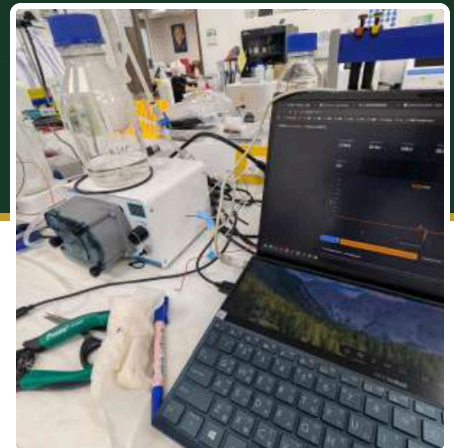
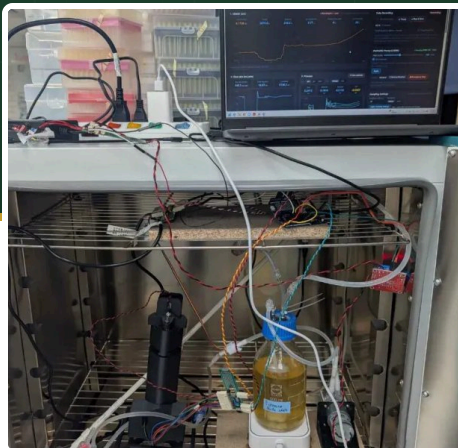


Hardware Notebook

Week by week, 23 March to 17 October 2026



WHAT THIS IS

A record of the hardware we built for ReLEAF, one week at a time. Nine things got made: a humidity box, an agar plate imaging station, two vertical agar stands, a hydroponic floating plate, an in-line photometer and a simplified one, the light plate apparatus (LPA, called DiOPAL until October), and the bioreactor.

HOW TO READ AN ENTRY

The points down the left are what happened and why. Photographs sit between them. Tables carry the numbers. The Decision block holds the choice and the option turned down. PROBLEMS is what was still broken when the week ended.

THIS EDITION

The first edition stopped on 13 August with its photo frames empty. This one fills them from the team photo bank, Discord and the hardware wiki, and adds 20 entries up to 17 October, drafted from the Discord record and the wiki and marked **ADDED 17 OCT**. Quotes are copied from Discord.

MARKS IN THE CORNER

BR bioreactor. **PH** photometer. **LP** light plate (LPA). **IS** imaging station. **FP** floating plate. **HB** humidity box. **FL** fluorometer. The tag underneath is the build or iteration.

Contents

51 entries. Numbers on the right are entry numbers, which run in the order the work happened; a letter marks a second entry in the same week.

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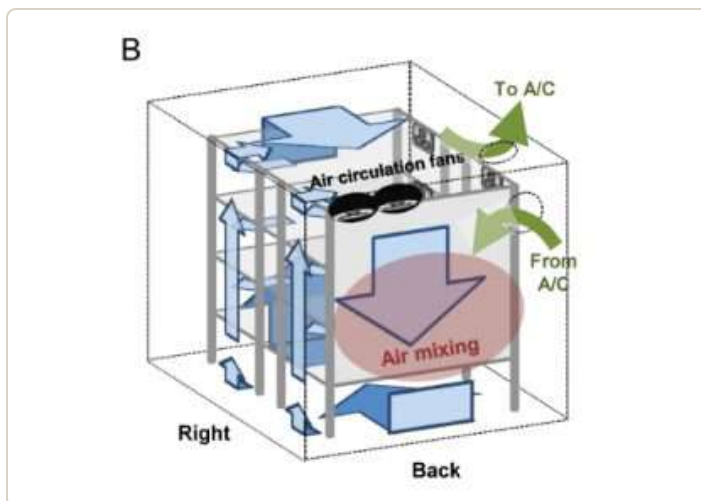
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Sourcing finished, purchasing frozen

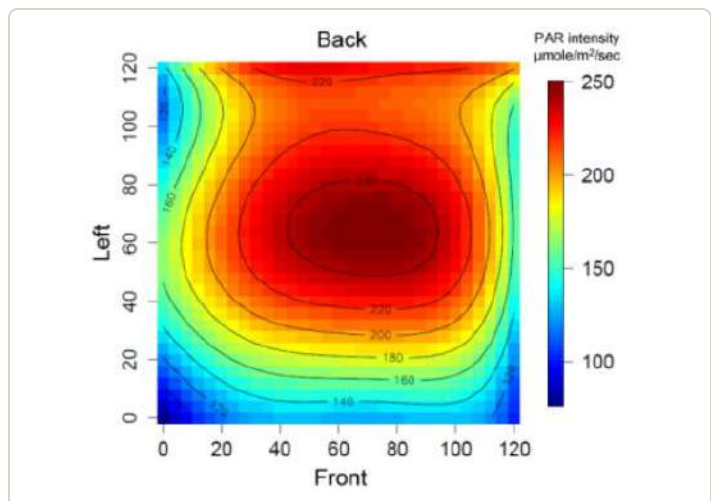
Our first plan was a sealed growth chamber with hydroponics inside it. Arabidopsis needs steady humidity, temperature and light to give comparable results, and the school lab could not hold any of those steady. The chamber was meant to give us a controlled box to run every plant experiment in. This was the last week of design before we started buying parts.

• Finished the chamber layout and ran airflow studies on the enclosure.

- Fans, ducting and shelf spacing sized around a 3 tray capacity.
- Inspired by the Katagiri chamber (2015) research paper.



Air circulation diagram



Light distribution graph

• Built four sourcing lists, split by where we would actually buy each part.

- Electronics and control from Guanghua. Structure from Test Rite. Plants and water systems from the Jianguo flower market. Containers from IKEA.
- Fans, timers, DS18B20 temperature sensors, blackout cloth, a Mylar substitute, air pumps and air stones.

Item	Category	Quantity	Unit Price	Total Price	Comments
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Combined sourcing list



27 March, NTU plant lab visit: the hydroponic set-ups we were trying to copy inside the chamber

• Costed the whole build and took it to the instructors.

- The total was never written down in this record.

- **Stopped on 28 March, told to buy nothing and print nothing.**

- The instructors were still weighing the effort against the risk and against what the chamber would be worth to us later.
- Nothing had been ordered, so the freeze cost us planning time and nothing else.

DECISION

Freeze purchasing instead of building in parallel

- If half of it was already built we'd have argued to keep going.
- We hadn't spent anything yet, so stopping was free.

REJECTED

Ordering the slow-delivery parts anyway to keep the option open. Nobody had defended the chamber yet, so that would have been buying our way into a decision.

PROBLEMS

HOW WE'LL FIX IT

We picked the chamber before checking it was the right build

SINCE THIS WEEK

→ Wait for the instructors' evaluation before any further design work, and agree a hardware budget before the next sourcing round.

NEXT

Read the new direction document when it lands. Brainstorm against it before defending the chamber.

PROJECT

Growth chamber · pre-pivot

DATE

29/03/2026

ENTRY

1

Visiting Prof. Verslues

We had a chamber design nobody had agreed to and a purchasing freeze. None of us had seen a working plant growth setup, so we went to look at one before designing any more of our own.

- **Visited Prof. Verslues's lab at Academia Sinica on 3 April.**

- Looked at how his incubator holds conditions across a whole tray at once.
- Trays sit on wire shelving with airflow coming from underneath.
- He grows at a much lower density than we had been planning for.



Incubator shelf with vertical agar plates



Photometer we saw at his lab that measures cell density

- **Came back and dropped the full chamber in favour of a humidity box.**

- Humidity is the condition that decides whether the seeds come up, and a box holding one tray is a build we could actually finish.

DECISION

Build a humidity box, not a growth chamber

- Small enough that we'd actually finish it.
- Humidity is the condition that decides whether the seeds come up.

REJECTED

Carrying on with the full chamber. It was frozen anyway, and after seeing a real one we couldn't justify the size.

PROBLEMS

No target humidity range written down, and nothing to measure it with

SINCE THIS WEEK

→ Get the range Arabidopsis needs, and put a sensor on the next electronics order.

HOW WE'LL FIX IT

NEXT

Design the box around a target humidity range, not around the space we happen to have.

PROJECT
Humidity box · origin

DATE
05/04/2026

ENTRY
2

Told to drop soil sensing

Our original plan was to sense drought stress in soil and release protectant into the soil directly. Before committing to it we wanted someone who sells into agriculture to tell us whether it held up.

- **Met Prof. Chen (陳文亮) on 10 April.**

- He has commercial products in the smart agriculture market we were aiming at.



Meeting in progress



Bioreactor start-up poster Prof. Chen pointed us to

- **Were told to drop soil moisture sensing entirely.**

- Cheap sensors already dominate that market and they are inaccurate.
- Calibrating a sensor across soil types takes three to four months of data for each one.

- **Took his second point, that soil release is hard to defend on biosafety.**

- Engineered bacteria going into open soil is a much harder case to make than bacteria kept inside a vessel. He pushed us toward containment.

- **Reframed the business model around the consumable instead of the device.**

- Sell the cartridge, not the box, the way printers and ink work. His idea, not ours.

DECISION

Drop soil sensing and move to a contained vessel

- A market already served by cheap sensors is not one we can enter with a school budget.
- Containment is easier to defend than release, and we were going to be asked about it.

NOT ACTED ON

Soil calibration across types. Three to four months of data for each one, which we do not have.

PROBLEMS

No bioreactor design exists yet

SINCE THIS WEEK

→ Ask Dr. Pak for the reactor landscape before choosing a configuration.

Soil compatibility now unclaimable

SINCE THIS WEEK

→ If we ever claim it, it needs the 3–4 months of data per soil he described.

HOW WE'LL FIX IT

NEXT

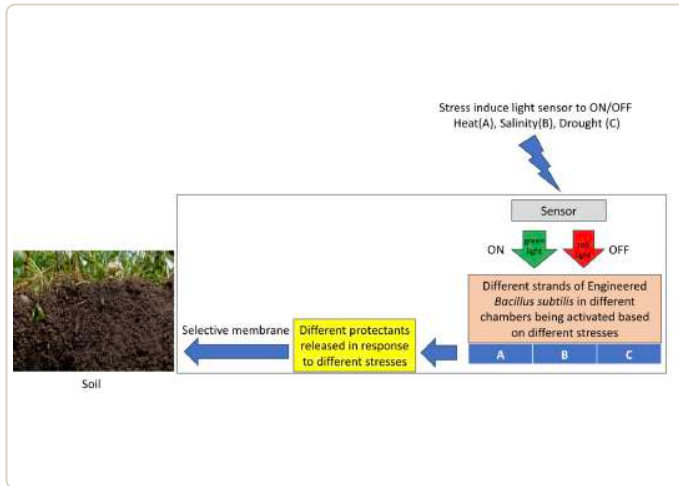
Get the reactor families from Dr. Pak so the new direction has a shape.

The pivot, and asking Dr. Pak where to start

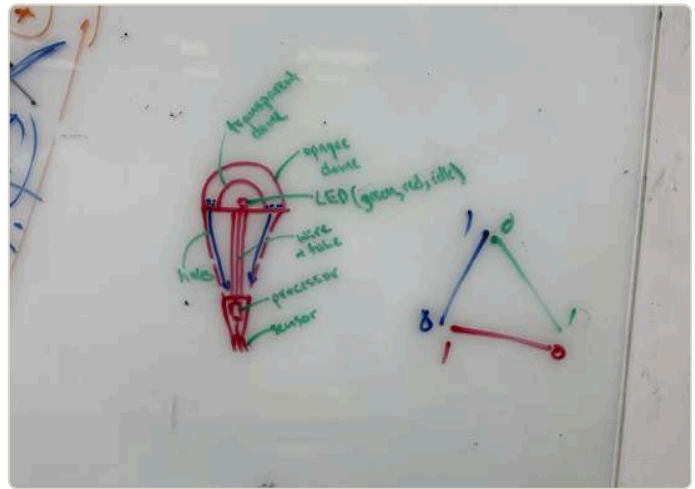
This is the week the project changed shape. The pivot document went up on 15 April: instead of sensing soil and releasing into it, engineered *B. subtilis* would live inside a sealed vessel, and light would tell them when to produce protectant. That vessel is a bioreactor, and none of us had built one or knew where to start.

- **Posted the pivot on 15 April. Input soil stress, output green or red light into a contained chamber.**

- Seven people reacted to the message. Every instrument in this notebook follows from it.



The pivot as posted on 15 April: stress sensed, light switches the strains, protectant crosses a membrane



18 April: our first hardware sketch on the whiteboard

- **Asked Dr. Pak, Dean of Research, for the reactor landscape.**

- He set out five families. Continuous stirred tank, bubble column, air lift, fluidised bed, packed bed.
- He suggested a packed bed for our case, with bacteria immobilised in the column.

- **Took his scoping advice, which mattered more than the recommendation itself.**

- He said bioreactor design is an enormous field and there is no need to invent something new. Adapting a common design to our needs would itself be the achievement.
- We went on to choose hollow-fibre tangential flow, which is not what he suggested. That conversation happened in person and nobody wrote down why.

DECISION

Adapt an existing reactor design instead of inventing one

- Adapting an existing design became the goal, so the scope stopped growing.
- Five families to choose from instead of a blank page.

NOT ACTED ON

Nothing yet. Hollow fibre was recommended in person and nobody wrote it down, so we can't say why we didn't take the packed-bed suggestion.

PROBLEMS

HOW WE'LL FIX IT

No record of why hollow fibre over packed bed

SINCE THIS WEEK

→ Ask Dr. Pak to put the reasoning in a message so it exists in writing.

No selection criteria were written down

SINCE THIS WEEK

→ Write the criteria out now and mark them as reconstructed.

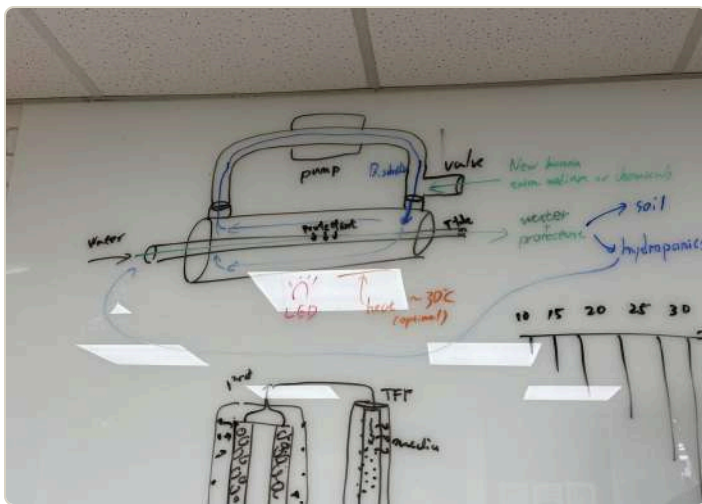
NEXT

Specify a hollow-fibre configuration we can actually buy in Taipei.

Working out what a stress assay should measure

The pivot had landed but the plant side of the project had no experiment behind it. Before building anything for the plants we needed to agree what stress we would apply, at what level, and what we would measure to say whether the protectant worked.

- **Argued out what a standard stress assay would look like for us.**
 - Salinity came up more than heat, mostly because it is easier to apply consistently.
- **Sketched the hollow-fibre loop and printed the first hydroponic plate.**
 - The whiteboard sketch is the first drawing of a membrane module in our record. The plate is a flat holder with seed holes, before any idea of floating it.



25 April: hollow-fibre membrane loop sketched on the whiteboard



26 April: first printed hydroponic plates

PROBLEMS

HOW WE'LL FIX IT

No agreed stress assay

SINCE THIS WEEK

→ Pick the stress, the concentration and the readout, and write them down.

NEXT

Set milestones and deadlines per task so the quiet weeks are visible in advance.

PROJECT

Hydroponics · assay standard

DATE

26/04/2026

ENTRY

4a

--

pre

WEEK 09

27 APRIL – 3 MAY 2026

LOW ACTIVITY WEEK · WEEK

Nothing much happened

A quiet week. Several of us were away. Kept in the record because a notebook containing only the productive weeks misrepresents how the summer actually went.

- **Bioreactor, 2 May: hollow-fibre availability confirmed as real, not catalogue-only.**
 - Hollow-fibre sourcing: FiberCell systems and a local supplier.
 - Fluidics reference: the open-source peristaltic pump from iGEM Aachen 2017.
 - Bioreactor material list drawn up by Joshua, Felix and Noah (team wiki, Dry Lab Notebook, 2 May).

PROBLEMS

HOW WE'LL FIX IT

A week lost with nothing scheduled

SINCE THIS WEEK

→ Agree deadlines per task so gaps are planned instead of discovered.

NEXT

Milestones per task, requested by the instructors.

PROJECT

Low activity week

DATE

03/05/2026

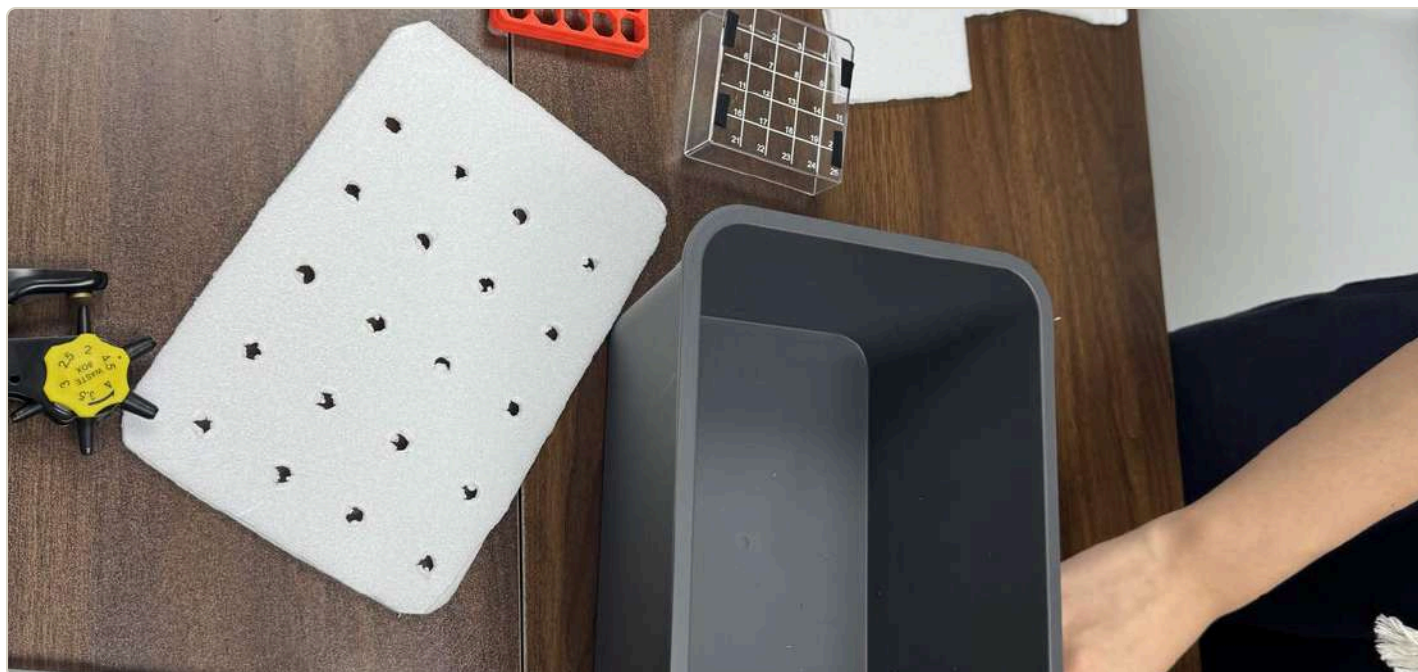
ENTRY

4b

Four instruments, three people

The instructors asked for a milestone and a deadline against every task in the project. Writing the list turned out to be more useful than the list itself.

- **Listed every task in progress with an owner and a date.**
 - Two tasks had no owner at all until the list was written.
- **Found we had four instruments in progress and three people to lead them.**
 - Humidity box, imaging station, light plate, fluorometer, with the bioreactor about to start.
- **Left the fluorometer decision to the following week.**
 - Nothing was built this week. The output was an uncomfortable conclusion.



9 May: the hydroponic prototype set up for the wet lab, the one piece of hardware that moved

PROBLEMS

HOW WE'LL FIX IT

Four instruments, not enough people

→ Drop one. Decide which next week.

SINCE THIS WEEK

NEXT

Decide on the fluorometer.

PROJECT
Milestones

DATE
10/05/2026

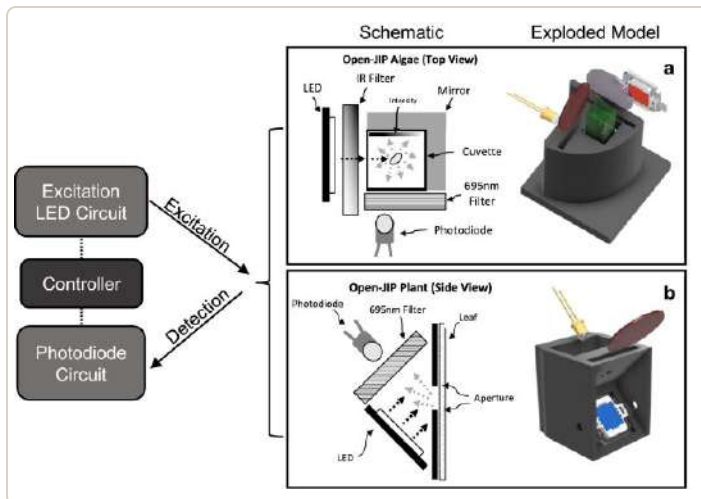
ENTRY
4c

Dropping the fluorometer

The chlorophyll fluorometer would have let us measure plant stress directly, by reading damage to photosystem II. Fv/Fm is the standard number for that, and a healthy plant sits around 0.78 to 0.83. It was the fourth instrument we had in progress and there were three of us.

- **Made the case for building it.**

- It measures the outcome the project claims to improve, so it would test our own claim directly.
- Commercial meters run past NT\$100,000 and the open-source Open-JIP design already exists, so the gap looked worth closing.



The Open-JIP layout we evaluated (published figure, shared in #dry-fluorometer on 9 April)



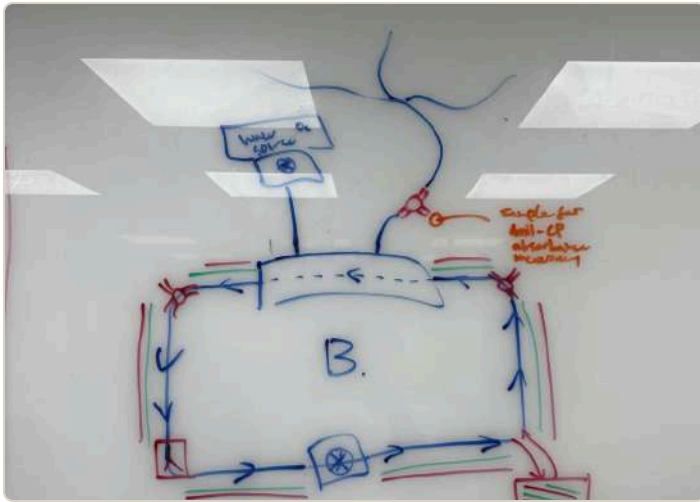
13 May: checking agar plants by eye, the measurement a fluorometer would have replaced

- **Dropped it on 11 May, on capacity, not feasibility.**

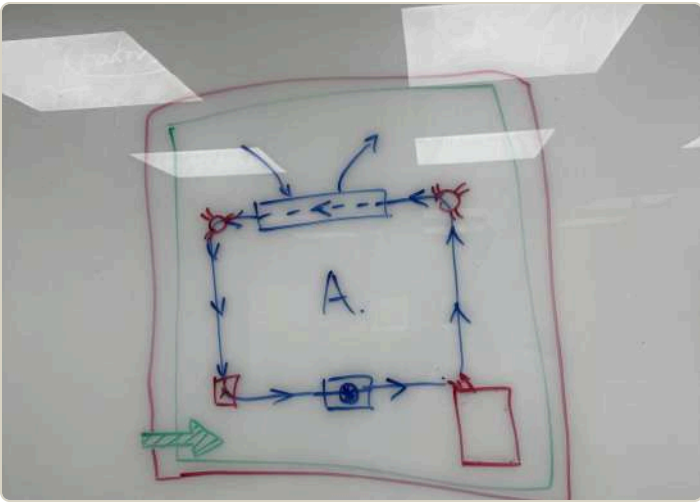
- Anton moved to the bioreactor. Eva took a different task.
- The Open-JIP evaluation was never written up, so anyone picking it up starts from nothing.

- **Wrote the photometer requirement on 16 May, in nine words.**

- We need to measure flow rate, and how much *B. subtilis* there is.
- The shape of the answer followed immediately: flow cuvette plus spectrometer, 600 nm beam, a sensor reading light decay, an intensity controller.



16 May: bioreactor layout A sketched the same day



16 May: layout B

DECISION	
Drop the fluorometer on capacity, not feasibility - The science holds up. It was never a feasibility problem, only a staffing one. - Better to finish two instruments than half-finish three.	
REJECTED	Building it anyway with a part-time lead. Three half-finished instruments is worse than two finished and one we admit we skipped.
PROBLEMS	
HOW WE'LL FIX IT	
No direct measure of plant stress response SINCE THIS WEEK	→ Either source a commercial meter for final validation, or state the gap on the wiki.
Open-JIP evaluation never written up SINCE THIS WEEK	→ Write it up anyway so a future team can start from it.
NEXT Specify the photometer optics. Flow cuvette, beam path, and what the sensor actually reads.	

PROJECT	DATE	ENTRY
Fluorometer · photometer	17/05/2026	5

Humidity box finished, agar photos useless

The humidity box is a small sealed enclosure that keeps humidity steady while *Arabidopsis* germinates. It came out of the Verslues visit and it is the first thing we finished. The same week we started growing on agar plates, and ran into a problem we had not planned for.

- **Finished the humidity box and put the first seeds in.**
 - We have no log of what humidity and temperature it actually holds.
- **Started photographing agar plates to track germination. The photos were useless.**
 - The angle moved between shots, the room light changed with the time of day, and the shadows moved with it.
 - Two plates photographed on different days told us nothing about how much had grown.
- **Spent two afternoons shooting a transparent dish on a white table, trying to find a repeatable setup by hand.**
 - It did not work, but it told us what was moving: angle, distance, background and ambient light.
 - A fix has to hold all four at once, which a person with a phone cannot do.
- **Bought the first round of electronics at Guanghua on 21 May.**
 - LEDs, breadboards, jumpers and an Arduino for the light plate and the imaging station.



21 May: the electronics run at Guanghua market

- **Split ownership. Anton took the light plate, Noah took the bioreactor.**
 - Both of us kept working on the other one.

DECISION

Build a station instead of writing a procedure

- A written procedure still depends on whoever is holding the phone.
- If the geometry is locked in plastic, the photos come out comparable whether you're careful or not.

REJECTED

A tripod and a taped mark on the bench. Cheaper, does nothing about room light, and it's wrong the moment someone moves the tripod.

PROBLEMS

No way yet to compare plates across days

SINCE THIS WEEK

→ Build the station. Lock the phone, the light and the background.

HOW WE'LL FIX IT

NEXT

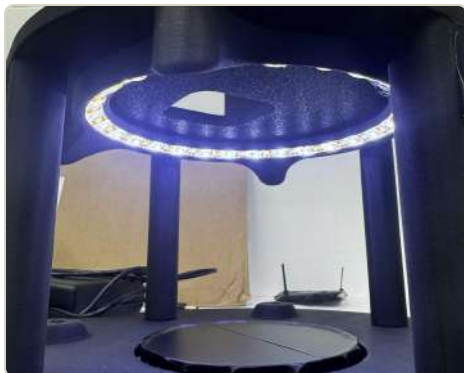
Design and build the imaging station around the four variables the hand tests exposed.

Building the agar plate imaging station

The imaging station is a rig that holds a phone in a fixed position over an agar plate, under fixed lighting, so photos taken days apart can be compared. It is the answer to the problem from last week.

- **Built a four-legged frame with a slot at the top for the phone.**

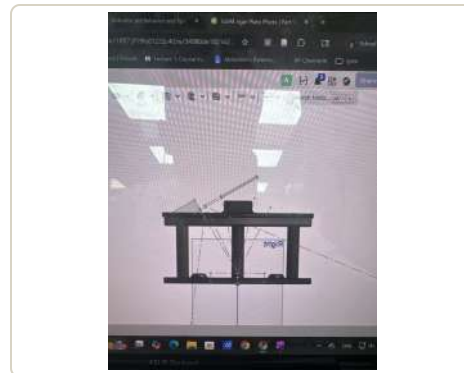
- The phone contacts the corner and locks, which fixes position and angle with no moving parts.



The light ring lit inside the station



31 May: phone seated over a plate in the station



CAD of the frame and phone slot

- **Added a dark lid so no room light reaches the plate, and an LED ring inside as the only light source.**

- **Worked out the light ring, which was the hard part.**

- We wanted the light in a circle and angled in toward the plate. Bending an LED strip into an angled circle makes it twist and compress along its length at once, and it buckles somewhere unpredictable.
- Putting ridges around the ring fixed it. The strip creases at each ridge, the tension goes out, and the creases land where we chose.

- **Cut a slot with two guide rails so the strip slides in instead of being glued down.**

- A dead LED can be replaced without reprinting the ring, which takes six hours.

- **Made the white bottom plate removable from underneath on four screws.**

- Swap it for black and the photo background changes with no reprint. Every part of the station comes apart the same way.



1 June: first use of the station



Checking the frame before the first plate



Wiring the LED ring

DECISION

Ridges to take the tension out, and a slide-in slot

- Creasing at the ridges is predictable. Left alone the strip buckles wherever it wants.
- With a slot we can replace the strip without reprinting the ring.

REJECTED

Gluing the strip onto a smooth angled ring. It works against the strip, and replacing an LED would mean reprinting the part.

PROBLEMS

HOW WE'LL FIX IT

Lighting evenness across the plate never measured

SINCE THIS WEEK

→ Photograph a blank plate and check for a brightness gradient across the frame.

No fixed camera settings recorded

SINCE THIS WEEK

→ Lock exposure and white balance, and write the settings into the protocol.

NEXT

Use it on the real salinity plates and find out whether day-to-day comparison holds up.

PROJECT

Imaging station

DATE

31/05/2026

ENTRY

7

Assembly guide tested by handing it over

The light plate apparatus (LPA, called DiOPAL until October) shines green and red light into wells of bacteria. Green switches the CcaS-CcaR circuit on and red switches it off, so the plate is how we control when the bacteria produce. Prototype 1 only had to prove we could light 24 wells evenly.

- **Seated the 24-well printed plate and wired the Arduino and breadboard to the first row.**

- Nothing is soldered. It is all breadboard and jumper leads.



27 May: 24-well plate mid-assembly



LED harness in the first row

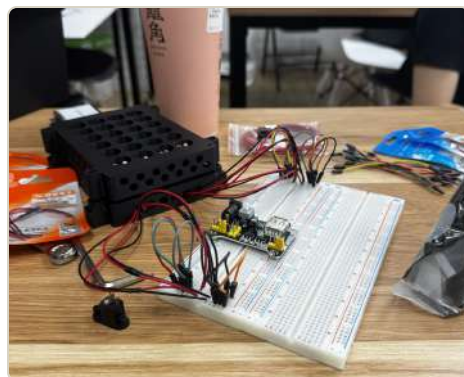


Plate wired to the breadboard

- **Wrote the assembly guide to step level, each step small enough to stop between.**

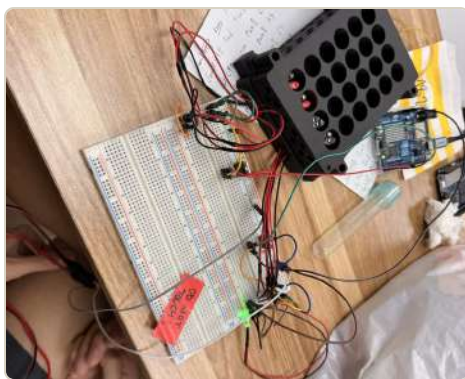
- LPA_Assembly_Guide_v2.docx.

- **Stopped at step 15 on purpose and left a note to continue from step 16.**

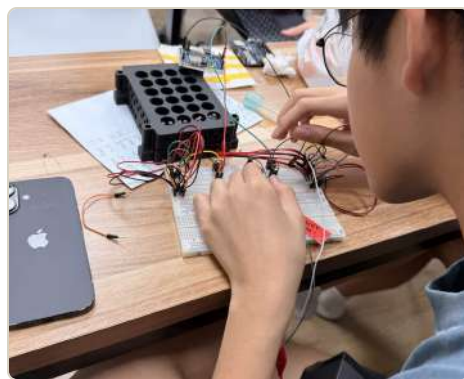
- The next person picked it up from the document alone with no verbal handoff. It is the only check we have that the guide is good enough for someone else to build from.



28 May: troubleshooting the assembly from the guide



30 May: plate handed over mid-build



30 May: working through the guide with our advisor Neo

- **Left the lid unfixed and wrote it down.**

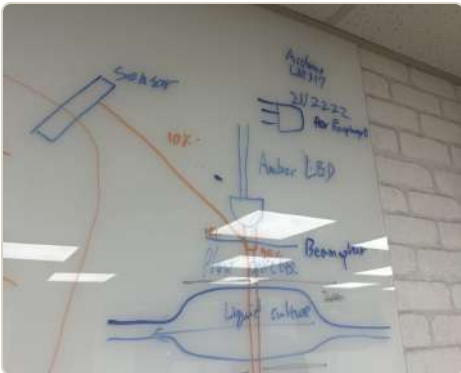
- It needs filing on the long axis and the school closed on us. Cosmetic for prototype 1, and the lid geometry changes at prototype 2 anyway.

TABLE 8

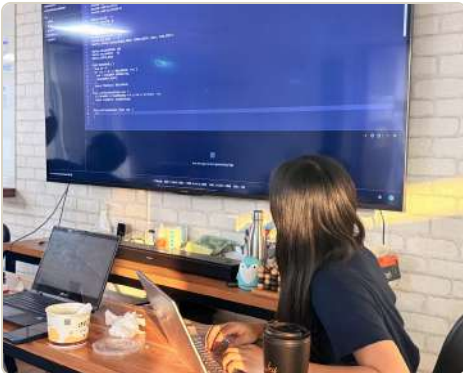
Part	Spec	Note
Plate	24-well, 3D printed	lid does not seat
LEDs	520 nm green, 660 nm red	first row only
MCU	Arduino Uno	breadboarded, not soldered
Guide	LPA_Assembly_Guide_v2.docx	step level, 20+ steps

Parts as actually fitted. The lid fault is recorded here instead of being left to the photographs.

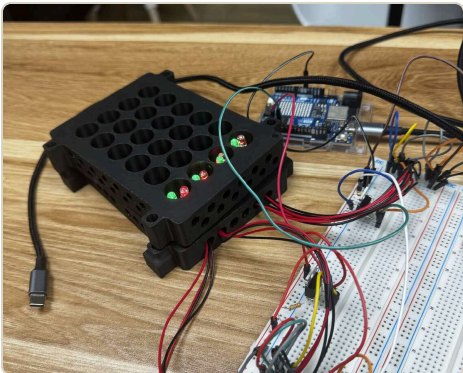
- On the same bench, the photometer lit for the first time on 28 May.
 - Two wet-lab members wired the amber LED after school. The whiteboard design it follows went up the day before.



27 May: photometer optics on the whiteboard



28 May: photometer first light, wired by the wet lab



31 May: plate at the end of the week

Decision		
Leave the lid and write it down - It does not block the 13 June date, and that is the only date that matters this month. - The geometry changes at prototype 2, so any fix now gets thrown away. REJECTED Reprinting at a looser tolerance. Nine hours of print time against five minutes with a file.		
Problems		How we'll fix it
Well-to-well output never measured SINCE W12	→ Lux meter at each of the 24 wells at fixed height, one pass per channel.	
Lid does not seat SINCE THIS WEEK	→ File the long axis, then measure what came off so prototype 2 starts there.	
Nothing soldered yet, it is all breadboard SINCE THIS WEEK	→ Solder the harness once the well spacing is final.	
NEXT Measure homogeneity. It is the stated acceptance criterion and we have not checked it once.		
PROJECT	DATE	ENTRY
Light plate · LPA-1	31/05/2026	8

Bioreactor prototype I built

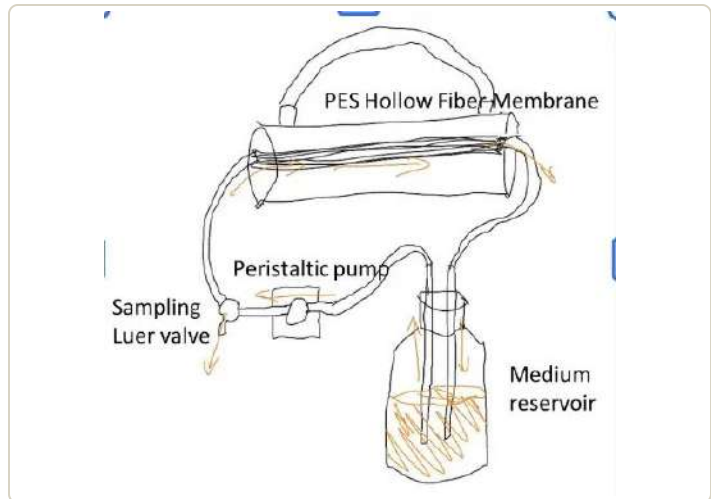
The bioreactor is the vessel the pivot committed us to. Bacteria live inside a hollow fibre membrane while the protectant they make crosses the membrane and leaves, which keeps the organism contained. Prototype I is the simplest version of that we could build.

- **Built prototype I on 6 June from four parts.**

- PES hollow fibre membrane with around 200 mL of lumen volume, a 500 mL reservoir holding 300 mL of LB, a peristaltic pump, and a luer valve on the loop for sampling.

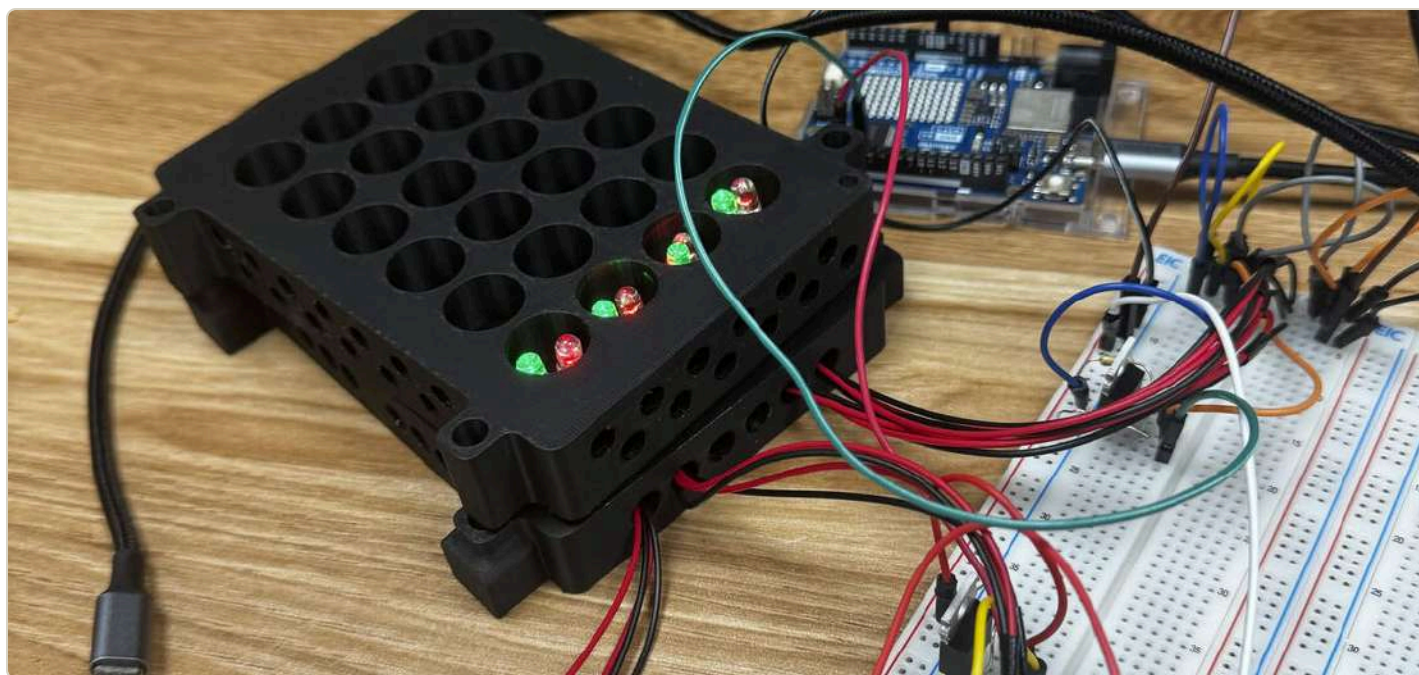


6 June: prototype I on the bench, culture going in



Prototype I as designed: membrane, pump, sampling valve, reservoir

- **Inoculated with 20 mL of a multi-overnight *B. subtilis* culture.**
- **Deliberately left everything else off. No stirring, no aeration, no pH control.**
 - We did not know which of those we needed. Starting with none means every addition later has a reason behind it we can point at.
 - Adding them all at once would have meant several things failing together with no way to tell which mattered.
- **Drove both light plate wavelengths for the first time, green 520 nm and red 660 nm.**
 - First row of wells only, driven independently. Green is the on command for the CcaS-CcaR circuit and red is the off command.



1 June: light plate, first light in both colours

• Built the round vertical agar stand.

TABLE 9

Component	Spec	Note
Membrane	PES hollow fibre	lumen ~200 mL
Reservoir	500 mL bottle, 300 mL LB	no stirring
Pump	peristaltic	target 94 mL/min
Sampling	luer valve	on the loop, not the reservoir

Prototype I as built on 6 June. Simple continuous flow-through, nothing active in the reservoir.

DECISION

Build the simplest loop we can

- Each thing we add later then has a reason behind it we can point at.
- It also means the first run tells us something even if it fails.

REJECTED

Building it fully specified from the start. More parts failing together, and no way to attribute anything.

PROBLEMS

HOW WE'LL FIX IT

No active mixing, and the sampling port is on the loop, not the reservoir

SINCE THIS WEEK

→ Add a stirrer if growth is poor, and move the port to the reservoir outlet where there is more volume.

No temperature control on the loop

SINCE THIS WEEK

→ Decide whether we run at room temperature or in the incubator, and keep it the same between runs.

NEXT

Run it and get a growth curve against a flask control.

PROJECT
Bioreactor · prototype I

DATE
07/06/2026

ENTRY
9

The cells barely grow in the reactor

This is the first run of prototype I. We grew the same culture in the reactor and in a flask at the same time, both at room temperature, so the flask acts as a control. If the reactor works, the two curves should look alike.

SYMPTOM

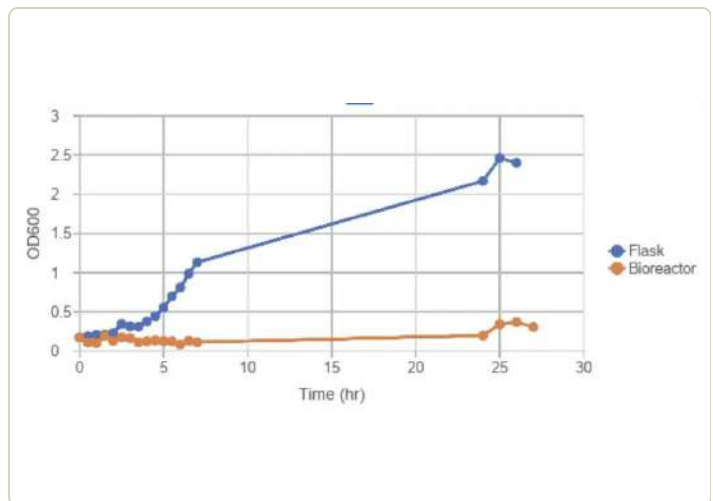
Paired growth curves against a flask control at room temperature. The flask climbed past 2.4 over 25 hours. The reactor stayed almost flat and ended near 0.3, and the run terminated early on a leak at the pump.

- **Sampled both arms every thirty minutes for eight hours, then again at 25 hours.**

- One person had to stay with it for the whole run.



Prototype I loop on the bench: pump, membrane cartridge, reservoir



OD600 against time: flask (blue) to ~2.4, reactor (orange) flat near 0.3

- **Got a flask that climbed past 2.4 and a reactor that stayed almost flat near 0.3.**

- The numbers inside the system disagreed too, 0.304 in the tube against 0.48 in the reservoir. That should not happen if the loop is mixed.

- **Terminated early when medium leaked at the peristaltic pump.**

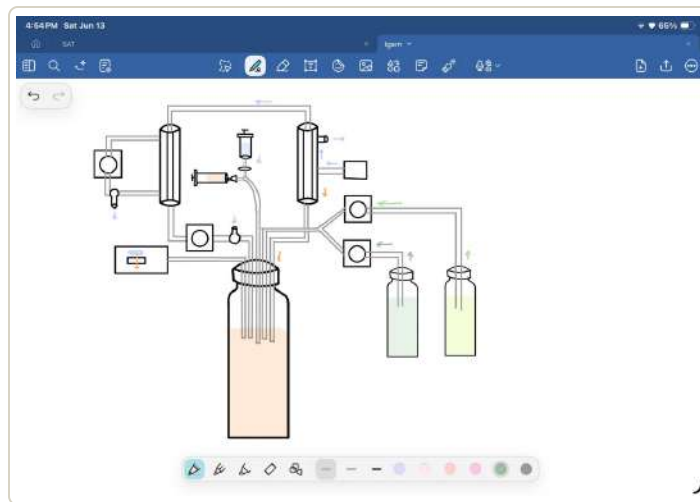
- The leak was at the pump head, where the tubing flexes most.

- **Plated 2 mL from the shell side of the membrane on LB and got no colonies at all.**

- That is our evidence the membrane holds the bacteria in. It came out of the run that otherwise failed.



Shell-side plate, no colonies



13 June: the loop redrawn for prototype II after this run

CANDIDATE CAUSES · TABLE 10

Candidate cause	How we would tell it apart	Status
No active mixing, cells settle	Add a stirrer and repeat.	to test
Nutrient stratification	Same test as above.	to test
Room temperature too low	Run the next attempt at 37 °C.	to test
Sampling port unrepresentative	Move the port to the reservoir outlet.	to fix

Ruled out means we ran the test. To test means we have not.

DECISION

Change three things at once and accept we will not know which worked

- Stirring, temperature and sampling position are all cheap to change and all plausible.
- We have weeks, not months. We couldn't afford to change one thing at a time.

REJECTED

Testing one variable at a time. That's the right way to do it and we chose speed instead. Writing it down here so nobody reads prototype II as proof that stirring alone fixed it.

PROBLEMS

HOW WE'LL FIX IT

Three variables change together in prototype II

SINCE THIS WEEK

→ Any of the three could be the real cause. Say that, instead of claiming stirring fixed it.

Leak at the peristaltic pump

SINCE THIS WEEK

→ Upgrade to BPT tubing before the next run.

NEXT

Prototype II. Magnetic stirring at 200 rpm, sampling moved to the reservoir outlet, run at 37 °C.

PROJECT

Bioreactor · prototype I

DATE

11/06/2026

ENTRY

10

Prototype II reaches plateau in two hours

Prototype I barely grew and we had four candidate reasons. Prototype II changes three of them at once, which is not how you isolate a cause, but we had weeks, not months.

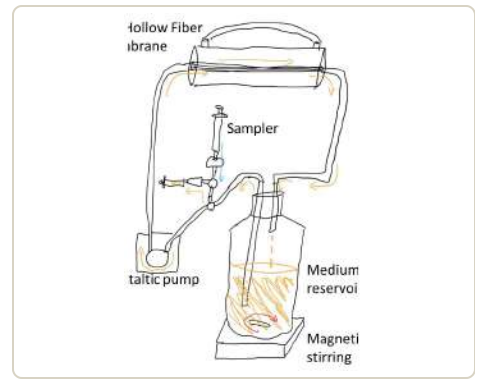
- **Added a 200 rpm magnetic stirrer to the reservoir to stop cells settling out.**
 - The stirrer bar was the largest one we had, which may be part of why it worked so well.
- **Moved the sampling port to the reservoir outlet, where there is far more volume.**
 - A sample from there represents the whole system, not one length of tube.
- **Ran both arms at 37 °C instead of room temperature, pump held at 94 mL/min.**



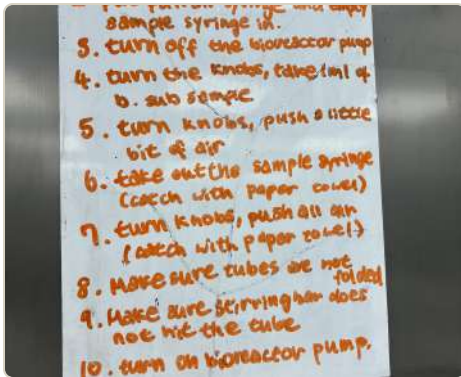
14 June: sampling the reactor arm



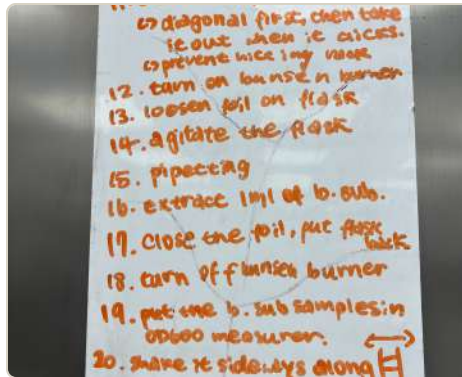
Sampling the flask arm



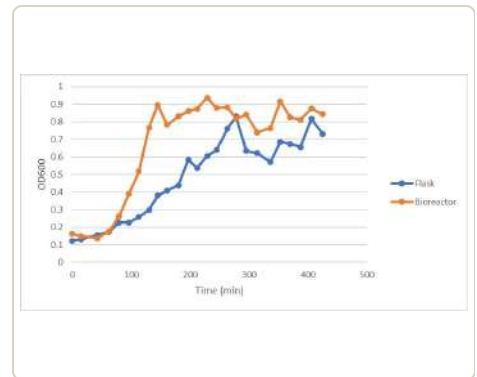
Prototype II: stirrer under the reservoir, sampler beside it



The sampling procedure, written out by hand for whoever took the next shift



Page 2 of the procedure



OD600 against minutes at 37 °C: reactor (orange) and flask (blue)

- **Got a full growth curve, and the reactor beat its own flask control.**
 - Reactor plateaued at OD600 0.8 to 0.9 after two hours. Flask reached 0.6 to 0.8 after four and a half.

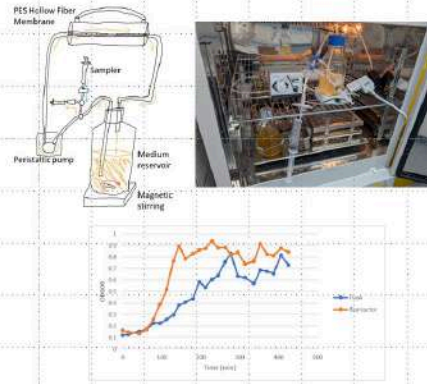
TABLE 11

Arm	Plateau OD600	Time to plateau	Against prototype I
Bioreactor	0.8 – 0.9	2 h	flat at ~0.3
Flask control	0.6 – 0.8	4.5 h	reached 2.4 at 25 h

Full growth curve secured. The reactor reached plateau faster and higher than the flask.

Bioreactor DBTL cycle 2:Prototype ver.260614

- **Design and Build**
 - Add following design compare to ver.260606
 - Magnetic stirring: 200 rpm
 - Sampler between reservoir and pump
- **Test**
 - Flow rate: 94 mL/min
 - Temperature: 37°C
 - Bioreactor reaches plateau phase (OD600 ~0.8-0.9) around 2 hr
 - Flask reaches plateau phase (OD600 ~0.6-0.8) around 4.5 hr
- **Learn**
 - Stirring is essential.
 - Next cycle we will try 22°C.
 - BPT tube is necessary in next round of trial.



The DBTL summary slide we made for prototype II

DECISION

Passed. Faster to plateau and higher than the control

- Faster to plateau and higher at plateau than the control, which is more than we expected.
- Whether stirring alone would have done it, we cannot say.

CONFIDENCE

Claiming stirring fixed it. Three variables moved and only one of them is in the headline.

PROBLEMS

Three changes at once, so we cannot say which one did it

SINCE THIS WEEK

→ Run stirring alone at 22 °C, which also gets us the temperature we would actually operate at.

HOW WE'LL FIX IT

NEXT

Evaluate at 22 °C, and upgrade to BPT tubing to stop the degradation seen in earlier trials.

PROJECT

Bioreactor · prototype II

DATE

14/06/2026

ENTRY

11

Prof. Chang finds the gap in the design

Prof. Chang (張嘉修) is a chair professor in chemical engineering at NCKU who has published on *B. subtilis* bioreactor systems, so he was the right person to show the design to. He found a hole in it that none of us had seen.

- **Showed him the design in person on 18 June.**

- He spent longer on containment than on the biology, which we had not expected.



18 June: presenting the design



Prof. Chang's feedback

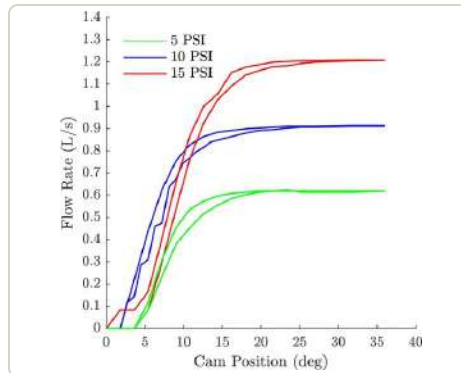


Discussing the membrane

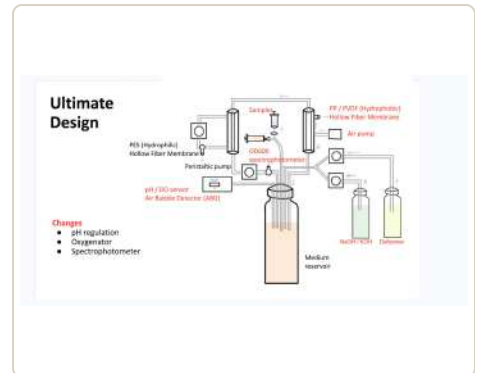
- **Were told the hollow fibre and the light module are the parts that make the project distinctive.**
 - But we need to be able to explain to a judge why hollow fibre specifically, and we could not.
- **Took the main criticism. We had no mechanism at all for getting protectant out of the membrane.**
 - His suggestion was a valve after the membrane, to build pressure and push the permeate through.
- **Posted a stepper pinch valve design to the build channel the next day, with a 27 June target.**
 - There was no valve on any plan before we spoke to him.



19 June: the stepper pinch valve design posted with a 27 June target



Flow against cam position at 5, 10 and 15 psi, posted with the valve design



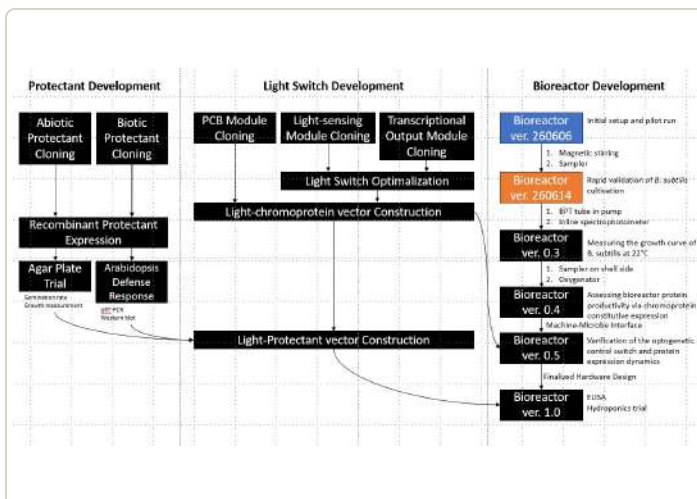
15 June: the 'ultimate design' drawn before the meeting, with no valve after the membrane

- **Logged three things he raised that we have still done nothing about.**

- Foaming from *B. subtilis* surfactant, which he mentioned twice. Resting cells. The cartridge format.



Group photo after the meeting



17 June: the roadmap redrawn around his points

DECISION

Add a valve after the membrane

- A valve after the membrane is the mechanism we were missing entirely.
- Hydroponics as the delivery target, which also narrows the biosafety case.
- Membrane sizing becomes a design variable, no longer a fixed part.

NOT ACTED ON

Resting cells, and the cartridge format. Raised in the meeting, no design response yet.

PROBLEMS

Foaming not addressed

SINCE THIS WEEK

→ Raised twice, no response. Add a foam trap or say why we didn't.

HOW WE'LL FIX IT

NEXT

Post the pinch valve design and set a print date. Chang's other points still need answers.

PROJECT

Bioreactor · Prof. Chang

DATE

21/06/2026

ENTRY

12

Wrong unit for the light dose

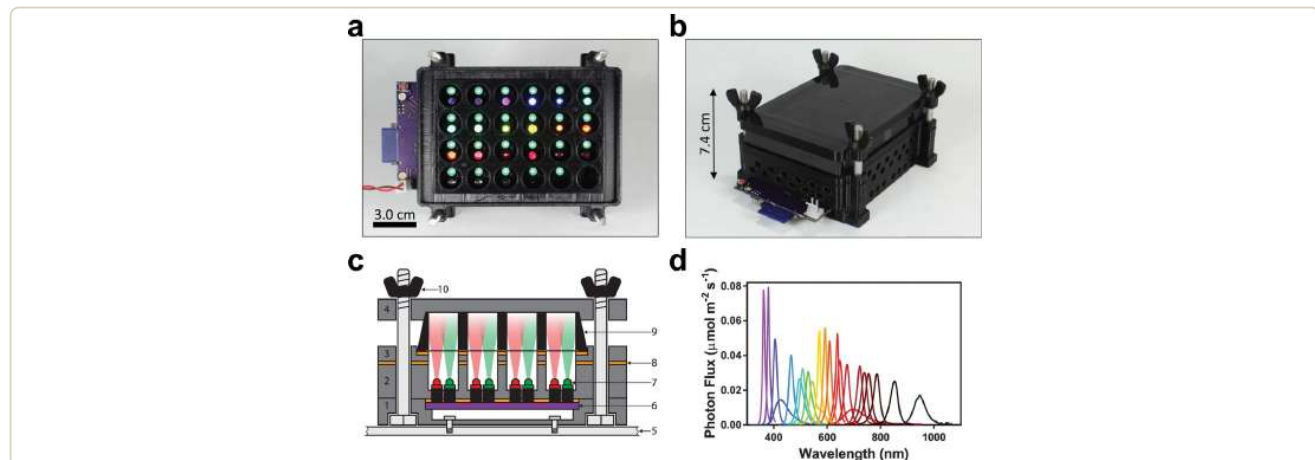
The CcaS-CcaR circuit responds to a specific photon flux, so the light dose the plate delivers has to be a known quantity. This week we found we had been about to measure it in entirely the wrong unit.

- **Checked the Castillo-Hair paper and found its half-maximal point is $4.66 \mu\text{mol per square metre per second}$.**
 - That is a photon flux density. It counts photons.
- **Checked what our meters read, and found every affordable one reads illuminance in lux.**
 - Lux is weighted for human vision, which peaks around 555 nm. Our green sits at 520 and our red at 660, both well off that peak.
 - So the conversion error is not even the same size on the two channels.
- **Bought a lux meter and set out to derive the conversion for our own LED spectra.**
 - A proper PPFD sensor was out of budget. A phone app was considered and rejected as not repeatable between handsets.
- **Caught it before any dose figure went out, so nothing published needs correcting.**
 - No conversion factor exists; every light dose is in lux.

TABLE 12a

Quantity	Value	Unit	Source
CcaS-CcaR half-maximal	4.66 ± 0.63	$\mu\text{mol m}^{-2} \text{s}^{-1}$	Castillo-Hair 2019
Hill coefficient	1.88 ± 0.16	—	same
$t_{1/2}$ ON / OFF	105.1 / 74.97	min	same
What our meter reads	—	lux	—

The two units measure different things and cannot be converted without knowing the spectrum.



The light plate apparatus we were following, shown with its photon-flux spectra (published figure, shared on 24 June)

DECISION

Buy a lux meter and derive the conversion ourselves

- A proper PPFD sensor was out of budget and we needed a number that week.

CONFIDENCE

Quoting the paper's number in lux and hoping. Every dose we published afterwards would have been wrong by a factor nobody could reproduce.

PROBLEMS

Green and red need different factors

SINCE THIS WEEK

→ Compute both from the LED spectra, not one number for the plate.

HOW WE'LL FIX IT

NEXT

Write the factor down. Until it exists, no light dose in this project is reproducible.

Temperature sensor driving the green channel

The whole project is one sentence: sense stress, emit light, release protectant. This is the first time the sensing end and the light end ran together on a bench, two months after the pivot.

- **Wired an SHT31 temperature and humidity sensor to the Arduino over I2C.**
 - It reports humidity too, which the code reads and then ignores.
- **Wrote a linear stress fraction between a floor and a ceiling temperature.**
 - Below 32 °C the LED is off. At 50 °C and above it is at full brightness. Between those it scales linearly.
- **Mapped the fraction onto a PWM green channel and ran it.**
 - The transfer function is four lines of code, deliberately. Anything more shaped would be invented, since we have no data on how stress response scales with temperature.
- **Wrote it up as `Stress_to_Light_Demo_Manual.docx`.**
 - 32 °C and 50 °C are guesses, not measurements. Only the green channel is driven, so the demo switches the circuit on but not off.

TABLE 12b

Constant	Value	Meaning
TEMP_BASE	32.0 °C	below this the LED is off
TEMP_MAX	50.0 °C	at or above this, full brightness
Between	linear	stress fraction 0 to 1 drives PWM duty
Sensor	SHT31	temperature and humidity, I2C

Four constants and a straight line between two of them.

DECISION

Linear between two thresholds, nothing more shaped

- Two thresholds are easy to change once the wet lab gives us real numbers.
- Anything more shaped would be a guess dressed up as a model.

REJECTED

A sigmoid or a lookup table. Neither is supported by anything we measured.

PROBLEMS

HOW WE'LL FIX IT

TEMP_BASE and TEMP_MAX are guesses

SINCE THIS WEEK

→ Get the real heat-stress thresholds for Arabidopsis from the wet lab and replace them.

Red channel not in the loop

SINCE THIS WEEK

→ Add the OFF command so the demo shows both directions, not just on.

Humidity is read but not used

SINCE THIS WEEK

→ The SHT31 gives it for free. Decide whether it should feed the stress fraction.

NEXT

Replace the placeholder thresholds with numbers from the wet lab.

PROJECT

Stress to light · firmware

DATE

20/06/2026

ENTRY

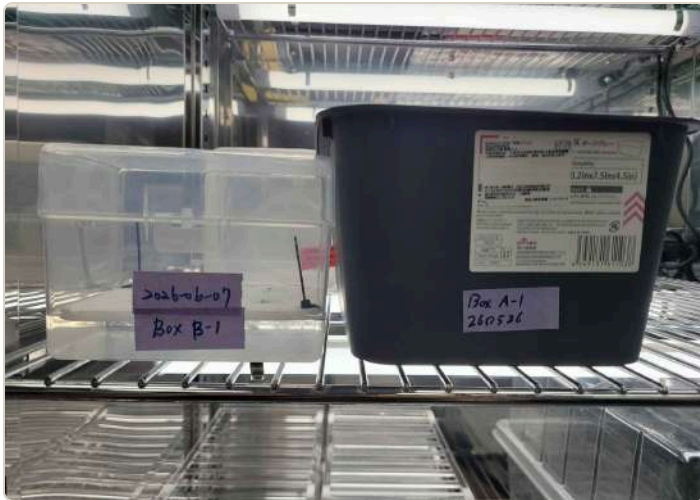
12b

Making the plate float

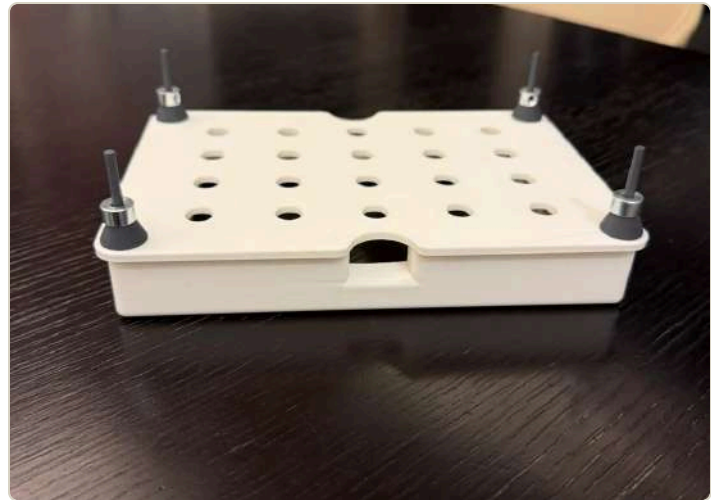
Arabidopsis grows hydroponically on a plate sitting over liquid medium. The roots have to reach the liquid without the plate flooding, and our first version was fixed in place, which meant setting the level by hand every day and getting it wrong.

- **Built a fixed plate with a liquid chamber underneath, and found the level impossible to hold.**

- It has to sit as high as possible without coming over the growing platform, and it drops as the plants drink, so the roots end up in air.



13 June: the fixed-plate hydroponic box in use



25 June: first floating plate, washer poles at the corners

- **Redesigned it to float on the medium instead.**

- The frame of the platform is built as sealed air chambers, so it rides on the surface and stays at the same height above the liquid whatever the level does.

- **Calculated the buoyancy before printing, not by tuning it afterwards.**

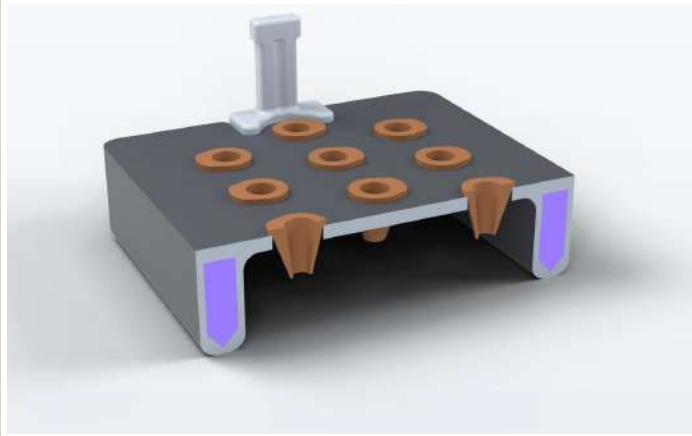
- A hollow frame cannot be adjusted once printed, so print orientation and wall thickness now decide whether it floats.

- **Added poles at the corners to take washers as weights.**

- Adding weight is easier than adding volume, so the poles are the margin for error. The washers we have are heavier than the calculation wanted, so the adjustment is coarse.

- **Printed the first iteration on 25 June.**

- A later iteration (Prototype 3, printed 27 June) shrank the footprint, added clip-in handles and dropped the poles once the chamber volume was tuned.



Prototype 3 in CAD, cut through the seed holders: sealed chambers in violet



Prototype 3 printed parts: plate, two clip-in handles, thirteen seed holders

DECISION

Float the platform instead of controlling the level

- The height stays correct as the medium level drops.

REJECTED

A level sensor and a top-up pump. More parts, more to break, and it solves something the shape solves for nothing.

PROBLEMS

Buoyancy not verified with plants on it, and the weight poles may be unnecessary

SINCE THIS WEEK

→ Float it fully loaded, measure the freeboard, and see whether the washers are needed at all.

HOW WE'LL FIX IT

NEXT

Print it, float it, and find out how far off the maths was.

PROJECT

Hydroponics · floating plate

DATE

28/06/2026

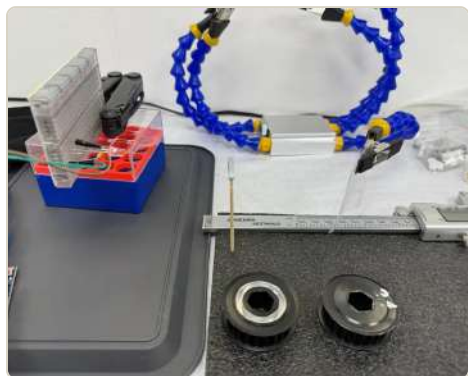
ENTRY

13

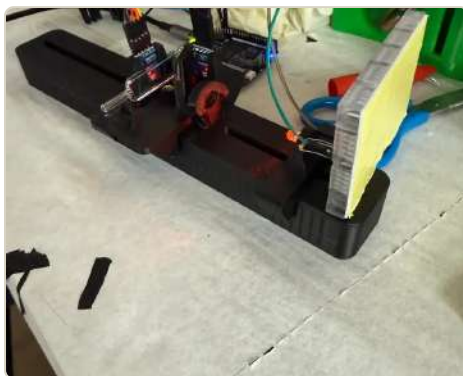
Iteration 1. Bubbles and drift

The photometer measures how much *B. subtilis* is in the reactor loop without taking samples out. An amber LED shines through a thin flow cuvette and we read how much light gets through. A beamsplitter sends part of the beam to a reference sensor first, so drift in the LED shows up in both channels and divides out. (The wiki numbers the bench layout as Prototype 1, so this iteration is its Prototype 2.)

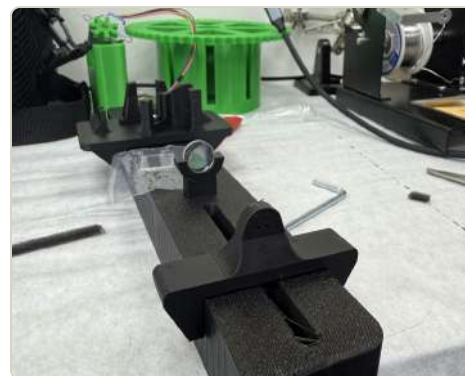
- **Printed a rail where the LED, lens, beamsplitter, cuvette holder and both sensors each position independently.**
 - None of us knew where the components should sit, so we made all of them movable and worked it out on the bench.



Before the rail: optics in magnetic clamps, spacings taken with a caliper

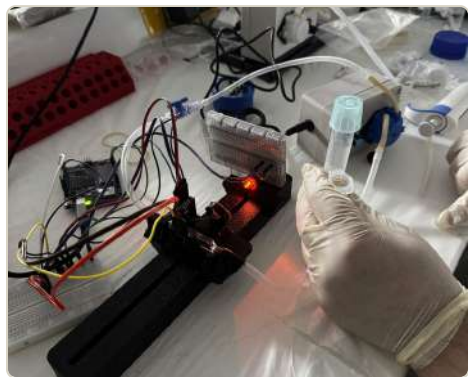


Iteration 1 on its printed rail

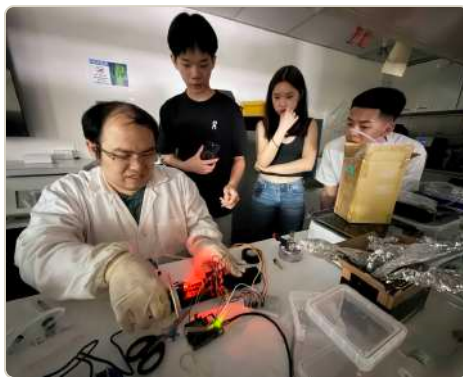


2 July: lens and beam line visible

- **Ran the beam horizontally through the flow cuvette and plumbed it into the loop.**
- **Got data that fluctuated far too much to use, for two reasons that made each other worse.**
 - Bubbles formed inside the cuvette and sat in the beam. A bubble moves the reading in a step, not as noise around it.
 - The lens and beamsplitter mounts were loose enough that the alignment drifted while we watched it.



LED lit through the cuvette



Instructor setting up the trial with us



Iteration 1 at work

- **Decided to move the cuvette down to the base for the next build.**
 - Bubbles rise, so putting the cuvette at the bottom takes them out of the beam without us doing anything. A dual luer valve and syringes let us pull gas out on demand.

DECISION

Move the cuvette to the base

- Bubbles rise, so putting the cuvette at the bottom takes them out of the beam without us doing anything.
- A dual luer valve and syringes let us pull the gas out on demand.
- Mounting vertically at the same time, since the geometry has to change anyway.

REJECTED

A fixed rail with no adjustment. More stable, but no way to find the alignment.

PROBLEMS

HOW WE'LL FIX IT

Bubbles in the flow cuvette

SINCE THIS WEEK

→ Move the cuvette to the base and add a dual luer valve and syringes to bleed the gas.

Loose lens and beamsplitter tolerances

SINCE THIS WEEK

→ Tighten the mounts on the next iteration.

NEXT

Rebuild with the cuvette low, tighter tolerances and a way to get the bubbles out.

PROJECT

Photometer · iteration 1

DATE

02/07/2026

ENTRY

14

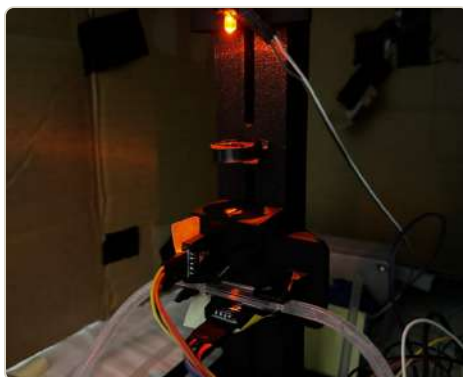
Iteration 2. Zeroed against the wrong thing

Iteration 1 drifted and bubbled. Iteration 2 moves the cuvette to the base, turns the whole assembly upright and tightens every mount. This is the first time we tested against a sample where we already knew the answer.

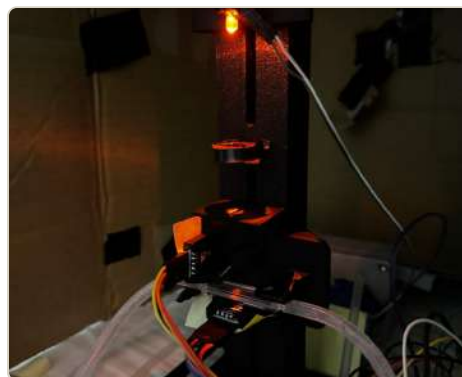
- Rebuilt with the cuvette at the base, mounted vertically, tolerances tightened.



Iteration 2 mounted vertically



4 July: amber beam visible through the box



TiO₂ in the flow cuvette

- Blank, then read medium alone, then medium with 2 mL of titanium dioxide as a known turbid sample.
 - The titanium dioxide settles within a couple of minutes, so readings have to be taken promptly after mixing.
- Got 62.5 au against a true value of 0.75.
 - The reference channel held steady at 92.5 lux across both readings, so that part of the design is behaving.
- Traced it to the blank, not the optics.
 - Every reading after a bad blank carries that error, however good the hardware is.

TABLE 15

Sample	Sample ch.	Reference ch.	OD
Blank	—	—	0
Medium	660 lux	92.5 lux	0 au
2 mL TiO ₂	495 lux	92.5 lux	62.5 au

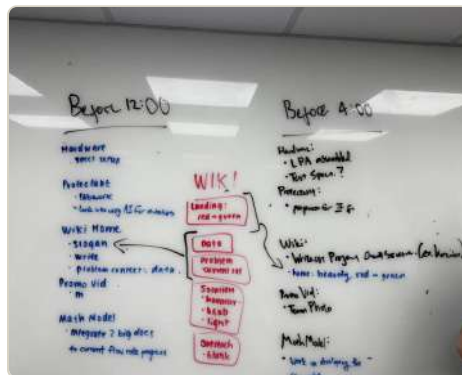
True value for the TiO₂ sample is 0.75 au. Noted later (wiki, part 8.2): the firmware then divided the absorbance, 0.125, by the path entered in metres, which is where 62.5 comes from. On a 1 cm path the same reading is 0.62.



Blank and sample side by side



Reading taken in the dark room



4 July: the to-do board after the test

DECISION

Did not pass. The procedure was wrong, not the optics

- We zeroed against the medium instead of clear water, so the zero was wrong from the start.
- Everything after a bad blank carries that error, no matter how good the optics are.

CONFIDENCE

One reading against one known sample. It tells us the zero was wrong. It doesn't tell us the instrument is linear.

PROBLEMS

HOW WE'LL FIX IT

Blank taken on medium instead of clear water

SINCE THIS WEEK

→ Reblank on distilled water and run the same TiO_2 readings again.

Component tolerances still loose

SINCE THIS WEEK

→ Decrease tolerances on the next build.

NEXT

Fix the procedure. Blank on clear water, tighten the tolerances, and run a dilution series.

PROJECT

Photometer · iteration 2

DATE

04/07/2026

ENTRY

15

Rewriting the spec, and pulling a claim

Bioreactor parts had been discussed across four Discord channels and several documents, and the numbers had drifted apart from each other. This week we wrote one specification and checked every line of it against the parts we had actually bought.

- **Wrote a single spec and marked what each line supersedes.**
 - Part numbers came off the invoices, not off the parts, so they should still be checked against what is fitted.
- **Corrected the microcontroller and the membrane to what we own.**
 - ESP32 with a 12-bit ADC became Arduino Uno R4 with 14-bit. The membrane record became 0.2 μm , 150 cm^2 , eight fibres.
- **Withdrew our own biosafety claim.**
 - The old spec claimed a 50 kDa molecular weight cut-off and said the membrane blocks outer membrane vesicles. Neither is true of the part we bought.
 - A 0.2 μm pore passes ACCD at around 42 kDa, which is what we want, but it also passes small vesicles and cell debris.
- **Kept the one containment claim that still stands.**
 - The membrane does block whole *B. subtilis*. The shell-side plate in prototype I showed that.

TABLE 15a

Item	Now	Was	Why it changed
MCU	Arduino Uno R4, 14-bit ADC	ESP32, 12-bit	board actually bought
TFF module	0.2 μm , 150 cm^2 , 8 fibres	M+, 200 cm^2 , 11 fibres	module actually bought
Pore claim	0.2 μm microfiltration	50 kDa MWCO	wrong. retracted
OMV blocking	not claimed	claimed	0.2 μm passes small OMVs
Pressure sensor	BP8G-AGA, 0–5 V	—	needs divider for the R4

Rows 3 and 4 withdraw a claim we had made.

DECISION

Retract the containment claim instead of restating it quietly

- The pore we bought passes small vesicles and debris, so the old wording claimed more containment than we have.

REJECTED

Leaving the old numbers in, once we had checked them against the datasheet.

PROBLEMS

Containment now rests on cell size alone

SINCE THIS WEEK

→ Say exactly what the membrane does and does not stop, on the wiki, in those words.

HOW WE'LL FIX IT

NEXT

Decide whether a second containment stage is needed now that the first claim is narrower.

PROJECT

Bioreactor · spec freeze

DATE

04/07/2026

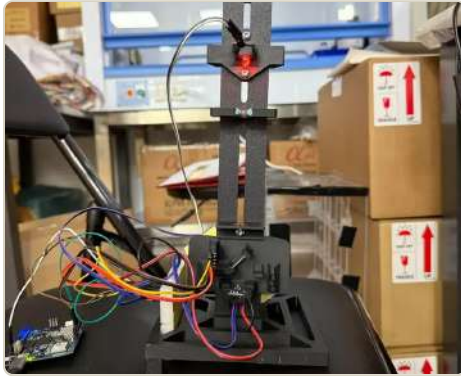
ENTRY

15a

Iteration 3. Response does not double

Iteration 2 was zeroed against the wrong reference, so its numbers meant nothing. Iteration 3 fixes the procedure, tilts the stand so bubbles clear, and this time reads two concentrations instead of one so we can see whether the response scales.

- Built iteration 3 with tighter tolerances and a tilted stand.



Iteration 3 on its tilted wedge



9 July: the column on its square stand



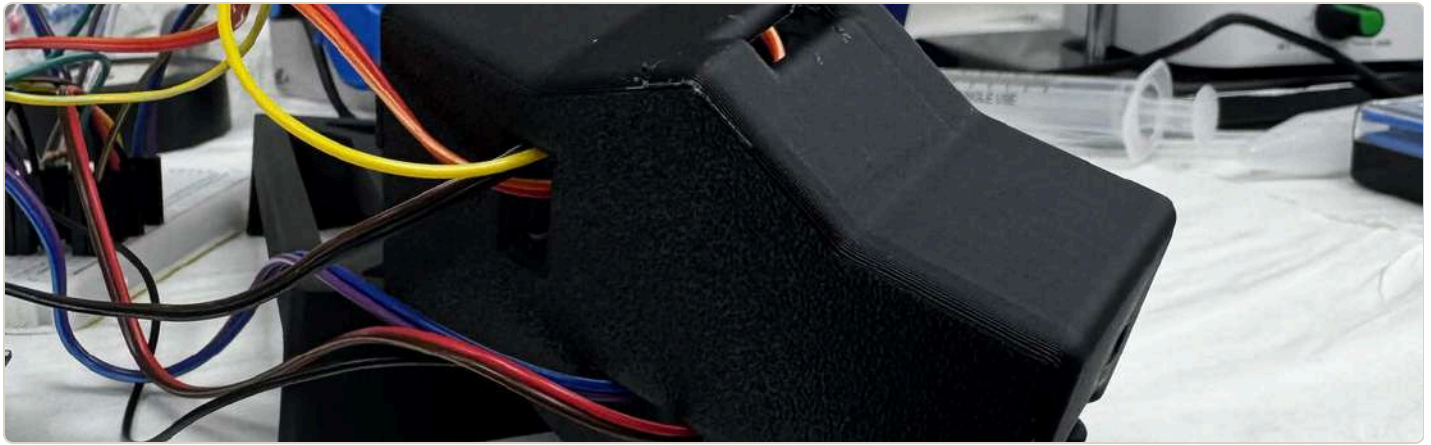
Side view, Luer valve and syringes for bleeding gas

- Blanked on clear water this time, not on medium.
 - That gives a zero we can defend.
- Read medium, then 1 mL of titanium dioxide, then 2 mL.
 - Medium reads zero. 1 mL gives 0.3712 au. 2 mL gives 0.5785.
 - Doubling the concentration gave 1.56 times the OD, not twice it. Either that is real Beer-Lambert behaviour at this path length or our transform is wrong, and two points cannot tell us which.
- Noticed two things we cannot explain.
 - Absolute light dropped hard between builds, 660 lux down to 137. Something changed in the LED drive or the optics and we did not write down which.
 - The reference moved from 17.23 to 18.33 between readings minutes apart. A reference should not do that.

TABLE 16

Sample	Sample ch.	Reference ch.	OD
Medium	137.63 lux	17.23 lux	0 au
1 mL TiO ₂	120.44 lux	18.33 lux	0.3712 au
2 mL TiO ₂	111.62 lux	18.33 lux	0.5785 au

Two concentrations instead of one. Doubling the TiO₂ moved OD from 0.3712 to 0.5785, not to 0.7424.



Wiring at the sensor end

DECISION

Procedure fixed, but the response does not scale

Blanking on water gives us a zero we can defend.

CONFIDENCE

Absolute lux dropped hard between iterations, 660 to 137. Something changed in the LED drive or the optics and we didn't write down which.

PROBLEMS

HOW WE'LL FIX IT

Response is not proportional to concentration

SINCE THIS WEEK

→ Run a five-point dilution series from 0.05 to 1.0 OD and plot it.

Reference channel drifted between two readings minutes apart

SINCE THIS WEEK

→ Log the reference on its own for an hour with nothing else changing.

NEXT

Build iteration 4 with the positions locked, then put it on the reactor.

PROJECT	DATE	ENTRY
Photometer · iteration 3	07/07/2026	16

Transmembrane pressure on a screen

A hollow fibre membrane fouls as it runs, and fouling shows up as pressure building across the membrane. Until this week we had no way of seeing that happen, so we could not tell a clean run from a blocked one.

- **Fitted a BP8G-AGA pressure transducer on the retentate side.**

- It reads 0 to 1 MPa and outputs 0 to 5 V. The board input is 0 to 3.3 V, so the divider is not optional.
- The divider is on a breadboard, not soldered, so the reading is only as steady as that joint.



10 July: transducer and Luer line before fitting



12 July: transmembrane pressure live on the laptop for the first time

- **Had transmembrane pressure on a screen by the evening of 12 July.**

- Logged but never zeroed against atmosphere, so the absolute values are suspect even though the shape is not.

Chars #dry-bioreactor • 12 July

We can monitor the transmembrane pressure now. All we need is pinch valve and *B. subtilis*.

- **Posted the trace and had the sawtooth on it explained the same day.**

- Dr. Pak looked at the photograph and asked in one line whether the pulses were the peristaltic pump. They were.
- The exchange is in the channel, so we can account for the oscillation.

- **Instrumented before fitting the pinch valve, even though the valve was designed and waiting.**

- A valve on a loop we cannot measure tells us nothing, and pressure is what the valve controls.

DECISION

Instrument the loop before fitting the valve

- Put a valve on a loop we can't measure and we won't see what it does.
- Pressure is what the valve is there to control.

REJECTED

Fitting the pinch valve first, which was already designed and waiting. Ordering it that way would have made the valve's effect invisible.

PROBLEMS

HOW WE'LL FIX IT

No pinch valve yet, so pressure cannot be controlled

SINCE THIS WEEK

→ Print the valve and fit it after the membrane.

Sawtooth amplitude never quantified

SINCE THIS WEEK

→ Measure it peak to peak and check against the pump head rate.

NEXT

Fit the valve. Start the long photometer run on the reactor.

LPA V3 finished

Prototype 1 of the light plate lit one row back on 1 June. Milestone 2 asked for tunable intensity in both colours across the whole array. This is the packaged version, V3.

- **Packaged the array into a white well block on a black base, four rows by six columns.**

- Twenty-four wells, which is more than any experiment we currently have planned needs.



17 July: printed parts arrived, first full assembly



From above with tubes in, both colours



On the base, side on

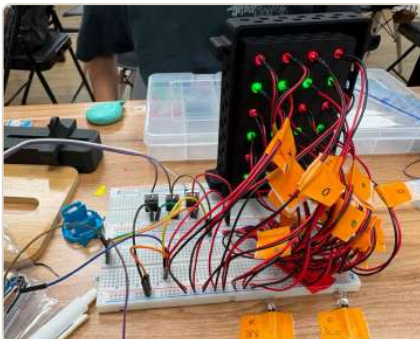
- **Paired the columns into high, mid and low intensity groups, alternating green and red within each pair.**

- **Added a printed light-blocking shroud with a front slider.**

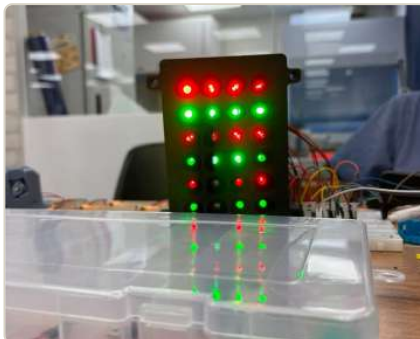
- The array can be opened without unmounting it. The slider rattles slightly when open, which affects nothing.

- **Drove all channels from the Arduino over PWM on separate pins.**

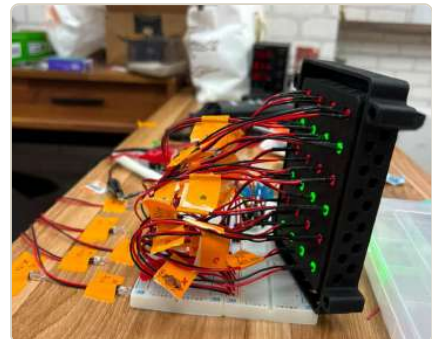
- The intensity tiers are set by the wiring as well as the code, because we measured every LED and rewired them by brightness. The tiers hold even if the firmware changes.



11 July: the LED holder lit before packaging, tagged leads behind



Front view: two LEDs not lighting



Fixing the dead pair

DECISION

Sort the LEDs by hand instead of correcting in firmware

- LEDs that are supposed to be identical varied enough that PWM alone wouldn't have kept the tiers apart.
- Sorting once is permanent. Correcting each LED in firmware would need redoing whenever one is replaced.

REJECTED

Driving them all at the same duty and living with the spread. HIGH, MID and LOW would have overlapped.

PROBLEMS

HOW WE'LL FIX IT

Still no measurement of what reaches each well, and it has never driven a real CcaS-CcaR experiment

SINCE W12

→ Lux meter at every well at fixed height, then run the optogenetic switch on it.

NEXT

Run a real optogenetic experiment on it. So far we've only checked the light.

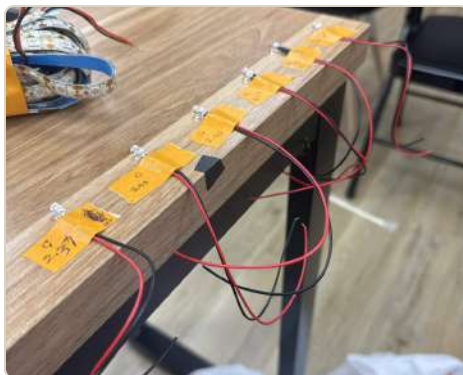
Measuring every LED before wiring

The intensity tiers on the light plate only mean something if the LEDs inside a tier actually match each other. Before wiring V3 we measured every LED we had bought, one at a time.

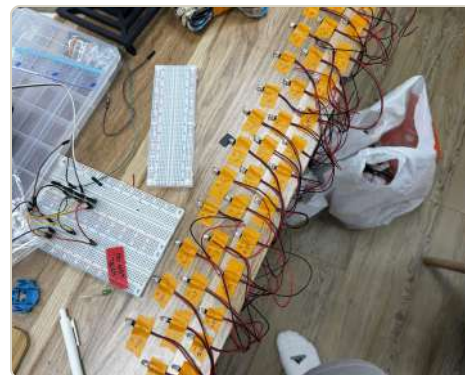
- **Measured all 20 green and all 20 red LEDs at 5 V with a lux meter.**
 - Two of the reds were dead out of the packet and are not in the counts.
- **Threw the first round of readings away.**
 - Moving the sensor around the structure changed the reading so much that the numbers were not comparable to each other.
- **Printed a jig to hold the sensor at a fixed position and did the whole thing again.**
 - The jig fixes height but not angle, so there is still some error we have not quantified.



The printed jig: one LED lit at the centre, lux meter behind



9 July: LEDs tagged by row and column



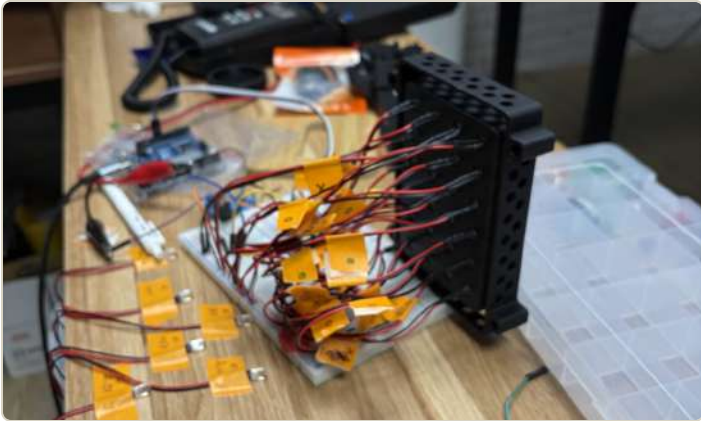
11 July: the full row of tagged LEDs

- **Found more than 25 percent spread across parts sold as identical.**
 - Greens ranged 2.01 to 2.54 kLux. Reds ranged 360 to 438 lux.
- **Tagged each LED by row and column, sorted them into matched sets of four, and rewired the array.**
 - After sorting, the low green tier spans 2.33 to 2.34 and the low red spans 0.390 to 0.397.
 - We measured green in kLux and red in lux, which we should have caught before writing the table.

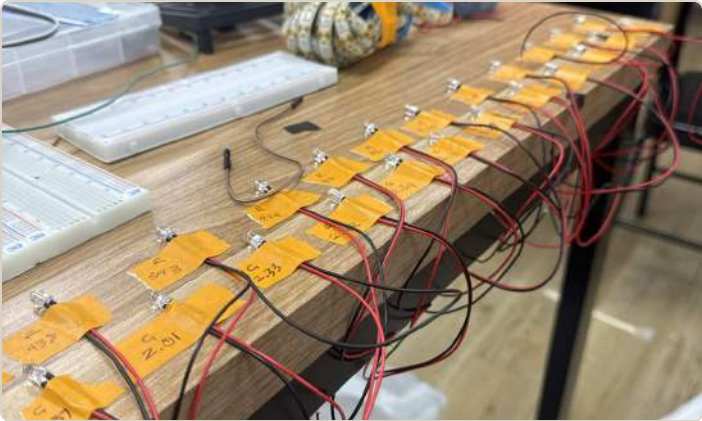
TABLE 19

Tier	Green (kLux)	Red (kLux)	Spread within tier
Low	2.33 – 2.34	0.390 – 0.397	green 0.01, red 0.007
Mid	2.35 – 2.37	0.410 – 0.416	green 0.02, red 0.006
High	2.38 – 2.50	0.424 – 0.431	green 0.12, red 0.007

Matched sets after sorting. Greens in kLux, reds converted to kLux here from the lux readings.



Sorting into matched sets



The sorted LEDs laid out before rewiring

DECISION

Passed. Matched sets hold the tiers apart

- Spread inside each tier after sorting is much smaller than the spread we started with.

CONFIDENCE

We characterised the LEDs, not the wells. What reaches each well is still unmeasured.

PROBLEMS

Green and red are on different scales

SINCE THIS WEEK

→ Green is in kLux and red is in lux. Pick one and redo the table.

HOW WE'LL FIX IT

NEXT

Measure light at the wells, not at the LEDs. That's the acceptance criterion still open from May.

Reading four times high on the reactor

Iteration 4 is the final photometer build, with the component positions fixed, TPU-lined mounts so the glass is not scratched, and snap-in covers along the light path to block room light. This is the first time it went onto the reactor and got read against a benchtop instrument on the same culture.

- **Fitted it in line on the TFF loop and took a reading against the benchtop BioDrop.**

- The BioDrop needs 2 mL per reading, which is a lot to take out of a running loop.



19 July: photometer in line on the loop, live data on the laptop



The benchtop BioDrop reading 0.150



Calibrating the light sensor on the black body

Chars #dry-bioreactor • 19 July

Inline spectrophotometer finally works and is able to measure the reasonable reading! ... Looks like it overestimates around 4-fold.

- **Got a first reading roughly four times high.**

- That is an offset, not drift. A loose rail drifts, so we knew it was not the rail.

- **Used Developer Mode to see both raw channels and rule them out.**

- It holds the LED on and streams the raw sample and reference values. Both read cleanly, which left the blank as the only term they share.
- It was written to debug this and stayed as a permanent feature.

- **Found the flow cuvette cannot be cleaned while it is inline, so the blank was taken through a dirty window.**

- Joshua suggested typing the blank in by hand instead of measuring it. Chars patched that the same evening.



The dashboard trace of the first in-line reading



Close-up of the concave lens



Iteration 4 assembled with its covers

- **Re-read the same culture and got 0.100 against the BioDrop 0.149.**

- The target agreed beforehand was 10 percent. We are 33 percent low, and the correction overshoots the other way.
- This is the second blanking failure on this instrument. Iteration 2 blanked on medium, this one blanked through a dirty cuvette.

TABLE 20

Trial	Ours	BioDrop	Ours / BioDrop
Before patch	not recorded	0.149	approx 4×
After patch	0.100	0.149	0.67×



18 July: the same week, the hollow-fibre set-ups we studied at BIO Asia-Taiwan

DECISION

Did not pass, but we know why

- A 4× error is an offset, not drift. A loose rail drifts, so it wasn't the rail.
- The correction overshoots. We now read under the BioDrop, not over it.

CONFIDENCE One paired reading. Three repeats and a dilution series before this number goes on the wiki.

PROBLEMS

In-line cuvette cannot be cleaned before blanking, and the whole result rests on one pair

SINCE THIS WEEK

→ Add a flush line, then repeat on three separate cultures before we quote the number.

HOW WE'LL FIX IT

NEXT

Start the long run and see whether it holds calibration on its own.

PROJECT	DATE	ENTRY
Photometer · on the reactor	19/07/2026	20

Starting the nineteen-day run

We had checked the photometer against a benchtop reading once, with someone watching. What we did not know was whether it holds up over days on its own. The reactor was running anyway, so we logged the whole thing from 21 July.

- **Logged sample and reference illuminance, the ratio, a rejection rate, the point count and elapsed time.**
 - Roughly one reading every nine minutes.



20 July: the loop running in the incubator, serum bottle of *B. subtilis* on the stirrer



The photometer column on its wedge inside the chamber

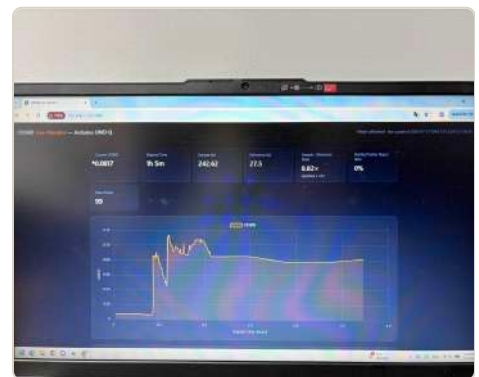
- **Served it on a live dashboard over the local network.**
 - Local network only, so nobody can check it from home. There is no alert of any kind, it only draws.
- **Reached 291 points at one day in, with a sample to reference ratio of 7.33.**
 - The optics were designed for 10 to 1. We noted the gap and did not explain it.
 - Bubble rejection read zero percent, which we did not question at the time. On other runs it has hit 43 percent.



Dashboard at 1 d 6 h 46 m, 291 points: OD600 0.4834, ratio 7.33x



23 July: the curve two days later



21 July: the one-hour mark

- **Left it running instead of tearing it down to chase the ratio.**
 - The ratio is a calibration problem we can come back to. The only way to find out whether it survives nineteen days unattended is to leave it alone.

TABLE 21

Reading at 1 d	Value	Designed	Note
Points logged	291	—	~1 per 8.9 min
Sample channel	195.54 lux	—	—
Reference channel	28.47 lux	—	—
Sample : reference	7.33×	10×	unexplained
Bubble reject rate	0 %	—	rule undocumented

Dashboard reading confirmed independently against the Discord record. Both give 291 points and 7.33×.

DECISION

Let it run instead of stopping to fix the ratio

- The ratio being off is a calibration question. Whether it survives nineteen days alone is a different one, and the only way to answer it is to leave it running.

CONFIDENCE

Tearing it down to chase the 7.33× straight away. We picked the endurance question over the accuracy one and that's a real trade.

PROBLEMS

HOW WE'LL FIX IT

Sample to reference sits at 7.33× against a designed 10:1

SINCE THIS WEEK

→ Measure both channels with the cuvette empty, then blanked, and compare.

No pass condition set, and no written bubble rejection rule

SINCE THIS WEEK

→ Decide what counts as holding calibration, and dig the rejection rule out of the firmware.

NEXT

Keep it running. Watch the shape of the curve, not just where it ends up.

PROJECT	DATE	ENTRY
Photometer · long run	26/07/2026	21

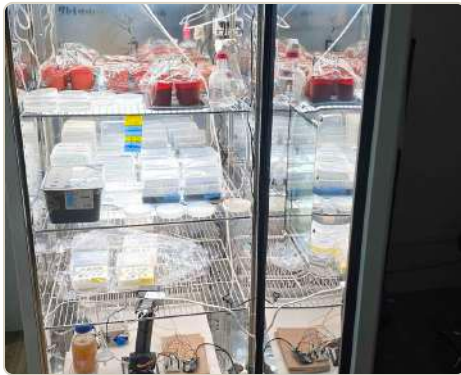
The photometer catches the pump failing

The run had been going since 21 July and the curve was not the shape any of us expected. We spent most of the week arguing about why, then on 1 August it dropped and stayed down.

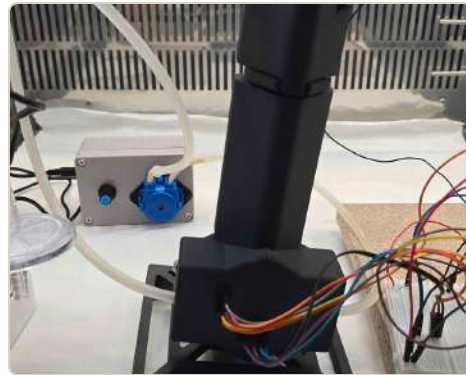
SYMPTOM

Nineteen days of continuous logging. No exponential phase at any point, a growth rate that fell away steadily, no plateau, then a rebound part way through. On 1 August the trace dropped sharply and stayed down.

- **Argued about a trace with no exponential phase, a steadily falling growth rate, no plateau, then a rebound.**
 - A healthy culture does not do that. We still cannot explain the shape.
- **Guessed contamination when it dropped, that we were watching a second organism take over.**
 - That was wrong. We have left it in the record.



3 August: the incubator with the loop, photometer and plants



The photometer in the loop at the end of the run

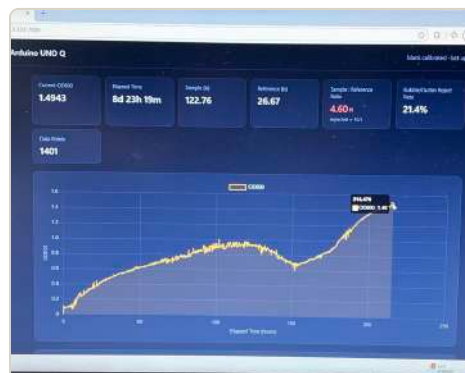


The curve on screen, 3 August

- **Found the recirculation pump had failed. Chars confirmed on inspection and replaced it the same evening.**
 - Nobody was rostered to check the trace daily, which is why the drop was noticed late.
- **Did not run the flush and reblank that would have separated fouling from biology.**
 - Once the run was torn down the chance was gone.



10 d 4 h: rejection 28.6 %, ratio 4.64x shown in red



30 July: the rebound in the curve



3 August: the culture bottle when the loop came apart

Candidate cause	How we would tell it apart	Status
Recirculation pump failed	Inspect the pump. If dead, replace and watch the trace.	confirmed
Contamination by another organism	Plate a sample and look for a different colony morphology.	not tested
Biowaste accumulation	Flush and reblank, then compare against the pre-flush reading.	not tested
Fouling on the cuvette window	Same flush and reblank test distinguishes this from biology.	not tested

Our first hypothesis was contamination. It was the pump.

DECISION

Replace the pump and leave the trace intact

- The photometer caught a failure in the reactor with nobody watching, which is what we built it to be able to do.

REJECTED

The flush-and-reblank test that would have separated fouling from biology. Once the run is torn down you can't go back, and we didn't do it.

PROBLEMS	HOW WE'LL FIX IT
Missing exponential phase unexplained SINCE W21	→ Run plate counts alongside OD next time and check whether OD tracks biomass at all.
Flush and reblank never run SINCE THIS WEEK	→ Do it at the start of the next run, before anything fouts.

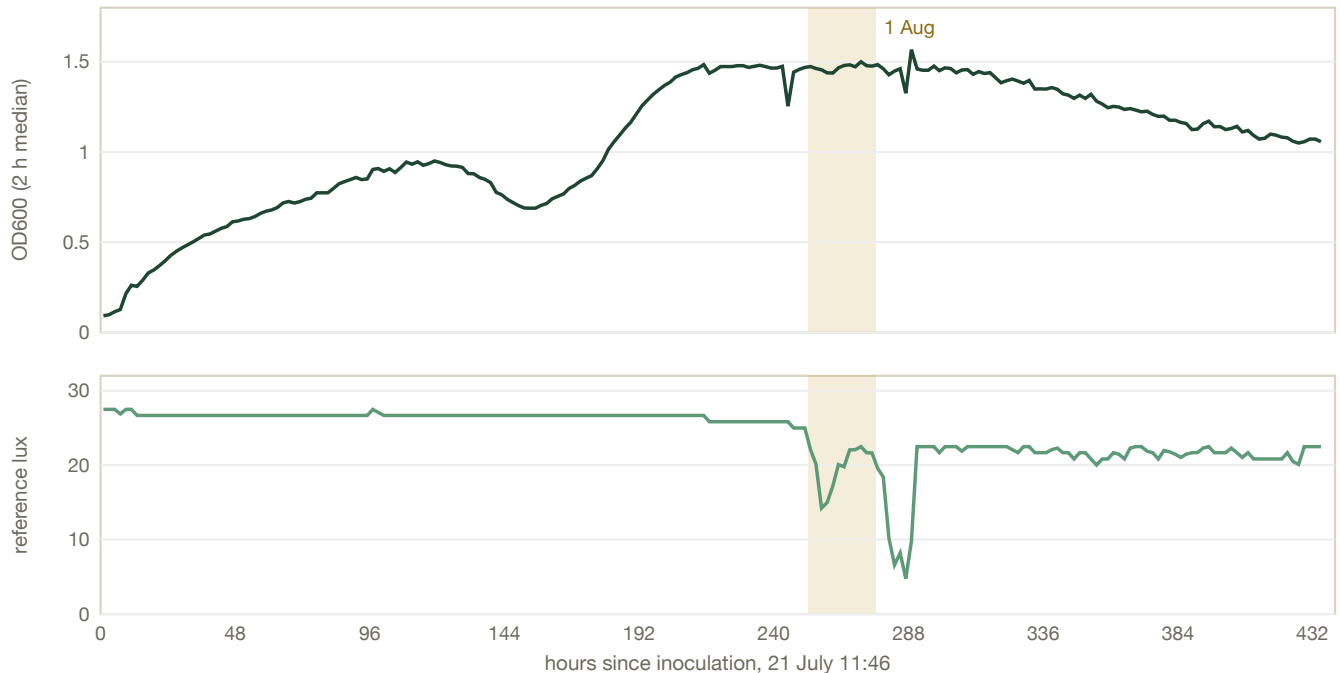
NEXT

Plot this trace with the pump-death event annotated. It is the hardware page's headline figure.

PROJECT	DATE	ENTRY
Photometer · pump failure	02/08/2026	22

Plotting the 434-hour trace with 1 August marked

Entry 22 ended with an action we never closed: plot the long run with the pump failure annotated. This is that plot, made from the raw log (0721, test3 20 day.csv: 2,720 rows, 434.2 hours, 21 July to 8 August). It does not look the way entry 22 describes it, so both are kept.



Top: OD600 as 2-hour medians of the valid readings. Bottom: the reference channel, which never passes through the culture. The gold band is 1 August, Taiwan time.

- **Plotted the OD in 2-hour medians, and the reference channel underneath it.**
 - OD climbs to about 0.94 by 110 h, dips to 0.70 at 145 h, climbs again to a plateau near 1.47 from about 210 h, and declines slowly to 1.07 at the end.
 - That dip and second rise is the ‘rebound’ entry 22 argued about.
- **Found no sharp drop in the OD medians on 1 August.**
 - What changes is the light. The reference channel, steady near 26 lux for ten days, drops sharply through 1 August, briefly to single figures, and settles near 22 lux. Around 256 h and again from 281 h individual readings jump by more than 0.3 OD between neighbours, and one reads below zero.
 - The OD is a ratio of sample to reference, so it can hold steady while both channels lose light. A median of that ratio hides the event; the raw lux shows it.
- **Checked it against the Digital Twin analysis, done after the run.**
 - Its sensor alarm, trained on the first 120 hours, flagged the photometer at 216.3 h, 26.7 hours before the reading became unusable. Its own table marks 240–434 h as ‘photometer and OD both unreliable’.

DECISION

Report the late part of the run as a sensor failure, not as biology

- The reference beam never touches the culture, so its collapse is the instrument.
- Entry 22's pump failure is still the confirmed event on the bench. What the log adds is that the photometer was losing light at the same time, and the curve after about 240 h cannot be read as growth.

REJECTED

Quoting the OD plateau and decline after 240 h as culture behaviour. Nothing in the log separates them from the failing optics.

PROBLEMS

HOW WE'LL FIX IT

No record of the hour the pump stopped, only the date

SINCE W22

→ Log pump state and flow in the same file as OD. Runs 4 to 6 do this.

Why both channels lost light

SINCE THIS WEEK

→ The team wiki (Engineering): swapping the pump knocked the optical axis.

NEXT

Back to August, where the first edition stopped.

PROJECT

Photometer · long run

DATE

17/10/2026

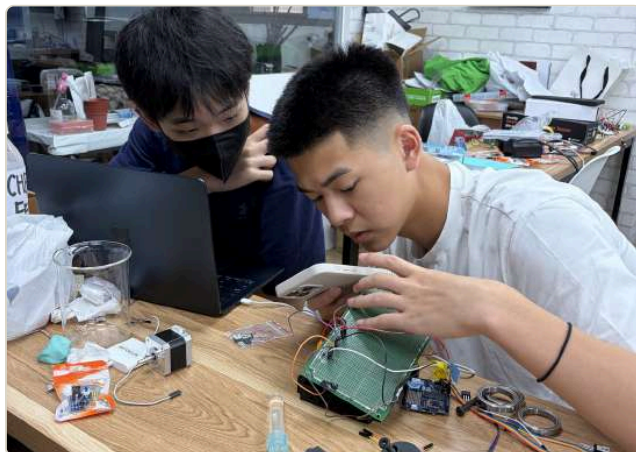
ENTRY

22a

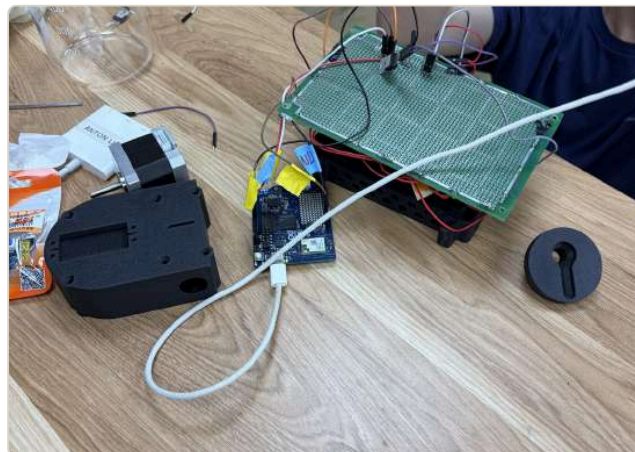
Decision matrix: pinch valve actuator

Prof. Chang told us in June we had no way to push protectant out of the membrane, so we built a stepper pinch valve. This week we replaced it, on criteria written before we scored anything.

- **Wrote the criteria first so they could not be bent toward the answer we wanted.**
 - Whether it holds when power is cut. Holding force against the permeate pressure. Whether we can build it from parts already in the lab. How much firmware it needs.
- **Scored a stepper, a servo and a solenoid out of five on each.**
 - The solenoid is unscored, not zero. We could not source one in time.
- **Chose the servo on the first criterion alone.**
 - A stepper lets go when it loses power and the loop is full of live culture. A servo stays tight. Holding on power loss is a safety property, so it outranks the other three.
 - The servo we used is a spare from the VEX kit, not a part chosen for this.



7 August: testing the printed valve parts



Tubing through the printed valve body

- **Caught a fit problem by eye before printing anything.**
 - The inlet hole needs to be 4 mm and the outlet 6 mm, with tolerance added at CAD.
 - Neither of us has measured what pressure the valve actually needs to hold against.

TABLE 23

Option	Holds on power loss	Holding force	Parts on hand	Control	Total
Stepper pinch valve	1	4	5	3	13
Servo pinch valve	5	4	4	4	17
Solenoid pinch valve	—	—	—	—	—

Scored out of 5 by each of us, then averaged. Row 3 is unscored, not zero. We could not source one in time.

DECISION

Servo pinch valve

- A stepper lets go when it loses power and the loop is full of live culture, so holding on power loss outranks the other criteria.

REJECTED

The stepper we'd already built and knew worked. The effort already spent on it is not a reason to keep it.

PROBLEMS

Scores are ours, not measured

SINCE THIS WEEK

→ Bench-test the holding force and power draw, then rescore rows 2 and 4.

HOW WE'LL FIX IT

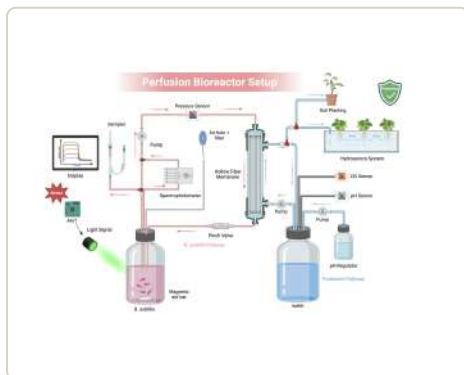
NEXT

Print the servo version with tolerance added and check the fit before committing the CAD.

Assembling the full rig

The valve, the sensors and the photometer had all been built separately. This is the week the whole thing went together as one machine.

- **Mounted the hollow fibre module first, lumen ports facing up.**
 - Air clears on fill and does not sit in the fibres. The ports are not marked on the module, so the orientation has to be remembered.
- **Plumbed the cross-flow loop and wired the electronics.**
- **Fitted the pressure transducer and put the photometer into the return leg.**
 - Downstream of the pump, which is a longer plumb. The pump puts a pulse into the flow, and putting the beam after it gives that pulse some line length to smooth out in.



4 August: the perfusion set-up as drawn for the wiki



8 August: the rig set up with the green light for the promotional video



The complete rig on the bench

- **Photographed the build across four days without agreeing what to photograph.**
 - Nineteen images with gaps, duplicates and no captions. We cannot work out the assembly order from them.

TABLE 23a

Part	Spec	Note
TFF module	HF-E-MI-M020-10-60-P	0.2 μm , 150 cm^2 , 8 fibres
Cross-flow pump	雷熔 ZP4000-N79H	230–2600 mL/min
Pressure sensor	BP8G-AGA	0–1 MPa, divider fitted
MCU	Arduino Uno R4 WiFi	14-bit ADC

Parts as fitted, not as drawn. The photometer sits downstream of the pump so pulsation is damped before the beam.



8 August: the hardware and bioreactor members with an instructor in front of the rig

DECISION

Photometer downstream of the pump

- The pump puts a sawtooth into the flow. We saw it in the pressure trace on 12 July.
- Putting the beam after the pump means the pulse has some line length to smooth out in.

REJECTED

Upstream, which is shorter and easier to plumb. It would have put the pulsation straight into the optical reading.

PROBLEMS

HOW WE'LL FIX IT

Nineteen build photographs uncaptioned

SINCE THIS WEEK

→ Caption each one with date, what it shows, and which assembly step it belongs to.

No written assembly order for the rig

SINCE THIS WEEK

→ Write it now from the photos, while the order is still in someone's head.

Lumen ports were not marked on the module

SINCE W18

→ Mark them, so the next person fitting it does not have to guess the orientation.

NEXT

Print the servo valve and fit it after the membrane.

PROJECT

Bioreactor · assembly

DATE

07/08/2026

ENTRY

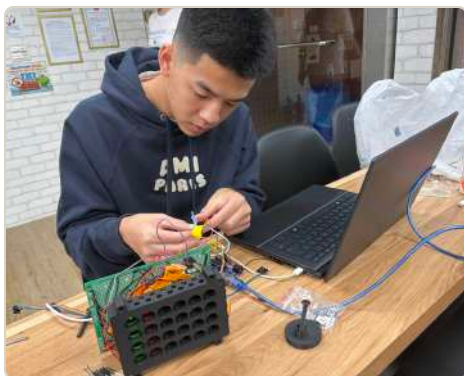
23a

Rewiring the light plate after it stopped lighting

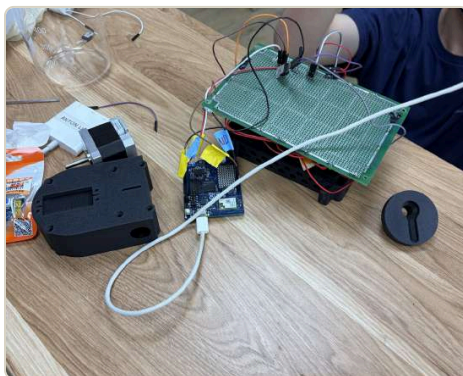
The packaged LPA had been sitting since July without running a culture. When we came back to it on 7 August, part of the array did not light. This entry was added on 17 October from the photographs and the photo bank; nobody wrote the fault down at the time.

- **Opened the LPA and traced the dead channel back through the jumper leads.**

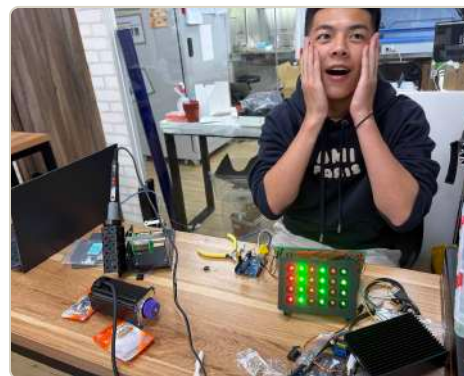
- The harness was still breadboard and jumpers, the open problem from May, and a loose lead is the likeliest cause. The record does not say which lead it was.



7 August: tracing the harness on the open array



Lit again on the bench



The moment it relit

PROBLEMS

HOW WE'LL FIX IT

Harness still on jumpers, so a knock can kill a channel

SINCE W13

→ Solder the MOSFET stage onto a perfboard inside the housing (done in September, entry 30a).

NEXT

Run the first culture under it.

PROJECT

Light plate · debugging

DATE

07/08/2026

ENTRY

23b

Where the bioreactor stood on 13 August

This was the last week the first edition of this notebook covered, and the bioreactor was part way through a rebuild with three problems open, all of them mechanical. We had expected the biology to be the hard part.

- **Tested the dissolved oxygen and pH probes on the bench on 5 August.**

- Both read in a beaker. Neither had a place in the reservoir yet.



5 August: testing the pH and DO probes



Probe readings checked against the meter



Wiring the probes to the board

- **Started moving from the peristaltic pump to a magnetic one.**

- A magnetic pump can be driven from the Arduino, which is what lets the system run without someone standing over it.
- It is weaker and cannot lift liquid out of the serum bottle.

- **Planned a PC-cooler-style clear rectangle with ports top and bottom to get round the head problem.**

- Feed in at the top, draw from the bottom, so gravity does some of the work. It was bought for its shape, not because it is designed for this.

- **Found the dissolved oxygen and pH probes do not fit the reservoir cap.**

- The cap has to be bored out. Keeping it airtight is the harder part, because the sensor body is thicker than its cable and the plug thicker again.

- **Designed a cap in two halves that clamps around the cable and screws shut.**

- Airtight, and nothing gets cut. The first approach was cutting each cable, threading it, and soldering it back.

- **Sketched a sealed cartridge for replenishing *B. subtilis*, on the printer ink model.**

- It opens only once it is inside the box, so a farmer can top up without a biosafety problem.
- That creates a second problem. Dead cells clog the loop and block the photometer, so it needs a flush into a waste box.



11 August: changing the hardware CAD on the visit to the 源鮮 hydroponic farm

DECISION

Design around the weak pump instead of reverting

- Arduino control is the difference between automated and somebody standing there. The peristaltic pump can't give us that.

REJECTED

Going back to the peristaltic pump. It works, and it would cost us the automation this design depends on. (Reversed three days later, entry 24a.)

PROBLEMS

HOW WE'LL FIX IT

DO and pH probes do not fit the cap

SINCE THIS WEEK

→ Bore the cap out, then print the two-half clamp cap for the cables.

No way to clear dead cells from the loop

SINCE THIS WEEK

→ Design the flush and the waste box at the same time as the cartridge.

NEXT

Wet and pressure-test the new membrane, and modify the PC cooler cap so the sensors fit.

PROJECT

Bioreactor · next phase

DATE

13/08/2026

ENTRY

24

Pressure on the new membrane, and the magnetic pump fails its first job

A new hollow fibre module arrived and had to be wetted and pressure-checked before any culture went into it. The same week the magnetic pump from entry 24 met the loop for the first time.

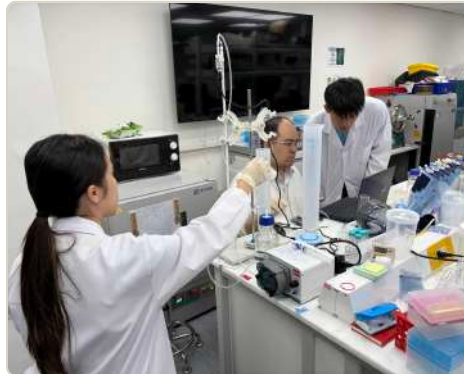
- **Checked what had to be tested before wetting the new module (12 August).**

- Phoebe and Joshua were asked to write the data and the design-build-test-learn steps into the dry lab notebook as they went.

- **Ran the pressure-transducer test on the new module on 13 August, with instructors at the bench.**



13 August: pressure-transducer test on the new membrane



Reading the transducers on the bench



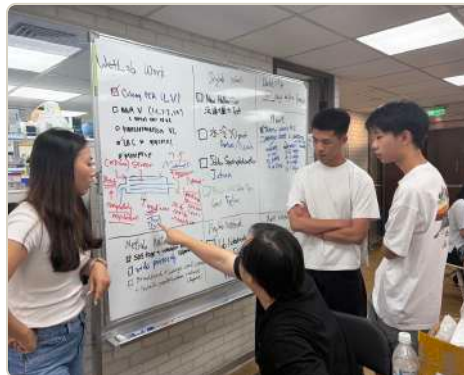
16 August: the water-cooling reservoir part Noah had taken home to modify

- **Spent 15 August at the whiteboard on what the next reactor chambers should look like.**

- The board lists the build steps and who owns each one.



15 August: future chamber designs on the whiteboard



Working through the to-do list



15 August: soldering the next board

- **Suspended the water-cooling tank modification on 16 August.**

- Chars found the magnetic pump was not powerful enough for our bioreactor. Noah had the tank part out for drilling and tapping, which was expected to take until the following week.

Chars #drylab · 16 August

Suspend modify water cooling tank. I just found our magnetic pump is not powerful enough to our bioreactor.

DECISION

Stay on the peristaltic pump

- The magnetic pump cannot drive the loop, and a reactor that cannot circulate is worse than one that needs a person nearby.
- On 4 September Joshua confirmed the rig runs a peristaltic pump, with a flow meter.

REJECTED

Pushing on with the cooler-tank reservoir built around the magnetic pump. It was being built to work around a pump we can no longer use.

PROBLEMS

HOW WE'LL FIX IT

Automation without a person present still depends on a pump the Arduino can run

SINCE W24

→ Drive the peristaltic pump from the board (the 4 September dashboard shows pump PWM in the log).

NEXT

Measure how pressure across the module depends on flow, before choosing an operating point.

PROJECT

Bioreactor · new membrane

DATE

16/08/2026

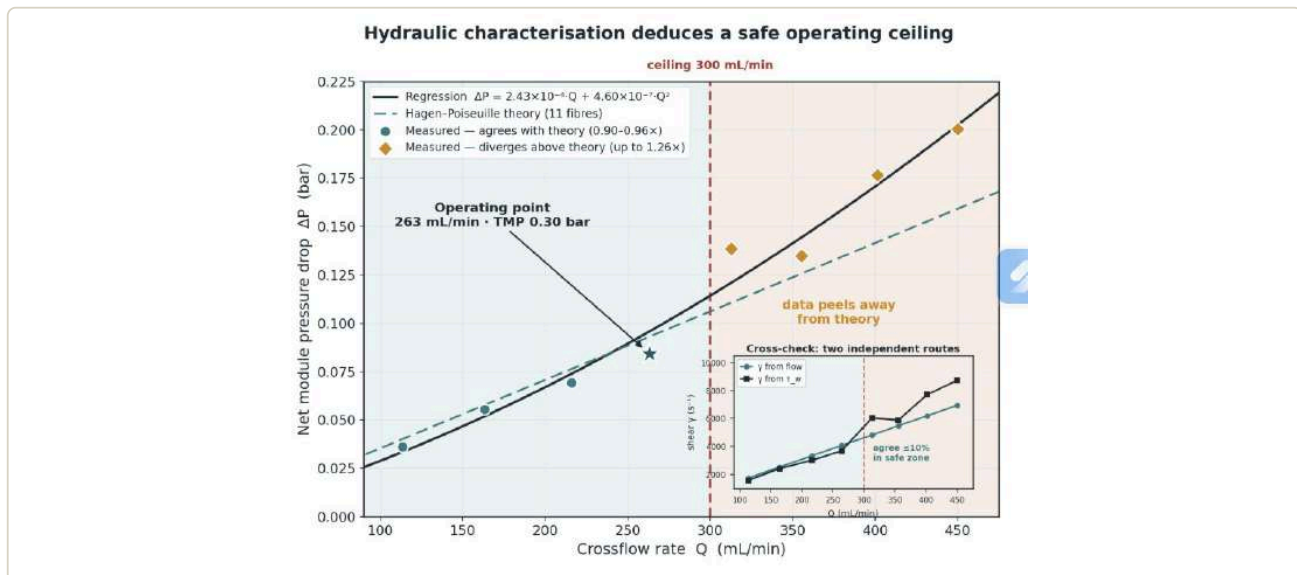
ENTRY

24a

Pressure drop against flow rate

We could read pressure (entry 17) but did not know what pressure the module should show at a given flow. Without that baseline, a rise from fouling and a rise from simply pumping faster look the same. Pass condition: measured pressure drop agrees with Hagen–Poiseuille theory for our fibre geometry over the range we would run.

- **Logged pressure against flow on 16 August with the transducers and the flow meter.**
 - Chars posted the spreadsheet (260816_pressure_to_flow_rate.xlsx) and an analysis on 18 August.
- **Fitted net module pressure drop, background subtracted, to $\Delta P = aQ + bQ^2$ through the origin.**
 - From 113 to 263 mL/min the measured points sit at 0.90 to 0.96 times the Hagen–Poiseuille prediction.
 - Above 300 mL/min they diverge to 1.26 times, as minor losses at the headers grow.
- **Checked the fibre geometry two independent ways.**
 - Wall shear rate computed from flow and geometry, and from the measured pressure drop, agree within 10 % across the safe range. That confirms the assumed fibre count and bore.



Net module pressure drop against cross-flow rate (Noah's draft figure, 5 September). Star: chosen operating point, 263 mL/min at TMP 0.30 bar. $n = 1$ per point.

- **Picked 263 mL/min as the operating point, with a ceiling at 300 mL/min.**

DECISION

Passed below 300 mL/min. Run at 263 mL/min

- Measured and theoretical pressure drop agree within 10 % up to 263 mL/min.
- Above 300 mL/min the header losses take over, so that is the ceiling.

CONFIDENCE

One point per flow rate. And see the problem below: the absolute pressures were later found to be scaled wrongly in the firmware.

PROBLEMS

Every logged pressure is out by 4.8×

FOUND 14 OCT, ENTRY 34A

→ The firmware scaled the 0–1 MPa transducer as 0–30 psi. Rescale this data set before quoting the TMP at the operating point, and recheck the ratio to theory.

$n = 1$ at every flow rate

SINCE THIS WEEK

→ Repeat the sweep, up and down in flow, on a clean module.

HOW WE'LL FIX IT

NEXT

Move the whole loop into one enclosure.

Rebuilding the reactor inside a computer case

The rig had grown across a bench: reservoir, pump, membrane, photometer, board and laptop, all loose. A farmer cannot be handed that. On 23 August we started moving it into a PC case, using water-cooling parts as the frame for the fluid path.

- **Chose a PC case and water-cooling hardware as the chassis.**

- PC water-cooling parts are made to carry liquid through a closed case, mount on standard holes and come with fittings. Charles bought the last parts at Guanghua at 9 pm on 16 August.



23 August: the empty case on the bench



Planning where the reservoir sits



Fitting the first parts



Marking mounting points



Working inside the case



Checking clearances with a second pair of eyes

- **Started a clean cost list for the commercial version the same day.**

- The instructors asked what a farmer's unit should contain, and which probes the basic plan leaves out. The list went into a shared sheet.

- **Studied every bioreactor in past iGEM projects.**

- Seventeen of them, collected on one page, so we knew what had been built before and how judges had seen it.



22 August: whiteboard session on the bioreactor before the rebuild



The case at the end of the first day

DECISION

Package the reactor in a PC case

- It turns a bench of loose parts into one object a farmer could be handed.
- Water-cooling parts solve the fluid path and the mounting together.

REJECTED

Designing a custom enclosure from scratch. Months of CAD and printing for something the case gives us on day one.

PROBLEMS

The case was built from the design, not from the working rig

SINCE THIS WEEK

HOW WE'LL FIX IT

→ Jacquelyn's cost sheet of 31 August notes its items are from the design, not the prototype. Reconcile the two before quoting a cost.

NEXT

Wire it.

PROJECT

Bioreactor · enclosure

DATE

23/08/2026

ENTRY

25a

Calibrating against weighed titanium dioxide

Entries 16 and 20 left two open problems: we did not know if the response was linear, and we had one paired reading against the BioDrop. A growing culture changes while it is measured, so we needed an inert standard added in weighed steps. Pass condition: both instruments linear against mass, and the raw photometer within 10 % of the BioDrop.

- **Suspended TiO_2 in 500 mL of 1 % SDS and circulated it through the loop past the photometer.**

- The iGEM protocol specifies silica. TiO_2 was on hand and behaved almost identically in SDS.



15 August: preparing the calibration run



About to start



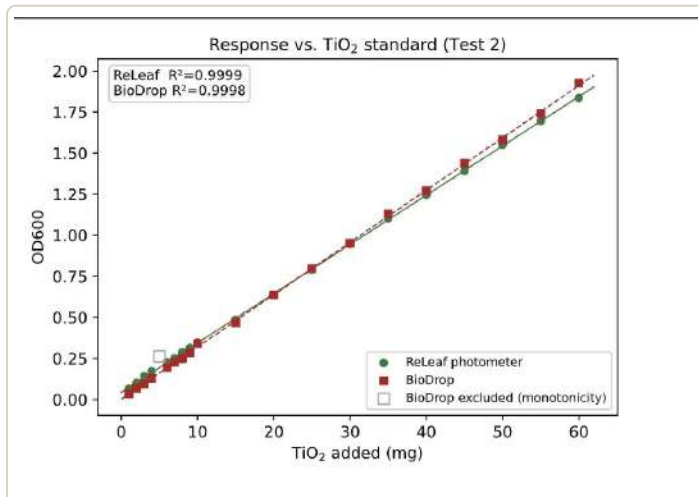
23 August: reading the BioDrop alongside the photometer, instructors watching

- **Ran two series, each step read on the BioDrop and the photometer.**

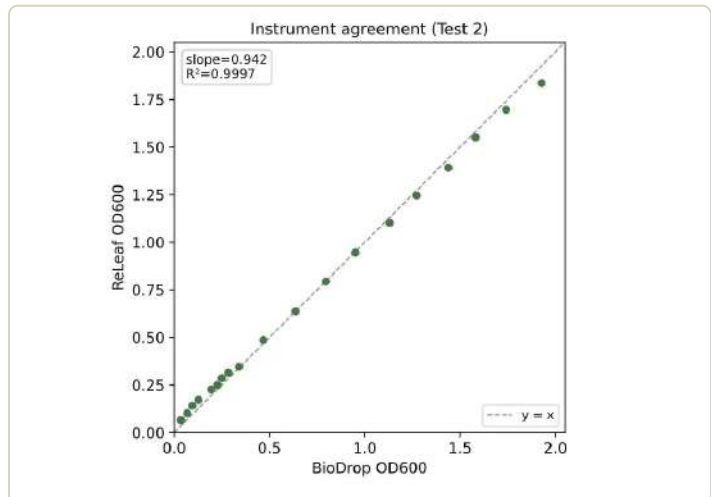
- Test 1: 1 mg per step, 40 points. Test 2: 1 mg per step to 10 mg, then 5 mg per step to 60 mg.

- **Got both instruments linear against mass, and the raw photometer close to the BioDrop.**

- Both regress against TiO_2 mass with $R^2 > 0.999$. The raw, uncalibrated output tracked the BioDrop with a median paired difference of 3.8 %.
- Test 2's raw points scatter about the line of identity with an RMSE of 0.011 OD600 ($R^2 = 0.9997$).



Test 2: OD600 of both instruments against TiO_2 added



Test 2: raw photometer against BioDrop, with the line of identity

- **Excluded two single BioDrop points and kept both in the plot as open markers.**

- 37 mg in Test 1 and 5 mg in Test 2 each sat off the trend of their neighbours while the paired photometer reading stayed on trend, which puts the error in the reference.

DECISION

Passed. No correction transform applied

- 3.8 % median difference against a 10 % target, with no calibration fitted.
- Fitting our readings to the BioDrop would only tie them to the BioDrop's own error.

CONFIDENCE

Neither TiO₂ series went above OD600 1.9, and TiO₂ does not scatter exactly like bacteria.

PROBLEMS

HOW WE'LL FIX IT

Top of the range untested

SINCE THIS WEEK

→ Run silica, the iGEM standard, further up (done 10 October, entry 33a).

A mineral standard is not a culture

SINCE THIS WEEK

→ Repeat with *B. subtilis* at known cell densities before quoting cell numbers.

NEXT

Back to the case. Five September is a public forum.

PROJECT

Photometer · TiO₂ calibration

DATE

23/08/2026

ENTRY

25b

Not ready for the forum

The Green Media forum on 5 September was the first time the cased reactor would be shown in public. On 30 August, six days out, Timmy listed what was missing.

• Assembled more of the fluid path inside the case on 29 August.



29 August: routing tubing in the case



Cutting tubing to length



Fitting parts from the outside

Timmy #dry-bioreactor · 30 August

Commercialized bioreactor is not ready for the 9/5 forum event. Electronics not wired. Screen not wired and tested. UI not fixed after version 1. LED not sorted. All sensors also not wired and tested.

• Agreed what would go to the forum.

- Noah: no sensors, only the pump, the LEDs and the screen. Timmy asked who actually owned the bioreactor; at that point the answer was Chars.



30 August: the case as it stood



Inside the case



Checking the build from the side

DECISION

Show the case as a display, and say it is one

- The pump, LEDs and screen could be made to work in six days. The sensors could not.
- A case that lights up explains the idea; it should not be presented as the working reactor.

REJECTED

Moving the working lab rig to the forum. It was the only rig that could run the first ACC deaminase test that week.

PROBLEMS

No clear owner for the bioreactor build

SINCE THIS WEEK

→ Name one. The lab rig and the case are now two machines with different jobs.

HOW WE'LL FIX IT

NEXT

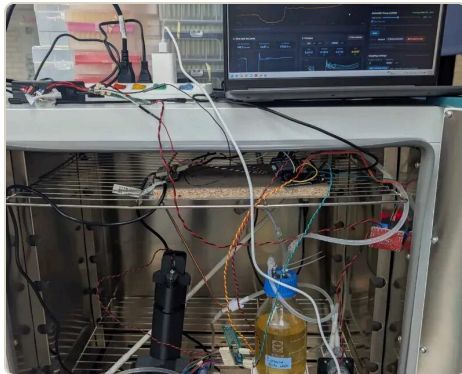
The first run with the protectant-secreting strain.

First integrated run: the protectant crosses the membrane

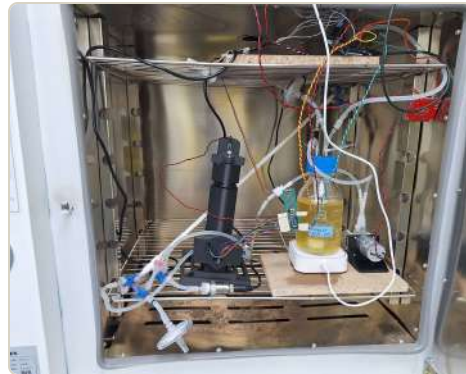
Every piece had been tested alone. This run put the culture, pump, membrane, photometer and pressure logging together with a strain that secretes ACC deaminase all the time (constitutive), so light control was outside the test. Pass condition: ACC deaminase detectable on the shell side, with the loop logged and no sample drawn for OD. The wiki calls this the integrative bioreactor's Prototype 1 and the Digital Twin calls it run 4.

- **Ran *B. subtilis* 168 with constitutive ACC deaminase secretion in the incubator, 1 L, full-length hollow fibre module, 1 to 6 September.**

– The log is two files: 3.2 h from near zero to OD 0.24, then 10.2 h unlogged, then 102 h from 0.84 to 3.77.



The integrated loop on a rack, dashboard on the laptop above



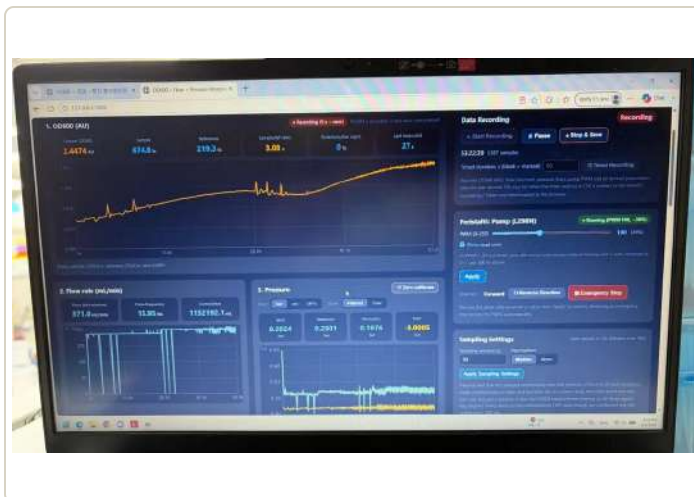
1 September: the loop inside the incubator



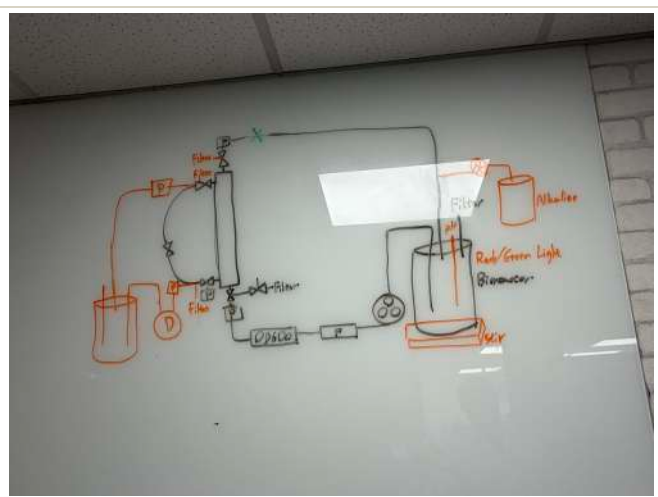
A pressure transducer on the loop

- **Logged OD600, flow, and feed, retentate and permeate pressure for 53 hours with no sample drawn for OD.**

– On the 4 September dashboard the three transducers each read near 0.20 bar and the flow about 371 mL/min.



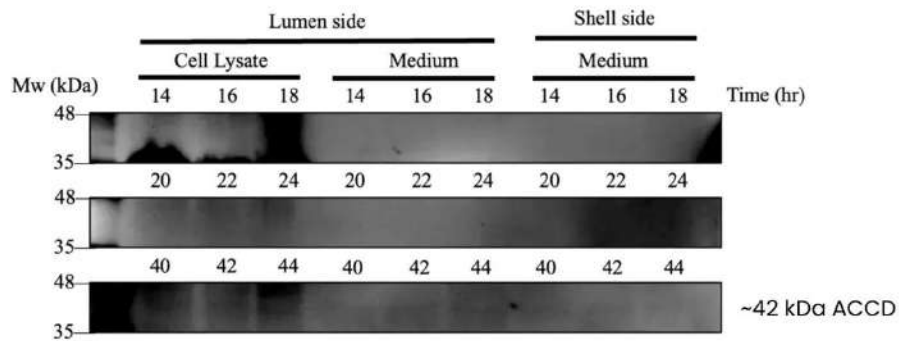
Operator dashboard on 4 September, 53 h into the recording



4 September: Chars's drawing of the loop for the user interface

- **Ran a Western blot on lumen-side cell lysate, lumen-side medium and shell-side medium sampled from 14 to 44 h.**

– Shell-side medium gave a faint band consistent with ACC deaminase at about 42 kDa.



Western blot: lumen lysate, lumen medium and shell medium, 14–44 h, ACC deaminase marked at ~42 kDa

DECISION

Passed, weakly. ACC deaminase reaches the shell side

- A band where it should be, on the side of the membrane the product is meant to reach.
- The loop ran for days with OD, flow and pressure logged and nobody drawing a sample.

CONFIDENCE

The band is faint and no concentration or transfer rate was measured. The pressure transducers had no filters on this build, so their readings could not be calibrated (Chars, 15 September).

PROBLEMS

HOW WE'LL FIX IT

Protectant transfer rate unmeasured

SINCE THIS WEEK

→ Measure shell-side concentration over time.

Expression is weak

SINCE THIS WEEK

→ Codon-optimised ACC deaminase is coming from the wet lab.

NEXT

Draw the rig exactly as built, with every transducer able to be calibrated.

PROJECT

Bioreactor · first integrated run

DATE

04/09/2026

ENTRY

27

The cased reactor in front of the public

On 5 September the cased reactor went to the Green Media forum booth as a display: pump, green LED strip and screen running, sensors not wired, as agreed in entry 26.

- **Explained the reactor at the booth to visitors, many of them families with children.**

- Children looked through the side panel at the green-lit loop. The public explanation used the case, the poster and a map.



5 September: looking into the case



The green light through the side panel



Explaining the project beside the case

At the forum the farmers raised questions about the number of bioreactors needed and the certification.

[NEXT](#)[Back to the lab rig.](#)

PROJECT
Bioreactor · public forum

DATE
05/09/2026

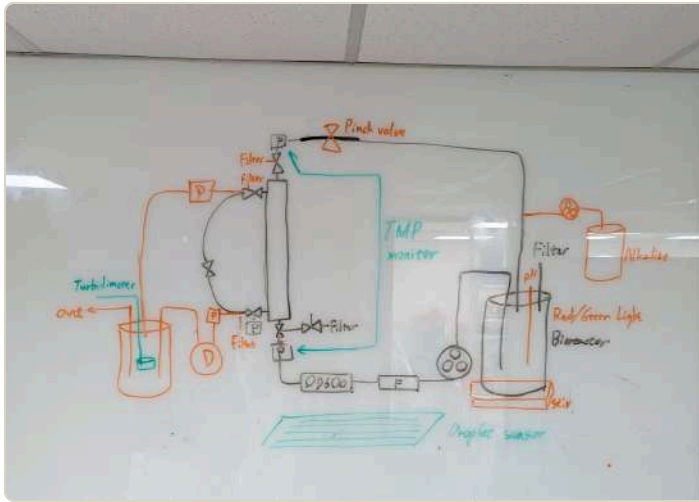
ENTRY
27a

Drawing the rig as built, and why every transducer gets a filter

Jacquelyn was drawing the bioreactor for the wiki and the 12 September meeting with Prof. Sattely and Prof. Endy, and kept finding that no drawing matched the rig. On 11 September Chars drew it by hand, coloured by status.

- **Drew the piping and instrumentation diagram by hand on 11 September.**

- Black for the current version, orange for future design, green for the biosecurity design. P is a pressure transducer, F a flow meter, D a diaphragm pump.



11 September: Chars's hand drawing. Black current, orange future, green biosecurity



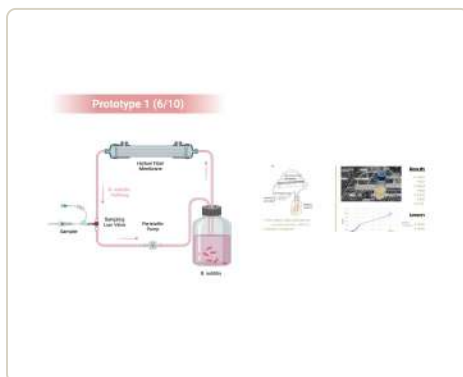
12 September: the hollow fibre module in the rig

- **Put a Luer valve and a filter on every pressure transducer.**

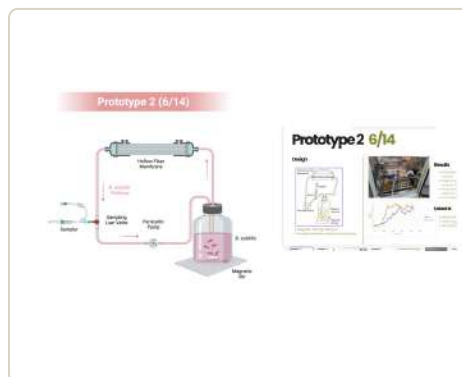
- A filter is what lets each transducer be calibrated; the prototype of early September had none, which is why its pressures could not be calibrated.

- **Corrected the drawings line by line in the channel.**

- Shell-side flow ran the wrong way in the first draft. 'OD600' became 'in-line photometer', 'pH sensor' became 'pH probe', every 'pressure sensor' became 'pressure transducer'.
- The pH probe and outlet tube sit below the liquid surface; the inlet tube and air filter above it. The flow meter goes in line, because a flow meter cannot work in a dead end, and the lumen loop has only one.



Prototype 1 (6 June) redrawn



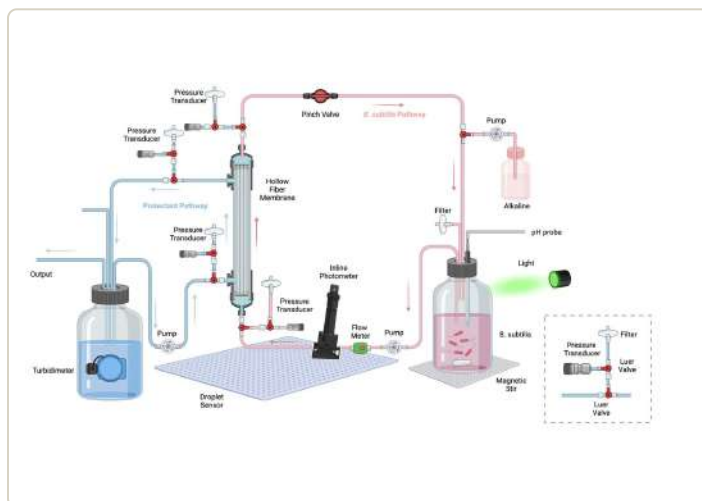
Prototype 2 (14 June) redrawn



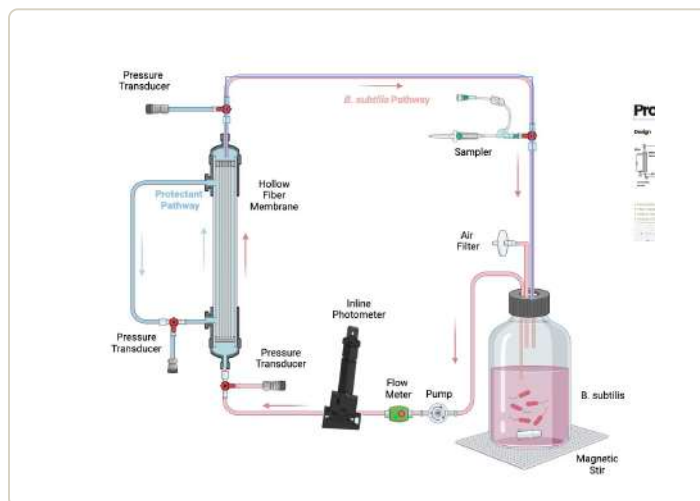
Prototype 3 (10 July) redrawn

- **Made the last two fixes on 15 September while Chars soldered.**

- A Luer valve on the left side of the pressure transducer, and the sampler moved from top right to bottom left.



Prototype 4 as drawn on 14 September



15 September: the two final fixes, marked

DECISION

A Luer valve and a filter on every transducer

- Without them a transducer cannot be calibrated, and an uncalibrated reading is what the 4 September run gave us.
- Four transducers, one at each membrane port, so a fault can be placed.

REJECTED

Keeping one transducer per side as in early September. It reads, but nobody can say how well.

PROBLEMS

Drawings follow the rig only as far as someone checks them

→ Redraw after every run that changes the plumbing.

SINCE THIS WEEK

HOW WE'LL FIX IT

NEXT

Run the first culture under the light plate.

PROJECT
Bioreactor · P&ID

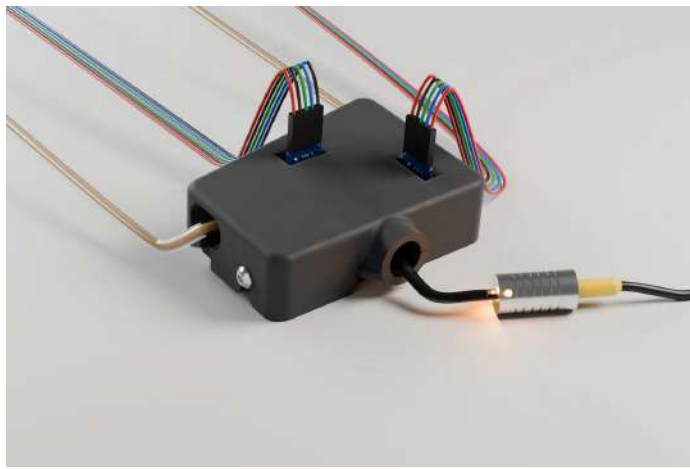
DATE
15/09/2026

ENTRY
28

A cheaper photometer: fibres in place of the lens and beam splitter

The beam splitter, the paralleling lens and the flow cuvette are nearly all of the complex photometer's cost. Optical fibres can carry the light in parallel and split it 1:1 between sample and reference, which removes the lens, the splitter and the long light path, and makes the device more than two-thirds smaller.

- **Wrote the silica calibration procedure on 13 September before building anything.**
 - Chars made it the must-do test before the next bioreactor run (SiO₂_OD600_Calibration_SOP_en.pdf). The silica was already in hand.
- **Soldered the simplified photometer's PCB on 14 September.**
 - Chars: the PCB had to come before the nanoparticle test.
- **Took the first silica readings on the simplified photometer on 19 September.**
 - Anton posted the data as `sio2_conc_vs_od.csv`.



The simplified photometer in CAD: sensors on top, cuvette through the side, light on a fibre

Serial ID	SiO ₂ 浓度 (mg/mL)	OD600
1	0.0900	0.12
2	0.0940	0.13
3	0.1470	0.14
4	0.1941	0.43
5	0.2402	0.35
6	0.2854	0.66
7	0.3297	0.76
8	0.3731	0.86
9	0.4186	0.96
10	0.4573	1.05
11	0.4982	1.15
12	0.5382	1.24
13	0.5778	1.33
14	0.6199	1.42
15	0.6536	1.50
16	0.6885	1.59
17	0.7247	1.67
18	0.7622	1.75
19	0.7994	1.83
20	0.8380	1.91

19 September: the first silica readings as logged

DECISION

Keep the flow cuvette, replace the lens and splitter with fibres

- The cuvette is what makes in-line measurement possible. The lens and splitter are what make it expensive.

REJECTED

Shrinking the complex design part by part. The cost sits in the optics, not the body.

PROBLEMS

The fibre split is designed to correct LED drift but is untested over a long run

SINCE THIS WEEK

HOW WE'LL FIX IT

→ Run it alongside the complex photometer for days, not hours.

NEXT

Run both photometers on one silica series.

PROJECT
Simplified photometer

DATE
19/09/2026

ENTRY
29

First culture under the light plate, and the post snaps on the shaker

The LPA had lit LEDs since May and never a culture. On 19 September it ran the first one, ACC deaminase level 2, with twelve tubes across green and red at three intensities.

SYMPTOM

Overnight on a shaker, a bottom-plate post broke off at its base and several wires came loose. Light also leaked through the white tube holder into neighbouring wells, which affected that run's data.

- **Set up twelve tubes under three green and one red intensity column.**

- Tubes 1–3 green 100 %; 5–7 green 12 %; 9–11 green 2 %; tubes 4, 8 and 12 red at 100 %, 12 % and 2 %.



19 September: the light-control assay set up under the LPA

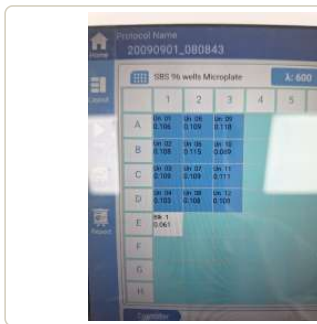
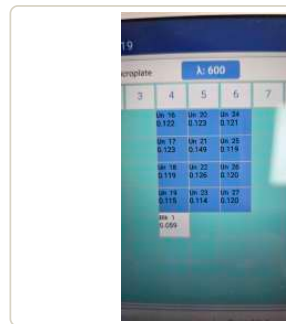


Plate-reader OD at 2 hours



Later read-out, 19 September

- **Read OD on the plate reader at 2 hours and through the evening.**

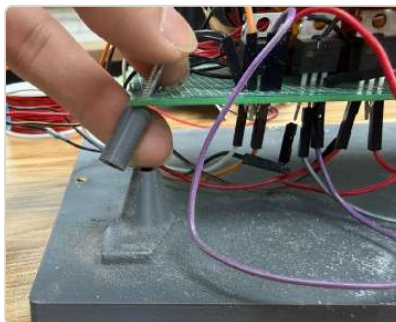
- The results are filed as 20260919_OptoLPA_ACCD_Run1_ODresults.xlsx.

- **Found the damage the next morning.**

- The shaker frequency was likely too high for the print. The post failed where it joins the plate.



The housing on the shaker: debris around a torn hole in the bottom plate



The snapped post, screw still through it



20 September: the last read-out of the run

DECISION

Do not use this run's numbers as a light-dose result

- Light leaking between wells means each tube saw more than its own setting.
- The rebuild has to fix the leak and the mounting before the next culture.

REJECTED

Correcting the readings for the leak afterwards. We never measured how much light crossed between wells.

PROBLEMS

Light leaks between wells through the white holder

SINCE THIS WEEK

→ Print the holder in black, with thicker walls.

Base fails on the shaker

SINCE THIS WEEK

→ Use all four screw positions and reinforce every solder joint.

HOW WE'LL FIX IT

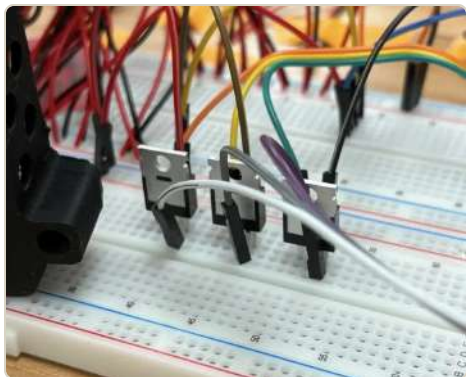
NEXT

Rebuild the base and the holder.

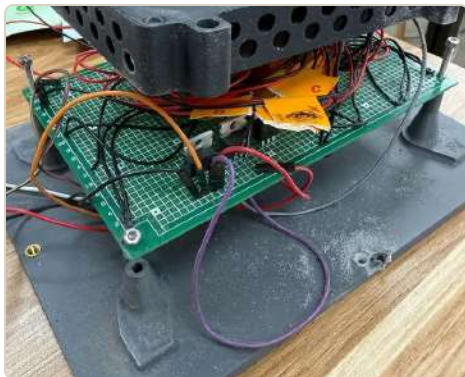
Black holder, four screws, MOSFETs inside

The rebuild after entry 30. The record gives no date for it, only that it came after the shaker failure and before the wiki's final design in October.

- **Moved the MOSFET stage from a breadboard beside the array onto a perfboard under the LED holder, inside the housing.**
 - One MOSFET per intensity tier, each switching a green and a red column of four, driven from PWM pins 9, 10 and 11.



Before: three MOSFETs on a breadboard beside the holder

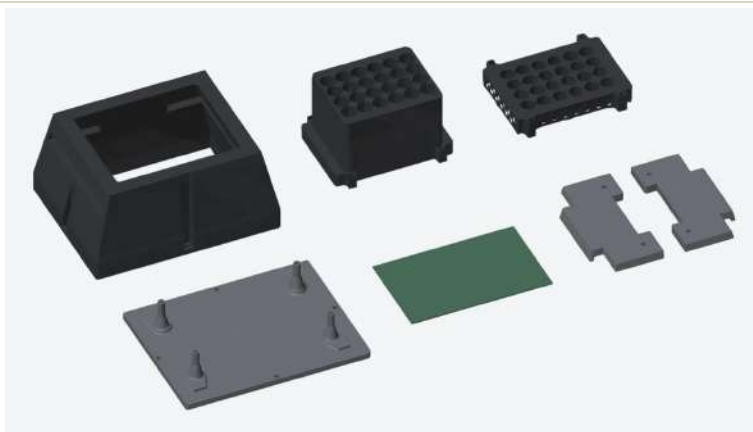


After: perfboard and MOSFETs beneath the LED holder



Final: the black tube holder seated on the housing

- **Used all four screw positions, up from two, and reinforced every solder joint.**
- **Printed the tube holder in black and raised its walls from 2 loops to 4.**
 - That is the fix for the light leaking between wells.



The CAD, part by part: bottom plate, sliders, housing, LED holder, tube holder, perfboard

FINAL DIMENSIONS

Dimension	Final design
Footprint	211 × 164 mm; 217 mm across sliders
Housing height	108 mm
Tube holder height	+80 mm
LED grid	4 × 6 on 18 mm pitch
Tube bores	24 × 17 mm

From the CAD.

DECISION

Fix the leak and the base in one rebuild

- Both failures came from the same run and both are print and assembly changes.

CONFIDENCE

The rebuilt base has not been back on a shaker, and no culture has run under the final design.

PROBLEMS

HOW WE'LL FIX IT

Rebuilt base not re-tested on a shaker

SINCE THIS WEEK

→ Run it overnight on the shaker empty first.

No end-to-end culture run under the final design

SINCE THIS WEEK

→ Repeat the 19 September assay.

NEXT

Power for the valves.

PROJECT

Light plate · final design

DATE

undated

ENTRY

30a

Soldering the valve power system

Prototype 2 adds control: servo pinch valves at the membrane and pH dosing. On 26 September Joshua's goal was to finish soldering the power system (電壓系統).

- **Finished six valves.**

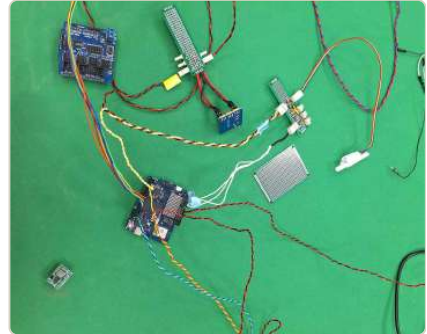
- Still to do at GEMS: the pumps and the pH probe, plus the wiki.



26 September: the soldering bench



The driver board



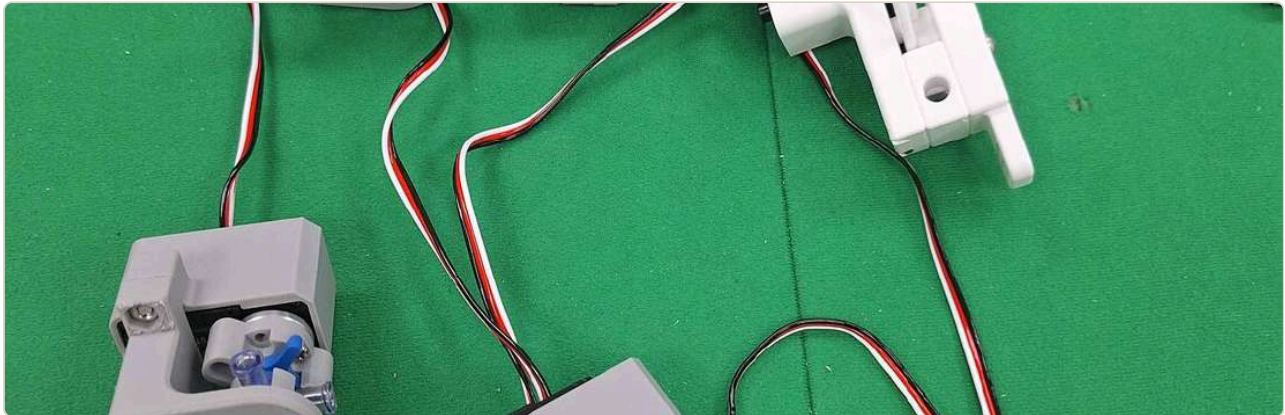
Valve wiring laid out

- **Fixed the pinch valve hardware for the build.**

- An STS3215 12 V servo drives each pinch valve, one near the out-lumen end of the membrane and one near the in-lumen end, each about 2 inches from the connection.

- **Placed the pH probe in the reservoir cap, plugged into the Arduino.**

- A small pump is designed to dose sodium hydroxide from a second bottle through a Luer valve into the out-lumen line.



The printed valve bodies with their servos

DECISION

Servo pinch valves at both lumen ends

- Entry 23 chose the servo because it holds when power is cut. Two of them let the lumen side be closed off at both ends.

NOT ACTED ON The servo choice has still not been bench-tested for holding force (entry 23).

PROBLEMS

HOW WE'LL FIX IT

Pinch valve design is not on record

SINCE THIS WEEK

→ Put the valve CAD and the holding-force test on the wiki.

pH dosing is designed, not run

SINCE THIS WEEK

→ Run the NaOH pump against a falling pH.

NEXT

Register what the next run should do, before it runs.

Registering a growth-rate forecast before the run

A model that is only ever checked against data it has already seen proves little. On 1 October, before any bioreactor run of WB800 secreting ACC deaminase, we registered what the next run's growth rate would be, with a pass criterion, and fixed the file.

- **Took the prior from a plate-reader fit (150 μ L wells) of the same strain.**
 - The plate's temperature was not recorded, and our 37 °C shake-flask fit is about four times faster, so the criterion does not apply to a batch run at 37 °C.

REGISTERED 1 OCTOBER

Prediction	Value	Passes if
Specific growth rate r	0.2986 h^{-1} , 90 % interval 0.2705 – 0.3300 (doubling 139 min, 126 – 154)	the fitted r falls inside the interval
Growth curve shape	logistic, prior-predicted trace	NRMSE below 15 %
Time to OD 0.5	7.3 h from OD 0.10; 9.8 h from 0.05; 13.0 h from 0.02	observed time inside the 5–95 % band

Only r is scored. K and X_0 were fitted on the plate-reader scale, and no cross-calibration to the in-line 2 mm cuvette exists yet.

- **Wrote down what each outcome would mean.**
 - If the rate fails and the shape passes, temperature is the first place to look. If both fail, the prior does not cross from plate to bioreactor, and we report that.
- **Set up a leaf temperature and wetness sensor on the bench on 2 October.**
 - The twin's field inputs were all online data until now. This is the first local sensor beside a crop; it is tested on its own, not yet in the loop.

DECISION

Register first, score on the first clean run

- A forecast written after the data cannot fail, so it cannot pass either.

REJECTED

Fitting the model to the next run and reporting the fit. It would look better and test nothing.

PROBLEMS

Plate and cuvette scales are not cross-calibrated

SINCE THIS WEEK

→ Read the same culture on both before scoring K or X_0 .

HOW WE'LL FIX IT

NEXT

The run with the codon-optimised strain.

PROJECT

Bioreactor · registered forecast

DATE

01/10/2026

ENTRY

32

Run 5: the reading breaks down after ten hours

On 8 October we began the second full run through the bioreactor, with WB800 secreting codon-optimised ACC deaminase constitutively, at 37 °C, permeate drawn at 24 mL/min (a flux of 72 LMH). It was the first run that could score the registered forecast.

SYMPTOM

37.5 h logged over 38 h in four files, because the run was restarted three times. In-line OD rose from 0.10 to 0.30 over the first nine hours, then fell away while the culture was still there. Nothing after 10.6 h can be read as a growth curve.

Chloe #gallery • 8 October

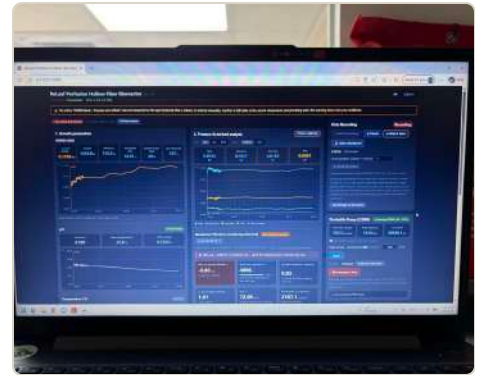
Historic moment!! We are beginning our second full bioreactor run through of the codon optimized ACCD.



8 October: the loop in the incubator at the start



The reservoir and photometer at the start



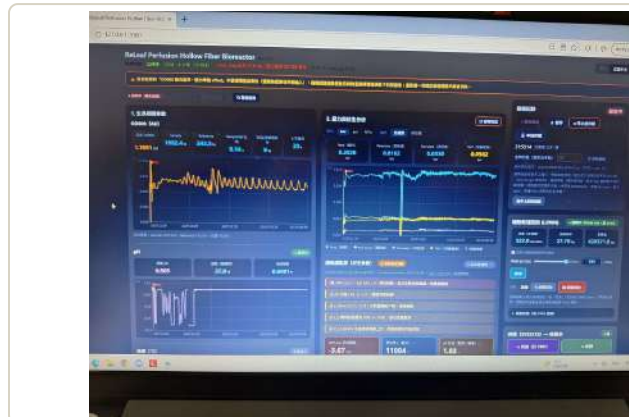
23:34 the same night: the dashboard

• Posted OD and pH by hand on 9 and 10 October alongside the logger.

– Joshua took readings at 8:45 on 9 October and 8:58 on 10 October.



9 October 08:45: the dashboard



10 October 08:58: OD and pH

What the log shows	What it means	Status
A sixth of windows carried more than 20 % bubbles	bubbles in the beam	confirmed in the log
Reference channel moved 4.8× across the run	the optics, not the culture: the reference never passes through it	confirmed in the log
pH held at 6.90 for twenty hours	the probe, not the culture	confirmed in the log
Permeate drawn too hard (72 LMH)	pulls gas and stresses the loop	tested in run 6

Run 5 cannot score the forecast.

DECISION

Halve the permeate flux and gate the photometer

- Permeate to 12 mL/min, 36 LMH.
- An acceptance gate on the OD channel: a window that fails its own checks holds the last accepted value and is flagged.

REJECTED

Scoring the forecast on the first nine hours. Too short, and the reading was already failing.

PROBLEMS	HOW WE'LL FIX IT
Bubbles reach the beam at high permeate flux SINCE THIS WEEK	→ Run 6 at half the flux.
pH probe sticks SINCE THIS WEEK	→ Check it against a bench meter at the start and end of the next run.

NEXT

Calibrate both photometers on silica before run 6.

PROJECT	DATE	ENTRY
Bioreactor · run 5	10/10/2026	33

Silica calibration: both photometers on one series

TiO₂ (entry 25b) stopped at OD600 1.9 and never included the simplified photometer. On 10 October we ran silica, the iGEM standard, through the same loop with the BioDrop, the complex photometer and the simplified photometer reading every step: the first run with all three on one series.

- **Added silica to 500 mL of 1 % SDS in 2.5 mg steps from 2.5 to 100 mg, forty points, stirred and circulated.**
 - Streamed live to a shared sheet so the team could watch.



10 October: both photometers running the final calibration



The complex photometer, CAD section



Preparing the next silica addition

- **Found the BioDrop is the ceiling, not our instruments.**
 - Its direct reading returns exactly 2.50 from 70 mg. Above OD 2.5 we measured dilutions and multiplied back, and that reconstruction falls as silica is added at 7 of 20 steps, which a weighed inert standard cannot do.

COMPLEX PHOTOMETER AGAINST THE BIODROP

Range	Slope	Intercept	R ²	Mean difference
OD 0–1.0	1.001	–0.123	0.988	–0.12
OD 0–2.5	0.995	–0.074	0.982	–0.08
above 2.5	0.594	+0.944	0.796	–0.33

Dilution-corrected BioDrop. Up to OD 2.5 the complex photometer reads absolute OD600 with no transform.

- **Got the simplified photometer linear across the whole range, but compressed.**
 - $R^2 = 0.992$ against silica mass (complex: 0.974). One linear conversion rescales it: $OD = 5.573 \times r - 0.073$. It spans 0.03 to 0.60 against 0.05 to 3.17 for the complex photometer.

SMALLEST RESOLVABLE CHANGE, AS SiO₂ MASS

Instrument	Noise	Low range	High range
Complex photometer	0.010 OD	0.21 mg	0.46 mg
Simplified photometer	0.004 OD	0.49 mg	0.78 mg
BioDrop	0.106 OD	2.20 mg	3.60 mg

Point-to-point scatter divided by the change in reading per mg. The BioDrop read one hand-pipetted cuvette per point, so this compares repeatability.

- **Argued about why the simplified reading is a fifth of the other.**
 - Dr. Pak's first thought was a shorter light path. Both use the same 2 mm flow cuvette, so it is not path length. Noah suspects light spreading from the fibre; Dr. Pak raised stray light. Not settled.

Timmy # -drylab · 11 October

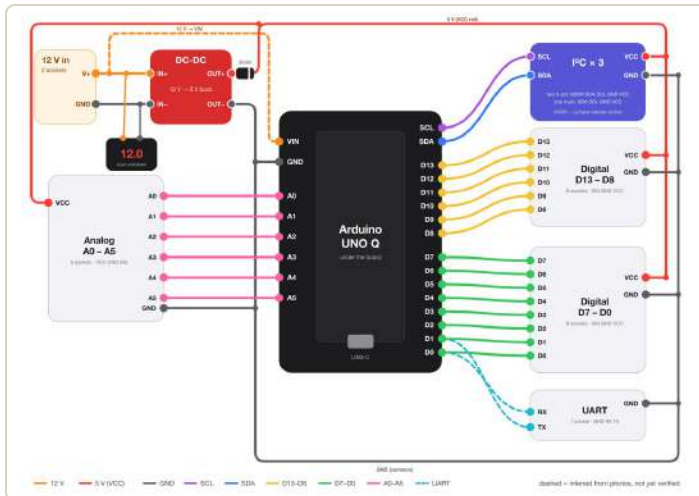
V1 more sheer light intensity, but shaky when OD gets high. V2 lower light intensity, but more stable, and less sensitivity so might miss small turbulence.

• **Tested eight filter estimators on the same readings, and added two gates after the median filter.**

- A bubble that fills the cuvette for seconds makes every reading wrong yet consistent; MAD caught 94 % of partial disturbances but none of these. Gate 1 rejects a reading when MAD and an upper percentile differ by more than 0.03 OD. Gate 2 holds any step above 0.05 OD or 5 % until three readings agree.



12 October: the newer photometer, light almost against the cuvette



The Uno Q breakout wiring both photometers share

DECISION

Complex photometer in the reactor, simplified where cost matters

- The complex photometer reads OD600 directly to 2.5, resolves changes twice as fine, and its reference beam stops slow LED drift being logged as growth.
- The simplified one is linear and cheaper, but needs its 5.57× factor and resolves half as finely.

CONFIDENCE

One run on one mineral standard. Silica and bacteria do not scatter identically.

PROBLEMS

Why the simplified reading is compressed is unexplained

SINCE THIS WEEK

→ Sit down with Dr. Pak with the hardware, and test stray light directly.

Both photometers untested on known cell densities

SINCE W25

→ Repeat the series with B. subtilis.

HOW WE'LL FIX IT

NEXT

Run 6, with the gate running.

PROJECT

Photometers · SiO₂ calibration

DATE

10/10/2026

ENTRY

33a

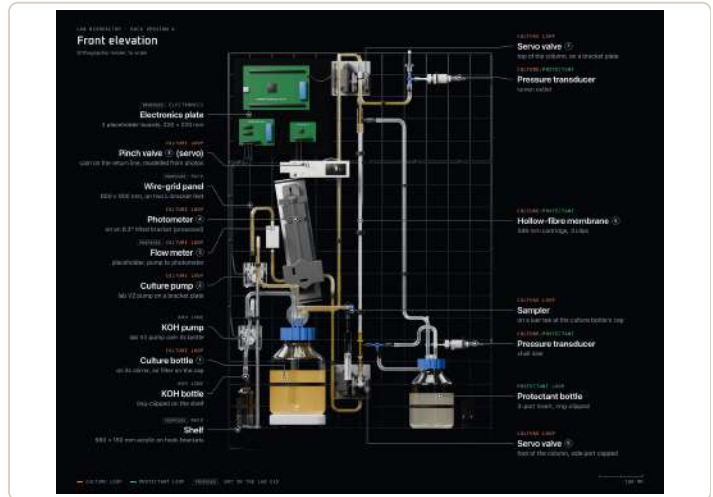
Modelling the lab bioreactor as it is plumbed

The wiki needed a model of the lab bioreactor that matched the rig, not the September drawings. Anton revised the rack model and asked Chars to check it on 9 October.

- Revised the lab bioreactor rack model with every part labelled.



9 October: the revised rack model



Front elevation with labels

- Took one correction from Chars.

- Only one shell-side outlet is open, the one at the top of the module on the lumen-outlet side. The bottom shell outlet has a Luer valve on it, closed and connected to nothing yet.

Chars #drylab · 10 October

Only one thing: currently, we just open one outlet on the shell side, the one on the top of HFM (lumen outlet side).

PROBLEMS

HOW WE'LL FIX IT

The model and the rig diverge whenever the plumbing changes

SINCE THIS WEEK

→ Same rule as entry 28: redraw after every plumbing change.

NEXT

Run 6.

PROJECT

Bioreactor · lab model

DATE

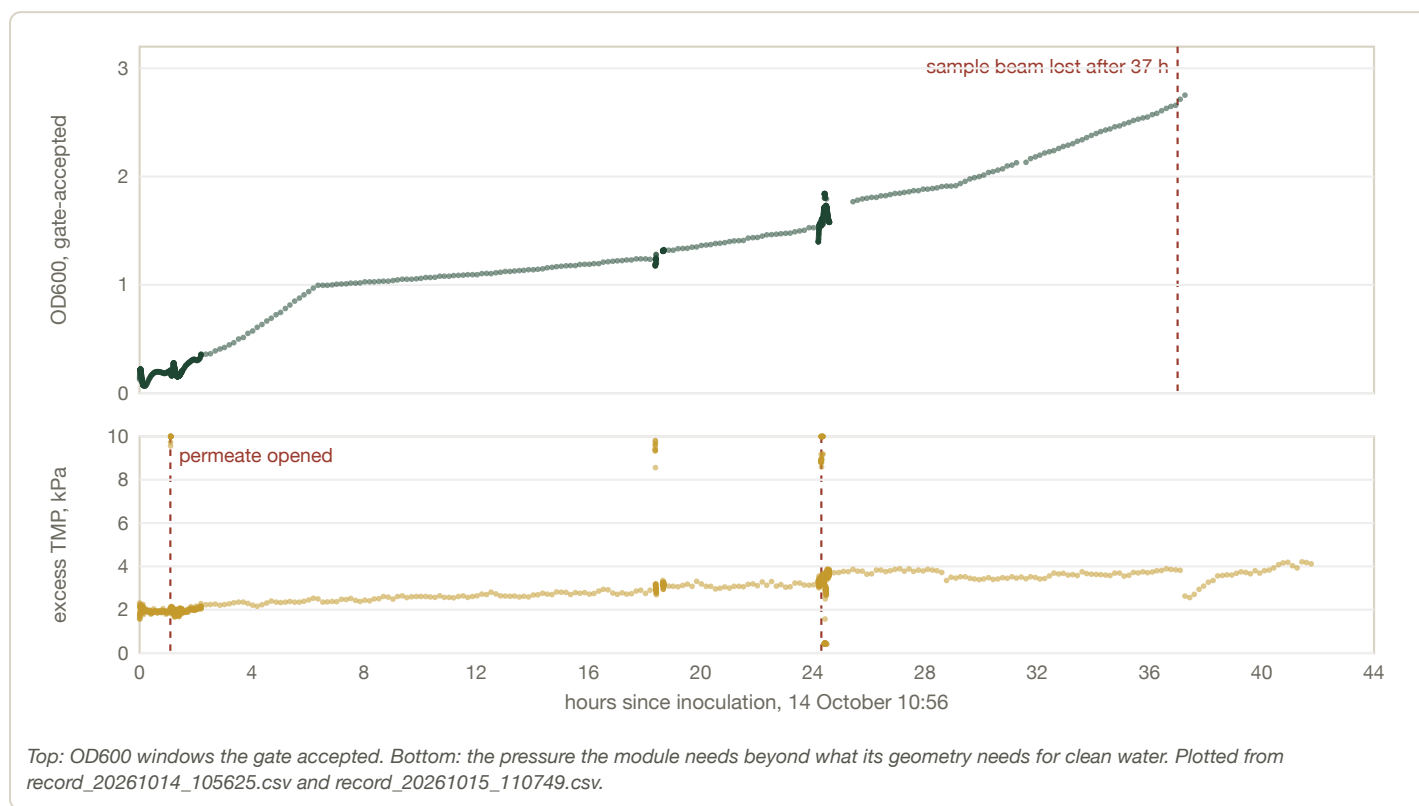
10/10/2026

ENTRY

33b

Run 6: a clean curve, and the forecast passes

Same strain as run 5, with two changes: permeate halved to 12 mL/min (36 LMH) and the photometer acceptance gate running. Pass condition, registered on 1 October: fitted growth rate inside 0.2705 to 0.3300 h⁻¹.



- **Ran 41.8 hours with no restart, 14 to 16 October.**

- The gate turned away 31 of 1,083 windows. No window carried more than 20 % bubbles and the reference held within 17 %.

- **Got a clean trace from 0.14 to 2.71.**

- 0.14 at the first window, 1.01 at 7 h, 2.71 at 37 h. After that the sample channel fell to a tenth of the reference and the reading stepped to about 9.9 and stayed there, flagged as low signal.

- **Scored the registered forecast.**

- $r = 0.286 \pm 0.010 \text{ h}^{-1}$ (doubling 145 min), $R^2 0.978$ on quarter-hourly medians from 1.5 to 6.5 h. Inside the interval.

REGISTERED AGAINST RUN 6

Endpoint	Registered	Run 6	Verdict
Growth rate r	0.2986, interval 0.2705–0.3300 h ⁻¹	$0.286 \pm 0.010 \text{ h}^{-1}$	inside
Curve shape	logistic, NRMSE < 15 %	misses the first 7 h by 30 %; passes the prior's ceiling of 1.005 before 7 h	not scored
Time to OD 0.5	6.1 h from 0.14	3.6 h	not scored

- **Logged a fouling trend for the first time.**

- Excess pressure rose from 2.0 to 3.8 kPa over 42 hours. The two spikes the Digital Twin names, at 1.1 h and 24.3 h, read zero on the permeate while the feed rises: the permeate side being opened, not the membrane. A third single window near 18.4 h reads 9.4 kPa and carries a low-reference flag.

- pH fell from 6.93 to 6.41 over seventeen hours, then stepped back to 7.0 inside one window.
 - The log does not explain the step.

DECISION

Passed on the one scored endpoint

- The rate fitted to run 6 sits inside the interval registered thirteen days before it.

CONFIDENCE

Over those five hours a straight line fits the readings with half the residual sum of squares of the exponential, so the rate comes from a stretch where the two shapes cannot be told apart. Run 6's pressures sit at the same magnitude as run 4's, so they appear to carry the firmware scaling problem in entry 34a.

PROBLEMS

HOW WE'LL FIX IT

The photometer loses the sample beam above OD about 2.7

SINCE THIS WEEK

→ A shorter path or a dilution loop for the top of the range.

Unexplained pH step

SINCE THIS WEEK

→ Log the probe temperature and check the probe against a bench meter.

No membrane breach test on record

SINCE W18

→ Induce a leak deliberately and see whether the transducers flag it.

NEXT

Settle the parts list before anything else is published.

PROJECT	DATE	ENTRY
Bioreactor · run 6	16/10/2026	34

Auditing the parts list, and finding the pressure scaling wrong

The hardware material list of 7 October was complete but unpublishable: eleven internal contradictions, two of them live on the wiki. On 14 October the instructors ruled on each, the same exercise as the spec freeze of 4 July (entry 15a).

- **Found the firmware scales the pressure transducers wrongly.**

- Both sketches convert the ADC as 0–30 psi, but the BP8G-AGA reads 0–1 MPa. Every logged pressure is out by 4.8×. Nothing may be published off the TMP traces until they are rescaled.
- At 1 % of full scale on 0–1 MPa the accuracy is ± 10 kPa, against a working TMP of about 30 kPa, so the TMP signal sits inside one accuracy unit either way.

TABLE 34A · WHAT THE AUDIT SETTLED

Item	Ruling	Was
Pressure scaling	0–1 MPa; firmware wrong by 4.8×	0–30 psi in the code
Rig	0906 P&ID plus a flow meter; five filters; valves on the lumen only	assembly draft: 4 membrane segments, 12 valves
Flow meter	fitted (its 4,380 pulses/L is still a placeholder)	one README said there is none
Cross-flow pump	雷熔 ZP4000-N79H	three draft part numbers that never existed on the rig
LPA controller	a plain Arduino Uno on a breadboard, PWM 9/10/11	Uno R4 WiFi
LPA red light	12 red LEDs in the holder	an LED strip
Droplet sensor	planned only	listed as fitted
Membrane price	NT\$7,800 each; sheet prices are per unit	ambiguous

Full rulings in [Updates/material-list-1014/RULINGS.md](#).

- **Caught a protocol problem in the LPA while checking LED counts.**

- 12 green and 12 red LEDs fill all 24 holes at one LED per hole, so each well gets green or red. A green-ladder protocol with constant red in all 24 wells cannot have run as written.

DECISION

Publish nothing from the pressure traces until they are rescaled

- A 4.8× scaling error moves every absolute TMP and pressure-drop number in entries 17, 25, 27 and 34.

REJECTED

Quoting the traces with a footnote. The error is in every number, not at the edges.

PROBLEMS

HOW WE'LL FIX IT

Pressure data unscaled

FOUND THIS WEEK

→ Fix the firmware constant, then rescale the stored logs from 12 July onward.

Flow meter K-factor is a placeholder

SINCE THIS WEEK

→ Take it from the flow meter's datasheet once the model is confirmed.

Two different cost totals published (NT\$30,450 and NT\$30,480)

SINCE THIS WEEK

→ Re-add the lines at per-unit prices and correct both pages.

NEXT

Where everything stands on 17 October, on the next pages.