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## Modeling Microbial Communities: Toward Digital Twins

Simon Labarthe

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# ➤ Modeling Microbial Communities: Toward Digital Twins



Simon Labarthe

Univ. Bordeaux, INRAE, BIOGECO

Univ. Bordeaux, Inria-Inrae, Pléiade

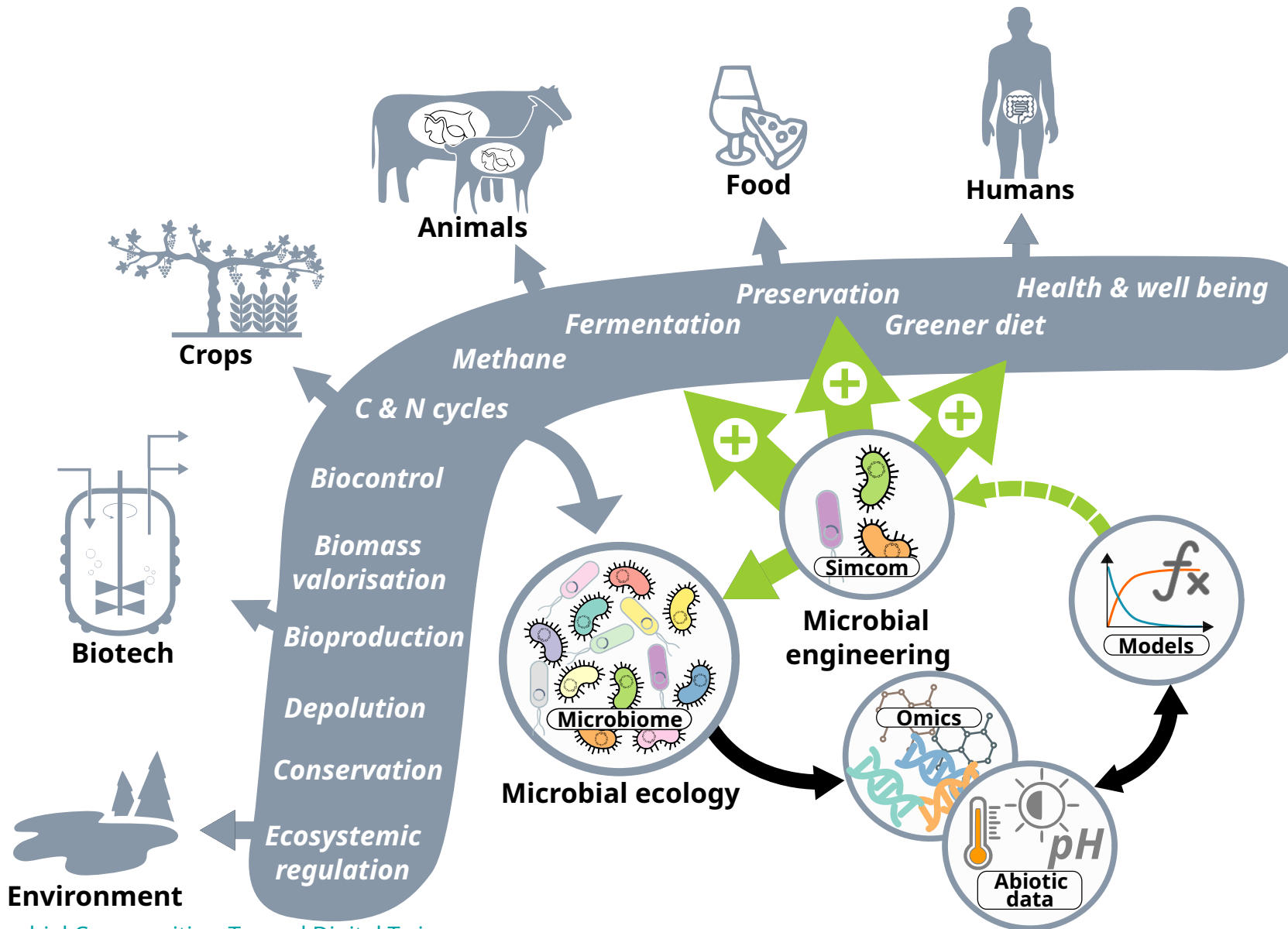
[simon.labarthe@inrae.fr](mailto:simon.labarthe@inrae.fr)

 [slabarthe@mathstodon.xyz](mailto:slabarthe@mathstodon.xyz)

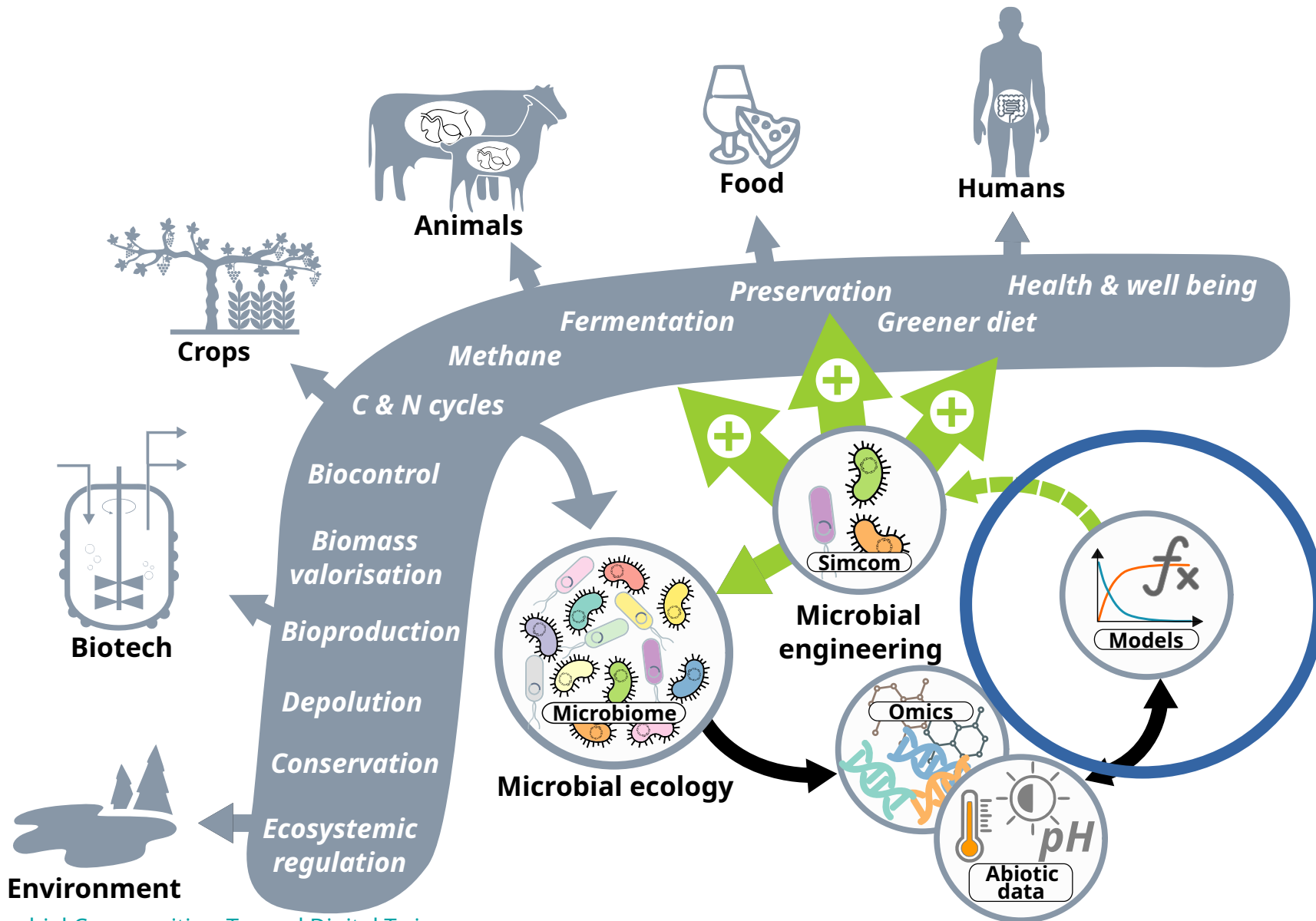
 [simon-labarthe-0302a435](https://www.linkedin.com/in/simon-labarthe-0302a435)

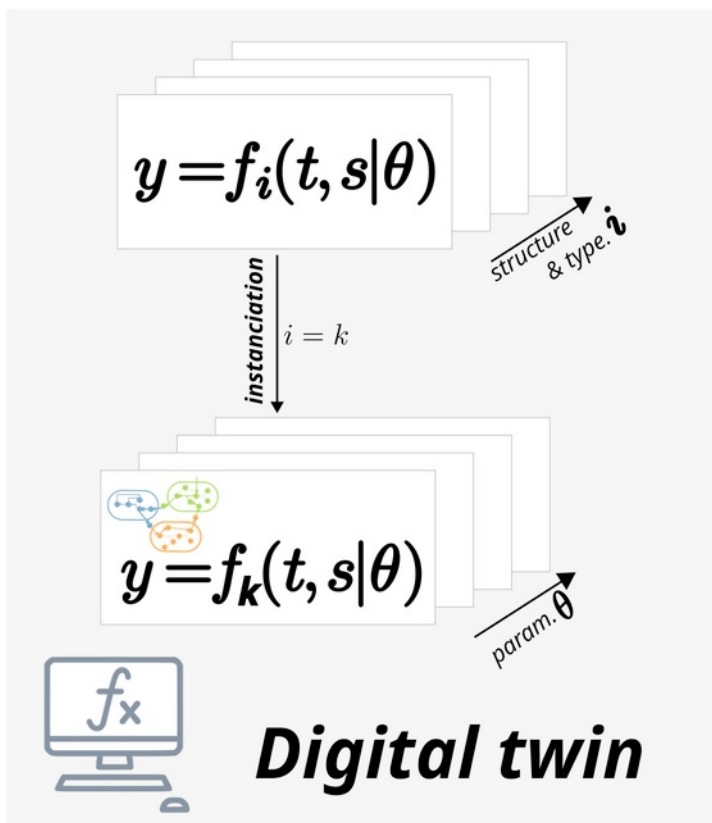


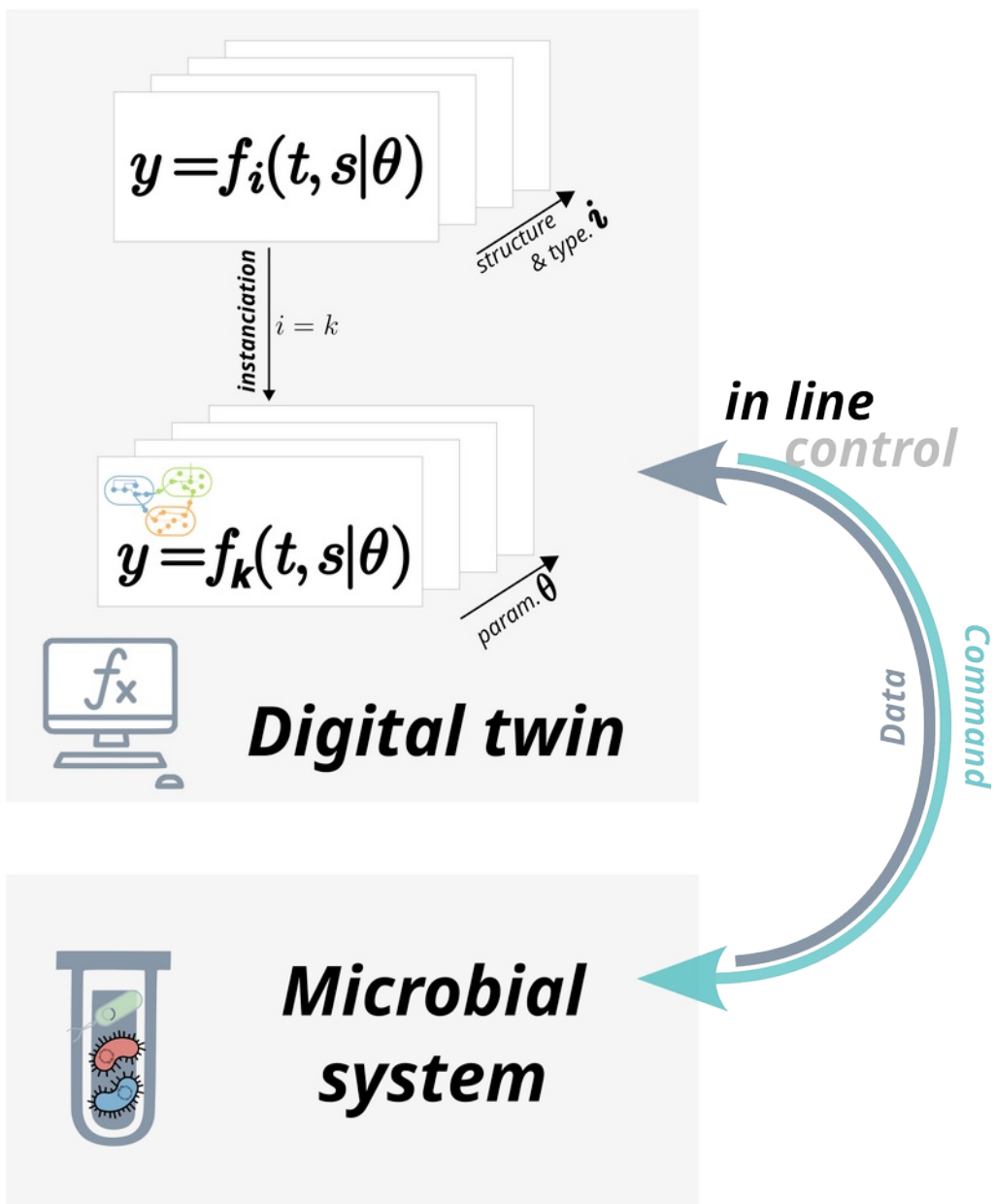
# Model-guided microbial community steering

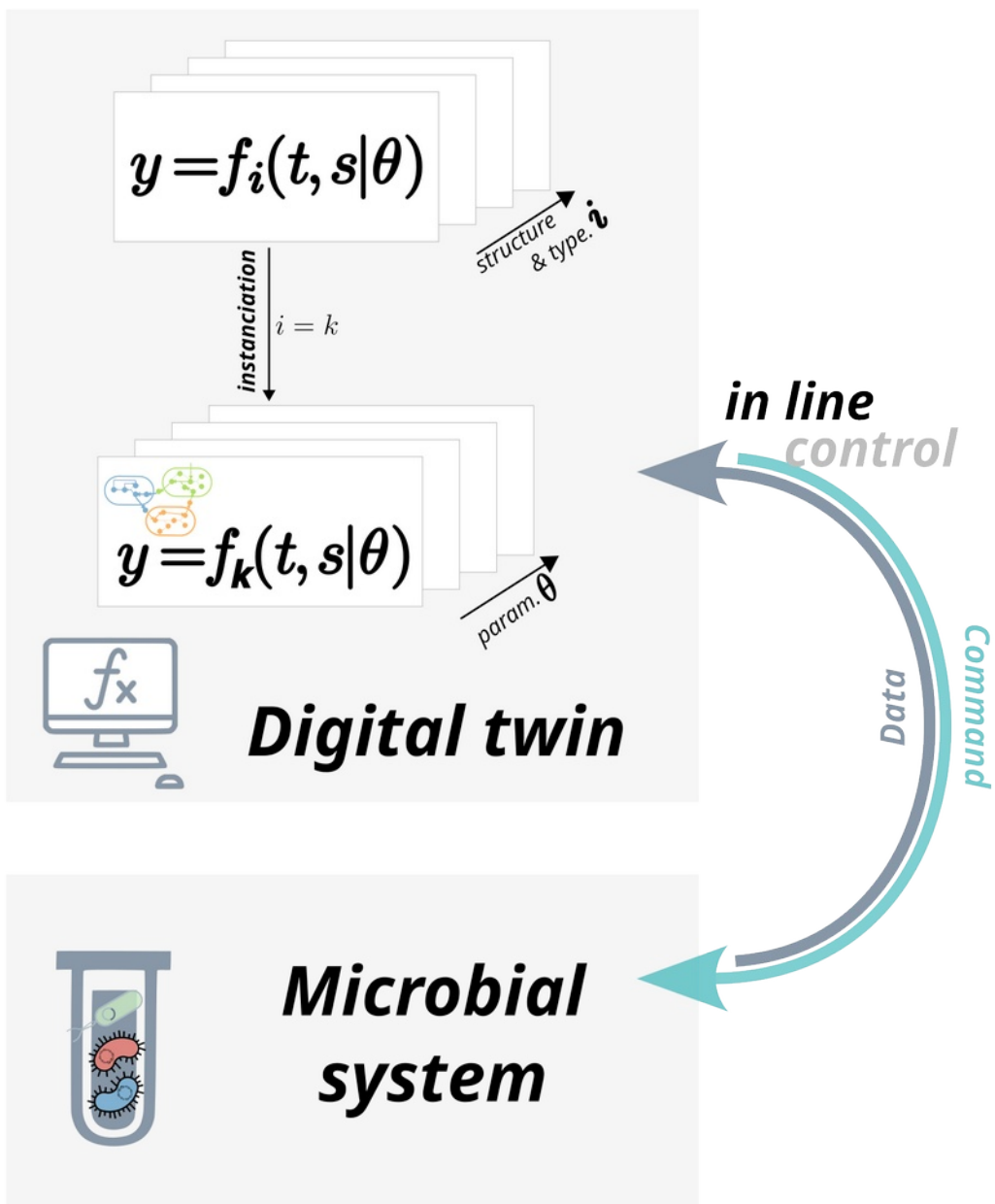


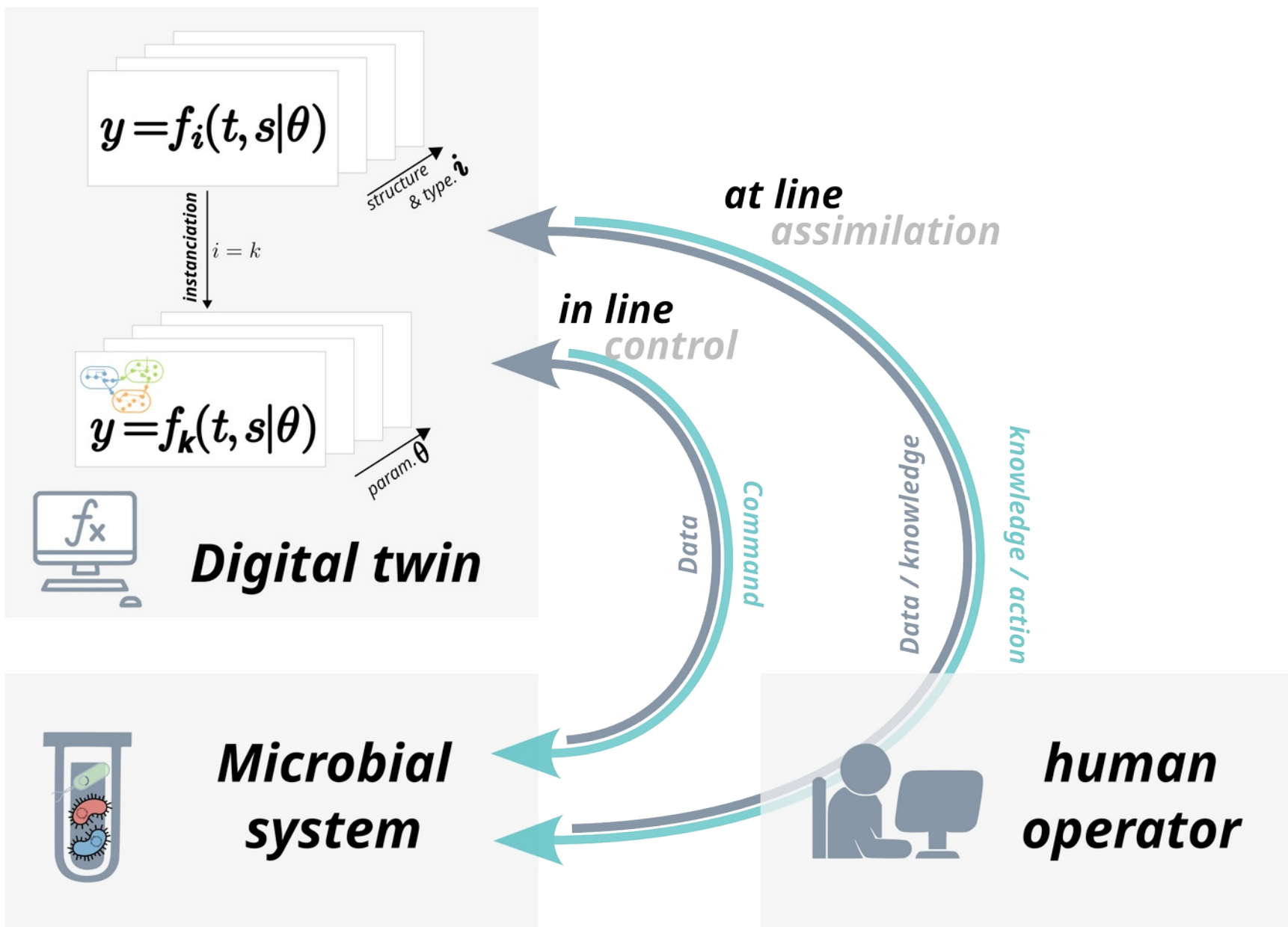
# Model-guided microbial community steering

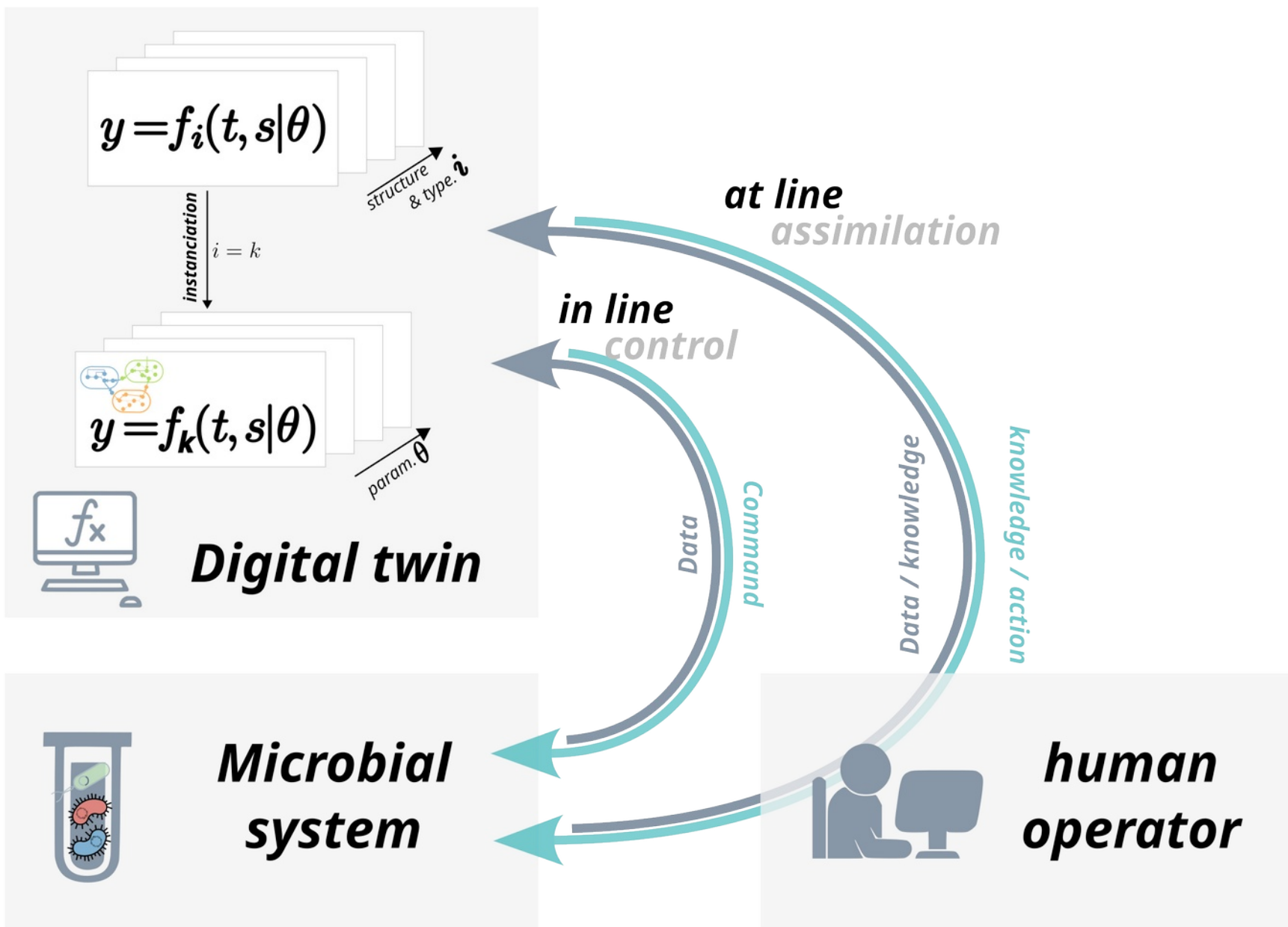


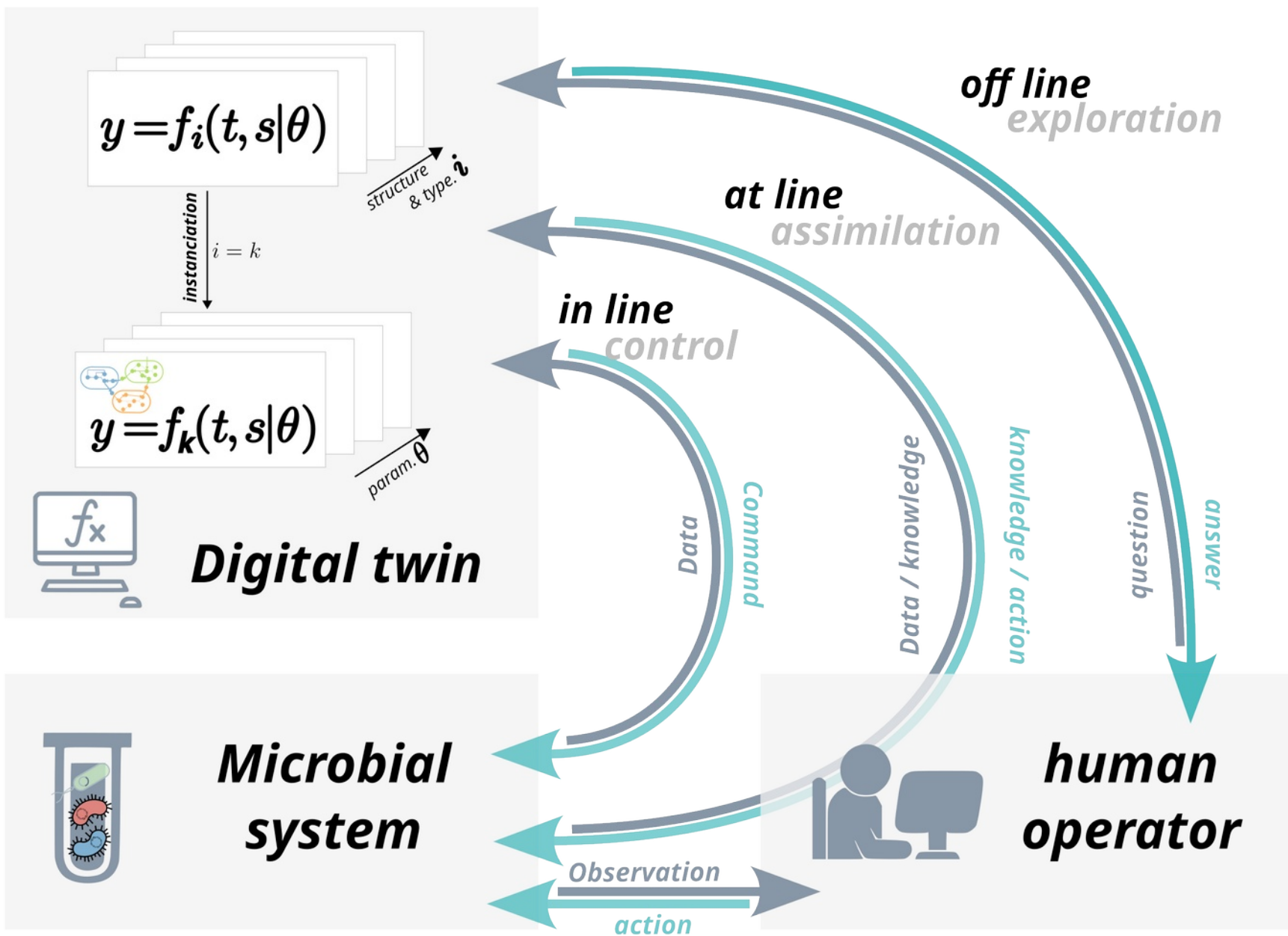


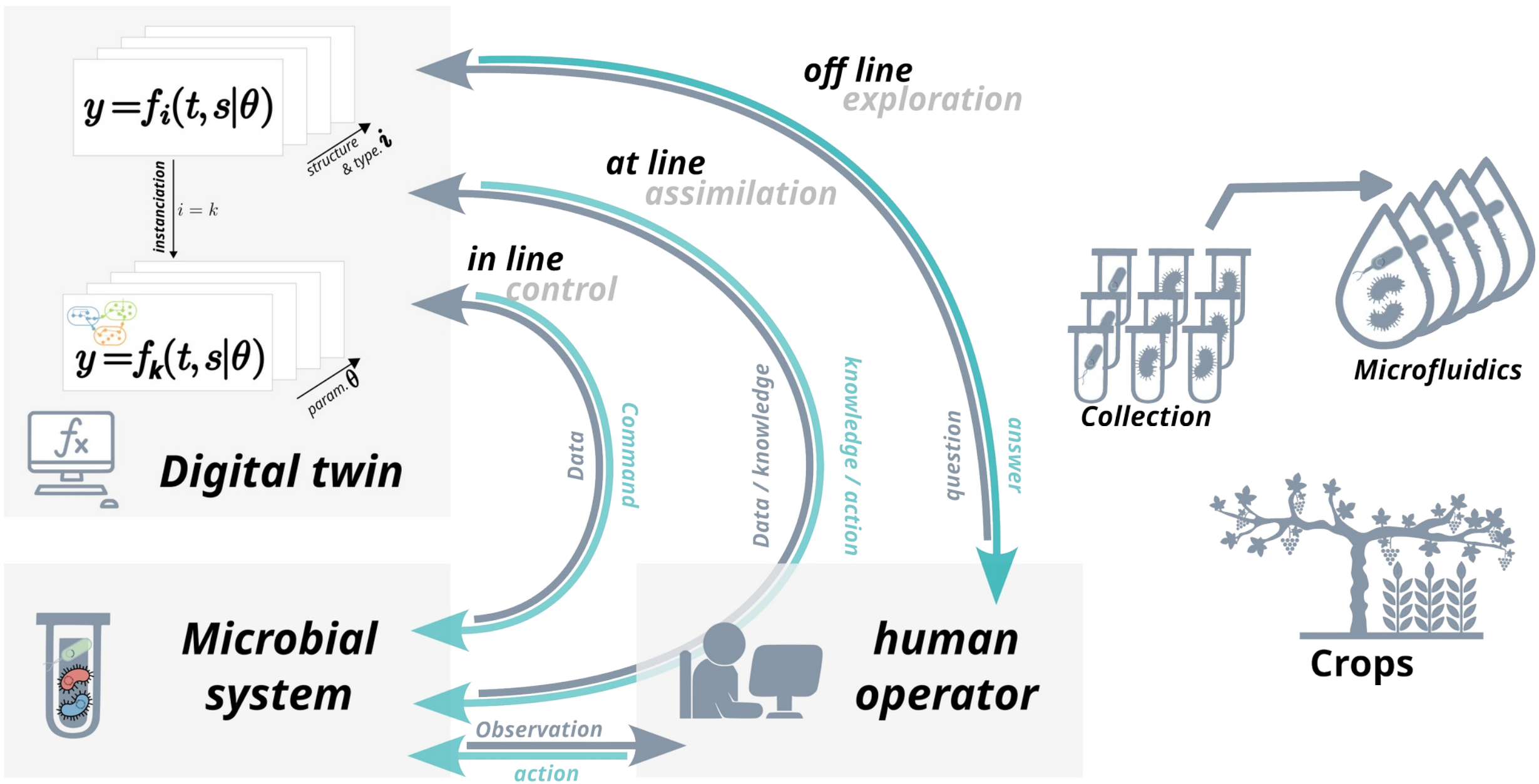




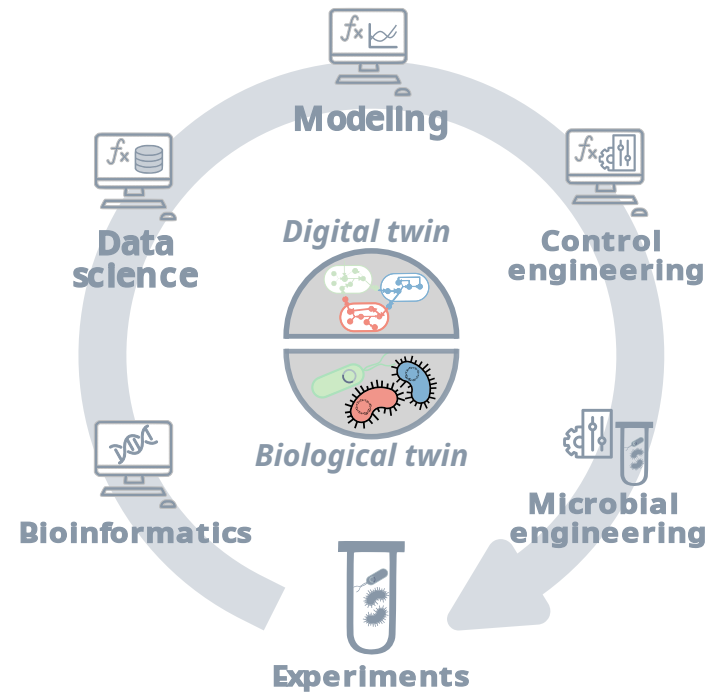






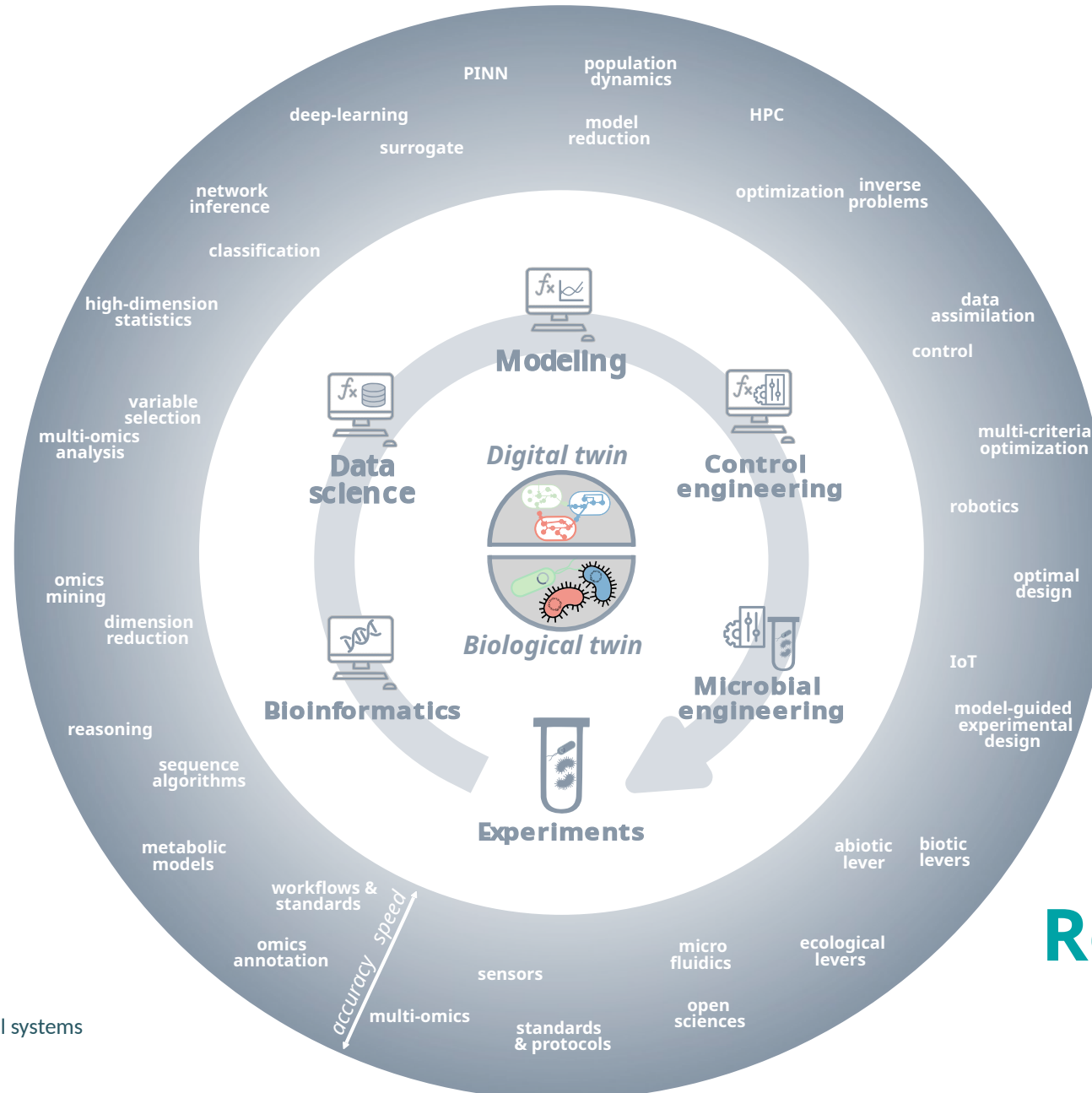


# Digital Twin: boosting interdisciplinarity





# Digital Twin: boosting interdisciplinarity



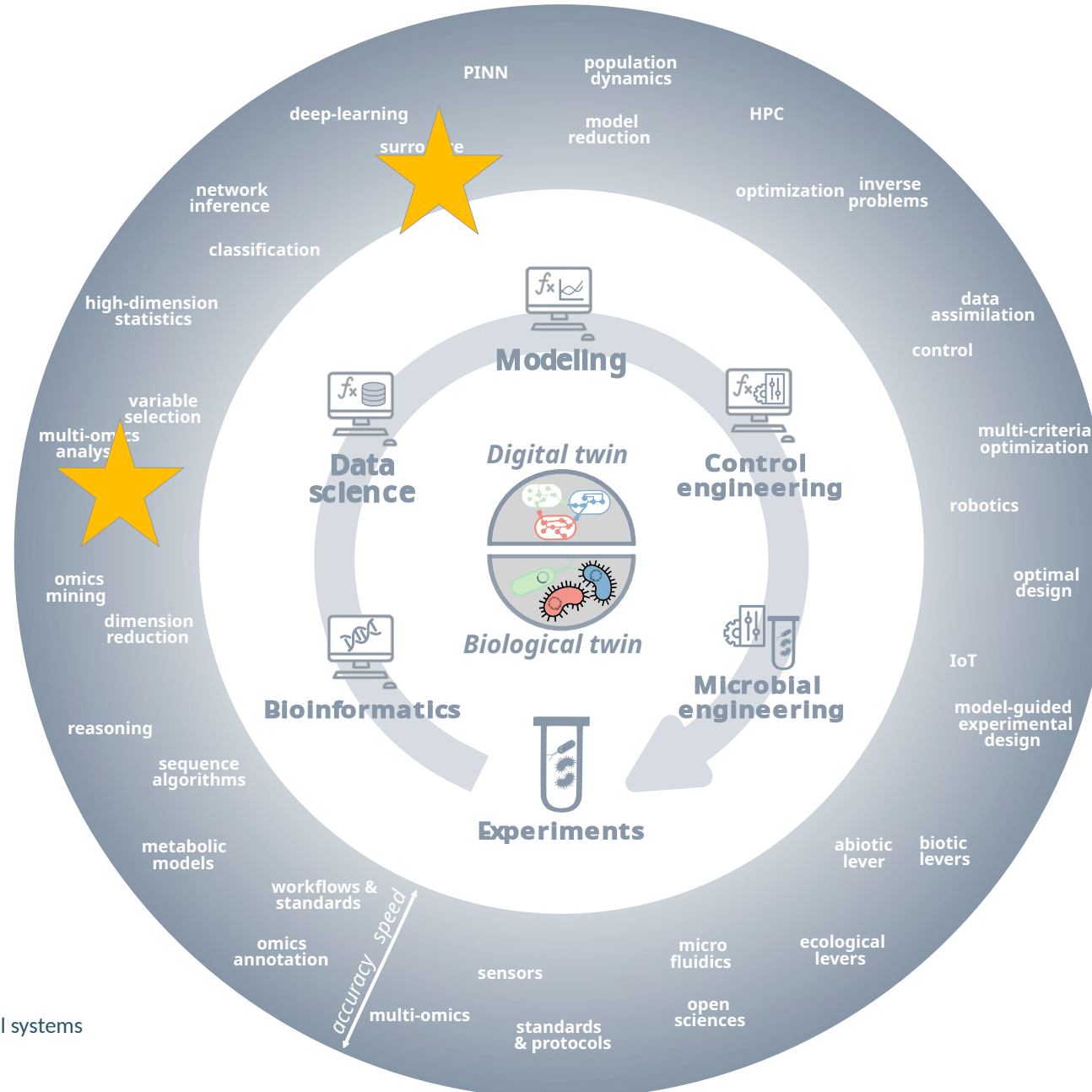
## Research object



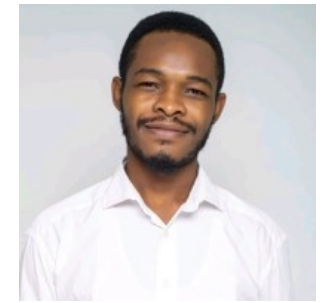
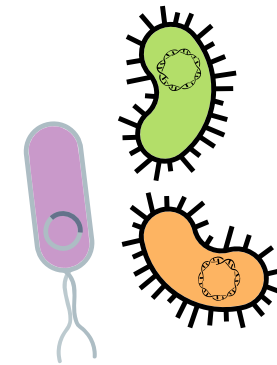
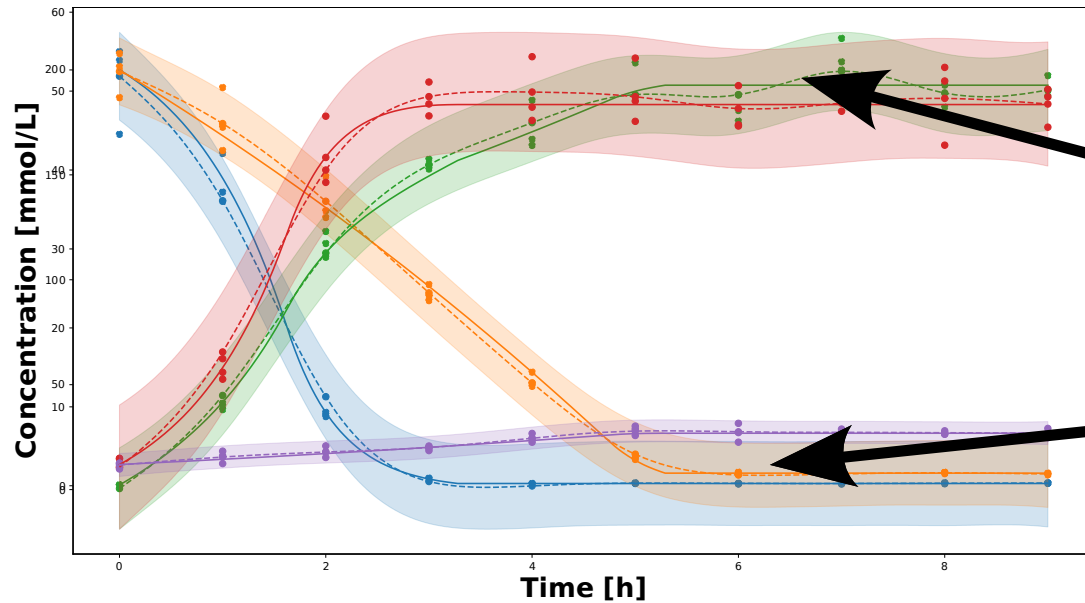
INRAE

Artemis: digital twins of microbial systems  
12/09/2025

# Digital Twin: boosting interdisciplinarity



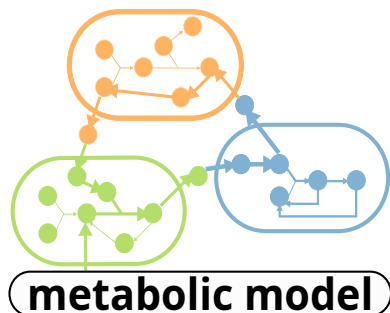
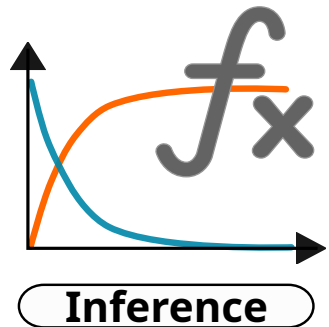
# SynCom growth experiments



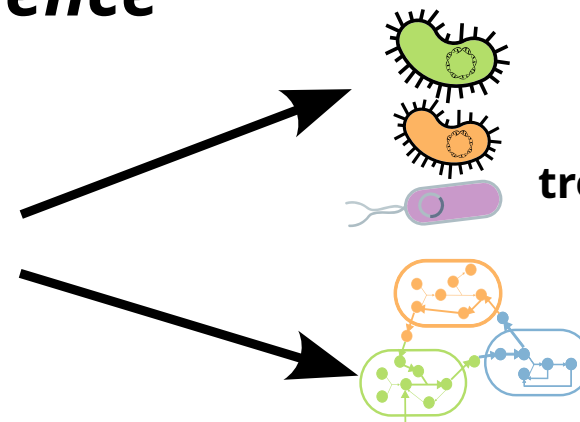
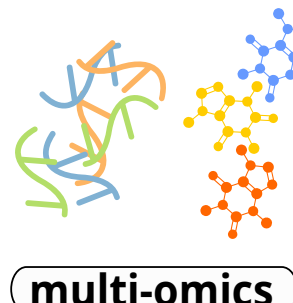
**Sthyye Tatho**  
**PhD Mystic**

Metabolism-driven correlations

## Goal : metabolism-informed inference



+



individual contributions,  
trophic interactions

Individual metabolism

## Residuals



$$\hat{\nu}(t) := \arg \min_{\nu_t} \sum_{m \in \mathcal{M}} \left\| R_{m,t} - \sum_{b \in \mathcal{B}_m} \chi_t^{(b)} \nu_{m,t}^{(b)} \right\|_2^2 + \lambda \mathcal{R}(\nu)$$



**Regularization**

**Metatranscp.**

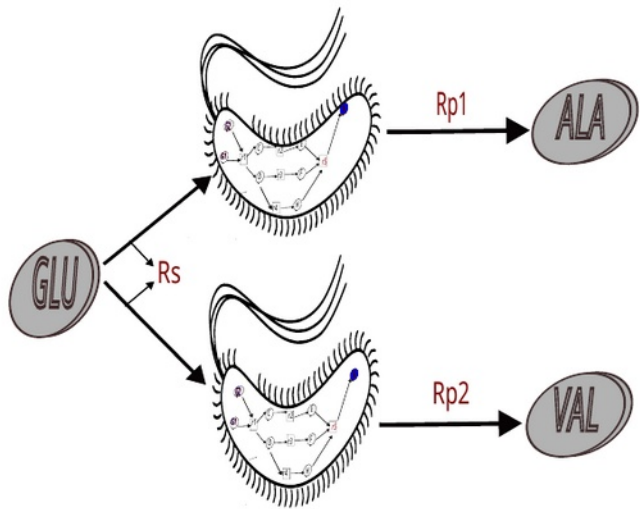
Subject to  $S^b \nu_{m,t}^{(b)} = 0$

$$C_{min} \leq \nu_{m,t}^{(b)} \leq C_{max}$$

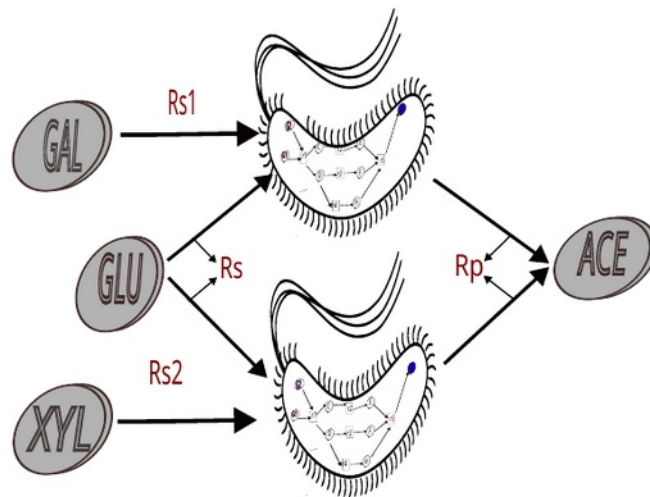


**Metabolic constraints**

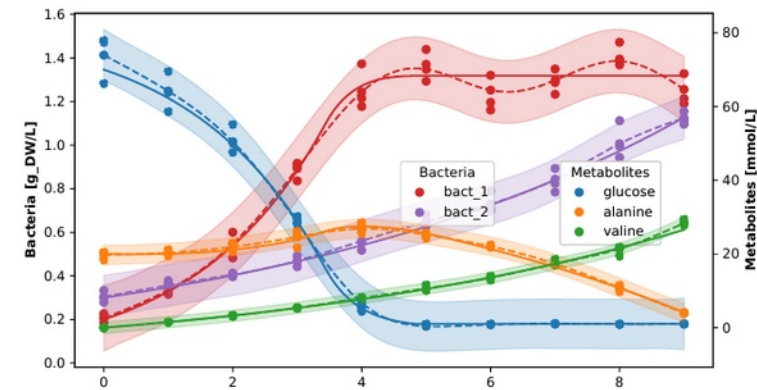
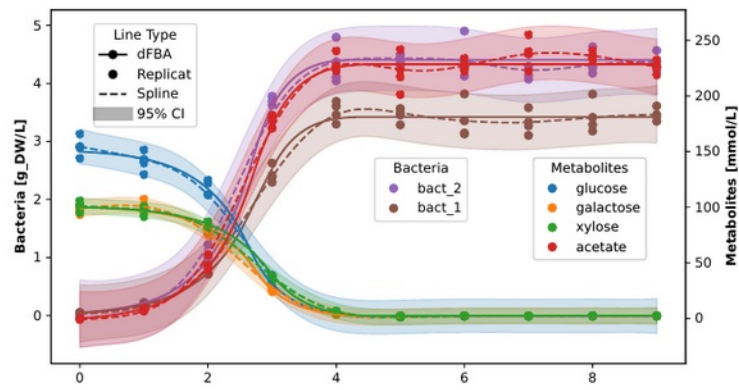
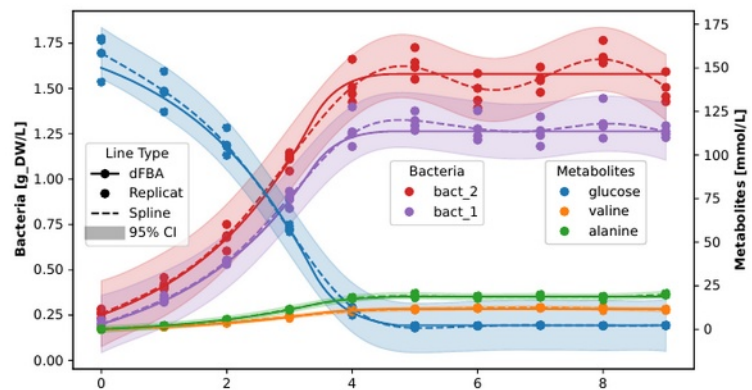
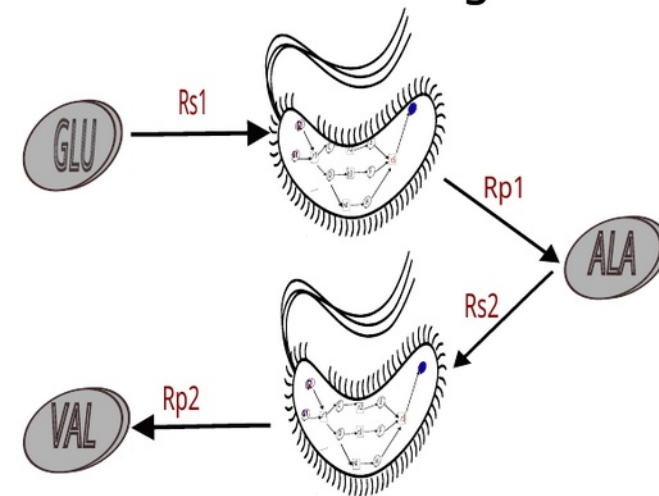
## Competition

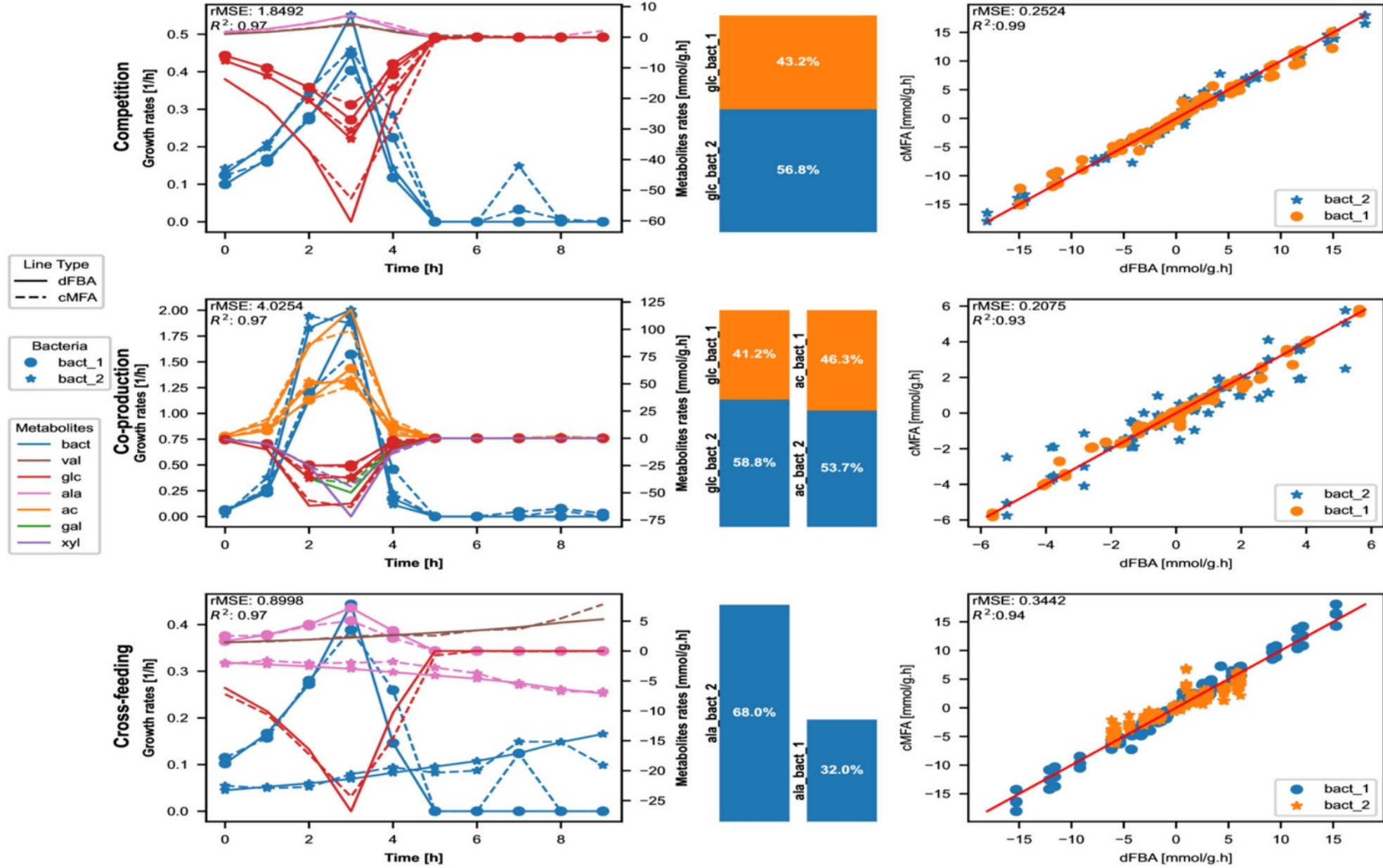


## Co-production

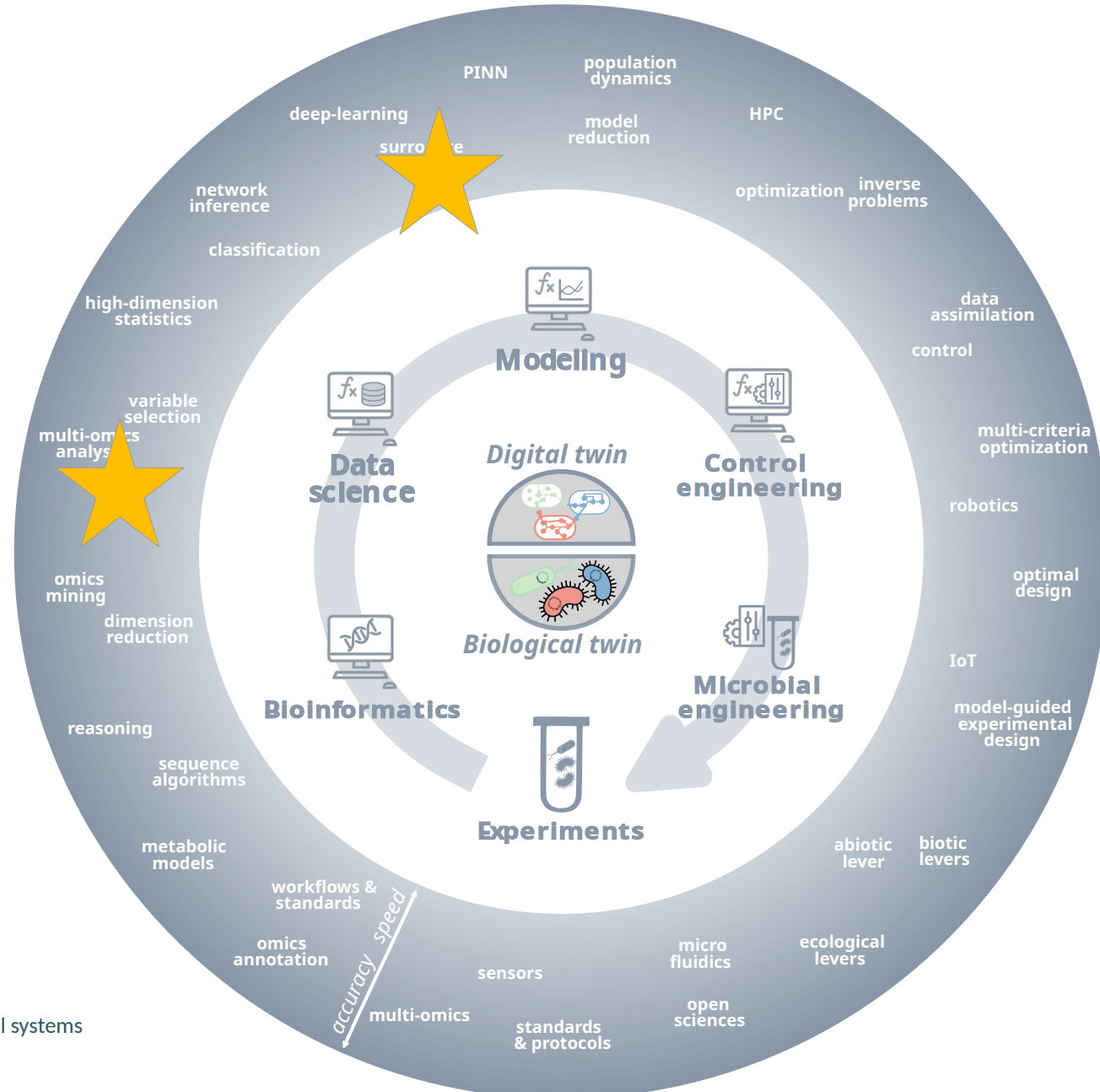


## Cross-feeding

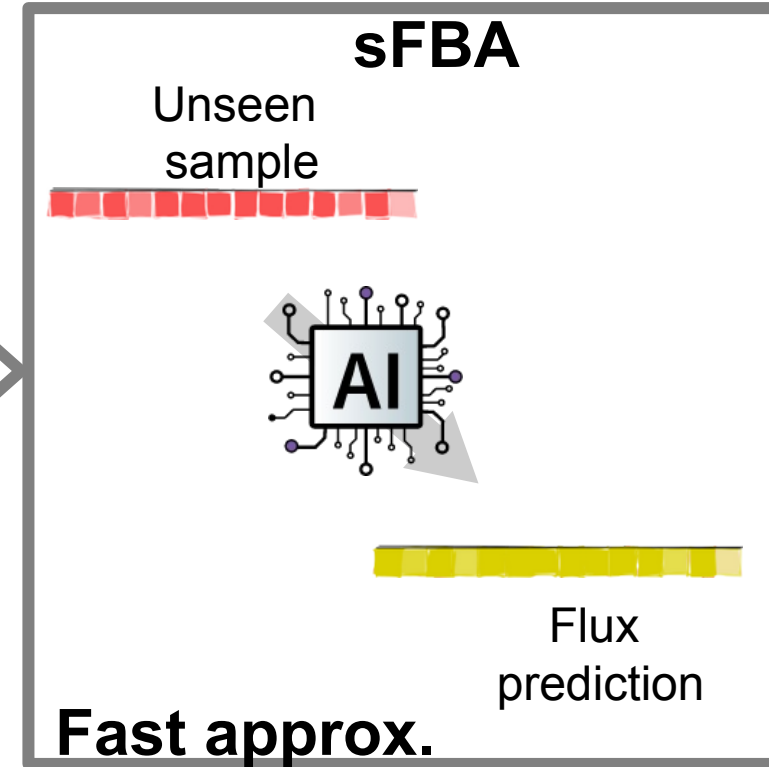
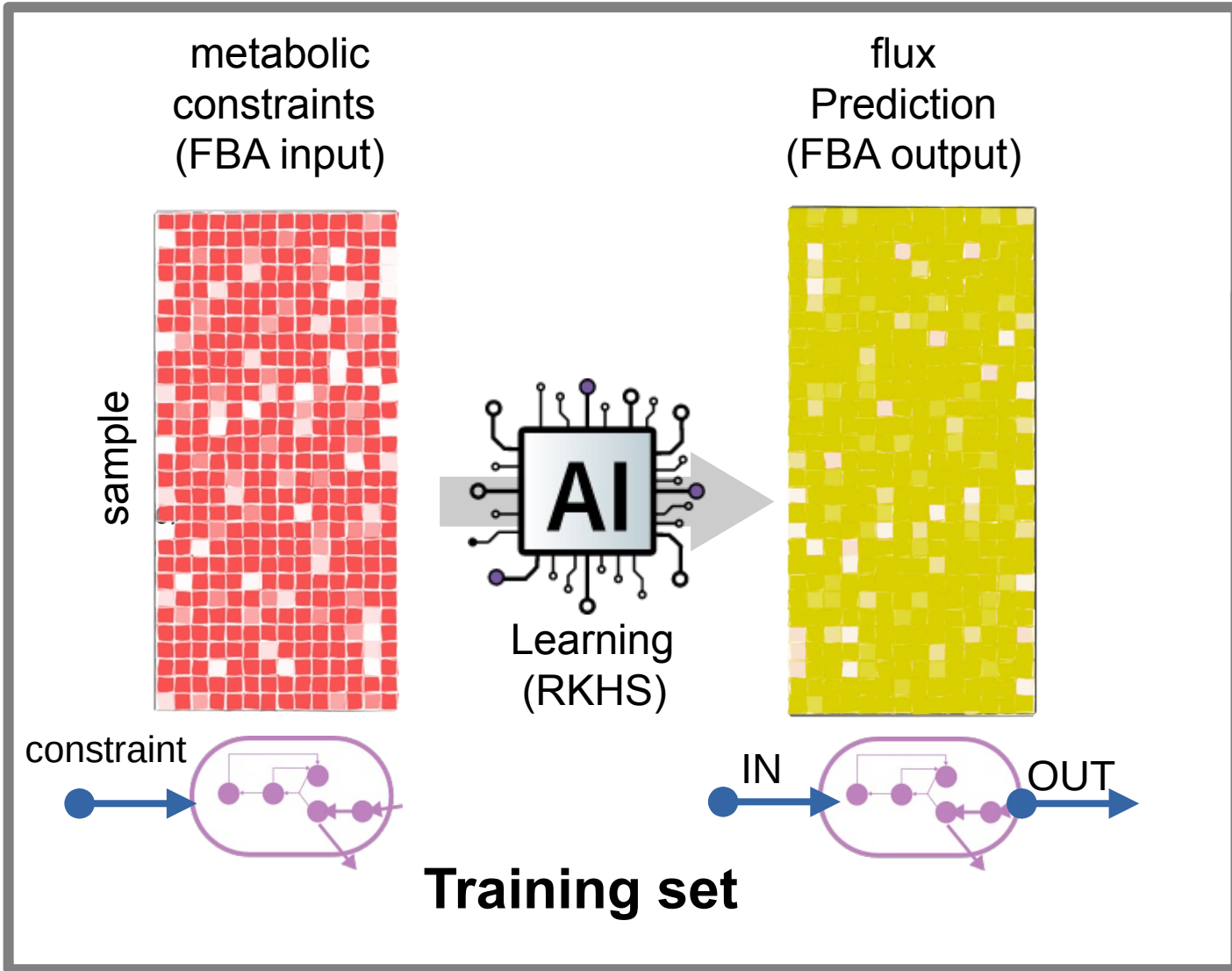




# Digital Twin: boosting interdisciplinarity



# Speeding-up metabolic prediction with surrogate FBA



C.Frioux

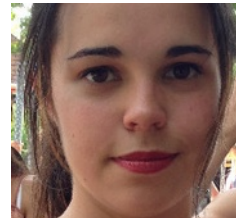


Aex Slimmest

P.Ugalde



C.Muller



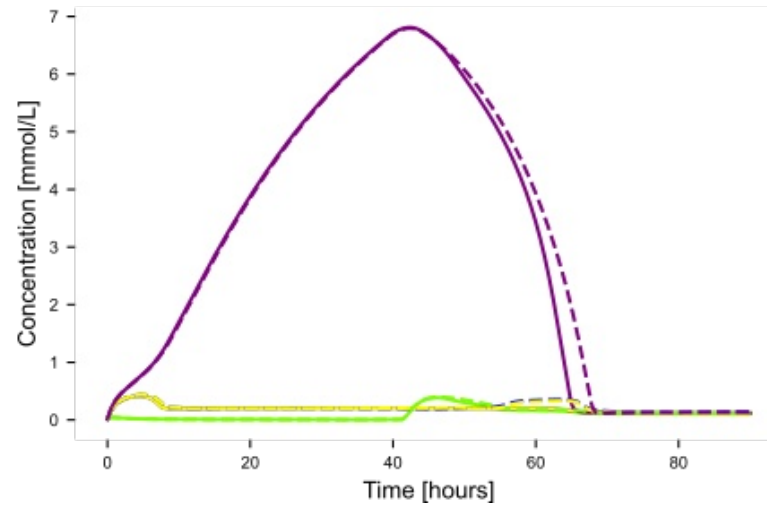
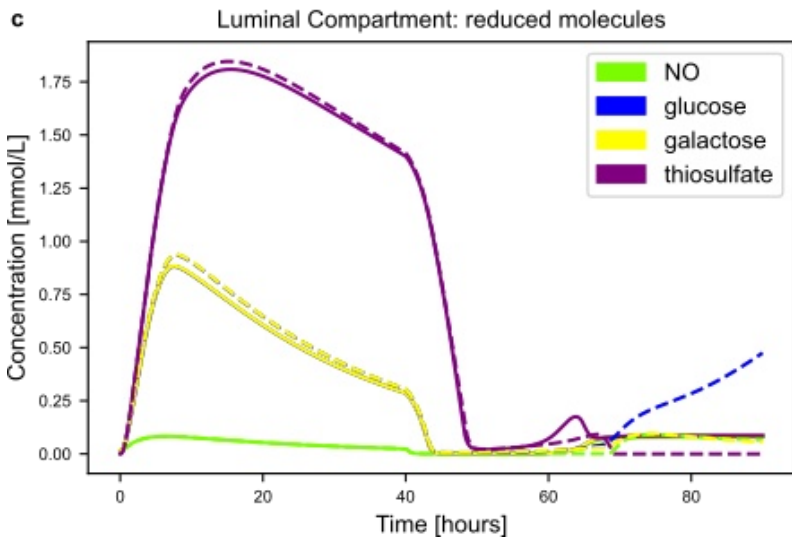
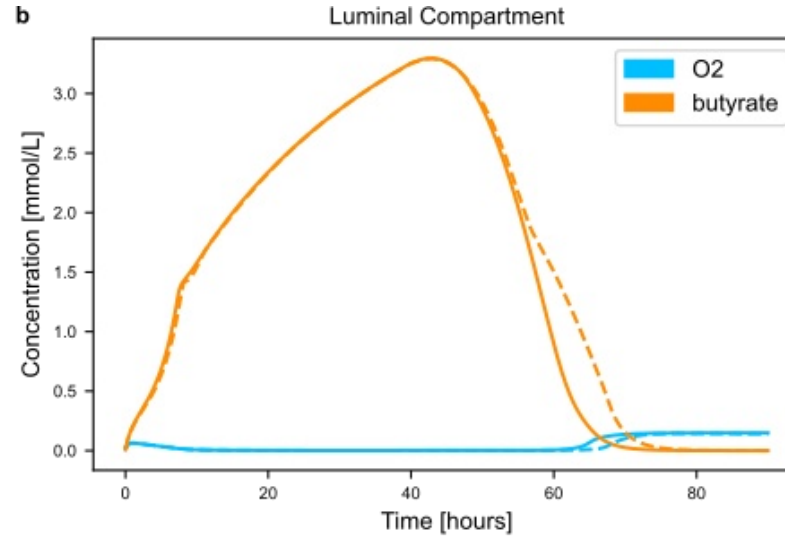
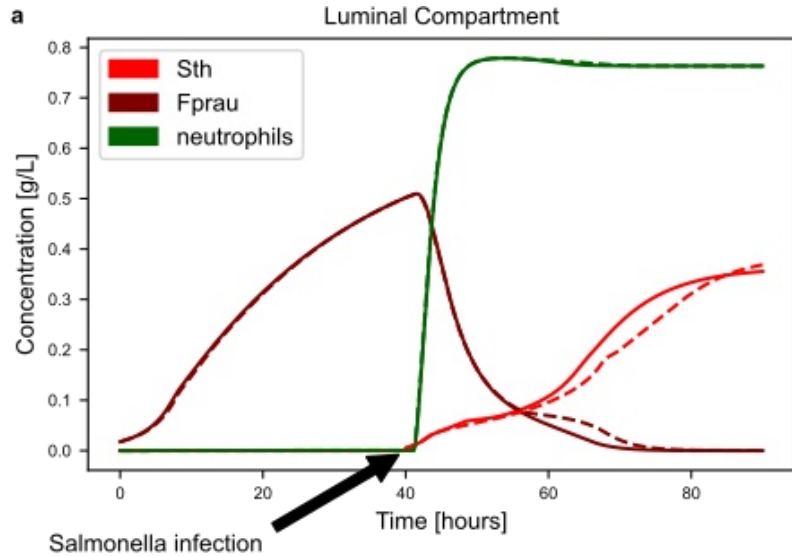
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Modelling the metabolism of microbial communities with numerical models  
18/03/2025, S.Labarthe, Pléiade (INRAE, Inria).

Frioux et al., ESAIM PROC, 2023  
<https://doi.org/10.1051/proc/202373187>

Inria

# Toy model: Salmonella infection



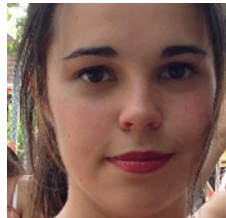
C.Frioux



P.Ugalde



C.Muller



Aex Slimmest



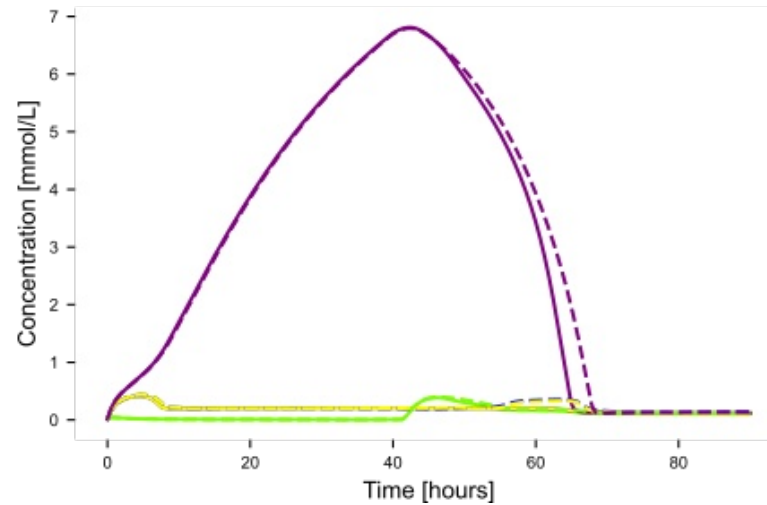
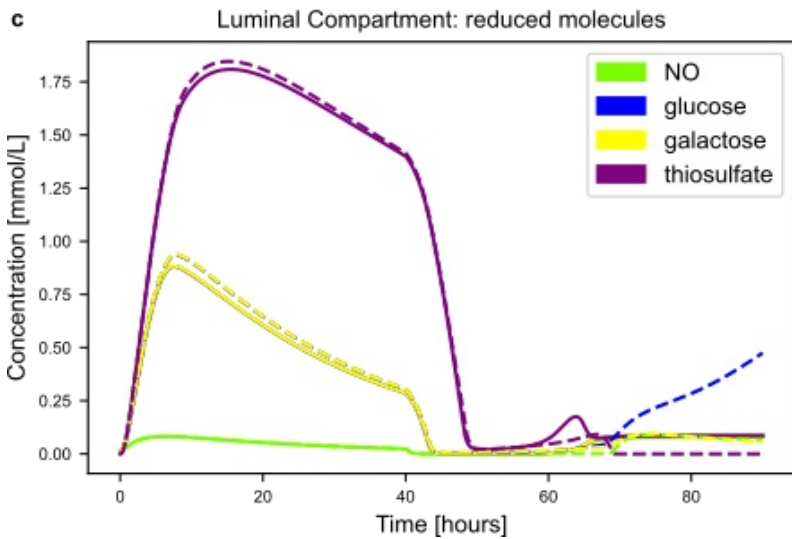
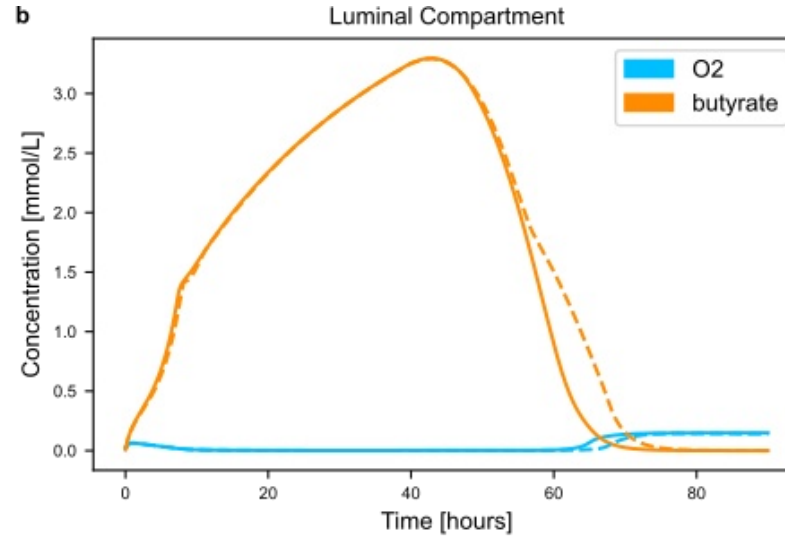
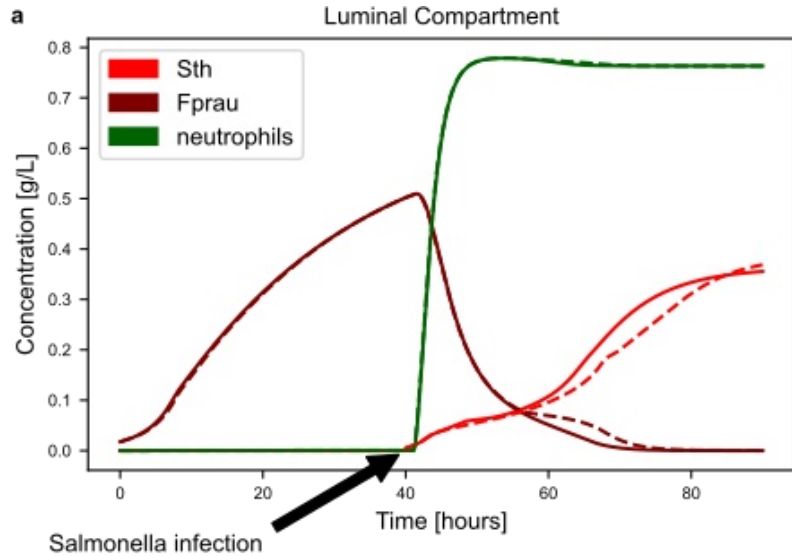
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# Toy model: Salmonella infection



Good approximation

Speed-up = 50 times faster

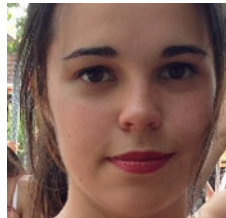
C.Frioux



P.Ugalde



C.Muller



Aex Slimmest

*Inria*

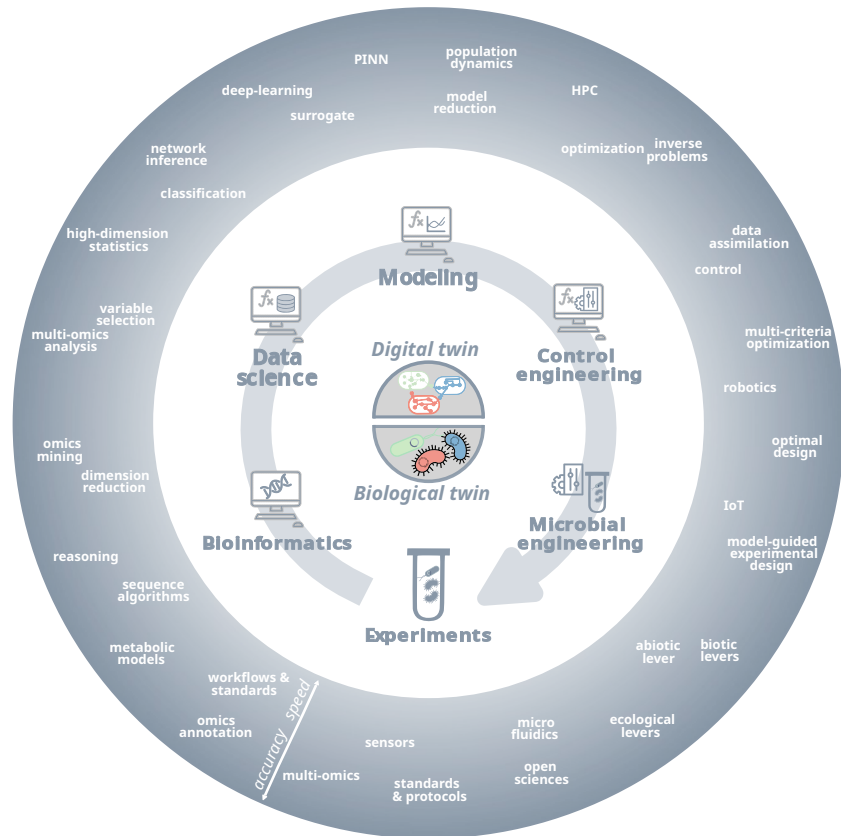
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# Conclusion



Digital twins can foster interdisciplinary science

Science fronts all along the pipeline

Increase accuracy, increase speed

ML for data integration & surrogate models



# Advertisement

2 postdoc positions  
in Mystic project

<https://jobs.inrae.fr/>



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