proves no more than the Difference of Time does in an (the) other.

Edwards, about to become president of the College of New Jersey, and at this date writing as a missionary to the Indians; "Pastor of the Church in Stockbridge," has in the same chapter, these Princetonian thoughts on evolution suggested by Sir Isaac Newton's "Laws of Motion & Gravitation."

> Let us suppose two Bodies moving the same Way, in strait Lines, perfectly parallel one to another; but to be diverted from this Parallel Course, and drawn one from another, as much as might be by the Attraction of an Atom, at the Distance of one of the furthest of the fix'd Stars from the Earth; these Bodies being turned out of the Lines of their parallel Motion, will, by Degrees, get further and further distant, one from the other; and tho' the Distance may be imperceptible for a long Time, yet at Length it may become very great. So the Revolution of a Planet round the Sun being retarded or accelerated, and the Orbit of it's Revolution made greater or less, and more or less elliptical, and so it's Periodical Time longer or shorter, no more than may be by the Influence of the least Atom, might in Length of Time perform a whole Revolution sooner or later than otherwise it would have done; which might make a vast Alteration with Regard to Millions of important Events. So the Influence of the least Particle may, for ought we know, have such Effect on something in the Constitution of some human Body, as to cause another Thought to arise in the Mind at a certain Time, than otherwise would have been; which in Length of Time (yea, and that not very great) might occasion a vast Alteration thro' the whole World of Mankind.

Thus the describer of the Ballooning Spiders. Einstein, Conklin; Behold your King!

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SCIENTIFIC BOOKS

Heredity and Evolution in Plants. By C. Stuart Gager. Philadelphia, 1920. P. Blakiston's Son and Co. Pp. xiii + 265. Figs. 113.

This very readable book is in part a reprint of certain sections of the author's "Fundamentals of Botany" but with considerable new matter added and much of the old recast. An account of the life history of the fern lays the foundation for a discussion of cell structure and the fundamentals of cell behavior in reproduction and at the critical periods of fertilization and reduction. Then comes a chapter on heredity followed by a consideration of results from experimental studies of Mendel, Johannsen, and others.

Chapters entitled "Evolution," "Darwinism" and "Experimental Evolution" give the views of Lamarck, Darwin, Wallace and de Vries. The statement of the mutation theory of de Vries is excellent but there is nothing to indicate to the reader how difficult it is to distinguish between mutations and the results of segregation in impure species the breeding behavior of which is complicated by the presence of lethal factors. There is no reference to the remarkable genetical complications which are known for *Œnothera* material rendering it among the most interesting and puzzling under investigation although correspondingly less favorable for the demonstration of mutations.

The latter half of the book considers the evolutionary history of the plant kingdom from evidence supplied by comparative morphology and life histories, geographical distribution, and paleobotany. In this section is brought together much scattered information which together with the discussion is likely to prove of particular interest to the general reader not familiar with geographical botany and with the striking contributions of recent years from studies of ancient plant remains.

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NOTES ON CLIMATOLOGY AND METEOROLOGY

AEROLOGICAL WORK IN THE UNITED STATES

Meteorology, until recent years, has been largely a two-dimensional science. Indeed, so strongly has the conception become rooted in the minds of meteorologists, that now, when the data from soundings of the upper air are becoming available in fairly large quantity, it is necessary to engage in a careful study to determine the most profitable and intelligent way to use them. In recent years, aerological work has been steadily advancing to its place in the forefront of meteorological endeavor, and to-day most national meteorological services have established, or are establishing, aerological divisions. In other words, it is realized that probably the real controls of surface weather lie somewhere in the upper air.

The first aerological work in the United States was done at Blue Hill Observatory, near Boston, under the directorship of Rotch. In 1907, the United States Weather Bureau established a station at Mt. Weather, Virginia. That station, which has a record of frequent kite flights and aerial soundings by captive balloons, was discontinued after seven years. Other stations have been established, however, at Drexel, Nebraska; Ellendale, North Dakota; Broken Arrow, Oklahoma; Groesbeck, Texas; Royal Center, Indiana; and Leesburg, Georgia. The data from the many thousands of kite flights made at these stations have been and are being published in the *Supplements* of the *Monthly Weather Review*. These data include temperatures, pressures, moisture content, wind speed and direction, at various levels in the free-air. It should be said, however, that one of the inherent features of kite data is that they represent conditions in moderate winds only, since kites can not be flown in very light or very strong winds.

A convenient summary of the work of the Drexel Aerological Station was recently published in the *Monthly Weather Review*.[1] The purpose of the summary, says Mr. Gregg, is "to present in brief and convenient form for the information and use of artillery and aviation services the results of free-air observations that have been secured by means of kites at Drexel, Nebraska." There are many tables and charts. The values obtained are the means of 1,074 kite flights. The author, in his synopsis, says:

> A discussion of the reliability of the data indicates that instrumental and observational errors have been largely eliminated; that the monthly distribution is good; that the diurnal distribution is less satisfactory, but probably fairly representative, at any rate for all levels a short distance above the surface; but that, owing to the shortness of the period under consideration and its wide departures at times from normal conditions, some of the monthly means can not be considered as normal values. These irregularities largely disappear, however, in the seasonal and annual averages; and the latter, especially, may be accepted as closely approximating true conditions.

Now that a number of years' data have accumulated, what are the benefits which may accrue from a study of them? Among others, there are two problems, which may be considered: one is of immediate importance, the other is an old one, long recognized, but attacked only at rare intervals, and with varying success. The first concerns itself with forecasting for aviation, the second with the reduction of pressure in the Plateau region of western United States. They represent only two of the many problems, the solution of which aerological data may aid.

A paper on the question of making pressure maps for stated levels in the free-air as aids in forecasting winds aloft for the use of aviation and as a suggested panacea for the long-recognized reduction difficulties in western United States, has just appeared.[2] The central idea about which the work is built is that the Laplacian hypsometric formula requires a value to be substituted for the term representing the mean temperature of the air column which exactly satisfies its definition. Reductions to sea-level obviously can not do

[1] Gregg, Willis Ray, "Average free-air conditions as observed by means of kites at Drexel Aerological Station, Nebr., during the period November, 1915 to December, 1918, inclusive," *Monthly Weather Review*, January, 1920, pp. 1–11. Reprints may be obtained upon application to the Chief of the Weather Bureau, Washington, D. C.

[2] Meisinger, C. LeRoy, "Preliminary Steps in the Making of Free-air Pressure and Wind Charts," *Monthly Weather Review*, May, 1920, pp. 251–263.

this because sea-level lies, in practically all cases, below the station level, hence *there is no air column.* The temperature argument at present employed in reducing to sea-level is the mean of the current surface temperature and the temperature as recorded at the observation twelve hours before, and this *happens* to do very well except in those regions where the so-called air column is quite long. The obvious solution of this difficulty is the measurement of the mean temperature of a *real* air-column above the station.

The work referred to above embraces over 3,000 kite flights made at Mt. Weather, Drexel, and Ellendale. The mean temperature between the surface and the levels of 1 and 2 kilometers above sea-level have been classified by surface wind directions and by months. These temperatures are not used as they stand, but, to render them comparable, they are each subtracted from the surface temperature, thus giving a series of values showing the difference between the mean temperature of the air column and the surface temperature. After doing this for the three stations it was found that they all show certain characteristics. For example, to quote from the synopsis of the paper:

> It was found, in general, that in winter, with southerly winds, the air column has a higher mean temperature than the surface; that in summer, with northerly winds, the air column has a temperature below that of the surface. These effects are due, primarily, to the seasonal variation of surface temperature. The amplitude of the values was much greater at the inland stations, Ellendale and Drexel, than at Mount Weather, near the coast. Aside from the geographical contrasts, the difference between the surface temperature and that of the air column to a height of 1 or 2 kilometers depends, so far as the surface factor is concerned, mostly on the season; and, so far as the temperatures aloft are involved, upon the wind direction.

A statistical study of the data reveals the fact that pressure can be reduced from the station to levels one or two kilometers above sea-level with a very satisfactory degree of accuracy. Indeed, in reducing through an air-column 2,000 meters in length, it is found that the probable error of the temperature determination is so small that, when translated into terms of pressure at the upper level, it amounts to only ± 1.3 mb. For the 1 kilometer level it is only $\pm 0{:}5$ mb.[3]

When this study is carried further, as is contemplated, all kite stations will be discussed and an endeavor will be made to work the scheme out with such simplicity that the observer can know the mean temperature of the air column from the direction of the surface wind, substitute this in his reduction formula and obtain the pressure at the upper level.

The advantages of such charts must be proved by experience. But it is obvious that if they can be constructed accurately, they must yield a far better basis for forecasting winds aloft than do the present sea-level maps —for it is in the very nature of the gradient, or geostrophic, wind to obey the pressure distribution *at its level.* The gradients on the sea-level map can not be of great assistance, even to the height of 500 meters above sea-level. If such charts are thus productive of greater accuracy in forecasting winds in the upper air, their existence is quite justified; and if, in the Plateau of western United States, we can free our weather maps of the barometric apparitions which haunt them at present, it is possible that these charts of the upper air may be of direct value in general forecasting.

The third paper to be mentioned is a short note by Mr. Gregg[4] on the program of aerological work instituted by the Weather Bureau for the hurricane season. It is believed that there is a relation between the velocity of motion of tropical hurricanes and the winds aloft. To collect data, pilot balloon stations have been placed at San Juan, P. R., and Key West, Fla. These, cooperating with the regular permanent pilot balloon stations in

[3] 1,000 millibars is equivalent to a pressure indicated by 750.1 millimeters, or 29.53 inches, of mercury.

[4] Gregg, W. R., "Aerological Observations in the West Indies," *Monthly Weather Review*, May, 1920, p. 264.

the Gulf States and the two Navy stations at Colon and Santo Domingo, will form a "network which, it is believed, will furnish information of great value in the study of these destructive storms and in forecasting their direction and rate of movement." Whether or not hurricanes occur, observations will be made twice daily and the data on trades, antitrades, etc., will well repay the effort, for very little is known of the winds aloft in those regions. If funds permit, this program will be extended during the next several years.

Not only is it essential that means be provided for the extension of pilot balloon work in the West Indies, but also in the United States proper. At present there are about two dozen stations sending daily reports of free-air wind conditions to the forecast centers of the Weather Bureau. This information forms the basis of forecasts that are issued for the information of aviators in the Aerial Mail Service and the Army and Navy Air Services. At least fifty, and preferably a hundred, additional stations are needed. It would be possible, with such a net-work, to construct upper-air wind charts from which accurate and detailed forecasts could be made. It is to be hoped that Congress will see the importance of providing this additional equipment, for its installation would find a direct and immediate reflection in the increased safety of aviation, and in the increased efficiency of our aerial services.

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SPECIAL ARTICLES

NOTE ON EINSTEIN'S THEORY OF GRAVITATION AND LIGHT

This paper contains a statement of some apparently unnoticed results dealing with light rays and orbits in Einstein's general theory of gravitation. The full proofs will be published in the mathematical journals.

We recall briefly that Einstein, in his general relativity theory, introduces ten potential functions g_{ik} (in contrast with the single function appearing in the Newtonian theory); these are the coefficients in the fundamental quadratic form

$$ds^2 = \Sigma g_{ik} dx_i dx_k,$$

which defines the four-dimensional space-time world $(x_1 x_2 x_3 x_4)$. When there is no actual gravitation the manifold can be written in the euclidean form $dx_1^2 + dx_2^2 + dx_3^2 + dx_4^2$, or $dx^2 + dy^2 + dz^2 - dt^2$ in the usual coordinates. The path of a free particle is then straight, and so is the path of a light pulse.

In the general gravitational case, the ten potentials obey (in space not occupied by matter) a certain set of ten differential equations of the second order $R_{ik} = 0$, where the left-hand members are the components of what is known in the literature as "the contracted Riemann-Christoffel curvature tensor" (Why not call it simply the Einstein tensor?). A free particle then describes a geodesic, or path of minimum length s. Light rays are found by adjoining the condition that ds vanishes. When the quadratic form is put equal to zero, the result will be described as the *light equation.*

I. Our first result is that if an Einstein manifold has straight geodesics it is necessarily euclidean. This means that if, in an unknown field with vanishing Einstein tensor, coordinates can be introduced such that the paths of all particles are expressible by linear equations, then the field is free from gravitation. It is to be noted that curved four-dimensional manifolds with linear geodesics exist: but our result shows that they do not obey Einstein's equations.

II. An analogous result holds for light rays. If in an unknown Einstein field four coordinates can be introduced so that the light equation takes the usual form $dx^2 + dy^2 + dz^2 - dt^2 = 0$, then there is no gravitation (that is, the manifold is euclidean). This requires proof since an arbitrary function may be introduced as factor in the first member without changing the light equation, although this in general changes the field and the geodesics.

III. We pass now to general manifolds where the paths can not be regarded as