stead being treated with animal manure at a total outlay of \$13 per acre. There was a general improvement in the inoculated crops with a gain of four bushels of grain to the acre. A similar improvement marked the clover tract, while the peas which had failed of cultivation upon the farm were completely successful. In the case of the beans six of the seven acres were inoculated, the remaining acre being reserved as a control. Prior to planting, three out of

others are similarly associated with Uranus. These various comets are frequently called the "planets" families" of comets, and they are supposed to have become so in the following way: A comet coming from outer space into our system toward the sun will have its rectilinear motion converted into a parabolic one, will approach the sun with increasing speed till it arrives at its nearest point (perihelion), and then once more recede from it. If, however, it comes near

tion of all three is in longitude 101 deg. and latitude 35 deg. S. Seven comets have been found having their greatest distance at about 100 times the earth's distance from the sun, and four of these have their orbits lying nearly in a plane passing through the sun. He, therefore, suggests that this is in all probability the true plane of the orbit of an unknown planet revolving at about that distance from the sun, and consequently having a period of revolution of about 1,000 years, in accordance with Kepler's third law. [The squares of the periodic times of revolution are as the cubes of the mean distances from the sun. Expressed in terms of the earth's distance and period as units $(100)^2 = 1,000,000 = (1,000)^2$.] The dates at which the comets were in aphelion were found to agree fairly well with the dates on which a planet of the periodic time of 1,000 years would be found in or near those four positions; so that the position of the unknown planet may be considered approximately known. Estimates formed by roughly calculating the probable disturbances produced by this planet upon Neptune give such small quantities for the perturbations that no certain evidence of its existence is likely to be obtained by this method at present, unless its mass be enormously greater than that of Neptune, though sooner or later its presence may be thus revealed. Prof. Forbes has estimated that the unknown planet has a mean distance from the sun 105 times that of the earth (more than three times Neptune's distance), that the inclination of the plane of its orbit to the ecliptic is about 52 deg., and that its elliptic orbit has an eccentricity of about 0.16. The fact of the inclination of its path to the ecliptic causing it to be for a large part of its revolution outside the region of the Zodiac, in which the search for new planets has been mainly carried on, may perhaps be the reason that it has hitherto escaped detection. Prof. Forbes concludes that its present longitude in its orbit is about 202 deg. (or 216 deg. with regard to the ecliptic), and its south latitude (distance from the ecliptic) is 34 deg. It is consequently at present only to be looked for in the southern hemisphere or from observatories nearer to the equator than we are.

Prof. W. H. Pickering has just given the place of a supposed trans-Neptunian planet. Its present position is in R. A. 7 h. 47 min., north declination 21 deg.; or in the southeastern part of the constellation Gemini (the Twins). This cannot be the same object as that referred to by Prof. Forbes, but nothing seems to prevent there being two or more bodies moving in planetary orbits outside the orbit of Neptune. It is quite certain that there are many comets revolving in elliptic orbits and thus returning from time to time to perihelion, which recede to far greater distances from the sun. For instance, the famous comet of 1680,

Accelerated Germination Due to Inoculation; Sweet Peas Sown in Moss. The inoculated on Right; Germination in 4 days. Non-inoculated, 7 days.

Clover After 54 Days' Growth. Top Box Inoculated; the Bottom Non-inoculated.

Inoculated Seed Sufficient for from Twelve to Fifteen Acres of Land Costs Only \$1.25.

the seven were manured at a cost of \$30 per acre. The yield of the inoculated showed an increase of 40 per cent, at a cost of \$1.25 as compared with \$120 for fertilizer. In some of the experiments it may be pointed out that the bacteria were two years old, which proves the efficiency of the preserving process.

At a recent exhibition of the Royal Society of Great Britain photographs and growing specimens were shown, illustrating the inoculation of the roots of the leguminosæ. Some of these are pictured in the accompanying half-tones. It will be observed that the inoculation produces a marked increase of nodules on the roots, these lumps contributing materially to the growth of the plant by augmented extraction of nitrogen from the air, also that plant germination is appreciably accelerated as well as the growth, thereby enabling the produce to be gathered in a much shorter period.

Owing to this success, Prof. Bottomley endeavored to discover a culture for the treatment of non-leguminous crops. The tomato plant was selected, and at last he succeeded in finding a culture for this species. He has found cultures for roses and strawberries. The experiments with these are still in progress, with the aim of determining the precise bacteriological culture suited to every type of plant. While making no claim to the discovery of the action of these organisms, which were first ascertained by Hellriegel, Prazmowski, and Nobbe, he has continued the work from the point where the last named failed to discover a preserving medium.

IS THERE A TRANS-NEPTUNIAN PLANET?

By F. W. HENKEL, B.A., F.R.A.S.

IN 1877 Prof. Todd, from a graphic investigation of the still outstanding differences between the computed and the observed places of Uranus, after allowing for the action of Neptune, considered that an unknown planet existed lying beyond the latter. He accordingly made search for it with the great Washington telescope, but was unable to find any such body.

Prof. George Forbes has recently revived some earlier calculations indicating the possible existence of a trans-Neptunian planet, and he considers his former speculations have been greatly strengthened by additional facts unknown to him at the earlier period. He thinks that three comets which appeared in 1843, 1880, and 1882 are in reality parts of the comet of 1556 (sometimes known as the comet of Charles V, from its appearing at the time of that monarch's abdication), which has been broken up by the action of an unknown planet lying beyond Neptune. It is well known that the planets Jupiter, Saturn, Uranus, and Neptune are associated in an especial way with particular comets. For instance, the short period comets known by the name of Faye, De Vico, Brorsen, and Encke, which revolve in elliptic orbits having periods of revolution round the sun of from three to eight years, all of them approach at certain parts of their orbits very close to that of the planet Jupiter. Similarly, Halley's comet, whose return is hourly expected, Olbers's comet of 1812, and Pons's comet of 1812, rediscovered by Mr. Brooks in 1833, approach very near to the orbit of Neptune, their greatest distance from the sun (aphelion) lying a little beyond that planet. Tempel's comet and two

a planet in its motion its speed will be either accelerated or retarded. If accelerated, the parabola becomes a hyperbola and the comet moves off even more quickly from the sun after perihelion. If, however, it is retarded, the parabolic orbit is changed into an ellipse, which is a closed curve, and the comet will now become a permanent member of the system, moving in a path which will pass through the region where the disturbance originally took place. The successive diminutions of velocity may greatly transform the comet's original orbit. The converse instance of an increase of speed seems to have happened in the case of Lexell's comet of 1770, which, it is thought, has had its elliptic orbit made hyperbolic by the action of Jupiter.

Another theory as to the origin of comet families, suggested by the late Mr. Proctor, supposes these bodies to have been thrown off by some kind of eruptions from the sun and planets—e. g., that the comets of Jupiter's family once formed part of his mass, but were rejected with sufficient speed to set them free in space, though still under the sun's influence.

Bean Roots, Showing Nodules in Which Nitrogen-Fixing Bacteria Work.

Peas. Left Inoculated, Giving Greater Root Growth and Vitality. Right Not Inoculated.

INCREASING THE SOIL'S NITROGEN CONTENT.

On either theory we see that there must be some connection between the comets and the planets to whose families they respectively belong.

As we have seen above, Prof. Forbes considers the three comets 1843, 1880, and 1882 were originally parts of one and the same body. Their aphelion (greatest) distance from the sun is about the same, 88 times the earth's distance, and the common posi-

which approached so very close to the sun at perihelion that it must have passed through the outer regions of the solar atmosphere, its distance being only about 55,000 miles from the sun's center at that time, recedes in its aphelion to a distance 850 times the earth's distance, or 28 times that of Neptune from the sun. The amount of light and heat received by an equal area of the comet at these respective times

must accordingly be 19,000 million times more in perihelion than in aphelion, and its velocity also subject to enormous variations. The apparent diameter of the sun would only be 2 sec. when seen from the comet at aphelion, while in perihelion, according to Newton, the comet would be subject to a heat "2,000 times that of red-hot iron," the sun subtending an angular diameter of 85 deg. Owing to the rapidity of its motion, however, the comet would only be subjected to this intense heat for a very short time.

At the other end of our system we have the question of an intra-Mercurial planet. Leverrier, the great French astronomer and one of the discoverers of Neptune, found in 1859 that the motion of Mercury is such that the perihelion (or point of least distance from the sun) changes its position in a manner which cannot be altogether accounted for by

the action of the other known planets. It might be explained by the attraction of a planet or a number of small planetoids revolving inside Mercury's orbit and lying nearly in the same plane.

Dr. Lescarbault, a French country physician, announced that he had seen a planet crossing the sun on March 29th, 1859. He was visited by Leverrier who, after severe cross-questioning, apparently satisfied himself that Lescarbault's observation was a genuine one, and calculated an orbit therefrom, the name of Vulcan being given to the supposed planet. However, it has never been certainly seen again, though, if real, it ought several times to have been visible in transit across the sun.

Very careful observations at the times of solar eclipses should certainly reveal the presence of such a body; but so far no one else has yet found the

planet, though both Prof. Watson and Mr. Swift, during the eclipse of 1878, thought they saw two bright objects which could not very well be identified with any known stars. Later investigations made by Dr. Peters have shown that Prof. Watson's stars may very possibly have been the stars θ and ζ Cancri; but, so far, Mr. Swift's observations remain unexplained. However, up to the present, no planet lying nearer to the sun than Mercury has been certainly found. Prof. Young considers it "extremely probable that there are a number—perhaps a very great number—of intra-Mercurial asteroids," perhaps each of them not having a diameter exceeding 50 miles or so. So small objects, lying very near to the sun, would be nearly certain to escape detection either in transit or during an eclipse.—Knowledge and Scientific News.

SOME COSMICAL ASPECTS OF RADIOACTIVITY.*

THE DISTRIBUTION OF RADIOACTIVE MATTER.

BY E. RUTHERFORD.

Concluded from Supplement No. 1739, page 283.

DISTRIBUTION OF RADIOACTIVE MATTER IN THE EARTH'S CRUST.

ELSTER and Geitel early observed that many caves and cellars, in which the air had been confined for long intervals of time, were unusually rich in the radium emanation. This was shown by the strong activity observed on negatively charged wires exposed in these confined places. Such a result is to be expected if the radium emanation continuously escapes from the soil, for the amount of it present must increase in such confined spaces. This led them to make an examination of the activity of soils. All were found to be active and many gave off the radium emanation. This effect was especially marked in clayey soils. J. J. Thomson and others showed that the water in many deep wells and springs was impregnated with the radium emanation. The presence of the radium emanation is especially marked in many of the hot springs distributed throughout Europe. Elster and Geitel observed that the sediment from certain hot springs in Italy was unusually rich in radium. Blanc showed that the sediment from certain hot springs gave off freely the thorium emanation. A very great deal of work has been done along these lines in the last few years, and radioactive matter has been found to be very widely distributed, in small quantity, over the earth's crust. The continent of North America has not been so systematically examined as Europe, but Boltwood has shown that a large amount of radium emanation is present in the waters from many deep-seated springs in various localities in the United States. McLennan and Burton have shown that the petroleum from the oil wells in Ontario contains a considerable quantity of radium emanation and also a trace of radium.

There appears to be no reasonable doubt that the earth is the source of the emanation in the atmosphere. This emanation escapes from the soil by the process of diffusion, or is borne to the surface in spring water and is then distributed by the winds. On account of the rapidity of the transformation of the emanations of thorium and actinium compared with that of radium, it is to be expected that the radium emanation will predominate in the atmosphere, and it is a matter of some surprise that the thorium emanation is present in such large amount as is observed in some localities. The emanation of radium must diffuse slowly through the earth, disappearing with time, and it is to be expected, that, apart from deep-seated springs, most of the emanation observed in the air must be derived from a thin skin of the earth's surface not more than a few feet deep.

INTERNAL HEAT OF THE EARTH.

It is thus natural to suppose that there is a very large quantity of radium and other radioactive matter distributed over the surface of the earth. This radioactive matter must be continuously supplying heat to the earth, and it is of great interest to examine the magnitude of this heating effect and its probable bearing on the question of the origin and duration of the earth's internal heat.

In addition to the various properties I have enumerated, radium also gives out heat continuously and uniformly at a rapid rate. A quantity of radium supplies enough heat to melt more than its weight of ice per hour. A pound of radium in the course of a year will emit as much heat as that resulting from

the combustion of 100 pounds of good coal. This heat emission of radium and of all the radioactive bodies is in reality a secondary property, for it is a consequence of the bombardment of the active matter by the α particles expelled from its own mass. The β and γ rays produce only a small percentage of the total heating effect. This heating effect of radium must always be proportional to the quantity of radium present and must persist, however sparse may be the distribution of radium throughout the earth's crust. Consequently, there must be a continuous supply of heat to the earth due to the radium and other radioactive matter distributed throughout it. But the heating effect due to a given quantity of radium does not last indefinitely. The radium breaks up into other forms, and after 20,000 years only a small fraction of the radium would remain. This difficulty, however, is not serious, for it is now definitely settled that radium is produced from uranium, and it is found that in old minerals the amount of radium is always proportional to the amount of uranium.

Now uranium is transformed extremely slowly in comparison with radium, and probably a period of at least one thousand million years would be required before the uranium was half transformed. Consequently, the supply of radium from the breaking up of uranium will keep up the amount of radium in the earth to a nearly constant value for periods measured by hundreds of millions of years.

We shall now consider briefly the ordinarily accepted theory of the origin of the earth's internal heat and of the age of the earth. It is known that the temperature of the earth steadily rises as we proceed from the surface inward, and on an average rises 1 deg. F. for every fifty feet of descent. From the evidence of volcanic action, it is concluded that the interior of the earth is at a high temperature.

Lord Kelvin attacked this question of the age of the earth by supposing that the earth was originally at a temperature of molten rock and has since that time gradually been cooling by the radiation of heat through the surface into space. According to this theory, the temperature gradient near the surface of the earth has been gradually decreasing. Knowing the temperature gradient to-day, and the average conductivity and specific heat of the materials of the earth, it is possible by the aid of Fourier's celebrated analysis to deduce the interval that has elapsed since the earth was a molten mass. Some of the values of the quantities necessary in the calculation are uncertain within limits, but Lord Kelvin concluded that certainly not more than 100 million years can have elapsed since the surface of the earth was at a temperature capable of supporting animal and vegetable life. In later papers this estimate has been still further reduced, and the age of the earth is put as low as forty million years. I cannot here enter into the intermittent controversy that has raged for nearly half a century between Lord Kelvin on the one hand and the geologists and biologists on the other. The latter initially required a much longer period for the progress of geologic and biologic evolution than that allowed by Kelvin, but there appears to be a general consensus of opinion among geologists and biologists to-day, that a period of 100 million years allows sufficient time for the process of evolution.

On the assumptions made by Lord Kelvin, there is no doubt of the general accuracy of the deductions. Let us, however, examine these fundamental premises.

The earth is assumed to be a cooling body isolated in space, and it is assumed that there has been no supply of heat to the earth since the cooling began; for Kelvin has conclusively shown that the heat supplied from ordinary chemical processes, that may be supposed to occur in the earth, is not sufficient to influence materially the conclusion as to the age of the earth's heat. But the discovery of the presence in the earth of active matter like radium which emits heat at a rapid rate, at once suggests the possibility that the earth is not a simple cooling body, but one in which heat is being steadily generated. In 1902, I made some calculations to determine how much radium (or other radioactive matter expressed in terms of radium) would be required to be uniformly distributed throughout the earth in order to maintain the present observed temperature gradient. In such a case, the heat supplied by the radium must exactly compensate for that lost from the earth by conduction to its surface and radiation into space. The calculations are simple, and show that a uniform distribution of radium amounting to only 1.7×10^{-13} gramme of radium per cubic centimeter would suffice. From the data then available, I calculated that the amount of radium present in the earth was probably of the right order of magnitude to produce such a result.

Recently, the Hon. R. J. Strutt has made a number of systematic observations to determine the distribution of radium in the typical rocks of the earth's crust, and has obtained results of remarkable interest. Strutt collected a number of typical rocks, both igneous and sedimentary, obtained from widely different localities, and determined the amount of radium contained in them. The rocks were first of all obtained in solution and placed aside in closed vessels. After a definite time the emanation, generated by the radium contained in them, was boiled out, and passed into a suitable electroscope. The amount of radium in the solution was then determined by comparison with the effect in the electroscope due to the emanation from a standard solution containing a known quantity of radium bromide.

The following table shows the observed amount of radium in grammes per cubic centimeter of rock for samples of igneous rocks.

I mentioned before that about 1.7×10^{-13} gramme of radium per cubic centimeter distributed uniformly throughout the volume of the earth, would keep up the earth's internal heat. An examination of the table, however, shows that the surface rocks contain far more radium than this. As we should expect, the radium content varies considerably, but the poorest rock of all, Greenland basalt, contains more than ten times this estimate, while the average rock contains fifty or sixty times as much. An examination of the sedimentary rocks shows an average amount of radium somewhat smaller than that of the igneous rocks, but still of the same order of magnitude. Strutt considers that 5×10^{-12} gramme of radium per cubic centimeter is a fair average for the surface rocks of the earth—a quantity thirty times greater than that required to maintain the present temperature gradient. This is a surprising result, for although of necessity only a small number of rocks have been examined, yet we must consider that the results obtained by Strutt probably give the right order of magnitude for the distribution of radium in the earth's crust. It will be observed that very few rocks from the American continent have a place in the list. This

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