on which he believes the originals were constructed. Some of these are shown in the accompanying illustrations. None was found in the ruins. The manner in which these writing instruments were used is also shown in one of the engravings herewith.

CARBORUNDUM AND SILICON DETECTORS FOR WIRELESS TELEGRAPHY.

BY A. FREDERICK COLLINS.

A novel detector for determining the presence of electric waves, has just been brought out by General H. H. C. Dunwoody, and has been found sufficiently sensitive and trustworthy to be used for commercial wireless telegraphic work.

The device in question consists of a minute mass or fragment of carborundum—an artificial compound made of carbon and silicon in the electric furnace—held in place between two metallic terminals or conductor plugs, usually formed of copper or brass.

This detector has recently been made the subject of exhaustive tests by Mr. G. W. Pickard, who has found that it is somewhat less sensitive than the magnetic detector of Marconi, which in turn follows the electrolytic detector of Fessenden; that is to say, while it requires from 350 to 400 micro-ergs (1 micro-erg being 1/1000 of an erg*) to operate the electrolytic detector, and from 400 to 500 micro-ergs to impress a magnetic detector, it requires between 9,000 and 14,000 micro-ergs to carry the conductivity of a carborundum detector so that it will produce an audible tone in a telephone receiver, with about the same amount of energy required by a microphone detector.

Notwithstanding this very considerable difference in the sensitiveness of the electrolytic and carborundum detectors when measured in the C. G. S. system of units, in the actual practice of wireless telegraphy the difference in receptiveness is barely perceptible over similar distances. In the first experiments with carborundum as an electric wave detector, it was found that its sensibility to the electric oscillations set up in the circuit of which it was a part, was a maximum when a certain critical potential prevailed in the local circuit of which it also formed a part.

In this respect it resembles the electrolytic detector when in action. For this reason a potentiometer or variable resistance is used in shunt with the detector. As carborundum is obtained in the form of crystalline masses, it has, in consequence, a very high resistance where the current flowing in the internal or dry cell circuit is small, but as the strength of the current is increased the resistance drops very rapidly.

Various curves have been plotted showing the resistance variation against the difference of potential across the conductor plugs of the detector, and in one of these it was demonstrated that the conductive charge occurred most rapidly between 1.0 and 1.1 volts. The conductance of the detector at this potential was about 250 microhms, or 0.4000 ohm, and a variation of 0.01 volt at the above potential value will produce a change in conductivity of about 10 microhms, or 4 per cent.

It is well known that the flat side of carborundum is a very poor conductor and in order to obtain good electrical contact, the sharp edges of the carborundum fragment must be clamped between the opposed surfaces of the plug ends of the detector, when the actual contact is limited to an exceedingly small area—not more than one millionth of an inch and probably less.

In common with the Fessenden hot-wire barretter and responders of the bolometric type, the action of the new Dunwoody detector is purely thermal. But instead of utilizing either an exceedingly fine metal wire of relatively low specific resistance and temperature coefficient, as does the barretter, or a large radiating or absorbing surface in proportion to its mass as does the bolometer, the carborundum detector employs a constricted current path lying along the edge of the crystal in contact with the oppositely-disposed surfaces of the conductor plugs.

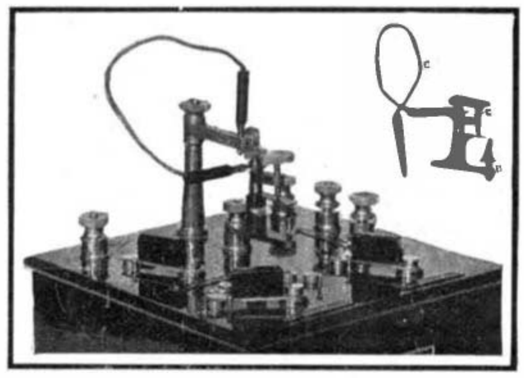
The new carborundum detector is so designed that it can be inserted in circuit with a De Forest receptor instead of the detector formerly used; in other words, the carborundum detector is made interchangeable with the electrolytic detector, which it has superseded. When placed in such a receiving circuit, the manifestation is greatest when the potential impressed upon the detector is between 1.0 and 1.2 volts.

In other tests, the conductor plugs supporting the carborundum crystals were heated by a spirit lamp, when the resistance of the detector was observed to decrease greatly, but on cooling again it assumed its former resistivity, which is of the order of a megohm.

The crystals of carborundum employed in the Dunwoody detector are microscopically selected and only those having the sharpest edges are chosen, since these have been found to give the best result. The fragment of carborundum is placed between a spring and an adjustable screw plug, and by varying the pressure of the spring by means of a screw the point of maximum sensitiveness can easily be obtained.

The exact proportions of the crystal are not essential and it may vary from one to three millimeters on the side. The crystal to be used should never be touched by the fingers, as this often reduces its sensitiveness to an appreciable extent; the proper way to handle the element is to use a pair of tweezers.

Since the advent of the Dunwoody carborundum de-



THE NEW DUNWOODY CARBORUNDUM DETECTOR INSERTED IN A RECEPTOR.

tector, Pickard has brought out one using silicon as the sensitive medium. Silicon is a non-metallic element, prepared as a dull-brown amorphous powder, as shining metallic scales or as dark steel-gray granules, sometimes showing crystallization. Any one of these may be used as a detector, and in any case it is pressed into good electrical contact between two conducting plugs as in the ordinary coherer.

Different from the coherer, this latest "thermo-electric regenerative detector" converts the energy of the oscillation set up in the receiving aerial, into heat at the junction of the silicon and the metal forming the conductor plugs by virtue of the high resistance of the former and the low resistance of the latter.

The amount of heat developed by the high thermo-electromotive force, and the consequent temperature rise, is proportional to the square of the resistance, according to the well-known law of Joule. The detector gets its name as indicated above from the fact that this thermal energy is converted or regenerated into a direct electric current, the detector performing the same function as all others that have been devised, namely, that of a very delicate relay.

*In the C. G. S. system the erg is the unit of work and of energy, being the work done in moving a body through a distance of one centimeter against the force of one dyne, or the kinetic force of two grammes moving at the rate of one centimeter per second.

A machine for applying screws at the rate of fifty a minute, if necessary, has recently been placed on the market and consists of a hopper connected by a vertical flexible shaft and tube to the driving mechanism below. The withdrawal of the bit from each screw as it is

THE DETECTOR APPLIED TO A DE FOREST RECEPTOR.

driven causes a new screw to drop out of a magazine and fall in line with the bit and also allows a screw to fall from the hopper into the magazine. The use of the intermediate magazine was found necessary, as the operation of the machine is so rapid that too much time would be wasted in waiting for it to drop from the hopper. The screws are caused to revolve at the rate of 1,200 revolutions a minute by means of a friction drive so adjusted that the screw stops after it has been driven the required distance.

LEDUC'S ARTIFICIAL PLANTS AND CELLS.

BY DR. ALFRED GRADENWITZ.

A strong reaction against the somewhat childish endeavors of the alchemists to convert one element into another and to generate living beings from inert matter, pervades the history of nineteenth century science. Perhaps we have been prone rather too eagerly to discard the doctrines of former times, banishing many theories which in the course of the last few years have again been found worthy of serious discussion.

We are no doubt at present on the eve of great revolutions in our scientific views; the phenomena of radioactivity have shaken the belief in the immutability of the atom and even the principle of the preservation of matter, at least in its familiar form. Nor does the distinction of three strictly separated states of aggregation stand the test of recent investigation; transitions are found to exist between the different states, and we are warranted in presuming that between the material and the immaterial (the luminous ether) there are likewise numberless intermediary states. Finally there have been discovered transitional stages between inert matter and living beings, from which many interesting conclusions in regard to the nature of life can be drawn.

While Prof. Lehmann's recent researches on apparently living crystals have shown that certain bodies, mineral in outward appearance, behave like living organisms of the lowest type (bacteria), Prof. Leduc, of Nantes, has found the vital functions in animal and vegetable cells to be controlled exclusively by the physical laws of diffusion (osmosis) and cohesion (molecular attraction). On the basis of these phenomena he has even succeeded in artificially producing objects which, not only in appearance but in behavior, closely resemble natural cells, growing, absorbing food, and propagating themselves in exactly the same way.

The botanist might be somewhat embarrassed when asked to incorporate in his familiar system of classes, orders, and families the forms illustrated in Figs. 1 to 4. Still he would hardly have any doubt of their genuineness, their whole aspect being typical of representatives of the vegetable kingdom, especially of certain water plants.

Nevertheless, they are not living beings of any sort, but artificial bodies formed in the laboratory of the chemist. While their very aspect is certain to inspire interest, it is obviously far more interesting to observe them in the making, to watch how from an artificial seed a shoot springs and develops (at a rate readily controlled by the experimenter) into stems, leaves, buds, twigs, ears, and blossoms, and after some time dies like a real plant. The birth and death of a plant can thus be artificially reproduced within the space of a few hours.

Below are given some details concerning the artificial seed and the medium in which it is immersed for germination. A seed one to two millimeters in diameter, consisting of two parts of saccharose (cane sugar) and one part of copper sulphate, is immersed in an aqueous solution containing two to four per cent of potassium ferrocyanide, one to ten per cent of sodium chloride or some other salt, and one to four per cent of gelatine. In this solution, the seed germinates in a few days or a few hours according to temperature; under favorable conditions the germinating process can even be shown as a lecture experiment in a few minutes.

The seed surrounds itself with a membrane of copper ferrocyanide which is permeable to water and to certain ions, but is impermeable to sugar. This semipermeability produces a high osmotic pressure in the interior of the artificial seed, resulting in the absorption of matter from the surrounding medium and thus in the growth of the whole structure. If the liquid be spread on a glass plate, the growth takes place in a horizontal plane. In a deep vessel, on the other hand, the plant form grows simultaneously in a horizontal and a vertical direction, forming stems which on arriving on the upper surface of the liquid, spread out in flat leaves resembling those of a water plant.

A single artificial seed one millimeter in diameter can thus produce 15 to 20 vertical stems which sometimes reach a height of 25 to 30 centimeters, being either simple or branched, frequently carrying lateral leaves or twigs and terminals shaped like spheres, mushrooms, ears, spires, etc., according to the composition of the culture liquid.

These experiments thus prove that the functions formerly considered as being characteristic of the process of life are due to and controlled by purely physical forces. In fact, the forms in question obviously receive their food by intussusception or internal absorption like living beings, whereas crystals, as is well known, increase by external accretion. Furthermore, the plant forms are really organized, possessing all those organs (stems, leaves, and terminal parts) which are characteristic of plants. As finally the substance used in building up these artificial plants, viz., copper sulphate, rises in stems up to 30 centimeters in height (with a diameter of one millimeter) they are necessarily provided with an apparatus of circulation. Their growth is thus no doubt a real one like that of a plant, a small (artificial) seed developing into a complex form several hundred times larger than itself.

It is further interesting that the products of growth arising from the artificial seed are, like real plants, susceptible to numerous chemical and physical reactions. In fact, their development is arrested by many poisons, while their direction and growth are determined by differences in the internal diffusion pressure and in temperature. However, there are still further analogies between these artificial organisms and real ones. The former, like the latter, are endowed with the power of healing any injury, as whenever a stem is broken before the completion of its growth, the fragments cling to and combine with one another, after which the process of growth again commences. There is only a single function of living plants which has not so far been artificially reproduced, viz., propagation in successive generations. Except for this defect the whole of the vital process of vegetable organisms would have been imitated artificially, at least in its outward appearance; this problem, however, seems to be susceptible of realization like those already solved.

The internal mechanism of the processes controlling the behavior of these artificial plants will be better understood by briefly referring to Leduc's previous experiments.* In these experiments two mutually precipitating solutions—e. g., potassium ferrocyanide and a salt of copper—were sprinkled on gelatine-coated glass. The copper ferrocyanide deposited at the surfaces of contact of the drops formed the envelopes of polygonal cells. Similar cells are formed when potassium solution alone is sprinkled on the gelatine.

During the process of formation the artificial cell is the seat of active molecular motion, consisting of an inward current of water from the moist gelatine and a current of dissolved matter flowing from the center to the surface. This apparent life can be prolonged by maintaining around the cell an environment that will feed it or replace the loss due to diffusion.

These movements are checked by premature drying but recommence on the addition of water, suggesting an analogy to the latent life of seeds and rotifera.

As the ions or constituents of dissolved salts diffuse independently, part of the molecule appears to be assimilated, or fixed in the cell, while the rest is eliminated. A diffusing drop of copper sulphate, for example, leaves at the center a yellow nucleus consisting of metallic copper. This is surrounded by a blue ring of the unaltered solution which is itself surrounded by a translucent ring containing bubbles of gas due to the action of the released sulphuric acid upon the gelatine.

Fig. 1.—An artificial plant which was produced in a test-tube.

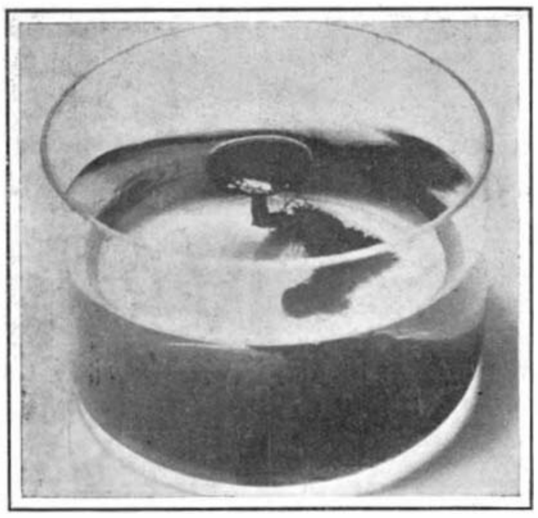


Fig. 3.—Culture of a single artificial grain.

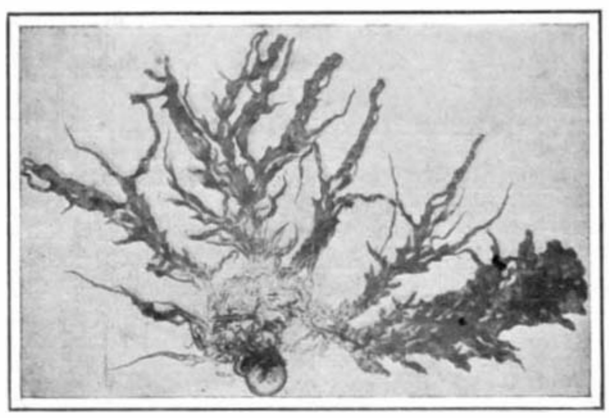


Fig. 4.—Artificial seaweed produced from an artificial cell.

Fig. 2.—Artificial organs showing mushroom shape.

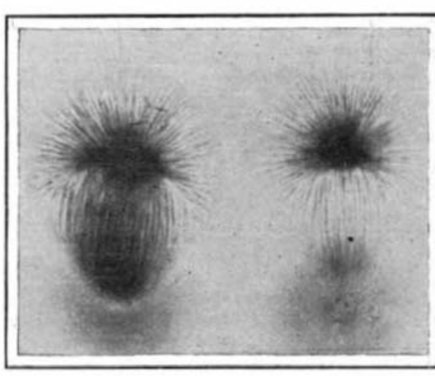


Fig. 5.—Field of diffusion between two opposite poles.

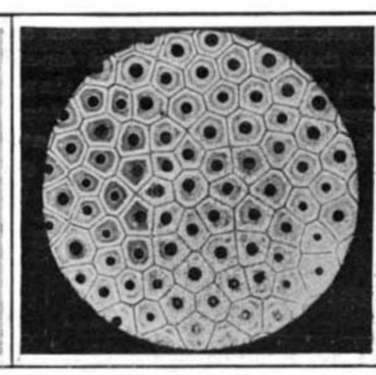


Fig. 6.—Artificial cell tissue.

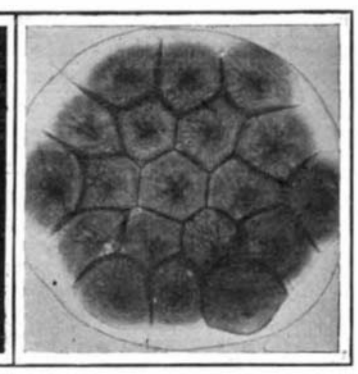


Fig. 7.—Liquid cell tissues.

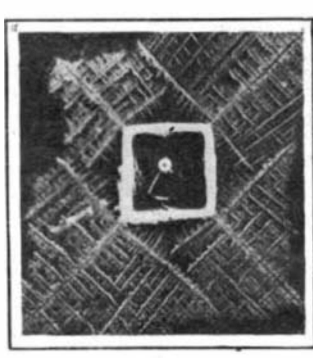


Fig. 8.—Sodium chloride crystal in its field of crystallization.

Fig. 9.—Morphogenetic effect of crystallization.

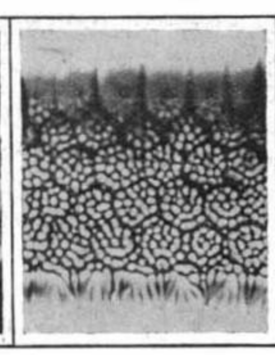


Fig. 10.—Segmentation of liquid artificial cells.

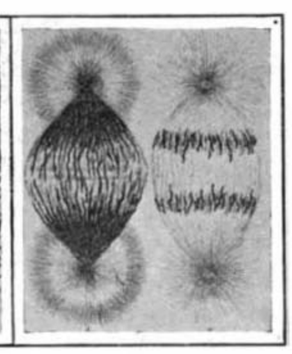


Fig. 11.—Artificial and natural karyokinesis.

LEDUC'S CURIOUS ARTIFICIAL PLANTS, CELLS, AND TISSUES, PRODUCED BY CANE SUGAR, COPPER SULPHATE AND POTASSIUM FERROCYANIDE.

Although they are composed of inert matter, these objects sprout, branch, and nourish themselves like actual living organisms.

Artificial cells are affected in structure and development by moisture, dryness, acids, alkalies, and various other substances added either to the drop of liquid or the surrounding gelatine. In this way many varieties can be produced, including cells with dark or light nuclei, with or without nucleoli, and cells of homogeneous protoplasm without nuclei, like the cells of blue algæ. The protoplasm may be separated from the cell wall and contracted about the nucleus, or it may fill the whole cell. The cells may be naked or surrounded by thick walls. They may be in contact with each other or separated by intercellular spaces, etc. If drops of water tinted with India ink are scattered over a solution of potassium nitrate, the cells, at first radially striped, soon become granular. Then segmentation takes place and the cells break up into polyhedral daughter cells.

The phenomenon of karyokinesis observed in the segmentation of living cells, with the characteristic spindle-shaped figure of curves connecting two focal points, is produced artificially by placing in a viscous fluid a tinted drop of the same fluid between two drops of greater osmotic pressure. The central drop represents the nucleus, the others the centrosomes of the living cell undergoing segmentation. The central drop becomes granular and develops a pigmented ring which represents the chromatic band of the natural process and, like it, breaks up into chromosomes. These move toward the centrosomes and collect about them, forming two nucleated pigmented masses. Meanwhile a partition has formed between these masses which is continuous with their spherical walls, so that finally we have the image of two cells, with nuclei, protoplasm, and cell walls, pressed closely together.

Prof. Leduc also produced in these experiments with drops phenomena of growth similar, on a small scale, to those obtained later with solid "seeds." When a solution of cane sugar containing a trace of potassium ferrocyanide is dropped into a dilute solution of copper sulphate the drop of syrup becomes covered with a pellicle of copper ferrocyanide, forming an artificial cell. Under the influence of the difference of osmotic pressure between the drop and the surrounding liquid, water passes inward through the membrane of copper ferrocyanide which the sugar cannot traverse. The drop, or cell, increases in size and puts forth a bud which is immediately surrounded by a pellicle and proliferates in turn. In this way is formed, slowly, a chain of connected cells, the last of which may have ten times the diameter of the original drop. This scientist, as above mentioned, had succeeded in proving the life of cells to be controlled by the forces of diffusion, the artificial cells and cell tissues obtained by him showing exactly the same behavior as that shown by animal and vegetable cells. The phenomena in question are best represented by considering the seat of the tendency to diffusion as a field of force, in every way resembling Faraday's magnetic and electric fields. In fact, any point in a liquid at which the concentration is greater than in the surrounding parts, represents a center of force of diffusion, and the same remark applies to points of lower concentration than their surroundings. If a point of the former kind be called a "positive pole of diffusion," a point of smaller concentration should be termed a "negative" pole. Now, poles of different kinds (Fig. 5) will attract each other in exactly the same manner as electric or magnetic poles of opposite signs, the general phenomena of motion being precisely the same in the two cases.

Mutual reactions of unlike poles, then, would account for the whole of the physiological phenomena of the organism. In fact they produce liquid currents which carry along any suspended particles, while the mutual reactions of like poles cause suspended particles to be accumulated in the neighborhood of a positive pole, thus producing the phenomenon of agglutination. Even in the production of cell tissues, as shown by the artificial tissue represented in Fig. 6, no other forces are present. By introducing a 5 to 10 per cent solution of potassium ferrocyanide into 5 to 10 per cent solutions of gelatine, the cell tissue represented in this figure is easily obtained; each such cell, like a natural one, possesses an enveloping membrane, protoplasm and a nucleus. With solutions of sodium chloride, however, entirely liquid cell tissues (Fig. 7) are obtained. All the varieties of cells observed in nature can thus be artificially produced by suitably regulating the conditions of the experiment. Even the strange karyokinetic figures produced during the segmentation of cells, and of which no adequate explanation has yet been given, are readily obtained in these artificial growths.

All living organisms are made up of solutions of crystalline substances and colloids; when their concentration increases, the molecular force of crystallization is manifested. Each center of crystallization surrounds itself with a field of force (Fig. 8) that in some cases is rather intricate, and whenever, besides the

* SCIENTIFIC AMERICAN, September 2, 1905.

forces of crystallization, other forces, differences in osmotic (diffusion) pressure, are present, forms are obtained which in their outward appearance resemble certain inferior organisms. As the solid tissues of organisms are produced by solidification from the solutions above referred to, their shape and structure necessarily are influenced by the force of crystallization (Fig. 9).

When drops of a solution are introduced into the same solution at different concentration, these drops at first spread out in all directions; owing, however, to the effect of molecular attraction (or cohesion) there soon takes place a granular segmentation of the liquid (Fig. 10). In fact, as this cohesion between the various molecules is different, those between which the attraction is greatest will combine into spherical grains as soon as the force of attraction exceeds the force of diffusion, while the other molecules fill the intervals between the grains. In this way the phenomena of segmentation observed in germinating eggs, which had previously seemed so puzzling, are not only accounted for but can be readily imitated by an artificial process.

From Lehmann's researches on apparently living crystals it is inferred that certain crystallized structures show a behavior quite analogous to inferior organisms, moving, growing, feeding, and propagating themselves like the latter. The investigations by Prof. Leduc which have been described above, on the other hand, prove that the fundamental element of animal and vegetable organisms, viz., the cell, is exclusively controlled in its vital functions by the same physical laws that govern the forms of the mineral kingdom. From both sides there is thus being constructed a bridge between the province of inert matter and that of living matter, and in the place of the strict barriers previously supposed, we are warranted in presuming the existence of a multitude of gradual transitions and intermediary stages.

It should be observed that the Leduc phenomena were first observed by Traube in 1867 (Archiv. f. Anatomie u. wissenschaftliche Medizin, 1867, p. 67), who produced them. Such artificial cells have long been known as Traube cells. Traube also produced them by means of tannin and lead acetate, water glass and lead acetate, gelatine and tannin, and the like. In repeating Leduc's experiments Prof. Hans Molisch found that the acetate and the chloride of copper produce better results than the sulphate. The sugar, salt, and gelatine serve to increase the growth and ramification, but it should be pointed out that Reinke described branched and tree-like artificial growths more than twenty years ago.* If crystals of copper sulphate are thrown into a solution of water glass they become enveloped in light blue pellicles of copper silicate and these silicate cells develop into tree-like forms if sufficient water glass is present.

Even Leduc's discovery that artificial cells, like natural cells, are affected by various influences was anticipated by Traube, who described the effects of light and gravitation and the variations in form and rapidity of growth produced by adding grape sugar, salt, etc. In Molisch's opinion Leduc's experiments mark no advance beyond the results obtained by Traube in 1867. His artificial cells teach nothing new and they are no more like living organisms than a paper flower is like a real flower or a wax doll is like a living child.

Prof. Gaston Bonnier, of the Académie des Sciences and the University of Paris, entertains very skeptical views of the biological value of Leduc's experiments. These views he has voiced as follows in La Science au XXme Siècle:

"I pointed out to the Academy, in the meeting of December 24, 1906, that these tubular precipitates had long been known and possessed no organization comparable with that of living things. I also repeated before the Academy, some interesting variations of these amusing experiments devised by one of my pupils—a minor. In La Revue of January, 1907, I showed that this alleged discovery was only a repetition of Traube's classical experiments.

"At the meeting of January 7, 1907, Prof. Leduc made a rejoinder to which I replied on January 14, as follows:

"In a lecture just published M. Leduc expresses his amazement that Pasteur's researches have for thirty years silenced the discussion of spontaneous generation, and the *brochure* ends with the words: 'To complete the synthesis of life only one function remains to be realized—successive reproduction. I regard this problem as of the same order with the preceding.' In his communication of last week M. Leduc asserts that his note of July 24, 1905, began with a mention of Traube's work. Here is the mention: 'We have an artificial cell similar to Traube's but differing from it in possessing the power, not only of expansion and enlargement, but also of emitting prolongations analogous to roots and stems, which grow visibly and slowly.' This sentence demonstrates Leduc's ignorance of Traube's writings,* from which I quote as follows:

"'Forms which sometimes resemble a rhizoma with long stemlike upward and rootlike downward extensions.'

"'Soon afterward the cell begins to grow exclusively at the top, so that it passes from a rounded to an elongated form. If the vessel is tipped the extremity continues to grow vertically.'

"'When the pellicle is ruptured the escaping solution soon becomes inclosed in a membrane of precipitate resembling a graft, excrescence, or branch of the cell.'

"Traube's forty-eight series of experiments made in 1865-7, and his later researches, published in 1875, include Leduc's results and many others. And these experiments have been varied almost *ad infinitum* by others. I need mention only Pfeffer's arborescent forms.†

"The conclusion to be drawn from all these experiments is that the form obtained depends on the medium and, to some degree, on the shape of the vessel.

"I have also obtained the Leduc forms by following Traube's general directions. The various salts were thrown into a 5 per cent solution of potassium ferrocyanide or a 10 per cent solution of sodium or potassium silicate. The production of these precipitates is a common lecture experiment. Leduc asserts that all forms obtained by earlier experiments were stunted, unstable, and shapeless but that his culture liquids produce large, stable growths with sharply differentiated roots, stems, and apical organs. But the descriptions cited above show that all of Leduc's results were obtained before him.

"Our colleague, M. Gerner, has produced growths which could be preserved in paper like dried plants and which were mistaken for seaweeds by amateur botanists. Some of these arborescent forms have long been exhibited in apothecaries' windows, especially at Nancy.

"It is difficult to see what new fact is brought out by Leduc's experiments. I am not now speaking of the curious experiments in which he reproduced the structure of organized tissues—that is a different question.

"In his notes to the Academy, Leduc asserts that his pretended artificial plants give evidence of cellular structure, circulating system, thermotropism, osmotropism, and nutrition.

"It is well known that the forces which act in living beings are simply physico-chemical forces. Traube and others have studied the effect of these forces on semipermeable membranes and Leduc has added nothing to their results. As for cellular structure and circulatory system nothing of the sort is to be found in these tubular precipitates.*

"It has been maintained that Leduc has made no claim to the creation of life by spontaneous generation, but this assertion is contradicted by his own words, quoted above.

"The net result of the whole affair is simply *nil*."

* Reinke, Botanische Zeitung, 1875, p. 432.

* Moritz Traube, Centralblatt für medizinische Wissenschaft, 1865. Archiv. für Anat., Phys. und wissenschaftliche Medizin, 1867, p. 87. Botanische Zeitung, 1875, p. 56.

† Pfeffer, Osmotische Untersuchungen, 1877, p. 11. Botanisches Institut, Tübingen, 1886, vol. ii., p. 30.

* Prof. D'Arsonval, who presented Leduc's note, has recently (January 21, 1907) presented a communication from Charrin and Goupil describing experiments which prove that no phenomenon analogous to nutrition occurs in the production of these arborescent growths.

AN EXPERIMENT IN ACOUSTICS.

As the running boys pass the bell there is a distinct drop in pitch

AN EXPERIMENT IN ACOUSTICS.

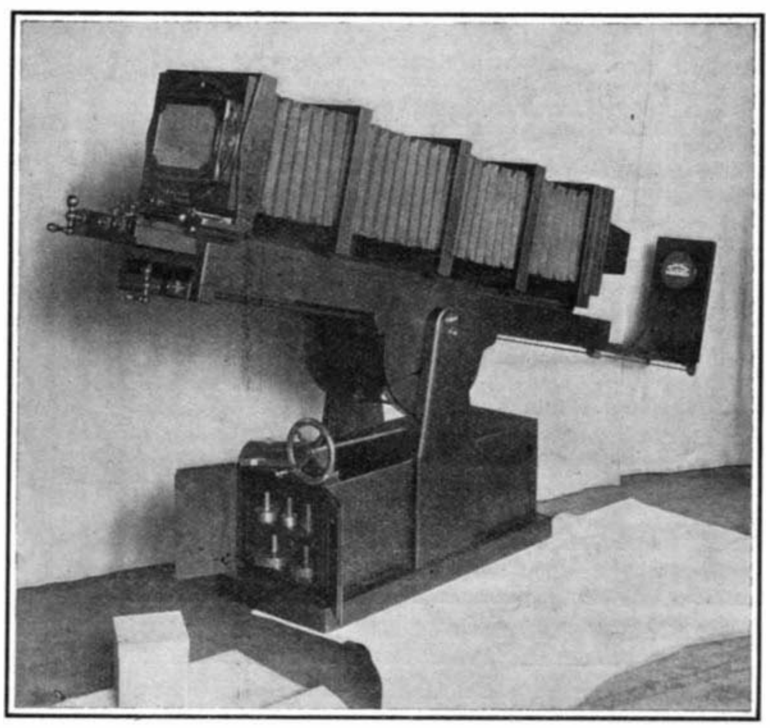
BY GUSTAVE MICHAUD.

The school bell and good legs are all that are needed for this experiment. Students who make it find it easier, as a rule, to understand the relation between pitch, wave length, and the number of vibrations. Where elementary astronomy is taught, the same experiment may prove to be a helpful as well as a healthful diversion during the study of a rather abstruse chapter—the application of the spectroscope to the determination of the radial motion of stars.

Select the swiftest runner of the school. Give him a bell, and place him on level ground at some hundred feet from the rest of the class. At a signal, the students run as fast as they can toward the bell bearer, while he himself runs toward the students, without ceasing for a moment to ring his bell. So long as some distance remains between the students and the bell, nothing abnormal seems to occur, although the students, without being aware of it, perceive a sound of a somewhat higher pitch than that which strikes the ear of the bell bearer. But at the precise moment when the runners pass the bell, and instead of running toward it begin to run away from it, there is an instantaneous and very distinct dropping of the pitch of the sound, which remains graver as long as the distance increases between the runners and the man who rings the bell.

While the hearers are running toward the source of vibrations, they meet, in a given time, a greater number of these than if both the bell and the boys had remained in the same place. When the bell bearer and the students ran away from each other, the hearers go in the same direction as the vibrations, and the reverse phenomenon occurs—the number of vibrations which reach the ear in every second is smaller than it would have been had all the participants remained on the spot. As the pitch of a sound depends upon the number of its vibrations per second, that of the bell will drop at the very moment when the distance between bell and hearers ceases to decrease and begins to increase.

If the man who rings the bell can be provided with a bicycle, the fall in the pitch of the sound is of course still more pronounced.



SPECIAL CAMERA FOR COPYING AND ENLARGING.

SPECIAL CAMERA FOR COPYING AND ENLARGING.

The camera illustrated here is one that was designed and built for the United States Geological Survey for photographing fossils or other similar objects. In photographing fossils the Survey uses a process known as the Williams process. This method was worked out by Prof. Henry S. Williams and Norman W. Carkhuff, and consists in an elimination of the color of the fossil by a process of sublimation.

Fossils cannot be photographed for scientific purposes in a haphazard manner. There are certain characteristics that must always be orientated in relatively