SCIENCE

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CONTENTS:

MSS. intended for publication and books etc., intended for review should be sent to the responsible editor, Prof. J. McKeen Cattell, Garrison-on-Hudson, N. Y.

*A MEMORIAL APPRECIATION OF CHARLES VALENTINE RILEY.**

THE name of Charles Valentine Riley is known in every part of the world where there are naturalists or intelligent agriculturists. His contributions to biological science and to agricultural economy were extensive and important, and were very highly esteemed abroad as well as at home.

At the time of his death he was fifty-two years old. Those who have known him only in recent days cannot have a full appreciation of many of his most characteristic and attractive traits. During the last ten years, worn out by intense devotion to his work, his energies exhausted by incessant application, his nervous vitality depleted by the friction of a long and arduous official career, though still remarkable for his force and productiveness, he was by no means the same as in the fourth decade of his life.

When, in 1894, he resigned his position as chief of the Bureau of Entomology, it was the belief and hope of his friends that, relieved from the official burden which had become so irksome to him, he would be able to devote the remainder of his life entirely to scientific pursuits. With his vast learning, his experience as an investigator, and the opportunities for leisurely study

* Presented at the annual meeting of the Joint Commission of the Scientific Societies of Washington, January 18, 1896.

which he possessed, it seemed as if the most useful period of his life was just about to begin. Many who are here present will remember the dinner given in his honor shortly after his fiftieth birthday, and how bright and promising his future then seemed. His untimely death prevented the realization of our anticipations; but yet, now that we can survey his career and review with care his achievements, it does not seem credible that they are those of one suddenly cut down in the prime of his life.

They are rather those of a man who, having lived to a good old age, had accomplished the work of fully two men during each year of his activities.

His energy was boundless and untiring; he did with ease and facility whatever he attempted, and rarely failed to accomplish that which he had undertaken to do; he had rare ability in selecting and training men to do the work for which he had himself no time, and in directing their labors towards the speedy attainment of results.

He acquired in early life those habits of feverish and restless activity which are characteristic of many of our countrymen, and which, though they contributed materially to magnify the results which he accomplished within comparatively few years, undoubtedly shortened the period of his usefulness.

The vast amount of work which he accomplished is shown by the catalogue of his published papers, of which there are more than 1,600, many of them of very considerable extent, and the whole equivalent to at least 20,000 octavo pages.

Professor Riley was a man of singularly striking appearance and agreeable presence. No one who had once seen him could forget him. Active and graceful, his bearing was such that, though perhaps not more than five feet ten inches in height, he seemed much taller. He never lost the easy, independent carriage which he had acquired during his early life in the West, and there was always something unconventional and picturesque about his costume and appearance. The broad-brimmed, sombrero-like hat, dark in winter, light in summer, which he almost always wore, seemed in keeping with his swarthy complexion. He looked like an artist or a musician, and indeed he possessed the artistic temperament in a high degree. As a youth he was urged to make painting his profession. In early years he drew thousands of illustrations of insects, which were characterized as much by beauty and delicacy of line as by minute accuracy. In later and busier times his taste for form and color were chiefly gratified in his favorite recreation of gardening. He was a most accomplished horticulturist, and his garden on Washington Heights was the best kept and most beautiful in the city, and gave evidence of the control of a master mind.

Riley was a thorough American in habits of thought and in sympathy, yet he often visited the little village of Walton, on the banks of the Thames, where he had passed the earlier years of his life. In these visits he learned something of his forefathers. His peculiar Southern features, his warm complexion, his dark eyes and hair, which made many people suppose him to be a Spaniard or an Italian, were derived from a more northern Celtic race, his ancestors, whose history he succeeded in tracing for many generations, having migrated from Wales to England at quite a recent day.

His schoolboy days were passed in France and Germany, and he was but seventeen when his restless spirit led him America.

"He went West and settled with Mr. G. H. Edwards, whom he had met in London and who had made arrangements to open a stock farm in Kankakee county, Illinois. Here, during three years, he acquired that experience of Western agriculture that can be gained only by actual farm work. Fond of all life as manifested on the farm, young Riley devoted himself enthusiastically to the calling he had chosen.

Of an inquiring and experimental turn of mind, he aimed to improve on the methods in vogue, and soon won the esteem of all who knew him ; and, though so young, was sought for in counsel and honored at public gatherings, at which he became intimate with Emory Cobb and other prominent farmers of Illinois. Under these circumstances, and with a deep love of nature in all her manifestations, it is no wonder that Professor Riley, as we have heard him avow, looks back to the farming days in Illinois as the happiest of his life.

"The experience gained on the farm has enabled him, more than anything else, to understand the position and needs of the farmer. In writing of Prof. Riley's farm life and the reasons why he abandoned it, a Kankakee friend who knew him well, remarks: 'Young Riley was simply too enthusiastic and too bent on excelling in everything. He took no rest. Often he would be up, actually get breakfast ready to relieve the womenfolk, and milk half a dozen cows before the others were about. When others were resting at noon in the shade, he would be working at his flowers under a July sun. There was not a sick animal of the three hundred on the place that he did not understand and help. He kept a lot of bees, got hold of the best bred colts and some of the best heifers in the county, secured a good quarter section, and spent his Sundays reading, sketching, and studying insects. Three years of this increasing effort under the trying climatic extremes of central Illinois broke the young fellow's health, for it was a great contrast to his previous life, and with every one telling him that he was wasting his talent he finally concluded to give up the idea of farming. But had his health not failed him, my opinion is that he would be a farmer to-day, and a successful one too, for he has intense love of rural life.'

"He went to Chicago in his twentieth year, with no definite trade or profession and with little experience of city life. Money was scarce among farmers in those days, and his little property was so invested that it was not available. The trials of his first few months in Chicago are familiar to only a few of his intimate friends, but the manner in which he overcame them while yet in but poor health was characteristic. Pride prevented him from asking help from his Kankakee friends, but did not prevent him from donning blue overalls and doing manual labor in a pork-packing establishment, or from adding to his slender income by making portraits of fellow-boarders, or sketches which he himself disposed of at evening in the abodes of wealth on Michigan avenue. After a while he obtained an engagement as reporter on the *Evening Journal*, but finally became connected with the *Prairie Farmer*, then the leading agricultural paper of the West. Besides a close application to the duties of his position as reporter, delineator and editor of the entomological department of this paper, he devoted his time and energies to the study of botany and entomology. His industry and versatility soon made him not only popular with his associates upon the paper, but gave him a widespread reputation as a writer upon natural history, especially on his specialty of economic entomology, the importance of which he soon made apparent."*

His adventurous temperament led him to enlist as a private in the 134th Illinois Volunteers, in which he served for several months during the Civil War in Kentucky and Tennessee.

Before entering the army he had made the acquaintance of the man whom he joined in 1868 in establishing the *American Entomologist*. This friend, who was senior editor until his death, was Dr. Benjamin D. Walsh, State Entomologist of Illinois, and it was Walsh to whom Riley always alluded as his master and the man to whom he was most indebted for his early training and inspiration. Mr. Walsh was a graduate of the University of Cambridge, in the class with Darwin, a man of great and scholarly attainments and a most careful and painstaking investigator. During the few years of his residence in Illinois he had done much to develop the interest in economic entomology, which resulted in the establishment of the position of State Entomologist of Missouri in 1868, which was the beginning of Riley's public labors.

An important outgrowth of Riley's personal activity in connection with his official work was the formation of the Riley Collection of insects, upon which he began immediately after he left the army in 1864, and which at the end of twenty-five years included over 20,000 species, and over 115,000 mounted specimens, besides much other material. The collection is in many respects unique, especially so because of the complete manner in which the life-history

*Colman's *Rural World*, St. Louis, May 12, 1892.

of numerous individual species is represented. It is the legitimate outgrowth and complement of Riley's investigations, and is a voucher for the accuracy and fulness of his personal work in entomology. This collection he gave in 1882, without condition, to the National Museum, at that time without a collection of insects. His purpose in doing this was to place in the Museum a worthy nucleus, and to be instrumental in the formation of a collection which would be worthy of the Nation. He was appointed at once honorary curator of the department of insects in the Museum, and gave much attention to the department, which thereafter made rapid advances.

Professor Riley's first interest in the study of insects was from this standpoint of a field naturalist. He did little in systematic entomology; the species which he described were but few, and he was quite content to leave monographic and critical work to others. His tastes led him to study the life histories, to trace each form through all its transformations, to know its habits, its food and its manner of life; and to understand its relations to, and its influence upon, the plants among which it lives and upon which it feeds. To the fact that he knew thoroughly the life histories of so many insects was due the importance of his contributions to economic entomology; but he was by no means content, as I have said, with the results in this field, although his deep interest in agriculture and horticulture led inevitably to practical conclusions with regard to every species which he studied. His writings are full of important and original observations in pure biology, and constitute a mine of reference for zoölogists and botanists, especially those studying the subject of transformism or evolution. He was indeed one of the earliest American transformists. He published an early and appreciative notice of Darwin's work, and I have seen many letters addressed to him by Darwin. He was also the correspondent and friend of Alfred Russell Wallace, Herbert Spencer, Henry Bates and of other eminent workers in kindred fields.

His writings abound in decisions of the greatest interest to students of evolution. His papers on 'The Caprification of the Fig,' on 'The Yucca Moth and Yucca Pollination' and on 'Some Interrelations of Plants and Insects' were especially interesting.

The most important of his philosophic papers was his address on 'The Cause of Variations in Organic Forms,' which he delivered when Vice-President of the American Association for the Advancement of Science, in 1888.

Passing allusion may be made to his interest in other branches of science. He had great interest in mechanical devices of all kinds, and in 1869 read before the French Academy of Sciences a paper on 'The Perfecting of the Graphophone,' which was regarded in France as suggestive and original. His studies of the flight of insects led him to take great interest in the problem of artificial flight; and his own skill as a prestidigitator, in which he took great delight, induced him to give much attention to spiritualism, in which he was no believer, but which attracted him on account of his own success in exposing frauds. During the last visit to Washington of Alfred Russell Wallace, who was a believer in spiritualism, he succeeded in proving impositions on the part of certain mediums whom the English philosopher was disposed to trust.

His standing as a naturalist was so high that three years ago, when the Hope professorship of entomology in the University of Oxford became vacant through the death of Professor Westwood, he was one of the two most prominent candidates for this position and failed of election by only a few votes. Indeed, it was known to have

been Professor Westwood's own wish that Riley should be his successor.

He was greatly interested in the establishment of an insectary, in connection with the Smithsonian Institution, where, in connection with his museum work, he might carry out still further his investigation into the life history of members of his favorite group.

It was as an economic entomologist that Riley was most widely famed. In this field he was eminent in two respects—in administration, as well as in his direct contributions to the science of practical entomology, and to the art which is its outgrowth.

As an administrator, he was associated with three prominent undertakings: the entomological work of the State of Missouri, the United States Entomological Commission, and the establishment of the division of entomology of the Department of Agriculture.

He held the position of entomologist to the State of Missouri for nearly ten years, entering upon this work at the age of twenty-three. Concerning what he accomplished and how he did it, I shall allow one more competent than myself to speak:

"In the spring of 1868 his writings upon injurious insects brought about his appointment to the newly created office of entomologist to the State of Missouri, and from that time until 1877 he was engaged in the investigation which thoroughly established his fame. During that period he published nine annual reports, which have become classics in entomological literature. At the time when his work was begun, the science of practical entomology was in its infancy. The writings of Harris and Fitch had resulted in the tracing of the life-history of many of the principal injurious insects, but the recommendations as to the remedies were more or less crude, many important points were left uninvestigated, even with the commonest crop enemies, and a few entirely erroneous conclusions had been reached. Beyond the work of these two men, practically nothing had been done except the first report of Benjamin D. Walsh, which had just appeared.

"Looking back over Professor Riley's work during these years, one cannot help being amazed at its extent and character, especially when one considers that he worked single-handed, had many obstacles to overcome, and great demands upon his time in the way of correspondence, lectures and addresses. Every insect which he took up (and he published upon an immense number, including all that were then of great importance) was treated from a standpoint of absolute originality. The statements were based upon actual field observation, and the remedies proposed were the results of experiment or deductions from a perfect knowledge of the insects' habits and life history. In fact, it is no exaggeration to say that the modern science of economic entomology is based upon and dates from the publication of these reports.

"The original edition of these reports has long since been exhausted, but they are still continually sought for and command high prices. They are replete with the results of original research, and their illustrations created an epoch in the science no less than their text. The reports of the State Board of Agriculture containing them have long been sought by book dealers, who detach the entomological portions and sell the rest to junk dealers.

"Of these Missouri reports the late Charles Darwin wrote that they contained a vast number of facts and generalizations valuable to him, and that he was struck with admiration at the author's powers of observation."*

The United States Entomological Commission was in existence for five years, Riley having having been its chief from the beginning.

"We all remember," said the *Pacific Rural Press* in 1887, "the sad experiences which our Western States and Territories passed through from 1873 to 1877, from locust or grasshopper ravages, which resulted in destitution and precipitated a financial crisis. These ravages seriously affected the western portion of his own State, and Prof. Riley took hold of the problem with that originality and vigor which have characterized all of his work. His last three reports to the State contain the first positive and accurate knowledge on the subject that has been published. But he early saw that the subject was one of National importance, and could not be fully dealt with by work

* L. O. Howard, A Distinguished Entomologist, *The Farmers' Magazine*, London, I., 23, F.

in any one State. To feel a necessity was sufficient for him to act, and consequently we find him in public lectures, in leading articles, through resolutions offered at societies' meetings, memorials to Congress, and in every other way urging the creation of a National Entomological Commission. After various bills had been introduced and discussed, Congress finally created the Entomological Commission, with a special view to investigate the Rocky Mountain locust, or so-called grasshopper, and Prof. Riley was tendered the position as Chief of the Commission, a distinction which his investigations into this insect had justly earned, for he had already not only made most important discoveries as to its habits and the best means of subduing it, but had ascertained sundry laws that govern it, so as to be able to predict the time of its coming and going and the limits of its spread. Consulted by Secretary Schurz as to the other appointments, it is no wonder that the members chosen were Doctor A. S. Packard, Jr., a naturalist of eminence, one of the first entomologists of the world, and a prominent author and editor, and Prof. Cyrus Thomas, who had likewise labored for the creation of the Commission and who was the authority on the family of insects to which the locusts belonged. Both of these gentlemen, like Prof. Riley, had been chosen by their respective States as official entomologists, and had a large personal experience in the West. Accepting charge of the Commission thus constituted in March, 1877, we find Riley travelling that year over most of the Western country, from the Gulf to the South Saskatchawan, in British America, now in company with the Governor of the State, and again with other special officials, but everywhere exhorting the farmers to action, making careful observations and experiments, and inspiring confidence."

The work of the Commission was carried on with all the originality and vigor which characterized his work, and its annual reports contain a mass of important results, embodying the first real and definite knowledge on the subject which had seen the light of print. One of his associates writes:

"It was mainly owing to his executive ability, business sagacity, experience in official life, together with the scientific knowledge and practical inventive turn of mind in devising remedies, or selecting those invented by others, that the work of the Commission was so popular and successful during the last five years of its existence."*

The publications of the Commission consisted of five illustrated reports and seven bulletins. Of the former, Riley, himself, wrote that "the five taken together represent an amount of original investigation and experiment, the practical outcome of which has certainly never been excelled in the annals of economic entomology." In these reports were discussed not only the Rocky Mountain locust and its allies, but the cotton worm, the Boll worm, the army worm, the cankerworms and insects injurious to forest trees.

The position of of United States Entomologist was held by him during fourteen years, or from 1878, with a brief intermission, until nearly the time of his death; and during the period of his incumbency the Division of Entomology was organized. His successor in this position wrote in 1890:

"The present efficient organization of the Division of Entomology was his own original conception, and he is responsible for its plan down to the smallest detail. It is unquestionably the foremost organization of its kind at present in existence. It has a small permanent corps of scientific workers, who have been trained under him and who assist in the preparation and editing of reports, in the care of insects, the life-histories of which are being studied, in the making of elaborate notes, in the mounting and arranging of specimens for permanent economic and classificatory collections, in making drawings for illustrations to the reports and in the very large correspondence. The training of these assistants and their present efficiency and standing in the scientific world is only another

*A. S. Packard, SCIENCE, N. S., II., 74, F.

instance of the thoroughness of Prof. Riley's methods. Several of them have gone out from this office to accept important positions under the State governments, and thus the influence of his training has become widespread."*

His achievements in the art of practical entomology were many, but these were they which have been recognized as of especial and permanent value.

He was the first to demonstrate the practicability of checking the ravages of an imported species of insect by enlisting the aid of the insect enemies which had kept it in check in its native habitat. This was effected by the introduction from Australia, in 1888, at his instance and by two agents sent out from his office, of the Australian *Vedalia*—a species of lady-bird, which is the natural enemy of the 'Fluted Scale' an insect which had found its way from Southern Australia to California, and was fast destroying the orange and lemon groves.

His studies in connection with *Phylloxera*, the French vine pest, although not more important than many others more purely American in interest, may well be referred to on account of the attention which they attracted in France and honors conferred upon him as a result. To him is generally attributed the idea of reviving etiolated French vineyards by using certain American phylloxera-proof stocks to graft upon. In a sketch recently published by Monsieur Valery Mayet, in the *Revue de Viticulture*, certain statements are made which I quote:

"This notice being written especially for grape culturists, especial mention should be made of Riley's work upon insects destructive to the grape vine.

"From 1866 to 1884, during which time Riley made numerous visits to France, there appeared a constant succession of notes and articles upon insects inimical to the vine, and especially upon *Phylloxera*. Riley was, most certainly, one of the very earliest investigators on this subject, and long before he discussed the insect in Europe, he published in the *Prairie Farmer*, of August 3, 1866, a description of the insect, the first good description, since as he remarks, 'It had before been described only very briefly by Dr. Fitch, in New York, in 1856, under the name of *Pemphigus vitifolii.*'

"As soon as the *Phylloxera* had been discovered in France; in 1868 Riley began a correspondence with the three naturalists who were especially interested in this insect, J. E. Planchon, Lichtenstein and Signoret. He even visited France in this connection. The first idea suggested to his mind was to compare the American species with that of Europe. 'Lichtenstein and I' wrote Planchon in 1865, 'had the idea that the *Pemphigus vitifolii* of Fitch was nothing but our *Phylloxera vastatrix*. This theory was confirmed as soon as Riley, coming for that express purpose to Europe, assured us of the identity of the insects of the two countries.' Riley, on the other hand, had remarked, in 1871:

"'The observations made by me in America and Europe, of the winged and wingless forms, leaves no doubt in my mind that the insects of the two continents are identical.'

"The successive notices published by Riley, from 1868 to 1880, upon the insect, which for a long period of time prevented the culture of the European vine in the United States, a series of notes, not less than fifty-five in number, demonstrated the important connection of this naturalist with this very important question. His name soon became as popular in America as that of Planchon in France."*

As long ago as 1873 the vine-growers of France presented him with a gold medal, struck in recognition of his investigations into the history of the Phylloxera. In 1889, as a further proof of their appreciation of his services, they presented to him a beautiful statue in bronze, while the French government conferred upon him the Cross of the Legion of Honor.

Associated prominently with his name are certain practical methods for the destruction of insects, the use of kerosene emulsions to protect plants and trees from the attacks of suctorial insects, and the invention and perfection, aided by Mr. W. S. Barnard, of a very ingenious series of mechanical devices for spraying insecticides and fungicides in a liquid form, often called the Riley system.

* Howard, *loc. cit.*

* Revue de Viticulture.

It may perhaps be unwise to ignore the fact that the credit of certain of Riley's achievements has been claimed by others, in some instances by those who were first to call attention to facts out of which these achievements have grown, in other instances by those who were employed by Professor Riley to carry his ideas into effect.

It would be fruitless to enter into the consideration of any of these claims. Some of the claimants are perhaps entitled to a larger share of credit than has been given them in the official publications in which the results of their work are discussed. It is doubtful, however, whether in any instance any other would have succeeded so soon, or so completely as did Riley. His, in every instance, was the directing mind. It was he who chose the man through whose agency the work was accomplished. It was the mind of Riley which directed, and the will of Riley which controlled, the activities of his agents. It is my honest conviction that in most instances the agents would neither have begun the work under other circumstances, or completed it, except under such control, and that he was able to have done the work unaided, the results of his first years' efforts, when he was laboring single-handed, fully demonstrate.

There cannot well be better evidence of the eminence of the man and the value of his work than the testimony of the numerous journals in their comments upon his death, and especially the journals which are devoted to ecomonic methods rather than those of the professional men of science.

The *Canadian Entomologist*, London, Ontario, said:

"As an economic entomologist, taking him for all in all, he was the most eminent the world has ever seen."*

Natural Science, London,† called him 'the prince of economic entomologists,' and says of his reports that they are "characterized by scientific accuracy coupled with clear and popular exposition, and while of special value to the farmer, fruit grower and forester, they abound with observations of interest to the pure naturalist."

Psyche, Cambridge, said:

"In his death America loses not only its best known entomologist, but one who by his ability, sagacity, example and the line his studies have taken, has done more for the advancement of our special science than any one America has ever reared." *

The editor of *The Farmers' Magazine*, of London, wrote:

"His studies of Hessian-fly and the Hop-fly, in England, have a direct bearing upon our agricultural prosperity, and his election as an honorary member of the Royal Agricultural Society, and still more recently as an Honorary Fellow of the Entomological Society of London, testify to the esteem in which he he is held, not only by our representatives of advanced agriculture, but also by those engaged here in investigations in the field of pure entomology." †

R. McLachlan, F. R. S., in the *Entomologists' Monthly Magazine*, London, said:

"The Missouri Reports proved the thoroughness of his work, his originality in divising mechanical means for distributing the remedial agents he adopted and his great skill as an artist. These Reports drew forth the highest encomiums all over the world. * * * Riley was nothing if not original. There was probably only one real *fiasco* in his career. The rapid spread of the Colorado Beetle induced him to predict its speedy appearance on this side of the Atlantic. The Colorado Beetle disappointed him by not acting up to his anticipations."‡

W. Fream, writing in the Journal of the Royal Agricultural Society of England, spoke of him as "the greatest agricultural entomologist of our age," and said:

"In him a striking presence was associated with a versatile genius. Naturalist, linguist, artist, soldier, he was withal a delightful companion, a sincere friend. In that branch of study which he made peculiarly his own he has established an ideal which few

* *Canadian Entomologist*, October, 1895, 273.

† *Natural Science*, November, 1895, 360.

* *Psyche*, November, 1895, p. 308.

† *The Farmers' Magazine*, I., 221.

‡ *Entomologists' Monthly Magazine*, No. 378, November, 1895, 269.

can hope to approach and none to excel. Taken from our midst in the early prime of life, it can nevertheless, with all truth, be said that in the voluminous records of his incessant work he has indeed left behind him *monumentum aere perennius.*"

G. BROWN GOODE.

SCIENTIFIC MATERIALISM.

AT the meeting of the Naturforscher-Versammlung, held last September, at Lübeck, Germany, Professor W. Ostwald, of Leipzig, delivered an address which was received with great interest, and gave rise to much discussion. The address has since been published in the *Zeitschrift für Physikalische Chemie* (Volume XVIII., p. 305), under the title 'Die Ueberwindung des wissenschaftlichen Materialismus,' and it seems desirable to call attention to it in this place, as it is highly suggestive, and its careful study is likely to be of benefit. The following is in the main a free translation of the more important parts of the address:

There is one point upon which scientific men agree, and that is that all things consist of moving atoms, and that these atoms and the forces acting upon them are the final realities. According to this, a natural phenomenon is explained when the exact nature of the motion of the atoms of the substance exhibiting the phenomenon is known. There is nothing beyond this. Matter and motion are ultimate conceptions. This is *scientific materialism*. The author believes that this view is untenable. It must be given up and a better view substituted for it. He states particularly that what he has to say has, at present, nothing to do with ethical and religious conceptions.

In investigating natural phenomena we first *register* and *classify*. From *registration* we reach the *system*; from this the *law of nature*, the most comprehensive form of which is the *general conception*. The most important element in the law is the *invariant*, a quantity that remains unchanged whatever changes may take place. Such an invariant is *mass*. This did not at first appear broad enough, and thus the conception of *matter* came to light, and the *physical law* of the *conservation of mass* was transformed into the *metaphysical axiom* of the *conservation of matter*. By this step a number of hypothetical elements are introduced into the conception that was originally free from hypothesis. It is now held that when, for example, iron and oxygen combine, the two forms of matter are in the compound, only they have new properties. This the author considers nonsense, for all that we know in regard to a certain stuff is that it has certain properties.

Galileo introduced the conception of the constant working *force* and thus explained the phenomenon of falling bodies. Newton assumed the same force as acting between the heavenly bodies and governing their motions. These great successes led to the conviction that all physical phenomena might be explained in the same way. Thus arose the *mechanical conception* of nature. It is not generally noticed to what an extent this conception is hypothetical, indeed metaphysical. On the other hand, it must be noted that this mechanical conception of heat, electricity, magnetism, chemism, has not been confirmed in a single case. It has not been possible to express the relations by a corresponding mechanical system, so that nothing is left unaccounted for.

The history of optics furnishes an excellent example. As long as optics included only the phenomena of reflection and refraction, the mechanical conception of Newton was satisfactory, according to which light consists of small particles sent out in straight lines. When later the phenomena of interference and polarization came to be studied, it was found that Newton's mechanical conception could not explain them, and the vibration theory of Huygens and Euler was adopted. But it was then necessary to imagine some medium