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# Designing Open Hardware for 21st century science

Future Forward: Science in the Open Era  
TU Delft April 10<sup>th</sup> 2019

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Baden lab @ University of Sussex

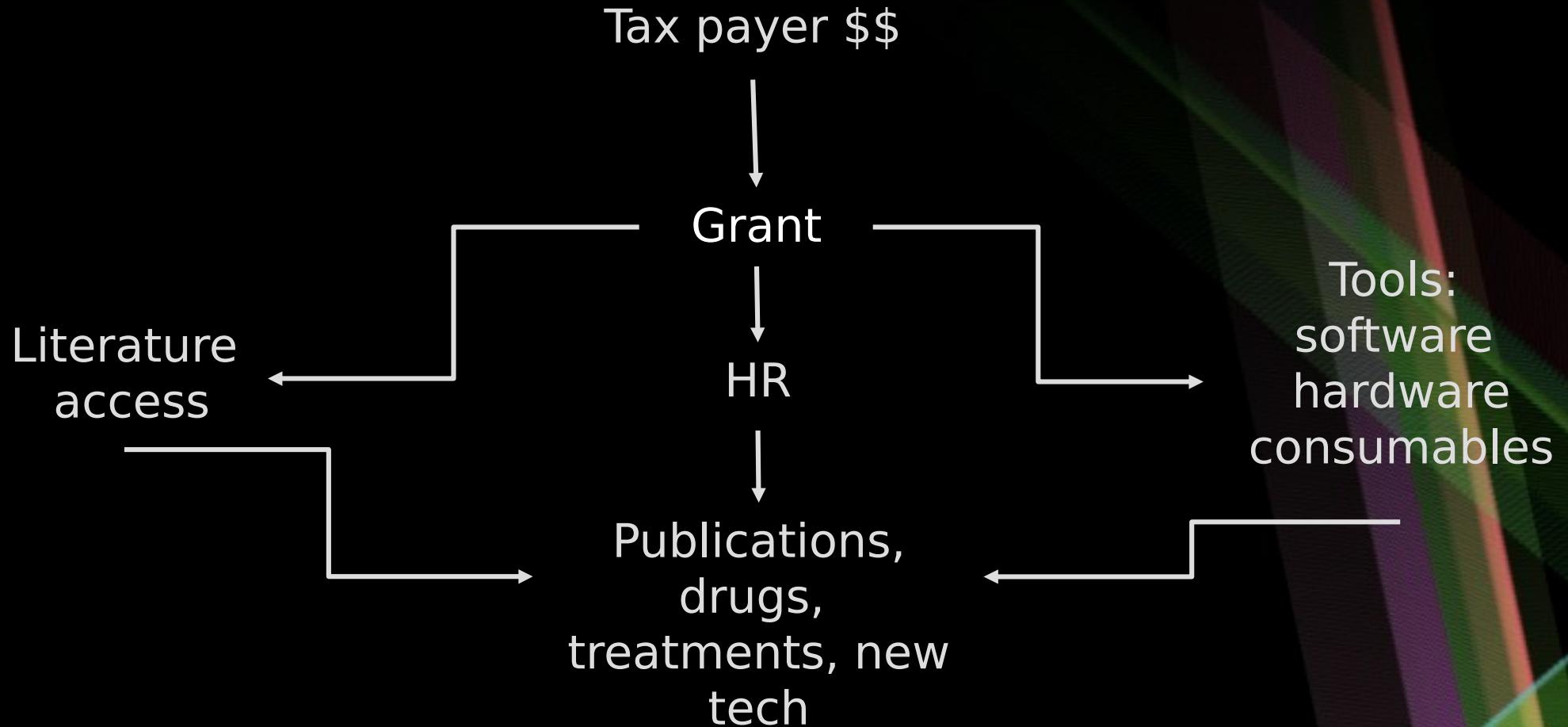
# Overview

- About me
- How we are funded
- Why open science
  - Open tools
  - Open source software
- Open source
- Scientific equipment: is open better?
  - Pumps, microscopes and robots
- PLOS repository
  - Build following demand
- GOSH community
- Repositories and questions

# About me

- Biology / Neurosciences
- Advocating Open Science:
  - Open Neuroscience (<http://bit.ly/OpenNeuro>)
  - Trend In Africa (<http://bit.ly/TIAfrica>)
  - Plos Channel: Open Source toolkit (<http://bit.ly/2yrVDnw>)
  - Mozilla & FreiesWissen Fellow
    - Mapping scientific equipment demand (<http://bit.ly/BFOSH>)
- Building tools @ BadenLab (<http://bit.ly/2TU7THW>)
  - visual stimulators
  - behavioural setups
  - customizing off-the-shelf equipment
- Prometheus Science:
  - Scientific tools as a service (together with Karen Haink)

# How we are funded



# How we are funded

Publications, drugs, treatments,  
new tech



Patent, copyright



Technology transfer



Distribution/production Oligopoly



High Costs

# Why Open Science

Rigorous replication effort succeeds for just two of five cancer papers

By Jocelyn Kaiser | Jan. 18, 2017 , 1:00 PM

NATURE | NEWS



## Over half of psychology studies fail reproducibility test

Largest replication study to date casts doubt on many published positive results.

Monya Baker

27 August 2015

# Why Open Science

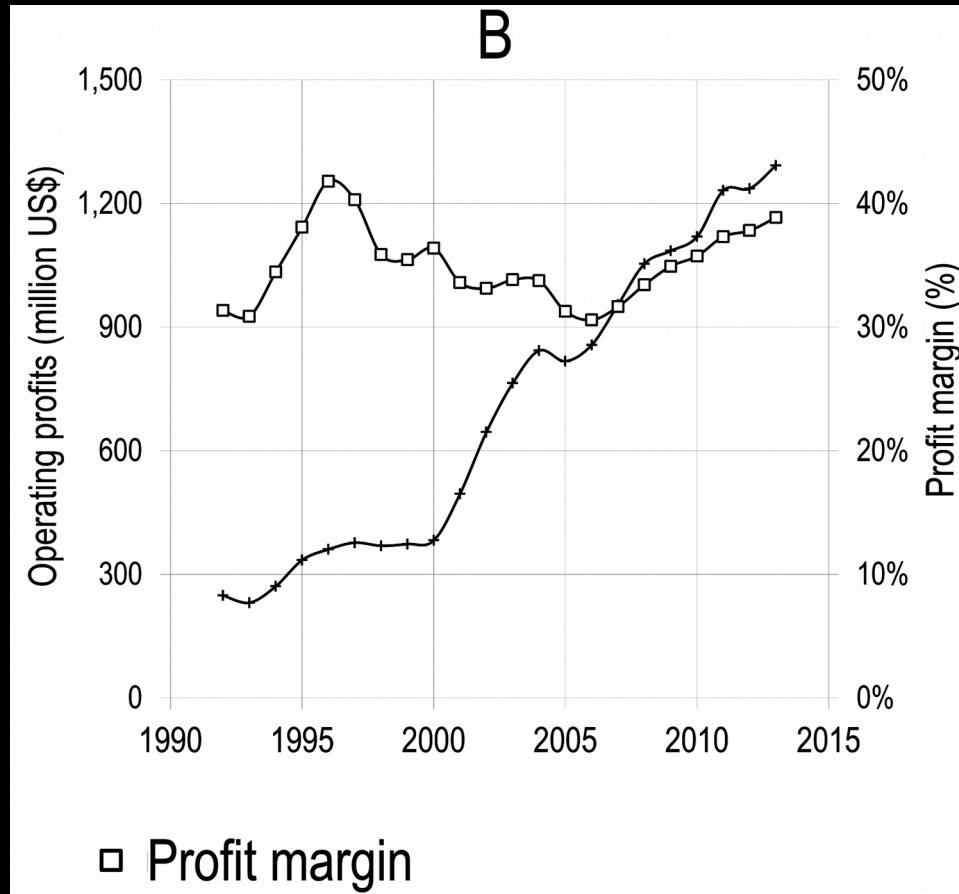
## Peer review post-mortem: how a flawed aging study was published in Nature

How could an article with numerous shortcomings be published in top-tier journal Nature? Hester van Santen reveals how the gate-keepers of science knowingly let flawed research slip through.

❖ Hester van Santen ⏰ 9 december 2016 om 6:00

*“Nature asks reviewers to look at statistics “if time is available”,*

# Why Open Science



In the same  
range:  
Banks  
Pharma  
Auto companies

“Gate keepers” make a lot of PROFIT:  
- Something they did not create!  
- Was already paid for with public money  
-Estimation 2017 (Germany):  
-1 paper 3800-5000 Euros

Larivière *et al* 2015

# Why open science

- Many reasons:
  - Reproducible
  - Robust
  - Accessible
  - Affordable
  - Accountable

# Why open science

- Luckily several initiatives are taking care of publication issues:
  - Center for Open Science
  - Pre prints (PreReview initiative)
  - Study pre-registration
  - Open Access journals
  - Post-review
  - Many other, but not our topic today...

# Open tools



# What about our tools?

Format: Abstract ▾

Genome Biol. 2016 Aug 23;17(1):177. doi: 10.1186/s13059-016-1044-7.

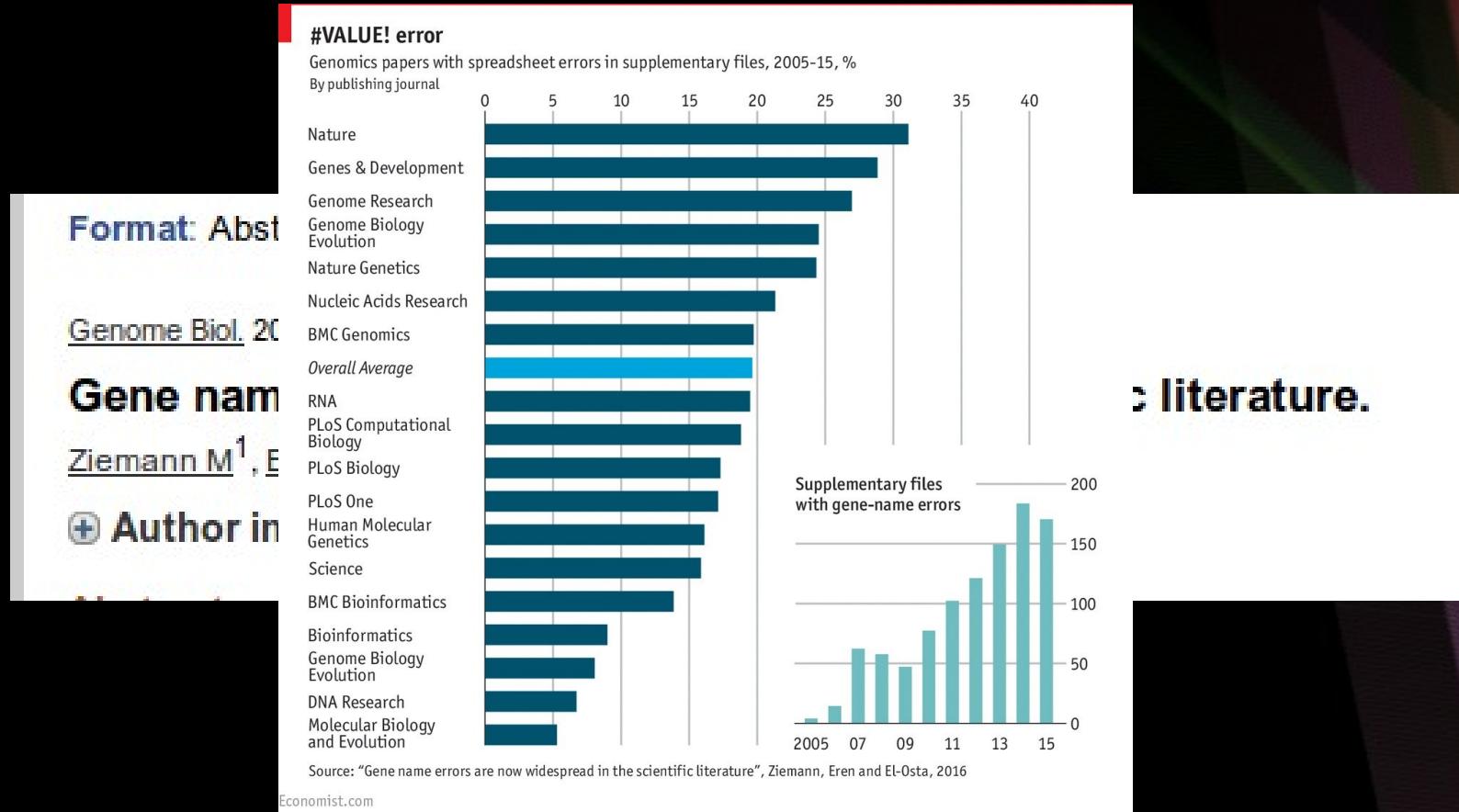
**Gene name errors are widespread in the scientific literature.**

Ziemann M<sup>1</sup>, Eren Y<sup>1,2</sup>, El-Osta A<sup>3,4</sup>.

 Author information

All 1 figure

# What about our tools?



# Open Source Software

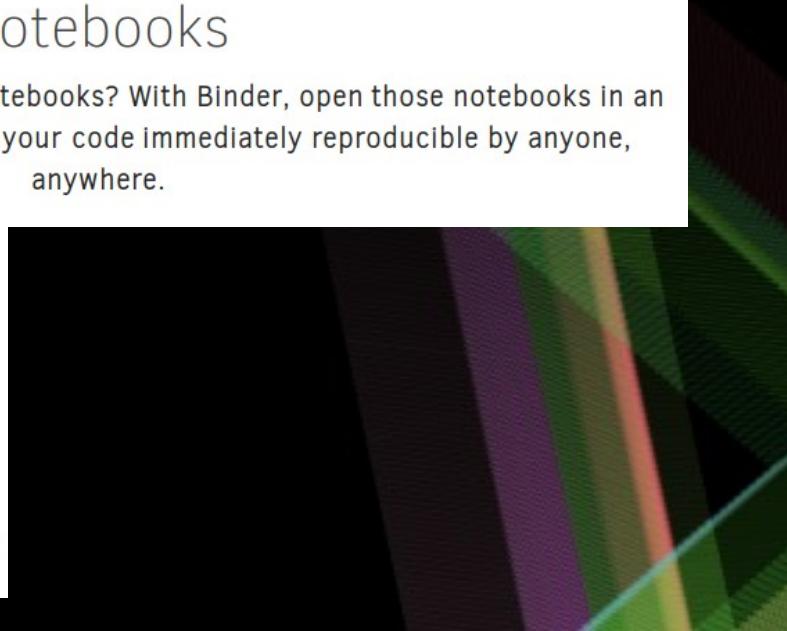


Project Jupyter exists to develop open-source software, open-standards, and services for interactive computing across dozens of programming languages.



Turn a Git repo into a collection of interactive notebooks

Have a repository full of Jupyter notebooks? With Binder, open those notebooks in an executable environment, making your code immediately reproducible by anyone, anywhere.

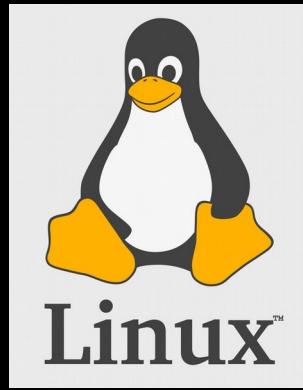


# 1 minute to master Open Source

- Everything (code, hardware design, protocols, cake recipes) created is shared freely via licenses (GNU, Creative Commons, OSHWA, and many other), using any means at hand (Internet, usb sticks, recipe notebook)
- We've always done it. Now we just have a fancy name for it and metrics so that all projects follow a certain standard.

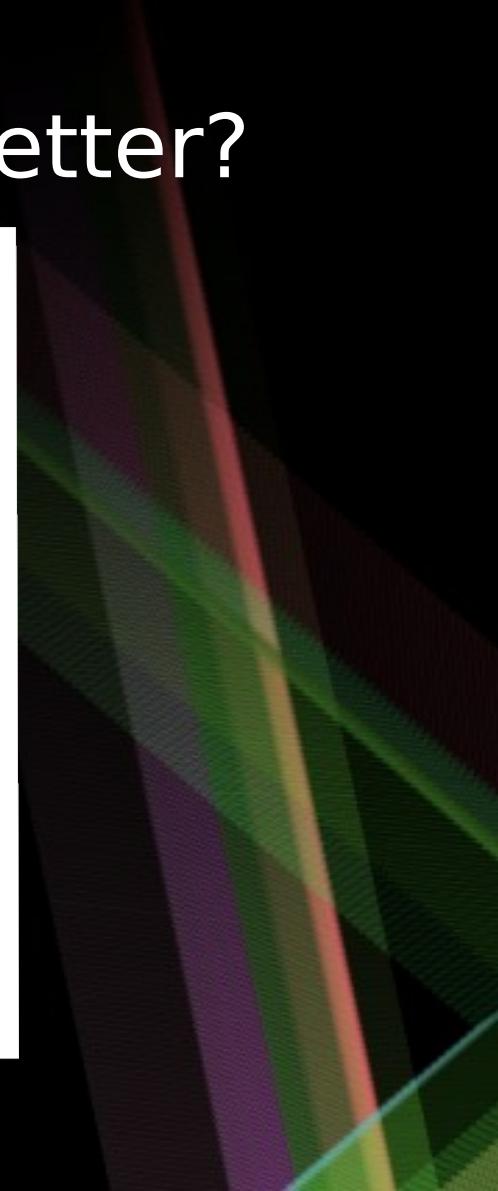
# 1 minute to master Open Source

- Powers your smartphones, data centers, computers in airplanes, supercomputers.



<https://www.zdnet.com/article/its-an-open-source-world-78-percent-of-companies-run-open-source-software/>

# Scientific equipment: is open better?



# Scientific equipment: is open better?



## Lead times:

Typical dispatch time for the following systems are:

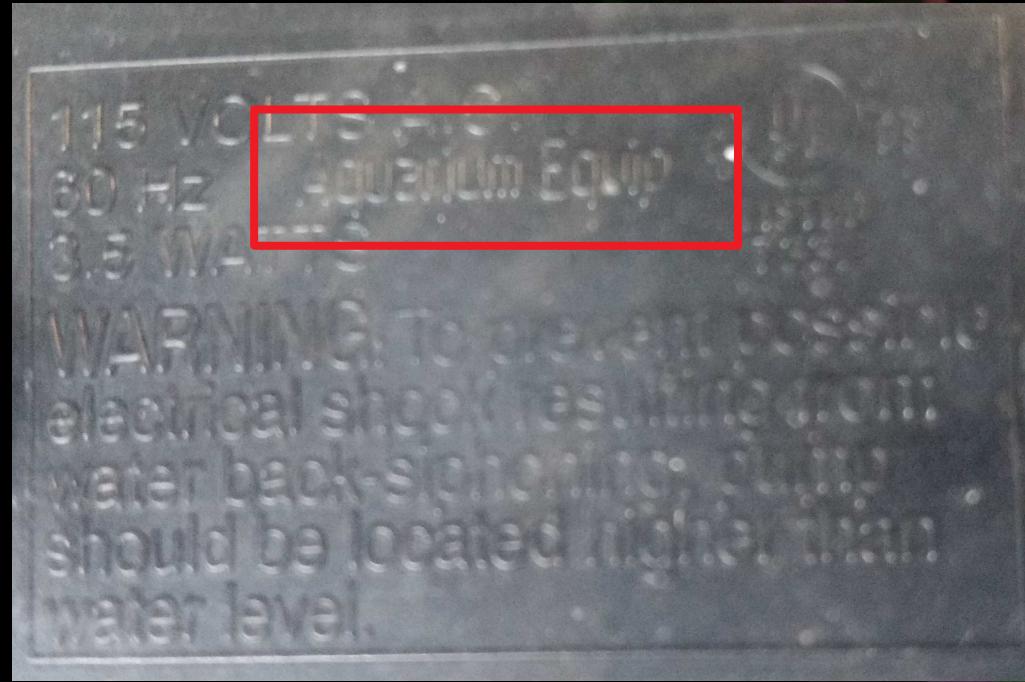
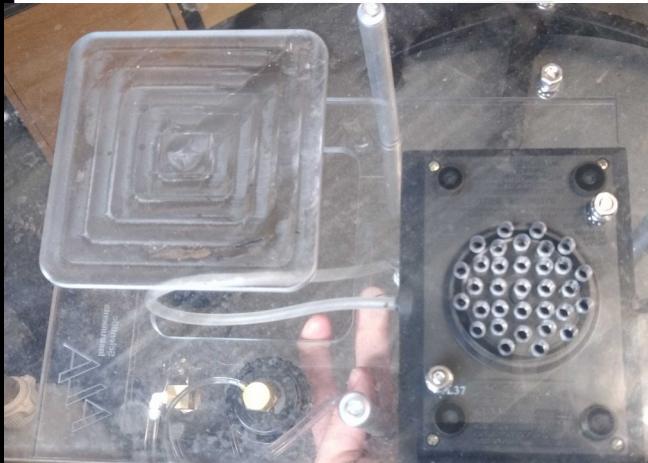
- Electrophysiology = 8 – 10 weeks
- Multiphoton = 16 -18 weeks
- LASU = 16 -18 weeks
- Hyperscope = 16 -18 weeks
- FLIM = 22 – 24 weeks

Item	Code	Description	Qty	Unit Price	Value
DEL	<b>Delivery Charge</b>		1.00	£39.00	£39.00
	Postage and packaging				
ALAVWK	<b>Vacuum Waste Kit</b>		1.00	£710.44	£710.44
	Vacuum Waste Kit - for use with Level Lock LL-2				

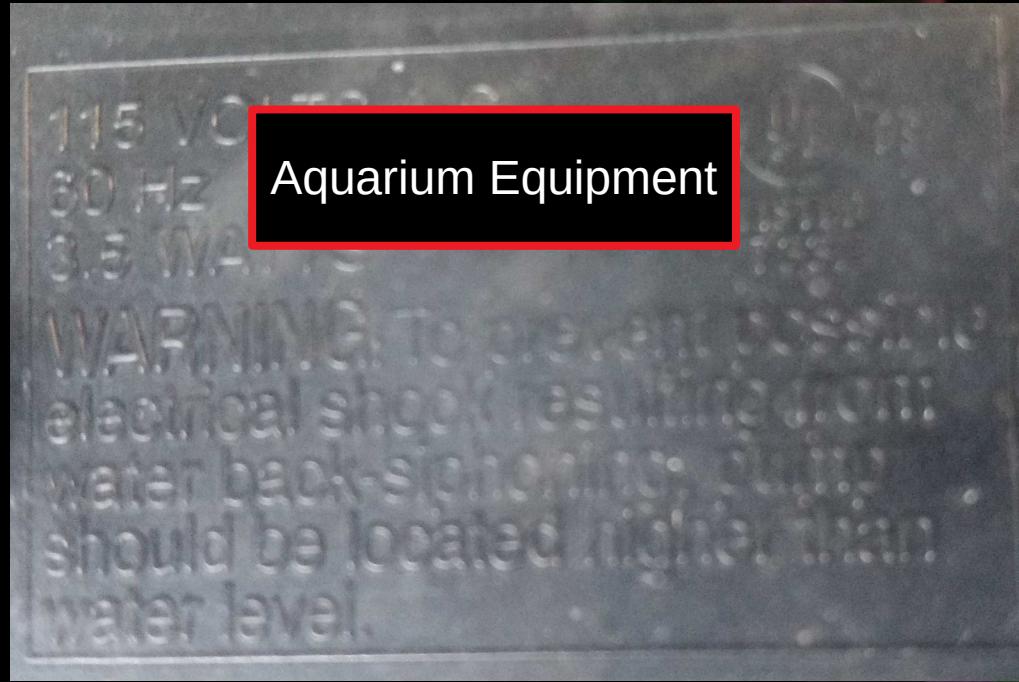
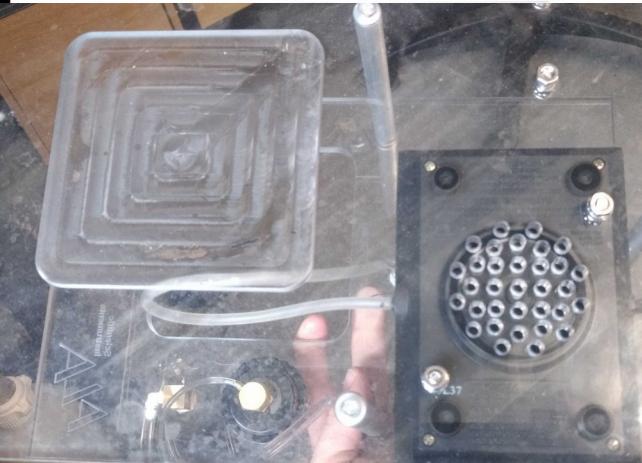
Item Total GBP 749.44

Grand Total GBP 749.44

# Scientific equipment: is open better?



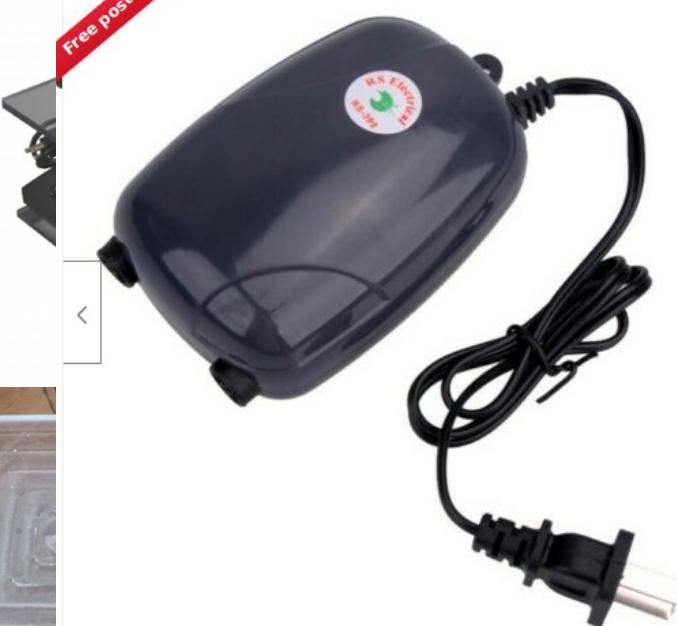
# Scientific equipment: is open better?



# Scientific equipment: is open better?

**BUY 1, GET 1 AT 5% OFF (add 2 to basket)** [See all eligible items ▾](#)

Free postage



Mouse over image to zoom



**Double Outlet Airpump /Aquarium Oxygen Air Pump Fish Tank Quiet Silent Single**

Condition: **New**

Colors: **Black**

Sizes: **Double Outlet**

Quantity: **1**      9 available  
[3 sold](#)

**£7.99**

**Buy it now**

**Add to basket**

[Add to watch list ▾](#)

**30-day returns**

Free postage

Posts from United Kingdom

Postage: **Free Economy Delivery** | [See details](#)

Item location: Leeds, United Kingdom

Posts to: United Kingdom [See exclusions](#)

Delivery: Estimated by **Wed. 17 Apr.** ⓘ

Payments:      Processed by PayPal  


Get more time to pay. [See payment information](#)

Returns: 30 days refund, buyer pays return postage | [See details](#)

# Scientific equipment: Is open better?

## Microscopes:

- ~17<sup>th</sup> century
- Scientific grade      ~5000€
- Fluorescence      +~5000€
- No patents
- Hard to repair
- Hard to customize
- Designed for european/US markets



By Chad Anderson, CC BY-SA 2.0,  
<https://commons.wikimedia.org/w/index.php?curid=45625745>



By Zephyris at the English language Wikipedia, CC BY-SA 3.0,  
<https://commons.wikimedia.org/w/index.php?curid=13320450>

# Scientific equipment: is open better?



**PLOS** | BIOLOGY

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COMMUNITY PAGE

The €100 lab: A 3D-printable open-source platform for fluorescence microscopy, optogenetics, and accurate temperature control during behaviour of zebrafish, *Drosophila*, and *Caenorhabditis elegans*

Andre Maia Chagas<sup>1,2,3,4\*</sup>, Lucia L. Prieto-Godino<sup>3,5</sup>, Aristides B. Arrenberg<sup>1,6</sup>, Tom Baden<sup>1,3,4,7\*</sup>

1 Werner Reichardt Centre for Integrative Neuroscience, University of Tübingen, Tübingen, Germany, 2 Graduate school for Neural and Behavioural Neuroscience, University of Tübingen, Tübingen, Germany, 3 TReND in Africa gUG, Bonn, Germany, 4 Institute of Ophthalmic Research, University of Tübingen, Tübingen, Germany, 5 Center of Integrative Genomics, University of Lausanne, Lausanne, Switzerland, 6 Institute of Neurobiology, University of Tübingen, Tübingen, Germany, 7 School of Life Sciences, University of Sussex, Brighton, United Kingdom

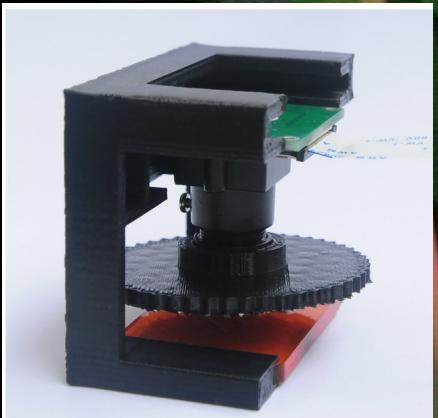
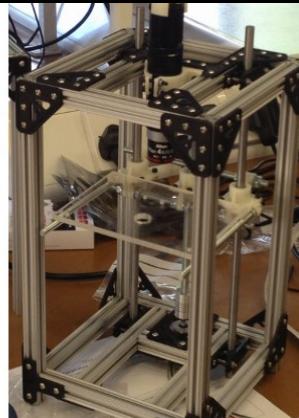
\* [andremaiachagas@gmail.com](mailto:andremaiachagas@gmail.com) (AMC); [t.baden@sussex.ac.uk](mailto:t.baden@sussex.ac.uk) (TB)

<http://bit.ly/flypios>

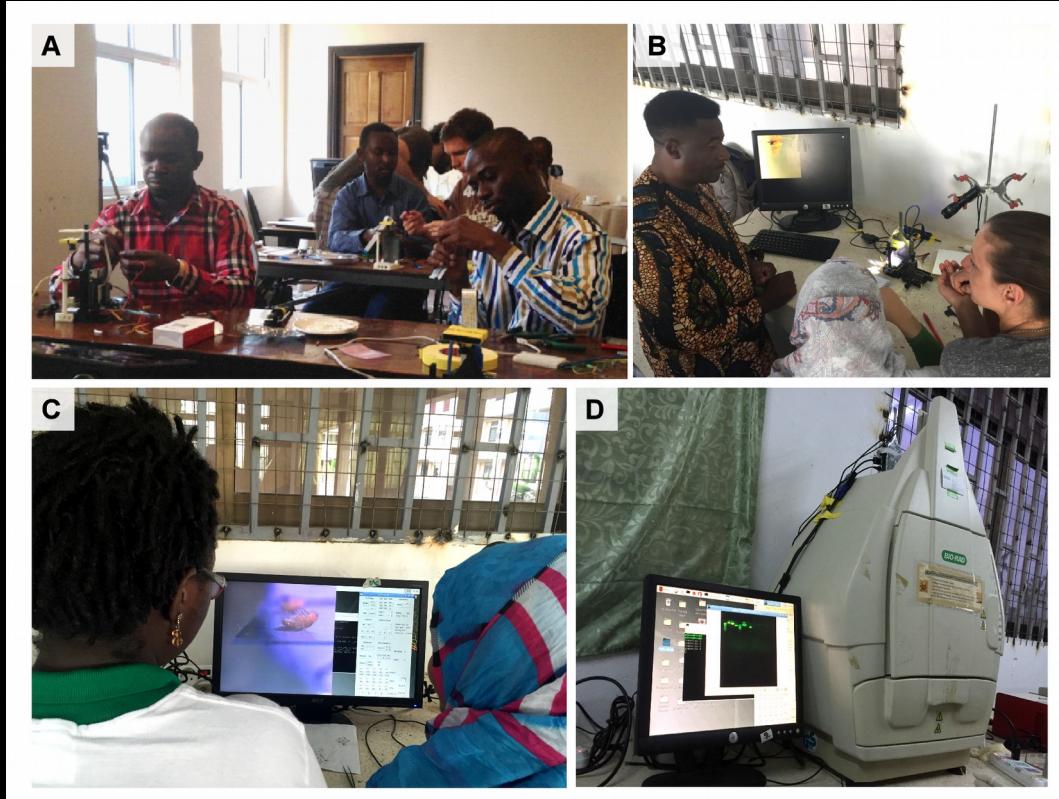


# Scientific equipment: is open better?

- Open Source Microscopes:
  - Different capabilities
  - Published in peer reviewed journals
  - Affordable (50 to 1000£) == many per lab?
  - Portable, battery driven, easy to customize



# Scientific equipment: is open better?



# Scientific equipment: is open better?



# Scientific equipment: is open better?

A collage of images at the top: two photographs labeled A and B; a Elsevier logo with a tree and the word ELSEVIER; a ScienceDirect logo with the text "Contents lists available at ScienceDirect"; a HardwareX logo with the text "HardwareX"; and a journal homepage URL "journal homepage: www.elsevier.com/locate/ohx".

Contents lists available at [ScienceDirect](#)

**HardwareX**

journal homepage: [www.elsevier.com/locate/ohx](http://www.elsevier.com/locate/ohx)

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Hardware Article

**Actifield, an automated open source actimeter for rodents**

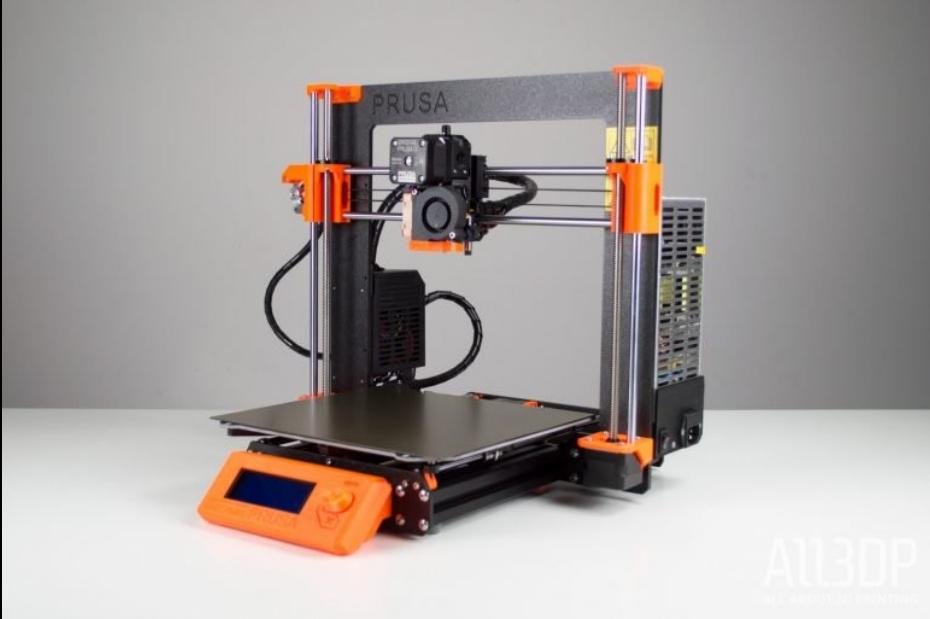
Victor Wumbor-Apin Kumbol <sup>a,\*</sup>, Elikplim Kwesi Ampofo <sup>b</sup>, Mary Ayeko Twumasi <sup>b</sup>

<sup>a</sup>*Department of Pharmacology, Faculty of Pharmacy & Pharmaceutical Sciences, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana*

<sup>b</sup>*Department of Pharmacognosy, Faculty of Pharmacy & Pharmaceutical Sciences, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana*

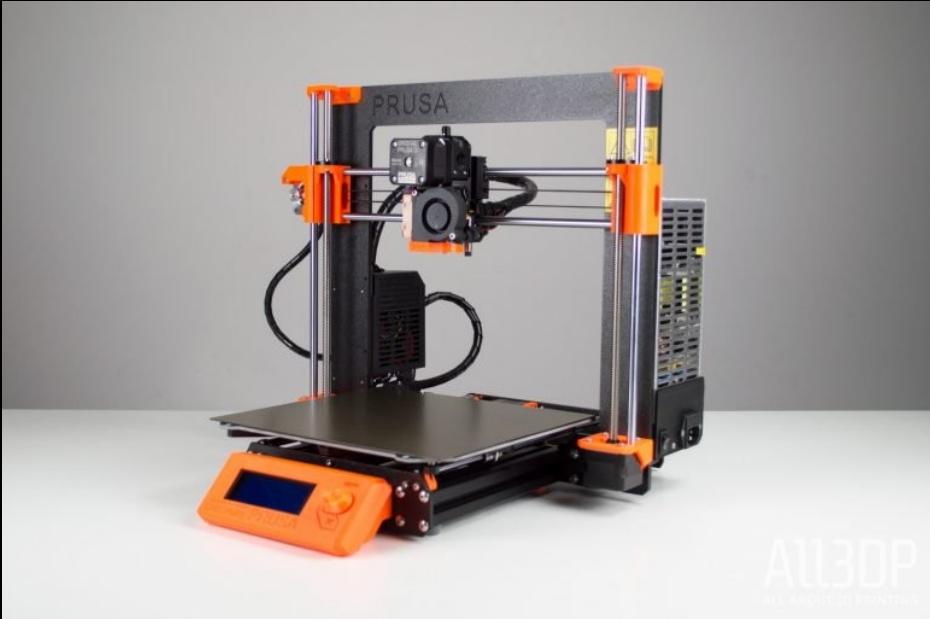
Two photographs at the bottom: one showing a white cloth or garment on a surface, and another showing a computer monitor displaying data next to a large piece of laboratory equipment.

# Scientific equipment: is open better?



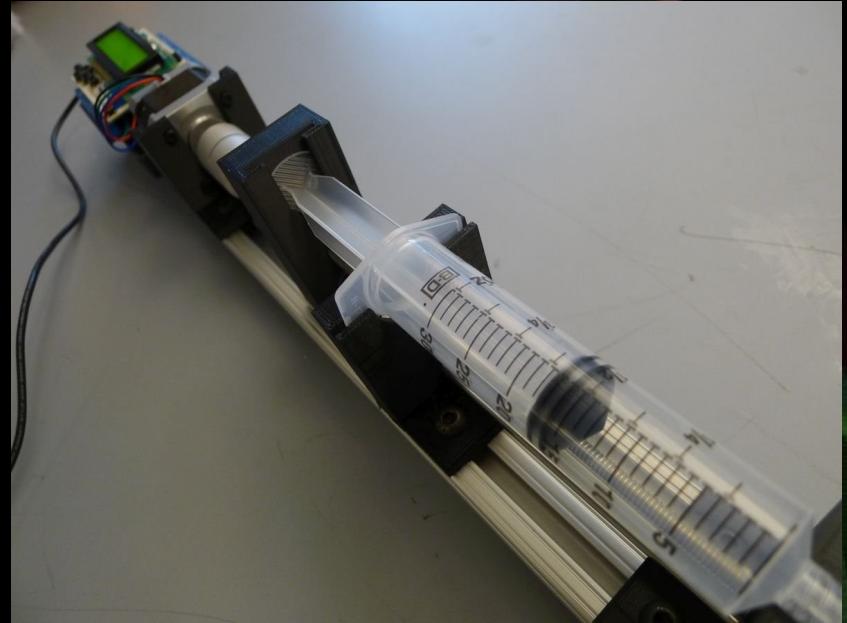
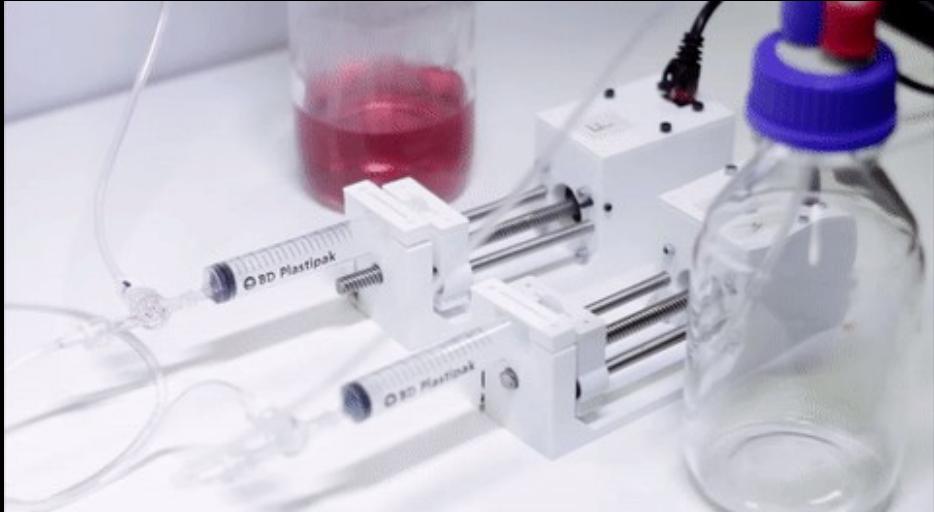
- Who can tell me what this is?
  - And how it became so popular?

# Scientific equipment: is open better?



- FDM technology patent:
  - Expired in 2009
  - First Reprap in 2007 inside university
  - 2018: 14 billion US\$ market in USA

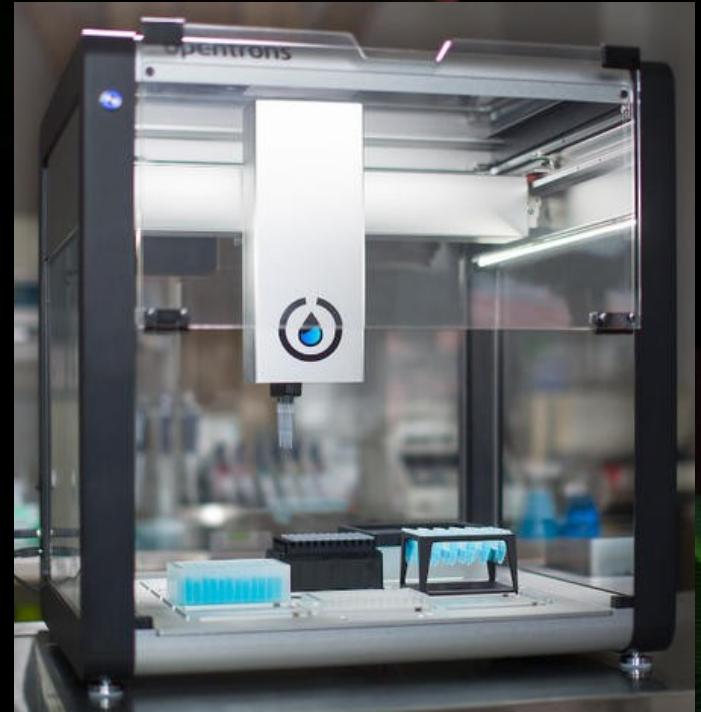
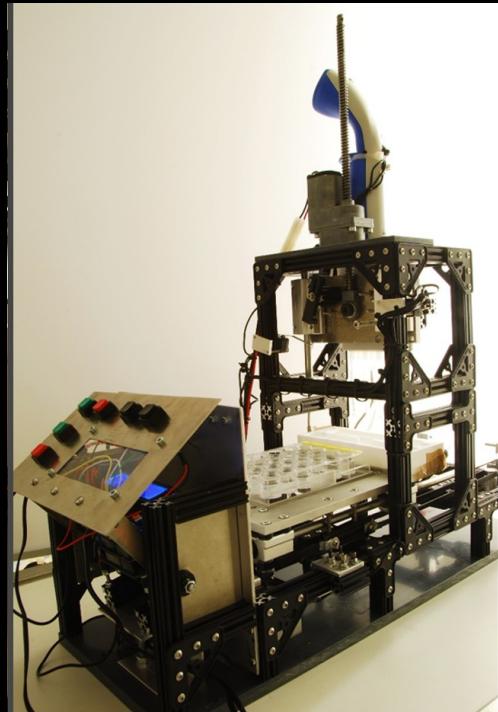
# Scientific equipment: is open better?



Made syringe pumps “easy”



# Scientific equipment: is open better?

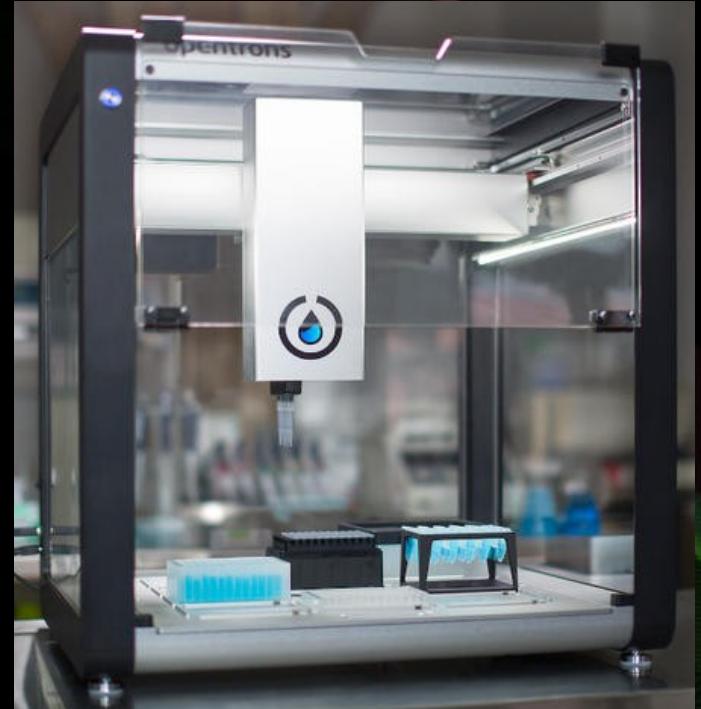


Made robots “easy”



# Scientific equipment: is open better?

- Opentrons:
  - 2014 Master thesis
  - 2015 kickstarter
  - 2016 Y combinator
  - 2017 begin 2<sup>nd</sup> gen robot
  - 2018 10M US\$ VC raised



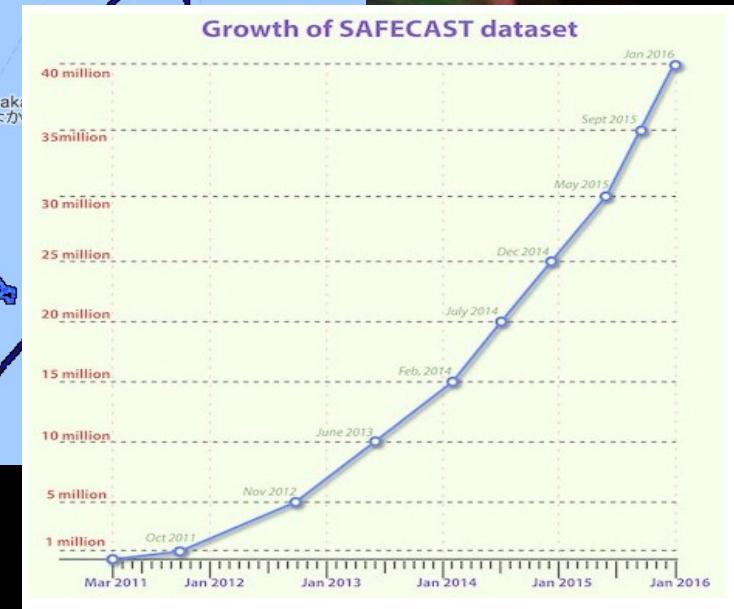
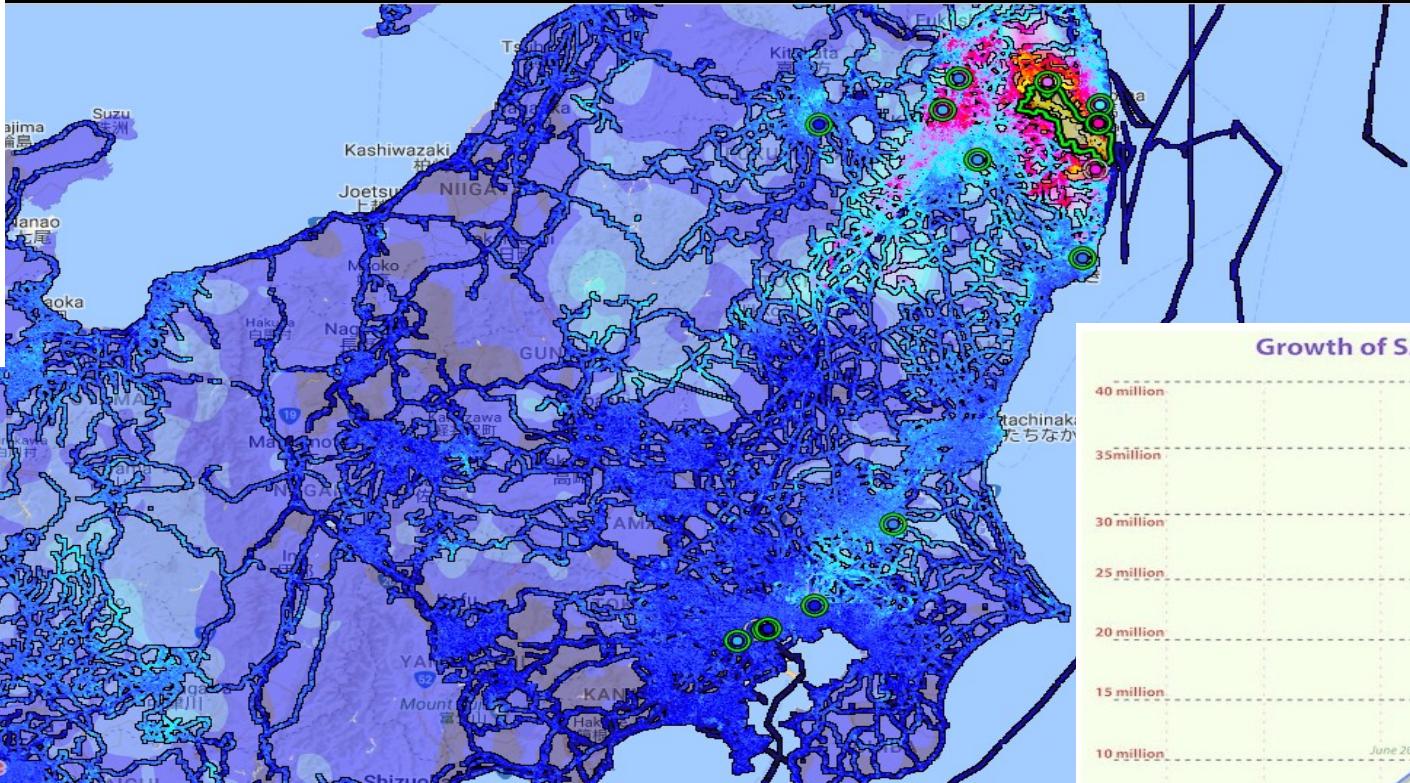
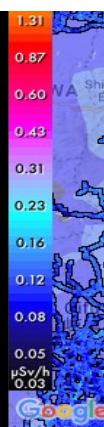
- Open does not kill market possibilities.
- Open as another path after academia (sparkfun, Adafruit, farmbot)

# Scientific equipment: is open better?

Build your own  
bGeigie Nano



KIT AVAILABLE NOW



# Companies & non-profits developing OS Hardware



WaterScope

Prometheus Science



NEURO TINKER



OPENBCI

OPENROV



Kithub

Sanworks



IO Rodeo

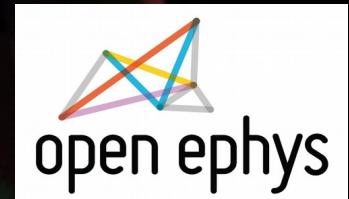
Smart Lab Technology



opentrons



seeedstudio  
Open Hardware Facilitator

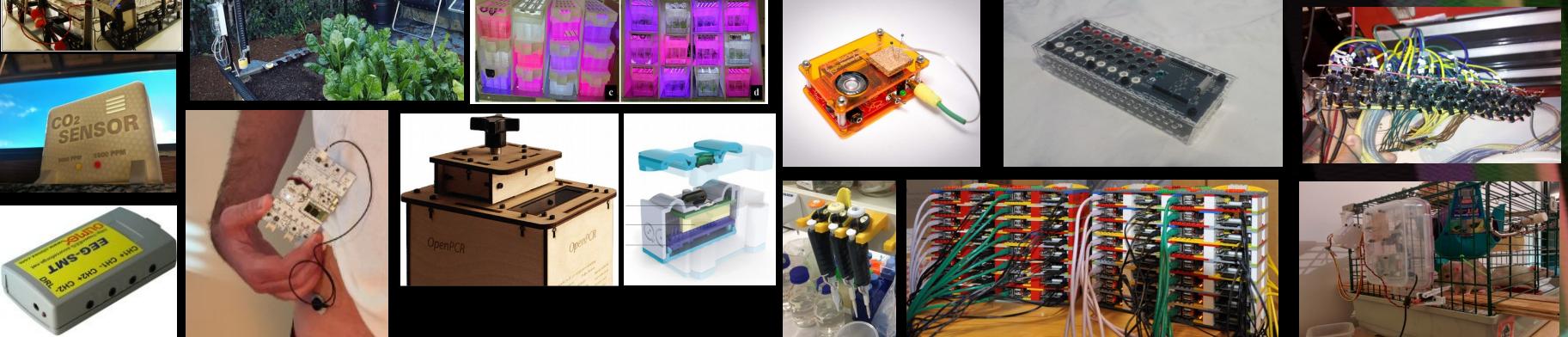
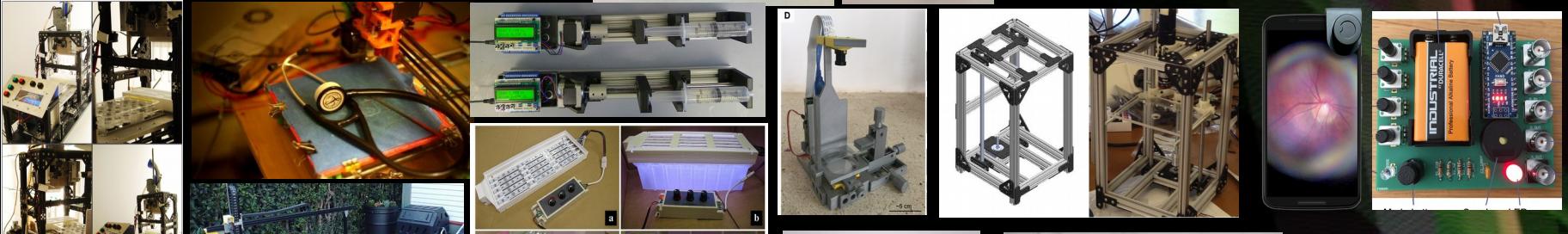
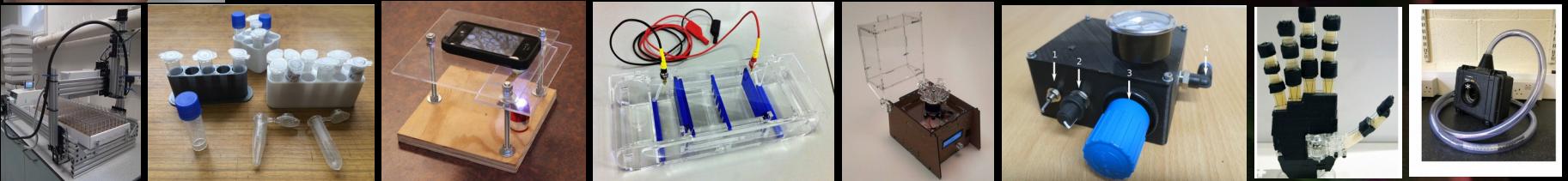
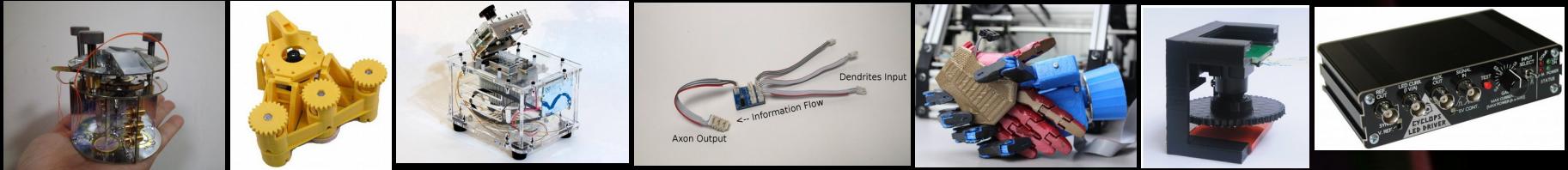


Sam and Tom  
industries



SAFECAST





# OS Hardware: Living in the “Cambrian explosion”

- Wikipedia >70 projects (only commercial level/big projects)
- In these slides at least another 36
- Many, MANY more in repositories online
- OS tools to create hardware are getting better and easier
- Software
- Fast prototyping
- Lower price for manufacturing
- Internet infrastructure
- Sharing videos, tutorials, documentation
- Some companies applying OS business models are >5 years old.

# OS in research and education

- “Traditional systems:
  - Expensive (fluoresc. Scope >5000€)
  - One supplier commitment
  - Hard to fix/customize/upgrade
  - One per lab/classroom
  - Costly calibrations
  - Bugs hard to spot
  - Fixed, one size (has to) fit all
- OS systems
  - Affordable (fluoresc. Scope <250€)
  - Buy parts from anywhere
  - Know your tools from inside out
  - Many per lab/classroom
  - Calibrate before every experiment
  - Bugs are easier to spot
  - Adaptable to local realities

# PLOS Open Source toolkit

 PLOS JOURNALS ▾



## Open Source Toolkit

A global forum for open source hardware and software research and applications

About the Editors

Curated collection of papers:  
- Open Source Software  
- Open Source Hardware

Editors:  
Jenny, Yo, Nikoleta, Tom and Andre

# Build following demand



- Projects normally start with a local need:
  - one lab, in one department, inside one institution...
- What if we could map the needs researchers have?
  - And build OS Hardware based on that demand?
    - Online survey <http://bit.ly/BFOSH> Please share!
    - Landing page: <https://fosh-following-demand.github.io/en/home>
    - Repos: <https://github.com/FOSH-following-demand>

Contributions and suggestions are welcome!!

# GOSH community

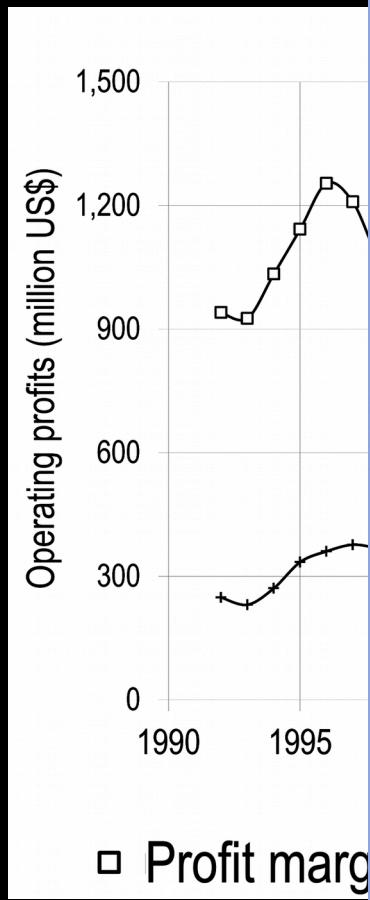


- Make open source hardware the norm for science by 2025

# Repositories and online communities

- GOSH (<http://openhardware.science/>)
- PLOS Channel (<https://channels.plos.org/open-source-toolkit>)
- Open Neuroscience ([openeuroscience.com](http://openeuroscience.com))
- Open Plant Science (<http://openplant.science/>)
- Hackaday.io ([hackaday.io](http://hackaday.io))
- CTA - UFGRS (<http://cta.if.ufrgs.br/capa/>)
- Instructables ([instructables.com](http://instructables.com))
- Journal of open Hardware (<https://openhardware.metajnl.com/>)
- HardwareX (<https://www.journals.elsevier.com/hardwarex>)
- Appropedia ([http://www.appropedia.org/Welcome\\_to\\_Appropedia](http://www.appropedia.org/Welcome_to_Appropedia))
- Hackteria ([hackteria.org](http://hackteria.org))
- Open Behaviour (<http://openbehavior.com/>)

- Thank you!
  - Let's open for questions/comments and discussion.
  - [bit.ly/OHDelft](https://bit.ly/OHDelft)
  - t: [chagas\\_am](#)
  - e: [andremaia.chagas@gmail.com](mailto:andremaia.chagas@gmail.com)



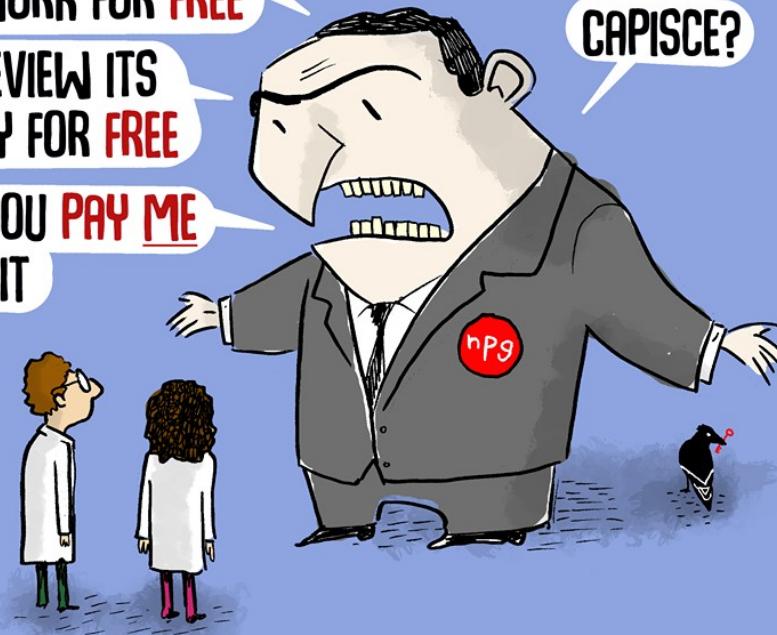
# LOOK YOU NERDS IT'S A SIMPLE BUSINESS MODEL

YOU HAND ME THE FRUIT  
OF YOUR WORK FOR **FREE**

YOU REVIEW ITS  
QUALITY FOR **FREE**

AND THEN YOU **PAY ME**  
TO ACCESS IT

CAPISCE?



PEDROMICS

ake a lot of PROFIT:  
d not create!  
or with public money  
(Germany):  
5000 Euros

# SI: Impact

New study: Research impact of paywalled versus open access papers

Study on 3.3 million papers and 35 million citations

-Open access papers:  
- 52% more citations