The Generator–Validator–Filter Architecture Across Biological Systems

Abstract

Biological systems face an intrinsic challenge: they must adapt to environments that change faster than any pre-specified control architecture can anticipate. Across molecular, cellular, organismal and ecological scales, organisms repeatedly employ a characteristic computational pattern: generation of variation, validation through environmental or internal constraints, and filtering of unsuccessful states. We propose that this Generator–Validator–Filter (GVF) architecture constitutes a general principle underlying adaptive processes in living systems.

1. Introduction

No biological system can rely solely on preprogrammed solutions. Environments shift, pathogens evolve, developmental noise accumulates, and ecological niches reorganize. To survive, organisms must generate possibilities, test them, and eliminate failures.

2. GVF Architecture

G produces possibilities, V evaluates them, F removes non-viable states. This enables adaptation under radical uncertainty.

3. Instances Across Biology

Immune system, neural development, embryogenesis, cancer suppression, microbiome ecology, molecular evolution.

4. Evolution as Meta-GVF

Evolution itself is a GVF system that produces other GVF systems, leading to a fractal recursion.

Conclusion

GVF is a universal computational pattern recurring across biological scales.