THE SIX GATEWAYS OF KNOWLEDGE[1]

I THANK you most warmly for the honour you have done me in electing me to be your president. I value the honour very highly; but when I look at the list of distinguished men who have preceded me in the office, I feel alarmed at the responsibility I have undertaken. A very pleasing duty, however, has been already performed in the interesting and not onerous function we have now gone through. I would gladly speak on the several subjects, for merit in the study of which these prizes have been awarded; but I am afraid that if I were to do so, it would be more for my own gratification than for your pleasure and profit, and I feel that I shall best consult your wishes in passing on at once to the subject of the address which it becomes my duty to give.

The title of the subject upon which I am going to speak this evening might be—if I were asked to give it a title—"The Six Gateways of Knowledge." I feel that the subject I am about to bring before you is closely connected with the studies for which the several prizes have been given. The question I am going to ask you to think of is: What are the means by which the human mind acquires knowledge of external matter?

John Bunyan likens the human soul to a citadel on a hill, self-contained, having no means of communication with the outer world, except by five gates—Eye Gate, Ear Gate, Mouth Gate, Nose Gate, and Feel Gate. Bunyan clearly was in want of a word here. He uses "feel" in the sense of "touch," a designation which to this day is so commonly used that I can scarcely accuse it of being incorrect. At the same time, the more correct and distinct designation undoubtedly is, the sense of touch. The late Dr. George Wilson, first Professor of Technology in the University of Edinburgh, gave, some time before his death, a beautiful little book under the title of "The Five Gateways of Knowledge," in which he quotes John Bunyan in the manner I have indicated to you. But I have said *six* gateways of knowledge, and I must endeavour to justify this saying. I am going to try to prove to you that we have six senses—that if we are to number the senses at all we must make them six.

The only census of the senses, so far as I am aware, that ever made them more than five before was the Irishman's reckoning of seven senses. I presume the Irishman's seventh sense was common sense; and I believe that the large possession of that virtue by my countrymen—I speak as an Irishman—I say the large possession of the seventh sense, which I believe Irishmen have, and the exercise of it, will do more to alleviate the woes of Ireland than even the removal of the melancholy ocean which surrounds its shores. Still I cannot scientifically see how we can make more than six senses. I shall, however, should time permit, return to this question of a seventh sense, and I shall endeavour to throw out suggestions towards answering the question—Is there, or is there not, a magnetic sense? It is possible that there is, but facts and observations so far give us no evidence that there is a magnetic sense.

The six senses that I intend to explain, so far as I can, this evening, are according to the ordinary enumeration, the sense of sight, the sense of hearing, the sense of smell, the sense of taste, and the sense of touch, divided into two departments. A hundred years ago Dr. Thomas Reid, Professor of Moral Philosophy in the University of Glasgow, pointed out that there was a broad distinction between the sense of roughness or of resistance, which was possessed by the hand, and the sense of heat. Reid's idea has not I think been carried out so much as it deserves. We do not, I believe, find in any of the elementary treatises on natural philosophy, or in the physiologists' writings upon the senses, a distinct reckoning of six senses. We have a great deal of explanation about the muscular sense, and the tactile sense; but we have not a clear and broad distinction of the sense of touch into two departments, which seems to me to follow from Dr. Thomas Reid's way of explaining the sense of touch, although he does not himself distinctly formulate the distinction I am now going to explain.

The sense of touch, of which the organ commonly considered is the hand, but which is possessed by the whole sensitive surface of the body, is very distinctly a double quality. If I touch any object, I perceive a complication of sensations. I perceive a certain sense of roughness, but I also perceive a very distinct sensation, which is not of roughness, or of smoothness. There are two sensations here, let us try to analyse them. Let me dip my hand into this bowl of hot water. The moment I touch the water, I perceive a very distinct sensation, a sensation of heat. Is that a sensation of roughness, or of smoothness? No. Again, I dip my hand into this basin of iced water. I perceive a very distinct sensation. Is this a sensation of roughness, or of smoothness? No. Is this comparable with that former sensation of heat? I say yes. Although it is opposite, it is comparable with the sensation of heat. I am not going to say that we have two sensations in this department—a sensation of heat, and a sensation of cold. I shall endeavour to explain that the perceptions of heat and of cold are perceptions of different degrees of one and the same quality, but that that quality is markedly different from the sense of roughness. Well now, what is this sense of roughness? It will take me some time to explain it fully. I shall therefore say in advance that it is a sense of force; and I shall tell you in advance, before I justify completely what I have to say, that the six senses, regarding which I wish to give some explanation, are: the sense of sight, the sense of hearing, the sense of taste, the sense of smell, the sense of heat, and the sense of force. The sense of force is the sixth sense; or the senses of heat and of force are the sense of touch divided into two, to complete the census of six that I am endeavouring to demonstrate.

Now I have hinted at a possible seventh sense—a magnetic sense—and though out of the line I propose to follow, and although time is precious, and does not permit much of digression, I wish just to remove the idea that I am in any way suggesting anything towards that wretched superstition of animal magnetism, and table-turning, and spiritualism, and mesmerism, and clairvoyance, and spirit-wrapping, of which we have heard so much. There is no seventh sense of the mystic kind. Clairvoyance, and the like, are the result of bad observation chiefly, somewhat mixed up, however, with the effects of wilful imposture, acting on an innocent, trusting mind. But if there is not a distinct magnetic sense, I say it is a very great wonder that there is not.

Many present know all about magnetism. A very large number of pupils have gained an immense amount of valuable knowledge in various subjects, from the classes carried on nightly within the walls of the Birmingham and Midland Institute; and I can see from the prizes that have been awarded, and that I have just now had the pleasure of distribuing for excellence and proficiency in this department, that many have learned of magnetism. I had the pleasure of seeing the class-rooms this morning, and I wished I could be in them in the evening to see the studies as carried on in them every evening. Well now, the study of magnetism is the study of a very recondite subject. We all know a little about the mariner's compass, the needle pointing to the north, and so on; but not many of us have gone far into the subject, and not many of us understand all the recent discoveries in electromagnetism. I could wish, had I the apparatus here, and if you would allow me, to show you an experiment in magnetism. If we had before us a powerful magnet, or say the machine that is giving us this beautiful electric light by which the hall is illuminated, it, serving to excite an electromagnet, would be one part of our apparatus; the other part would be a piece of copper. Suppose then we had this apparatus, I would show you a very wonderful discovery made by Faraday and worked out admirably by Foucault, an excellent French experimenter. I have said that one part of this apparatus would be a piece of copper, but silver would answer as well. Probably no other metal than copper or silver—certainly no other one, of all the metals that are well known, and obtainable for ordinary experiments—possesses, and no other metal or substance, whether metallic or not, is known to possess, in anything like the same degree as copper and silver, the quality I am now going to call attention to.

The quality I refer to is "electric conductivity," and the result of that quality in the experiment I am now going to describe is, that a piece of copper or a piece of silver, let fall between the poles of a magnet, will fall down slowly as if it were falling through mud. I take this body and let it fall. Many of you here will be able to calculate what fraction of a second it takes to fall one foot. If I took this piece of copper, placed it just above the space between the poles of a powerful electromagnet and let it go, you would see it fall slowly down before you; it would perhaps take a quarter of a minute to fall a few inches.

This experiment was carried out in a most powerful manner by Lord Lindsay (now Lord Crawford), assisted by Mr. Crom-

[1] An Address at the Midland Institute, Birmingham, October 3, 1883, by Prof. Sir William Thomson, LL.D., F.R.S., president.

well F. Varley. Both of those eminent men desired to investigate the phenomena of mesmerism, which had been called animal magnetism; and they very earnestly set to work to make a real physical experiment. They asked themselves, Is it conceivable that, if a piece of copper can scarcely move through the air between the poles of an electromagnet, a human being or other living creature placed there would experience no effect? Lord Lindsay got an enormous electromagnet made, so large that the head of any person wishing to try the experiment could get well between the poles, in a region of excessively powerful magnetic force. What was the result of the experiment? If I were to say *nothing!* I should do it scant justice. The result was marvellous, and the marvel is that nothing was perceived. Your head, in a space through which a piece of copper falls as if through mud, perceives nothing. I say this is a very great wonder; but I do not admit, I do not feel, that the investigation of the subject is completed. I cannot think that the quality of matter in space which produces such a prodigious effect upon a piece of metal can be absolutely without any—it is certainly not without any—effect whatever on the matter of a living body; and that it can be absolutely without any *perceptible* effect whatever on the matter of a living body placed there seems to me not proved even yet, although nothing has been found. It is so marvellous that there should be no effect at all, that I do believe and feel that the experiment is worth repeating; and that it is worth examining, whether or not an exceedingly powerful magnetic force has any perceptible effect upon a living vegetable or animal body. I spoke then of a seventh sense. I think it just possible that there may be a magnetic sense. I think it possible that an exceeding powerful magnetic effect may produce a sensation that we cannot compare with heat or force or any other sensation.

Another question that often occurs is, "Is there an electric sense?" Has any human being a perception of electricity in the air? Well, somewhat similar proposals for experiment might, perhaps, be made with reference to electricity; but there are certain reasons, that would take too long for me to explain, that prevent me from placing the electric force at all in the same category with magnetic force. There would be a surface action that would annul practically the force in the interior, there would be a definite sensation which we could distinctly trace to the sense of touch. Any one putting his hand, or his face, or his hair, in the neighbourhood of an electric machine perceives a sensation, and on examining it he finds that there is a current of air blowing, and his hair is attracted; and if he puts his hand too near he finds that there are sparks passing between his hand or face and the machine; so that, before we come to any subtle question of a possible sense of electric force, we have distinct mechanical agencies which give rise to senses of temperature and force; but that this mysterious, wonderful, magnetic force, due, as we know, to rotations of the molecules, could be absolutely without effect—without perceptible effect—on animal economy, seems a very wonderful result, and at all events it is a subject deserving careful investigation. I hope no one will think I am favouring the superstition of mesmerism in what I have said.

I intend to explain a little more fully our perceptions in connection with the double sense of touch—the sense of temperature and the sense of force—should time permit before I conclude. But I must first say something of the other senses, because if I speak too much about the senses of force and heat no time will be left for any of the others. Well, now, let us think what it is we perceive in the sense of hearing. Acoustics is one of the studies of the Birmingham and Midland Institute, of which we have heard many times this evening. Acoustics is the science of hearing. And what is hearing? Hearing is perceiving something with the ear. What is it we perceive with the ear? It is something we can also perceive without the ear; something that the greatest master of sound, in the poetic and artistic sense of the word at all events, that ever lived—Beethoven—for a great part of his life could not perceive with his ear at all. He was deaf for a great part of his life, and during that period were composed some of his grandest musical compositions, and without the possibility of his ever hearing them by ear himself; for his hearing by ear was gone from him for ever. But he used to stand with a stick pressed against the piano and touching his teeth, and thus he could hear the sounds that he called forth from the instrument. Hence, besides the Ear Gate of John Bunyan, there is another gate or access for the sense of hearing.

What is it that you perceive ordinarily by the ear—that a healthy person, without the loss of any of his natural organs of sense, perceives with his ear, but which can otherwise be perceived, although not so satisfactorily or completely? It is distinctly a sense of varying pressure. When the barometer rises, the pressure on the ear increases; when the barometer falls, that is an indication that the pressure on the ear is diminishing. Well, if the pressure of air were suddenly to increase and diminish, say in the course of a quarter of a minute—suppose in a quarter of a minute the barometer rose one-tenth of an inch and fell again, would you perceive anything? I doubt it; I do not think you would. If the barometer were to rise two inches, or three inches, or four inches, in the course of half a minute, most people would perceive it. I say this as a result of observation, because people going down in a diving bell have exactly the same sensation as they would experience if from some unknown cause the barometer quickly, in the course of half a minute, were to rise five or six inches—far above the greatest height it ever stands at in the open air. Well, now, we have a sense of barometric pressure, but we have not a continued indication that allows us to perceive the difference between the high and low barometer. People living at great altitudes—up several thousand feet above the level of the sea, where the barometer stands several inches lower than at sea-level—feel very much as they would do at the surface of the sea, so far as any sensation of pressure is concerned. Keen mountain air feels different from air in lower places, partly because it is colder and drier, but also because it is less dense, and you must breathe more of it to get the same quantity of oxygen into your lungs to perform those functions, which the students of the Institute who study animal physiology—and I understand there are a large number—will perfectly understand. The effect of the air in the lungs—the function it performs—depends chiefly on the oxygen taken in. If the air has only three-quarters of the density it has in our ordinary atmosphere here, then one and one-third times as much must be inhaled, to produce the same oxidising effect on the blood, and the same general effect in the animal economy; and in that way undoubtedly mountain air has a very different effect on living creatures from the air of the plains. This effect is distinctly perceptible in its relation to health.

But I am wandering from my subject, which is the consideration of the changes of pressure comparable with those that produce sound. A diving bell allows us to perceive a sudden increase of pressure, but not by the ordinary sense of touch. The hand does not perceive the difference between 15 lbs. per square inch pressing it all around, and 17 lbs., or 18 lbs., or 20 lbs., or even 30 lbs. per square inch, as is experienced when you go down in a diving bell. If you go down five and a half fathoms in a diving bell, your hand is pressed all round with a force of 30 lbs. to the square inch; but yet you do not perceive any difference in the sense of force, any perception of pressure. What you do perceive is this: behind the tympanum, is a certain cavity filled with air, and a greater pressure on one side of the tympanum than on the other gives rise to a painful sensation, and sometimes produces rupture of it in a person going down in a diving bell suddenly. The remedy for the painful sensation thus experienced, or rather I should say its prevention, is to keep chewing a piece of hard biscuit, or making believe to do so. If you are chewing a hard biscuit, the operation keeps open a certain passage, by which the air pressure gets access to the inside of the tympanum, and balances the outside pressure and thus prevents the painful effect. This painful effect on the ear experienced by going down in a diving bell is simply because a certain piece of tissue is being pressed more on one side than on the other; and when we get such a tremendous force on a delicate thing like the tympanum, we may experience a great deal of pain, and it may be dangerous; indeed it is dangerous, and produces rupture or damage to the tympanum unless means be adopted for obviating the difference in the pressures; but the simple means I have indicated are, I believe, with all ordinary healthy persons, perfectly successful.

I am afraid we are no nearer, however, to understanding what it is we perceive when we hear. To be short it is simply this: it is exceedingly sudden changes of pressure acting on the tympanum of the ear, through such a short time and with such moderate force as not to hurt it; but to give rise to a very distinct sensation, which is communicated through a train of bones to the auditory nerve. I must merely pass over this; the details are full of interest, but they would occupy us far more than an hour if I entered upon them at all. As soon as we get to the nerves and the bones, we have gone beyond the subject I proposed to speak upon. My subject belongs to physical science;—what is called in Scotland, Natural Philosophy. Physical science refers to dead matter, and I have gone beyond the range whenever I speak of a living body; but we must speak of a living body in dealing with the senses as the means of perceiving—as the means by which, in John Bunyan's language, the soul in its citadel acquires a knowledge of external matter. The physicist has to think of the organs of sense, merely as he thinks of the microscope; he has nothing to do with physiology. He has a great deal to do with his own eyes and hands, however, and must think of them, if he would understand what he is doing, and wishes to get a reasonable view of the subject, whatever it may be, which is before him in his own department.

Now what is the external object of this internal action of hearing and perceiving sound? The external object is a change of pressure of air. Well, how are we to define a sound simply? It looks a little like a vicious circle, but indeed it is not so, to say it is sound if we call it a sound—if we perceive it as sound, it *is* sound. Any change of pressure, which is so sudden as to let us perceive it as sound is a sound. There [giving a sudden clap of the hands]—that is a sound. There is no question about it—nobody will ever ask, Is it a sound or not? It is sound if you hear it. If you do not hear it, it is not to you a sound. That is all I can say to define sound. To explain what it is, I can say, it is change of pressure, and it differs from a gradual change of pressure as seen on the barometer only in being more rapid, so rapid that we perceive it as a sound. If you could perceive by the ear, that the barometer has fallen two-tenths of an inch to day, that would be sound. But nobody hears by his ear that the barometer has fallen, and so he does not perceive the fall as a sound. But the same difference of pressure coming on us suddenly—a fall of the barometer, if by any means it could happen, amounting to a tenth of an inch, and taking place in a thousandth of a second,—would affect us quite like sound. A sudden rise of the barometer would produce a sound analogous to what happened when I clapped my hands. What is the difference between a noise and a musical sound? Musical sound is a regular and periodic change of pressure. It is an alternate augmentation and diminution of air pressure, occurring rapidly enough to be perceived as a sound, and taking place with perfect regularity, period after period. Noises and musical sounds merge into one another. Musical sounds have a possibility at least of sometimes ending in a noise, or tending too much to a noise, to altogether please a fastidious musical ear. All roughness, irregularity, want of regular, smooth periodicity, has the effect of playing out of tune, or of music that is so complicated that it is impossible to say whether it is in tune or not.

But now, with reference to this sense of sound, there is something I should like to say as to the practical lesson to be drawn from the great mathematical treatises which were placed before the British Association, in the addresses of its president, Prof. Cayley, and of the president of the mathematical and physical section, Prof. Henrici. Both of these professors dwelt on the importance of graphical illustration, and one graphical illustration of Prof. Cayley's address may be adduced in respect of this very quality of sound. In the language of mathematics we have just "one independent variable" to deal with in sound, and that is air pressure. We have not a complication of motions in various directions. We have not the complication that we shall have to think of presently, in connection with the sense of force; complication as to the place of application, and the direction, of the force. We have not the infinite complications we have in some of the other senses, notably smell and taste. We have distinctly only one thing to consider, and that is air pressure or the variation of air pressure. Now when we have one thing that varies, that, in the language of mathematics, is "one independent variable." Do not imagine that mathematics is harsh, and crabbed, and repulsive to common sense. It is merely the etherealisation of common sense. The function of one independent variable that you have here to deal with is the pressure of air on the tympanum. Well now in a thousand counting houses and business offices in Birmingham and London, and Glasgow, and Manchester, a curve, as Prof. Cayley pointed out, is regularly used to show to the eye a function of one independent variable. The function of one independent variable most important in Liverpool perhaps may be the price of cotton. A curve showing the price of cotton, rising when the price of cotton is high, and sinking when the price of cotton is low, shows all the complicated changes of that independent variable to the eye. And so in the Registrar-General's tables of mortality, we have curves showing the number of deaths from day to day—the painful history of an epidemic, shown in a rising branch, and the long gradual talus in a falling branch of the curve, when the epidemic is overcome, and the normal state of health is again approached. All that is shown to the eye; and one of the most beautiful results of mathematics is the means of showing to the eye the law of variation, however complicated, of one independendent variable. But now for what really to me seems a marvel of marvels: think what a complicated thing is the result of an orchestra playing—a hundred instruments and two hundred voices singing in chorus accompanied by the orchestra. Think of the condition of the air, how it is lacerated sometimes in a complicated effect. Think of the smooth gradual increase and diminution of pressure—smooth and gradual, though taking place several hundred times in a second—when a piece of beautiful harmony is heard! Whether, however, it be the single note of the most delicate sound of a flute, or the purest piece of harmony of two voices singing perfectly in tune; or whether it be the crash of an orchestra, and the high notes, sometimes even screechings and tearings of the air, which you may hear fluttering above the sound of the chorus—think of all that, and yet that is not too complicated to be represented by Prof. Cayley, with a piece of chalk in his hand, drawing on the blackboard a single line. A single curve, drawn in the manner of the curve of prices of cotton, describes all that the ear can possibly hear, as the result of the most complicated musical performance. How is one sound more complicated than another? It is simply that in the complicated sound the variations of our one independent variable, pressure of air, are more abrupt, more sudden, less smooth, and less distinctly periodic, than they are in the softer, and purer, and simpler sound. But the superposition of the different effects is really a marvel of marvels; and to think that all the different effects of all the different instruments can be so represented! Think of it in this way. I suppose everybody present knows what a musical score is—you know, at all events, what the notes of a hymn tune look like, and can understand the like for a chorus of voices, and accompanying orchestra—a "score" of a whole page with a line for each instrument, and with perhaps four different lines for four voice parts. Think of how much you have to put down on a page of manuscript or print, to show what the different performers are to do. Think, too, how much more there is to be done than anything the composer can put on the page. Think of the expression which each player is able to give, and of the difference between a great player on the violin and a person who simply grinds successfully through his part; think, too, of the difference in singing, and of all the expression put into a note or a sequence of notes in singing that cannot be written down. There is, on the written or printed page, a little wedge showing a diminuendo, and a wedge turned the other way showing a crescendo, and that is all that the musician can put on paper to mark the difference of expression which is to be given. Well now, all that can be represented by a whole page or two pages of orchestral score, as the specification of the sound to be produced in say ten seconds of time, is shown to the eye with perfect clearness by a single curve on a riband of paper a hundred inches long. That to my mind is a wonderful proof of the potency of mathematics. Do not let any student in this Institute be deterred for a moment from the pursuit of mathematical studies by thinking that the great mathematicians get into the realm of four dimensions, where you cannot follow them. Take what Prof. Cayley himself, in his admirable address, which I have already referred to, told us of the beautiful and splendid power of mathematics for etherealising and illustrating common sense, and you need not be disheartened in your study of mathematics, but may rather be reinvigorated when you think of the power which mathematicians, devoting their whole lives to the study of mathematics, have succeeded in giving to that marvellous science.

(*To be continued.*)

THE GEOLOGICAL POSITION OF THE HUMAN SKELETON FOUND AT TILBURY

In a paper on this subject read by Mr. T. V. Holmes, F.G.S., at the meeting of the Essex Field Club on Saturday, February 23, at Buckhurst Hill, the author pointed out that the Tilbury skeleton was found in recent alluvium. The section at