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Microbial life cycles link global modularity in regulation to mosaic evolution

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Abstract: Microbes are exposed to changing environments, to which they can respond by adopting various lifestyles such as swimming, colony formation or dormancy. These lifestyles are often studied in isolation, thereby giving a fragmented view of the life cycle as a whole. Here, we study lifestyles in the context of this whole. We first use machine learning to reconstruct the expression changes underlying life cycle progression in the bacterium *Bacillus subtilis*, based on hundreds of previously acquired expression profiles. This yields a timeline that reveals the modular organization of the life cycle. By analysing over 380 *Bacillales* genomes, we then show that life cycle modularity gives rise to mosaic evolution in which life stages such as motility and sporulation are conserved and lost as discrete units. We postulate that this mosaic conservation pattern results from habitat changes that make these life stages obsolete or detrimental. Indeed, when evolving eight distinct *Bacillales* strains and species under laboratory conditions that favour colony growth, we observe rapid and parallel losses of the sporulation life stage across species, induced by mutations that affect the same global regulator. We conclude that a life cycle perspective is pivotal to understanding the causes and consequences of modularity in both regulation and evolution.

DOI: <https://doi.org/10.1038/s41559-019-0939-6>

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ZORA URL: <https://doi.org/10.5167/uzh-182147>

Journal Article

Supplemental Material

Originally published at:

van Gestel, Jordi; Ackermann, Martin; Wagner, Andreas (2019). Microbial life cycles link global modularity in regulation to mosaic evolution. *Nature Ecology and Evolution*, 3(8):1184-1196.

DOI: <https://doi.org/10.1038/s41559-019-0939-6>

○ = spore

● = germinating spore