(3) In general the curves show that as the dose is increased it produces relatively less effect. This holds true for each of the growing parts. A dose of 1,000 *r*-units reduces the growth of the primary root 53 per cent.; 8,000 *r*-units reduces the growth only about 60 per cent.

(4) Differences between the controls and the irradiated seedlings can be detected a few hours after treatment. In general these differences become greater as the period between treatment and measurement is lengthened. The forty-eight hour period was chosen because the effects of the x-rays were pronounced at this time, and because the methods of seedling cultivation used would not have been so satisfactory had a longer period been adopted.

(5) Within the range studied it was found that when the product of the intensity and time of exposure is kept constant the effect produced is the same. The intensity can be cut down to 1/12 and the time of treatment increased twelve times without noticeably changing the biological effect.

(6) Seedlings which are heavily irradiated exhibit abnormalities. Instead of tapering gradually to a delicate slender tip, the roots are thickened throughout their whole length. At the end there forms a tuberous enlargement, the diameter of which is two or three times that of a normal root. The coleoptile becomes tough and much thickened, especially at its base.

(7) The growth-promoting vitamin B in the embryo is destroyed by heavy doses. The physical conditions in this phase of the work were identical with those in the other experiments except that the copper filter was omitted and the time of exposure was increased to 120 minutes. This dose is approximately 72,000 *r*-units. It requires one per cent. of embryo in a vitamin-B-free synthetic diet to sustain normal growth in a young albino rat. A similar diet containing 6 per cent. of irradiated material does not permit normal growth. I am under obligations to Dr. Kanematsu Suguira, who carried out this work in his laboratory.

Packard has brought out the fact that the effect of x-rays on *Drosophila* eggs is independent of the wavelength. Other investigators have found that short or long x-rays are more effective in inhibiting the growth of different organisms. Because of these conflicting results, extensive parallel experiments were carried out using low potentials of between 40 and 50 kv. After the completion of the work, however, new measurements showed that the graphite chamber used measured only a proportion of the energy of the soft radiation. Further interpretation of these data, therefore, must await the calibration of the graphite chamber with a standard ionization chamber.

The writer is under obligations to the physical department of the hospital for providing the apparatus and for making the physical measurements.

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RESPIRATION STUDIES ON AZOTOBACTER UNDER CONTROLLED CONDITIONS

SINCE the discovery of *Azotobacter* by Beijerinck, considerable work has been done on their physiology. As a result of the free energy data published by Lewis and Randall, the interest in these organisms has recently centered on the energetics and mechanism of the nitrogen fixation process. Careful studies on the rate of respiration over the entire range of oxygen tension is of utmost importance and is indispensable when the nitrogen fixation process is considered thermodynamically.

To measure the metabolic activity of *Azotobacter* at different partial pressures of oxygen, the rate of formation of carbon dioxide and the heat energy evolved was measured at the same time. The differential calorimeter built by Randall and Rossini[1] was

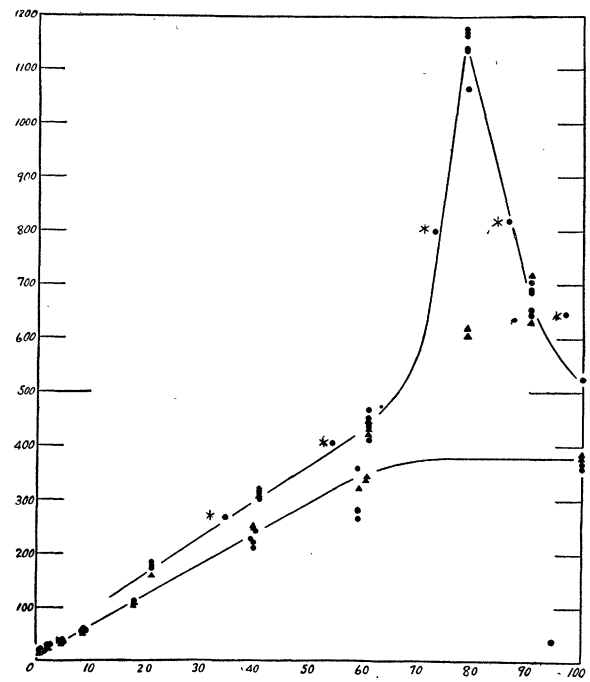

FIG. 1

Ordinate represents the calories produced;
Abscissae, the per cent. oxygen.
▲ Calories per hour measured.
● Calories calculated from the carbon dioxide evolved.
* These points represent the carbon dioxide evolved during 1 hour, 20 minutes of which the oxygen tension was at the lower value and at the higher value for the remaining 40 minutes. The average oxygen tension is therefore the lower tension plus two thirds the difference between it and the next higher oxygen tension.

[1] *Jour. Am. Chem. Soc.*, 51: 325, 1929.

reconstructed so that the culture could be aerated vigorously with preconditioned carbon-dioxide free gas, which was conveyed through alkali towers where the carbon dioxide evolved was adsorbed and measured. Twelve hundred cc of a 24-hour culture of *Azotobacter chroococcum* in a nitrogen free medium was transferred aseptically to the previously sterilized calorimeter. Aeration and mechanical stirring was at once started and the heat and carbon dioxide measurements made.

In every case where equilibrium with respect to the gas phases was maintained the same results, as shown in the figure, were obtained. The rate of respiration remained constant at 78 per cent. oxygen for 4½ hours. The oxygen concentration was between 60 and 90 per cent. oxygen for 6½ hours as shown by eight carbon dioxide determinations. It is interesting to note from the nitrogen fixation standpoint that the oxygen-nitrogen ratio (78 per cent. oxygen), that gave the maximum rate of respiration, is the same as it is in the nitrate ion.

The data just reported are not in accord with those published by Meyerhof and Burk.[2] They measured the rate of respiration of a culture of *Azotobacter* over the entire range of oxygen concentration by the Warburg[3] method. They found the rate of respiration to increase with increasing oxygen tension up to 15 to 20 per cent. oxygen, above which the rate of respiration rapidly decreased until it was from one third to one half that of air at 100 per cent. oxygen. In their experiments the ratio of the gas confined above the culture to volume of culture was about 6 to 1 and the total volume of the apparatus was 12 cc. The gas did not bubble through the medium. The author found it difficult to effectively remove the carbon dioxide at the higher oxygen concentrations when the carbon dioxide free gas bubbled continuously through the mechanically stirred culture at the rate of 20 to 22 liters per hour. This was found to be true even when the ratio of carbon dioxide free gas to the volume of culture was 15 to 1. In some experiments, it was necessary to increase the ratio to 18 to 1.

It is quite possible that the method used by Meyerhof and Burk to remove the carbon dioxide from the culture and to supply oxygen adequately is extremely inefficient and totally unreliable, especially at the higher oxygen concentrations.

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THE NATIONAL ACADEMY OF SCIENCES. II

Examples of the uncertainty principle: C. G. DARWIN (by invitation). This principle asserts that a simultaneous measurement of the position and momentum of a body can only be carried to a certain degree of accuracy. In the present work an electron is supposed to be at rest, and its position is to be measured by the electric force it exerts on an electrometer. It is shown that the electrometer will exert a reactive force so as to set the electron in motion to just the degree required by the principle. Further examples deal with magnetic forces and with the impossibility of measuring the magnetic moment of the free electron.

The distribution of stresses in welded and riveted connections: WILLIAM HOVGAARD. This paper describes a new method for determining the stresses in a line of weld or rivets and the adjoining structures when the connection is subject to shearing in its own direction. Consider first the elementary case of a bar or narrow plate attached to a plate of greater length and width. We refer to the minor structure as the "bar" and to the major structure as the "plate." Suppose that the plate is subject to elongation due to a simple uniform pull at its ends, then the bar is forced to follow due to shearing in the weld or rivets which connect it to the plate; but it is clear that the bar will resist elongation and that there will be a certain elastic creeping of the bar relative to the plate. Thus every section of the bar will suffer a displacement relative to the corresponding section of the plate, but by symmetry this displacement is zero at the middle, and it is obvious that it will increase to a maximum at the ends of the bar. The assumption is made that the displacement at any transverse section is equal to the shearing stress at that section multiplied by a constant, which we call the "displacement coefficient." The theoretical solution of the problem is obtained by variation of the integral expressing the internal elastic work and furnishes a very simple expression for the shearing stresses in the connection, as well as for the average tensile stresses in the bar and in the plate. The proposed method finds application to several important cases in naval architecture and civil engineering. *Deckhouses* fitted on the strength deck of a ship near the half length where great bending stresses are apt to occur will be in a position similar to that of a bar connected to a strained plate. No shearing stresses will exist at the middle of the deckhouse in its connection to the deck, but excessive shearing stresses are liable to be found at the corners of the deckhouse, and have in fact occurred in many cases. The usual remedy of cutting the deckhouse in two or more sections connected by

[2] *Zeitschr. f. physikalische Chemie,* Abt. A, 139; *Bd. Zeit.,* 117–142, 1928.

[3] "Stoffwechsel der Tumoren," Julius Springer, 1926.