Nanotechnology in Vascular Tissue Engineering

Lori A. Jackson
Biology Teacher Consultant

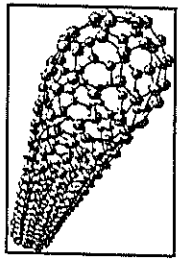
Whetstone High School
4405 Scenic Drive
Columbus, Ohio 43214

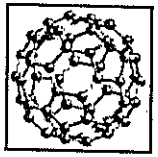
Overview

- Background
- Nanotechnology
  - based on utilization of the nanoscale, that level of material assembly just above atoms and molecules
- Summary of selected Vascular Scaffolds
- Classroom Activity Modeling Vascular Tissue Engineering

Background Information

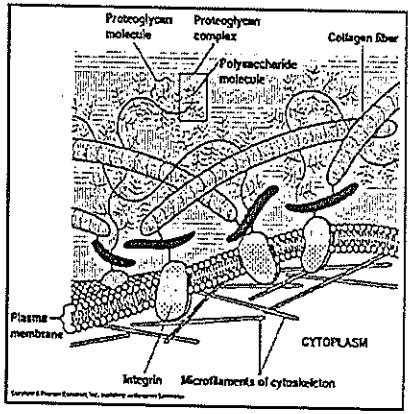
- Recent articles have noted how Nanoparticles can be injected to help heal broken bones
- Current Approaches
  - Carbon nanotubes
  - Cell Differentiation
  - Hydrogels
  - Electrospinning scaffolding matrix
  - Cell sheets Technology
- Advantages of engineered nano-scaled vascular tissue:
  - Reduced donor rejection
  - Reduced use of stem cell therapy
  - Bottom-up building approach





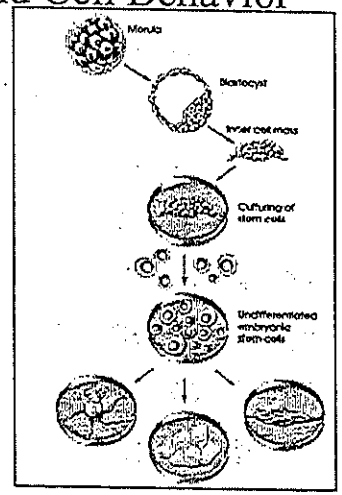
- The ECM –extra cellular matrix- of a eukaryotic cell is supported on microfilaments of cytoskeleton
- Nano-structuralized polymer-based biodegradable scaffold – mimics the ECM
- Customized process of electrospinning and chemical treatments can be used to form a matrix

Cell Membrane Structure



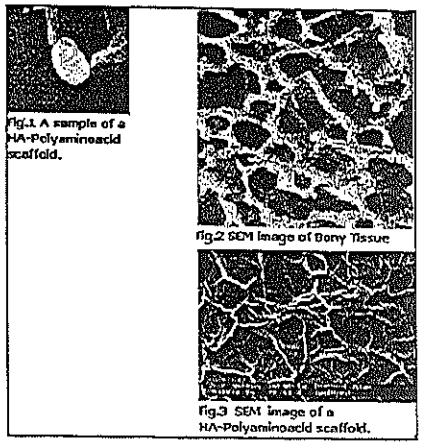
Cell Differentiation and Cell Behavior

- Transition of a cell from one cell 'phenotype' to another and how that differentiated cell functions
- The nanoscaffold and stem cells are implanted at the site of the damaged neural tissue
- Nerve cells are re-generated
- Nano-scaffolding is biodegradable and disappears without harm to the tissues around it
- Skin cells and hair follicle stem cell are currently being investigated as sources of 'adult' stem cells



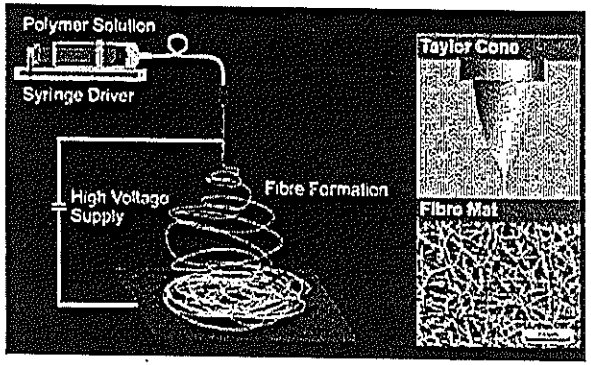
Hyaluronic hydrogels developed by Carnegie Mellon University researchers

- Hydrogels, which are considered to be the state-of-the-art in tissue design, are made from polymers that swell in water to form a gel-like material.
- They interact with growth factors much like demineralized bone matrix does, providing scaffolding for bone cells to proliferate and form new tissue.



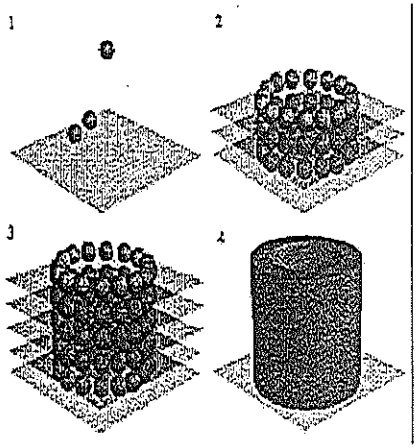
Electrospinning Matrix to form a collagen nanofibers scaffolding

- Bio-Fabrication- for donor cell attachment

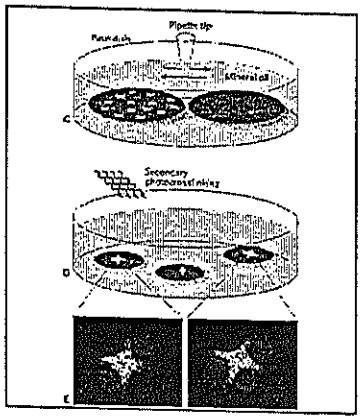


Nanotechnology Cell sheets in Organ Printing Technology

- Advantage
  - Reduces undesirable cell differentiation that can be activated by nanoparticles
  - Precision controlled robotic bio-fabrication of organs and vessels
- Nanoscaled spheres are fused with cell sheet tissues to form vessels or cardiac tissues

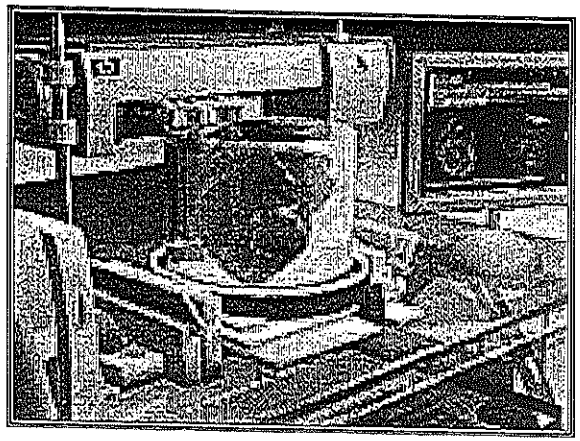


Bottom-up Building
"lego" block–based approach to tissue engineering

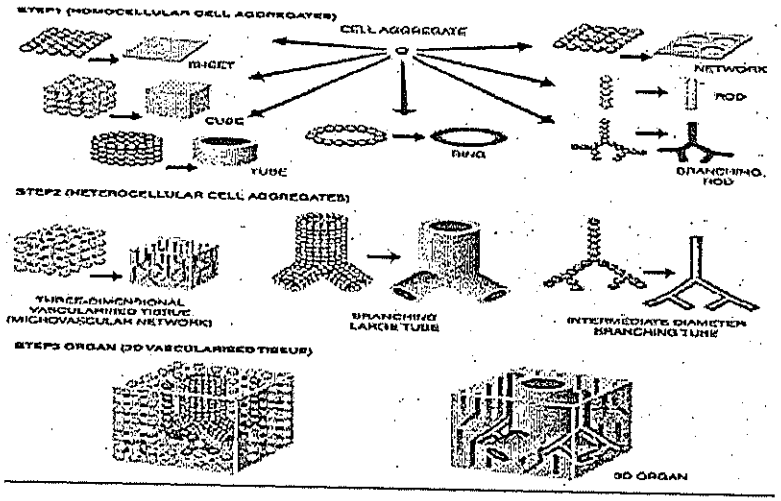


Yanan Du and Ali Khademhosseini
Harvard Medical School Aug. 2008

Organ "Ink Jet" Printing
Imagine the Practical uses in Medicine



Designing a 3-D Organ



How to Mend a "broken" Heart

- Click to watch a video of a pulsating cardiac muscle that was made with stem cells on a flexible scaffold patch.
- http://www.ptei.org/interior.php?pageID=171
- Google search: Pittsburgh Tissue Engineering Initiative | Regenerative Medicine for the Heart

References and Articles for Student Perusal

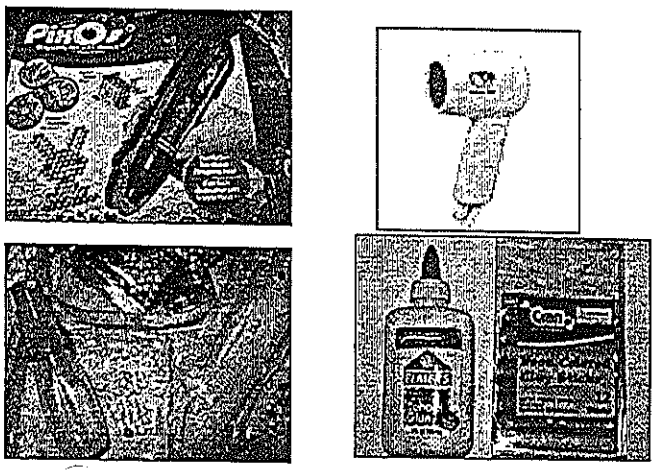
- Vladimir Mironov, Vladimir Kasyanov and Roger R. Markwald, 2008 "Nanotechnology in vascular tissue engineering: from nanoscaffolding towards rapid vessel biofabrication" Medical University of South Carolina, Charleston, SC.
- "Nanotubes inspire new technique for healing broken bones",American Chemical Society. 2005
- Ardebili Hooman, "Nanotechnology & Nanotube & Nanomedcine", 2005
- "Nano Scaffold Developed To Rebuild Nerve Damage" ScienceDaily (Feb. 27, 2008)
- Stem Cells From Hair Follicles May Help 'Grow' New Blood Vessels ScienceDaily (Mar. 29, 2008)
- "Hydrogels Provide Scaffolding For Growth Of Bone Cells",ScienceDaily (Aug. 21, 2008)
- "Student Achieves Control Of Collagen Nanofibers To Manufacture Synthetic Knee Cartilage", ScienceDaily (Nov. 19, 2008)
- Silverstein, Jonathan. "'Organ Printing' Could Drastically Change Medicine Scientists Want to 'Print' Organs Rather Than Wait for Them to be Donated" Feb. 10, 2006

Modeling Nanotechnology Tissue Engineering and Fabrication in the High School Classroom

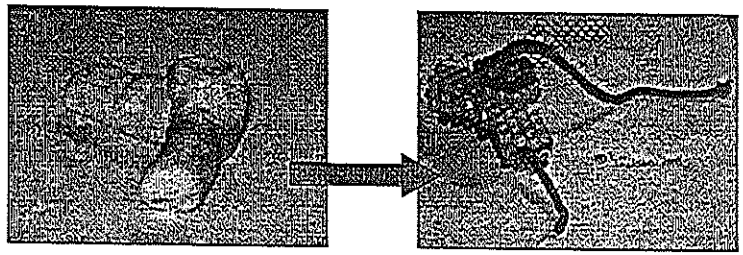
Lori A. Jackson

- Inexpensive materials
- 2-3 class periods in student groups of four
- Highly creative
- Hands-on student engagement
- Teacher user friendly approach
- Potential chance of successfully bringing nanotechnology into the classroom

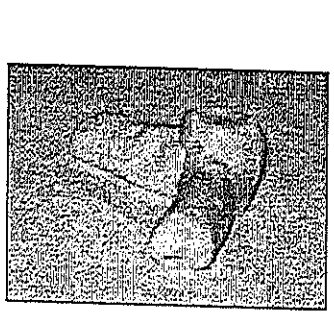
Just a few supplies from Meijers or Wal-mart needed for Modeling Organ 'Printing'

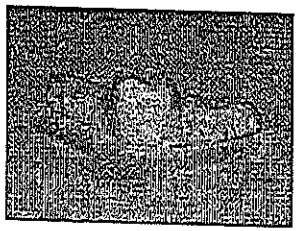


Goal: transform a clay model into a 3-D model of a vessel tissue

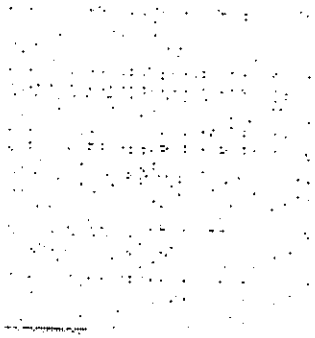


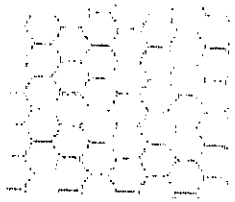
Step 1: Shape the clay into a branched vascular tissue "vessel"





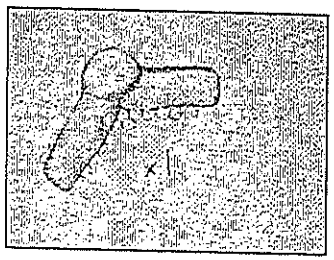
Step 2: Place the "vessel" on a 5mm hexagonal graph and adjust the model to fit the grids

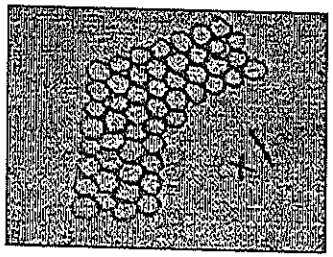




Step 3: Base Layer

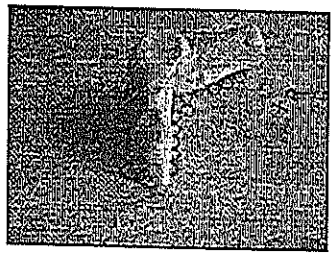
Trace around the clay "vessel" and outline each circle that represents the area of the vessel

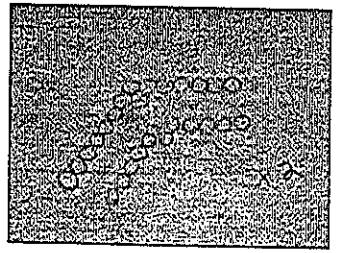




Step 4: Layer 2

Trace around the clay "vessel" and outline each circle that touches the periphery

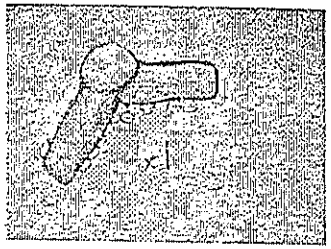


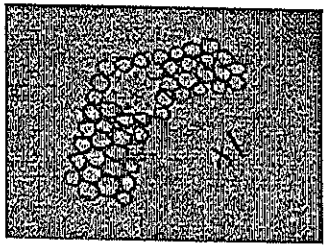


**Repeat this process to make Layer 3*

Step 5: Layer 4

Trace around the clay "vessel" and outline each circle that represents the area of the vessel, leaving an opening where indicated

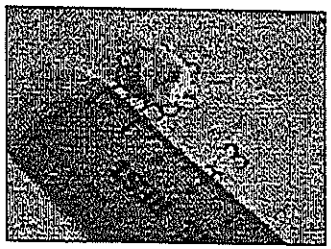


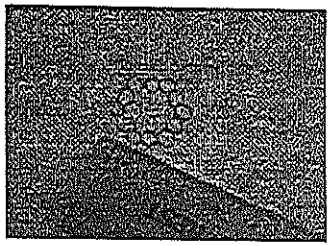


Step 6: Layer 5

Remove a 3 mm thick section from the top portion of the clay "vessel"

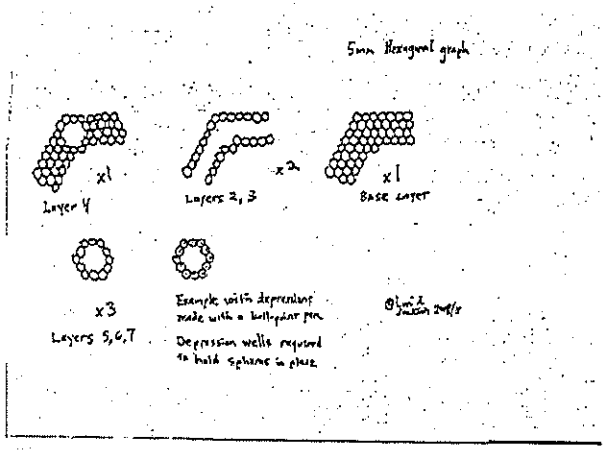
Trace the outline of this section on the grid





* *Repeat tracing to make Layer 6 and Layer 7*

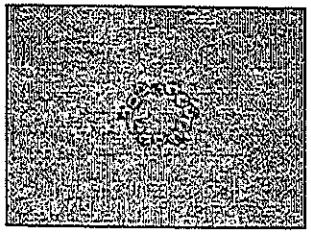
Example of the "Cell Sheet" Scaffolding

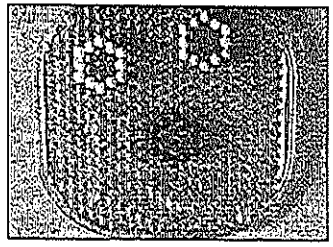


Step 7:

Build the scaffolding by placing the hexagonal paper graph under the plastic toy grid.

Add the "nanoparticles" spheres to the grid

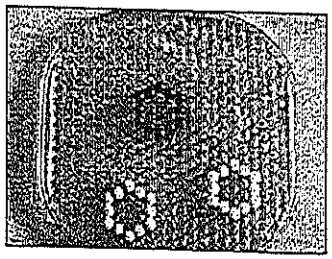


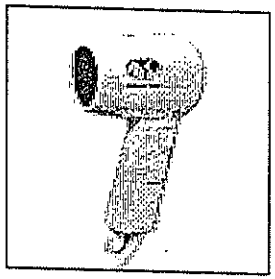


**Repeat this process for each of the forms on the grid*

Step 8: Lightly moisten the "nanoparticles" spheres to each other with the water sprayer.

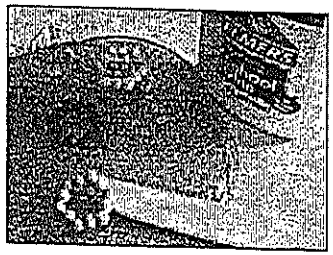
When the forms are complete,
use the hair dryer to set the "Cell Sheet" layers.

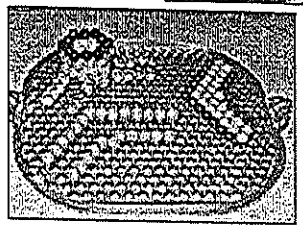




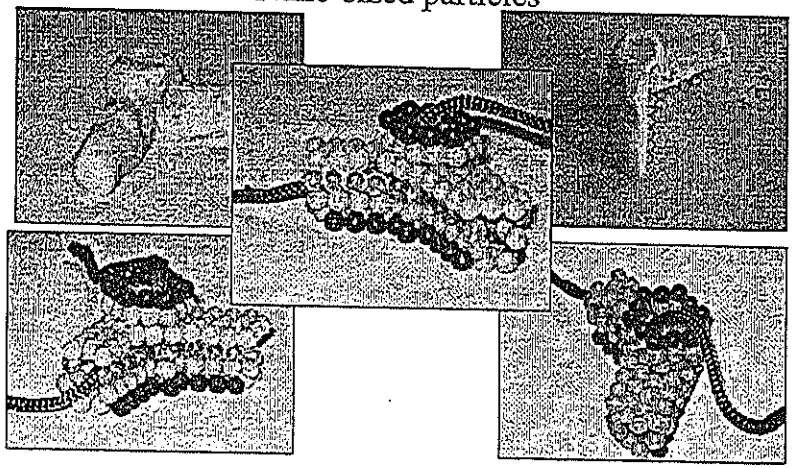
**This diagonal grid plate was form the "PixOs" Starter Pack*

Step 9: Bio-Fabrication
Gently remove the forms from their grids.
Assemble the "cell sheets" in order by Layers with glue





Step 10:
Final Assembly and Modeled Completion of a Vascular Tissue Engineered with
Nano-sized particles



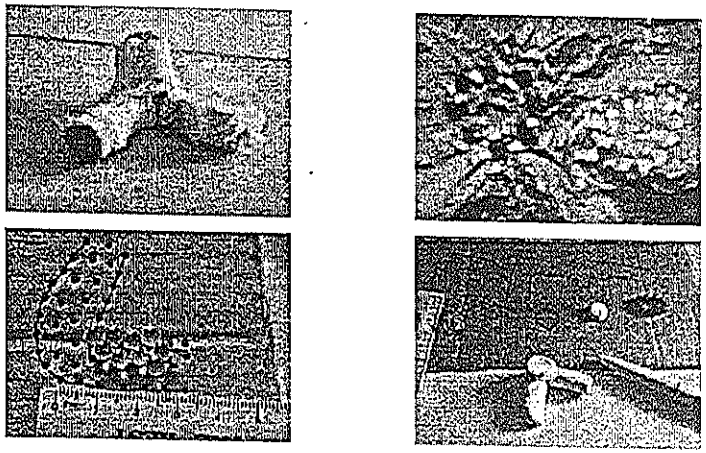
Questions for Further Review

- How would you define Nanotechnology?
- Describe what happens in Vascular Tissue Engineering from a biodegradable scaffolding.
- How would you outline the steps involved in Vascular Tissue Engineering?
- How would you modify this activity?
- Peruse an article or two about Nanotechnology Tissue Engineering and construct a thoughtful opinion about its future in America.

Materials for 4 Student Groups
Each Group needs about 184 "nanoparticles" spheres

- (4) PixOs Refill Pack (750 spheres, 1 diagonal grid)
- (4) School Glue
- (4) 5mm Hexagonal Grid Sheets ($0)
  (www.printfreegraphpaper.com)
- (1) Modeling Clay Sticks Package of 12
- (4) Travel Size Water Sprayers 5 oz
- (4) Hair Dryer 1200 watts +
- (4) Small cups to hold the "nanoparticles" sphere

Blooper Attempts by Ms. Jackson



Other Cool Views