Center Overview

- Research
- Education
- Outreach
- Diversity

L. James Lee

Director

NSF NSEC for Affordable Nanoengineering of Polymeric Biomedical Devices (CANPBD)

- 30 OSU faculty members (Engineering, Science, and Pharmacy Colleges)

- **Duke:** **Kam Leong** (Biomedical Eng.) – gene therapy

- **MIT:** **Martin Culpepper** (Mechanical Eng.) – manipulation

- **UIUC:** **Rashid Bashir** (Electrical Eng.) – device integration

- **UCSF:** **Tejal Desai** (Biomedical Eng.) – nanofabrication

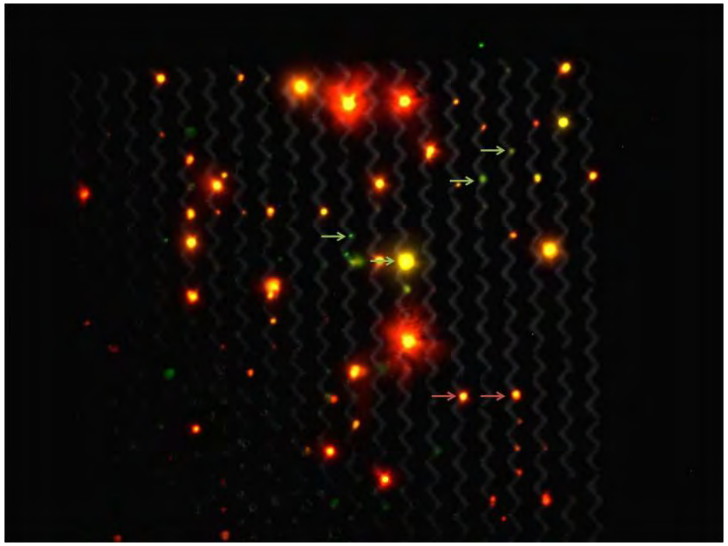
- **UM:** **Ron Larson** (Chemical Eng.) – molecular simulation

- **Oakwood U.:** **Ken LaiHing** (Chemistry) – surface phenomena

- **SUNY Albany:** **Yubing Xie** (Nanobioscience) – tissue engineering

CANPBD Phase I and Phase II Vision

- **Phase I (2004-09):**
  - **Developing polymer nanoconstructs, nanomanufacturing and nanofluidics technology for biomedical devices**

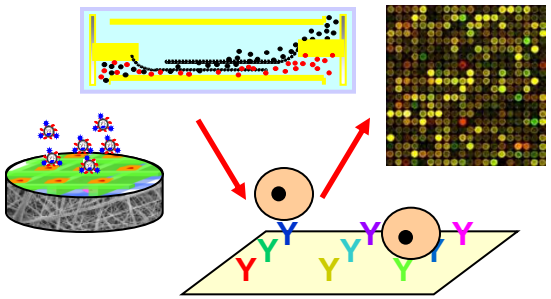


- **Phase II (2009-14):**
  - **System level integration of Phase I technologies for nanomedicine applications**

Nanotechnology Pathway to Personalized Nanomedicine

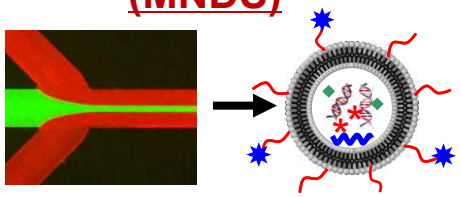
NSEC- CANPBD

Automated Cell to Biomolecule Analysis (ACBA)



cancer cell separation and analysis

Multifunctional Nanoparticle Design and Synthesis (MNDS)



targeted nanoparticles produced by nanofactory

OSU Comprehensive Cancer Center and James Cancer Hospital

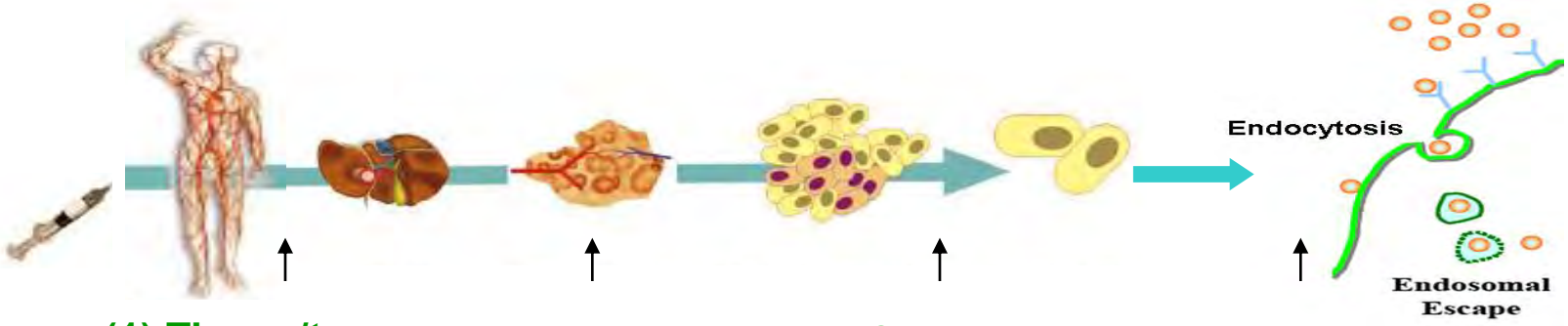
Patient blood or tissue samples

Clinical trial

Animal study

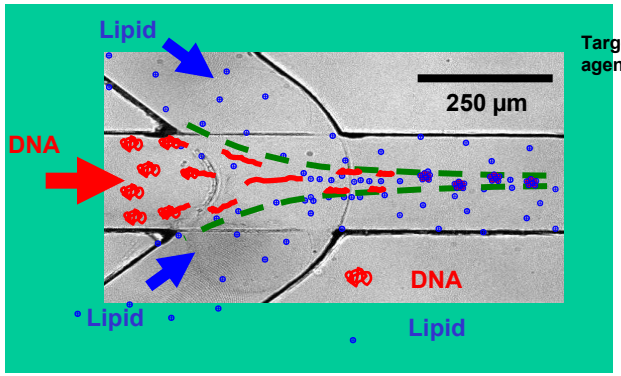
Biotechnology Industry

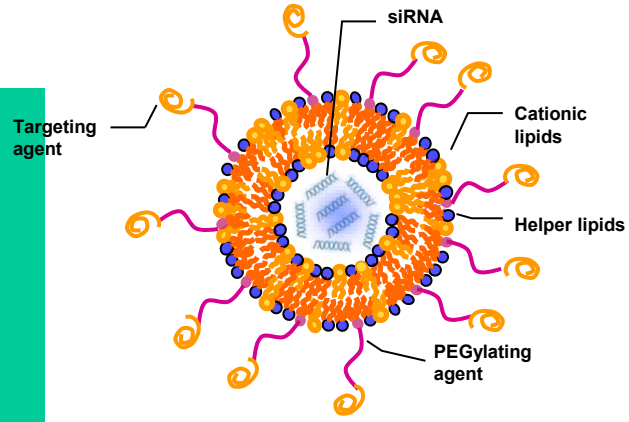
Multifunctional Nanoparticle Design and Synthesis



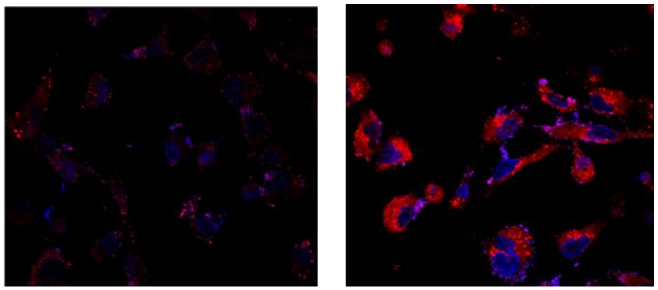
(1) Tissue/tumor localization (2) Penetration (3) Cellular uptake (4) Intracellular release

Hydrodynamic focusing





Effect of targeting in liver tumor



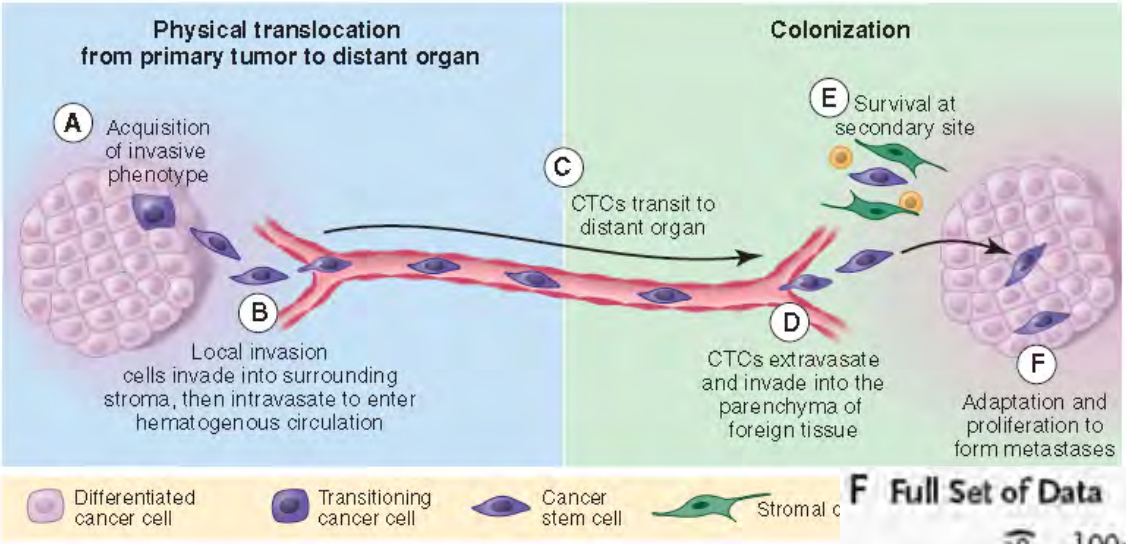
Non-targeted Targeted

Leukemia 2 R01, 2 R21,1 SPORE, 1 SBIR, NCL

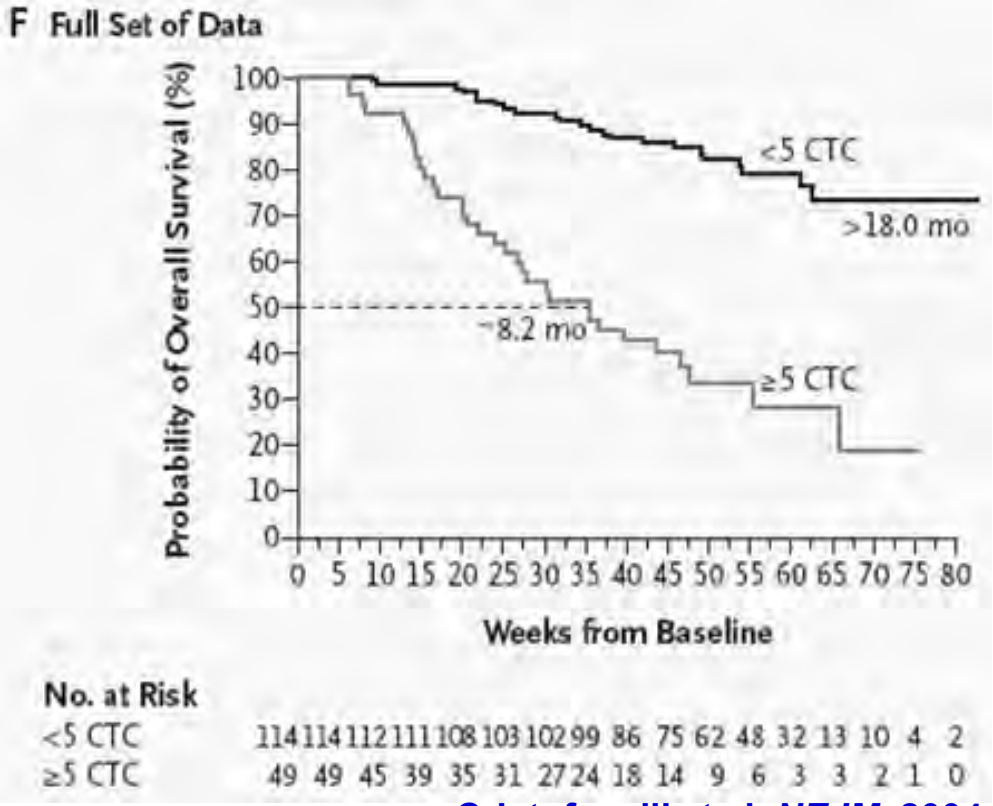
Liver cancer (HCC) 1 R01, 1 R21

Breast cancer 1 DOD grant, CCTS grant

Circulating Tumor Cells (CTCs) in Metastatic Breast Cancer



Chaffer *et al. Science*, 2011

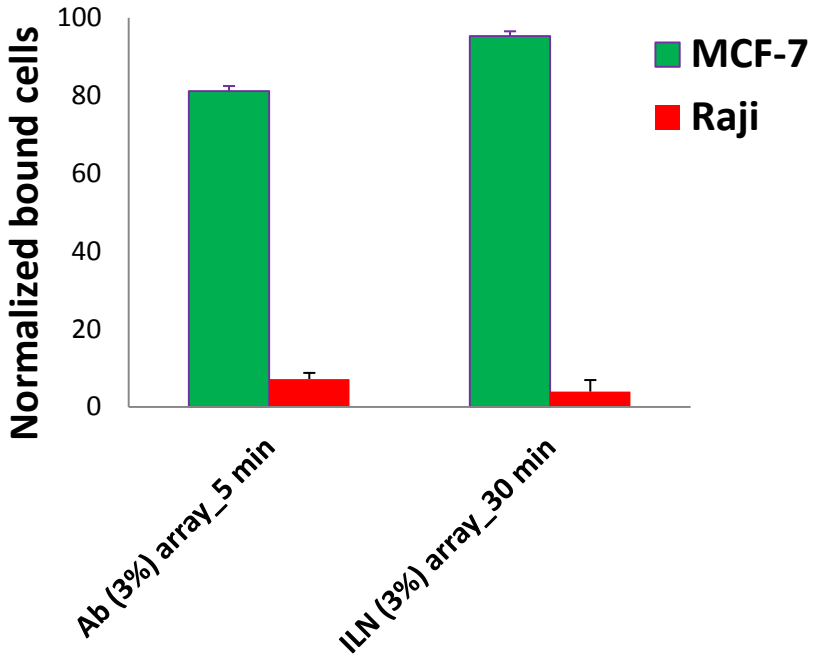


Cristofanelli et al, *NEJM*, 2004

Cell Separation and MicroRNA Detection

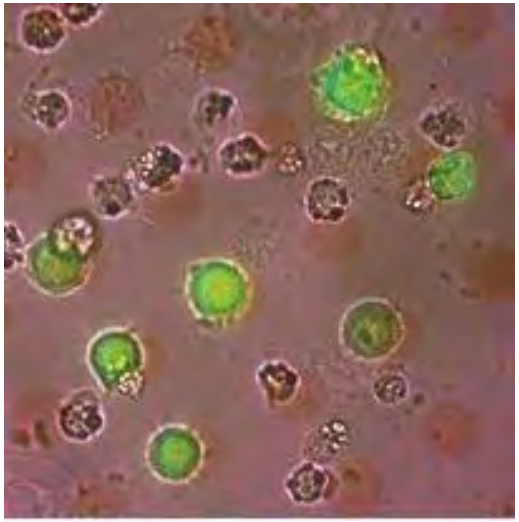
MCF-7 and Raji Cells

Incubation time & Anti-EpCAM density

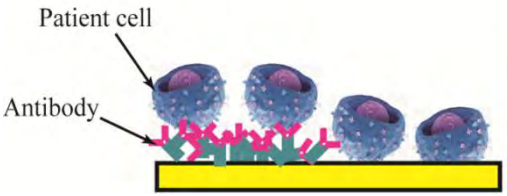


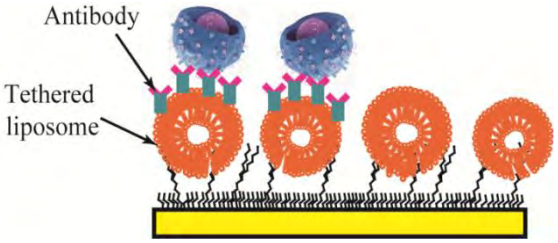
miR-21 LNA Molecular Beacon

4 hr



Anti-EpCAM Lipoplex Microarray

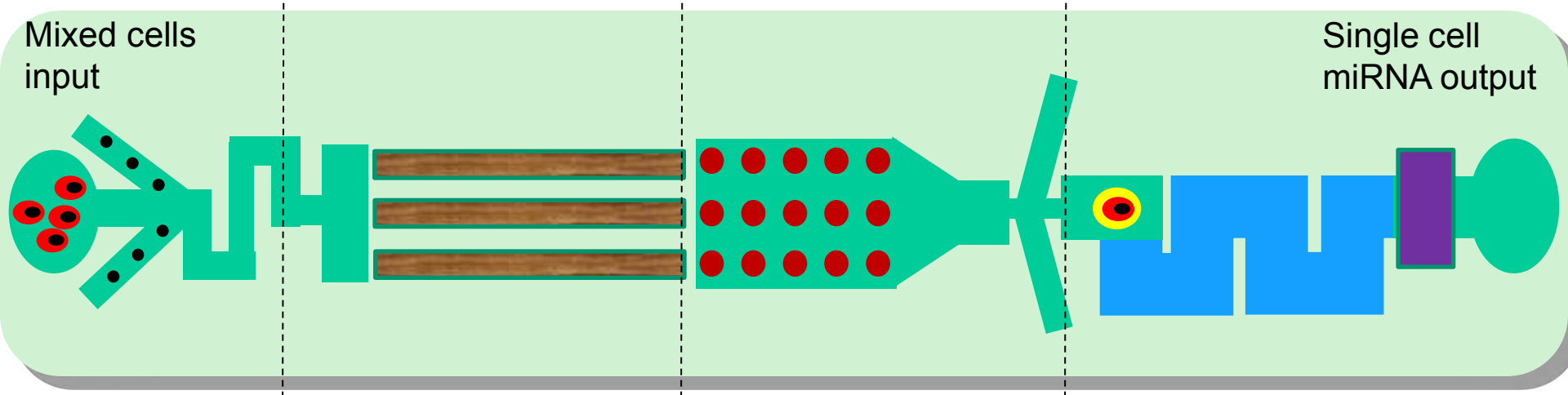




- antibody-cell interaction only
- cell capture only

- antibody-cell and lipid-cell interactions
- cell capture and identify cells

Automated Cell to Biomolecule Analysis (ACBA) Platform



System Integration

- i. Cell surface biomarkers by antibody microarray
- ii. Cell surface biomarkers by magnetic particles

- i. Optical tweezers array
- ii. Magnetic tweezers array

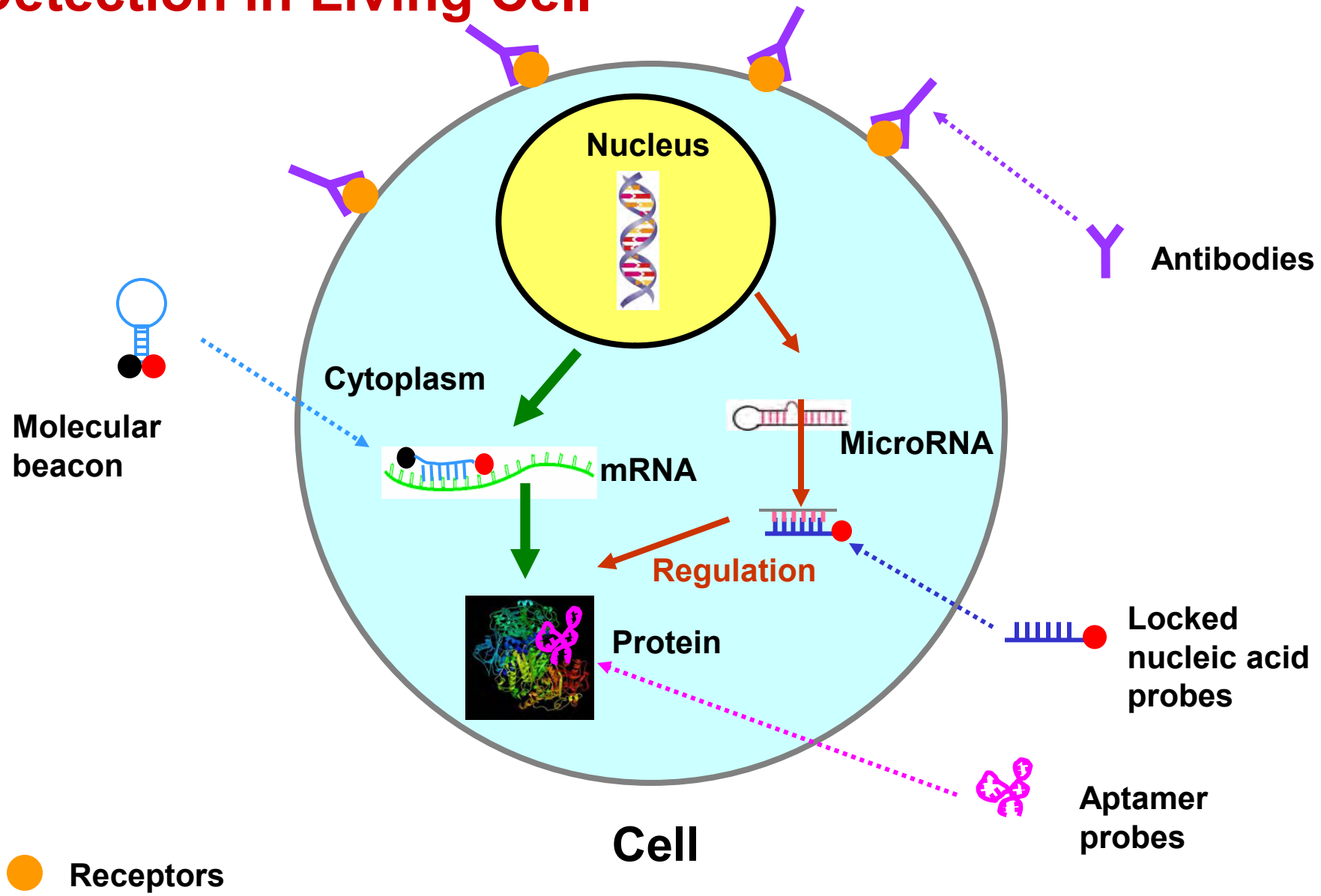
- i. Molecular probes by nanoelectroporation
- ii. Nanowire in single cell droplet

New Technologies

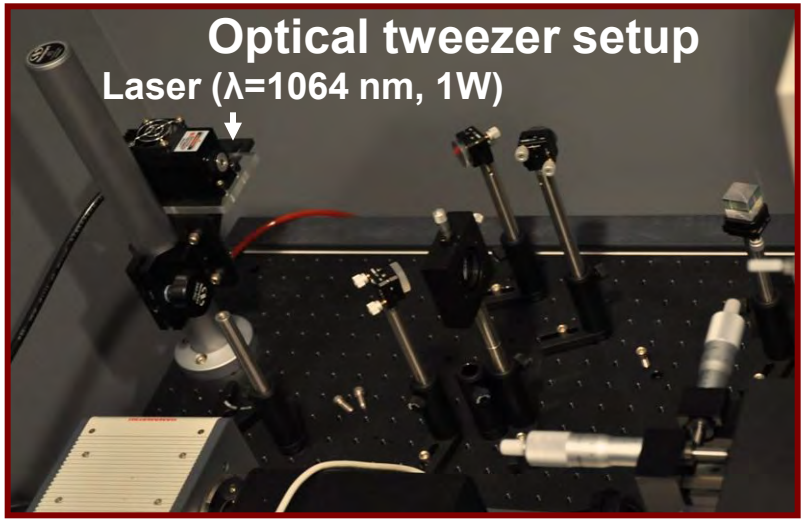
- iii. Cell migration by nanofiber 'race track'

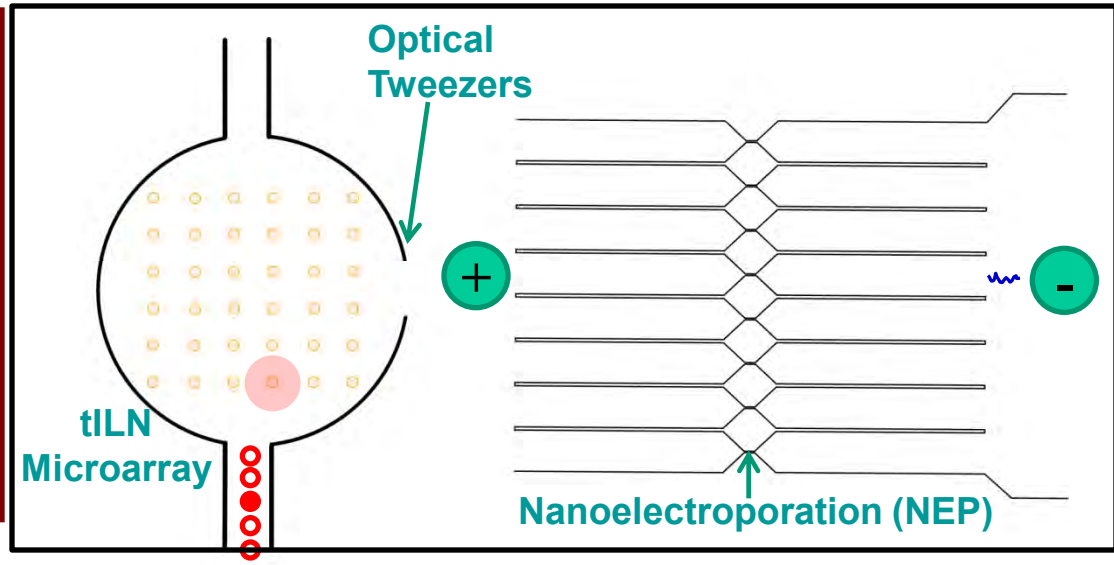
- iii. ECL in microwells
- vi. EIS in microwells
- v. Ion transport through DNA nanostrands

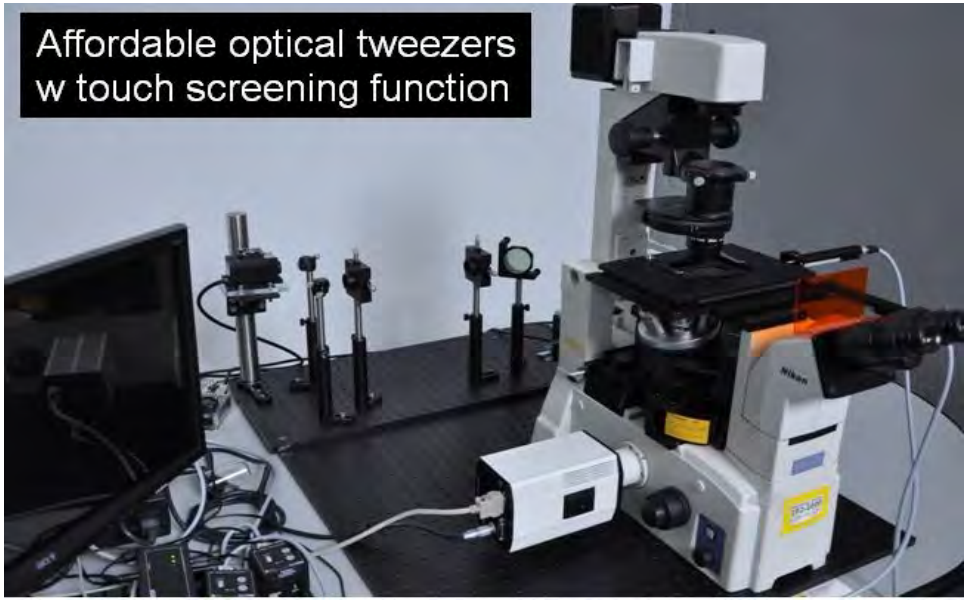
Antibody Cell Separation and Molecular Probe Detection in Living Cell

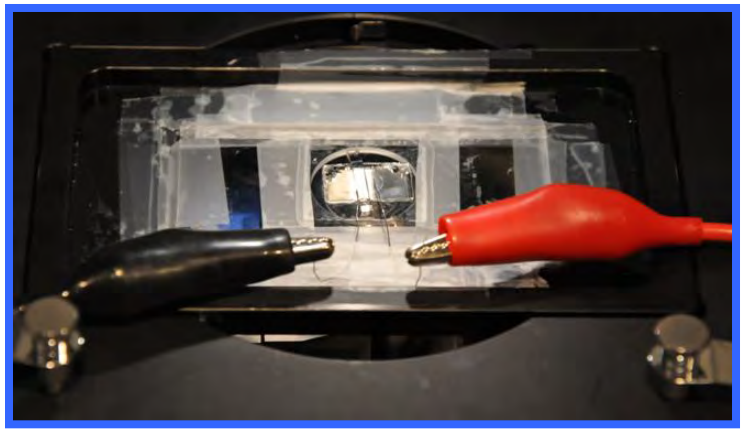


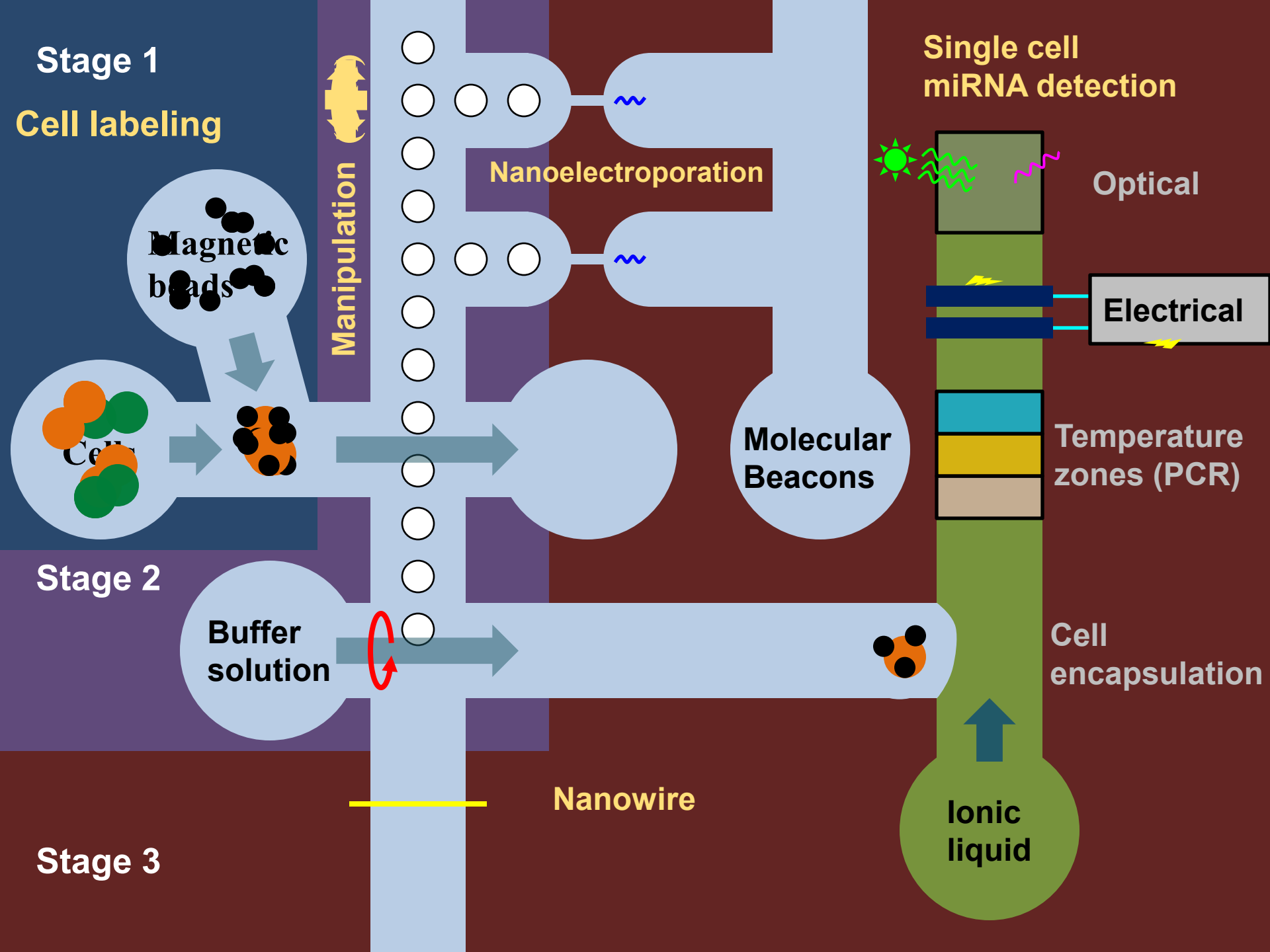
ACBA Platform: *tILN Microarray - Optical Tweezer - NEP*



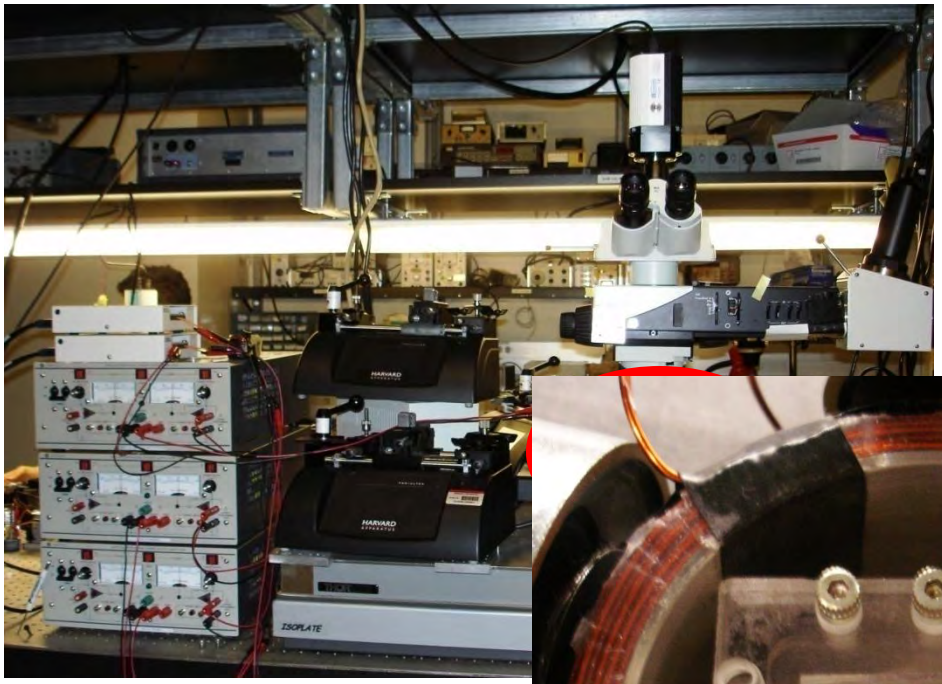


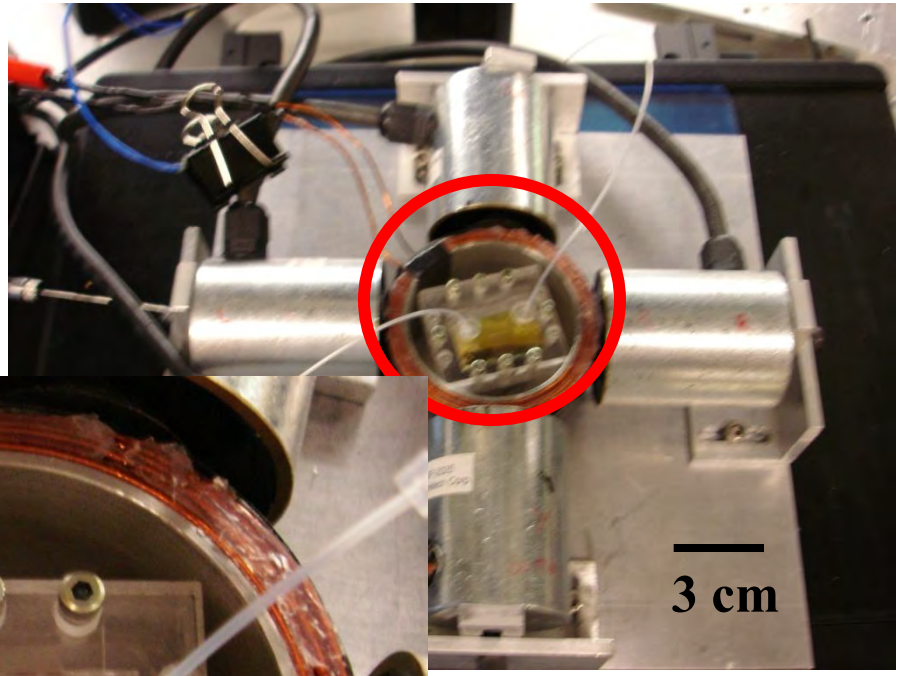


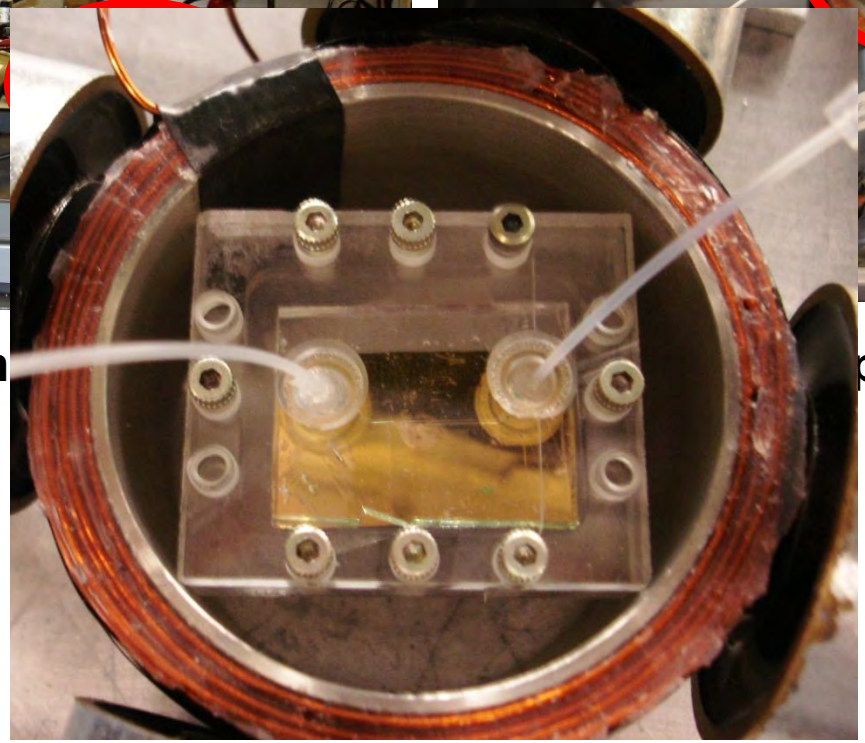



Stage 1
Cell labeling
Magnetic beads
Cells
Manipulation
Nanoelectroporation
Molecular Beacons
Single cell miRNA detection
Optical
Electrical
Temperature zones (PCR)
Cell encapsulation
Stage 2
Buffer solution
Nanowire
Ionic liquid
Stage 3

“Magnetic Tweezers” Instrumentation Setup







Power supplies, syrin providing external microscope

Z-coil and microfluidic device

Accomplishments in Phase II and Impact on Institution

John Lannutti
Deputy Director

2009-Present Major Accomplishments

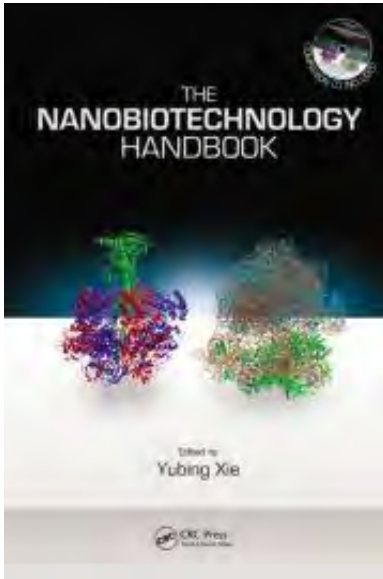
- >335 refereed papers (>135 joint publications) including *Nature Nanotechnology, PNAS, Physical Review Letters, Nanoletters, Advanced Materials, Biomaterials, Lab on Chips, Blood, Clinic Cancer Research*
- 63 invention disclosures, patent applications and patent awarded, 4 licensed

- 42 PhD (50% increase over baseline) and 11 MS degrees completed, 21 post-docs trained (16 in industry)
- 23 CANPBD faculty taught 90 new or modified classes related to nanobiotechnology to 2361 graduate and undergrad students
- >3450 K-12 students impacted by Center activities
- 59 high school science teachers trained in teacher workshops

- >$12M leveraged federal funding, ~$1.1M industrial funding
- 6 recent SBIR/STTR awards
- 7 new spin-off companies

2009-Present Major Accomplishments

- Yubing Xie, CAREER Award
- Control of Embryonic Stem Cell Fate Using Nanoengineered Microenvironments
- Bioengineering Embryonic Microenvironments to Understand and Restrict Breast Cancer Metastasis
- Construction of 3-D Tissue Network for Drug Screening and Nanotoxicity Testing
- Nanoporous Membrane-Based Biosensors



Outcomes for our REU Alumni

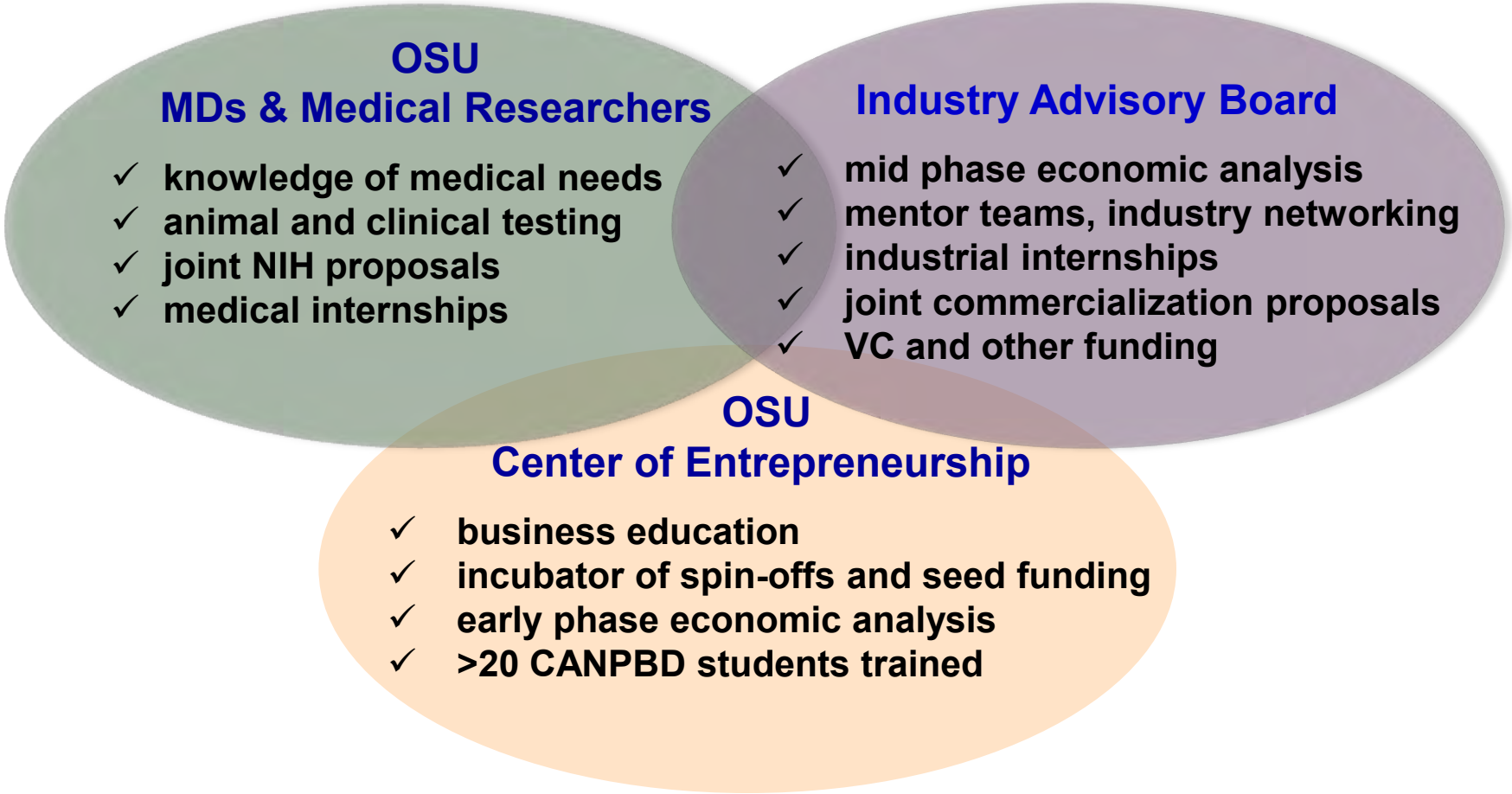
STEM PhD	STEM MS	STEM BS	MD	Medical Professionals
51.5%	3.2%	6.5%	12.9%	6.5%

Fred Crawford ('06-07)

- Caesar Buie ('05) named a GEM scholar at Cornell
- Craig Buckley ('07) pursuing a PhD in Chemical Engineering at Stanford
- Mitchell Thayer ('11) pursuing a PhD in Chemistry at Wisconsin

Crystal Lewis ('10)

CANPBD-Medicine-Business Partnership



- 5 NSEC project teams won local and national awards
- 4 NSEC spin-off companies initiated from Center of Entrepreneurship

2007 Business Plan Competition Winners

2009 Business Plan Competition Winners

2013 Business Plan Competition Winners

Impact on Medical School

- 38 on-going joint CANPBD-OSU Comprehensive Cancer Center (CCC) projects

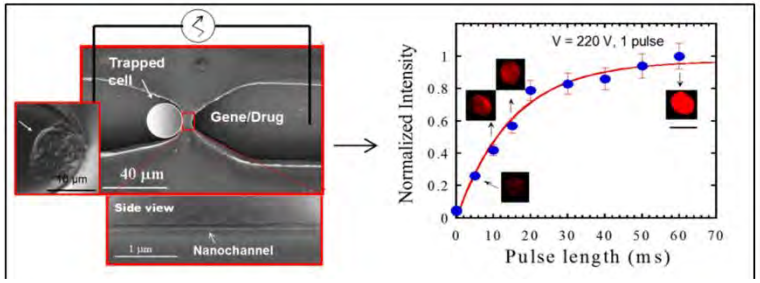
- Strong technical support from CCC– CANPBD technologies used in developing treatments for leukemia as well as breast, brain, lung, head and neck cancer

- >$10M NIH leverage funding from joint CANPBD- CCC proposals since 2004

- Joint seed grants to pursue large NIH funding

- Nanotech West (NTW) lab used to support Medical faculty recruiting

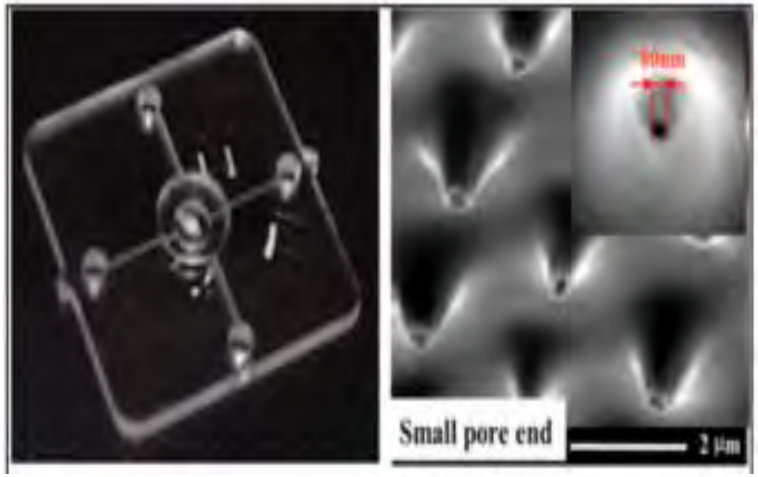
Nanochannel Electroporation (NEP) for Precise Gene/Drug Delivery



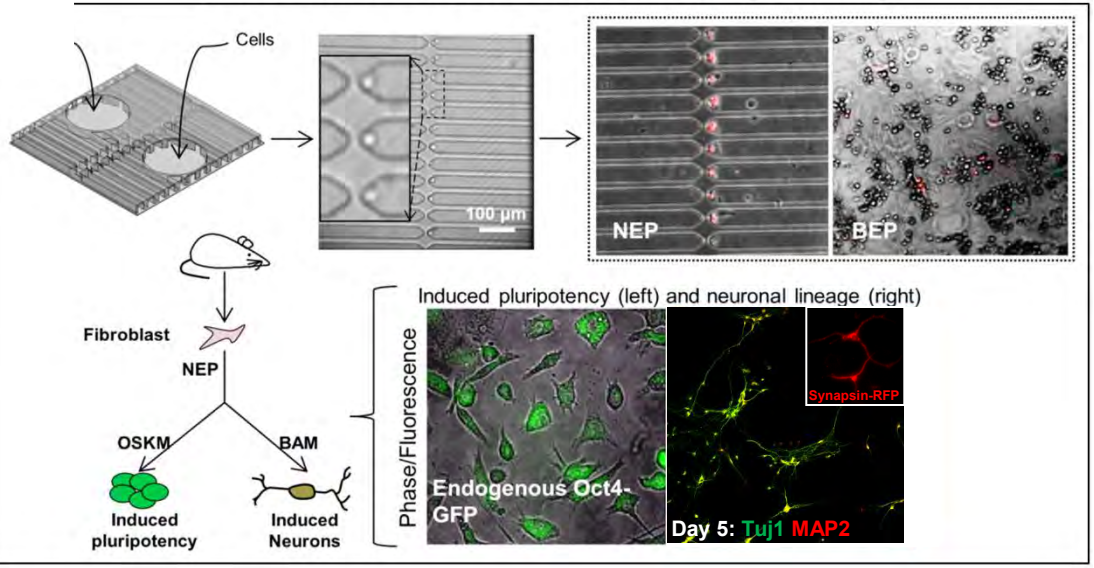
Bounkany et al., Nature Nanotechnology, 2011

- **NEP is a unique nanotechnology that can deliver a <u>precise amount</u> of any substance (DNA, RNA, CNT's etc) into a cell nucleus with 100% efficiency**
- **NEP has a fundamental role in studies of cell biology, cell reprogramming and regenerative medicine**

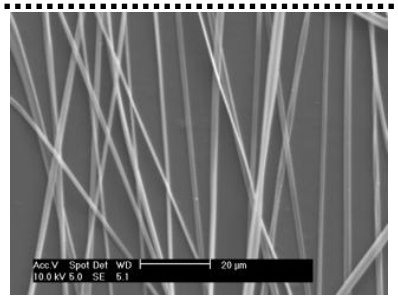
John Byrd, M.D. –Hematologic Malignancies
Guido Marcucci, M.D. – Hematology/Oncology
Raj Muthusamy, Ph.D. – Hematology/Oncology
Ichiro Nakano, M.D./Ph/D. –Neural Cancer Stem Cell Program
Pat Nana-Sinkam, M.D. – Medical Oncology
John McLaughlin, PhD - Transgenic and Embryonic Stem Cell Core, Nationwide Children's Hospital
Jose Otero, M.D. - Neuropathology
Chandan Sen, Ph.D. – Regenerative Medicine

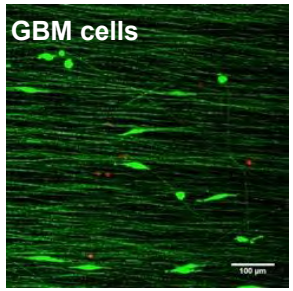


<u>Safe, efficient and uniform cell reprogramming</u>



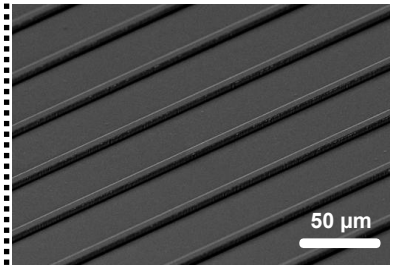
Migrational Chromatography

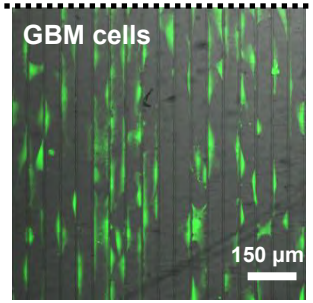




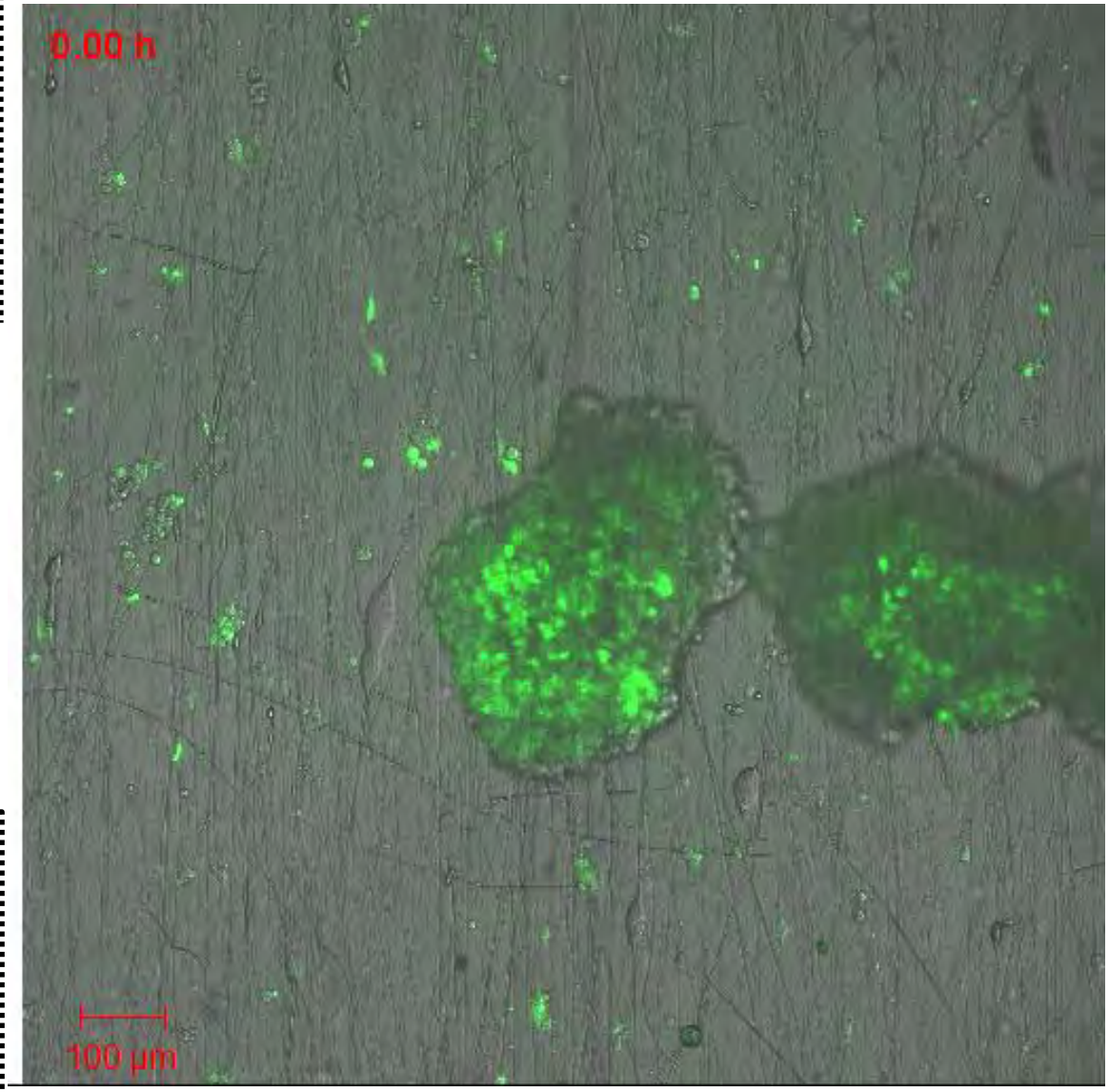
Electrospinning (Johnson J, Lannutti J. Tissue Engineering C, 2009)

Nino Chiocca, M.D. – Neuro-Oncology
Mariano Viapiano, PhD – Neuro-Oncology
Sean Lawer, Ph.D. – Neuro-Oncology
Pat Nana-Sinkam, M.D. – Oncology/Lung
Charles Shapiro, M.D. – Oncology/Breast
Gail Besner, M.D. - Nationwide Children's Hospital
Jose Otero, M.D. - Neuropathology
Clay Marsh, M.D. – Oncology/Breast
Tim Eubank, PhD – Oncology/Breast
Jas Lang, PhD – Oncology/Head&Neck





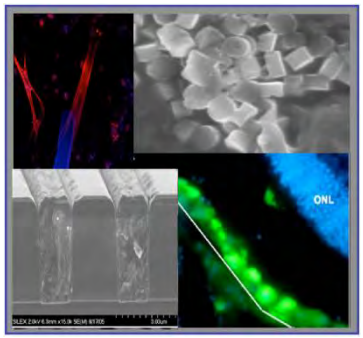
Soft lithography micromolding (Gallego-Perez D, Hansford D. Lab on Chip, 2012)



CANPBD Spin-off Companies (>40 jobs, >$18M)

Cell Habitats (Desai)

Structus (Desai)



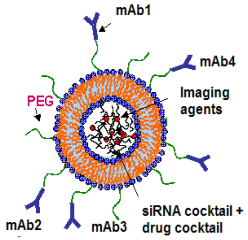
NPM (Desai)

CELL HABITATS

Nano Precision Medical

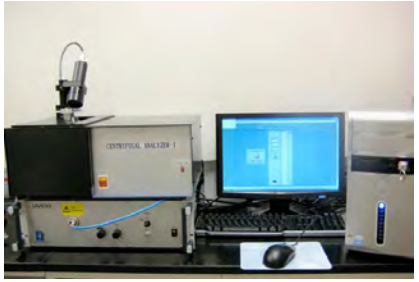
Revolutionizing Implantable Drug Delivery

Ohio Nanomed, Inc. (R. Lee)

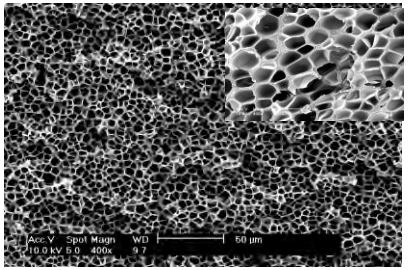


NanoMED (J. Lee)

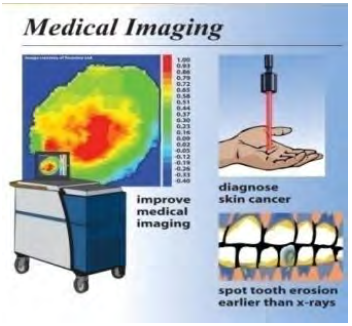
BioLOC (J. Lee)



Nanomaterial Innovation Ltd. (J. Lee)



Traycer (Epstein)



Nanofiber Solutions (Lannutti)

Combining the Best of 3D and 2D Cell Culture

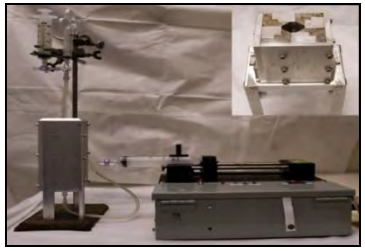
Nanofiber SOLUTIONS

COLUMBUS NANOWORKS INC.

(Chalmers)

Precelleon (Chalmers)

Ikotech LLC (Chalmers)

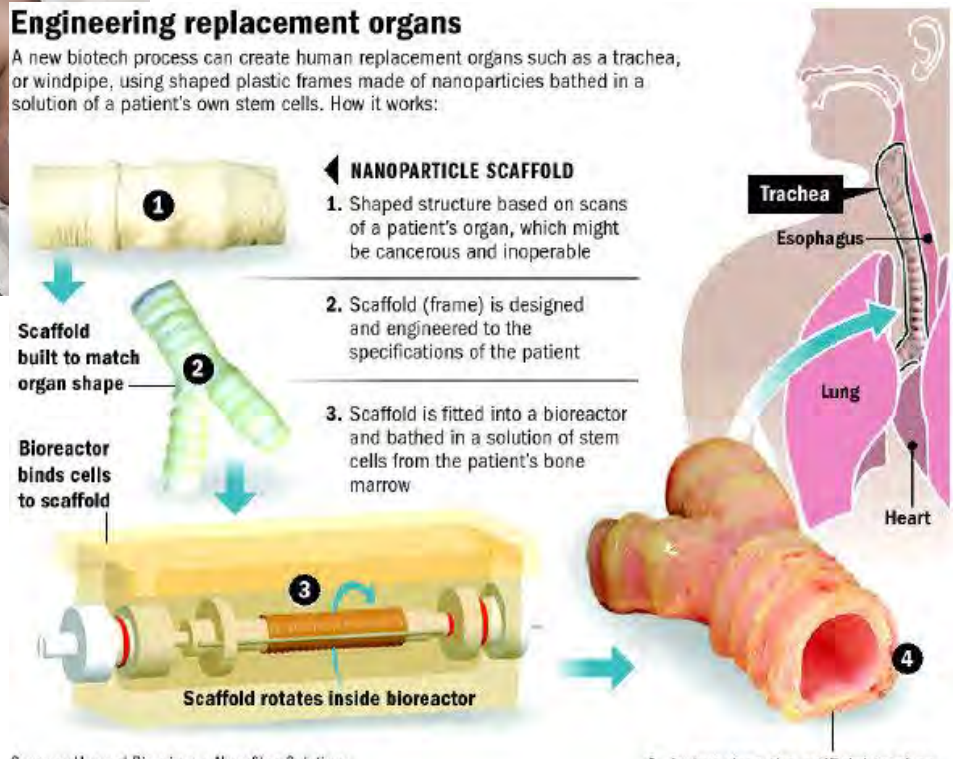


Core Quantum Technologies, Inc. (Winter)

The Columbus Dispatch May 1, 2013

Engineering replacement organs

A new biotech process can create human replacement organs such as a trachea, or windpipe, using shaped plastic frames made of nanoparticles bathed in a solution of a patient's own stem cells. How it works:



Sources: Harvard Bioscience, Nanofiber Solutions, Plastics Today, University College London

McCLATCHY NEWSPAPERS | DISPATCH

Combining the Best of 3D and 2D Cell Culture.
Nanofiber SOLUTIONS

Next Year Research and Post-Graduation Plans

Moving Forward after 2014

Mike Paulaitis
Executive Committee Chair

Technical Barriers/Systems-Level Challenges to ACBA and MNDS Development

Nanotechnology Pathway to Personalized Nanomedicine

Key Technical Barriers

Automated Cell to Biomolecule Analysis (ACBA)

Multifunctional Nanoparticle Design and Synthesis (MNDS)

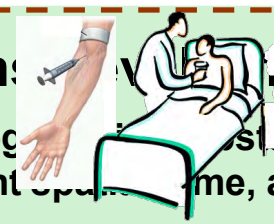
- Optimization, resolution, and control of various nanoconstructs by guided assembly.
- Combination of top-down and bottom-up methods, and cleanroom and non-cleanroom fabrication for [illegible] of hybrid polymer-[illegible] devices at low-cost.
- Manipula[illegible]ecules with high capacity.
- Optimization, resolution, and control of electrokinetically driven nanofluidics.

cancer cell separation and analysis

targeted nanoparticles produced by nanofactory

Systems [illegible] Challenge

Ohio State Univ. Comprehensive Cancer Center



Patient blood or tissue samples

Clinical trials

Animal studies

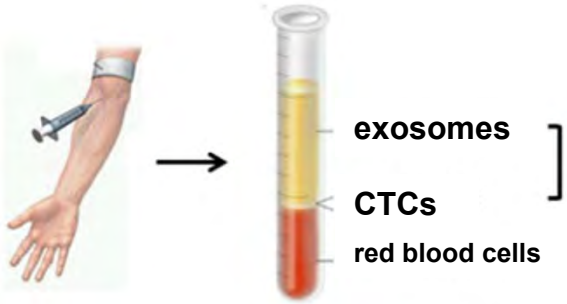
- Integration of various nanotechnolog[illegible]stential mate[illegible]cation and operational differences, and different [illegible]me, and resolution requirements.
- Scale up of the ACBA and MNDS platforms and associated nanotechnologies while maintaining system performance.
- Identifying the materials/technology advantages and limitations at the systems level of the proposed ACBA and MNDS systems that make them reliable and affordable.

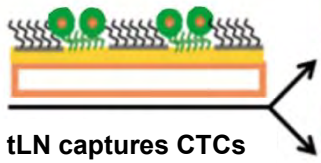
Biotechnology Industry

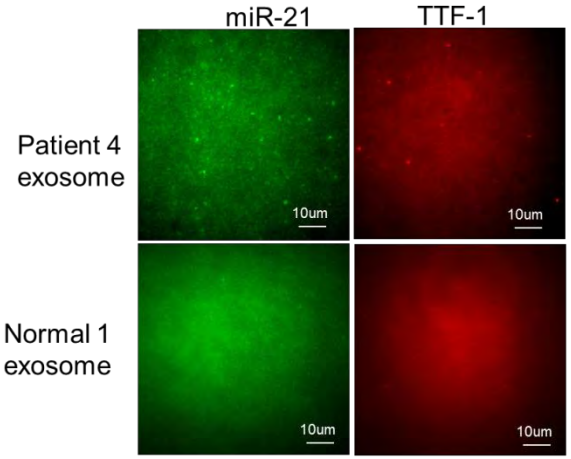
Center Research Going Forward

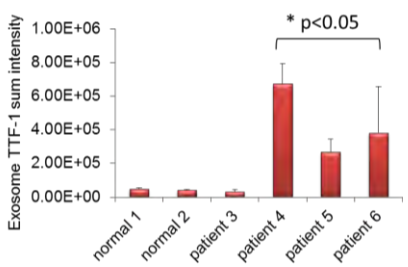
Example of Testbed Application

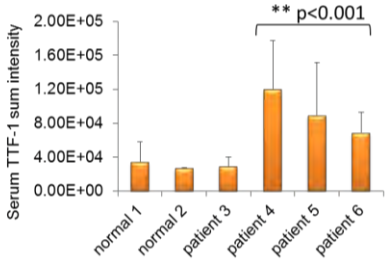
Tethered Cationic Lipoplex Nanoparticle Assay for Early Detection/Monitoring of Lung Cancer

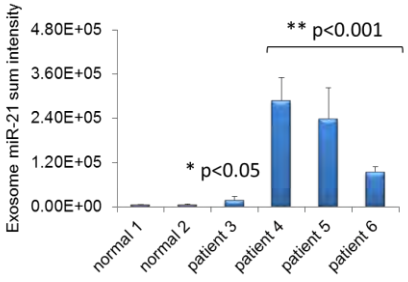


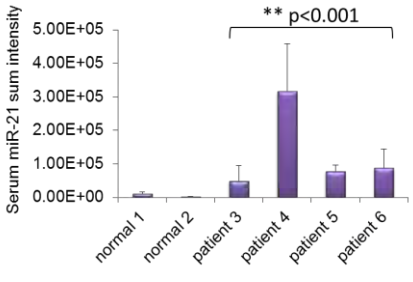












Center Research Going Forward

A Multi-Track Post-Graduation Research Plan

Target Post-Graduation Budget: $4.0M/yr.

Commercialization and high-value applications of polymer-based nanomaterials/devices

Target funding level: $1M/yr

Nanotechnologies applied to translational cancer research/clinical practice

Target funding level: $1.5M/yr

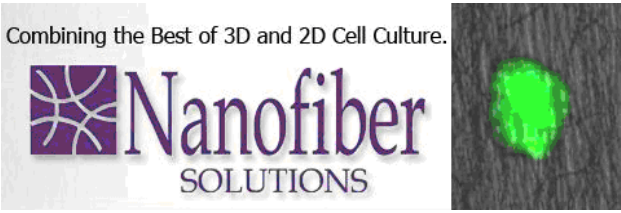
Multi-institutional partnerships to advance nanotechnology applications

Target funding level: $1.5M/yr

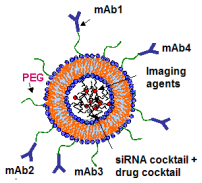
Post-Graduation Research Plan: Track 1

Industrial Collaborations/Commercialization

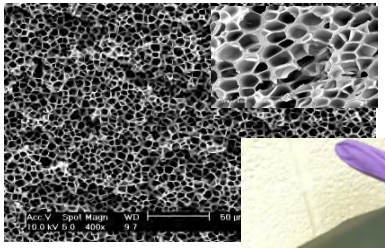
Objective: Polymer nanotechnology commercialization program with leveraged industrial support together with federal government and State of Ohio funding.

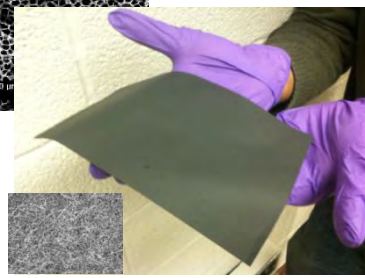


- **Local nanobiotech companies and our 13 spin-off companies**
  - e.g. *Nanofiber Solutions* – nanofiber-cell devices
    Nanomaterial Innovation – lipoplex nanoparticles for siRNA delivery

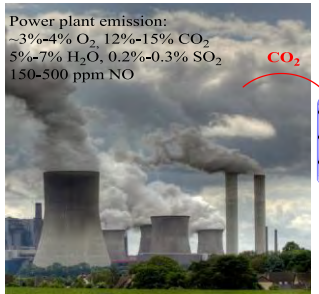


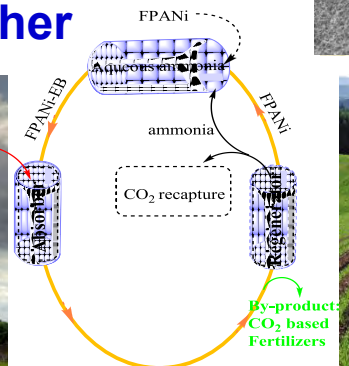
- **Research contracts with large companies**
  - e.g. *Owens Corning, Dow* – nanocomposite foams
    OmnovaSolution, Bell Helicopter, Honda – nanopapers
    AEP – CO_2 sequestration





- **Redwood Innovation Partners retained to identify Center technologies for commercialization potential and other high value applications.**





Redwood Innovation Partners

- Met with lead PIs to review research briefs.
- Selected and applied triage criteria.
- Met with OSU Technology Commercialization Office
- Developed recommendations at the technology and overall levels

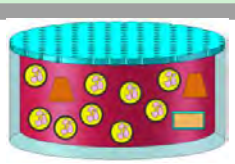
Platform	Functionalized nanofibers	Nanoparticles: detection	Nanoparticles: therapeutics	Nanochannel arrays/nano-electroporation	Magnetic arrays
Market Attractiveness					
IP					
Technology Differentiation					
Technical Maturity					
Conflict with Prior Deals					
Bundling Potential					
Recommen-dation	IP diligence	Pursue further grants	Move forward	Move forward	Bundle

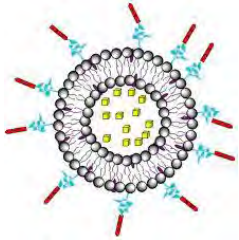
Key: Encouraging; Caution / additional diligence; Significant concern; Need more info.

Post-Graduation Research Plan: Track 2

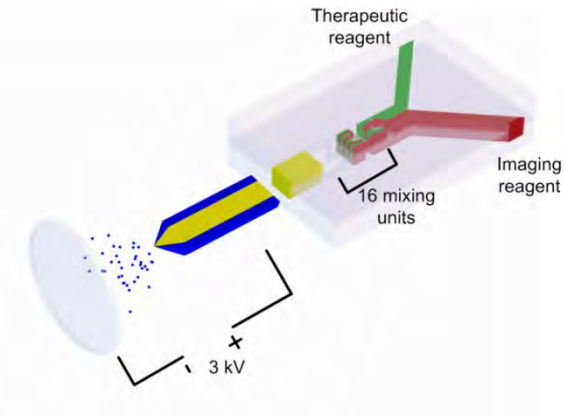
Collaborations with OSU Comprehensive Cancer Center

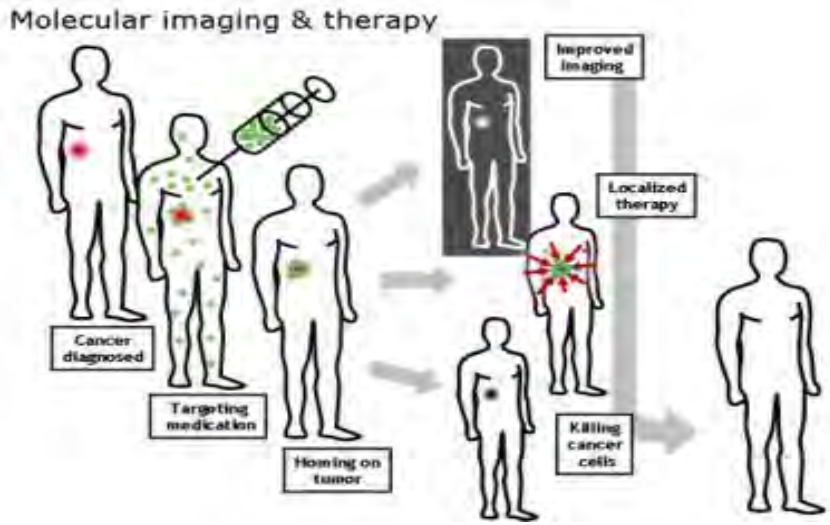
Objective: Organize CANPBD/OSUCCC as a premier science and engineering center on cancer diagnostics and targeted therapies at the interface of nanobiotechnology and translational cancer research.





- NIH research and training proposals: P01, R01, T32, U54
- OSU Cancer Center/College of Engineering Seed Grant Program





- 6 funded R01/R21 research projects.
- 3 programmatic proposals submitted or in final stages of preparation.

Post-Graduation Research Plan: Track 3

Multi-institutional partnerships to advance nanotechnology/nanoscience and engineering applications

Objective: Contribute to multi-institution, public-private research, education and technology transfer partnerships aimed at developing cutting edge nanotechnologies.

- NSF ERC for **P**ort**a**ble **N**anosensor **Dia**gnostics (**PANDA**).

  -- dedicated to creating diagnostic platforms built on new advances in biosensing and micro/nanofluidics to improve public health worldwide.

  -- Notre Dame (lead institution), Imperial College London, Missouri, OSU, Purdue, RMIT University (Australia), and UT El Paso.

- **NSF ERC for NanoReporters in Extreme Environments (NREE).**

  -- dedicated to developing devices for interrogating and reporting information originating from extreme (stressed) environments.

  -- OSU (lead institution), Florida State, UMass, MIT.

- **NSF INSPIRE program.**

  -- e.g. Multiplex Automated Genomic Engineering (MAGE) at the Wyss Institute, Harvard.

Accomplishments in Phase II of Education, Outreach and Diversity

Susan V. Olesik
Director of Education, Outreach and Diversity

Education and Outreach for Phase II

Develop STEM outreach nationally …

- collaboration with award-winning EdHeads
- REU program with strong outcomes
- Collaboration with Oakwood University students

… state-wide …

- YES days
- high school teachers nanotechnology workshop

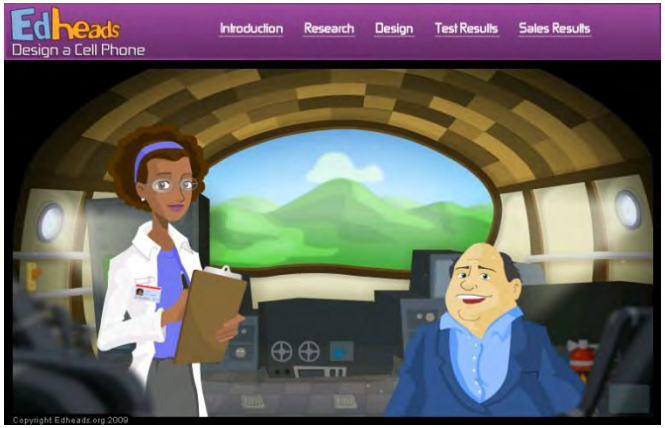
… community-wide …

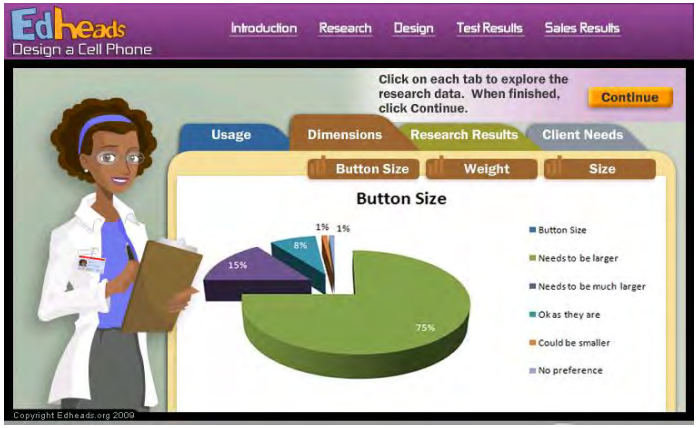
- Nanodays: adapt activities to COSI science museum carts
- Breakfast of Science Champions

… university-wide …

- non-cleanroom tabletop machining techniques for OSU freshman engineering lab-on-a-chip fabrication experience
- Many courses developed or modified

Edheads





- **Flash-based interactive projects, targeted to high and advanced middle schools**
- **Draws in the user when required to use science and math skills to successfully complete a task.**
- **Users ~10^6, many awards (www.edheads.org/awards.shtml)**
- **Promotes career exploration.**

AWESOME LIBRARY

YAHOOLIGANS! COOL! THIS WEEK'S 5 COOLEST SITES!

enc ONLINE

C M Y K THE NEXT GENERATION OF VISUAL COMMUNICATION

HOW TOP TEN

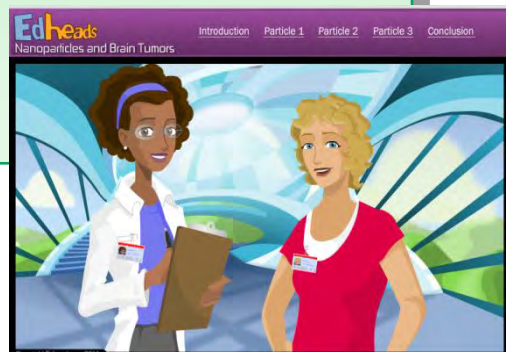
The Educators Network where teachers come first

editor's choice BONUS.COM THE SUPERSITE FOR KIDS

USA TODAY Tech Hot Sites

Edheads – Nanoparticles and Brain Tumors

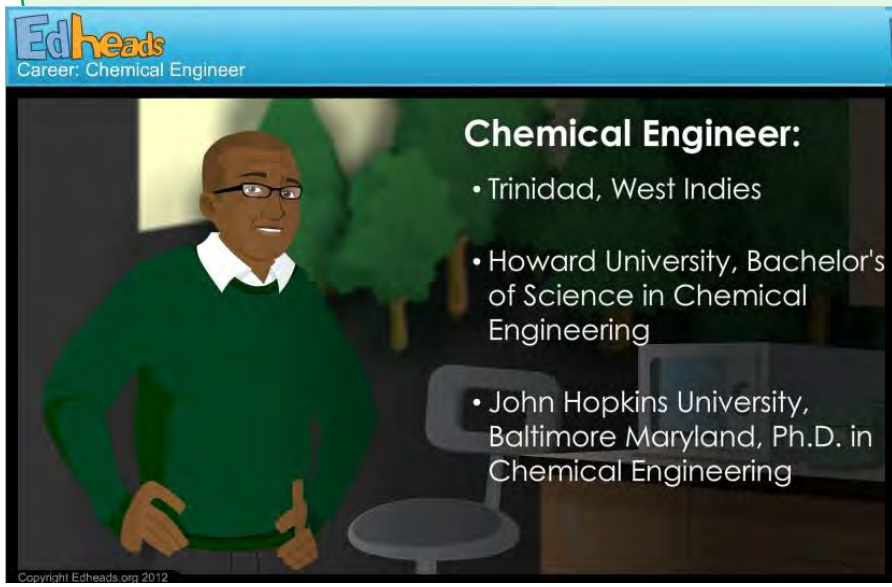
- Explain nanoparticles, present an engineering challenge.
- 577,618 different viewers since launch of website (Dec. 2011)
- Meets state and national science education standards.
- Based on research of Jessica Winter.

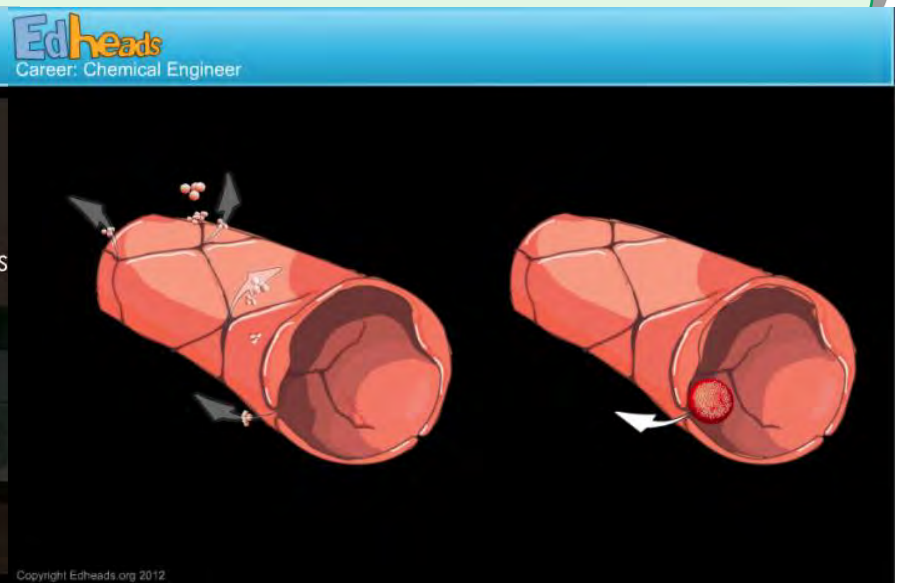


Activity 1: Design a nanoparticle to delineate brain tumors.
Activity 2: Design a nanofactory to sort cells and measure molecules within cells for the detection of cancer.

Edheads – Sickle Cell Anemia its Molecular Basis

- Explain molecular basis of disease, how nanotechnology addresses treatment challenges.
- Developed in collaboration with high school teachers.
- Meets state and national science education standards.
- Based on research of Andre Palmer.
- 80,139 unique viewers since launch of website (Mar. 2013)





REU Program

32 Students served in REU program during Phase II

22%, 32%, 60%, 83%, 88%, 80%, 43% having minority status in years 2005-2011

STEM PhD	STEM MS	STEM BS	MD	Medical prof.	not in school	unknown
51.6%	3.2%	6.5%	12.9%	6.5%	9.7%	9.7%

Nanotechnology Workshop for High School Science Teachers:

- 59 attended these workshop during Phase II
- Bonnies Schuette, Mt. Vernon High School, developed a course for freshman physical science based on this initial workshop and through collaborations with the faculty of CANPBD
- Sarah Vandermeer, St. Charles Academy, published article in *The Science Teacher* (Sept. 2010, p. 58) on how her high school students are contributing new science through their classroom studies on nanoscience.

Adaptations of Nanotechnology Experiments to Accommodate the Disabled

Using the principles of universal design, our teacher advisory panel members are adapting four nanotechnology experiments to accommodate disabled students.

Experiment	Adapted for:
Modeling Tissue Engineering	Visual impairment
Wavelength and Resolution	Visual impairment
Measuring the Visible to Understand the Invisible	Visual impairment
Introduction to Sun Protection*	Visual and hearing impairment

These were used in the 2011 Summer Teacher workshop

*Device to detect UV rays using tone as well as light is under development

YES DAYS - Washington State Community College, Southeast OH

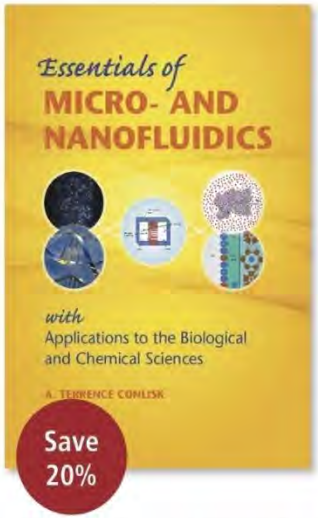
Middle school outreach: ~700 students served in Phase II.

COSI NanoDay

Typically over 1000 visit COSI per day

New or Modified Courses and text books

CAMBRIDGE www.cambridge.org/9780521881685



Available from December 2012 | 560 pp
117 b/w illus. | 40 tables | 170 exercises
Hardback | 978-0-521-88168-5
~~List Price: USD 130.00~~
Discounted Price: USD 104.00

A new textbook!

Essentials of Micro- and Nanofluidics

With Applications to the Biological and Chemical Sciences

A. Terrence Conlisk
Ohio State University

About the Book

This book introduces students to the basic physical principles to analyze fluid flow in micro and nano-size devices. This is the first book that unifies the thermal sciences with electrostatics and electrokinetics and colloid science; electrochemistry; and molecular biology. The author discusses key concepts and principles, such as the essentials of viscous flows, an introduction to electrochemistry, heat and mass transfer phenomena, elements of molecular and cell biology, and much more. This textbook presents state-of-the-art analytical and computational approaches to problems in all of these areas, especially electrokinetic flows, and gives examples of the use of these disciplines to design devices used for rapid molecular analysis, biochemical sensing, drug delivery, DNA analysis, the design of an artificial kidney, and other transport phenomena. This textbook includes exercise problems, modern examples of the applications of these sciences, and a solutions manual available to qualified instructors.

How To Order

Visit www.cambridge.org/us/9780521881685
or Call 1.800.872.7423

Enter Discount Code CONLISK13 at checkout to receive the discount.
Offer expires 12/1/2013

CAMBRIDGE
UNIVERSITY PRESS

- **2009 Courses-26**
  Total Enrollment-708
- **2010 Courses- 26**
  Total Enrollment-598
- **2011 Courses- 20**
  Total Enrollment-496
- **2012 Courses-18**
  (change to semesters)
  Total Enrollment-559

Freshman Engineering Curriculum Development

Current lab-on-a-chip fabrication uses tabletop CNC mills to fabricate patterns in acrylic wafers covered by PDMS lids with access holes. Chip is designed to study adhesion of yeast cells to nanopatterned surfaces.

673 students participated during Phase II.

Phase II Deployment Chart

	REU	Courses	K12 Visits & Lab Tours	Grad Wkshp	High School Teachers	Teacher Wkshp	VIE	# people impacted/yr
Year 1	✓	✓						60
Year 2	✓	✓	✓	✓	✓			217
Year 3	✓	✓	✓	✓	✓	✓	✓	786
Year 4	✓	✓	✓	✓	✓	✓	✓	2600
Year 5	✓	✓	✓	✓	✓	✓	✓	≈3000
Yrs 6-7	✓	✓	✓	✓	✓	✓	✓	≈10000+
Yrs 8-10	✓	✓	✓	✓	✓	✓	✓	≈15000+

Future Education Plans

Develop STEM outreach nationally …

- Edheads websites will continue for a few years.
- REU program subgroups will continue to submit NSF REU proposals.

… state-wide …

- YES days collaboration will continue through OSU support.

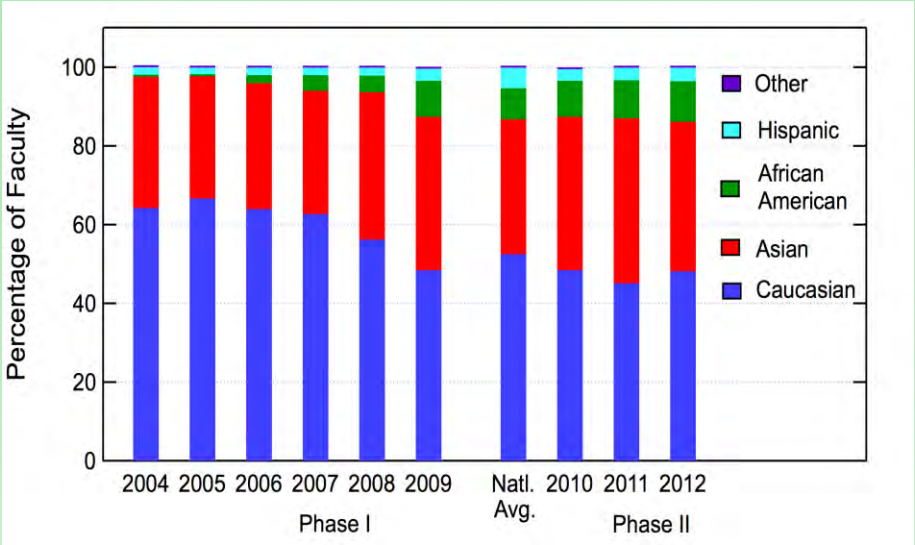
… community-wide …

- Breakfast of Science Champions will continue through OSU support.

… university-wide …

- Freshman Engineering classes now have a nanotechnology unit.
- Most nanoscience related courses will continue.

Diversity Progress – NSEC-CANPBD Faculty



CANPBD exceeds national averages for minorities and domestic females

Progress

Phase I:

2005: 3 new faculty: 2 females;

15% underrepresented overall

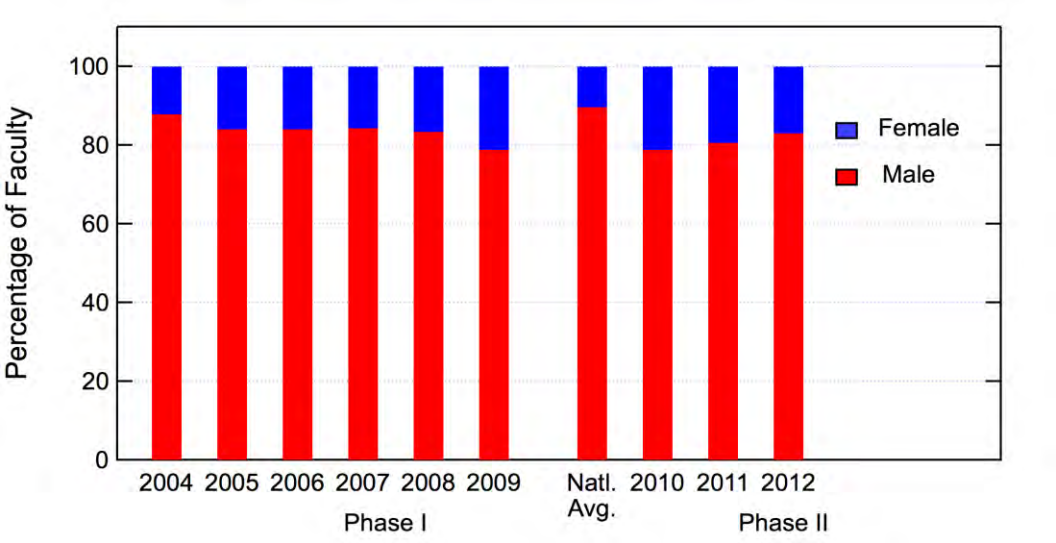
Phase II:

2012: of 29 faculty members:

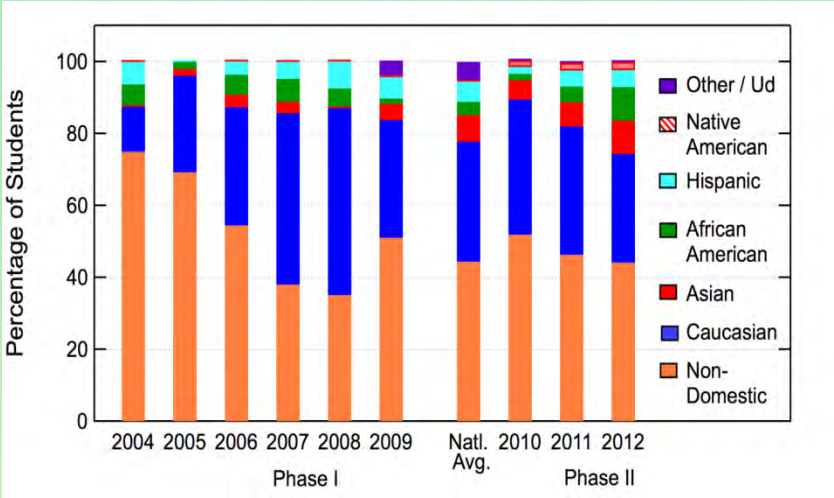
5 females, 1 Hispanic,

3 African American

31% underrepresented in 2012



Diversity Progress – NSEC-CANPBD Graduate Students



Goal

An increase of 5% per year in underrepresented graduate domestic students

New CANPBD graduate fellowship positions for underrepresented minority students made available in 2009-2013.

Progress

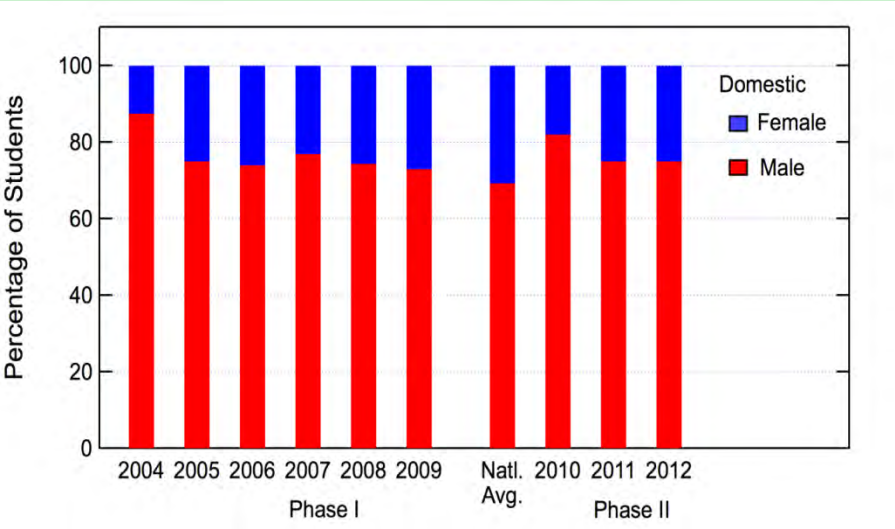
Phase I: 2005 – 2009 Increased underrepresented students from 10% to 21%

Phase II:

underrepresented NSEC grad students

2010: 16% 2011: 19% 2012: 21%

5 females, 3 African Americans (2 males, 1 female), 2 Hispanics (1 male, 1 female), and 1 Native American male

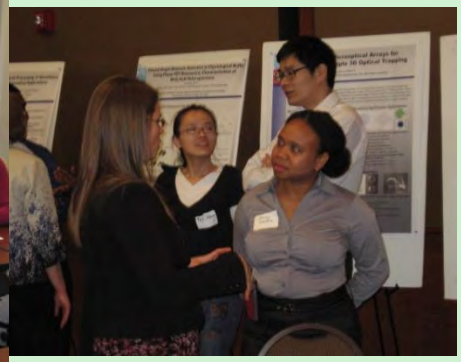


2013: Added 1 African American student in January.

Diversity - Summary

OSU NSEC has made significant progress in increasing diversity at all levels.

- CANPBD faculty exceeds national averages for minorities and domestic females.
- CANPBD now exceeds the national average in the proportion of domestic female postdoctoral researchers.
- CANPBD compares well with the national average for domestic female engineering graduate students and minorities in most categories.



Future Diversity Plans

- Continued recruitment of graduate students through existing contacts at Oakwood University, Alabama A and M, University of Puerto Rico, FAMU, LSU, FSU, etc.
- Use existing minority graduate students and faculty to assist with recruiting under represented groups. (*Effort increases with our increased numbers*.)
- Use lessons learned in CANPBD to continue recruitment of diverse faculty and graduate students.
- Apply for NSF AGEP, REU, IGERT, NUE, INSPIRE, etc. grants to hold assembly of diversity efforts together.

Medical Advisory and Evaluation Board

- Provide medical advice and assess clinical applicability.
- Enhance research collaborations between CANPBD and the medical community.
- Co-advise CANPBD fellows and provide medical internships.

William Carson, M.D. (Chair) – Surgery, Associate Director of OSU Comprehensive Cancer Center (CCC)
John Byrd, M.D. – Director of Hematologic Maligancies at CCC
Sam Jacob, Ph.D. – Hematology, Co-Director of Experimental Therapeutics at CCC
Jas Lang, Ph.D. – Otolaryngology
Mariano Viapiano, Ph.D. – Brain Tumors and Neuroscience
Maryam Lusterg, M.D. – Breast Cancer
Guido Marcucci, M.D. – Hematology/Oncology
Raj Muthusamy, Ph.D. – Leukemia
Patrick Nana-Sinkam, M.D. – Lung Cancer
Matthew Ringel, M.D. – Molecular Virology

Industry Outreach

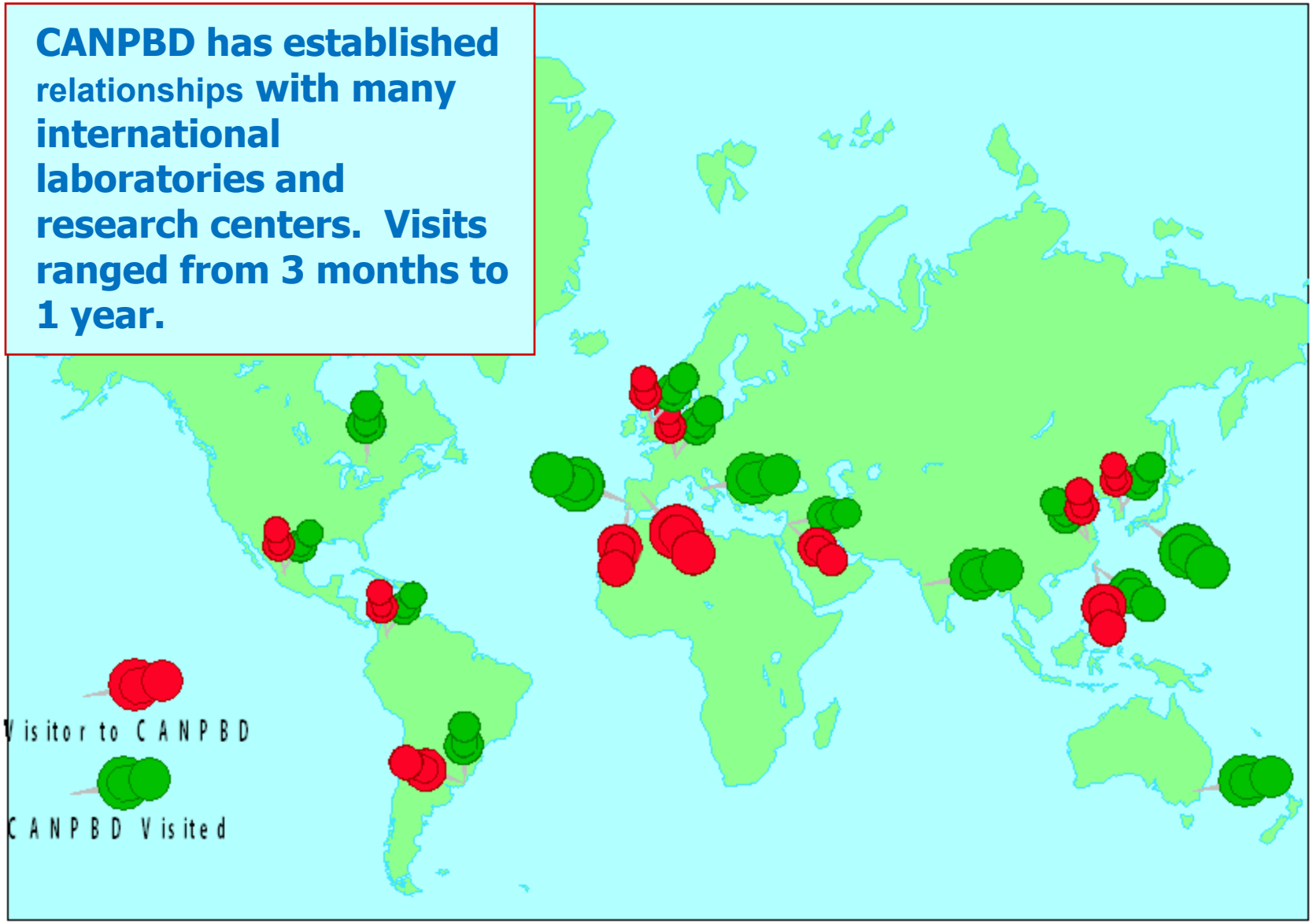
Vision: To promote technology transfer, lay the groundwork for U.S. industrial leadership, and foster inexpensive products for widespread societal benefit.

Key Elements:

- Nanobiotechnology Workshops
- Semi-Annual Nanobiotechnology Symposia
- Collaboration, Reciprocal Visits & Spin-Off Companies; **build on commercialization experience via SBIRs/STTRs, NIST-ATPs,SBIRs:**
  - **State of Ohio with Bioprocessing Innovative Inc. $1.0M**
    biochips for diagnostics, biological weapon detection
  - **DARPA with iMEDD $1.4M**
    biofluid transport in nanochannels
  - **NCI (R01) with SHOT and CCF $2.4M**
    magnetic cell sorting
  - **SBIR with Sibyl Parmaceutical Inc. $0.5M Phase I**
    targeted liposomal daunorubicin to myeloid leukemia

International Collaboration

CANPBD has established relationships with many international laboratories and research centers. Visits ranged from 3 months to 1 year.



NSEC for Affordable Nanoengineering of Polymeric Biomedical Devices (CANPBD)

- Nanobiotechnology in 2004
- Challenges in 2004
- Progress since 2004
- Future Opportunities/Challenges

L. James Lee

Director

State and Challenge of Nanobiotechnology in 2004

- *Proteomic and Genomic Analysis*

Single Cell and Exosome Analysis

- *MicroElectroMechanicalSystem (MEMS)*

NanoElectroMechanicalSystem (NEMS)

- *Cleanroom/Photolithography/Semiconductor*

Non-cleanroom/Assembly/Soft Materials

- *Single Functional, Simple Devices, High-cost, Top-down or Bottom-up*

Multifunctional, System Integration, Low-Cost, Top-down and Bottom-up

Non-Cleanroom 3D Polymer Nanofabrication

Mold (Master) Making

High cost: X - ray Lithography; Electron Beam Lithography

Low cost: Scanning Probe Lithography (e.g., Dip Pen Lithography); *Differential Etching*

↓

Silicon, Quartz, Soft Metals [2D]

Ultraprecision Machining (≈1nm)
+
Pulse Laser-Proximal Ablation/SFF (≈10 nm)
+
Nano-Polishing

↓

Steel [3D]

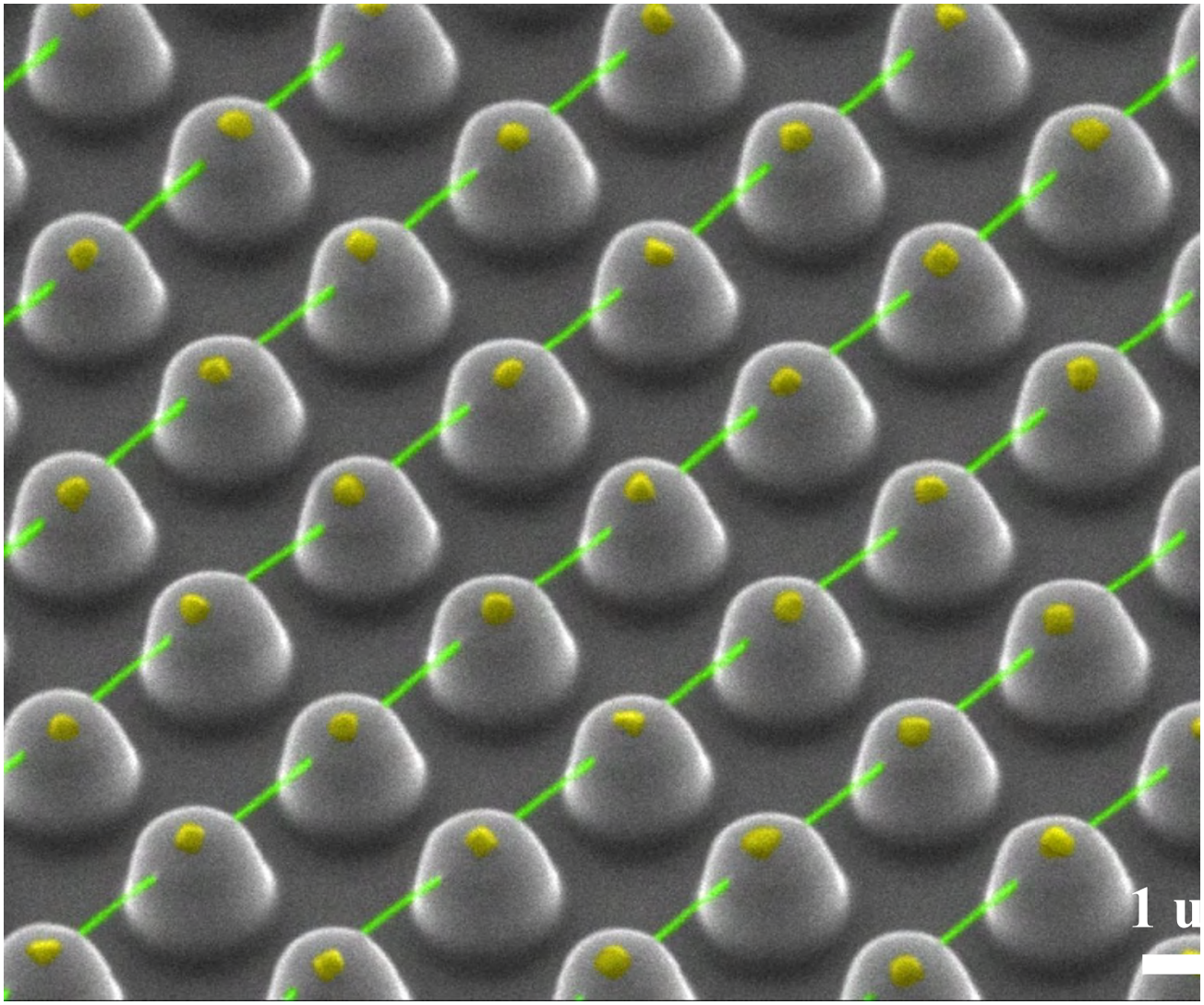
Polymer Replication

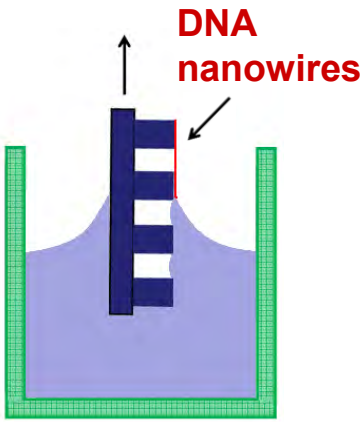
"Top-down": Nano-Imprinting; Soft Lithography

"Bottom-up" --- Self-Assembly

"Top-down" *Sacrificial Template Nano-Imprinting*
+
"Bottom-up" *DNA Combing and Imprinting (DCI)*
+
Dynamic Assembly

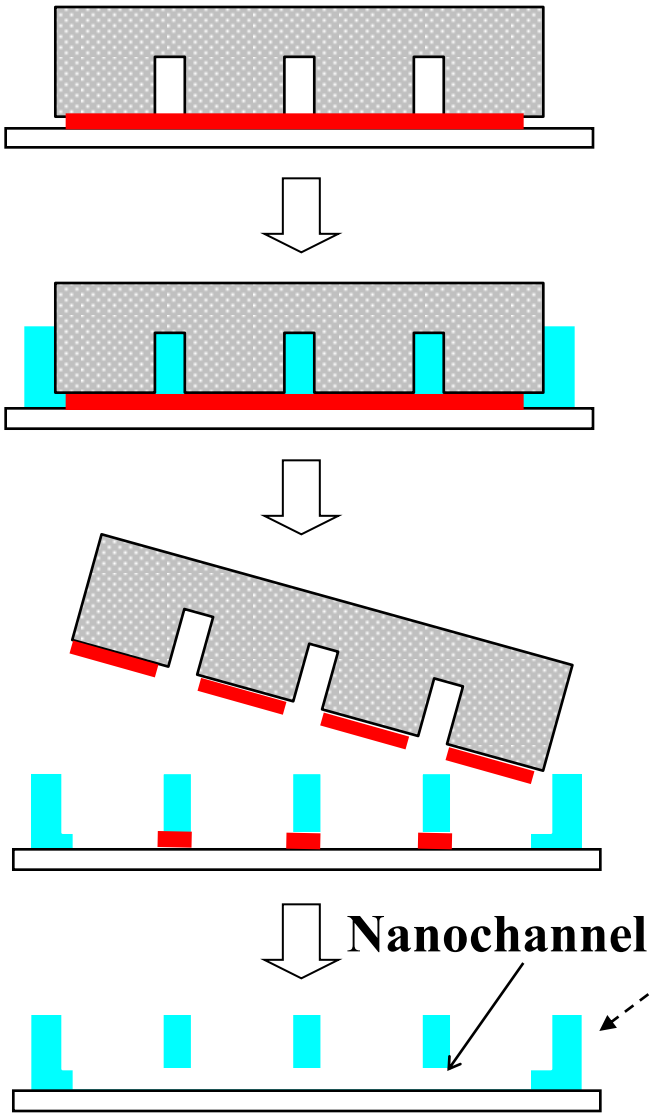
DNA Nanowire Array by Combing

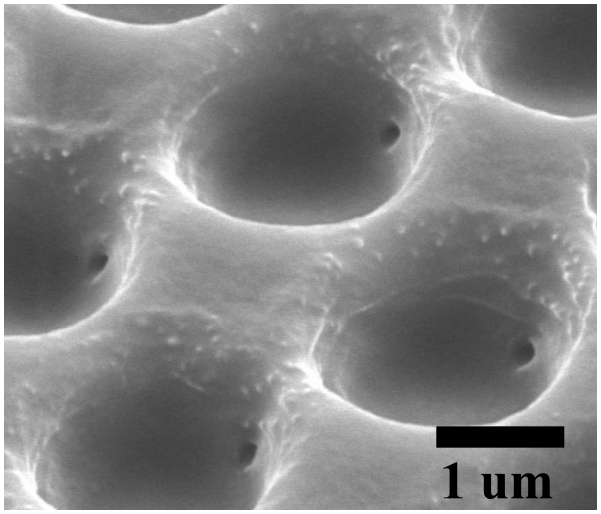


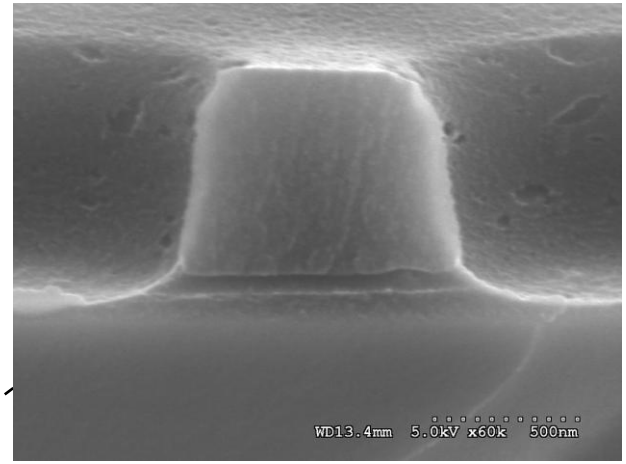


Guan and Lee, *PNAS*, 2005
Guan, et al, *Advanced Materials*, 2007

Fabrication of Nanochannel Array- Imprinting

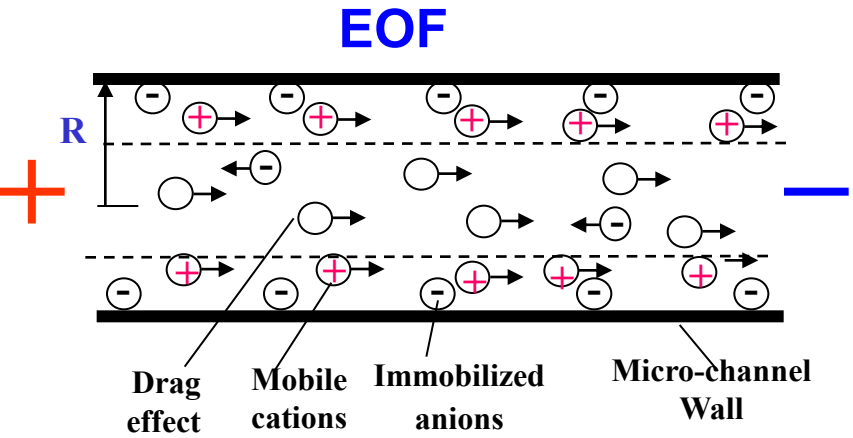


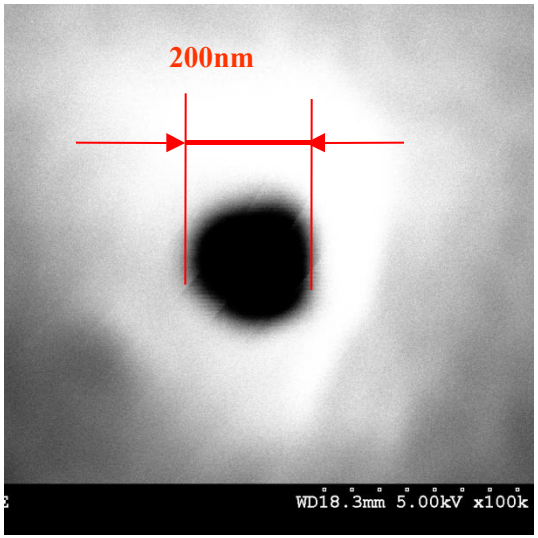


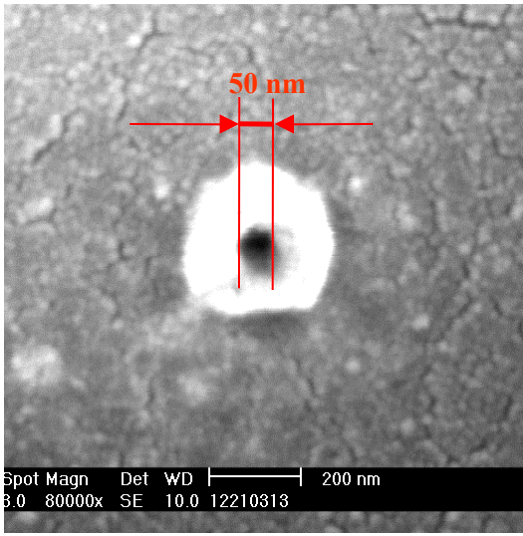


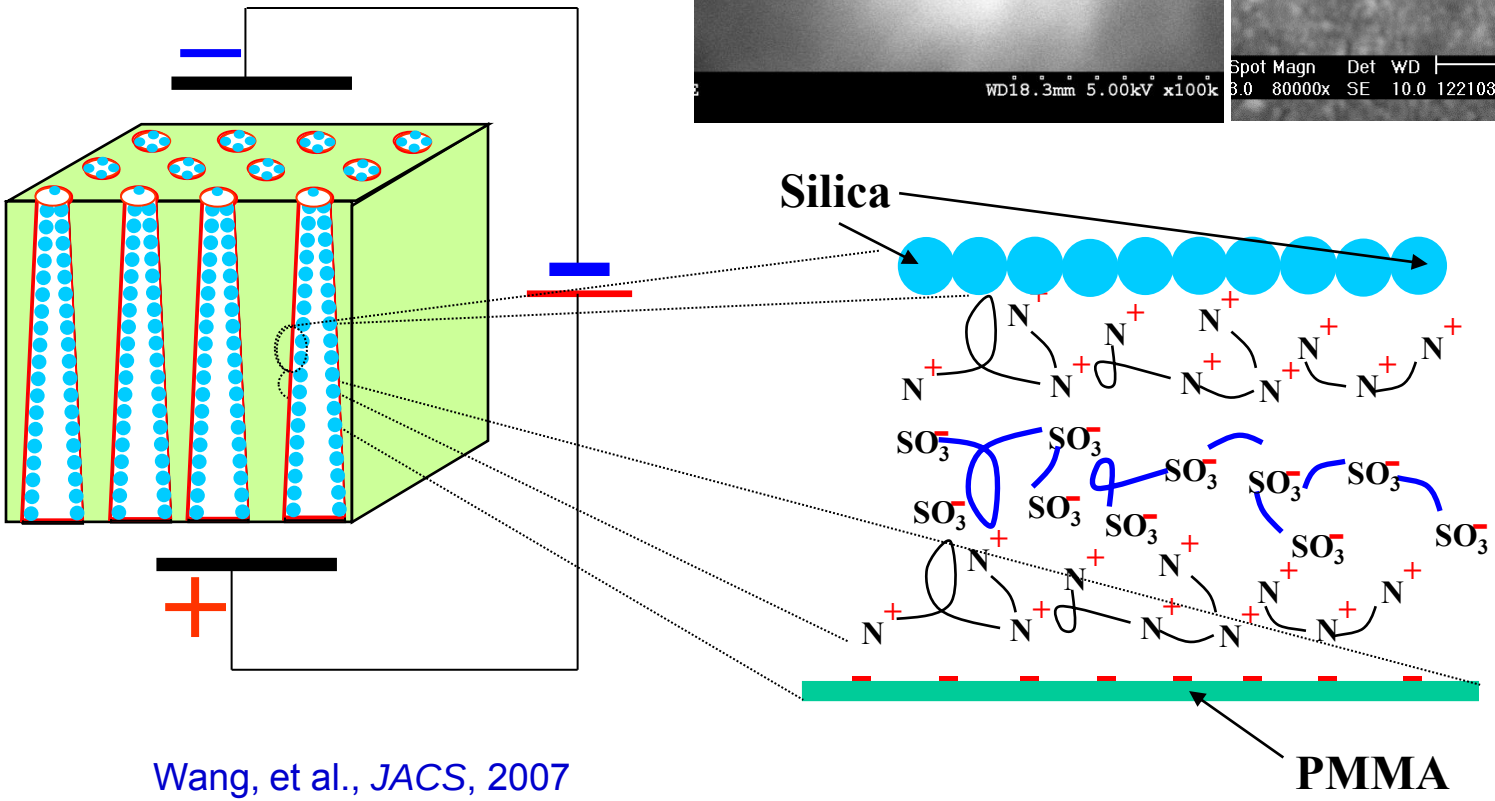
Guan, et al., *Advanced Materials*, 2010

Dynamic (Electric/Magnetic) Assembly in Nanochannels









Wang, et al., *JACS*, 2007

Nanoparticles, Nanofibers/wires and Nanofluidics for Biomedical Applications

Nanonozzle array cell patch for *ex vivo* gene delivery - Nanochannel ElectroPoration (NEP)

Multifunctional nanoparticles for *in vivo* gene delivery and *in vitro* diagnosis -"Theranostic" lipoplex nanoparticles

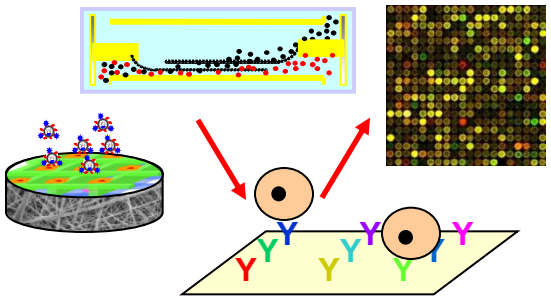
Nanofibers-based cell devices for separation and Culture- "Migrational Chromatography"

Integrated magnetic and optical platforms for early cancer detection - Automated Cell to Biomolecule Analysis (ACBA) systems

Future Opportunities: Personalized Nanomedicine

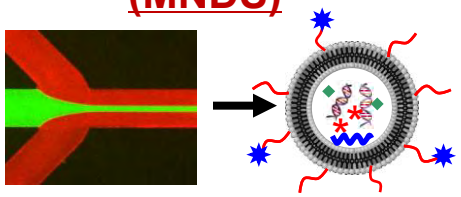
NSEC- CANPBD

Automated Cell to Biomolecule Analysis (ACBA)



cancer cell separation and analysis

Multifunctional Nanoparticle Design and Synthesis (MNDS)



targeted nanoparticles produced by nanofactory

OSU Comprehensive Cancer Center and James Cancer Hospital

Patient blood or tissue samples

Clinical trial

Animal study

Biotechnology Industry

Challenges to Achieving ACBA and MNDS Systems

- **Optimization, resolution, and control of various nanoconstructs by guided assembly**

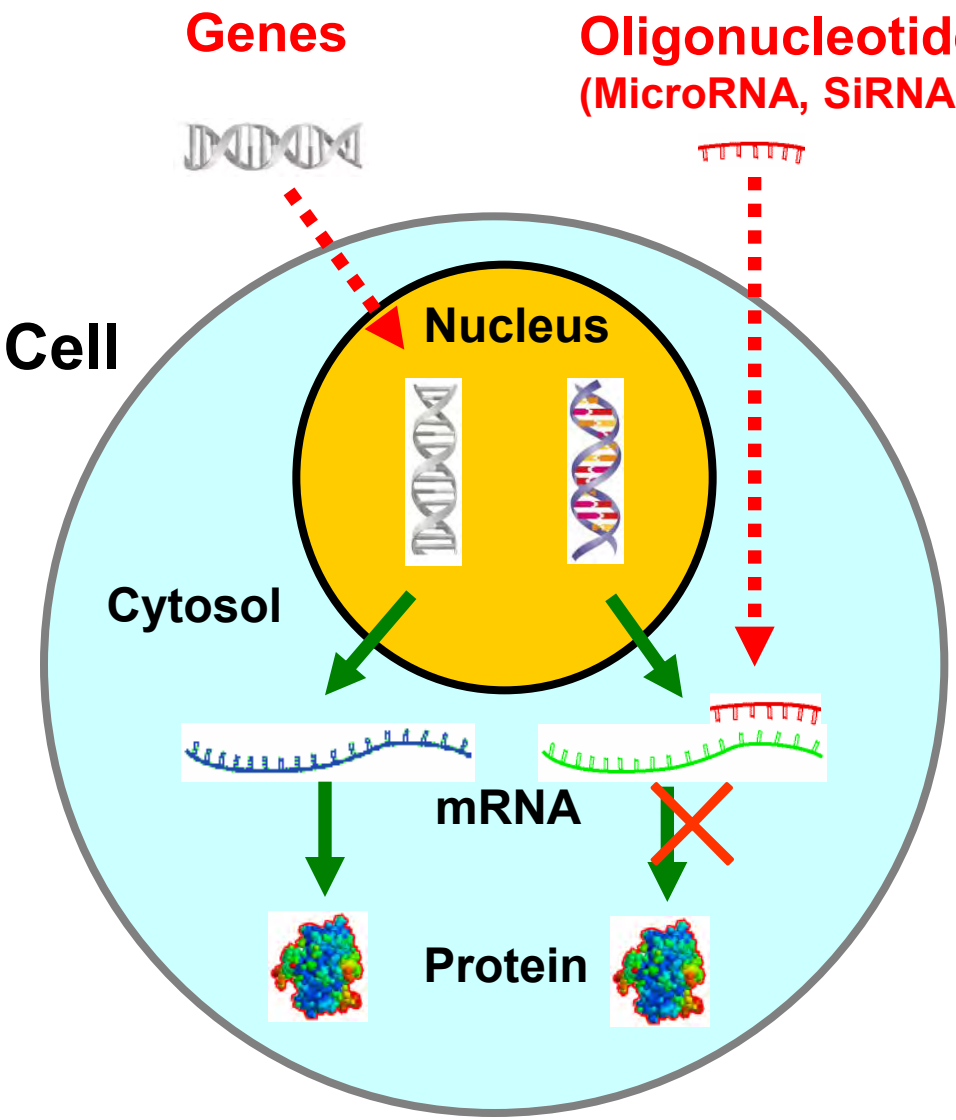
- **Combination of top-down and bottom-up methods, and cleanroom and non-cleanroom fabrication for mass production of hybrid polymer-semiconductor devices at low-cost**

- **Manipulation of cells and biomolecules with high capacity**

- **Optimization, resolution, and control of electrokinetically driven nanofluidics**

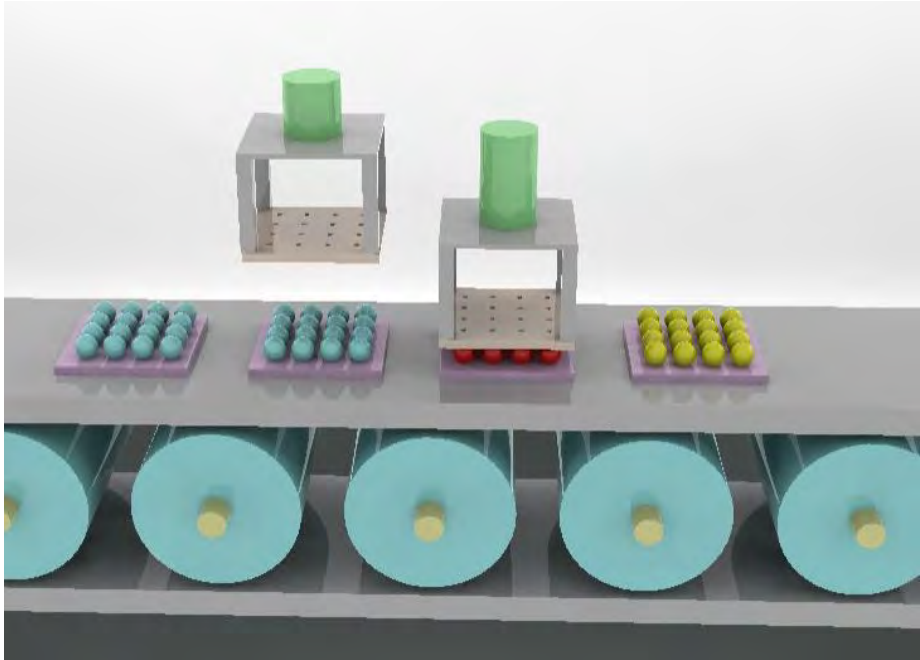
Gene and Oligonucleotide Therapy

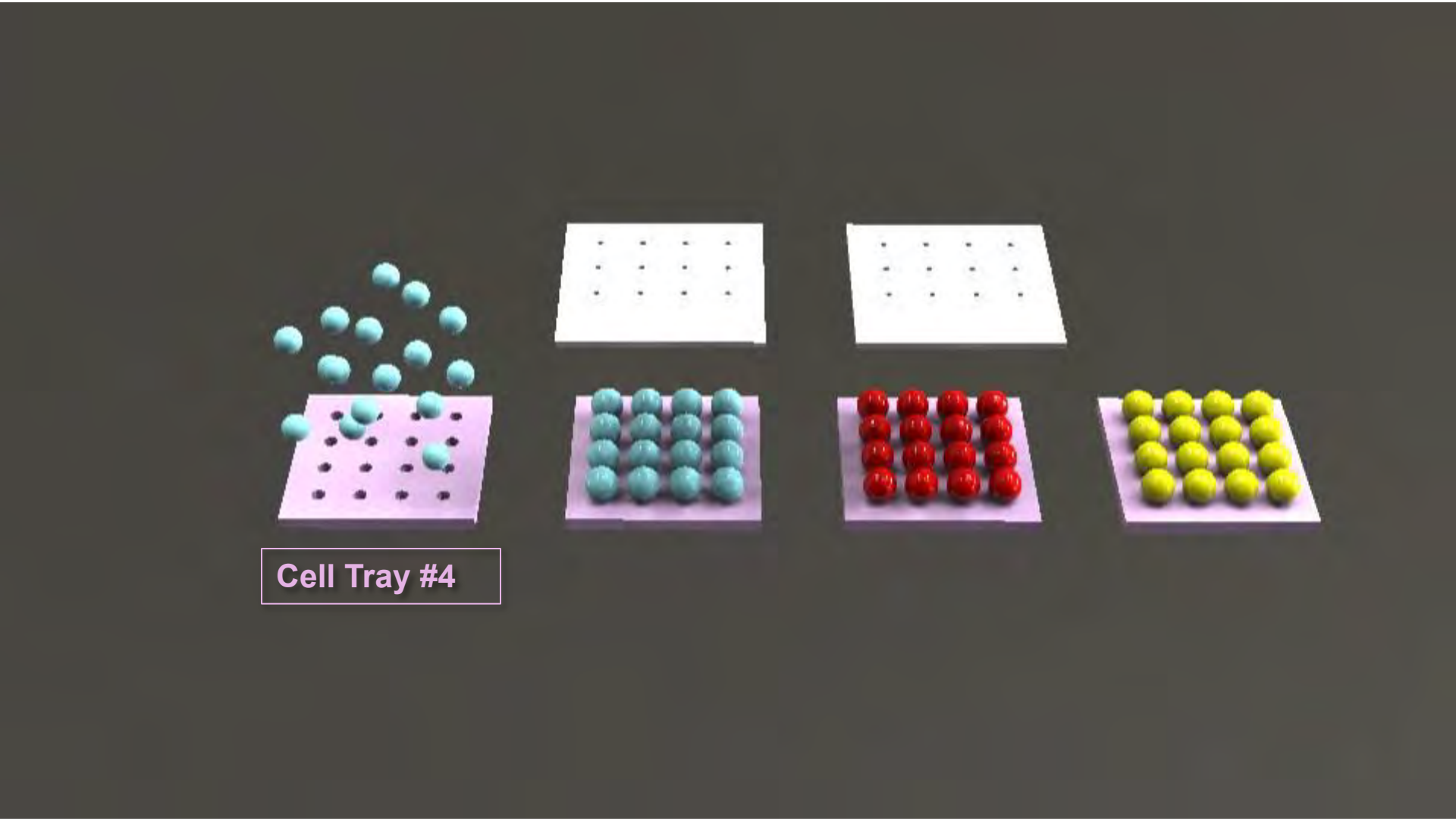
Use of nucleic acids for the treatment of diseases



Engineering Cells

NEP Based Cell Transfection Nanofactory




Cell Tray #4