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Ezra Cornell's Book
Presented By
Miss Dorothy Cornell
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Upon Telegraphic Communications, Especially by means
of Galvanism. By Dr Sternhille, Prof of Mathematics
and Natural Philosophy, at the University of Munich &c

Telegraphic communications may in its most
general sense be defined as the method em-
ployed by one individual to render himself
intelligible to others, and being, when viewed in
this light, synonymous with intercourse is
no human discovery, but one of the most
wonderfull gifts of nature, not to man alone,
but in common with him to all social
creatures is granted the faculty of commun-
-icating his sensations to others, and of exten-
-ding in them conditions similar to his own.

Communication is the most powerful tie
of the living creation; it connects one indivi-
-dual existence with another, reproduces in
one what is general to all, thus forming out
of individuals, species, which in their turn
present themselves as organic beings.

There is assuredly nothing in nature

never to have originated in a leading fundamental idea of what conditions it is essential and indispensable to have in view. It has hitherto been considered sufficient to add another new possible means of correspondence to those already known, without examining whether there are not yet other methods better suited to the purpose and of greater simplicity.

The more advisable course would be to establish at the outset what conditions are indispensable in complete telegraphic communication, and not to grapple with any difficulties with which the practical application of the scheme may be beset, for in most cases the method of carrying a plan into effect suggests itself to us as soon as we form a clear idea of what we have in view. Let us now make the attempt.

What we propose to attain by telegraphic communication is the transmission of ideas with the utmost rapidity at all times and

and to any distance; and when the distance are but moderate this problem is at once completely solved by speech. Hence for more considerable distances nothing more is required than that the telegraph should imitate speech. It appears to be evidently not the shortest way to make telegraph imitate an imperfect method of communication.

The signs for instance made use of by the deaf and dumb; it should be made to copy the most perfect of all methods of communication — speech, in which the sound as it falls on the ear of itself arrests the attention, and is at once understood.

At the first blush this appears to be a very difficult task, inasmuch as oral communication has such different sounds at its disposal, and is hence enabled to convey notions by means of a few combinations; and this difficult

no former arrangement of the telegraph has been completely able to surmount.

Inventors previous to Gauss were bent on producing a vast number of distinct signals, without reflecting that this was only to be attained at the cost of simplicity. It escaped them that a rapid communication is to be attained by other means besides a multiplication of signs, and that in point of fact one single sign, if it can be repeated with sufficient rapidity and employed in groups properly combined, is all that we require. In order to explain this I should wish to enter upon the analysis of our written language.

I select the great Roman letters for this purpose. They consist of six different signs, namely, a straight line in four ~~different~~ positions, horizontal, perpendicular, sloping from left to right, and from right to left, and lastly a semicircle turned to the

right or left. Of these six different signs never more than four are met with in the same letter, as in M and W. Now if we calculate how many different letters may be formed out of these six signs, never using above four of them however in the same group, we find the number amounts to no fewer than 1554; whereas we require but 25. We see from this example how much more numerous than the case called for has been the amount of signs employed in our written language.

Let us now suppose that we have but two kinds of signs and see if those are not quite sufficient for a complete series of letters. Let the signs be as simple as possible, each a dot for instance, and let them be distinguished by their position, that is to say, by one being always on a higher line than the other. Now if it was an understood thing that in each sign

there was not to be more than a single dot, it is clear there could be but two signs; if two dots might be united in the same sign, four more new signs would have to be added to the two above, giving in all therefore six different signs. Assuming that three dots, but no more, might be combined for one sign we should get eight in addition to the above, making therefore in all fourteen distinct signs. Supposing, in fine, that four dots can be united for one sign would give us sixteen more signs, making in all therefore thirty, a number quite enough for giving not only all the letters but the numerals as well. Two signs may however be dispensed with, if instead of a second sign a quick repetition of a single one is employed.

Hence we see that one sign, a dot for instance, enables us to render writing with greater conciseness than by the use of the various signs now ordinarily use; and what one dot is as the

simplest sign for writing, one sound is for speech. By repetition and by combination we may by habit form a language intelligible to the ear.

We are now therefore enabled to state the conditions which a telegraph of the simplest possible construction must fulfill. It needs communicate but a single sign but must give that with the utmost rapidity. If it was besides to be got up in the most convenient method this sign should be made audible.

Let us now enquire in succession to what natural phenomena we may have recourse in order to make this single sign as we have described.

Light is only partially applicable to this purpose. Its transmission may, it is true, be considered as infinitely rapid, but we shall never be able to make it affect more than our sight.

Moreover owing to the straight path it takes and the spherical shape of the earth, there are certain limits beyond

which its use is not applicable.

A Telegraph whose signals are founded on the use of light can therefore only communicate with other stations when ^{the} attention of the observer at those stations is drawn to it, when the distance does not exceed a moderate number of miles, and when the weather is favourable. Notwithstanding these very confined limits imposed on its use the telegraph as constructed by Chappe has met with a favourable reception, and since 1793, when the first telegraph line was established in France, been very generally adopted. It is remarkable that all the improvements proposed to be made in it should be but of minor importance. But although the principal defects, common to optical telegraphs, cannot of course be got over, yet it strikes me to be capable of being

considerably improved. I shall therefore confine myself to the following.

The first thing must always be making the communications as rapidly as possible, and there are two methods of reducing the time required for this.

It can be brought about by stenographic constructions, in other words, by the introduction of numerous signals, but the employment of a few of which any idea may be rendered. The same can also be attained by diminishing the time required for giving the signal, and this appears the preferable method. All the motions of long levers, of which our telegraphs are composed, and of which in order to be seen at a distance they must always consist, require considerable time, in accordance with the laws of dynamics. Hence it would be well to retain the present mechanical arrangement of the telegraph no longer.

The proposal of Gauss, to which he was led by his experience in the transmission of signals by means of the Heliotrope, appears to me to be capable of being employed in practice without difficulty.*

It is well known that a glass mirror of not above a few square inches in size appears to the naked eye like a star at the distance of five and twenty miles and upwards, when so directed as to show an observed part of the image of the sun.

For the time there is no sunshin during the night, or when the weather is cloudy for instance, recourse may be had to the glare produced by directing the flame of hydro-oxygen gas upon lime. The signals would consist of flashes produced by turning ~~the~~ covering the mirror.

* For a detailed description of the construction and use of the Heliotrope of Gauss see "Brithausfts Magazine von neuesten Mathematischen Instrumenten" 2tes. Heft. p. 47. Cassel 1835

This arrangement, a more detailed account of which in this place would detain us too long, would present the advantage of giving the signals with great rapidity.

It is easy to distinguish six separate flashes of light in a second, and which on their disappearance leaves a corresponding impression on the memory, as is the case with tones in rapped succession. We could therefore give at least thirty signs by means of flashes, while one is now given by the Telegraph. There would ~~further~~ be the additional advantage of dispensing with telescopes, and, what appears to be of still more importance only the observers at the stations would notice anything of the signals. I do not however deny that these advantages are more than ballanced by insurmountable defects.

If we wish to carry on telegraphic correspondence without the attention of those at the other station being previously called, we are compelled to affect the sense of hearing, whose impressions are alone constant, and which, within certain limits, allows ~~the~~ liberty of motion and permits us to occupy ourselves with other affairs. But in order to produce signs that may be audible without difficulty, some piece of mechanism must be put in motion at the other station and made to strike on a bell or do something of that kind.

One would say it must be by no means an easy task to transfer a power to so great a distance, and cause it to perform there, certain functions at our pleasure, and yet there are several possible methods of affecting this. Sound, radiant heat, electric and galvanic currents, may, when applied in certain ways

be employed for this purpose. The practical application however of each of these methods presents its own particular difficulties, and each comes with it its own insuperable defects, so that it appears advisable to examine them more closely in order to pronounce which of them presents the greatest advantages in its application.

We first come to the ordinary transmission of sound through the air, to the voice strengthened as were by means of speaking trumpets. But this manner of giving signals can only be employed with effect when distances are but trifling. The boatswain's whistle, the signal horn, and the alarm bell, and all similar methods, answering their particular purposes but inapplicable to telegraphic communication at considerable distances, inasmuch as any considerable increase of a sound would be too annoying to the immediate neighbourhood.

but principally because the transmission of sound through the air, at the rate of about 1142 feet in a second, is not rapid enough. The case is different in the transmission of sound through water.

Here the rapidity is nearly four times as great, and forms at least no longer an insuperable obstacle. The experiments which Braudant instituted at Marseilles and the more recent investigations of Colladon and Strunk at the Lake of Geneva* put it beyond a doubt that one can transmit audible tones through water to a distance of many miles. The nature of the transmission of the tone is however of such a kind that one ^{not} only hears it but is also enabled to render it visible as a molecular motion by means of a peculiar apparatus, the lever of contact. Consequently in place of the troublesome method of hearing under water a plan may be contrived which by the trembling motion of the particles of

water shall repeat that motion on a larger scale, thus placing the mechanical power we require for producing sound directly within our reach. In this way of carrying on correspondence, and which we merely notice here in passing, it appears not ^{un}important when compared with telegraphs founded on optical principles, that the communications may be made under all circumstances.

Consequently should it be established that sounds are transmitted through the plane surface of water we have all around us, of which there is hardly a doubt, and if the employment of this method might therefore be generally applicable, the subject will merit a more complete investigation, the more so from its not requiring any particular conductor for the transmission of the sound, and from the circumstance of no interruption of the signals being to be anticipated.

* Ann. de Chimie et Phys XXXV. 113 Gilberts Annalen, LXXXVIII. 39.

Another possible method of bringing about transient movements at great distance without any intervening artificial conductor is furnished by radiant heat when directed by means of ~~a~~ condensing mirrors upon a thermo-Electric pile. A galvanic current is called into play which in its turn is employed to produce deflections of a magnetic needle. The difficulties attending the construction of such an instrument though certainly considerable are not in themselves insuperable. Such a telegraph however would only have this advantage over those based upon optical principles, namely, that it does not require the constant attention of the observer. But like the optical one it would cease to act during cloudy weather, and hence partake of the intrinsic defects of that instrument; this method therefore is not probably able to stand a comparison with others.

The three principles of telegraphic intercourse here brought forward, namely,

light, radiant heat, and the propagation of sound, have this in common, ~~defect~~ they do not require that there should be a direct connection between the two stations. The air, water, and the ground, form the natural conductors of the conditions excited or rendered available, and which serve for making the communications. In this essential circumstance they differ advantageously from other feasible plans which we will now proceed to consider at some length.

The velocity with which frictional electricity is transmitted along metallic conductors called forth as long ago as in the last century the idea of employing it for telegraphic communications.

Winkler^x at Leipsic in the year 1746 discharged several Leyden jars through a wire of considerable length, and on that occasion the river Pleiss formed part of his circuit. Lestonmier in Paris[†] produced shocks through a length of wire amounting

^x Priestley's History of Electricity, P. 59.

[†] Philosophical Trans. Vol. XLIV. P. 1290

to 12789 feet. Watson* extended the experiment over a space of four miles near Shooter's Hill, composing his circuit of two miles of wire and an equal distance of dry ground. Lomond† transmitted telegraphic signals to a neighbouring room by means of a pith ball electrometer acted upon by frictional electricity. Reiser‡ illuminated by the electric spark, letters, formed upon plates of glass with strips of tin foil.

Gauss§ makes mention of a communication from Humboldt according to which Bétancourt in 1789 established a communication between Madrid and Aranjuez, a distance of 26 miles by means of a wire through which a Leyden jar used to be discharged which was intended to be used as a telegraphic signal.

* Phil. Trans. Vol. XLV. for 1748

† Youngs travels in France, 1784 Vol 1. P 79.

‡ Voigt's Magazine, Vol IX Part 1st

§ Gauss and Weber Resultate d. Mag. Versuchs, Vol 2, P 4

All these experiments put it beyond a doubt that frictional electricity may be employed for giving signals at any distance, and that when these signals are properly contrived they offer convenient means of telegraphic intercourse.

Frictional electricity has besides, as Gauss has already observed, the great advantage of not losing any of its force by increasing the length of the conducting wire, inasmuch as the whole of the electricity of one coating of the jar must traverse the entire length of the wire, be it what it may, to neutralize that of the other coating.

The experiments which Wheatstone instituted with a mirror in rapid motion to ascertain the rate at which the electric spark is transmitted, through copper conductors, shows that it travels with a velocity of 288,000 miles in a second, || a velocity exceeding that of the light of Jupiter's Satellites. ¶ Using this as a standard, all distances

¶ 192,500 miles in a second, Brewster's Optics, P. 2

|| Phil. Trans actions 1834, P 595

upon our globe are done away with, and we accordingly see in electricity the instantaneous messenger of thought for all distances and in every circumstance.

Nevertheless the practical execution of a telegraph founded on this principle presents some difficulty. Francis Ronalds constructed one at Hammersmith in 1816 and published a description of the instrument in 1825. In his arrangement there was a clock which kept time employed at the stations and which were furnished with a light disk of cyphers in place of hands, and having twenty different signs towards their circumference. At the moment the proper sign passed before the index the spark is discharged with an electrometer upon which the same sign is rendered visible on the clock at the other station. The disadvantage of being obliged to wait every time between each sign one gives till the disc has completed an entire revolution of ~~course~~ renders the plan impracticable. The old proposal of

Cavalli^x to employ the passage of the spark for a signal, would, when properly modified, be more applicable. It would be necessary, so that the signals may succeed each other with the utmost rapidity, and the arrangements be as simple as possible, that we should content ourselves with the discharging spark of a small coated plate. The sound which is always heard on the passage of the spark where there is a break in the chain would serve as an unequivocal signal, directly affecting the sense of hearing as already laid down by us in our general remarks upon convenient telegraphic intercourse. An electrical machine of moderate dimensions would continually furnish fresh charges at short intervals. It would not however be so easy to get over the difficulties attendant on the changes in electric excitation and the various hygrometric states of the atmosphere.

^x Cavalli's Treatise on Electricity.

But these difficulties are not insurmountable, and it is as yet by no means certain what this plan, if followed up by a thorough knowledge of the subject, might not from its simplicity be brought in to competition with any other principle, and this the more if due use is made of the important principle discovered as we have said by Winkler.

Of late years however we have become acquainted with a peculiar modification of Electricity, which, affecting as it does with a reciprocal action several of the other powers of nature, in a wonderful manner, even at first sight presents essential advantages for its application to the problem of telegraphic intercourse by means of Electricity. We allude to the power of Galvanism.

As long ago as 1807 Lönnermark erected in the apartments of the Academy of Sciences at Munich a galvanic telegraph, of which he published a detailed description in the

Philosophical Transactions of Bavaria. He employed the energy of a powerful voltaic pile to bring about the decomposition of water by means of 35 gold pins immersed in an oblong glass trough, each of these pins being marked with a letter or number, and admitting of connection with the pile by an insulated wire. The ascension of the air bubbles of the water decomposition was to serve as the telegraph signal.

It should be borne in mind that our knowledge of the effects of the galvanic pile was at that period but very limited. The discoveries of Oersted in 1809 from which we learnt that a magnetized needle can be deflected by a galvanic current, have opened a fresh field for the application of this power to telegraphic intercourse.

Under this head may be comprised the hints for a Galvanic telegraph thrown out by Fechner in his Manual

+ München Denkschr. d. K. Akad. d. W. für 1809, 1810 Math. Phys. Class. 2, 40.

of Galvanism^x and Ampère's scheme of an electro magnetic telegraph which has been executed on a small scale by the late Prof. Ritchie.[†] In this plan however Ampère departs to totally from the desirable principle of simplicity that upwards of 60 metallic connections would be required for the telegraph. The arrangement which Davy[‡] has proposed, in which illuminated letters are shown by the removal of screens placed in front of them, appears, also to be far too complicated. The experiments instituted by Schilling § by the deflection of a single ~~needle~~ seems much better contrived, he did not however succeed in surmounting the mechanical difficulties that attended the question in this shape.

The subsequent discovery of Faraday, according to which the generation of galvanic currents is reduced to the mere motion of.

^x Lehrbuch des Galvanismus 1829 P 269

[†] Froriep's Not. Vol. XXVII. No. 6 P 86.

[‡] Mechon Mag. No 752, P 261; No 756, P. 296; No. 758, P. 327

[§] Allgemeine Wissenschaften 1837, No 52 P 240.

multiplicers placed near fixed magnets has very materially simplified the problem, inasmuch as the voltaic pile becomes there by no longer necessary.

To Gauss and Weber^x is due the merit of having in 1833 actually constructed the first simplified Galvanic Magnetic Telegraph.

It was Gauss who first employed the experiment of induction, and who demonstrated that the appropriate combination of a limited number of signs is all that is required for the transmission of communications. Weber discovered that a copper wire 7460 feet long which he had led across the houses and steeples at Göttingen from the observatory to the cabinet of Natural Philosophy required no especial insulation was one of great importance.

The principle was thereby at once established of bringing the Galvanic Telegraph to the most convenient form. All that was required was an appropriate method of inducing or exciting the current with the power of changing its direction without

^x Gött. gel. Anz 1834, P 1273, and Thunners

having recourse to any special contrivances for that purpose. In accordance with the principles we have laid down, all that was required in addition to this was to render the signals audible, a task that apparently presented no very practical difficulties, inasmuch as in the very scheme itself a mechanical motion, namely, the deflection of the magnetic bar, was given.

All that we had to do therefore was to contrive that the motion should be made available for striking bells or for making indelible. This falls within the province of mechanics, and there are therefore many ways than one to solve the problem. Hence the alterations that I have made in the telegraph of Goss and by which it has assumed its present form may be said to be founded on my perception and improvement of its imperfections, in harmony with what I had previously laid down as necessary for perfect telegraphic communication. I by no means however look at the arrangement I have selected

as complete; but as it answers the purpose I had in view, and it may be well to abide by it till some simpler arrangement is contrived.

As an inductor or exciter I employ a rotating apparatus whose construction speaking in a general way, is similar to those of Clark, of London, the multipliers of which however my inductor is composed, consists of a vast number of turns of fine insulated copper wire; and this arrangement is necessary in order that the resistance offered by the thicker wire completing the circuit, even should it be many miles long, may be but little increased. Of the galvanic influence excited during the entire half-turn of the rotating double multiplier only a small portion is employed, and that when it is at the maximum of its energy. By this means the duration of the current is but very short, an arrangement which therefore in a manner can cause merely a momentary deflection of the little magnetic bars employed for giving the signals

In order to heighten the action of these indicators as much as possible they are surrounded by powerful multipliers. Small detached magnets are so placed near these indicators that they are thrown by brought back to their original position immediately that the induced current ceases, or in other words, as soon as the deflection has taken place: we thus are enabled to repeat signals in very rapid succession. The same indicator can be brought with ease to make five deflection in a second, succeeding each other as fast as the sound of a repeater when striking. Hence if bells are placed at the proper striking distance from these indicators they will ring at each deflection produced, and as it is quite immaterial at what part of the wire, composing the circuit the multiplier containing the indicator is inserted, we have it in our power to produce the sign excited by induction at any part of the course the wire takes

Should it be desired that the inductor instead of producing sound should write, it is merely required to adapt to one end of the little magnetic bar a small vessel filled with a black culler, and terminating in a capillary tube. This tube instead of striking on a bell, thus makes a black spot upon some flat surface held in front of it. If these spots are to compose writing, the surface upon which they are printed must be kept moving on in front of the indicator with a uniform velocity, and this is easily brought about by an endless strip of paper which is rolled off of one cylinder on to another by clock work. This is in a general way the construction followed in the telegraph erected here, a fuller account of which now would be out of place, as it may be found on referring to the appendix.

As far as the employment of the telegraph is concerned, it may be fairly said to perform all that can be reasonably required of it.

The excitation of the current is produced by half a turn of the indicator, and is equally available at all times. The sound of the bells close to the person making the signals, and which being produced ^{at the other stations} too are also audible there, become, by practice, intelligible as a language.

Should they however be overheard or misunderstood, the communication presents itself simultaneously written down.

This can be done with closed doors, without any but the parties concerned being aware of it: the communications may be made at any distance, and and either by day or night without any appreciable loss of time. There is, therefore, every reason to be content with the performance of the instrument.

It is not however to be denied that the establishment of certain conditions indispensable to its action is nevertheless a matter of some difficulty. We allude to the connecting wire joining the stations.

It has been stated above that Ampère

required more than sixty such wires, whereas thirty or so were sufficient for communicating.

Whitstone and Cooke* reduced their number to five; Gauss and, probably in imitation of him, Schilling, as likewise Morset in New York, made use of but a single wire running to the distant station and back. One might imagine that this part of the arrangement could not be further simplified, such however is by no means the case. I have found that even the half of this length of wire may be dispensed with, and that with certain precautions its place is supplied by the ground itself. We know in theory that the conducting powers of the ground and of water are very small, compared with that of the metals, especially copper. It seems however to have been previously overlooked that we have it within our reach to make a perfectly good conductor out of water or any other of the so called semi-conductors.

* La France industrielle, 1838, April 5, p. 3

+ Elec. Mag, No 775 p. 332. Sil Jour Oct 1837. Annals of Electricity, &c Vol 2: p. 116

All that is required is that the surface that its section presents should be as much greater than that of the metal as its conducting power is less. In that case the resistance offered by the same conductor will equal that of the perfect conductor; and as we can make conductors of the ground of any size we please simply by adopting to the ends of the wires plates presenting a sufficient surface of contact, it is evident ^{that} we can diminish the resistance offered by the ground or by water to any extent we like. We can indeed so reduce this resistance as to make it quite insensible when compared to that offered by the metallic circuit, so that not only is half the wire spared, but even the resistance that such a circuit would present is diminished by one half. This fact, the importance of which in the erection of galvanic telegraphs speaks for itself, furnishes us with another additional feature in which galvanism resembles electricity. The experiments of Winkler, at Leipzig, had already

shown us that with frictional electricity the ground may replace a portion of the discharging wire. The same is now known to hold good with respects to galvanic currents.

The enquiry into the laws of dispersion according to which the ground, whose mass is unlimited, is acted upon by the passage of the galvanic current, appears to be a subject replete with interest.

The galvanic excitation cannot be confined to the position of the earth situated between the two ends of the wire; on the contrary it cannot but extend itself indefinitely, ~~to the portions of the earth~~ and it becomes therefore now only dependent on the law that obtained the excitation of the ground and the distance of the exciting terminations of the wire whether it was necessary or not to have any metallic communication at all for carrying on telegraphic intercourse.

I can here only state in a general way that I have succeeded in deducing this law experimentally from the phenomena it presents; and that the results of the

investigation is, that the excitation diminishes rapidly as the distance between the terminal wires increases.

An apparatus can it is true, be constructed in which the inductor, having no metallic connection whatever with the multiplier, by nothing more than excitation transmitted through ^{the ground}, shall produce galvanic currents in that multiplier sufficient to cause a visible deflection of the bar. This is a hitherto unobserved fact, and may be classed upon the most extraordinary phenomena that science has revealed to us. It only holds good, however, for small distances. It must be left to the future to decide whether we shall ever succeed in telegraphing at great distances without any metallic communication at all. My experiments prove that such a thing is possible to a distance of 50 feet. For distant stations we can only conceive it feasible by augmenting the power of the galvanic induction, or by appropriate multipliers

constructed for the purpose or, in conclusion, by increasing the surface of contact presented by the ends of the multiplier.

At all events the phenomenon merits our best attention, and its influence will not perhaps be altogether overlooked in the theoretic views we may form with regard to galvanism itself.

To sum up in a few words what are the results of what we have here brought forward respecting telegraphic communications, we see that, with the present arrangement of the apparatus, no principle can be brought into competition with the Galvanic telegraph, but that the establishing the metallic connexion indispensable to its action, although now materially simplified, still presents great difficulties in practice. Indeed such a connexion is only practicable where it can be constantly watched, as, for instance, in the vicinity of railroads.

For very considerable distances without intermediate stations, galvanic or electric,

excitation must, on account of their rapidity, be always the best power to have recourse to. For lesser distances it yet remains open to enquiry whether, with proper modifications, some of the other methods we have pointed out would not be preferable, as they dispence with a metallic connexion.

Extracts from Dr Sturtevant's second article as in the Annals of Electricity No for Apr 1839.

(Page 570) "Numerous trials to insulate wires and to conduct them below the surface of the ~~earth~~ ground have led me to the conviction that such attempts can never answer at great distances, inasmuch as our most perfect insulators are at best but very bad conductors. And since in a wire of very great length, the surface in contact with the so-called insulator is uncommonly large when compared with the section of the metallic conductor there necessarily arises a gradual diminution of the force, inasmuch as the out and home wire, although blit slightly, yet do communicate in intermediate points. It would be wrong to think that this difficulty would be got over by placing the outer and home wire very far apart. The distance between them is, as we shall

see in the sequel, almost a matter of indifference. And as we shall never succeed in laying down conductors that are sufficiently insulated beneath the surface of the ground which is always damp, there is but one other course open to us, namely, leading the wire through the air. Upon this plan, it is true, the conductor must be supported from time to time; it is liable to be injured by the evil disposed, and it is apt to suffer from violent storms or from ice which forms upon it. As we have however no other method that we can avail ourselves of we must endeavor by suitable arrangements to get the better of these, not immaterial, faults in the best way we can."

Whole length of Stenhiel's wire, thus—

"The conducting chain of the Telegraph erected here, consists of three parts: one leads from the Royal Academy to the Royal Observatory, at Bogenhausen, and back, and

the total length of its wire is 32508 feet. The weight of the copper employed amounts to 260 pounds. Both wires (there are two) are stretched across the stupells of the town at a distance of four feet one inch. The greatest distance from support is 1279 feet: this is undoubtably far too great for a single wire. &c."

Between poles where they are used is from 640 to 880 feet. Poles 40 or 50 feet long 5 feet in the ground."

(Page 511) "The conducting wire thus mounted is by no means completely insulated.

When, for example, the ~~point~~ is broken at Bogenhausen, an induction shock given in Munich ought to produce no galvanic excitation whatever in the parts of the chain thus disconnected. Gauss's Galvanometer, however, ~~even~~ then gives indications of a weak current: measurements indeed go to show that this current goes on increasing as the point at which the interruption of the ~~str~~ ^{am}

is made ~~needed~~ from the inductor. (or battery). The absolute amount of this current is not constant. Generally it is strongest when the weather is damp.

When there are heavy showers of rain, it may be fairly said to be five times as strong as when the weather is settled dry.

At moderate distances of a few miles this small loss of power is of almost no importance, and that the more as the construction of the inductors places currents of almost any strength at our command. When the distance however amounts to upwards of 200 miles, the greatest part of the effect would be dissipated. In such cases much greater precaution must be taken with regard to the points of support of the metallic circuit.

(Page 572) Quite recently I made the discovery that the ground may be employed as one half of the connecting chain. As in the case of frictional electricity, water or the

ground may with the galvanic current form a portion of the connecting wire. Owing to the low conducting power of these bodies ~~compared~~ **compared with metals** it is necessary that at the two places where the metallic conductor is in connection with the semiconductor the former should present very large surfaces of contact.

Take Water, for instance, to conduct two millions times worse than copper, a surface of water proportional to this must be brought in contact with the copper to enable the galvanic current to meet with equal resistance, in equal distance of water and metal.

For ~~an~~ instance, if the section of a copper wire is 0.5 of a square line it will require a copper plate of sixty one square feet surface in order to conduct the galvanic current through the ground, as the wire in question would conduct it. But as the

thickness of the metal is quite immaterial in this case, it will be always within our reach to get the requisite surfaces of conduct at no great expense. Not only do we by this means save half the conducting wire, but we can even reduce the resistance of the ground below what that of the wire would be, as have been fully established by experiments made here with the experimental telegraph.