The Scientific Underpinnings of Sustainability

Introduction to the three scientific laws that govern all sustainable systems

1. The Law of Limits to Growth

Limits to growth at the organismic level

Limits to growth at the ecosystem level—old-growth ecosystems

Limits to growth at the biospheric level occurred 250,000,000 years ago

The limitations of technology and the economic principle of Unlimited Substitutability in sustaining continuous growth

2. The Second Law of Thermodynamics or the Entropy Law

Although energy can't be created or destroyed, it can be transformed from one state to another. Each transformation results in a loss of energy from the system where the transformation occurs. If the energy isn't replaced within the system these losses cause entropy.

Entropy is a process, due to losses of energy, where systems become increasingly disorganized and simplified as their energy and materials diffuse

Anti-entropic, dynamic equilibrium, and entropic system states

All our current environmental problems at their core are entropic situations where complex ecosystems are being simplified and energy and materials are being diffused

3. The Law of Self-organization

Self-organization occurs in all biological and ecological systems and is key to sustainability. Self-organizing systems increase their complexity through time as the parts within the system become ever more specialized and tightly integrated. As each part services itself it also services the whole. As a result self-organized systems become increasingly resilient, stable, and efficient in their use of material and energy resources.

Self-organization at the organismic level

Self-organization at the ecosystem level through the co-evolution of symbioses—energy is nature's hard rock currency

Young symbiotic interactions tend to be highly negative and energy wasteful, co-evolution through natural selection forces these interactions to become more energy efficient

Co-evolution of the bull's-horn acacia and its acacia ant

Niche separation to avoid wasteful energy losses due to competition

Microhabitat separation
Temporal separation
Resource partitioning

Co-evolution, driven by energy efficiency, selects for specialization, niches get smaller, more species can be supported in ecosystems, so these systems become more complex, resilient, stable, and efficient.

Factors that foster high levels of self-organization

Increased physical stability

Increased physical structure

Low levels of competitive exclusion

Self-organization in a designed landscape; self-organization in an economy