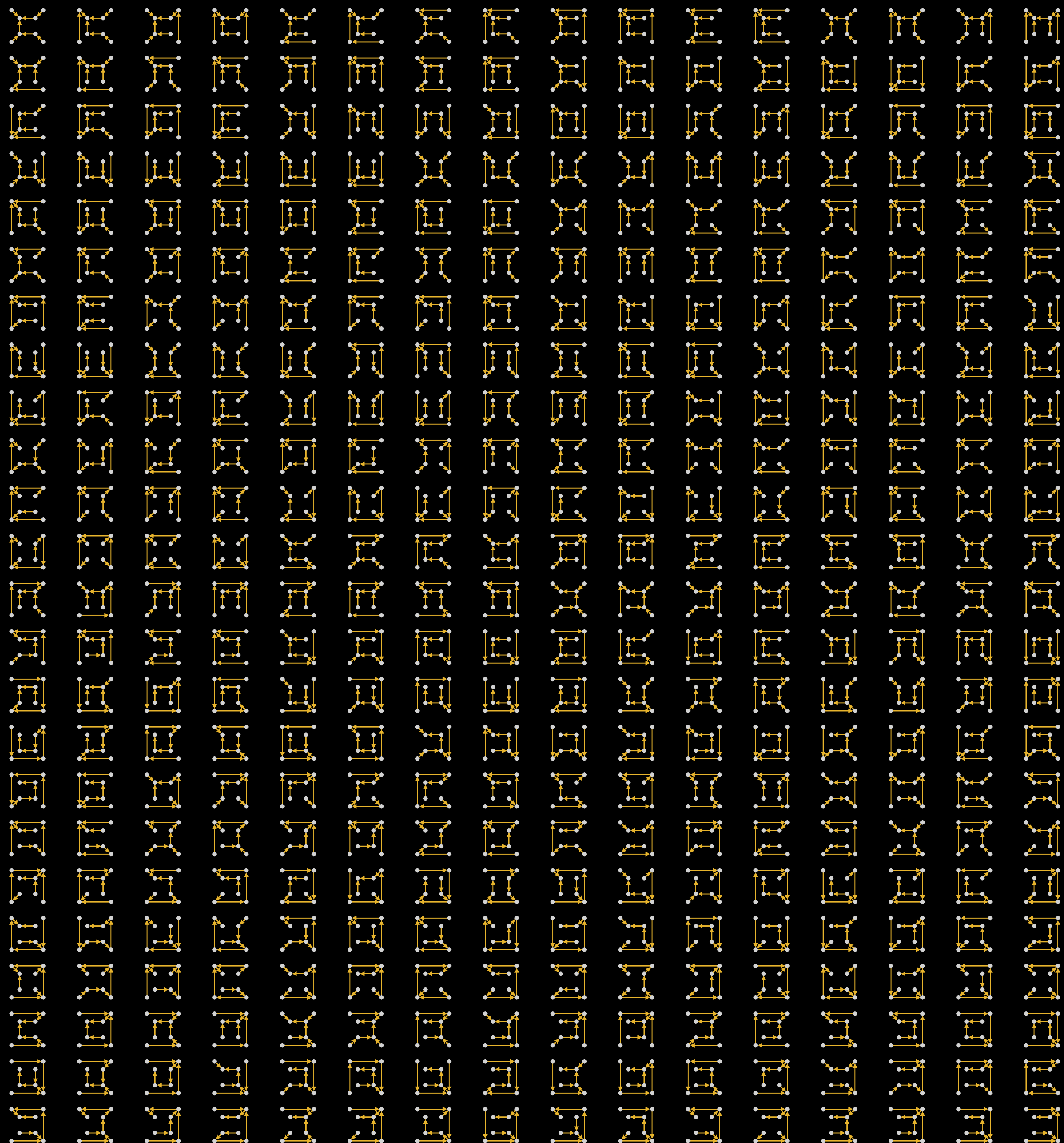

1/8th of the spanning trees on the d=3 cube

Precisely how do cells, organisms, and ecosystems spend energy to build and sustain their liveliness?

We discuss human tools for thinking about mathematical regularity in such dissipative biological systems, with case studies in gene regulation, minimal cell metabolism, and biomolecular gradients.

TO SEE A WORLD IN A GRAIN OF CELLS

GABRIEL L. SALMON

TO SEE A WORLD IN A GRAIN OF CELLS: STATISTICAL AUGURIES OF NONEQUILIBRIUM

GABRIEL L. SALMON

A THESIS

PHILLIPS LAB

CALTECH 2025

front cover: A spanning tree, rooted in the upper right yellow node, on the eight nodes of a cube graph in $d = 3$ dimensions. The directions of edges are specified by the directions in which the text is read.

back cover: All 384 spanning trees on the $d = 3$-dimensional cube graph rooted in a given node. (The other seven possible root nodes give their own sets of 384 spanning trees each, making 3072 spanning trees set the nonequilibrium partition function (and ultimately state probabilities) for this simple network.) Such trees are a powerful way to organize the complexity of nonequilibrium biology, as chapters in this thesis explore.