Identification and Characterization of Multifunctionality in Escherichia coli *K-12 Substr. MG1655*

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Abstract

•Multifunctional enzymes are enzymes that catalyze more than one reaction. Certain multifunctional enzymes have functions that act in opposition to each other such as forward modification or reverse modification. While in others the two functions represent consecutive enzymatic steps in some metabolic pathways.

•To understand very well the second class of multifunctionality, this study was done on Escherichia coli k-12 substr. MG1655. 178 multifunctional enzymes literature-reported were collected and characterized using EcoCyc and BLAST databases. They were further specified in different types of multifunctionality based on whether the reactions they catalyze are sequential or not.

•Multifunctional enzymes are non-evenly distributed in species; Bacteria have more multifunctional enzymes than Archaebacteria and Eukaryotes. Comparative analysis indicated that the multifunctional enzymes experienced a fluctuation of gene loss during the evolution from Escherichia coli to H. sapiens.

Background:

•Previous research has shown the existence of 6799 multifunctional enzymes in all species. Multifunctionality seems to be a common mechanism of communication and cooperation between different functions and pathways within a complex cellular system or between cells.

•They are further specified as promiscuous enzymes or moonlighting enzymes. Promiscuous enzymes are characterized as enzymes of catalytic domains executing several functions. Unlike promiscuous enzymes, moonlighting enzymes are acknowledged to have at least a single catalytic domain and a non-catalytic domain.

Methods:

•All data analysis was performed using version 17.1 of the EcoCyc database, released on June 11,2013. All the multifunctional enzymes were manually validated. BLAST2.2.28+ released in April 2013 was used to examine the sequence similarity of the multifunctional enzymes in both E. coli and in Humans.

Results

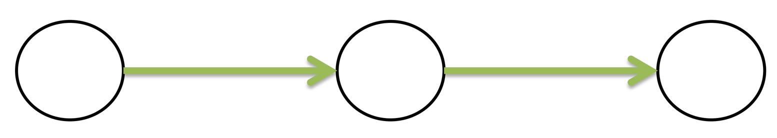

Figure 1a: These multifunctional enzymes catalyze sequential enzymatic steps in a metabolic pathways, 31 of them were found in E. coli.

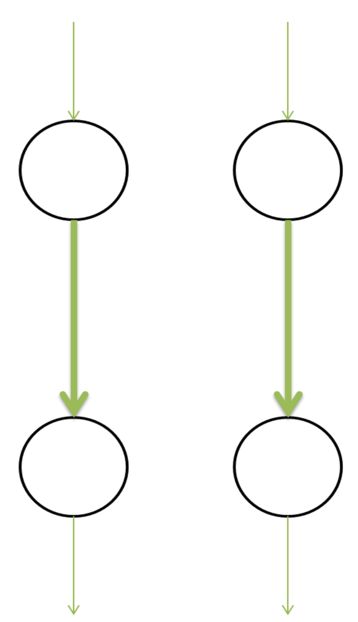

Figure 1b: The functions of these multifunctional enzymes represent enzymatic steps in different metabolic pathways. For example N-succinyldiaminopimelate aminotransferase / acetylornithine aminotransferase is found in both superpathway of aspartate and superpathway of arginine and polyamine biosynthesis.

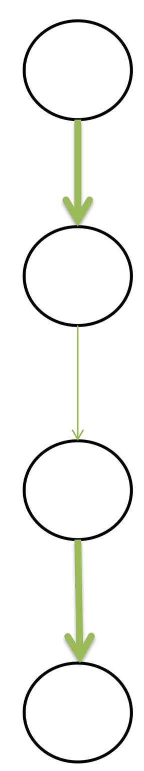

Figure 1c: The multifunctional enzymes catalyze non sequential reactions as the picture shows.

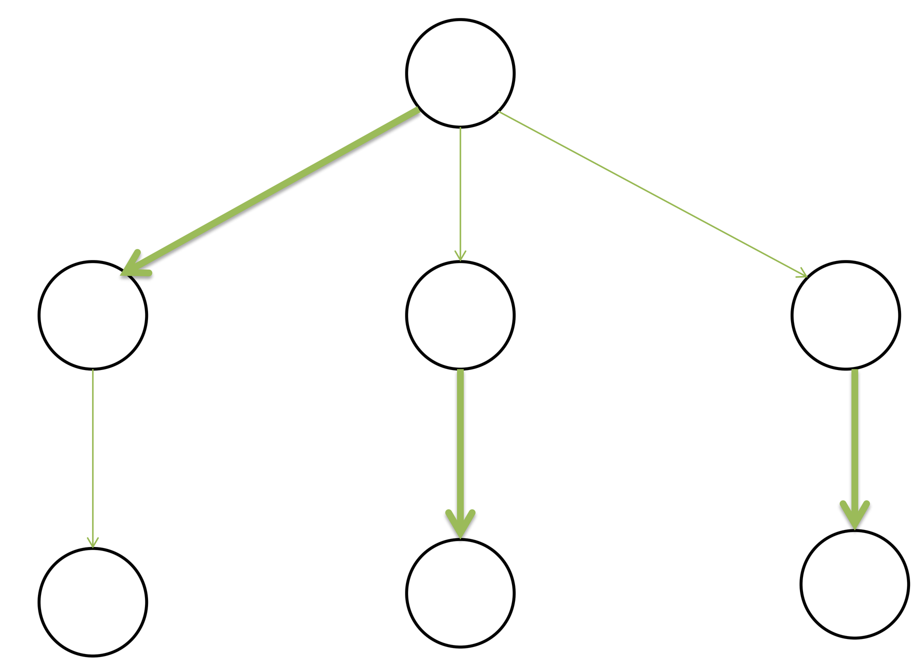

Figure 1d: One example of this type of multifunctionality is bifunctional folylpolyglutamate synthetase / dihydrofolate synthetase in the pathway of folate polyglutamylation.

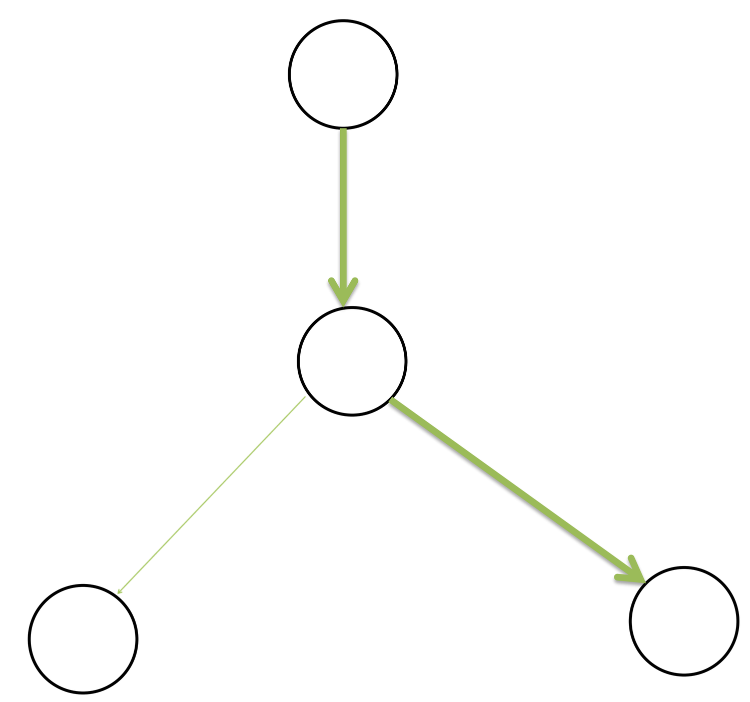

Figure 1e: Bifunctional chorismate mutase / prephenate dehydrogenase (TyrA) carries out the shared first step in the parallel biosynthetic pathways for the aromatic amino acids tyrosine and phenylalanine, as well as the second step in tyrosine biosynthesis.

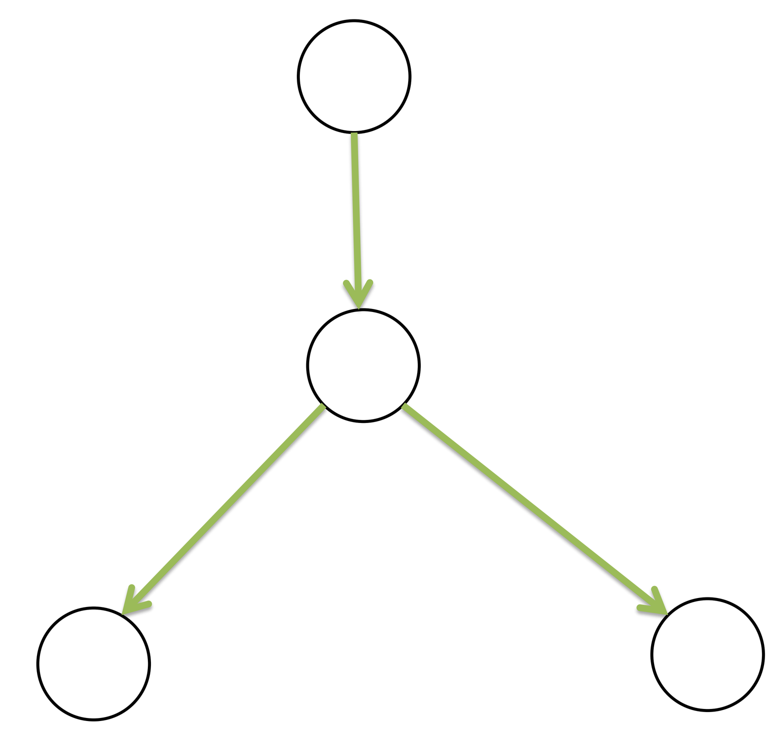

Figure 1f: An example of this type of multifunctionality is fatty acid oxidation complex, α component in the pathway of fatty acid β-oxidation I.

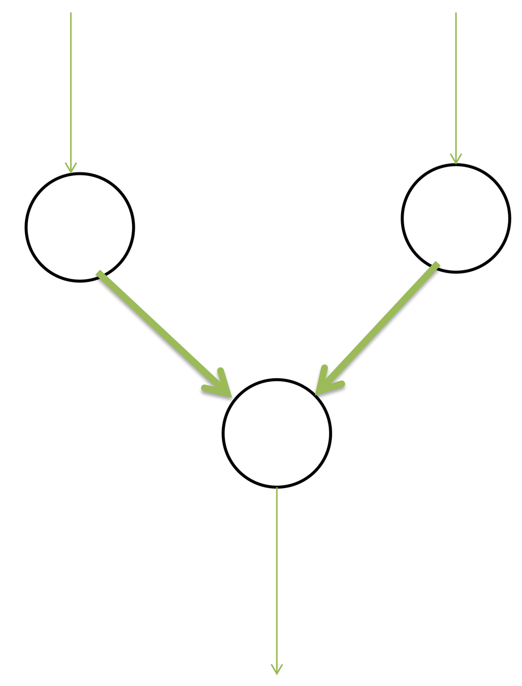

Figure 1g: pyridoxine 5'-phosphate oxidase / pyridoxamine 5'-phosphate oxidase carries out two reactions of this type in superpathway of pyridoxal 5'-phosphate biosynthesis and salvage.

Figure 1h: 45 multifunctional enzymes of this type were found in E. coli; most of them are involved in signal transduction pathways.

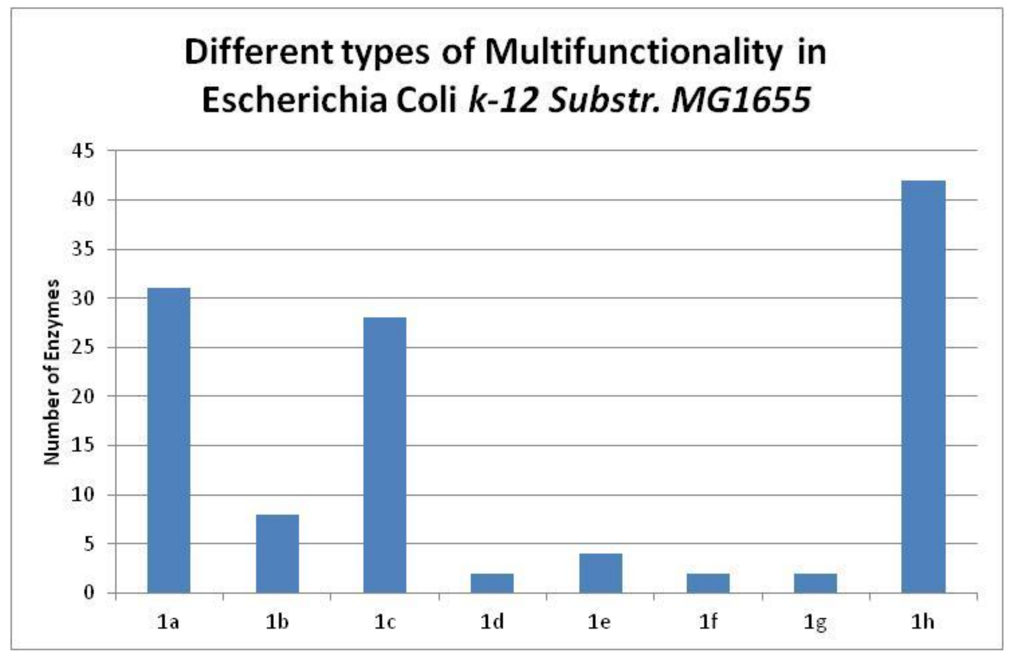

Figure 2: Diagram showing the number of enzymes in each type of Multifunctionality in Escherichia coli *K-12 substr. MG1655*

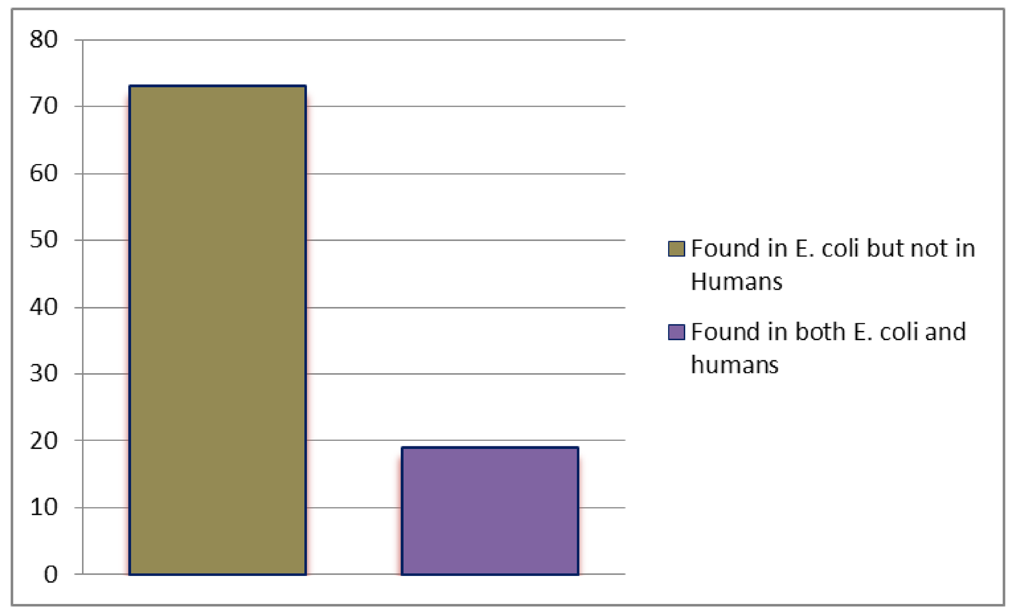

Figure 3: Diagram showing the loss of multifunctionality; examining the sequence similarity of multifunctional enzymes both in Escherichia coli and in humans.

Conclusion

In our study, multifunctional enzymes in Escherichia *Coli K-12 substr. MG1655* were characterized and identified; there exist eight different types of multifunctionality based on the reactions they catalyze. Our data show that the multifunctionality can be lost during evolution; some multifunctional enzymes were found in Escherichia coli but not in humans for example pyruvate formate-lyase deactivase was found to be only trifunctional in E. coli, fused heptose 7-phosphate kinase/heptose 1-phosphate adenyltransferase is not bifunctional in higher organisms. Also, the concept of preventing the intermediate from being released into the solution does not apply for all multifunctional enzymes.

References

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- Cheng, Xian-Ying, Wei-Juan Huang, Shi-Chang Hu, and Zhi-Liang Ji. "A Global Characterization and Identification of Multifunctional Enzymes." *PLoS ONE*. N.p., n.d. Web.

Acknowledgments

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