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Determination of the Minimal Temperature for Growth of *Escherichia coli*

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The minimal temperature for growth of *Escherichia coli* ML30 in glucose minimal medium is between 7.5 and 7.8 C. After transfer to subminimal temperature, growth occurs but is not sustained.

The minimal temperature for growth may be defined as that temperature below which sustained, balanced growth does not occur. The value for the minimal temperature for growth is commonly cited as part of the basic description of a particular bacterium, yet careful measurements of this fundamental parameter of growth are rare. Because of the low specific growth rate, approaching zero as the temperature approaches the minimum, the measurement is necessarily time consuming or arbitrary. Estimates for *Escherichia coli* (3) including the particularly careful measurements of Hoffman (1) indicate that its minimal temperature of growth is about 8 C. Still it seemed possible to us that these estimates were biased high as a consequence of the growth lag which follows the shifting of a culture to low temperature. We observed that, as the temperature to which the culture is transferred is decreased, the length of the time before growth recommences increases. Thus, failure of a culture to grow over a given interval of time after a shift to a certain low temperature could be attributed to either: (i) the temperature being below the minimum for growth or (ii) the lag at that temperature exceeding the interval of time.

We attempted to solve this problem by allowing cultures to grow exponentially at temperatures only slightly above the minimum and then shifting the cultures over small intervals to lower temperatures. We found that the minimal temperature estimated by this technique agrees with previous estimates.

A culture of *E. coli* ML30 was allowed to grow exponentially at 10 C in minimal medium 56 (2) for at least 10 doubling times (7 days), after which it was diluted into fresh medium which was precooled to 7.8 C (Fig. 1); after a transient period of growth at a more rapid rate, sustained exponential growth at a constant rate (k = 0.0088/hr) ensued. When the shift was made to 7.5, 7.0, or 6.0 C (Fig. 2), the transient period of growth was followed by cessation of growth. (Dilution of the culture which had stopped growing at 7.5 C failed to reinitiate growth.) Similarly, shifting an exponentially growing culture from 7.8 to 6 C (Fig. 1) results in a growth pattern which is virtually identical to that which follows the shift from 10 to 6 C.

It seems clear from these experiments that the minimal temperature for growth of *E. coli* in

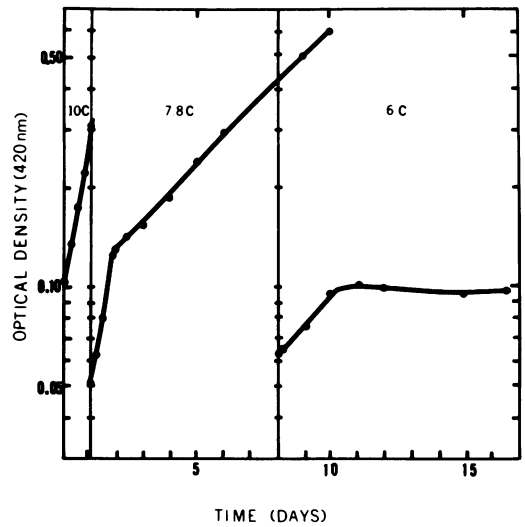

FIG. 1. *Growth of E. coli ML30 aerobically at low temperature in 0.1% glucose minimal medium. A culture growing exponentially in minimal medium at 10 C (first panel) was shifted to 7.8 C (second panel) and then to 6.0 C (third panel). Culture conditions and measurement of cell density are those previously described (3).*

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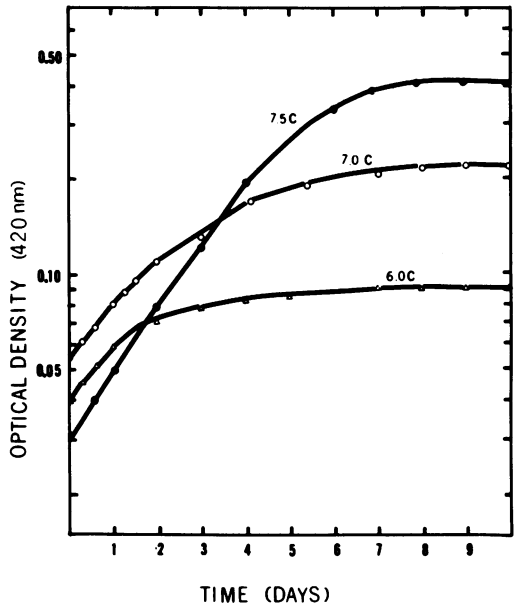

FIG. 2. *Growth of E. coli ML30 in 0.1% glucose minimal medium at 7.5 (●), 7.0 (○), and 6.0 C (△) after shift from 10 C.*

minimal medium lies between 7.8 and 7.5 C. A prolonged lag period cannot account for the cessation of growth; in fact, an increase in mass (without lag) occurs at temperatures below the minimum. Interestingly, the amount of transient incremental growth which occurs at subminimal temperatures decreases very rapidly as the growth temperature is lowered; optical density increases 15-fold at 7.5 C, 4-fold at 7.0 C, and only 2-fold at 6.0 C.

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