the Java cases by long-continued consumption of white rice and that the act of polishing removes an important constituent of the rice. The Dutch investigators, however, failed to see the full significance of their findings. Eijkman himself believed that the starch of the rice grain gave rise to toxins or poisons which acted on the nervous system and that this toxic action was prevented by material in the silver skin or, as he later showed, in the pericarp of the grain. The foundations laid by Eijkman stimulated many other workers to follow up his lead and his greatest contribution was in providing a test animal in which could be induced the disease and with which diets could be tested quantitatively.

The search for the preventive substance to which rice polishings owed their beri-beri protecting power, however, began actively with Eijkman's contribution in 1897. Other foodstuffs were studied and Grijns found certain beans to carry this protective substance. Schaumann extended the list of curative substances to include yeast. Other workers then sought to determine the value of the curative material itself. It was thought at one time that phosphorus compounds were the responsible factors. In his book, "The Vitamines," Casimir Funk, the author of the term vitamin, summarizes the situation up to the time of introduction of the vitamin theory (1911) as follows:

To summarize our knowledge of the chemical nature of the active principle prior to the introduction of the vitamin theory (till 1911) the following may be set down with certainty:

1. The substance is soluble in water, alcohol, and acidified alcohol.
2. The substance is dialysable.
3. The substance is destroyed at 130° c.

When we took up the question in 1911 it was not known whether the active substance was organic or inorganic, in nature, whether or not it was a constituent of proteins, nucleins, or phosphatides. It was not certain that we were not dealing with a ferment, nor was it known if the substance belonged to some chemical group already described, or to some new unknown class of substances.

Casimir Funk began his researches in this field shortly prior to 1911. He set himself the task of isolating the anti-beri-beri substance from its sources and the establishment of its chemical identity. In combination with Cooper, Funk had shown that when pressed yeast was boiled with 20 per cent. sulfuric acid for twenty-four hours and the sulfuric acid completely removed with baryta, the evaporated filtrate still exhibited marked anti-beri-beri qualities. This stability in the presence of an acid led him to believe that the substance must be an organic base. With this assumption he began a systematic investigation of large amounts of rice polishings, the results of which he published in 1911. In testing his fractions he made use of pigeons which had been shown, like chickens, to be particularly susceptible to this disease when fed on polished rice. By careful fractioning Funk was able to isolate from 100 pounds of rice polishings less than 2-100ths of an ounce of needle-shaped crystals which melted sharply at 233° F. and were highly curative.

Analysis of these crystals showed the presence of nitrogen. Hence, in a later publication Funk christened these crystals the anti-beri-beri vita-amine or "vitamine." Amine has long designated to chemists a substance basic in action and with a nitrogen content. Since the crystals prevented loss of life it was natural to call them the life (vita) amine. It is no discredit to Funk that later, largely through his own studies and partly through the work of others, the crystals which he believed to be pure vitamin were found to consist mainly of something else. To-day we have not yet succeeded in isolating the pure substance but Funk's researches laid a basis upon which all fractioning attempts have been based. The later discovery of other types of these substances developed a controversy in which he was criticised for his selection of a name but none of the substitutes proved more acceptable and his term is now in universal use. Drummond suggested recently that since the presence of nitrogen had not been demonstrated in what we now know as vitamin A and C, we drop the final *e* in the word and call them vitamins. Funk himself rather deprecates this change but the suggestion has been generally accepted by workers in this field.

Had the vitamin theory concerned solely this oriental disease and its prevention, we would not have had the extended public interest that exists in the subject today. To see how this has come about we must turn to the second line of investigations in 1906. Hopkins and his pupils in England had arrived at an interesting result in connection with their attempts to prove the adequacy of the food evaluation principles which we have

listed. As a result of feeding mice on food mixtures composed of purified nutrients and meeting all the views expressed in our qualifications for a perfect food, the animals failed to grow. Hopkins expressed his views at the time as follows:

> But further, no animal can live upon a mixture of pure protein, fat, and carbohydrate, and even when the necessary inorganic material is carefully supplied, the animal still cannot flourish. . . . The field is almost unexplored, only it is certain that there are many minor factors in all diets of which the body takes account.

In 1912, Hopkins first published the evidence on which he based these prophetic utterances. In this paper he demonstrated that a small quantity of milk contains something other than purified nutrient substances of suitable quality, which is necessary to rat growth. He suggested the name "accessory factor" for this substance.

In 1911 appeared the classical work of Osborne and Mendel in demonstration of the significance of the amino acids for maintenance and growth. They also used rat-feeding experiments and, like Hopkins, soon found that rats fed on purified substances alone would not grow. They believed that they had found an accessory factor in milk, and by removing the protein from the milk obtained a factor which they called "Protein-free milk," and which, when added to their otherwise adequate food mixtures, actually promoted growth. They thought at first that the mineral content of the milk was the answer, but when they carefully analyzed their milk and substituted for natural

protein-free milk an artificial mixture built of the salts in the proportions indicated in the analysis, it failed to produce the same effect.

Stepp, a worker in Germany, had been attracted to the problem by the researches in protein quality and on the hypothesis that fats also might differ in quality experimented along this line with rats. He first demonstrated that bread and milk constitute a growth-producing diet for rats. He then extracted his bread-and-milk mixture with ether and found the residue inadequate for growth. This result seemed confirmatory of his viewpoint. But when he added to the residue purified fat which he assumed was what had been removed by the ether extraction, no growth resulted. On the other hand, the residue obtained by evaporation of his ether extract when mingled with the other residue produced normal growth. Stepp failed to grasp the entire significance of these experiments at the time, but he did provide additional evidence that milk contains something that is neither protein nor fat and which is essential to growth.

In 1906 an experiment was begun at the Wisconsin Experiment Station which was planned by S. M. Babcock and carried out by Hart and Humphrey. In the *later stages* of this experiment McCollum and Steenbock coöperated. The object of this experiment was to determine whether rations for cattle, so made up as to be alike so far as chemical analysis would show, but derived each from a single plant, would prove to be of equal nutritive value for growth and the maintenance of vigour. The plants selected were wheat, corn, and

oats and a control group of a ration of the same chemical composition, but blended of corn, oats, and wheat. Young heifer calves were used, weighing 350 pounds and as near alike as possible. They were given all the salt they cared for, and allowed to exercise in an open lot free of vegetation, but the diet was absolutely restricted aside from salt (NaCl) to the particular ration. Differences failed to develop until after a year or more of time had elapsed. At that time the corn-fed animals were in much superior condition to all the others, even the control group. The wheat-fed ones were in the worst condition of all. Body condition, milk production, and the bearing of young paralleled one another in demonstrating the distinction between the diets.

This experiment marked the entrance of McCollum into a field which was to make him one of the important contributors to the vitamin hypothesis. He began the study of the cause of the failure of animals to grow on mixtures of purified foodstuffs in 1907 and employed the domestic rat as the experimental animal. In 1909, McCollum introduced a new feature by seeking to increase the variety of foodstuffs in the diet as far as possible, but every organic component of the diet was required to be pure and free from phosphorus in any form, practically the only source of phosphorus in the diet being finely ground tricalcium phosphate. The paper in which the results were published is important, for it reported the first successful growth experiments with a food supply which was at the time considered to be composed only of foodstuffs which could be named. It seemed to demonstrate the adequacy of the views

set forth in our basal principles for food selection and that the failure of animals fed upon purified food mixtures such as those used by Hopkins and Osborne and Mendel is due to lack of palatability and consequent failure of the animals to eat enough. McCollum's food mixture was made up of the proteins edestin from hemp seed and zein from corn. With these were given cornstarch, wheat starch, milk sugar, glucose, cane sugar, butter fat, bacon fat, and cholesterol and a salt mixture. The striking result was normal growth. In 1909, Osborne and Mendel began their work to evaluate the importance of the protein components of the diet. Instead of duplicating the diet of McCollum they substituted a simple mixture consisting of milk-casein, starch, lard, and a salt mixture recommended by Röhmann. These animals, unlike McCollum's, failed to grow and by carefully measuring the food intake it was proved that this failure was not due to lack of appetite. At that time no one was able to see any important chemical difference between the two diets. But by substituting for 28 per cent. of the diet the milk residue which they called protein-free milk, they obtained growth.

It would take too long to follow out all the lines of this experimentation. Out of it came the important information which has brought us recognition of the differences in protein quality. But from the vitamin viewpoint it was still more important. As a result of McCollum's study of his own diet he finally demonstrated the presence of a hitherto unsuspected factor in his butter fat that is absent in lard. He also found that egg yolk contained this substance. At the time of this

discovery he believed that this was the key to the difference between his diets and those of Osborne and Mendel and he christened this new substance "unidentified dietary factor fat-soluble A."

But there was another factor in the mixtures entirely unsuspected by either McCollum or Osborne and Mendel at the time. This factor was present in the protein-free milk and also in McCollum's lactose. The publication of Funk's work and his vitamin suggestions set the investigators on a new trail. McCollum objected to the idea that his fat factor was Funk's vitamin. Funk tried to show that the factor in butter fat was his vitamin substance. The literature of 1912–1915 is full of data bearing on this phase of the subject. Osborne and Mendel were able to confirm the presence of a stimulatory factor in certain fats as McCollum contended, but still believed that their protein-free milk supplied something else equally important. All the world knows to-day that the truth was that two vitamins were present. McCollum's butter fat did contain one, and we now call it vitamin A, or fat-soluble A. The one in his lactose and in the milk was proven to be apparently the anti-beri-beri type, and to reconcile the nomenclature it was listed as Funk's vitamin or "unidentified dietary factory water-soluble B."

By the time this tangle was ordered, the field of investigators had increased enormously and universal recognition was now given to the idea that in addition to nutrients of proper kind and quality, animals require for their growth and maintenance at least two other chemical substances hitherto unsuspected. It really

didn't matter much what these were called. We might have adopted Hopkins' term, "accessory food factors," or McCollum's phrases, "unidentified dietary factors fat-soluble A and water-soluble B," but Funk's term at least provided brevity and by common consent these factors have become vitamins A and B.

It now became fashionable to suspect diseases of hitherto unknown cause to be matters of vitamin deficiency. Scurvy had been known for years and its prevention by the use of lime juice had earned a name for the British mercantile navy of "lime juicers." Two workers in Europe, Holst and Fröhlich, published in the years 1907–1912 a series of brilliant studies which appeared to demonstrate this disease to be due to the absence of a specific vitamin, unlike the anti-beri-beri type and carried in abundance by substances such as lemon and orange juice. McCollum, however, reported in 1918 certain observations on experimental scurvy in guinea pigs which seemed to him to prove that this disease was explicable as a result of the absorption of toxic products from the intestines of the animals. A new controversy arose. Partisans of the two views arose also, but in time the truth confirmed the viewpoint of Holst and Fröhlich and vitamin C was added to the list. This matter was barely settled when a new controversy began, this time over the causes of rickets. Mellanby in England, working for the British Medical Research Committee, arrived at a viewpoint which the Committee published and to which they gave their support. This view was in brief that vitamin A, in which cod-liver oil is especially rich, is not only a growth

factor and a preventive of eye disease as was already demonstrated, but was also the factor which determined the proper deposition of lime salts in bone formation. Mellanby believed it to be entitled to the term anti-rachitic vitamin. The whole problem of rickets and its prevention was then reopened. Much valuable new data developed. It was found possible to cure rickets by regulation of the phosphorus in the diet, by using the ultra-violet ray or direct sunlight and by the use of cod-liver oil in the diet. The vitamin interest, however, centred about the use of the oil. Butter fat, known to be rich in A vitamin, was shown to be valueless as a preventive. On the other hand cod-liver oil was shown to be many times richer in A than butter fat and it was felt that perhaps Mellanby was right and that the distinction was a matter of quantity in the dosage. In August, 1922, however, McCollum published a series of studies which seem to leave no other conclusion than that cod-liver oil owes its antirachitic power to a new vitamin, that the antirachitic vitamin is not vitamin A. For this McCollum suggests the term D unless it shall be shown conclusively that vitamin B is actually composed of at least two factors. Funk has already offered evidence that the B concentrates contain a factor which is essential to the cure of beri-beri and another factor that seems to have a specific power in stimulating yeast growth. For the latter he had already suggested the term vitamin D. McCollum raises the question as to whether we should include in the vitamin series other factors than those proved of significance in mammalian nutrition. This

matter is purely a question of nomenclature and we have at least satisfactory evidence to-day of five substances which were hitherto unrecognized in dietary demands and which we consider entitled to names. The list is probably still far from complete. Very recently Evans and Bishop have shown that when rats are fed on diets adequate in every known way and including vitamins A, B, and C, they are often infertile. The addition of lettuce to the diet prevents this sterility. While the distribution of this fertility factor is still to be worked out it is certain that they are dealing with a hitherto unrecognized factor, perhaps the sixth vitamin. These new substances so far as present knowledge is concerned are all alike in being potent in very small amounts and in defying chemical separation or identification except by physiological effects. It may well be that when isolated in free form they will show similar structure, but at present we have no data on which to base even a reasonable guess in this direction.

The review preceding is essential to make clear exactly the relation of the vitamin discovery to proper food evaluation. Enough experimentation has been carried out to date to show that these factors are widespread in nature. The following table from the author's Vitamin Manual will give a little idea of this widespread distribution:

SOURCE OF VITAMINS

FOODSTUFF	"A"	"B"	"C"
Meats:			
Beef heart	+	+	?
Brains	++	+++	+?
Codfish	+	+	?
Fish roe	+	++	?
Herring	++	++	?
Kidney	++	++	
Lean muscle	o	o	+?
Liver	+	+	+?
Pancreas	o	+++	
Pig heart	+	+	?
Vegetables:			
Beet root	+	+	++
Cabbage, fresh	+++	+++	++++
Carrots	+++	+++	++
Cauliflower	++	+++	++
Celery	?	+++	?
Chard	+++	++	?
Lettuce	++	++	++++
Onions	?	+++	+++
Parsnips	++	+++	
Peas (fresh)	+	++	+++
Potatoes	o	+++	++
Potatoes (sweet)	+++	++	?
Spinach	+++	+++	+++
Cereals:			
Barley	+	+++	?
Bread (white)		+?	
Bread (whole meal)	+	+++	?
Maize	+ In yellow o In white	+++	?
Oats	+	+++	o
Rice polished	o	o	o
Rice (whole grain)	+	+++	o
Rye	+	+++	o
Corn embryo		+++	

FOODSTUFF	"A"	"B"	"C"
Cereals—Continued:			
Corn (see maize)			
Malt extract	o	o	o
Wheat bran	o	+	o
Wheat embryo	++	+++	o
Wheat kernel	+	+++	o
Other seeds:			
Beans, navy		+++	o
Cotton seed	++	+++	
Peanuts	+	++	
Peas (dry)	+?	++	o
Fruits:			
Apples		++	++
Bananas	?	+	++
Grapefruit		+++	+++
Grape juice		+	+
Grapes	o	+	+
Lemons		+++	++++
Limes		++	++
Oranges		+++	++++
Pears		++	++
Raisins		+	+
Tomatoes	++	+++	++++
Oils and fats:			
Beef fat	+	o	o
Butter	++++	o	o
Cocoanut oil	o	o	o
Cod-liver oil	++++	o	o
Corn oil	o	o	o
Cotton seed oil	o?	o	o
Egg yolk fat	++++	o	o
Fish oils	++	o	o
Lard	o?	o	o
Oleo, animal	+	o	o
Oleo, vegetable	o	o	o
Olive oil	o	o	o
Pork fat	o?	o	
Tallow	o	o	o

FOODSTUFF	"A"	"B"	"C"
Nuts:			
Almonds	+	+++	
Chestnut		+++	
Cocoanut	++	+++	
English walnuts		+++	
Hickory	+	+	+
Dairy products:			
Butter	++++	o	o
Cheese	++	+	?
Condensed milk	++	+	o
Cream	+++	+	?
Eggs	++++	++	o
Milk powder (skim)	+	+++	+?
Milk powder (whole)	+++	+++	+?
Milk whole	+++	+++	++
Miscellaneous:			
Alfalfa	+++	+++	?
Clover	+++	++++	?
Honey		++	o
Timothy	++	+++	
Yeast cakes	o	++	o

It will also serve to point an important viewpoint which needs special emphasis. When we select our daily diet now we must of course include our quota of vitamins. But in view of the small amounts essential, bear in mind that this selection can be made without going outside the usual list of foodstuffs. We need no pills or nostrums. The slogan of a quart of milk a day for the growing child is still good advice in more than its original sense. In milk, vitamins A, B, C, and perhaps D, are present in abundance. Green vegetables and fruits supply the A and C lacking in a purely meat

and cereal diet. Look to your green stuffs. But let us learn to pick our vitamins out of the food market and there will be no need to go to the druggist.

A final word is perhaps desirable to explain the compilation of a table such as shown above. How is such information obtained? No other discovery emphasizes more strikingly the value of animal experimentation as a means of furthering human knowledge. Until Eijkman discovered that beri-beri could be induced in fowls, no tool was available for measuring quantitatively the amounts of the anti-beri-beri vitamin in foodstuffs. The white rat has provided all the data for distribution figures in regard to vitamin A and much for B. To the guinea pig the race is indebted for the proof of presence and quantity distribution of vitamin C. If we can find an animal in which we can induce pellagra, that controversy may be cleared up. In brief, then, several methods of experimentation are now in universal use in the study of vitamin nature or distribution, but all are alike in principle. They all consist in either feeding to the experimental animal a diet lacking in a given factor and then attempting cure by addition of the foodstuff under investigation, or incorporating the foodstuff in the original diet in varying amounts and noting the prevention or lack of prevention of symptoms that follow. In all these diets the principles laid down in our original list are utilized and are essential if we are to be sure the results measure vitamin deficiency.

We end then, as we began, with reiterating that the vitamin hypothesis has not destroyed old ideas about

food selection, but merely extended our bases for selection. We continue to require calories, nutrients, proper protein quality, but to these we must now add vitamin content. Someone has compared vitamins to the spark in the gasolene engine. It does not replace the gas but makes it work. So in the animal mechanism the fuel is food, but the food fails to function properly without its controlling vitamins.

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