"The Digital Transformation to Predictive & Preventive Personalized Medicine"

Invited Talk

Center for Digital Transformation Advisory Board Meeting

UC Irvine

September 28, 2012

Dr. Larry Smarr

Director, California Institute for Telecommunications and Information Technology

Harry E. Gruber Professor,

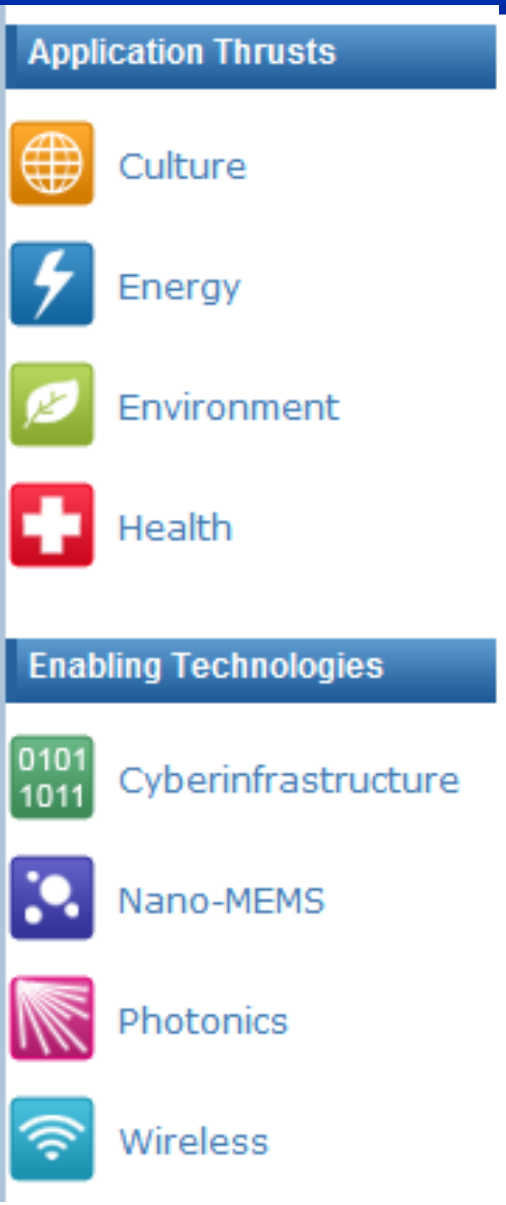
Dept. of Computer Science and Engineering

Jacobs School of Engineering, UCSD

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The Ten Year
Calit2 Path Forward



- **A Ten-Year Vision of Digital Transformation**
  - **Affiliated Academic Units**
  - **Calit2 News and Videos**
- **This Talk Focuses in on:**
  - **The Digital Transformation of Health**

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www.calit2.net/research/index.php

Where I Believe We are Headed: Predictive, Personalized, Preventive, & Participatory Medicine

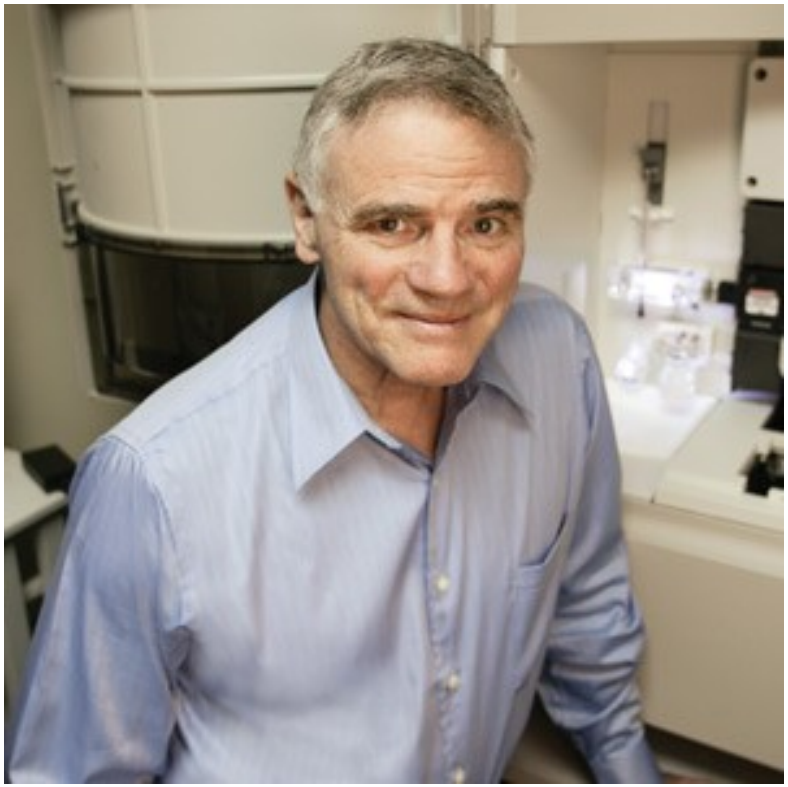
Newsweek

I am Leroy Hood's Lab Rat!

A Doctor's Vision of the Future of Medicine

Leroy Hood
NEWSWEEK

From the magazine issue dated Jul 13, 2009



Using a "LifeChip"
Quantify ~2500 Blood Proteins,
50 Each from 50 Organs or Cell Types
from a Single Drop of Blood
To Create a Time Series

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www.newsweek.com/2009/06/26/a-doctor-s-vision-of-the-future-of-medicine.html

it²

Invited Paper for Focus Issue of Biotechnology Journal, Edited by Profs. Leroy Hood and Charles Auffray.

Perspective

Quantifying your body: A how-to guide from a systems biology perspective

Larry Smarr

University of California, San Diego, CA, USA

Download Pdfs from my Portal:

http://lsmarr.calit2.net/repository/Biotech_J._LS_published_article.pdf

http://lsmarr.calit2.net/repository/Biotech_J._Supporting_Info_published.pdf



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Biotechnol. J. 2012, 7, 980–991

Calit2 Has Been Had a Vision of "the Digital Transformation of Health" for a Decade

www.bodymedia.com



- **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

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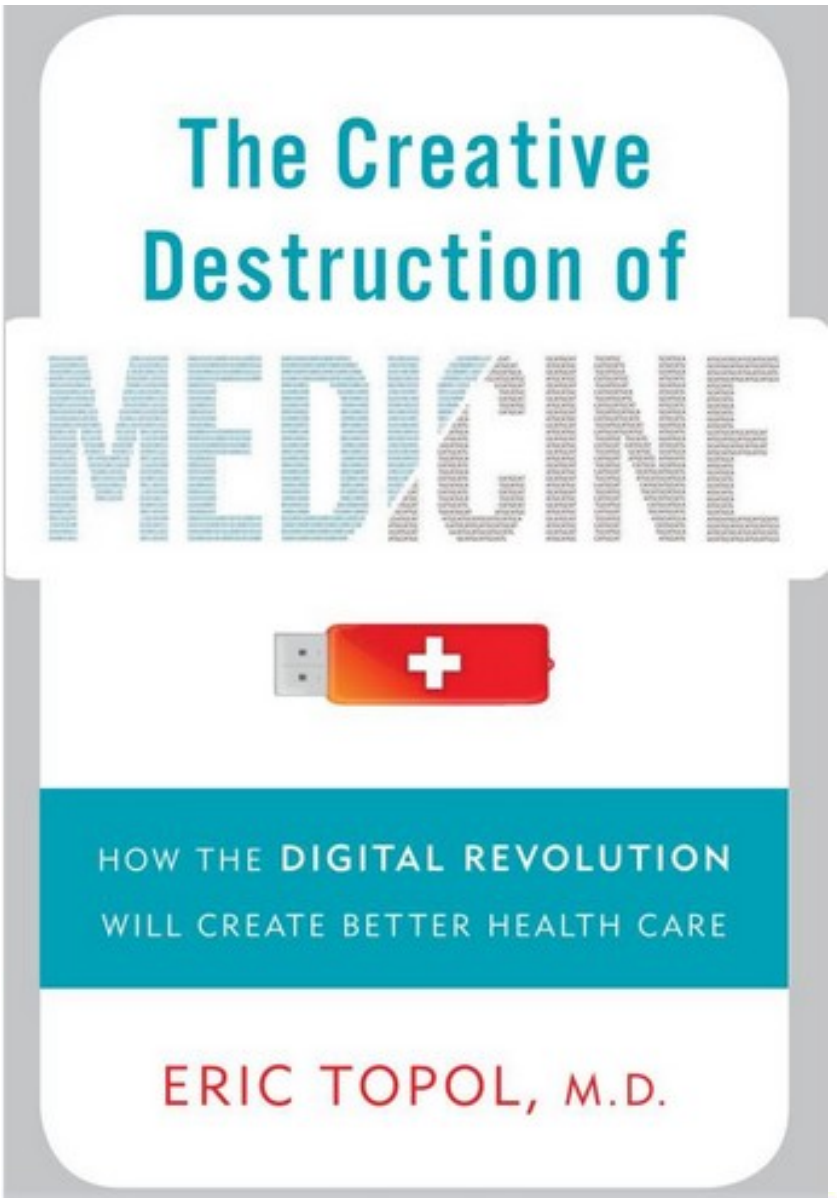
The Content of This Slide from 2001 Larry Smarr Calit2 Talk on Digitally Enabled Genomic Medicine

it²

The Calit2 Vision of Digitally Enabled Genomic Medicine is an Emerging Reality



July/August 2011



February 2012

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Combining the Wireless Internet, Body Sensors, Smart Phones, and Social Networks to Drive Healthier Lifestyles



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Example project: Personal Health Monitoring



"Stability sole" integrates miniaturized flexible sensors and electronics into standard athletic insoles.

Devices are easy to use, invisible, and socially acceptable.

Body worn sensors and electronics are an important technology area for TLC technology.

Collaborators: Hamid Djalilian and Mark Bachman

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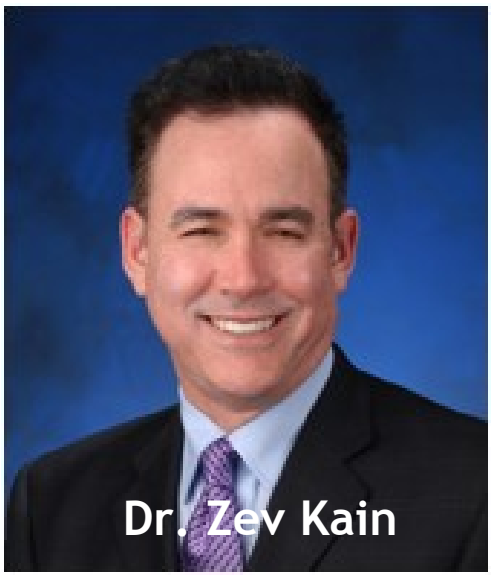
Source: Mark Bachman and G.-P. Li, eHealth and LifeChips at UC Irvine

it²

Example project: Media feedback for pain

Biofeedback with media

Use of physiological monitoring combined with computer generated imagery to produce relaxation states for improved pain and stress management.







Collaborators: Zev Kain, Michelle Fortier, and Mark Bachman



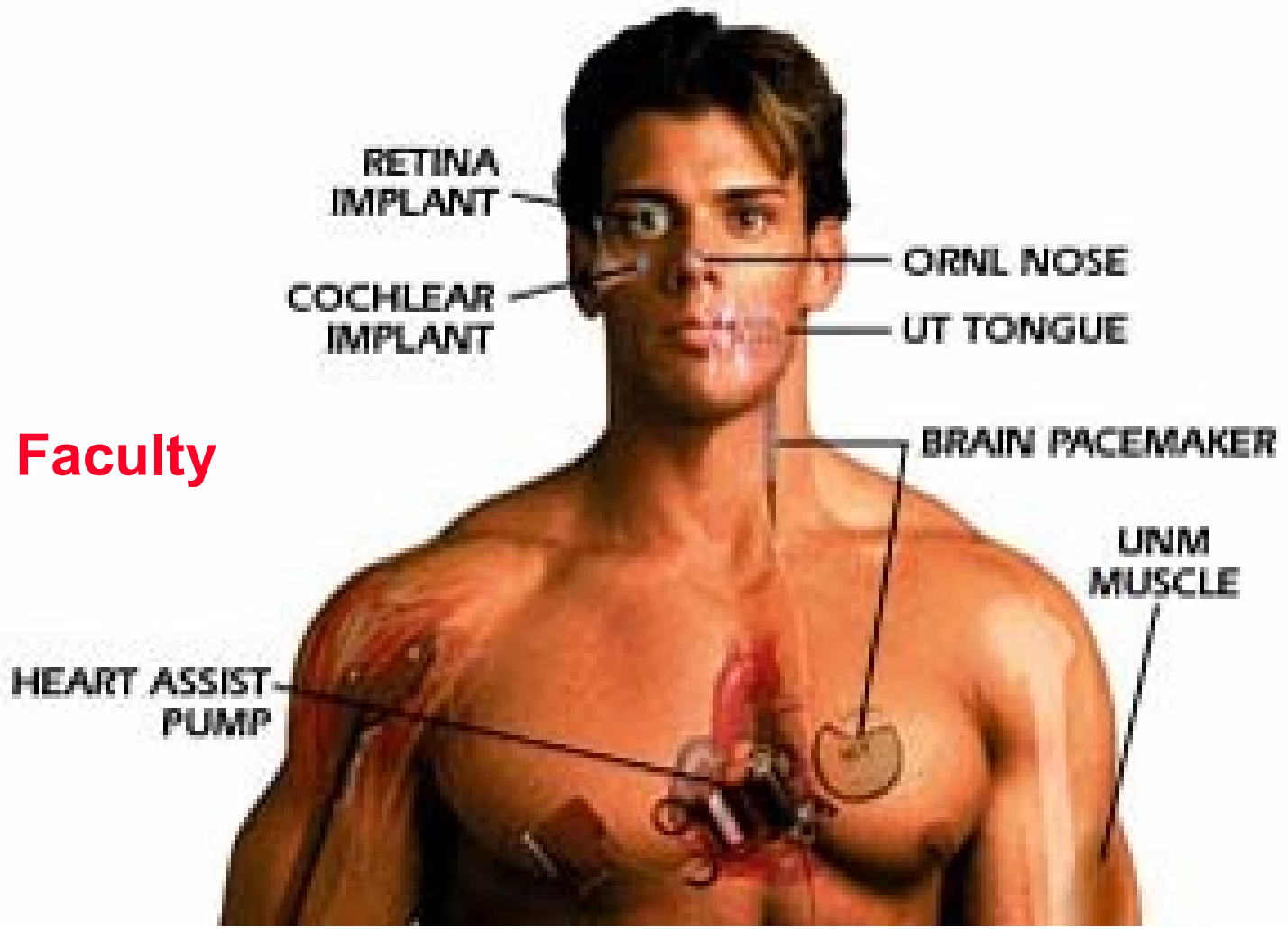
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Source: Mark Bachman and G.-P. Li, eHealth and LifeChips at UC Irvine

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

65 UCI Faculty



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lifechips
university of california, irvine
www.lifechips.org

it²

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**





CW PHS
CENTER FOR WIRELESS & POPULATION HEALTH SYSTEMS

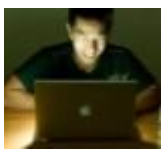
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Source: Kevin Patrick, UCSD SOM & Calit2

it²

CitiSense –UCSD NSF Grant for Fine-Grained Environmental Sensing Using Cell Phones





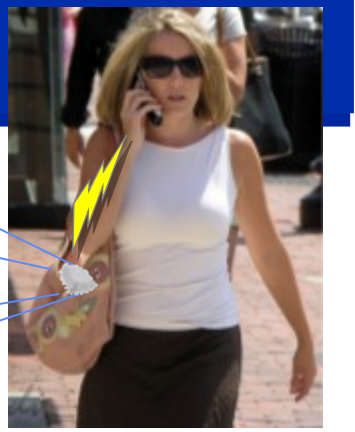
4oz
30 compounds

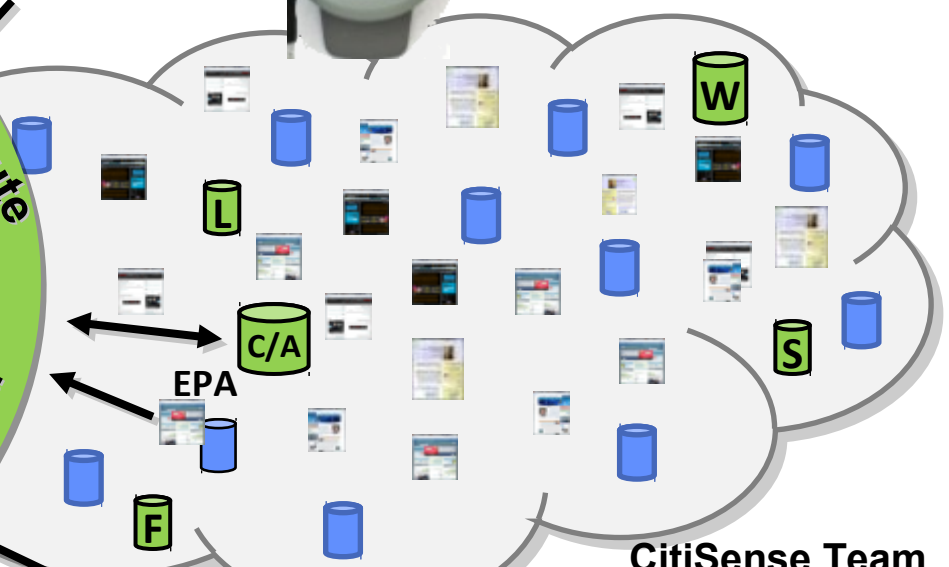


Seacoast Sci.

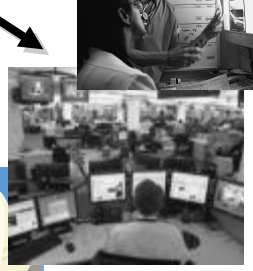
Intel MS













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

Age 51



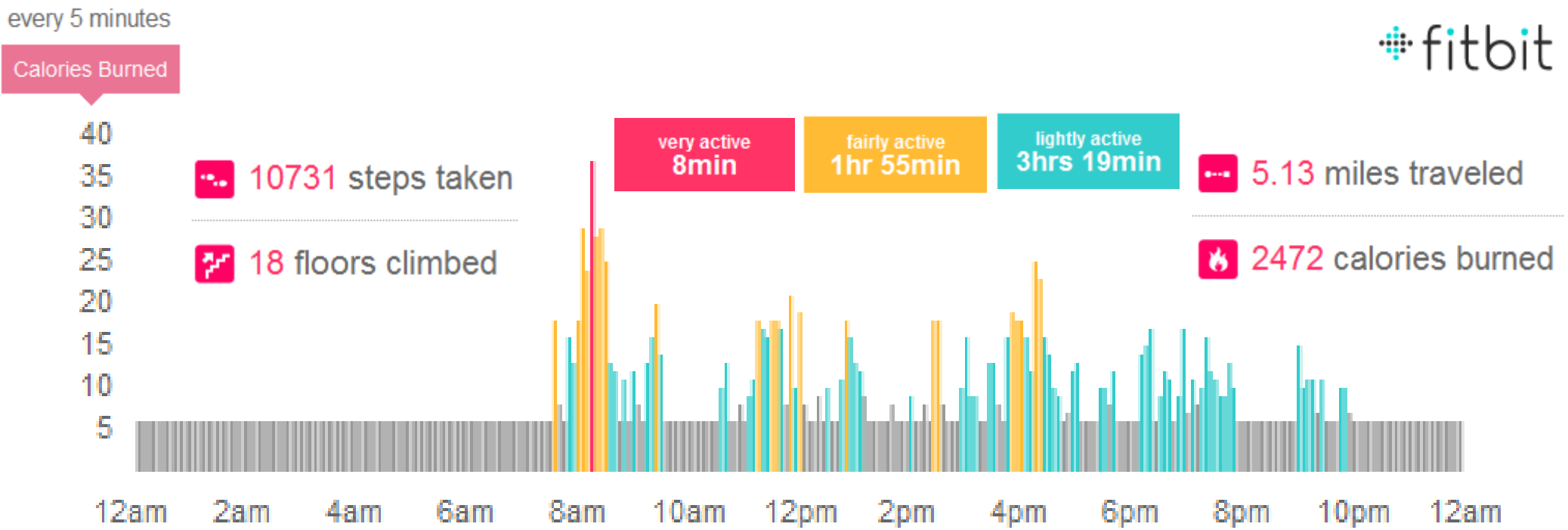


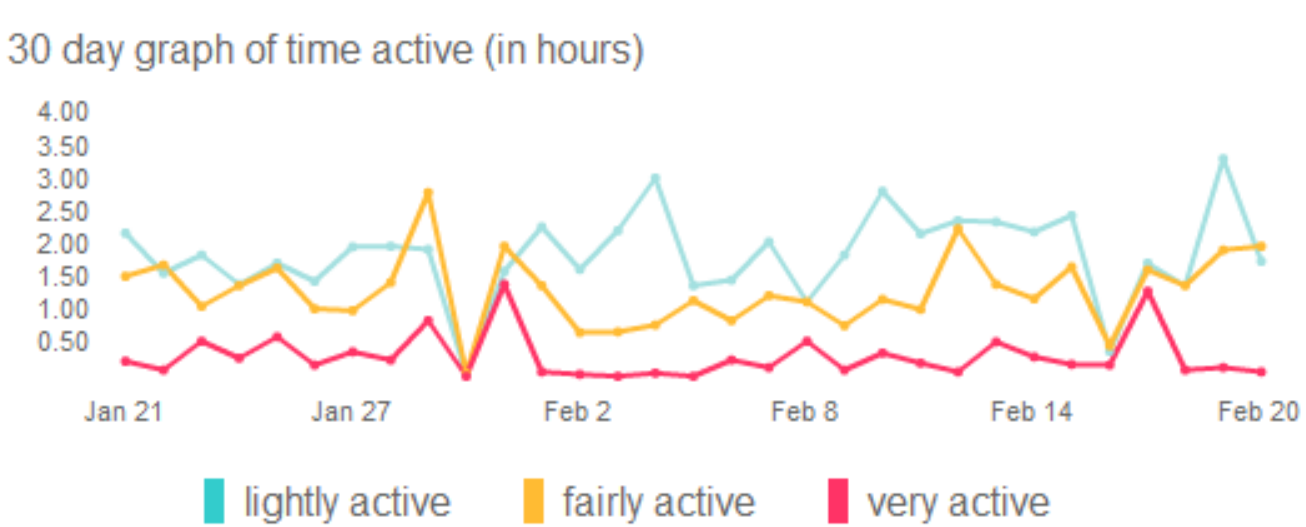
Age 61

I Arrived in La Jolla in 2000 After 20 Years in the Midwest and Discovered I was Pre-Diabetic

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Wireless Monitoring Helps Drive Exercise Goals



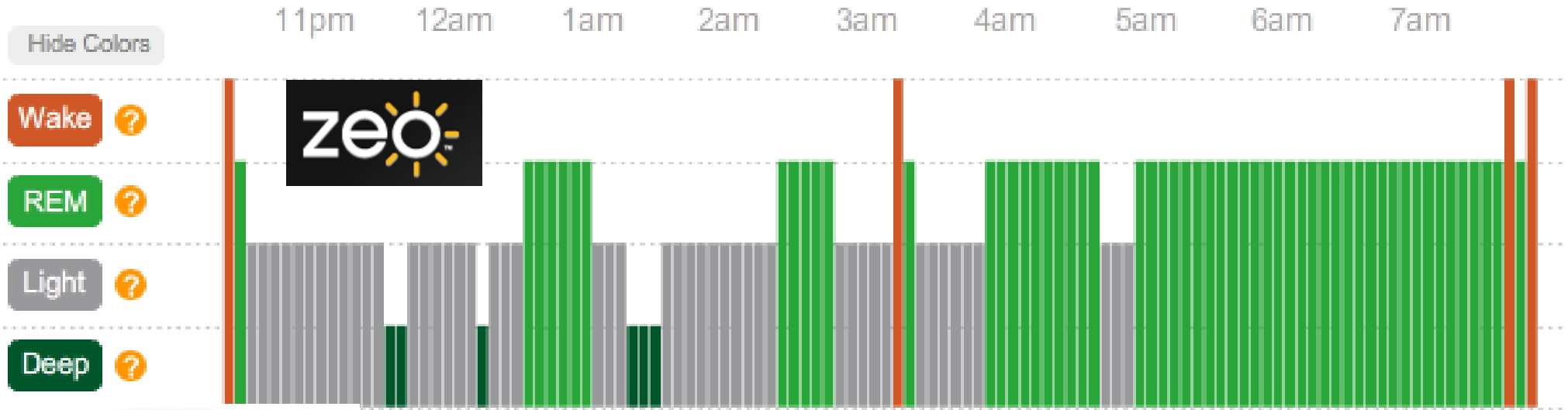




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Quantifying My Sleep Pattern Using a Zeo - Increased My Average to 8 Hours/Night

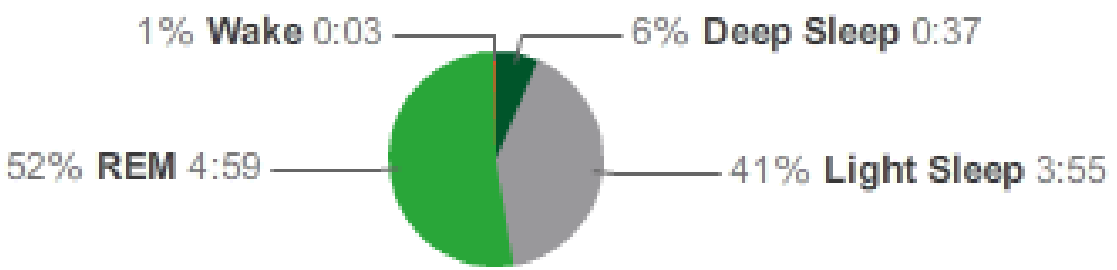




Stroke risk increased by sleeping less than six hours a night
-M. Ruiter, *Sleep* 2012

Total Z: 9 hr 31 min

Time to Z: 0 hr 2 min



Why are these numbers different from the sleep graph above?

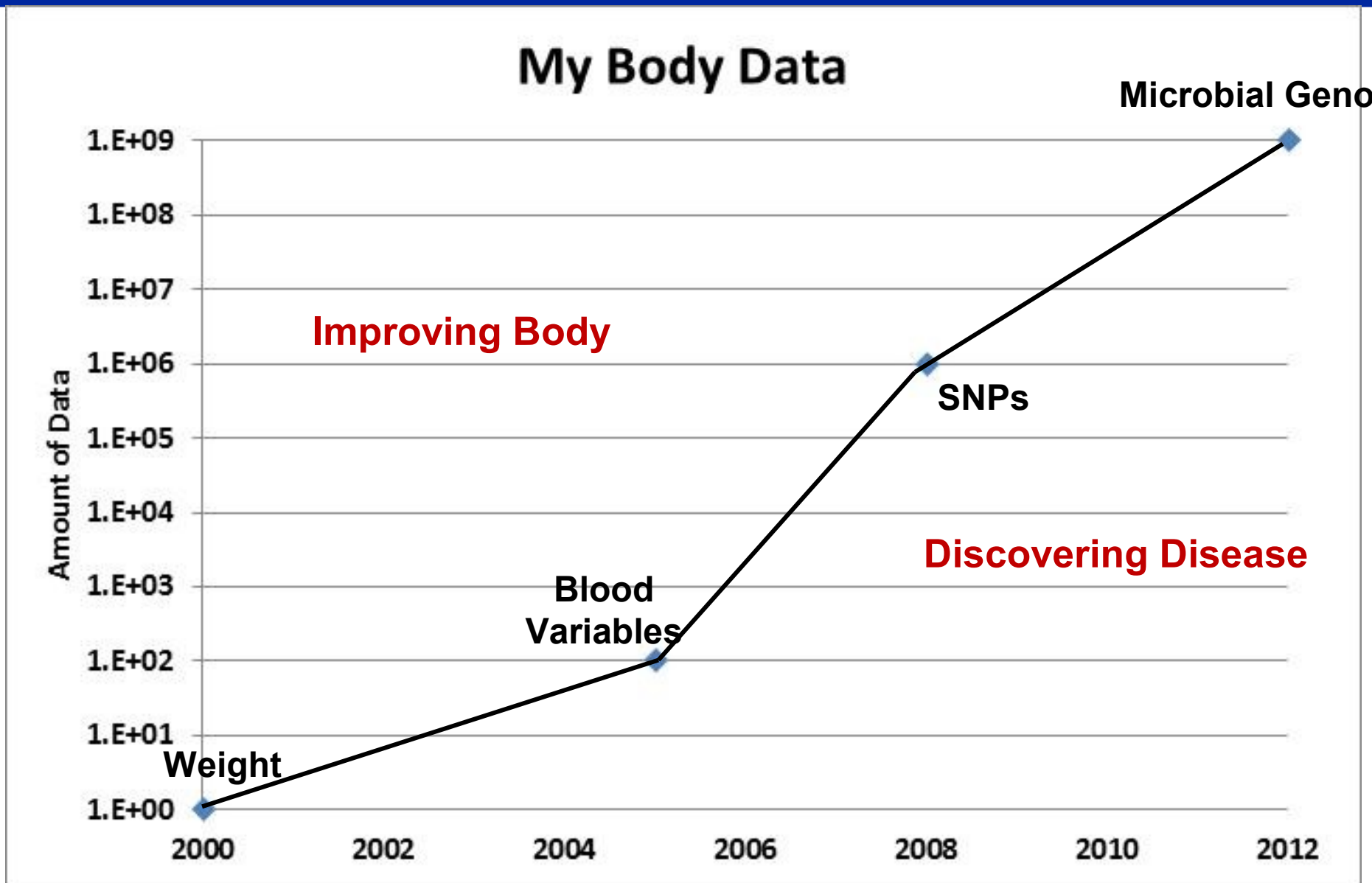
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REM is Normally 20% of Sleep
Mine is Between 45-65% of Sleep

An Infant Typically Has 50% REM

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From One to a Billion Data Points Defining Me: The Exponential Rise in Body Data in Just One Decade!



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From Measuring Macro-Variables to Measuring Your Internal Variables



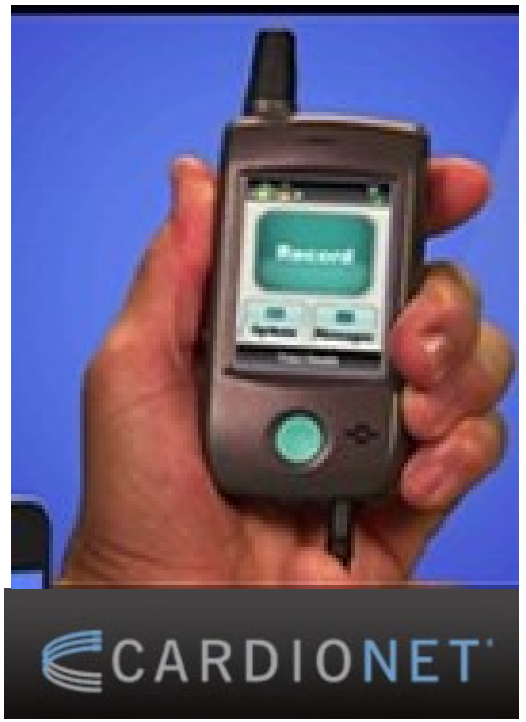
www.technologyreview.com/biomedicine/39636

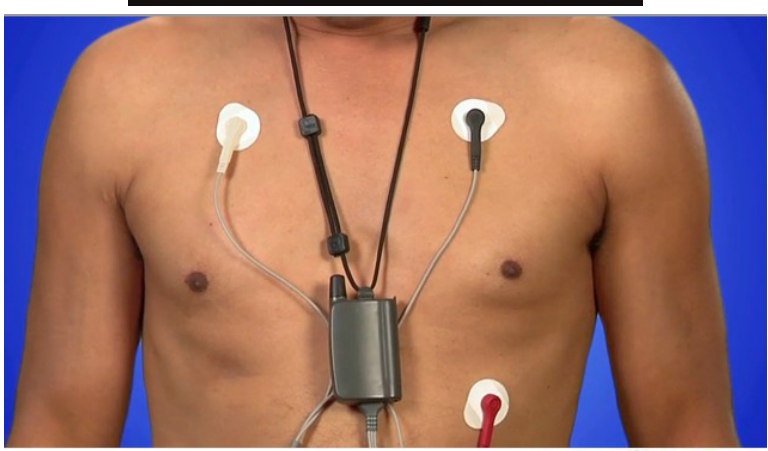
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Putting Your Heart On-line - I Will Be Wearing One Starting Tomorrow







QUALCOMM

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I Track 100 Variables in Blood Tests Done Quarterly to Annually

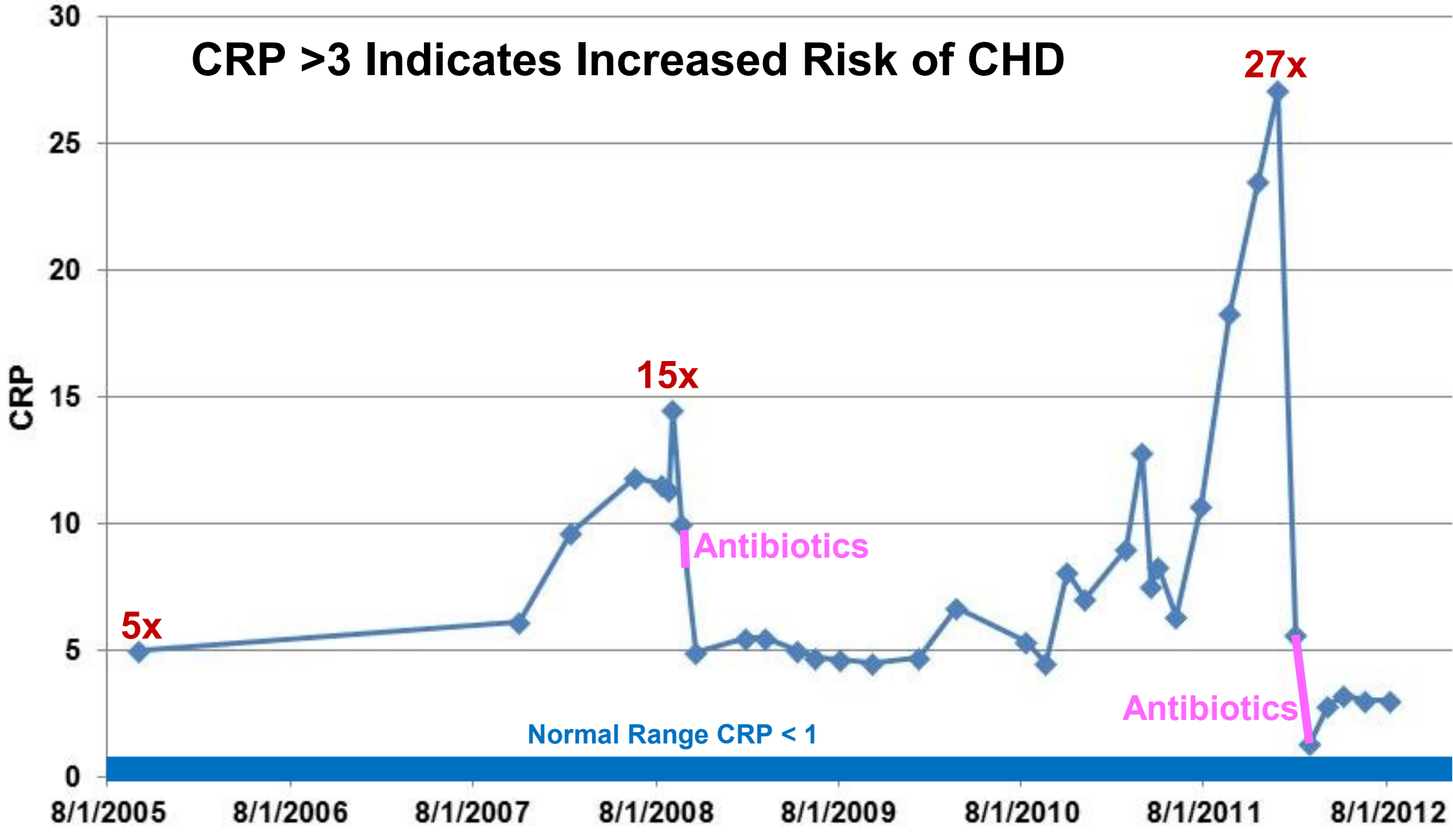
- **Electrolytes**
  - Sodium, Potassium, Calcium, Magnesium, Phosphorus, Boron, Chlorine, CO_2
- **Micronutrients**
  - Arsenic, Chromium, Cobalt, Copper, Iron, Manganese, Molybdenum, Selenium, Zinc
- **Blood Sugar Cycle**
  - Glucose, Insulin, A1C Hemoglobin
- **Cardio Risk**
  - Complex Reactive Protein
  - 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.

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Only One of These Was Far Out of Normal Range

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My Blood Measurements Revealed Chronic Inflammation

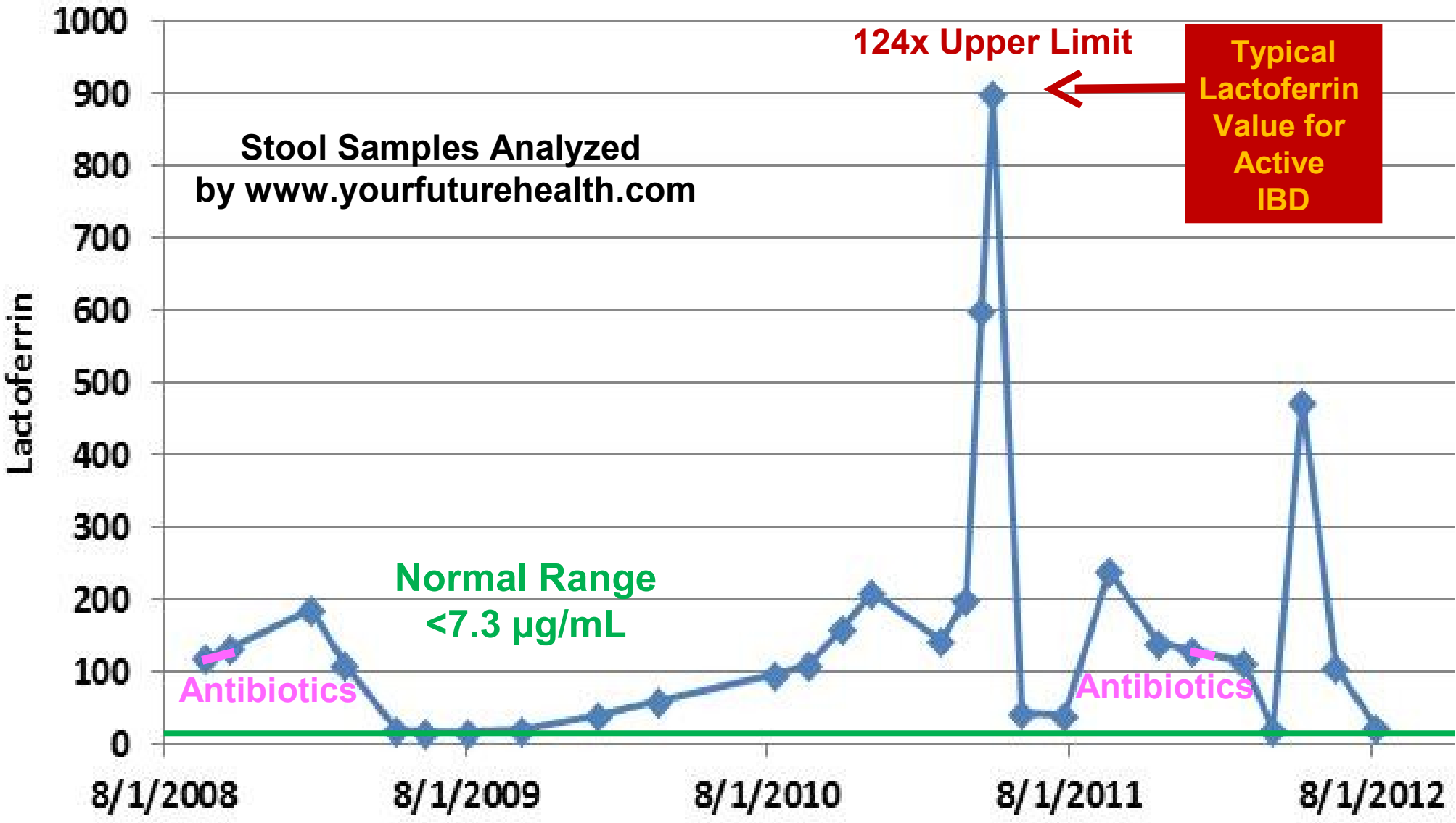


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Complex Reactive Protein (CRP) is a Blood Biomarker for Detecting Presence of Inflammation

it²

By Quantifying Stool Measurements Over Time I Discovered Source of Inflammation Was Likely in Colon

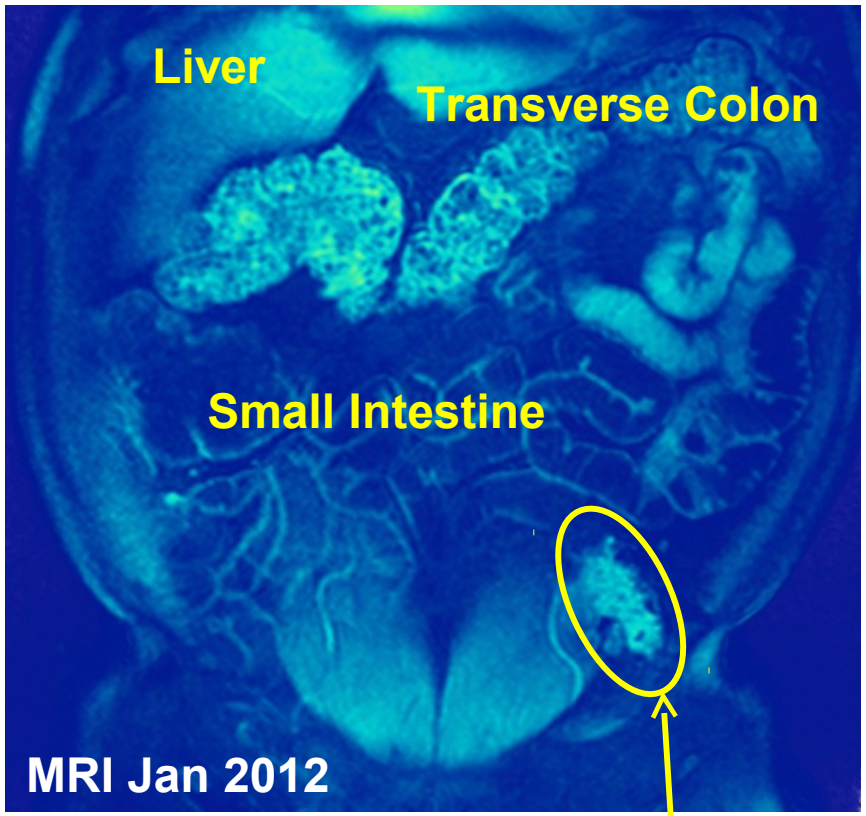


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Lactoferrin is a Sensitive and Specific Biomarker for Detecting Presence of Inflammatory Bowel Disease (IBD)

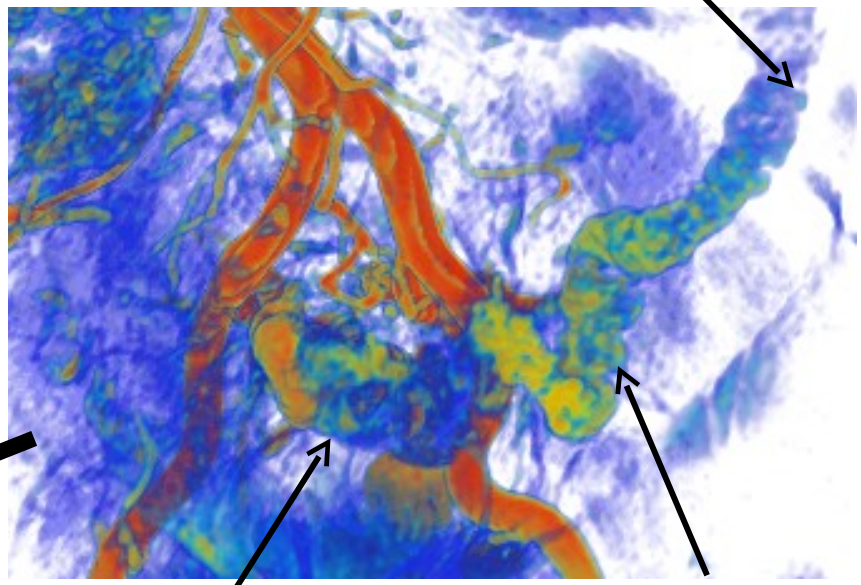
it²

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

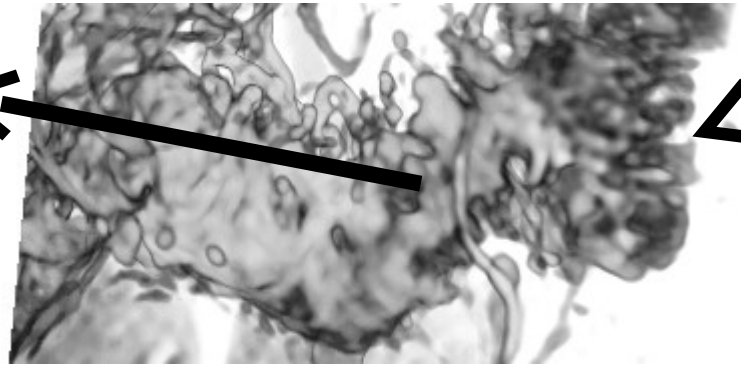
Descending Colon



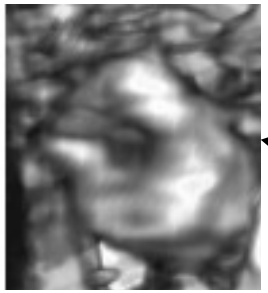
Major Kink

Sigmoid Colon Threading Iliac Arteries

Diseased Sigmoid Colon



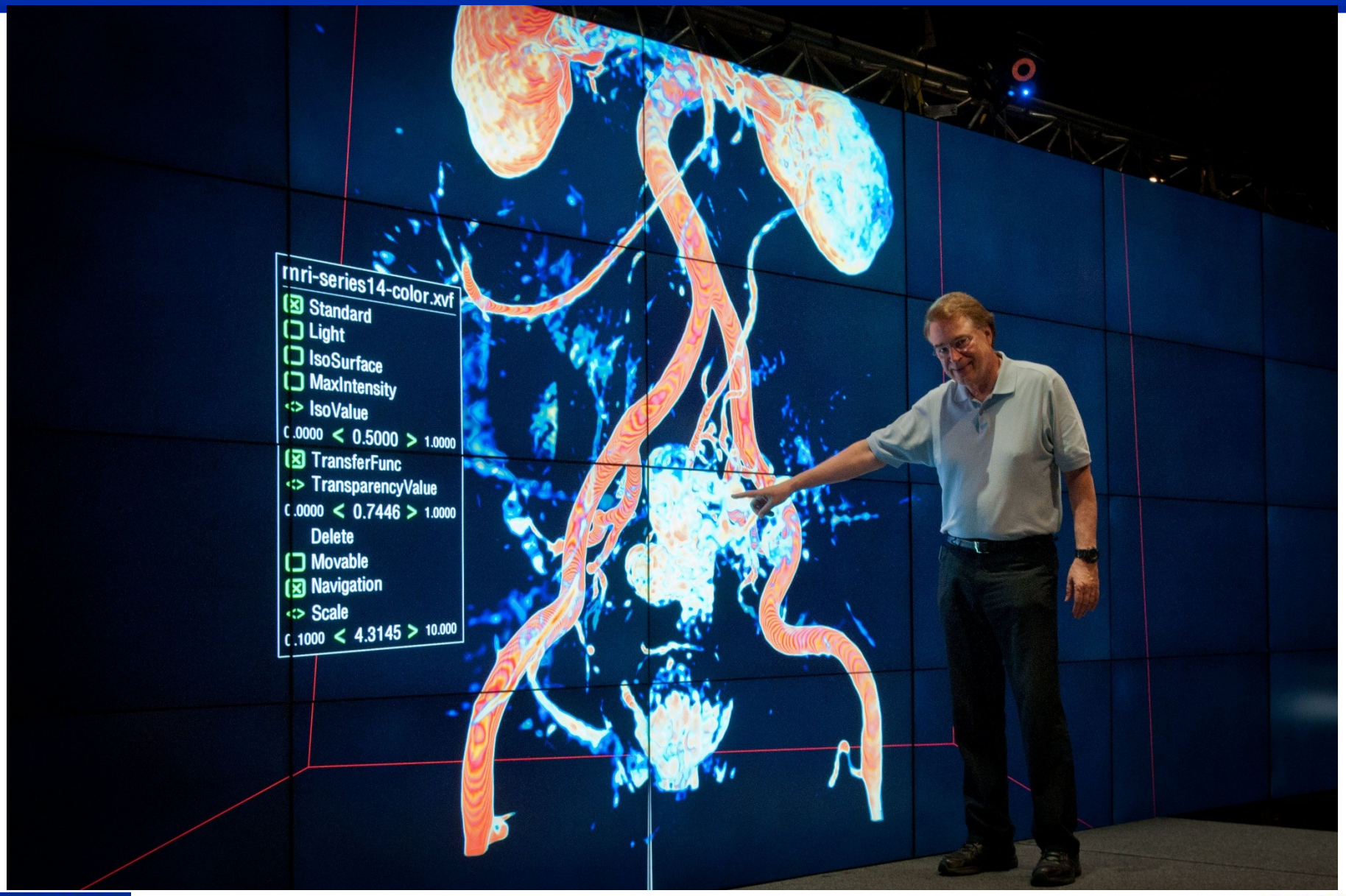
Cross Section



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Scalable Visualization for 3D Interactive Body Imaging



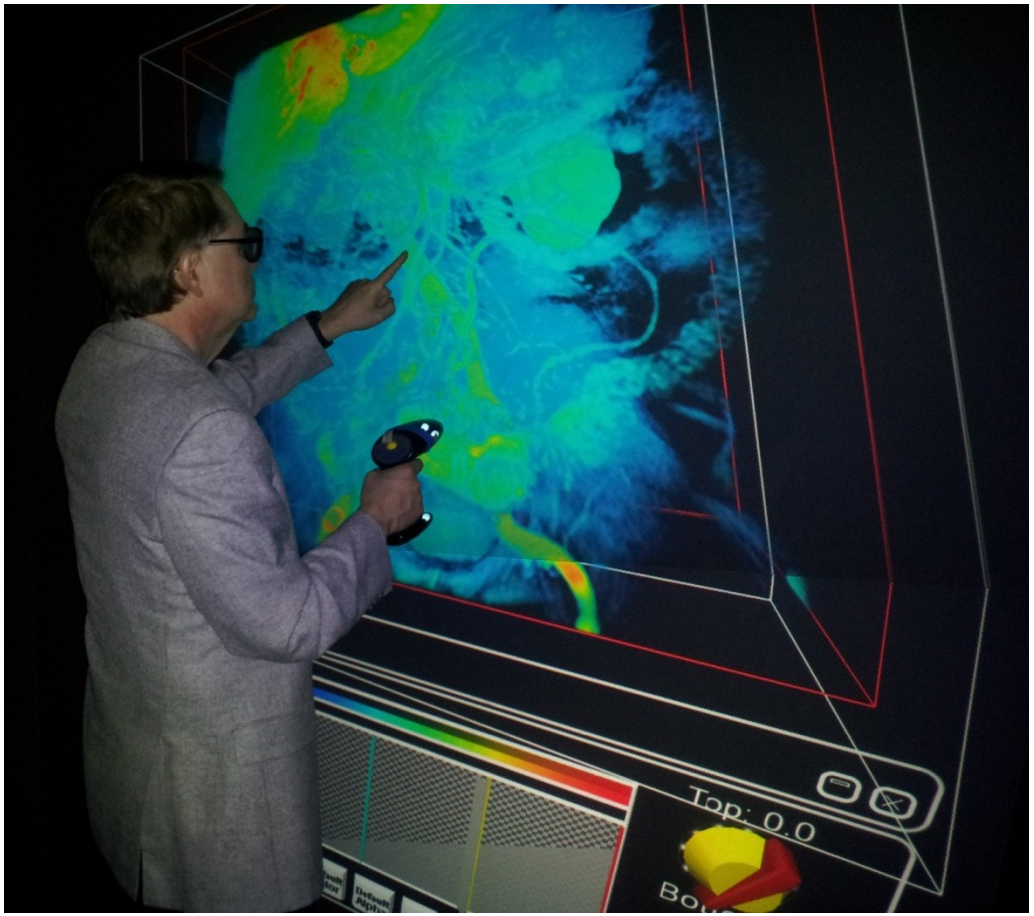
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DeskVOX Software Courtesy of Jurgen Schulze, Calit2

it²

3D Imaging of MR Enterography Data: Virtual Reality and Hard Copy

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





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Photo & DeskVOX Software Courtesy of Jurgen Schulze, Calit2

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Why Did I Have an Autoimmune Disease like IBD?

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

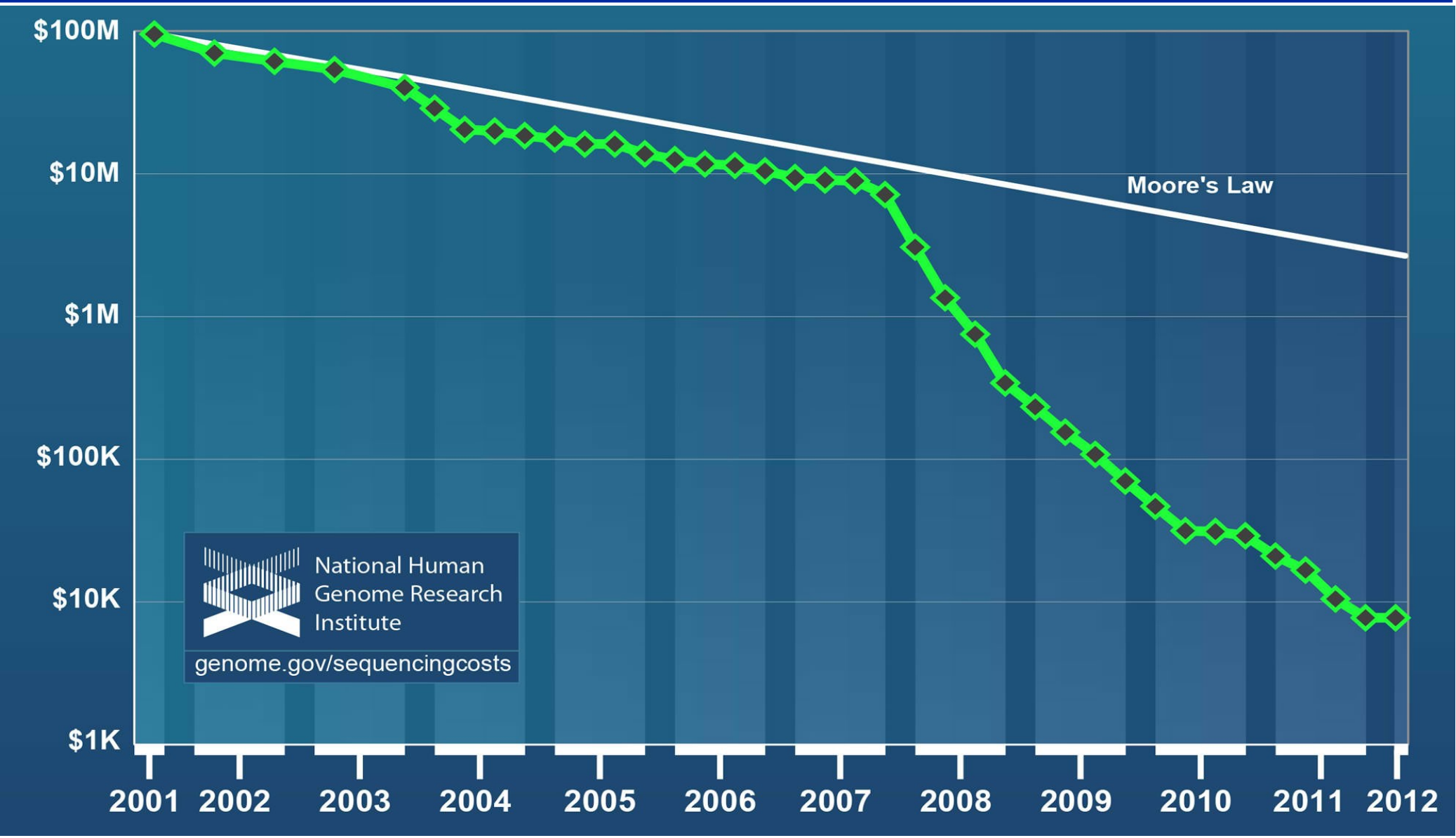
So I Set Out to Quantify All Three!

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Paul B. Eckburg & David A. Relman
Clin Infect Dis. 44:256-262 (2007)

it²

The Cost of Sequencing a Human Genome Has Fallen Over 10,000x in the Last Ten Years!



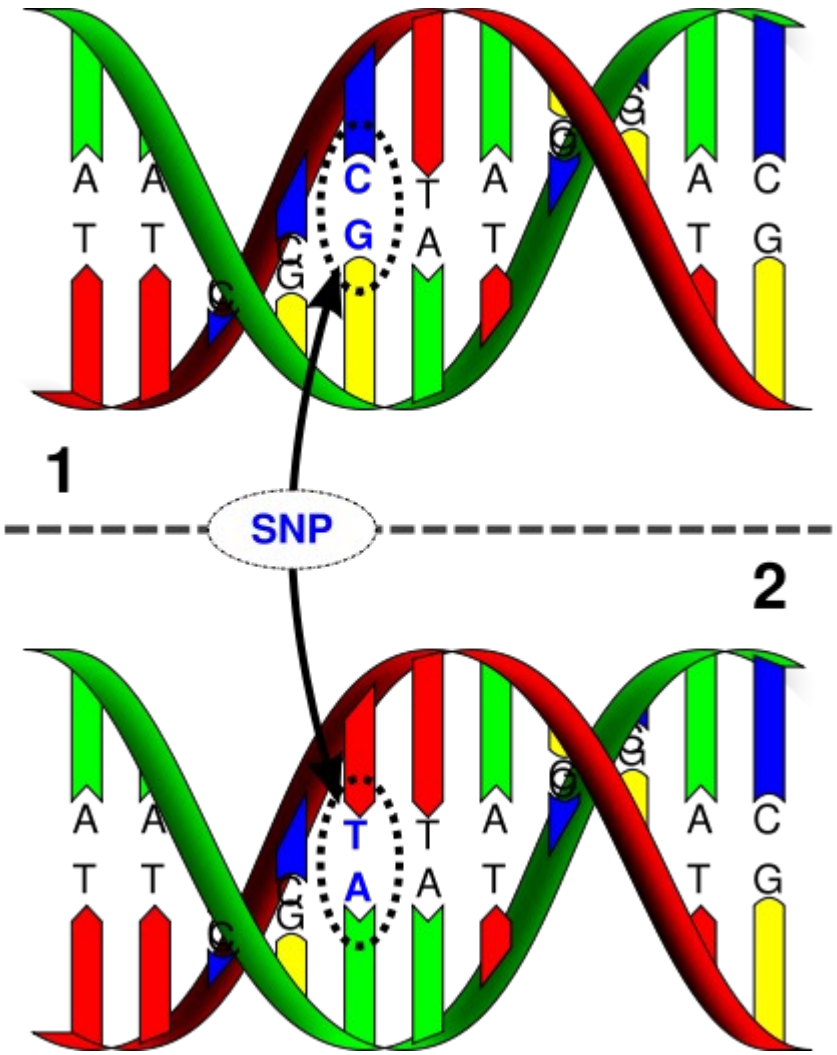
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This Has Enabled Sequencing of Both Human and Microbial Genomes

it²

Single Nucleotide Polymorphisms (SNPs) Make Up About 90% of All Human Genetic Variation

Person A



Person B

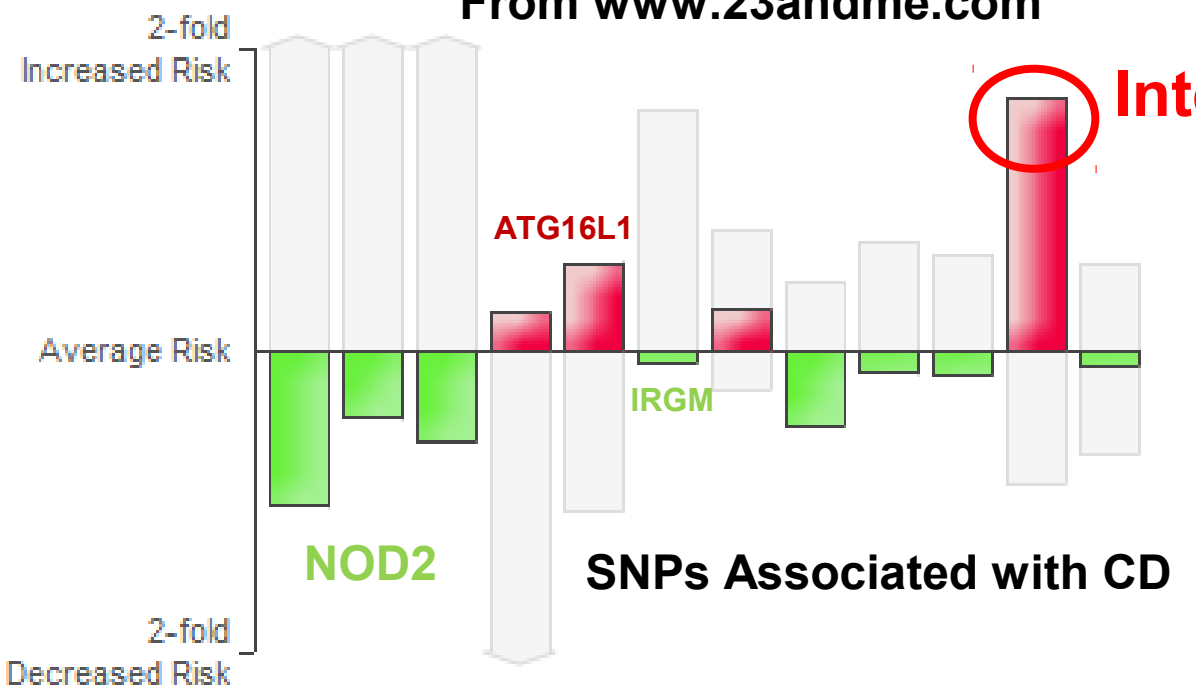
SNPs Occur Every 100 to 300 Bases Along Human DNA

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www.23andme.com Tracks One Million SNPs

I Wondered if Crohn's is an Autoimmune Disease, Did I Have a Personal Genomic Polymorphism?

From www.23andme.com



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

News and Views

Nature Medicine **13**, 26 - 28 (2007)
doi:10.1038/nm0107-26

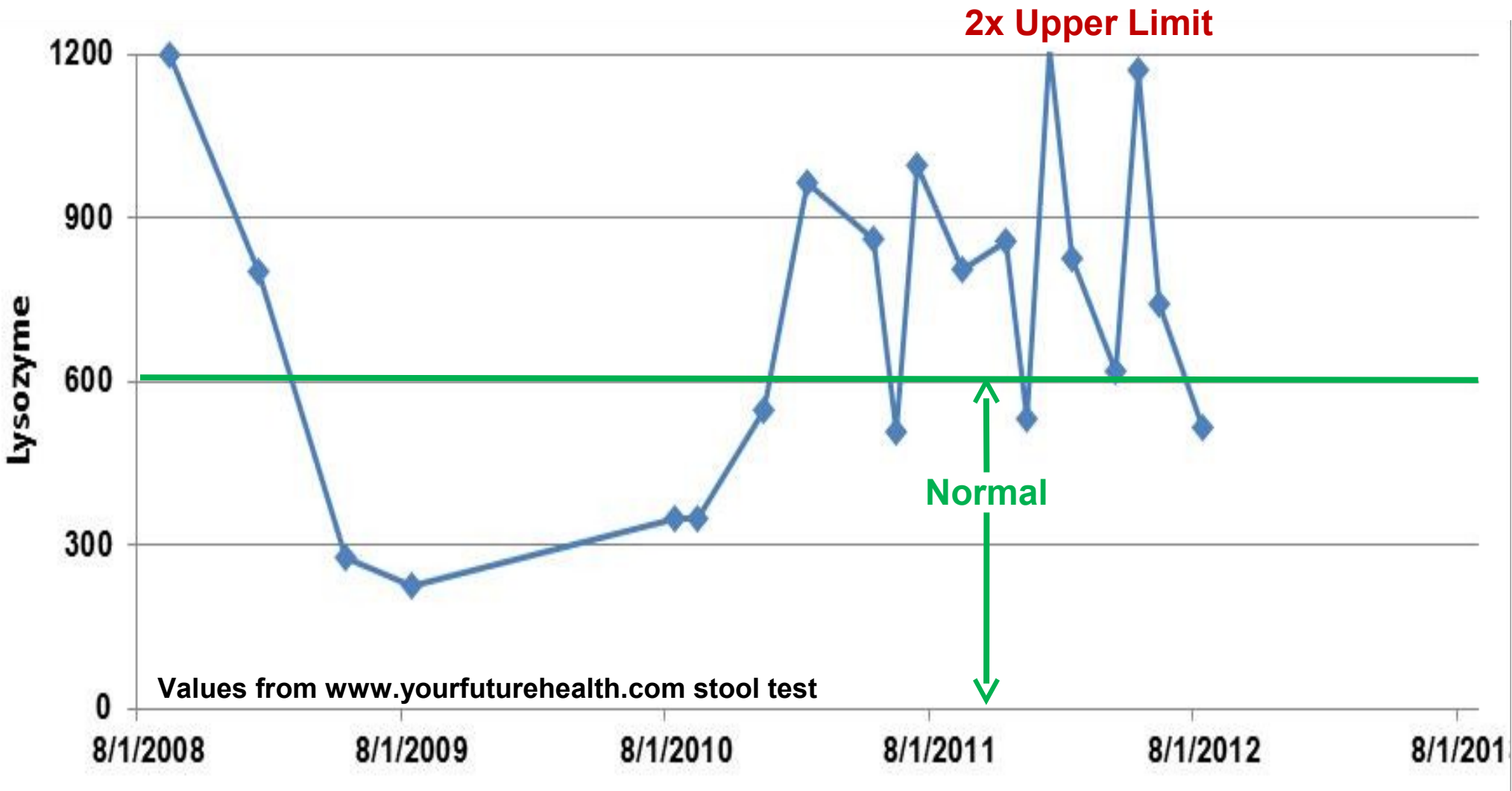
IL-23: a master regulator in Crohn disease

Markus F Neurath[1]

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

My Immune System Seems to Be Fighting Bacteria Episodically

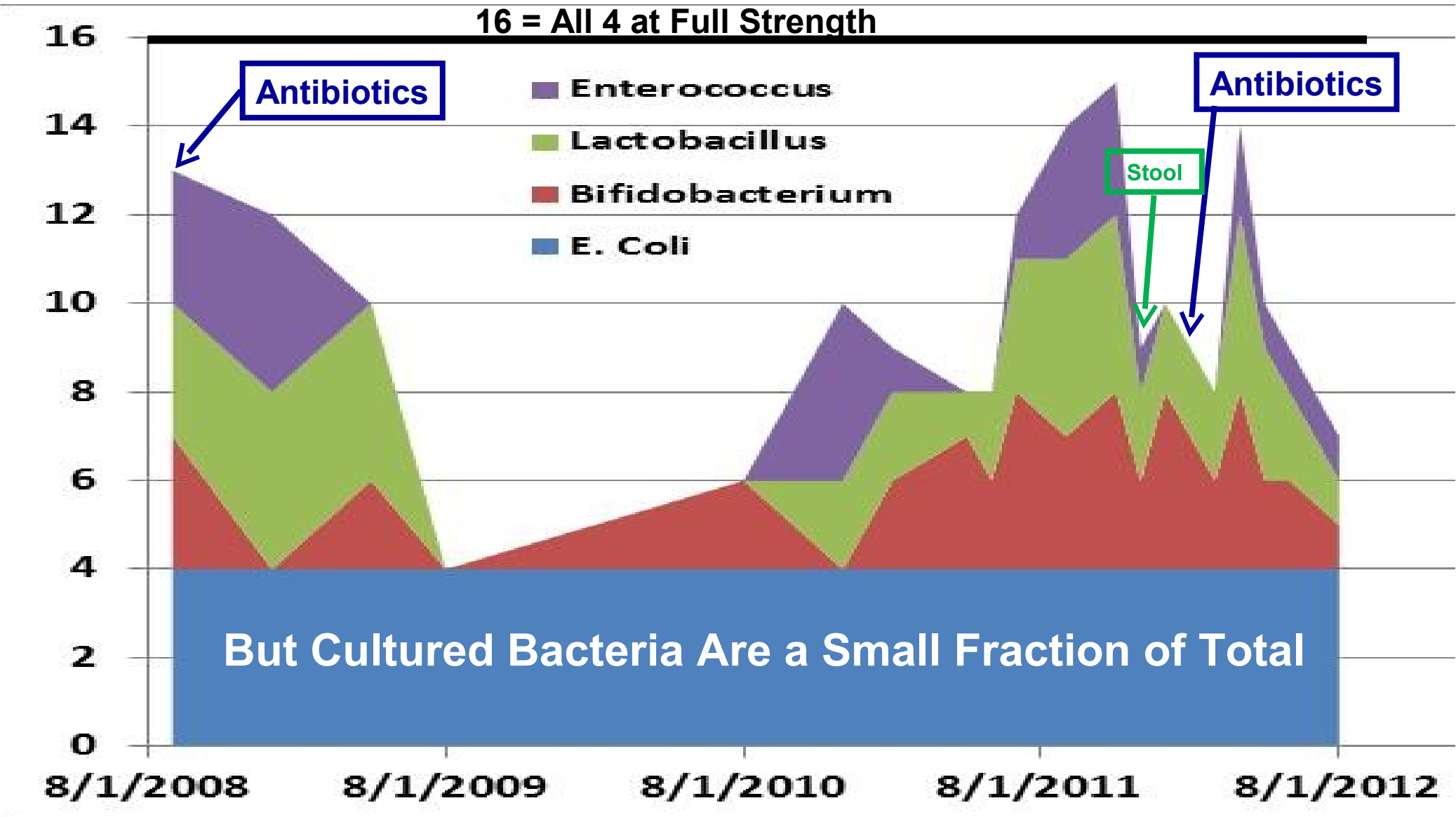


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Lysozyme is an Enzyme of the Innate Immune System that Attacks Bacterial Cell Walls

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Your Human Cells are Only 10% of Your Superorganism: How Can We Track the 90% which are Microbes?



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Values From www.yourfuturehealth.com stool test

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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!

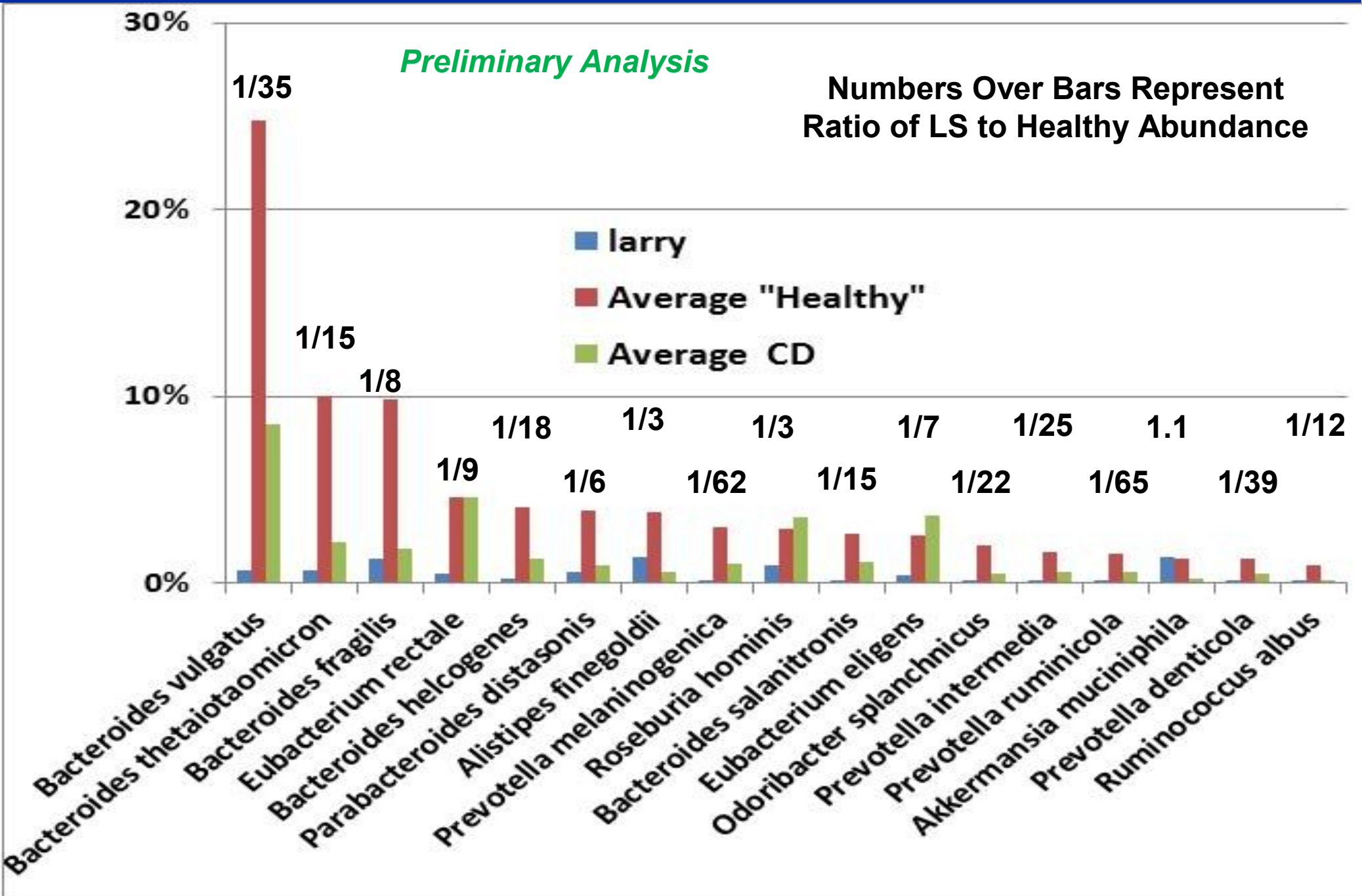
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UC San Diego
HEALTH SCIENCES

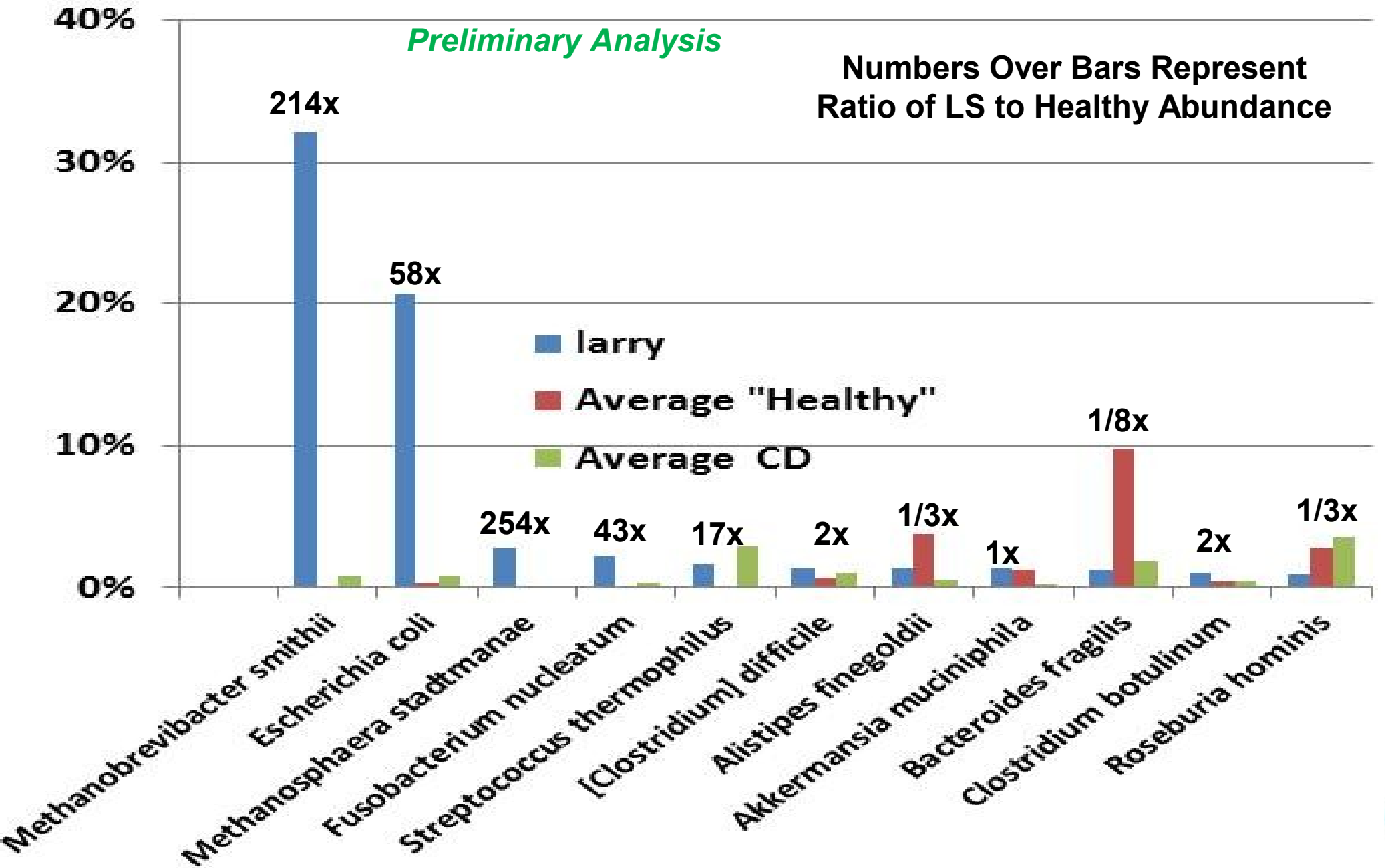
J. Craig Venter
INSTITUTE

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Almost All Abundant Species (≥1%) in Healthy Subjects Are *Severely Depleted* in LS Gut



LS Abundant Microbe Species (≥1%) Are *Dominated by Rare Species* in Healthy Subjects



Next Step: Use Microarray to Measure Time Series of Microbial Diversity

www.secondgenome.com

SECOND GENOME
THE MICROBIOME COMPANY



LBL's Gary Andersen and his PhyloChip

"Second Genome has developed a sensitive, flexible and robust platform for the identification of microbiome-based signatures for the rapid identification of microbial gut health biomarkers."

DNA microarray that can identify, within hours, over 50,000 different microbes

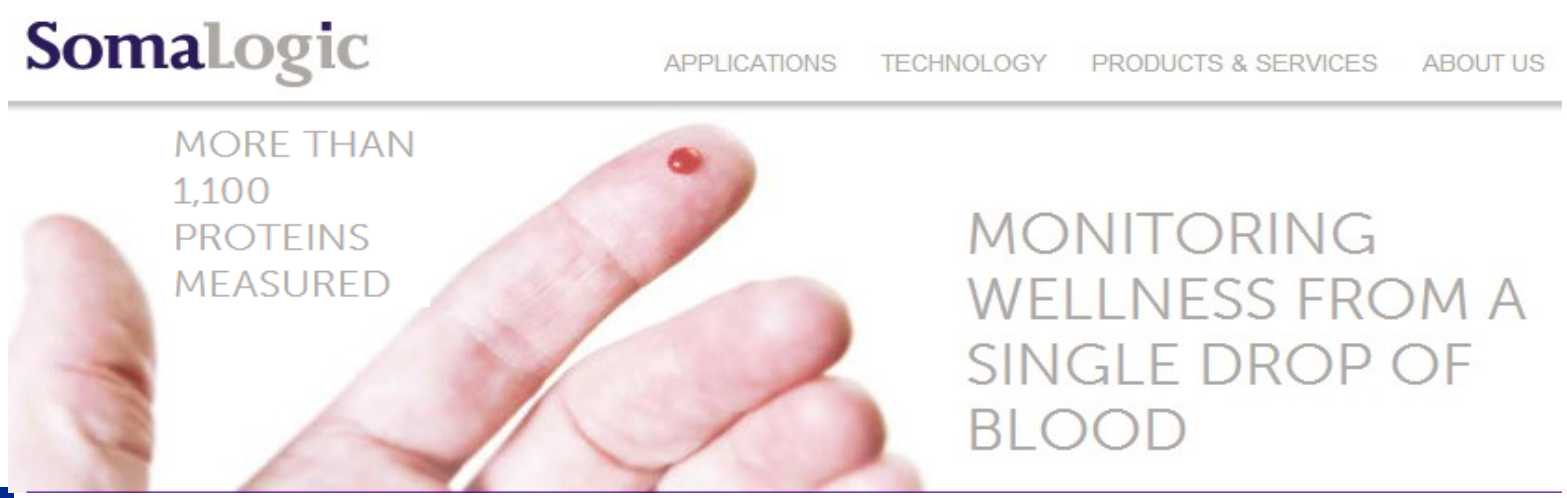


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From Vials of Blood for a Few Variables to Thousands of Proteins from a Single Drop





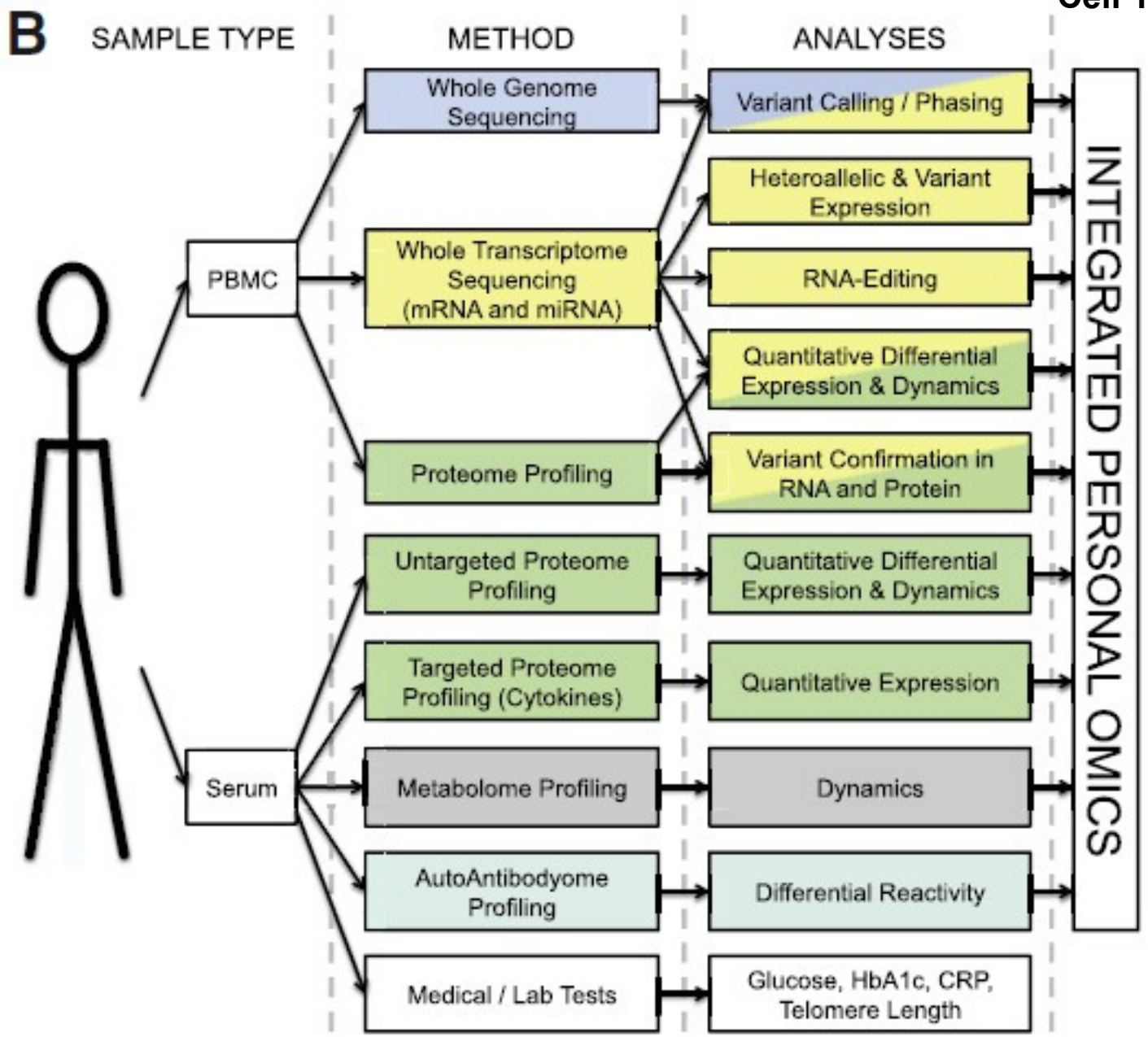
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www.somalogic.com/

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Integrative Personal Omics Profiling Reveals Details of Clinical Onset of Viruses and Diabetes

Cell 148, 1293–1307, March 16, 2012



- **Michael Snyder, Chair of Genomics Stanford Univ.**
- **Genome 140x Coverage**
- **Blood Tests 20 Times in 14 Months**
  - **tracked nearly 20,000 distinct transcripts coding for 12,000 genes**
  - **measured the relative levels of more than 6,000 proteins and 1,000 metabolites in Snyder's blood**

Publically Sharing Your Genome and Medical Records: Is it Crazy or the Future?

World DNA Day: April 25, 2012

GET Genomes Environments Traits CONFERENCE

I Have Been Accepted by PGP and Spoke at GET 2012

Personal Genome Project

Posted 06.01.08 | NOVA scienceNOW

The Personal Genome Project, spearheaded by George Church of Harvard's Center for Computational Genetics, aims to recruit 100,000 people willing to offer up their DNA and personal life histories. It's all in an effort to further knowledge of human genetics and why we get—or don't get—diseases.

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Crowd-Sourcing Health Studies Is Rapidly Growing With More Open Health Data



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

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