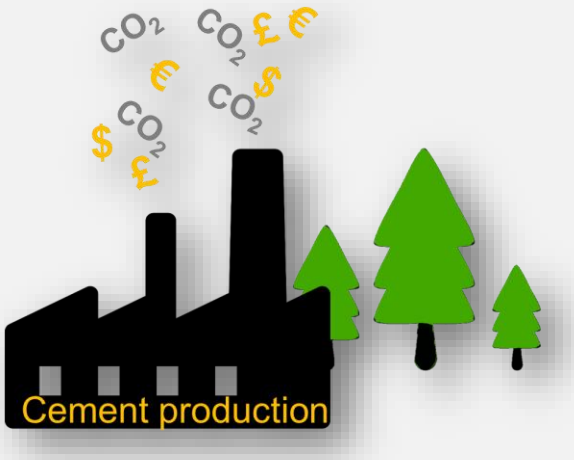
OPTIMISING BACTERIA-INDUCED CALCITE PRECIPITATION IN CONCRETE

Bianca Reeksting, Timothy Hoffmann, Susanne Gebhard

Department of Biology & Biochemistry

RESILIENTMATERIALS4LIFE

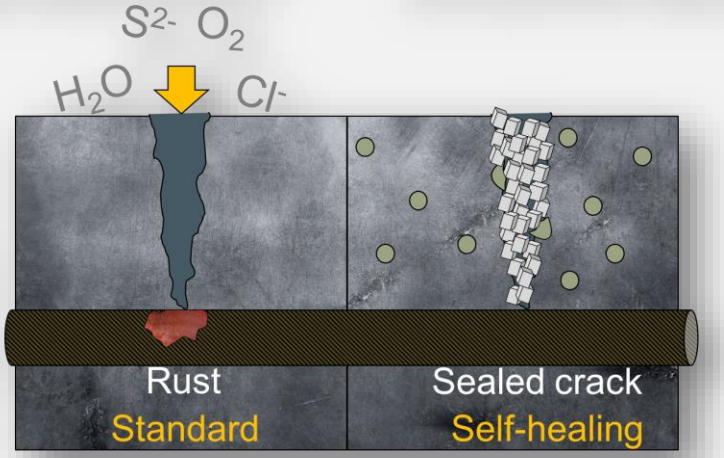
BACTERIA AS SELF-HEALING AGENTS

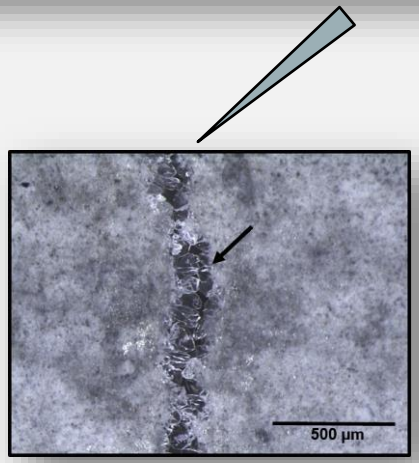


Increased by maintenance costs

Cracks increase permeability and accelerate deterioration

Bacteria precipitate $CaCO_3$ and prevent damage

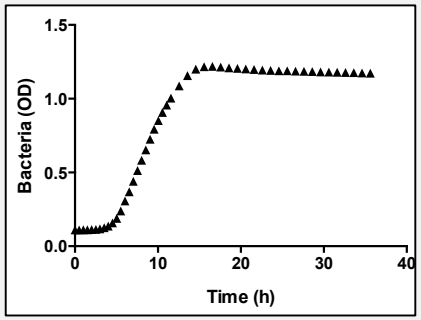




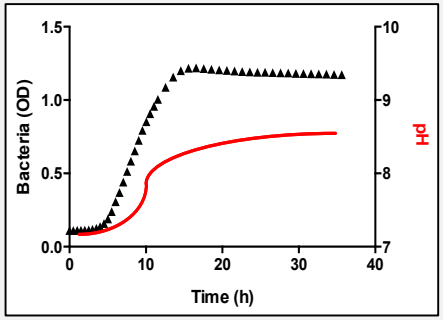
REQUIRED BACTERIAL TRAITS

Basic principle of bacteria-induced calcite precipitation

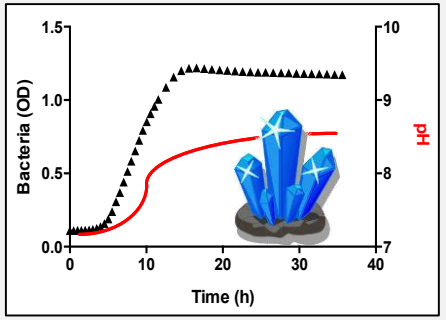
Growth



pH change



Formation of calcite from Ca^{2+} and HCO_3^-



Requirements:

Calcite precipitation

- Quantity
- Speed (?)

&

Thrive in/on concrete

- high pH
- high salt
- low temperature

IDENTIFYING THE BEST BACTERIA FOR THE JOB

Isolation from the environment
(*ca.* 70 isolates)

✓

Microbiology

Characterisation in the lab
(15 isolates)

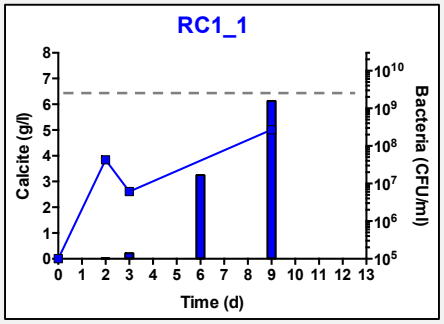
?

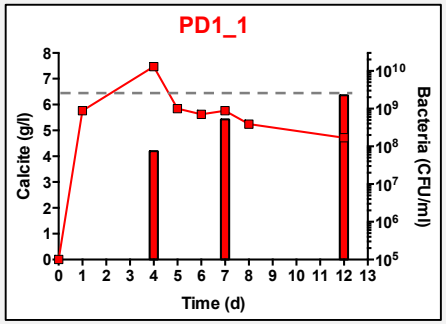
Maths?

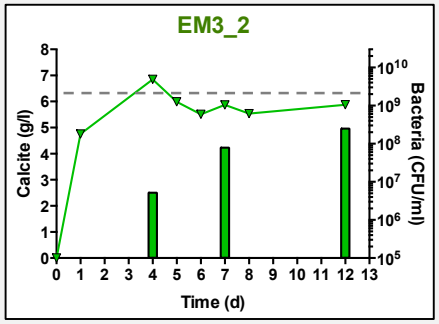
Optimum bacterium
(1 isolate, 1 community?)

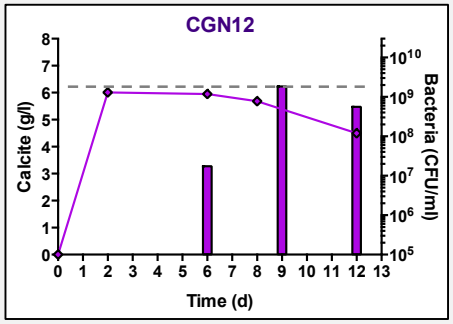
OBSERVED CALCITE PRECIPITATION

- Bacteria grow quickly *(lines)*, calcite appears more slowly *(bars)*









- Bacteria differ in
  - how fast they grow
  - how high they grow
  - how much calcite is precipitated *(dashed line = theoretical maximum)*
  - how fast calcite is precipitated

➢ Is there any mathematical logic in these data, relating growth and precipitation?

THRIVING IN CONCRETE

High pH

Low temperature

High salt

Bacteria need to be able to cope with all three conditions

In the lab, we only test one condition at a time

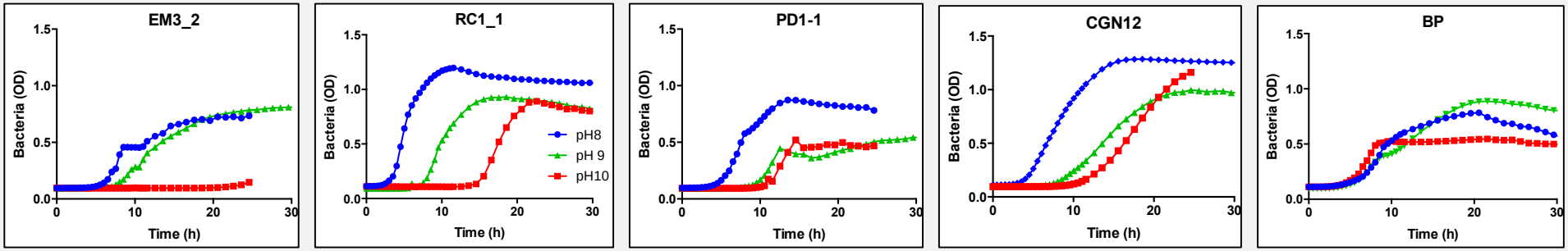
THRIVING IN CONCRETE

High pH

Low temperature

High salt

pH 8 *(near neutral)* ⟶ pH 9 *(high)* ⟶ pH 10 *(very high)*



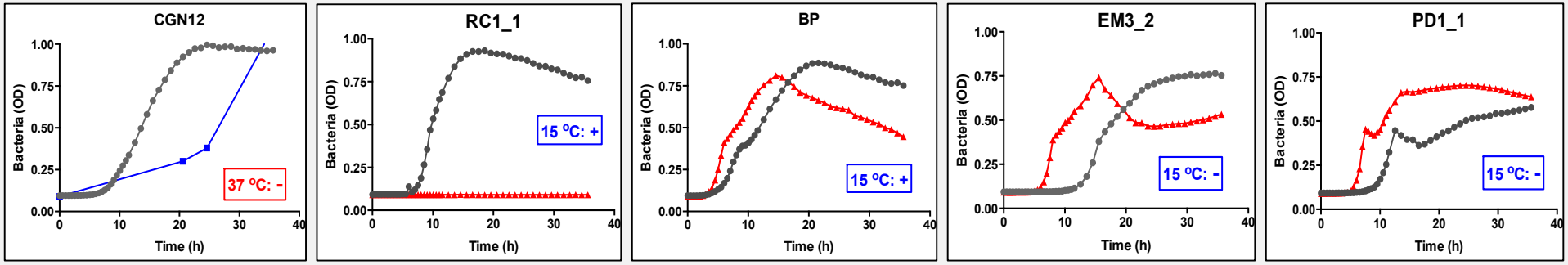
- Bacteria differ in
  - how fast and high they grow at the near neutral pH (blue)
  - how strongly they are affected by high and very high pH

THRIVING IN CONCRETE

High pH | **Low temperature** | High salt

15 °C ⟵ 30 °C ⟶ 37 °C

*(**cold**)* *(standard)* *(**warm**)*



(Temperature experiments were done at pH 9)

- Bacteria differ in
  - how fast and high they grow at the medium temperature (grey)
  - how strongly they are affected by different temperatures
  - whether they can grow at all at low temperatures (blue)
  - whether they can grow at all at high temperatures (red)

THRIVING IN CONCRETE

High pH Low temperature High salt

Growth was scored qualitatively, as -, +, ++, +++

NaCl	0 %	2.5 %	5 %	7.5 %	15 %
EM3_2	+++	++	++	+	-
RC1_1	+++	++	+	-	-
PD1_1	+++	++	++	+	-

(NaCl experiments were done at pH 9)

- Bacteria differ in
  - how much salt they can tolerate

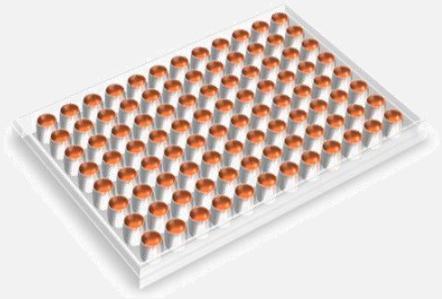
THRIVING IN CONCRETE

We currently characterise each bacterium and each condition in isolation

- Calcite-precipitation experiments take 2 weeks and only give low resolution of time as a variable
- Growth experiments are faster, but require access to shared instrumentation

➢ Parameter space is too large to test all combinations

AIMS AND HOPES

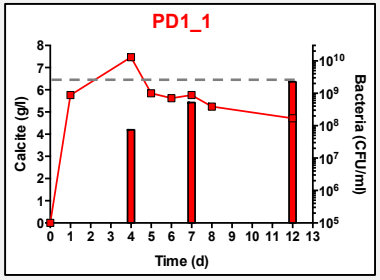


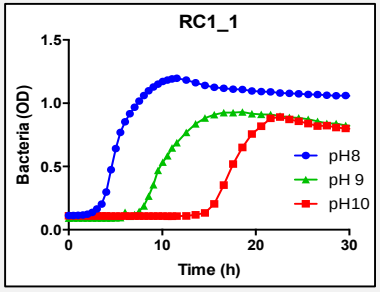
<u>Ultimate goal: Mix & Match Library:</u>

- Collection of bacteria capable of calcite precipitation
- A set of known parameters for each bacterium
  - pH tolerance
  - temperature tolerance
  - …
- A model that will predict the best bacterium/community for specific applications, e.g.
  - concrete structure in a tunnel *(cold, high pH)*
  - concrete structure in exposed costal area *(salt, range of temperatures, high pH)*
  - soil consolidation project (*range of temperatures, high/low pH, medium salt)*
  - …

➢ *We can supply a bespoke solution to a range of customers*

AIMS AND HOPES

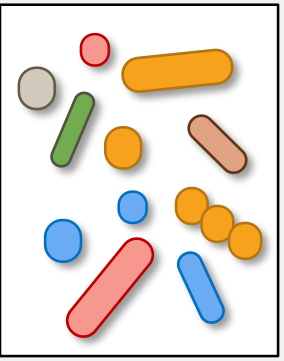




Growth:

- What test would we do to see if there is a correlation between bacterial growth and calcite precipitation? *(amount? speed?)*
- Is it possible to model the effects of pH and temperature on growth using standard mathematical models of growth?

AIMS AND HOPES



<u>Best bug for the job:</u>

- How do we use our experimental data to predict the best bacterium or community for calcite precipitation under concrete-like conditions?

- We are measuring each bacterium and condition in isolation
  - ➢ How can we build a model to predict community behaviour in complex conditions, ultimately to find the optimal community
  - ➢ Would we need other data? E.g. testing pairs of conditions to predict higher-order interactions?

- Do we need to monitor calcite precipitation under each condition, or can we 'mash together' the growth/calcite correlation from earlier with the ability of the bacteria to simply cope with conditions?

Over to you!