Becoming a Quantified Self

Invited Speaker
Technology, Media and Telecom (TMT) Summit
Deloitte University
Dallas, TX
April 26, 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

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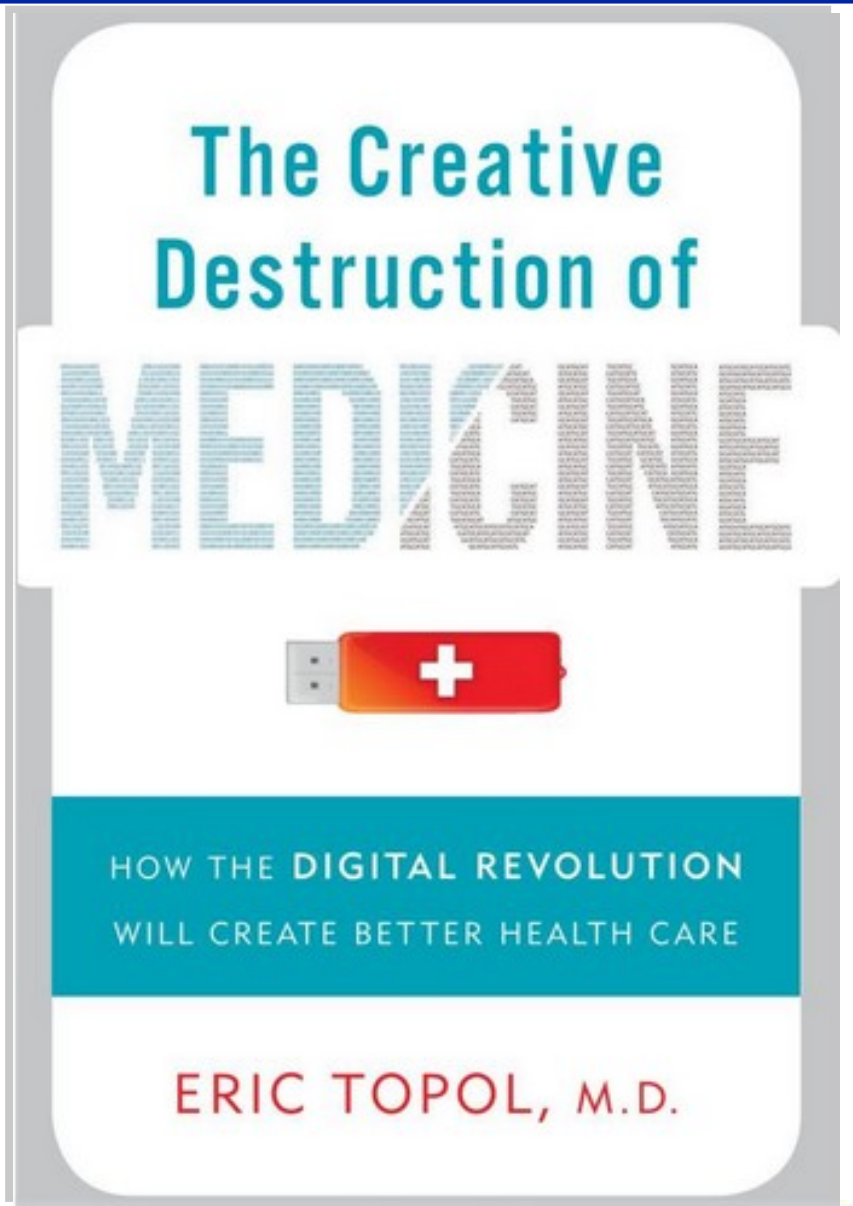
The Content of This Slide from 2001 Larry Smarr
Calit2 Talk on Digitally Enabled Genomic Medicine

it²

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



July/August 2011



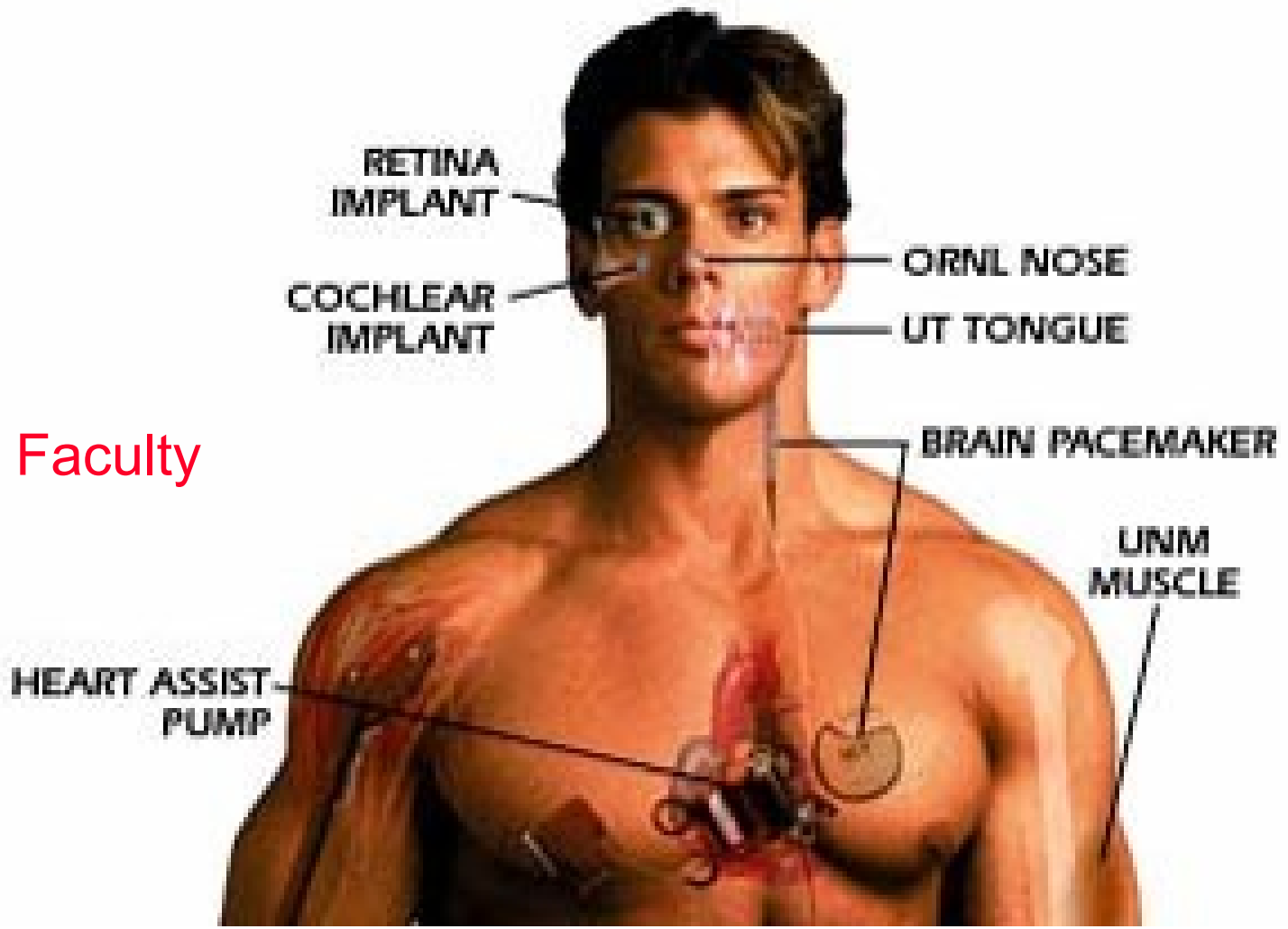
February 2012

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

65 UCI Faculty

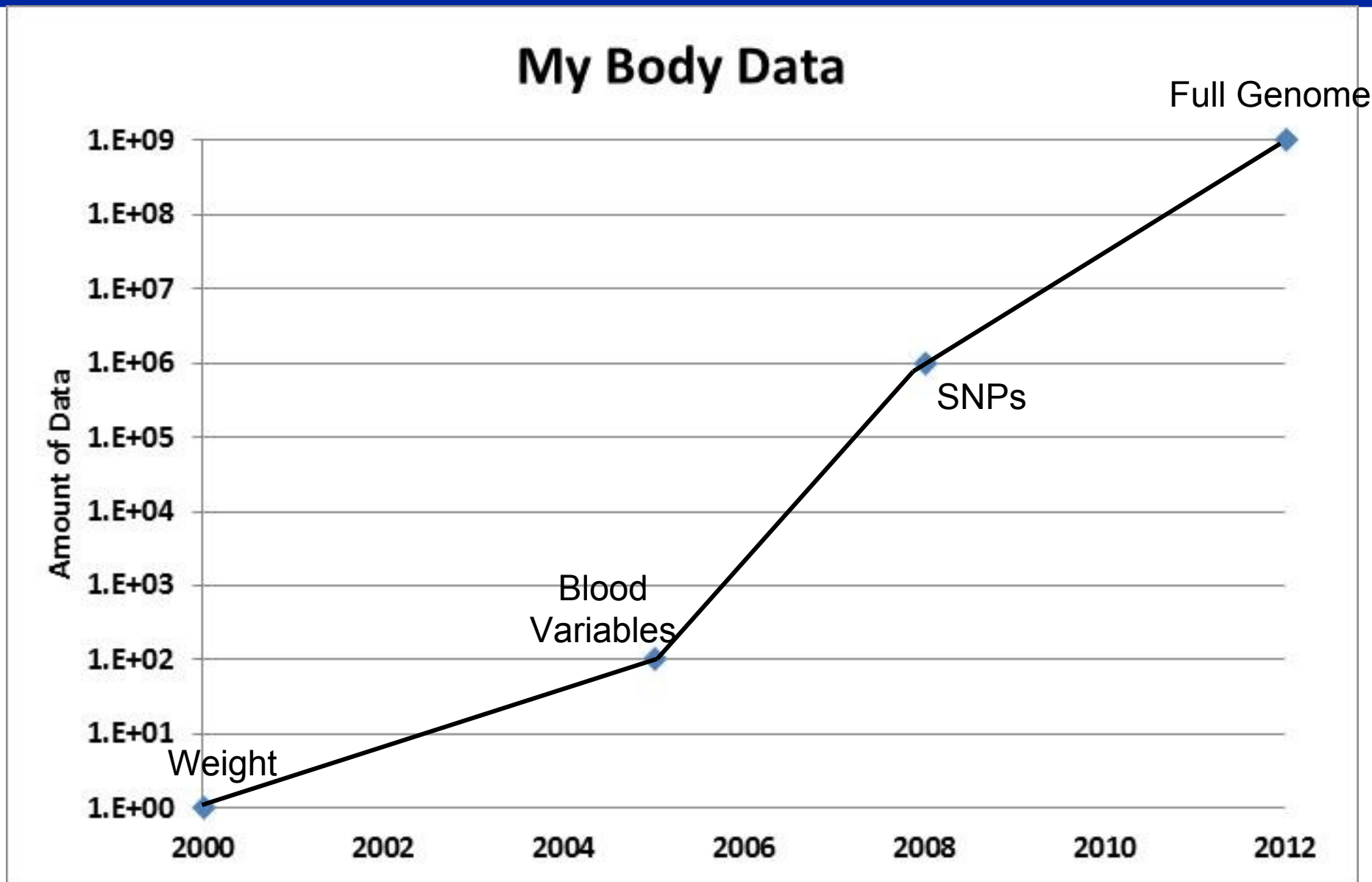


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lifechips
university of california, irvine
www.lifechips.org

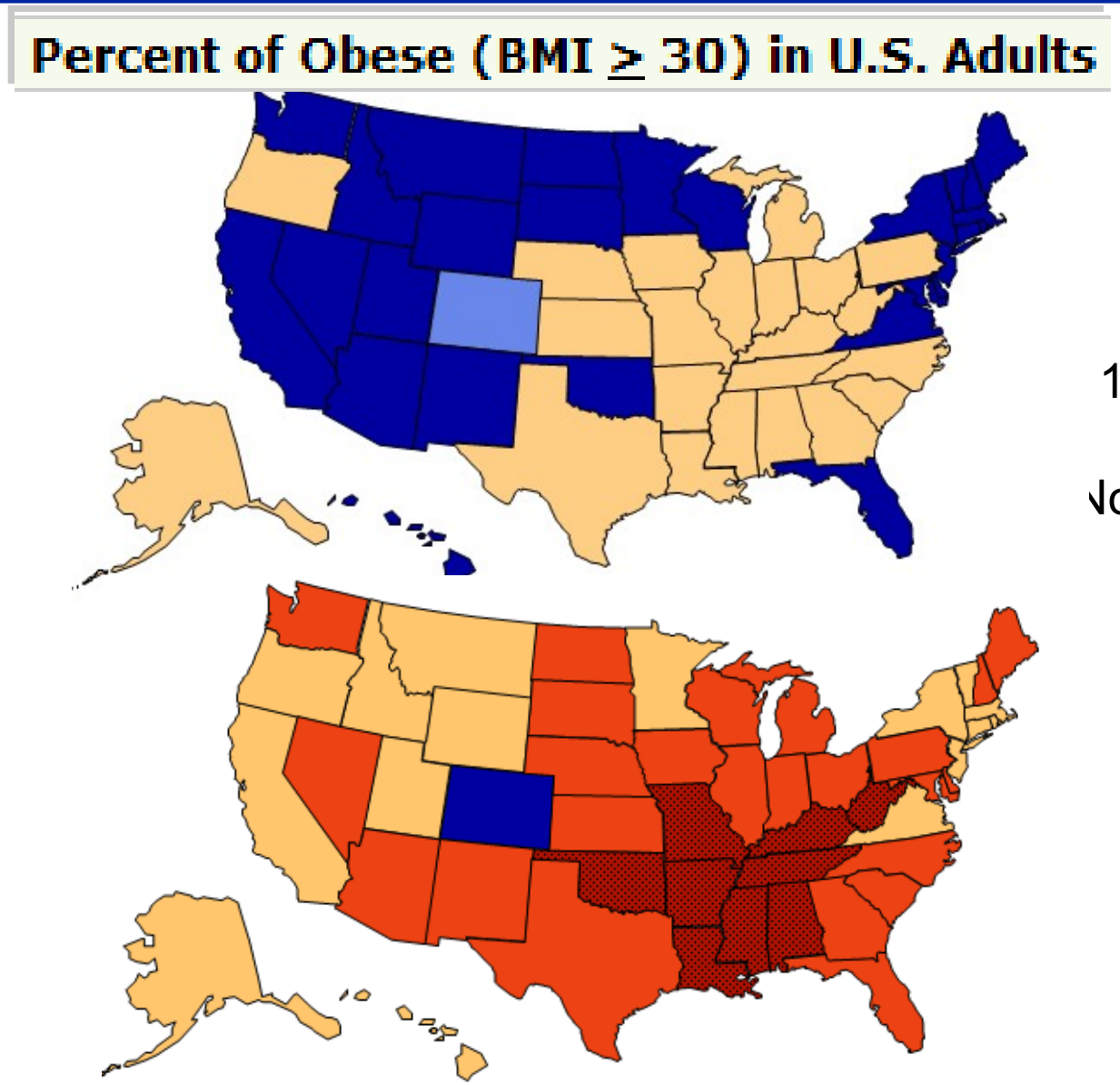
it²

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



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During the 2000s, The Fraction of the Population That is Obese Has Greatly Increased



35% of Adults
17% of Children

No State Reduced its % Obese In 2010

Source: Behavioral Risk Factor Surveillance System, CDC

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I Arrived in La Jolla in 2000 After 20 Years in the Midwest and Decided to Move Against the National Trend

Age 51



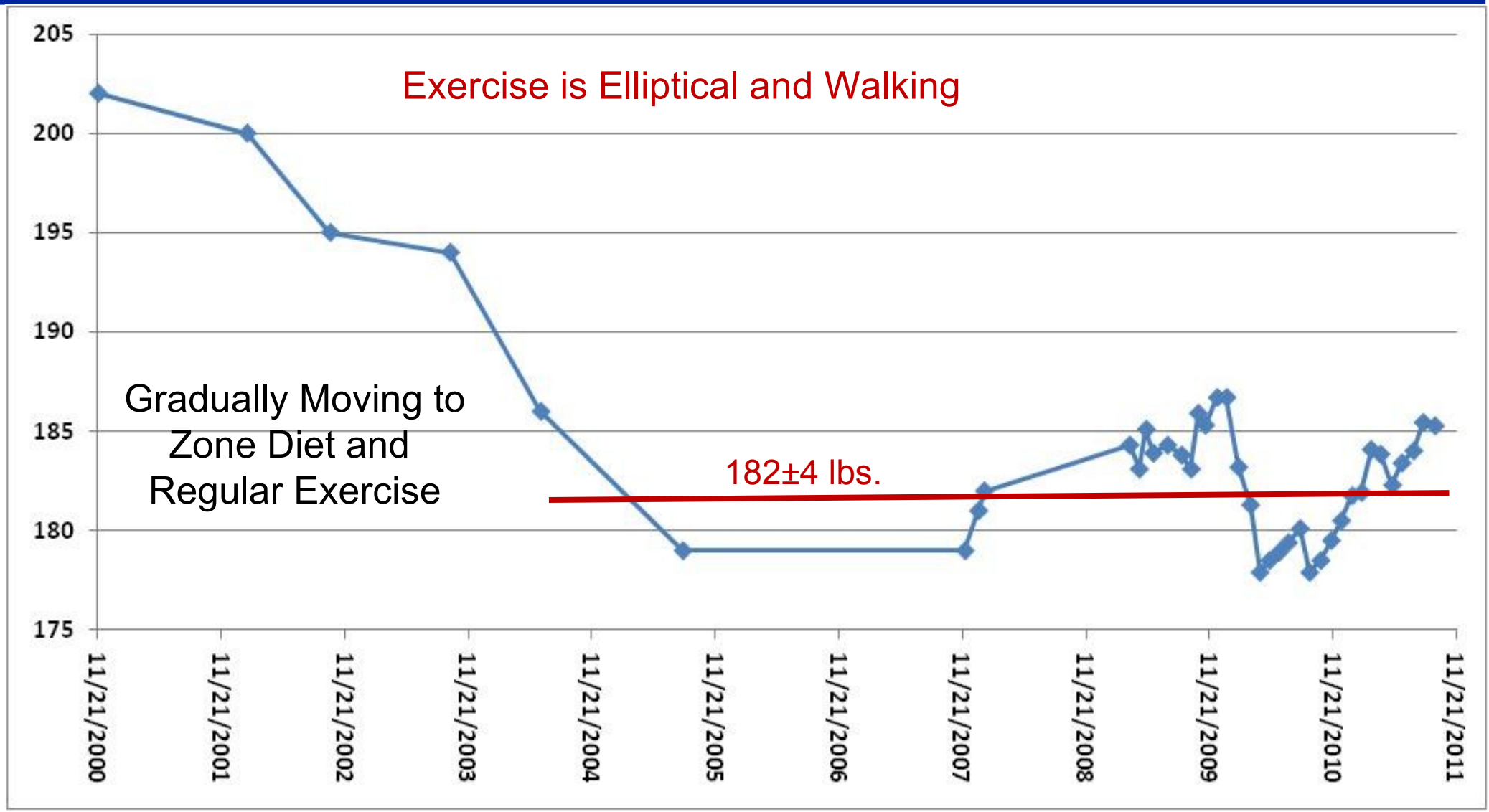


Age 61

I Reversed My Body's Decline By Altering My Nutrition and Exercise

See the full story at:
http://lsmarr.calit2.net/repository/092811_Special_Letter,_Smarr.final.pdf

I Lost Weight by Changing What & How Much I Eat, While Increasing Aerobic and Weight Bearing Exercise



Current Weight 180

Average Blood Pressure 134/73, Pulse 55

Resting Pulse Lowered to 45

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I Quantify My Food Intake So I Can "Tune" My Glucose/Insulin System and Lower Inflammation

Computed Average Over 12 Days When at Home for Maximum Accuracy
Measure All Food and Drink Components,
Then Use USDA Lookup to Compute Each Item

calories	fat	carb	protein		fiber	sugar	sodium
kcal	g	g	g		g	g	mg
1441	46	122	80	0	26	53	1358

Measuring Daily Food Intake Needs More "LifeChips"!

- **Quality of Food**
  - **All Organic and Mostly Locally Grown**
  - **Carbs are Low Glycemic Index**
    - **No Added Sugar or Refined Flour – Mostly Fruits and Vegetables**
  - **Proteins are Lean**
    - **Meat is Grass Fed – No Corn or Antibiotics**
    - **Fish is Wild, Often Locally Caught**
  - **Fats are Omega-3 Rich**
    - **Supplemented by 7g Daily Pharmaceutically Purified Fish Oil Pills**

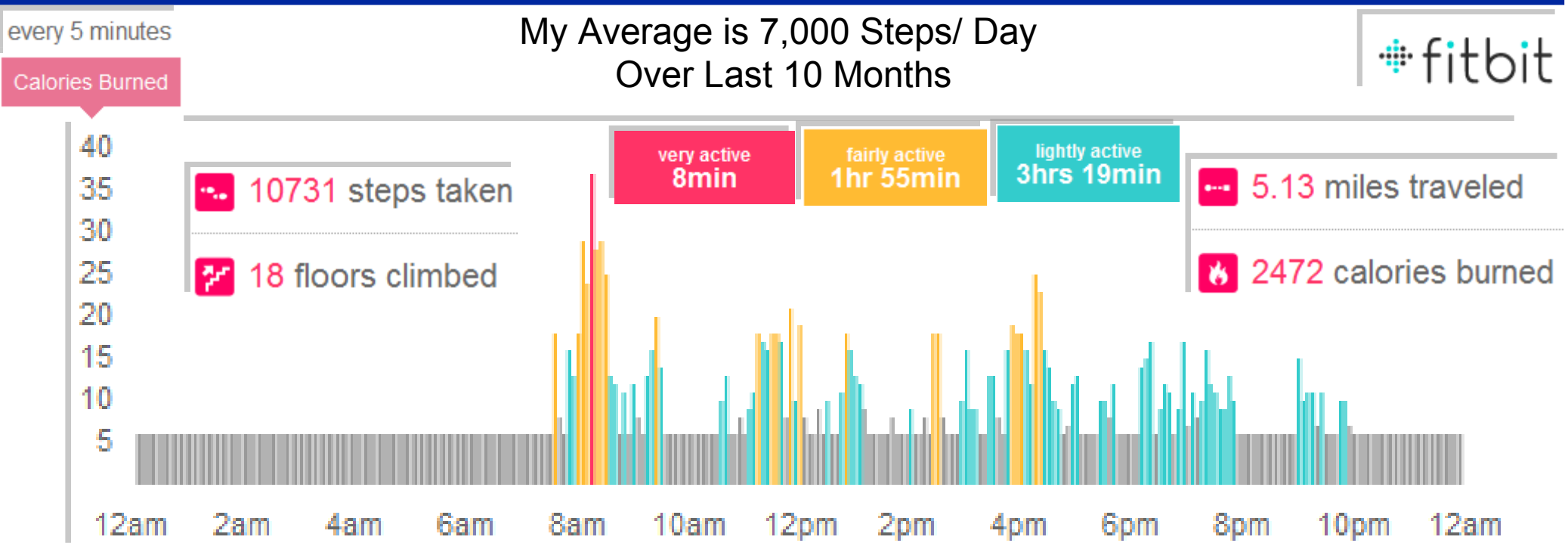
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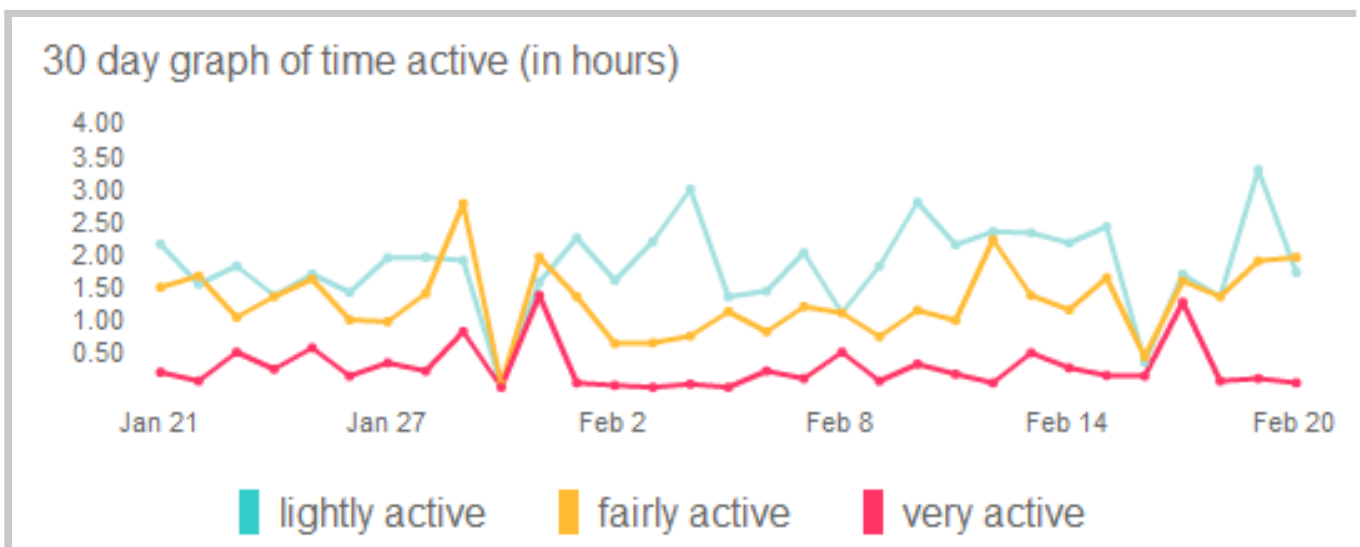
For my recommendations on nutrition, exercise, sleep and stress, see:
http://lsmarr.calit2.net/repository/LS_reading_recommendations_FiRe_2011.pdf

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Wireless Monitoring Helps Drive Exercise Goals

My Average is 7,000 Steps/ Day
Over Last 10 Months



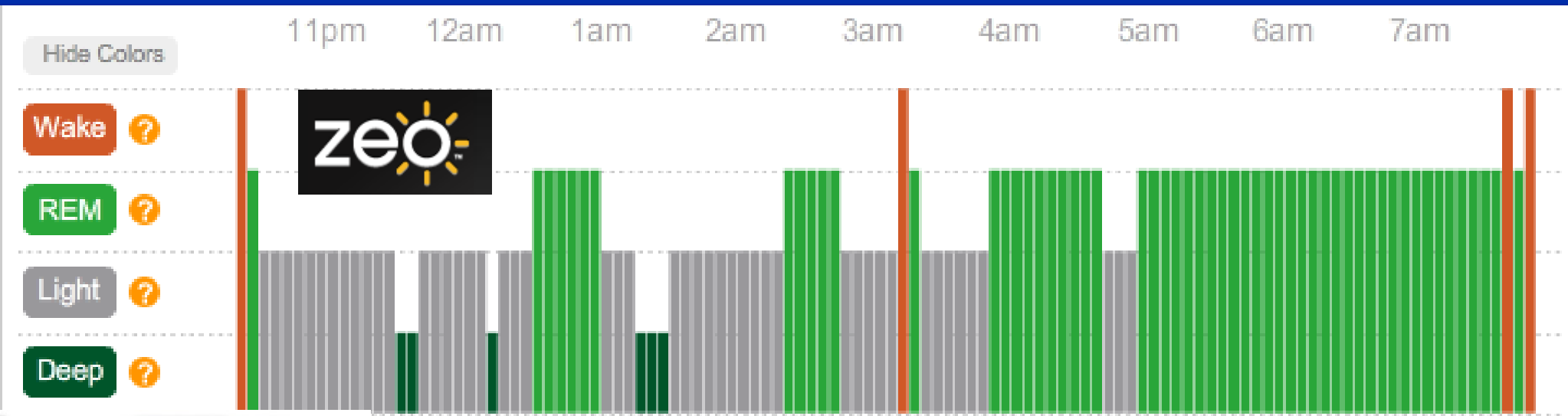




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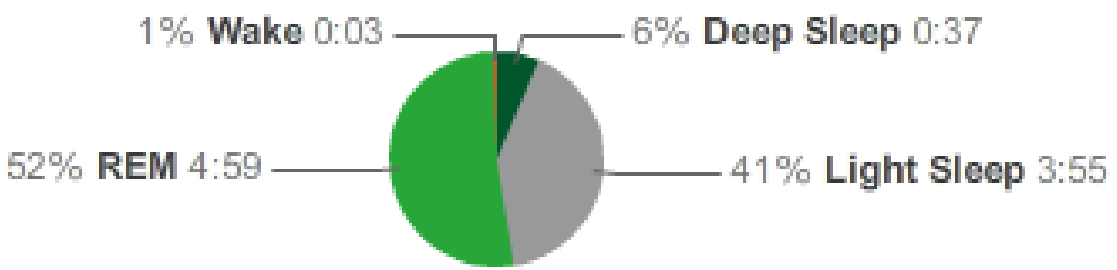
Quantifying My Sleep Pattern Using a Zeo - Surprisingly About Half My Sleep is REM!





Total Z: 9 hr 31 min

Time to Z: 0 hr 2 min



Why are these numbers different from the sleep graph above?

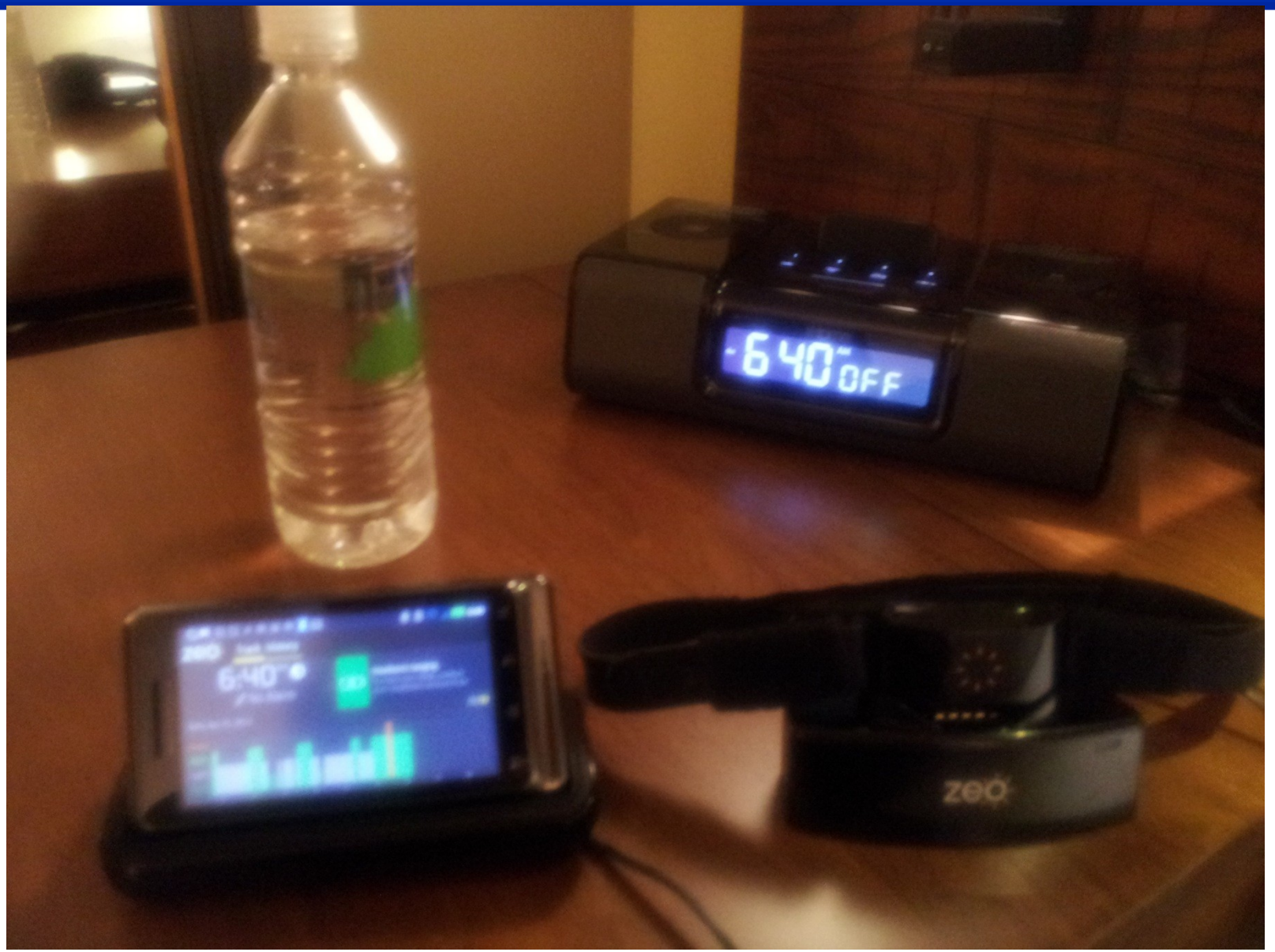
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REM is Normally 20% of Sleep
Mine is Between 45-65% of Sleep

An Infant Typically
Has 50% REM

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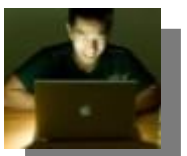
On the Road Zeo Solution:
Link Headband to Android Smartphone



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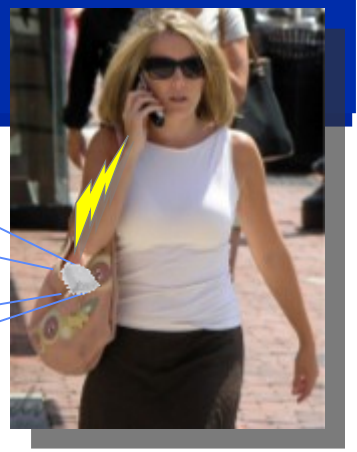
CitiSense –New NSF Grant for Fine-Grained Environmental Sensing Using Cell Phones

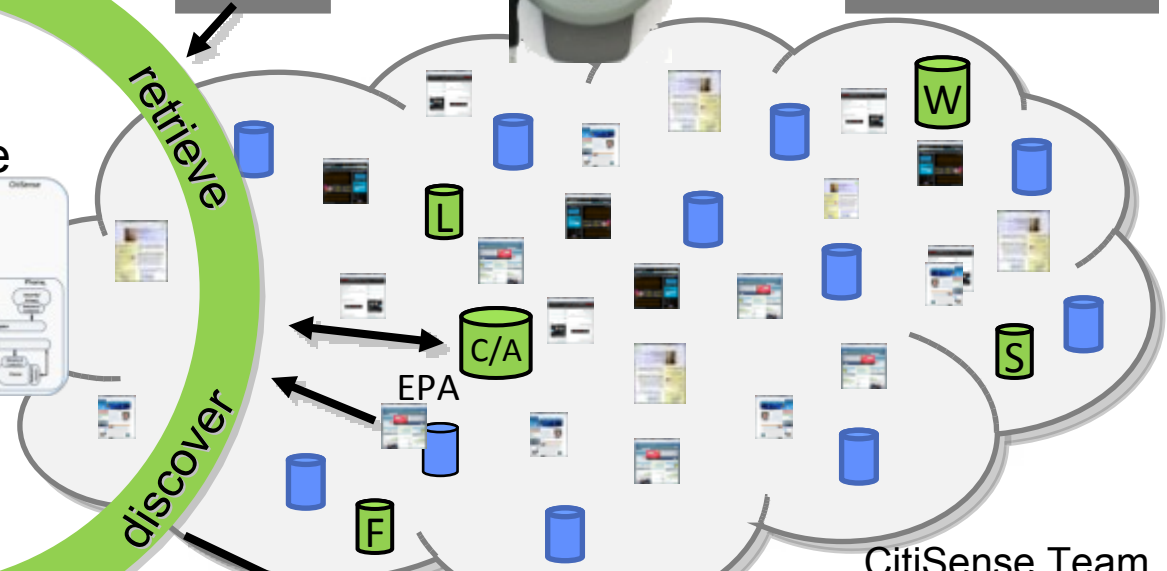




4oz
30 compounds

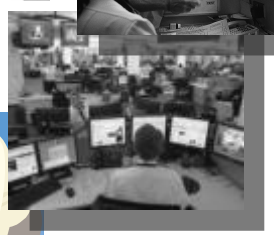












Integrate Into a "LifeChip"

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



From Measuring Macro-Variables to Measuring Your Internal Variables



www.technologyreview.com/biomedicine/39636

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

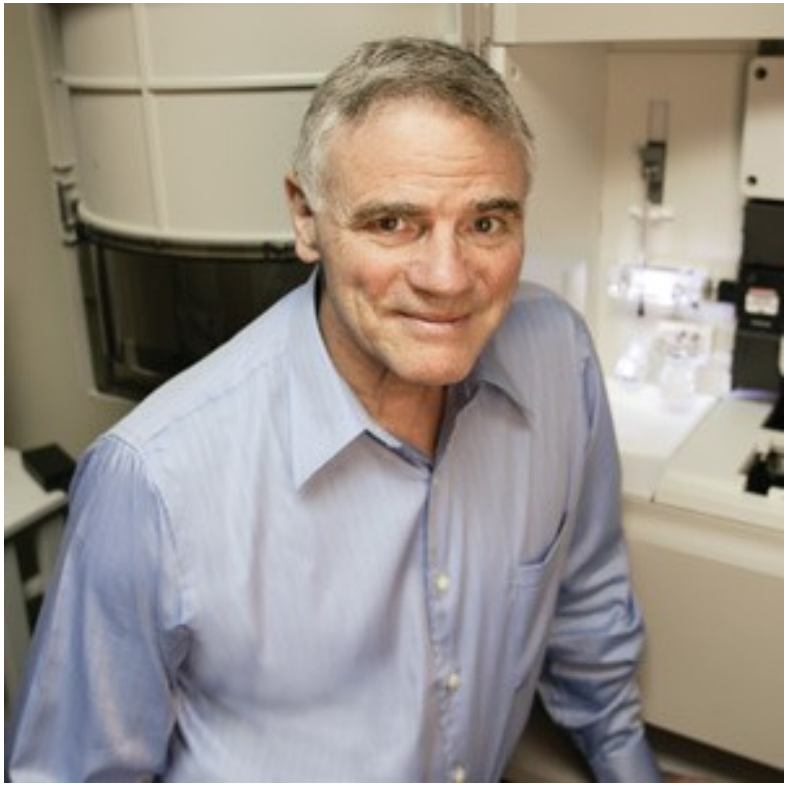
Newsweek

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

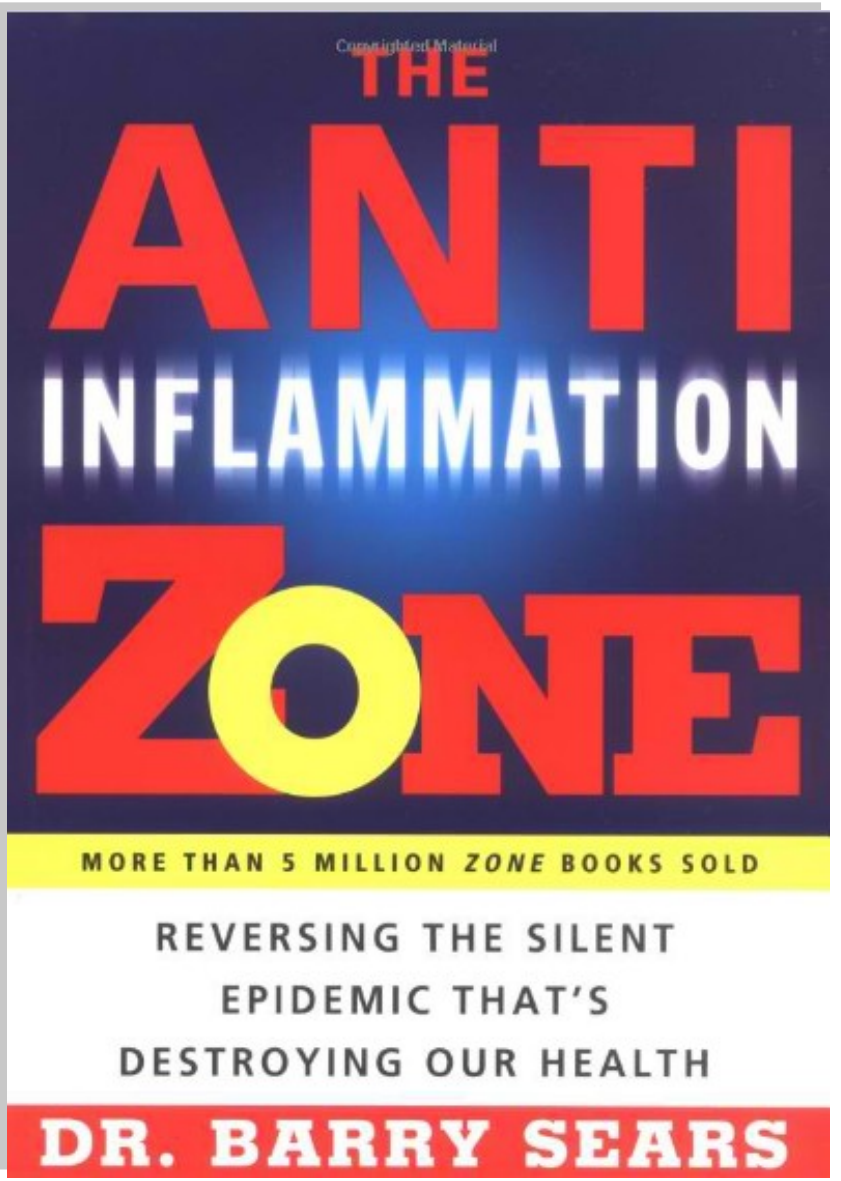
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www.newsweek.com/2009/06/26/a-doctor-s-vision-of-the-future-of-medicine.html

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Tracking and Reducing Inflammation is Critical to Your Health



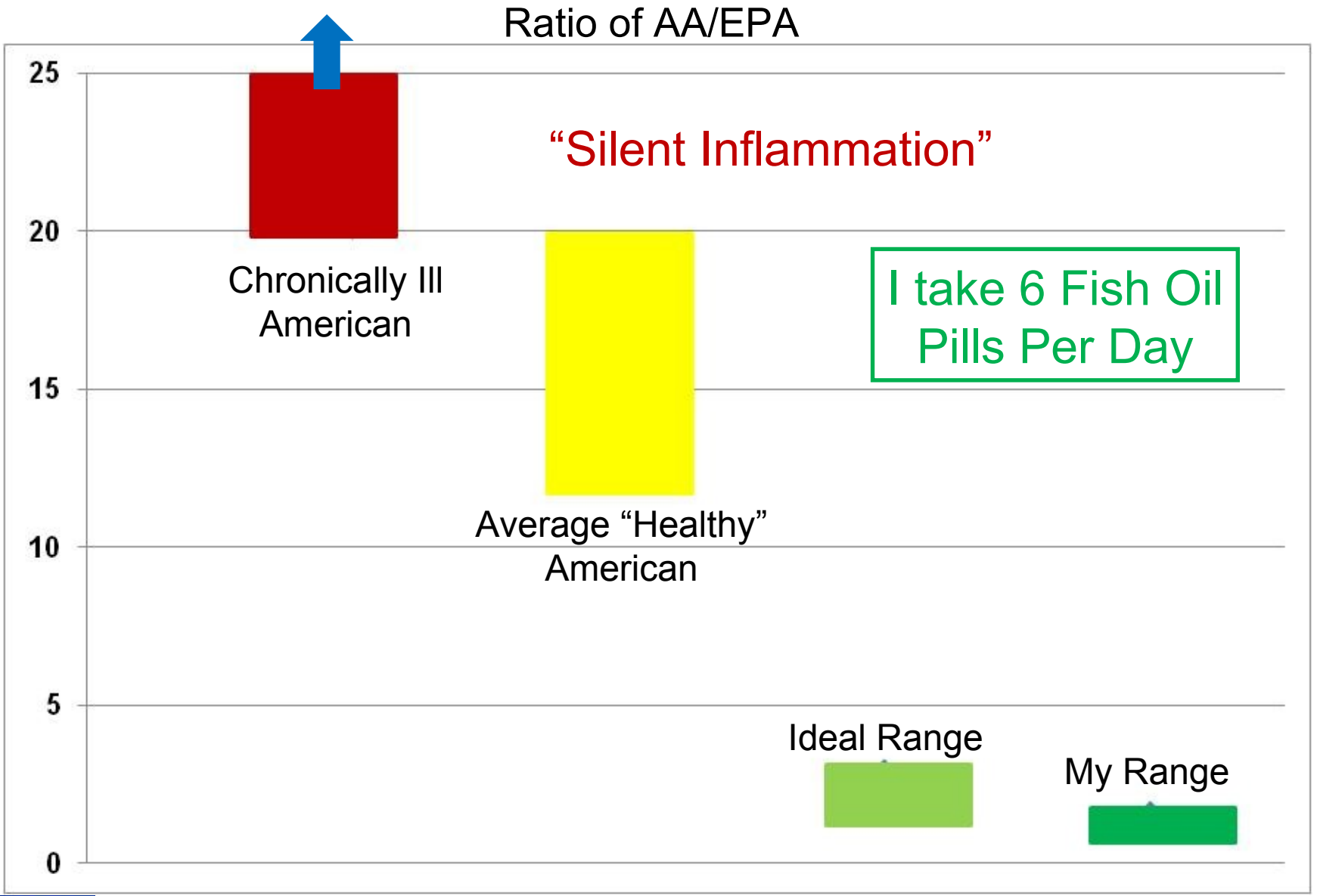


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I Have Greatly Lowered My Body's Inflammation From Food By Increasing Omega-3s

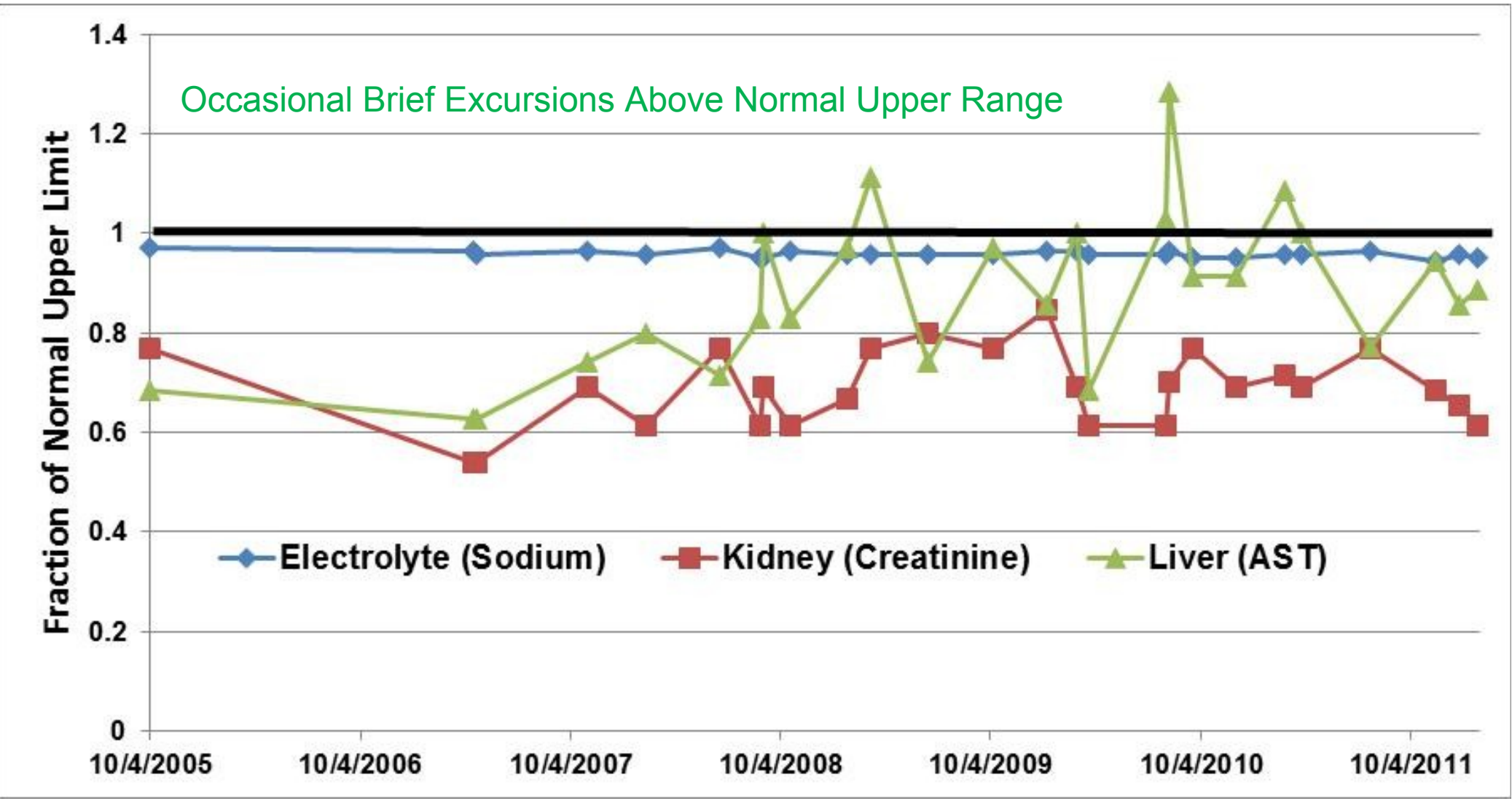


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Range Source: Barry Sears
My Tests by www.yourfuturehealth.com

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Most Blood Variables Stay Within Normal Range: Fraction of Normal Upper Range For Three Variables



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My Quarterly Blood Tests In Addition to Lipids: Only One Was Far Beyond Normal Limits

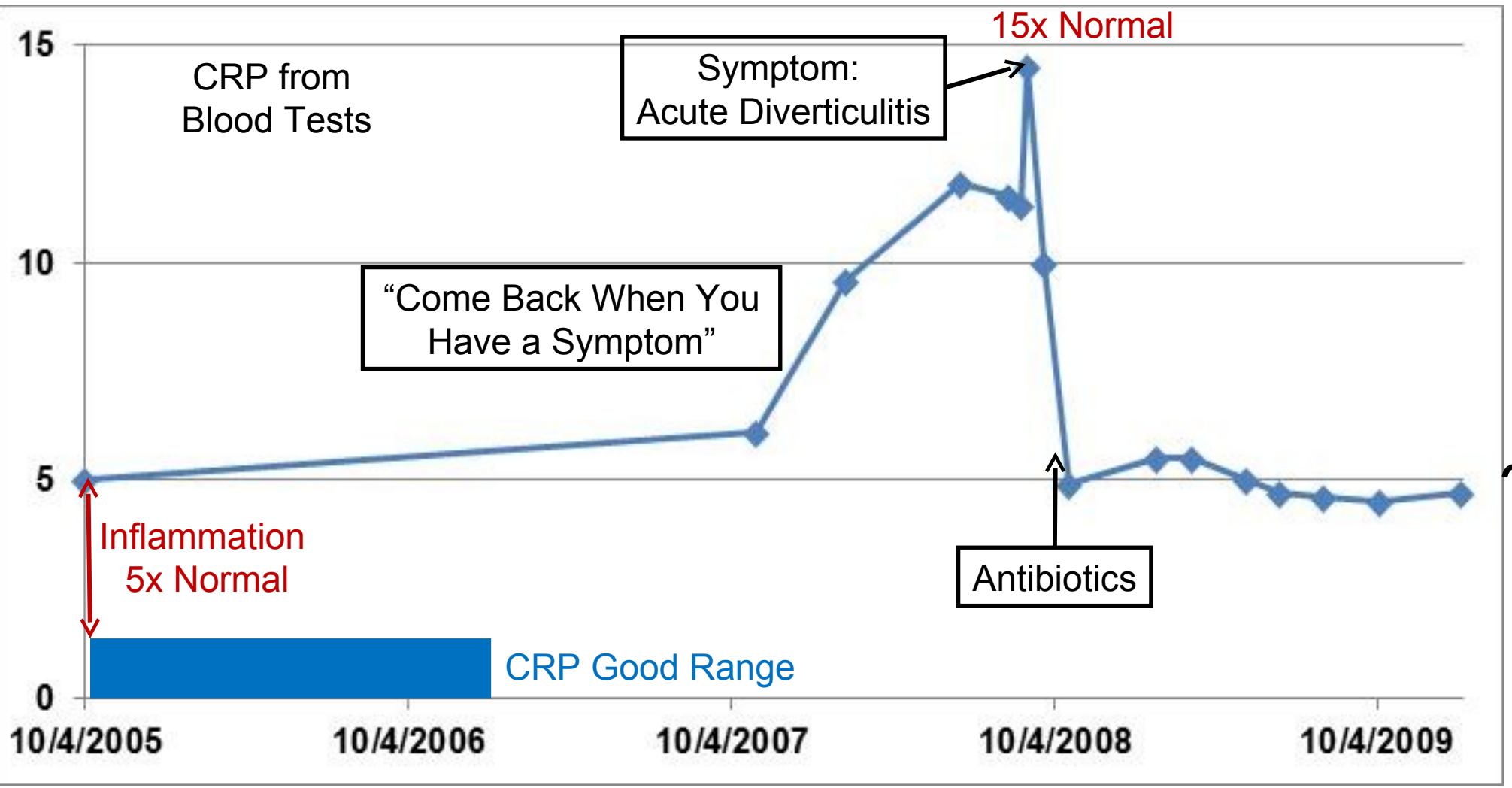
- **Electrolytes**
  - Sodium, Potassium, Calcium, Magnesium, Phosphorus, Boron, Chlorine, CO_2
- **Micronutrients**
  - Arsenic, Chromium, Cobalt, Copper, Iron, Manganese, Molybdenum, Selenium, Zinc
- **Blood Sugar Cycle**
  - Glucose, Insulin, A1C Hemoglobin
- **Cardio Risk**
  - Complex Reactive Protein (CRP)
  - 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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I Track Over 100 Blood Variables Over Time

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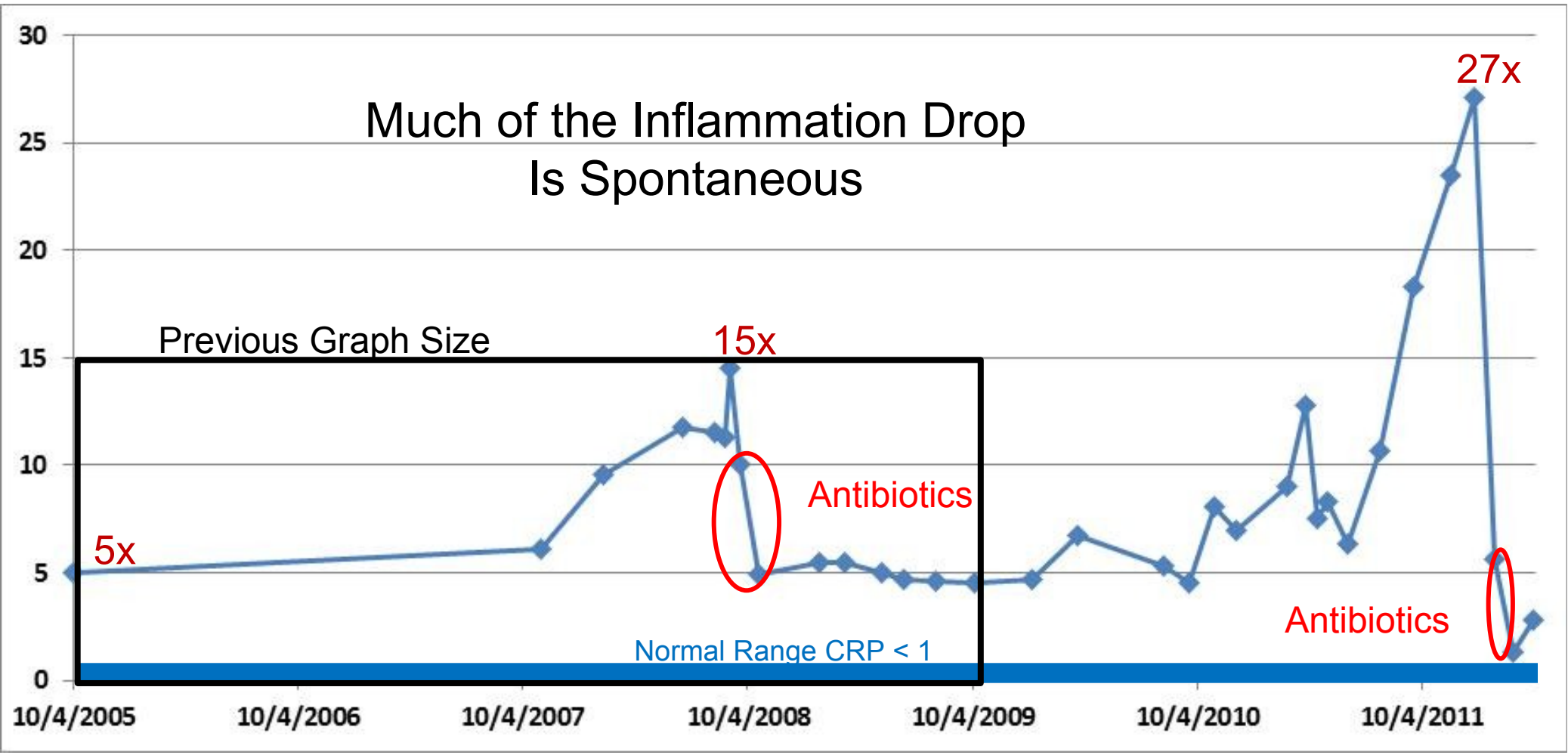
Blood Measurements Reveal Chronic Inflammation Via Complex Reactive Protein Biomarker



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Inflammation is Episodic and Growing: What Could be the Cause?



Demonstrates Value of Fine-Grained Time Series

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CRP and LDL Cholesterol Co-Create Arterial Plaque

High CRP



Arterial Plaque Formation

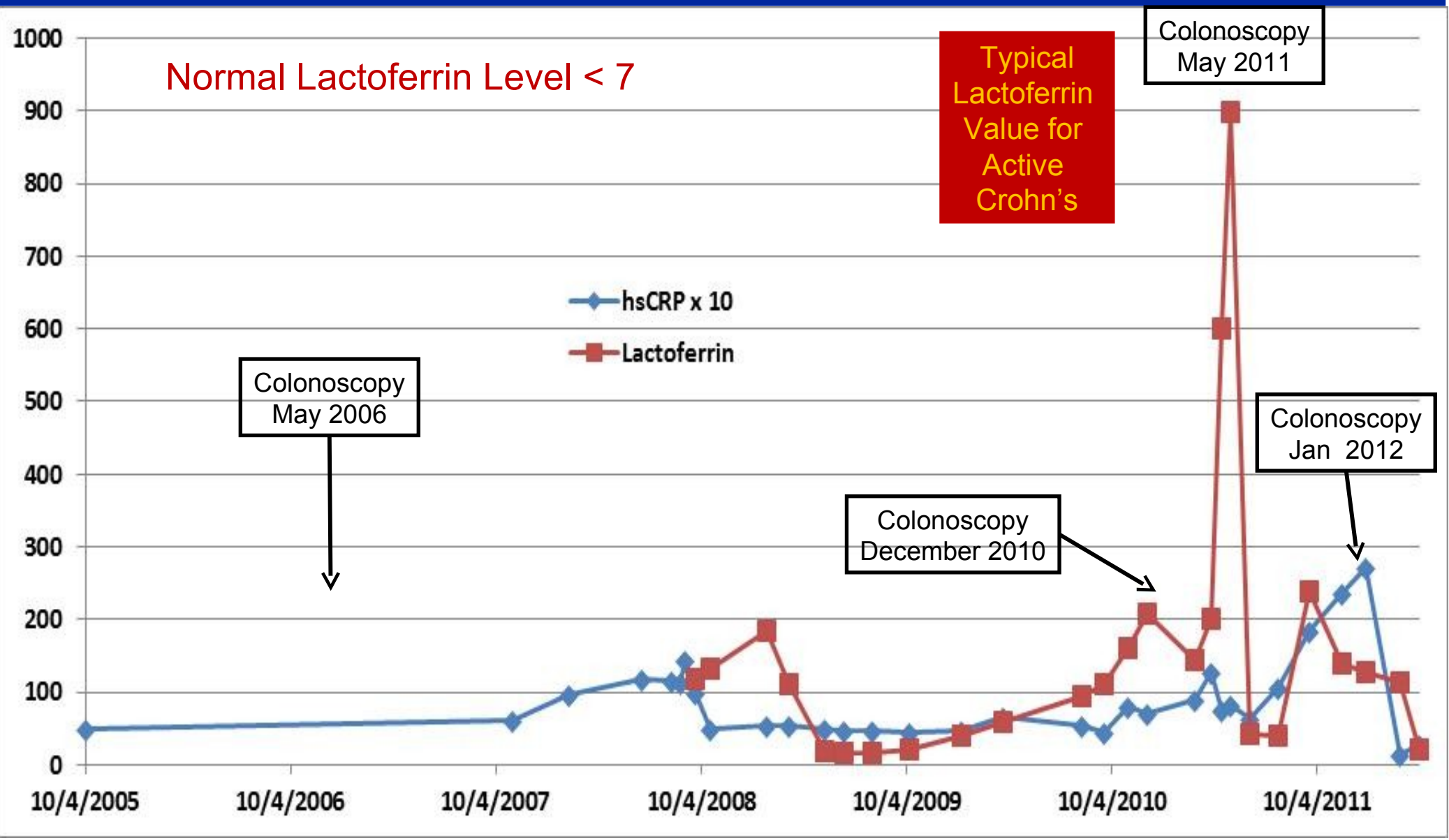
CRP > 4.2, 5x Risk of Future Heart Disease

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http://sjog.org.au/pathology/pathology_wa/doctor_resources/clinical_articles/high_sensitivity_crp.aspx

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Frequent Stool Analysis Reveals Lactoferrin Spike to Active Crohn's Disease (CD) Level

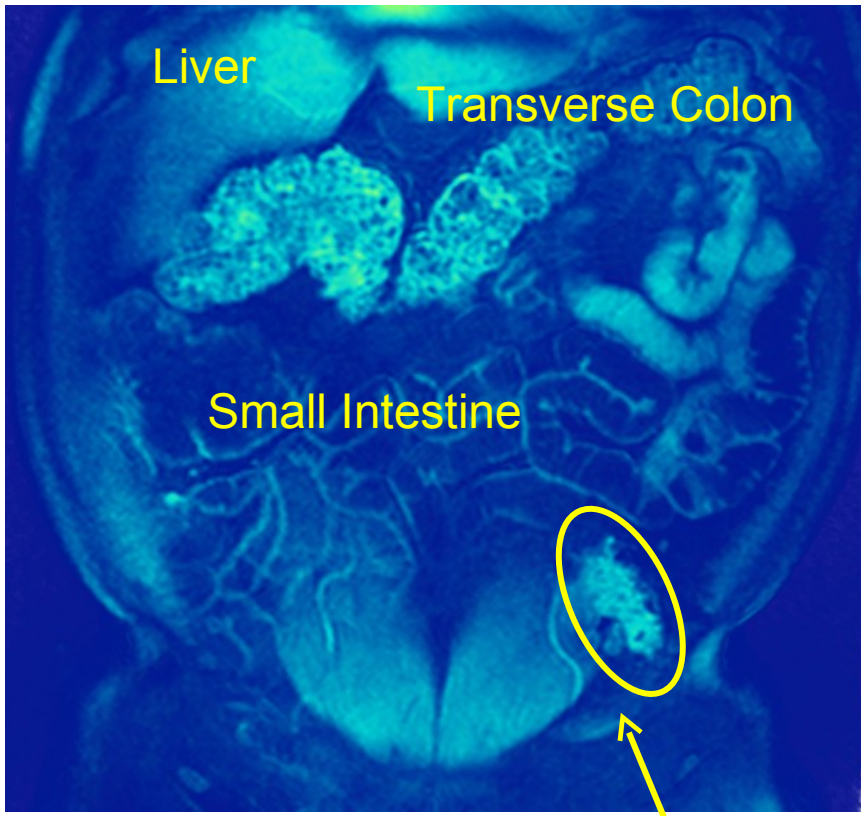


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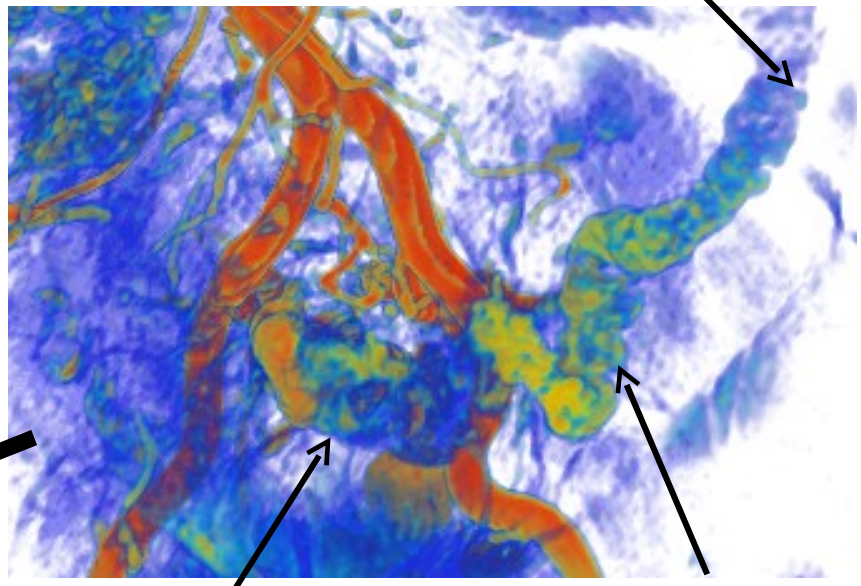
Colonoscopy and Biopsies Support CD Diagnosis

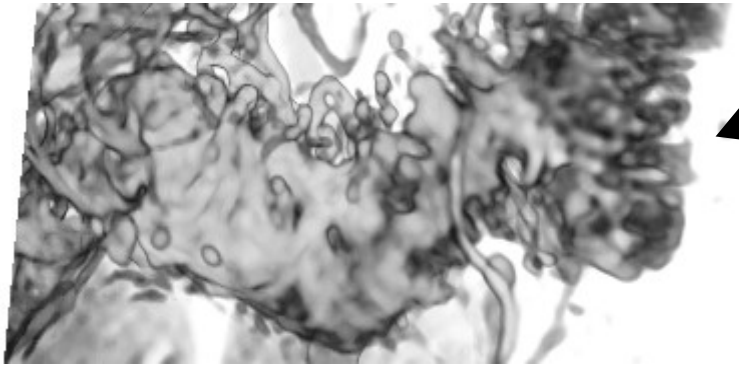
it²

Confirming the 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





Sigmoid Colon
Threading Iliac Arteries

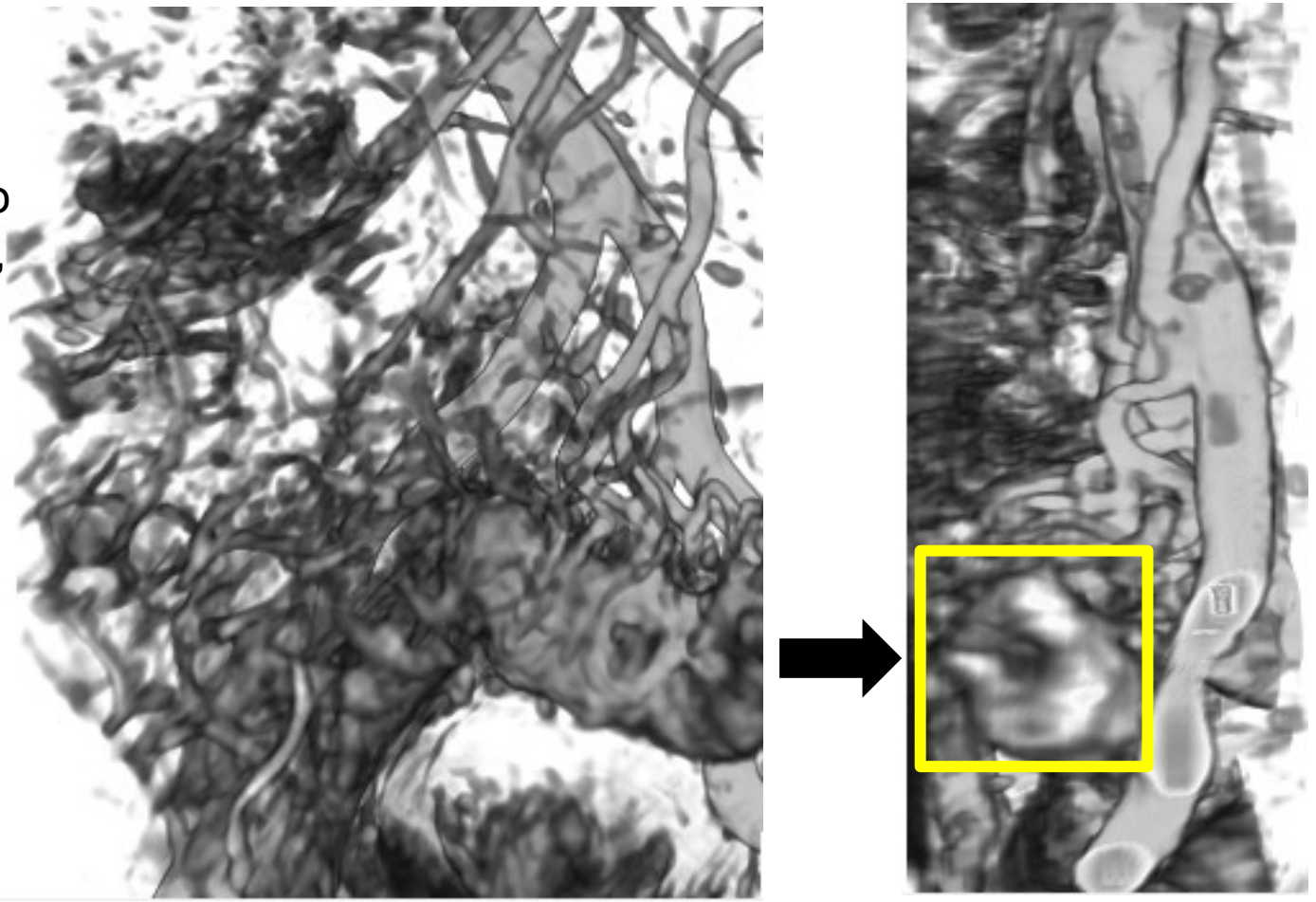
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LS Sigmoid Colon Cross Sections Showing Inflamed Wall

Jan 2012 MRI Enterography report: “long segment wall thickening in the proximal and mid portions of the sigmoid colon, extending over a segment of approximately 16 cm, with suggestion of intramural sinus tracts.

Ulcerative Colitis is Restricted to the Mucosa, while Crohn's Disease Affects the Whole Bowel Wall

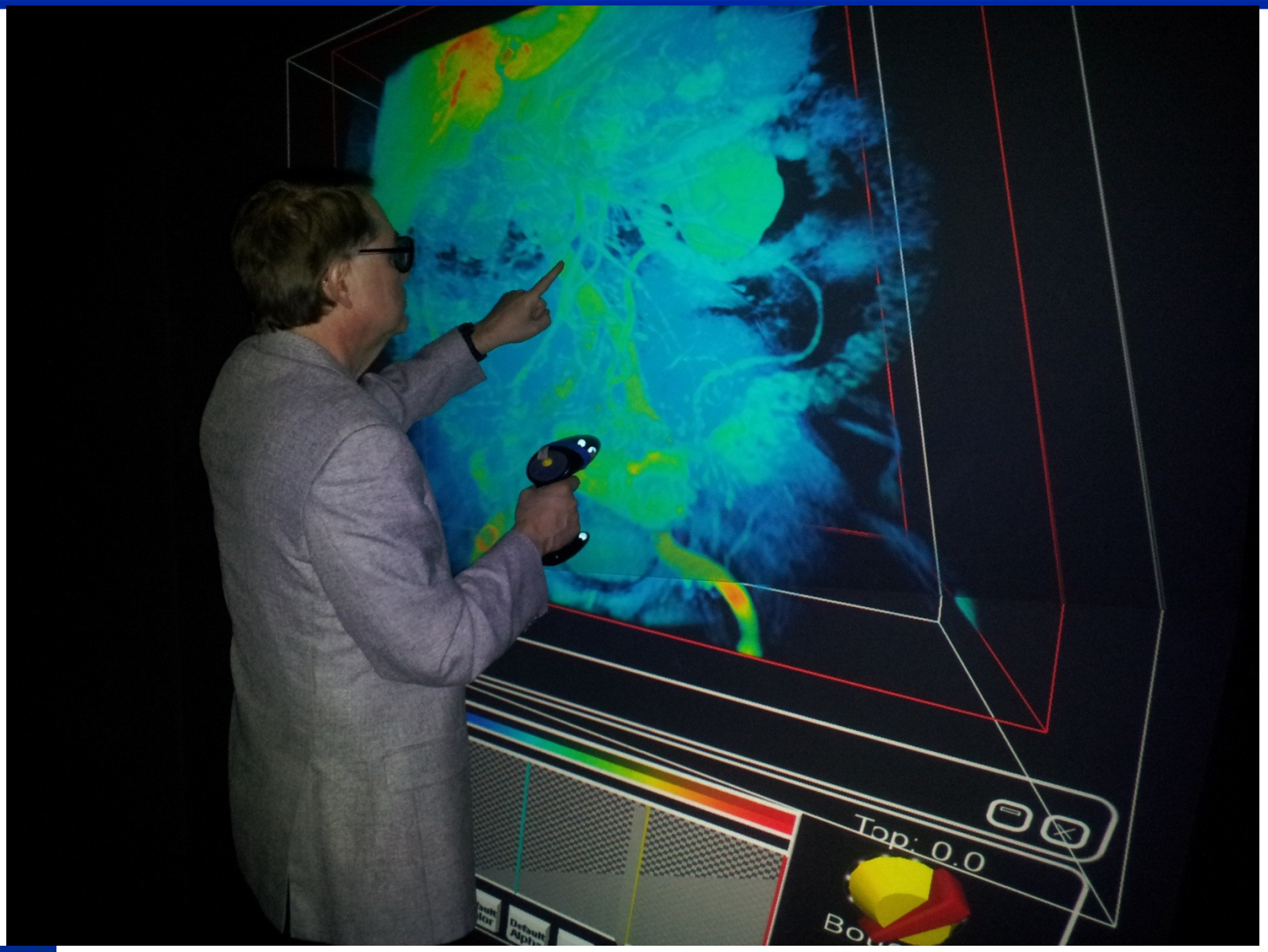


Note Thickness of Wall - Normal is 3mm (like a Balloon)

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Source: L Smarr Using Calit2’s Jurgen Schultz Software

Exploring My Internal Organs in the Calit2 Virtual Reality CAVE Using DeskVOX Software



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Photo & DeskVOX Software Courtesy of Jurgen Schulze, Calit2

it²

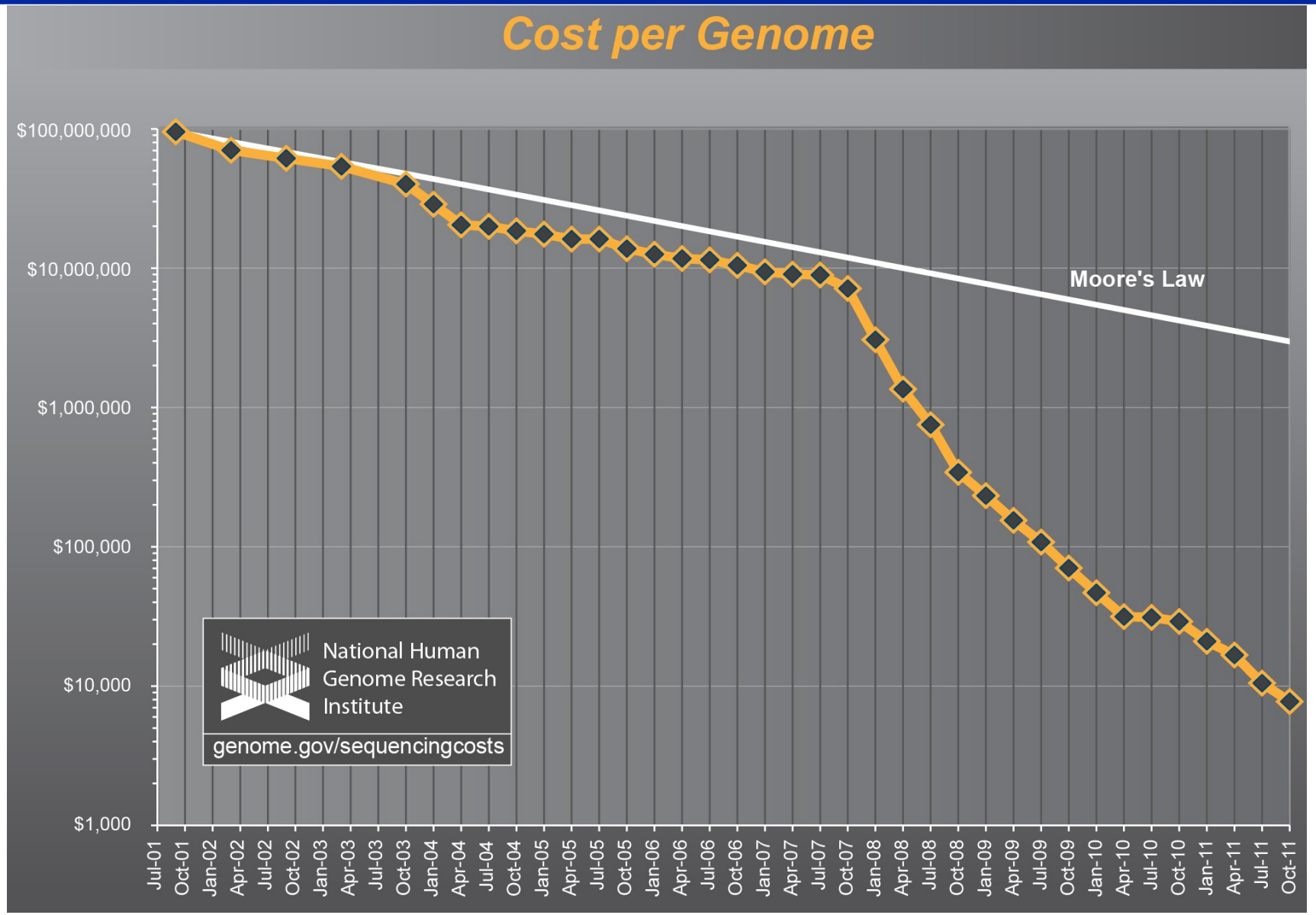
Autoimmune Diseases
Effect 5-8% of Americans

- **Crohn's Disease**
- **Ulcerative Colitis**
- **Rheumatoid Arthritis**
- **Multiple Sclerosis**
- **Psoriasis**
- **Type 1 Diabetes,**
- **Ankylosing Spondylitis**
- **Lupus Erythematosus**
- **Plus Over 70 Others**

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

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



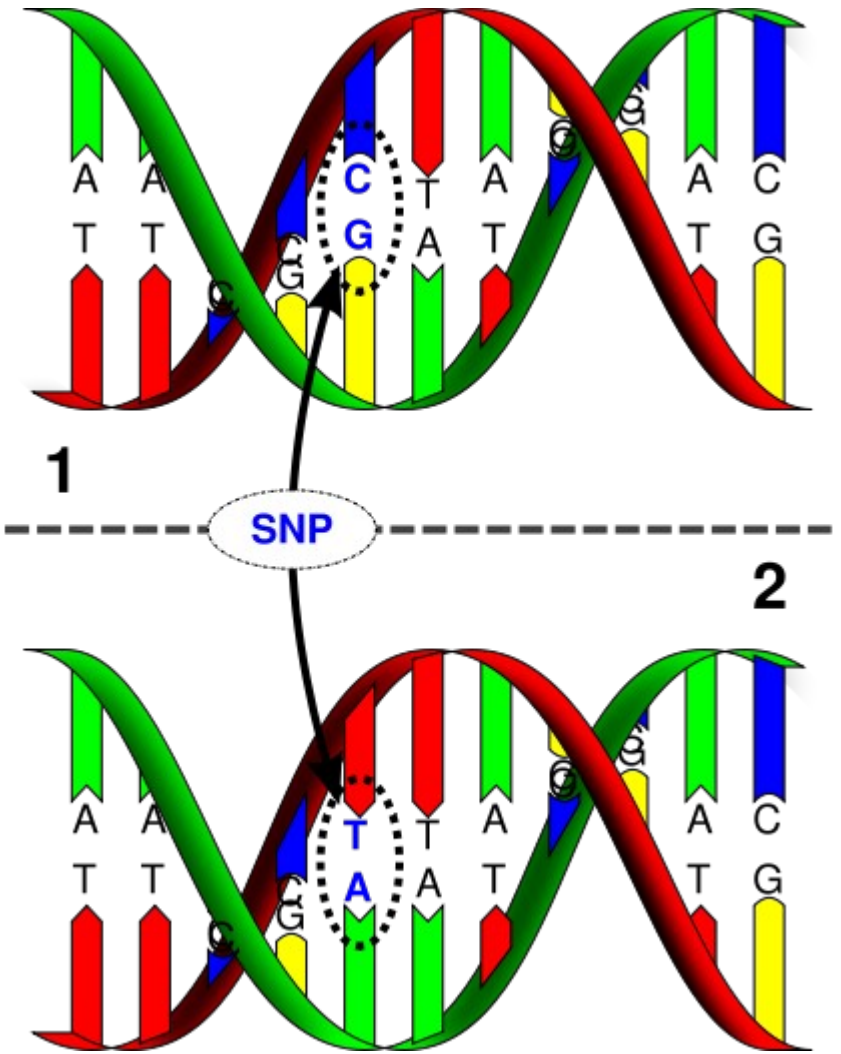
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This Has Enabled Sequencing of
Both Human and Microbial Genomes

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

Person A



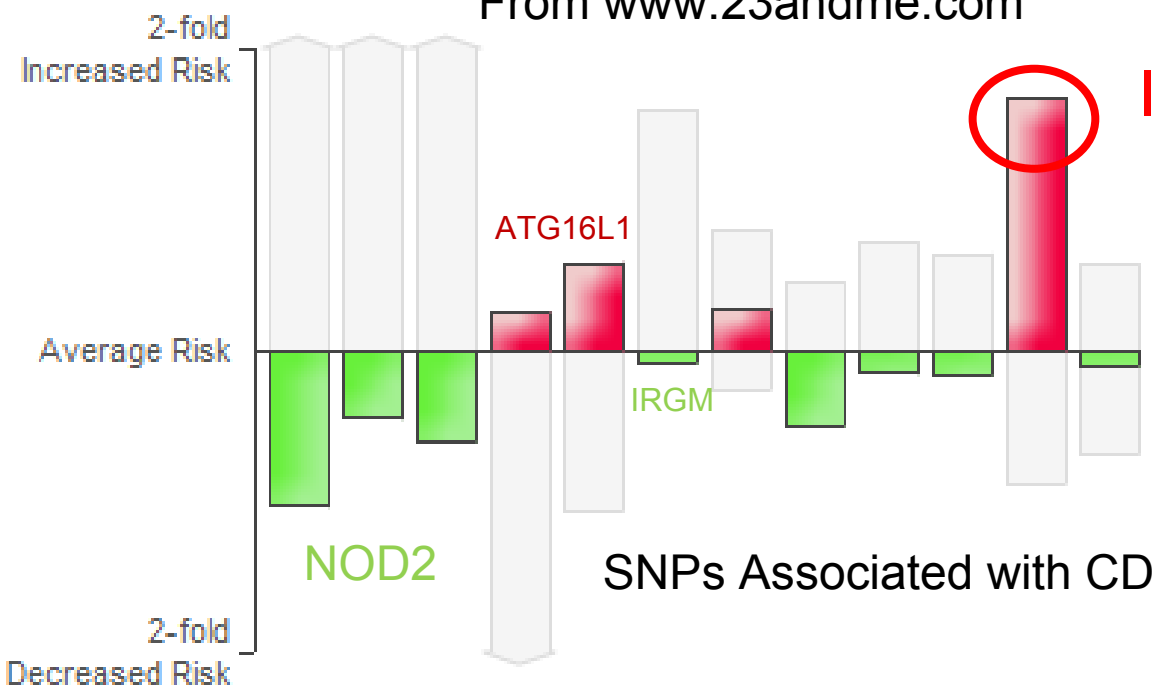
Person B

SNPs Occur Every 100 to 300 Bases Along Human DNA

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

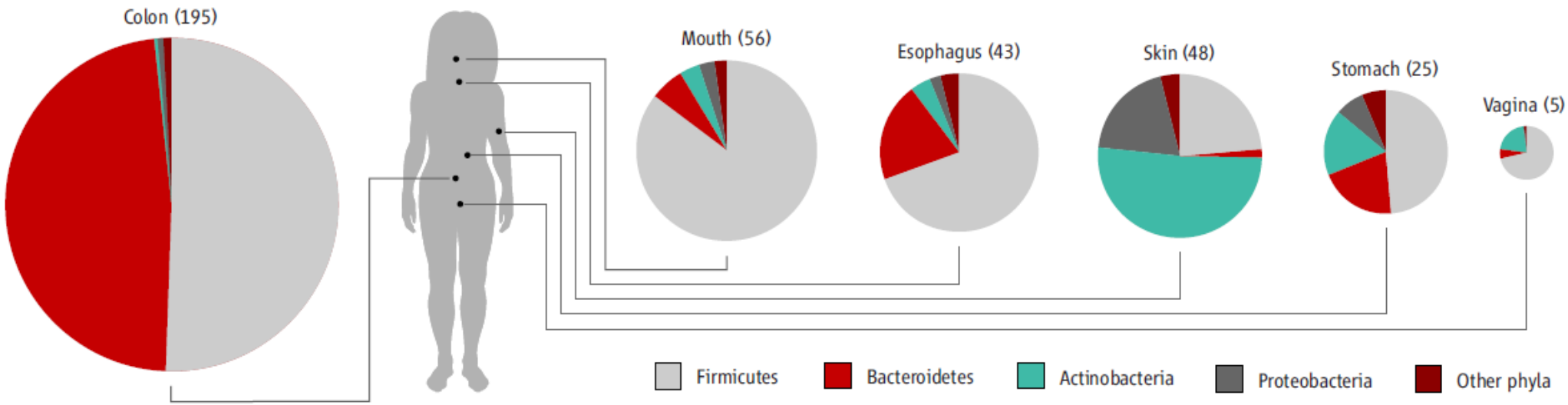
Markus F Neurath[1]

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You are a Superorganism:
Your Body Has Ten Microbes for Every Human Cell!

Human Microbiome Project

The NIH Common Fund
WE ACCELERATE DISCOVERY.



Firmicutes Are the Dominant Phyla
in the Human Microbiome

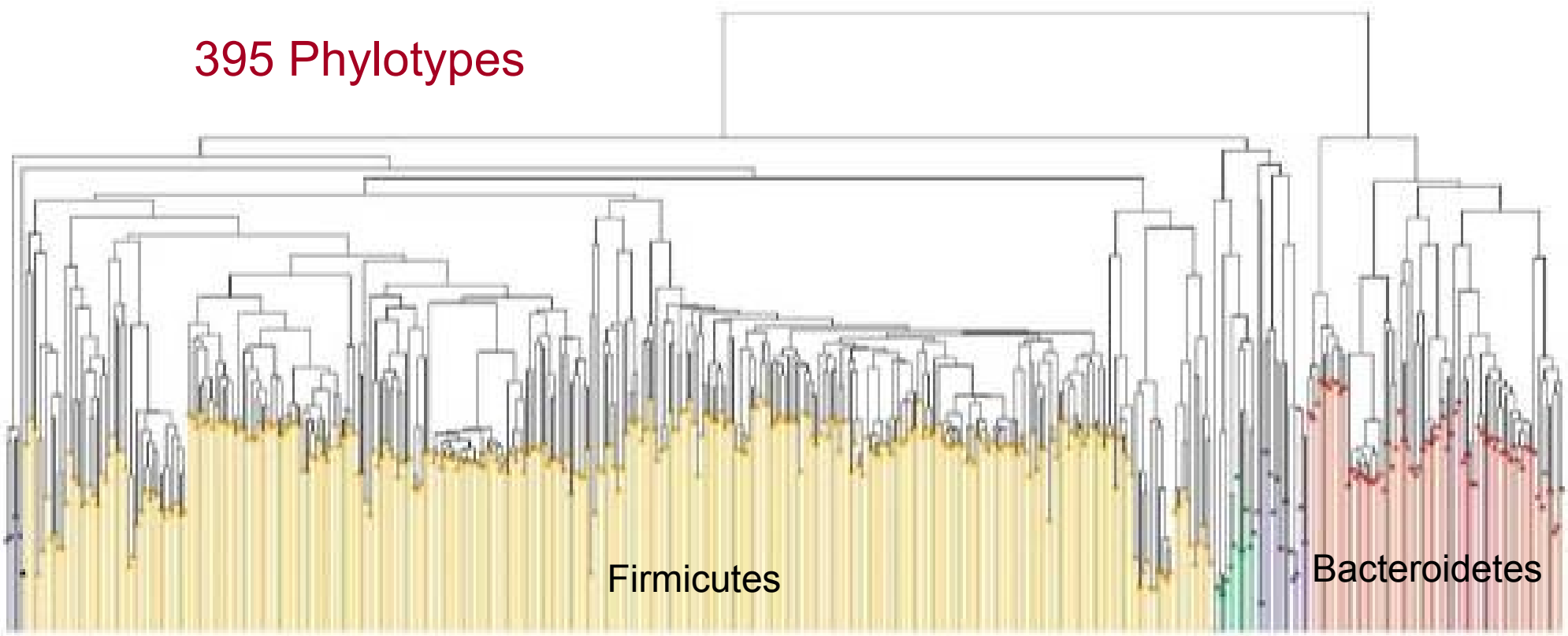
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Science v.330, p. 1619 (2010)

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The Gut Microbiome Has Been Mapped in the Last Five Years Using Genome Sequencing

"A majority of the bacterial sequences corresponded to uncultivated species and novel microorganisms."

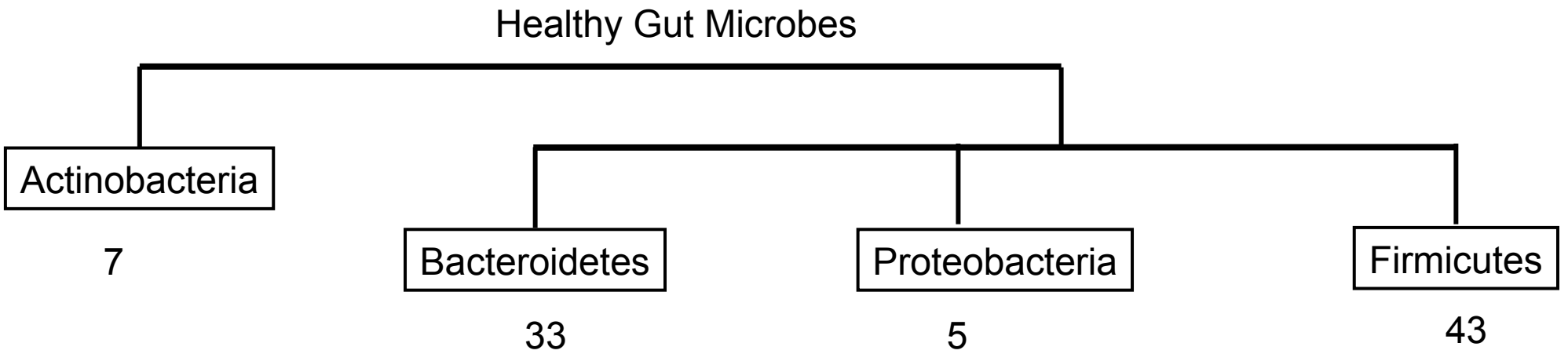


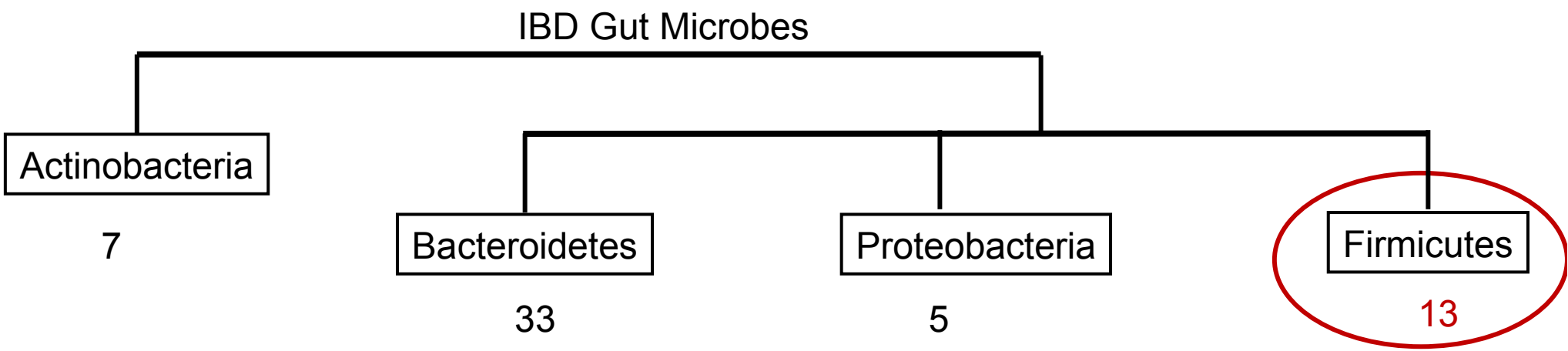
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"Diversity of the Human Intestinal Microbial Flora"
Paul B. Eckburg, et al *Science* 308, 1635-8 (2005)

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Crohn's Disease Patients Have Number of Firmicute Gut Microbe Species Reduced by Over 2/3!





The Missing Firmicutes Inhibit Pro-Inflammation

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Manichanh, et al, *Gut* 2006;55:205–211

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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."

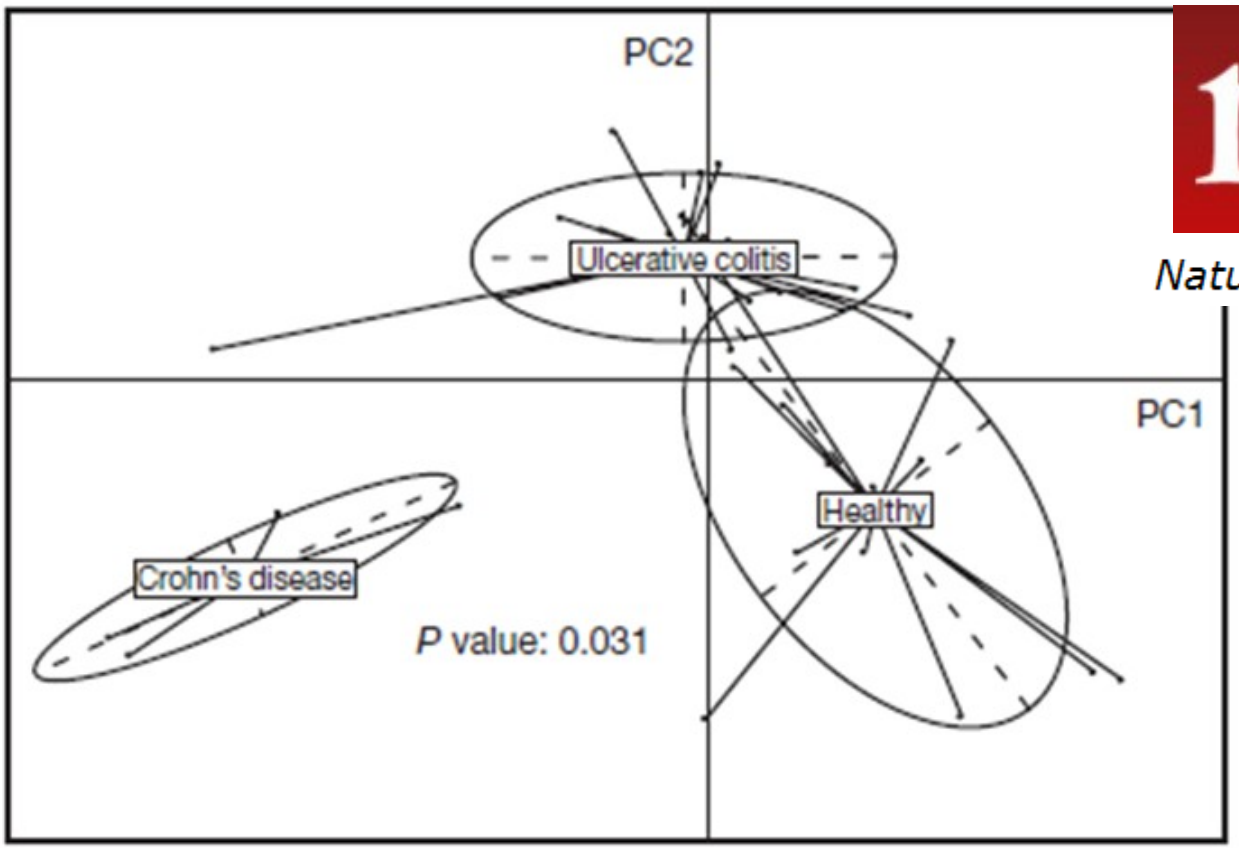
DNA microarray that can identify, within hours, over 50,000 different microbes



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Microbial Metagenomics Can Diagnose Disease States



nature

Nature **464**, 59-65 (4 March 2010)

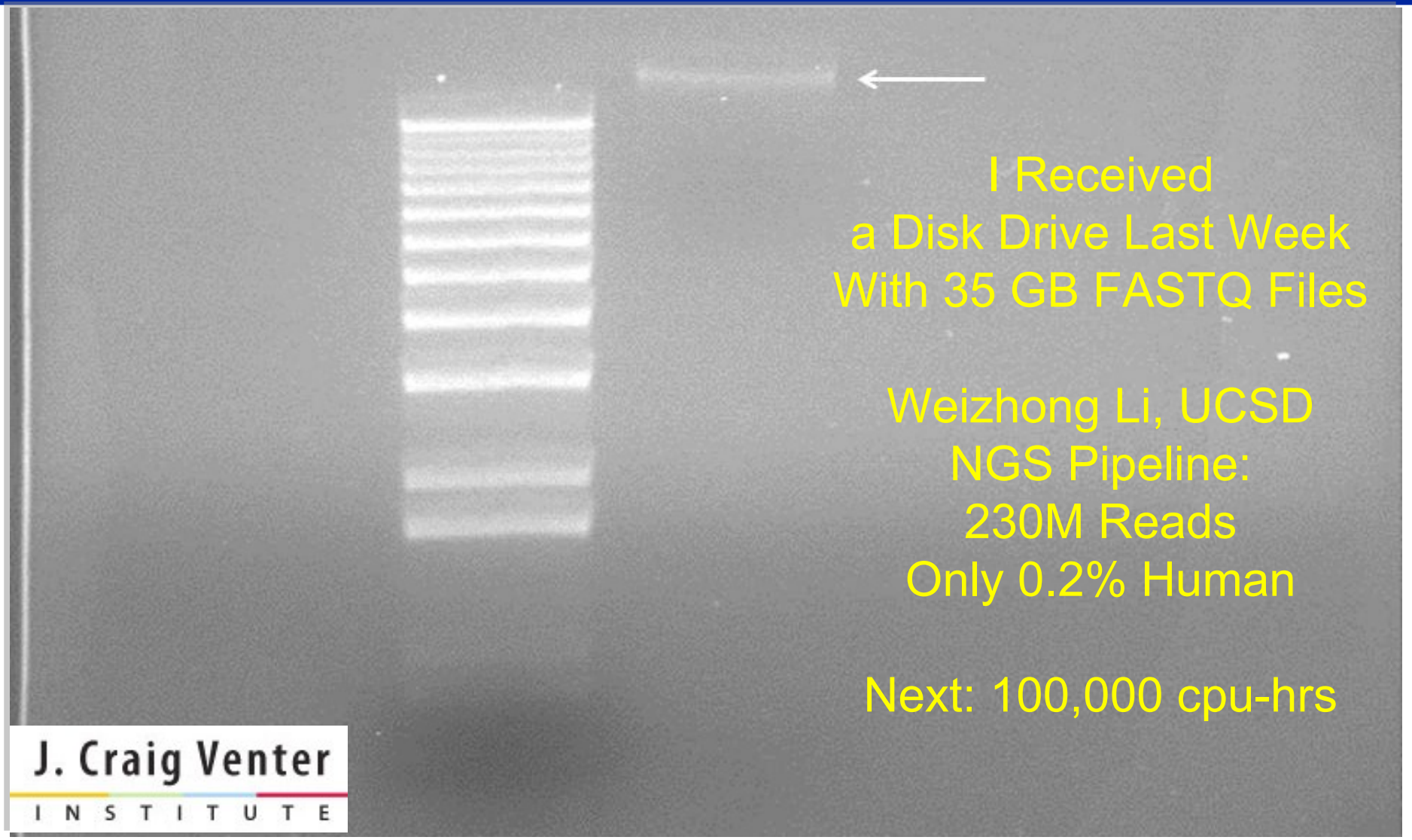
IBD Patients Harbored, on Average, *25% Fewer Microbial Genes* than the Individuals Not Suffering from IBD.

Figure 4 | Bacterial species abundance differentiates IBD patients and healthy individuals. Principal component analysis with health status as

A human gut microbial gene catalogue established by metagenomic sequencing

Junjie Qin[1]*, Ruiqiang Li[1]*, Jeroen Raes[2,3], Manimozhiyan Arumugam[2], Kristoffer Solvsten Burgdorf[4],

Finding Out if I Have Missing Microbes: Metagenomic Sequencing of My Gut Microbiome



Gel Image of Extract from Smarr Sample-Next is Library Construction

Manny Torralba, Project Lead - Human Genomic Medicine
J Craig Venter Institute

January 25, 2012

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100,000 People Like Me Are Uploading Their Genomes and Medical Records

World DNA Day: April 25, 2012

GET Genomes Environments Traits CONFERENCE

I Have Been Accepted by PGP and Spoke at GET 2012:
"N=1: Pioneers of self-tracking"

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.

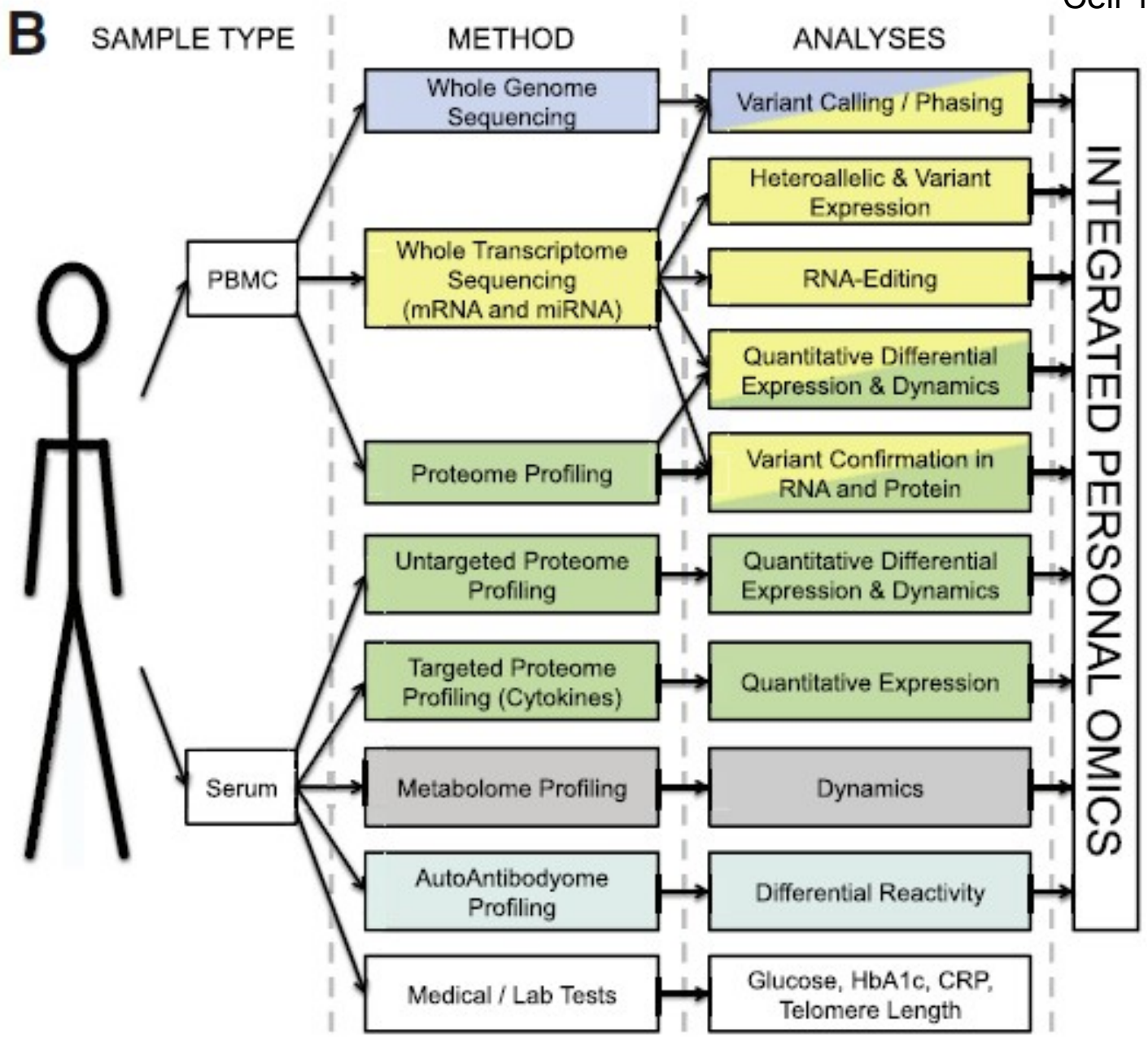
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GET Held at the Harvard Medical School

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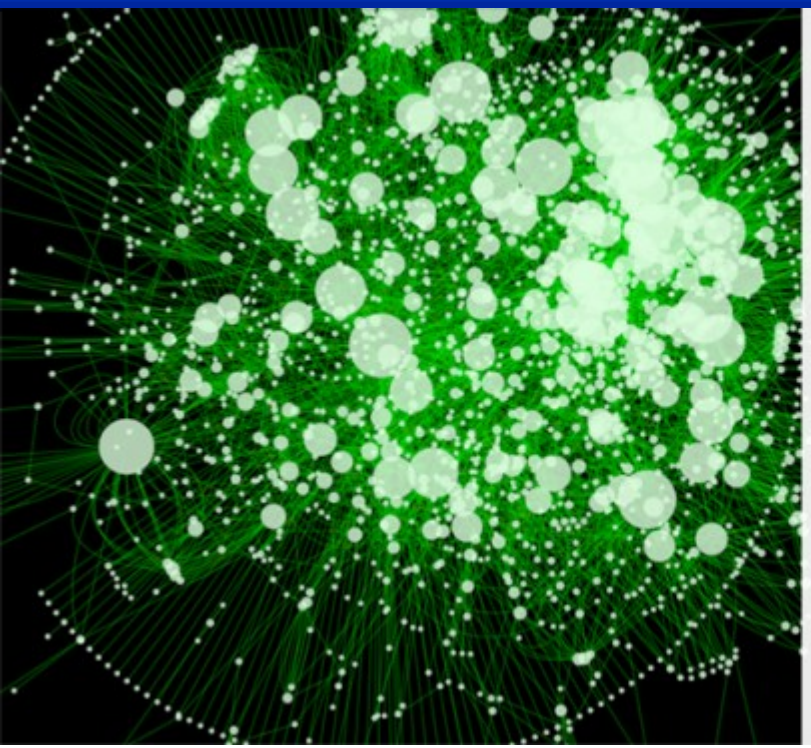
Integrative Personal Omics Profiling: 1000x the Data I Have Taken

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**

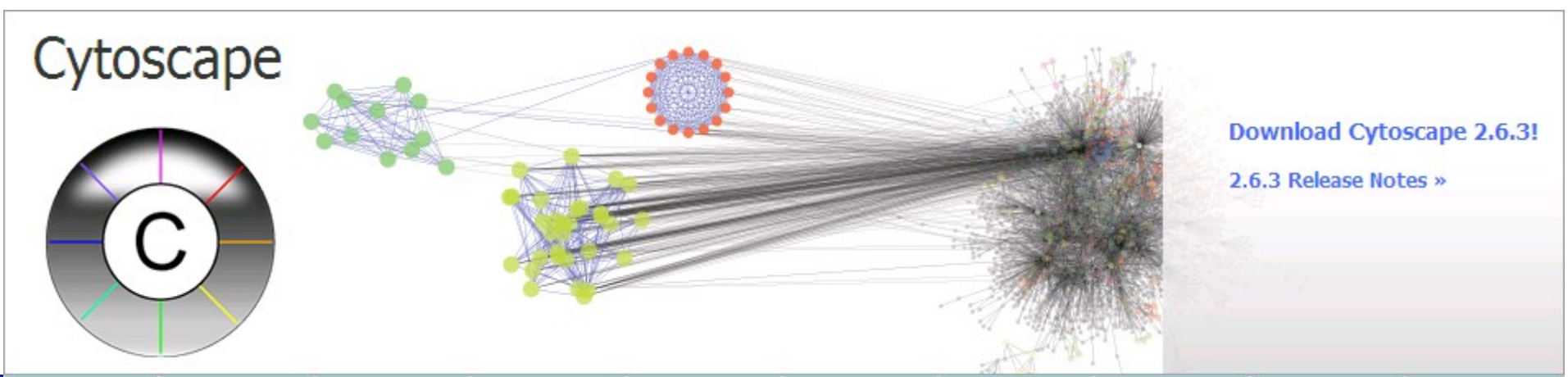
Integrating Systems Biology Data: Cytoscape



Cytoscape

An Open Source Platform for Network Analysis and Visualization

- **OPEN SOURCE Java Platform for Integration of Systems Biology Data**
- **Layout and Query of Interaction Networks (Physical And Genetic)**
- **Visual and Programmatic Integration of Molecular State Data (Attributes)**

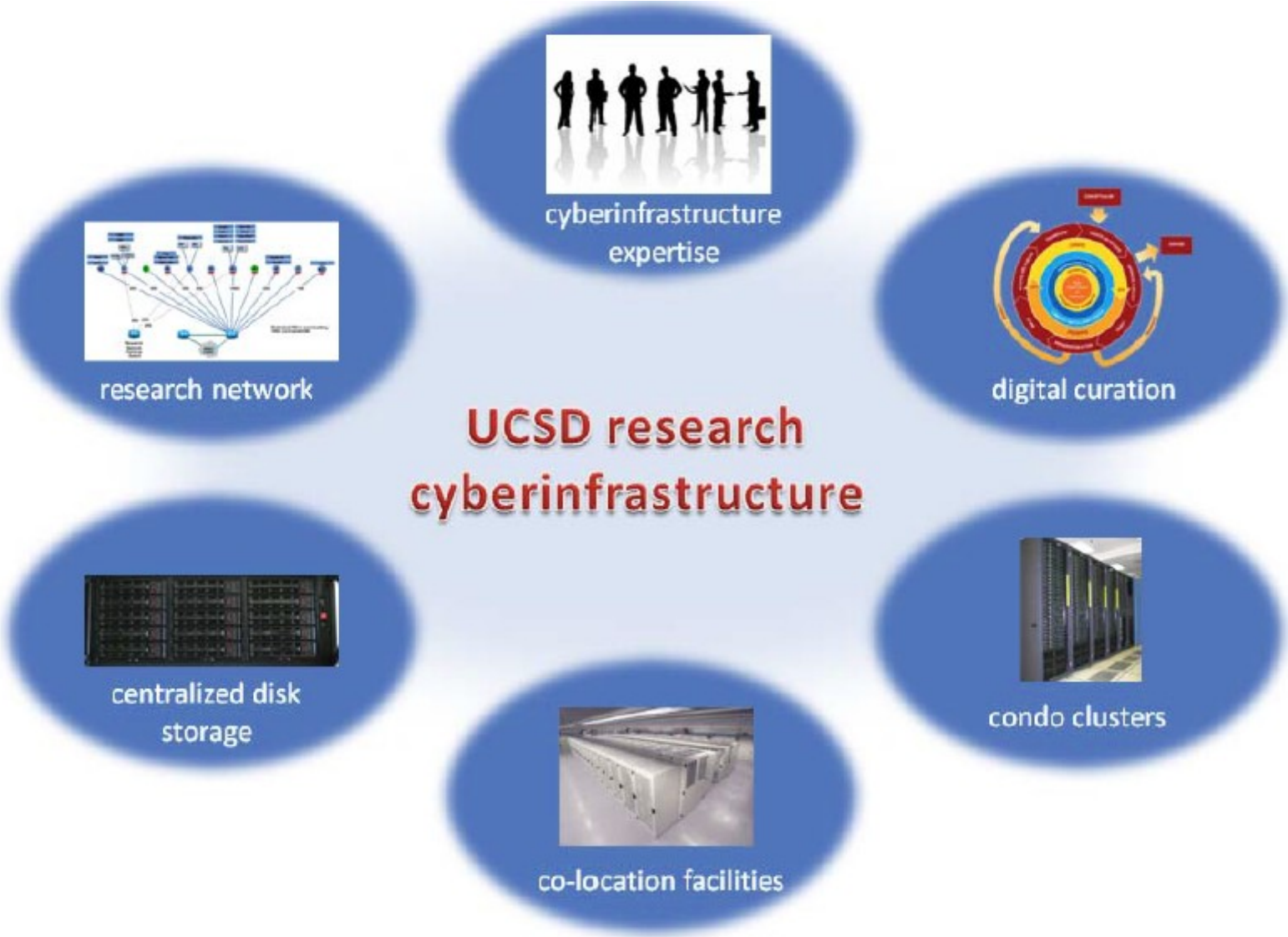


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www.cytoscape.org

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With the Explosion in Biomedical Data, What is the Required Cyberinfrastructure?



UCSD SDSC

Report 2009

http://rci.ucsd.edu

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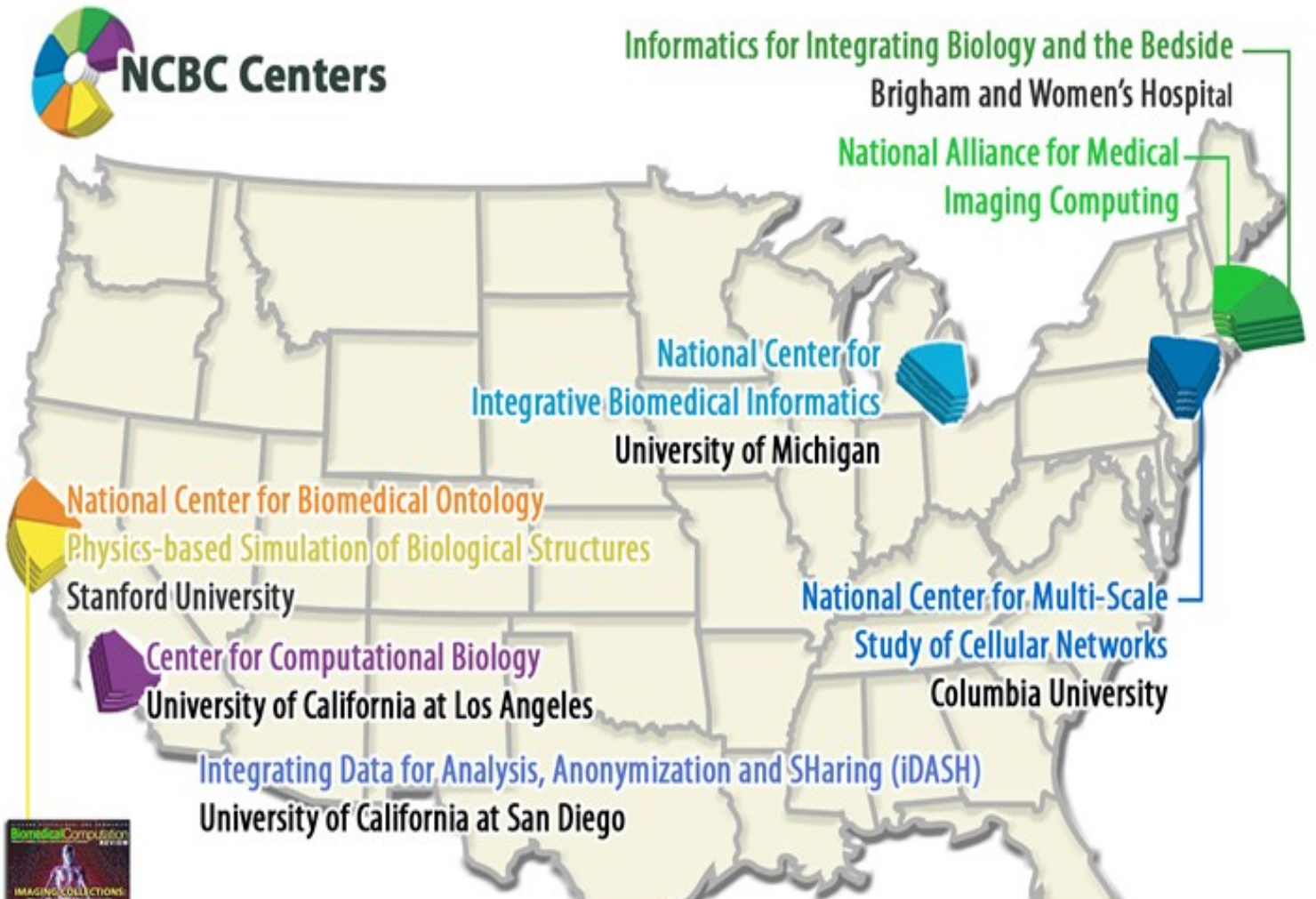
NIH Roadmap

Source: Lucila Ohno-Machado, UCSD SOM

National Centers for Biomedical Computing

Home | NCBC Summary | Calendar | All Hands Meetings | Biological Projects | Biositemaps Projects | Working Group Archive

Search for NCBC resources in the new Resource Discovery System (RDS)





Outcome of NIH Botstein-Smarr Report (1999)

http://acd.od.nih.gov/agendas/060399_Biomed_Computing_WG_RPT.htm

New NCBC: integrating Data for Analysis, Anonymization, and SHaring (iDASH)

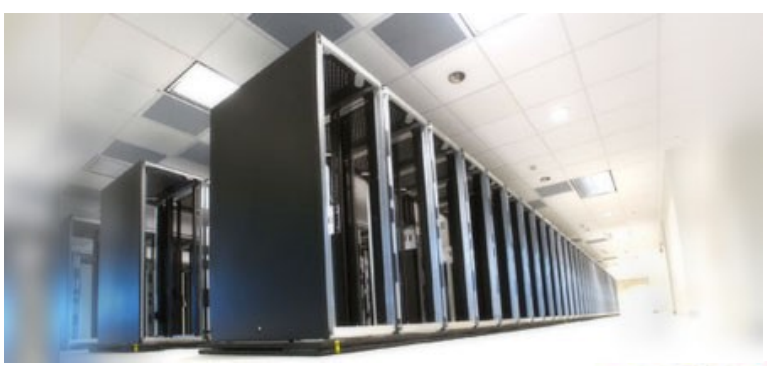
- **Data Exported for Computation Elsewhere**
  - Users download data from iDASH



- **Computation Comes to the Data**
  - Users access data in iDASH
  - Users upload algorithms into iDASH

- **iDASH Exportable Cyberinfrastructure**
  - Users download infrastructure

Private Cloud at SD Supercomputer Center
Medical Center Data Hosting
HIPAA certified facility



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Source: Lucila Ohno-Machado, UCSD SOM

funded by NIH U54HL108460

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UCSD Next Generation Sequencer Example: Professor Trey Idekar

Leichtag/Sequencer



Storage



Skaggs/Users













Next Gen Sequencers Generate ~1TB/Run



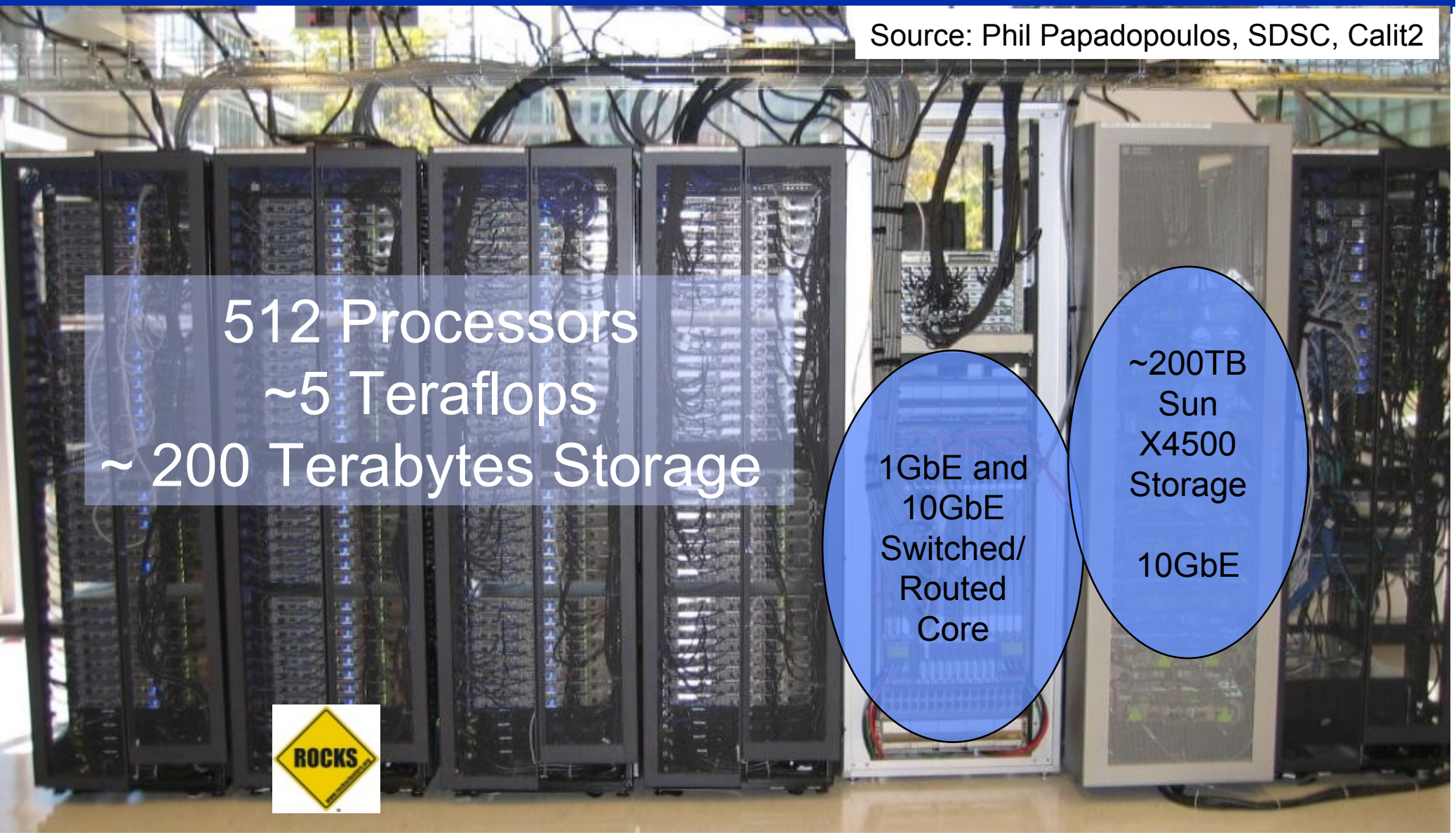
Calit2/Storage



SDSC/Triton

Source: Chris Misleh, Calit2/SOM

Calit2 Community Cyberinfrastructure for Advanced Microbial Ecology Research and Analysis (CAMERA)



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5000 Users
90 Countries

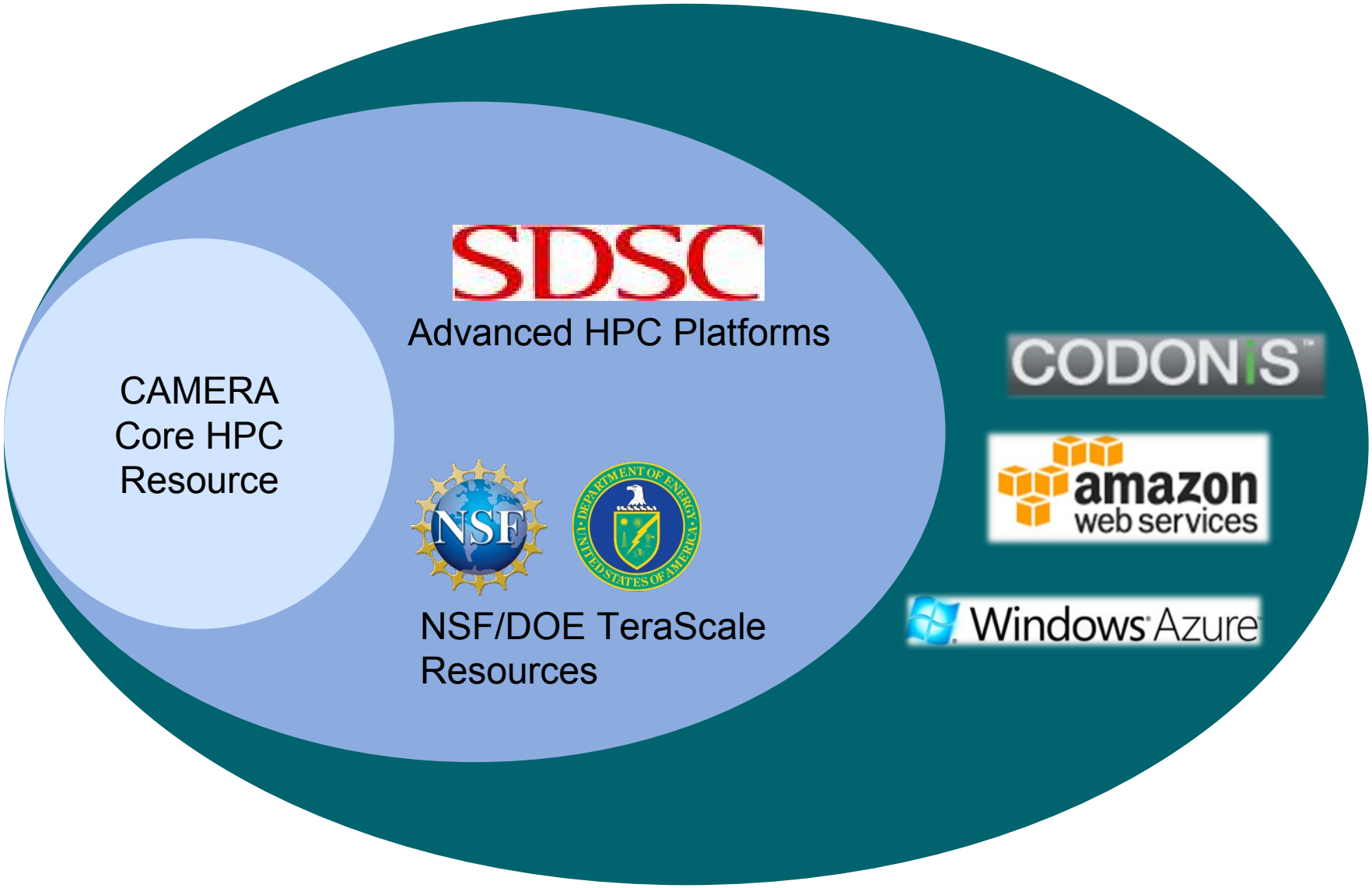
Gordon and Betty MOORE FOUNDATION

SDSC

J. Craig Venter INSTITUTE

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Access to Computing Resources Tailored by User's Requirements and Resources



Source: Jeff Grethe, CAMERA

NSF Funds a Data-Intensive Track 2 Supercomputer: SDSC's Gordon-Coming Summer 2011

- **Data-Intensive Supercomputer Based on SSD Flash Memory and Virtual Shared Memory SW**
  - *Emphasizes MEM and IOPS over FLOPS*
  - *Supernode has Virtual Shared Memory:*
    - *2 TB RAM Aggregate*
    - *8 TB SSD Aggregate*
    - *Total Machine = 32 Supernodes*
    - *4 PB Disk Parallel File System >100 GB/s I/O*



- **System Designed to Accelerate Access to Massive Data Bases being Generated in Many Fields of Science, Engineering, Medicine, and Social Science**

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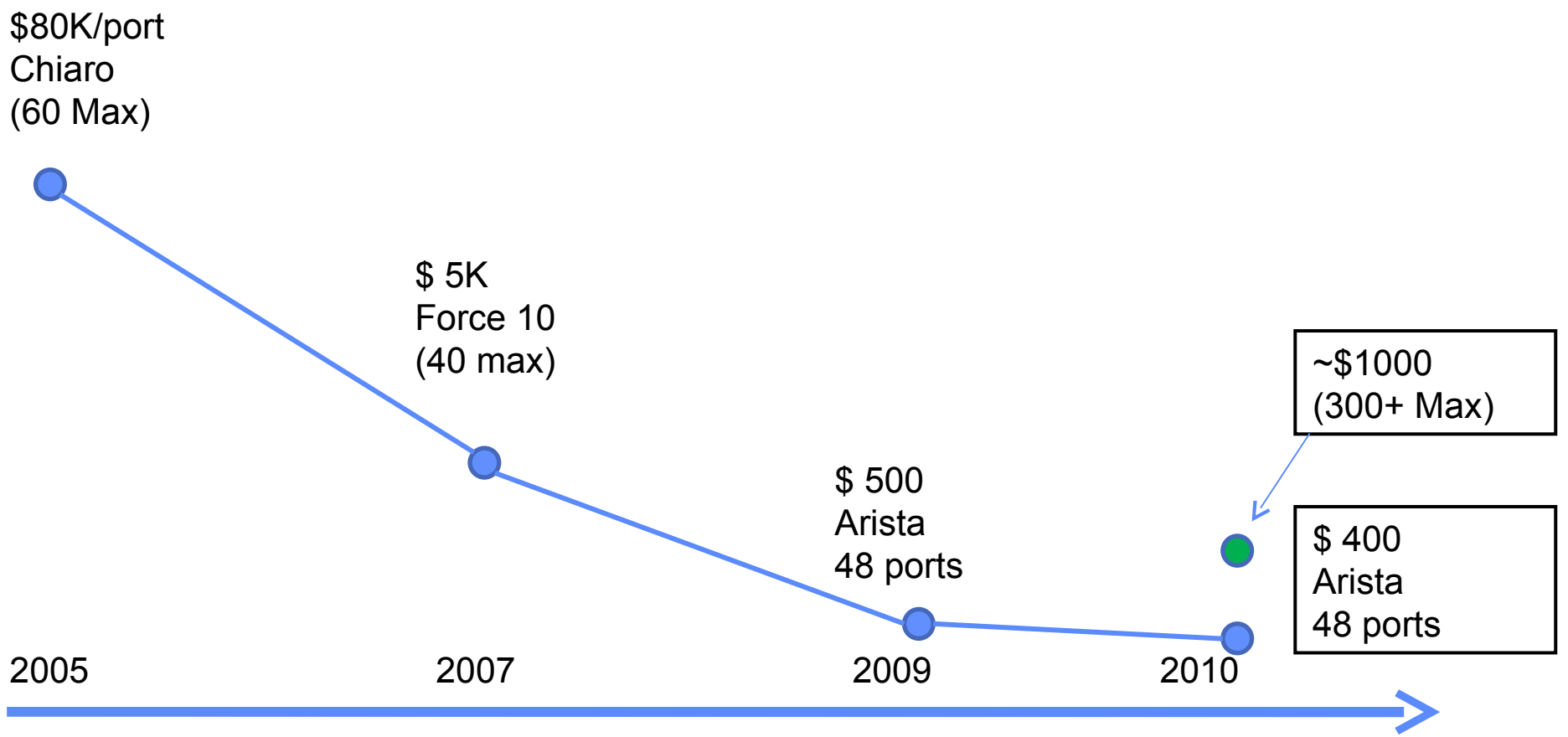
SDSC

Source: Mike Norman, Allan Snavely SDSC

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Rapid Evolution of 10GbE Port Prices Makes Campus-Scale 10Gbps CI Affordable

- Port Pricing is Falling
- Density is Rising – Dramatically
- Cost of 10GbE Approaching Cluster HPC Interconnects



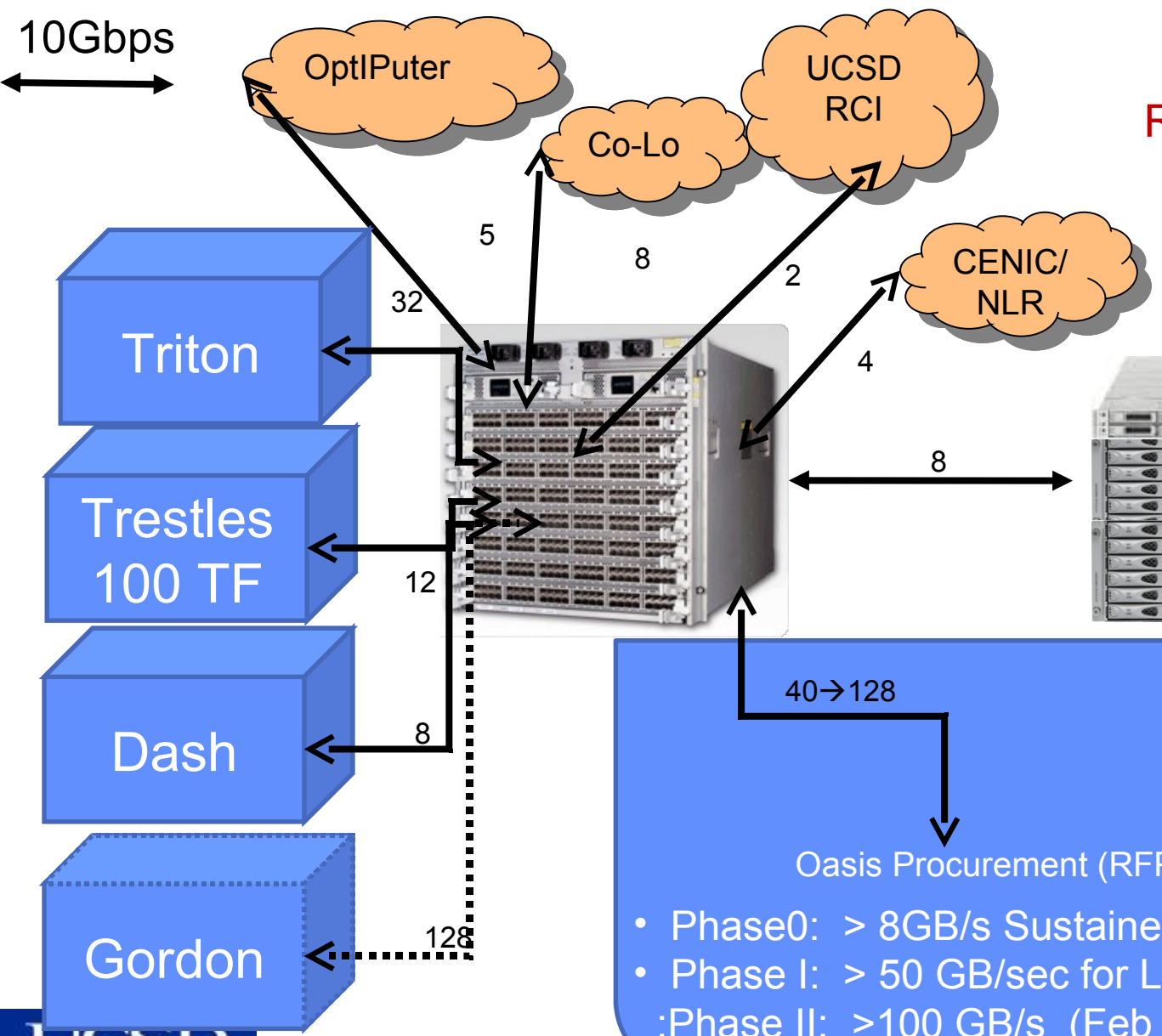
SDSC

UCSD
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Source: Philip Papadopoulos, SDSC/Calit2

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10G Switched Data Analysis Resource: SDSC's Data Oasis – Scaled Performance



Radical Change Enabled by Arista 7508 10G Switch 384 10G Capable

Existing Commodity Storage 1/3 PB

Oasis Procurement (RFP)

2000 TB
> 50 GB/s

- Phase0: > 8GB/s Sustained Today
- Phase I: > 50 GB/sec for Lustre (May 2011)
- :Phase II: >100 GB/s (Feb 2012)

Source: Philip Papadopoulos, SDSC/Calit2

UCSD UCIrvine SDSC

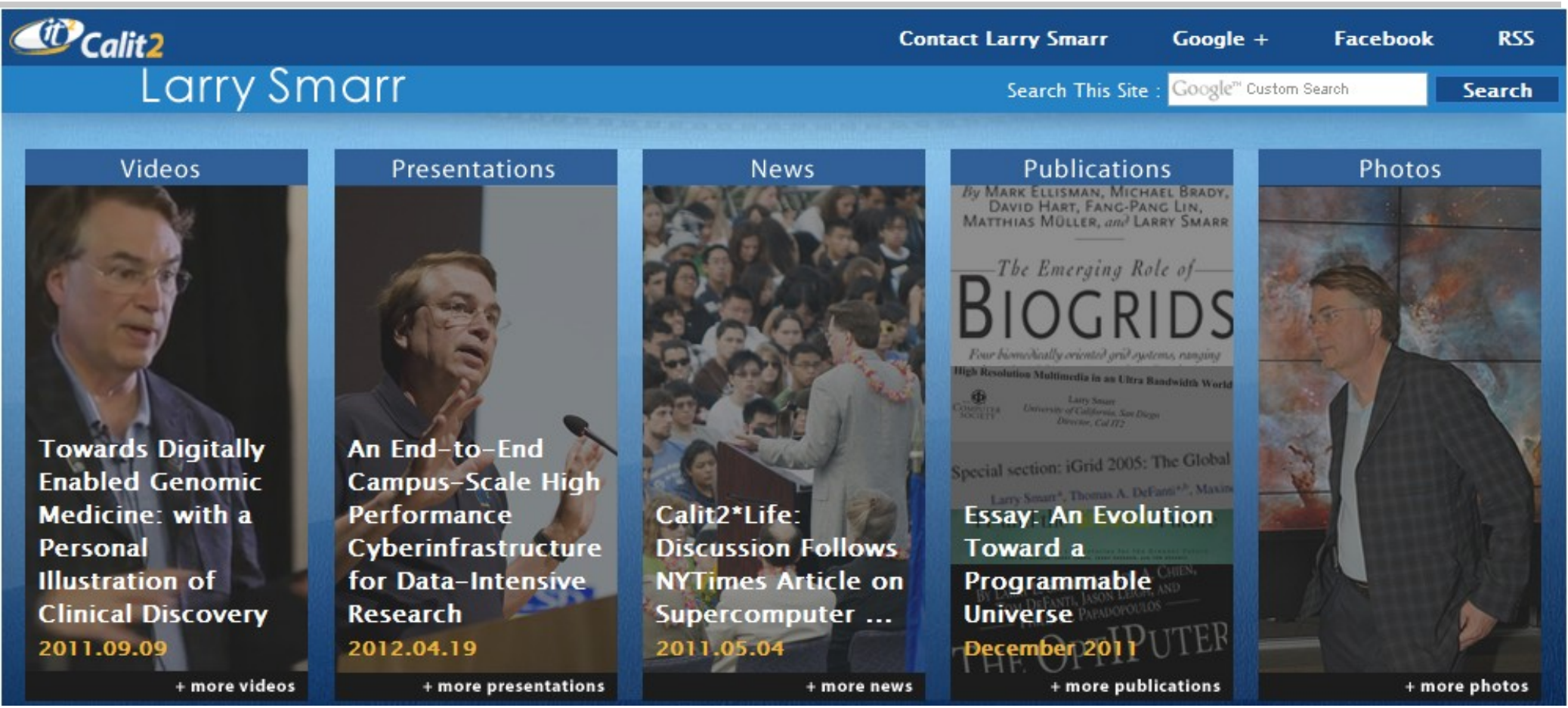
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From “How Do You Feel?”, to “What Are Your Numbers?”

Where’s There’s Data
There’s Hope

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For Further Information
Visit My Portal



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http://lsmarr.calit2.net/