evident opportunities for fraud." Quite true — not in many only, but in all; and not only in psychical but in physical experiments of all sorts, which people accept without verifying the results for themselves. But *whose* fraud? We have always been content to rely on the very large class of cases in which the fraud would have had to be *our own*, — fraud in which the investigators actively shared, not merely which they failed to detect. I am far from saying that Dr. Minot or any one else is bound to accept this condition as crucial. But it is surely obvious that he who carries his experiments to the point where they can only be impugned by impugning his good faith, has done — as far as the *quality* of his results is concerned — all that any experimenter in any branch of science ever can do. Nothing remains, after this, but to try to increase the *quantity* of the results, whereby the responsibility for them may be spread over other shoulders.

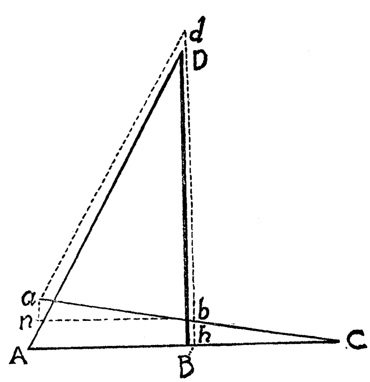
EDMUND GURNEY.

London, Feb. 17.

On tiptoe.

About two years ago Mr. F. A. Pond requested me to work out for him the problem of the human foot regarded as a lever. He thought the essential feature of the case — namely, the attachment of the calf-muscle to the leg below the knee, as well as to the heel, by a tendon — had been ignored.

The question has been of interest to a number of people; and it may be well to bring the true state of the case before writers on anatomy and physiology, inasmuch as it appears to be generally stated that the foot is a lever of the second order when used in rising 'on tiptoe.'



It will do to assume the change of position so small that the foot may be treated as a straight lever. Let $A\ B\ C$ be the foot-lever: A, the point of attachment of tendon to heel; B, the ankle pivot; and C, the point where the foot rests upon the ground. At B erect a perpendicular, BD, to represent the leg-bones, the calf-muscle being attached at D. Now let the muscle contract, and raise B to b. The work done is equal to the weight of the body (supposing one foot used) multiplied by the perpendicular distance through which B is raised, that is, bh of the figure. The power exerted by the muscle is equal to its pull multiplied by the diminution of the distance AD. As B rises to b, let A rise to a, and D to d. Through b draw bn parallel to AC, and drop an. Now, bC is to bh as ba is to an. The line an is very approximately the amount of shortening of the muscle. The sign of the 'mechanical advantage' will be positive, zero, or negative, according as AB is greater than, equal to, or less than, BC. A lever of the 'second order' implies advantage of positive sign; that is, so-called 'mechanical advantage.' A lever of the 'third order' implies mechanical disadvantage. A lever of the 'first order' is capable of affording mechanical advantage or mechanical disadvantage, as the ratio of the arms determines: hence, when one rises on tiptoe, the foot is a lever of the first order.

An attempt has been made to regard the case as of the second order, by calling the upward pull at A, y, and the pressure of the body at B, x. The pull y will be transferred as a downward thrust of y to B; so that we have (if, for instance, $AB = BC$) an upward force of y at A, and a downward force of $x + y$, equal to $2y$, at B. But the traverse of y is not twice the traverse of $2y$. Thus the 'principle of work' limits the case to the 'first order.'

F. C. VAN DYCK.

New Brunswick, N.J., Feb. 28.

Increase of the electrical potential of the atmosphere with elevation.

Very many observations of the electrical potential of the atmosphere have been made at different places in this country during the past year, under the auspices of the U.S. signal office. Among others, at Washington, D.C., a series of simultaneous observations has been carried on at the instrument room of the signal office and at the top of the Washington monument, the highest known edifice. The object of the present paper, published by permission of the chief signal officer, Gen. A. W. Greely, is to present in brief some of the results of those observations, particularly those bearing on the value of the intensity of the electrical force of the atmosphere at an elevation of five hundred feet, and the variations of the potential under different conditions of weather.

Beccaria, De Romas, Henley, and Cavallo, all noticed that the more elevated the position of the collecting apparatus, the greater the degree of electrification. Schübler (*Schweigg. journ.* ix. 348) was the first to make measurements of the difference, and found that a positive electrification increased, at least up to a height of 50.5 metres. His results with an electroscope were as follows: —

Height (metres)..........	9.7	16.2	24.4	47.1	49.4	55.6	58.5
Deflection (degrees)......	15	20	26	50	53	58	64

Sir William Thomson, it is sometimes stated, found an increase of from 200 to 300 volts for three metres. This value, however, was one obtained with a portable electrometer on a flat open sea-beach on the island of Arran, the height of the match being nine feet above the earth. The readings varied from 200 to 400 volts, so that "the intensity of electric force, perpendicular to the earth's surface, must have amounted to from 22 to 44 Daniell elements per foot of air" (Thomson, reprint of papers, xvi. 281). It is also intimated that on other dates this value might have been twice as large, or yet much smaller. Mascart and Joubert found that if two water-collectors were placed in the same vertical line, the one five, the other ten metres high, the indications were in the main alike, and in the ratio of 1 to 2. Some experiments made by me in May, 1886, confirm this general statement, although the actual values would vary greatly from day to day. Thus, with two collectors, on one date I obtained as mean values, for 80 feet elevation, 150 volts; for 55 feet elevation, 40 volts; while on another date the values for the same elevations were respectively 300 volts and 100 volts.

Professor Exner (*Repertorium der Physik*, xxii. heft 8, 451) gives the results of some experiments of a similar nature made about the same time, which show the potential gradient to be of uncertain value, and influenced largely by the proximity of buildings and walls. The following values for the potential were obtained with a water-dropper in an enclosed court: —

Two metres from wall	Height (metres).....	0	5	10	15	20
	Potential (volts).....	0	2	7	17	48
In centre of court.....	Height (metres).....	0	5	10	15	20
	Potential (volts).....	0	5	11	32	68

From measurements made with small balloons filled with hydrogen gas, Exner obtained, for the potential in free air, these values: —

Height (met.)	17	18	20	21	22	24	25	27	30	34	40	48
Poten. (volts)	100	110	{120, 140}	130	160	160	160	170	{195, 210}	250	280	350

from which

$$F = \frac{d\,V}{d\,n} = 6.8\,\frac{\text{volt}}{\text{metre}}.$$

These values were obtained with a burning match. According to Pellat (*Comptes rendus*, c. 1885), the collecting efficiency of the match, compared with water-dropper and flame, is in the ratio of 1 to 5 to 10; so that, for comparison with the observations made here, where a water-dropping collector is employed, we have as a value for the electric force, during calm fine weather,

$$F = 34\,\frac{\text{volt}}{\text{metre}}.$$

Another set of observations, made on an exposed mountain-side, gave these results: —

Height (metres)	3	5	6	7	12	14	18	19	20	25	30
Potential (volts)	110	{140, 150}	210	{230, 250}	{380, 405}	480	{520, 550}	550	660	820	970

or there is a linear potential gradient, but with a higher value than in the preceding experiments. Supposing a water-dropper to have been employed instead of flame as the collecting agency, we have the value

$$\frac{d\,V}{d\,n} = 159\,\frac{\text{volt}}{\text{metre}}.$$

It is evident, then, that this value of the electrical force of the atmosphere is uncertain, and determined largely by local surroundings. It is also further affected by the conditions of temperature and relative humidity, and, as intimated, by inconstancy of the collecting agency. In working toward that 'electrogeodesy' which Sir William Thomson has proposed, we must determine and allow for these and doubtless other influences. By taking the mean of many observations made at different times, the influences of temperature and humidity are to some extent avoided. As said above, the following observations were made simultaneously, in 1886–87, at the top of the monument, 500 feet above the ground, and at the signal office, at an elevation of 50 feet. The instruments used were modified Mascart electrometers, and large water-droppers with nozzles of the same size. Similar methods and adjunct apparatus were employed at both places. The values in the following table appear to be too small, judging from the results quoted above. But it is to be remembered that these observations are made in both cases from buildings, and the points in air at which the collecting stream breaks away are not very distant from the side of the building.

Values of electric force of the atmosphere.

Date.	Number of observations.	Mean value of potential.		Difference for 450 feet.
		Monument.	Signal office.	
		Volts.	*Volts.*	*Volts.*
June 26	399 consecutive 5-minute observations	289	134	155
" 27				
" 28				
July 17	60	1129	93	1036
" 20	107	389	70	319
Sept. 21	40	212	107	105
Oct. 4	94	586	192	394
" 5	82	300	108	192
" 7	97	435	112	323
" 14	87	140	24 (*a*)	116 (*a*)
Nov. 1	4 (*b*)	1137	265	872
" 3	98	943	248	695
" 12	15	—849 (*c*)	—245 (*c*)	—604 (*c*)
" 12	65	458	36	422
Dec. 15	13	487	4 (*d*)	483 (*d*)
Jan. 29	26	413	141	272
Feb. 9	54	1825	89	1736

(*a*) On this date some of the values at the lower station were below the zero, i.e., negative: 69 observations gave positive indications, averaging 38 volts, and 18 observations gave negative values, averaging 31 volts. The negative values have been subtracted from the positive, and the remainder divided by the total number of observations.
(*b*) Not simultaneous.
(*c*) At both stations during rain the observations continued for some little while negative.
(*d*) As in (*a*).

We have, therefore, from the above table, a mean value of the potential for the top of the monument of 637 volts, and a value of

$$\frac{d\,V}{d\,n} = 4.33\,\frac{\text{volt}}{\text{metre}};$$

and at the lower station a mean value of the potential of 124 volts and a value of

$$\frac{d\,V}{d\,n} = 8.43\,\frac{\text{volt}}{\text{metre}}.$$

Therefore it would seem that the mean value of the potential at the upper station is about five times that at the lower station. Among the observations, I find one striking confirmation of this ratio. On Nov. 3, 1886, if we multiply the results obtained at the lower station by 5, we shall obtain approximately a duplicate of those at the upper elevation; this for a series extending from 11 A.M. until 3 P.M. In some respects this date was most satisfactory, being a dry, somewhat hazy, autumn day, with light southerly winds, and sky about half covered with ill-defined cirro-stratus clouds. The electrification at the top of the monument was sufficient to give a spark a millimetre in length.

These experiments were begun under the direction of Prof. T. C. Mendenhall, to whom, and to Col. T. L. Casey, of the Engineer corps, U.S.A., more than acknowledgment of kindness is due.

ALEXANDER MCADIE, M.A.