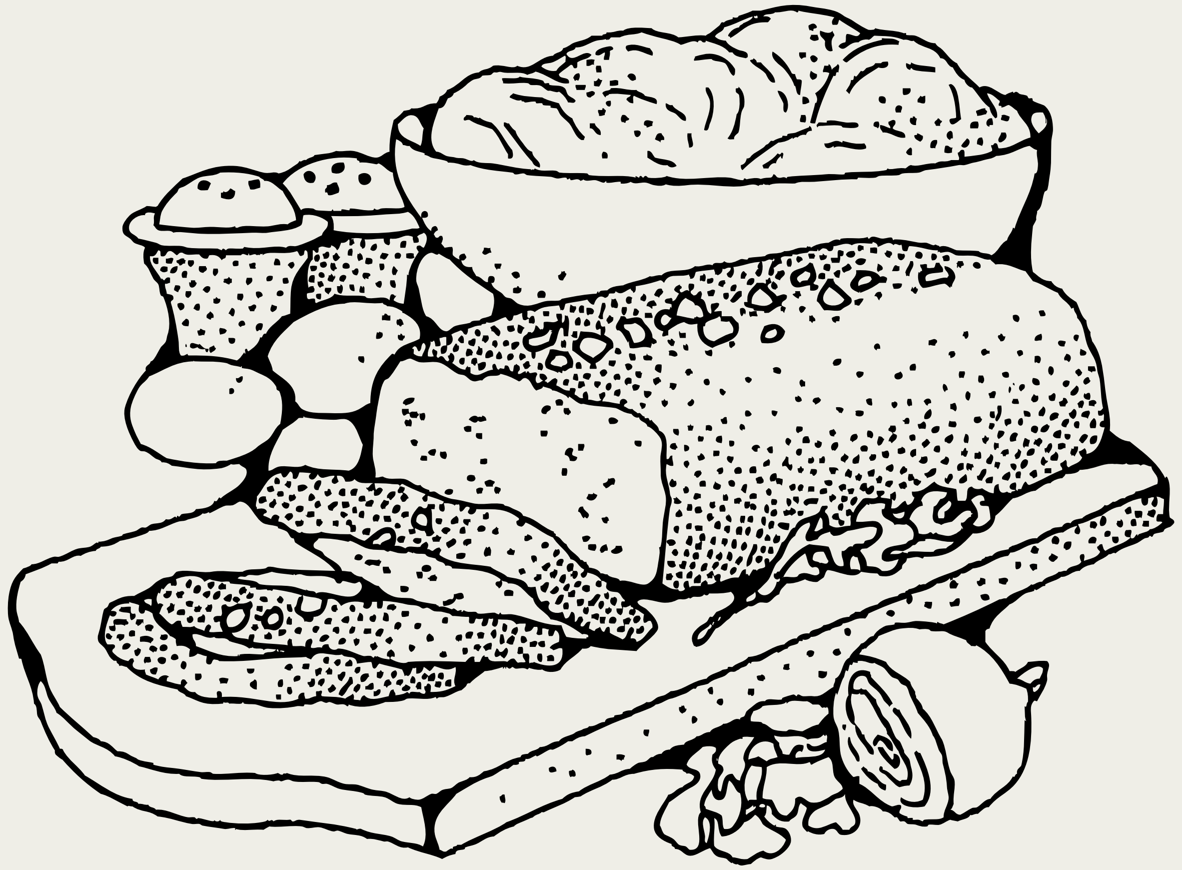
# 3D Printing Food

## AND THE FUTURE OF ORGANIC PRINTING



Elizabeth Saunders
Prof Brian Toohey, STIA 331 Fall 2023
Presented on November 28, 2023

# AGENDA

- Part 1: History and the Current State of 3D Printing
  - Current Commercialization of the
  - Regulatory Environment
- Part 2: Active Research and Development in the Field (Interview Findings)
  - Jack Kraynak
  - Dr. Jonathan Blutinger
  - Dr. Michael Rivera

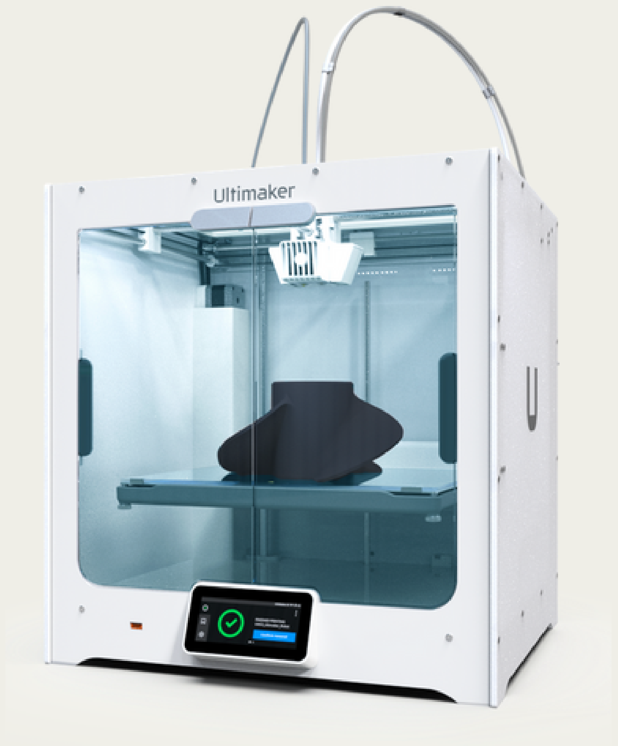
# Part 1

## HISTORY AND THE CURRENT STATE OF 3D PRINTING

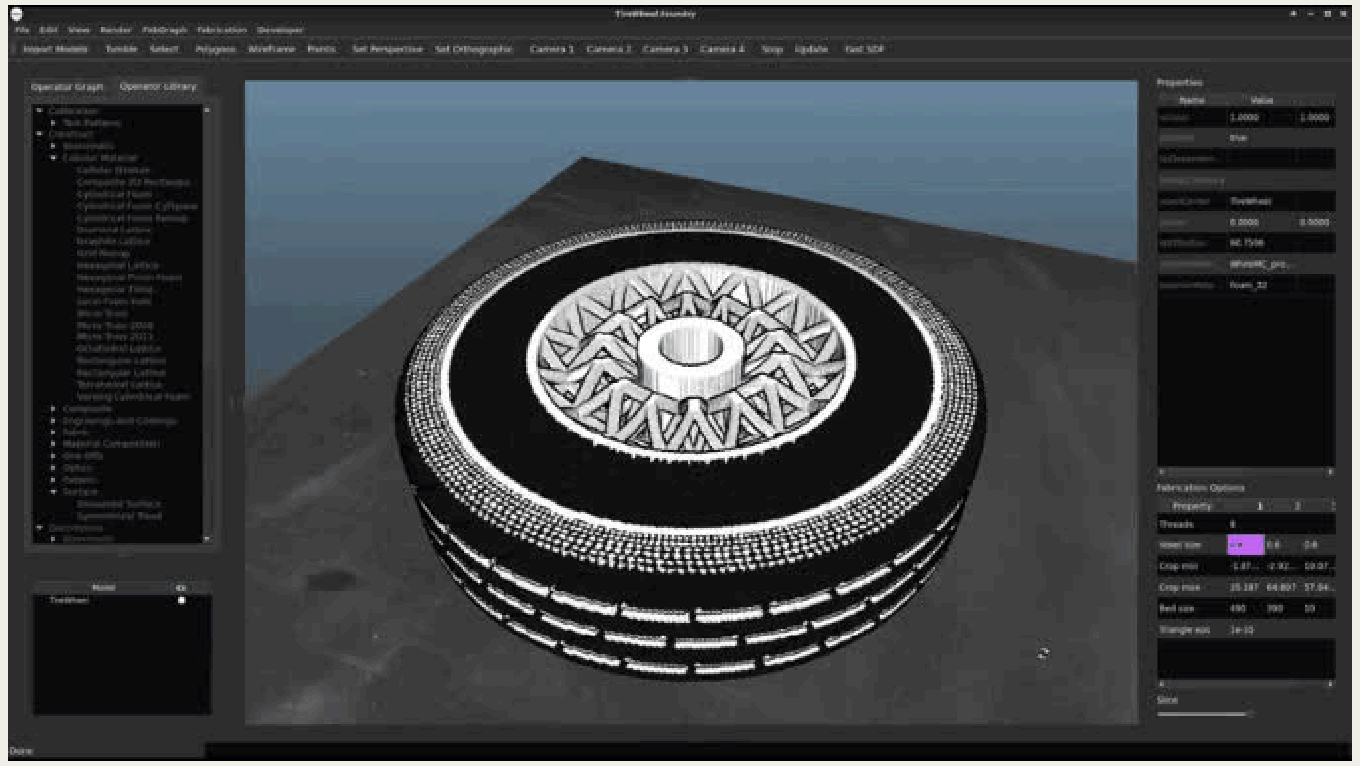
# HISTORY OF 3D PRINTING

## Definition:

*"3D Printing is an additive manufacturing process that creates a physical object from a digital design." (Hayes)*




UltiMaker S5
(top-of-the-line consumer product)



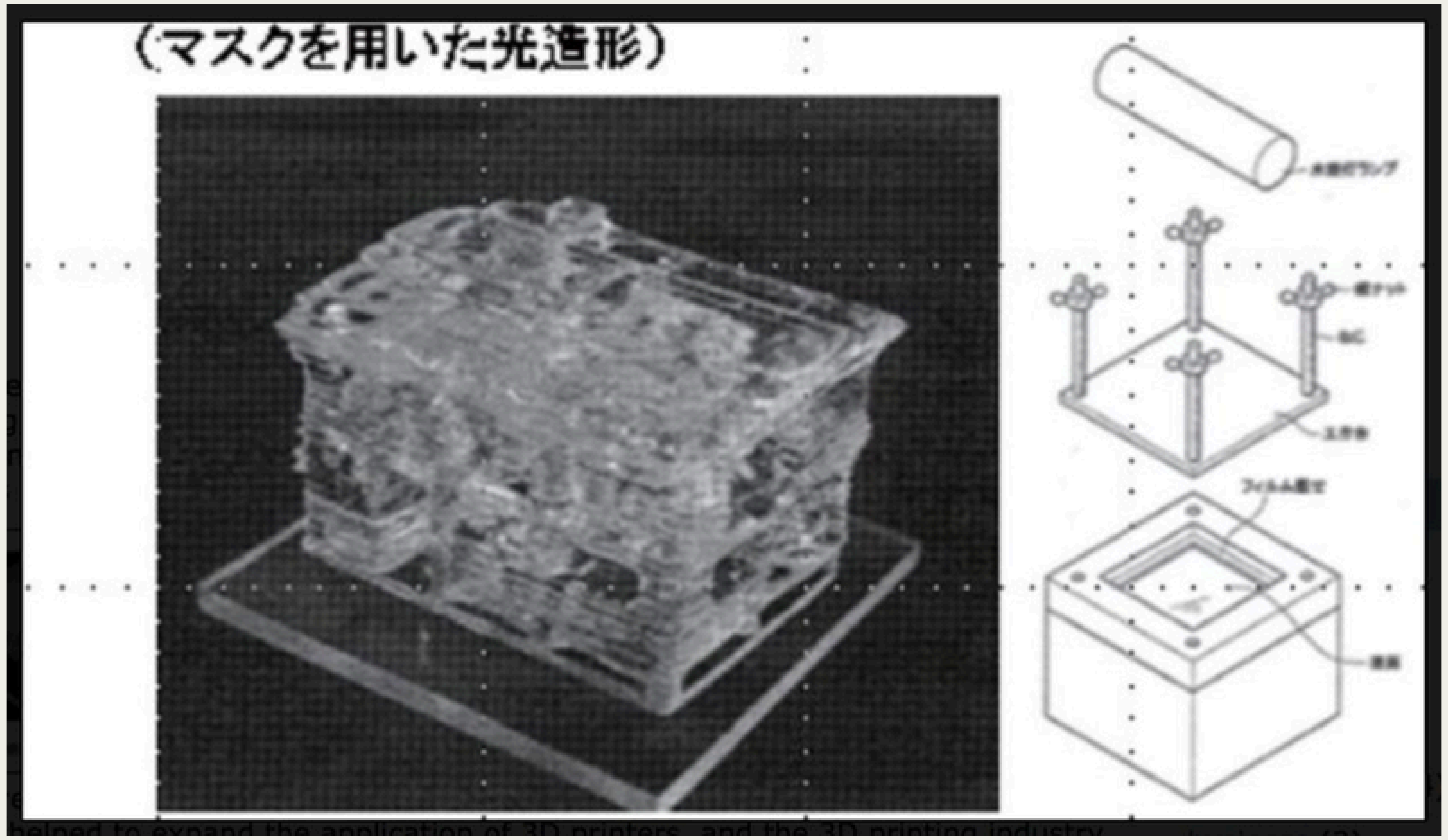
"MIT's new software makes multi-material 3D printing easy" (TechCrunch)
Here: the digital design is shown in both its digital and physical stages.


Massivit 10000 (used for mold production for composite manufacturing)

# HISTORY OF 3D PRINTING

## International History:

In 1981 Japan, Hideo Kodama was trying to find a way to develop a rapid prototyping system. He came up with a layer-by-layer approach for manufacturing, using a photosensitive resin that was polymerized by UV light.




Kodama's early patent -- which was rejected.

Kodama is most often credited as being the first inventor of this manufacturing system, which is an early version of the modern SLA (Stereolithography) machine.

1981

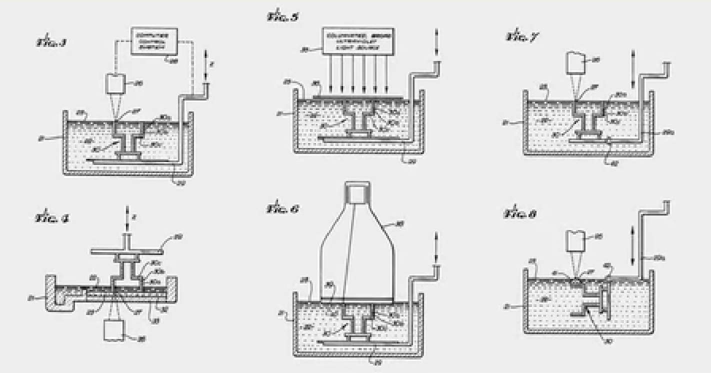
# HISTORY OF 3D PRINTING

## American History:

In 1981 USA, Charles Hull used his frustration with not being able to easily create small custom parts for furniture to develop a system for creating 3D models by curing photosensitive resin layer by layer.

First 3D part is successfully printed (inventing SLA)

Hull files his patent



3D Systems is co-founded by Chuck Hull and becomes the first 3D printing company in the world

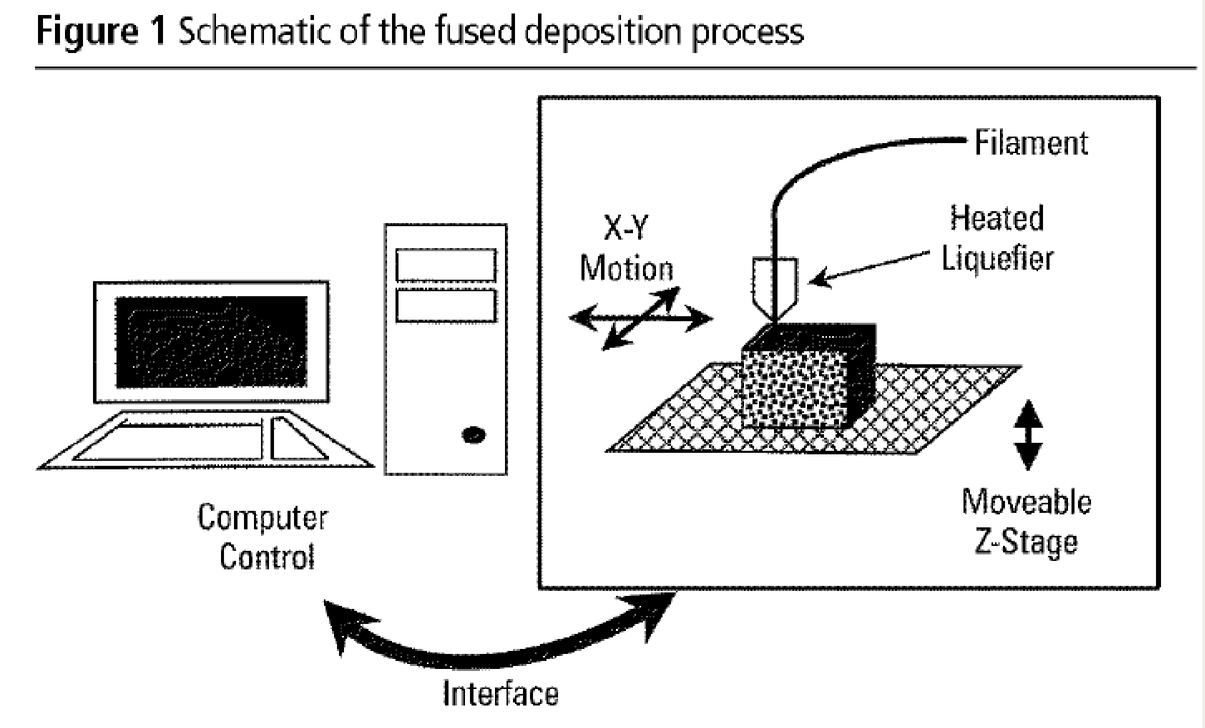
3D Systems commercializes the first 3D printer, the SLA-1 Stereolithography (SLA) printer

1981
1983
1984
1986
1988

# HISTORY OF 3D PRINTING

## American History:

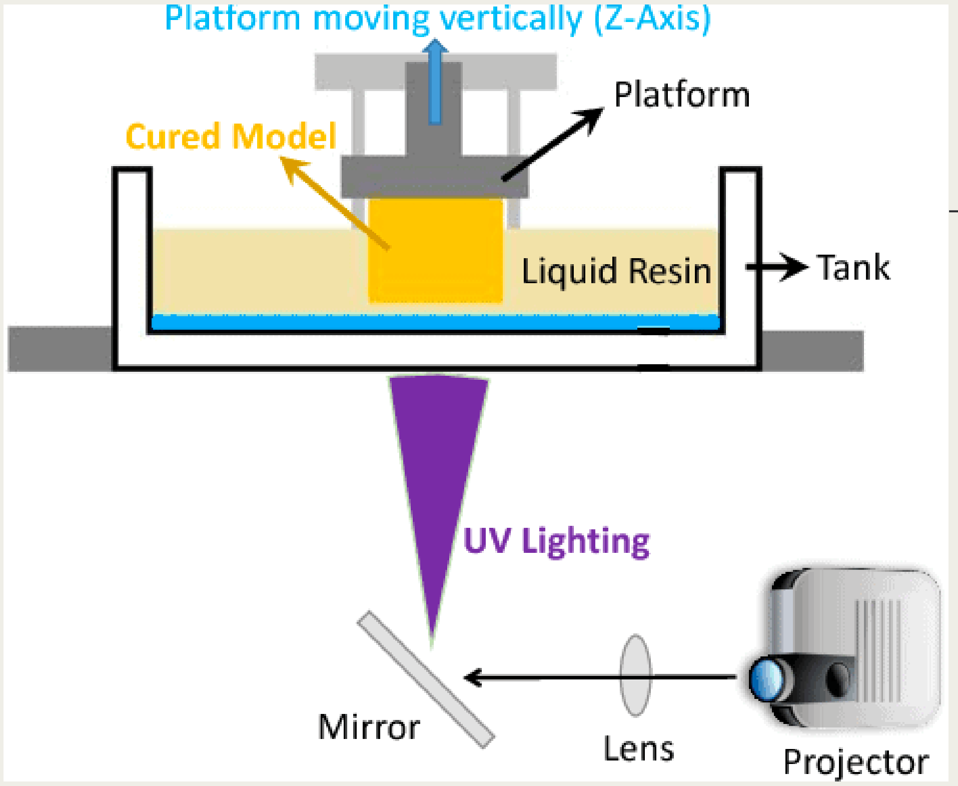
Carl Deckard at the University of Texas filed the patent for Selective Laser Sintering (SLS) technology. This system fused powders, instead of liquid, using a laser.




Fused Deposition Modeling (FDM) was also patented around the same time by Scott Crump. FDM, also called Fused Filament Fabrication, differs from SLS and SLA in that rather than using light, the filament is directly extruded from a heated nozzle. FFF technology has gone on to become the most common form of 3D printing we see today.

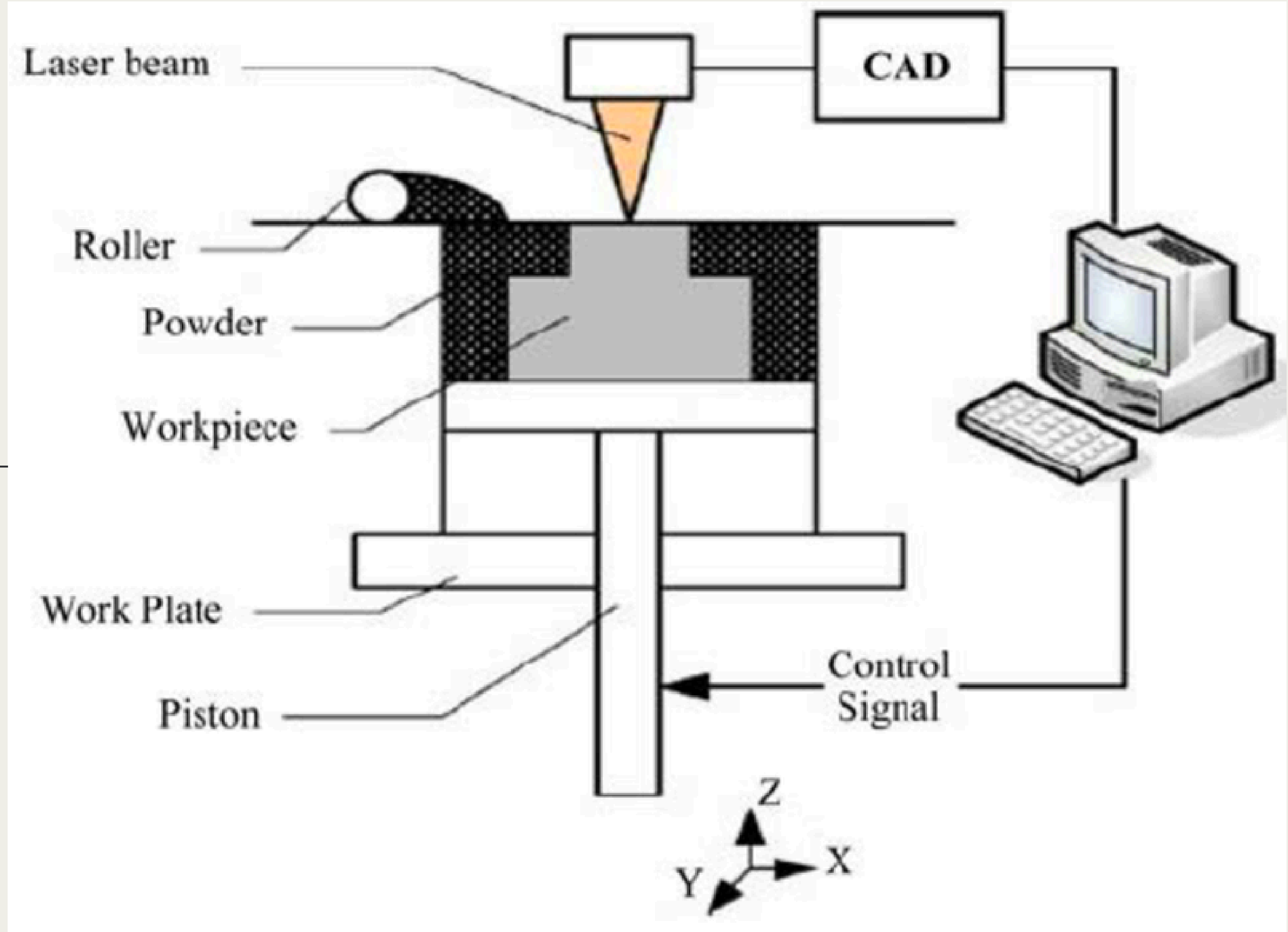
1988

1990

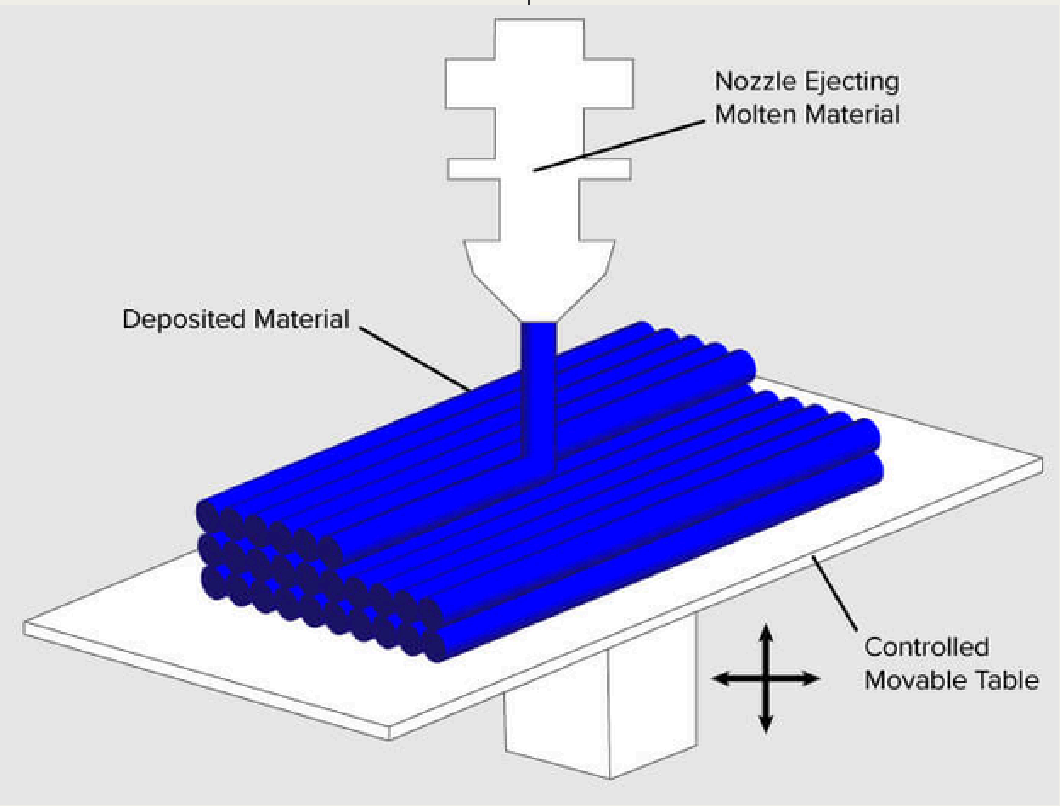



SLA - Charles Hull

SLS - Carl Deckard




FDM - Scott Crump




These three technologies are not the only types of 3D printing methods that exist. But, **they are the three that serve as the building blocks that would lay the groundwork for the technology to grow and for the industry to be disrupted.**

# 3D PRINTING CAPABILITIES EXPANDS

**1999**
Wake Forest Institute of Regenerative Medicine grows the first 3D-printed organ for transplant surgery

**2000**
a miniature kidney is printed

**2005**
Dr. Adrian Bowyer invented the RepRap open-source concept to create a self-replicating 3D printer process.

**2006**
a printer that can print multiple materials like Ceramic, Plastics, clay, and wood fiber was built

**2008**
“Darwin” becomes the first commercially available 3D printer that was designed under the open source concept

**2008**
the first 3D-printed prosthetic limb

**2012**
the first prosthetic jaw is printed and implanted.

**2013**
“3D printing” was mentioned as a major issue for the future in Obama’s State of the Union speech.

**2016**
Daniel Kelly’s lab announces being able to 3D print bone

**2018**
the first family moves into a 3D-printed house.

**3D printing innovation type:**
**medical**
**consumer**
**printer capabilities**

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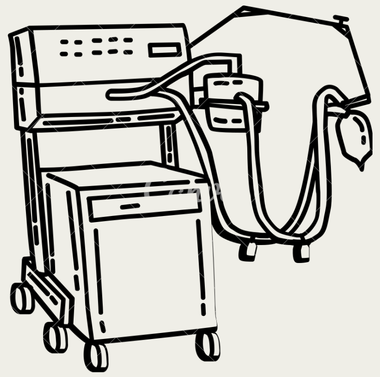
**FOOD!**

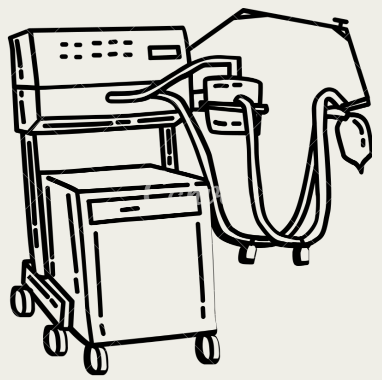
# REGULATORY ENVIRONMENT



## FDA - Medical Use

FDA does not regulate 3D printers themselves; instead, FDA regulates the medical products made via 3D printing. The type of regulatory review required depends on the kind of product being made, the intended use of the product, and the potential risks posed to patients.

# REGULATORY ENVIRONMENT



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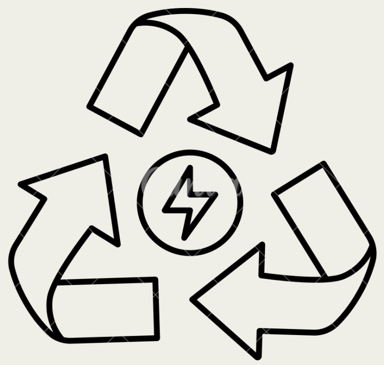
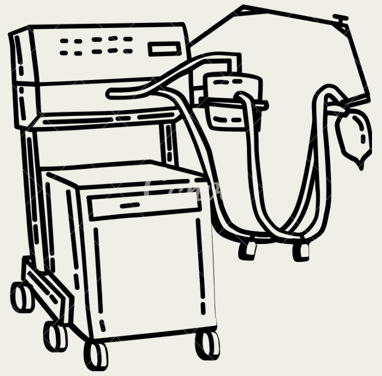


## Environmental Regulations

“The technology uses larger amounts of energy than milling and drilling machines. And to produce an object of the same weight, the 3D printing process may require 50 to 100 times more electrical energy than standard machines, thereby causing more emissions.”

However, there are no regulatory oversights on this process.

# REGULATORY ENVIRONMENT



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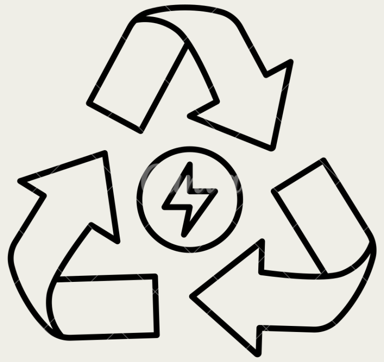

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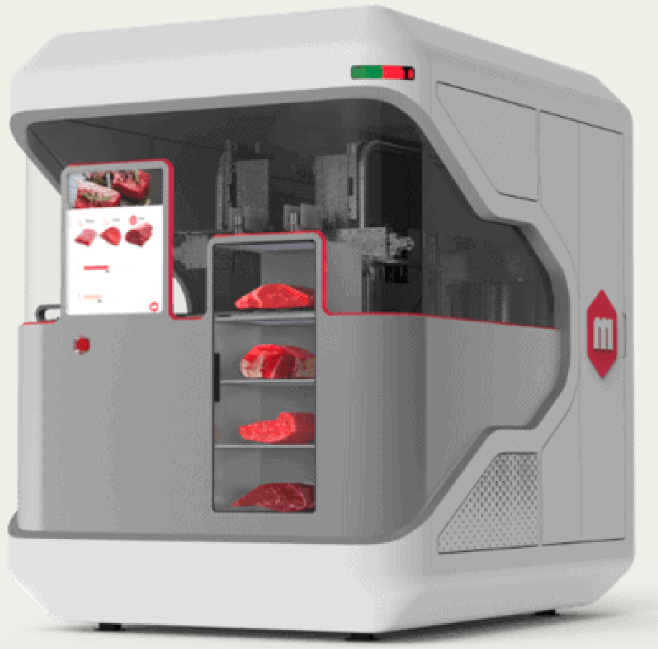
## FDA - Food Consumption

“3D-printed food is safe to eat so long as all its ingredients and additives are FDA-approved and the printer uses food-grade materials for the nozzle, syringe, and base plate.”
Food-safe 3D printing filaments include PLA, PP, co-polyester, PET, PET-G, HIPS, and nylon-6, as well as some brands of ABS, ASA, and PEI. However, organic material is less specific.

# FOODS THAT ARE CURRENTLY BEING 3D PRINTED

- 3D printed pasta
- Plant-based “steaks” (ReDefine Meat)
- 3D-printed chocolate art
- Fruit flavor drops for cocktails
- Protein-fortified snack bars
- Pancake and waffle printers with built-in cooking
- 3D-printed seaweed snacks
- Intricate sugar art and dessert casings





Barilla - Italy
*2016 published research*

ReDefine Meat - Israel
*current*

While there are no specific regulations for 3D-printed food, using ingredients that the FDA already recognizes as safe ensures the food is fit for consumption.

# Part 2

## PART 2: ACTIVE RESEARCH AND DEVELOPMENT IN THE FIELD (INTERVIEW FINDINGS)

*US BASED RESEARCH COMES PRIMARILY FROM UNIVERSITIES
THINK: BAYH–DOLE ACT

# CURRENT RESEARCH AND DEVELOPERS

*Grad Student*

**Jack Kraynak**

Jack Kraynak recently graduated from Temple University (majoring in bioengineering) and is now pursuing a 3D Printing Master's Degree where he will focus on bioprinting.

*Research focus:*
*bioprinting*

*Post-Doc Researcher*

**Dr. Jonathan Blutinger**

Dr. Jonathan Blutinger is a postdoctoral fellow in Hod Lipson's Creative Machines Lab at Columbia University's School of Engineering.

Funded by ReDefine Meats (Isreal)

*Research focus:*
*digital cooking and food modeling.*

*Research Lab Director*

**Dr. Michael Rivera**

Dr. Michael Rivera leads the Utility Research Lab of CU Boulder's ATLAS Program — a highly interdisciplinary group that invents and investigates digital fabrication technology, tools, and techniques.

Funded by NSF (USG)

*Research focus:*
*sustainability, organic printing*

# JACK KRAYNAK0 - BIOPRINTING

Jack Kraynak recently graduated from Temple University (majoring in bioengineering) and is now pursuing a 3D Printing Master's Degree where he will focus on bioprinting.

During his time at Temple, Jack researched the mechanical aspects of extrusion bioprinting that directly affect the viability and number of cells that die during each ‘print’.

His work won the 2021 Livingstone Undergraduate Research Award in STEM.

## Minimizing Cell Death During the Extrusion Bioprinting of Gelatin-Alginate Bioinks

Export

Minimizing Cell Death During the Extrusion Bioprinting of Gelatin-Alginate Bioinks

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**Genre**
Research project

**Date**
2021

**Author**
Kraynak, Jack

**Advisor**
Danowsky, Joseph

**Department**
Bioengineering

**Subject**
Bioprint
Bioprinting
Bioink
Bioprinted scaffold
Cell death
Cell death bioprinting
Extrusion bioprinting
Gelatin-alginate bioink
Hydrogel bioprinting

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**Abstract**
This proposal seeks to minimize cell death while extrusion bioprinting with a gelatin-alginate bioink. Extrusion bioprinting was chosen over other types of bioprinting due to its accessibility and cost to researchers. Two different nozzles, cylindrical and conical, are examined to determine a mechanical aspect of extrusion bioprinting that can be modified to greatly minimize the cell death of bioprinted scaffolds. Gelatin-algiate bioinks can vary in concentration, and this concentration was also varied as a candidate solution to obtain the optimal concentration while maintaining a high cell survivability. The conical nozzle was chosen as the optimal printing nozzle with low shear stress, low cell damage, and highest cell viability. The 4% gelatin 5% alginate bioink was chosen as the optimal bioink concentration with optimal viscosity and high cell viability. Together, the use of this nozzle and this concentration bioink will greatly minimize the cell damage that occurs during extrusion bioprinting, boosting the quality of extrusion printing, and making it all-around more viable. Extrusion bioprinting, due to its improved cell death percentage, will be utilized more often by researchers – this will potentially accelerate the innovation of bioprinting as an overall technology towards the final goal of bioprinting a fully functioning organ.

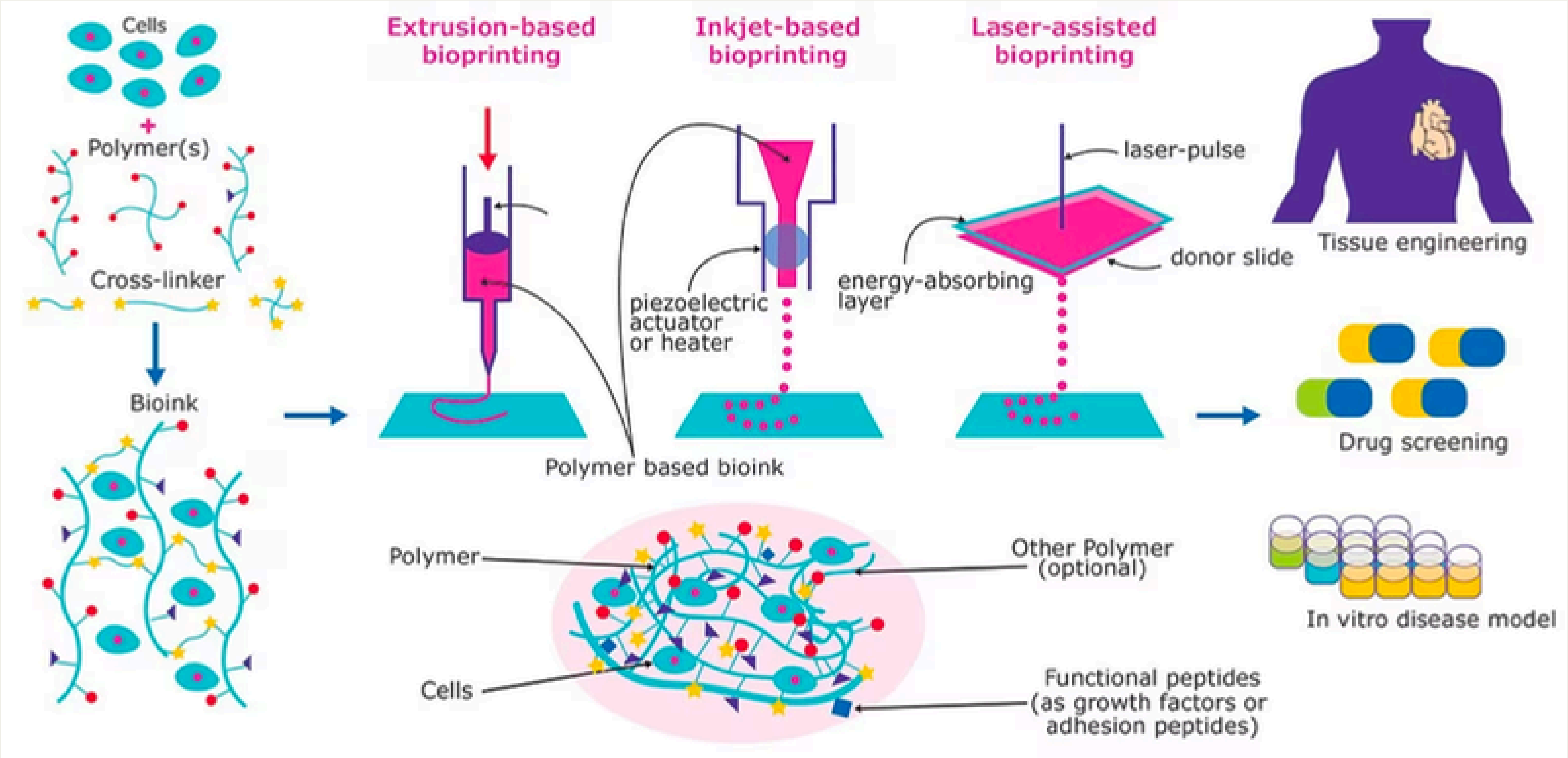
**Description**
This research project was completed as part of the Honors Technical Communication by Design course.

**Citation to related work**
Livingstone Undergraduate Research Awards website:
https://sites.temple.edu/livingstone/2021-livingstone-undergraduate-research-award-in-stem/



**Collections**
Livingstone Undergraduate Research Awards

# JACK KRAYNAKO - BIOPRINTING




Bioprinting is the most common form of organic 3D printing. It serves as the stepping stone from mechanical applications of 3D printing to FOOD!

# Key Take Away:

- Majority of 3D printing academia in the US is focused on bioprinting (and therefore interdisciplinary)

- In order to pursue a research program in working with organic material or food development, the academic programs you apply for the need to rely largely on interdisciplinary approaches and applications of 3D printing (thus, this research is student-driven rather than program)
  - 3D printing is still young

# DR. JONATHAN BLUTINGER

Dr. Jon graduated with a BS in Mechanical Engineering from UPenn. He then went on to get a MSE in Integrated Product Design from UPenn where his research focused on redesigning cardboard boxes (see picture, right). He then went on to get his PhD in Mechanical Engineering from Columbia where he researched using digital lasers in 3D printing to create food (see video, right). He is still at Columbia as a post-doc with funding from ReDefine Meat to work as a food robotics engineer (see 3D printed meat, right).

Perspective | Open access | Published: 21 March 2023

# The future of software-controlled cooking

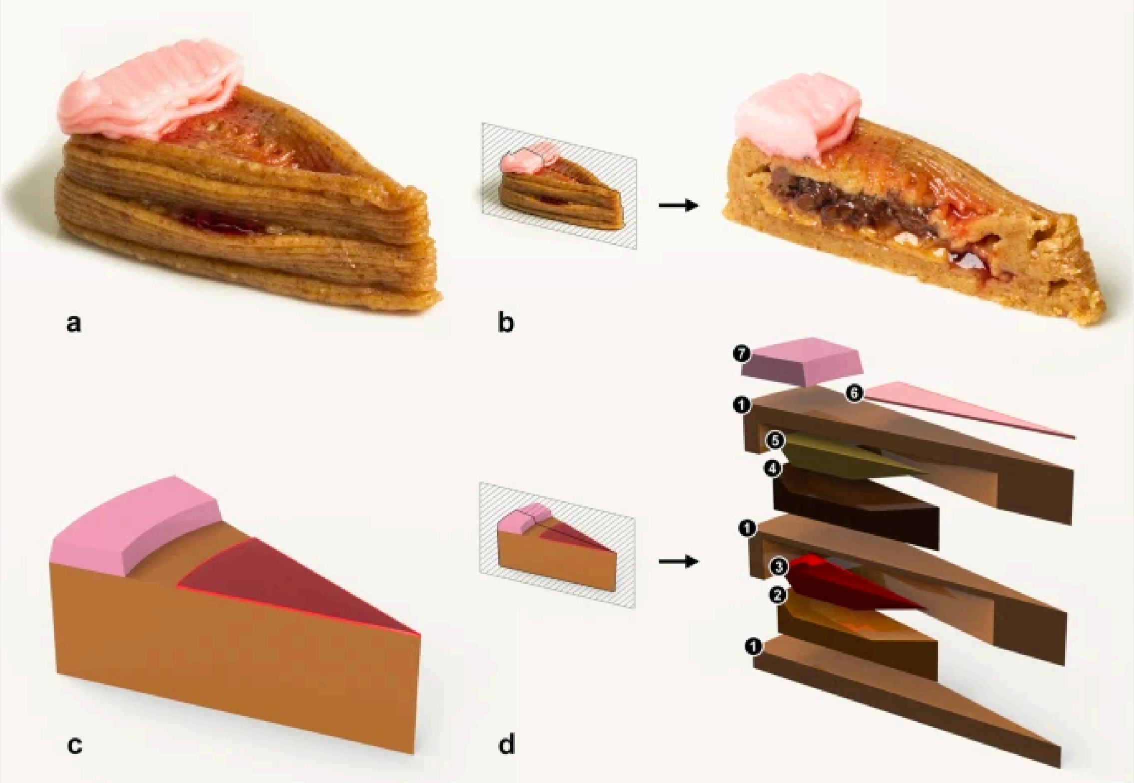
Jonathan David Blutinger, Christen Cupples Cooper, Shravan Karthik, Alissa Tsai, Noà Samarelli, Erika Storvick, Gabriel Seymour, Elise Liu, Yorán Meijers & Hod Lipson

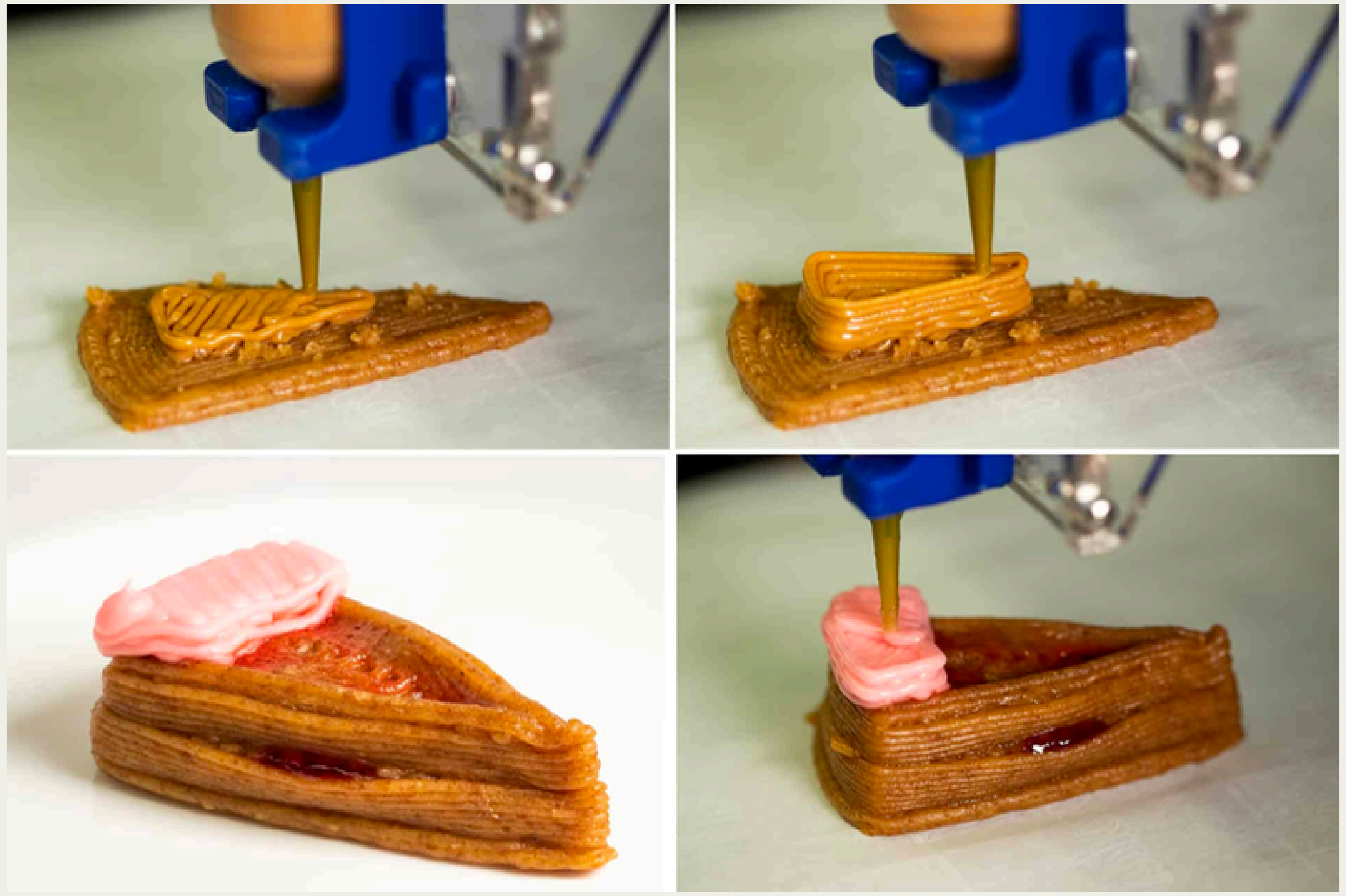
*npj Science of Food* **7**, Article number: 6 (2023) | Cite this article



## Abstract

To date, analog methods of cooking such as by grills, cooktops, stoves and microwaves have remained the world's predominant cooking modalities. With the continual evolution of digital technologies, however, laser cooking and 3D food printing may present nutritious, convenient and cost-effective cooking opportunities. Food printing is an application of additive manufacturing that utilizes user-generated models to construct 3D shapes from edible food inks and laser cooking uses high-energy targeted light for high-resolution tailored heating. Using software to combine and cook ingredients allows a chef to more easily control the nutrient content of a meal, which could lead to healthier and more customized meals. With more emphasis on food safety following COVID-19, food prepared with less human handling may lower the risk of foodborne illness and disease transmission. Digital cooking technologies allow an end consumer to take more control of the macro and micro nutrients that they consume on a per meal basis and due to the rapid growth and potential benefits of 3D technology advancements, a 3D printer may become a staple home and industrial cooking device.

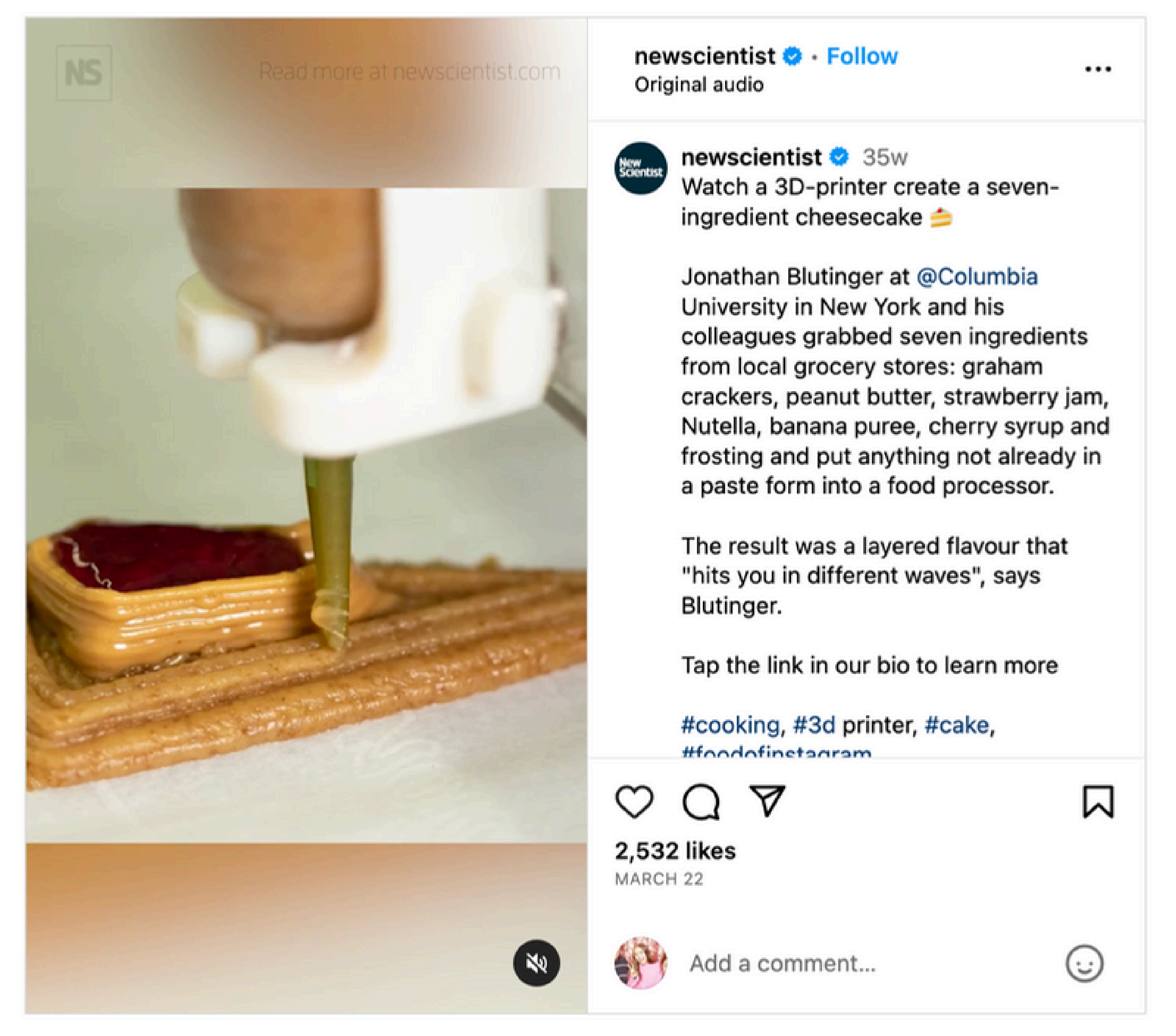


“Nice gimmick but not the future of nutrition”

“I’m not impressed because of the obvious error the stupid robot made where the strawberry jam sept out. Humans are still superior!”

“And? A) not great ingredients and b) is it for toothless people, all puréed up? Ever heard actually enjoying the process of making?”




“Bakers can sleep easy”

“No 😫”

“disgusting”

“Double it and give it to the next person”

“That s called “industrial bakeries” and it sucks”

“Why did you refer to this as cheesecake?”

“Cheesecake looks like a type 6 stool 🤮”

“I like 3D printing. But this is one of the most revolting pieces of 'nutrition' I've ever seen.”

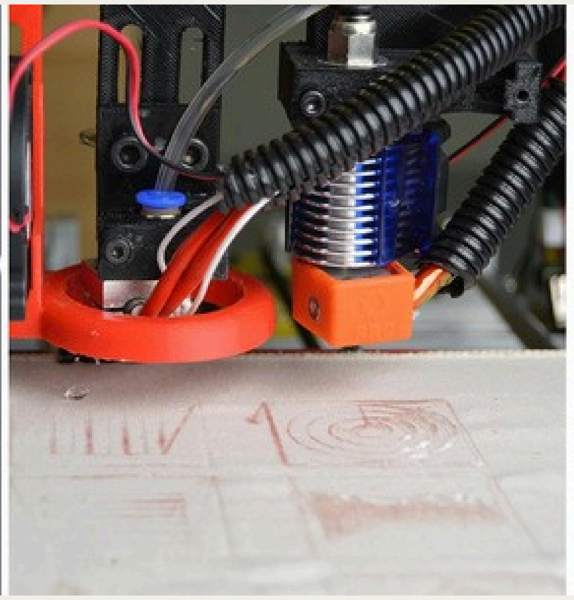
# Key Take Away:

- “The reasonable man adapts himself to the world: the unreasonable one persists in trying to adapt the world to himself. Therefore all progress depends on the unreasonable man.”

- Funding for 3D printing research is LARGELY abroad (Israel, Sweden, Germany, ex.)
    - interesting case considering that the US was so active in funding R&D of 3D printing in its conception (1980s-1990s)

# DR. MICHAEL RIVERA

Dr. Mike graduated cum laude with a BSE in Digital Media Design at UPenn. He then went on to get a MSE in Computer Graphics and Game Technology from UPenn where his research focused on 3D printing uses for customized patient care (see picture, right). He then went on to get his PhD in Human-Computer Interaction from Carnegie Melon University where he researched how to use everyday items in 3D printing (see video, right). He is now the ATLAS Institute at CU Boulder where he was a post-doc, but now the lab director of the Utility Research Lab.



# Designing a Sustainable Material for 3D Printing with Spent Coffee Grounds

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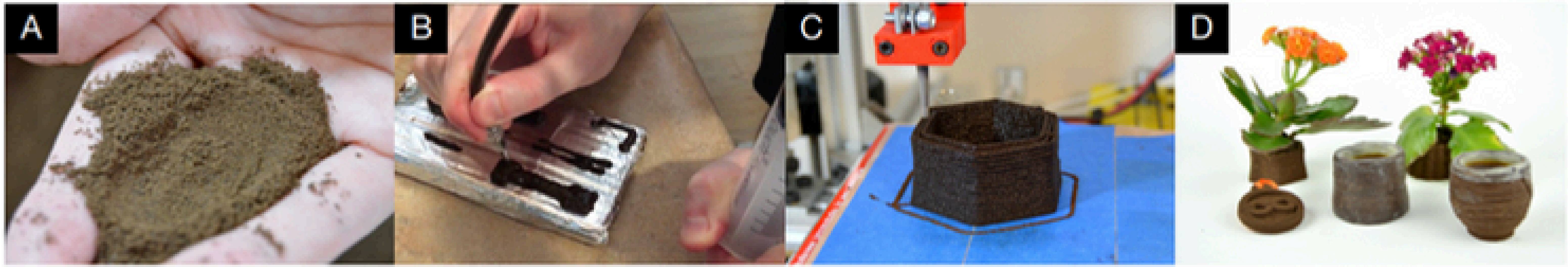


**Figure 1: Design Process Overview. We investigated spent coffee grounds—a commonly wasted natural material—as a sustainable material for 3D printing (A). We experimented with different food-based binders and adjusted material composition to make the material self-supporting with hand-extrusion (B). We tuned 3D printing parameters for quality and reliability (C). We then explored how our material could enable sustainable prototyping workflows and creating objects like biodegradable espresso cups and planter pots (D).**

# My tour of his lab:


environmental discussion


published research


unpublished research

(discussion on viscosity)

# Key Take Away:

- Enhancing sustainability efforts through 3D printing will be imperative for increased consumption (researching alternative filaments like organic material and food waste)

- Making 3D more sustainable (less energy, not printing things “just to print”)

- US-based funding largely exists as NSF grants
    - US companies are not funding 3D printing innovation as heavily as seen in international companies

# Thank you!

ANY QUESTIONS?

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