Assessing the Exposome Using Wearable Sensors: Challenges and Opportunities

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Health Scientist Administrator
National Institute of Environmental Health Sciences

The Outstanding Challenge: Environmental Exposure Assessment

Editorial

Complementing the Genome with an "Exposome": The Outstanding Challenge of Environmental Exposure Measurement in Molecular Epidemiology

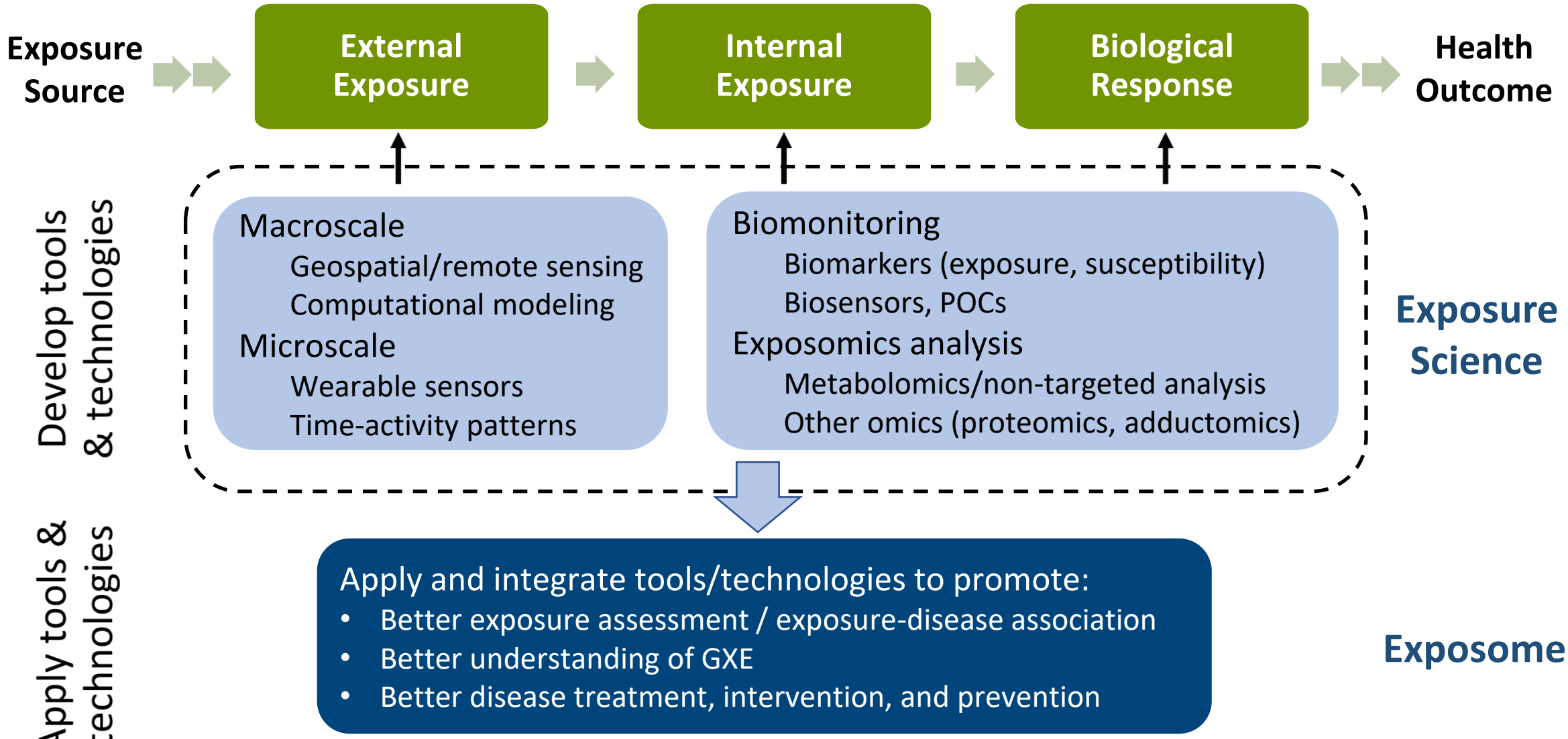
Christopher Paul Wild

Molecular Epidemiology Unit, Centre for Epidemiology and Biostatistics, Leeds Institute of Genetics, Health and Therapeutics, Faculty of Medicine and Health, University of Leeds, Leeds, United Kingdom

"This concept of an exposome may be useful in drawing attention to the need for methodologic developments in exposure assessment."

Chris Wild, Cancer Epidemiology, Biomarkers & Prevention, 2005; 14 (8): 1847-50

NIEHS Exposure Science and the Exposome Program



The Human Health Exposure Analysis Resource: 2019 - 2024

Goal

Provide infrastructure for adding or expanding exposure analysis to advance understanding of the impact of environmental exposures on human health throughout the life course

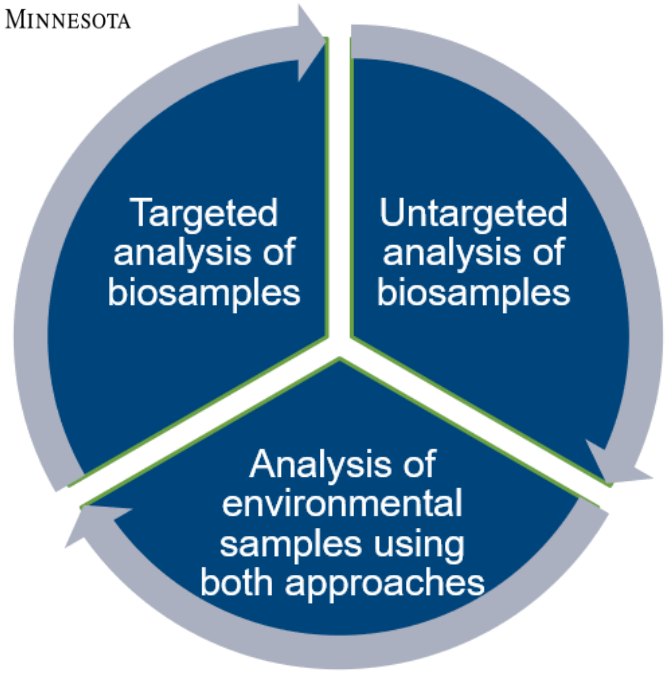
HHEAR Laboratory Network

University of Minnesota

Icahn School of Medicine at Mount Sinai

Icahn School of Medicine at Mount Sinai

Wadsworth Center
New York State Department of Health



RTI International

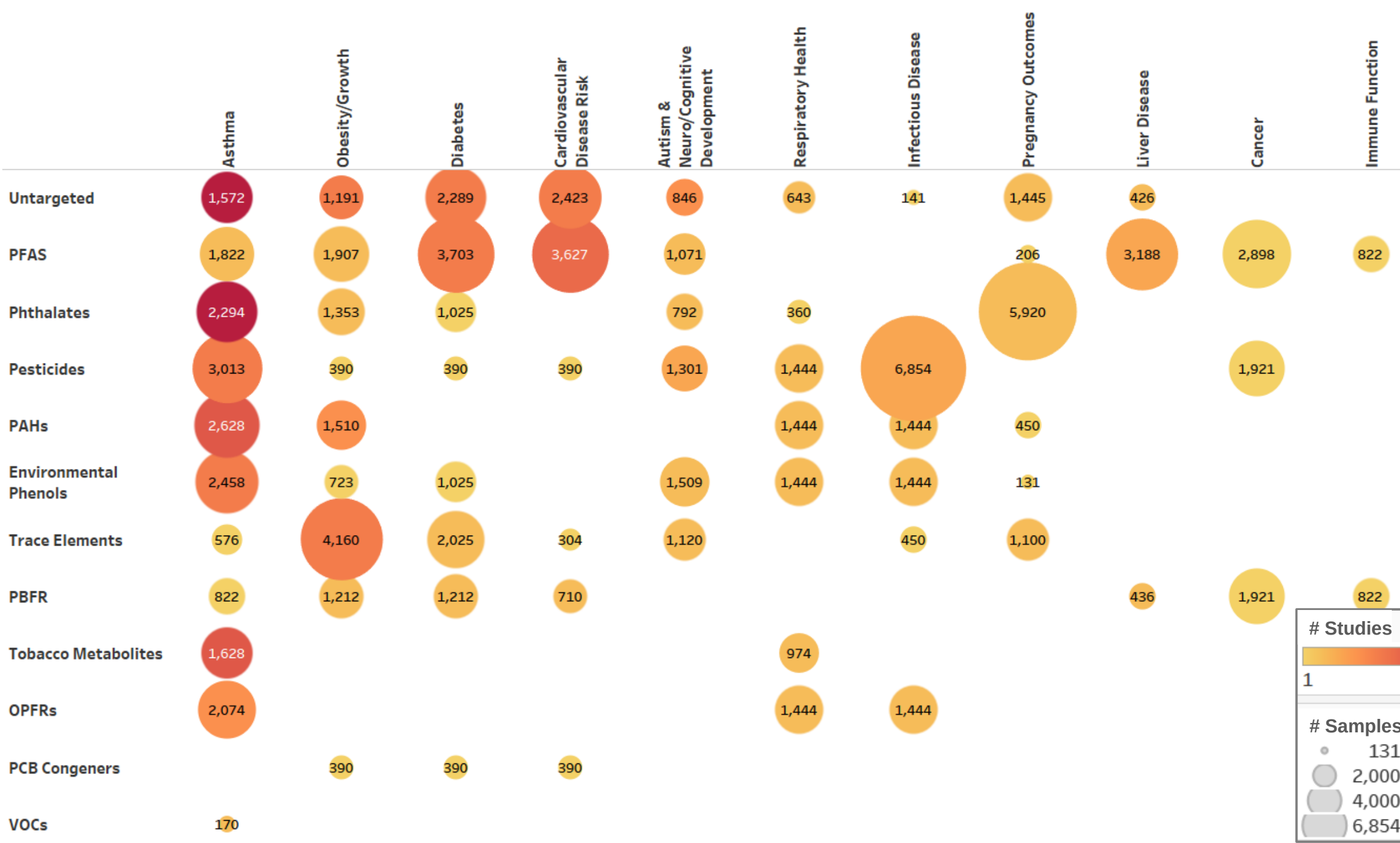
Duke

HHEAR Coordinating Center

Westat

HHEAR Data Center

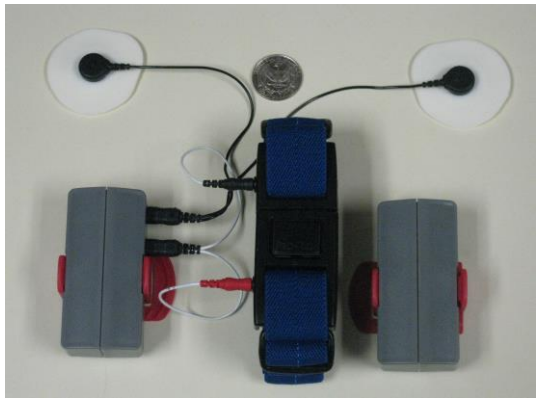
Icahn School of Medicine at Mount Sinai


Asthma
Obesity/Growth
Diabetes
Cardiovascular Disease Risk
Autism & Neuro/Cognitive Development
Respiratory Health
Infectious Disease
Pregnancy Outcomes
Liver Disease
Cancer
Immune Function
Untargeted 1,572 1,191 2,289 2,423 846 643 141 1,445 426
PFAS 1,822 1,907 3,703 3,627 1,071 206 3,188 2,898 822
Phthalates 2,294 1,353 1,025 792 360 5,920
Pesticides 3,013 390 390 390 1,301 1,444 6,854 1,921
PAHs 2,628 1,510 1,444 1,444 450
Environmental Phenols 2,458 723 1,025 1,509 1,444 1,444 131
Trace Elements 576 4,160 2,025 304 1,120 450 1,100
PBFR 822 1,212 1,212 710 436 1,921 822
Tobacco Metabolites 1,628 974
OPFRs 2,074 1,444 1,444
PCB Congeners 390 390 390
VOCs 170
Studies
1
10
Samples
131
2,000
4,000
6,854

Sensors for Personal Monitoring

MicroPEM
RTI International

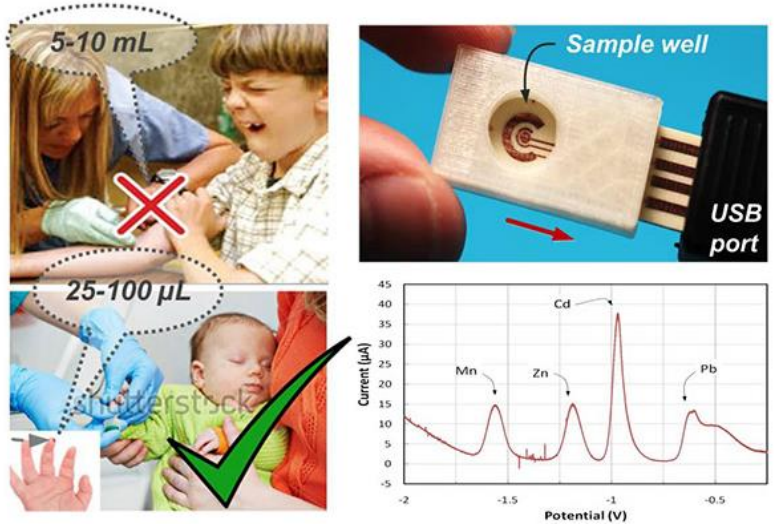
Silicone Wristbands
Oregon State University



AutoSense Sensor Suite, U of Memphis

Personal Ultrafine Particle Counter (PUPF), Enmont

Personal Ozone Monitor (POM), 2B Technologies



POC sensor for Multi-Metal Measurement
U of Illinois Chicago

NIEHS Supported Sensor Research

- Hardware
  - Continuous measurements
  - GPS technology
  - Wireless data transmission
- Software
  - Data processing and statistical analysis
  - User interface (computer or smartphone)
- Miniaturize
  - More wearable
- Improve battery life
  - Less user interference
- Laboratory and field testing
  - More accurate and reliable measurement

Example 1: the New York City Biking Study

Steve Chillrud/Darby Jack, Columbia University

- **Background**
  - Approximately eight hundred thousand (773,000) New Yorkers ride a bike regularly (NYC DOT)
  - How does air pollution affect these cyclists?

- **Hypothesis**
  - Potential inhaled dose is a better exposure metric to study the impacts of air pollution on HR, BP

Potential inhaled dose = concentration * minute respiration

MicroAeth
Black Carbon

MicroPEM
PM2.5, accelerometer

Hexoskin Shirt

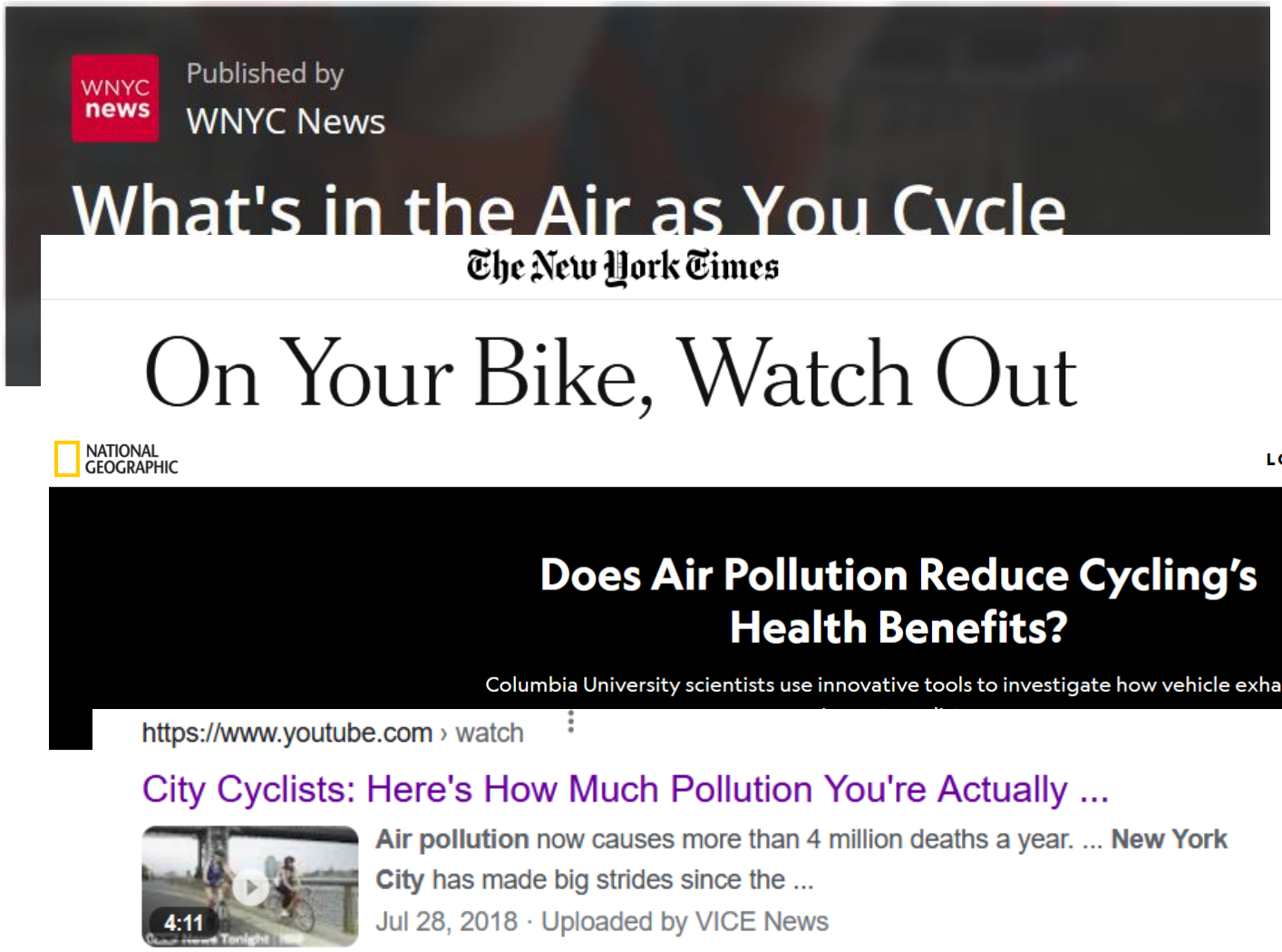
Respiratory sensors
(minute respiration)
Cardiac sensors (HR)

Blood pressure
monitors, GPS

Example 1: the New York City Biking Study

Data collection

- 149 study participants
- Five to six 24-hr sessions
- Exposure
  - PM2.5, Black Carbon, GPS
- Physiological
  - respiration, BP, HR, physical activity



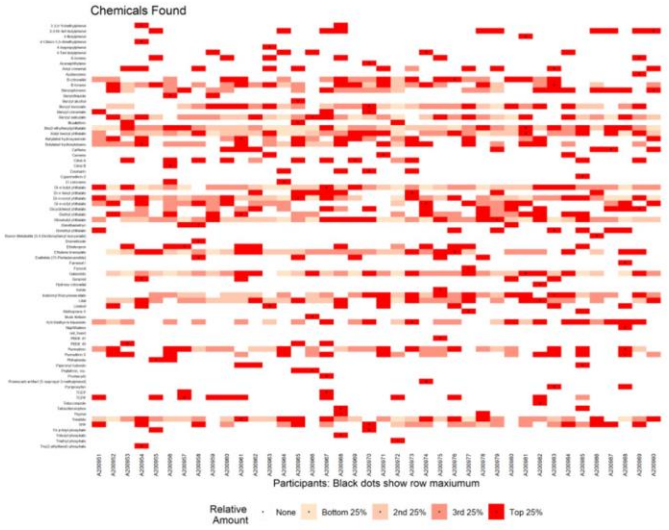
Example 2: Wristbands

Development of a Route of Exposure Model Using Silicone Wristbands as Personal Samplers

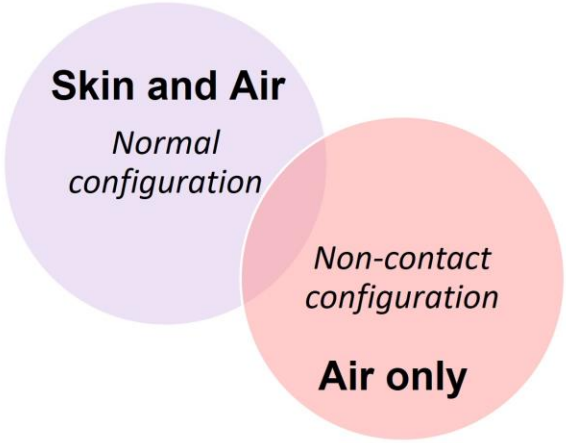
Project Number	Contact PI/Project Leader	Awardee Organization
1R43ES033586-01	O'CONNELL, STEVEN GEHRIG	MYEXPOSOME, INC.

MyExposome

FIELD SAMPLING



1528 CHEMICAL SCREEN



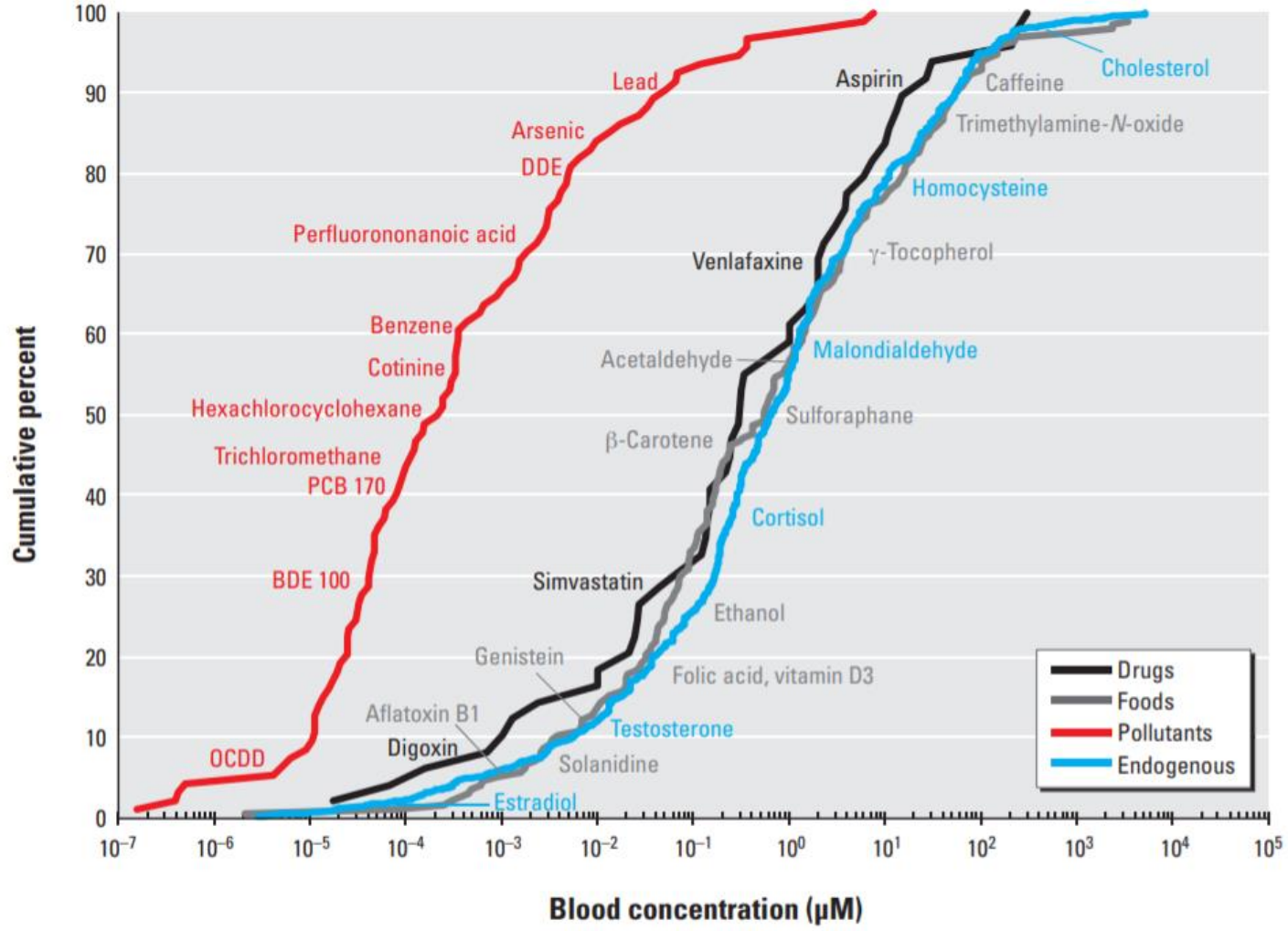
DATA COMPARISONS/ MODELING

The Concept of Microneedle Based Biosensing in Health Care

Fig. 1. Graphical concept. Application of microneedle-based sensors in the healthcare sector.

Juan Jose García-Guzman, et al. Trends in Analytical Chemistry, 135 (2021) 116148

Challenge: Exposure Biomarkers Are Low Abundance

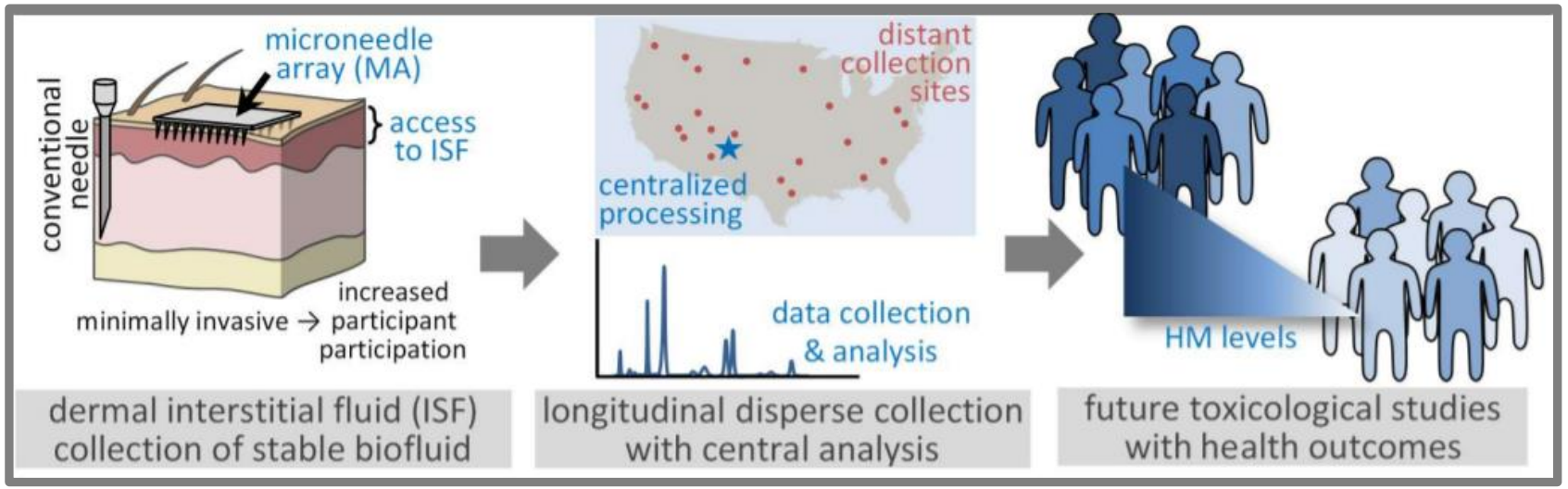


Rappaport SM, et al. Environ. Health Perspect., 122(8):769–74, 2014

Example 3: Microneedle Arrays (MA)

Quantifying Heavy Metals in Interstitial Fluid for Remote Monitoring of Chronic Exposures

Project Number	Contact PI/Project Leader	Awardee Organization
1R03ES031724-01	BACA, JUSTIN THOMAS	UNIVERSITY OF NEW MEXICO HEALTH SCIS CTR



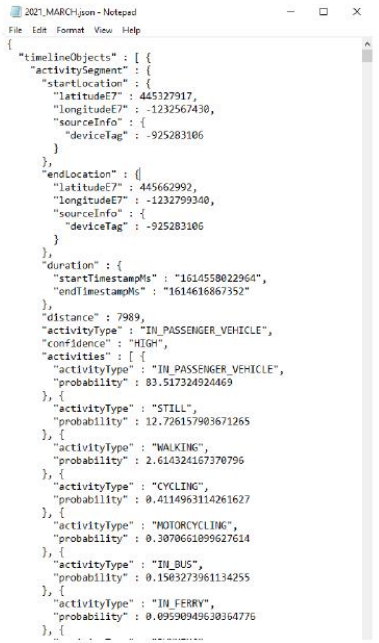
Advantages:

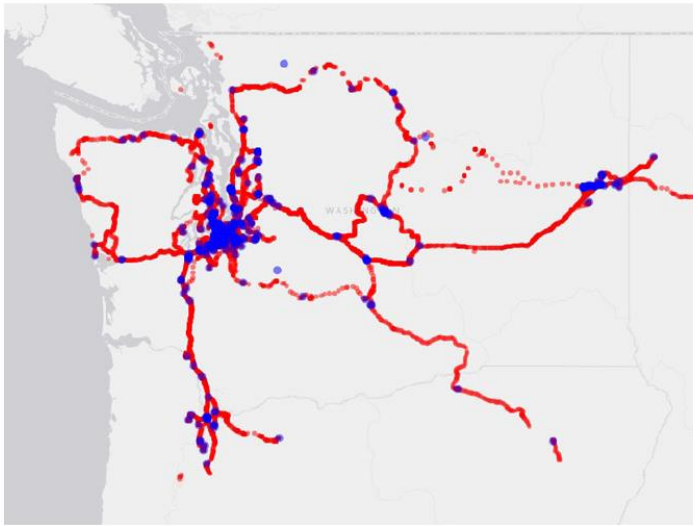
- Minimally invasive sampling can increase subject recruitment and number of samples per subject
- Potential for remote monitoring

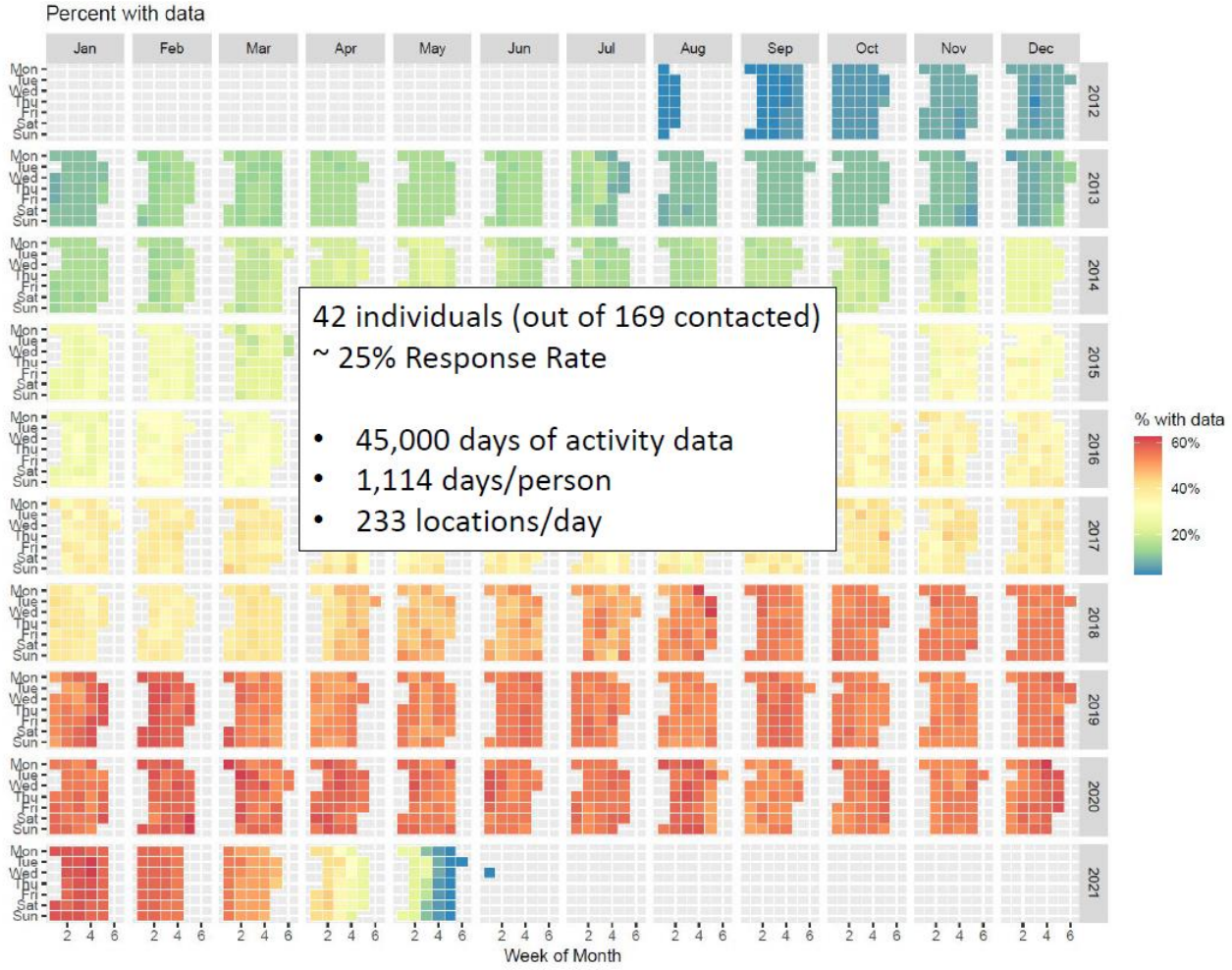
Example 4: Self-tracking Wearables (smart phone GPS data)

Perry Hystad, Oregon State University

Evaluating and Applying Google Timeline Data for Built Environment and Physical Activity Research





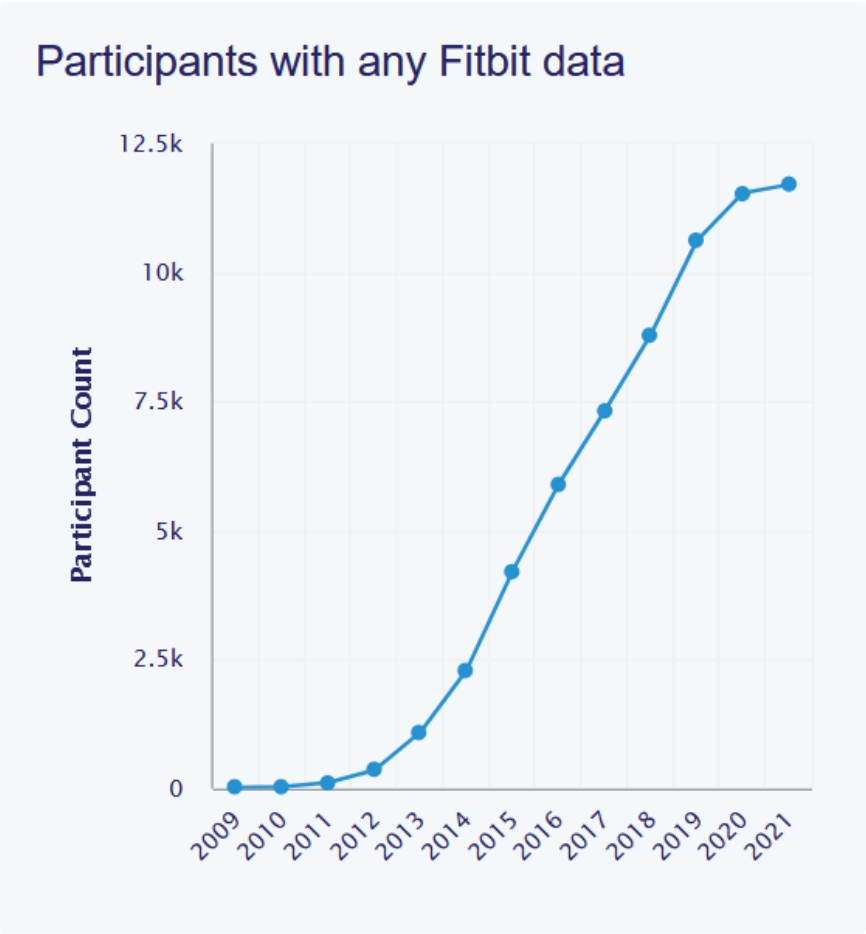


Example 5: Self-tracking Wearables (Fitbit)

Fitbit Data

- **Any Fitbit Data**
- Heart Rate By Zone Summary
- Heart Rate (Minute-level)
- Activity (Daily Summary)
- Activity Intraday Steps (Minute-level)

Any Fitbit Data



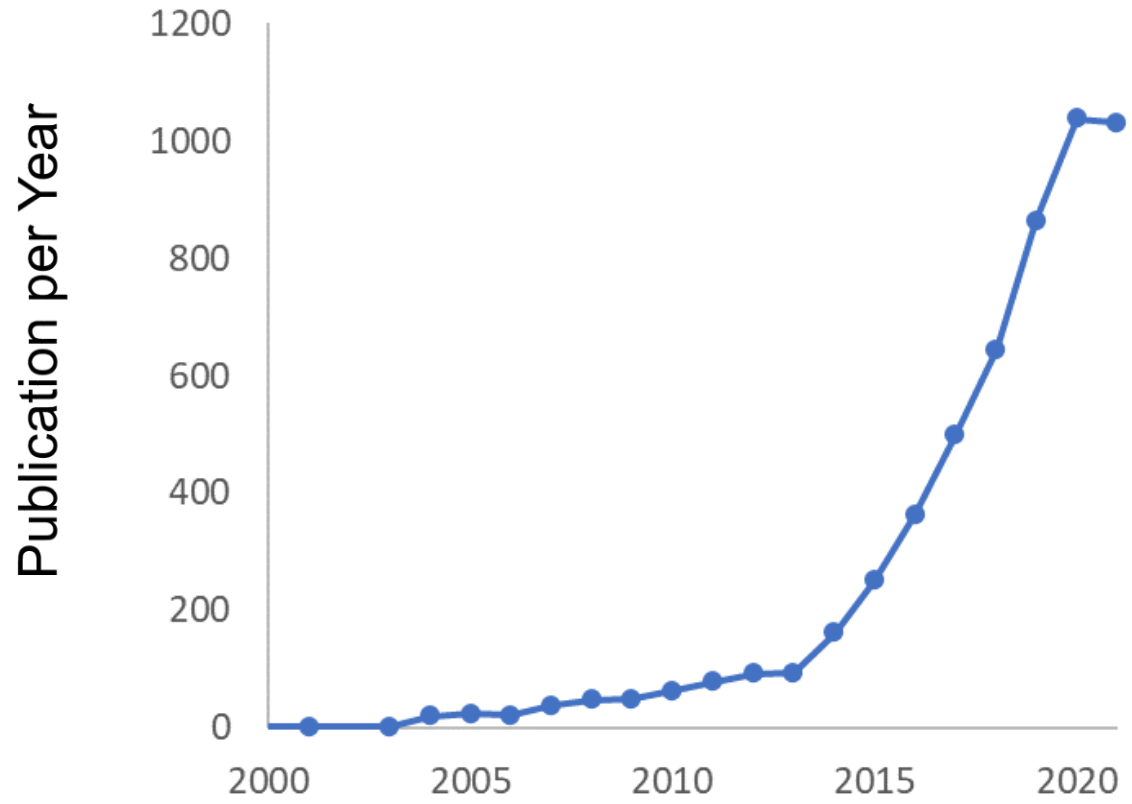
https://databrowser.researchallofus.org/fitbit

Summary

- Significant advancement in wearable technologies
  - Environmental minoring
  - Physical activity
  - Physiological monitoring (metabolic, cardiovascular, reparatory, temperature, …)
- Continuous monitoring of small molecules at low concentrations is problematic
  - Alternatives (decentralized, non-invasive sampling + centralized analysis)
- Data challenges
- Privacy concerns

Wearable Technology is a Rapidly Growing Field

PubMed Search on Wearable Sensor



Acknowledgement

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Daniel Shaughnessy, Ph.D.