When calculating cell-growth thermodynamics, reconsider using the Gibbs free energy equation

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A forthcoming article in *The Quarterly Review of Biology* provides the basis for an argument against using the Gibbs free energy equation to accurately determine the thermodynamics of microbial growth.

Microbial growth is a biological process that has been previously treated as a chemical reaction operating in accord with the Gibbs free energy equation, developed during the 1870s. The heat of yeast growth was the first to be measured by direct calorimetry, in 1856.

However, the full application of the Gibbs equation to microbial growth did not occur until 1997, with the experimental measurement of yeast cell entropy. Subsequent investigations showed that the quantity of absorbed thermal energy for solid substances had two values, depending on how it was calculated. Because there can be only one correct value at a given temperature, Dr. Edwin H. Battley, emeritus of Stony Brook University and recipient of the International Society for Biological Calorimetry's Dubrunfaut Award (1994) and Lavoisier Medal (2010), examined the use of the Gibbs free energy equation to accurately determine the change in energy that accompanies cellular growth.

In many systems, the values for some variables cannot be determined experimentally and so must be calculated from theoretically derived values. The free energy change accompanying cellular growth cannot be directly measured but, if the heat of growth can be measured and the entropy change accompanying growth can be calculated indirectly from heat measurements, the free energy change can be calculated using the Gibbs free energy equation.

The basis for Battley's review is in the observation of an apparent discrepancy between the amounts of growth obtained when *S. cerevisiae* was grown on glucose in aerobic or anaerobic conditions. Assuming it is the change in the Gibbs energy that drives the reactions that occur in both conditions, it is expected that the amount of growth would be proportional to the amount of nonthermal energy initially available and there would be 13.2 times more growth aerobically than anaerobically. However, when the growth for these two systems was measured turbidometrically, this value was found to be only 3.4. It is clear that a discrepancy exists between what is theoretically expected and what is experimentally determined.

Using results of earlier studies, Battley devised a different equation to calculate the thermodynamics of microbial growth. This involves using a different mathematical procedure to calculate enthalpy values for absorbed thermal energy exchange. As a consequence, values for entropy used for this purpose are removed. He found that the application of this equation (which he calls the Battley free energy equation) achieved values different from those obtained using the Gibbs free energy equation for the same system. Because the Battley free energy equation uses an absorbed thermal energy variable that is easier to understand in the context of the real-world system in which microbes exist, Battley argues that his free energy equation more realistically represents real-world conditions, and in a way that is more simple and parsimonious to calculate. As such, it is superior for determining the thermodynamics of microbial growth than is the Gibbs free energy equation.

More information: Battley, Edwin H. "A Theoretical Study of the Thermodynamics of Microbial Growth Using Saccharomyces cerevisiae

and a Different Free Energy Equation." *Quarterly Review of Biology* Vol. 88, No. 2 (June 2013).

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