sure than did the extracts of the opposite normal kidney of the same animal. (Table I.)

A few observations have been made on the effect of extracts of human kidney. It appears that the extracts of the kidney of certain patients with essential hypertension may have an increased pressor effect but this is not yet clearly established.

Our findings, which have been confirmed concurrently by Friedman and Prinzmetal,[7] indicate that a relationship exists between experimental renal hypertension and the production in ischemic renal tissue of an increased amount of some pressor substance. Whether the latter is actually the cause of the rise in blood pressure is not yet certain. The findings are also compatible with the idea of a diminution in the rate of formation of a depressor substance in the ischemic kidney as a factor in the production of renal hypertension. Definite conclusions cannot be drawn until more is known concerning the chemical nature of the pressor and depressor agents. Attempts at separation and purification of these substances are now being made.

8847 C

Metabolic Activities of *Escherichia coli* in a Synthetic Medium.

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Recent studies by Martin,[1] Mooney and Winslow,[2] and Clifton[3, 4, 5] on the metabolic activities of bacteria indicate that the rate of metabolic activity per cell varies widely at various phases of the growth-cycle. The maximal oxygen-consumption, carbon dioxide-production or ferricyanide-reduction per cell per unit-time was noted near the end of the lag-period of growth and could be only in part explained by increased cellular size during the same period of growth. The metabolic activities per unit-volume of the cultures, as measured by the above indices, reached maximal values

7 Friedman, B., and Prinzmetal, M. Personal communication.

1 Martin, D. S., *J. Gen. Physiol.*, 1932, **13**, 691.

2 Mooney, G., and Winslow, C.-E. A., *J. Bact.*, 1935, **30**, 427.

3 Clifton, C. E., Cleary, J. P., and Beard, P. J., *J. Bact.*, 1934, **28**, 541.

4 Clifton, C. E., PROC. SOC. EXP. BIOL. AND MED., 1936, **34**, 291.

5 Clifton, C. E., *J. Bact.*, 1936. In press.

near the end of the logarithmic period of growth and then decreased rapidly as the age of the cultures increased. Peptone or other complex media were employed in these studies.

The present paper reports the influence of the concentration of lactic acid (sodium salt) on the oxygen-consumption, carbon dioxide-production and growth of *Escherichia coli* (K-12) in an inorganic medium of the following composition: NH_4Cl, 5.0 gm.; Na_2SO_4, 2.0 gm.; $MgSO_4$, 0.1 gm.; K_2HPO_4, 3.0 gm.; KH_2PO_4, 1.0 gm.; $FeCl_3$ (0.5% solution), 0.5 ml.; $CaCl_2$ (0.5% solution), 0.5 ml.; distilled water to make 1000 ml.

Oxygen-consumption was measured by the usual Warburg technic and carbon dioxide-production by the technic described by Walker.[6] All tests were carried out at 37.5°C.

The influence of the concentration of lactic acid on the growth of *Esch. coli,* as measured with the aid of a photoelectric turbidimeter (Clifton[7]), is illustrated in Fig. 1, A. Concentrations of sodium lactate greater than 0.1 N markedly inhibited the growth of this organism.

The influence of 4 different initial concentrations of lactic acid

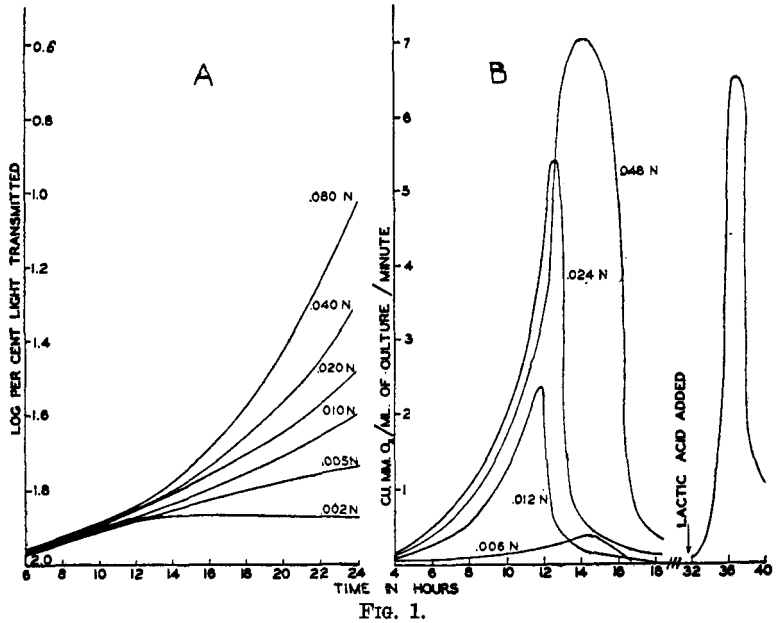

FIG. 1.

Influence of initial sodium lactate-concentration on the growth of *Esch. coli* (A) and on the oxygen-consumption of cultures of *Esch. coli* (B).

6 Walker, H. H., *J. Bact.*, 1932, **24**, 169.

7 Clifton, C. E., Mueller, Elizabeth, and Rogers, W., *J. Immunol.*, 1935, **29**, 377.

on the oxygen-consumption of *Esch. coli* is illustrated in Fig. 1, B, in which cubic millimeters of oxygen consumed per minute per millimeter of the cultures is plotted against time in hours. The typical change in oxygen-consumption following the addition of sufficient 2.0 N sodium lactate to make the cultures approximately 0.05 N with respect to the lactate is shown by the right-hand curve in Fig. 1, B. The lactate was added when the cultures were 31 hours old.

The influence of 4 different initial concentrations of lactic acid on the carbon dioxide-production and growth (viable count by dilution and plating) of *Esch. coli* is illustrated in Fig. 2, together with the changes in concentration of lactic acid during growth of the organisms. Lactic acid was determined by the method described by Friedemann and Kendall,[8] the values reported being only approximate since duplicate determinations often varied by as much as $\pm 5\%$.

The rates of oxygen-consumption and of carbon dioxide-production per cell per unit-time reached maximal values during the lag or early logarithmic period of growth in this synthetic medium and then decreased rapidly with increasing age of the cultures.

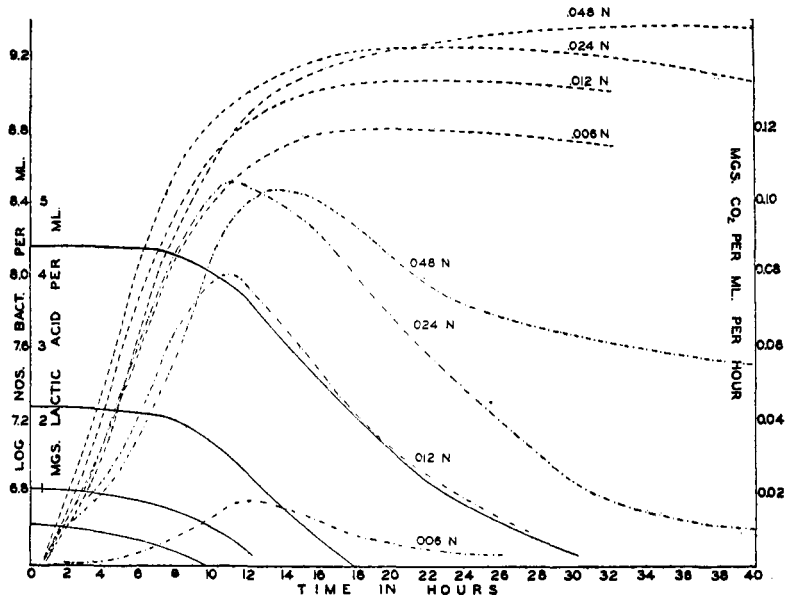

FIG. 2.

Influence of sodium lactate-concentration on growth (- - - -) and on carbon dioxide-production (— — —) of cultures of *Esch. coli*. Solid lines represent the change in concentration of lactic acid with time during growth of the organisms.

[8] Friedemann, T. E., and Kendall, A. I., *J. Biol. Chem.*, 1929, **82**, 23.

The cells also appeared to be of maximal size during the early phases of growth. Typical values of the rate of carbon dioxide-production per cell per unit-time are presented in Table I.

TABLE I.
Results Illustrating the Changes in Lactic Acid-Concentration (mg. per ml.) and in Rates of Carbon Dioxide-Production (mg. x 10^{-10}) per cell per hour in Cultures of *Esch. coli.*

Age of culture in hours	Lactic acid	CO_2	Lactic acid	CO_2	Lactic acid	CO_2	Lactic acid	CO_2
2-4	4.4	21.5	2.2	20.0	1.1	19.9	.5	—
4-6	4.3	10.9	2.2	7.6	1.0	12.5	.4	.9
6-8	4.3	4.6	2.1	2.9	0.8	5.5	.3	.6
8-10	4.1	2.3	1.8	1.9	0.6	2.2	.1	.6
10-12	3.8	1.6	1.5	1.2	0.3	1.3	—	.5
12-14	3.3	1.1	1.0	0.9	0.1	0.9	—	.3
22-24	0.6	0.4	—	0.2	—	0.1	—	—

Maximal metabolic activity per unit-volume of the cultures was observed later in the growth-cycle, at a time which appears to be dependent upon the initial concentration of sodium lactate. Also, the total amount of carbon dioxide produced by the cultures appears to be directly proportional to the initial concentration of lactate. The pH of the cultures remained quite constant near 7.2.

The addition of lactic acid to 24-hour or older cultures resulted in an increased carbon dioxide-production, the rate changing with time in a manner similar to that reported for oxygen-consumption in Fig. 1.

The rate of oxygen-consumption of buffered suspensions of *Esch. coli* was almost independent of the concentration of lactic acid (concentration of bacteria constant) over the range of 0.4 to 20 mg. per ml., but rapidly decreased when the concentration of lactic acid was below or above the concentrations stated. The rate of oxygen-consumption was directly proportional to the number of bacteria with the exception that the rate per organism appeared to increase as the concentration of bacteria was decreased when the concentration of lactic acid was less than one mg. per ml.

These results suggest that as the numbers of bacteria increase in a culture the total amount of oxygen consumed, or of carbon dioxide produced, increases to a maximal value determined by concentrations of the reactants, the nature and size of the organisms and the physical and chemical influence of the environment on the cells. The decrease, increasing with age of the culture, in the rate of metabolic activity per cell may be interpreted on a basis of probability. As the number of bacteria increases the concentration-gradient of food-

stuffs between the cell and the environment decreases. Therefore, the probability of sufficient materials being available per cell per unit-time, to provide for the maximal possible requirement of the cells, decreases.

These results also lend further support to the hypothesis advanced by Cleary, Beard and Clifton[9] that growth may be primarily controlled by this above probability-relationship, the growth-rate decreasing as the concentration per cell of materials essential for growth decreases in cultures of bacteria in which a relatively high population has been established. The maximal population developed under favorable conditions may also be primarily controlled by these concentration-relationships.

8848 P

Cysteine-Gelatin as a Differential Medium for *Salmonella pullorum* and *Salmonella gallinarum*.

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Differentiation of *Salmonella pullorum* from *Salmonella gallinarum* cannot be made by agglutination or agglutinin-absorption, because of a similar antigenic structure. This similarity and the fact that the 2 diseases produced in fowls are alike in some respects have caused certain European investigators[1, 2, 3] to consider them as variants of the same species.

Mallman's[4] work on the use of sodium-mucate agar, Jordan and Harmon's on tartrate-agar,[5] and Naidu's[6] and Nobrega's[7] studies on differentiation by bacteriophage, are examples of investigations which supply further evidence that these organisms are separate entities. This report deals mainly with the use of cysteine-gelatin as another differential medium.

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9 Cleary, J. P., Beard, P. J., and Clifton, C. E., *J. Bact.*, 1935, **29**, 205.

* On sabbatical leave from the University of California.

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4 Mallman, W. L., PROC. SOC. EXP. BIOL. AND MED., 1931, **28**, 501.

5 Jordan, E. D., and Harmon, P. H., *J. Inf. Dis.*, 1928, **42**, 238.

6 Naidu, P. M. N., *Bul. Acad. Vet. France*, 1935, **8** (6), 306.

7 Nobrega, P., *Arch. do Instit. Biol. de S. Paulo, Brazil*, 1936, **6** (Artigo 9), 72.