two species of Orchestidæ found at Woods Holl, Mass., *Talorchestia longicornis* and *Orchestia agilis*. *Talorchestia* was found to be positively phototactic at all times both in strong and in weak light. *Orchestia agilis* is somewhat less strongly positive since, for a short time after it is taken from the dark, it becomes negatively phototactic, but exposure to the light soon makes all the individuals strongly positive and they remain so even in direct sunlight. Both these species when exposed to direct sunlight remain positively phototactic until overcome by the heat of the sun. Yet the animals when they come to rest are found in shaded spots and, during the daytime, remain unexposed to the light; they are photophobic, but positively phototactic. Observations were made on twenty-two species of aquatic amphipods, all of which were found to be negatively phototactic. It was found that when the terrestrial *Orchestia agilis* were thrown into sea water their phototaxis immediately changed from positive to negative; when taken out of the water the reverse change occurs, and this change was shown to be independent of temperature.

Orchestia agilis, when brought from strong light, in which it is strongly positive, to weak light, immediately becomes strongly negative, a result which, it is believed, has been observed in no other form. When left in weak light the negative phototaxis disappears and all the specimens become positive again. This result was shown to be independent of temperature. Specimens rendered negative by being brought into a dimly lighted room after exposure to strong light become positive more quickly if the temperature is raised. Exposure to darkness or to very strong light renders *Orchestia agilis* temporarily negative in light of medium intensity.

In *Talorchestia*, *Orchestia*, and several species of insects that are positively phototactic it was found that, when one eye is blackened over, the animal travels in circles with the unblackened eye looking towards the center. In several negatively phototactic forms blackening one eye was found to produce circus movements in the other direction, the unblackened eye looking away from the center. *Orchestia agilis* may be caused to execute circus movements in the one or the other direction according to whether it is placed in air or water.

H. S. JENNINGS,
Secretary.

DISCUSSION AND CORRESPONDENCE.

THE ELECTRICAL THEORY OF GRAVITATION.

PROFESSOR FESSENDEN in a recent number of SCIENCE discusses the nature and velocity of gravitation. There is, no doubt, something of value in Professor Fessenden's suggestions and much that is new. However, the explanation of gravitation which Professor Fessenden offers is by no means so adequate as would appear from Professor Fessenden's discussion.

In the first place, *Quantitative Mathematics*, as Professor Fessenden styles his papers on Dimensions, has little or nothing to do with the thing. The present writer makes this statement not entirely as an expression of his own opinion, but quite as much as an expression of opinion of every physicist with whom he has talked on the matter. Professor Fessenden claims to have derived *numerical functional relations*, with the aid of his 'Qualitative Mathematics,' and this is believed on definite rational grounds by most physicists to be impossible.

One of the best examples of the application of 'Qualitative Mathematics' is its application by Lord Rayleigh (*Philosophical Magazine*, October, 1899), in his 'Investigation on Capillarity.' In this instance the weight of a drop of water falling from the end of a glass tube is shown to be a certain function of radius of tube, density of water, acceleration of gravity and surface tension of water *multiplied by an unknown function of these quantities having zero dimensions in length, mass and time.* This unknown and unknowable function—to be determined by experiment only—Fessenden seems to lose sight of in his 'Qualitative Mathematics.' The reader who wishes to get the gist of Professor Fessenden's suggestions as to the nature of Gravity may therefore, as it seems to us, ignore what he says of, and is led to say by 'Qualitative Mathematics.'

The following is a brief and fairly simple outline of the electrical hypotheses which are now held by physicists in the attempt to explain the ultimate constitution of matter and the nature of inertia and of gravitation.

Electrically charged bodies are of two kinds, namely, positive and negative. Like charges repel and unlike charges attract. The energy associated with two charged bodies is seated in the ether which surrounds the two bodies and is due to the electrical field or ether stress. When *unlike* charges approach, the energy of the ether stress diminishes and the outside work done by the attraction of the charges is equal to the diminution of the energy of the ether stress. Similarly, the energy of ether stress, which is associated with two *like* charges, increases when the charges are pushed towards each other and the increase of the energy of the ether stress is equal to the work done in pushing the two charges nearer together.

In general, attraction of two bodies is to be attributed to ether energy, which *decreases* as the bodies approach each other, and repulsion of two bodies is to be attributed to ether energy, which *increases* as the bodies are made to approach each other. Physicists have known this many years and, as regards gravitation, no satisfactory clue has yet been found concerning the nature of the accompanying ether energy and concerning its mode of propagation from place to place.

It is now pretty well established, that the ether energy having to do with electrical attraction and repulsion is dependent upon a sort of *shearing distortion* of the ether unaccompanied by any sensible diminution of volume, that this ether distortion is what is known as *electric field*, that the propagation of this energy constitutes *electrical waves*, and that the movement of the ether which comes into play during the establishment of this shearing distortion, or which comes into play while distortion at one place is relieved and distortion at a contiguous place is built up, is what is known as *magnetic field*.

It may be that the ether distortion which we call electrical field is accompanied by a very slight diminution of volume of the ether, especially inasmuch as Maxwell showed that the mechanical stresses in the dielectric tend to produce diminution of volume as well as to produce shearing distortion. These mechanical stresses are proportional to the square of the field intensity at each point.

If we admit that the diminution of volume of the ether at each point is proportional to the resultant intensity of the electric field, then the part of the energy which depends upon diminution of volume cannot be separated in its effects from the part of the energy which depends upon the shearing distortion, inasmuch as both are proportional to the square of the resultant field intensity. Therefore a diminution of volume of the ether could not explain gravitation, but would only be involved in the explanation of ordinary electric attraction and repulsion. Professor Fessenden in his article above referred to speaks quite in general of the compression of the ether near a charged body (or ion) without localizing this distortion.

Before proceeding to a statement of what must constitute the characteristic features of an explanation of gravitation, as opposed to an explanation of electric attraction and repulsion, for the reader will certainly think of an explanation of the one as applying satisfactorily to the other also, so far as the above discussion goes, it is necessary to outline briefly the present hypothesis that the inertia of an atom, or rather that the inertia of a corpuscle, is due to its electric charge.

It has been known for some years that a moving electrically charged body has more kinetic energy for a given velocity than if it were not charged; that is, the acceleration of a charged body by a given force is less than if the body were not charged; that is, the inertia of a charged body is greater than if it were not charged. This excess of energy of a moving, charged body—for the whole matter lies in the question of energy—is due to two things, as follows:

First, The dying away of the electric field in regions passed through by the body and the building up of electric field in regions newly reached by the body is accompanied by an ether motion known as magnetic field, as above stated, and this magnetic field represents energy.

Second, The motion of a charged body tends to concentrate the electrical field or ether stress in and about a plane passing through the body and at right angles to the direction in which the body is moving. This concentration of the electric field causes, on the whole, an increase in the total energy of the electric field.

A curious fact, assuming the truth of the following hypothesis, is that the energy of a moving body is *not* proportional to the square of its velocity, but exceeds this by an amount which becomes infinite when the body attains the velocity of light, although this excess of energy at ordinary velocities is exceedingly small. If it were not for the tendency of electrical field to become concentrated in a certain plane as described above, the energy of a moving body would be strictly proportional to the square of the velocity, assuming the truth of the hypothesis which is now to be stated.

The excess inertia due to the electric charge on a body, or briefly, the inertia of the charge is greater and greater the smaller the body. Atoms, however, are not small enough for us to attribute *all* their inertia to the charge which they carry when they are in the form of ions. The corpuscles, of which J. J. Thomson builds an atom like a bricklayer builds a house, and to the hypothetical existence of which Thomson was led by the study of cathode rays, are perhaps small enough.

The electrical hypothesis of the constitution of matter, is that atoms of matter are built up of corpuscles, and that these corpuscles are mere bits of electric charge, some positive and some negative surrounded by electric fields, or rather that these corpuscles are mere strain centers in the ether surrounded by regions of ether stress.

This hypothesis of the constitution of matter serves well for the interpretation of the perplexing class of phenomena attending the discharge of electricity through gases and it explains that fundamental property of matter, inertia.

Now we have two distinct measures of mass, namely: One body is said to be twice as massive as another, or to contain twice as much matter, when it is *accelerated* at half as great a rate by the same force or when it is *attracted* by the earth or any third body by twice as great a force. The first measure of mass is sometimes called inertia and the second is often, in daily life, called weight, and it is remarkable that these two measures agree with each other to a great degree of precision. One might expect, therefore, that an hypothesis as to the constitution of matter which clears up the nature of inertia, even provisionally, would throw some light upon the nature of gravitation, but it does not seem to be so, and Professor Fessenden must needs say more from his point of view and with greater precision before we shall be convinced. The difficulty to be encountered in the explanation of gravitation from the point of view of the electron hypothesis, as Johnstone Stoney calls it, seems to be as follows:

Imagine all corpuscles to consist of equal positive or negative charges, this indeed is assumed by J. J. Thomson, the only present need of this assumption is to permit of simple statements. Then, if those approximate facts which we call the laws of electrostatics were true, Newton's law of gravitation (?) would have to do only with *electric attraction and repulsion*, and it would run thus: every corpuscle of matter in the universe attracts or repels every other particle with a force which is inversely proportional to the square of the distance between them.

Two opposite charges may be said to be equal in value when they are acted upon by equal and opposite forces when placed in a uniform electric field. Now if two such charges of opposite sign attract each other with a slightly greater force than the force of repulsion of two precisely equal charges of the same sign, then two aggregations of equal numbers of positive and negative corpuscles would on the whole attract each other, because the oppositely charged corpuscles in the two aggregations would attract each other a little more than the similarly charged corpuscles would repel. Thus gravitation would be due to the fact that the *attraction* of equal and opposite charges would be slightly greater than the *repulsion* of like charges of the same value. This inequality of attraction and repulsion of equal charges would exist if the relation between stress and strain in the ether were not a linear relation, that is, if ether strain were not proportional to ether stress, for in the case of opposite charges the ether stresses are on the whole more intense and less widely distributed than are the ether stresses in case of two like charges of the same value at the same distance apart. It would be a comparatively simple matter to determine the amount of deviation from proportionality of stress and

strain which would suffice to account for gravitation. But the outstanding difficulty would be to explain the high velocity of propagation of gravitation which seems to be required by the known behavior of the solar system under the action of the sun's gavitation.

Of course it may be that the failure of the linear relation between ether stress (electric field) and ether strain is associated with ether compression, and it might be possible to explain in this way the high velocity of the propagation of gravitation. The point, however, which we wish to emphasize is that mere ether compression alone is not sufficient to explain gravitation; at least the compressional energy must not be proportional simply to the square of the resultant field intensity, for in this case the compressional energy would not be distinguishable from the distortional energy which gives rise to the ordinary electric attraction and repulsion. If, however, the compressional energy were proportional to the fourth power of the resultant field intensity, then the ether compression would not stand in a linear relation to electric field intensity (ether stress), and the above remarks concerning excess of the electric attraction over repulsion would apply and gravitation would be provisionally explained.

W. S. Franklin.

THE HOMING INSTINCT OF A TURTLE.

To the Editor of Science: The following account from a friend, Miss Victoria Hayward, of Bermuda, may be of interest to your readers. I can vouch for the accuracy of the relater, and know from experience that the locating of an area on the reefs is as easy to a Bermudan as if it were on dry land. Miss Hayward writes:

"My father caught a turtle in June that weighed seventy-five pounds. He placed it in a pond in the harbor of St. George. In August on going to the pond he found that some person had thrown a piece of iron weighing about fifty pounds into the pond and it had broken a large hole in the turtle's back. It had been wounded apparently about a week and was weak and seemingly dead. My father thought he had better kill it, but he changed his mind, and let it go alive into the harbor.

"In the latter part of October he and another man recaptured it in the same place where they had caught it before—about four miles from land, on the flats (reefs) that lie to the north of the islands. The back was nicely healed and the turtle was altogether in excellent condition. You know that it requires no little knowledge of the art of navigation for a turtle to find the way from the southern side of St. George's Harbor through some one of the many little channels to its own special home on the north reefs—four miles out to sea."

C. L. Bristol.

BOTANICAL NOTES.

PEACH LEAF CURL.

According to a bulletin (No. 20) prepared by N. B. Pierce and recently issued by the Division of Vegetable Physiology and Pathology of the United States Department of Agriculture, this disease appears to exist wherever the peach is grown. It is known to occur in North America, South America, Europe, South Africa, New Zealand, Australia, Japan and China. It is due to the presence of a minute parasitic fungus—*Exoascus deformans*—one of the simpler of the sac fungi—(Ascomyceteae). The fungus attacks the parenchyma of the leaves and twigs, enlarging, thickening, curling and distorting them. Eventually the leaves become yellowish and fall off, involving as a consequence the wilting and dropping of the fruit. It has been estimated that the annual loss in the United States from this source alone amounts to between two and three millions of dollars.

Mr. Pierce's paper discusses not only the structure of the fungus and the nature of the disease, but includes records of the many experiments which he made in order to determine what are the most efficient means for preventing or combating the disease in the orchard. He recommends spraying with Bordeaux Mixture of the following proportions: Copper sulphate, five pounds; lime, five pounds; water, forty-five gallons; applying it with what is known as a 'Cyclone Nozzle,' and doing the work from one to three weeks before the opening of the blossoms in the spring.