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FOCUS

PROJECT

The Evolutionary Design of Biological Control Systems

I am organizing the Gene Regulation and Organismal Diversity focus group. My particular interest in this group concerns how natural selection shapes the biochemical control systems that regulate organismal form, physiology, and behavior. Natural selection designs regulatory control like an engineer, with close attention to the costs and benefits of each component and how the components work together. However, natural selection and the resulting evolutionary history do not exactly follow the textbooks of human engineering and design. Nature has its own logic.

One problem is the tendency for natural selection to cause the deterioration in the performance of particular components within a system. The idea is that, as biological systems evolve mechanisms to make them more stable and less sensitive to environmental fluctuations, these protective mechanisms reduce the exposure of the internal components of the system to direct challenge by the environment. With less direct challenge to the internal components, there will be an inevitable tendency for these internal components to decay evolutionarily, because a weakening of environmental pressure typically leads to evolutionary decay. This process leads to a coupling of evolutionary improvement at the system level and evolutionary decay of internal components - a coupling between system robustness and internal maladaptation.

Another problem concerns variations in the regulatory control of bacterial metabolism. Evolution, having designed a system to transform sugar into energy once in early biological history, has mostly retained that system, but with variations. It is the variations in the regulatory control of metabolism that lead to fascinating questions. For example, a fundamental tradeoff occurs between how fast a cell can extract resources from the environment (rate) and how efficiently it can turn those resources into energy (yield). This rate-versus-yield tradeoff sets a fundamental design constraint on metabolism, the most basic process shared by all of life.

Recommended Reading

Frank, S. A. (2007). Dynamics of Cancer: Incidence, Inheritance, and Evolution. Princeton: Princeton University Press.

Frank, S. A. (2002). Immunology and Evolution of Infectious Disease. Princeton: Princeton University Press.

Frank, S. A. (1998). Foundations of Social Evolution. Princeton: Princeton University Press.

COLLOQUIUM, 30.09.2014

The Patterns of Nature

Science is about explaining the patterns of nature. For example, trees come in different shapes and sizes. Those shapes and sizes form a pattern. A biologist tries to explain the pattern of trees.

When explaining pattern, we must separate constraint from process. First, we remove those aspects of pattern that we do not try to explain. For example, trees are made from certain kinds of basic materials. Those materials set constraints on the patterns of trees. Second, within those basic constraints, we try to understand the processes that lead from the range of possible patterns to the actual observable patterns.

Much of the constraint on pattern arises from randomness itself. That may seem like a contradiction, because pattern seems to be the opposite of randomness. Yet, when we combine many random processes, very strict patterns arise. For example, if we measure the height of the first adult to walk by, that particular height is highly unpredictable - it is highly random. But if we measure the heights of the first 1000 adults who walk by, the aggregate pattern of variability among those 1000 individuals will follow a very strict and predictable pattern.

Observable patterns create puzzles in which we must separate randomness from process. For example, the risk of getting cancer changes with age. Some of the pattern that relates risk to age comes from the constraints set by the way that randomness influences cancer. Other aspects of cancer risk arise from particular biological processes, such as the number of different ways that our bodies normally protect us from disease. To understand the biological processes, we must learn to parse pattern into random components and biological components. Parsing requires a deep understanding of the various ways in which randomness creates pattern.

Randomness creates pattern by information obtained through measurement. The information that we obtain through measurement changes with magnitude. For example, a 30cm ruler provides useful information about distances within my office, but provides little information about the relative distances of Venus and Mars. That change in information with magnitude shapes the observable patterns created by randomness.

Frank, Steven A. (2017)

Universal expressions of population change by the Price equation : natural selection, information, and maximum entropy production

https://kxp.k10plus.de/DB=9.663/PPNSET?PPN=1041215436

Frank, Steven A. (2016)

Common probability patterns arise from simple invariances

https://kxp.k10plus.de/DB=9.663/PPNSET?PPN=1041216467

Frank, Steven A. (2015)

D'Alembert's direct and inertial forces acting on populations : the price equation and the fundamental theorem of natural selection

https://kxp.k10plus.de/DB=9.663/PPNSET?PPN=1041216041

Frank, Steven A. (2014)

Microbial metabolism : optimal control of uptake versus synthesis

https://kxp.k10plus.de/DB=9.663/PPNSET?PPN=788299956

Frank, Steven A. (2013)

A new theory of cooperation

https://kxp.k10plus.de/DB=9.663/PPNSET?PPN=794275001

Frank, Steven A. (2013)

Natural selection : VII. History and interpretation of kin selection theory

https://kxp.k10plus.de/DB=9.663/PPNSET?PPN=789394502

Frank, Steven A. (2013)

Natural selection : VI. Partitioning the information in fitness and characters by path analysis

https://kxp.k10plus.de/DB=9.663/PPNSET?PPN=789394278

Frank, Steven A. (2013)

Microbial evolution : regulatory design prevents cancer-like overgrowths

https://kxp.k10plus.de/DB=9.663/PPNSET?PPN=788299816

Frank, Steven A. (2013)

Input-output relations in biological systems : measurement, information and the Hill equation

https://kxp.k10plus.de/DB=9.663/PPNSET?PPN=788298585

Frank, Steven A. (2013)

Evolution of robustness and cellular stochasticity of gene expression

https://kxp.k10plus.de/DB=9.663/PPNSET?PPN=786606509