Models to determine functions of the oral microbiome for personal care products safety assessments

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3rd March 2026

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Introduction – who we are, why we are using oral models

Caries models

Experimental gingivitis model

Conclusions and future work

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- **Protect Consumers and Unilever** by providing the technical expertise needed to ensure that our products are **safe and sustainable by design** and **comply with regulatory requirements**

- Deploy our **industry-leading expertise** in ingredient and product safety (without animal testing), environmental sustainability and regulatory science to:
  - enable **commercialisation** of innovative new technologies
  - advocate for regulatory change to secure **freedom to innovate**
  - enhance **consumer and stakeholder trust** in Unilever's brands and products

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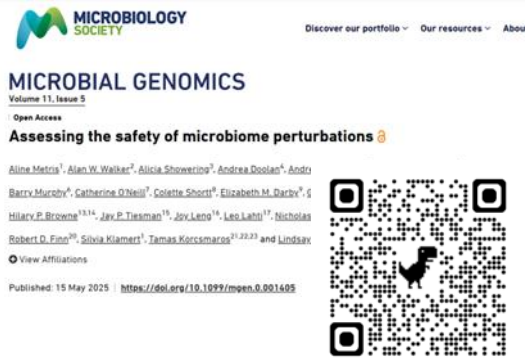
Introduction: the microbiome and risk assessments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MICROBIAL GENOMICS

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Assessing the safety of microbiome perturbations

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A tiered approach to risk assess microbiome perturbations induced by application of beauty and personal care products

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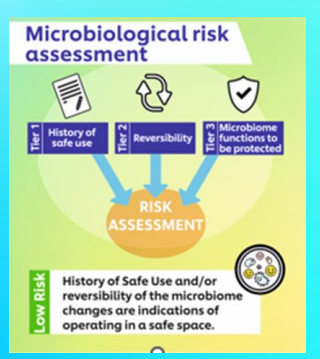
The microbiome composition has been associated to health and disease states (e.g. psoriasis, acne, atopic dermatitis, caries, periodontitis…) however there is no reference for what constitutes a healthy microbiome or dysbiosis.

- Research is needed to define microbiome functions to be protected in case of perturbations by personal care products

We developed a tiered framework to risk assess perturbations induced by the application of beauty and personal care products.

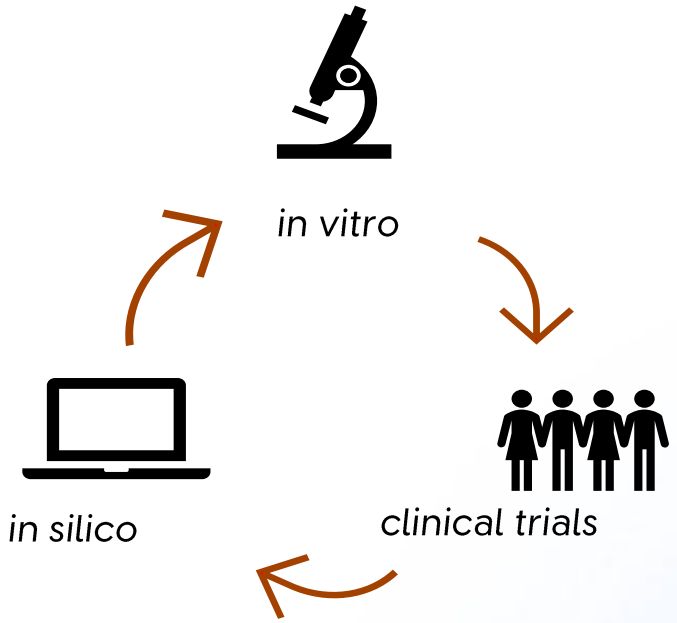
- In the tier 3 (when reversibility of change cannot be demonstrated), we aim at defining and characterising microbiome functions to be protected using a combination of *in silico-in vitro* and clinical models.

See our poster "A tiered framework to risk assess perturbations induced by the application of beauty and personal care products"



Microbiome functions to be protected

Oral models are ideal for proof of principle (biomass, accessibility, models)



- Defining the factors influencing resistance to colonisation: case study with an *in vitro* models combined with *in silico* models (Individual Based Models, IBMs & genome scale metabolic models, GEMs) for investigation of caries formation (with *Streptococcus mutans as a pathobiont).*
- Finding functional markers of resilience with multi-omics in an experimental gingivitis study.

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Caries models

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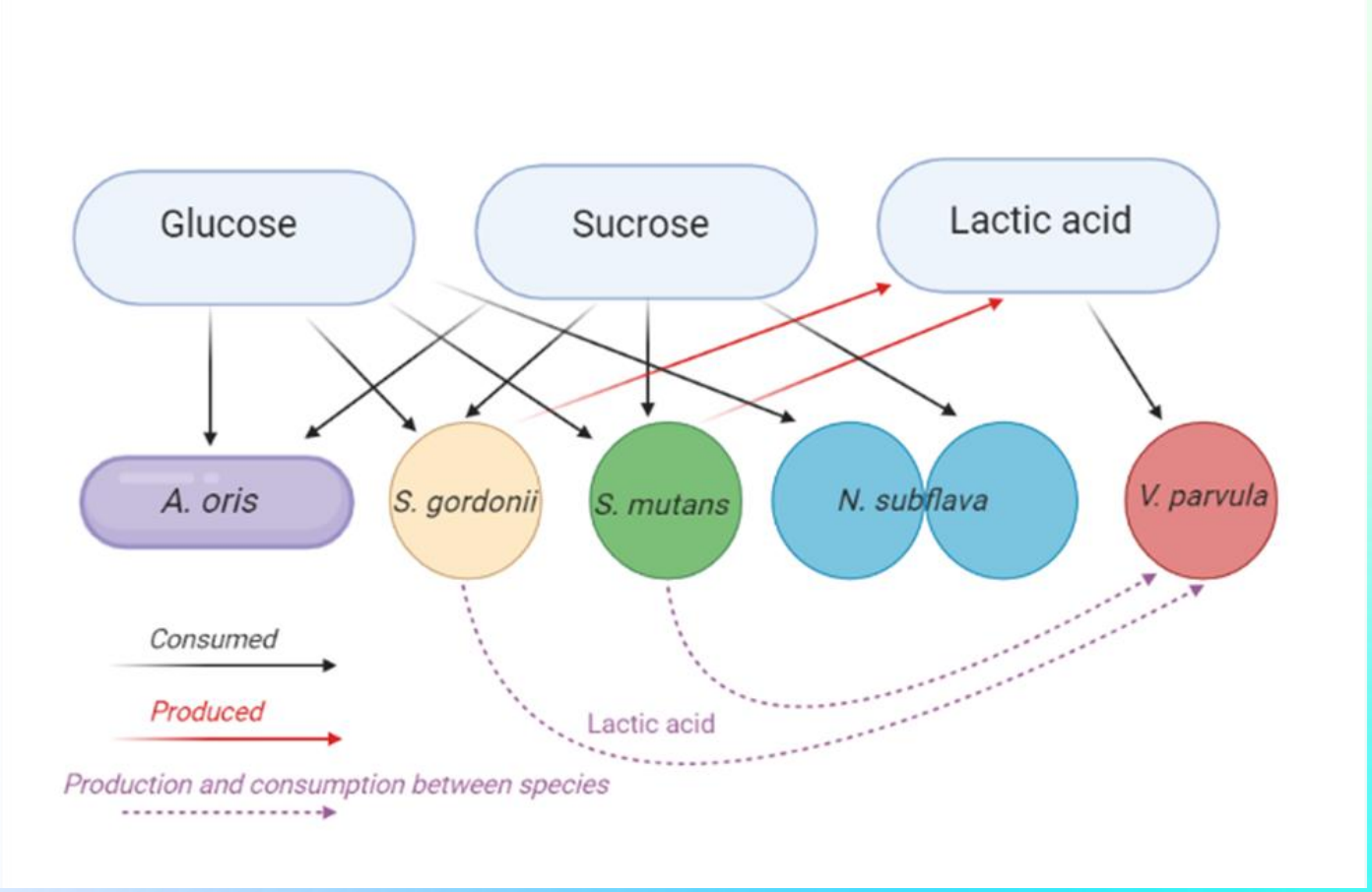
Case study: Effect of the environment on *Streptococcus mutans* (pathobiont associated to caries).

Synthetic community with "early colonisers".



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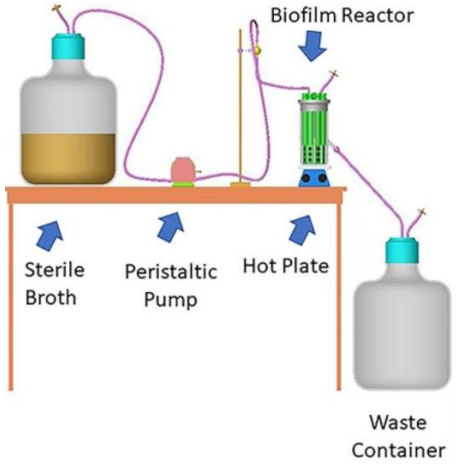
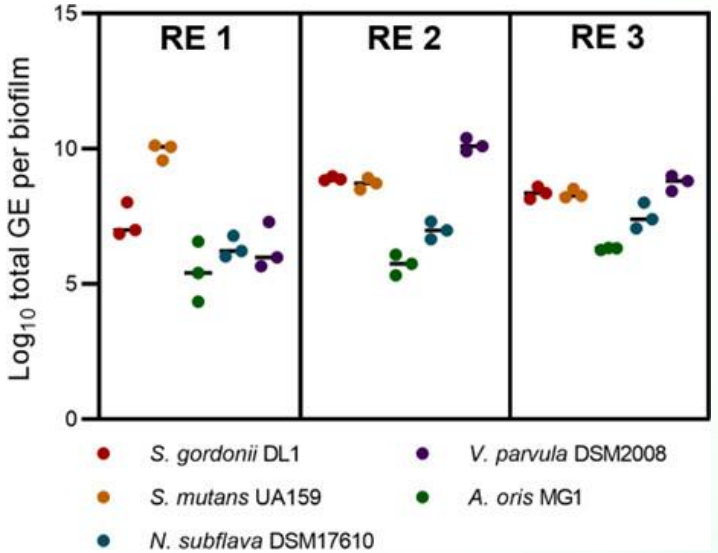
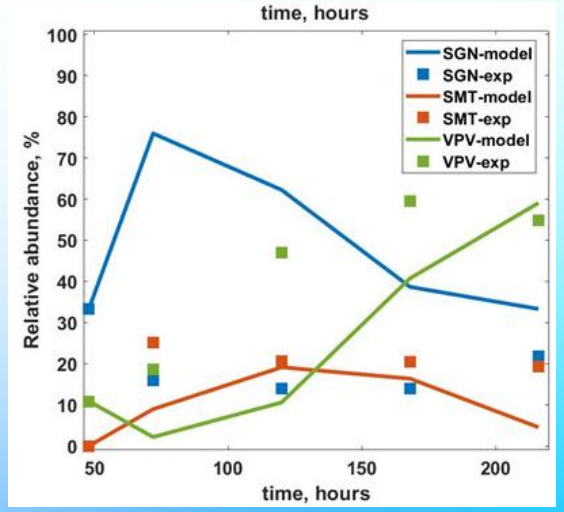
Modelling dental caries *in vitro* and *in silico*

imaging
qPCR
pH
[glucose] and [lactate]



In vitro *In silico*





Individual base modelling (IBM)
for biofilm formation simulations

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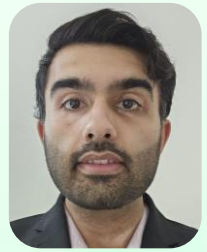

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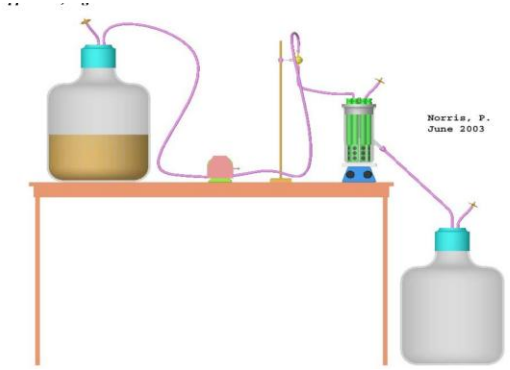
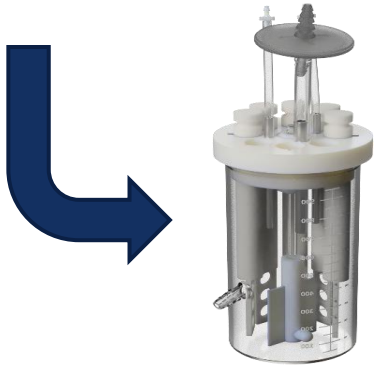
Sangha *et al.* (2024) Microbiol Spectr 12:e0371323





Picture from the CDC operation manual (accessed 2019)

Set-up

- 8 x 3 hydroxyapatite coupons (enamel)
- Temperature controlled at 37 °C
- Defined media flow rate of 0.5 ml/min (saliva flow)

Inoculation

Day 0

Actinomyces oris MG1

Day 1

Streptococcus gordonii DL1
Neisseria subflava DSM17610
Veillonella parvula DSM2008

Day 2

S. mutans UA159

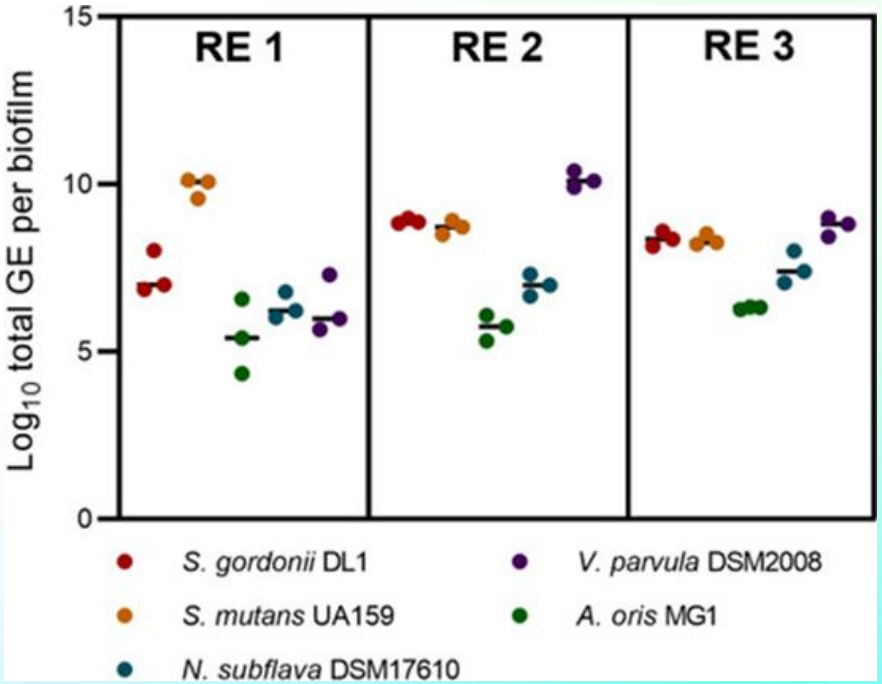


Fig 5 Total cells in the biofilm (qPCR) at Day 9, in GE, Genome Equivalents. Bars show mean values (n = 3) for high glucose concentration (RE 1), high lactate (RE 2), and low equimolar concentrations of glucose and lactate (RE 3).

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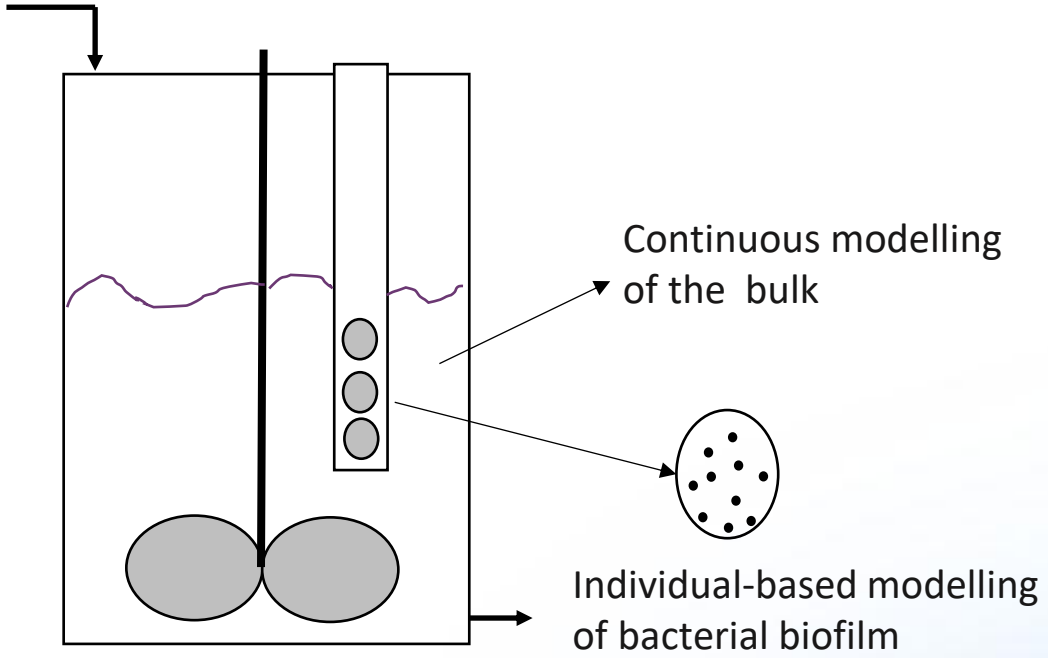
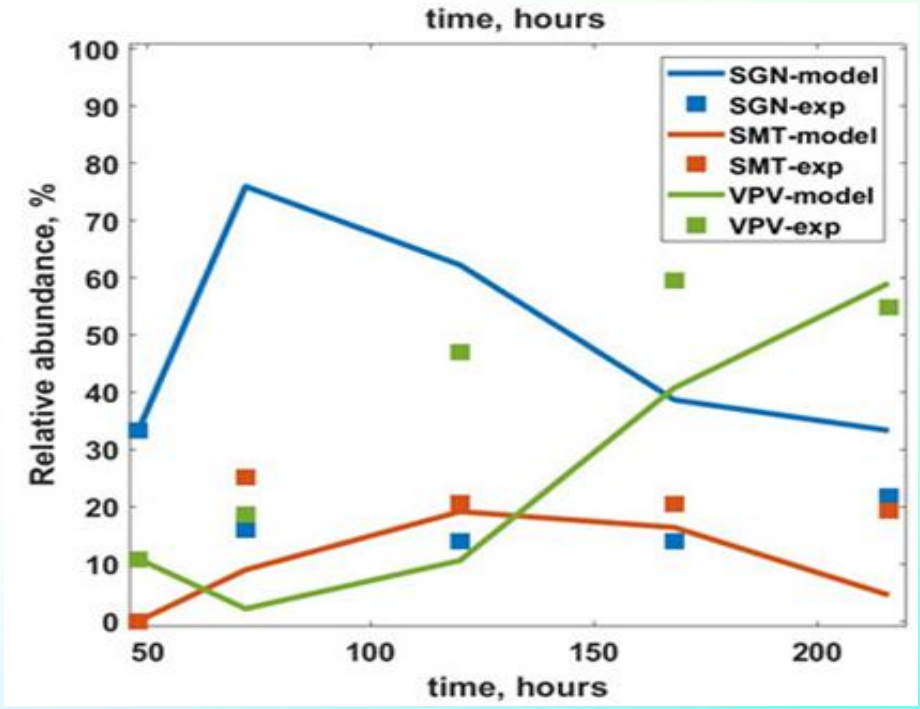
Sangha *et al.* (2025) mSphere 10:e0074324



2D model where each agent is a bacteria integrating chemical equilibrium, diffusion and metabolism based on a mixed thermodynamics - empirical Monod approach.



The simulations suggested that *S. mutans* ability to withstand low pH is a significant factor.

However…. metabolism equations derived from general literature equations => metabolic models for each species

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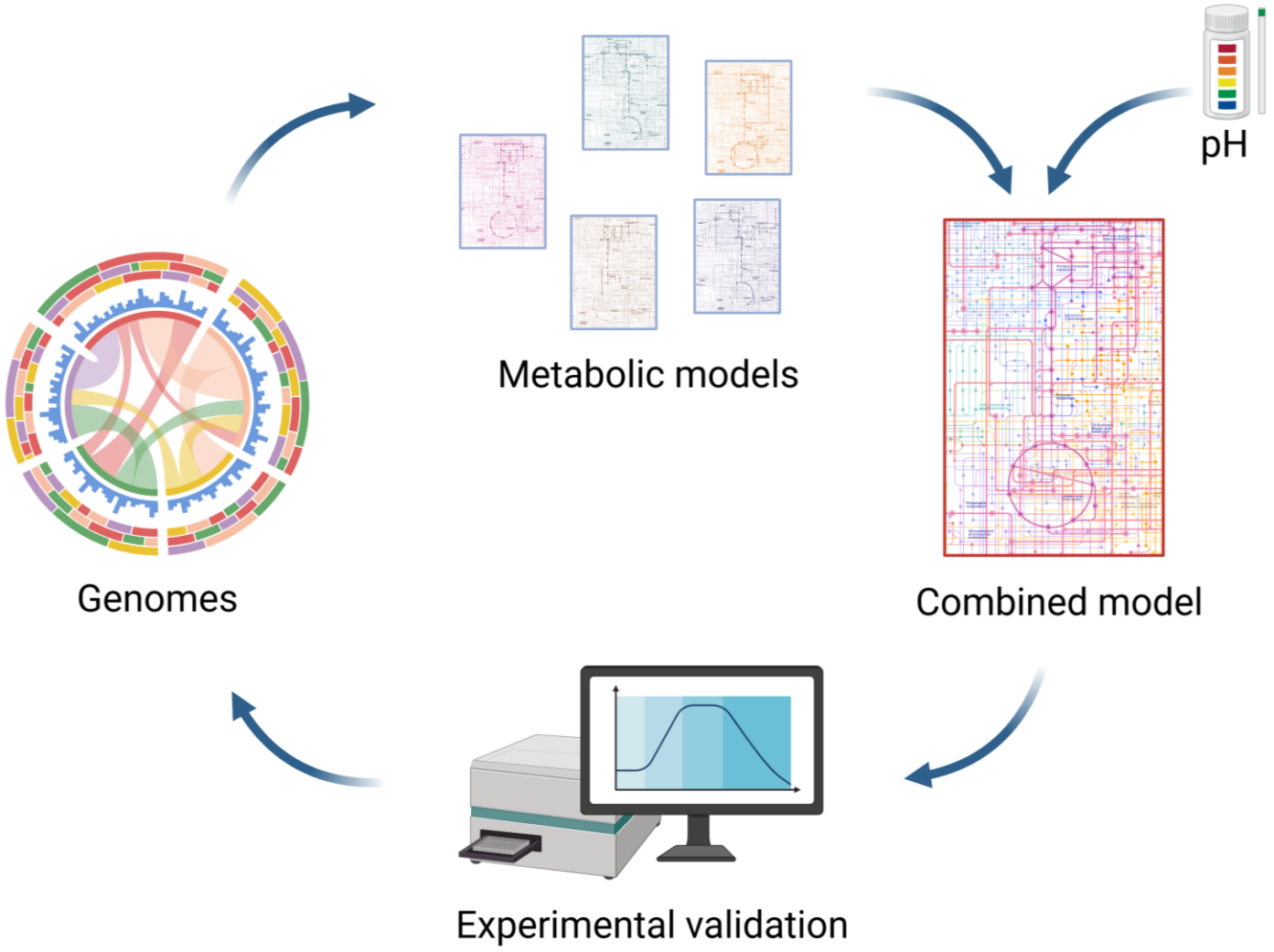

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Includes fermentation pathways leading to acid production & pH effect on metabolism, both measured experimentally

Experimental gingivitis model

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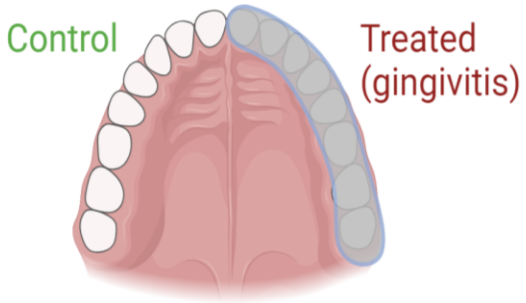
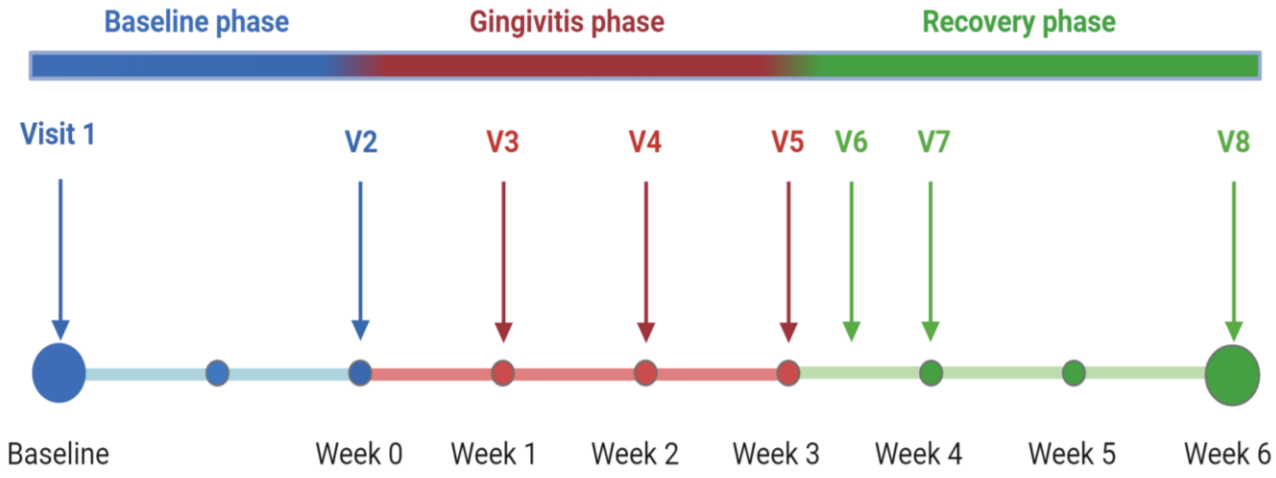
Resilience of the microbiome is underpinning tier 2 and 3 of our safety framework.

Functions rather than taxa

=> Experimental gingivitis (reversible periodontal disease) with shotgun sequencing (deriving gene functions as well as taxa) and meta-transcriptomics data ("active functions") to define biomarkers of resilience.





Cohort 1: Metagenomics + Metatranscriptomics

Cohort 2: Metagenomics

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Conclusions and future research

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- For caries, we have developed an *in vitro* model with a synthetic community of 5 which complemented with *in silico* approaches allows to test hypotheses about environmental factors influencing microbiome composition.
- An IBM confirmed the importance of relationship between pH (environment) and metabolism of the *S. mutans* pathobiont, suggesting this is an important feature to record with oral microbiome studies.
- An experimental gingivitis study has been designed to assess whether functional markers of resilience can be sought from sequencing data.

=> Oral microbiome models are useful for determining endpoints of microbiome perturbations.

- AI-augmented *in silico* and *in vitro* models have potential to unlock fast, reliable, functional characterization of host–microbiome-environment interactions provided the relevant factors (e.g. host state, pH) are considered.

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Acknowledgements

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