Sweet Science: 3D Printed Sugar Templates for Regenerative Medicine

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open source hardware

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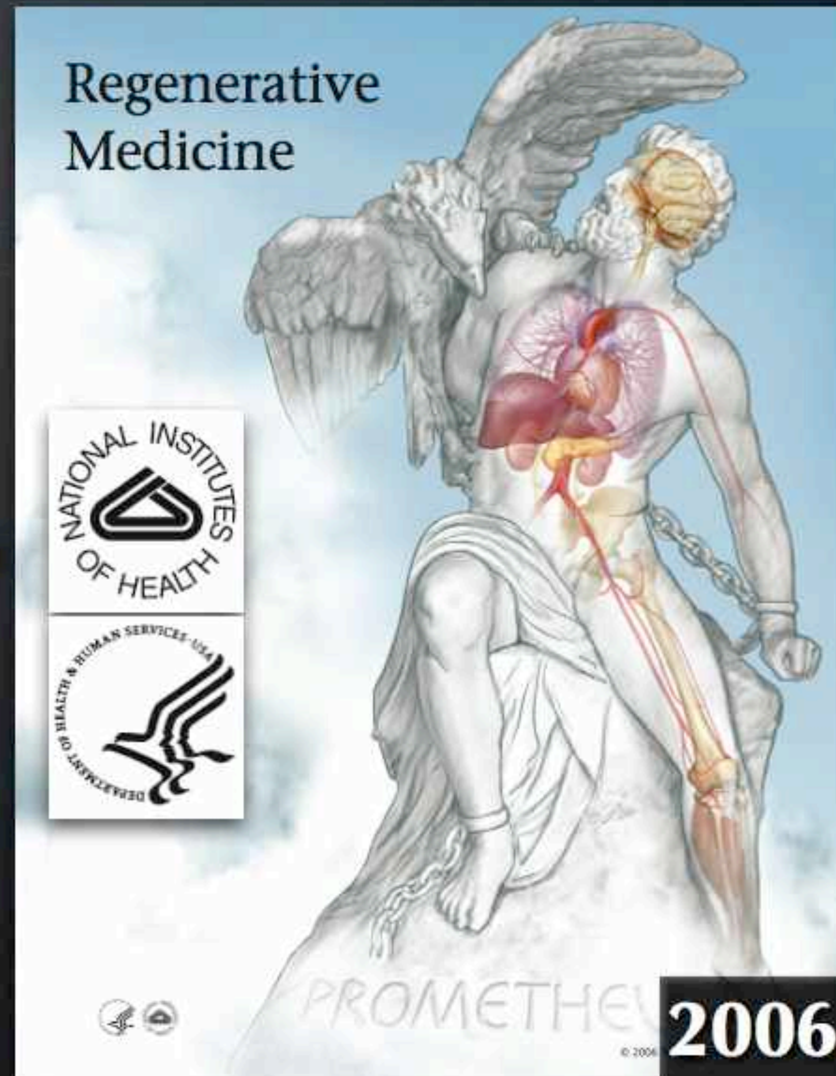
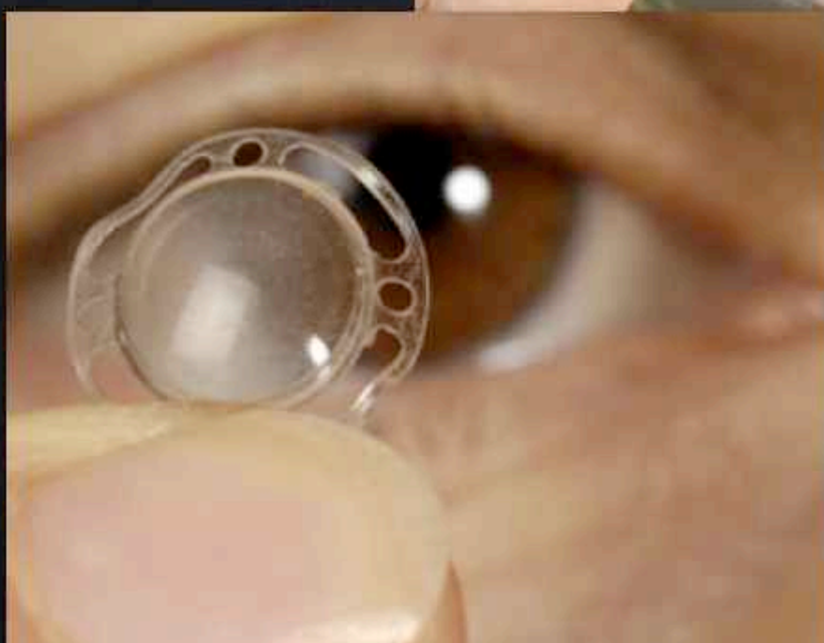
Tissue Engineering → Regenerative Medicine

→



Cells Outperform Devices.

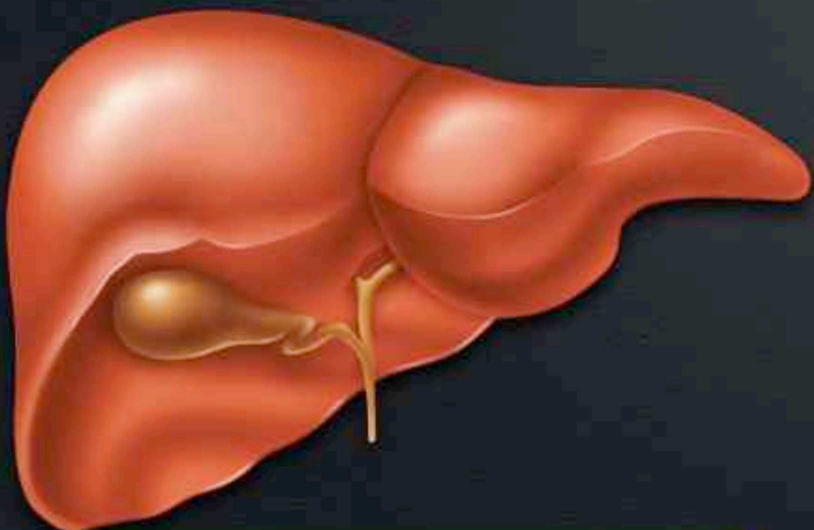
Some Successes in Regenerative Medicine



Yannas IV+. Science 1982; 215:174-6.
Heimbach D+. Ann. Surg. 1988; 208(3):313-20.
Yannas IV. Chembiochem 2004; 5(1):26-39.
Nishida+. NEJM 2004; 351(12):1187-96.
Atala+. Lancet 2006; 367:1241-6.

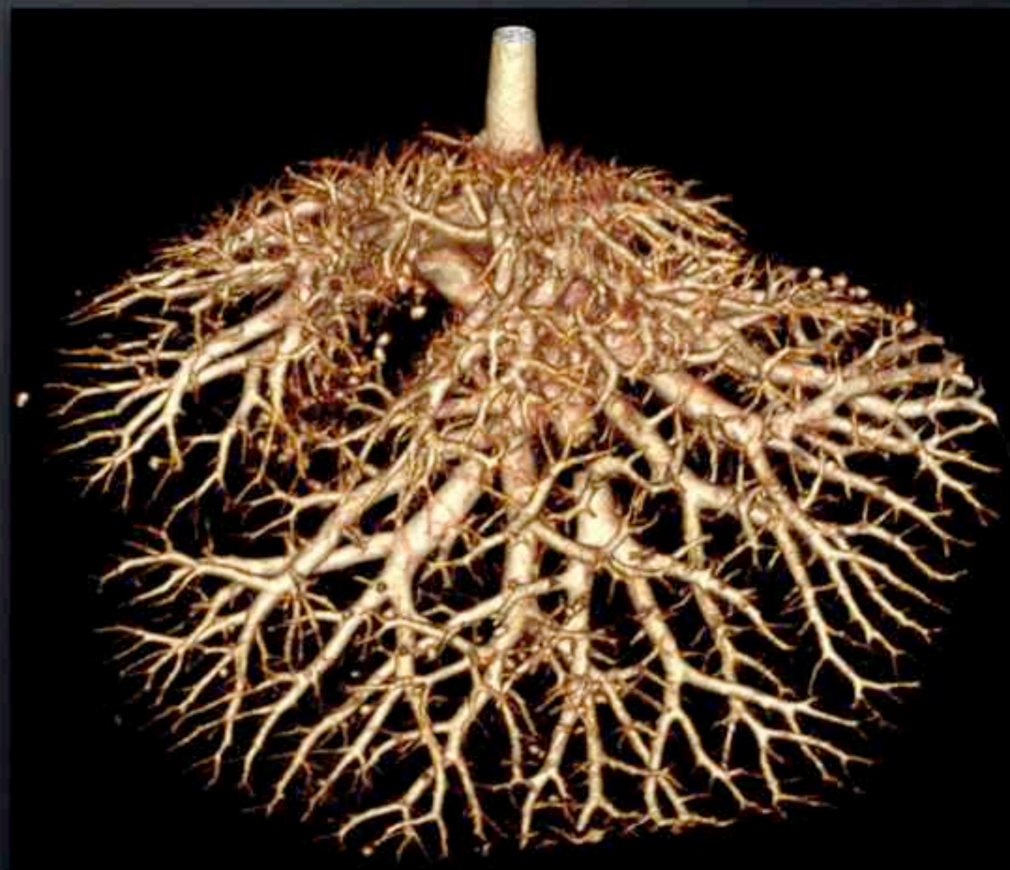
Solid Organs have Multiscale Vasculature

Human Liver



3.5 lbs (1.6 kg)
1.5 L volume
750 mL vasculature

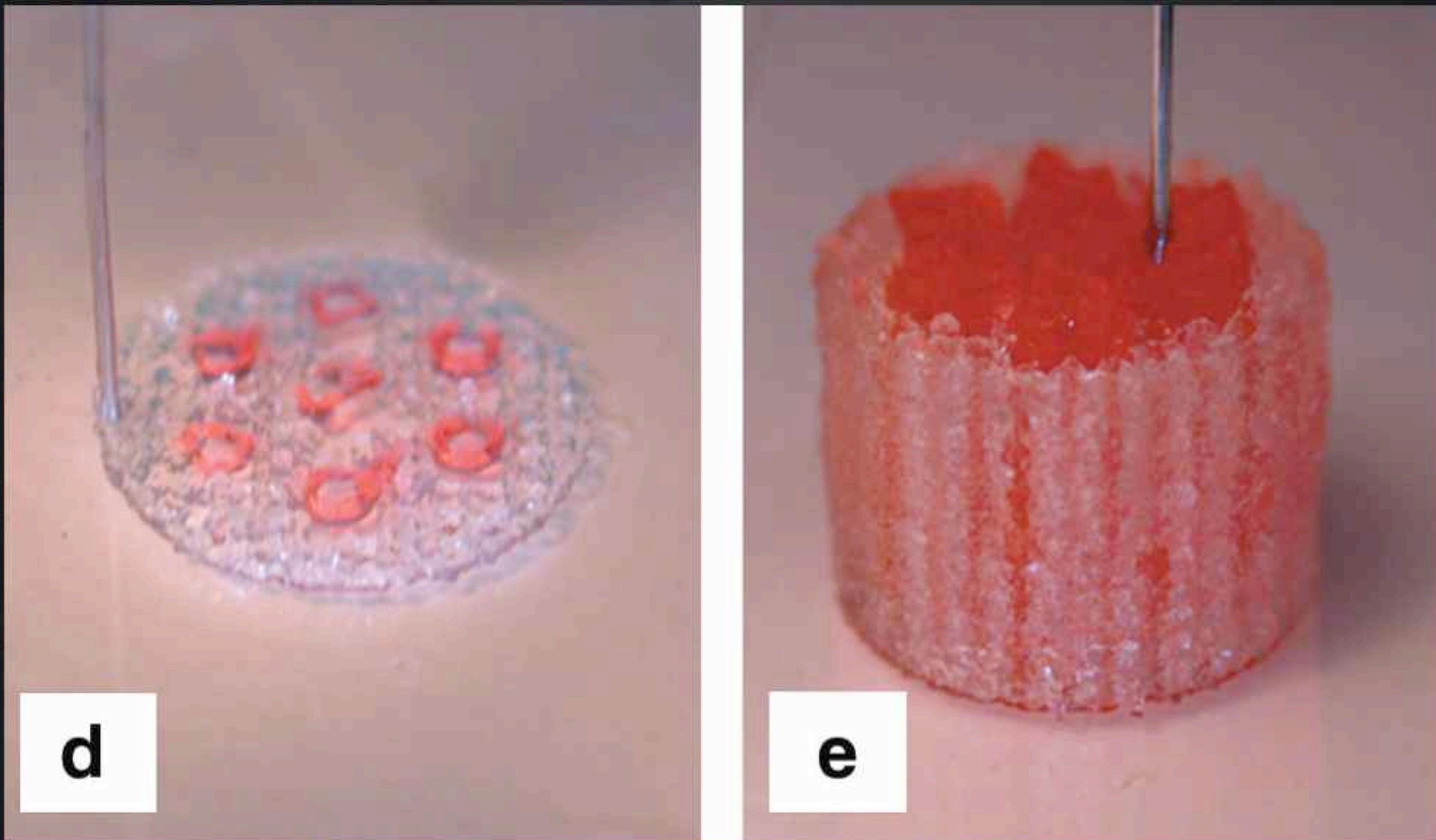
Mouse Liver



µCT of mouse liver vasculature, 2 lobes
processed data from Bhatia lab, MIT

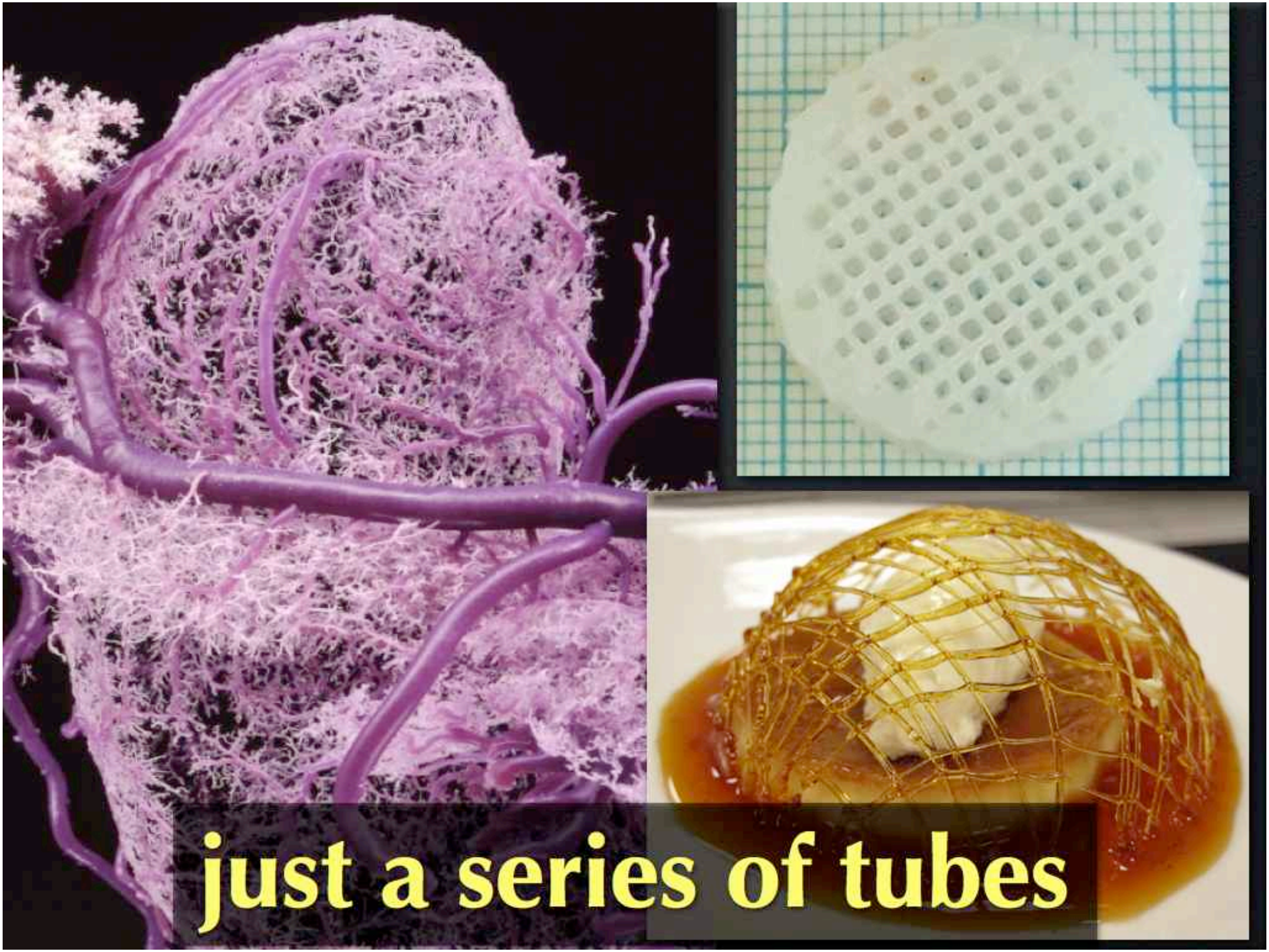
http://zdsolutions.it/
Andersen V+. Alcohol Alcohol 2000; 35(5):531-2.

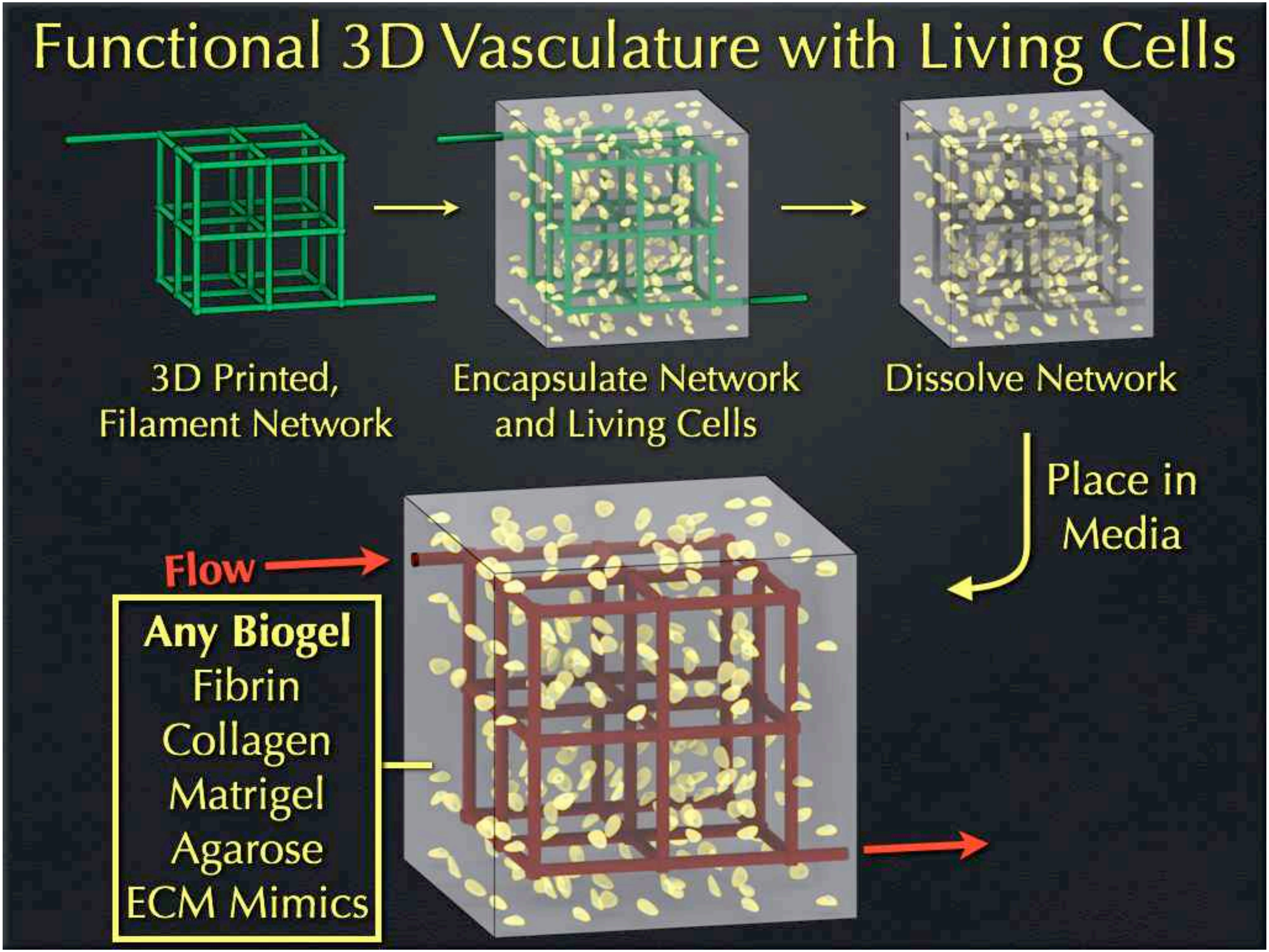
Bioprinting Cells and Gel



Hypoxia, Shear Stress, Cell Type and Gel Type limitations are major challenges

Wang, et al. (2010). Tissue Engineering PART B, 16(2), 189–197.


just a series of tubes


Functional 3D Vasculature with Living Cells
3D Printed,
Filament Network
Encapsulate Network
and Living Cells
Dissolve Network
Place in
Media
Flow
Any Biogel
Fibrin
Collagen
Matrigel
Agarose
ECM Mimics

Rhymes with Stratasys

Me: "Hi, I'd like to buy one of your awesome machines, rip out the internals and replace it with my own modifications. Can you send me the schematics?"

Company: "......uh..."

Science ❤'s Open Hardware

Open source is why Science works.

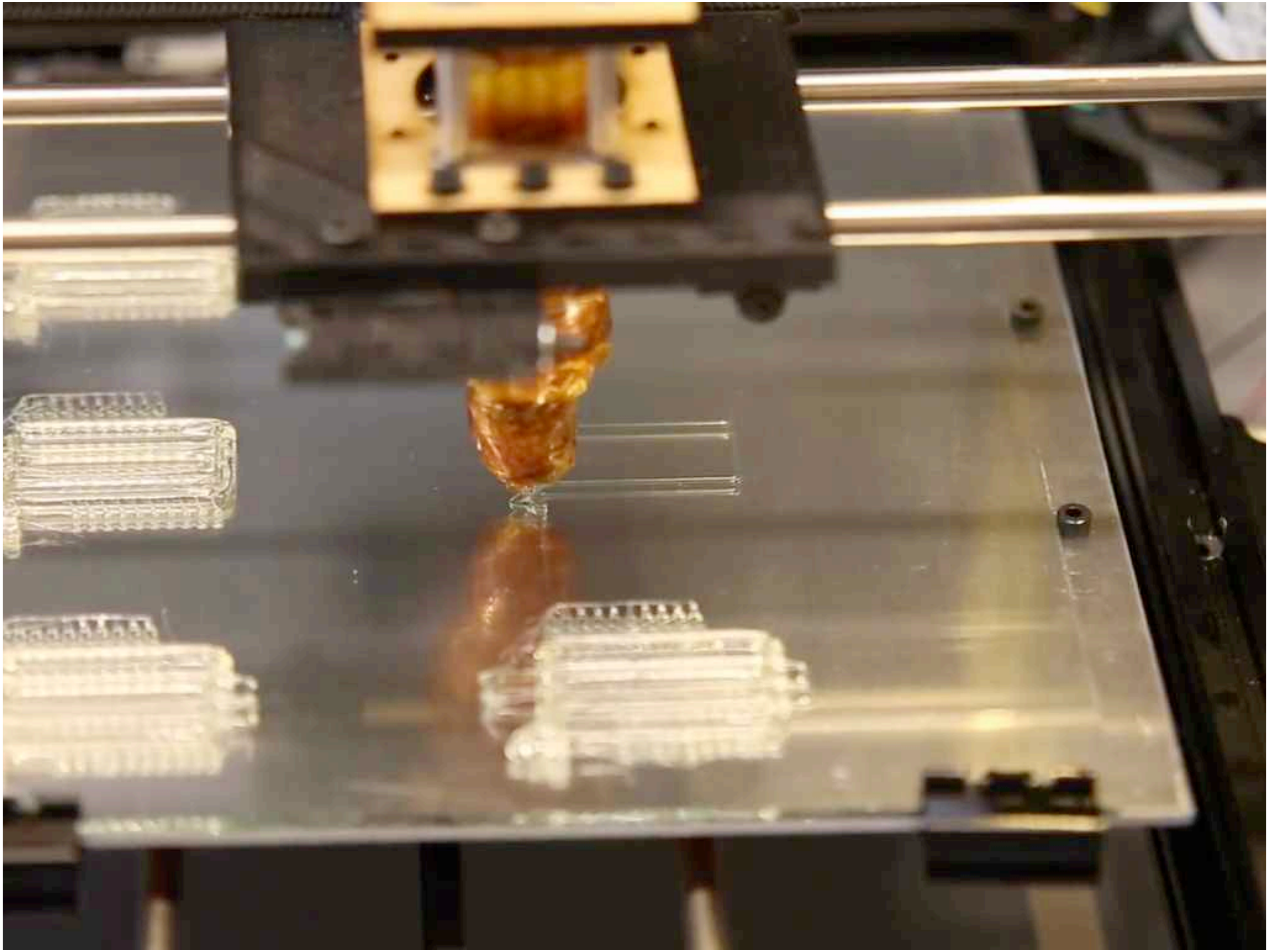
Open source gives you zero overhead to find collaborators everywhere in the world.

Open source defines the standards on which the future is built.

Closed source robs the future of ingenuity.

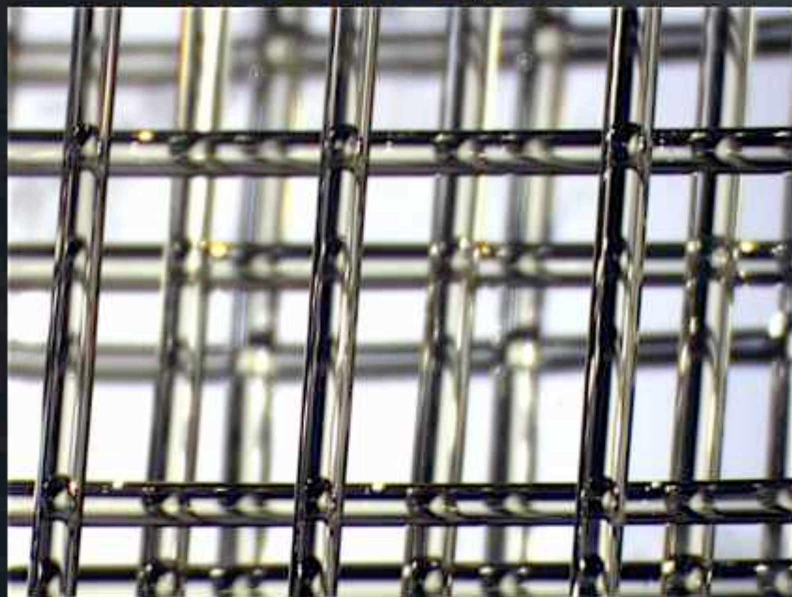
Closed source prevents the radical remixing and experimenting that are the hallmark of major advances.

Closed source makes you easy to forget.

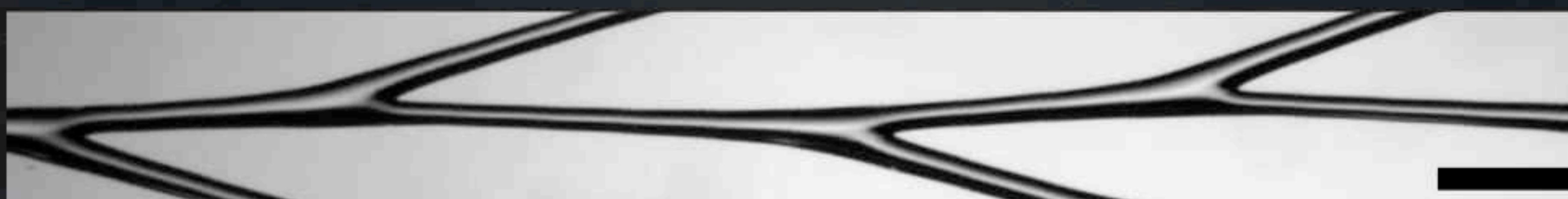


Reproducible Printing of Glass Lattice Architectures

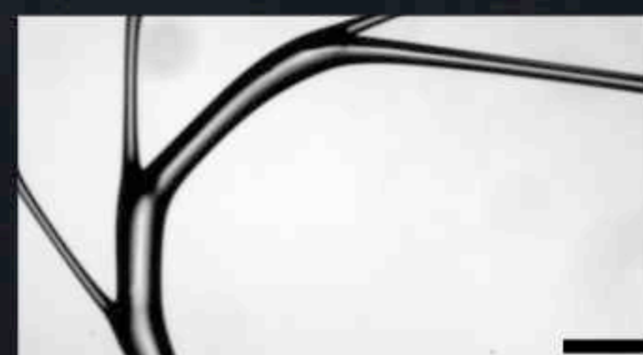
Multilayer

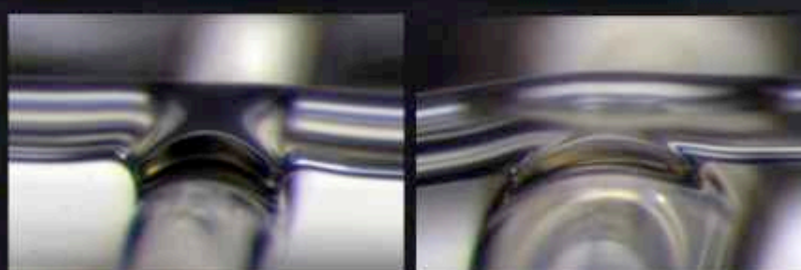


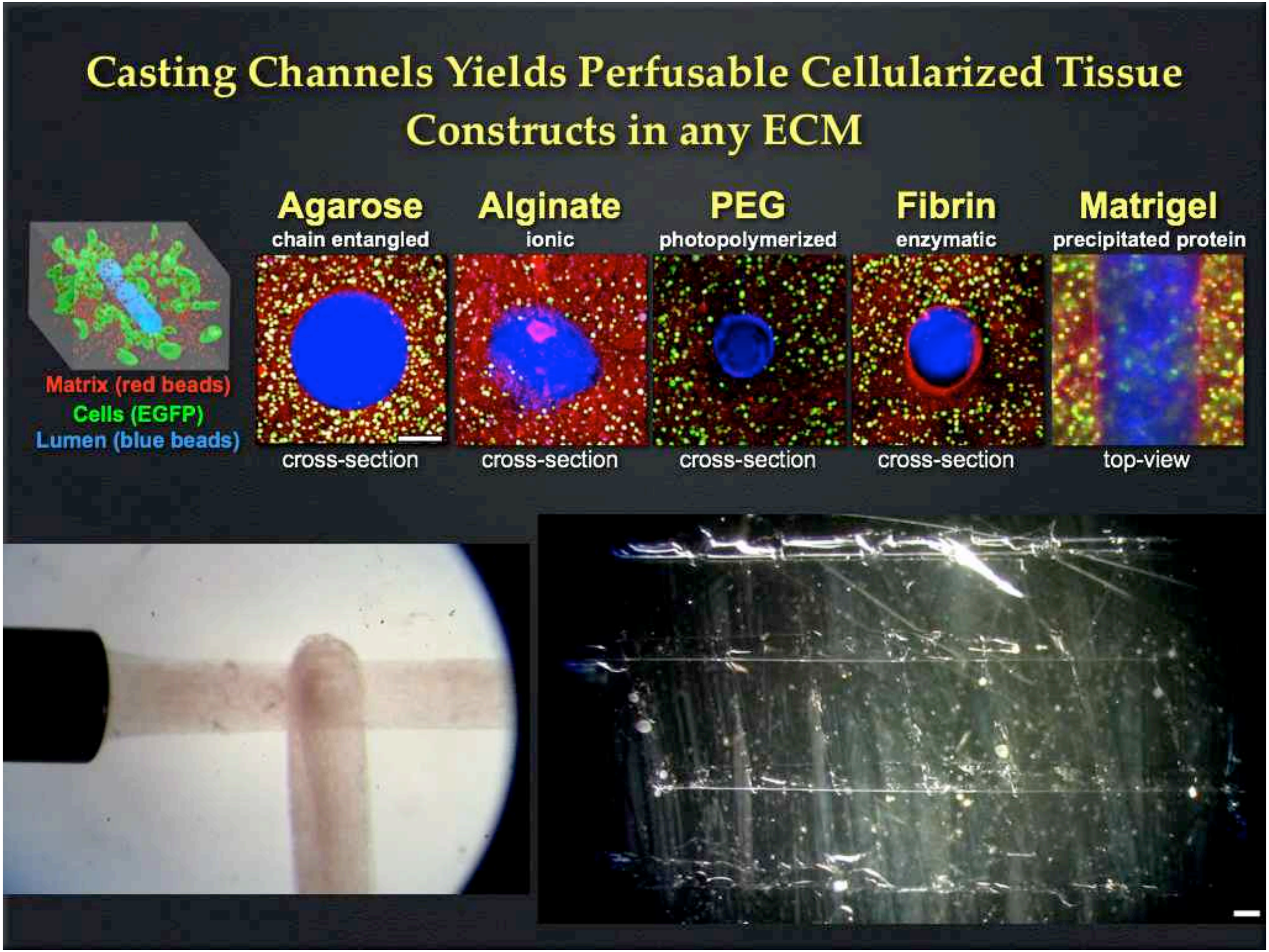
Multiscale



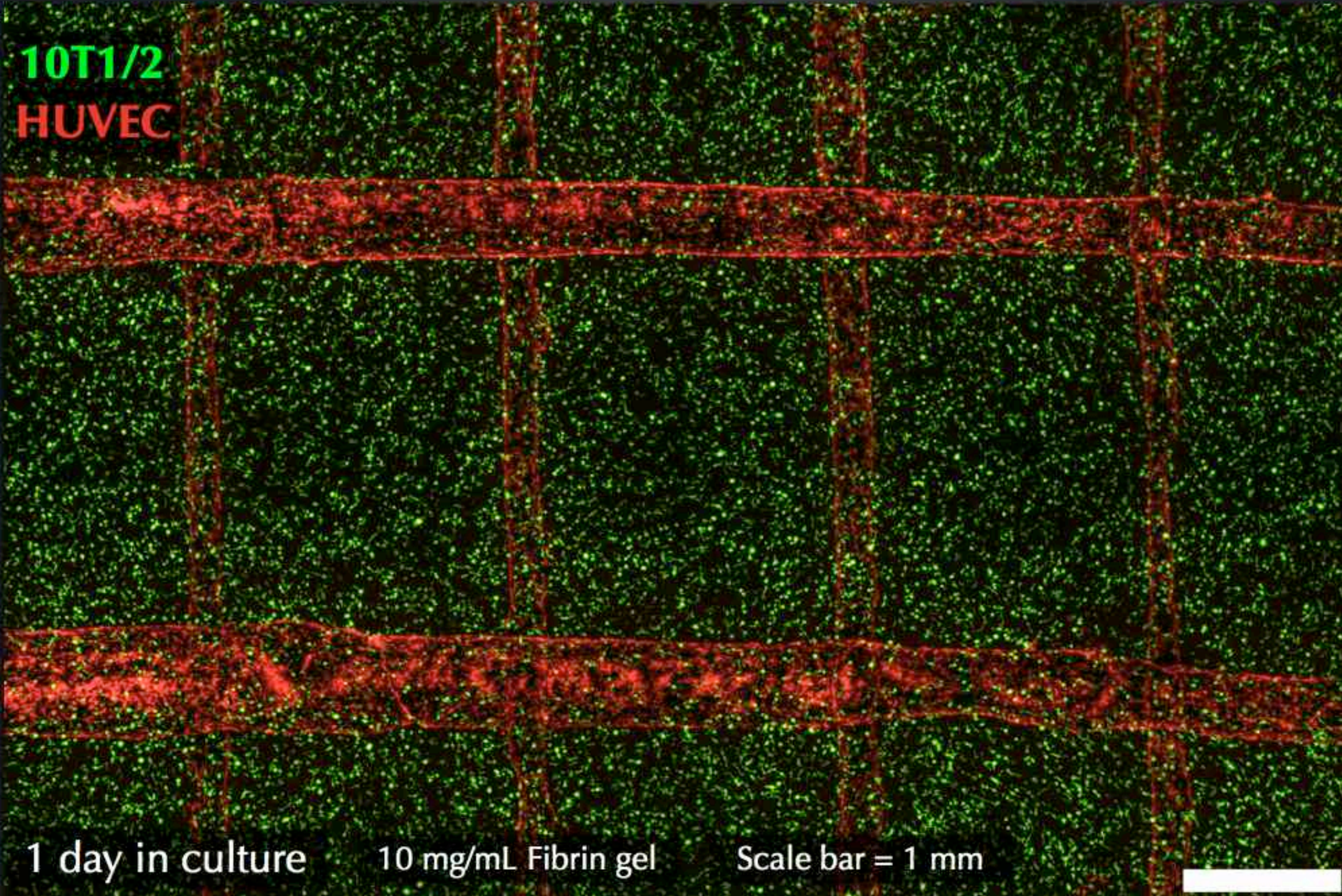
Smooth Interfilament Fusions






Casting Channels Yields Perfusable Cellularized Tissue Constructs in any ECM
Matrix (red beads)
Cells (EGFP)
Lumen (blue beads)
Agarose
chain entangled
cross-section
Alginate
ionic
cross-section
PEG
photopolymerized
cross-section
Fibrin
enzymatic
cross-section
Matrigel
precipitated protein
top-view

Endothelialization of the Vasculature

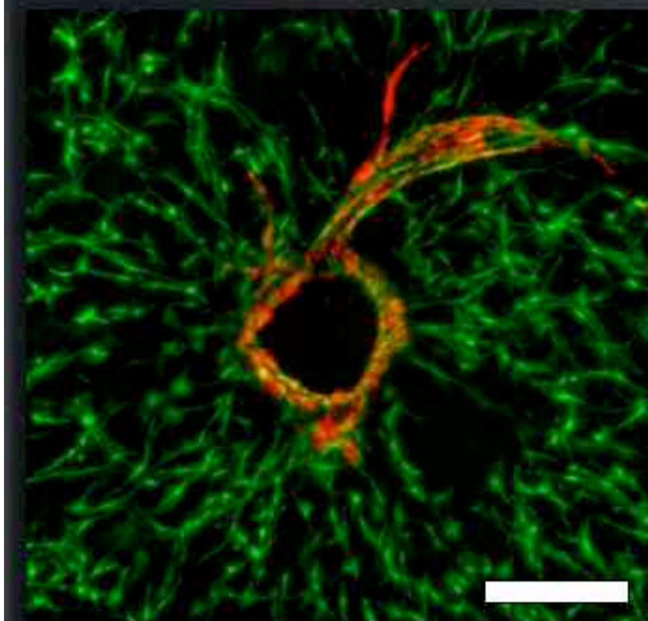


Endothelial Cells Sprout from Patterned Channels

10T1/2

HUVEC

Partial z-stack

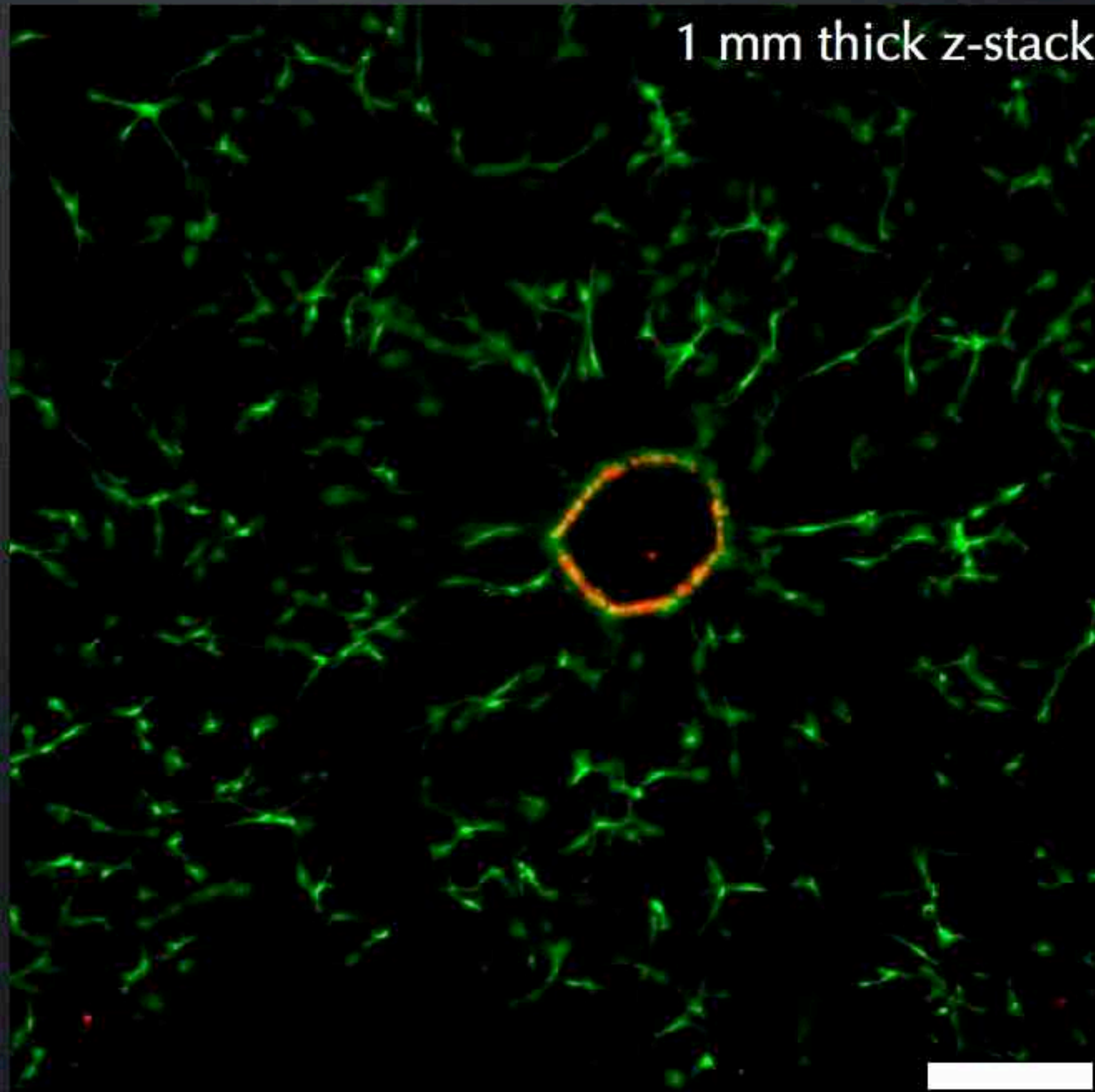


9 days in culture

***with Serum and GFs**

10 mg/mL Fibrin gel

Scale bar = 200 μm



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nature materials

Rapid casting of patterned vascular networks for perfusable engineered three-dimensional tissues

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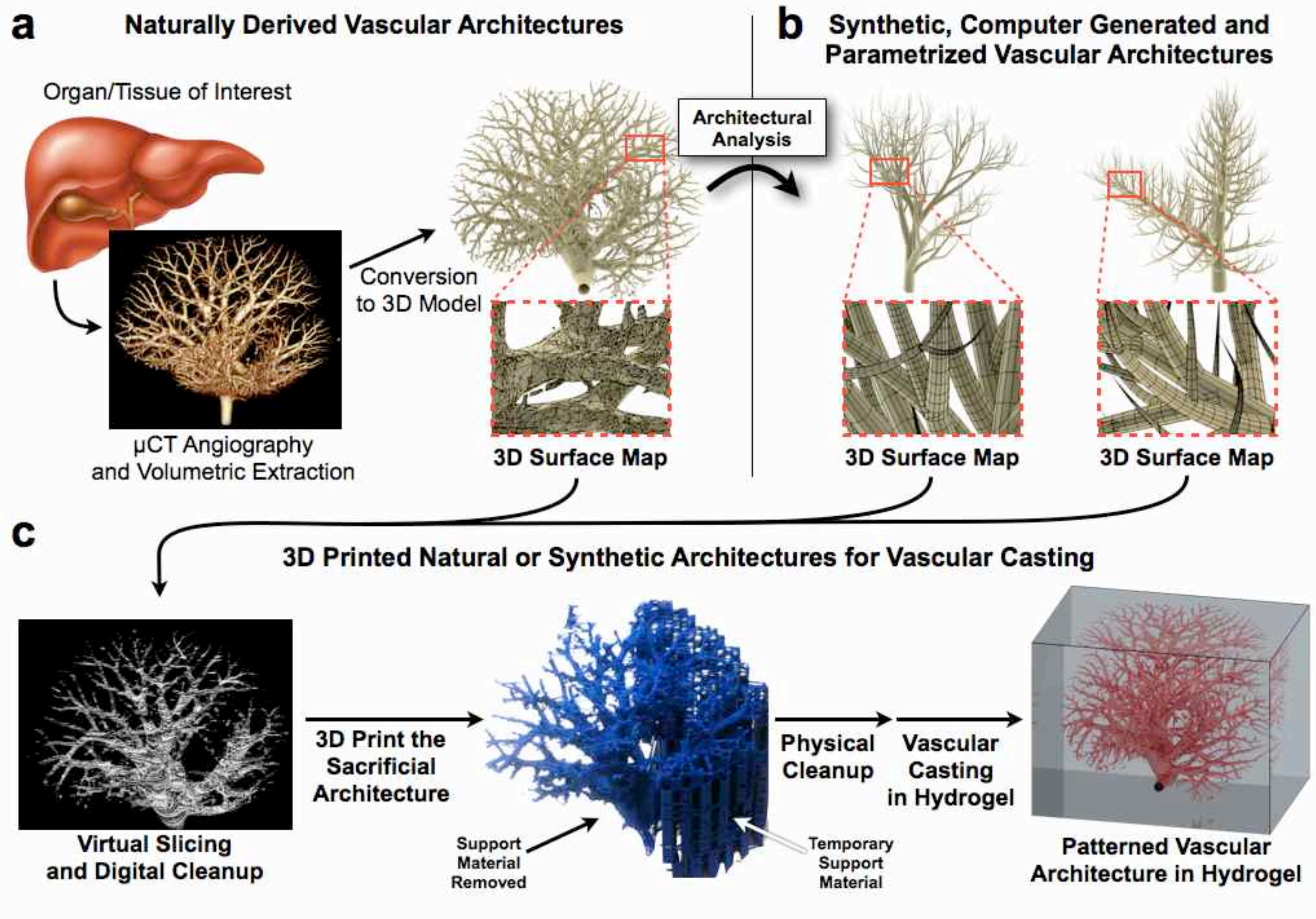
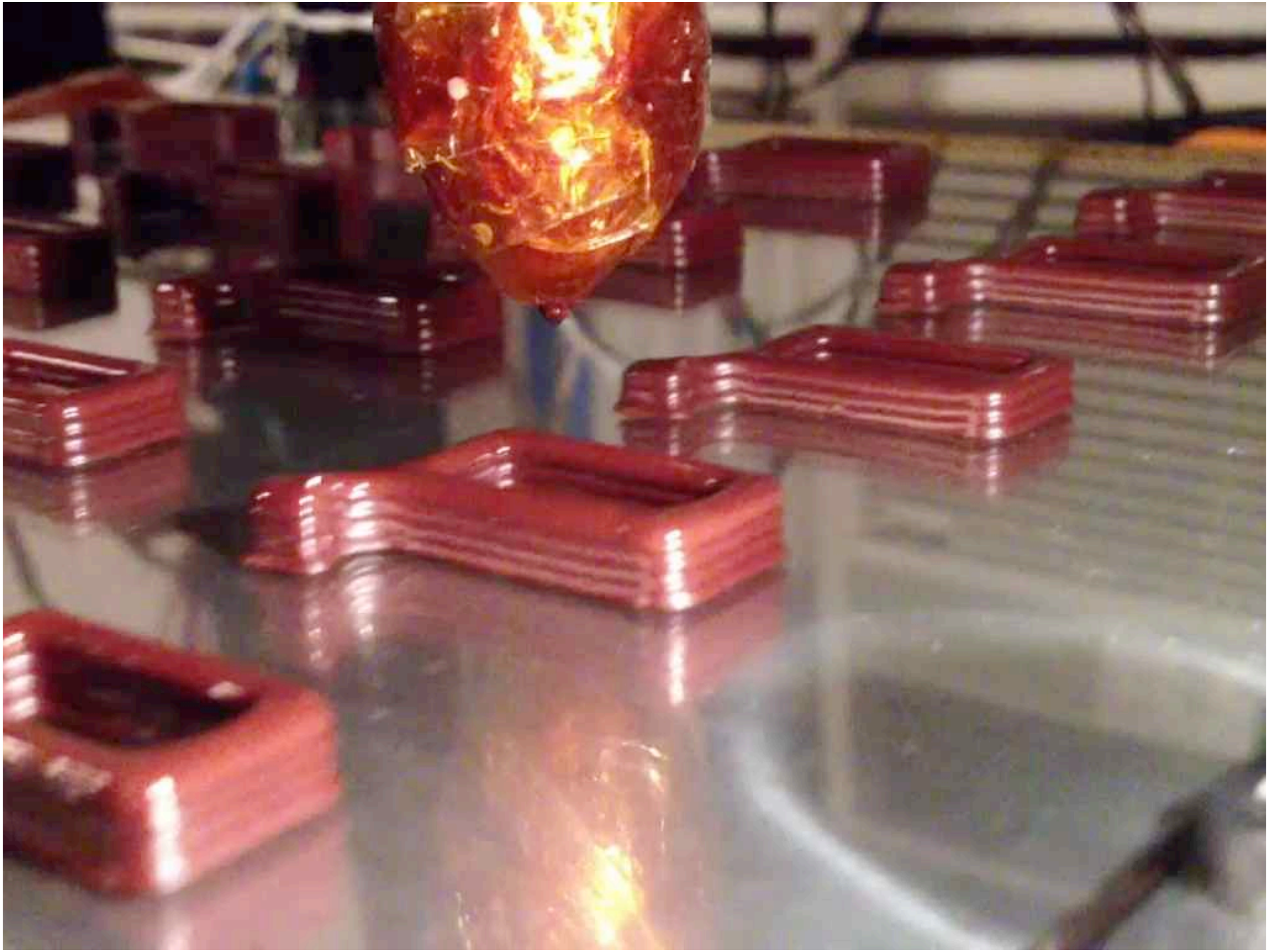
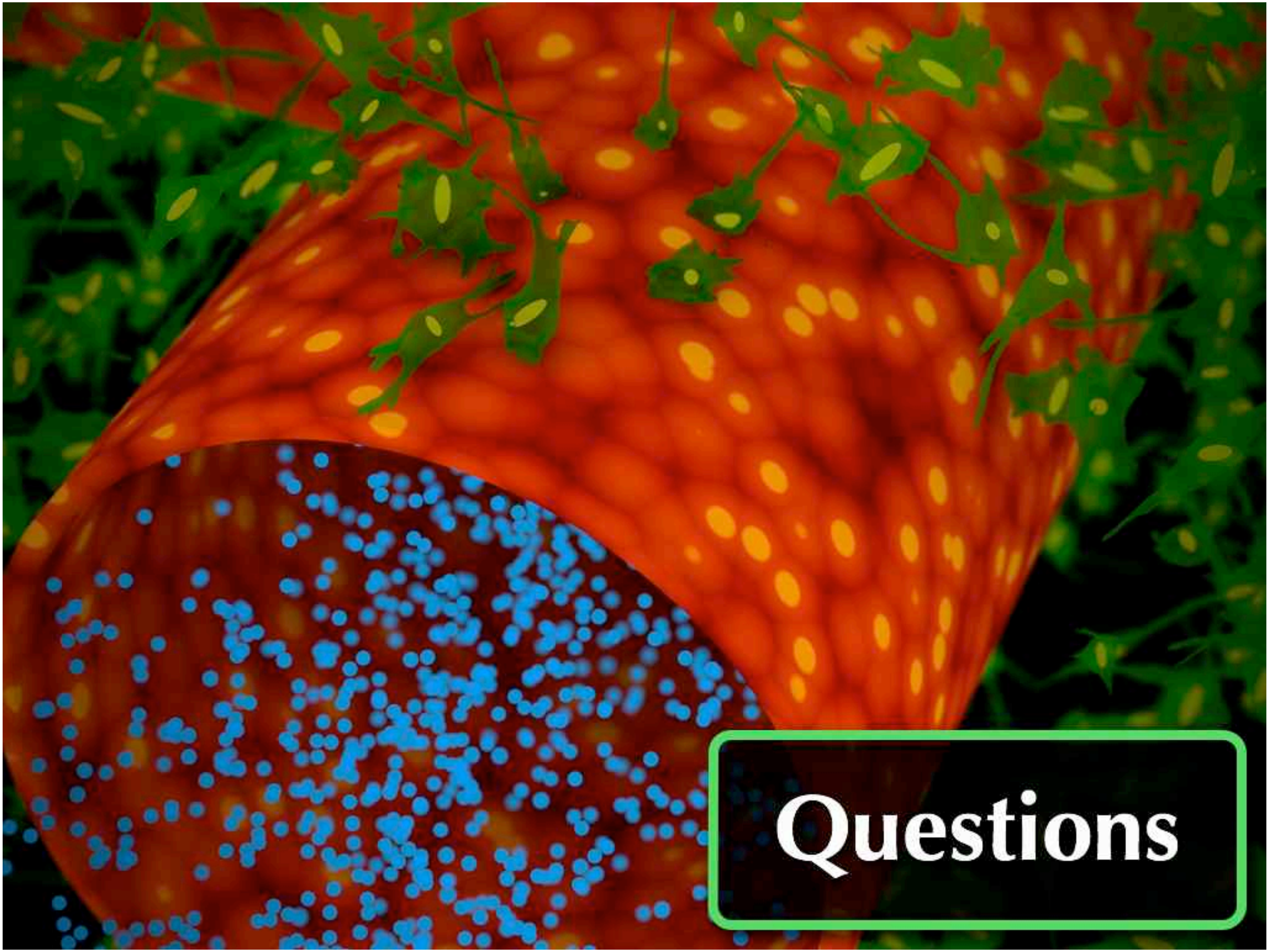

a
Naturally Derived Vascular Architectures
b
Synthetic, Computer Generated and
Parametrized Vascular Architectures
Organ/Tissue of Interest
Architectural
Analysis
Conversion
to 3D Model
µCT Angiography
and Volumetric Extraction
3D Surface Map
3D Surface Map
3D Surface Map
c
3D Printed Natural or Synthetic Architectures for Vascular Casting
3D Print the
Sacrificial
Architecture
Physical
Cleanup
Vascular
Casting
in Hydrogel
Virtual Slicing
and Digital Cleanup
Support
Material
Removed
Temporary
Support
Material
Patterned Vascular
Architecture in Hydrogel




Questions