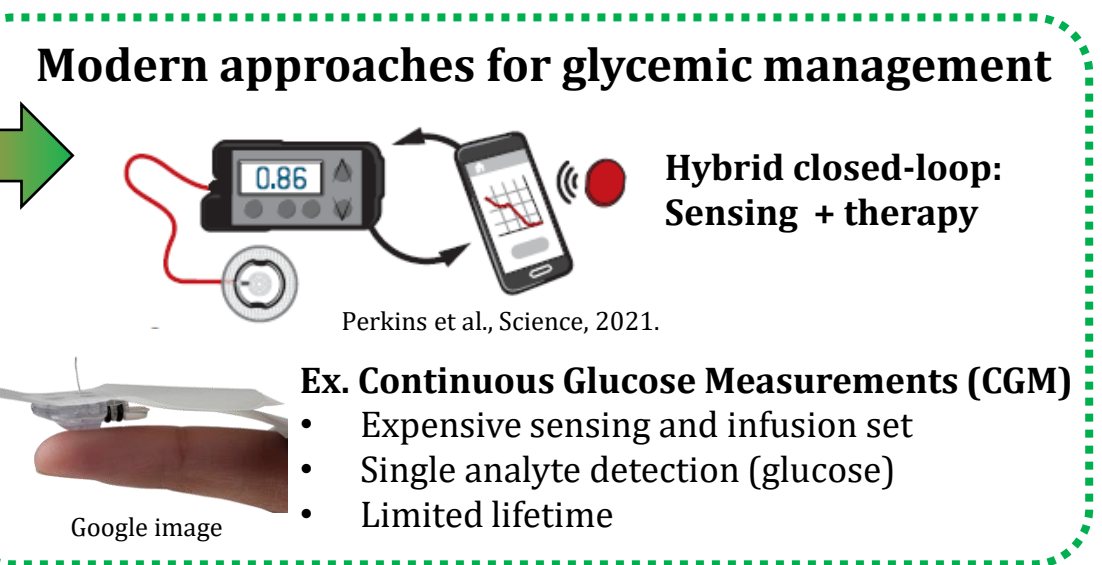
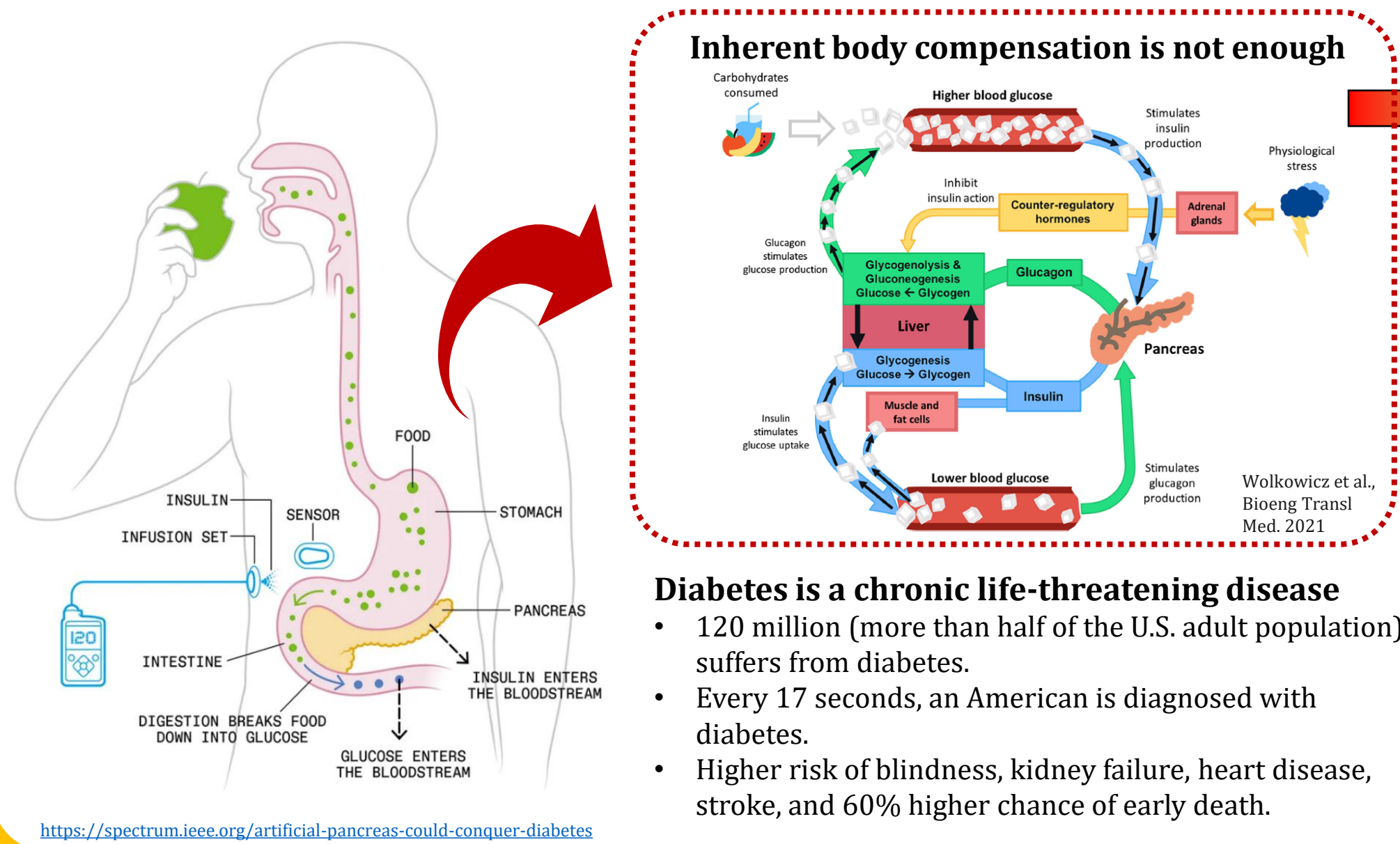




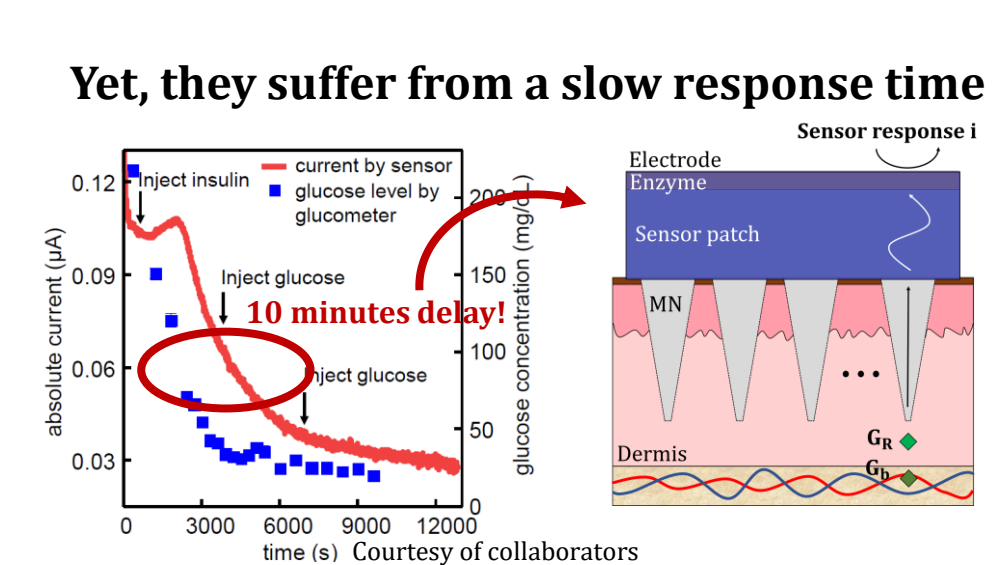
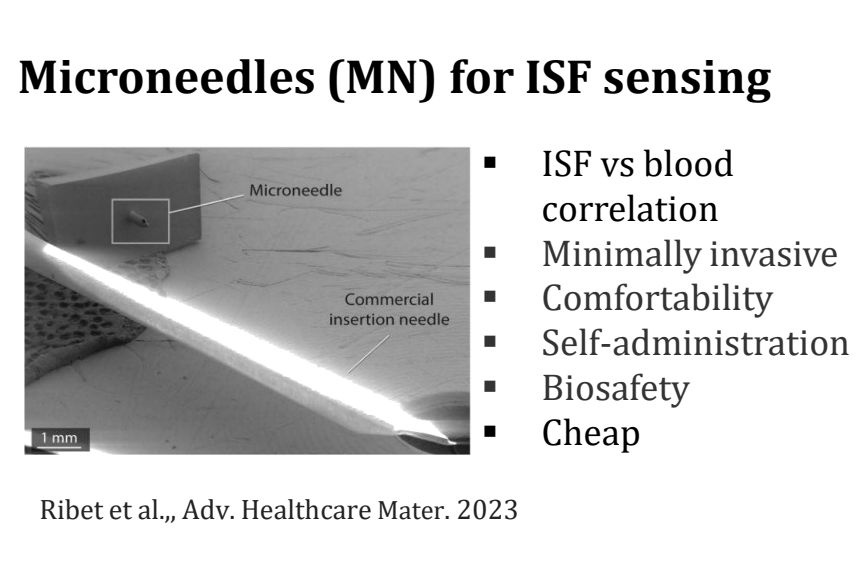
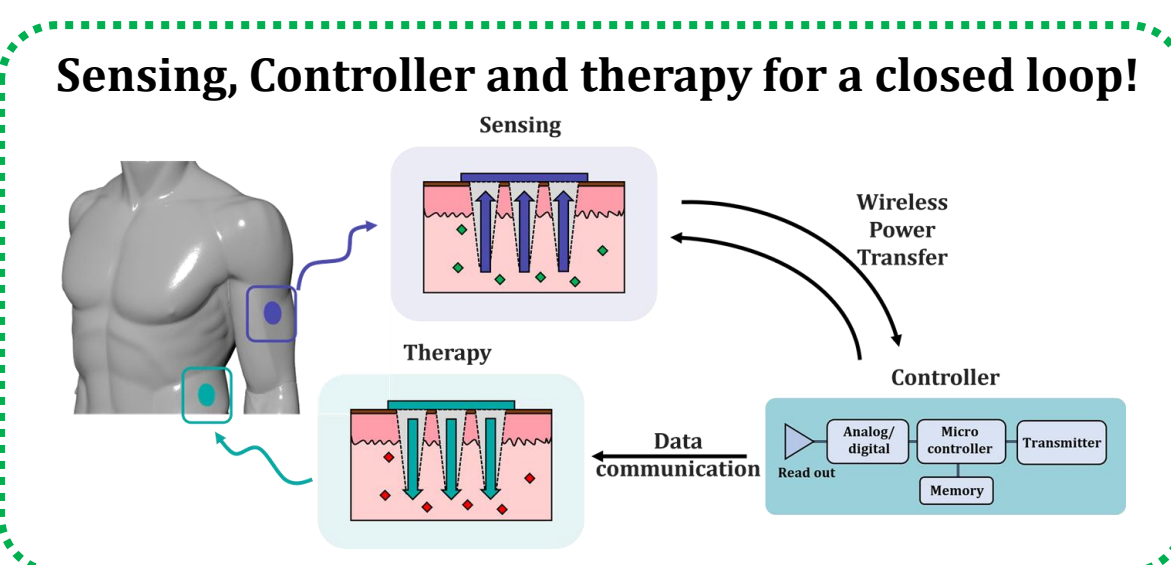
# The Emergence of Microneedle-based Smart Sensor/Drug-Delivery Patches: A Scaling Theory Defines the Trade-off between Response Time and Limits of Detection

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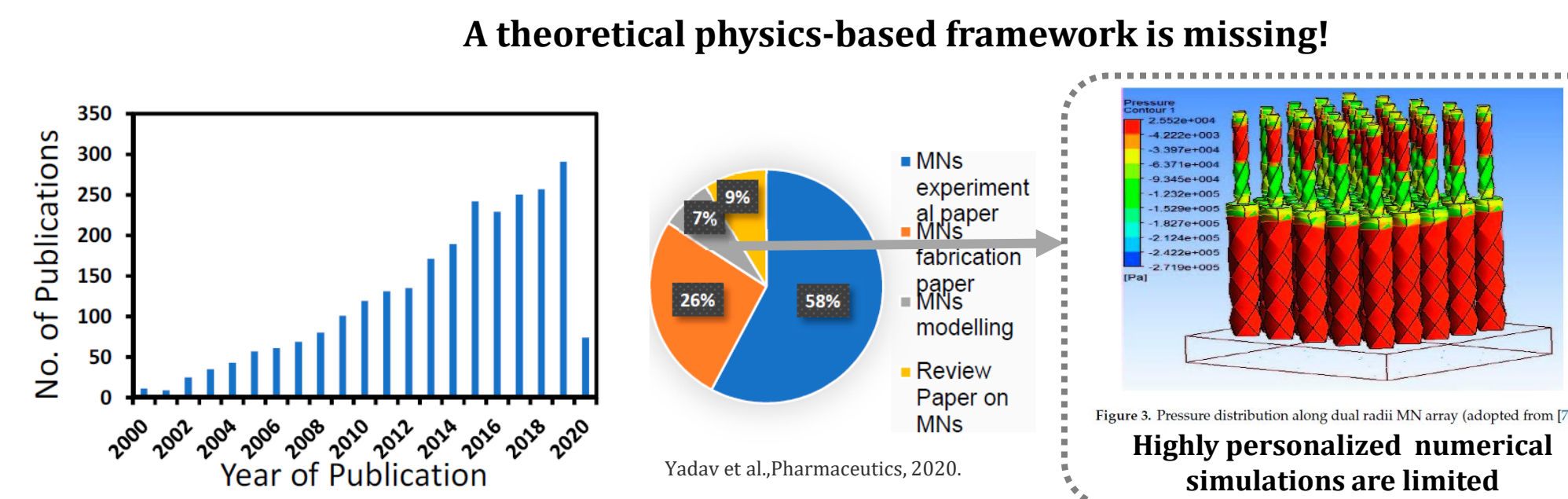
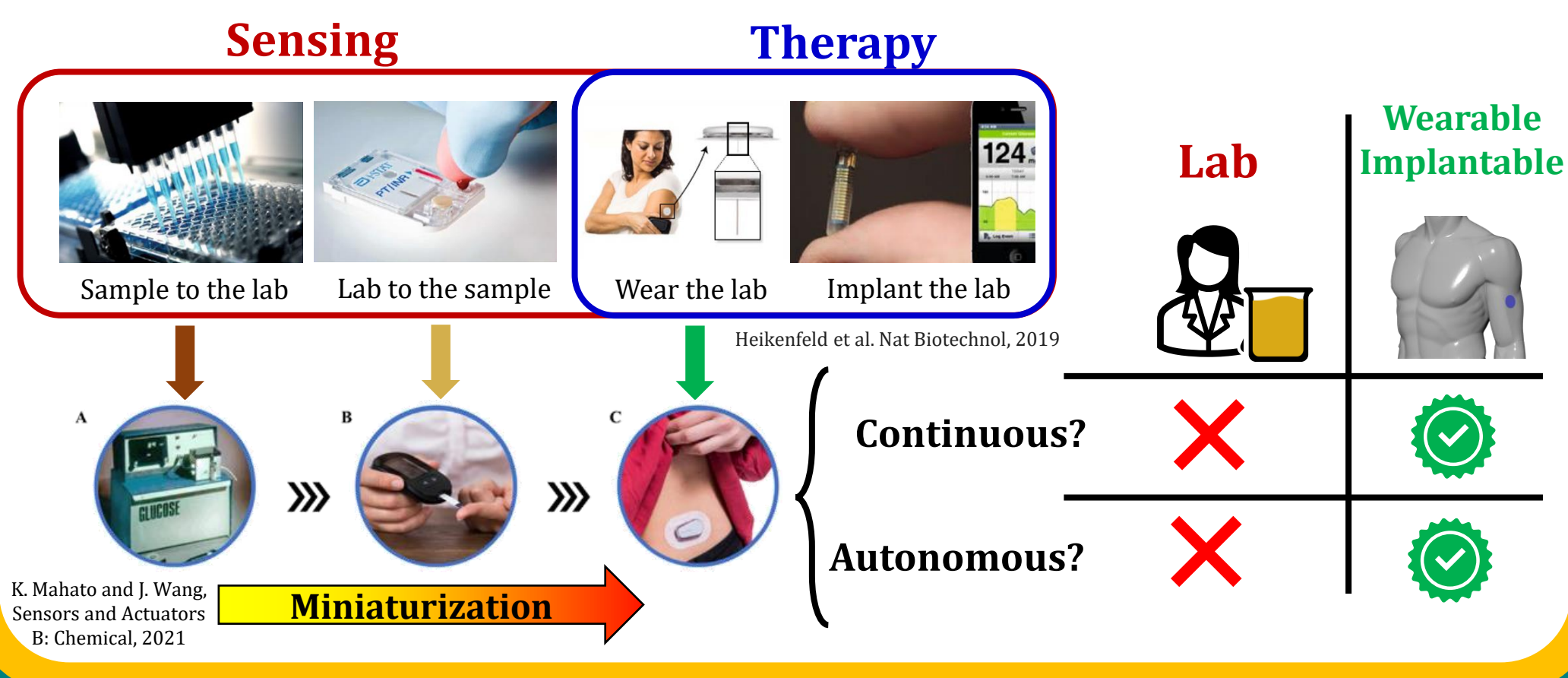
## 1. Diabetes, where time is critical for corrective interventions



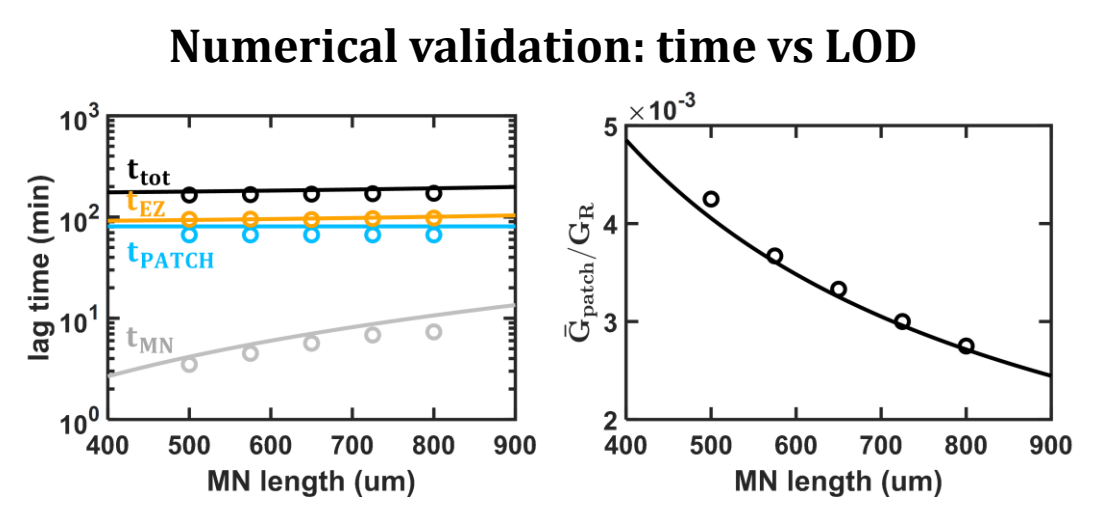
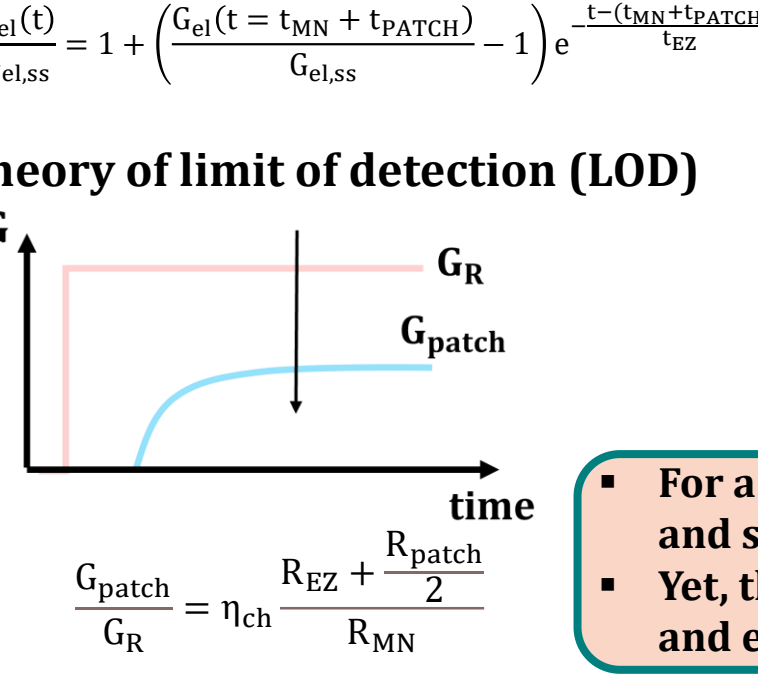
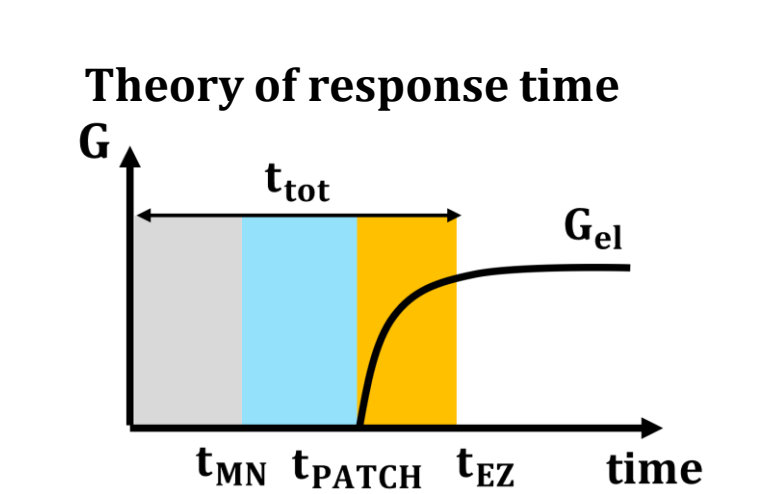
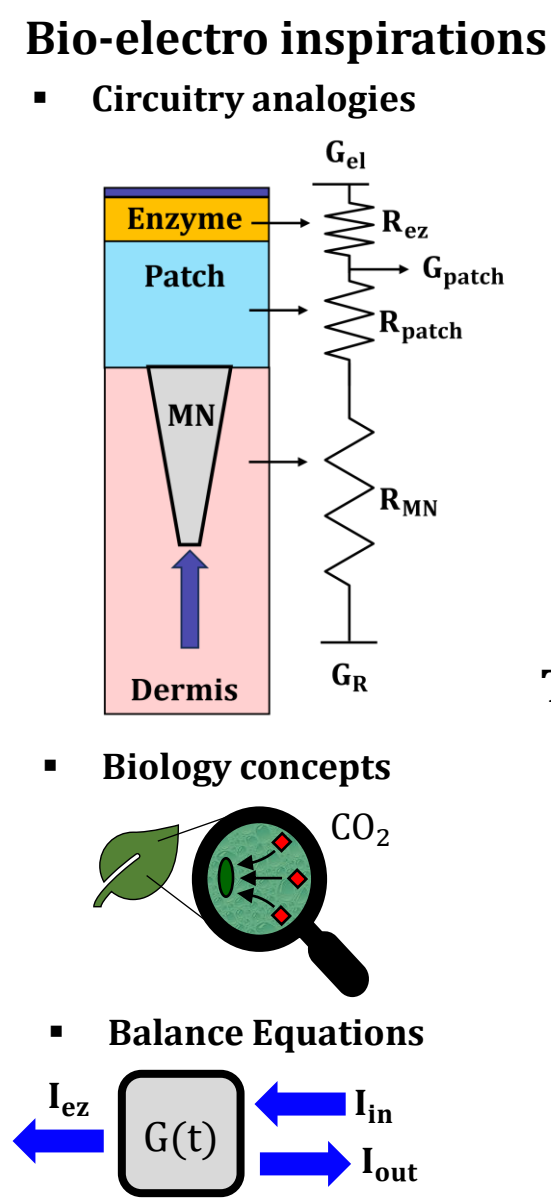
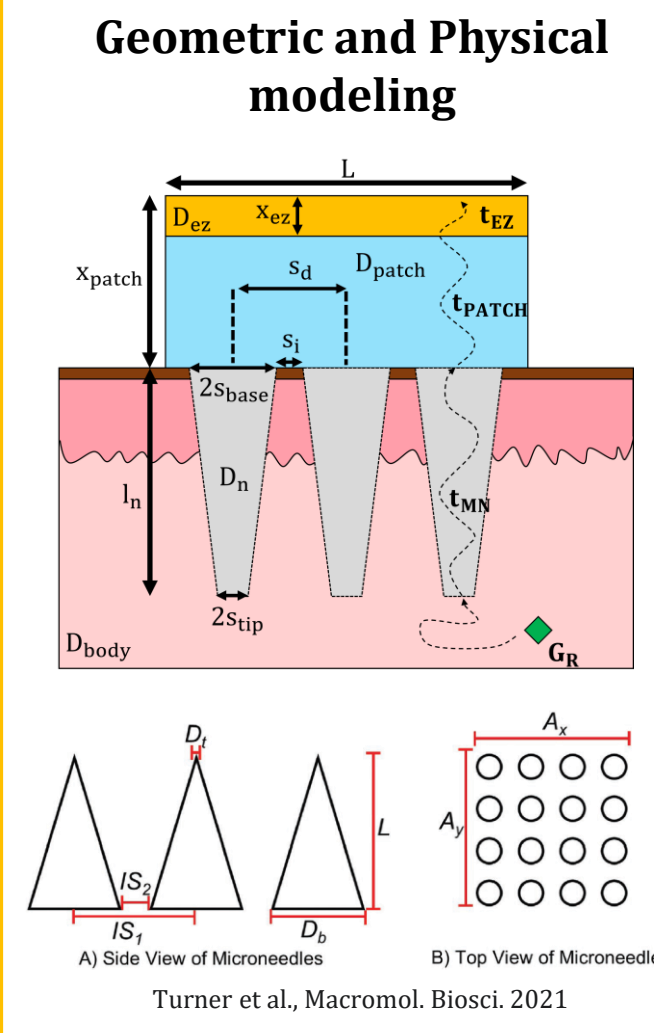
## 2. Theory of microneedles for an optimized response time - limit of detection



## Healthcare: From bench to on/under the skin

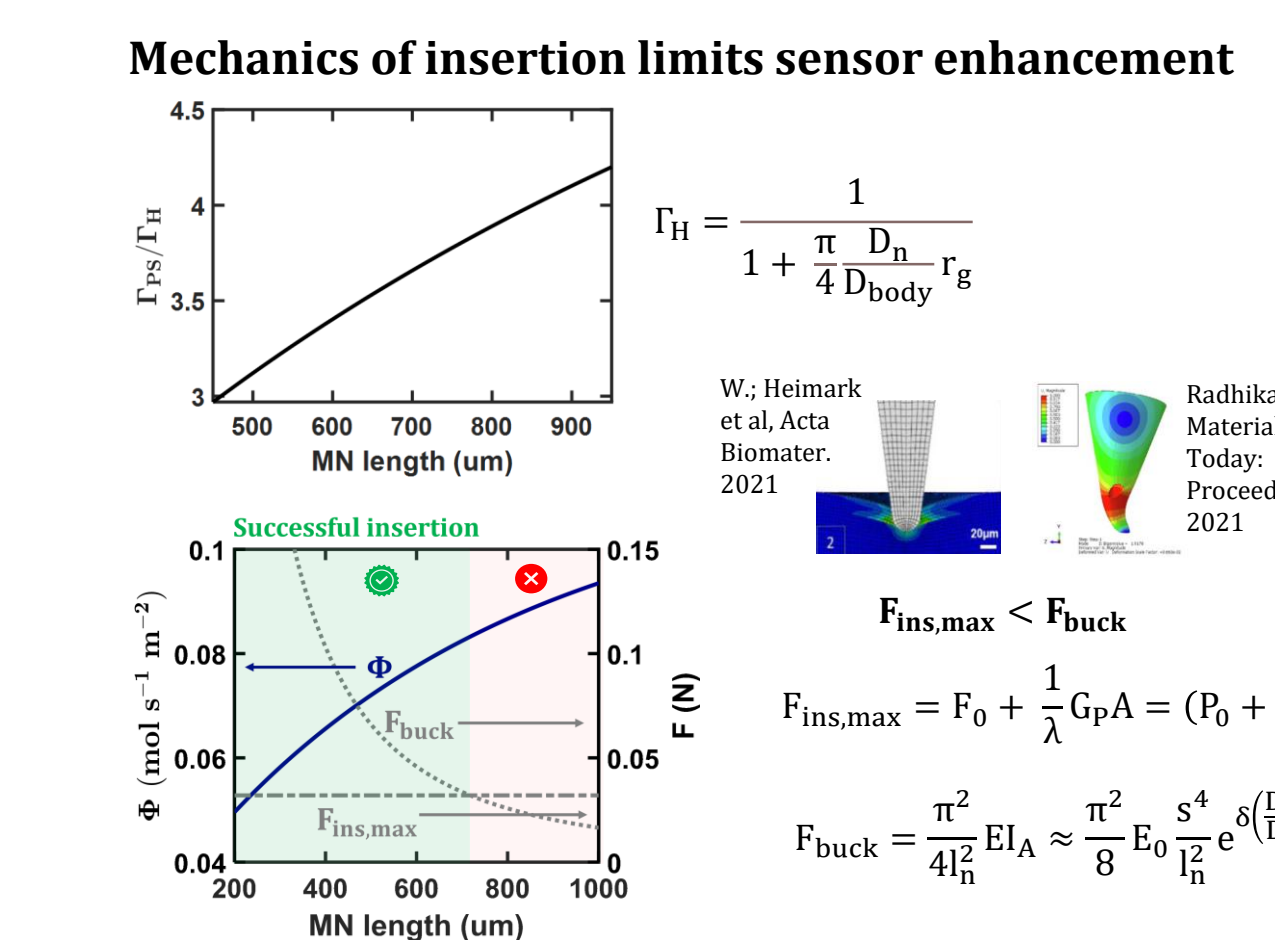
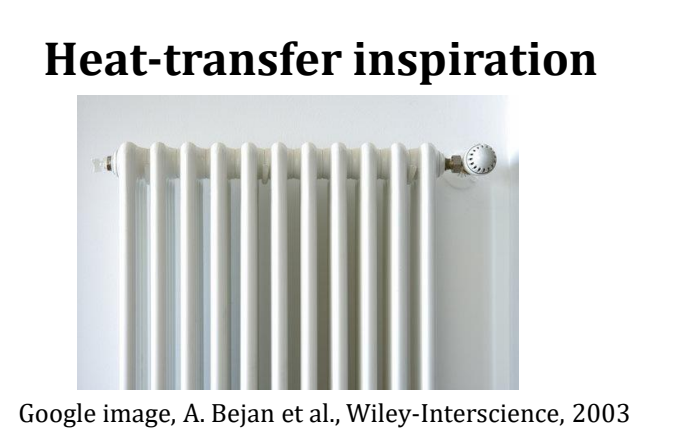


## 3. Hollow microneedles have limitations

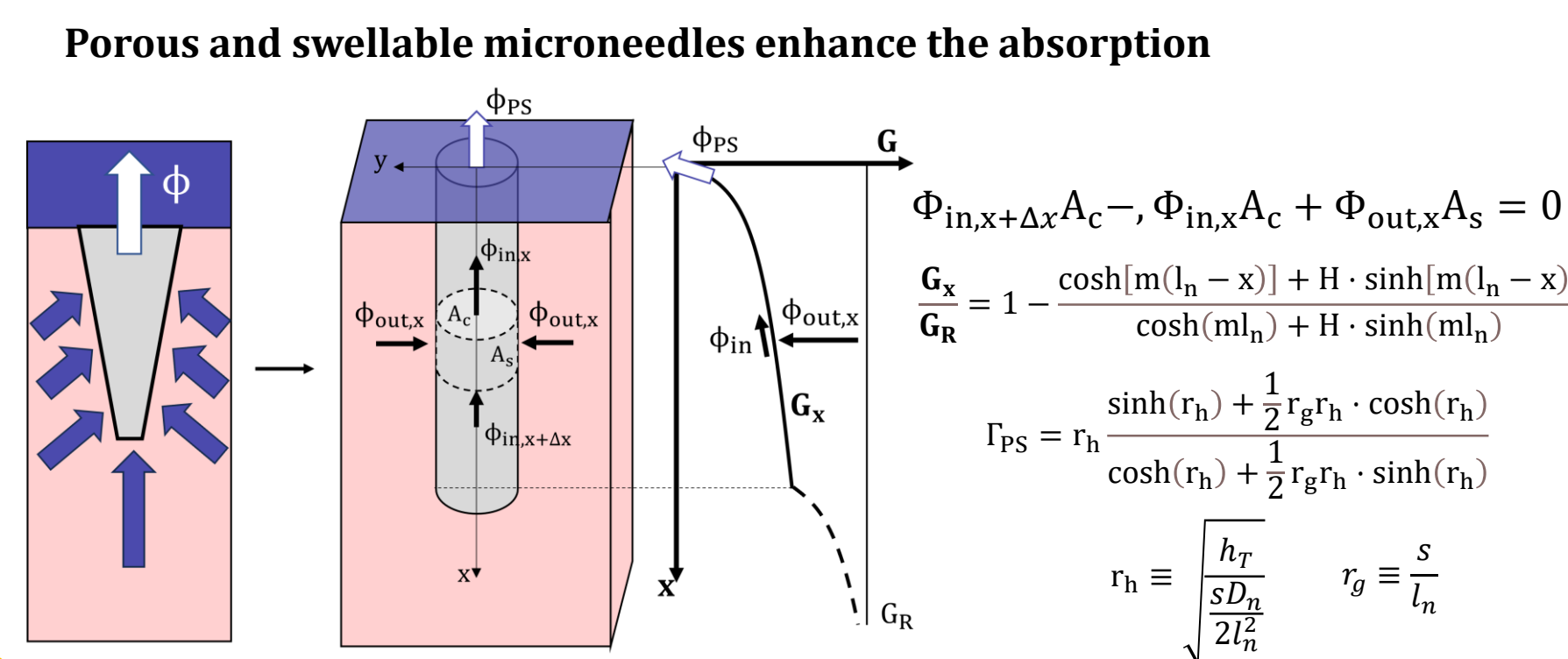


- For a minimized delay, thin patches with maximized apertures and short microneedles should be designed.
- Yet, there exists an intrinsic trade-off between response time and extracted analyte concentration, degrading LOD

## 4. Porous microneedles perform better, but...



- Porous microneedles can achieve an enhanced performance of 2-6x compared to hollow microneedles.
- Yet, mechanics of insertion due to poorer Young modulus degrades the benefits of this technology.



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[1] M. A. Alam et al., "Reliable sensing with unreliable sensors: Rethinking the theoretical foundation of field-deployed wearable/implantable/environmental sensors", Innovation and Emerging Technologies, 2022.

[2] M. Fratus et al., "Geometry-defined Response Time and Sensitivity for Microneedle-based Amperometric Sensors", IEEE sensors, 2023.

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## Conclusions

- Without a theoretical framework, design and optimization of microneedle-based patches rely on iterative costly approaches.
- A physics-guided model is necessary for appropriate interpretation of experimental trends and systematic optimization of devices.
- Here, we quantify the sensor performance (response time, limit of detection) against geometry and composition of the MN-patch.
- Porous microneedles outperform hollow microneedles in terms of enhanced flux; yet mechanical requirements limit the improvement.
- For an optimized design, response time must be weighted against mechanical requirements and bioinflammation tests.

## Future works

- The comprehensive goal is to provide a theoretical framework for prediction, design and optimization of wearable and implantable device for a real-time monitoring and on-demand sensing.
- The individual building blocks (sensing, controller, therapy) should be optimized
- Definition of a new set of performance metrics is required for technology comparison
- Additional challenges due to biofouling deposition degrade the time dependent sensor operation, leading to device failure. How can we deal with it?