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.

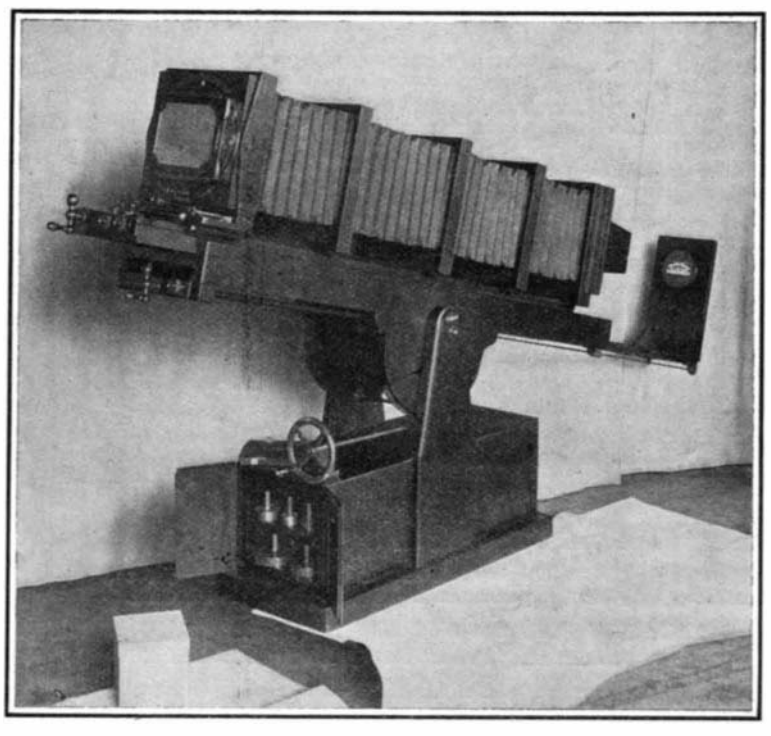
"It is well known that the forces which act in living beings are simply physico-chemical forces. Traube and others have studied the effect of these forces on semi-permeable membranes and Leduc has added nothing to their results. As for cellular structure and circulatory system nothing of the sort is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

AN EXPERIMENT IN ACOUSTICS.

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



SPECIAL CAMERA FOR COPYING AND ENLARGING.

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.

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

* 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.