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February 7, 1918 THE COMPANION FOR ALL THE FAMILY OBSERVATION: TWIN BROTHER TO INVENTION The only copy we have Observation & Experiment no. 9 By Alexander Graham Bell

DID you ever put your head under water and knock two stones together to find out what the sound is like?

If you have never done that, try it and you will get a new sensation. I did it once, and it sounded as if a man were hammering at my very ear. I then took two tiny pebbles and tapped them lightly together under the water. It sounded like a man knocking at the door. I was rather startled to hear such a loud noise from such a slight cause, and of course the question at once came to my mind: How far away could I hear the sound?

So I sent a boy a couple of hundred feet up the beach, and directed him to strike two stones together under the water. When I submerged my head I could hear the sound as readily as before. Then, determining to try the maximum possible distance, I sent the boy across the bay in a boat, to a point at least a mile away from where I stood. Through my field glass I saw him land on the other side, go down to a little plank wharf, lie face downward upon the wharf and put his hands into the water. I then knew that he was signaling with the stones.

Slipping into the water on my side of the bay, I submerged my head and listened intently. Clear and perfectly distinct the signals came to my ear through more than a mile of water! It was an astonishing revelation of what can be done with water. In air, sound travels about a thousand feet a second; but in water it goes five times as fast as that—about five thousand feet a second—because water is a much better conductor than air.

In reflecting upon those experiments the thought occurred to me: If two little stones tapped together under the water make such a big sound, every tiny lobster that snaps his claws must make an audible click. Are there, I asked myself, creatures in the water that signal to one another by sound?

I had occasion once to make the experiment. While bathing in the Grand River in Ontario, I put my head very gently under the water and listened. *Tick! tick!* came a sound from one side like the chirrup of a grasshopper, followed by a similar chirrup from the other side. Evidently there were creatures under the water calling to one another. I do not know whether all fish make sounds or not, but there are certainly some fish that do. The drumfish on our coast, for example, drums away in the water so loud that he can often be heard on the shore. It is also a significant fact that all fish have ears. Why should they have those organs if there is nothing for them to hear?

Therefore, of this we may be certain: there is a whole world of sound beneath the waves waiting to be explored.

We are all too much inclined, I think, to walk through life with our eyes closed. There are things round us and right at our very feet that we have never seen, because we have never really looked. We should not keep forever on the public road, going only where others have gone; we should leave the beaten track occasionally and enter the woods. Every time you do that you will be certain to find something that you have never seen before. Of course, it will be a little thing; but do not ignore it. Follow it up, explore all round it; one discovery will lead to another, and before you know it you will have something worth thinking about to occupy your mind, for all really big discoveries are the results of thought.

The Falling Apple

Let us return to the experiment of knocking the stones together under the water and think about it.

Why should we not simply put an ear to the water instead of submerging the whole head? Why should we not ring a bell under the water, instead of clicking stones together to make a noise? An ordinary dinner bell would do. Empty it of air and ring it under the water, and a person with his ear submerged can hear it at a great distance. But would it not be better to transmit the sound vibrations from the water to the ear through some intervening mechanism and thus obviate the necessity of submerging the ear at all?

I have tried submerged hearing tubes of various kinds and planks partly submerged, with the ear applied to the part out of the water. If you put your ear to the bottom of a boat—inside, of course—you can readily hear a bell ring under the water some distance away. Still better, fasten a telephone transmitter to the bottom of the boat and you can sit at ease with the telephone! receiver at your ear. Or you may put the transmitter overboard. It then becomes a submerged ear and will listen for you under the water. That is the principle of the submarine signaling that is now in use on many large commercial and naval vessels.

Alexander Graham Bell. recognized as one of the eminent men of science of modern times, is best known as the inventor of the telephone

On those ships the telephone transmitters are attached to the thin iron skin of the hull and the receiving telephone is on the bridge. On shore there are huge bells at lighthouse stations making underwater fog signals that a steamer ten miles away can pick up. It is doubtful whether a fog signal could be heard through the air at any such distance. The air is at best a poor conductor of sound, and it affords many chances for illusions of hearing. For example, an island casts a “sound shadow” upon the water. The sound wave striking the island is deflected into the sky, and a person would have to be up in a balloon to hear it, for it might not come down again to the surface for a mile or two beyond the island. A ship close to the island may, therefore, not hear the signal at all, until too late to avoid running aground.

The transmitting qualities of the air are likewise subject to variations on account of unusual atmospheric conditions. You may be near a fog station and yet hear the sound so faintly that it seems to be far away. The sounds echo from the clouds or from the sails of a ship and thus add other puzzling aspects to the problem. There is always room for something new, for the list of inventions is far from being closed. Consider, for example, the ramifications suggested by the transmission of sound through water.

Three quarters of the earth's surface is submerged and has not yet been explored to any great degree. The only way we have of reaching the mountains and valleys at the bottom of the sea is by sending down a sounding line and bringing up a specimen of the bottom attached to the sinker. It is not easy, however, to reach the bed of the sea through a mile or two miles of water and it requires several hours to take a single sounding. It is therefore expensive both in time and in labor to ascertain the depth of the ocean.

Why not send down a sound instead and listen for the echo from the bottom? Knowing the velocity of sound in water and the time taken for the echo to reach the ear, we should be able to ascertain the depth of the deepest part of the ocean in a few seconds. Here is an idea that would certainly appear to be worth trying. I have suggested it several times, but I do not know that it has ever been acted upon. The experiment might reveal not only the depth of the ocean but something of the nature of the bottom. A flat bottom should give a single sharp return, whereas an undulating bottom should give a multiple echo, such as you hear when a pistol is fired among hills. Many important conclusions might be drawn from the facts so obtained.

Thus a small observation—like knocking the stones together under the water—patiently followed up by other observations equally small, may lead gradually to a big conclusion.

Have you an ambition to found a new science? Why not measure a smell? Can you tell whether one smell is just twice as strong as another? Can you measure the difference between one kind of smell and another? It is obvious that we have very many different

kinds of smells, from the odor of violets down to asafetida, but until you can measure their likenesses and differences you can have no science of odor.

In the first place we have to define an odor. Is it an emanation of material particles into the air or is it a form of vibration, like sound? If you can decide that question, you will have the starting point for an entirely new investigation. If odor is an emanation, it could be weighed; if it is a vibration, it could be reflected from a mirror. Light and sound and heat can be reflected. I have even warmed my hands at the reflection of a fire in a mirror of polished metal.

That a cultivation of the sense of smell may be very valuable was proved in the discovery of the substance selenium. In experimenting with the waste products obtained in manufacturing sulphuric acid, a distinguished chemist noticed the characteristic smell of tellurium—an odor that has no counterpart on earth or in heaven. But the smell was the only indication of the presence of the substance; all the chemical reactions declared that there was no tellurium present in the powder. The chemist therefore concluded that, if no tellurium was present, there must be a new substance there, as yet undiscovered, which resembled tellurium. When he had extracted from the mass all the materials that he knew were present, he found a residue, which proved to be, as he had suspected, a new elementary substance.

This new substance, which was named selenium, resembled black sealing wax in appearance. In its vitreous form it was a nonconductor of electricity, but when heated almost to the fusing point and allowed to cool very slowly it completely changed its appearance. It acquired a dull, metallic look, like lead; and in that, its crystalline condition, it was a conductor of electricity, but of extremely high resistance. A little pencil of crystalline selenium, not much more than an inch long, offered as much resistance to the passage of an electrical current as ninety-six million miles of wire, enough to reach from here to the sun. Yet it was a conductor.

In laying the Atlantic cable, Willoughby Smith found it advisable to balance the electrical resistance of the cable, during the process of submersion, by tremendous coils of well-insulated wire. The thought occurred to him that he might be able to get rid of all that complication of wire by balancing the entire cable with a bit of selenium.

He succeeded in doing so, but found the electrical resistance very variable. At times the selenium would balance the whole cable and at other times not one half of it. His assistant, Mr. May, made further observations, and discovered that the resistance of the selenium was greater at night than by day.

That at once suggested to Willoughby Smith the thought that perhaps the electrical resistance of selenium was affected by light, and he proceeded to put his idea to the test of experiment. He shut up the selenium in a dark box near a bright light, and found that when the lid was open the resistance went down and that when it was closed the resistance went up again.

Then other men of science took up the matter. Prof. Adams of King's College, England, found that the electrical resistance of selenium varied directly with the intensity of the light that fell upon it. Then I made some speculations concerning the possibilities of telephoning without wires by varying the intensity of a beam of light by the action of the voice and by allowing the light to fall upon a piece of crystalline selenium. In that way I thought it might be possible to get speech from a sunbeam.

There is no need to go into details, but my supposition was true. I produced the photophone, an instrument for talking along a beam of light instead of a telegraph wire. It is interesting to remember that all those results rose from observing smell!

It is only a few years since the first man flew, and we are now only at the beginning of aviation. Here, then, is a subject for exploration: How to improve the safety of the flying machine; how to produce such flying machines that anyone can fly? It is very likely that

the inventions that answer these questions will, when they are perfected, each have for its basis some “slight” observation that a thinker has put to a practical and highly utilitarian use.

I cannot overestimate the importance of observing every little thing and of reasoning upon it. The history of invention is full of incidents in which apparently trivial observations have proved of immense value to the world. Indeed, as Smiles very happily put it, “The close observation of little things is the secret of success in business, in art, in science and in every pursuit of life.”

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