come equal to the electrostatic repulsion until the charges move with the velocity of light. This used to seem very puzzling to me, for I reasoned as follows: Imagine a positively charged hopper filled with steel balls, which continually dropped into two parallel inclined glass troughs. As the motion of the charged balls is constantly accelerated, the electromagnetic attraction which they exert on the charged balls in the other trough grows larger and larger until the velocity is that of light, when the streams of balls in the two troughs are exerting zero force on each other (for their electrostatic repulsion is then exactly balanced by their electromagnetic attraction), and yet they are said to be behaving like electric currents. Why, then, do parallel currents actually attract each other? No one supposes that a current in a wire travels *faster* than light. Some years ago in Cambridge I asked Professor (now Sir) J. J. Thomson about it, and he replied that my analogy was all right, except that according to the electron theory the glass troughs should have a metal covering outside, which is *positively* charged, the hopper should be *negatively* charged, and the positive charge on a unit's length of a trough should equal the sum of the negative charges on the balls contained in that length. Then the analogy, while crude, would be complete: the steel balls would represent electrons, and the current in the ordinary sense would flow *up* the trough instead of down. The charge on the metal covering of the trough would represent the charges on the positive atoms in a conductor. Under these circumstances it is easy to see that attraction between the troughs would ensue as soon as the balls began to move. Professor Nipher's explanation, therefore, would seem to be valid only on the supposition that the positive ions in the line of the disruptive discharge (which are dashing towards the negative terminal) would take the place of the metal-covered trough in my analogy, thus rendering the electromagnetic attraction of the moving electrons effective in drawing them together in a column which continually thins out towards the positive terminal. If this be true, the effect ought to be rendered more intense because of this consideration: the analogy would then be that of the trough itself (carrying a positive charge) *moving in the opposite direction to the motion of the steel balls,* thus making the relative velocity of the balls greater and the attraction more intense.

But there is another way of looking at it which may be more natural. The negative terminal is a large sphere 10 cm. in diameter, while the positive terminal is but 1 cm. in diameter. The lines of force are therefore strongly convergent from the negative to the positive sphere, somewhat like the ropes from the gas bag of a balloon to the much smaller basket beneath, and electrons sliding down these lines (along their negative direction, of course) would naturally arrange themselves in a column larger at the negative end, especially as these lines are themselves falling towards the center line of the discharge. In this case would not the phenomenon simply show the pinch effect in gaseous discharge?

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December 7, 1908

MR. MANSON'S THEORY OF GEOLOGICAL CLIMATES

MR. MANSON'S theory of geological climates has been commended latterly in the columns of SCIENCE and elsewhere, and it may be desirable to point out why it is unsatisfactory.

The theory as set forth in Mr. Manson's communication to the Tenth International Geological Congress, in Mexico, in 1906,[1] is briefly as follows: During Paleozoic time the climate of the earth was practically uniform from equator to poles, and torrid temperatures were everywhere maintained by heat derived from the earth and warm oceans; the heat was prevented from radiating into space and being lost by a blanket of clouds surrounding the whole earth. Recognizing that the heat brought to the earth's surface by conduction is not enough to keep up a high atmospheric temperature, Mr. Manson thinks that much heat was made available by the erosion of the land and by hot springs, volcanic eruptions, etc. Let us calculate how much heat can be

[1] *Proceedings*, Vol. I., pp. 349–405.

obtained by this means, and in making this calculation we give every possible advantage to the theory. Let us assume with Dr. Becker[2] that at the time of consolidation the surface of the earth was at a temperature of 1300° C., and increased at a uniform rate at least to a depth of 0.02 of the radius or 126 kilometers, and that up to the present time no appreciable change of temperature has taken place beyond that depth. Let us further assume that the surface has been reduced to 0° and that the present temperature gradient is a straight line from the surface to a depth of 126 kilometers. The average loss of temperature within this shell is 1300/2 or 650°, and if we take the specific heat per cu. cm. as 0.5 calories, the total heat which has been lost per sq. cm. of surface is $12,600,000 \times 650 \times 0.5 = 4.1 \times 10^9$ calories. This is a very liberal allowance.

Assuming an ocean 5 kilometers deep covering the whole earth, whose original temperature was 40° C. and which has cooled to 0°, the total heat given out per sq. cm. of surface would be (specific heat per cu. cm. = 1), $500,000 \times 40 = 2 \times 10^7$ calories. This is only one half of 1 per cent. of the heat furnished by the land and may therefore be neglected.

The heat at present being received from the sun equals 2 calories per sq. cm. per minute, measured at right angles to the sun's rays.[3] As this falls on the section of the earth it must be divided by 4 to give the average amount on the earth's surface. Let us suppose, further, that three fifths of the remainder is lost by reflection and other causes and does not heat the earth's surface. This leaves 0.2 calorie for the average amount received by 1 sq. cm. of the earth's surface per minute; and in one year the total amount received would be $0.2 \times 60 \times 24 \times 365 = 10^5$ calories, and as the earth has a practically stationary temperature it is losing this much heat per year by radiation into space. At this rate all the heat lost from the earth since consolidation could only keep up the present average temperature for a number of years equal to $4.1 \times 10^9/10^5 = 41,000$ years; but if on account of the cloud-blanket only 10 per cent. as much heat is necessary to maintain the temperature it would last 410,000 years; if only 1 per cent. were needed, it would last 4,100,000 years, a period much shorter than pre-Mesozoic time.

But what would establish and maintain a blanket of clouds around the earth, and especially over great inland regions like the centers of Africa and Asia? The only places where clouds are now prevalent are places in high latitudes where moisture is continually precipitated from the winds which blow pretty steadily from warm seas; but even with our present atmospheric circulation the interior of the great continents are rather dry. With the uniform temperature which Mr. Manson predicates in Paleozoic time there would be no winds, and the sun would soon break up the cloud-covering over the interior of the continents, as there would be no steady supply of moisture. Moreover, an atmosphere heated at the bottom is in unstable equilibrium, and convection currents would be set up which would carry the moist air to high altitudes and result in heavy downpours of rain and a clearing of the atmosphere; for the available heat would be entirely inadequate to supply moisture to form clouds as fast as it would be precipitated as rain. The existence of clouds would have no influence on the convection currents. Mr. Manson mentions these currents, but does not attach any great importance to them.

It is to be noted that geologists who have given attention to the earlier glacial periods do not consider that they were due merely to small glaciers at high altitudes, but that they represented real, even if not very extensive, changes in climate. Moreover, Professor J. W. Gregory firmly maintains that throughout g ological times we have had a zonal distribution of temperature very similar to that of the present day.[4] It is therefore, quite possible that the continued uniform climate which Mr. Manson's theory was developed to explain, did not really exist.

Professor Schaeberle[5] approves Mr. Manson's theory and states that "The inherent

[2] Science, February 7, 1908.

[3] Science, April 24, 1908, p. 663.

[4] "Climatic Variations," *Proc. Tenth Intern. Geol. Cong. Mexico*, 1906, Vol. I., pp. 407–26.

[5] Science, March 6, 1908, p. 392.

heat of the earth still plays an important if not controlling part in all terrestrial phenomena. . . ." This idea is based on an earlier communication[6] whose conclusions are invalidated by his erroneous definition of temperature and by his erroneous assumption that a body placed in a stream of radiant energy has its temperature raised by an amount proportional to the quantity of radiant energy falling upon it in a unit of time.

It can readily be shown that the heat received by conduction from the earth is insignificant in comparison with that received from the sun, as was long ago done by Lord Kelvin. The quantity of heat reaching the earth's surface per minute through each sq. cm. equals the conductivity of the rock multiplied by the temperature gradient multiplied by 60 seconds. If we take the conductivity of rock at 0.005 and the temperature gradient at 0.00032° C. per cm. (which corresponds to 1° C. per 31 m. or 1° F. per 50 feet) we find 9.6×10^{-5} for the quantity of heat conducted to the surface per sq. cm. each minute, and since we can take the quantity received from the sun for the same area in the same time as 0.2 calorie, we see that the earth's surface receives from the sun at least 2,000 times as much heat as from its interior. The latter, therefore, could not have a material effect on the surface temperature or on atmospheric phenomena.

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[6] SCIENCE, December 20, 1908, p. 877.

ON MISLEADING STATEMENTS

SINCE misleading statements occur in the publications of certain writers concerning my participation in, and experimental contributions to the subject of blood-vessel anastomosis and transplantations, in justice to myself and in the interest of investigators in general, it is incumbent upon me to perform the disagreeable task of making a statement once for all, that the facts may be made readily accessible. The task will be made easier if I am permitted to quote rather freely.

Carrel in a paper appearing in the *Journal of the American Medical Association,* November 14, 1908, LI., p. 1664, says:

> The transplantation of devitalized arteries has been attempted by Levin and Larkin in New York, but in almost every case thrombosis occurred. However, after the transplantation of a segment of aorta fixed in formalin into the aorta of a dog, excellent circulation was observed. Histologic examination ten days after the transplantation showed that the wall was composed of amorphous tissue in which the elastic framework was seen to be very well preserved. In another case of Levin and Larkin, twenty days after the operation, the wall of the vessel was completely amorphous and surrounded by dense connective tissue. *A similar experiment has been performed in St. Louis by Guthrie,* who obtained an excellent functional result, but no histologic examination of the vessel has yet been published.

Levin and Larkin, in *Proceedings of the Society for Experimental Biology and Medicine,* 1907–8, V., p. 110, say:

> On January 23, 1908, we transplanted a segment of aorta from a dog hardened in 4 per cent. formalin into the abdominal aorta of another dog. *Meanwhile Guthrie reported successful implantation of formaldehyde segments into the carotid of the dog.*

The facts regarding the transplantation of formaldehyde-fixed segments are as follows: In the *American Journal of Physiology,* September 2, 1907, XIX., 482–7, in the paper entitled, "Heterotransplantations of Blood Vessels," I stated:

> In this connection it may be mentioned that a segment of aorta from a cat preserved in formaldehyde for about a month, then washed in very dilute ammonia water, partially dehydrated in alcohol and impregnated with vaseline, when similarly transplanted into a dog gave excellent temporary results. On killing the animal with ether and examining the segment, it was found to resemble the artery of the dog in a much greater degree than before being transplanted, being more pliant and having a flesh color, the latter due, no doubt, largely to the presence of blood that got into or between the coats from the outside. The union of the intimas was excellent, and they both had the characteristic glistening appearance. My thanks are due Dr. Bartlett for assistance with this operation. A series of operations are being made with the view of determining the permanent results of similarly prepared and transplanted blood vessels.

My records show that this experiment was performed June 20, 1907. In SCIENCE, N. S.,