its first cost." The correctness of the principle has been established by Sir William Thomson and others.[1]

In the three-wire system, Edison reduces the current to one-half its value in the two-wire system, and increases the total resistance of the same number of lamps to four times the former value, by the arrangement shown in the second diagram of the article referred to. The total heat-energy developed in the lamps, then, remains the same, since it is represented by C^2r, where r is the combined resistance of the lamps in multiple arc. The inference is, that the resistance of the leading wires should also be increased fourfold. In the articles referred to at the bottom of the page; it is shown that the cross-section of the conductor should vary simply as the current strength. Hence the conductors in Edison's three-wire system should be diminished only one-half in size for greatest economy of working. That this is entirely correct will appear from an examination of the energy expended in heating the leading wires in the several cases. In the two-wire system

$$C = \frac{E}{R + r}, \qquad (1)$$

in which R and r are the resistance of conductors and lamps respectively. In the three-wire system as arranged by Edison

$$\tfrac{1}{2}C = \frac{2E}{4R + 4r}. \qquad (2)$$

In the three-wire system, with conductors half size,

$$\tfrac{1}{2}C = \frac{2E'}{2R + 4r}, \qquad (3)$$

in which E' equals the electromotive force of each of the two dynamos in series. This electromotive force can be lower than in cases one and two. From (1), $E = CR + Cr$, and $EC = C^2R + C^2r$, for total electrical energy expended; the first term being the heat-waste in the conductors, and the second the energy expended in the lamps.

From (2), $E = CR + Cr$, as before. The total energy is $\frac{1}{2}C \cdot 2E = CE$, the same as before. From (3), $E' = \frac{1}{2}CR + Cr$, and the total electrical energy is $\frac{1}{2}C \cdot 2E' = CE' = \frac{1}{2}C^2R + C^2r$. The energy expended upon the lamps is the same in the three cases, being represented by C^2r; but in the third case the heat-waste is $\frac{1}{2}C^2R$, or only one-half as much as in the other cases. In Edison's arrangement the ratio between energy expended in the lamps, and heat-waste in the mains, is the same in his three-wire system as in the two-wire system. If the conductors be reduced to only half their former cross-section, the ratio of heat expended in conductors to heat developed in lamps is only half as great as before. Edison saves 62.5 % of the cost of conductors, or 62.5 % of the interest on their cost, the running-expenses remaining the same. With half-size conductors, the saving would be 25 % in interest on cost of conductors, and 50 % in heat-waste on conductors, or a total of 75 %, — a gain of 12.5 % over the plan adopted by Edison. Moreover, the electromotive force of each machine being lower, the dynamos could be reduced in size, and their cost would be less. In reducing the conductors three-fourths in cross-section, the rise of temperature for the same quantity of heat developed in them is four times as great as in the two-wire system, since their capacity for heat is reduced to one-fourth. In the case of conductors reduced one-half in size, the rise of temperature would be the same as with the two-wire plan, since the energy expended in heating them is one-half, and their thermal capacity is also one-half. We have supposed, in the calculated economy, that the three wires are all of the same size. Their combined cross-section would then be $\frac{3}{2} \cdot \frac{1}{2} = \frac{3}{4}$ of the combined cross-section of the two wires in the first plan. The saving in interest on conductors would then be 25 %. Edison sacrifices running-expenses in order to diminish the size of his conductors beyond what is clearly the most economical arrangement. We take it for granted that the principle of making loss by heat-waste in conductors equal to interest on their first cost was taken into account in calculating the size of conductors in the two-wire plan.

H. S. CARHART.

Evanston, Ill., Dec. 1.

[1] *Nature*, vol. xxiv. p. 489; *American engineer*, Nov. 7, 1884.

CAN GHOSTS BE INVESTIGATED?

IN the last number of *Science*, Mr. Gurney, honorary secretary of the Society for psychical research, replies to my paper in *Science* of Oct. 17, 1884. To one whose experience has been that scientific discussion is often nugatory because the parties sedulously refuse to understand each other, it is a great pleasure to read Mr. Gurney's paper. The reader who compares it with my own, will, I think, have a fair view of the two sides of the question from the special point of view which we have heretofore taken. I therefore ask permission to consider the subject from a somewhat different standpoint.

When one adduces evidence in favor of telepathy between living persons, each having the other in mind, I am prepared to listen in the spirit of one who feels that there may be many things on earth not yet dreamed of in our philosophy. But when an imposing array of evidence is presented, tending to show telepathy between a live man and a dead one, I must frankly confess that I cannot help receiving it in the spirit of the African monarch of whom the following story is told. He had captured a Dutchman who had been trespassing on his territory, and was about to put him to death. The prisoner, however, like the heroine of the 'Arabian nights,' managed to postpone the fatal day from time to time by inventing stories about the wonders of civilization with which to regale the royal mind. When his inventive powers had reached their limit, he felt obliged to fall back upon facts,

and so told the king that the water in the lakes and rivers of his native country annually became so hard that people walked and drove upon it. The king, in a fit of rage, informed the Dutchman that he not only did not believe this story, but now he did not believe any thing he had been telling him, and ordered him to immediate execution. The reader can point the moral.

Let us now inquire whether the ghost side of telepathy can possibly be established by the methods hitherto employed for that purpose. I will start out by trying to answer the question asked Mr. Gurney in the last number, respecting the probable number of respectable credible people in the British Islands who would not be above amusing themselves at the expense of a learned society. Without waiting for his reply, I roughly estimate that the number of respectable credible people alluded to exceeds fifteen million. Knowing what we do of human nature, I conceive that it will not be considered excessive to suppose that one out of every thousand would come into the category in question. This would give fifteen thousand people who would be capable of the pleasantry alluded to. It must be expected that some of them would forward replies to such requests for information as have been circulated in England. How are the reports of such people to be eliminated from the mass? It will be hard to establish even the possibility of detecting the frauds.

It may be asked in reply whether the conclusion thus intimated, if extended to other departments of inquiry, would not lead to a general lack of confidence between man and man, and to an unjustifiable incredulity in regard to human testimony in a very wide field. My reply is, that there are wide fields in which human testimony would be wholly unreliable, but that methods for eliminating the false, and preserving the true, have come into use. These methods are so common and familiar that we forget all about them. Let us suppose that a paleontological society should advertise for human skulls found in the tertiary deposits of a country. Suppose, also, that any ingenious person could in fifteen minutes manufacture a skull which the most diligent investigation of paleontologists could not distinguish from a genuine fossil. Can any one doubt that the society would be deluged with skulls? Could any investigator be made to believe in a single one of them? I trow not. The fact is, that the only security that paleontologists have from being imposed upon by manufactured specimens lies in their power of distinguishing at a glance the true from the false. When, as in a case known to the writer, a man who has spent several months in elaborating a row of fossil bird-tracks brings his production to a museum, and is informed on sight by the professor in charge that this specimen is very interesting, because he recognizes the tracks as those of the domestic turkey, it produces a depressing effect upon all manufactures of this class. When psychic zoography is so far developed that a spurious ghost can be distinguished from a real one with the readiness with which Cuvier is said to have detected a spurious devil, there will be some outlook for establishing the existence of such beings. For this stage the reasonably incredulous will be likely to wait.

I have spoken as though the question were that of intentional deception. In fact, however, it is hardly necessary to suppose any thing of the sort. It is only the fortunate few of mankind who are not subject to lapses of memory, and illusions respecting the time and place at which events have happened, as well as to illusions of the senses. So far is this true, that a prudent person will rarely trust implicitly to a presentation of any complicated statement made by another, unless it is verified by independent evidence. If two persons could see and describe the same psychic phenomenon, the case might be better; but, as it really stands, there is no way of eliminating delusions, deceptions, or mistakes of any kind.

There is, however, a conceivable method by which every thing except intentional deception may be avoided. Let any psychical society issue to the people of a country a request that any person impressed in an unusual manner,

whether in his sleeping or waking hours, with the apparent sight or presence of a person whom he knows, shall immediately, without waiting for further investigation, state that fact on a postal-card, and mail it to the society, being careful to give the name of the person; also that any remarkable connection between this impression and any other circumstance subsequently discovered shall be sent in another communication. It should be distinctly understood that no case will be taken into account unless it is shown that the first card was mailed before the knowledge contained in the second was acquired. A correspondence of this sort might lead to something worthy of inquiry and investigation.

The evidence of haunted houses is entirely different in kind, but I must frankly admit that Mr. Gurney's reply to what I said on the subject in my previous paper does not strike me as satisfactory: indeed, he quite mistakes the point of my illustration, which was intended to show that events are all the time happening which we are unable to explain. The same logic that he uses would, it seems to me, lead to the conclusion that all tricks of the juggler which we could not explain after the most careful examination must be due to some other than known general causes. The general rule which we all unconsciously apply is, that if, upon investigating a class of seemingly unaccountable phenomena, we readily explain one-half, then explain another portion after much investigation, and with yet additional toil and industry succeed in explaining a third, but finally still have an inexplicable residuum, we conclude that this residuum could also be explained if we knew all the circumstances. This is the conclusion which everybody adopts in the affairs of common life; and I see no reason for making an exception to it in the case of that small collection of haunted houses which the committee on the subject has found it impossible to explain.

To sum up, I deem it essential that psychic investigators should find stronger evidence for the improbable than for the impossible.

SIMON NEWCOMB.

SOME IMPLEMENTS OF THE MINNESOTA OJIBWAS.

THE uses of a portion of the implements figured in Abbott's 'Ancient stone implements of eastern North America' are still somewhat open to conjecture. One group, comprising oval, grooved pebbles, has recently been reduced by Dr. Abbott to a classification comprehending mauls, club-heads, bone-breakers, and net-weights respectively (*Science*, iii. 701). These neolithic objects, and a second series closely allied to them, appearing in considerable numbers upon the New-Jersey coast, are attributed by their discoverer to the Indian races inhabiting the country when first colonized by Europeans; that is to say, to the Lenni Lenapé, or Delawares.

Now, the latter tribe, if it may still be called a tribe, is a cognate of our Algonkin-Ojibwas of the north-west. The languages of the two peoples are essentially the same, being dialects of the common Algonkin tongue, like the speech of the Canadian Crees, of the New-England Indians (preserved to us by the Eliot Bible), and of other nations. The Ojibwas, therefore, may not unreasonably be expected to retain, at the present time, vestiges of early race-ideas and race-practices which may, perhaps, serve in some way to illustrate the archeology of dead branches of the parent stock. Hence the writer of this paper thought it not amiss to set on foot inquiries touching the actual use of the two sets of implements instanced among the Ojibwas of Red Lake, northern Minnesota, where, owing to peculiar isolation, tribal peculiarities are believed to have been retained to an exceptional degree.

The members of the second series of implements, indicated above, are described as flat, discoidal pebbles, with side-notches, which in thickness vary little from about half an inch. These Dr. Abbott regards as almost certainly net-weights, considering that there would be no room for doubt upon the subject, were it an ascertained fact that the Delawares of prehistoric time were actually acquainted with the manufacture and management of nets. Now, the Ojibwas are credited by their native historian, Mr. William Warren, with making and using fishing-nets before the appearance of the whites in North America. In describing the Ojibwas seated upon the shores of Lake Superior, at La Pointe and vicinity, prior to the advent of the whites, he says: —

"The waters of the lake also afforded them fish of many kinds, — the trout, siskowit, white-fish, and sturgeon, — which in spawning-time would fill their