NUTRIOMICS CHALLENGE

Optimization of Dietary Nutrient Supplementation for Rational Rebalancing of Human Gut Microbiome

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The Biological Problem

The human gut consists of microbes and bacterial species that form a unique and dynamic ecosystem called a microbiome. The gut microbiome serves multiple essential functions, including producing vitamins, defending against pathogens, and digesting fibre. In a healthy body, these species maintain homeostasis–the diverse bacterial composition is stable and well-balanced. However, once homeostasis is perturbed, the human body becomes vulnerable to a wide array of dysbiosis-related syndromes. Therefore, rebalancing human gut microbiome via nutritional intervention to enhance taxonomic diversity is essential for health. The gut microbiome varies massively from person to person–thus, it is vital to be able to generate smart, personalized prebiotics to cater to each individual's needs.

The Algorithmic Challenge

1. Understanding Normal and Abnormal Microbiome Composition. While our goal is to rebalance human gut microbiome, a major obstacle is that we not only lack a standard definition of normal and abnormal microbiome compositions, but also how to measure the abnormality. To formulate this task into a computational problem, a crucial algorithmic challenge is to define what a normal microbiome composition is. Fortunately, we have access to a reference sample collection profiling human gut microbiome composition, which we believe can be used to define normality. However, one thing to note is that the reference comes from a wide variety of people and should be better categorized later on.

2. Understanding How Nutrients Affect Each Species. Since we plan to provide a diet to re-balance the microbiome composition, we also have to define how the nutrients in the diet would affect the patient's microbiome composition and be able to quantitatively predict the outcome of nutrient supplementation on the relative abundance of any species. To tackle this, we could set up a nutrient impact score, quantifying impact of selected nutrients on each ASV.

3. Optimal selection of nutrients for rebalancing taxonomic diversity. Given the definition of normality of microbiome composition and the effect of nutrients on bacterial composition, the problem of selecting nutrients to balance the taxonomic diversity is well-defined. However, solving this optimization problem algorithmically remains a challenge. Since there are about 100 different nutrients, naively trying every combination of nutrients (at most 10 nutrients), would mean that we need to consider about 2×10^{14} different combinations. If for each combination, we also need to check the changed relative abundance for each species and the normality, we might end up with at least 4×10^{18} arithmetic operations (about 2000 species), this is even too much for a modern computer.

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