COLLEGE PHYSIOGRAPHY

BY

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EDITOR'S PREFACE

THIS text-book of College Physiography is written for use in elementary physical geography courses in universities, colleges, and normal schools, for supplementary reference-reading by high school students who are using a more elementary text, and for general reading by laymen of mature years.

The plan of the book is to present, in order, (1) the geographical features of the earth as a planet, (2) the processes in operation and the topographic forms in existence on the lands, (3) the physical geography of the ocean, and (4) the nature and effects of the atmosphere. Combined with each of these are illustrations of the relations of physical geography to life and especially to man.

No attempt has been made to cover all topics simply because they are usually included in a course in physical geography. Instead, each topic is discussed where it naturally comes up in the logical development of the subject. It is assumed that a certain elementary knowledge, for example of latitude, longitude, standard time, the seasons, etc., is retained from grammar school geography or high school physiography. They will naturally be reviewed in the laboratory work of a good course in college physiography or, when necessary, can be looked up in a school geography. For schools desiring a shorter list of assignments than is here presented, an abridgment might be accomplished by omitting such matters as the Specific Instances of Volcanic Eruptions (pp. 449–475), Relief Features of the Earth (Chapter XVI), or the Earth's Interior (Chapter XVII). It is desirable that both field and laboratory work accompany the study of the text. For courses in advanced physiography or geomorphology, the study of the maps and the reading of selected papers from the original sources listed at the ends of the chapters is recommended. The photographs and diagrams in the text have been chosen with great care and are as well worth study as the text itself.

The book was written by the late Professor Tarr, chiefly during the winter 1910–11, although there are indications that he began work on it as early as 1895. He had completed the first draft of the manuscript dealing with the earth as a planet, the lands, and the ocean before his death on March 21, 1912. He died suddenly and left no directions as to the disposal of this manuscript. With the approval of Mrs. Tarr and after conference with several of Professor Tarr's more intimate friends among the geographers of the United States, the editor undertook the task of preparing the book for publication. He edited the existing manuscript, added data in connection with new discoveries in physical geography, prepared the illustrations and the bibliographies and map lists at the ends of the chapters, and wrote seven chapters to complete the book. These are the chapters dealing with the atmosphere and with terrestrial magnetism. In writing the original twenty chapters the author had followed the outline of the printed syllabus of his course in elementary physical geography at Cornell University. Accordingly this syllabus has been followed in the new chapters, amplified by as many as possible of the illustrative features which Professor Tarr used in his work of instruction at Cornell. In preparing the bibliographies and map lists, use was made of such materials as were left by Professor Tarr, some of them partly drawn up on catalogue cards for use in this book and some published in earlier books, together with some from the editor's own materials used in instruction at the University of Wisconsin. In all respects he sought to carry out the plan and style of presentation which he thought Professor Tarr would have followed in completing the book. In addition to five years of study and teaching at Cornell University the editor had the privilege of intimate association with Professor Tarr in four summers of field work in Alaska and in New York. He also assisted the author in clerical work while he was preparing three of his text-books and collaborated with him in writing two scientific books and a number of technical and popular articles. With this experience in mind constantly, the editor has striven to complete the book along the lines which the author would have followed, although with obvious imperfections in execution.

As a matter of professional acknowledgment the editor does not feel that he can do better than to quote the author's own words, from the preface of Tarr's New Physical Geography, written eleven years ago. "It goes without saying that the author is profoundly indebted to the host of workers in physiography, from whom he has drawn so much inspiration, suggestion, and fact: Gilbert, Davis, Powell, Geikie, Penck, de Lapparent, Russell, Shaler, Dutton, Chamberlin, Hayes, Campbell, Salisbury, Brigham, Dodge, Dryer, and many others. From the writings of these physiographers the author has culled whatever seemed to him suited to a scheme of elementary instruction; and so numerous, and often so unconscious, is the influence of these fellow-workers, that specific acknowledgment would be quite impossible. Doubtless the most profound influence upon the author is that of his two teachers, Professors Shaler and Davis, the importance of which to him cannot be overestimated. Together with other physiographers, the author further recognizes in Professor Davis a leader in American physiography, from whom even some of the fundamental principles of the subject have been derived. An examination of the following pages would show the influence of this physiographer in many places, an influence not confined to the pure science, but extending to the pedagogy of the subject as well."

The illustrations, many of which are new, are taken from photographs by the author, or pictures taken under his direction by J. O. Martin of Wilbraham, Mass., by O. D. von Engeln of Ithaca, N.Y., by the editor of this volume, and others. A number were purchased for use in this and earlier books by the author, the collections of certain American physiographers, and of the United States Geological Survey, the department of geology at Cornell University, W. H. Rau of Philadelphia, F. J. Haynes of St. Paul, S. R. Stoddard of Glens Falls, N.Y., and the Detroit Photographic Company supplying a great many. The photographer's name, where known, appears in the legends of the illustrations. Most of the foreign photographs were purchased in Europe by the author. Many of the photographs by the author and the editor were taken under the auspices of the National Geographic Society of Washington, the American Geographical Society of New York, and the United States Geological Survey. Most of the models are by the late E. E. Howell of Washington. A large proportion of the block diagrams were drawn by C. W. Furlong of Boston. Mr. E. F. Bean of the University of Wisconsin helped materially in preparing the illustrations.

Acknowledgment is particularly due to Professor R. de C. Ward of Harvard University, who was good enough to read the manuscript of the six chapters dealing with the atmosphere, and to Dr. L. A. Bauer of the Carnegie Institution of Washington, who kindly read the manuscript of the chapter on terrestrial magnetism. Each of these gentlemen made valuable criticisms and suggestions, but the editor takes full responsibility for any shortcomings in these chapters.

The editor feels keenly the responsibility which he is incurring by preparing this book for the press, for the author's reputation is so high that nothing should be done that could possibly mar it. Professor Tarr prepared only the first draft of twenty out of the twenty-seven chapters. His experience in twenty years of college teaching, his facility in writing, and especially in writing three successful high school physiographies, a laboratory manual of physical geography, an elementary geology, an economic geology of the United States, a series of grammar school geographies, a regional geography of his own state, three scientific books on physiography, glaciers, and earthquakes in Alaska, and scores of technical and popular articles, based upon his investigations in various parts of North America and Europe, all qualified him to produce a book of the first quality. Had he lived to complete it, there would surely be an improvement along many lines; but, as it is, the book must stand upon its merits.

LAWRENCE MARTIN.

MADISON, WISCONSIN,
July 13, 1914.

ACKNOWLEDGMENT OF ILLUSTRATIONS

In addition to the credit for illustrations given in the Preface and in the legends of the half tones and text figures, acknowledgment is due the following authors and publishers for kindly permitting the use of illustrative material and, in several cases, for supplying electrotypes. The numbers below refer to figures in this book.

Bowman's *Forest Physiography*, John Wiley & Sons, New York, — Figs. 28, 183, 290, 351, 358, 362, 367, 378, 468.

Davis's *Elementary Meteorology*, Ginn & Co., Boston, — Figs. 429, 500.

Davis's *Erklärende Beschreibung der Landformen*, B. G. Teubner, Leipzig, — Fig. 150.

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Hobbs's *Earth Features and their Meaning*, Macmillan Co., New York, — Figs. 36, 54, 59, 73, 139, 162, 164, 165, 166, 173, 181, 184, 190, 196, 221, 237, 255, 257, 261, 278, 279, 280, 283, 289, 296, 322, 336, 384, 433.

The editor of this volume, — (Photographs), Figs. 1, 122, 128, 136, 138, 151, 153, 175, 176, 202, 203, 231, 360, 363, 376; (Maps and Diagrams), Figs. 123, 126, 143, 154, 155, 156, 159, 195, 227, 272, 276, 286, 364, 377.

Milham's *Meteorology*, Macmillan Co., New York, — Figs. 424, 457, 465, 470, 477, 495, 498.

Moulton's *Introduction to Astronomy*, Macmillan Co., New York, — Figs. 7, 8, 389.

Murray and Hjort's *Depths of the Ocean*, Macmillan & Co., London, Fig. 398.

Murray's *The Ocean*, Henry Holt & Co., New York, — Figs. 390, 391, 395, 408, 413.

Scott's *Introduction to Geology*, Macmillan Co., New York, — Figs. 17, 211, 277, 292, 304.

Todd's *New Astronomy*, American Book Co., New York, — Fig. 11.

Ward's *Practical Exercises in Elementary Meteorology*, Ginn & Co., Boston, — Figs. 460, 502.

Ward's *Climate, Considered Especially in Relation to Man*, G. P. Putnam's Sons, New York, — Figs. 431, 435, 447, 483, 484, 492, 503.

Wyoming Historical and Geological Society; also Connecticut Geological and Natural History Survey, diagrams by J. Barrell, — Figs. 345, 346.

INTRODUCTION

THE EARTH SCIENCES

The earth consists of three quite distinct portions, a solid central mass, a partial envelope of liquid, and a complete blanket of gases, each of which is the seat of a series of interesting phenomena. Their investigation has attracted the thoughtful attention of many scientific men, both in the past and at present. The study of the gaseous portion, or atmosphere, has led to the development of *Meteorology*, and one phase of this study has been recognized as the science of *Climatology*. The science of the study of the waters is called *Hydrography*, and of that larger part of the liquid envelope which occupies the ocean basins, *Oceanography*.

Several distinct sciences deal with the study of the solid earth itself. For example, *Mineralogy* concerns itself with the minerals of which this solid earth is composed; and *Petrology* with the study of the rocks of the earth; while the study of certain special phenomena has given rise to special sciences with limited scope, such as *Seismology*, which is concerned with a study of earthquakes, and *Vulcanology*, with volcanic phenomena. But the two chief sciences dealing with the solid earth are *Geology* and *Geography*, and each of these is concerned also, to a certain extent, with the waters and the air. These are, therefore, of broader scope than either of the other sciences, since they involve, to a degree, a consideration of the earth as a whole, not a single phase of it.

Geology deals with the past history of the earth and its development through the ages. Geography, on the other hand, is concerned with the present condition of the earth in its relation to life. One of the divisions of geography is called *Physical Geography*, or, sometimes, *Physiography*, which may be defined as *that science which investigates the physical features of the earth and their influence on life, especially man.* It is a fundamental part of geography, and basal to any scientific study of that subject. To some, it seems difficult of separation from geology, and in certain of its aspects it might indeed be considered the latest chapter in geology, — the history of the present surface of the earth, or *Geomorphology*. But it is broader than this, for it deals not merely with the latest chapter in the history of the earth, but also with the influence of the surface features on human and other life, and the interaction and interrelation between air, water, land, and life.

Physical geography is an integral part of geography, and not to be separated from it, having independent subrank under the larger whole, side by side with *Political Geography*, *Anthropogeography*, etc., and having for its special field the more physical aspects of geography, as its name indicates. Dealing as it does with air, land, and water, physical geography of necessity draws from meteorology, geology, and oceanography for some of its facts and methods, and even for some of its field of investigation. Did it not do so, it could be little more than a descriptive science, telling merely what the earth's surface is, and leaving to other sciences the statement of how it came to be. In the study of the land in particular, it is necessary to borrow from geology, for no interpretation of the present surface features is possible without a knowledge of at least some of the past events by which they have come to be.

The Principle of Vast Lapse of Time

One of the most fundamentally important contributions to an understanding of the history of the earth is the proof which geologists have presented of the vast lapse of time during which this earth history has been in progress. It is equally fundamental to an understanding and interpretation of the surface features of the earth with which physical geography has to do. So long as it was thought that the age of the earth was to be numbered in a few thousand years, no real progress was possible, either in unravelling its history or in interpreting the earth forms by which man is surrounded. It has now been demonstrated, by a series of proofs that are incontrovertible, that the age of the earth is to be reckoned in millions of years, and that even those slowly operating processes with which we are surrounded, and which, in a human life-time, may not cause visible change, are capable of performing vast tasks and of bringing about great changes, when in incessant operation through not merely hundreds of years, but tens of thousands and hundreds of thousands of years.

The acceptance of this principle, which during the last century required long and heated argument to establish, and the patient accumulation of a great mass of observations before it was finally and universally accepted even by scientific men, is fundamental to an appreciation of the phenomena of the surface of the earth. It is as basal a principle in geology and physical geography as a broad conception of the distances in space is basal to astronomy. In both cases the full appreciation of the conception is denied the human mind, for in his experience man deals only with inches, feet, and miles, and with seconds, minutes, and years. It is, therefore, quite beyond our power to fully realize the true significance of the $92\frac{3}{4}$ million miles which separate the sun and earth, or the scores of millions of years which separate us from the early ages of geological time. Yet the one is as truly a fact as the other, and neither the principles of astronomy nor of physical geography can be really appreciated without accepting as a basal principle the measure of the space or the time which lies far beyond our limited range of experience. The principle is so well established that it may fairly be stated as such without a preliminary attempt at proof, leaving the verification to appear as the subject is developed.

Development of Physical Geography

The development of science, in general, up to its present standard was primarily the work of the last century, though it was preceded by a series of brilliant discoveries, notably of basal principles in astronomy and physics. The study of the earth, partly descriptive, had occupied the attention of many workers in the preceding centuries; and naturally the phenomena of the earth upon which man lived, and by which he was surrounded, led to some investigation and to still more speculation, often most fantastic. Thus earthquakes, volcanoes, fossils in the rocks, and other phenomena early attracted attention and were subjects of investigation and speculation; and naturally the question of the origin of the earth itself was a source of interest and wonder which led to speculation, as is proved by the cosmologies of the ancients, and the even more vague speculations of more primitive peoples.

Although much thought had been given to the subject, and much had been written upon it and some important facts and principles had been put forward by the beginning of the last century, there had been little real progress in the development of any phase of earth science up to the beginning of the nineteenth century. This lack of progress was in part due to the general unorganized state of science. This affected all sciences to almost equal extent. It was even further due to the prevalence of the fundamental fallacy that the cosmology presented in the first chapter of *Genesis* was to be taken literally, and was to serve as the basal principle in an interpretation of earth history. It required more than ordinary evidence to overcome this fallacy, for it was given the stamp of infallibility by theological dogma. Any facts that seemed to controvert the Jewish cosmology must needs be thrown out; and any argument based upon such facts was regarded as an attack upon the very foundation of religious belief. There arose, therefore, a conflict between science and religion, or, as White better phrases it, a "Warfare of Science with Theology." This conflict just alluded to led to bitter controversy, increasing in extent and intensity in the first half of the nineteenth century, and not completely extinguished even in the second half, though now, happily, almost completely at an end.

There were also bitter controversies among geologists, of which one of the most serious was between the school of *Werner*, a German, and *Hutton*, a Scotchman. The former held that the earth had developed its present form with rapidity through a succession of catastrophic phenomena in which water was the prime agent, and the Wernerian School became known as the *Neptunists*. Hutton held that the present earth form was the result of slower evolution in which both water and heat were involved, and his school became known as the School of the *Vulcanists*. In its main elements, the theory of Hutton has prevailed; and to it we may look for some of the basal principles of the physical geography of the lands. Playfair's "Illustrations of the Huttonian Theory of the Earth," published in 1802, is the real beginning of the modern physical geography, for it postulates the idea of vast lapse of time in which "we can see neither the beginning nor the end," the importance of the forces at present in operation, when operating through long periods of time, the true origin of river valleys, and other basal principles of physical geography.

For a generation, so bitter was the controversy, and so opposed was the Huttonian theory to the supposed demands of true religion, that the brilliant assemblage of facts and logical deductions from them put forward by Hutton, Playfair, and others, failed of acceptance and apparently left little or no impression upon the science of the time. The Huttonian theory was revived, elaborated, and amplified in 1830 in Lyell's "Principles of Geology." He fostered it with all the vigour of his brilliant mind. Primarily by Lyell's work, aided by the researches of a number of other students of earth science, the Huttonian principle became established, and the doctrine of *Uniformitarianism*, as opposed to that of *Catastrophism* presented. With some modification in detail it is basal to the study of the development of the surface forms of the earth. This doctrine holds that by the processes of the present, working through the lapse of time, the present features of the earth have been evolved; and that catastrophes, though probably occurring, are not essential to the underlying causes.

In the further development of physical geography a multitude of workers have taken part in bringing it to its present standard. This is not the place to attempt to trace the development of the subject in detail, nor to list the names and contributions of the principal workers. The names of three Americans, — Gilbert, Powell, and Davis, — however, stand out with such special prominence in the history of the development of modern physical geography that they call for mention even in this generalized view. In two reports, written at about the same time, 1875, — Gilbert's chapter on Land Sculpture in "The Geology of the Henry Mountains" and Powell's "Exploration of the Colorado River of the West," — there are stated for the first time some of the underlying principles of land sculpture, upon which the scientific study of the surface of the earth is based. Professor Davis has added still other principles, has outlined and developed the idea of the progressive stage in the development of land forms, and has given to physical geography an organization which has won many followers, including the writer of this book, who was fortunate enough to be one of his early pupils, and at the same time to come under the inspiring influence of that great teacher and geographer, Professor N. S. Shaler. Some of Professor Davis's papers have been collected in a single volume entitled "Geographical Essays," 1909; see also Davis's "Physical Geography," 1898; "Practical Exercises in Physical Geography," 1908; "Grundzüge der Physiogeographie," 1911; "Erklärende Beschreibung der Landformen," 1912.

In a study of the air and of the oceans, as well as of the lands, many men have been at work, and the development of the sciences of the air, ocean, and land is dependent upon the combined effort of them all, though with some more potent than others in the discovery, verification, and exposition of underlying principles. Modern physical geography has developed out of the work of this army of students, specific reference to some of whose contributions will appear in the succeeding chapters of this book.

References to Literature

The literature of physical geography is extensive. Among the writings upon the subject are elementary school textbooks, special articles upon particular processes or areas, books upon special topics such as rivers, earthquakes, etc., books and articles relating specifically to the atmosphere and the oceans, and books of a general nature. Reference to all but the first of these classes of publications will be found in later pages, but there are a number of publications of such a general nature that they are listed below, mainly of books and magazines, relating specifically to the Physical Geography of the Lands, deferring reference to the atmosphere and oceans to those sections dealing specifically with these topics. The list also includes a few books on human geography. This subject is discussed incidentally throughout the book along the line of the splendid contributions by Friedrich Ratzel, Elisée Réclus, J. Brunhes, and others in Europe, and Miss E. C. Semple, A. P. Brigham, and others in America. It is not claimed that the following list is complete, nor that it has included all that are of importance and value.

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CONTENTS

PART I. THE PLANET AND THE LANDS

CHAPTER I

FUNDAMENTAL GENERAL FACTS

THE EARTH AS A PLANET

The Solar System. — The earth is one of a vast number of spheres in space, about most of which relatively little is known. A small group of these spheres, revolving about a central body, the star which we know as the sun, are better known, and together constitute the *solar system*. Omitting (*a*) occasional visitors to the solar system, or comets, (*b*) the small spheres or asteroids, (*c*) the still smaller meteorites, and (*d*) the rings of Saturn, there remain three quite distinct classes of bodies as constituent parts of the solar system: (1) the central sun, (2) the planets, (3) the satellites.

Similarities of Members of the Solar System. — Among the spheres that revolve about the sun, and especially the eight moderate-sized spheres called *planets*, there is a striking uniformity in some important respects. First and foremost, each has a spherical form. This is familiar in the case of the earth from the proofs in connection with (*a*) the circumnavigation of the globe, (*b*) the method of disappearance of ships upon the sea, and (*c*) the curved shadow of the earth during an eclipse of the moon (Fig. 2), as was well known to some of the ancients. Each planet is distorted by protuberance in the equatorial region into the form of an oblate spheroid.

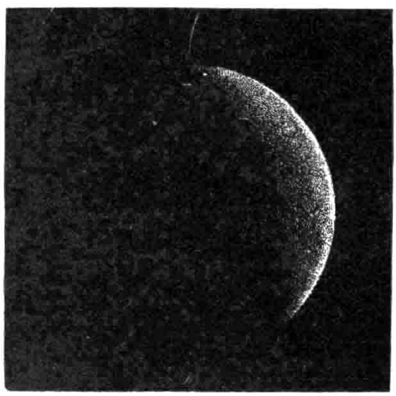

FIG. 2. — Proof of the roundness of the earth from curved shadow during eclipse of moon. (Photograph by Harvard College Observatory.)

Secondly, all are *rotating* about an axis inclined to the plane through which they are *revolving* about the central body; but the inclination of the axis and the rate of rotation vary from sphere to sphere. In the third place, they are all engaged in a revolution about the central body, the sun, following an elliptical path, or *orbit;* while the satellites, in addition, are revolving about the planet to which they are attached. A fourth resemblance is that they all receive their light and heat from the central sun, though in amounts varying with the distance. Finally, it is probable, though not certainly proved, that all these spheres are composed of essentially the same materials.

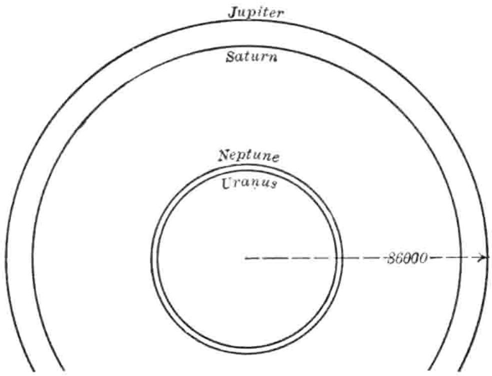

FIG. 3. — Relative sizes of the four larger planets.

Contrasts within the Solar System. — While there are these resemblances, there are also notable differences. The spheres differ greatly in size (Figs. 3, 4), ranging from the sun, with a diameter of 860,000 miles (Fig. 9), to the earth, with about $\frac{1}{100}$ this diameter, and the satellites with diameters of but two or three thousand miles, and to the still smaller asteroids. They differ also in their distance from the sun, and consequently in the length of the orbit through which they circle about it, as well as in the time required to complete the revolution (Fig. 5). Thus Mercury, the planet nearest the sun (Fig. 6), being approximately 36,000,000 miles distant, requires about 88 days for its journey about the sun; the earth, 92,750,000 miles distant, requires a little over 365 days, determining the length of our *year;* and Neptune, the most distant planet, 2,775,000,000 miles from the sun, requires about 165 years for its revolution.

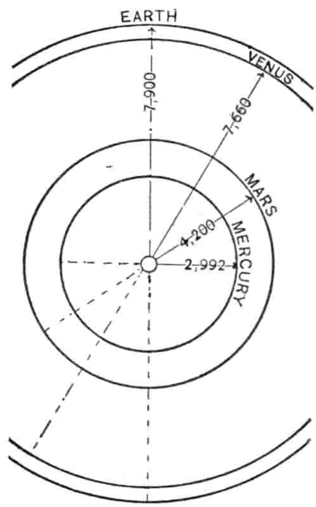

FIG. 4. — Sizes of the four smaller planets, given in diameters in miles.

A third noteworthy difference among the members of the solar system is the different periods of rotation, the earth turning on its axis in about 24 hours, and, therefore, determining the length of a *day*, while the sun rotates in 25 days, the moon in $27\frac{1}{3}$ days, and Jupiter in 9 hours and 55 minutes. That the earth does rotate from west to east upon its axis was long ago demonstrated by Galileo. In investigating the behaviour of objects falling through the air, he discovered that they always fell a little to the east of a point directly below that from which they were dropped (Fig. 7). At the Leaning Tower of Pisa, for example, the rotation of the earth causes an object at the top of the tower to move faster than one at its base, as Galileo correctly reasoned.

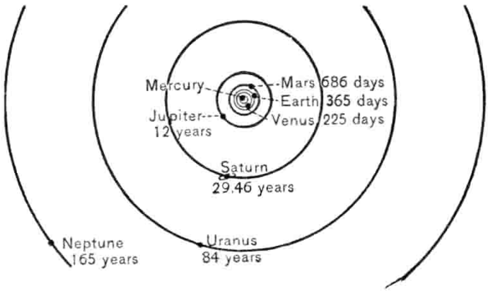

FIG. 5. — Diagram showing the time required for each planet to revolve around the sun.

The proof of the earth's rotation by *Foucault's pendulum* (Fig. 8) was first carried out in 1851 and is repeated every year in the physics or the geography departments of many

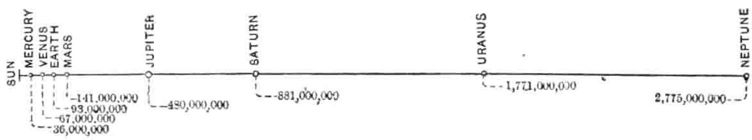

FIG. 6. — Diagram showing the distance from the sun to the various planets in miles.

colleges. Foucault's method was to suspend a heavy weight from the dome of the Pantheon in Paris, and set it to swinging. A pendulum will continue to swing indefinitely in exactly the same plane. After being set in motion it *appears* to cease to vibrate parallel to a mark on the floor, gradually comes to a position of swinging at right angles to the mark, and, in 24 hours or a little more, depending on the part of the earth, it seems to shift until it once more swings parallel to the mark. This is because the building turns around the pendulum as the earth rotates.

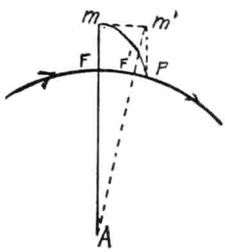

FIG. 7. — To show the deviation of falling bodies. (After Moulton.) An object dropped from the tower *MF* reaching the earth at *P* rather than at *F'*.

Still another contrast within the solar system is the condition of the spheres. On some, like the earth and Mars, there is an atmosphere, while on others, like the moon, there is no gaseous envelope. There seems also to be a gradation in temperature from the highly heated sun to the completely cold moon, with intermediate stages, such as Jupiter, which is evidently highly heated, though not glowing, and the earth, which, though cold at the surface, is apparently heated within.