Department of Health & Human Services
National Institutes of Health

SENSORS AND SYSTEMS: ESSENTIAL INGREDIENTS IN TRANSFORMING HEALTH CARE

Government-University-Industry Research Roundtable Meeting
February 23, 2010

The National Academies Keck Center

William Heetderks, M.D., Ph.D.
Associate Director for Science Programs
National Institute for Biomedical Imaging and Bioengineering, NIH

One Hundred Sixth Congress of the United States of America

AT THE SECOND SESSION

Begun and held at the City of Washington on Monday, the twenty-fourth day of January, two thousand

An Act

To amend the Public Health Service Act to establish the National Institute of Biomedical Imaging and Bioengineering.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SECTION 1. SHORT TITLE.

This Act may be cited as the "National Institute of Biomedical Imaging and Bioengineering Establishment Act".

APPROVED
DEC 2 9 2000

Speaker of the House Pro Tempore

Strom Thurmond

President of the Senate Pro Tempore

William J. Clinton

NIBIB Mission:

Improve human health by leading the development and accelerating the application of biomedical technologies. The Institute is committed to integrating the physical and engineering sciences with the life sciences to advance basic research and medical care.

Sensors and Systems in Health Care

- Screening/surveillance
- Disease monitoring/diagnostics/ state change/response to therapy
- Closed-loop control of therapy
- Theragnostics

The challenge of maintaining quality health care

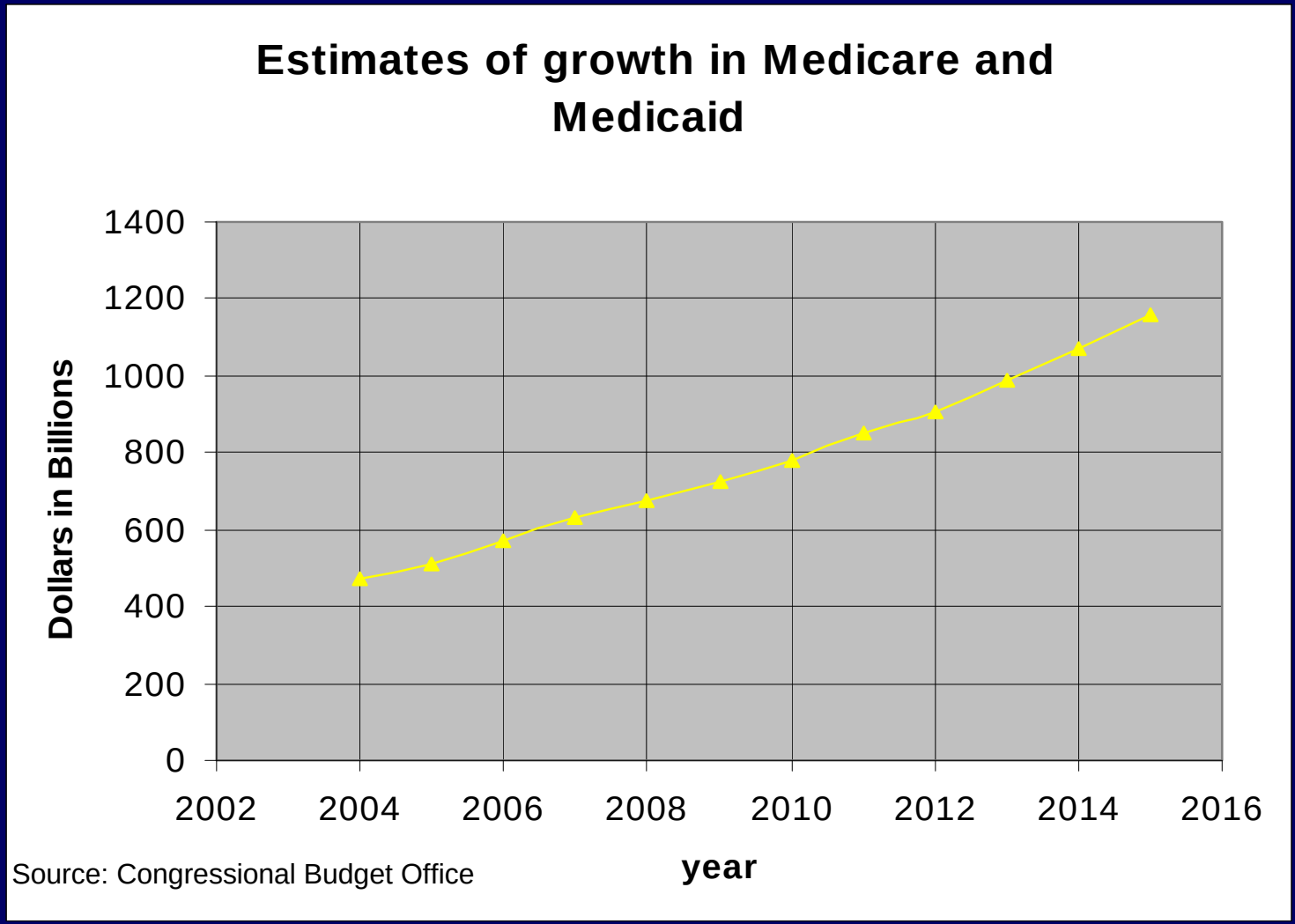
- **GM reports that its payments for retirees' health care - more than what the company spent for steel - add about $1,525 to the cost of every vehicle the company sells.**

Company	Retirees Health costs
GM	$3.6 Billion
Ford	$2.0 Billion
Chrysler	$1.3 Billion

Source: Automotive News, 4/05


AGING
THUNDER

Growth in Medicare and Medicaid



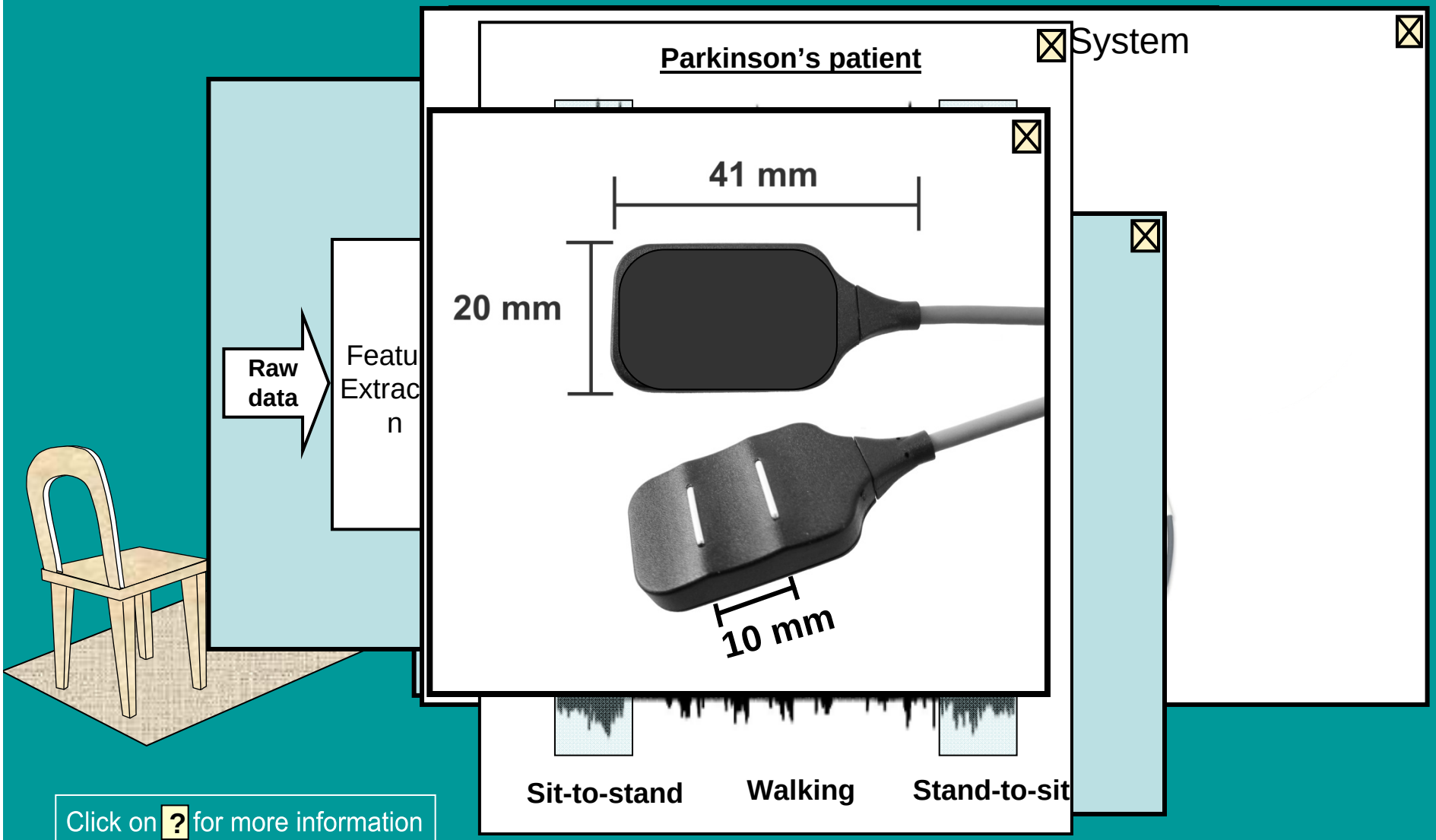
Source: Congressional Budget Office


AirMesh
EASY ENTRY

The potential role of sensor technology in home health care

"Wearable-Sensor System for Monitoring Motor Function"

PI: Carlo J. De Luca, PhD



Monitor Diet / Electrolyte Intake in ESRD

DIMA

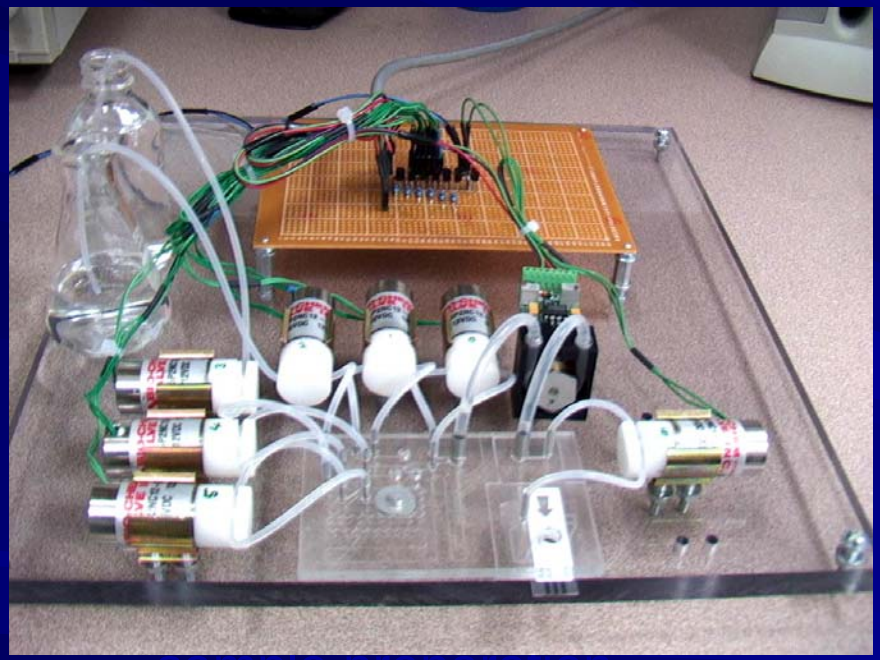
Dietary Intake Monitoring Application

PDA :

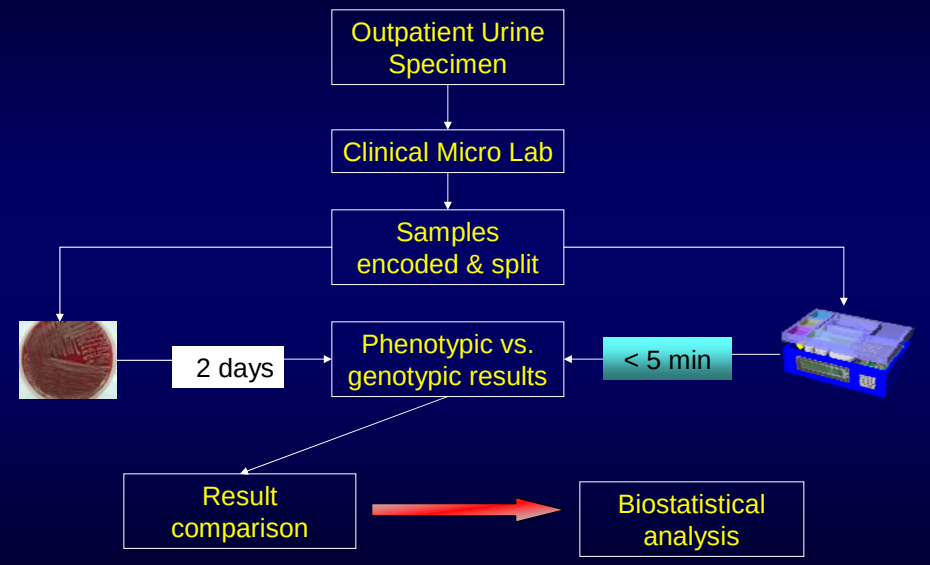
- ***Renal Failure:***
  Monitor dietary nutrients
- **Input:**
  Visual Interface, scan bar code
- **Output:**
  Visual display of nutrients
- **Dietary Hx:**
  Recall of previous meals

Sensor Development for Point of Care Systems
Uropathogen Detection using DNA Biosensors

Bernard M. Churchill, M.D., University of California, Los Angeles



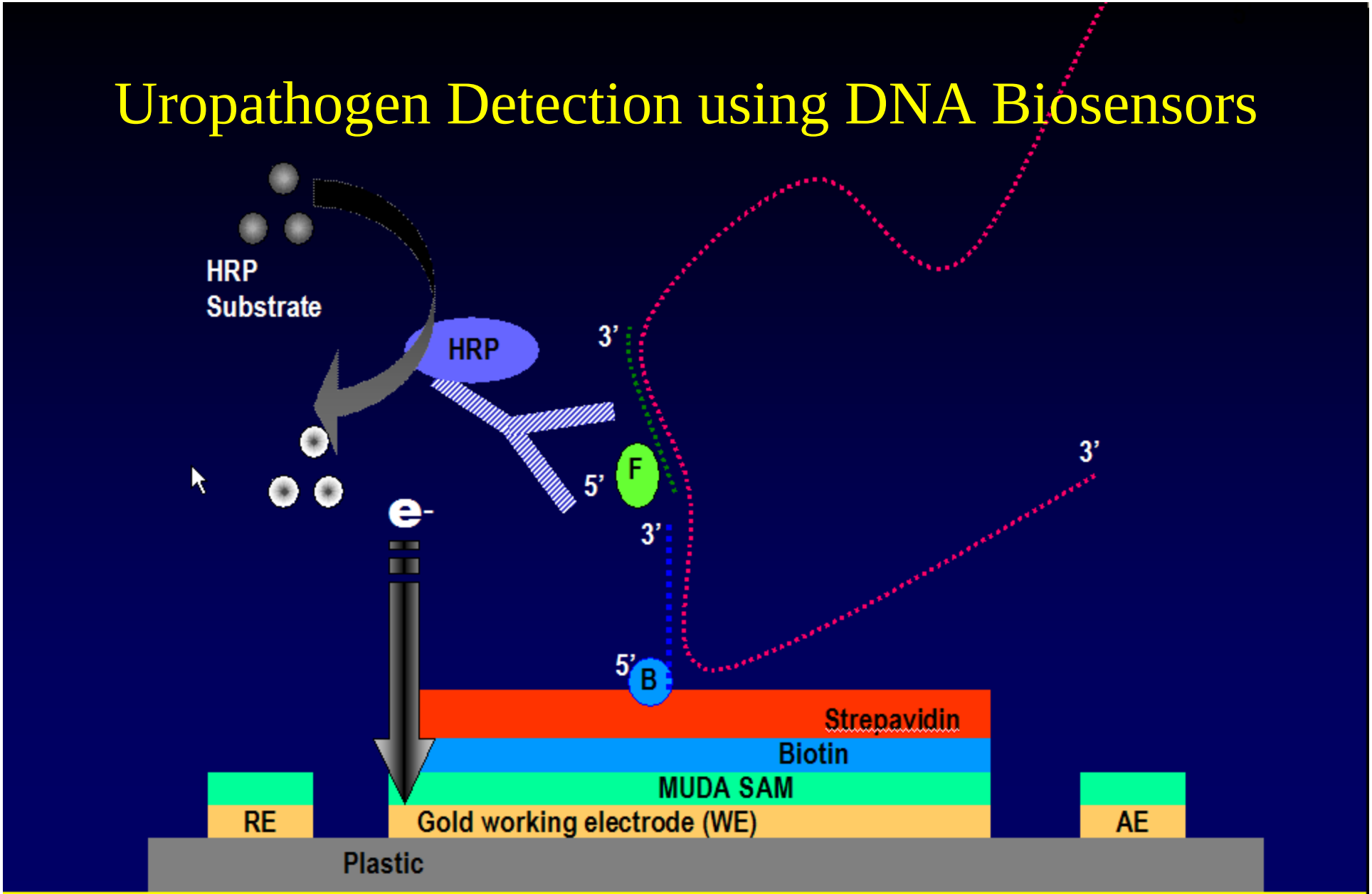
Clinical Sample Testing: *Clinical Validity*



sample preparation

testing

Uropathogen Detection using DNA Biosensors



Electrochemical DNA Sandwich Assay

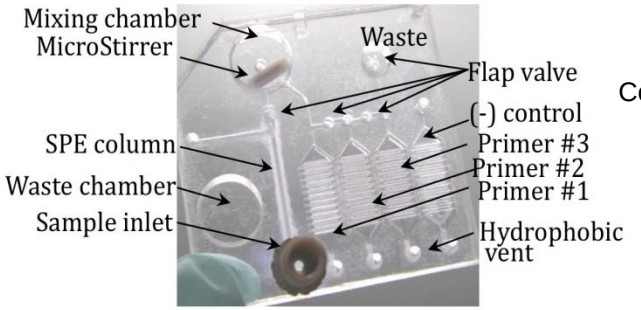
Microchip to Detect Influenza Infection and Type in Nasopharyngeal Swabs (EB008268-03)

• ***We have developed a microscale solid phase extraction process that can isolate purified nucleic acids from complex samples in a microfluidic chip.***

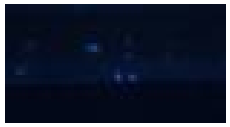
- –Urine - Bacteria (gram positive and negative)
- –Blood - ***Virus (influenza A)***
- –Stool - Mammalian Cells (RNA, mRNA, DNA)
- –Saliva
- **–Nasopharyngeal Washes**

• The columns have been proven sensitive down to fewer than 100 cells (for bacteria). Virus work still in progress.

• The technology eliminates many off-chip sample preparation steps, potentially moving molecular detection closer to the point of care.

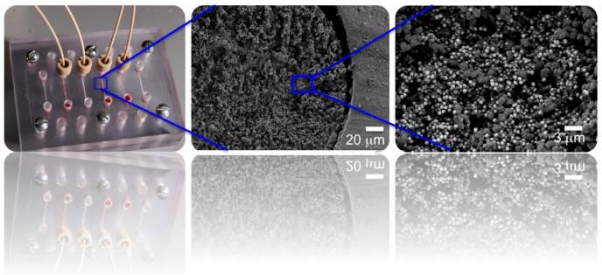


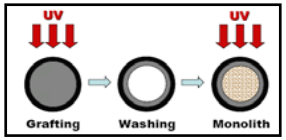

Column with DNA bound.


After water elution.

•Integrated chip above incorporates sample preparation and nucleic acid amplification steps. Fluorescence detection.

•Amplification is achieved using PCR or Isothermal Methods.





• Porous solid phase fabricated after chip is sealed.
• Light directed chemistry.
• Micro and nanocomposite materials.
• Covalently bound to channel, no weirs necessary.
• Scalable manufacturing processes.
• Compatible with conventional microfabrication processes.
•*On chip valving and mixing.*

Relevant Publications and Contact Info

1. M. Mahalanabis, et al., "Cell lysis and DNA extraction of Gram-positive and Gram-negative Bacteria from Whole Blood in a Disposable Microfluidic Chip", *Lab on a Chip*, DOI: 10.1039/B905065P, (2009).
2.Sauer-Budge, et al., "Low cost and manufacturable complete microTAS for detecting bacteria," *Lab on a Chip*, DOI: 10.1039/B904854E, (2009).
3. Gillers, et al., "Microscale sample preparation for PCR of *C. difficile* infected stool," *Journal of Microbiological Methods*, DOI:10.1016/j.mimet.2009.05.020, (2009).
4. Kulinski, M.D.et al., "Sample Preparation Module for Bacterial Lysis and Isolation of DNA from Human Urine," *Biomedical Microdevices*, 11(3), pp.671-678, (2009).

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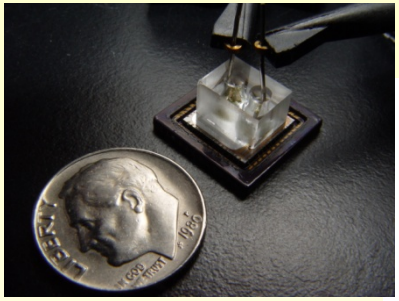
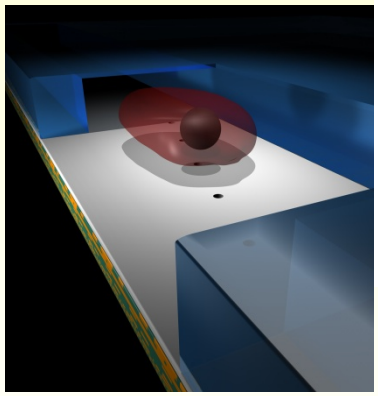
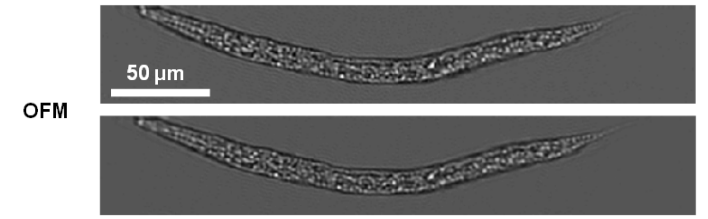
$10 On-Chip Microscope System – High-resolution, Cheap, and Compact

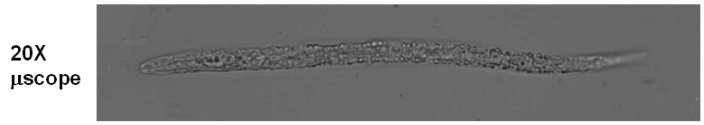
conventional microscope

optofluidic microscope









floaters in our eyes

The optofluidic microscope (OFM) enables high-resolution (~ 1 micron) on-chip cell and micro-organism imaging by drawing inspiration from the 'floater' phenomenon. The system is lensless, high-resolution and cheap to mass-produce.

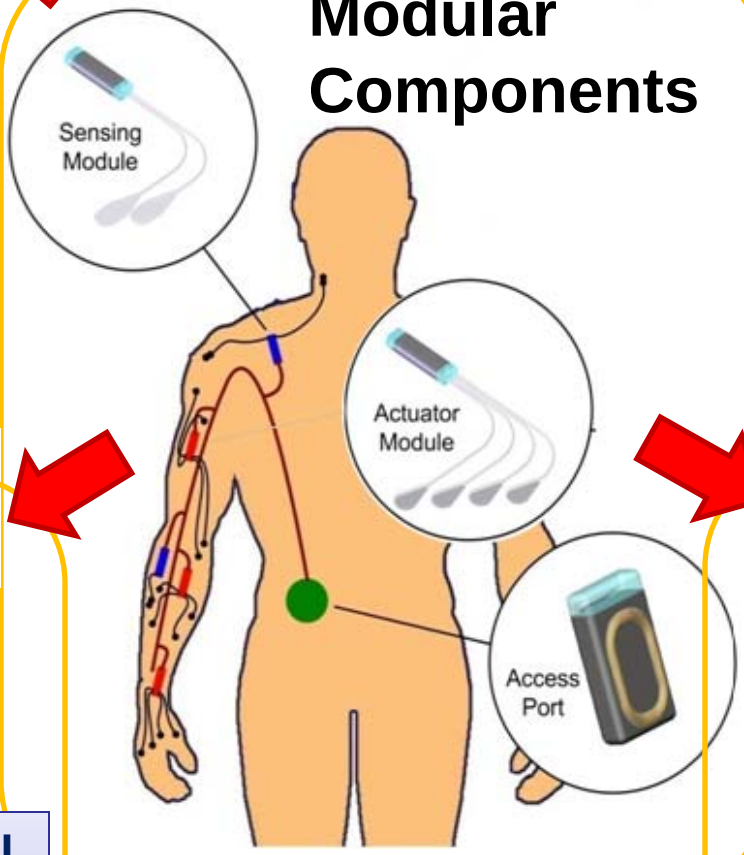
X Cui, L Lee, X Heng, W Zhong, PW Sternberg, D Psaltis & C Yang, PNAS Vol 105, 10670 (2008)

Closed –Loop Sensor Systems

Customizable

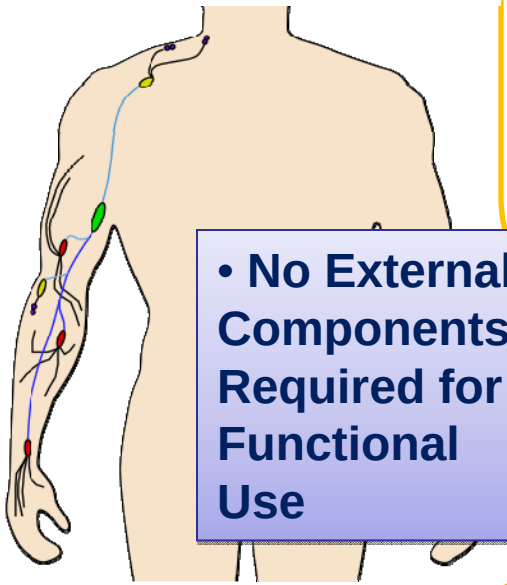
- Modular Components can be customized to each user's needs:
  - Grasp Function
  - Standing
  - Bladder/Bowel
  - Respiratory/Cough
  - etc.

Modular Components



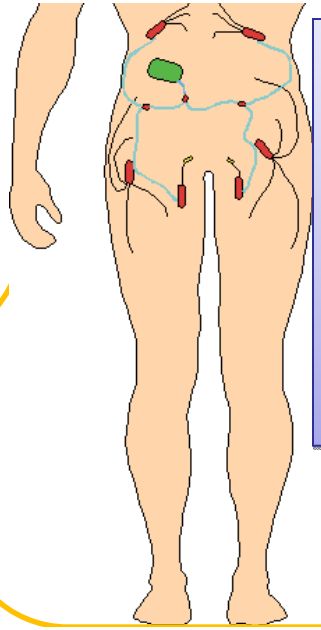
- Capacity to implement anticipated advances:
  - Combined Reaching and Standing (Kirsch)
  - Nerve Conduction Block (Kilgore)
  - Interface to Cortical Control (Donaghue)
  - Etc.

Fully Implantable



- No External Components Required for Functional Use

Scalable

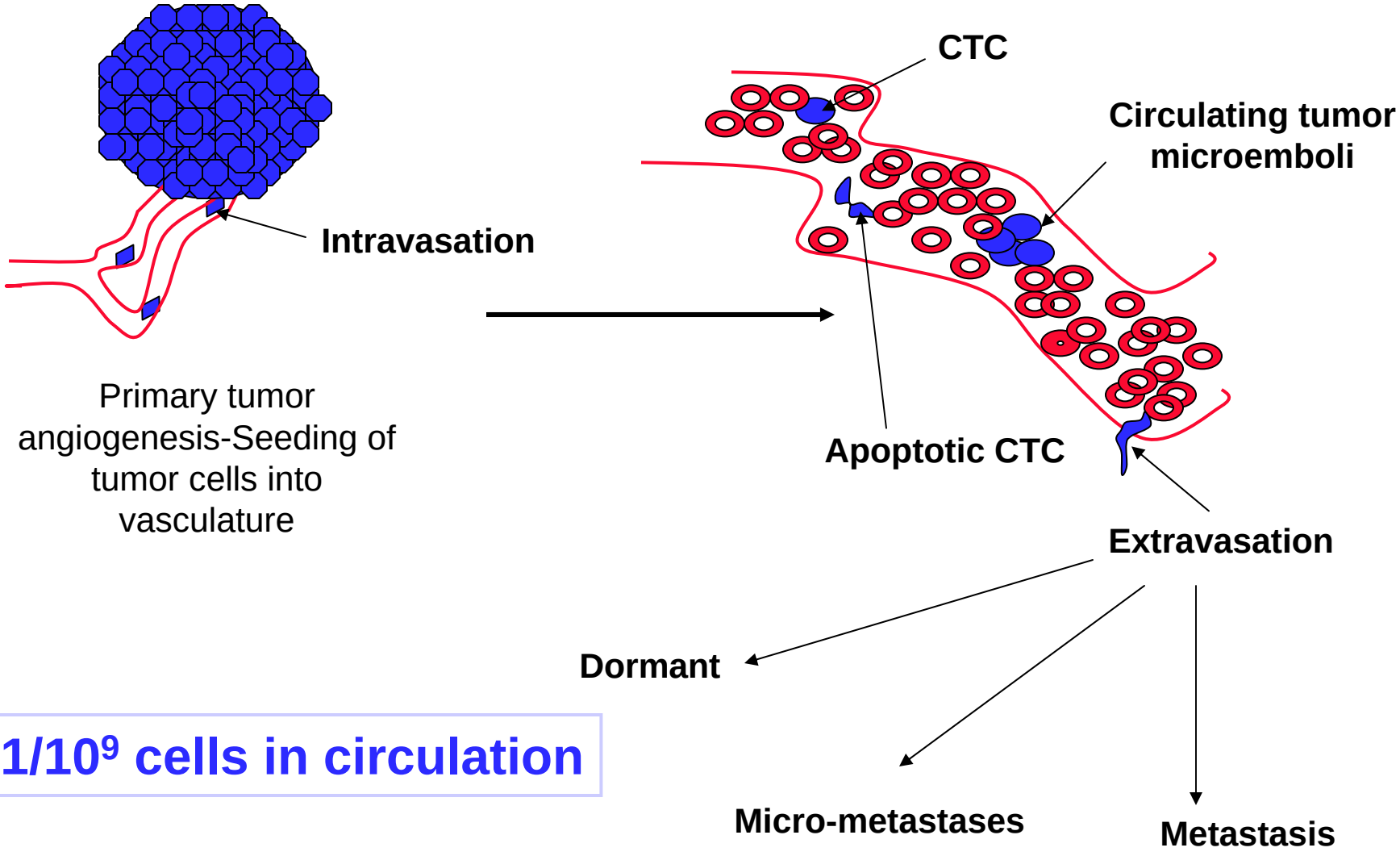


- Subjects can receive upgrades to gain enhanced function

P. Hunter Peckham
Case Western Reserve University

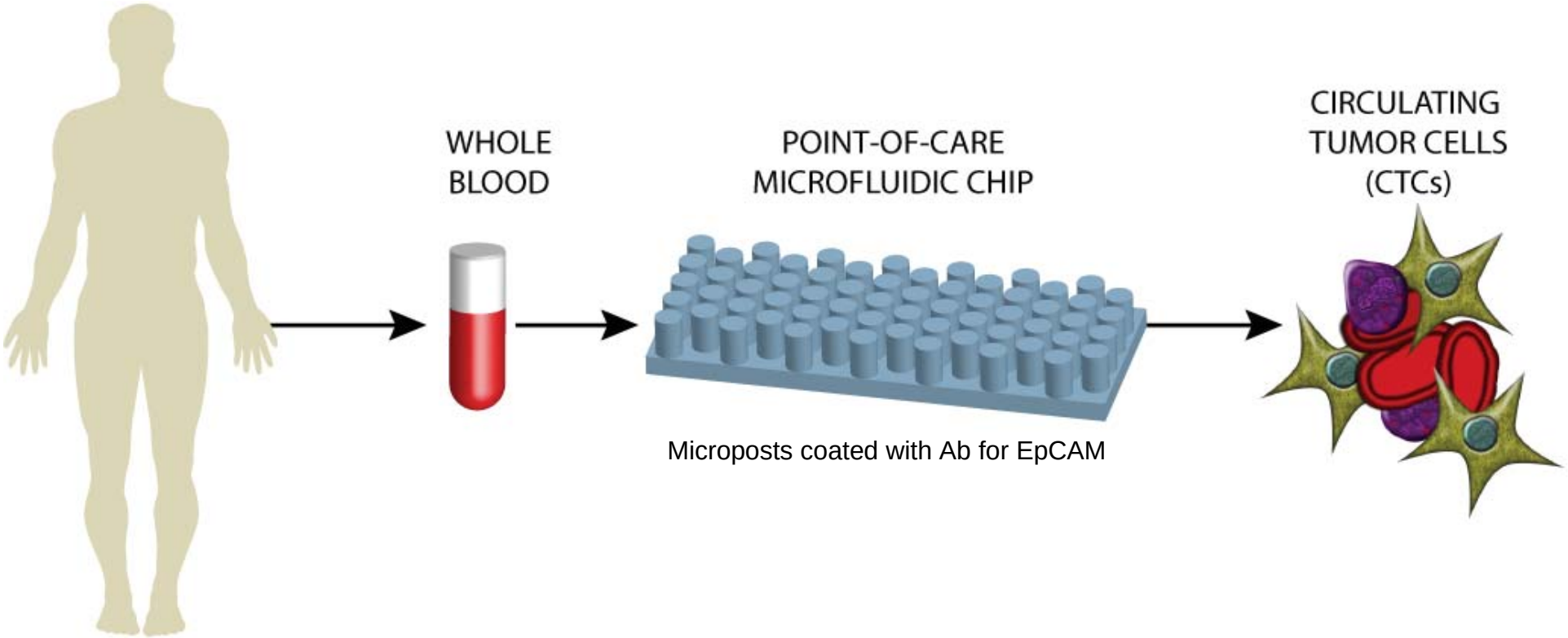
Clinic Based Sensor Systems
Detecting Circulating Tumor Cells

The seeding of tumor cells and/or tumor microemboli into the peripheral blood is the hallmark of tumor invasiveness



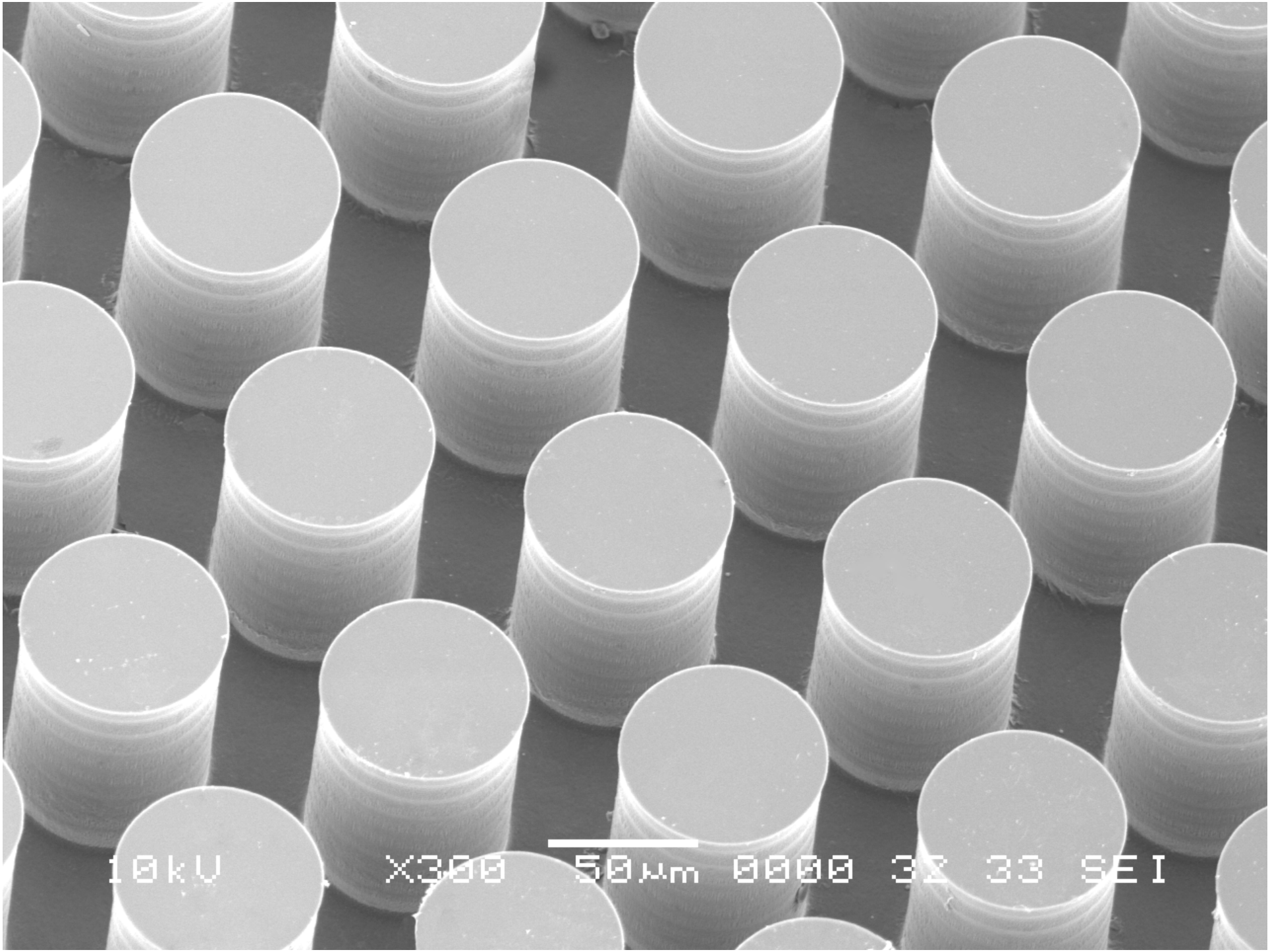
$1/10^9$ cells in circulation

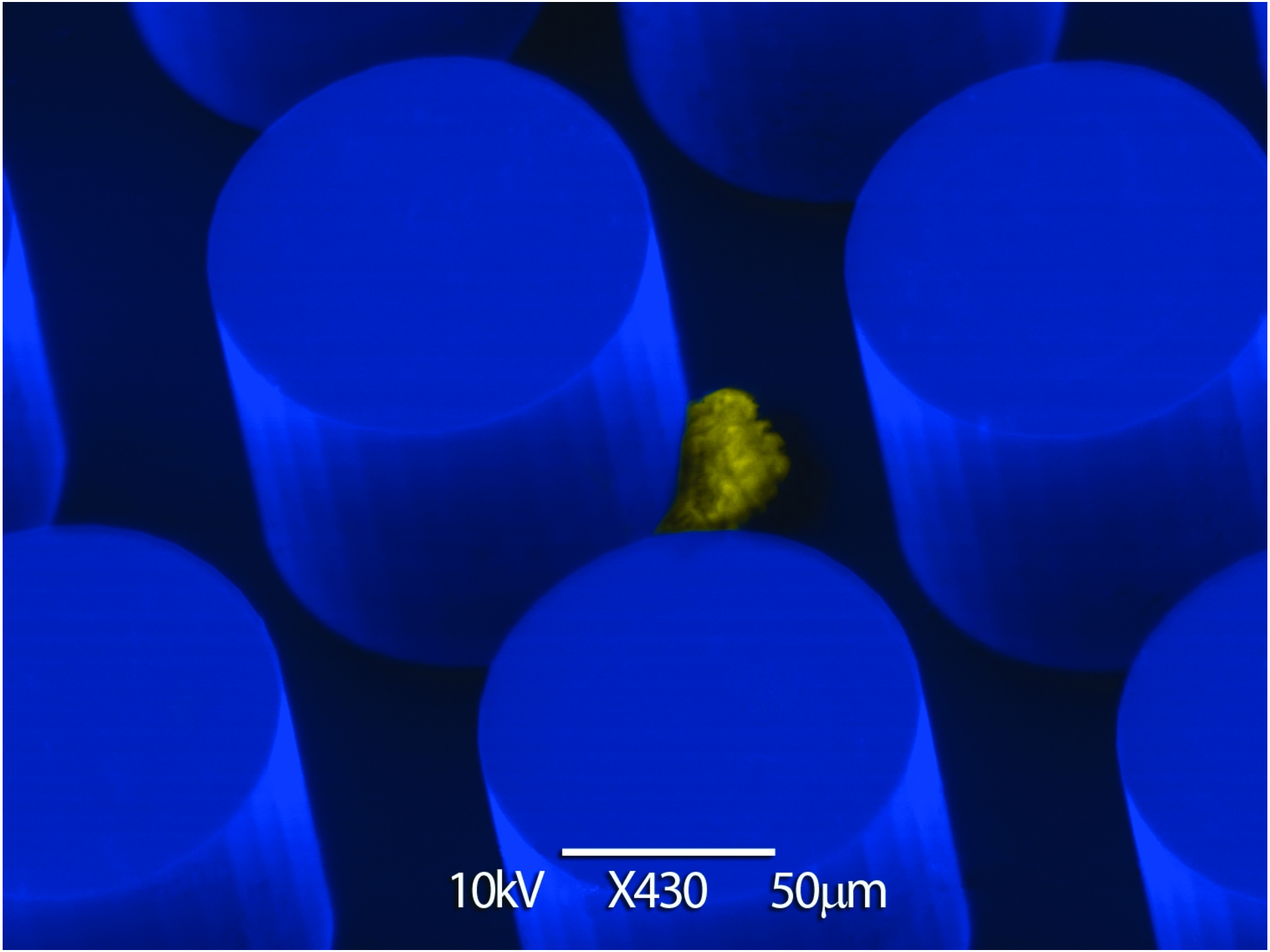
Overall Process and CTC-chip



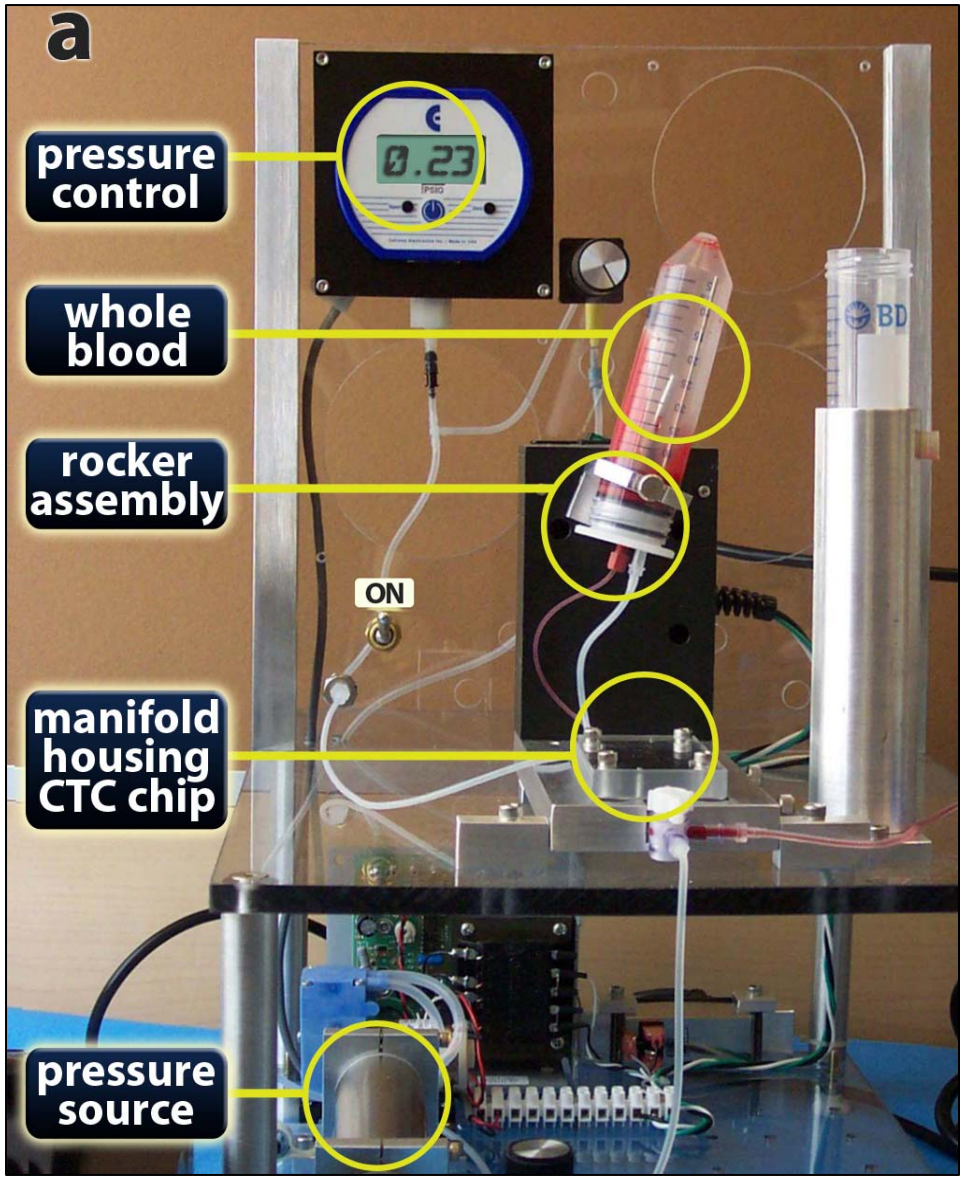
CTC-Chip Design Goals:

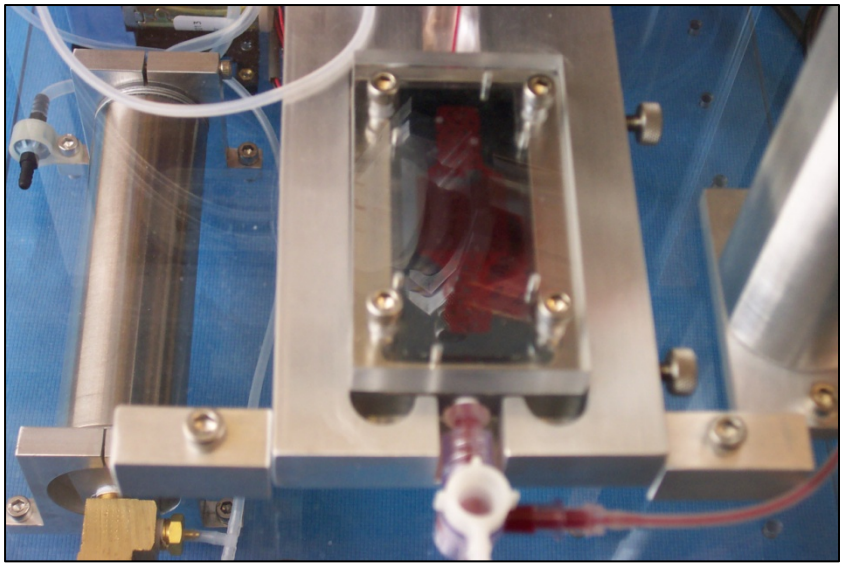
- Minimal handling
  - single-step, no pre-labeling, no pre-processing of the sample
- Gentle
- Uniform processing conditions

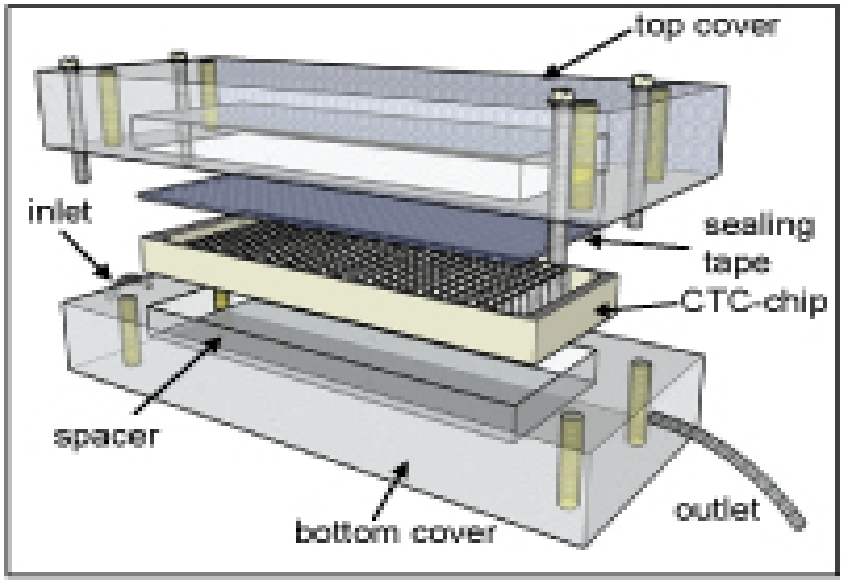

10kV X300 50µm 0000 32 33 SEI


10kV X430 50µm

‘World-to-Chip’ Coupling





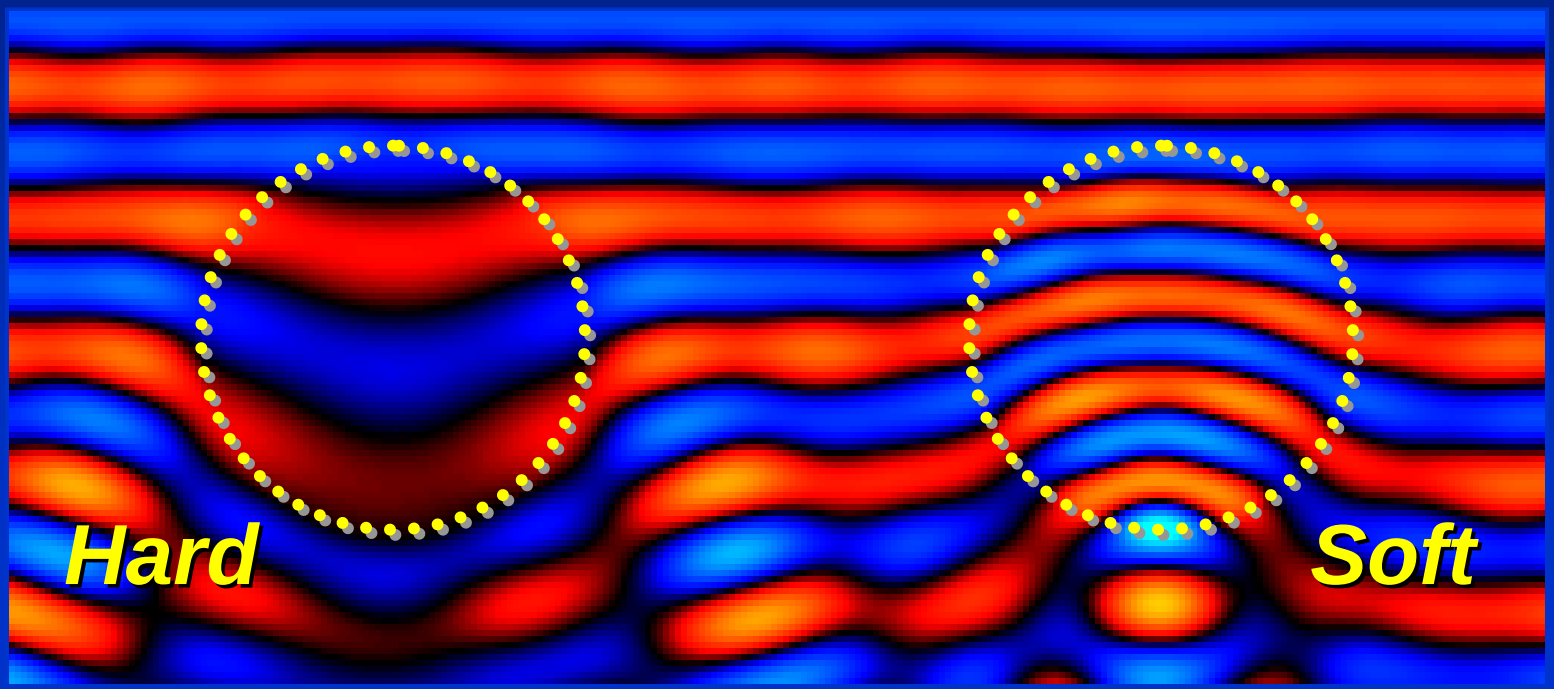



Palpation

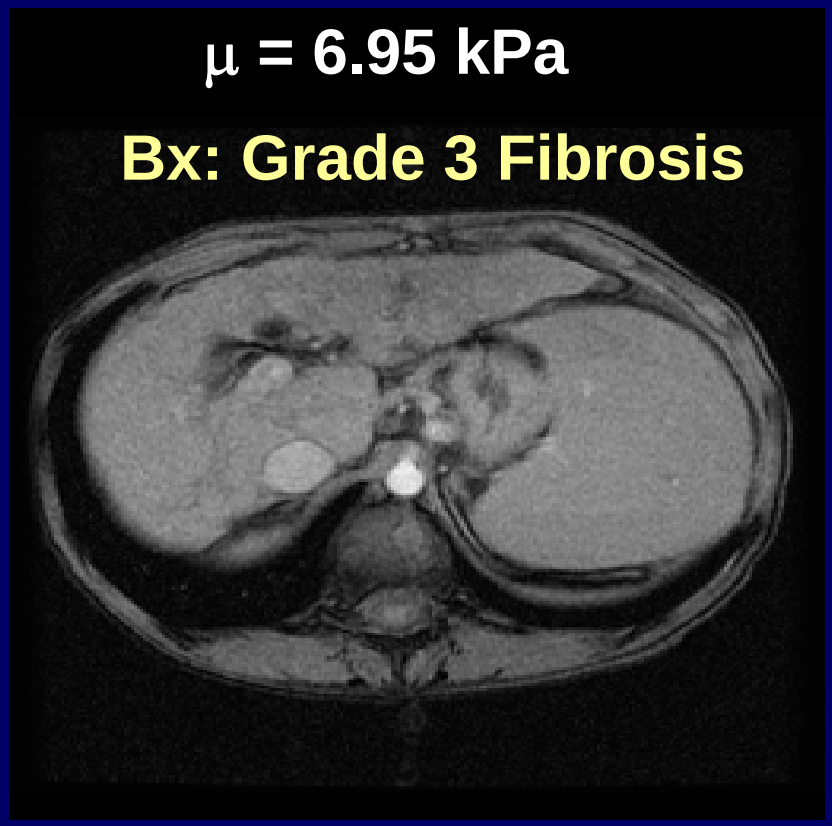
An Approach for Elasticity Imaging

Dynamic Stress

Apply mechanical waves and somehow image their propagation pattern



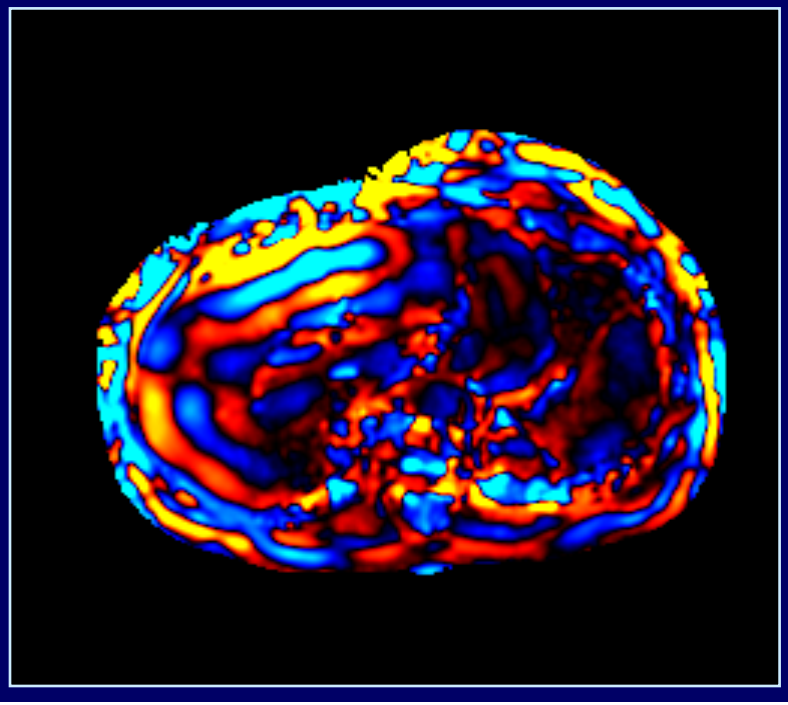
Liver MR Elastography

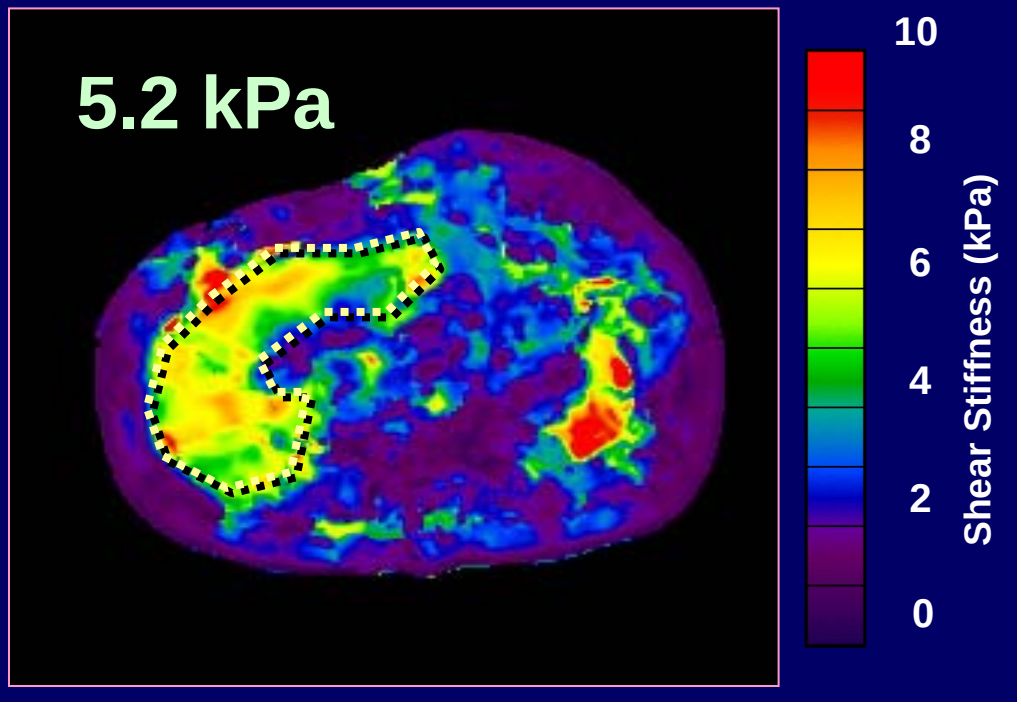


Patient Impact

- 66/M - chronic Hepatitis C
- Needs biopsy to rule out fibrosis – but…
- Biopsy contraindicated - patient also has *Hemophilia*

- MRE: Positive for fibrosis
- Consistent with Stage 3
- Pt. started on antiviral Rx for Hepatitis C





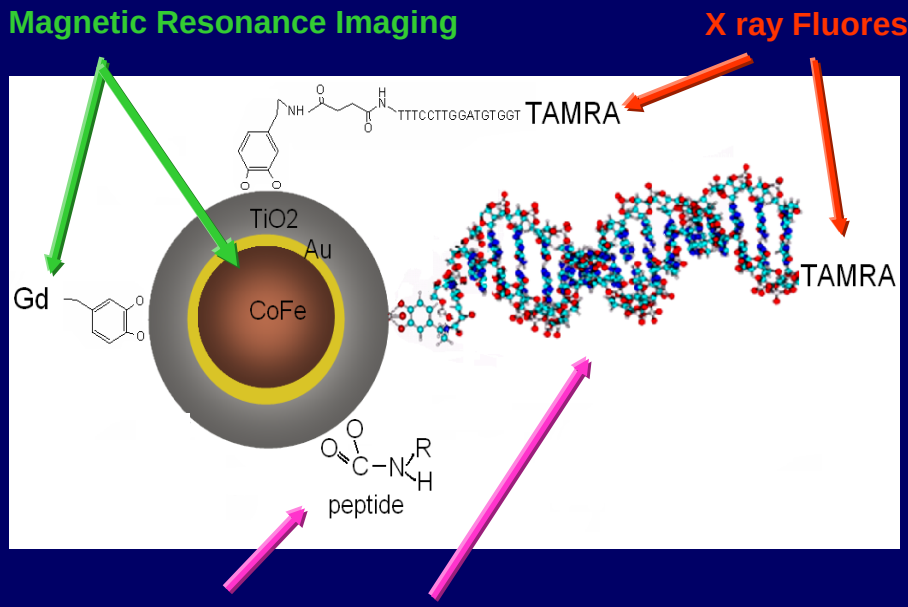
MOLECULAR THERANOSTICS

Nano-scale Engineering of Multifunctional Probes for Gene-specific Intervention and Treatment

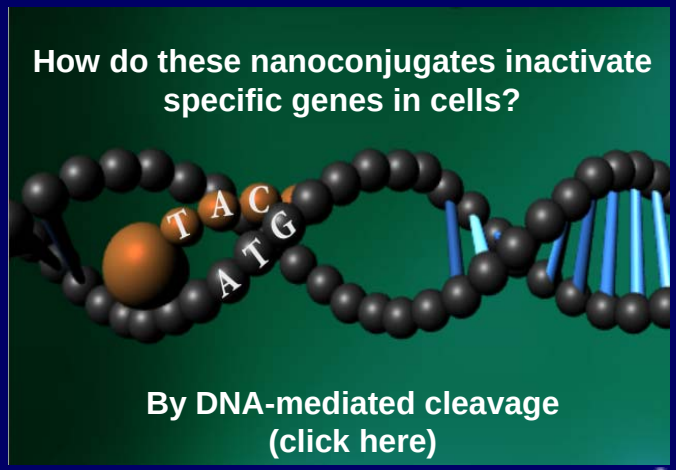
Gayle Woloschak, Ph.D.; Dept. of Radiology and Radiation Oncology; Northwestern University

Goal: To develop therapeutic MR probes based on the semiconducting properties of titanium dioxide (TiO_2). Dr. Woloschak's laboratory focused on conjugating specific DNA oligonucleotides to TiO_2 nanoparticles for intracellular manipulation, imaging, and gene silencing

Nanoparticle Design



Therapeutic Function



NIBIB

Summary

- Sensors and sensor systems will be important in developing high quality, efficient health care in the 21st century with an increasing chronic disease burden
- Sensor systems will be important in home health, point of care health delivery, and in traditional hospital settings and the sensor system must be designed for the environment
- Sensor data must be integrated into an individuals medical record in a seamless fashion
- Nanosensors that combine sensing and therapy hold significant promise for merging of diagnostic and therapeutic functions