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PROTEIN EVOLUTION

Norvaline and Norleucine May Have Been More Abundant Protein Components during Early Stages of Cell Evolution

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Abstract The absence of the hydrophobic norvaline and norleucine in the inventory of protein amino acids is readdressed. The well-documented intracellular accumulation of these two amino acids results from the low-substrate specificity of the branched-chain amino acid biosynthetic enzymes that act over a number of related α-ketoacids. The lack of absolute substrate specificity of leucyl-tRNA synthase leads to a mischarged norvalyl-tRNA^{Leu} that evades the translational proofreading activites and produces norvaline-containing proteins, (cf. Apostol et al. J Biol Chem 272:28980–28988, 1997). A similar situation explains the presence of minute but detectable amounts of norleucine in place of methionine. Since with few exceptions both leucine and methionine are rarely found in the catalytic sites of most enzymes, their substitution by norvaline and norleucine, respectively, would have not been strongly hindered in small structurally simple catalytic polypeptides during the early stages of biological evolution. The report that down-shifts of free oxygen lead to high levels of intracellular accumulation of pyruvate and the subsequent biosynthesis of norvaline (Soini et al. Microb Cell Factories 7:30, 2008) demonstrates the biochemical and metabolic consequences of the development of a highly oxidizing environment. The results discussed here also suggest that a broader definition of biomarkers in the search for extraterrestrial life may be required.

Keywords Norvaline · Norleucine · Prebiotic amino acids · Misincorporation of norvaline and norleucine in proteins · Aminoacyl-tRNA synthases

Introduction

A major unsolved issue in the study of the origin of life is the nature of the evolutionary processes that led to the selection of the L α-amino acids found in proteins from the large pool of prebiotic compounds. The ease of their formation in one-pot reactions such as those in Miller-Urey type experiments suggest they were present in the primitive Earth, a possibility strongly supported by the

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