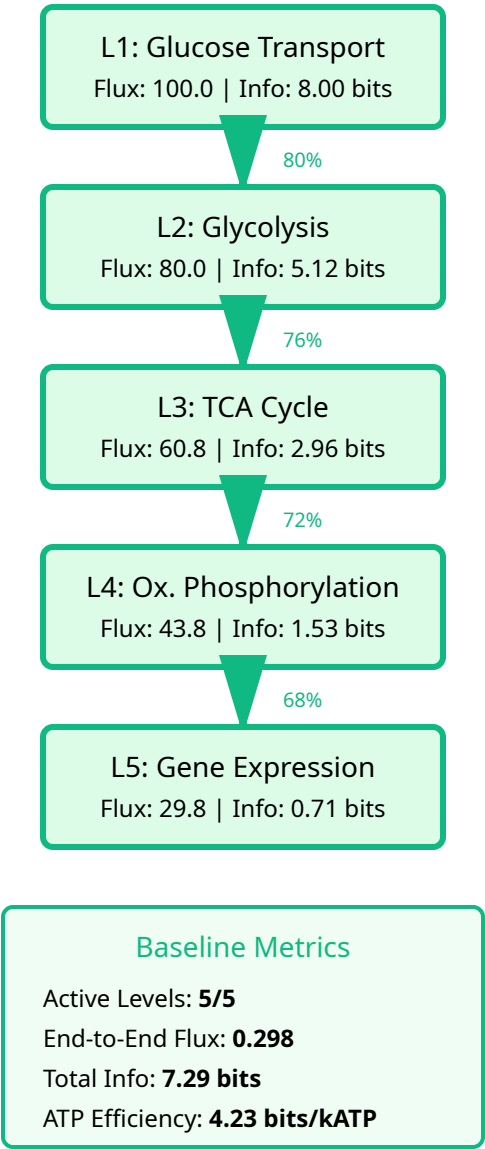
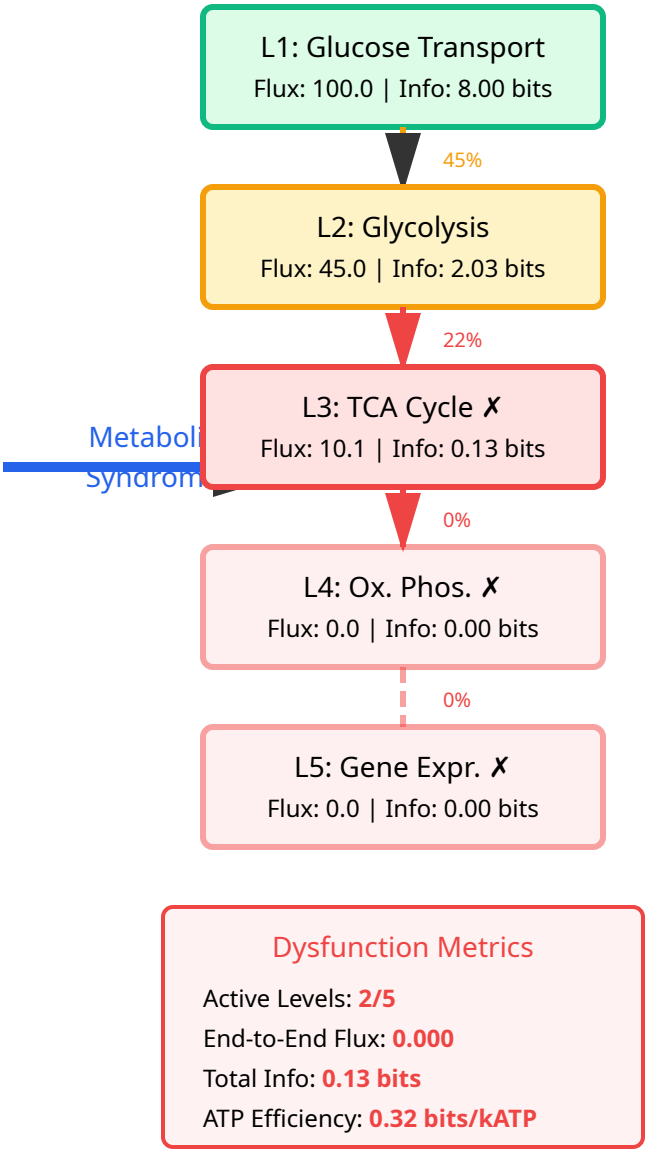


Hierarchical BMD Metabolic Flux Cascade

A. Baseline (Healthy)



B. Metabolic Syndrome (Dysfunction)



Hierarchical Information Cascade Failure

Baseline: All 5 levels active with 29.8% end-to-end flux, 7.29 bits total information compression, 4.23 bits/kATP efficiency. Smooth cascade from glucose (100.0 flux) to gene expression (29.8 flux).

Metabolic Syndrome: Cascade failure at L3 (TCA cycle) blocks downstream levels L4-L5, reducing active levels to 2/5, end-to-end flux to 0%, information to 0.13 bits, and efficiency to 0.32 bits/kATP (13× drop).