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Single Molecule Bioelectronics for Healthcare and HLS Apps

Application

- **Driver:** Real-time, label-free detection, identification, & quantification of biological molecules
- **Market:** Healthcare accounts for ~14% ($2T) of the US GDP: the fastest growing sector in the economy
- **Need:** New methodologies for faster, cheaper & better diagnostics will enable personalized medicine based on an individual's biochemistry as determined from measurements of the patient's biosignature (DNA, RNA, proteins, metabolites, etc.), identify bioterrorism threats, & develop therapeutics against biowarfare agents

Research Needs

Scientific/technological problems and barriers:

- Most commercial devices are limited by 19th & early 20th century technologies
- The number of unique biomolecules is enormous. Discriminating between them requires highly-selective, single-molecule detectors
- Integrating nanoscale sensors, micro/nanofluidics into electronic chips
- A quantitative understanding of the measurements' fundamental physical basis

Advantages

Impact, if successful

- Affordable personalized medicine
- On-site rapid detection and biowarfare agent remediation

Benefits/advantages over current capabilities

- Highly selective (needle in a haystack capability)
- Highly scalable (detect ~ 1000 unique molecules/chip)
- Low cost (e.g., < $1k per genome)
- Electrical detection with single-molecule sensitivity

Metric(s) of Progress

Present:

- Nanopore based metrology: Detect/characterize RNA, DNA, proteins, anthrax toxins; single-molecule mass spectrometry can discriminate to better than 1.5 Angstroms!

3 to 5 years:

- Develop multiple unique nanopores (solid state & biological) for greater selectivity. Coupling to fluidic structures & electronic chips.

10 years:

A device for personalized medicine & HLS applications

Resource requirements: $4M/year, 12 scientists, interdisciplinary teams with access to nano-electronics fabrication, NIST Neutron Center, & clinical test facilities.

Measurements and Standards for Quantitative Medical Imaging

What is the Big Idea?

- Revolutionize the use of medical imaging in the health care enterprise
- Transform medical imaging
  - from a qualitative technology (what's there?)
  - to a quantitative one
    - how much is there
    - how much has it changed
    - how is healthy
    - and how much is diseased tissue

Areas of Engagement

- CT and Medical Imaging with X-Rays (PL)
- PET, PET-CT, and PET-MRI Medical Imaging (PL)
- MRI and Terahertz Imaging (EEEL et al.)
- Enhanced MRI with Magnetic Nanoparticles (PL et al.)
- Software Validation, Visualization, Change Analysis, Benchmarking (ITL)
- Optical Medical Imaging (PL)
- Molecular Imaging (PL, MSEL, CNST, EEEL)
- Bone Density X-Ray Standards (PL)
- Imaging Ontology: From Imaging to Diagnosis (ITL)

Partnerships & Collaborations

- NIH, NCI, FDA
- NCI Nanotechnology Characterization Laboratory
- Ohio State University School of Medicine
- Quantitative Imaging Biomarker Alliance (QIBA)
- NIST/NIH postdoc program
- University of Washington
- University of Texas (Arlington)
- Catholic University of America
- Weill Cornell Medical College
- University of Alabama (Birmingham)
- Craig Venter Institute