

# NEUROSCIENCE & THE OPEN HARDWARE STORY

**Royhaan O. Folarin** *PhD FASLN*

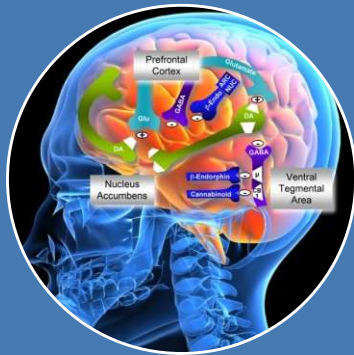
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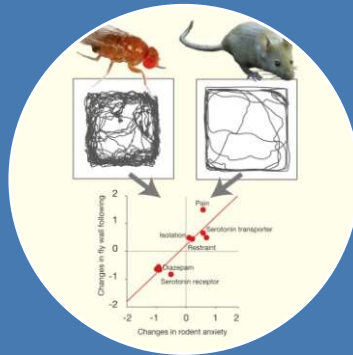


Pretoria, South Africa,  
December, 2022

# Pleasure Meeting You...



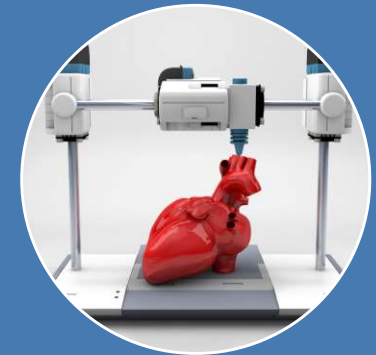
**Biopsychiatry &  
Neuroregeneration**



**Mice & *Drosophila*  
Models**



**Phytotherapeutic  
Investigations**



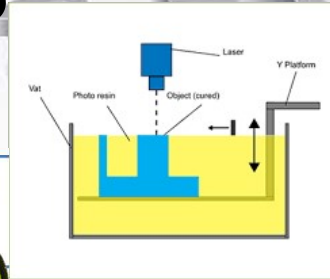
**Free & Open Source  
Labware  
(3D Printing)**

**Things I do...**

# Seven 3D Printing categories

## Vat polymerization

- liquid photopolymer (resin) cured by light



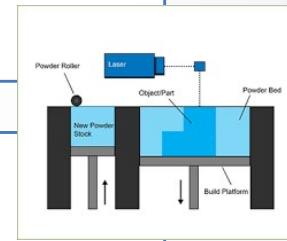
## Material extrusion:

- molten thermoplastic (filament) deposited through a heated nozzle



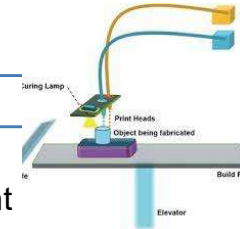
## Powder bed fusion (PBF)

- powder particles fused by a high-energy source



## Material jetting

- droplets of liquid photosensitive fusing agent deposited on a powder bed and cured by light



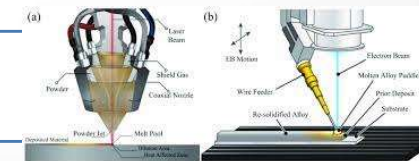
## Binder jetting

- droplets of liquid binding agent deposited on a bed of granulated materials, which are later sintered together



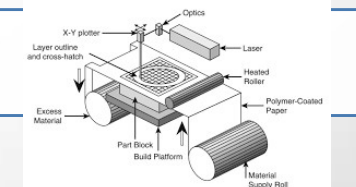
## Direct energy deposition

- molten metal simultaneously deposited and fused



## Sheet lamination

- individual sheets of material cut to shape and laminated together



# FDM System

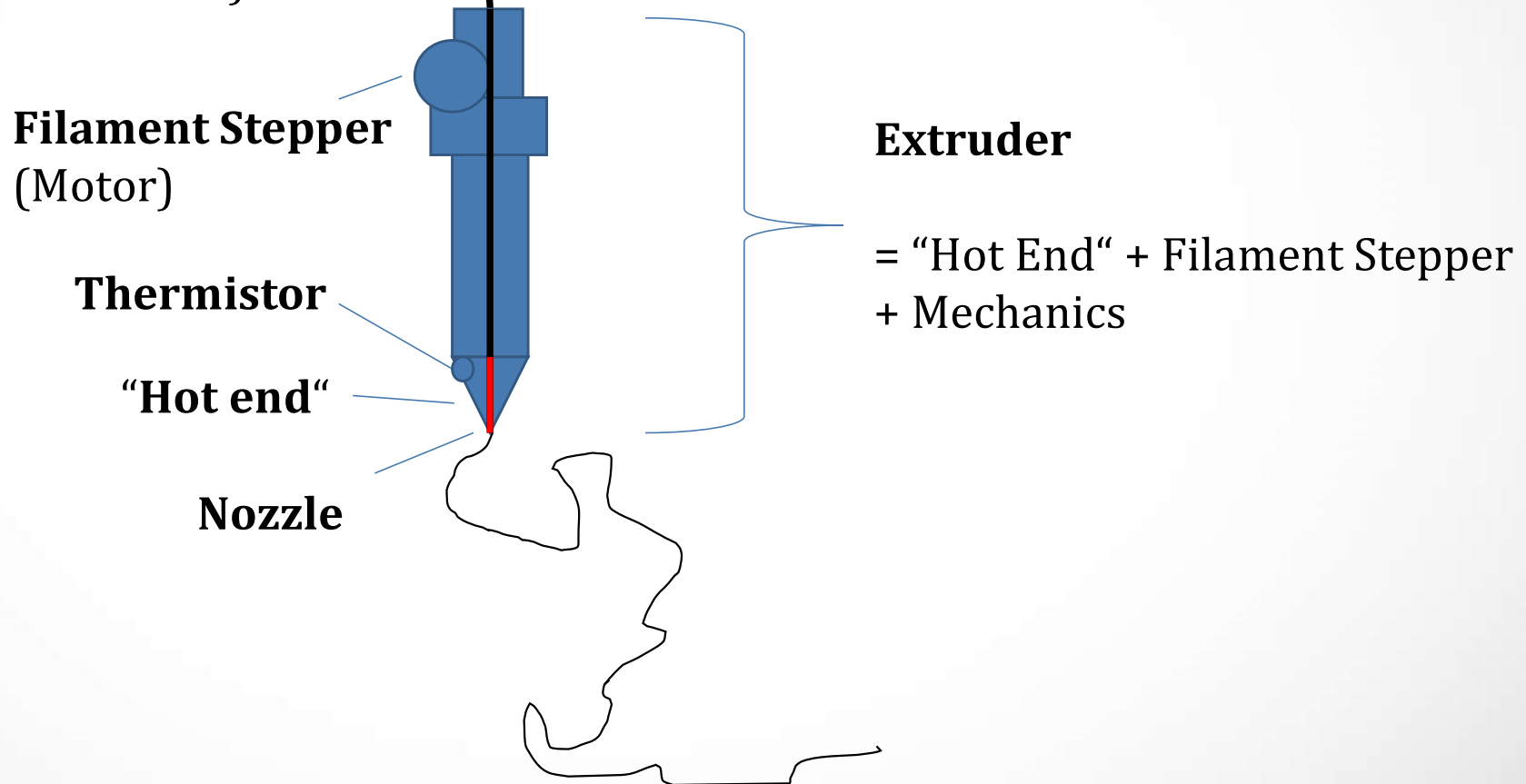


3D Printing in Neuroscience...

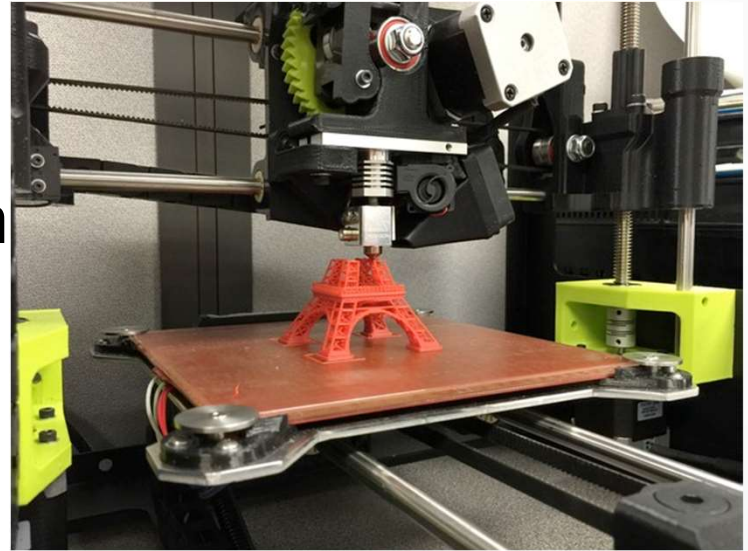
# Basic principle



Filament (ABS in this case)  
1.75 mm  
(other printers use "PLA")



# Some Applications of 3D Printing in **Neuroscience**



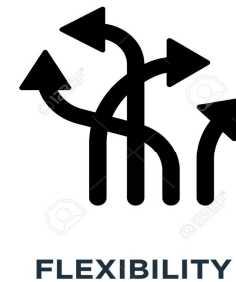
# Diverse Research Questions



3D Printing in Neuroscience...

# Common Research Denominator

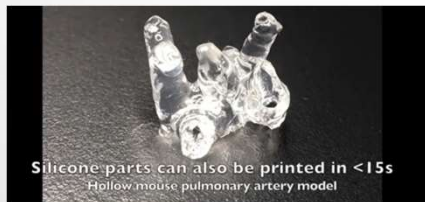
- Things companies won't readily make for you,
- To make common technology more flexible,
- High detail of customized design
- To make crucial instrumentation cheaper and more accessible



# Limitless Printing Materials



CS429660



3D Printing in Neuroscience...

**IT'S NOT JUST PLASTIC ANYMORE!**  
*A Sampling of 3D Printing Materials*

**METAL**

3D printing with metals differs from using plastic, and it takes a couple of different forms. One popular process, direct metal laser sintering (DMLS), involves melting metal powders with a laser and layering them together. The process can be used to print anything from jewelry to tools, and even parts for aircraft.

**CHOCOLATE**

Printing with chocolate is clearly an idea whose time has come, as demonstrated by the number of companies that are getting into the 3D chocolate printing game – including, naturally, Hershey's.

**BIO-INK**

The ability to print living tissue has radical implications for medicine. Recently, engineers at Harvard developed a novel combination of bio-inks that can be used to print tissue that mimics human tissue, complete with blood vessels.

**BONE**

3D printed "bone" has already been used to replace 75 percent of a man's skull using plastic, and to replace a vertebra in a 12-year-old boy with a titanium implant. More impressively, a research team at Washington State University recently demonstrated that 3D printed bone can be made out of actual bone – or material very close to it.

**SANDSTONE**

Unlike 3D printing with plastic, sandstone offers a rich and vibrant array of colors, making it an increasingly popular choice for action figures.

**GLASS**

3D printing with glass involves the use of recycled glass powder, which is spread out on a bed and sprayed with a binding agent. Why not turn some old beer bottles into jewelry?

**MEDICATION**

By printing capsules that can be swallowed, 3D printers could allow pharmacies to manufacture your medicine on the premises, and to create custom dosages based on a patient's needs.

**SKIN**

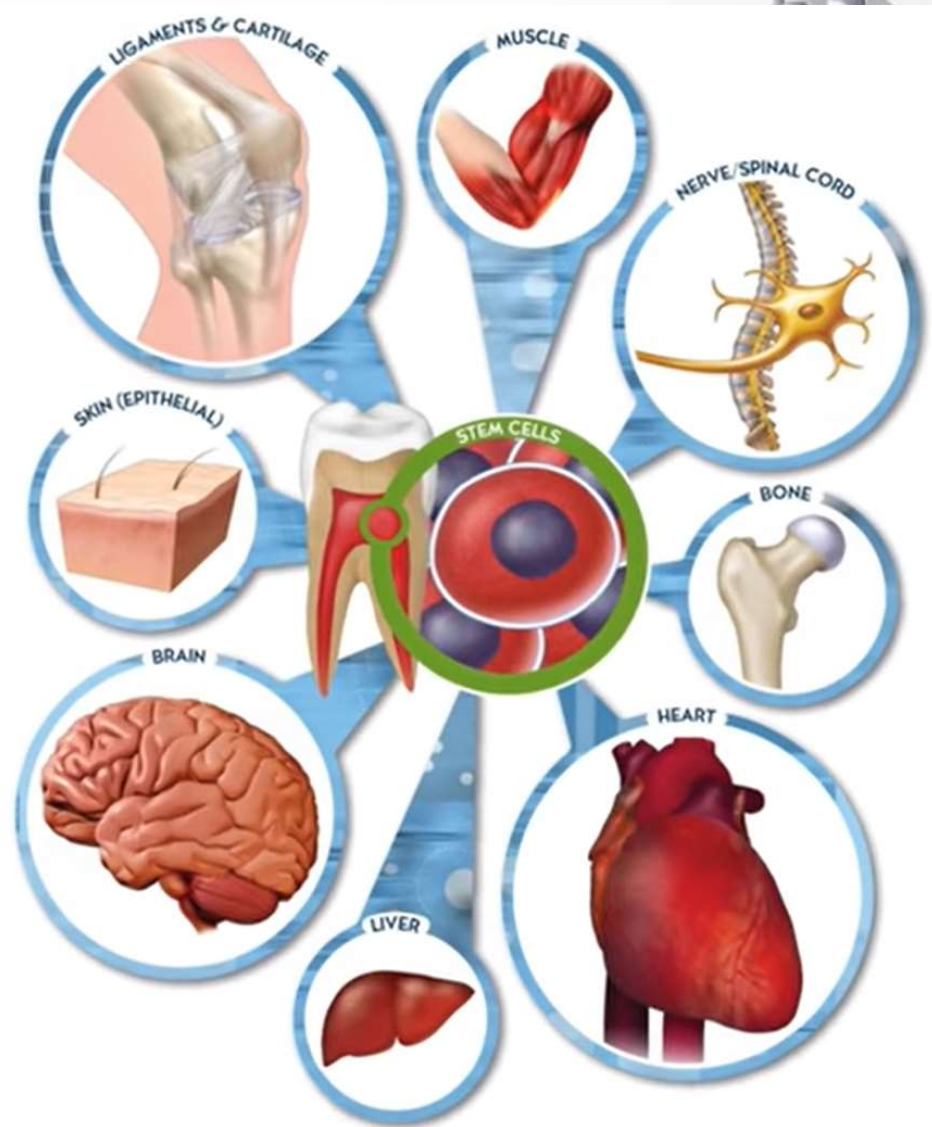
Soon, burn victims and others in need of skin grafts could have new skin printed out for them. The US Army is close to entering human trials to test out 3D printed skin being developed at Wake Forest University's Institute for Regenerative Medicine.

Sources: choicedge.com; money.cnn.com; solididea.com; movingbrands.com; seas.harvard.edu; gizmodo.com; euronews.com; shapeways.com; rt.com; motherboard.vice.com;

**BUSINESS INSIDER**

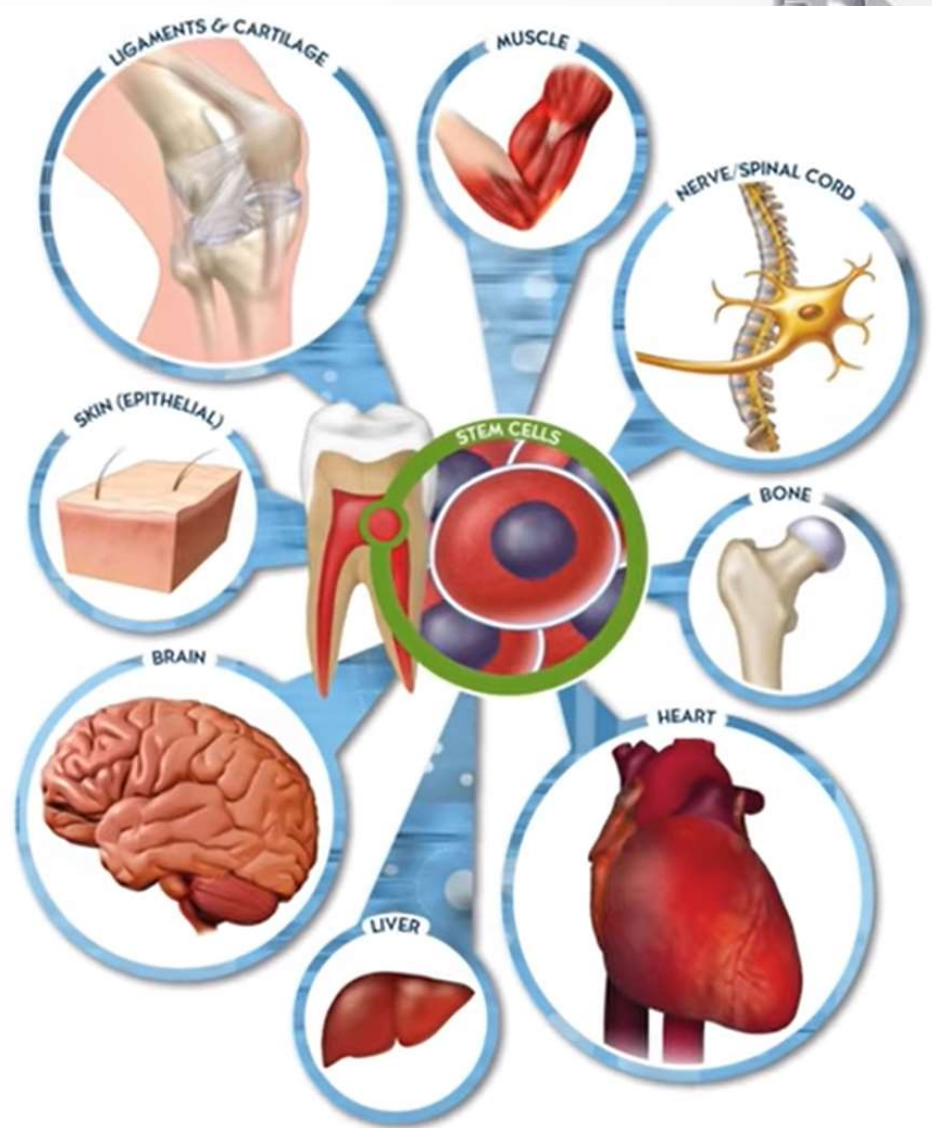
# Stem Cells

- Pluripotent elements
- The body's raw materials
- Isolation & production help understand human cell function
- Regeneration in disease and trauma



# 3D-Printing Stem Cells

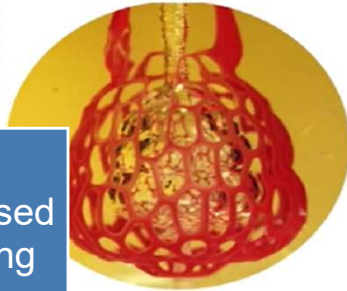
- Assembly of neural 3D networks
- Well-defined duplicatable 3D scaffold, capable of imitating brain activity
- Test the modulatory effects of pharmacological and toxicological compounds



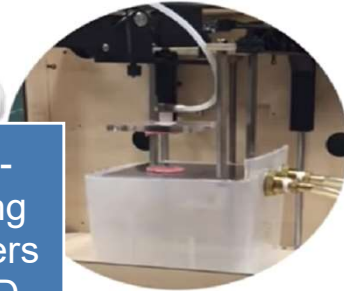
# 3D Printing Approaches to Stem Cells



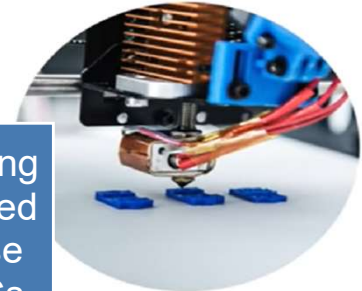
Dye-based Layering



Flash-freezing 2D layers into 3D



Populating 3D-printed cellulose with SCs



Ultrasound corraling of cell placement



Integrating live cells into bionic prosthetics



## METHODS article

Front. Syst. Neurosci., 13 May 2013  
<https://doi.org/10.3389/fnsys.2013.00008>

# The flexDrive: an ultra-light implant for optical control and highly parallel chronic recording of neuronal ensembles in freely moving mice

Jakob Voigts<sup>1,2</sup>, Joshua H. Siegle<sup>1,2</sup>, Dominique L. Pritchett<sup>2,3</sup> and Christopher I. Moore<sup>2\*</sup>

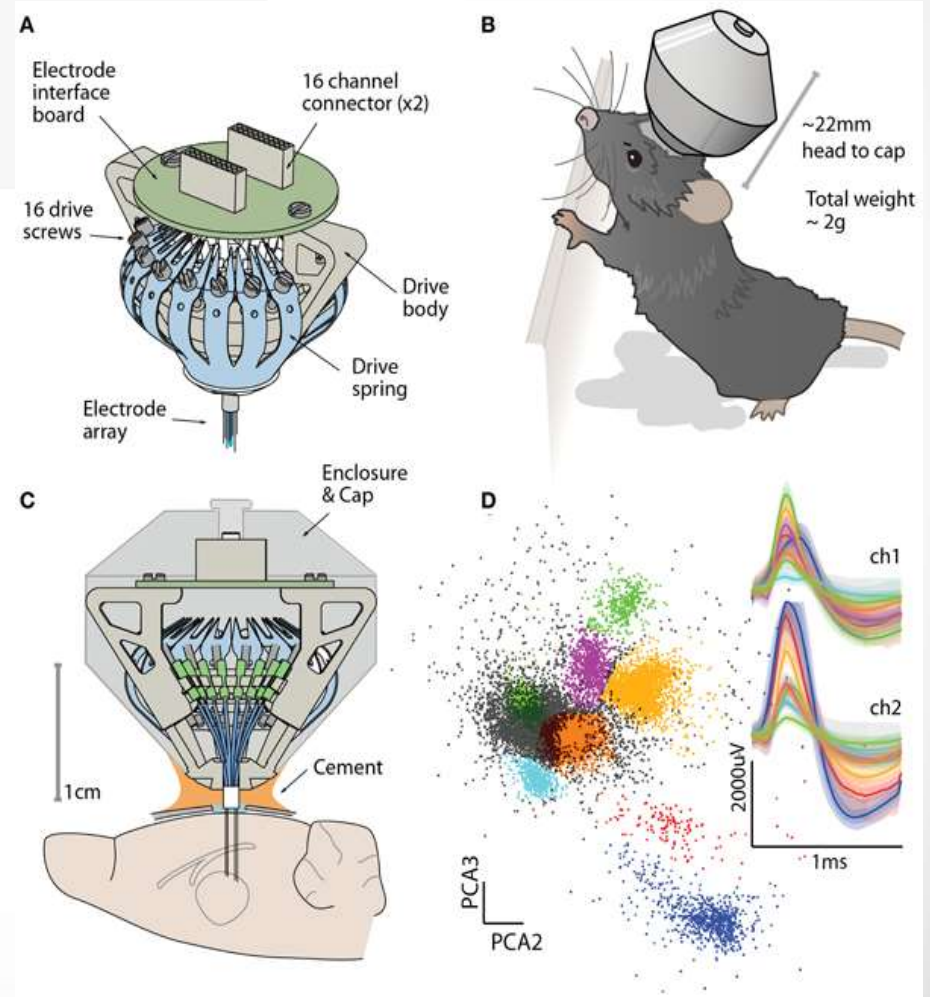
<sup>1</sup> Department of Brain and Cognitive Sciences, Massachusetts Institute of Technology, Cambridge, MA, USA

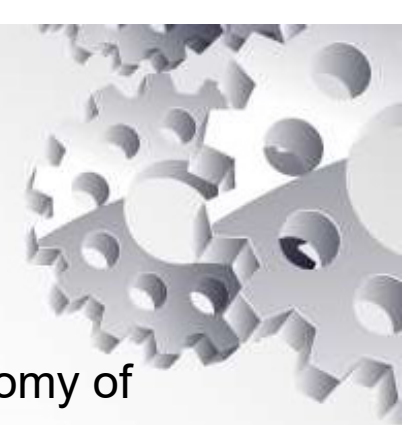
<sup>2</sup> Department of Neuroscience, Brown University, Providence, RI, USA

<sup>3</sup> Center for Neuroscience, Boston University, Boston, MA, USA

## Flexdrive

- Voigts et al. (2013)
- Spring-based drive mechanism that reduces implant weight and complexity
- For **optical control** & highly parallel **chronic recording of neuronal ensembles** in freely moving mice
- Ultra-light implant
  - 16 electrodes, 64 channels, weighs ~2 g





## 3D printing and modelling of customized implants and surgical guides for non-human primates

Xing Chen <sup>1,2,3,4</sup>, Jessy K. Possel <sup>3</sup>, Catherine Wacongne <sup>3</sup>, Anne F. van Ham <sup>2</sup>, P. Christiaan Klink <sup>2,3,4,5,6</sup>, Pieter R. Roelfsema <sup>3,4,6</sup>

Show more

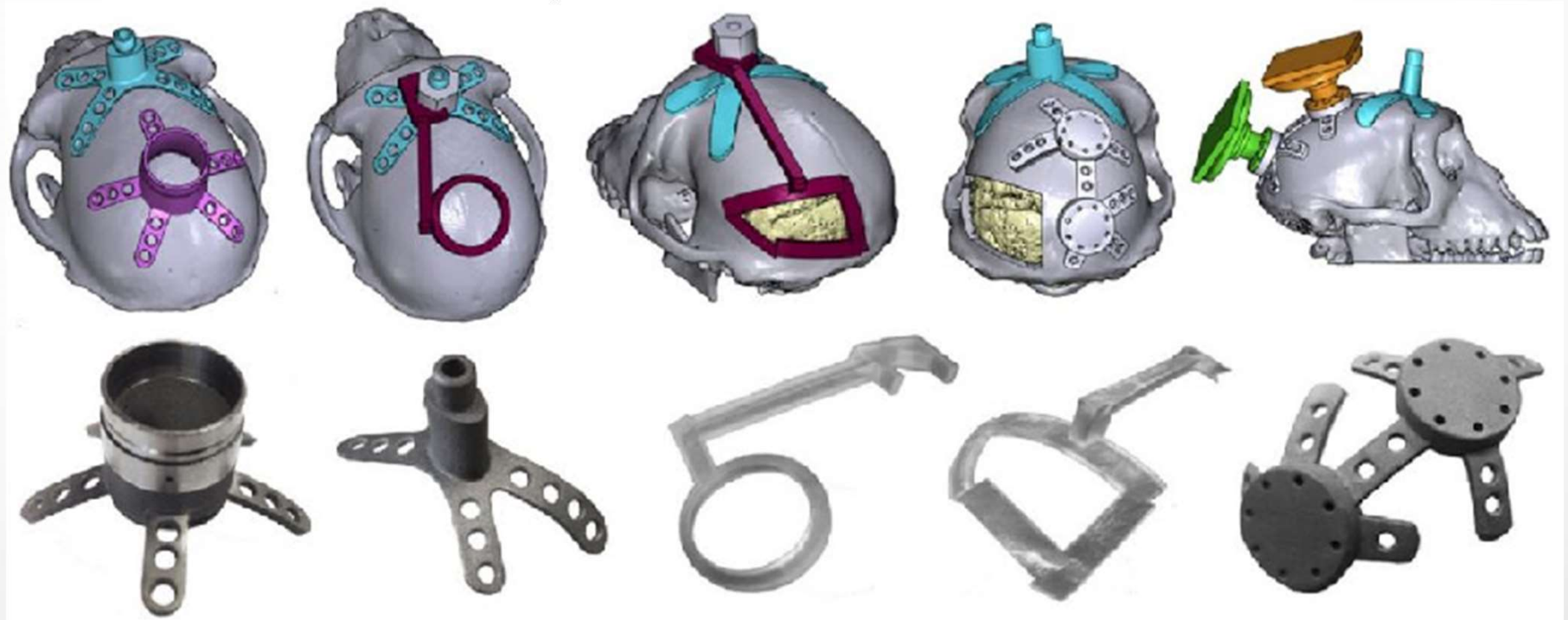
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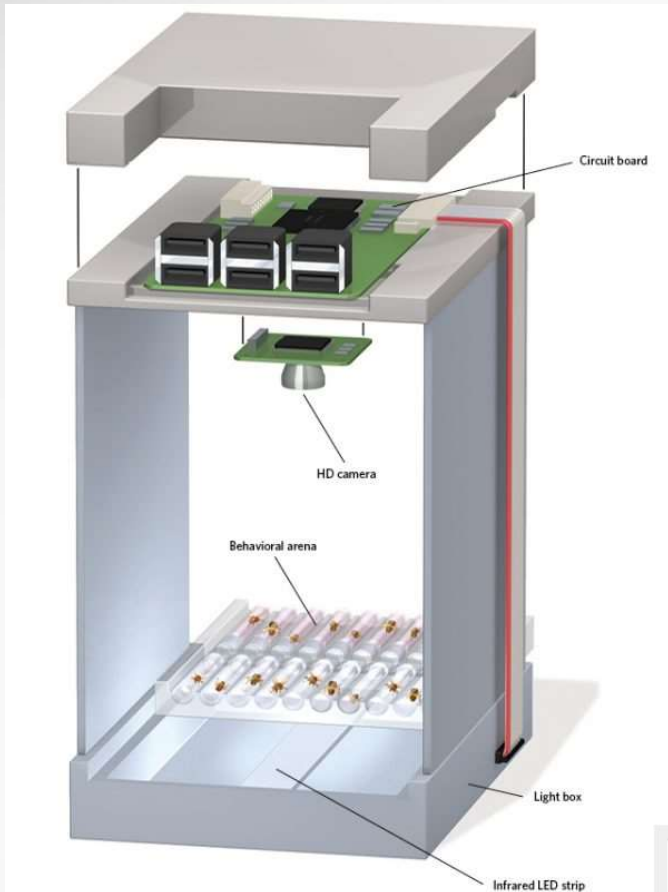
<https://doi.org/10.1016/j.jneumeth.2017.05.013>  
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# Customized Cranial Implants

- Chen et al. (2017)
- Titanium 3D prints Tailored to the anatomy of individual animals
- for primate electrophysiology
- plastic prototyping,
- titanium final prints





# 3D-printed Ethoscope

- Geissman et al. (2017)
- Behavior quantification box for flies
- 5 to 8 times less expensive than commercial alternatives

**PLOS BIOLOGY**

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## Ethoscopes: An open platform for high-throughput *ethomics*

Quentin Geissmann, Luis Garcia Rodriguez, Esteban J. Beckwith, Alice S. French, Arian R. Jamasb, Giorgio F. Gilestro 

Published: October 19, 2017 • <https://doi.org/10.1371/journal.pbio.2003026>

[See the preprint](#)

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## 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*

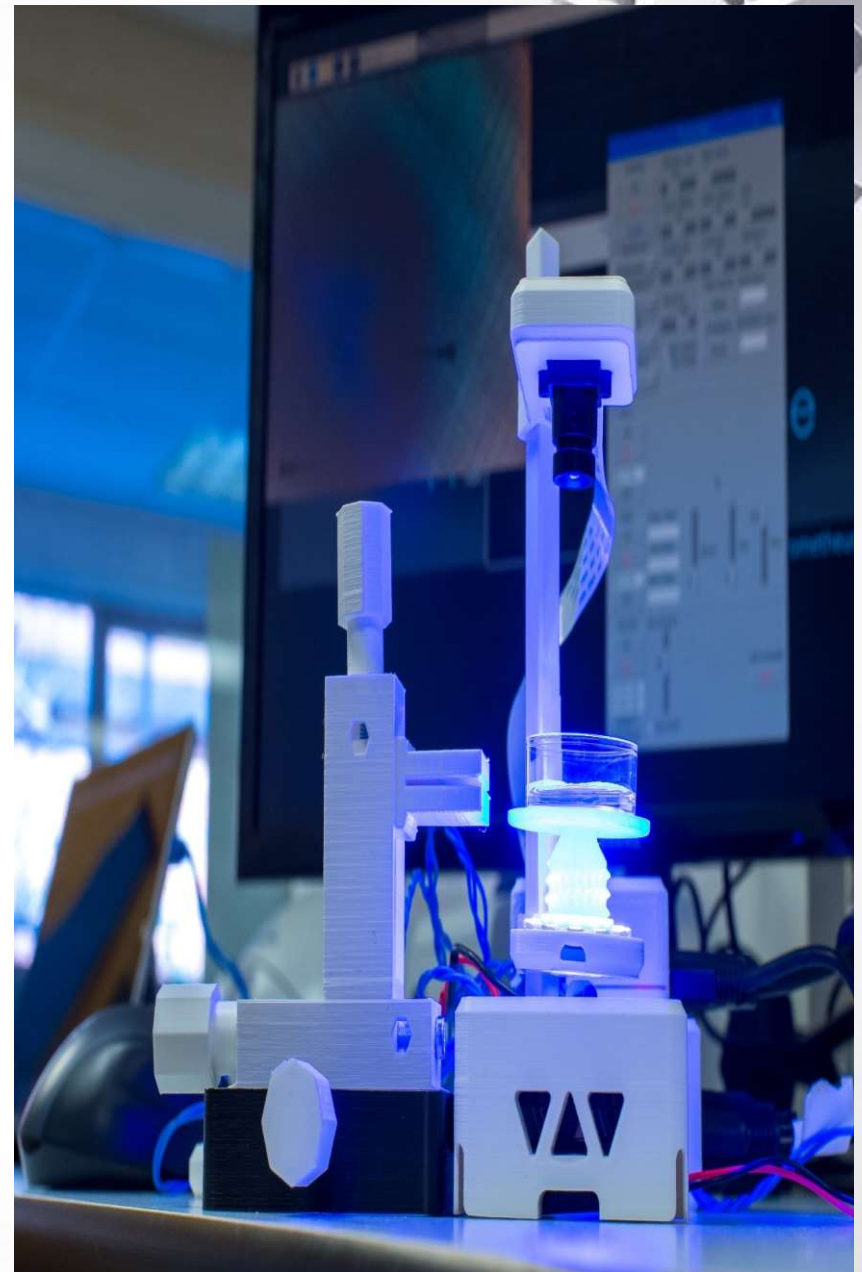
Andre Maia Chagas<sup>1,2,3,4\*</sup>, Lucia L. Prieto-Godino<sup>3,5</sup>, Aristides B. Arrenberg<sup>1,6</sup>, Tom Baden<sup>1,3,4,7\*</sup>

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 TRReND 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

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# Labwares

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**PLOS** BIOLOGY  
FIFTEENTH ANNIVERSARY

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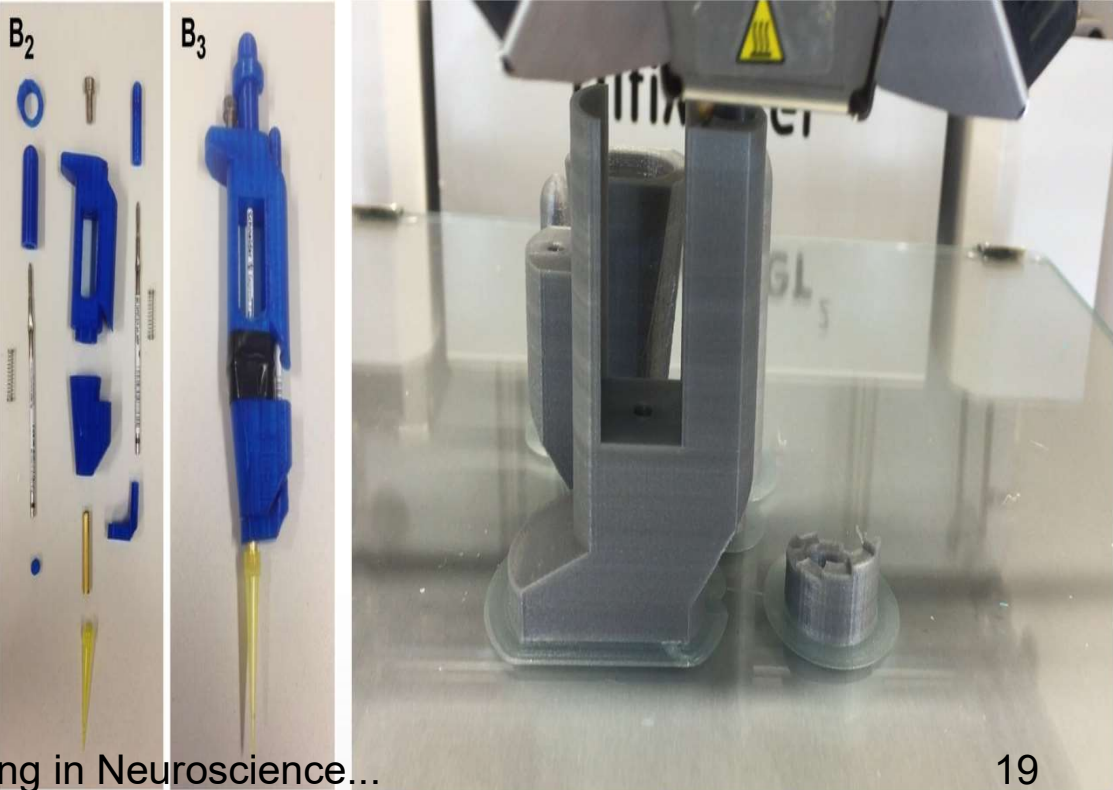
## Open Labware: 3-D Printing Your Own Lab Equipment

Tom Baden , Andre Maia Chagas, Greg Gage, Timothy Marzullo, Lucia L. Prieto-Godino, Thomas Euler

Published: March 20, 2015 • <https://doi.org/10.1371/journal.pbio.1002086>

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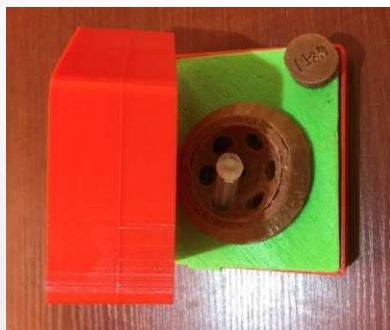
# Open Design 3D-Printable Adjustable Micropipette that Meets the ISO Standard for Accuracy

Martin D. Brennan , Fahad F. Bokhari  and David T. Eddington \* 

Department of Bioengineering, University of Illinois at Chicago, Chicago, IL 60607, USA



# 3D-Printed Centrifuge, from NPTRL



3D F

COMMUNITY PAGE

## Bypassing shortages of personal protective equipment in low-income settings using local production and open source tools

Royhaan Olamide Folarin<sup>1,2\*</sup>, Mahmoud Bukar Maina<sup>2,3,4</sup>, Abisola Kaosara Akinbo<sup>1</sup>, Tamramat Iyabo Runsewe-Abiodun<sup>5</sup>, Omobola Abioye Ogundahunsi<sup>6</sup>, Ahmed Adebowale Adedeji<sup>7\*</sup>, Andre Maia Chagas<sup>2,3,4\*</sup>

**1** Department of Anatomy, Olabisi Onabanjo University, Sagamu (Ogun State), Nigeria, **2** TRenD in Africa, Brighton, United Kingdom, **3** Sussex Neuroscience, School of Life Sciences, University of Sussex, Brighton, United Kingdom, **4** Department of Anatomy, Olabisi Onabanjo University, Sagamu (Ogun State), Nigeria, **5** Department of Anatomy, Olabisi Onabanjo University, Sagamu (Ogun State), Nigeria, **6** Department of Anatomy, Olabisi Onabanjo University, Sagamu (Ogun State), Nigeria, **7** Department of Anatomy, Olabisi Onabanjo University, Sagamu (Ogun State), Nigeria

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### OPEN ACCESS

**Citation:** Folarin RO, Maina MB, Akinbo AK, Runsewe-Abiodun TI, Ogundahunsi OA, Adedeji AA, et al. (2022) Bypassing shortages of personal protective equipment in low-income settings using local production and open source tools. PLoS Biol 20(5): e3001658. <https://doi.org/10.1371/journal.pbio.3001658>

**Published:** May 20, 2022

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**Funding:** The author(s) received no specific funding for this work.

**Competing interests:** The authors have declared that no competing interests exist.

**Abbreviations:** COVID-19, Coronavirus Disease 2019; FOSH, free and open-source hardware; PETG, polyethylene terephthalate glycol; PLA, polylactic acid; PPE, personal protective equipment.



Free and open-sourced masks proven by COVID-19

of locally solving, as shields and during the

### Body text

As the infectious disease burden in health systems is increasing, and so is the demand for personal protective equipment (PPE) in low-income settings, where PPE is reportedly in short supply and often sold at the highest bidder [2]. To help tackle this issue, alternative means of achieving PPE production and distribution were explored, including the use of 3D-Printed Nose masks (inset shows packaged & sealed nose masks with filters)

personal protective equipment (PPE) such as surgical gowns [1], while others have reported the use of locally produced PPE [2].



Harnessing the underlying principles...

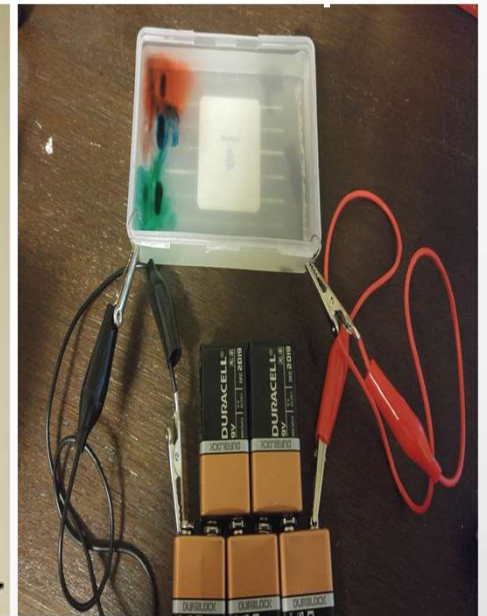


Incubate

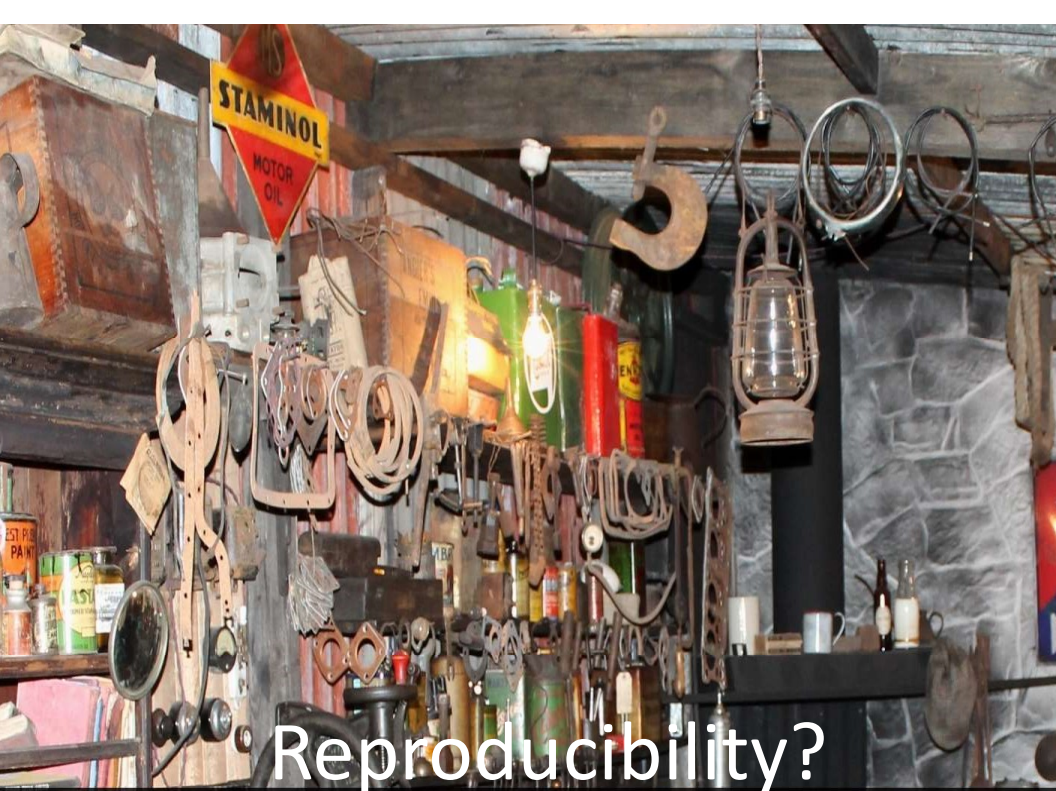
Spin

Heat+Cool

Zap...



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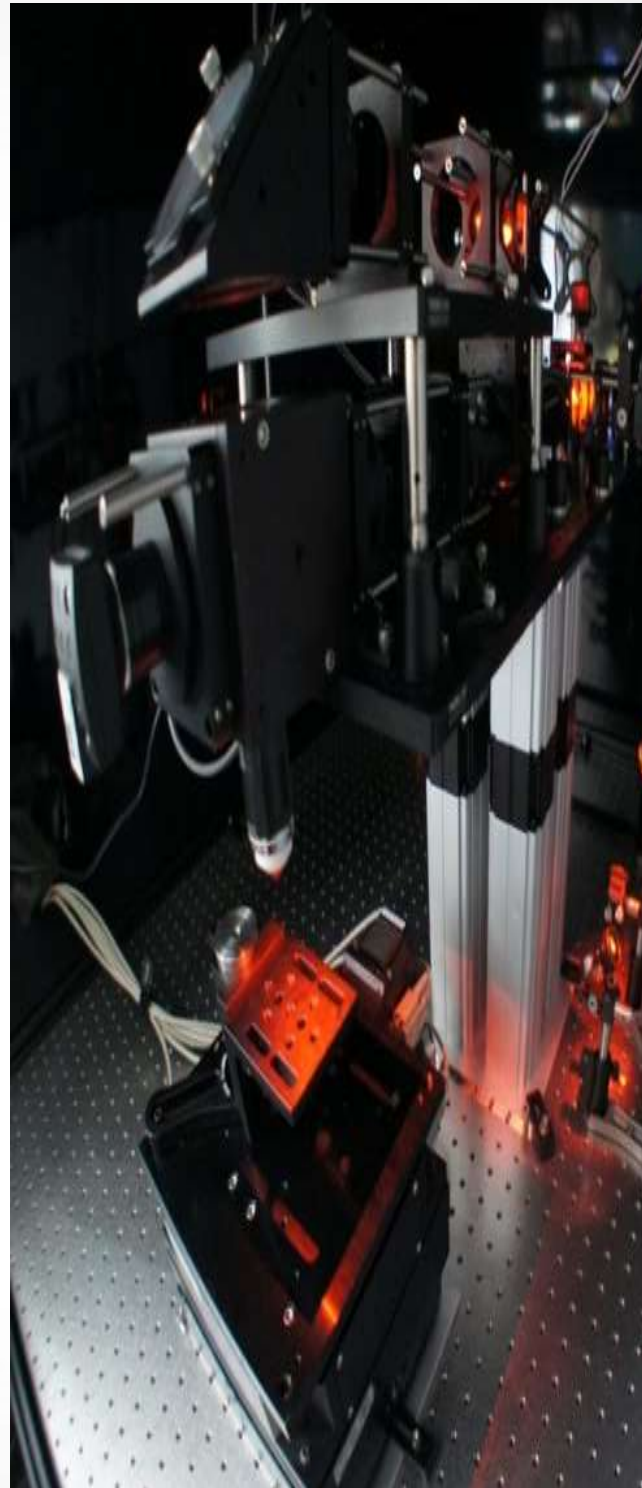


Reproducibility?



3D Printing in Neuroscience...

# 2-photon microscope



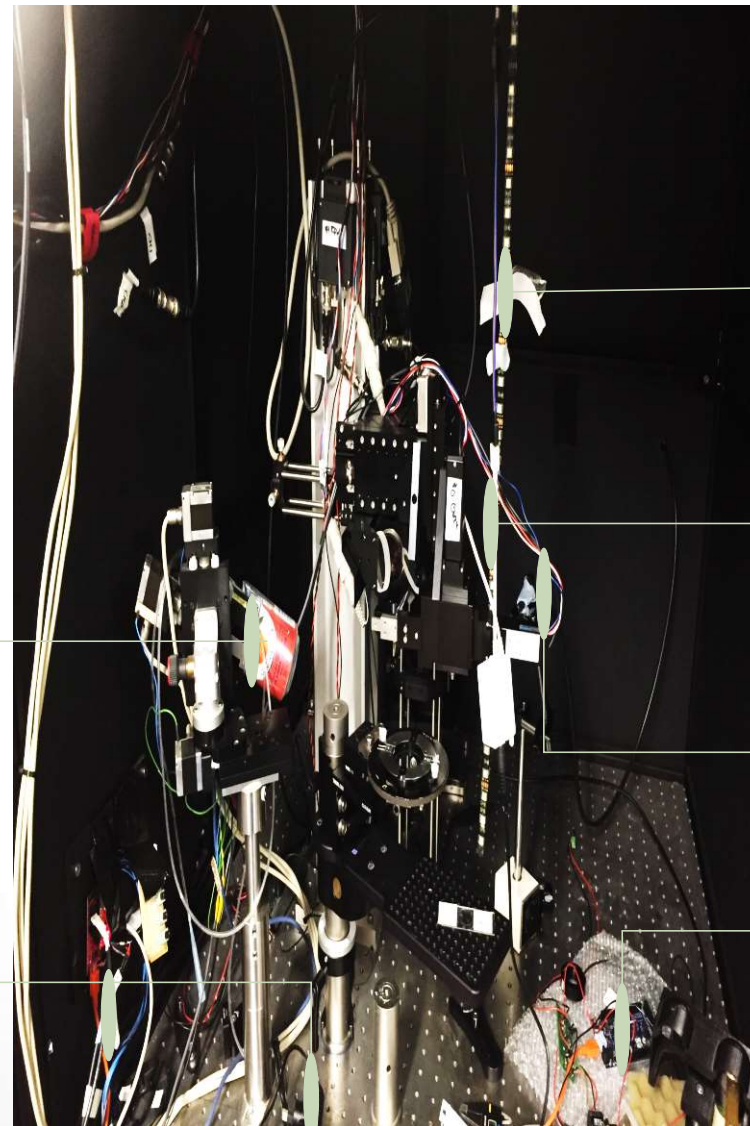
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# Complicated = Simple \* n



Soda  
can

Phone-  
charger



Tape

LED  
strips

Putty

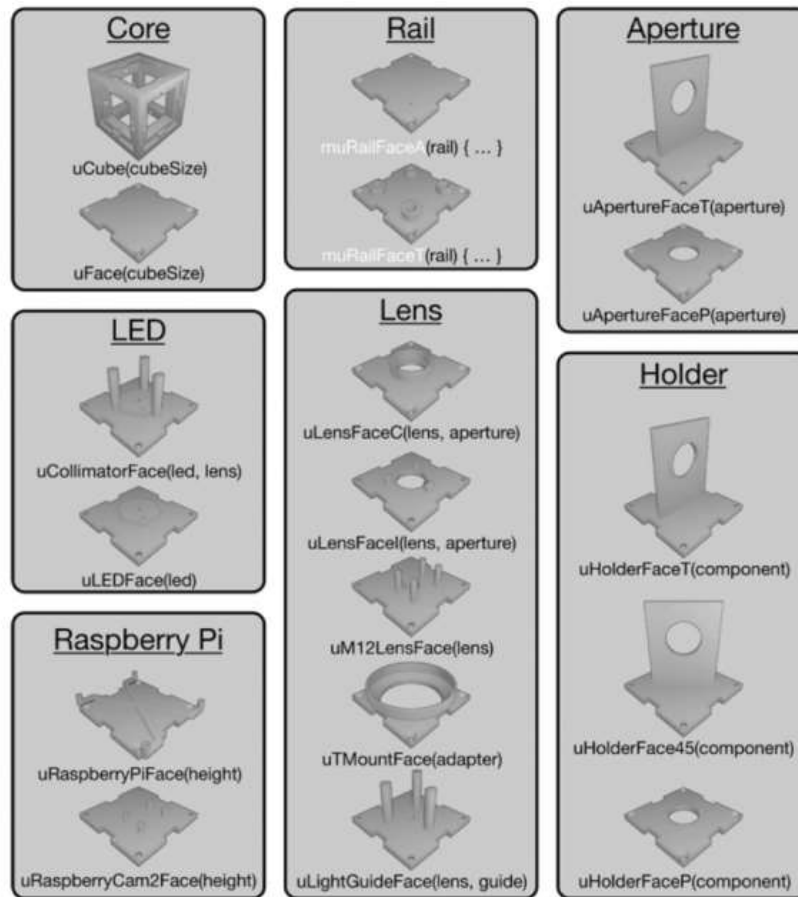
Micro-  
controllers

3D Printing in Neuroscience...

HARDWARE METAPAPER

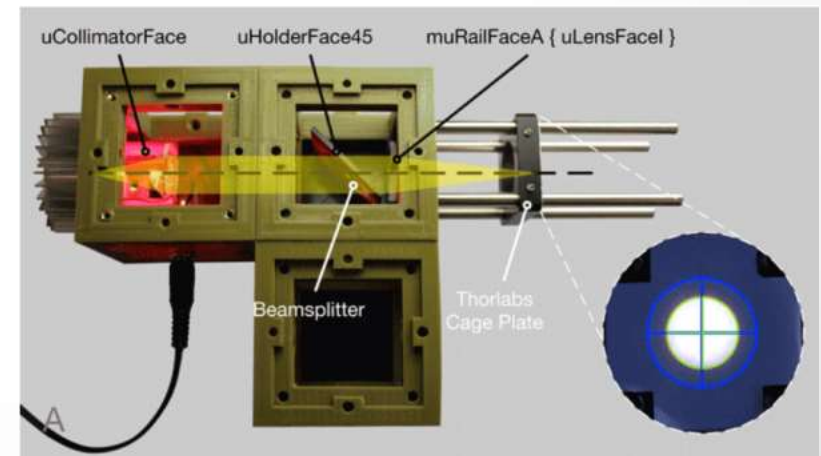
# $\mu$ Cube: A Framework for 3D Printable Optomechanics

Mihails Delmans and Jim Haseloff



## Optomechanics components

- Delmans and Haselhof (2018)
- $\mu$ Cube system Parts library
- easily adjust the dimensions
- metal is the material of choice



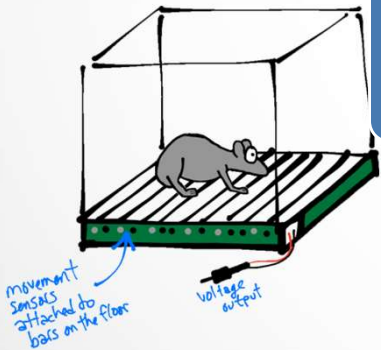
# Current Project

Neuropsychiatric Disorders (NPDs)

NPD Patients show Impaired Prepulse inhibition (PPI) (sensorimotor gating)

Mice Models of NPDs & the measurement of PPI

## Startle Reflex Apparatus

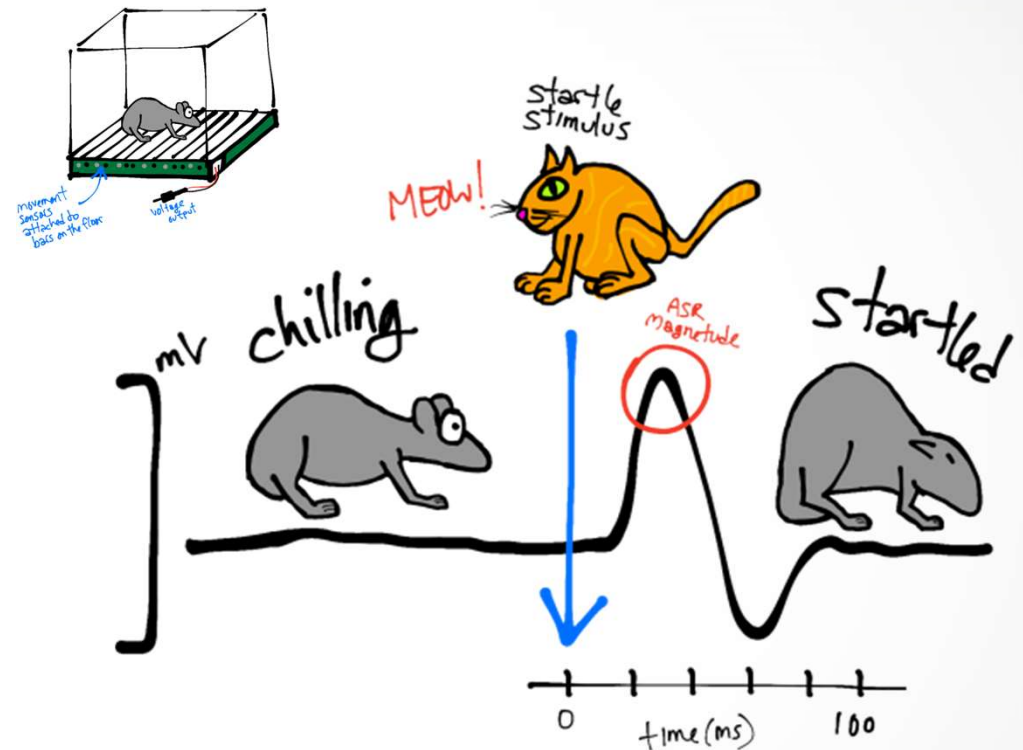


<https://conductscience.com/maze/acoustic-startle-response/>



# How it works

- Weak acoustic impulse before stronger **acoustic impulse**.
- Reactivity scores based on **timing** and **intensity** of the **body movement** during startle



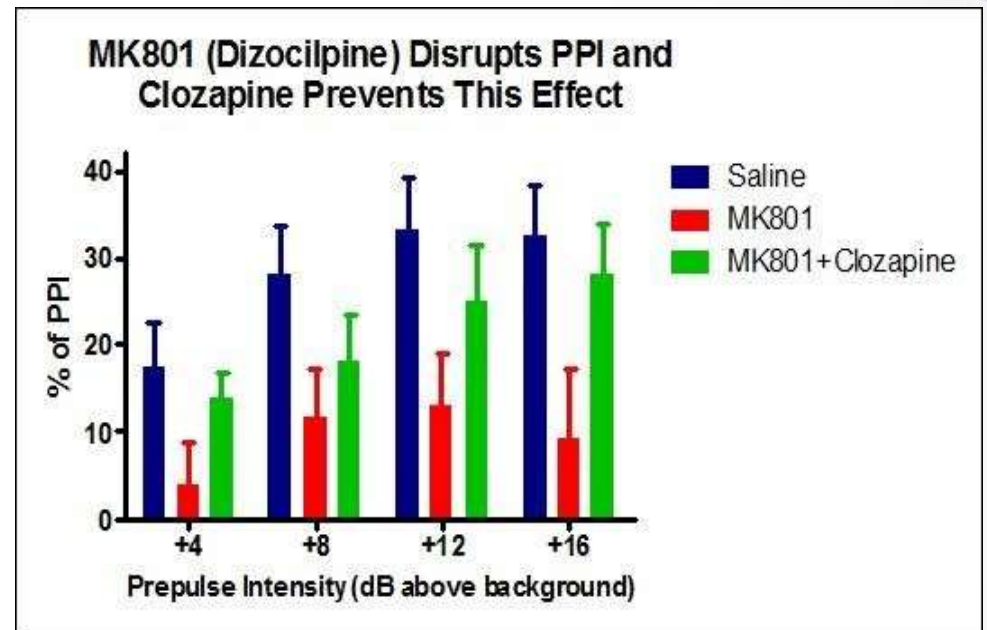
<https://conductscience.com/maze/acoustic-startle-response/>

# Users

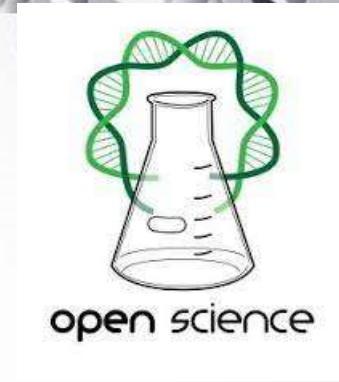
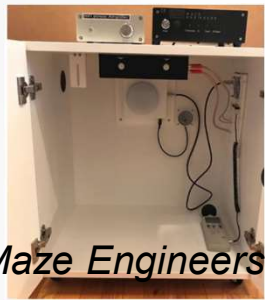
- Researchers who model neuropsychiatric disorders in



<https://speakingofresearch.com/2015/01/22/why-i-became-an-animal-technologist/>



<https://med.stanford.edu/sbfnl/services/bm/ep/pre-pulse.html>



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www.MazeEngineers.com  
DUNS #: 079187988

Date: November 7, 2022

Product number	Name	Price per unit	Quantity	Total	Shipping
5821	<b>Acoustic Startle reflex chamber, mouse</b> Speaker Transducer Shock Grid Sound Attenuation Chamber Grid holder, medium	\$7,990.00	1	\$7,990.00	
5827	<b>Conduct Software</b>	\$1,295.00	1	\$1,295.00	
				<b>\$8,356.50</b>	

# So,...

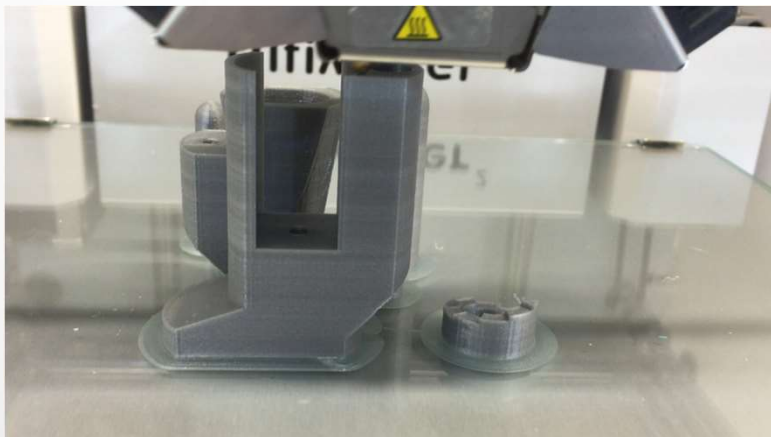
- What 1,2,3... things do you consider worthy of 3D-Printing in your research project?

thinking  right





A whole lot of needs on the continent ...



### Histology Laboratory Equipment

 <a href="#">SliceMaster Sample Preparation Tools</a>	 <a href="#">Paraffin Dispenser</a>	 <a href="#">Manual Rotary Microtome</a>	 <a href="#">Paraffin Block Trimmer +</a>
 <a href="#">LED Tissue Flootation Water Bath &amp; Slide Dryer Combo</a>	 <a href="#">Tissue Flootation Bath</a>	 <a href="#">Tissue Flootation Water Bath</a>	 <a href="#">Small Slide Warmers</a>
 <a href="#">Large Slide Warmers</a>	 <a href="#">Step Up™ Slide Warmer for 40 Slides</a>	 <a href="#">Mini Section/Slide Dryers</a>	 <a href="#">IHC Slide Manager &amp; Slide Dryer Combo</a>
 <a href="#">PELCO BioWave® Pro+</a>	 <a href="#">Convection Ovens</a>	 <a href="#">Stereo Microscopes</a>	 <a href="#">Biological Microscopes</a>
 <a href="#">MagFuge® Centrifuge &amp; Stirrer</a>	 <a href="#">Magnetic Induction Stirrers</a>	 <a href="#">Mini Centrifuges</a>	 <a href="#">Vortexer</a>
 <a href="#">NEW nuVaClean™ UV Pipette Cartridge</a>	 <a href="#">NEW nuVaClean™ UV Pipette Cartridge</a>		



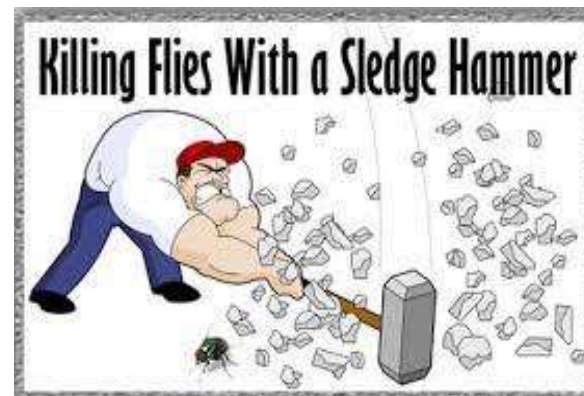
# Just before you go...



# When to Use 3D Printing

- Relatively low quantities (1-50)
  - Otherwise, start exploring alternatives
- Complex geometrical design that is critical to part's function
- Not killing a fly with a hammer
- Aligning technology's peculiarities with your most important requirements

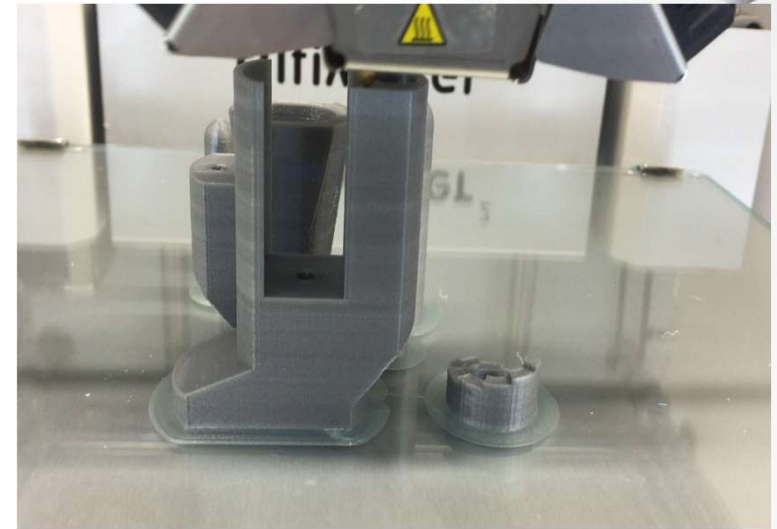
**Yes, BUT...**



# So,...



- Assess your needs effectively
- Imagine your solution
- Clarify your goals
- Determine your desired materials
- Acquire a reliable and non-technical printing method/machine
  - Fused deposition modeling (FDM)  
most affordable & ideal for beginners
  - Makerbot, Ultimaker or Creality Ender
- Get a design that is sound and grounded in the limitations of the 3D printing process.



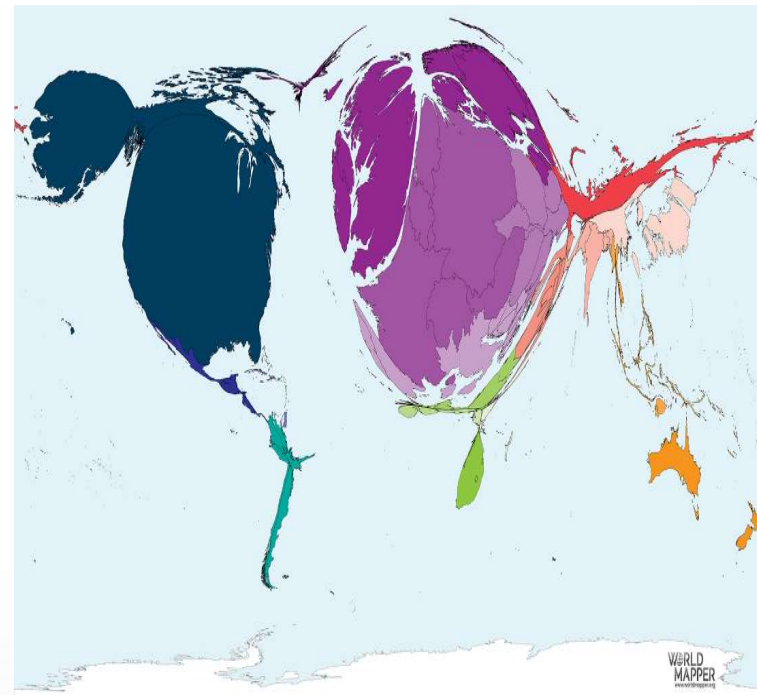
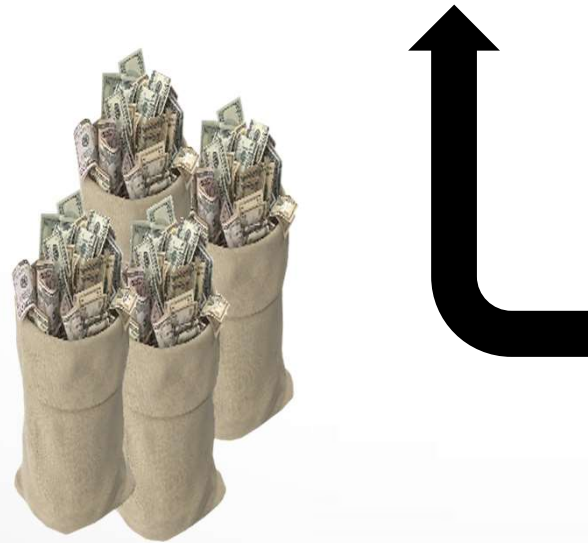
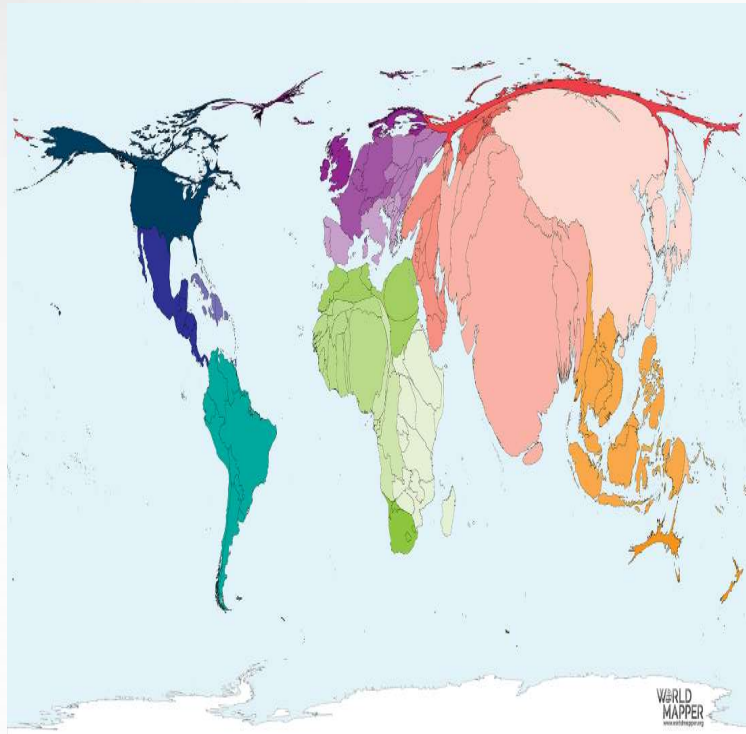
# 3D PRINTING IN NEUROSCIENCE?



- Far-reaching possibilities
- vast neuroscience potential .



# The worthy alternative...



3D Printing in Neuroscience...

# Self help



## “Education

is the most powerful weapon which you  
can use to

## change the world”

-Nelson Mandela



# References

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