

## Citation Classics

Eagle H. Amino acid metabolism in mammalian cell cultures.  
*Science* 130:432-37. 1959.

The present article "is a progress report rather than a review and in large part summarizes studies from a single laboratory" on the minimal essential medium for cultivation of mammalian cells in either monolayer or suspension. Every cell culture examined, whether human or animal in origin, required at least 13 amino acids for survival and growth. All the cultured human cells examined were found to contain large amounts of glutathione, taurine, glutamine, ammonia, and glutamic acid. [The SCI® indicates that this paper was cited 2,255 times in the period 1961-1975.]

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"The growth media characterized as BME (Basal Medium, Eagle) and MEM (Minimal Essential Medium) which have been used for 20 years, did not result from a planned attempt to develop a culture medium. The original objective was rather to define those components which were essential for the survival and growth of animal cells; and that objective was realized with the demonstration that 13 amino acids, 6 vitamins, 6 ionic species and glucose, plus an unknown complex of compounds present in serum, were both necessary and sufficient for the propagation of a wide variety of animal cells. The composite of these constituents constitutes the basal (1955)<sup>1</sup> or minimum essen-

tial (1959) medium, the latter differing primarily in the increased concentration of some of the factors described as being growth limiting. Obviously, whole serum contained all 26 of the essential defined components, but not in optimal or sufficient concentrations. A widespread practical application thus grew out of an interest in growth requirements, which was not initially directed at the practical objective of a growth medium.

"A number of nutritionally non-essential compounds which are essential for the cellular economy, and which are normally synthesized by the cells in amounts sufficient for growth, may be added to the minimal or basal medium; and some of these become essential at low population densities, or in cells with genetically determined defects in a specific biosynthetic pathway. Later studies from this laboratory dealt with such matters as the utilization of peptides and cofactors; the determination of the minimal intracellular concentrations of amino acids necessary for protein synthesis; amino acid transport; protein turnover; the synthesis of purines and pyrimidines; carbohydrate metabolism; *in vitro* screening of carcinolytic agents; population density effects on cellular metabolism, including contact inhibition of growth; pH effects; etc. Even now, however, 20 years after the description of the original basal medium, the role of serum, whether in terms of small molecules which may be bound to protein and slowly released to the medium, or in terms of the protein moieties themselves, has yet to be defined."

1. Eagle H. Nutrition needs of mammalian cells in tissue culture. *Science* 122:501-04, 1955.