Experimental design:

- To unravel the origin of molecular complexity, we evolved populations in the simplest possible environment: the Aevol target is a triangle.
- We evolved 300 populations of 1024 individuals for 250,000 generations under 3 mutation rates and monitored the evolution of genomic and functional complexity.

(1) Organisms evolved complex functional structures in 66% of the simulations.
Whatever the mutation rate, 1/3 of the simulations led to “simple” organisms with few genes and a low functional complexity (A). 2/3 of the simulations led to “complex” organisms despite the simplicity of the target function (B).

(2) Complex organisms accumulate more information at the genomic and functional levels
Genomic complexity is strongly bounded by mutation rates (A) due to robustness constraints on the genome (Knibbe et al., 2007; Fischer et al., 2014). Mutation rates also constrain the functional complexity (B) but this effect is less stringent at the functional level.

(3) Simple organisms are fitter than complex ones
Whatever the complexity measure, we observe a clear trend for simple organisms to be fitter than complex ones after 250,000 generations. This demonstrates that in our simulations complexity is not driven by selection.
On the opposite, complex functional structures have evolved in spite of selection.

(4) Despite the advantage of being simple, complex organisms evolve greater complexity on the long term
The simple/complex identities are determined early on in the simulation and generally conserved thereafter (A).
Complex organisms evolve greater complexity (B); their fitness grows but remains far below simple organisms.

Discussion

The emergence of complex organisms in a simple environment is a strong argument in favor of a complexity ratchet, i.e. an irreversible mechanism that adds components to a system but that cannot get rid of existing ones, even though this could be more favorable. Indeed, in our experiments this ratchet clicks and goes on clicking despite the selective advantage of being simple. Evolution of fitness in complex organisms shows that the ratchet is empowered by negative epistasis. Our results show that complex biological structures can flourish in conditions where complexity is not needed and that, reciprocally, the global function of complex structures could very well be simple.