Embodied Game of Life with Diffusive Food:
A Minimal Arena for Open-Ended Evolution

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Abstract

We describe a simple artificial-life environment: Conway's Game of Life (GoL) embedded in a continuous food field that diffuses and is consumed by alive cells. Diffusion is *faster near living tissue* to promote organism formation and *food sharing along connected structures.* GoL remains the base logic; food influences survival with a *hard, local gate*: on scheduled checks, any currently-alive cell sitting in food below a fixed threshold is deterministically killed. The aim is to study open-ended evolutionary dynamics where structures must forage, coordinate, and compete for resources.

Note: this document was written with the help of AI.

Design Rationale (Why These Choices)

- **Keep GoL dynamics familiar.** Use standard GoL to propose births/survivals; apply only a simple local gate so recognizable structures (gliders, oscillators, etc.) still emerge.
- **Embodiment via diffusion + consumption.** Food flows by diffusion and is consumed where cells are alive. This creates local deficits that surrounding regions refill.
- **Faster diffusion around life.** Diffusivity is higher near living cells. This supports formation of *organisms* (connected tissue) and enables *passive sharing* of food along those connections—favoring coordinated morphologies over isolated cells.
- **Simple, conservative transport.** No velocities or forces. Transport is just diffusion; total food is conserved during transport and only decreases by consumption (and optional tiny decay).

Environment

Grid: 2-D torus with binary life $C \in \{0,1\}^{H\times W}$ and food $F \in [0,1]^{H\times W}$.
Tick order: (1) GoL proposal $\to$ (2) food gate $\to$ (3) optional central seeding $\to$ (4) diffusion $\to$ (5) consumption.

Hard food gate (deterministic, periodic). Let $T_g \in (0,1)$ be a fixed threshold and $k \in \mathbb{N}$ a check cadence. Define a local food measure $\tilde{F}$ (we use a 3×3 mean: $\tilde{F} = \mathrm{mean}_{3\times3}(F)$). After computing classic GoL,

$$C^*_{t+1} \;=\; \mathrm{GoL}(C_t),$$

apply the gate *only on scheduled ticks* ($t \equiv 0 \pmod{k}$):

$$C_{t+1}(i,j) \;=\; \begin{cases} 0, & \text{if } C_t(i,j) = 1 \text{ and } \tilde{F}_t(i,j) < T_g, \\ C^*_{t+1}(i,j), & \text{otherwise.} \end{cases}$$

Thus, the gate never creates births and never rescues deaths: it can only *kill* currently-alive cells when local food is scarce. Births are accepted strictly from GoL, and cells that were dead at t are unaffected by the gate.

Diffusion (why it helps organisms). Compute a simple life density $\rho = \mathrm{mean}_{3\times3}(C)$ and set

$$D = D_{\mathrm{dead}} + (D_{\mathrm{alive}} - D_{\mathrm{dead}})\,\rho, \quad 0 < D_{\mathrm{dead}} \le D_{\mathrm{alive}}.$$

Food diffuses with coefficient D: where tissue is present (ρ large), diffusion is faster. Because alive cells also consume food, this combination creates *inward flux toward connected clusters* and then *rapid sharing* along them. (Implementation tip: use standard finite-difference/finite-volume diffusion with periodic wrap; choose $\Delta t \le 1/(4D_{\max})$.)

Consumption (only sink). On alive cells, apply a stable multiplicative uptake

$$F \leftarrow F \cdot e^{-\mu\,\Delta t} \quad \text{(only where } C = 1\text{)},$$

and optionally a tiny global leak $-\lambda F \Delta t$.

Central seeding In a small centered $D \times D$ square, flip dead sites to alive with a tiny probability p_{seed} each tick to keep exploration going.

Evolution Experiment (Free, Ongoing)

We do *not* impose an external fitness function or reset episodes. The simulation runs indefinitely; variation and selection arise from the physics plus the gate. Local consumption and diffusion set the ecological pressures (access to food, connectivity for sharing). Small deviations from deterministic GoL can be dialed to zero; with the hard gate present, lineages that happen to forage, move, replicate, and maintain connected tissue tend to persist and spread, while others fade.

What to Look For

Foraging swarms (glider streams feeding tissue), diffusion "corridors" that enable sharing, arms races between dismantlers and defenders, and niche formation between mobile and high-retention strategies. Track gate-triggered deaths, total/consumed food, cluster sizes, and glider flux.