interest if it had been written by an unknown personage. But in its permanent form the relatively trivial press errors and slips of the pen should be corrected and all extraneous matter not connected with natural history, cut out.

The illustrations—drawings as well as photographs—are admirable. Mr. Roosevelt deserves praise for having carefully photographed the small mammals as well as the big.

Special triumphs of the expedition were the shooting by Mr. Theodore Roosevelt of the rare Somali retioulated giraffe, and by Mr. Kermit Roosevelt, of the East African sable antelope. In regard to this achievement, the writer of this review has enjoyed some satisfaction. In describing his own journey to Kilimanjaro in 1884, he stated that he had seen the sable antelope on the way thither. This statement was somewhat rudely derided by a succeeding traveller, who declared that the sable antelope was never found north of the region opposite Zanzibar Island.

H. H. JOHNSTON.

ATMOSPHERIC ELECTRICITY AND RAIN.

THE fact that raindrops often bring down a measurable charge of electricity has been known for twenty years, but numerical measurements have been comparatively few, and data of even moderate trustworthiness are scarce. A recent memoir of the Indian Meteorological Department[1] contains an account of the important work done on this subject in 1908 and 1909 by Dr. G. C. Simpson. This work is partly observational, partly experimental, and partly theoretical. To see its true bearing, reference is necessary to some other aspects of atmospheric electricity.

If we denote by v the electric potential at a height z above the ground, and if dv/dz represents the rate of increase of v with height just above ground level, then treating the conductivity of the air as negligible the earth must have a charge the surface density σ of which is $-(dv/dz)/4\pi$. In ordinary fine weather v increases as we go upwards, and so σ is negative. In practice one usually derives dv/dz from the difference of potential between two points in the same vertical one metre apart. This quantity, termed the *potential gradient,* varies much from day to day, or even hour to hour, and the average value seems to vary considerably at different parts of the earth. If, for example, we suppose it to be 150 volts, then remembering that the centimetre is the unit of length, and that the electrostatic unit equals 300 volts, we deduce $\sigma=-(1/4\pi)(1\cdot5/300)=-4\cdot0\times10^{-4}$ E.U. (or electrostatic units).

Atmospheric air is in reality not a perfect nonconductor. If one gives a body in air on a perfectly insulating support a charge, whether positive or negative, this is gradually lost. Of the numerous observations on the rate of loss of charge those made by Mr. C. T. R. Wilson, with an apparatus which he devised a few years ago, appear least open to criticism. In a paper published in 1908, Wilson[2] gives the result of a considerable number of observations on the loss of negative electricity under fine weather conditions. His mean rate of loss exceeded 8 per cent. of the charge per minute of time. In other words, a charge equal to the earth's charge at any instant was lost every twelve minutes. During these observations the mean value of the potential gradient was 187. This answers to a surface density of $-10^{-4}\times4\cdot97$ E.U., or $-16\cdot6\times10^{-14}$ coulombs. Taking an 8 per cent. loss per minute, the loss per second—*i.e.* the value of an upwardly directed negative, or downwardly directed positive current—is $(8/60)10^{-2}\times16\cdot6\times10^{-14}$ or $2\cdot2\times10^{-16}$ in amperes. If this represented average conditions, we should have in the course of a year from each sq. cm. of the earth's surface a loss of 7×10^{-9} coulombs, or 21 E.U. of negative electricity. During rain the potential gradient is often negative, but the total duration of negative gradient in the course of a year is not large. We are thus led to the conclusion that whilst 21 E.U. is probably an overestimate of the charge lost annually per sq. cm. of surface by conduction through the air, it is unlikely to be much in excess of the truth unless the conductivity of the air is exceptionally high at times when the gradient is negative. The question thus arises: How is the earth's charge maintained?

Of the hypotheses advanced of late years, the one that has met with most approval is due to C. T. R. Wilson, who suggested that while districts enjoying fine weather are losing negative charge, other districts are deriving a corresponding amount of negative electricity from falling rain, the circuit being completed below by earth currents, and overhead by horizontal currents at a considerable height. Our knowledge of earth currents at the present moment does not enable us either to affirm or to deny a systematic transfer of electricity between wet and dry areas.

When Wilson's suggestion was made, it was believed that while the electricity brought down by rain was sometimes positive, still negative largely predominated, that being the result arrived at by Elster and Geitel, who were the chief of the early observers. Dr. Simpson's first contribution to the subject was the invention of an ingenious apparatus giving a continuous record of the amount and sign of rainfall electricity. This apparatus has been in operation at Simla during the monsoon or rainy seasons of 1908 and 1909, and the results are of an unexpected character. What the apparatus really does is to collect and record rainfall electricity for two-minute intervals. The data represent the total charges received for each successive interval and the corresponding rainfall. During the two monsoons 172·1 cm. of rain were recorded, with 44·0 E.U. of positive and 13·8 E.U. of negative electricity, or a balance of 30·2 E.U. of *positive*. The two-minute intervals during which a positive charge was measured amounted in all to 4·16 days, as against 1·70 days of negative. During about 37 per cent. of the total duration of rainfall no sensible charge was measured. Snow is rare at Simla, but for such snow as fell there was much the same relative excess of positive electricity as in the case of rain, the chief difference being that snow brought down more electricity than an equal weight of rain. An annual rainfall of 86 cm. is normal enough, and if the corresponding balance, 15 E.U., of electricity had been negative, it would have fitted Wilson's theory well so far; but being positive, it adds to the mystery respecting the source of supply of the fine weather current.

There are some features which raise doubts as to whether Simla phenomena are fairly representative. Rain there seems to be accompanied by much thunder and lightning, and the excess of positive electricity was especially prominent during the very heavy rain accompanying thunderstorms. In 1908, when rain was falling at a less rate than 0·17 inch per hour, the time during which negative electricity was recorded was about 90 per cent. of that during which positive was recorded, and the mean charge per c.c. was 2·2 E.U. for negative, as against 1·7 E.U. for positive, so that in the lightest

[1] Vol. xx., part 8, "On the Electricity of Rain and its Origin in Thunderstorms." By Dr. George C. Simpson, Imperial Meteorologist (also in Trans. and Proc. R.S.).

[2] Roy. Soc. Proc., A, vol. lxxx., p. 537.

rains negative electricity was slightly in excess. The charge per c.c. tended to be larger the lighter the rain, but the fall in two minutes was so small in light rains that it seems by no means improbable that with a more sensitive apparatus there would have been a smaller total excess of positive electricity recorded. Observations covering the complete annual precipitation, whether rain or snow, at a number of stations in different latitudes will be necessary before we can safely draw conclusions respecting the earth as a whole.

It was discovered by Lenard many years ago that in the case of an ordinary waterfall, or when water falls on a solid obstacle, the water drops formed take a positive, the surrounding air a negative charge. Lenard believed, however, that no such separation occurred when drops split up without falling on an obstacle. Simpson found a similar absence of charge when experimenting with Simla tap-water, but on trying distilled water he found that the splitting up of drops by means of a vertical air jet is accompanied by a marked separation of electricity, the water taking the positive charge. The breaking up of drops, each containing about 1/4 c.c. of water, gave the water a charge of about $+23 \times 10^{-3}$ E.U. per c.c. If the drops were already charged, this additional charge was added when they broke, so that the action is cumulative. Raindrops become unstable on attaining a certain size, and tend to break, so that natural conditions approach those of Simpson's experiments. A rational explanation is thus given of a positive charge on rain if it behaves as distilled water. This we should expect it to do, except perhaps in smoky districts, but further experiments on actual rain-water in various localities seem desirable. The presence on some rain of negative electricity is ascribed by Simpson to a transfer of charge from air which has previously surrounded breaking raindrops.

The theoretical problem mainly considered by Simpson is the relation of rain to thunderstorms. He believes that there are normally present in thunderstorm areas upward currents of air with velocities of at least 8 metres per second (18 m.p.h.). Such currents prevent raindrops from falling, and Simpson supposes the drops to go through frequent repetitions of the cycle; growth, breaking up (with separation of electricity), fresh growth, and so on, at a nearly constant height in the atmosphere until the charge is so great as to produce at a certain level a gradient larger than 30,000 volts per cm., which he takes to be the electric strength of air. When this limit is reached, a lightning flash neutralises the accumulated charge over a limited area, and the process goes on repeating itself. There are various difficulties in the way of accepting this explanation as complete, but some represent our present ignorance rather than positive knowledge. We should like to know, for instance, whether vertical air currents such as Simpson postulates really do exist near the precise level where the air breaks down, also what the true nature of a lightning flash is, whether unidirectional or oscillatory, what charge passes, and what is the expenditure of energy. For all we know, the air may be in a strongly ionised condition, possibly even there may be separation of the constituent gases, and a potential gradient much under 30,000 volts per cm. may suffice to cause a discharge. In the meantime, Simpson's theory of thunderstorms had better be regarded as a hypothesis, but, unlike some hypotheses, it promises to be useful in suggesting promising lines for observation and experiment. The separation of electricity by the breaking up of raindrops may not play quite so fundamental a part as Simpson supposes, but assuming it to take place with natural rain, it can hardly fail to play an important part in thunderstorm phenomena.

The memoir as a whole is most original and suggestive, and is one on which the meteorological service of India deserves to be congratulated. As many readers of NATURE are doubtless aware, Dr. Simpson's services have been lent by the Indian Government to the present British Antarctic Expedition, principally with the view of his studying electrical conditions in high latitudes, and we may, I think, entertain high hopes that the resulting increase of knowledge will be eminently satisfactory both to India and to this country.

C. CHREE.

THE PREVENTION OF PLAGUE.

A MEMORANDUM on plague has recently been prepared by Dr. Newsholme, medical officer of the Local Government Board, and has been sent to the sanitary authorities of England and Wales, with a request that their officers should endeavour to secure the adoption of the suggestions contained therein. The memorandum gives an interesting conspectus of the essential features of the disease, and deals mainly with its methods of spread and the measures which, in the light of recent researches, must be taken for its prevention. Fortunately, plague, although a disease capable of manifesting itself as an epidemic of a widespread and virulent character, is now so well understood on its epidemiological side, that the direction which preventive measures should take is obvious. The situation may be summarised in the dictum—"no rats, no plague." Practically, however, the matter is perhaps not so simple as it may seem.

The first section of the memorandum describes briefly the symptoms in plague. The injected eyes and the thick, "drunken" speech are noted as characteristic signs of the disease. There is no mention, however, of the tendency to "shouting" delirium and the impulse to get out of bed and wander off, utterly heedless of their condition—well-known symptoms in the natives of India. The "acute" ward of a plague hospital is at times a very noisy place, and mild restraint requires to be put upon patients to prevent their unconscious excursions.

The "ambulant" form of plague is referred to, and it is stated that persons with this type of the disease may spread the infection. Spread of infection by such persons would seem, however, to be very doubtful, by direct personal contagion at least, and it is equally doubtful whether effective carriers of the disease in the sense of typhoid carriers exist. The evidence for the existence of such carriers is not satisfactory, and although the possibility of the occurrence of "pneumonic" carriers must be considered, the rarity of this type, at least in India, and its extreme fatality, considerably limit its importance from this point of view.

The statement that there is little or no liability to infection from contaminated food is a comforting one, and is justified by the accurate observations on the pathology of human plague made some years ago in Bombay by the Austrian Plague Commission, and by the results of experiments on susceptible animals.

The memorandum accepts in its entirety the results of the recent investigations of the Plague Research Commission, viz., that the sole infective agents in an epidemic of bubonic plague to be reckoned with are the infected rat and the infected rat flea—the former an indirect agent and the latter the immediate infecting agent. It follows that the measures suggested for attempting to stamp out the disease are directed solely towards the destruction of rats and their parasites. It has indeed been claimed that domestic