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Questions
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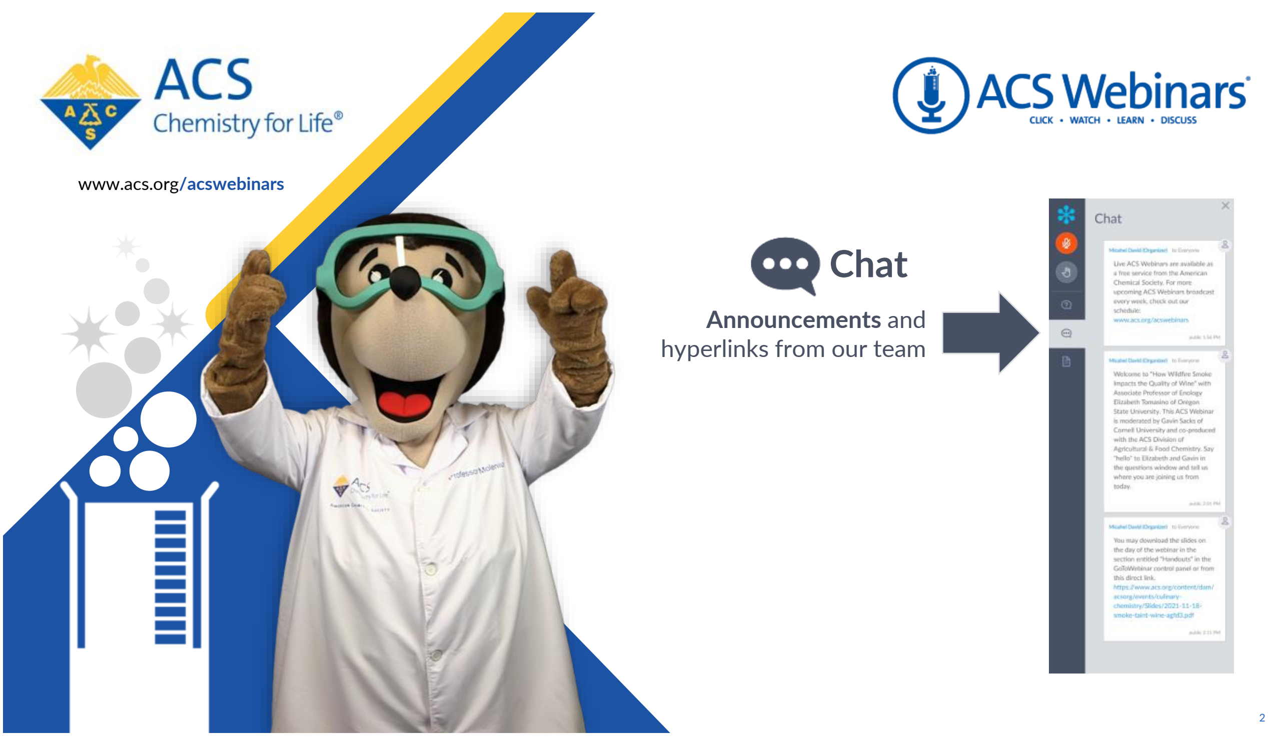
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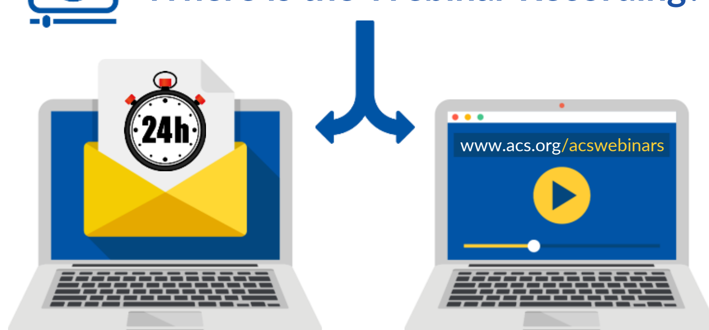

All Registrants

Watch the unedited recording linked in the **Thank You Email for 24 hours.**

ACS Members w/Premium Package

Visit the ACS Webinars® Library to watch the **edited and captioned recording.**

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A Career Planning Tool For Chemical Scientists

ChemIDP is an Individual Development Plan designed specifically for graduate students and postdoctoral scholars in the chemical sciences. Through immersive, self-paced activities, users explore potential careers, determine specific skills needed for success, and develop plans to achieve professional goals. **ChemIDP** tracks user progress and input, providing tips and strategies to complete goals and guide career exploration.

https://chemidp.acs.org

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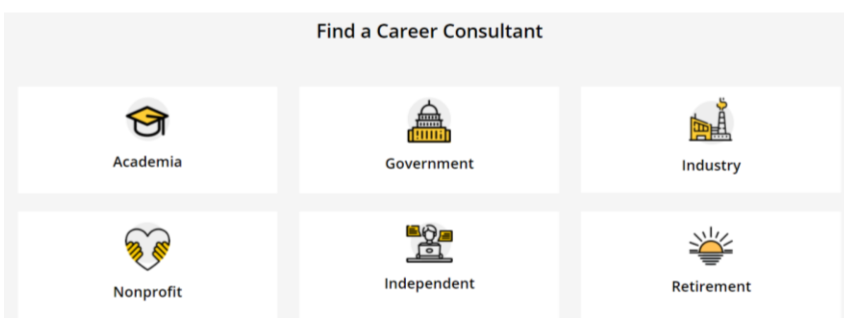
Career Consultant Directory



- ACS Member-exclusive program that allows you to arrange a one-on-one appointment with a certified ACS Career Consultant.
- Consultants provide personalized career advice to ACS Members.
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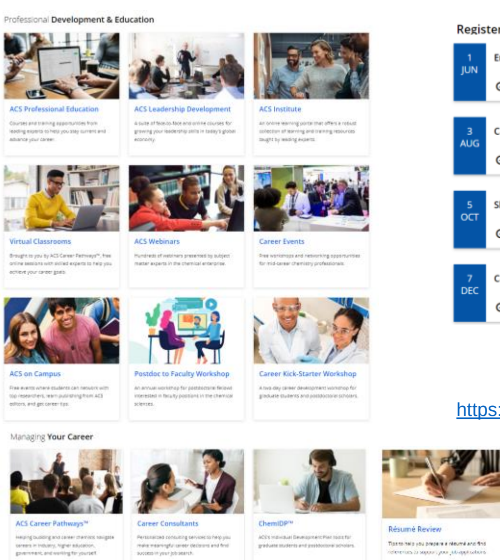
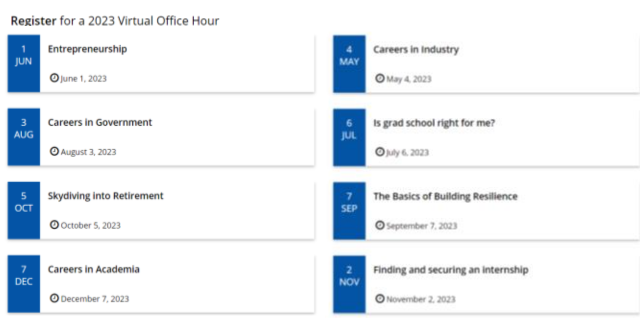
ACS Career Resources





https://www.acs.org/content/acs/en/careers/personal-career-consulting.html

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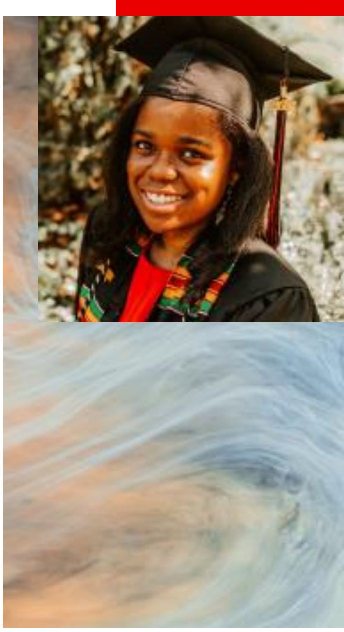

ACS Scholar Adunoluwa Obisesan

BS, Massachusetts Institute of Technology, June 2021
(Chemical-biological Engineering, Computer Science & Molecular Biology)

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ACS Webinars on Diversity
Covering diversity and inclusion at the workplace

ACS Publications DEIR Hub
See what ACS Publications is doing for fostering inclusivity in scholarly publishing

ACS Volunteer and ACS Meetings Code of Conduct
Fostering a positive and welcoming environment for attendees, volunteers and staff.

C&EN Trailblazers
C&EN highlights scientists from different backgrounds who are making an impact in chemistry.

NEW! Download DEIR Educational Resources
Download this educational guide for additional recommendations on videos, articles, books, podcasts, and more on diversity, inclusion, and related topics.

Quick Guide: Inclusion Moments
Learn more about what Inclusion Moments are and see ideas to host them during your meetings.

Quick Guide: How to host inclusive in-person events
Recommendations and best practices to ensure that your events can accommodate everyone.

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**Adapted from definitions from the Ford Foundation Center for Social Justice:

Equity**
Seeks to ensure fair treatment, equality of opportunity, and fairness in access to information and resources for all. We believe this is only possible in an environment built on respect and dignity. Equity requires the identification and elimination of barriers that have prevented the full participation of some groups.

Diversity**
The representation of varied identities and differences (race, ethnicity, gender, disability, sexual orientation, gender identity, national origin, tribe, caste, socio-economic status, thinking and communication styles, etc.), collectively and as individuals. ACS seeks to proactively engage, understand, and draw on a variety of perspectives.

Inclusion**
Builds a culture of belonging by actively inviting the contribution and participation of all people. Every person's voice adds value, and ACS strives to create balance in the face of power differences. In addition, no one person can or should be called upon to represent an entire community.

Respect
Ensures that each person is treated with professionalism, integrity, and ethics underpinning all interpersonal interactions.

https://www.acs.org/content/acs/en/about/diversity.html

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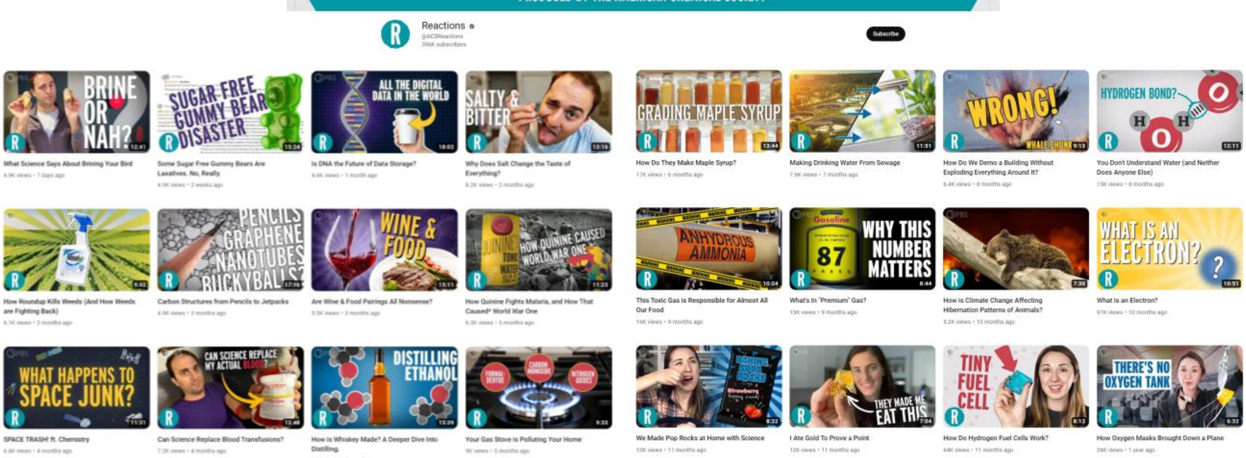

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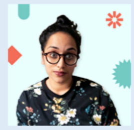
Sam Jones, PhD
Science Writer & Exec Producer



Deboki Chakravarti, PhD
Science Writer & Co-Host

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December 6, 2022

Bioorthogonal, click chemistry clinch the Nobel Prize
October 5, 2022

Lithium mining's water use sparks bitter conflicts and novel chemistry
September 13, 2022

For John Goodenough's 100th birthday, *Stereo Chemistry* revisits a fan-favorite interview with the renowned scientist
July 25, 2022

Jess Wade on Wikipedia and work-life balance
June 21, 2022

The sticky science of why we eat so much sugar
May 31, 2022

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ACS on Campus is the American Chemical Society's initiative dedicated to helping students advance their education and careers.

ACS ON CAMPUS

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Respect
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https://www.acs.org/diversity

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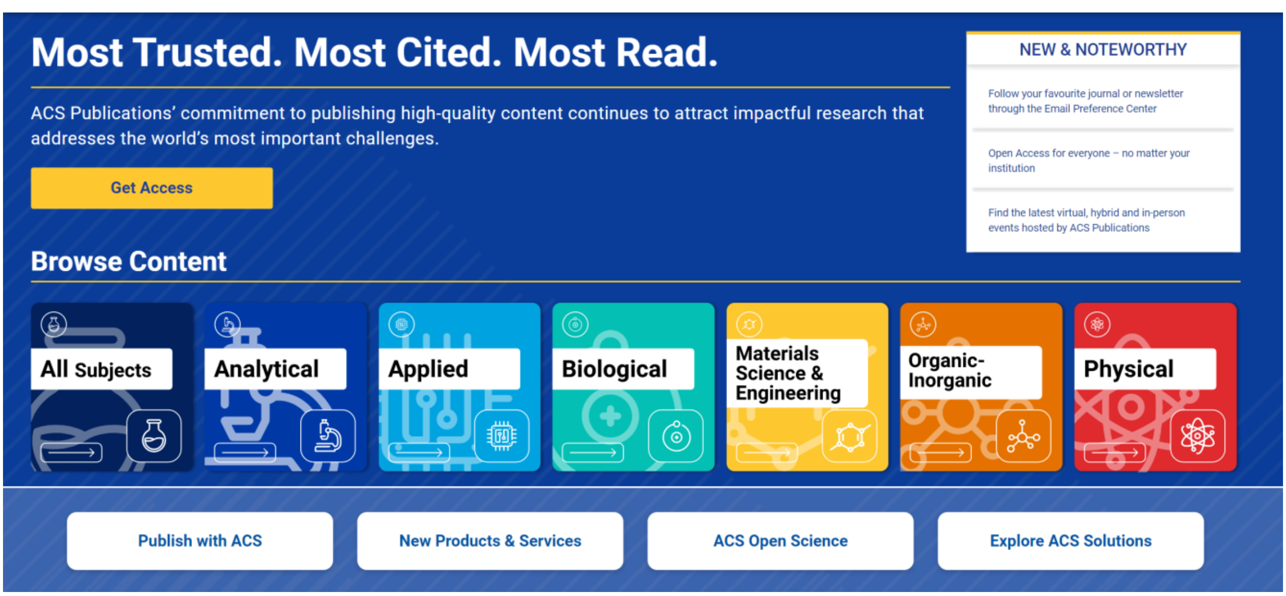

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questions window!
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Biomedical 3D Printing: Research Landscape,
Applications, and New Innovative Materials
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Assistant Professor, Harvard Medical School
AXEL GUENTHER, PhD
Professor and Co-Director, Collaborative Centre for Research and Applications in Fluidic Technologies (CRAFT), University of Toronto
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A landscape view

ADVANCEMENTS IN BIOMEDICAL 3D PRINTING

Chia-Wei Hsu, Ph.D., Information Scientist

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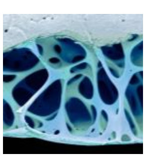
Breakthroughs in biomedical 3D printing

Decades in the making, recent advances have accelerated innovation

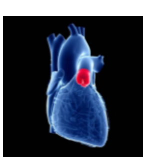


Tissues/organs

First printed lung

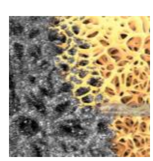
Pharmaceuticals

Customized 3D printed drugs



Bioprinting

3D bioprinting of heart valve



Orthopedics

Hybrid biomaterials

26

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Advancements in materials and techniques

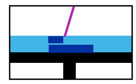
Have enabled faster progress across the entire biomedical landscape

Materials

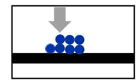
- **Natural**: gelatin, alginic acid, hyaluronic acid
- **Synthetic**: polycaprolactone, poly(lactic acid), polyethylene glycol
- **Inorganic**: titanium, hydroxylapatite

Techniques

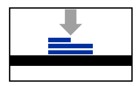
Powder bed fusion



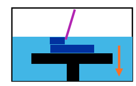
Jetting



Extrusion



Photopolymerization



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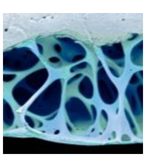
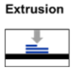
Technique and materials are crucial drivers

Use cases and applications may dictate different prioritization across categories



Tissues/organs

Extrusion



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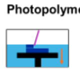
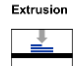
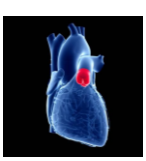


Pharmaceuticals

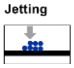
Extrusion



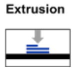


Bioprinting

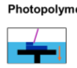
Jetting

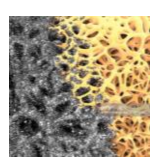


Extrusion



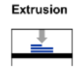
Photopolymerization



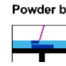


Orthopedics

Extrusion



Powder bed fusion



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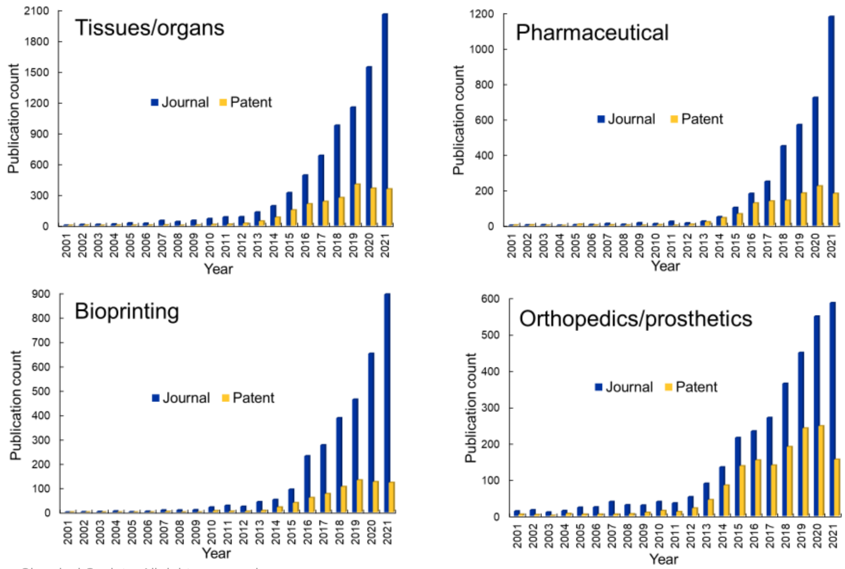
Biomedical 3D printing application trend



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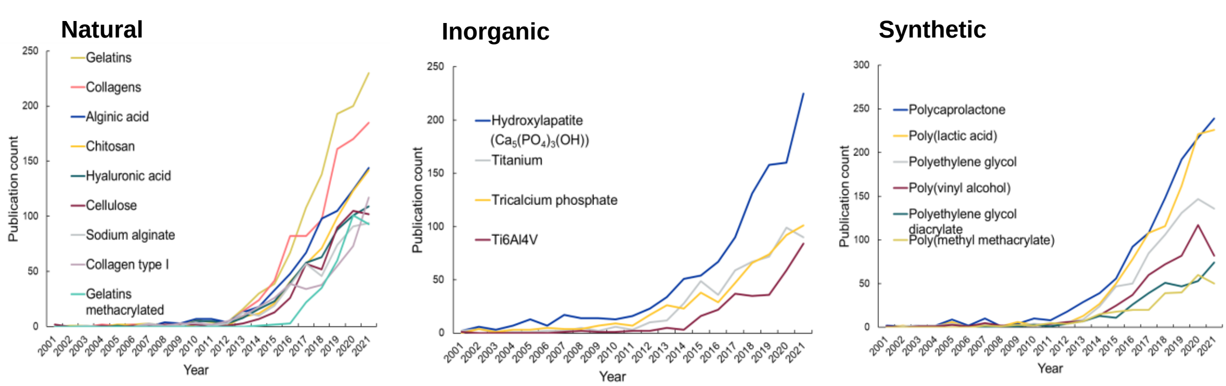
Growth in materials is evident in all three classes

With key players emerging as publication trends



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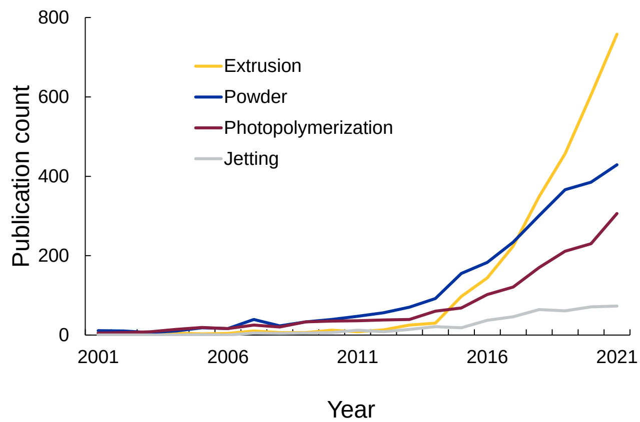
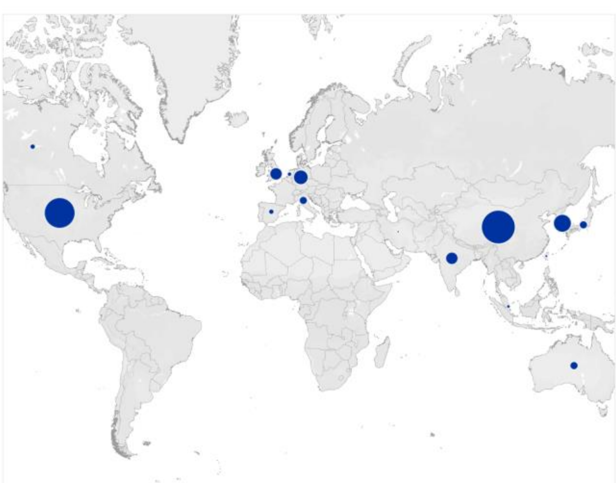
Growth in technique is driven by

Lower costs and material advancements



Global participation in biomedical 3D printing

Journals and patents



Country	Publications (journals and patents)
China	5,112
United States	4,255
Rep. of Korea	1,542
Germany	1,102
India	857

For more details on landscape of biomedical 3D printing

Visit cas.org/3D-report

- Articles
- Executive Summaries
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Handheld Skin Printer:

Rapid, wound-conformal delivery of skin precursor sheets improves healing in full-thickness burns

CAS-ACS webinar, 3D Printing Materials in Biomedical Applications

May 4, 2023

Axel Guenther
University of Toronto

axel.guenther@utoronto.ca

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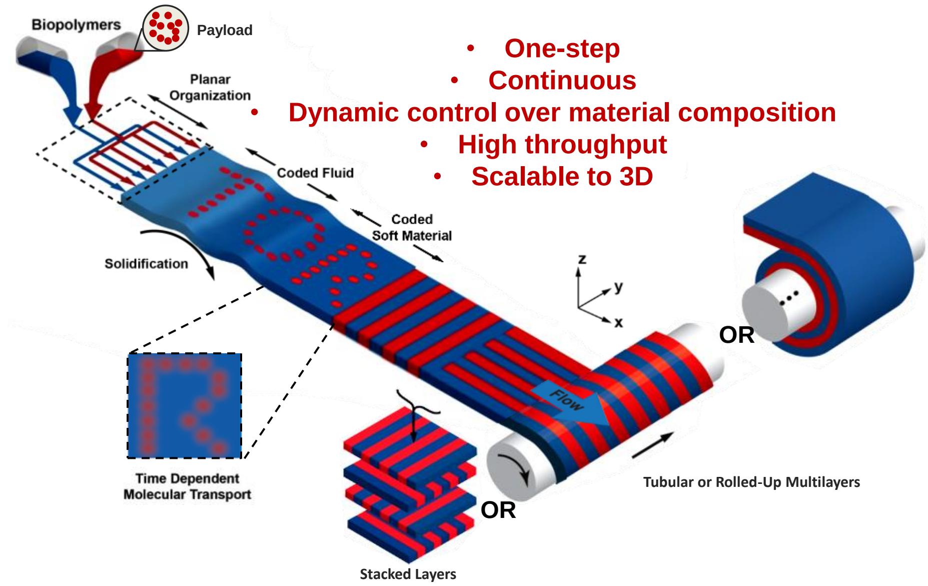
UNIVERSITY of TORONTO

Multinozzle Microfluidic Printhead for Biomaterial Sheet Extrusion

- One-step
- Continuous
- Dynamic control over material composition
- High throughput
- Scalable to 3D



Leng *et al.* Adv. Mat. 2012, 24, 3650–3658

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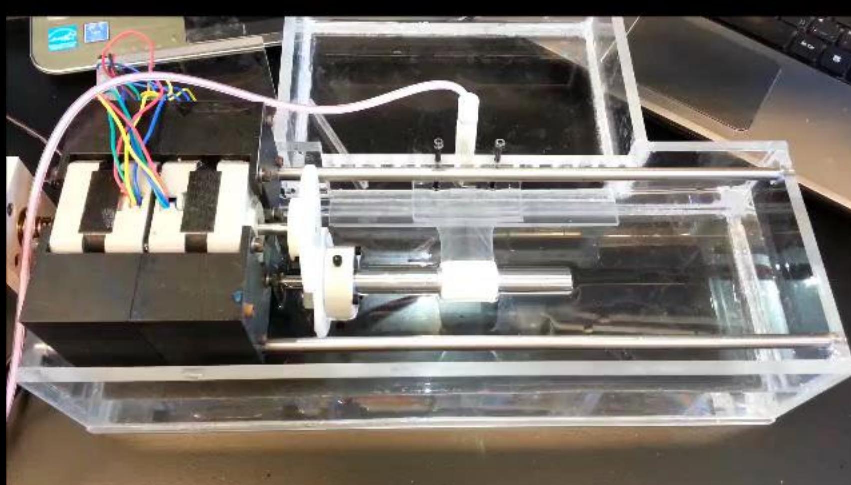
Microfluidic Printhead for Biomaterial Sheet Extrusion



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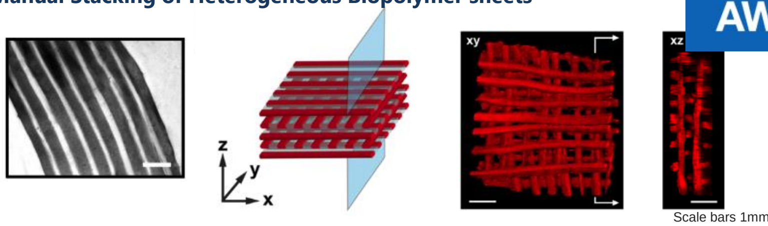
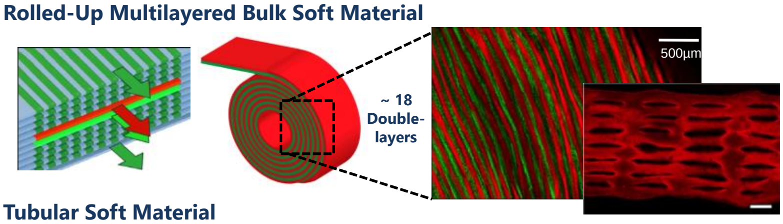
Architected Biomaterial Sheets

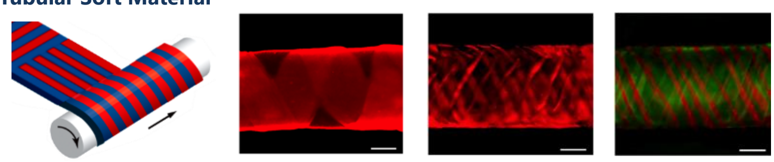
Manual Stacking of Heterogeneous Biopolymer sheets



Rolled-Up Multilayered Bulk Soft Material



Tubular Soft Material



Leng *et al.* Adv. Mat. 2012, 24, 3650–3658

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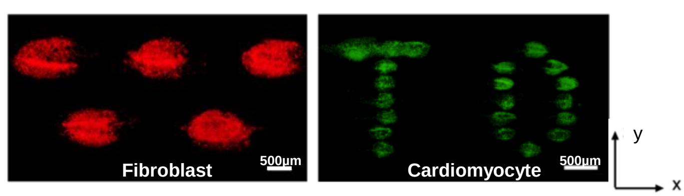
Architected Biomaterial Sheets with Cellular Payloads

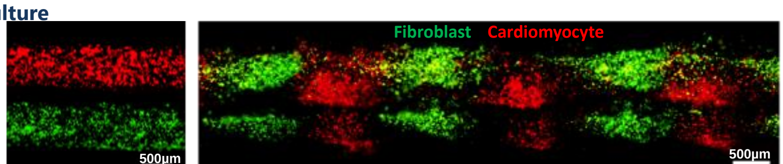
Single Cell Patterning

- 1.2%w.v. alginate
- 19%v.v. Matrigel ™
- 1.8mg/ml Collagen Type I
- 0.46mg/ml RGDs-functionalized[1]
- 10million cell/ml

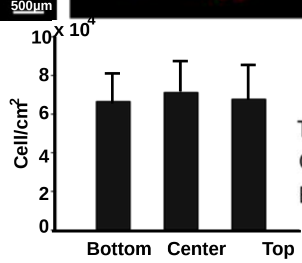


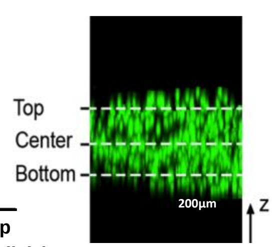
[1]Plouffe *et al.* Lab Chip **9**, 2009.

Co-Culture



Cell Distribution





Leng *et al.* Adv. Mat. 2012, 24, 3650–3658 (with Milica Radisic)

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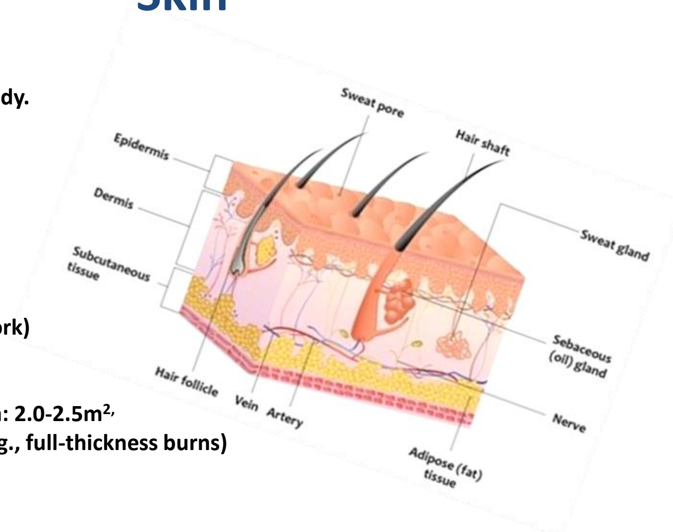
Skin

- **Largest organ of the body.**

- **Layered organization**
  Epidermis, 0.2-0.5mm
  (dense barrier)

  Dermis, 0.5-20mm
  (fibrous collagen network)

- **Total body surface area: 2.0-2.5m^{2},**
  Severe skin injuries (e.g., full-thickness burns)
  up to 80% skin loss



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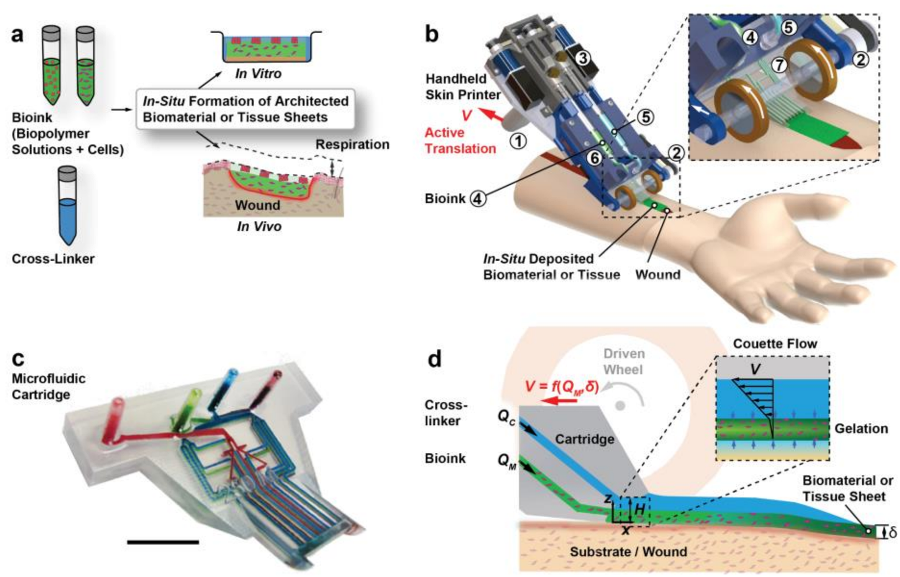
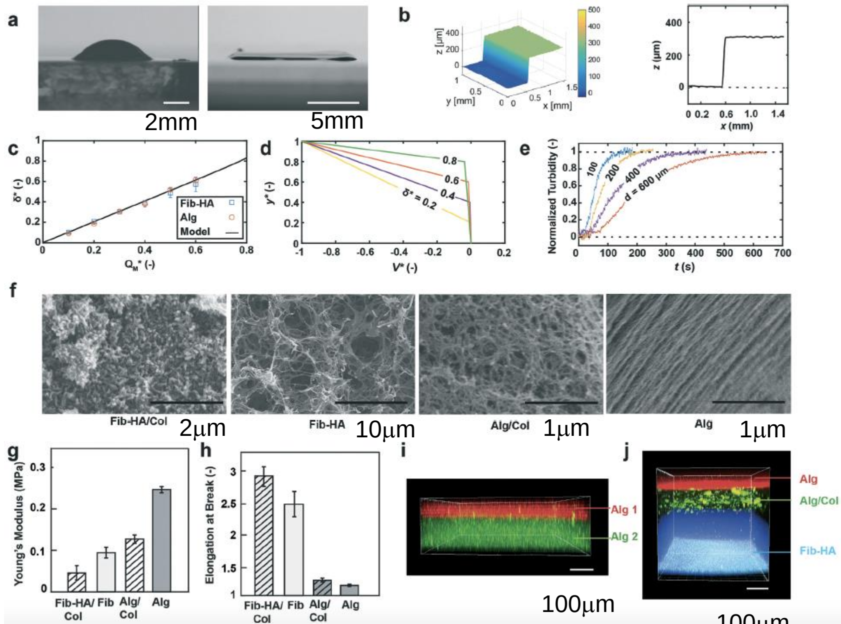
Handheld Skin Printer



Hakimi *et al. Lab Ch*ip (2018) **18**, 1440-145

55

Characterization of Biomaterial Sheets



Hakimi *et al.* *Lab Chi*p (2018) **18**, 1440-145

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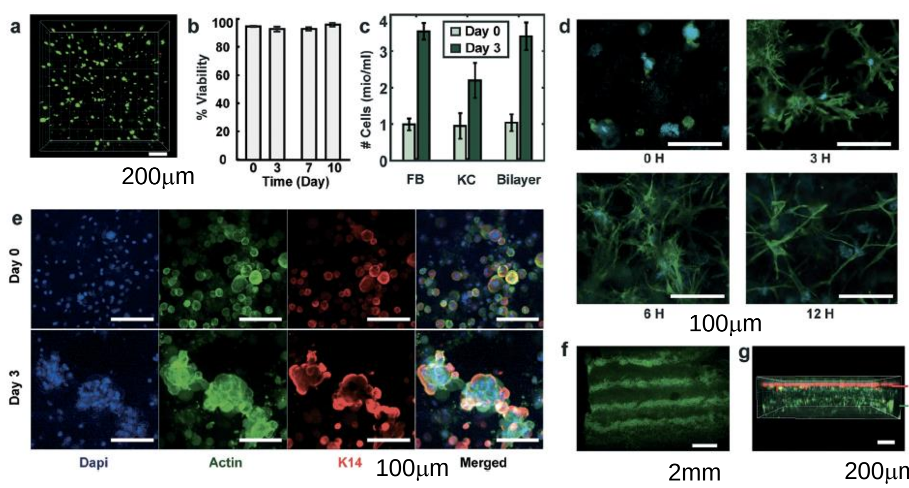
In-Situ Formation of Skin Tissues *in vitro*



Hakimi *et al.* *Lab Chi*p (2018) **18**, 1440-145.

57

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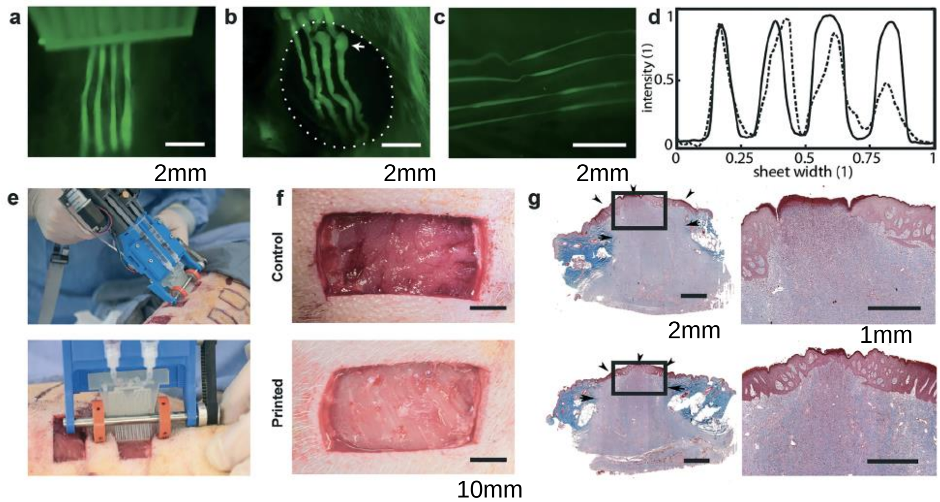
In-Situ Delivery of Biomaterials *in vivo*



Hakimi *et al. Lab Ch*ip (2018) **18**, 1440-145. (with Marc G. Jeschke)

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in-vivo deposition on a porcine excisional wound model

60

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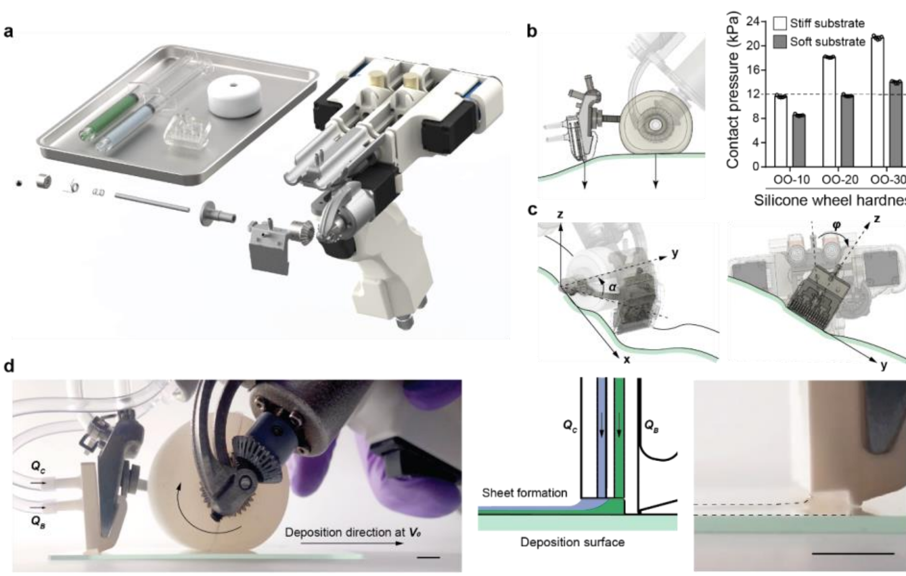

Cheng, *et al*. (2020) *Biofabrication* **12** (2) 025002

61

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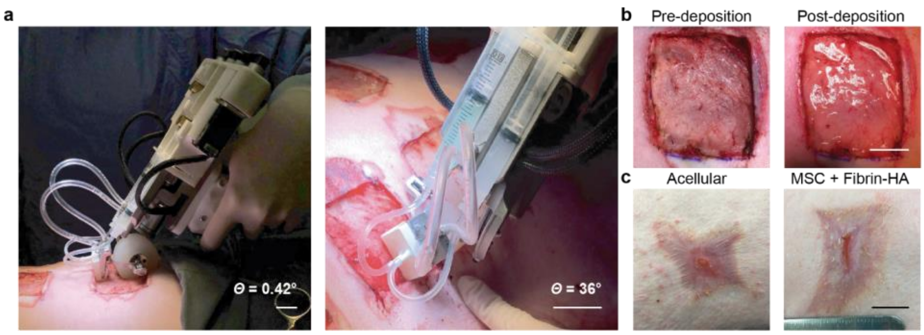

Cheng, *et al*. (2020) *Biofabrication* **12** (2) 025002

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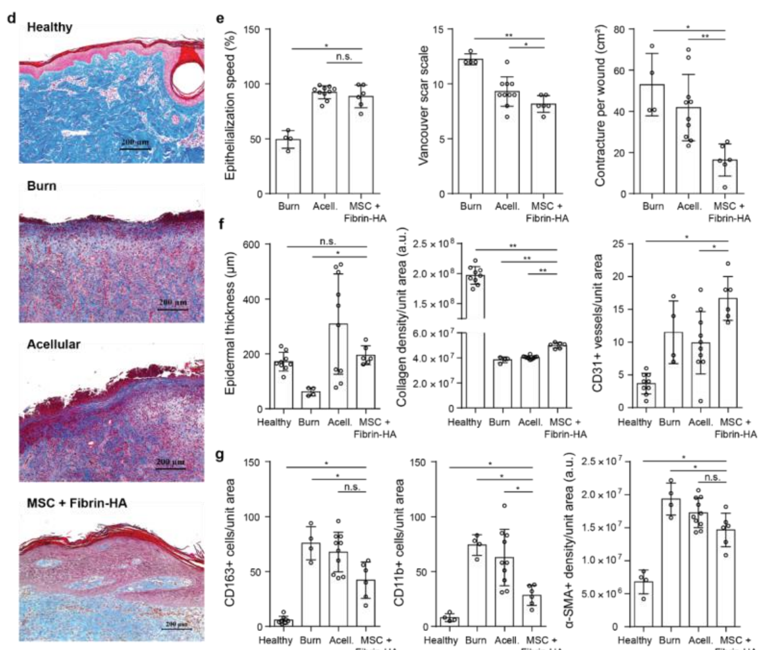

Cheng, *et al*. (2020) *Biofabrication* **12** (2) 025002

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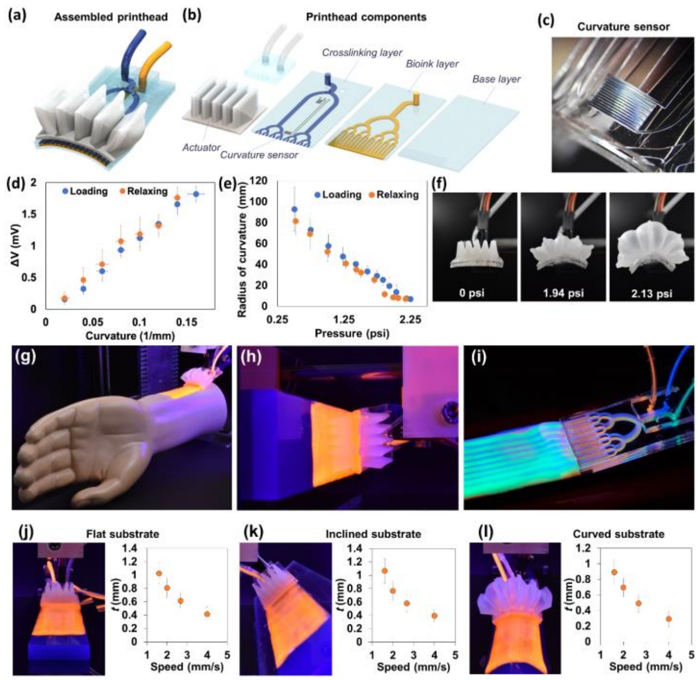

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Summary

- Rapid in-situ bioprinting strategies based on multinozzle microfluidic printheads
- Formation of ECM-based biomaterial sheets and precursor tissues conformal to wound surface accelerates wound healing
- Current work: ECM-based granular bioinks with tailored printability and wound contraction, rapid biofabrication strategies for load bearing tissues.

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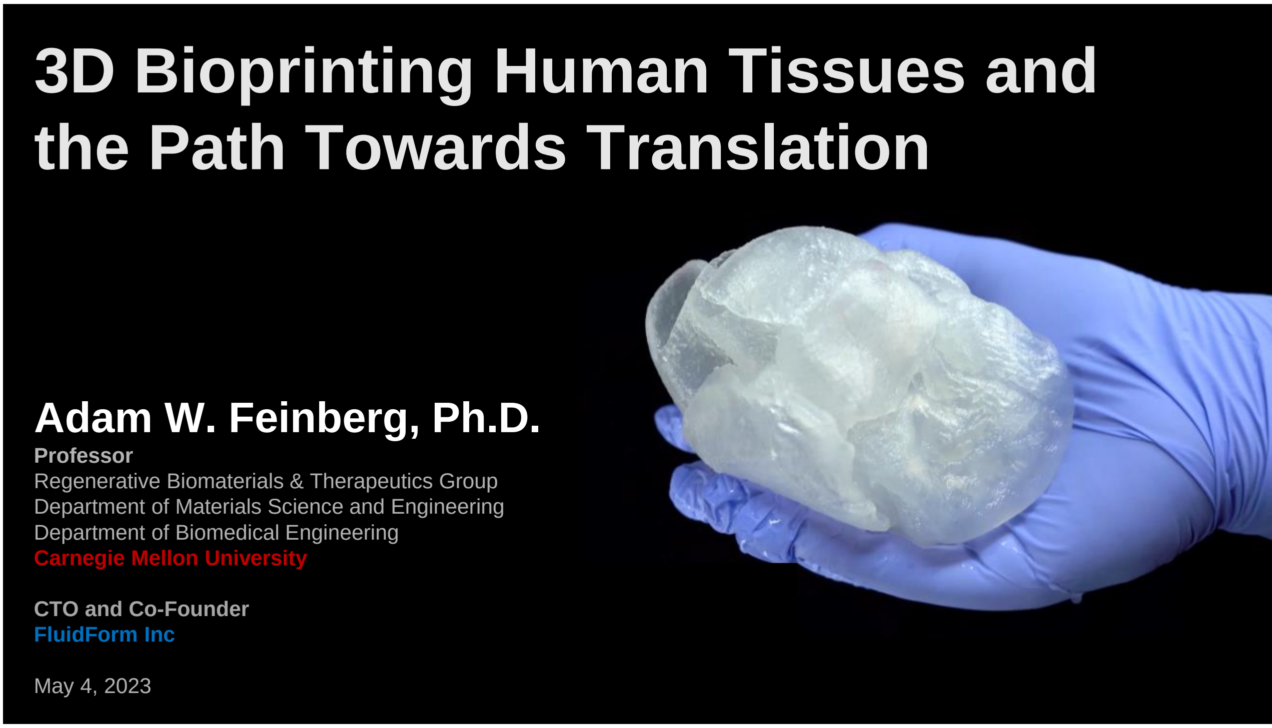
3D Bioprinting Human Tissues and the Path Towards Translation
Adam W. Feinberg, Ph.D.
Professor
Regenerative Biomaterials & Therapeutics Group
Department of Materials Science and Engineering
Department of Biomedical Engineering
Carnegie Mellon University
CTO and Co-Founder
FluidForm Inc
May 4, 2023

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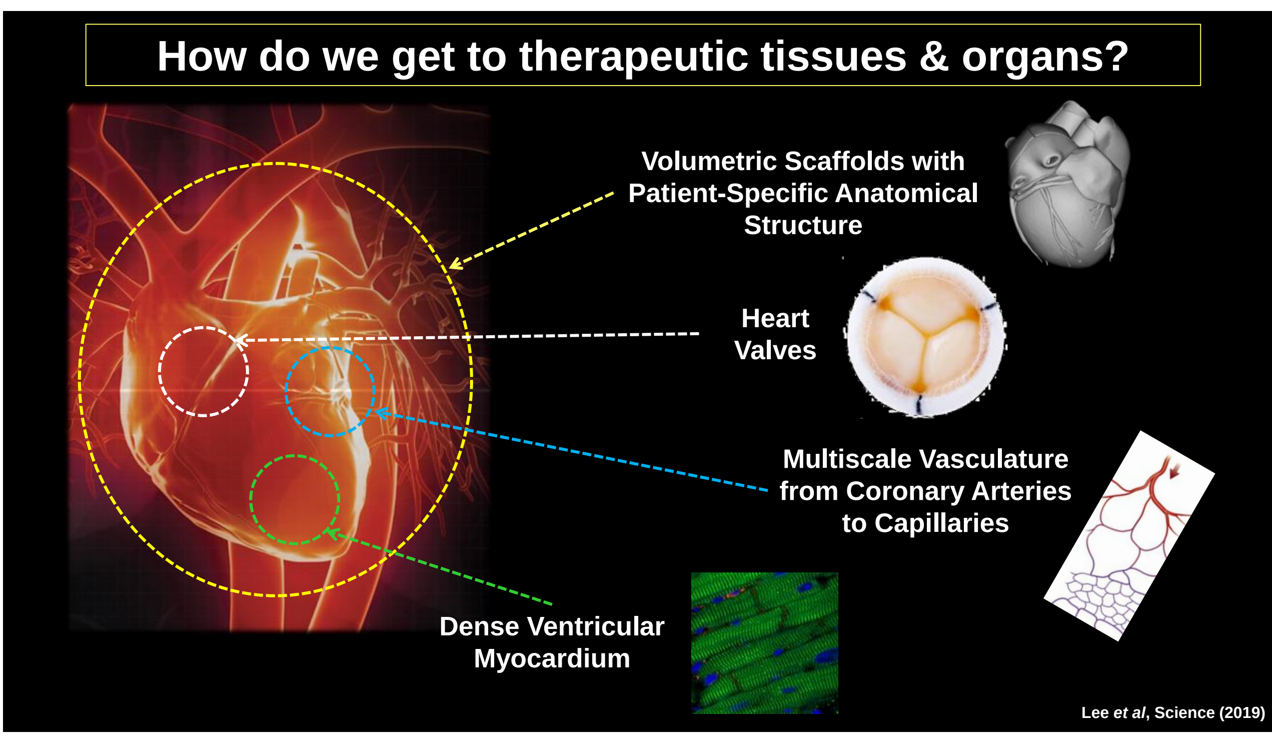
How do we get to therapeutic tissues & organs?
Volumetric Scaffolds with Patient-Specific Anatomical Structure
Heart Valves
Multiscale Vasculature from Coronary Arteries to Capillaries
Dense Ventricular Myocardium
Lee et al, Science (2019)

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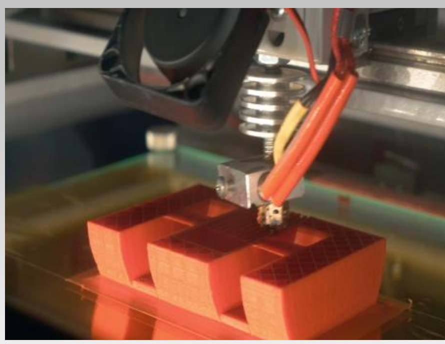
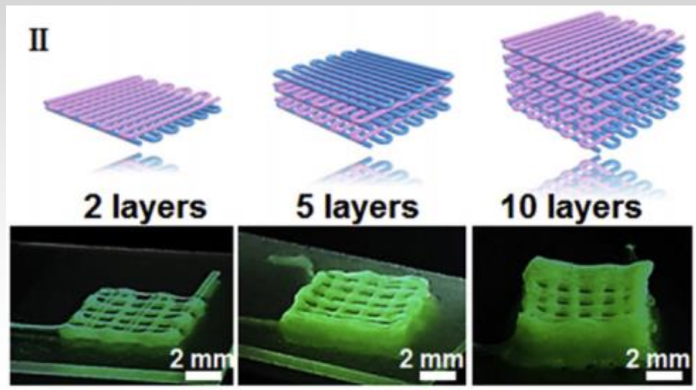
3D Printing → A Problem for Hydrogels & Cells



Fidelity is lost when printing hydrogels



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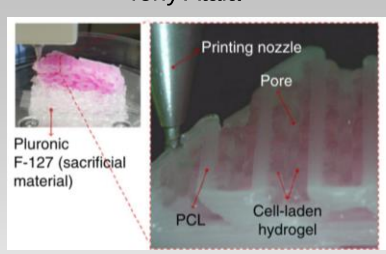
3D Bioprinting of Soft Materials - SUPPORT

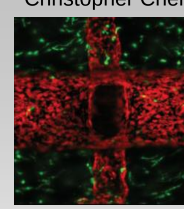
Tony Atala



Gabor Forgacs

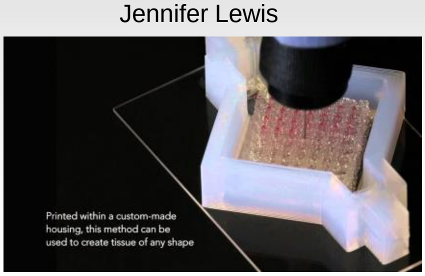
Mironov et al. Biomaterials, 2009

Christopher Chen



Miller et al. Nature Materials, 2012

Jennifer Lewis



Jordan Miller

Grigoryan et al. Science, 2019

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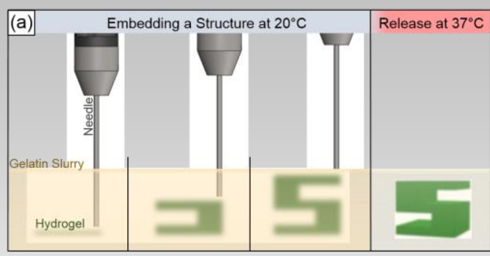
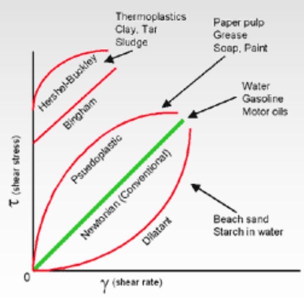
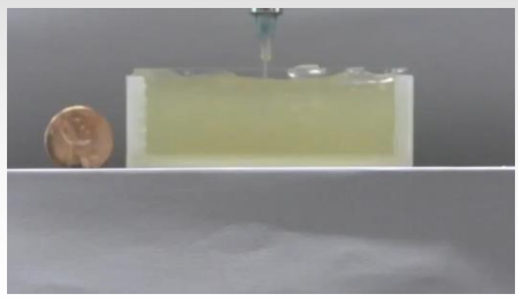
FRESH → Supports Soft & Living Materials



- **F**reeform **R**eversible **E**mbedding of **S**uspended **H**ydrogels (FRESH)
- Gelling fluid bioink is embedded into sacrificial support material
- Bath behaves as a yield stress fluid
- BioInk is uniformly supported during printing while it gels
- Support is melted to retrieve print

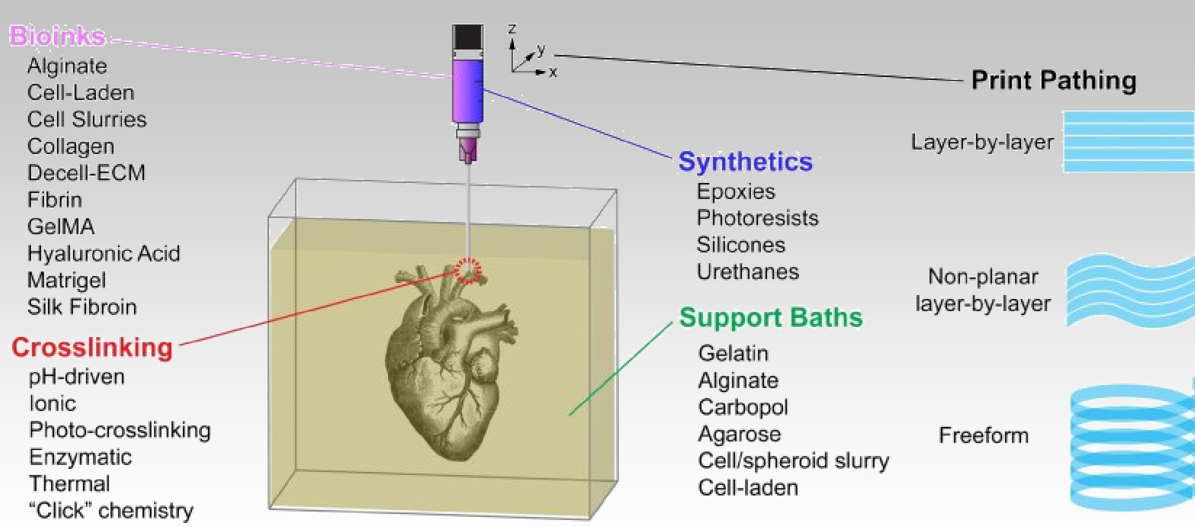




Embedded printing leaders
- Adam Feinberg (CMU)
- Jennifer Lewis (Wyss)
- Jason Burdick (UC)
- Tommy Angelini (UF)

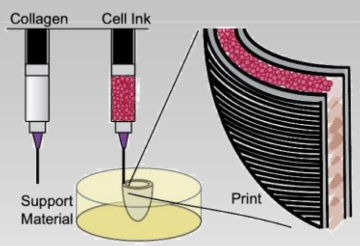
Hinton *et al*, Science Advance (2015)

FRESH → An Advanced Biofabrication Platform

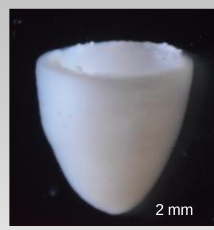


Shiwarski *et al*, APL Bioengineering (2021)

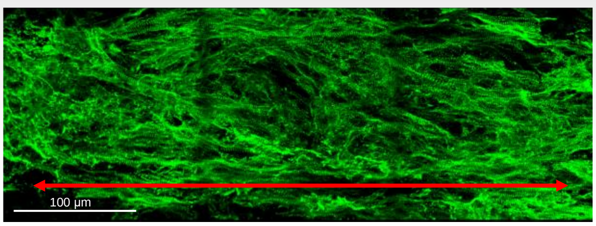
Engineering a Contractile Human Ventricle



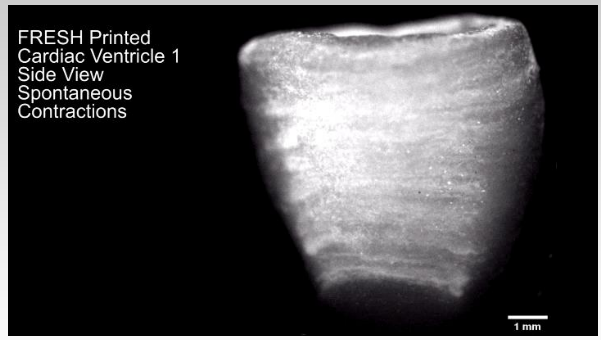
Printed Ventricle



Cardiomyocyte alignment in printed ventricle wall



Calcium Imaging of Ventricle



Lee *et al*, *Science* (2019)

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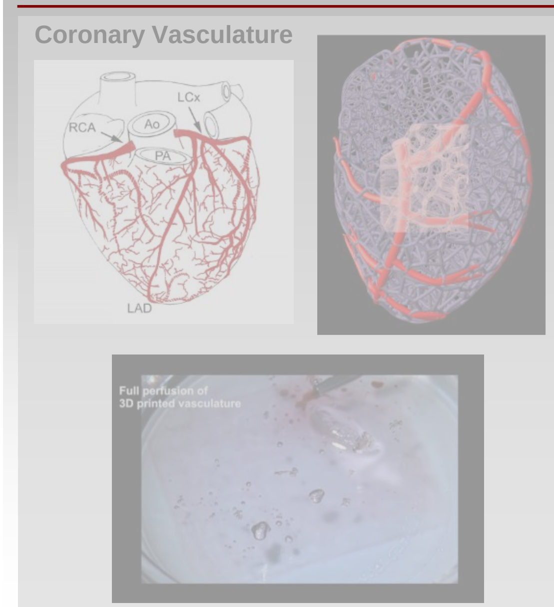
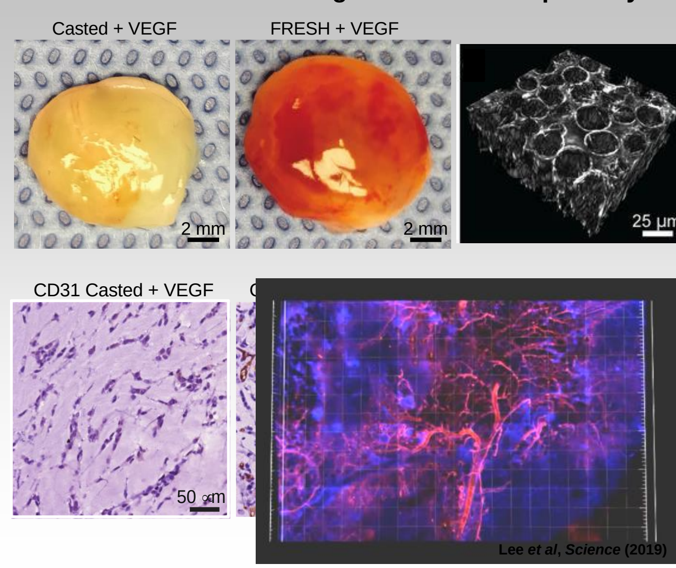
Building Multiscale Vasculature – Printing / Self-Assembly



Microvasculature Through GFs and Microporosity



Lee *et al*, *Science* (2019)

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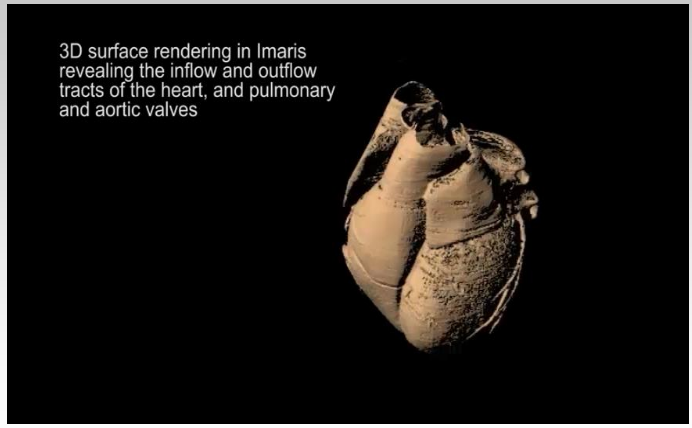
Functional and Large-Scale Collagen Devices

Tri-leaflet Heart Valve

Organ-Scale 3D Printing



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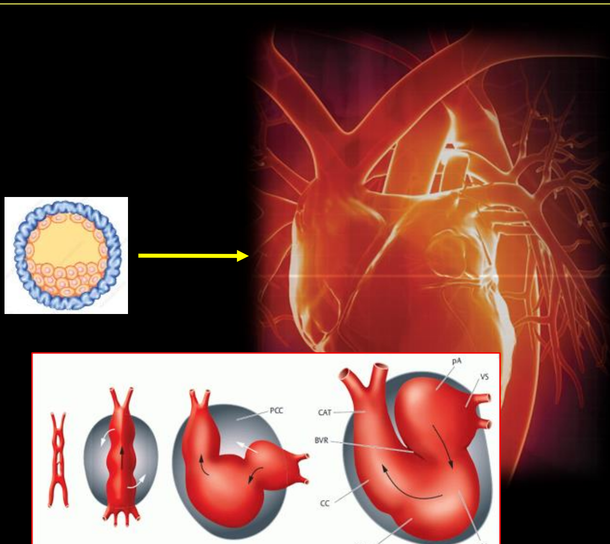
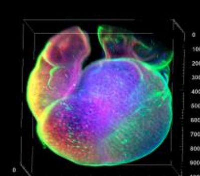
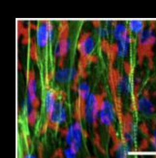
Now that we can 3D bioprint cells and ECM, how exactly do we create tissues & organs?



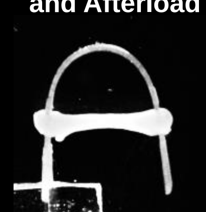
ECM in the Developing Heart



Bioinspired Matrix Design



EHTs w/ Preload and Afterload



Contractile Heart Tubes

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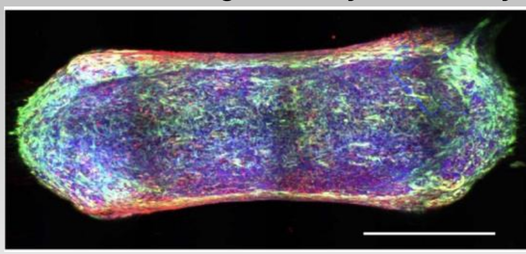
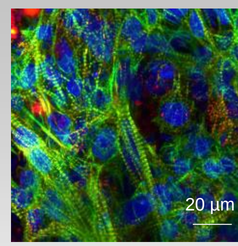
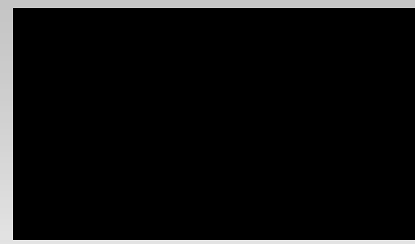
Building a Functional Human Heart Tube

High-density Cardiac Syncytium



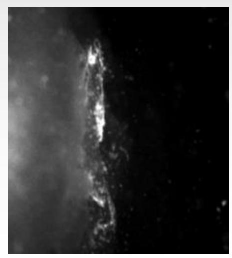


Calcium Handling

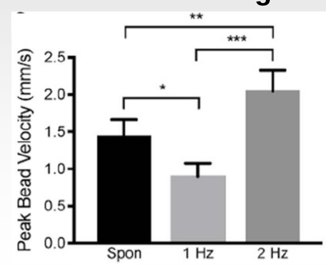


Contractile Function

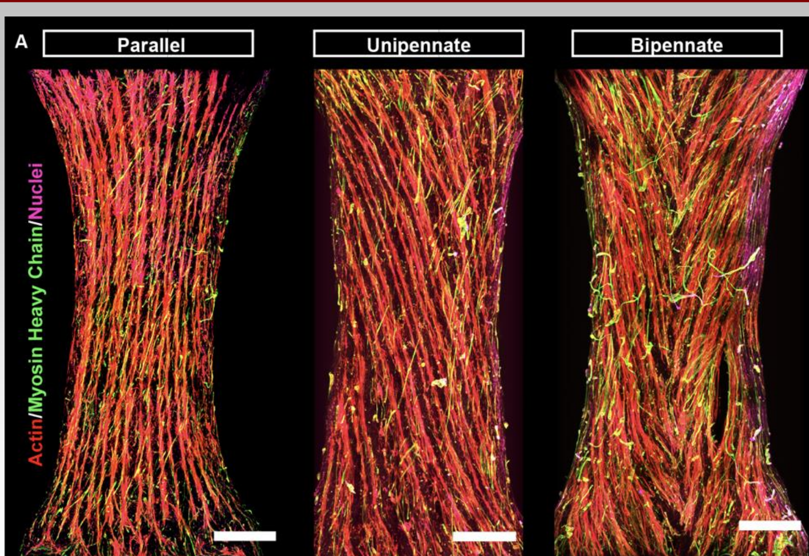
Pumping

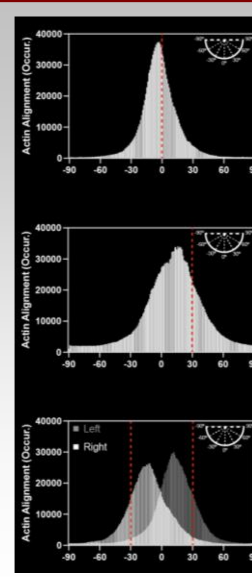


Bead Tracking



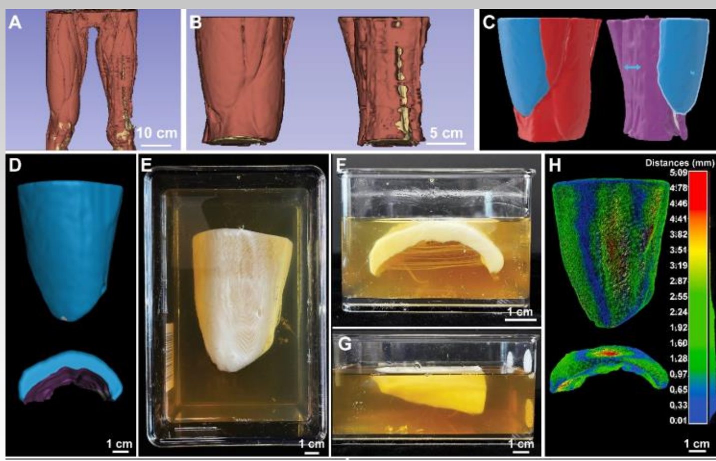
Collagen Scaffolds Guide Muscle Organization





Stang *et al* (Unpublished)

Patient-specific Decellularized ECM Scaffold for VML



- De-identified human CT image showing volumetric muscle loss (VML) injury with contralateral uninjured leg
- The scaffold (blue) was created by isolating the vastus lateralis muscle from the uninjured leg and overlaying it onto the injured leg
- The ECM scaffold was FRESH printed using decellularized ECM bioink with a length of ~14 cm
- Dimensional analysis of the 3D printed scaffold shows excellent fidelity with <1.5 mm mean deviation

Behre *et al*, *Advanced Healthcare Materials* (2022)

Driving Tissue Biofabrication Forward

- Advanced tissue engineering applications, including disease models
- Multiscale solutions to vascularization
- Biomanufacturing platforms w/ advanced 3D imaging
- Translation to large animal pre-clinical models
- Supporting the research community through education and open-source technologies
- Development of commercial applications including biomanufactured medical devices & in vitro disease models

Acknowledgements

@RegenBio http://regenerativebiomaterials.com

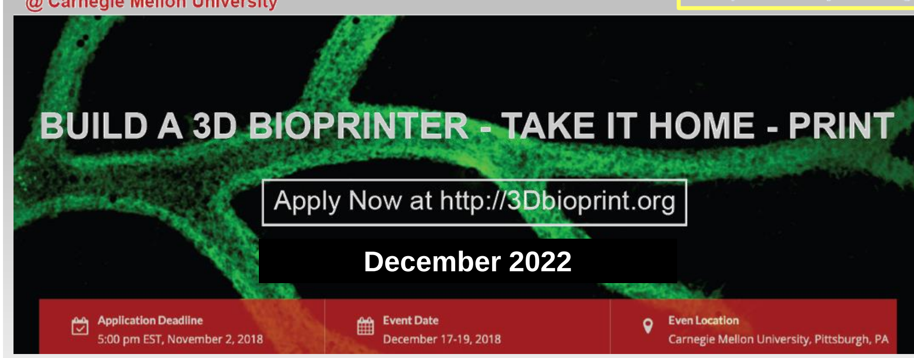
Collaborators
- Phil Campbell (CMU)
- Jana Kainerstorfer (CMU)
- Steve Badylak (Pitt)
- Peter Van der Meer (UGMC)
- Daniel Pijnappels (Leiden)

Disclosures
- FluidForm, Inc.
  CTO & Co-founder

FDA NIH NSF HFSP ONR JDRF ADDITIONAL VENTURES CDMRP Department of Defense American Heart Association Bioengineered Organs Initiative Carnegie Mellon University DARPA CYSTIC FIBROSIS FOUNDATION

3D BIOPRINTING OPEN-SOURCE WORKSHOP
@ Carnegie Mellon University

http://3Dbioprint.org



- Annual workshop to build an open-source 3D bioprinter
- Modifications released as open-source (CC-BY-SA)
- Step-by-step instructions, STL files, configuration files, and tutorial videos published or in preparation
- Designs at NIH 3D Print Exchange
- Complete instructions – Tashman *et al*, BioRxiv (2022)

Participants/Collaborators

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Beth Pruitt, UC Santa Barbara
Sarah Heilshorn, Stanford
Gordana Vunjak-Novakovic, Columbia
Ronke Olabisi, UC Irvine
Kevin Costa, Mount Sinai
Emilio Alacron, Univ of Ottawa
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Marcelle Machluf, Technion
Eben Alsberg, UI Chicago
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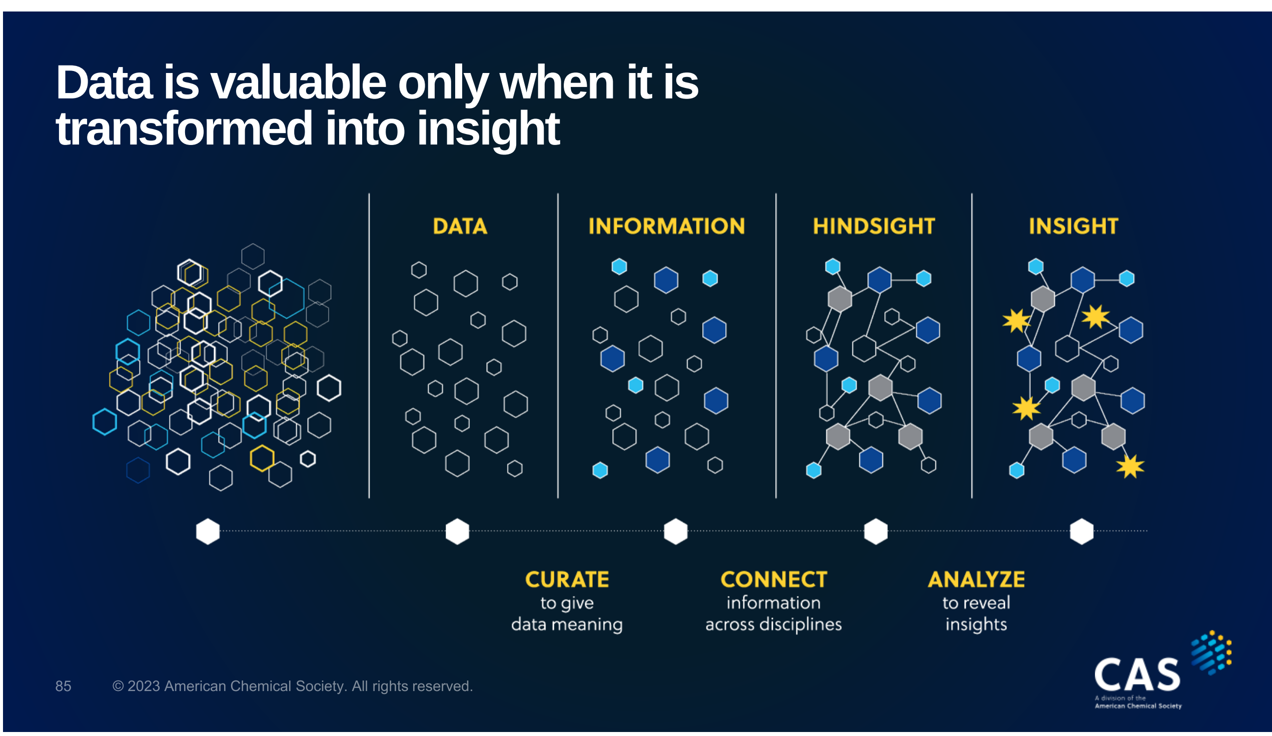
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transformed into insight
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INFORMATION
HINDSIGHT
INSIGHT
CURATE
to give
data meaning
CONNECT
information
across disciplines
ANALYZE
to reveal
insights
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