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*OBSERVATION AND EXPERIMENT.**

THE near coincidence of this anniversary meeting of the Academy with the end of the nineteenth and with the beginning of the twentieth century imposes peculiar and quite unexpected restrictions in the way of freedom of choice of a fitting subject for an address. Naturally one would like to pass in review some of the brilliant achievements of science in the past century, and perhaps forecast the still more brilliant advances that may be expected to mature in the present century. Especially might one feel tempted to present a semi-popular inventory of the more striking or recondite scientific events with which he is particularly familiar. But all this and more, strange as it may seem, has been done, or is being done, by the public press. Specialists in almost every branch of science have been employed to expound and to summarize the discoveries, the theories, and the useful applications which have rendered science, by common consent, the most important factor in the civilization of the nineteenth century. Statesmen, philosophers and divines are likewise sounding the praises of science and the scientific method with a warmth of recognition and with a stamp of approval which tend to make one who is

*Address of the President of the New York Academy of Sciences, read before the Academy on February 25, 1901.

old enough to have lived in the pre-scientific, as well as in the present epoch, feel as if a millennium were close at hand. Indeed, such a wealth of good scientific literature is just now thrust before us and such a wealth of praise is just now bestowed on scientific achievement that the modest man of science must hesitate before adding a word to that literature or a qualification to that praise.

The requirements of official position are remorseless, however, and one must speak his thought, although silence with respect to science may appear to be the most urgent need of the hour. In view of these circumstances, it seems best to avoid topics of current interest and to invite your attention to a brief consideration of the elements which lie at the basis of scientific investigation and scientific progress. A recurrence to the slow and painful beginnings of knowledge and the first principles evolved therefrom is always instructive; and it is especially fitting at a time, like the present, when the ardor of research is somewhat in danger of the sedative influences which spring from the popular glorification of triumphant successes.

The fundamental data from which all scientific knowledge grows are furnished by observation and experiment. After these come the higher steps of comparison, hypothesis, and finally the correlation and unification of phenomena under theory. Even pure mathematics, though long held apart from the other sciences, must be founded, I think, in the last analysis, on observation and experiment.

Of the infinite variety of phenomena which appeal to our senses, some, like those of sideral astronomy, are subject, in the main, to observation only; while others, like those of terrestrial physics, chemistry and biology, are subject to both observation and experiment. All phenomena are more or less entangled. They point backward and forward in time; any one of them appears and disappears only in connection with others; and the record any one of them leaves is known only by its interaction with others. Out of this plexus of relations and interrelations it is the business of science to discover the conditions of occurrence and the laws of continuity. Happily for man, although the ultimate complexity of phenomena is everywhere very great, it is frequently possible to discern those conditions and occasionally possible to trace out those laws. But the results we reach are essentially first approximations, depending, in general, on the extent to which we may ignore other phenomena than those specially considered. In fact, a first step towards the solution of a problem in science consists in determining how much of the universe may be safely left out of account. Thus the method of approximating to a knowledge of the laws, of nature is somewhat like the method of infinite series so much used by mathematicians in numerical calculations; and as it is a condition of success in the use of such series that they be convergent rather than divergent, so is it an essential of scientific sanity that the mind be restricted by observed facts rather than diverted by pleasing fancies.

The prime characteristic of the kind of knowledge that leads up to science is its dependence on facts which are permanent, and hence verifiable. In the course of the progress of our race there have been certain luminous epochs during which observers and experimentalists have revealed more or less of such knowledge. These epochs have been followed, generally, by others of comparative dullness, or positive darkness, during which fact has been replaced by fancy and what is permanent and verifiable has been eclipsed by what is ephemeral and illusory. It is my purpose to-night to recall some of the principal events of these epochs, and to enforce, as well as I may, the great lesson they seem to teach us, namely, that science can be maintained only, and can be advanced only, by a constant appeal to observation and experiment.

As we look out on the universe about us the most striking phenomena visible are those which belong to what Galileo and his successors have fitly called 'the system of the world.' The rising and setting of the sun and moon; the majestic procession of the seasons; the splendid array of the stars in the heavens; the ebb and flow of the sea, and the never-ending variety from wind and weather, need only to be mentioned to enable us to understand why astronomy is at once the oldest and one of the most highly developed of the sciences. No classes of phenomena are so obvious, so omnipresent and so enduring. They have furnished the symbols of continuity and permanence for all languages in all historic times. The 'fixed stars,' for example, are in fact, as well as in fiction, our standards of reference in the reckoning of time and space; for are not 'Sirius and Orion and the Pleiades,' as Carlyle has remarked, 'still shining young and clear in their course as when the shepherds first noted them on the plains of Shinar?'

But before astronomy there were mythology and astrology, and we may well marvel how it has been possible, even after the lapse of twenty odd centuries, to educe the orderly precision of science out of the complicated miscellany of fiction, fact, religion, and politics bequeathed to our era by the fertile imaginations of our distinguished ancestors. What, for example, could be more confusing than the paleontological jungle called the stellar constellations, with its gods and godesses; with its dogs, lions, bears and fish, great and small, northern and southern; with its horse, whale and goat; and with the slimy forms of serpents intertwining them all?

Although it is impossible to set any date for the emergence of astronomy out of mythology and astrology, the epoch of Hipparchus undoubtedly is the earliest one of conspicuous advances known to us. This epoch, which may be called also the epoch of the Alexandrian school of science, extends from about 300 B.C. to about 150 A.D. It is distinguished by the remarkably perfect work in pure geometry of Euclid and Apollonius, and by the still more noteworthy work of Archimedes in laying the foundations of statics and hydrostatics; it comprises the measurements according to correct principles of the obliquity of the ecliptic and the dimensions of the earth by Eratosthenes; it includes the observations of the sun, moon, stars and planets collected by Aristyllus and Timocharis and later turned to so good account by Hipparchus; it embraces the work of Aristarchus, who maintained the heliocentric theory of the solar system and who was the first to attempt a measure of the dimensions of that system by means of the fine fact of observation that the earth, sun and moon form a right triangle, with the right angle at the moon when the latter is in dichotomy—or when its face is just half illuminated; and finally it includes the work of Ptolemy, a worthy disciple of Hipparchus, whose Almagest has come down to our own time.

From the observational point of view we must rank the principles with respect to fluids at rest discovered by Archimedes as amongst the capital contributions to the science of all times; for while his successors, of the last two centuries especially, have added to hydromechanics the large and vastly more difficult branch of hydrokinetics, they have found no change essential in his laws of hydrostatics.

Equally important, also, in its far reaching connections was the work of Eratosthenes in determining the size of the earth. This work required an hypothesis as to the shape of the earth and appropriate observations. Supposing the earth to be spherical, an assumption which Eratosthenes knew well how to justify, he saw that to determine its size it is only necessary to apply the rule of three to the measured length of an arc of a meridian and to the measured difference of the latitudes of the ends of such arc. He observed that at the city of Syene, which is about 500 miles south of Alexandria, the sun shone vertically downwards into deep wells at noon on the day of the summer solstice, showing thus that at that place and time the sun was in the zenith. On the same day at Alexandria he observed, by means of the gnomon, that the sun at noon was south of the zenith by one-fiftieth of a circle, or 7°.2. The distance between the two points was found by the royal road masters of the country to be 5,000 stadia, thus giving for the complete circumference of the earth 250,000 stadia. Although the measurements thus made by Eratosthenes were very crude and undoubtedly subject to large errors, we see in them the beginnings of some of the most refined geodetic operations of the present day. Unfortunately for us, also, the measurement of the distance is expressed in a unit whose relation to modern units is only roughly known.*

But commendable as was the work of his predecessors and contemporaries, the work of Hipparchus rises to a still higher plane. He was an observer and a theorist of the highest type, being able at once to collect facts and to interpret their relations, and he deserves to be ranked among the great astronomers of all times. He was the first to clearly appreciate the value of a catalogue of the fixed stars and constructed one giving the relative positions of 1,080 stars. He observed with surprising precision the interval of the tropical year; he made the first tables of the sun and moon; he discovered the remarkable fact of the precession of the equinoxes, and he thus early led the way to the great advances of modern times.

The peculiar merit of the work of Hipparchus lies not alone in the fact that he saw how the apparent motions of the heavenly bodies may be determined by observations, but also in the fact that he saw how these motions may be determined by a very small number of appropriate observations. Thus, for example, the interval from the vernal equinox to the summer solstice and the interval from the latter to the autumnal equinox sufficed to give him a close approximation to the apparent motion of the sun; while the records of a few eclipses of the moon enabled him to deduce a closely correct value of the precession of the equinoxes, that shifting of the line of intersection of the equator and the ecliptic which goes on so slowly that an interval of nearly 26,000 years is required for a complete circuit.

Hipparchus may be called the founder of the geocentric theory, since he demonstrated the accordance of the phenomena known to him with that theory. The fact that this theory is false detracts little from his merits; for the sole requisites of a good theory are simplicity of statement and conformity with observation. We now know, indeed, that mechanical phenomena are, in general, susceptible of multiple interpretations, and that

* As illustrating the slow growth of ideas with respect to precision, it may be related that when the Arabians in the ninth century undertook, for the same purpose, the measurement of a meridional arc on the plain of Singiar, in Mesopotamia, they were not more successful in preserving for posterity the standard of length used by them. This standard is said to have been the 'black cubit, which consists of 27 inches, each inch being the thickness of six grains of barley.'

observation must decide which of them is to be preferred.

The method which Hipparchus used to measure the sun's apparent motion among the fixed stars is very noteworthy, especially when we consider the utter lack of effective instruments in his time. If the sun moves regularly about the earth, as first supposed by Hipparchus, it ought to return at any epoch, as that of an equinox, to the same position among the fixed stars. Imagine a line drawn at the time of the vernal equinox, say, from the center of the earth to the center of the sun. This line prolonged will pierce the celestial sphere in two points, and, if either point can be located, the position of the sun with reference to the stars becomes known. Hipparchus fixed this position by noting the location among the stars of the center of the shadow cast by the earth at the times of eclipses of the moon. By a comparison of his own observations of such eclipses with those made by his predecessors he was able to determine the apparent motion of the sun with reference to the stars, or what we now know to be the motion of the equinoxes with reference to stars. To establish this fact of precession from such meager observations was a great step; and it seems not a little singular that a phenomenon so striking should not have led to speedy investigations for its source. But about eighteen centuries elapsed before Newton clearly visualized the mechanical interpretation of this phenomenon, and it was only after an additional half-century that the interpretation was fully worked out by d'Alembert.

How rapidly the spirit of science dies out when its devotees cease to observe and experiment is shown by the failure of the 'Divine School of Alexandria' to maintain the high standard set by Hipparchus. His immediate successors became at best only commentators. They wrote much but observed little; and it does not appear that any of them attempted even to verify the remarkable discoveries of Hipparchus during the two hundred and fifty years which elapsed between the period of his activity and the advent of his worthy disciple and expounder Ptolemy.

It is to the work of Ptolemy chiefly that we owe our knowledge of the discoveries and theories of the Hipparchian epoch. His treatise on the 'Great Construction,' the Megiste Syntaxis, or the Al Magisti and hence Almagest of the Arabians, is the earliest of the great systematic treatises on astronomy. It is in this work that the theory of eccentrics and epicycles of Hipparchus is explained and elaborated, and it is this work which has given the name of Ptolemy, rather than that of his acknowledged master, to a system of the world which dominated scientific thought for nearly fifteen hundred years.

The period during which the observations and researches of Ptolemy were carried on is commonly referred to in history as extending from the reign of the Emperor Hadrian to that of Marcus Aurelius. Thus, while Ptolemy was an Egyptian by birth, the fact that he was permitted to pursue his astronomical studies under the empire helps to some extent to relieve the Romans of the charge that they were, as regards science, the most ignorant people of antiquity. But the gravity of that charge is only palliated by the work of Ptolemy, for he left no successors. Roman astronomy did not rise above the level of astrology; the spirit of scientific enquiry gave way to speculation and declamation; and the long night which followed was not broken until the dawn of the epoch of Galileo—the modern epoch, whose advances have been founded on observation and experiment.

If astronomy is preeminent among the sciences for its dependence on observation, chemistry and physics are equally preeminent for their dependence on experiment. This difference in methods of investigation between the former and the two latter sciences is a difference imposed by the circumstances that astronomy deals chiefly with objects at long range while chemistry and physics are concerned with objects near at hand. It seems not a little singular, however, at first thought, that progress in the development of knowledge concerning the behavior of distant bodies should have been almost as rapid up to the present time as the development of knowledge concerning bodies much more familiar and accessible to us.

Chemistry and physics, like astronomy, had their forerunners in mythological follies and extravagances. Semi-civilized and civilized man required a long time after he had learned how to talk and to write well, after he had founded states and constructed systems of philosophy and religion, before he could reason rationally and successfully with respect to the commonest material things about him. Thus, chemistry was long obscured by merely verbal speculations on the 'four elements, earth, air, fire and water' or on the 'three elements, salt, sulphur and mercury'; while the beginnings of physics were perhaps even more clouded by the fantastic unrealities of fertile but unchecked imaginations.

But man early learned to measure the value of chemistry by the 'gold standard.' It is hinted, in fact, though without adequate evidence, that the Golden Fleece of the Argonautic expedition was a manuscript containing valuable secrets of the chemist's art; and Suidas, of the eleventh century, to whom the word chemistry is attributed, relates that Diocletian, fearing that the Egyptians, by reason of their knowledge, might become rich and restive, ordered, in true Roman fashion, that their books on chemistry should be burned. The thirst for gold assisted also in the development of alchemy, which flourished from the eleventh to the fifteenth century especially, and has had not a few adherents, it would seem, during all the centuries down to and including the one just past. The philosopher's stone was almost universally believed to be a real agent in medieval times; and this strange fiction also has its survivals in the 'mad stones,' 'moon stones,' 'lucky stones,' and other 'charms' whose use even at the present time is not uncommonly justified by the wise saying that 'there may be something in them.'

The difficulty in getting the human mind started with the elements of physical science is well illustrated, likewise, by the superstitious rubbish that encumbered the early progress of knowledge concerning magnets. They were endowed with imaginary qualities far more wonderful than subsequent observation and experiment have disclosed. It was believed, for example, that they would cause some diseases and cure others; that they were effective as love philters; that they would lose their properties when rubbed with garlic (which seems not so unlikely), but that a bath in goat's blood would readily counteract this destructive effect. And in this case, also, as with alchemy and the philosopher's stone, it is to be noted that such crude notions of the phenomena of matter find their survivals at the present day in a wide acceptance of the unverified efficacy of 'magnetic healers' and 'electric belts,' and in the ease with which capitalists can be persuaded to invest in a 'Keely motor' or in anything that promises the marvelous.

With the decline of alchemy the field for chemistry shifted somewhat. Not unnaturally, since most chemists were also physicians in those days, a knowledge of the chemical properties of substances came to occupy a prominent place in the physician's art. Thus Paracelsus in the sixteenth century, cutting loose from the teachings of Aristotle and Galen, boldly asserted that the true use of chemistry is not to make gold, but to prepare medicine; and he and his follower Van Helmont, in addition to attaining fame for skill in compounding remedies, were amongst the first to appreciate the true import of the processes of analysis and synthesis which came to be called in their day the spagyric art. Then followed the doctrine of the mutually neutralizing substances, acid and alkali; the fruitful hypothesis of elective attractions, or affinities; the ingenious, if erroneous, theory of phlogiston, and the more permanent theory of oxygen. All these led up through more and more searching experimentation to the first great epoch in the history of chemistry—the epoch of Lavoisier.

Among the early workers in the century preceding the epoch of Lavoisier the names of Becher and his disciple Stahl deserve especial mention, not only by reason of their introduction of the theory of phlogiston, but also by reason of their enthusiastic and steadfast devotion to science without hope of pecuniary reward. In his remarkable treatise entitled 'Physica Subterraneæ,' published in 1681, Becher defends the scientific pursuit of chemistry as not less worthy of attention than philosophical and theological studies. He insists especially on the need of careful observations and on the necessity of constantly verifying theory by experiment. With true scientific enthusiasm he describes the chemist as one willing to work amid the flames and fumes, and, if need be, the poisons and poverty of the laboratory. He has no patience with the charlatans, of which it appears there were still many in his day, who are looking chiefly for ways and means of extracting the precious from the baser metals. As for himself, he says: "My kingdom is not of this world. I trust that I have got hold of my pitcher by the right handle—the true method of treating this study; for the pseudo-chemists seek gold, but the true philosophers, science, which is more precious than any gold."

It is a peculiarly noteworthy fact that while much attention was given to chemistry during ancient and medieval times, comparatively little attention was given to the other branches of physical science. Our knowledge of heat, light, electricity and magnetism is almost wholly a development of modern times. The Greeks were acquainted with a few of the more elementary phenomena of electricity and light; and Ptolemy and Alhazen came near discovering the law of optical refraction; but there was no contribution made to either of those physical sciences comparable with the discoveries of Hipparchus in astronomy until the epoch of Galileo. What a marvelous increase in the rate of scientific progress began with this epoch is shown on nearly every page of the subsequent history of science. Galileo and his contemporaries may be said to have established the methods of observation and experiment. Their systematic application has borne fruit in every science. Almost every step forward has led to additional advances, until now each of the physical sciences has its wide array of determinate facts correlated under a great theory. In the domain of light, for example, the only solid contribution of the ancients is the obvious fact of radiation in straight lines. After nearly sixteen hundred years of our era had elapsed, there came Galileo's invention of the telescope, and about the same time Snell's discovery of the law of refraction. To the telescope was soon added the microscope and the camera obscura. Then followed Newton with explanations of the rainbow, dispersion and kindred phenomena; Hooke with his discovery of the colors of thin plates; Dolland with the combination of two lenses to produce achromatism, and Huygens with his discoveries and explanations of double refraction and polarization; while in the meantime Roemer had measured the velocity of light. All these accessions crowded one another so closely that the emission theory of Newton and the undulatory theory of Huygens followed almost as a matter of necessity. The battle royal of these two rival theories, as you know, lasted for nearly a century, until the emission theory, by the sheer force of critical observations and experiments, was displaced by the undulatory theory through the brilliant researches of Young and Fresnel.

When we turn from the physical to the geological and biological sciences, the same lessons of the necessity and the efficiency of observation and experiment are still more strikingly apparent. For although geology and biology are the youngest of the grand divisions of science, they have accomplished more than all others toward giving man a proper orientation with respect to the rest of the universe. Geology as we now understand the term is but little more than a hundred years old, and biology, in the sense now attached to the word, is less than fifty years old. Nevertheless, these sciences have been the chief contributors to the doctrine of evolution, which, in view of the wide range of its applicability, must be regarded as the most important generalization of science.

It is a singular circumstance, however, considering the early advances made in the interpretation of the phenomena of astronomy, that the equally ubiquitous and far more accessible phenomena of geology and biology should have been so tardily investigated. The cause of this delay seems to lie in the fact, not without examples in the present day, that our remote ancestors had the habit of constructing their theories first and making their observations, if at all, afterwards; and in the cases of geology and biology they were so well satisfied with their theories that the trouble of making observations was for a long time dispensed with.

We of the present day have no right, perhaps—and I for one would not be disposed to use such a right if conceded—to blame our predecessors for the narrow, and in some instances crooked, views they held with regard to these subjects. But on the other hand, we shall fail, I think, to make proper use of our opportunities if we do not learn speedily to conduct scientific investigations in the future so as to avoid such colossal blunders as mar the history of geology and biology from its beginnings down almost to our own time.

As an illustration of the blunders referred to I may cite the profound reluctance, even of eminent men of science, to accept the plainest teachings of observation with respect to geological time up to the middle of the century just passed. Not until Lyell, the great champion of uniformitarianism as opposed to catastrophism, had published his 'Principles' (1830) did scientific opinion show a tendency to accept the fact of the hoary age of the earth, everywhere attested by the rocks in her crust.

And what a storm of opposition and condemnation, amounting almost in some cases to social ostracism, was visited by the very 'salt of the earth' against those who ventured during the sixties and the seventies of the last century to consider favorably the arguments of the 'Origin of Species'! All this has about it the freshness, and possibly the pain and the humor, of personal recollection for those of us who are old enough to have lived in two epochs. That a mistake of this sort could have been made thirty or forty years ago seems strange enough in these peaceful times of ours. But while we may properly let the recollection of the storm and stress of this earlier period fade away, the moral of the conflict should be held up as a permanent warning to scientific as well as unscientific men; for no episode in the previous experience of the race demonstrates so clearly the sources of knowledge and the methods of attaining it.

As a final illustration of the validity of my thesis I would invite your attention to one of the most instructive and beneficent of the many brilliant biological researches of recent times. No one who has suffered from repeated attacks of intermittent fever, and has survived the ravages of the materia medica, can fail to take a lively interest in the wonderful progress made during the last twenty years towards a definite knowledge of the natural history of that disease. Nor can any one interested in the general aspects of science fail to see in the investigations leading up to this progress some of the finest examples of the scientific method.

It would appear that malarial fever has been one of the commonest disorders, in certain localities, with which man in his struggle for existence has had to cope; and before the discovery of the properties of Peruvian bark it must have been a very serious affliction by reason of its secondary if not by reason of its primary effects. The symptoms, course and distinguishing characteristics of the disease, as well as the remedies therefor, were long known, however, before it was suspected that the mosquito had anything to do with its dissemination. Bad water, foul air, and sudden or extreme changes of temperature were supposed to be promoting causes. The dampness of marshes, swamps and other areas holding stagnant water was held to be an especially common attendant, if not inducing, condition. There was, indeed, no lack of acute and painstaking observations and no lack of ingenious and well-supported hypotheses with regard to this widely prevalent but obscure disorder. The details of its diagnosis, prognosis, nature and causation, as laid down in the medical manuals of a few decades ago, are particularly interesting and instructive reading now in view of recent developments. For example, Hartshorne in his 'Essentials of the Principles and Practice of Medicine,' published in 1871, gives the following explanations:

"No disease has ordinarily so regular a succession of definite stages as intermittent fever, namely, the cold, the hot, and the sweating stage." * * * "Upon the origin of malarial fevers," he adds, "the following facts seem to be established: 1. They are reasonably designated as autumnal fevers, because very much the largest number of cases occur in the fall of the year. Spring has the next greatest number of cases. 2. They are always strictly localized in prevalence. 3. They never prevail in the thickly built portions of cities. 4. An average summer heat of at least 60° F. for two months is necessary for their development. Their violence and mortality are greatest, however, in tropical and subtropical climates. 5. They prevail least where the surface of the earth is rocky; and most near marshes, shallow lakes and slow streams. The vicinity of the sea is free from them, unless marshes lie near it. 6. The draining of dams or ponds, and the first culture of new soil, often originates them. 7. Their local prevalence in the autumn is always checked by a decided frost."

Here we have the facts with regard to the symptoms and cause of the disease stated with a clearness and a conciseness that could hardly be surpassed. But the real cause of the malady eluded the insight of the discriminating observers who collected those facts. A quite different class of facts required consideration. It was essential to concentrate attention on the pathological aspects of the enquiry. As to the nature of the disease, Hartshorne writes, with commendable caution, "It is only possible to speculate at present. It is most probable that ague is a toxemic neurosis. The importance of the blood change attending it is shown by the disintegration of the blood corpuscles, and deposit of pigment in various organs." This destruction of the blood corpuscles was the critical point on which the investigation turned. About 1880, Laveran, a French army surgeon, discovered the destructive agency in a minute parasite, one of the protozoa, which takes up its residence in, and then, ungratefully enough, destroys, our red blood corpuscles. What a splendid problem was presented by the facts thus brought to light! The exquisite refinement of the researches which followed may be inferred when we reflect on the minuteness of an organism which can work out a part of its life history within blood corpuscles so small that four to six millions of them find plenty of room in a cubic millimeter. But stranger still is the fact, established within the past year or two, that the mosquito plays the rôle of an intermediary host and transmits the parasites to us while feasting upon our blood. The details of this remarkable discovery need only be alluded to here, for they have been so recently explained by the experts participating in them that their essential features are a part of popular information. Suffice it to remark that they show how we may secure almost complete immunity from malarial fevers at no distant day.

Thus, in whatever direction we look for the sources of scientific progress, the same elementary methods of advancement are found to be effective. Whether we consider the dimensions of the solar system or the distances between the molecules of a gas; whether we seek the history of a star as revealed by its light or the history of the earth as recorded in its crust; whether we would learn the evolution of man or the development of a protozoon; whether we would study the physical and chemical properties of the sun or the corresponding properties of a grain of sand; in short, whether we turn to the macrocosm or to the microcosm for definite, verifiable, knowledge, it is found to originate in and to advance with observation and experiment.

R. S. WOODWARD.

*ON THE HOMOLOGIES AND PROBABLE ORIGIN OF THE EMBRYO-SAC.**

THE problems connected with the origin and interpretation of the embryo-sac have been of great interest to the student of plant morphology, from the time that they began to inquire into the relation of the ovule to the formation of the embryo plant. It is now a matter only of historical interest that Morland (1702), Geoffrey (1714) and others contended so seriously that the embryo-sac of the angiosperms was a sort of incubator where the embryo, brought in by the pollen tube, was hatched out into the young plantlet. While great advances have been made in our knowledge of the development and function of the embryo-sac, there are still unsettled problems of its origin and homology upon which we speculate, perhaps with no nearer approach to the truth than were the speculations by the founders of the science of plant morphology.

The first important contribution to the morphology of the embryo-sac was made by Hofmeister during the middle of the present (19th) century, extending over a period from 1849 (Die Entstehung des Embryo der Phanerogamen) to 1861 (Neue Beiträge zur Kenntniss der Phanerogamen). In the

* Paper presented before the joint session of Section G, American Association for the Advancement of Science, and the Botanical Society of America, at its sixth annual meeting, New York City, June 28, 1900.