

variation in oxygen consumption with temperature (between 25° and 2°) was of the form :

$$(1) \quad \ln k = c - \frac{A}{T};$$

which equation after being differentiated and then integrated between the limits k_1 , T_1 , and k_2 , T_2 results in a form of the Arrhenius equation :

$$(2) \quad \ln \frac{k_1}{k_2} = \frac{Q}{R} \left(\frac{1}{T_2} - \frac{1}{T_1} \right),$$

which frequently represents in a satisfactory manner the effect of temperature on biological reactions over limited temperature ranges.

Upon determination of the constant Q (R is the gas constant) from the average consumption values at 24° and 11°, each of the 18 pairs of values obtained at these temperatures were reduced by means of the Arrhenius equation to values corresponding to observed temperatures (range 25°–2°) at the depths from which the samples were taken, and the means of each pair of values (after multiplying by 365) are plotted against depth in Fig. 1. It is realized that this method of extrapolation may not hold for this particular phenomenon over the entire temperature range of 25° to 2°, but it does furnish an approximation.

The results (Fig. 1) after reduction are too high, particularly in the deeper levels, to be used in estimating oxygen consumption *in situ* in the water column itself. For example, at Station 2886, water from the minimum oxygen layer (less than 60 per cent saturated, occurring approximately between depths of 700 and 1000 metres) had an average daily adjusted oxygen consumption of 0.0363 c.c. per litre, which is about 32 times greater than the value of 0.42 c.c. per litre per year previously estimated for this layer; and water from between 1000 and 2000 metres had an adjusted daily consumption in the laboratory of 0.0385 c.c. per litre, which is more than 100 times greater than the more reasonable previously estimated value of 0.103 c.c. per litre per year for this part of the water column.

Thus, it appears that conditions in the sea, other than temperature, restrict the rate of oxygen consumption, and the above results are of interest since they indicate the potential rates of oxygen consumption throughout a water column of the sea when its equilibrium is disturbed by laboratory conditions.

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Role of Heteroauxones in Legume Nodule Formation, Beneficial Host Effects of Nodules, and Soil Fertility

FOLLOWING identification of β -indolacetic acid¹ as a constituent of ether extracts of cultures of *Rhizobium phaseoli* in dextrose-bacto-tryptophane and in dextrose-bacto-tryptophane-peptone broths, these crude extracts were tested for auxones by applications to coleoptiles of *Avena*, and to hypocotyls and internodes of *Phaseolus vulgaris*, var. Red Kidney. The tests were strongly positive. Thus far we have been unable to determine whether β -indolacetic acid is the only heteroauxone in the preparations because of the scarcity of material.

Further, extraction of nodules of spontaneously infected Red Kidney bean plants first with acidulated 95 per cent alcohol (in which the nodules were ground

with pumice) and then with peroxide-free ether has yielded preparations which feebly affect growth of coleoptiles of *Avena* and of hypocotyls and internodes of the Red Kidney bean. Thimann's² method of extraction with acidulated chloroform probably will reveal a higher auxone content. Possibly the lot of nodules extracted was too old on the average to give a maximum auxone yield and possibly the sample used (50 gm.) was too small. Work is under way with larger and younger samples and with other methods of extraction. Tests with ferric chloride, hydrochloric acid and amyl alcohol indicate β -indolacetic acid as a nodular constituent. Unfortunately, the test is made with difficulty and uncertainty because of the dark colour of the crude extracts. Until more material and better tests are available, it will be impossible to identify β -indolacetic acid more positively or to determine whether the extracts contain growth substances other than β -indolacetic acid.

In conjunction with our findings¹ that pure β -indolacetic acid, applied in different concentrations and amounts in lanolin paste to primary roots of Red Kidney bean induces: (1) positive bending; (2) coiling; (3) retardation or suppression of root elongation; (4) premature and excessive lateral root initiation; (5) local diameter increase and nodulation, and with Thimann's³ findings that pea nodules are hyperauxonic in relation to normal healthy pea roots and that β -indolacetic acid incites nodulation in roots of *Pisum sativum*, our new findings indicate that β -indolacetic acid is one of the chemical agents, if not the agent, responsible for incitation of nodulation in susceptible hosts by *Rhizobium phaseoli* and other nodule-forming organisms.

The relative yields of total crude extracts from equal weights of nodules and of healthy roots as well as the greater growth-affecting capacity of the former, indicate hyperauxony for the nodules. These observations, together with Thimann's³ report that nodules of pea have a greater auxone content than non-infected root tips of the pea, seem to support the hypothesis¹ that tumours (including callus and galls) are brought about by local hyperauxony. This may be due to autoauxones, to heteroauxones, or to both added to the normal autoauxone content.

Coupled with our earlier findings¹ that β -indolacetic acid applied experimentally to the bean may augment or be in part a substitute for its autoauxones, the results reported here suggested the hypothesis that the beneficial effects of suitable concentrations of β -indolacetic acid and other auxones acting as heteroauxones may account in part for the characteristically beneficial effects of: (1) nodules for some host plants; (2) green manuring with nodule-bearing plants; (3) fertilizing with manures rich in dung and urine, or with compost; (4) humus soils; and (5) mycorrhizal fungi for some host plants.

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¹ Link, G. K. K., Wilcox, H. W., and Link, A. DeS., *Bot. Gaz.*, **98**, 816–867 (1937).

² Thimann, K. V., *J. Gen. Physiol.*, **18**, 23–34 (1934).

³ Thimann, K. V., *Proc. Nat. Acad. Sci.*, **22**, 511–514 (1936).