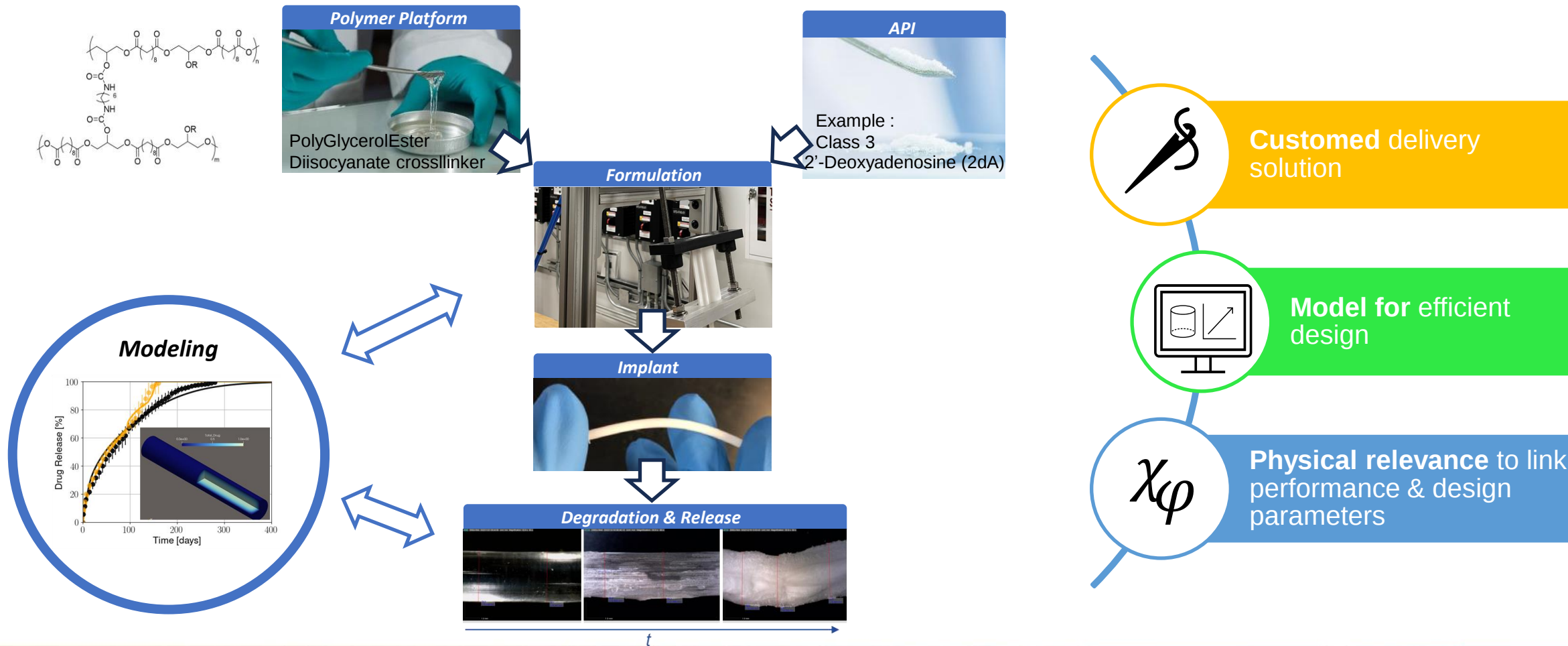


Unleashing Multiphysics Modeling for Drug Implant Design

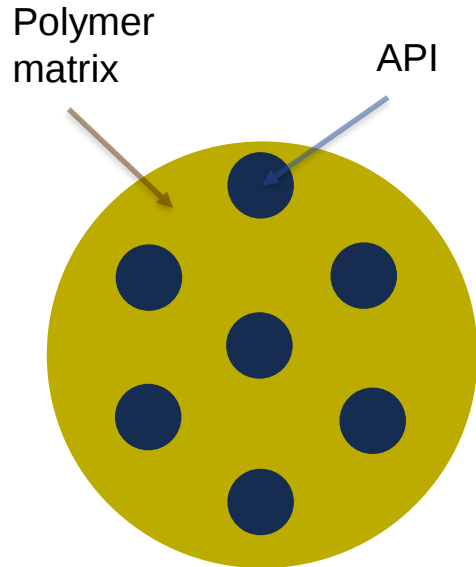
Marion Krapez, PhD
Victor Mishin

marion.krapez@michelin.com

Towards a digital twin platform to accelerate development of biodegradable polymer payload delivery



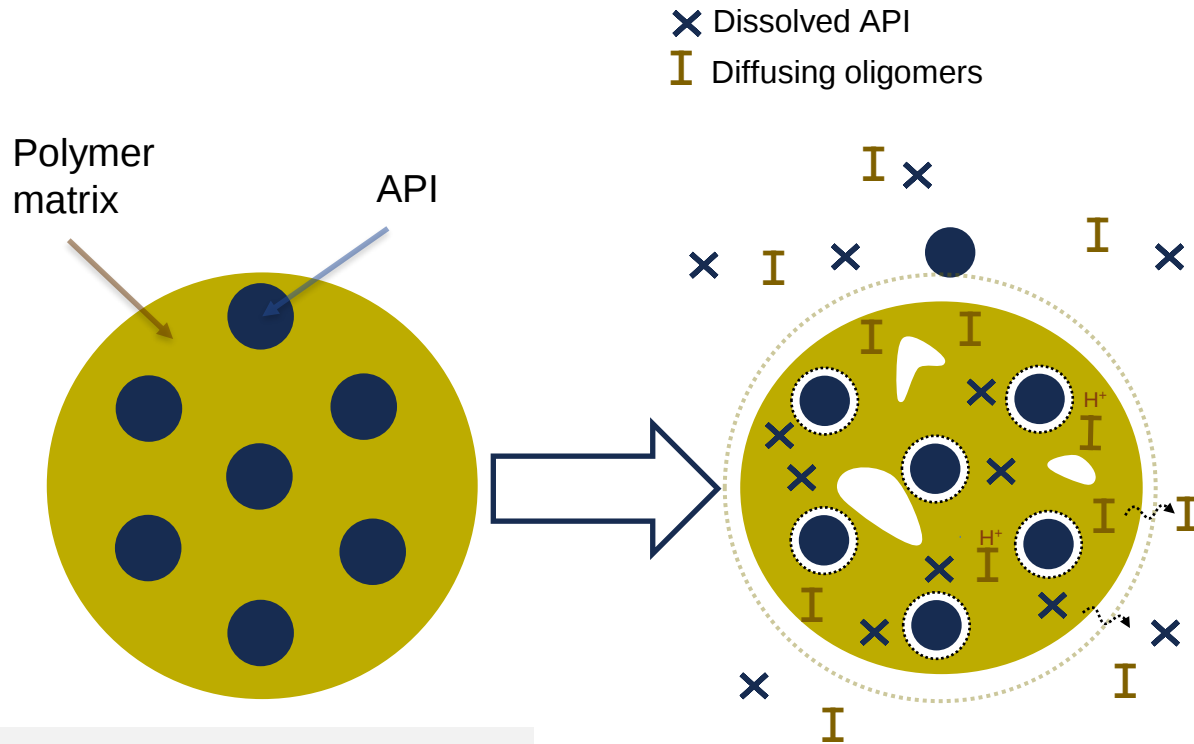
The devil is in the coupling...



Assumptions:

- Spherical monodisperse API particles ●
- Uniform repartition
- Water abundant

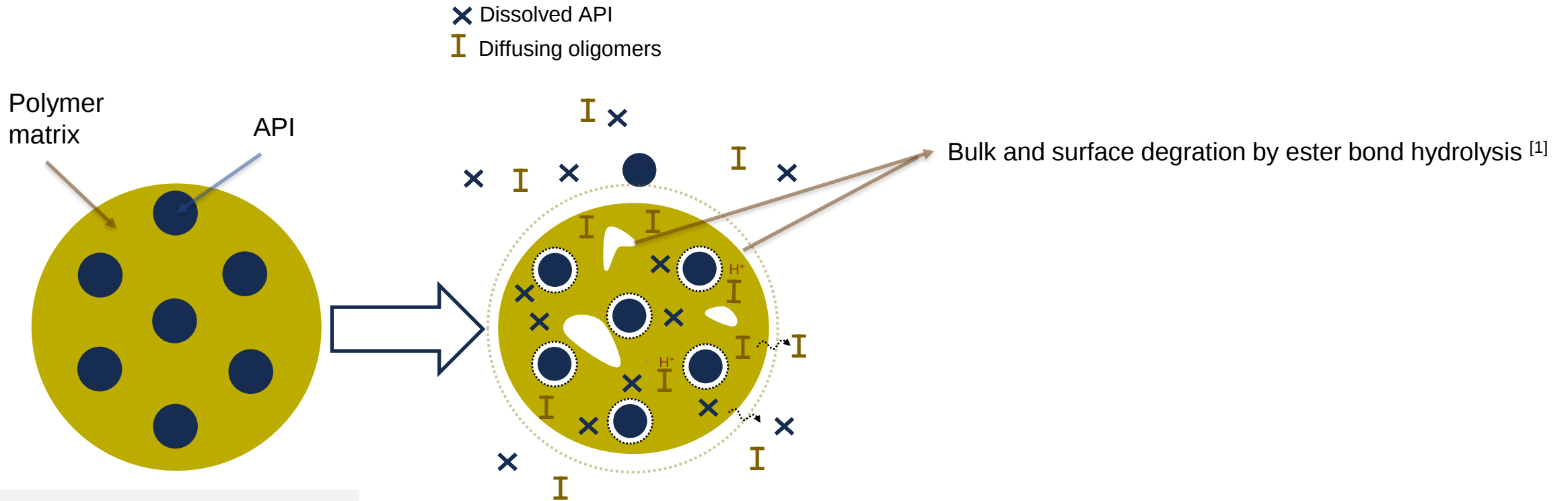
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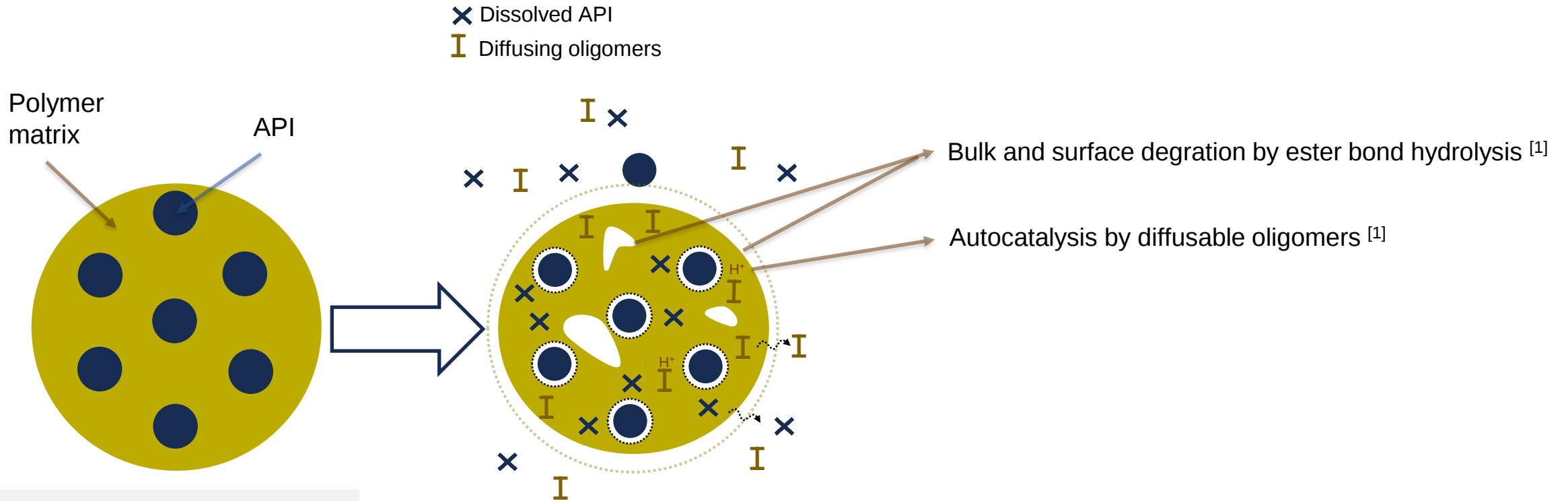
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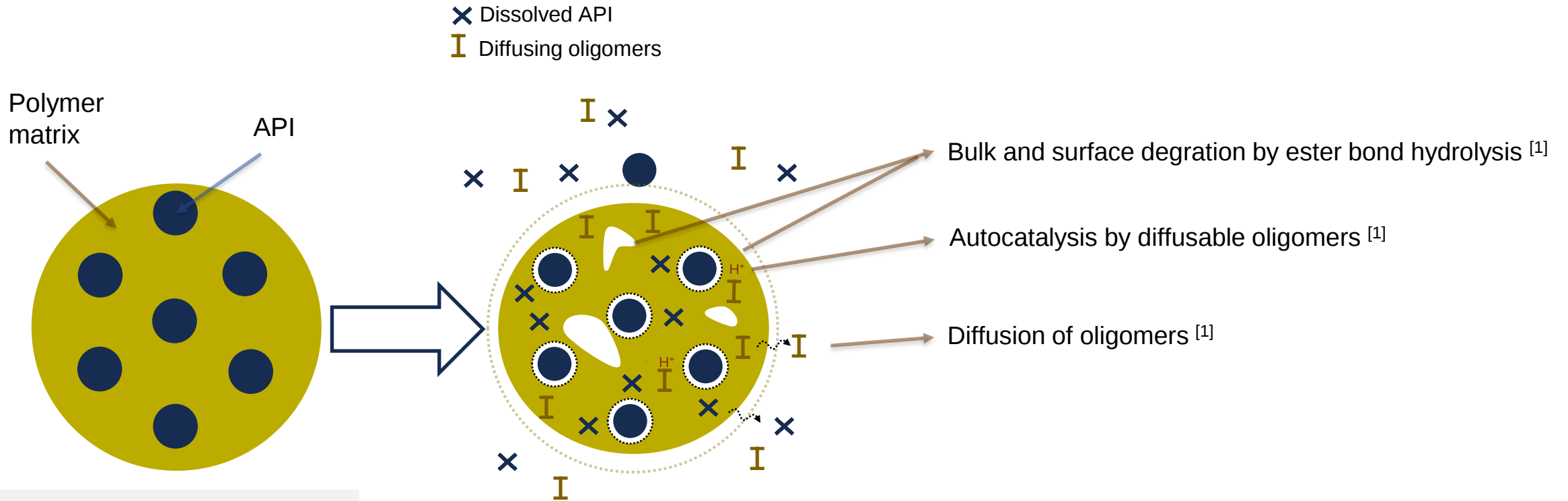
The devil is in the coupling...



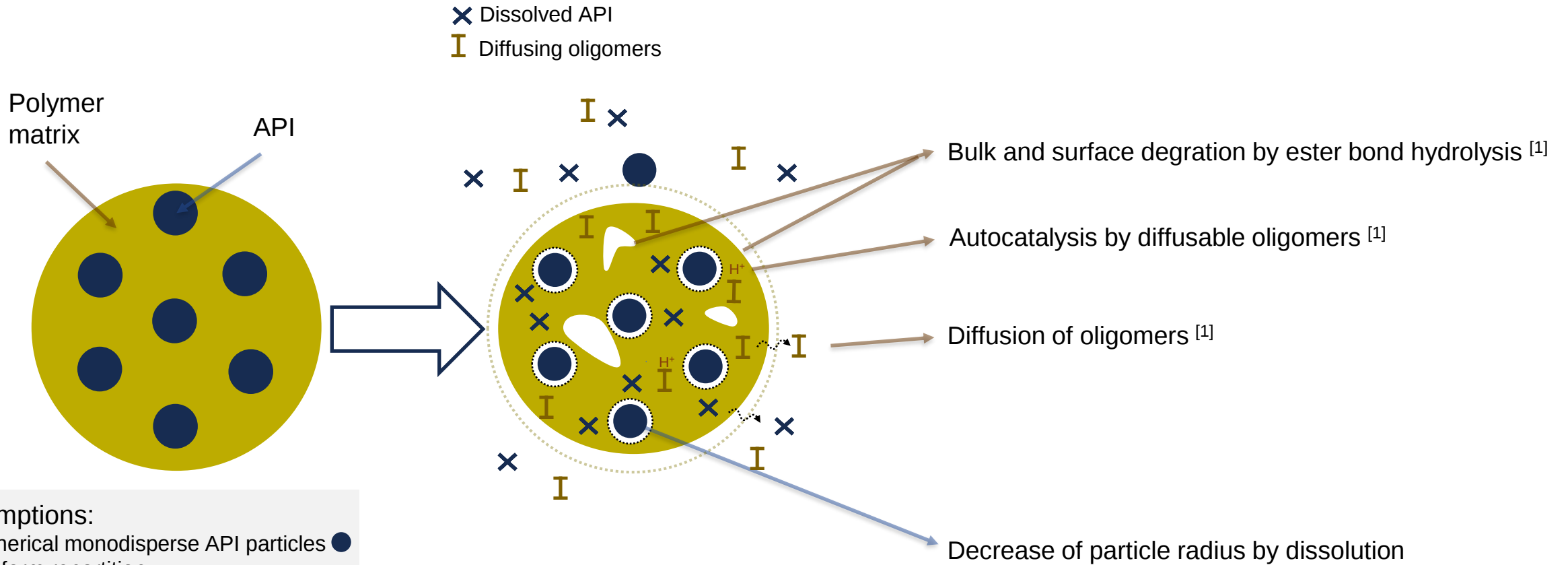
Assumptions:

- Spherical monodisperse API particles ●
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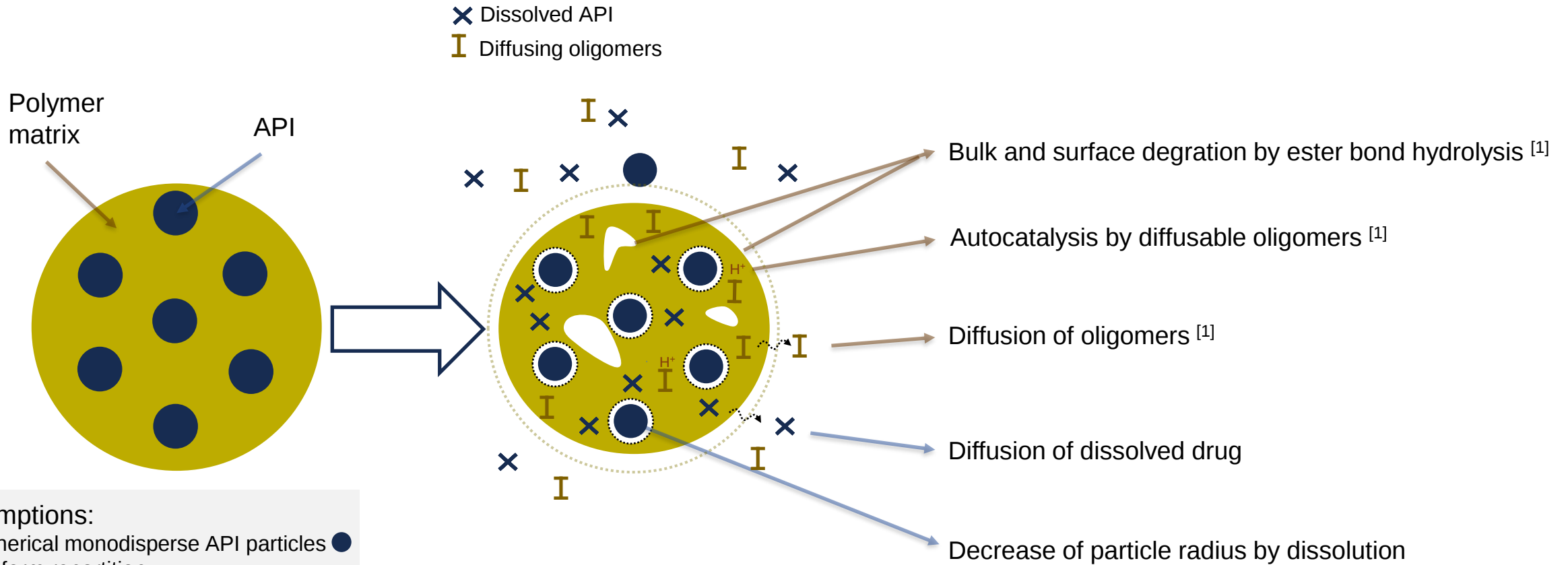
The devil is in the coupling...



The devil is in the coupling...



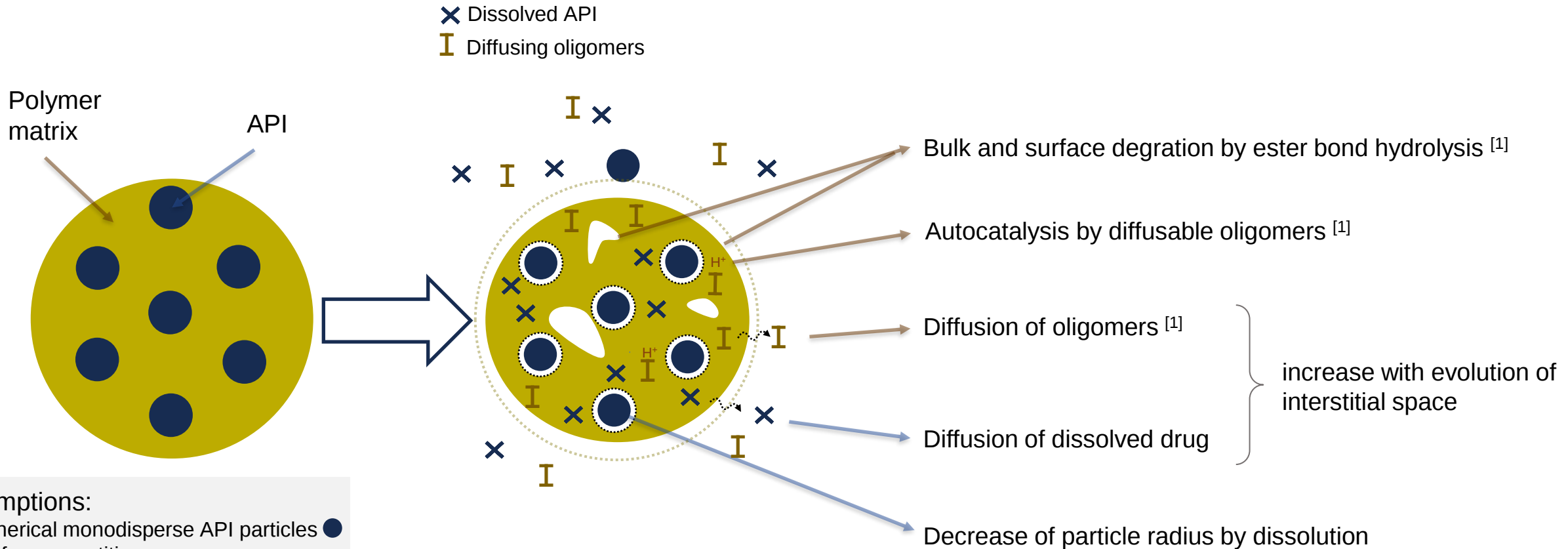
The devil is in the coupling...



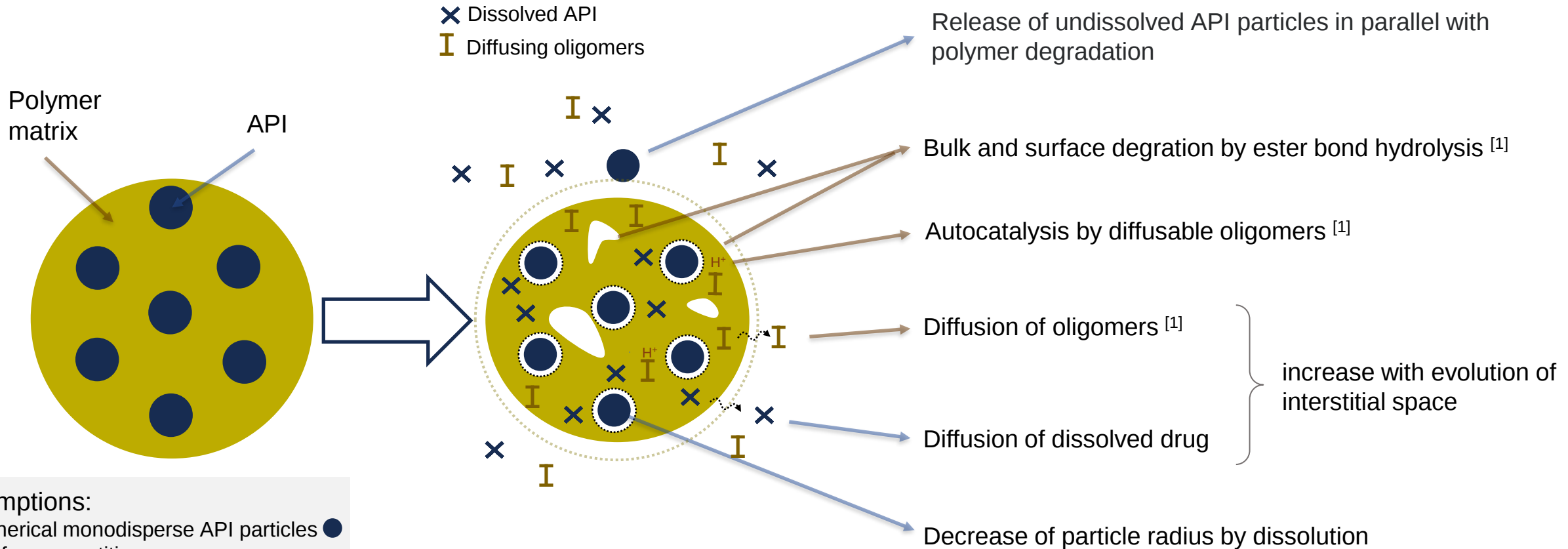
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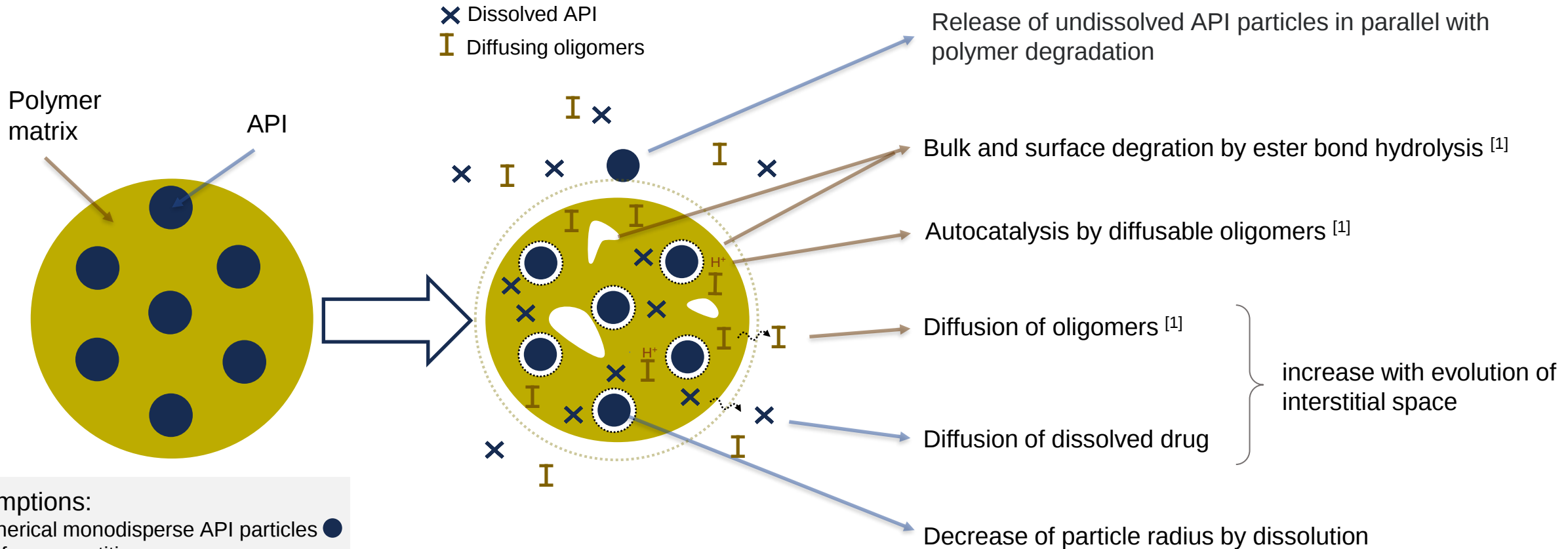
The devil is in the coupling...



The devil is in the coupling...



The devil is in the coupling...

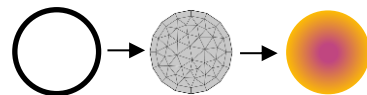


Assumptions:

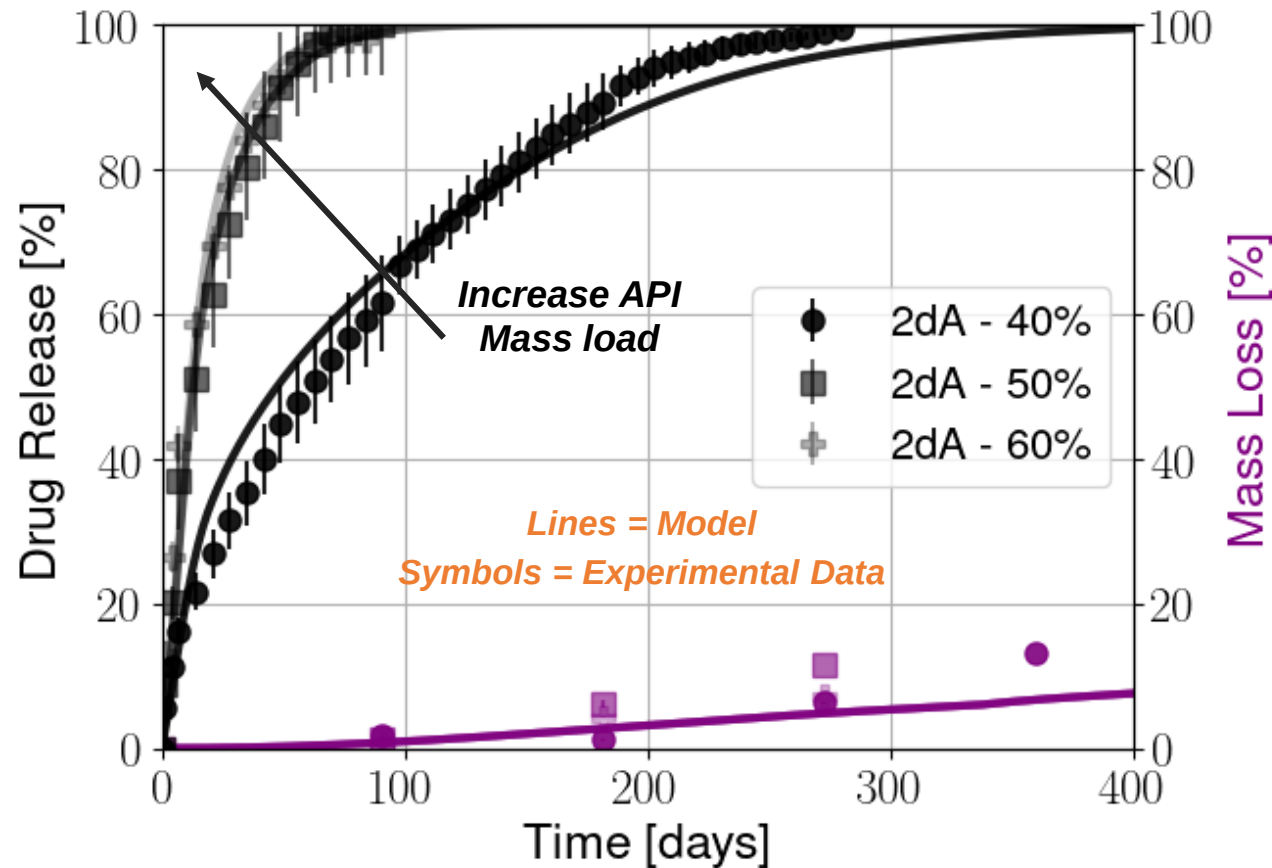
- Spherical monodisperse API particles ●
- Uniform repartition
- Water abundant

+ Homogenization of properties

→ Finite element software (FreeFEM)



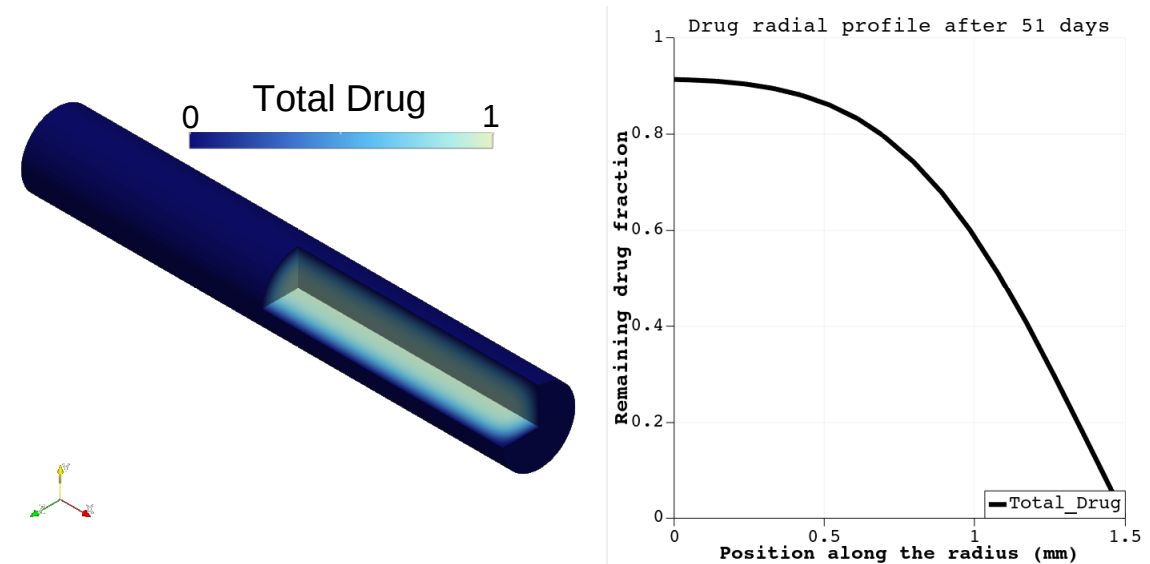
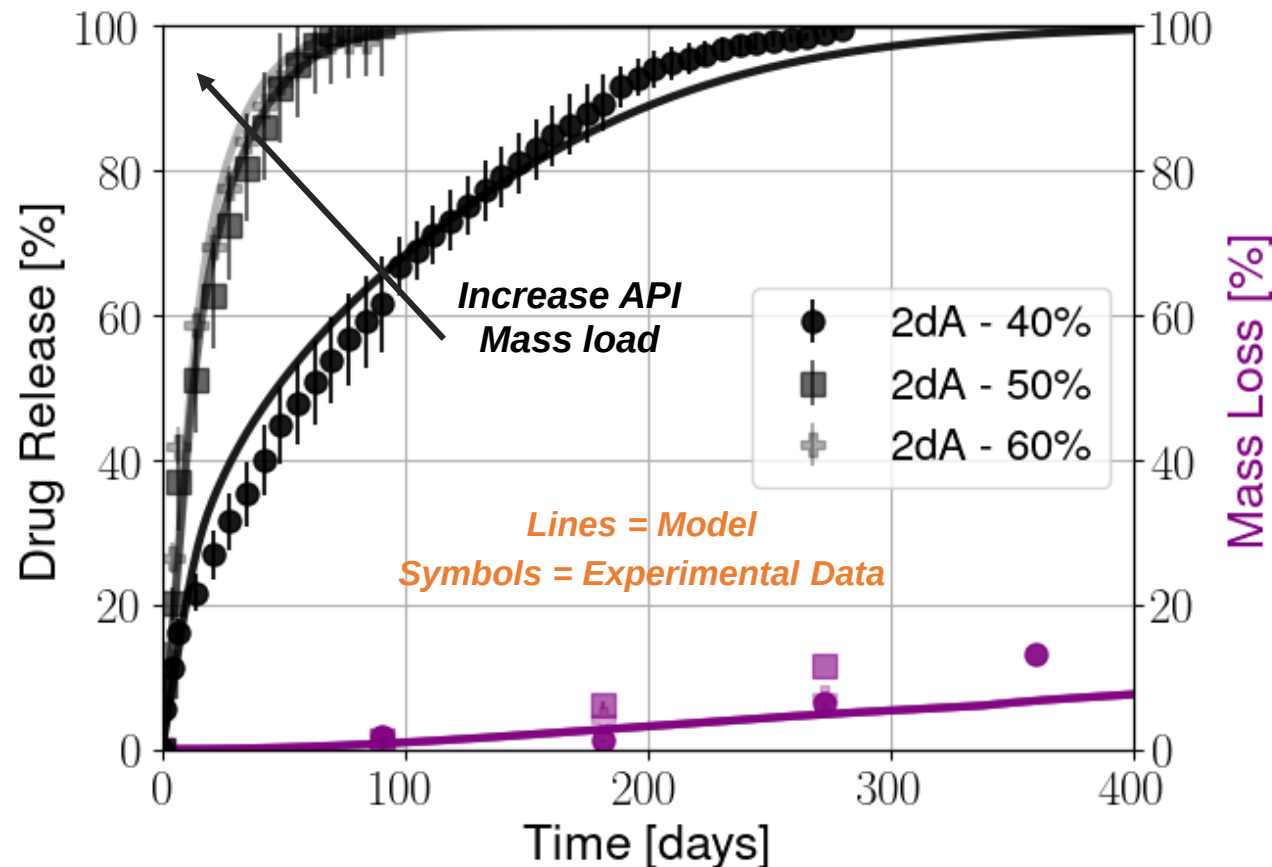
First model validation: diffusion of API



Take home messages:

- **Good model** matching (no modification of matrix-related coefficient)
- Drug loading has **negligible effect** on matrix degradation
- Observed **percolation**-like phenomenon between 40% and 50% mass load

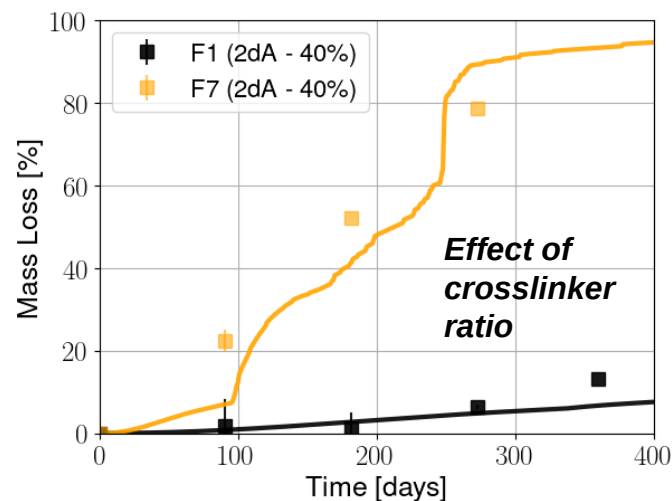
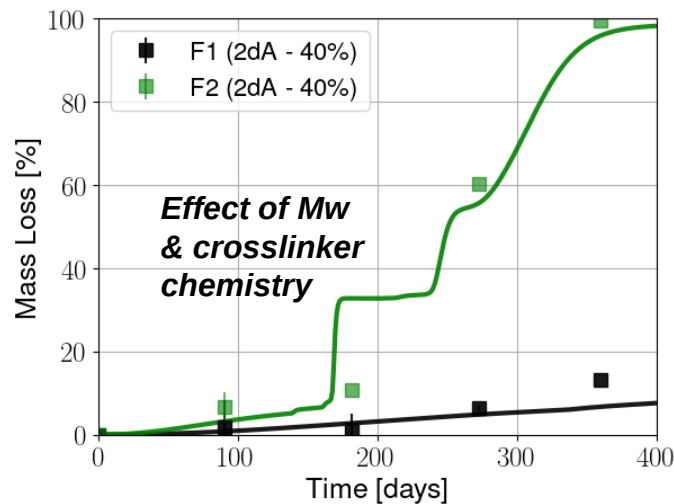
First model validation: diffusion of API



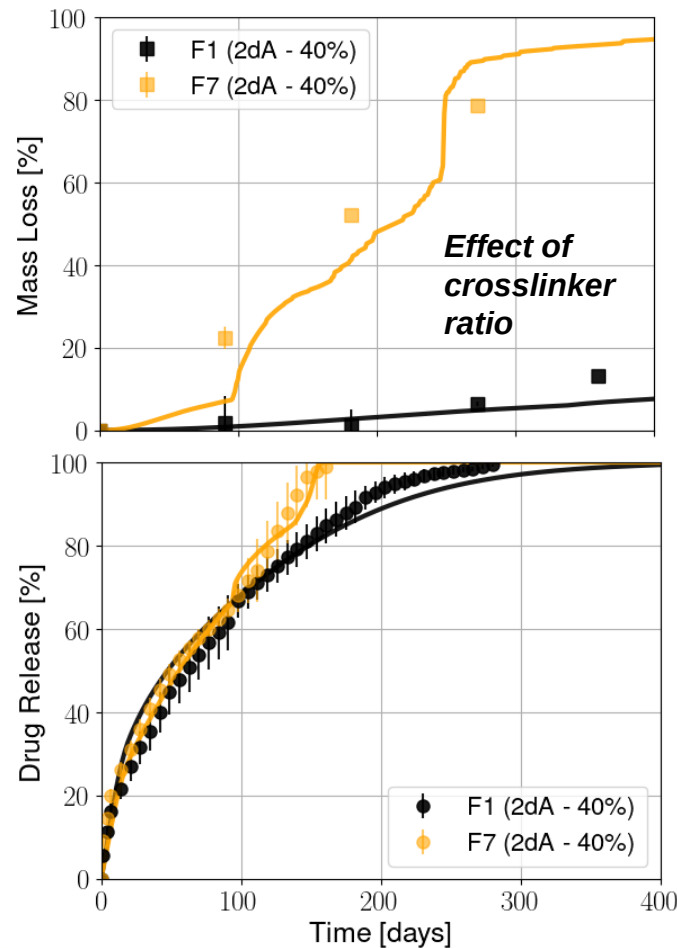
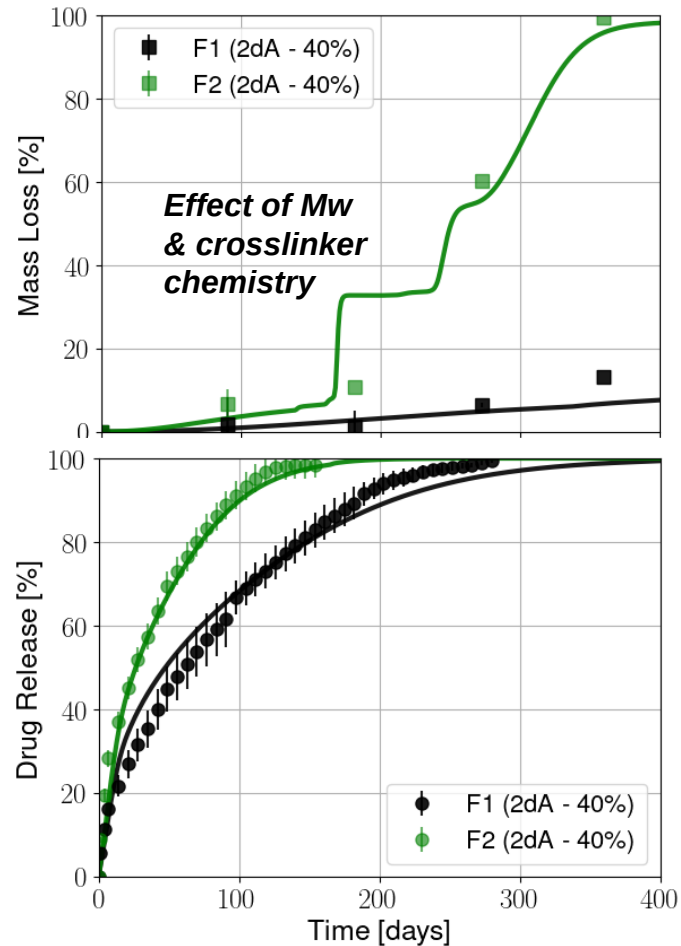
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Degradation/release coupling tuned experimentally and captured by the model



Degradation/release coupling tuned experimentally and captured by the model

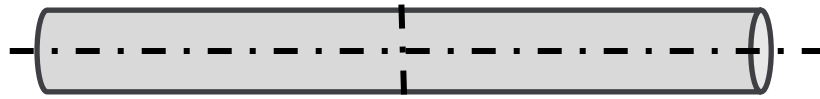


Take home messages:

- **Consistency** in model matching of experiments
- **Coupling confirmed by the model:** Drug release kinetics can be accelerated by faster matrix degradation
- The **coupling strength can be tuned via polymer formulation** for a given API

A visual understanding of release/degradation coupling through drug concentration fields

Rod implant

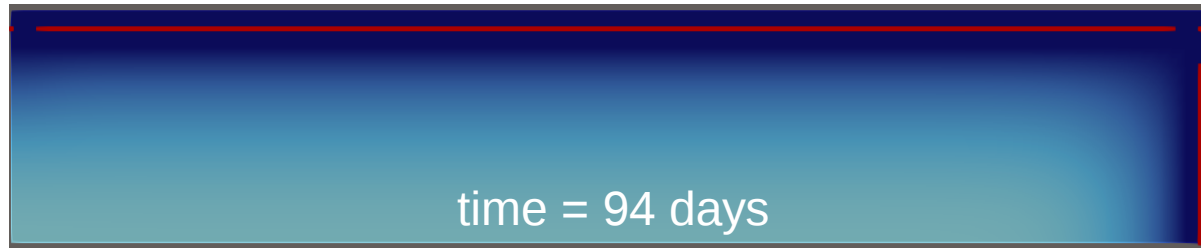


$Length/2 \approx 10\text{ mm}$

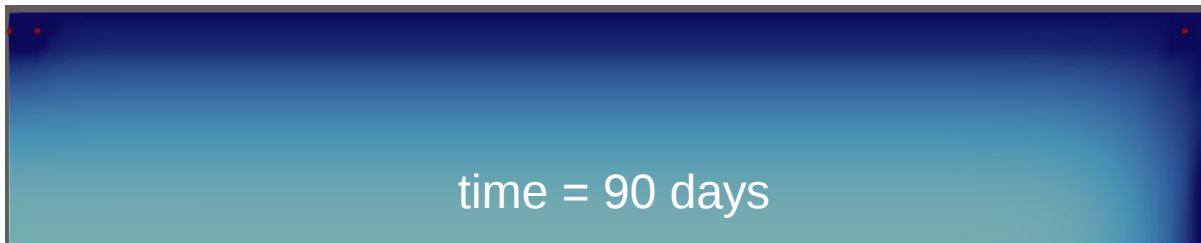


$Radius \approx 1.5\text{ mm}$

Drug release by diffusion + matrix degradation

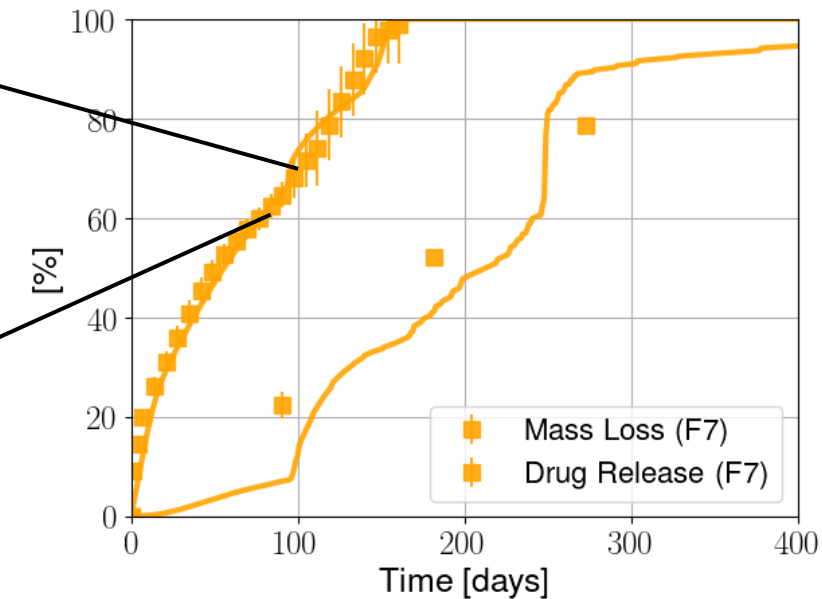


Drug release by diffusion



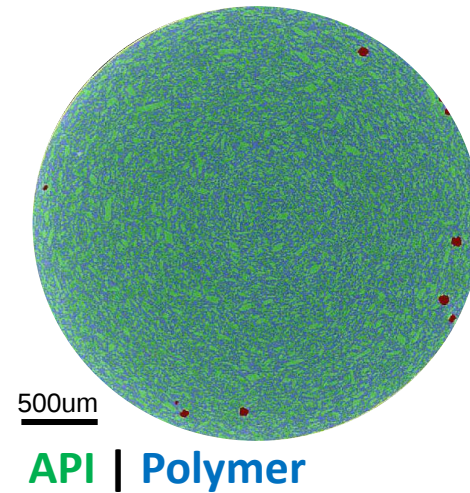
Pore propagation inside the implant

Initial position of pore formation from the matrix degradation



Perspectives

- Future model improvements:
 - Add solvent dynamics
 - Polydisperse API
- Extension of model validation to:
 - A **polymer platform** to diversify impact on API release and degradation abilities
 - **Different types of API**
- Database for machine learning prediction of performances



The work presented today is part of a collaboration between Solesis and Michelin

Michelin Contributors:

- Joel Tchoufag
- Marion Krapez
- Melaine Guillou
- Salvatore Pagano



Solesis Contributors:

- Victor Mishin
- Denise Preddie



marion.krapez@michelin.com

Thank you !