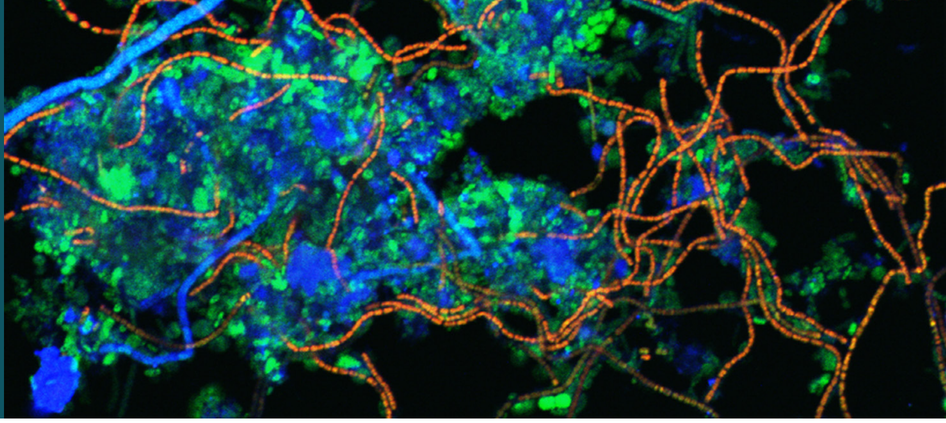

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Simple models to predict complex microbial community metabolism—with applications for environmental biotechnology

Read more

Desmond-Le Quemener E, Bouchez T

A thermodynamic theory of microbial growth.

ISME Journal . 2014

Delattre H, Desmond-Le Quemener E, Duquennoi C, Filali A, Bouchez T

Consistent microbial dynamics and functional community patterns derived from first principles.

ISME Journal . 2019

Collaboration

Development of the microbial transition state theory and assessment of the potential power of microbial thermodynamics models is the focus of an ongoing ANR-sponsored project (ANR THERMOMIC 2016–2020) that is coordinated by INRAE–PROSE with LBE and TBI on board.

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Context

Microorganisms are not just the most abundant forms of life on Earth—microbial communities are key engines that drive Earth's biogeochemical cycles. They essentially cycle chemical elements across the entire planet, and the TRANSFORM division harnesses their extraordinary biocatalytic capacities in a catalogue of biotech processes. Successful development of the bioeconomy needs solid foundations to understand and methodize the use of microbial communities for biotransformation purposes.

Results

Models of microbial dynamics are grounded in phenomenological equations, and foremost the seminal equation proposed by Jacques Monod in the 1940s. However, these models cannot be used without first calibrating parameters against population-specific experimental data. Attempts to explore complex microbial communities dominated by uncultured microorganisms quickly run up against this constraint, which limits use of these models and bottlenecks their predictive abilities. That said, in a given set of physical-chemical conditions, whether in nature or in unconfined biotechnology processes, biotransformation will generally repeat the same functional patterns of metabolism, which suggests that there are generic deterministic processes at work to assemble functional microbial communities. We contend that energy balances play a major role in lending structure to microbial functions within ecosystems.

We propose a theory framework grounded in a manageably small set of simple physical concepts to capture, through generic first principles and mathematically explicit expression, the influence of energy on rate of growth in microbial populations. The overarching objective is to use known physical-chemical conditions to emerge the metabolic functions of microbial ecosystems. We have brought illustration of the predictive abilities of our new approach by modelling an increasingly complex gradient of microbial ecosystems using a compact number of parameters. We showed that an activated sludge process community can be modelled with three times fewer parameters than conventional approaches.

Future Outlook

We anticipate this approach as a starting point towards a whole new class of microbial ecosystem models potentially demonstrating more powerful predictive capabilities. To take this pure research into applied practice, we have started work on translating the new kinetics equations from our theory into simulation software to support environmental biotechnology process engineering.