"The Coming Digital Transformation of Health"

Remote HD Lecture
To Monash Undergraduate Research Projects Abroad (MURPA)
At Monash University, Melbourne, Australia
From Calit2@UCSD HD Studios
September 20, 2012

Dr. Larry Smarr
Director, California Institute for Telecommunications and Information Technology
Harry E. Gruber Professor,
Dept. of Computer Science and Engineering
Jacobs School of Engineering, UCSD
http://lsmarr.calit2.net
Abstract

Calit2 has, for over a decade, had a driving vision that healthcare is being transformed into digitally enabled genomic medicine. To put a more personal face on the "patient of the future," I have been increasingly quantifying my own body over the last ten years. This involves not only non-invasive macro-variables such as weight, pulse, blood pressure, caloric intake and burn, but also invasive blood, saliva, and stool measurements. I currently track over 100 molecular and blood cell types in my blood and dozens of molecular and microbial variables in my stool. Through saliva I have 1 million single nucleotide polymorphisms (SNPs) in my human DNA. My gut microbiome is currently being genetically sequenced. I will show how one can discover emerging disease states before they develop serious symptoms by graphing time series of these key variables. Also I will illustrate the power of multi-variant analysis across all these internal variables. My hope is that by "living in the future" I can be a model for understanding more clearly the new approaches that will arise in wellness and health care.
The Ten Year Calit2 Path Forward

Ten-Year Vision of Digital Transformation
- Affiliated Academic Units
- Calit2 News and Videos

This Talk Focuses in on:
- The Digital Transformation of Health

www.calit2.net/research/index.php
A Doctor’s Vision of the Future of Medicine

Leroy Hood
NEWSWEEK

From the magazine issue dated Jul 13, 2009
Calit2 Has Been Had a Vision of "the Digital Transformation of Health" for a Decade

• Next Step—Putting You On-Line!
  – Wireless Internet Transmission
  – Key Metabolic and Physical Variables
  – Model -- Dozens of Processors and 60 Sensors / Actuators Inside of our Cars

• Post-Genomic Individualized Medicine
  – Combine
    – Genetic Code
    – Body Data Flow
  – Use Powerful AI Data Mining Techniques

The Content of This Slide from 2001 Larry Smarr Calit2 Talk on Digitally Enabled Genomic Medicine
The Calit2 Vision of Digitally Enabled Genomic Medicine is an Emerging Reality

July/August 2011

February 2012
Lifechips--Merging Two Major Industries: Microelectronic Chips & Life Sciences

65 UCI Faculty

UCSD
UCIrvine
SMART: Social Mobile Approach to Reduce Weight

• Leveraging social networks, social media, mobile phones, and the web for weight loss among 18-35 year old young adults
  – Funded with a 5-year grant from NHLBI/NIH

Source: Kevin Patrick, UCSD SOM & Calit2
CitiSense – UCSD NSF Grant for Fine-Grained Environmental Sensing Using Cell Phones

CitiSense Team
PI: Bill Griswold
Ingolf Krueger
Tajana Simunic Rosing
Sanjoy Dasgupta
Hovav Shacham
Kevin Patrick

Integrate Into a “LifeChip”
By Measuring the State of My Body and “Tuning” It Using Nutrition and Exercise, I Became Healthier

I Arrived in La Jolla in 2000 After 20 Years in the Midwest and Discovered I was Pre-Diabetic
Wireless Monitoring Helps Drive Exercise Goals

- 10731 steps taken
- 18 floors climbed
- 5.13 miles traveled
- 2472 calories burned
Quantifying My Sleep Pattern Using a Zeo “LifeChip” - Surprisingly About Half My Sleep is REM!

REM is Normally 20% of Sleep
Mine is Between 45-65% of Sleep

An Infant Typically Has 50% REM
Combining the Wireless Internet, Body Sensors, Smart Phones, and Social Networks to Drive Healthier Lifestyles
From One to a Billion Data Points Defining Me: The Exponential Rise in Body Data in Just One Decade!

My Body Data

- Million: My DNA SNPs, Zeo, FitBit
- Hundred: My Blood Variables
- One: My Weight
- Billion: My Full DNA, MRI/CT Images

Graph showing the exponential rise in body data from 2000 to 2012, with data categories including weight, blood variables, SNPs, and microbial genome.

UCSD UC Irvine
The Patient of the Future

Internet pioneer Larry Smarr's quest to quantify everything about his health led him to a startling discovery, an unusual partnership with his doctor, and more control over his life.

www.technologyreview.com/biomedicine/39636
Putting Your Heart On-line

- **Sensors**
  - Strap and Shirt Sensors
  - Medical Sensors (BP, SPO2)
  - Additional Sensors (Radiological, Gas, etc)

- **Communication**
  - Military Tactical Radio
  - First Responder Radio
  - Consumer Cell Phone

- **Display**
  - Wrist Devices
  - Portable/Mobile Displays
  - PC/Laptop

- **Cardionet**

- **Zephyr technology**
I Have Greatly Lowered My Body’s Inflammation From Food By Increasing Omega-3s

"Silent Inflammation"

Chronically Ill American

Average “Healthy” American

Blood Ratio of Omega 6 to Omega 3

I take 6 Fish Oil Pills Per Day

Ideal Range

My Range

Range Source: Barry Sears
My Tests by www.yourfuturehealth.com
I Track 100 Variables in Blood Tests Done Quarterly to Annually

- **Electrolytes**
  - Sodium, Potassium, Calcium, Magnesium, Phosphorus, Boron, Chlorine, CO₂

- **Micronutrients**
  - Arsenic, Chromium, Cobalt, Copper, Iron, Manganese, Molybdenum, Selenium, Zinc

- **Blood Sugar Cycle**
  - Glucose, Insulin, A1C Hemoglobin

- **Cardio Risk**
  - Complex Reactive Protein, Homocysteine

- **Kidneys**
  - Bun, Creatinine, Uric Acid

- **Protein**
  - Total Protein, Albumin, Globulin

- **Liver**
  - GGTP, SGOT, SGPT, LDH, Total Direct Bilirubin, Alkaline Phosphatase

- **Thyroid**
  - T3 Uptake, T4, Free Thyroxine Index, FT4, 2nd Gen TSH

- **Blood Cells**
  - Complete Blood Cell Count
  - Red Blood Cell Subtypes
  - White Blood Cell Subtypes

- **Cancer Screen**
  - CEA, Total PSA, % Free PSA
  - CA-19-9

- **Vitamins & Antioxidant Screen**
  - Vit D, E; Selenium, ALA, coQ10, Glutathione, Total Antioxidant Fn.

Only One of These Was Far Out of Normal Range
But, In Spite of My High Levels of Omega-3s, My Blood Measurements Revealed Chronic Inflammation

Episodic Peaks in Inflammation Followed by Spontaneous Drop

Complex Reactive Protein (CRP) is a Blood Biomarker for Detecting Presence of Inflammation

Normal Range CRP < 1
By Quantifying Stool Measurements Over Time I Discovered Source of Inflammation Was Likely in Colon

Stool Samples Analyzed by www.yourfuturehealth.com

Lactoferrin is a Sensitive and Specific Biomarker for Detecting Presence of Inflammatory Bowel Disease (IBD)

Normal Range <7.3 µg/mL

124x Upper Limit

Typical Lactoferrin Value for Active IBD
Confirming the IBD (Crohn’s) Hypothesis: Finding the “Smoking Gun” with MRI Imaging

I Obtained the MRI Slices From UCSD Medical Services and Converted to Interactive 3D Working With Calit2 Staff & DeskVOX Software
Putting Your Organs On-line

- Videos of Me Giving Tours of My Insides:
  - http://www.youtube.com/watch?v=9c4DtJ_L_Ps
  - www.theatlantic.com/magazine/archive/2012/07/the-measured-man/309018/

Photo & DeskVOX Software Courtesy of Jurgen Schulze, Calit2
Despite decades of research, the etiology of Crohn's disease remains unknown. Its pathogenesis may involve a complex interplay between host genetics, immune dysfunction, and microbial or environmental factors.

--The Role of Microbes in Crohn's Disease

So I Set Out to Quantify All Three!
I Wondered if Crohn’s is an Autoimmune Disease, Did I Have a Personal Genomic Polymorphism?

From www.23andme.com

SNPs Associated with CD

Polymorphism in Interleukin-23 Receptor Gene — 80% Higher Risk of Pro-inflammatory Immune Response

News and Views

doi:10.1038/nm0107-26

**IL-23: a master regulator in Crohn disease**
Markus F Neurath

UCSD
UCIrvine
I Tracked My Innate Immune System
By Measuring Lysozyme From Stool Samples Over Time

My Immune System Seems to Be Fighting Bacteria Episodically

Lysozyme is an Enzyme of the Innate Immune System
that Attacks Bacterial Cell Walls

Values from www.yourfuturehealth.com stool test
Your Human Cells are Only 10% of Your Superorganism: How Can We Track the 90% which are Microbes?

But Cultured Bacteria Are a Small Fraction of Total

Values From www.yourfuturehealth.com stool test
Determining My Gut Microbes and Their Time Variation

Shipped Stool Sample
December 28, 2011

I Received a Disk Drive April 3, 2012
With 35 GB FASTQ Files

Weizhong Li, UCSD
NGS Pipeline:
230M Reads
Only 0.2% Human

Required 1/2 cpu-yr
Per Person Analyzed!
Almost All Abundant Species (≥1%) in Healthy Subjects Are **Severely Depleted** in LS Gut

Numbers Over Bars Represent Ratio of LS to Healthy Abundance
LS Abundant Microbe Species (≥1%) Are Dominated by Rare Species in Healthy Subjects

Numbers Over Bars Represent Ratio of LS to Healthy Abundance
Principal Component Analysis
On Microbial Species Abundance
Crowd-Sourcing Health Studies Is Rapidly Growing With More Open Health Data

Quantified Self
tools for knowing your own body and mind

patientslikeme®

transparency life sciences

clinical studies YOU design

research surveys

23andWe begins with you. Learn about yourself while contributing to research.

Genomera
@genomera
Open health studies on the web. Breaking open bottlenecks in health research and discovery with collective data sharing and analysis. The next wave in health.
Mountain View, CA · http://genomera.com