The formative force, then, is a diffused tendency. The very vagueness of the expression serves to emphasize our ignorance concerning the real nature of the force. In this connection, I venture to insist upon the fact that we know little or nothing concerning any of the fundamental properties of life, because I think the lesson of our ignorance has not been learned by biologists. We encounter not infrequently the assertion that life is nothing but a series of physical phenomena; or, on the other hand, what is less fashionable science just now, that life is due to a special vital force. Such assertions are thoroughly unscientific; most of them are entirely, the remainder nearly worthless. Of what seem to me the prerequisites to be fulfilled before a general theory of life is advanced, I have written elsewhere.[1] CHARLES S. MINOT.

UNDERGROUND WIRES.

DURING the last few years the number of electric wires in all of our large cities has rapidly increased, especially since the introduction of the telephone and the electric light; and the probability is that the next few years will show a further large increase. If these wires run on poles, they not only disfigure the streets, but seriously interfere with the operations of firemen, as we have repeatedly seen during the last few years. A cobweb of wires supported on housetops requires the line-men to continually tramp through the houses and over the roofs, causing annoyance to the tenants, and damage to the buildings. Moreover, wires fixed to housetops are subject to removal at the whim of the owner, and they have to be continually removed from building to building as the good will of each owner is exhausted. Again: overhead wires, whether placed on poles or housetops, are continually coming in contact with each other, causing annoyance and danger; and an extra heavy rain or sleet storm so entangles and breaks them as to entirely interrupt communication. The annual cost of repairs of overhead wires in cities is not less than thirty per cent of the first cost of construction.

In almost all of the large cities the question is being asked, Why cannot these wires be gathered into cables and buried, along with the gas and water pipes, under the streets? In answer, it is proposed to review briefly the technical difficulties that arise, and to show how they may be and are overcome. It is proposed, further, to compare the cost of construction and maintenance of overhead wires with the cost of construction and maintenance of underground cables, and thus to see which is desirable from economical considerations.

There are two reasons, apart from the difficulty of securing good insulation, why underground lines are comparatively inefficient: —

1. If an electric conductor be brought near to a large mass of conducting-matter, as is a wire when it is taken down from a pole and buried in the earth, there appears in the current the phenomenon of retardation, by which each signal, instead of being sharp and distinct, is partly kept back, so that it overlaps and mingles with the next. The result is to limit the speed of working of the apparatus, or, if, like the telephone, it be an apparatus in which the currents are necessarily extremely frequent, to confuse and destroy the signals altogether.

2. The second difficulty is called induction, and is noticed when two or more wires are run side by side and near together, as they necessarily are in an underground cable. If the signals on one wire of such a cable be sharp and quick, they cause facsimile signals on all of the neighboring wires; and this, too, though the insulation may be absolutely perfect. The result of this phenomenon is, that messages sent over one wire are liable to be received on all of the other wires; and in telephony each person can easily overhear all that the others are saying.

Fortunately, however, both of these difficulties vary with the electrical qualities of the cable; and while I have seen cables of a thousand feet, over which it was difficult to talk, and in which the cross-talk was nearly as loud as the direct conversation, on the other hand, I have conversed easily over an underground cable extending from Paris to Orleans, eighty-five miles; and this, too, while other parties similarly separated were talking over other conductors of the same cable. There was absolute secrecy.

Last summer I visited France and Germany, and made, together with Mr. Berthon (chief engineer of the French telephone company), Mr. Cäel (chief engineer of the French government telegraph), and Herr Guillaume (constructor of the underground lines of the German empire), a series of telephone experiments on underground lines, varying from 5 to 100 miles in length, from 2.87 to 48 ohms resistance, and from 0.06 to 0.35 microfarads capacity per mile.

These experiments furnish us with ample

[1] C. S. MINOT. *On the conditions to be filled by a theory of life.* Proc. Amer. assoc. adv. sc., xxviii. 411.

data from which to deduce the requisites of any cable, in order that it may transmit speech, and without cross-talk from the neighboring conductors. These are briefly as follows: —

1. Good conductivity.

2. High insulation; for without this the current leaks from one conductor to the others, giving rise to cross-talk; and it is possible to talk by direct leakage between two conductors whose insulation is several million ohms.

3. Low specific inductive capacity; for, the greater the capacity, the greater the retardation, and the greater also the cross-talk due to induction.

Below is a table showing the specific inductive capacity and insulation of various insulators. The measurements were all made on a wire 0.05 of an inch in diameter, coated with insulation to a thickness of 0.10 of an inch.

Cable.	Maker.	Insulation per mile in meghoms.	Specific inductive capacity in micro-farads.
Gutta-percha,	Siemens Bros., London.	190	4.2
India-rubber,	Rattier, Paris.	170	3.7
Kenti . . .	A. G. Day, New York.	150	4.0
Faraday . .	Faraday cable-works, Cambridge, Mass.	15,000	1.6
Patterson . .	Western electric company, Chicago.	450	3.1
Brooks . .	David Brooks, Philadelphia.	–	2.8

Let us take a special case, and compare a gutta-percha cable having a specific inductive capacity of 4.2 with a Faraday cable of 1.6. The table predicts that we can talk three times as far with the latter as with the former, and experiment shows that we can. Again: the cross-talk on the gutta-percha cables ought to greatly exceed that on a Faraday cable; and experiment has shown, that, while conversation over a two-mile gutta-percha cable was continually disturbed by existing cross-talk, conversation was carried on over a similarly constructed Faraday cable five miles in length without the cross-talk being appreciable.

By proper attention to the electrical qualities, then, we may talk underground a much greater distance than we shall ever have reason to in any city system, and this without cross-talk from the neighboring circuits.

We have seen that telegraph and electric-lighting currents are not subject to the technical difficulties we have been discussing, and that, provided good conductivity and good insulation are assured, it is with them purely a question of expense. Let us, then, determine the relative expense of overhead and underground wires.

Suppose we have a large city with a telegraph-office near the centre, and that it is desired to carry a hundred wires to the city limits, say, three miles distant. Let us suppose that the wires for the first mile rest on housetops, and for the remainder of the distance on poles. The cost will be: —

35 roof-fixtures	@ $45	$1,575
80 poles, with arms, etc.	@ 65	5,200
300 miles No. 9 wire	@ 16	4,800
Stringing 300 miles wire	@ 8	2,400
		$13,975

Underground, the cost would be: —

6 miles (50 conductors) No. 17 lead-covered cable	@ $3,000	$18,000
3 miles trenching, troughing, laying, and refilling	@ 2,000	6,000
		$24,000

That is, the relative first cost of an overhead and an underground line, to do the same work, would be, say, $14,000 and $24,000.

The same conclusion will hold true for telephone-wires, provided we confine ourselves to the problem of running out from the central office, by fifty or a hundred conductor cables, to a large number of distributing-points so situated about the city that any subscriber would be easy of access, by a short overhead line, to one or another of them; and this is the problem that really occurs. So much for construction.

The yearly cost of repairing an overhead system, including roof-rentals, is not less than thirty per cent of the cost of construction; and the line would have to be renewed once in twelve years. The cost of repairing an underground system is practically *nil*. The Paris telephone company, with wires extending to three thousand subscribers, does not keep any repair-men. The durability of an underground system, provided lead-covered cables are used, and there is no internal cause of deterioration, is at least thirty years. Last summer we examined some lead-incased gutta-percha cables that had been in use by the French government for that length of time, and found them in perfectly good condition. The same is true of India-rubber cables incased in lead.

Herr Guillaume says of a cable in use by the German government, similar to the Faraday cable, "We are using it altogether in our new construction. I do not see how it can ever decay. We tried cotton-covered wires soaked in paraffine and drawn into lead pipes; and, though they worked well at first, after a few years they failed."

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