“Experiences of a Quantified Self”

Lecture

Nokia Bell Labs

Murray Hill, NJ

July 6, 2018

Dr. Larry Smarr

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Harry E. Gruber Professor,

Dept. of Computer Science and Engineering

Jacobs School of Engineering, UCSD

http://lsmarr.calit2.net

Abstract

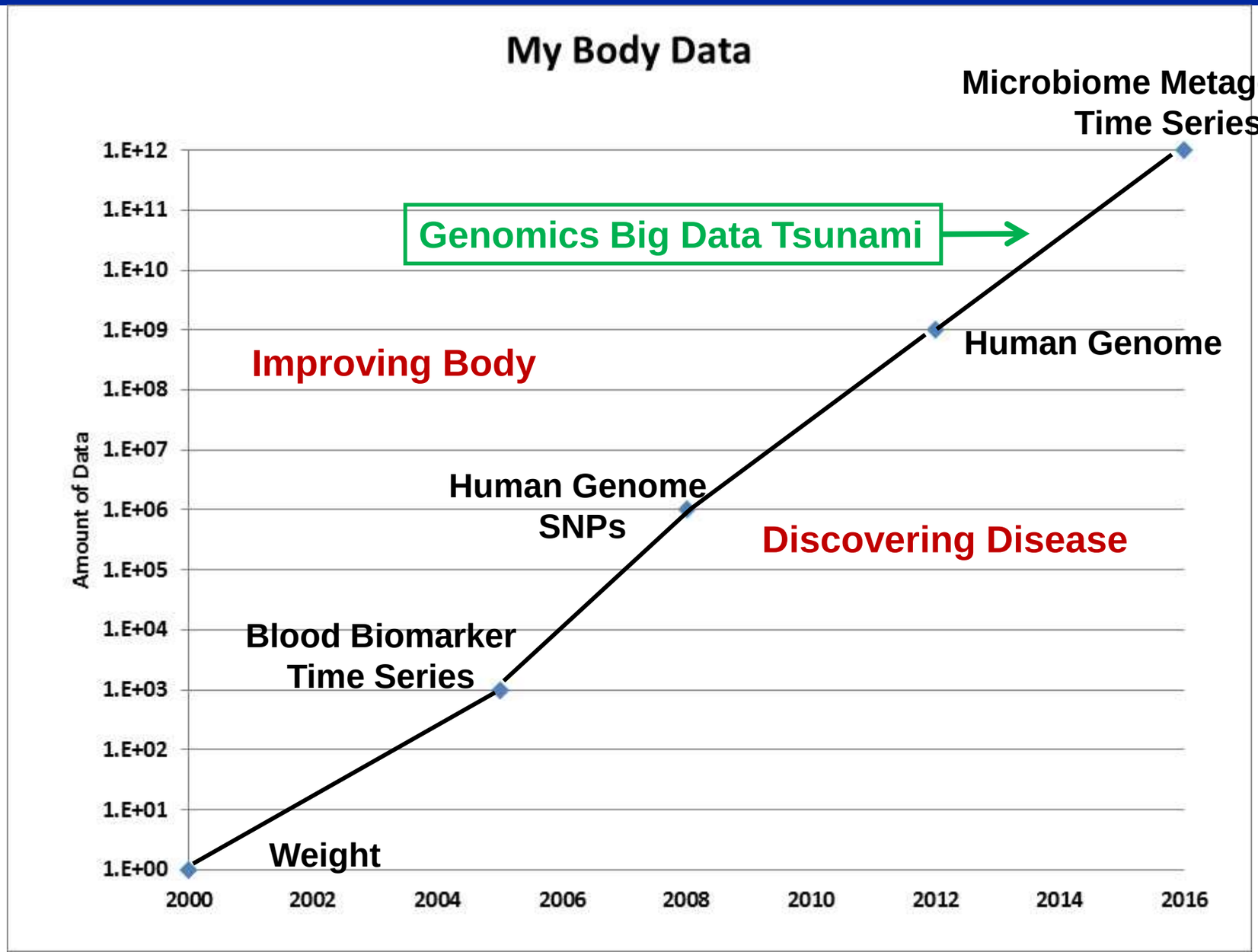
I will describe a large number of experiments in self-quantification I have carried out over the last decade. These include high time resolution longitudinal monitoring of my heart rate, steps, sleep, food intake, blood glucose, electrogastrogram, body temperature, 150 blood and stool biomarkers, and gut microbiome. In addition, I have multiple MRI, CAT, and colonoscopy videos. All this data has allowed me to detect chronic disease early and take remedial actions. This experiment gives an early view into the future of personalized healthcare and preventative medicine.

“Know Thyself”
From the Temple of Apollo to the Quantified Self



From the Reichert-Haus in Ludwigshafen, Germany

Knowing Me:
From One to a Trillion Data Points Defining Me in 15 Years



Calit2 Has Been Had a Vision of How to Digitally "Know Thyself" for 15 Years

- **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

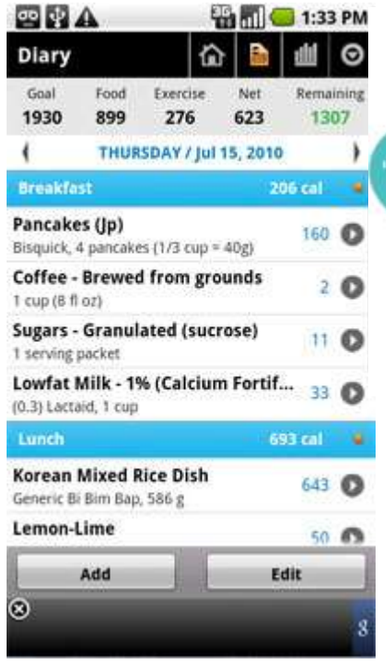
www.bodymedia.com



- **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

I Used a Variety of Emerging Personal Sensors To Quantify My Body & Drive Behavioral Change for the Last Decade



MyFitnessPal-
Calories Ingested



FitBit -
Daily Steps &
Calories Burned



Withings/iPhone-
Blood Pressure





Withings WiFi Scale -
Daily Weight



Zeo-Sleep

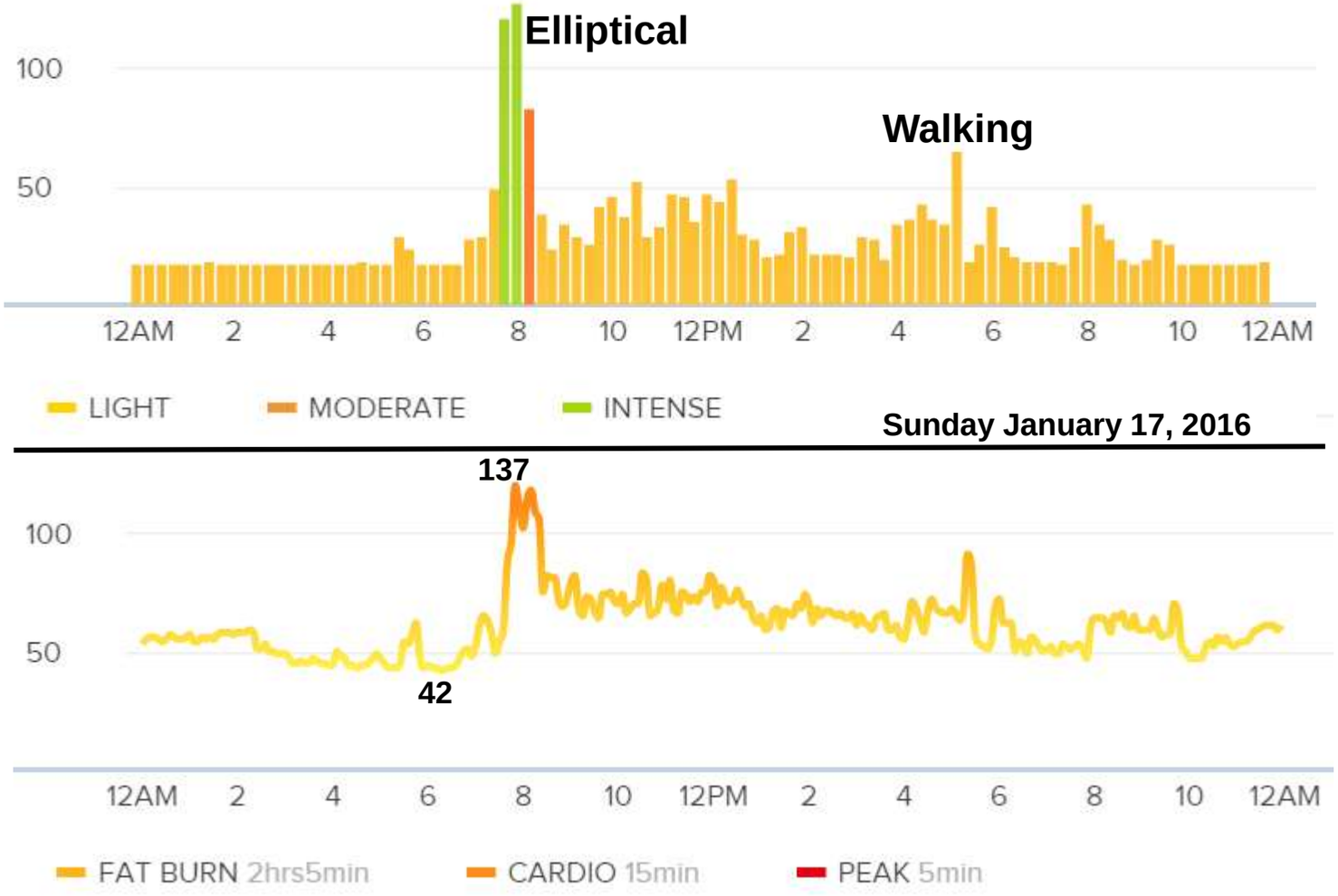


Azumio-Heart Rate

Wireless Monitoring
Produced Time Series That Helped Me Improve My Health

Since Starting November 3, 2011
Total Distance Tracked 8300 miles = 3x San Diego to Bell Labs
Total Vertical Distance Climbed 230,000 ft. = 8x Mt. Everest

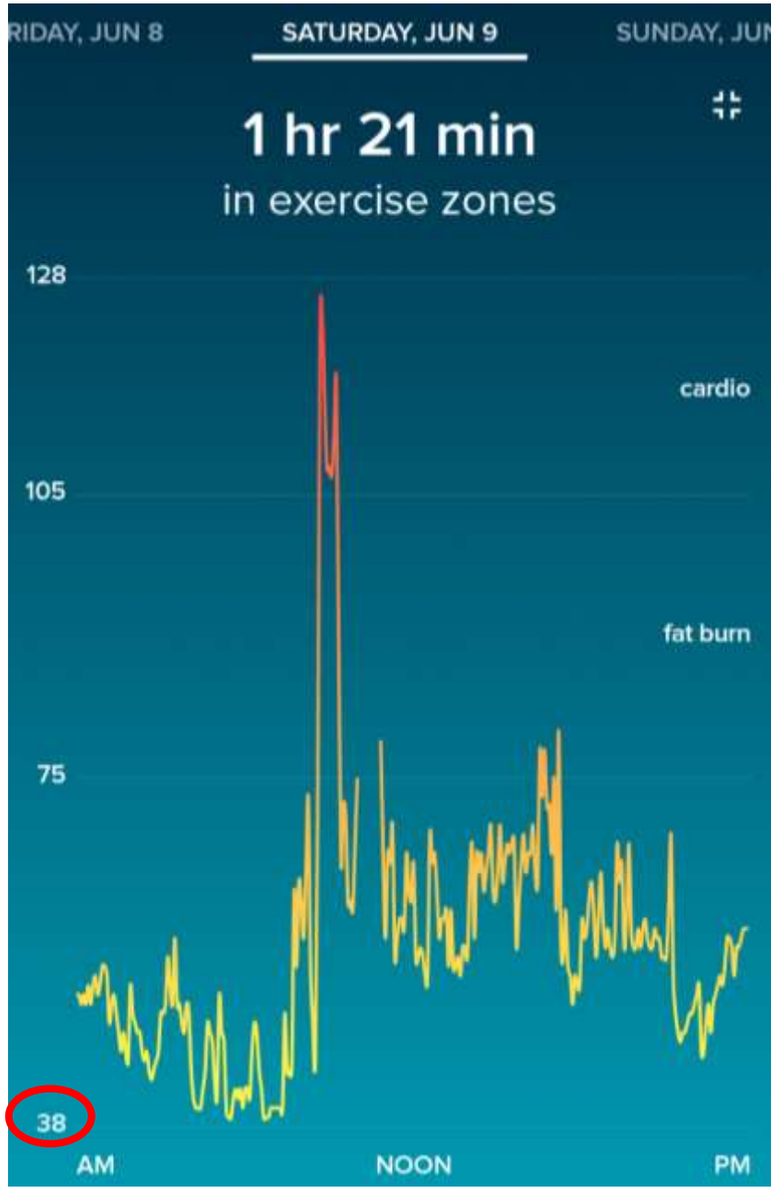
I Increased Walking, Aerobic, and Resistance Training, All of Which Have Health Benefits



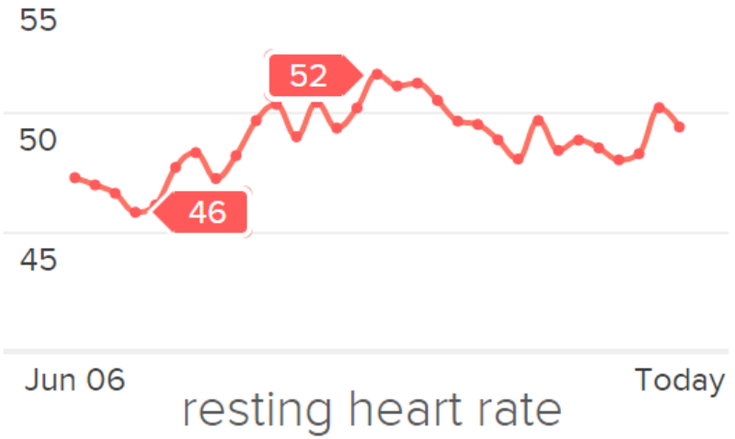
fitbit



Walking 3.5 Miles/Day and 1 Elliptical Session Per Week Has Lowered My Resting Heartrate







In Search of My Sleep Architecture I Wore A Zeo for 700 Nights From October 2010 to March 2013

Zeo Used Brain Waves And Forehead Micromuscle Movement To Estimate Sleep Stages

The Measured Life

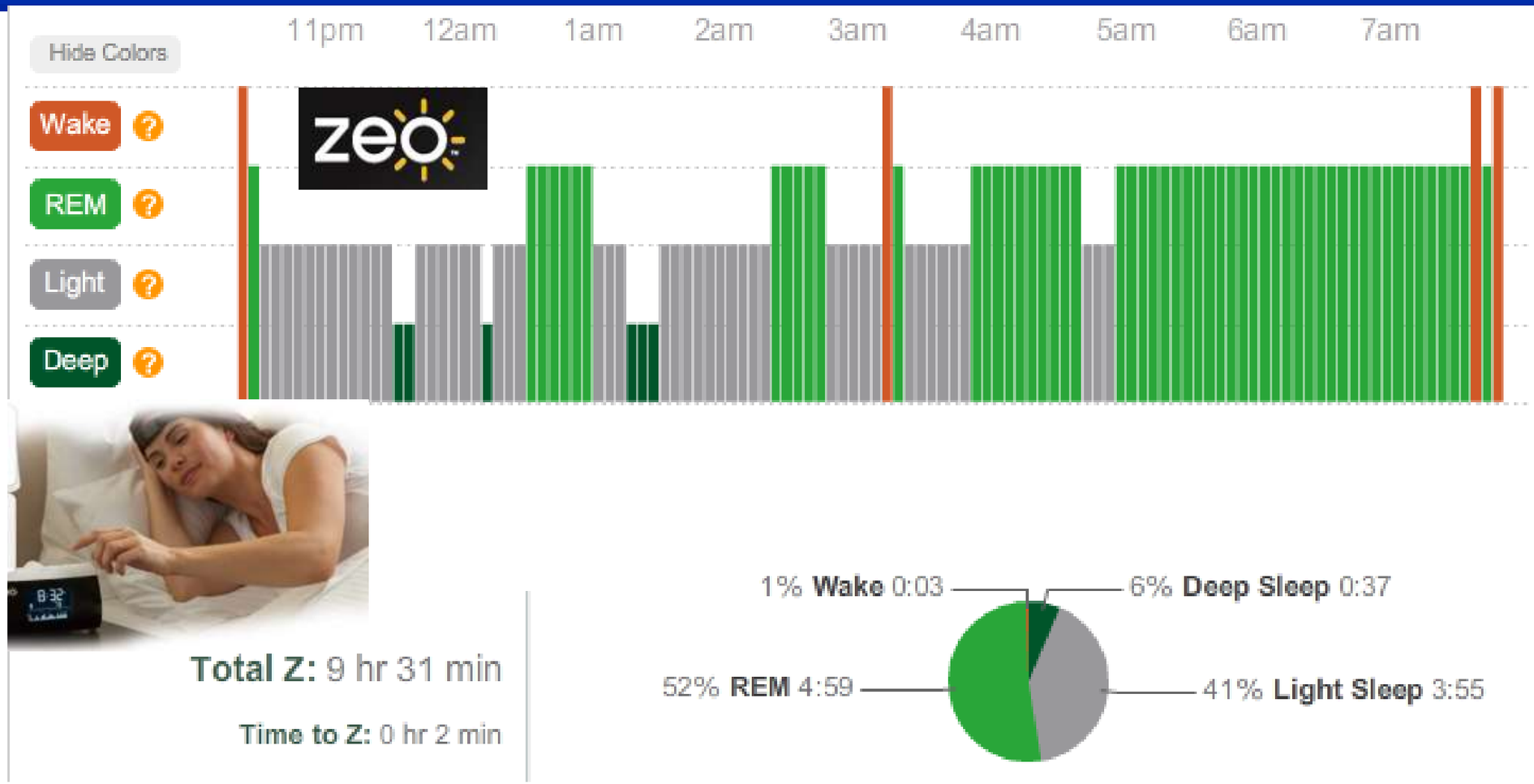
Do you know how much REM sleep you got last night? New types of devices that monitor activity, sleep, diet, and even mood could make us healthier and more productive.

JULY/AUGUST 2011 | BY EMILY SINGER



technology review
Published by MIT

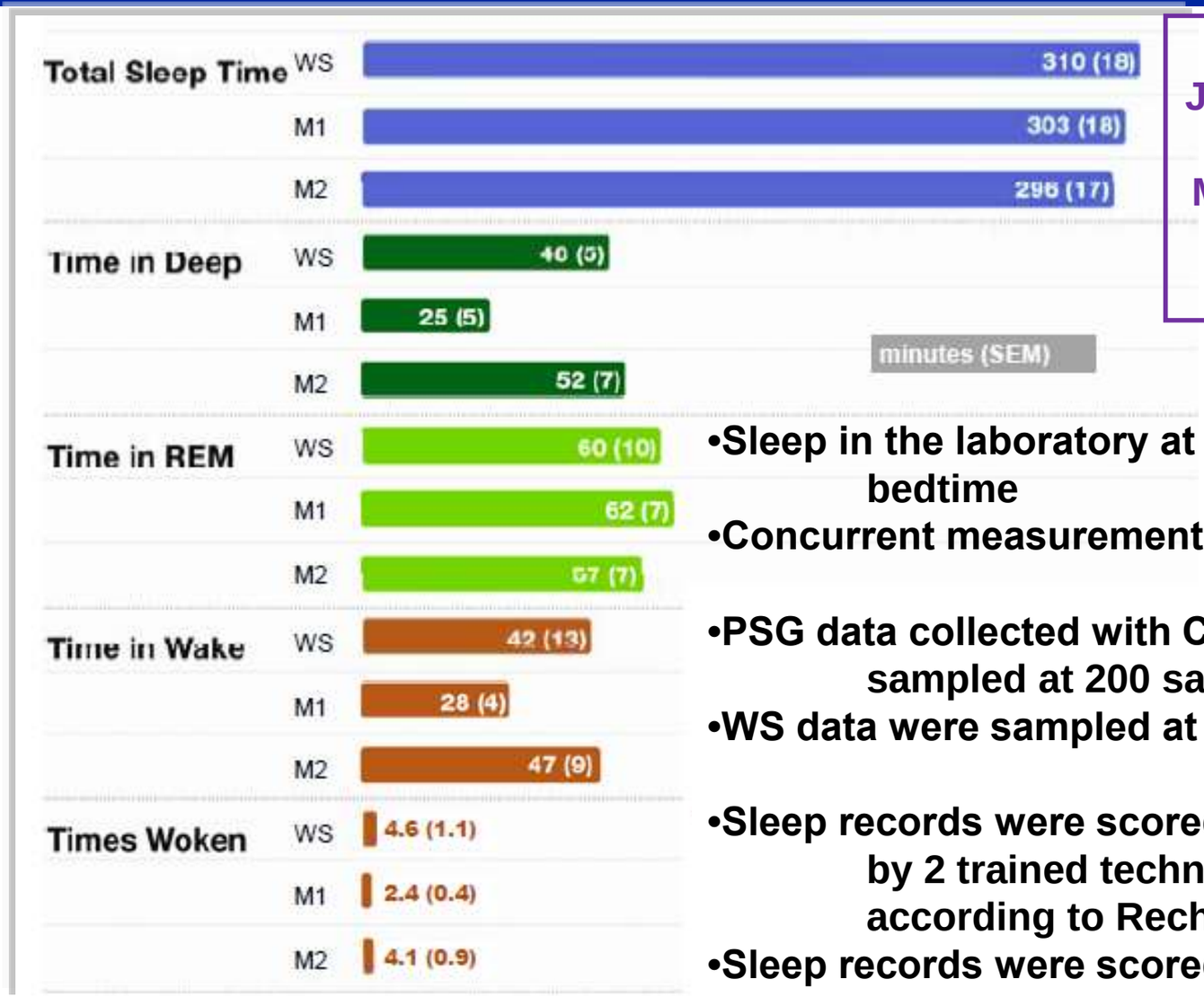
Quantifying My Sleep Pattern Using Zeo - Surprisingly About Half My Sleep is REM!



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

An Infant Typically Has 50% REM

Published Comparison of Zeo with Sleep Lab Polysomnography (PSG)



Shambroom JR, Johnstone J, Fabregas SE. Evaluation of Portable Monitor for Sleep Staging. Sleep. 2009;32 (Suppl.): A386. Abstract 1182.

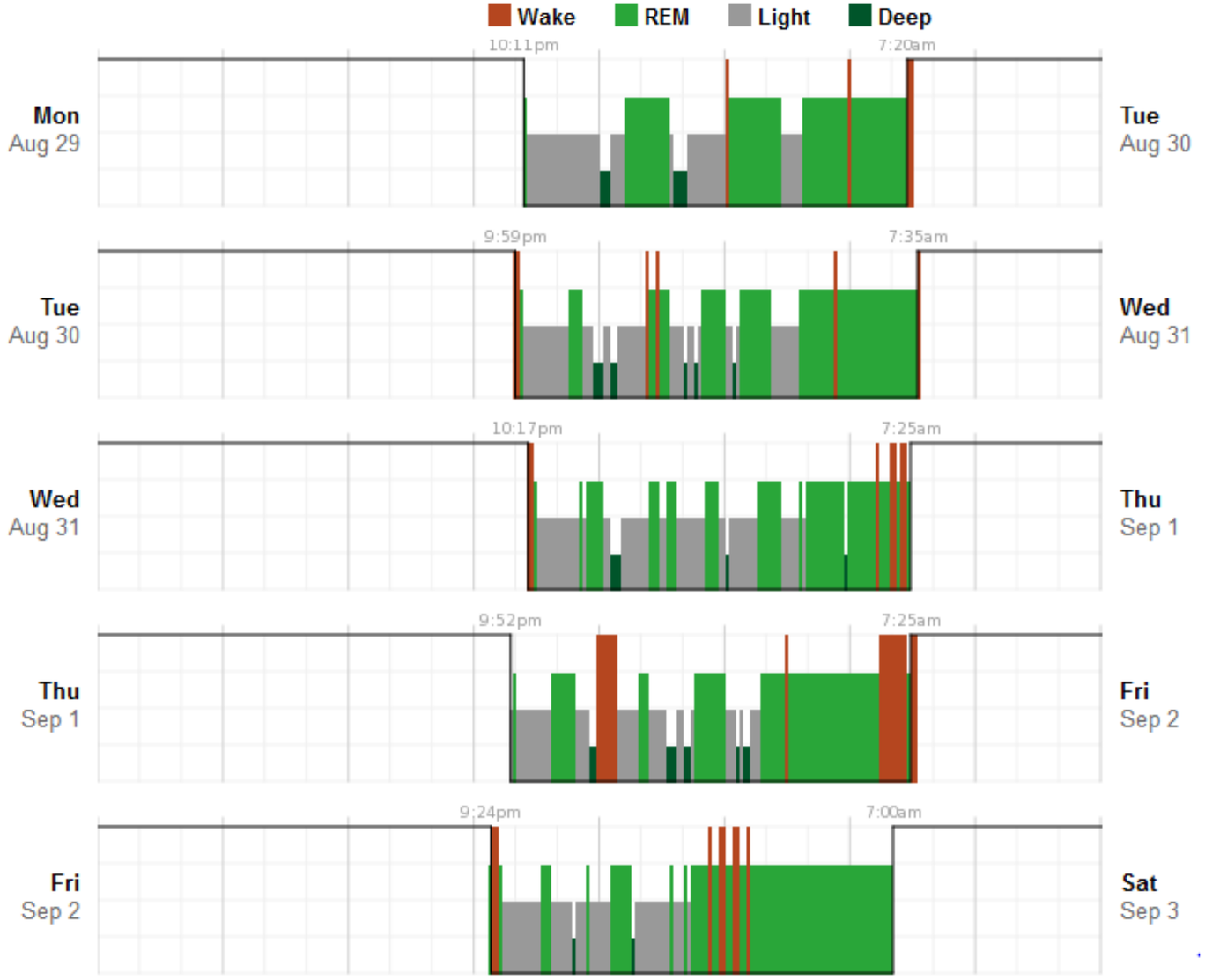
- Sleep in the laboratory at the participant's habitual bedtime
- Concurrent measurement of PSG and WS

- PSG data collected with Cadwell Easy II PSG, sampled at 200 samples per second
- WS data were sampled at 128 samples per second

- Sleep records were scored blinded to WS by 2 trained technicians (M1 and M2) according to Rechtschaffen & Kales
- Sleep records were scored automatically by the WS

www.myzeo.com/sleep/sites/default/files/Shambroom%2C%20Johnstone%2C%20Fabregas_Validation_2009_APSS_poster.pdf

I Have a Fairly Consistent Sleep Architecture: A Few REM Blocks Early, Then a "Wall of REM"

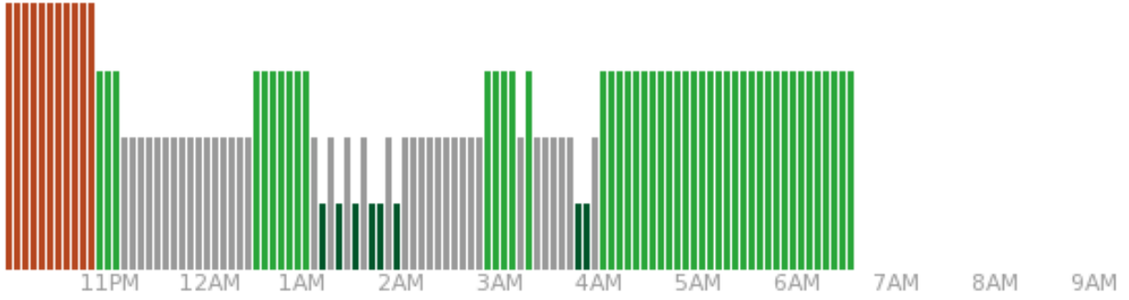


Source: Zeo 2011

Trip La Jolla to Perth, Australia
Takes Roughly 4 Days for REM to Re-adjust to ~50%

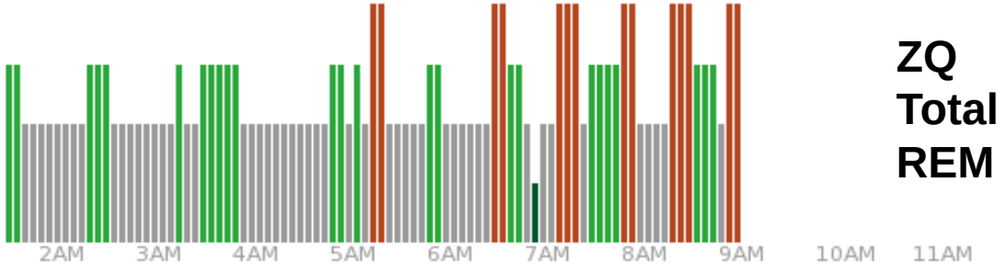
All Graphs Are Aligned to La Jolla Pacific Time Zone

8/2/11
La Jolla



ZQ	89
Total Z	7:35
REM	50%

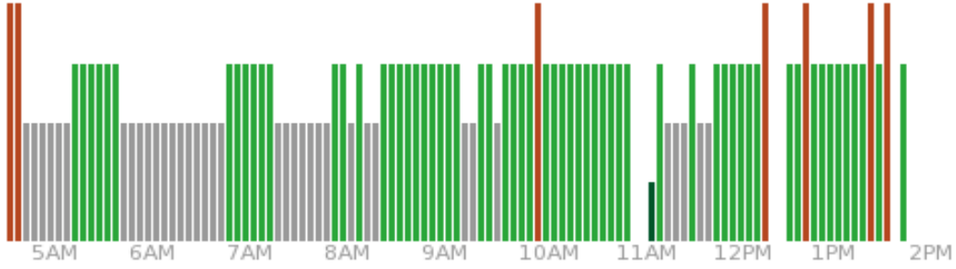
8/6/11
Qantas LAX-Brisbane



ZQ	71
Total Z	7:16
REM	29%

8/9/11
Perth

ZQ	91
Total Z	8:12
REM	61%

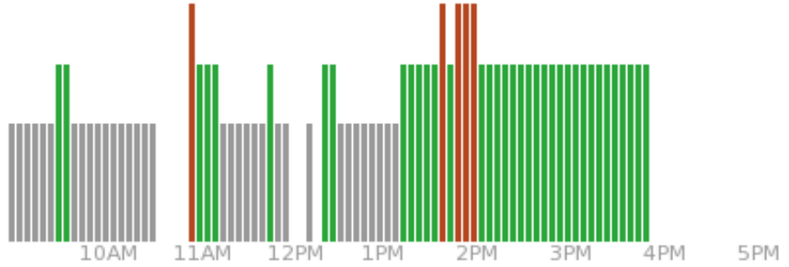


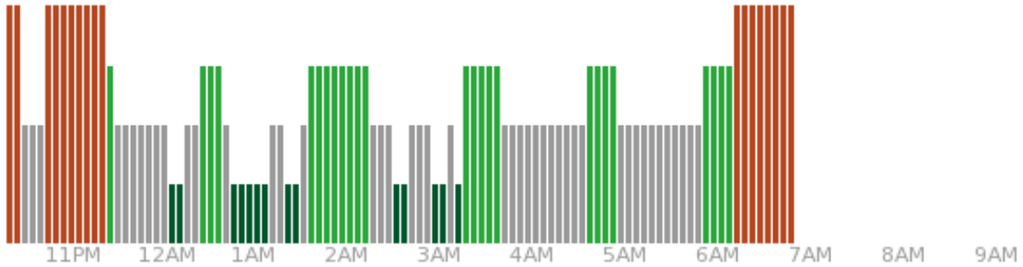
Return Trip Perth to La Jolla
Takes 4 Days for REM to Re-establish ~50%

All Graphs Are Aligned to La Jolla Pacific Time Zone

8/13/11
Perth

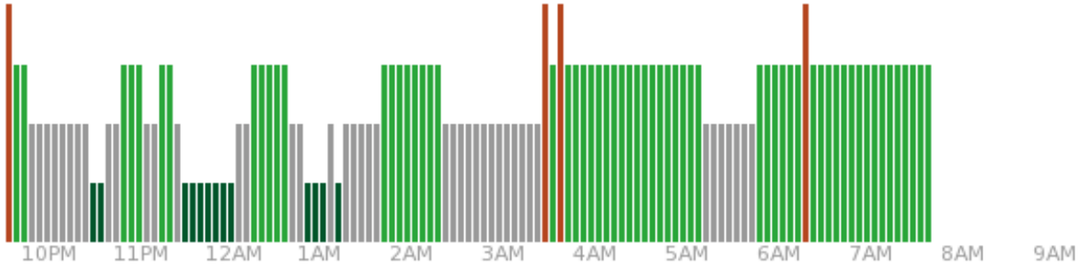
ZQ	63
Total Z	5:54
REM	47%





8/16/11
La Jolla

ZQ	83
Total Z	7:09
REM	28%

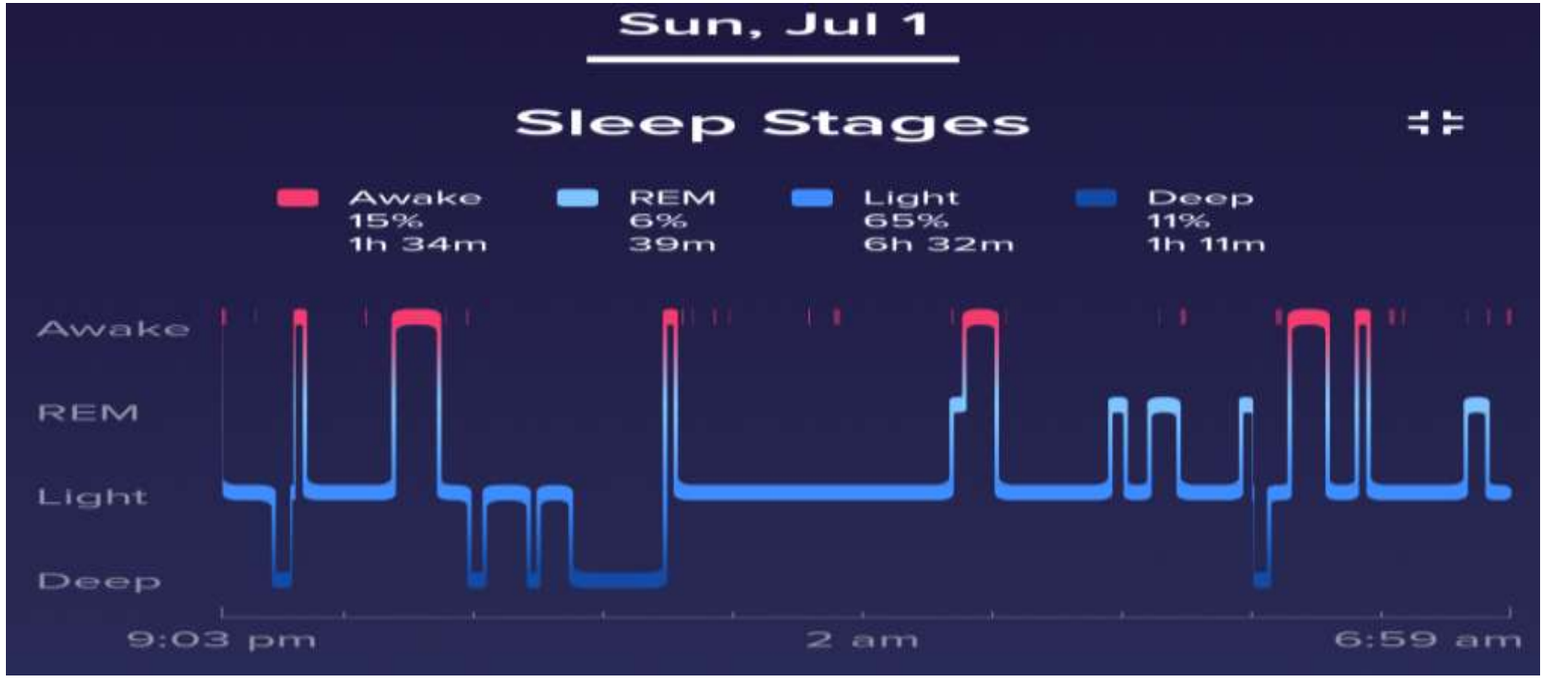


8/19/11
La Jolla

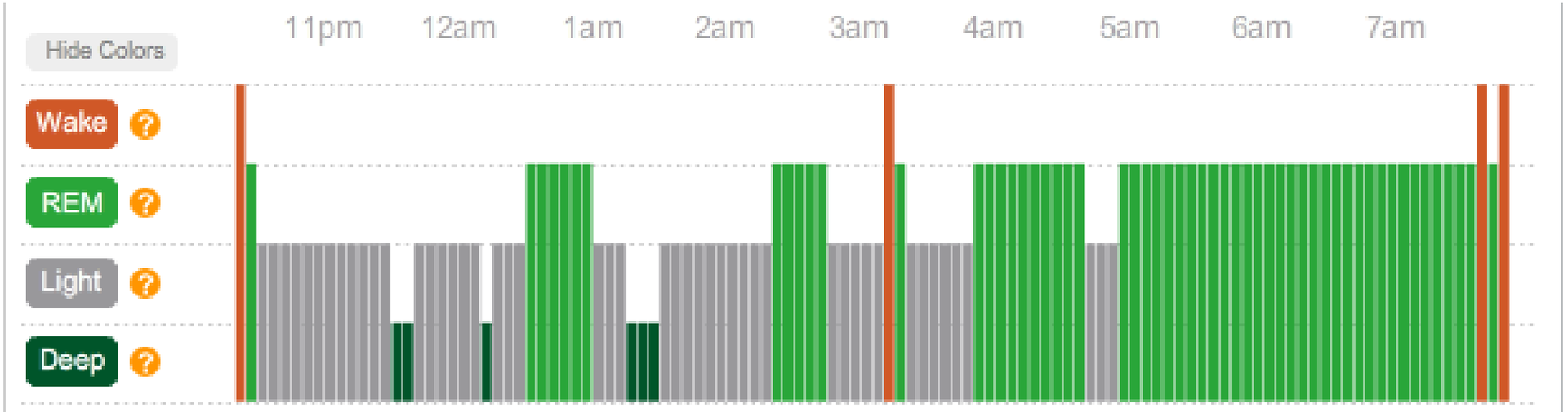
ZQ	117
Total Z	9:52
REM	51%

Fitbit Combines Movement and Heart Rate To Estimate Sleep Stages

fitbit



zeo

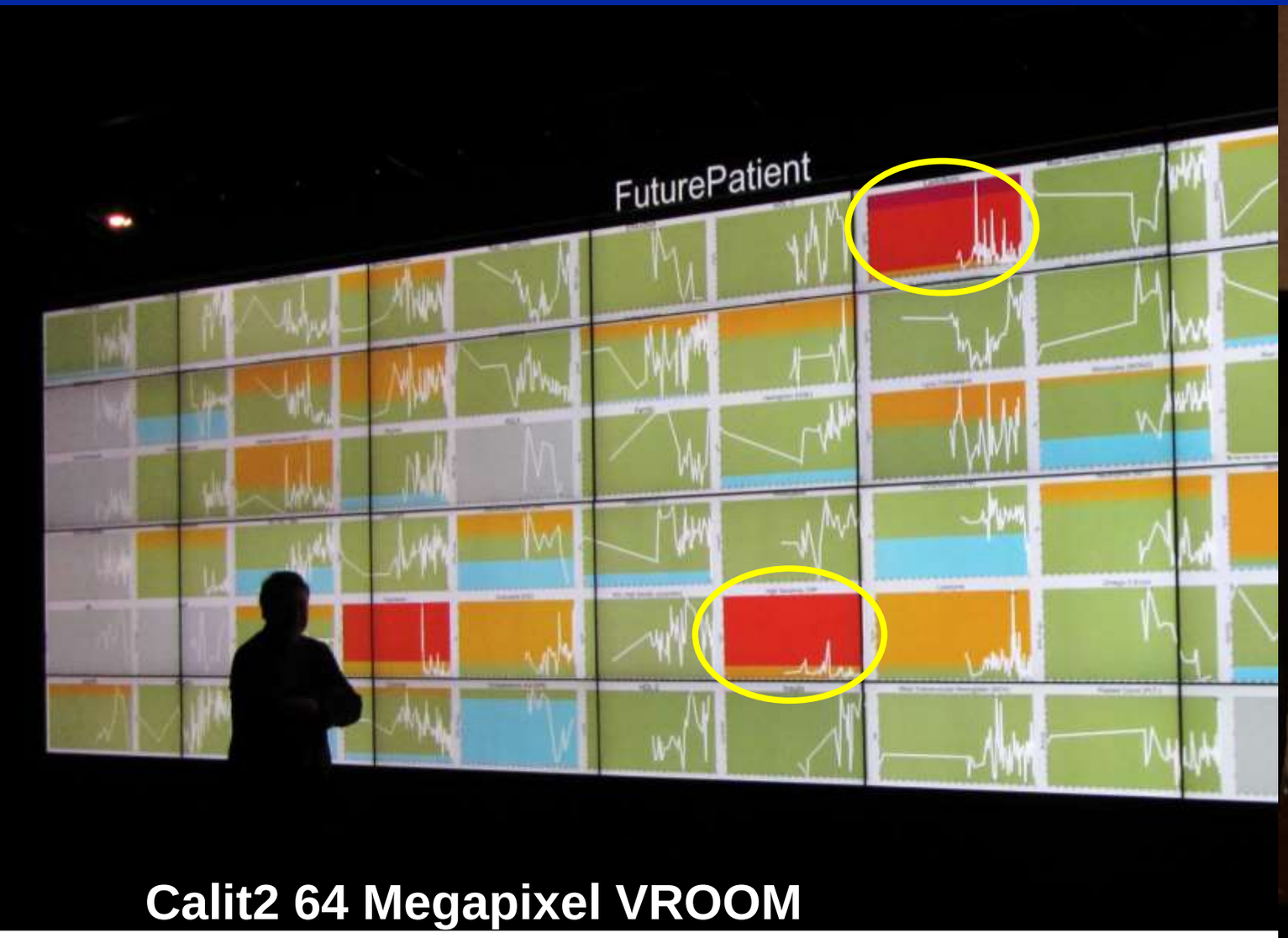


From Measuring Macro-Variables to Measuring Your Internal Variables



www.technologyreview.com/biomedicine/39636

I Have Been Tracking My Internal Biomarkers For A Decade To Better Understand My Body's Dynamics

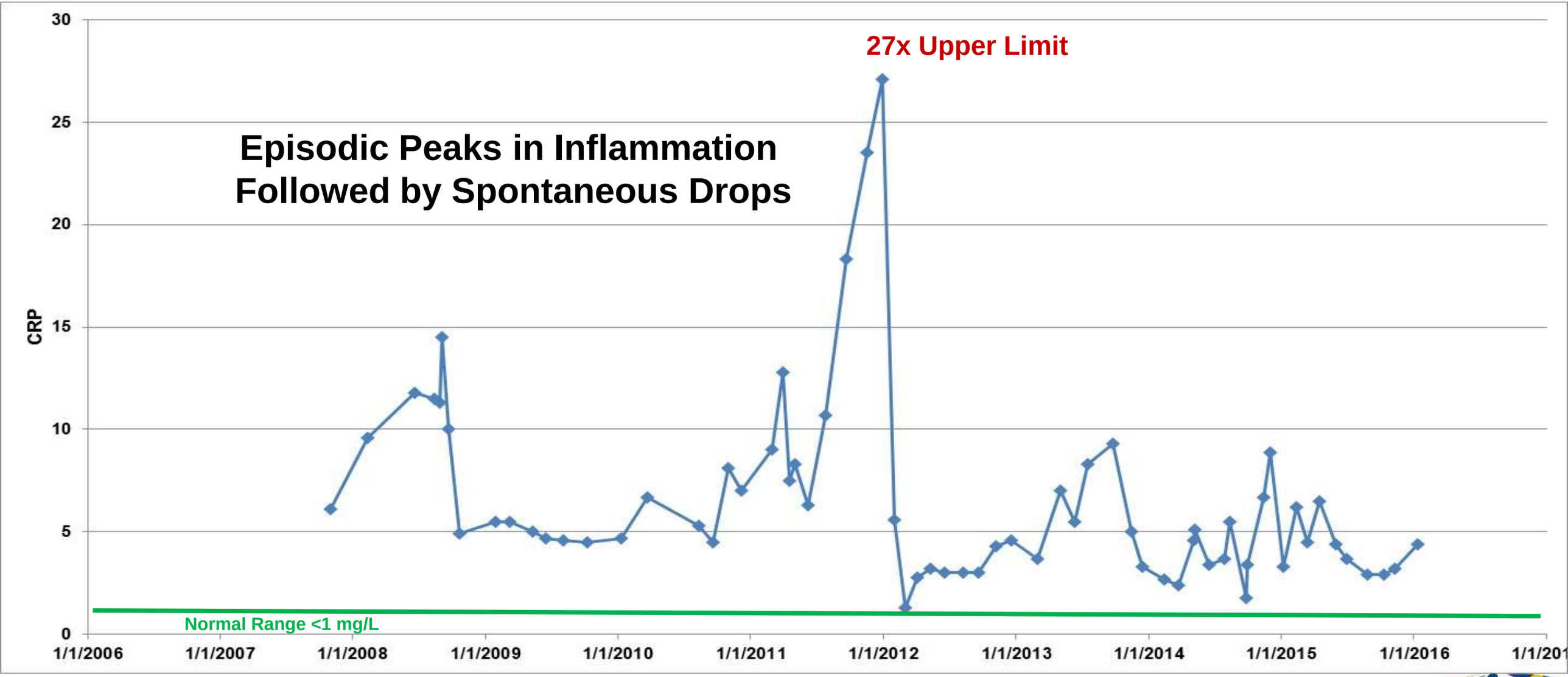


Calit2 64 Megapixel VROOM



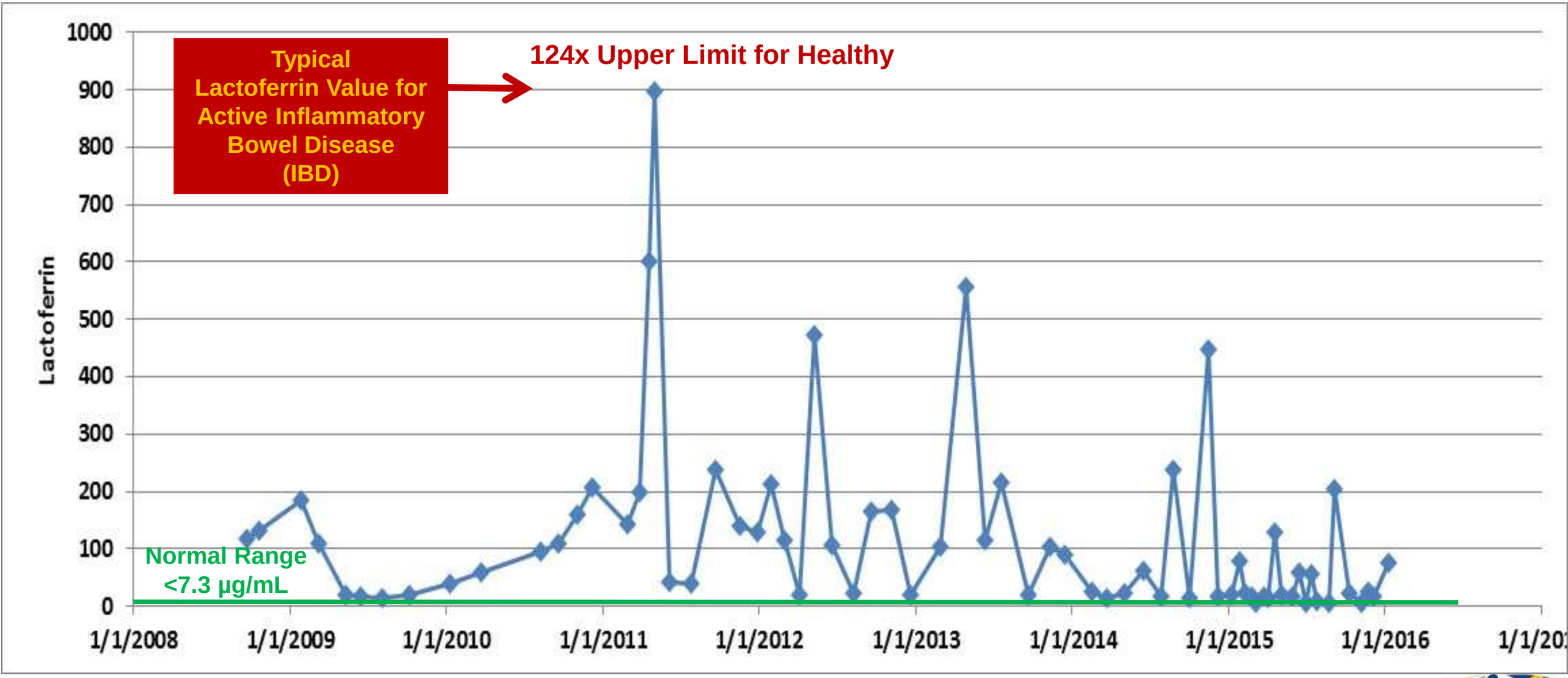
My Quarterly Blood Draw

Only One of My Blood Measurements Was Far Out of Range--Indicating Chronic Inflammation



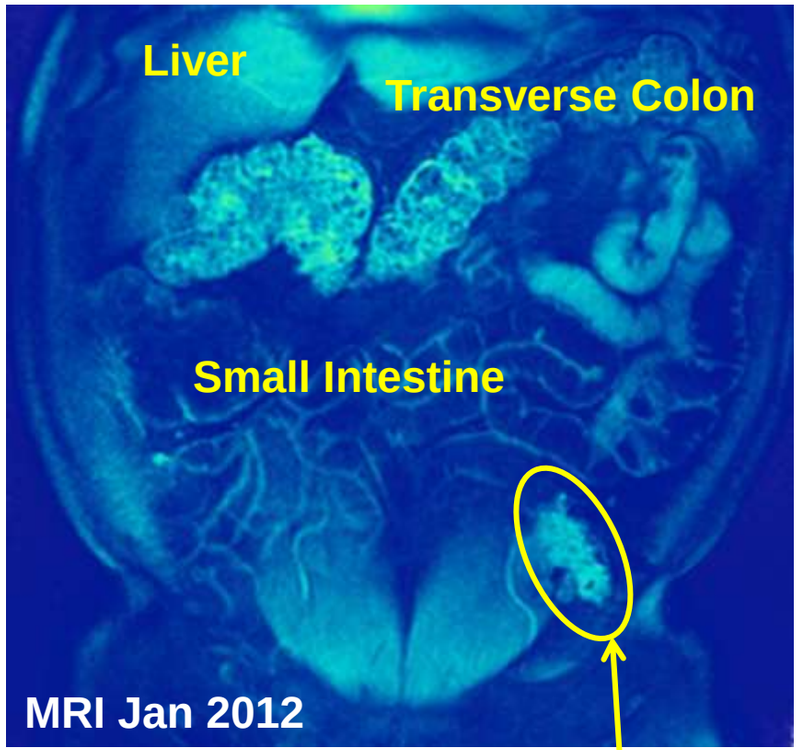
Complex Reactive Protein (CRP) is a Blood Biomarker for Detecting Presence of Inflammation

A Time Series of Stool Tests Suggested I Had Inflammatory Bowel Disease



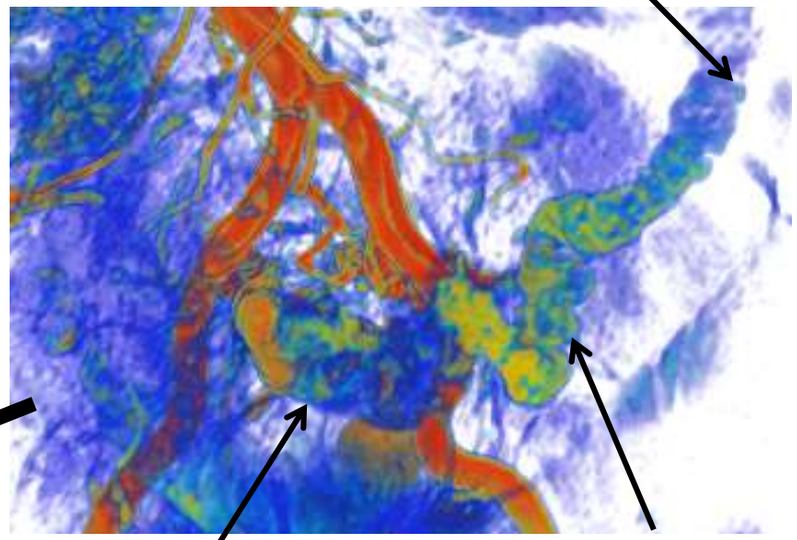
Lactoferrin is a Protein Shed from Neutrophils - An Antibacterial that Sequesters Iron

Confirming the IBD (Colonic 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

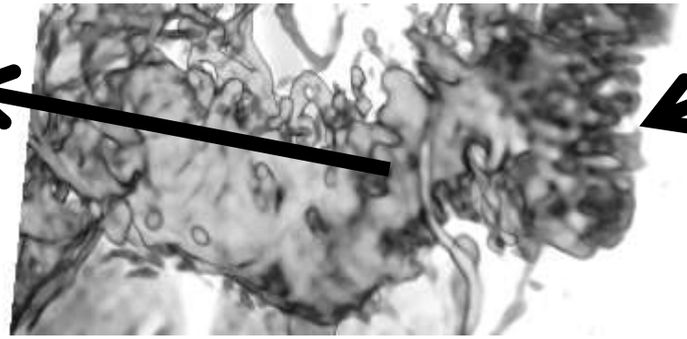
Descending Colon



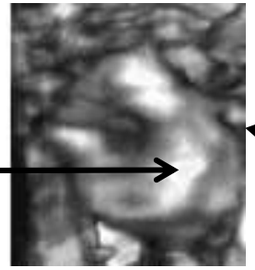
Major Kink

Sigmoid Colon
Threading Iliac Arteries

Diseased Sigmoid Colon



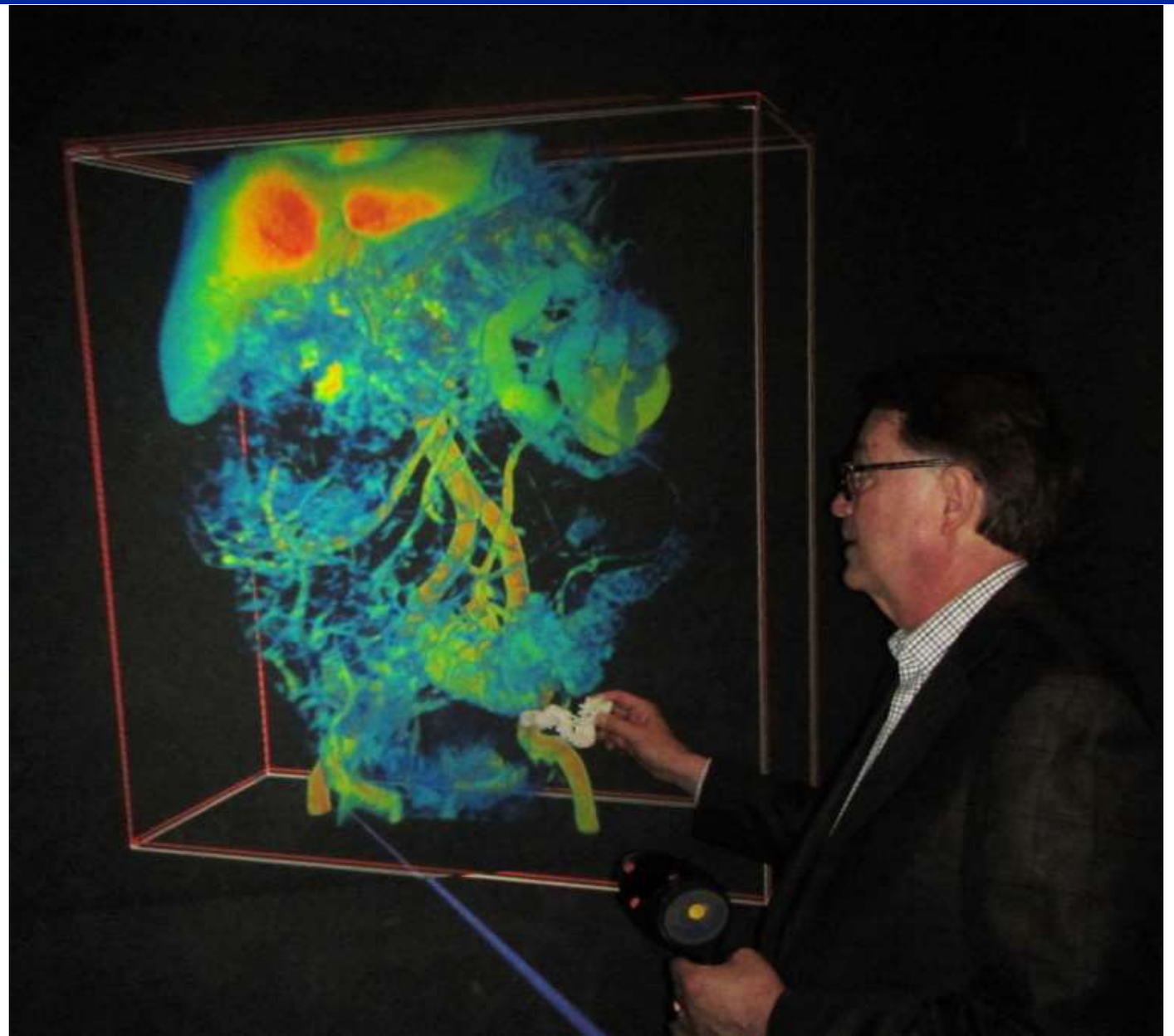
Cross Section



Severe Colon
Wall Swelling

I Have Been Giving Virtual Reality Tours of “Transparent Larry” for Six Years at Calit2

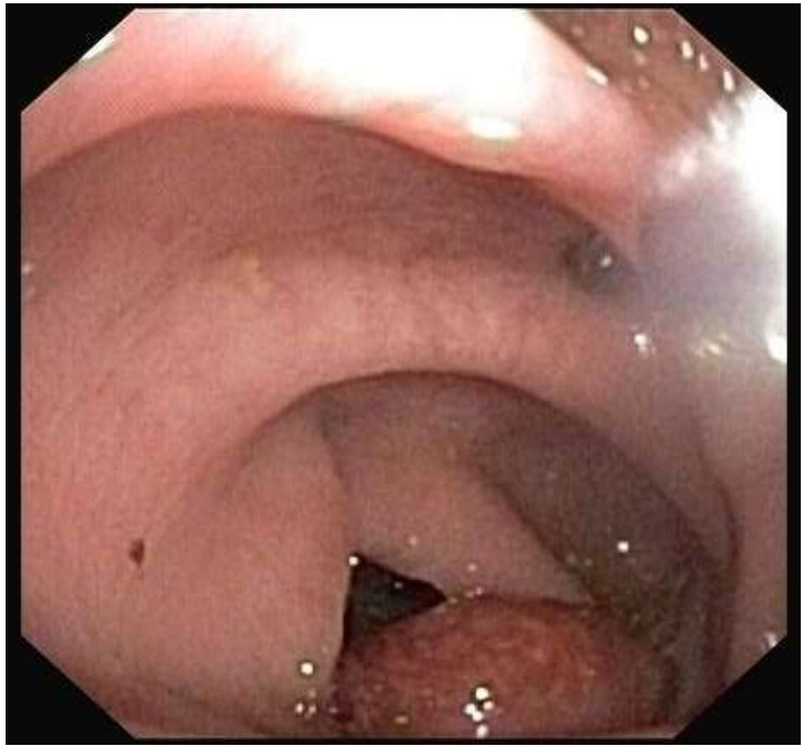
3D Volumetric Visualization Created by Calit2’s Jurgen Schulze from January 2012 MRI



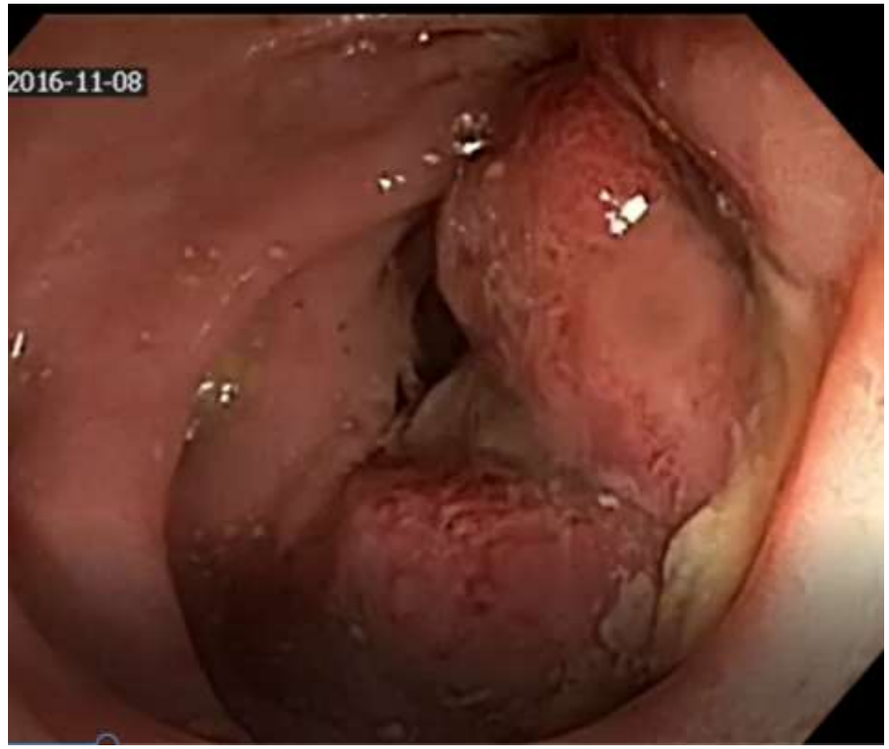
Colonoscopy Images Shows Growth Over Six Years of Inflamed Pseudopolyps in 6 inches of Sigmoid Colon



Dec 2010



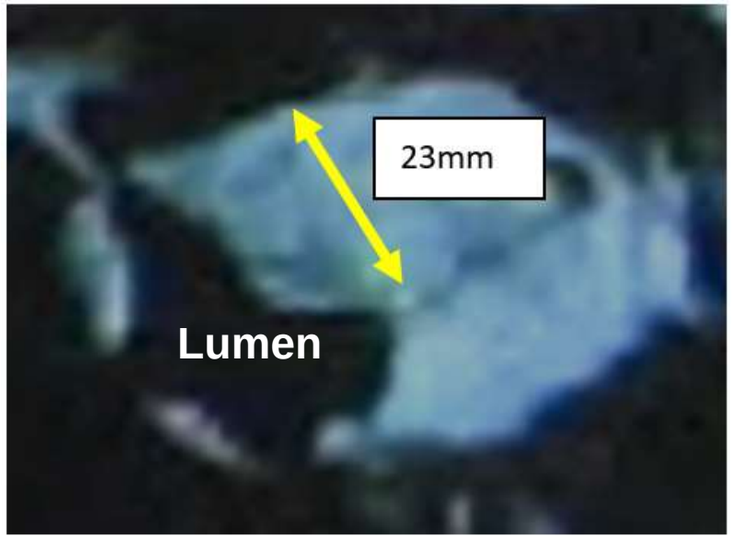
Jan 2012



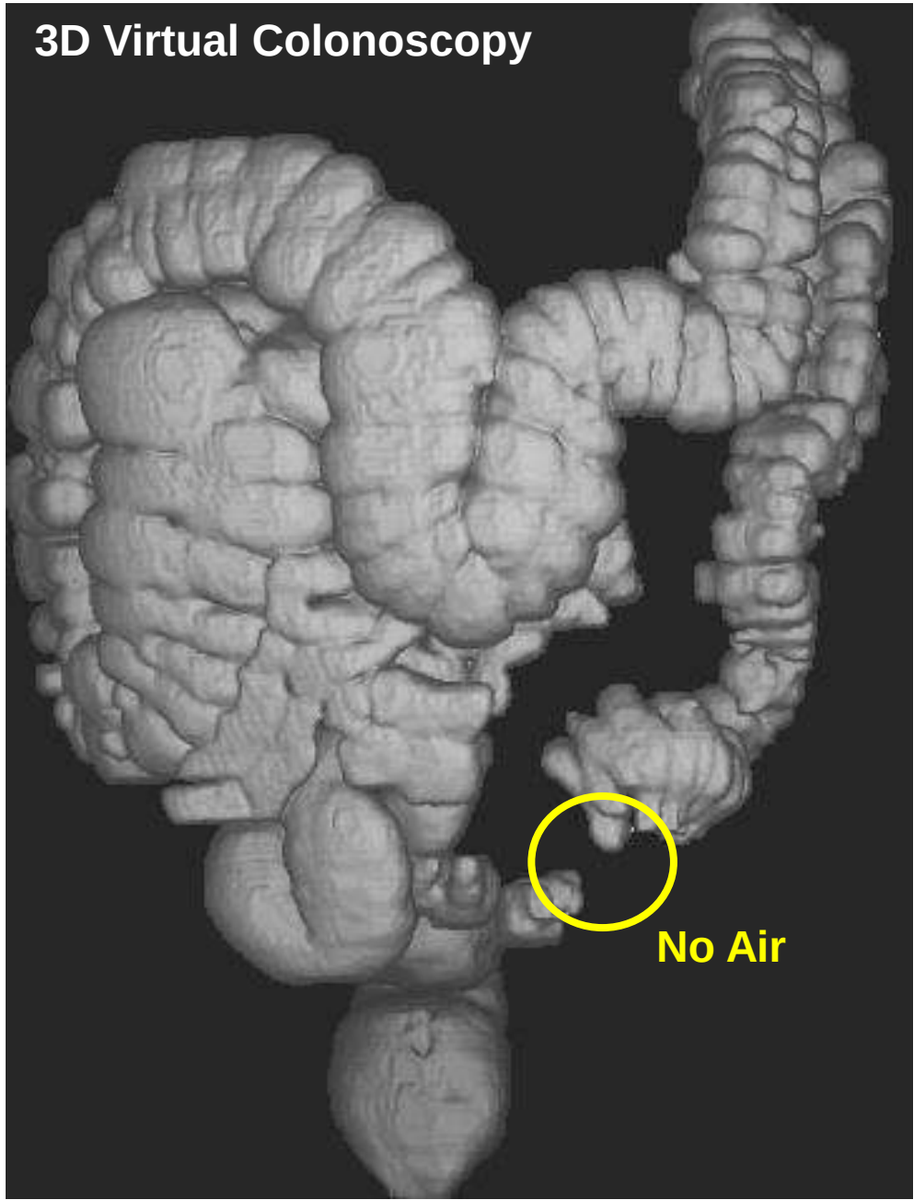
Nov 2016

By November 2016 they Almost Totally Block the Colon Lumen Passageway

Full Body CAT Scan at mm Resolution, Including Virtual Colonoscopy June 2016 Convinced Me Time Had Come for Surgery



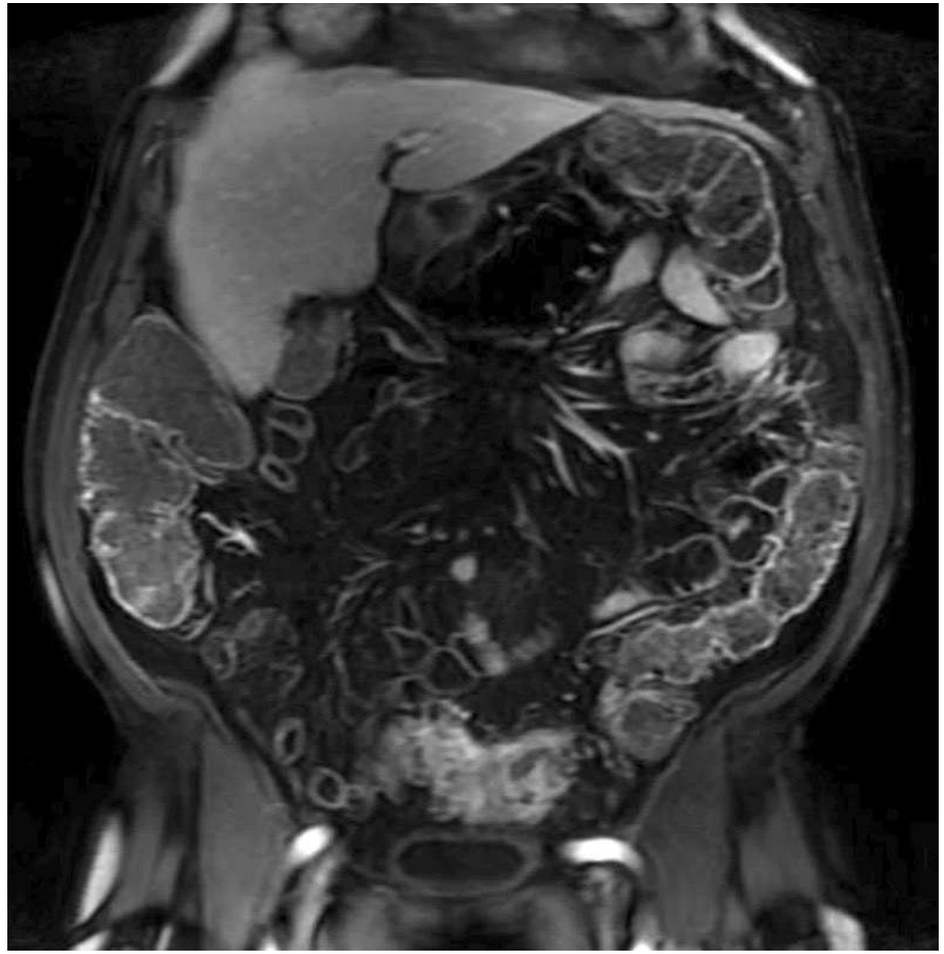
**“I would take it out.
All it can do is cause you trouble.”
-Harvey Eisenberg, MD
June 2016**



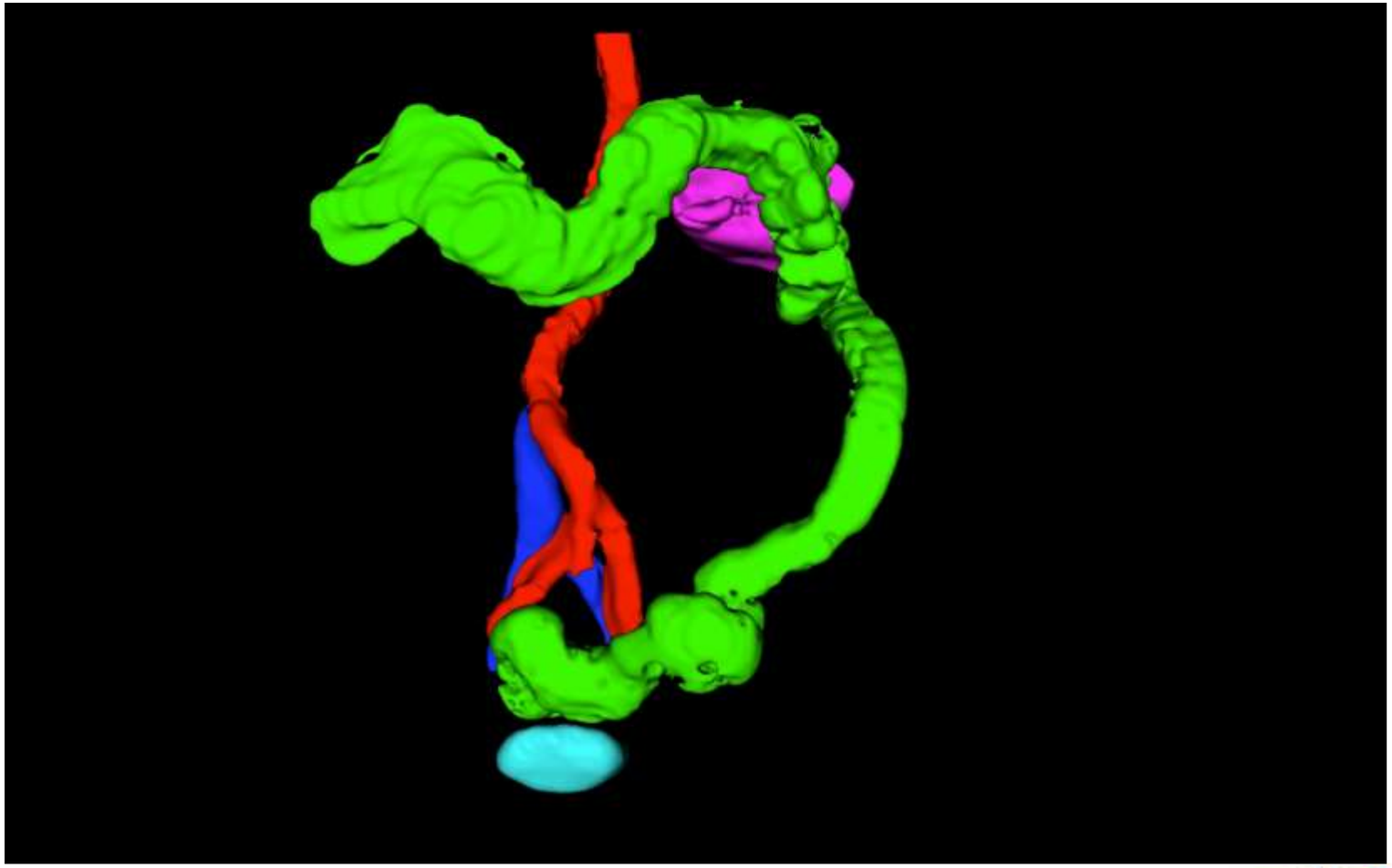
Source: Body Scan Intl., Irvine, CA

From Quantified Self to Quantified Surgery: Converting MRI Slices to 3D Organ Segmentation for Surgical Pre-Planning

High Resolution 3 Tesla MRI in UCSD's Center for Translational Imaging and Precision Medicine



Calit2's Dr. Jurgen Schulze Developed Software to Convert 150 2D MRI Slices to 3D Organs



MRI Radiology Team to Enable 3D:
Dr. Anders Dale, Dr. Stephen Dorros, Dr. Christine Chung, and Dr. Cynthia Santillan

Pre-Surgical Planning in QI Virtual Reality:
Using Virtual Reality As Input for Positioning The Two Resection Cuts



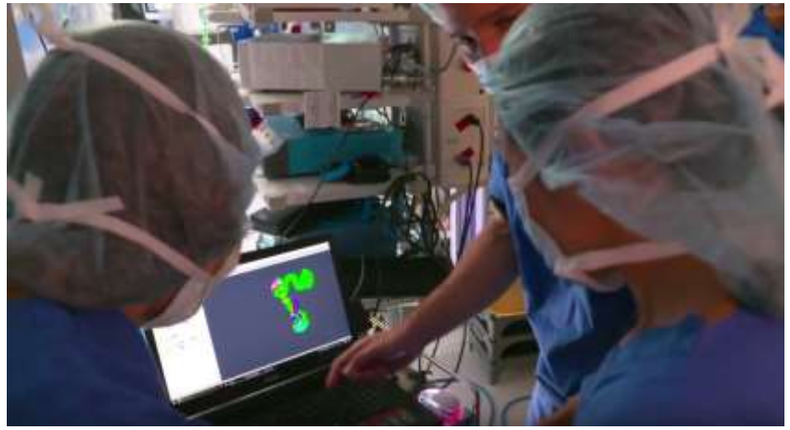
Surgeon Sonia Ramamoorthy, MD
in QI Virtual Reality CAVE



Colon Visualization by Jurgen Schulze, Calit2;
Photo Credit Tom DeFanti, Calit2

Using QI Organ Segmentation in Jacobs OR on Tuesday November 29, 2016

Dr. Schulze Rotating 3D Organs To Match Up With da Vinci Arms and Internal Camera





Patient Smarr With da Vinci Robot Arms Inside Him



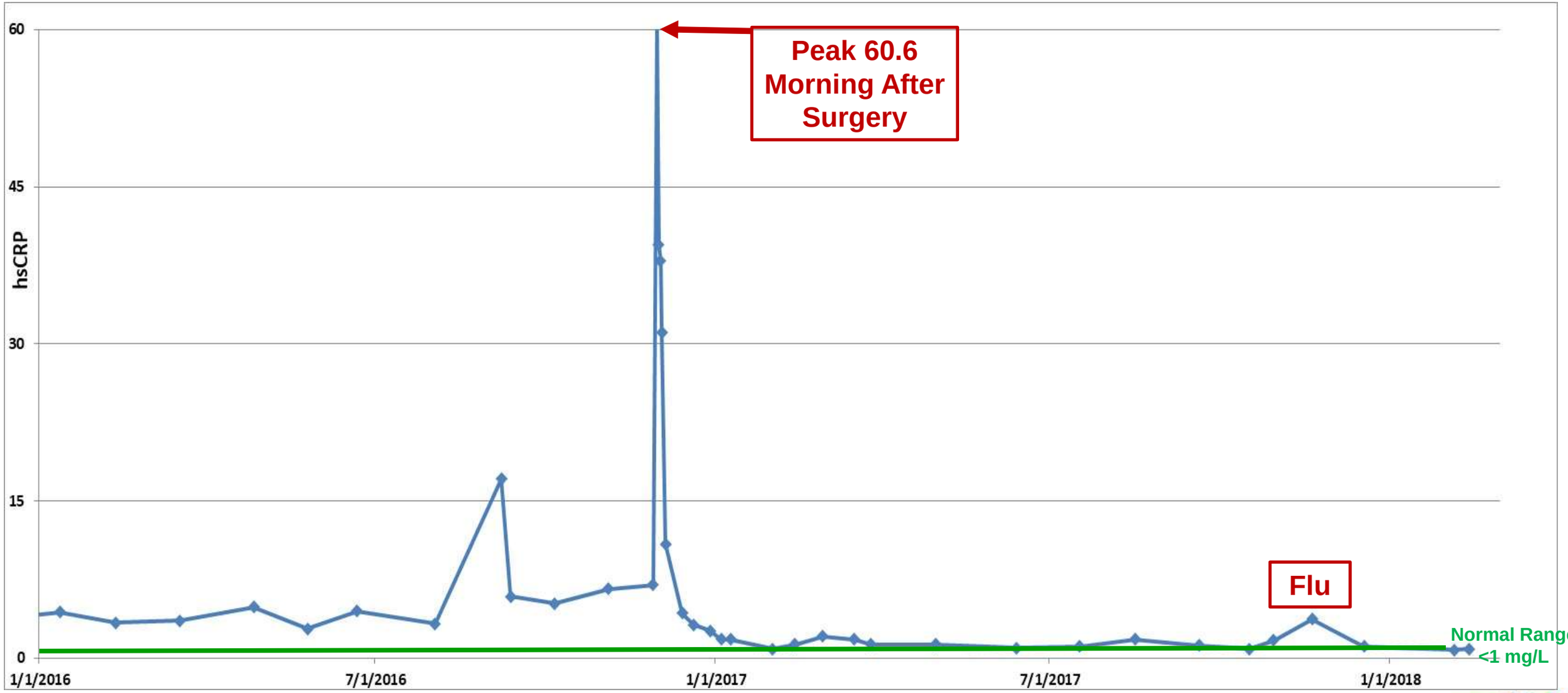


Dr. Ramamoorthy Operating Da Vinci Xi Robot During Surgery

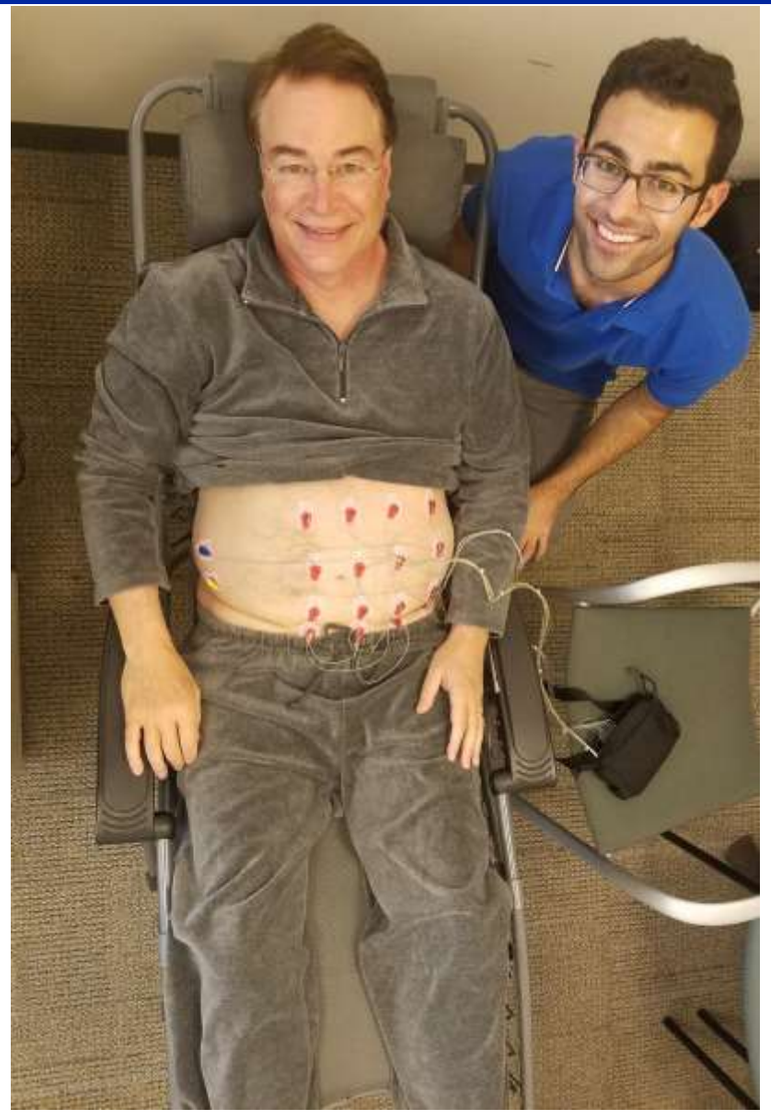


OR Team Using Large Screens To Watch Dr. Schulze's da Vinci Images

Using hsCRP to Track Inflammation Following Surgery to Detect Post-Surgical Complications



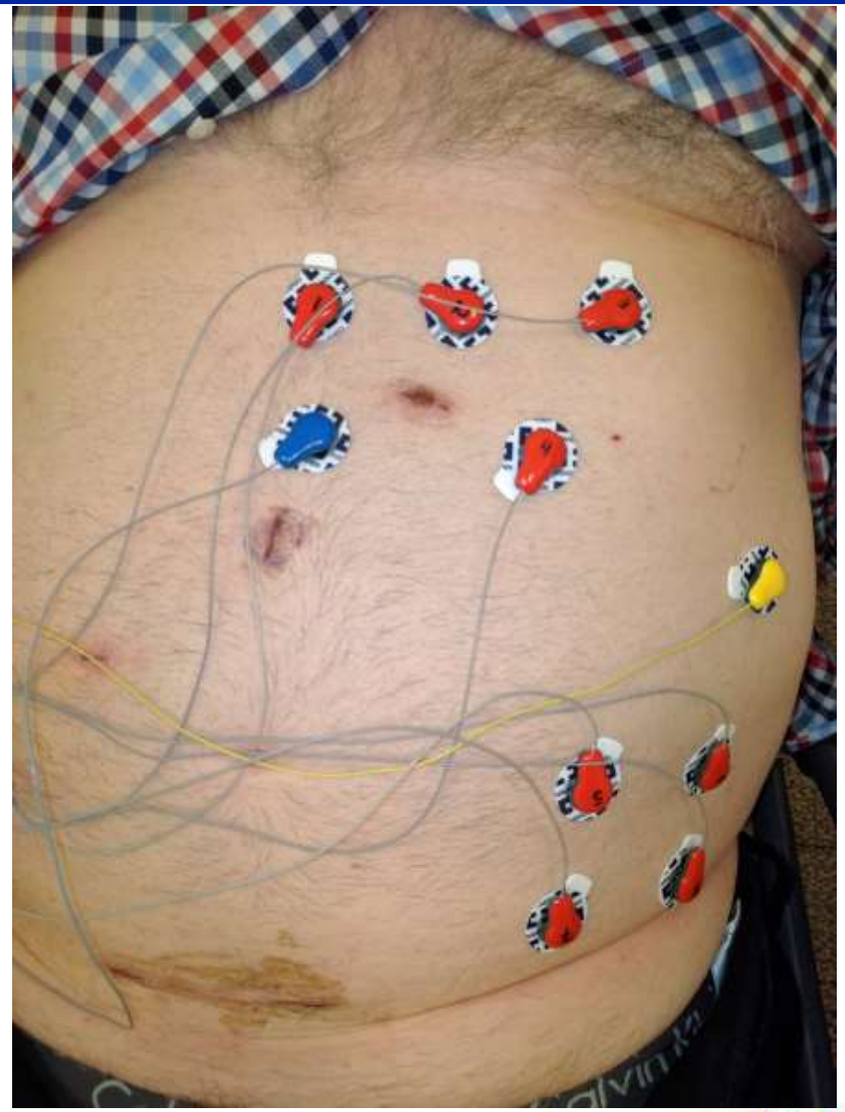
EGG Array From UCSD Professor Todd Coleman's Lab: Experiment with PhD Student Armen Gharibans



1 Week Before Surgery



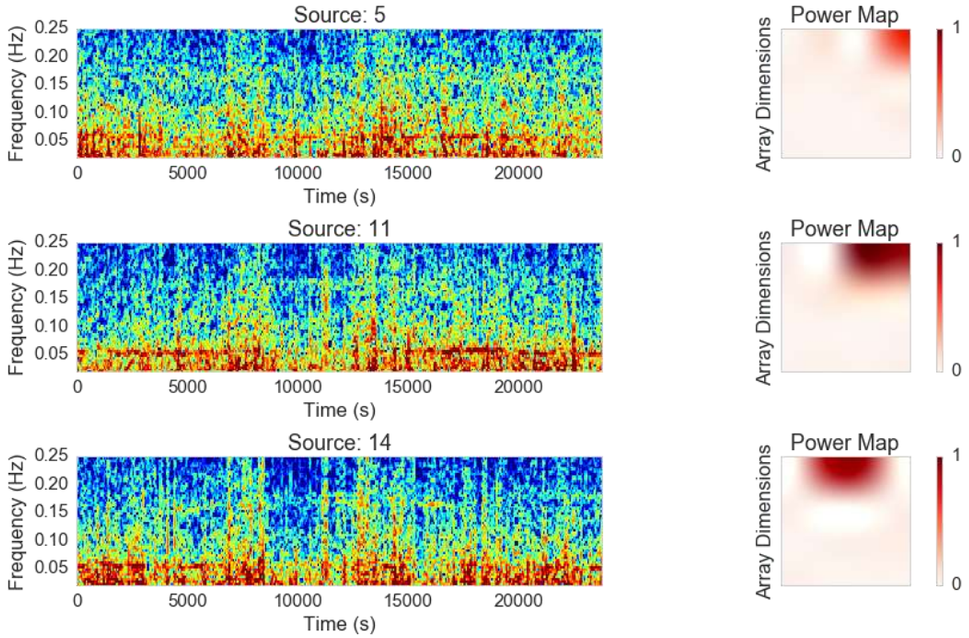
2 Days After Surgery

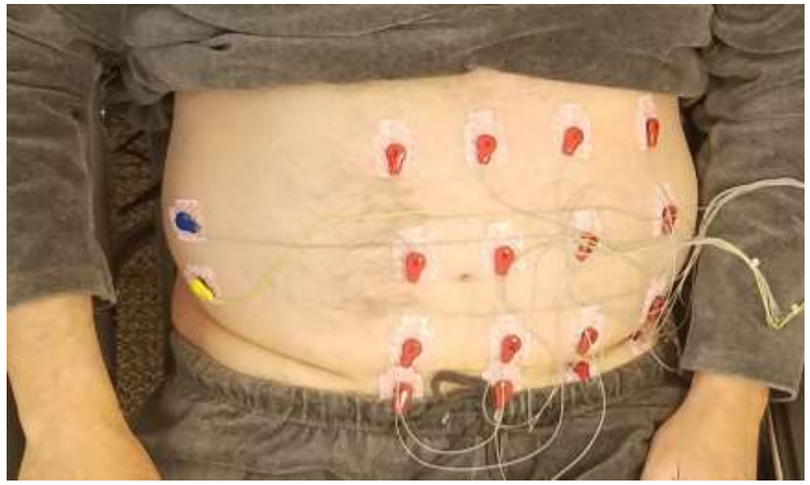


2 Weeks After Surgery

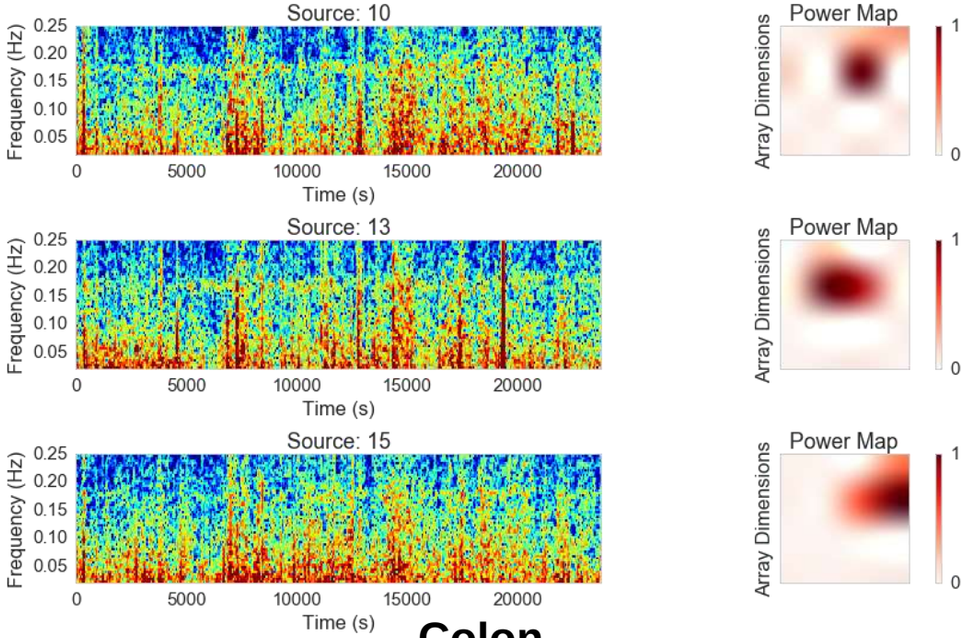
Using EGG to Separate Out the Components of the GI Tract

Stomach (0.05 Hz)

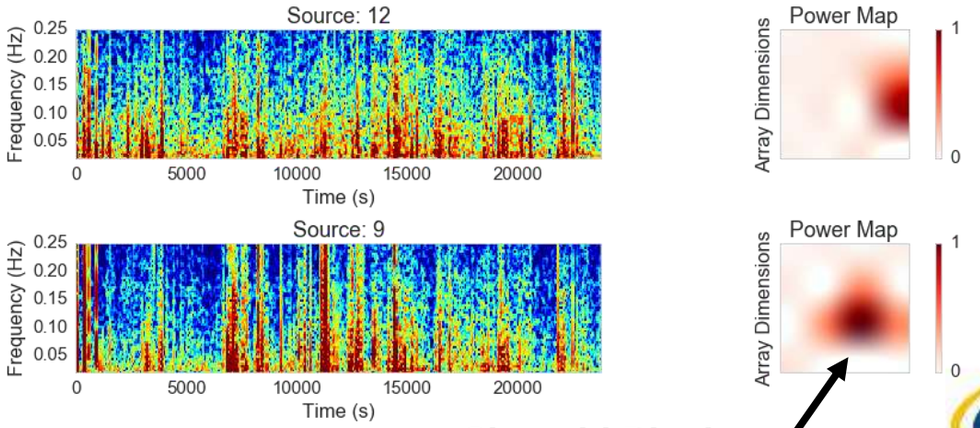




Small Intestines (0.18 Hz)



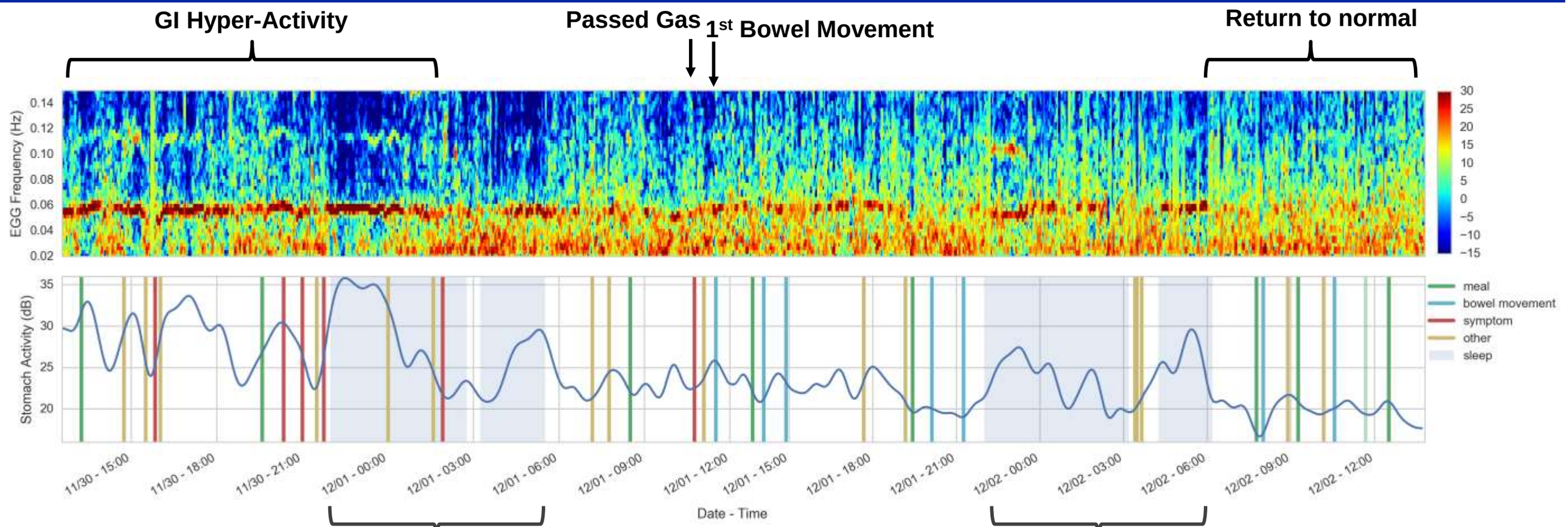
Colon



Sigmoid Blockage

Source: Armen Gharibans, UCSD

Using EGG to Detect Colon Restart: GI Activity 24 to 72 Hours After Surgery



2nd Night of Sleep

3rd Night of Sleep

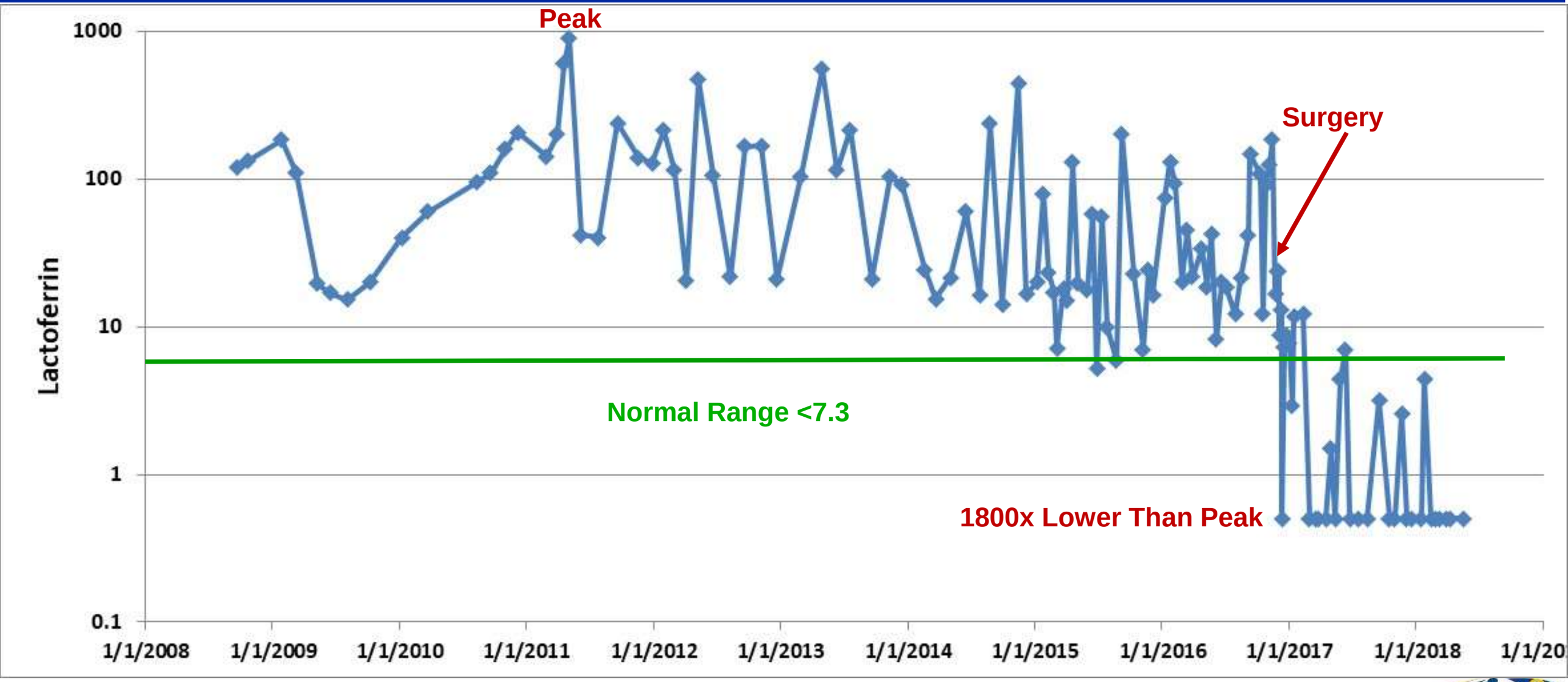
High power, irregular

Low power, periodic

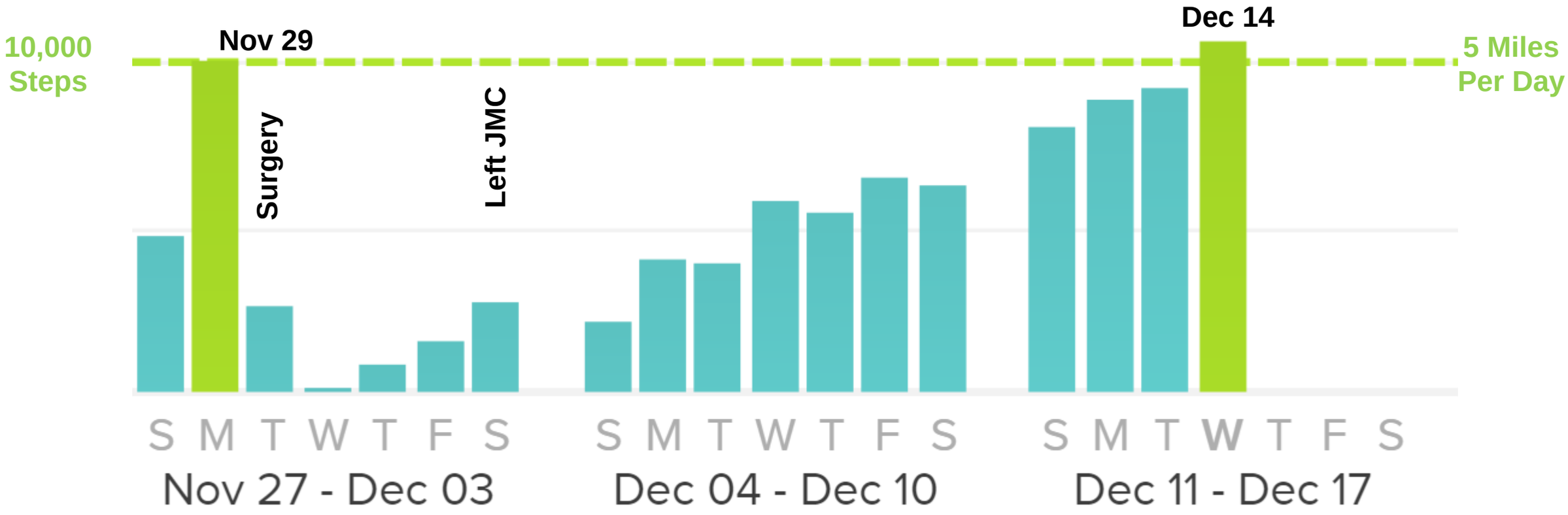
Low power, regular

Source: Armen Gharibans, UCSD; Analysis by Benjamin Smarr, UCB

Colonic Inflammation:
Abrupt Shift to Healthy Following Surgical Resection



Quantified Recovery (Steps Walked Per Day) - Recovered to Pre-Surgery Level in Two Weeks



Your Body Has 10 Times
As Many Microbe Cells As DNA-Bearing Human Cells

Your Body Hosts 40 Trillion Microbes

Your Microbiome is
Your "Near-Body" Environment
and its Cells
Contain ~100x as Many DNA Genes
As Your Human DNA-Bearing Cells

Inclusion of this "Dark Matter" of the Body
Will Radically Alter Medicine

I Have Been Collaborating with the UCSD Knight Lab To Sequence My Stool Time Series

LOCAL TOPICS | SCIENCE & ENVIRONMENT | SCIENCE

UCSD hires star biologist Rob Knight

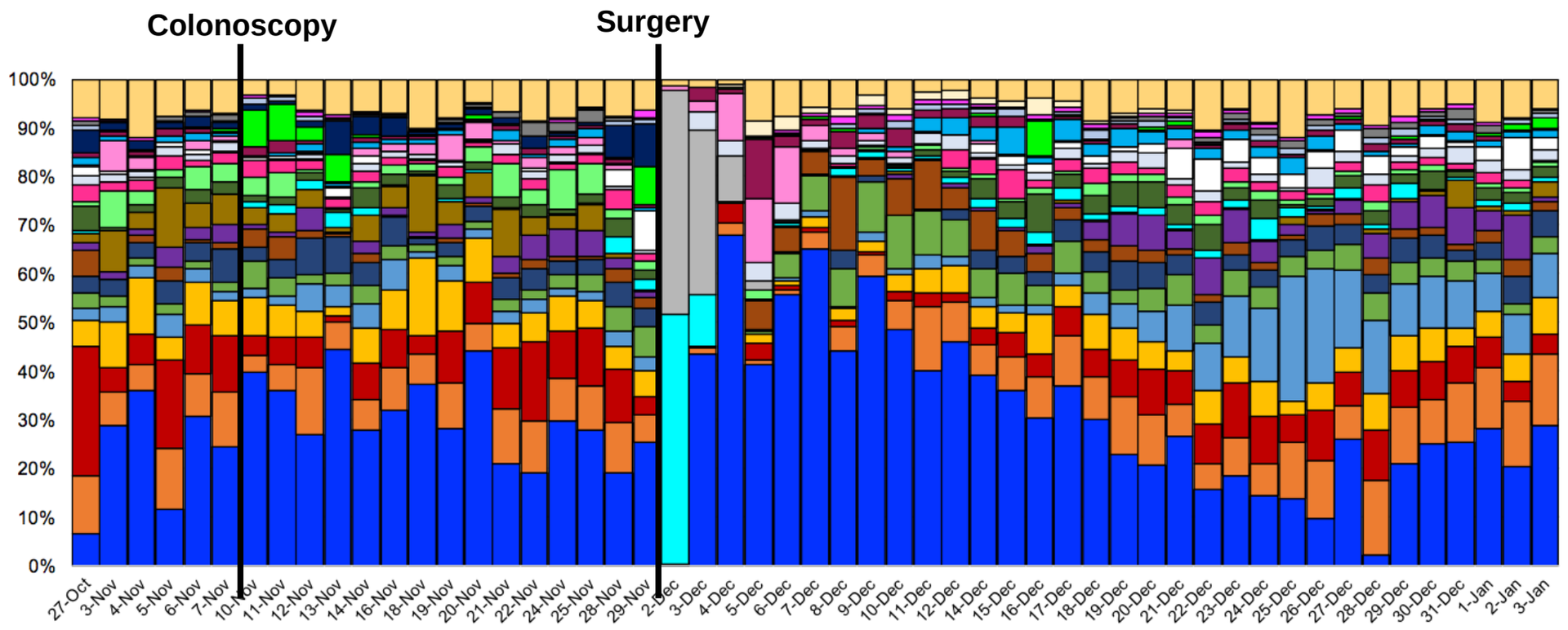
By Gary Robbins 1:30 P.M. JAN. 11, 2015 Updated 12:17 P.M. JAN. 12, 2015 PRINT COMMENTS 0





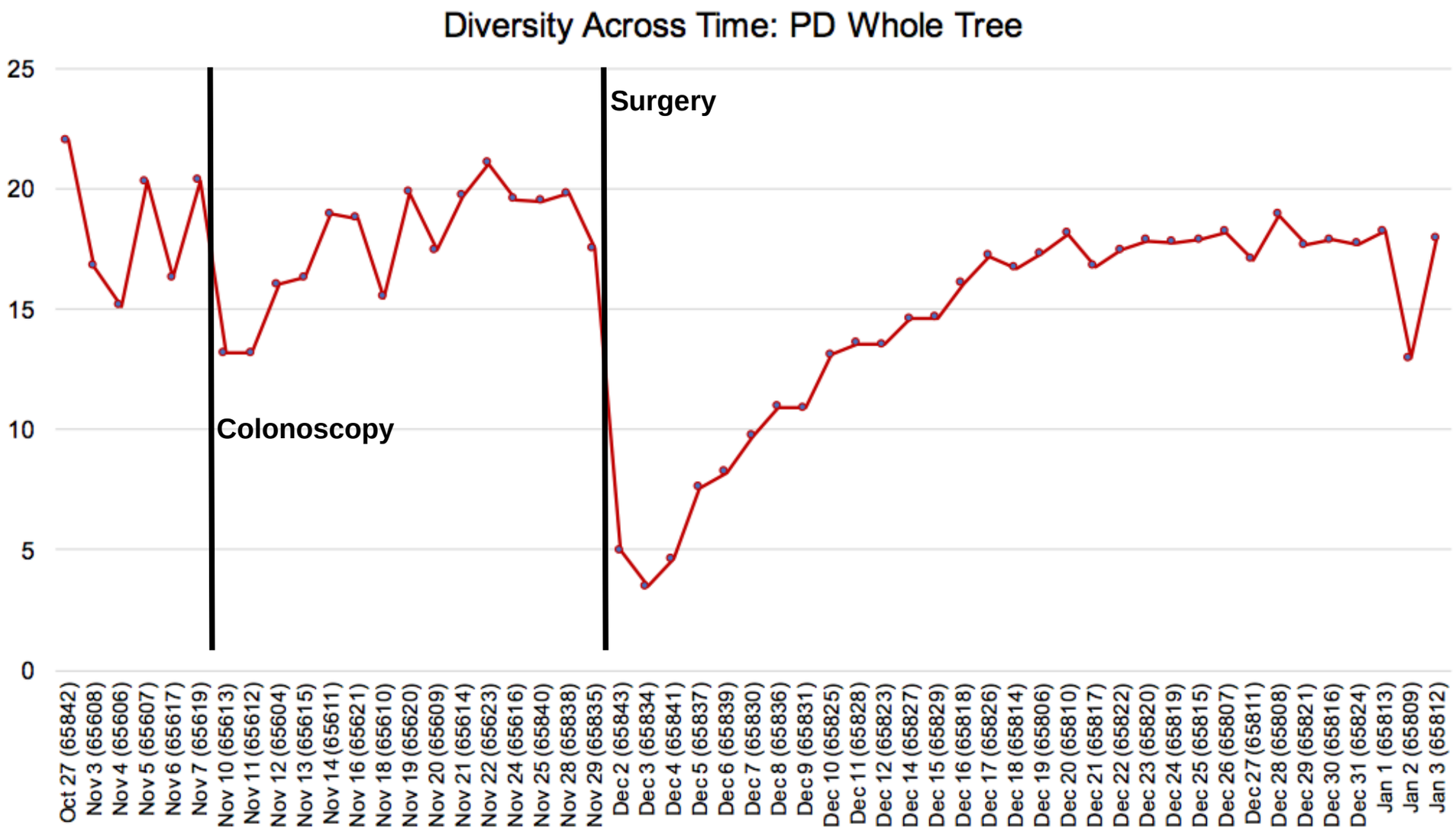
Larry's 40 Stool Samples Over 3.5 Years
to Rob's lab on April 30, 2015

Gut Microbiome Genus-Level Profiles
Daily Samples Before and After Abdominal Surgery



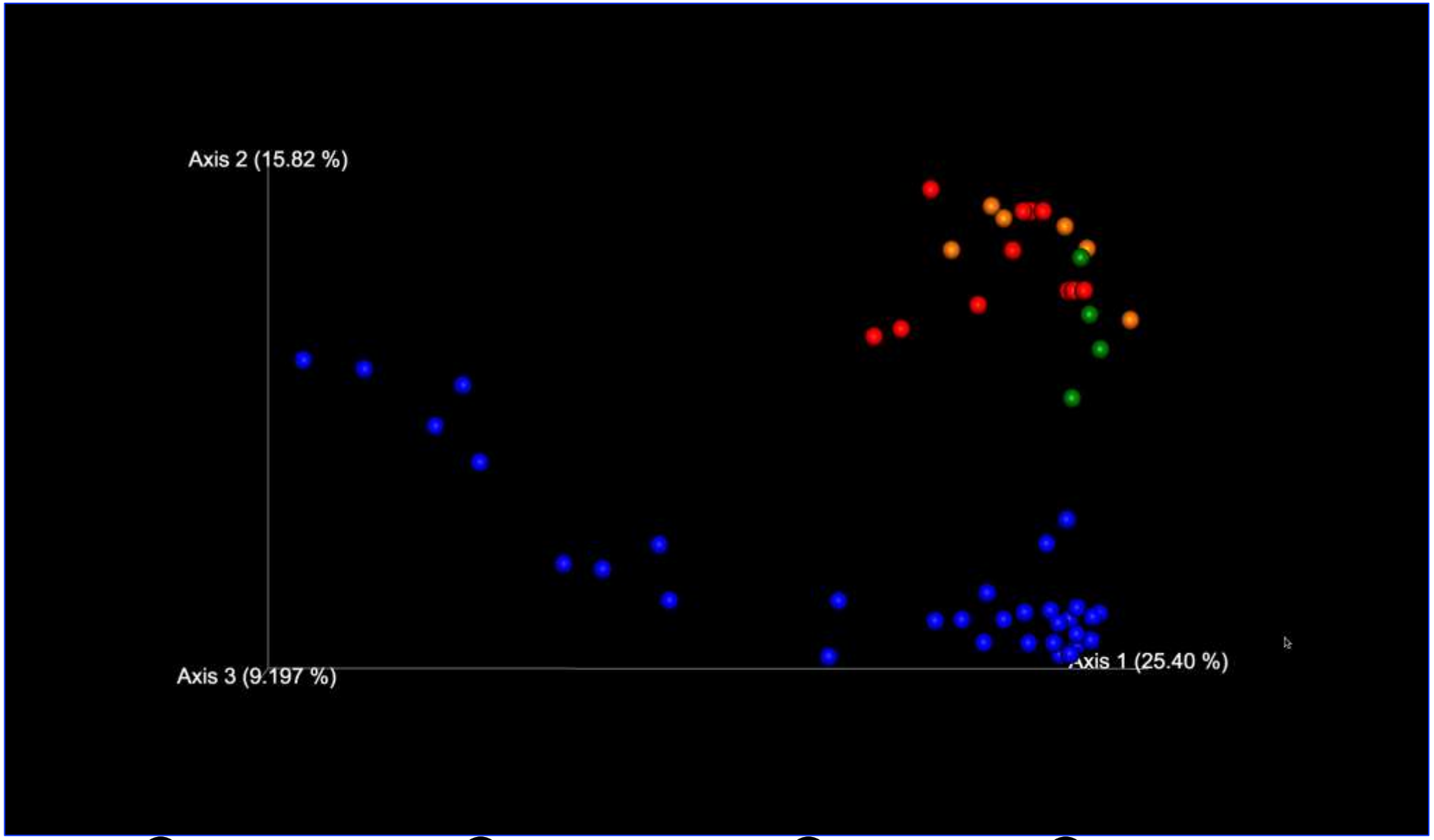
Source: Embriette Hyde, UCSD

Much Larger Drop in Microbiome Ecology Diversity Following Surgery Than Following Colonoscopy



Source: Embriette Hyde, UCSD

Major Shift in Gut Microbiome Ecology Following Abdominal Surgery With Return to New Equilibrium State



Inflamed Disease State

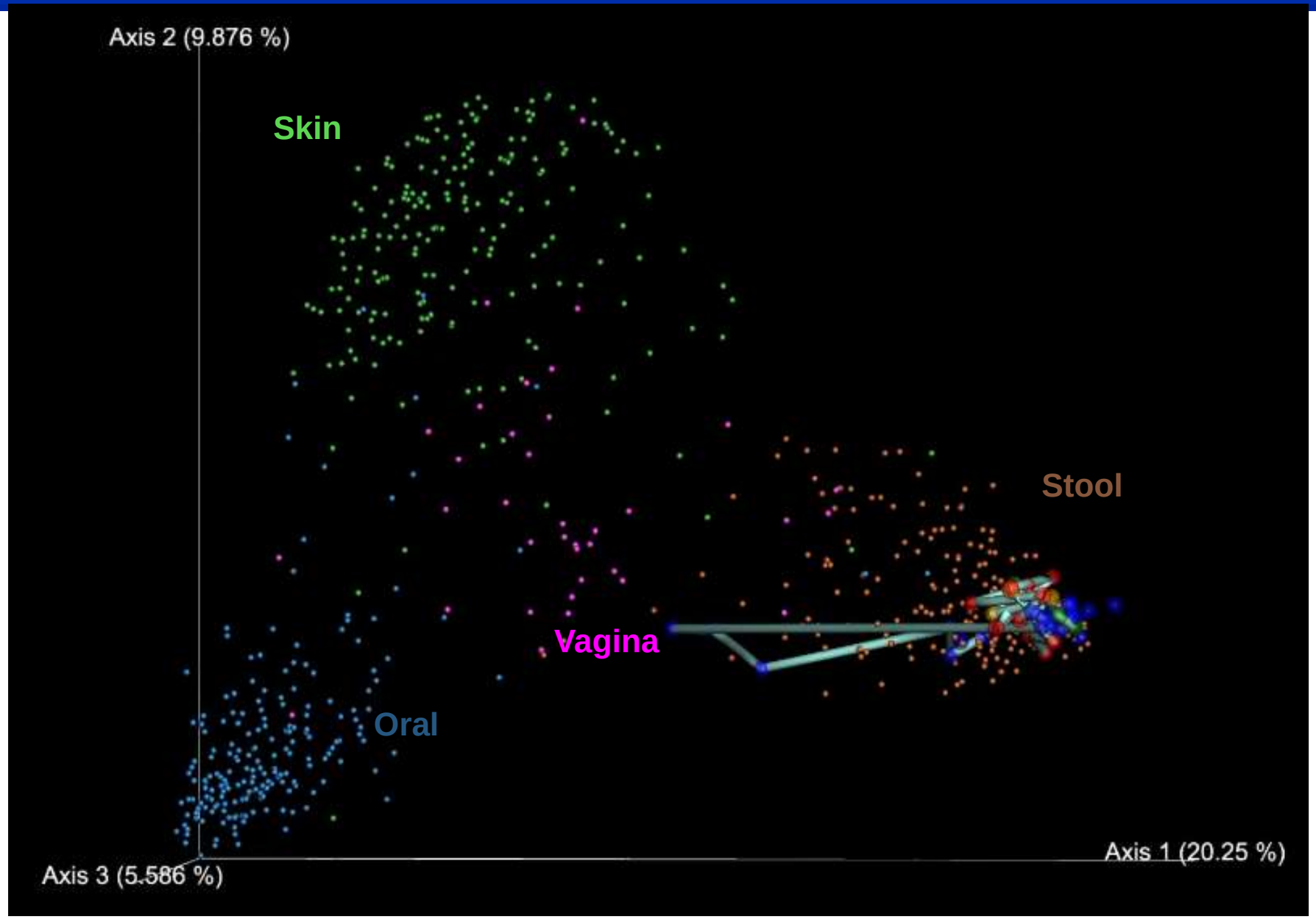
⇩

Healthy Post-Surgery State

Pre-colonoscopy Post-colonoscopy Pre-surgery Post-surgery

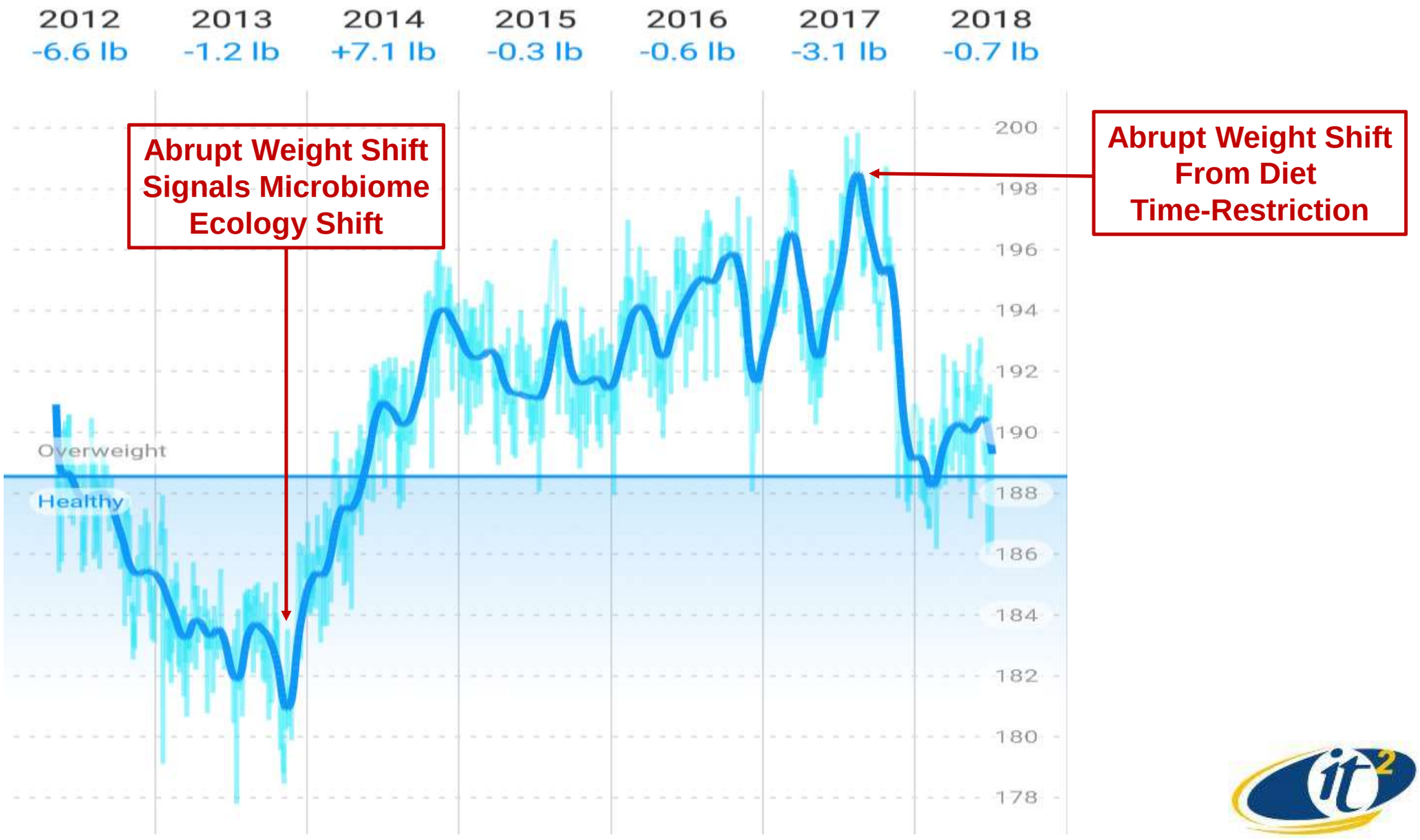
Source: Embriette Hyde, Yoshiki Vázquez Baeza, Knight Lab, UCSD

My Gut Microbiome Changed More After Surgery Than the Difference Between 10,000 Individuals!



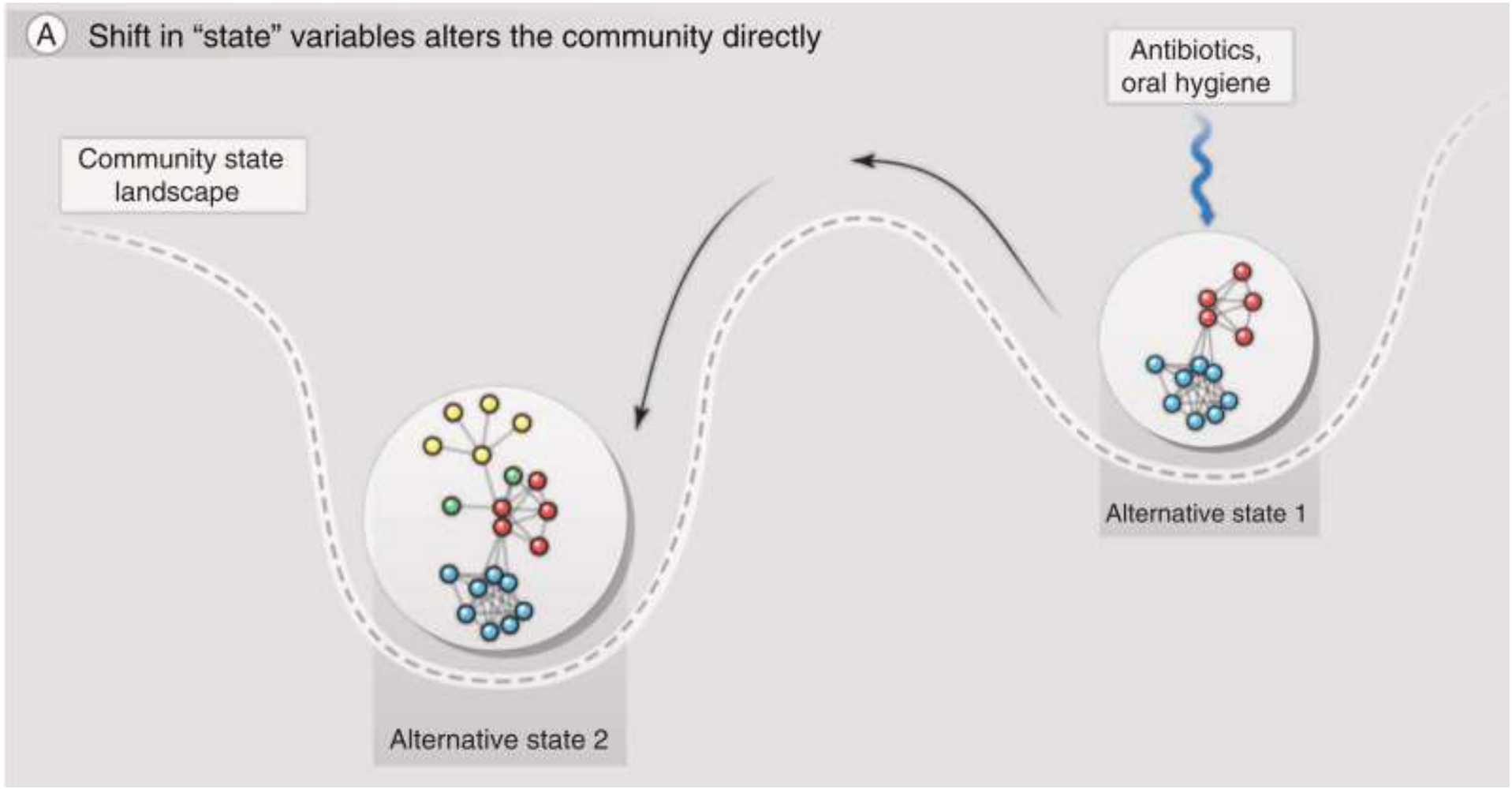
Data From American Gut Project, UCSD. Rob Knight, Director

Using My Daily Weight Time Series To Detect Internal Changes



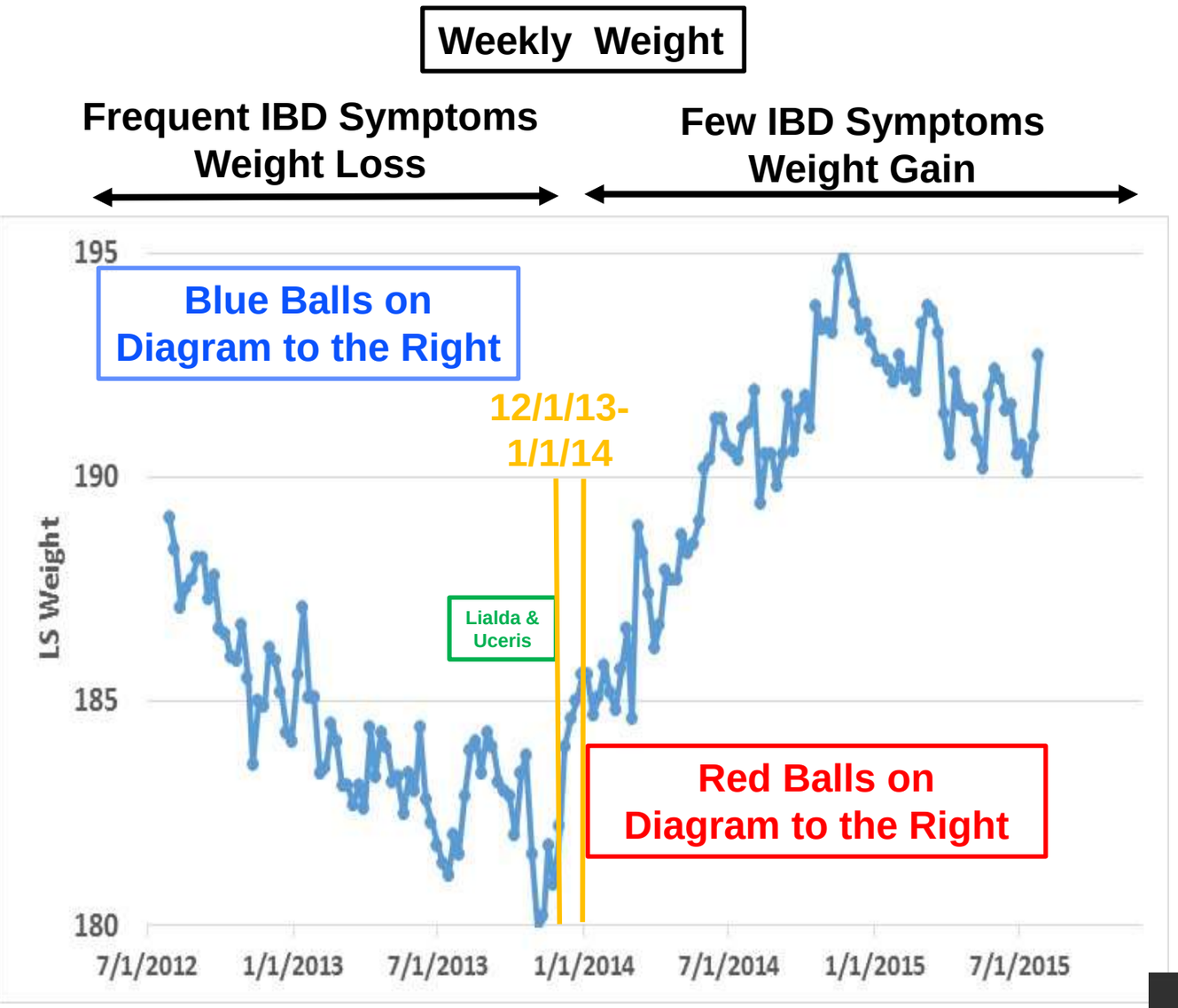
Data From Withings WiFi Bathroom Scale

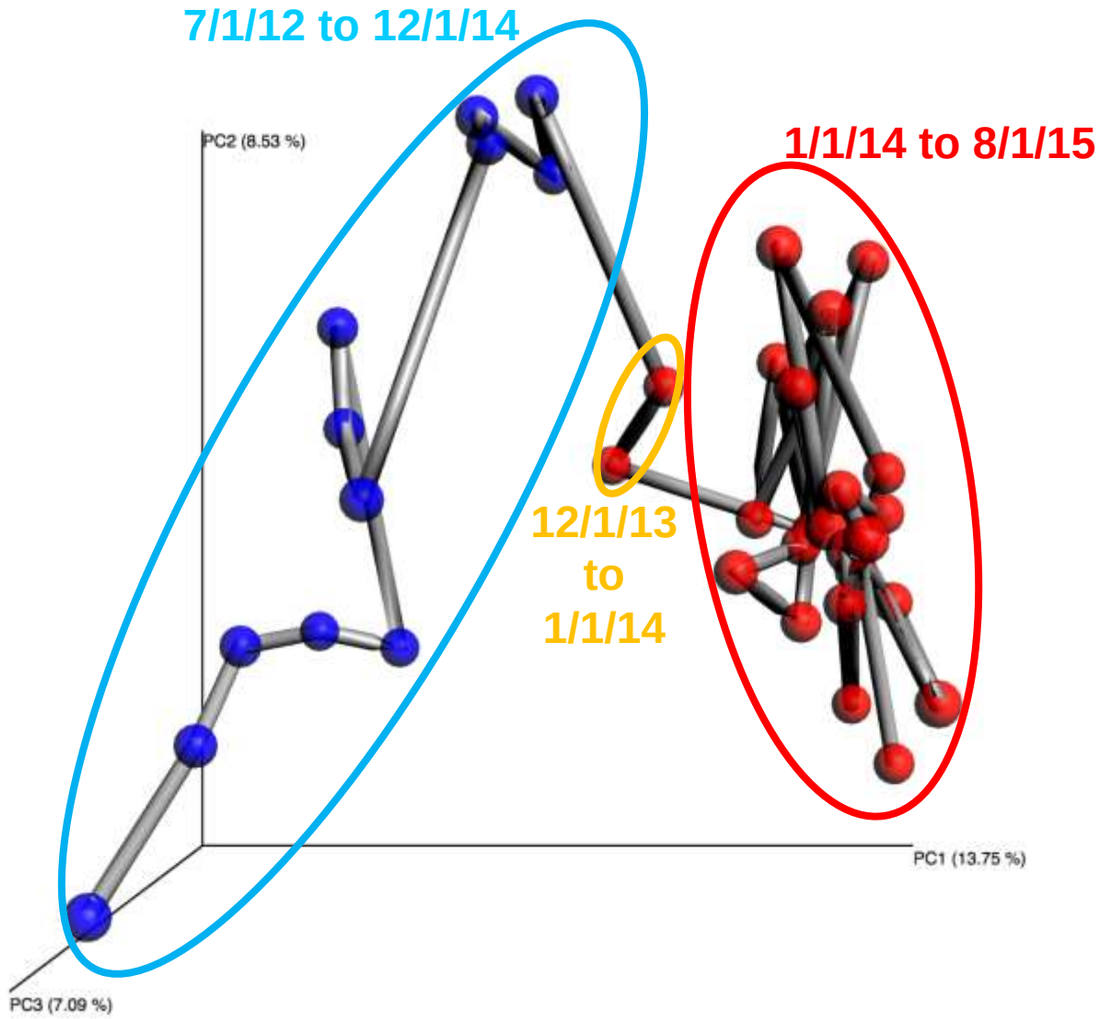
Lessons from Ecological Dynamics: Gut Microbiome Has Multiple Relatively Stable Equilibria



"The Application of Ecological Theory Toward an Understanding of the Human Microbiome," Elizabeth Costello, Keaton Stagaman, Les Dethlefsen, Brendan Bohannan, David Relman Science 336, 1255-62 (2012)

My Gut Microbiome Ecology Shifted After Drug Therapy Leading to Rapid Weight Gain, But Drop in IBD Symptoms

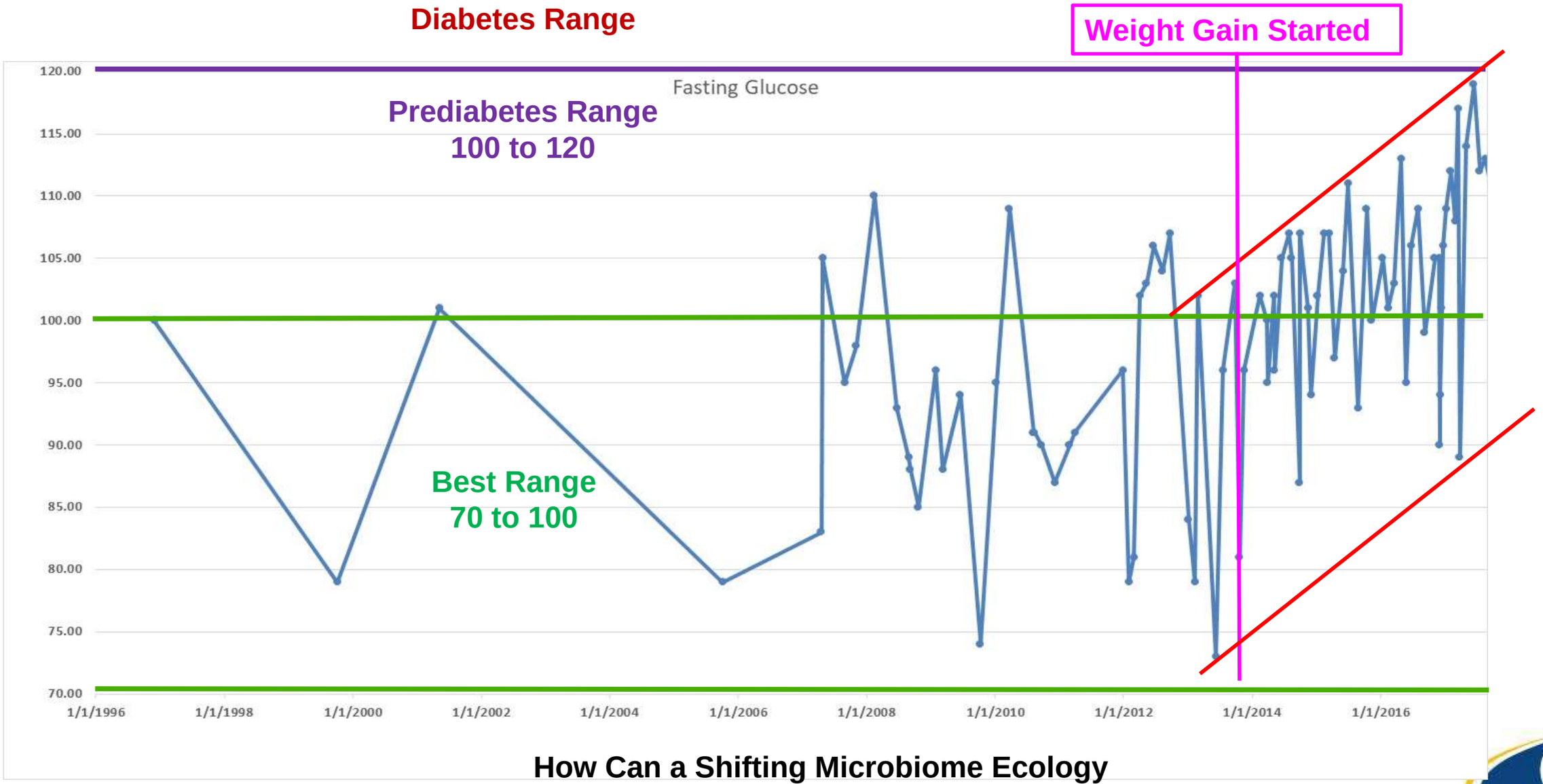




Weight Data from Larry Smarr, Calit2, UCSD

PCoA by Justine Debelius and Jose Navas, Knight Lab, UCSD

My Fasting Glucose Level Began to Rise After the Microbiome Shift – I Was Developing Metabolic Syndrome and Prediabetes



How Can a Shifting Microbiome Ecology Alter Your Glucose Pathway?

Aligning Your Eating Pattern With Your Body's Circadian Rhythm Is As Important As What You Eat

Reverse Insulin Resistance with Intermittent Fasting



By: COURTNEY SPERLAZZA, MPH

Time-Restricted Feeding Is a Preventative and Therapeutic Intervention against Diverse Nutritional Challenges

Cell Metabolism
December 2, 2014

Amandine Chaix,[1] Amir Zarrinpar,[1,2] Phuong Miu,[1] and Satchidananda Panda[1,*]
[1]Salk Institute for Biological Studies, La Jolla, CA 92037, USA
[2]Division of Gastroenterology, University of California, San Diego, La Jolla, CA 92093, USA

I Volunteered to Become a Patient in the UCSD/Salk Pilot Study of Time-Restricted Eating (TRE) in Metabolic Syndrome

- **Hypothesis**
  - **In patients with metabolic syndrome who eat for ≥ 14 hours per day, limiting daily oral intake to 10 hours per day for 3 months while using a smartphone application will result in:**
    - Weight loss
    - Improved glucose metabolism
    - Improved biomarkers associated with cardiovascular disease risk
- **First study of TRE in metabolic syndrome**
- **First use of continuous glucose monitoring during TRE**
- **November 2017 to February 2018**

- **My Improvements:**
  - **Fasting Glucose Peak Dropped From 119 to 101**
  - **Waist 108cm to 102 cm**
  - **Weight 197 to 189**
  - **Blood Pressure 140/74 to 130/69**

UC San Diego

salk
Where cures begin.

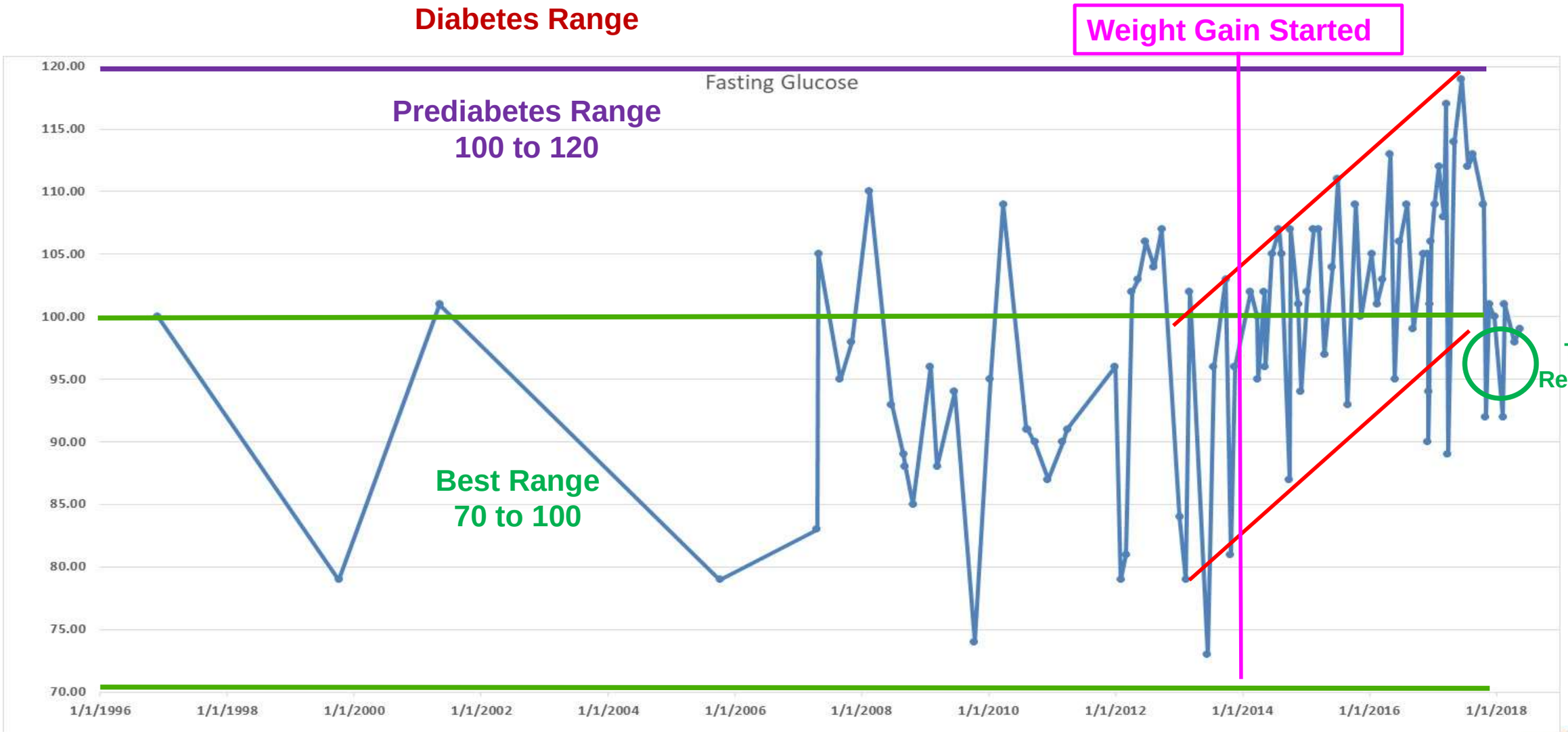


Pam Taub, MD
Cardiology

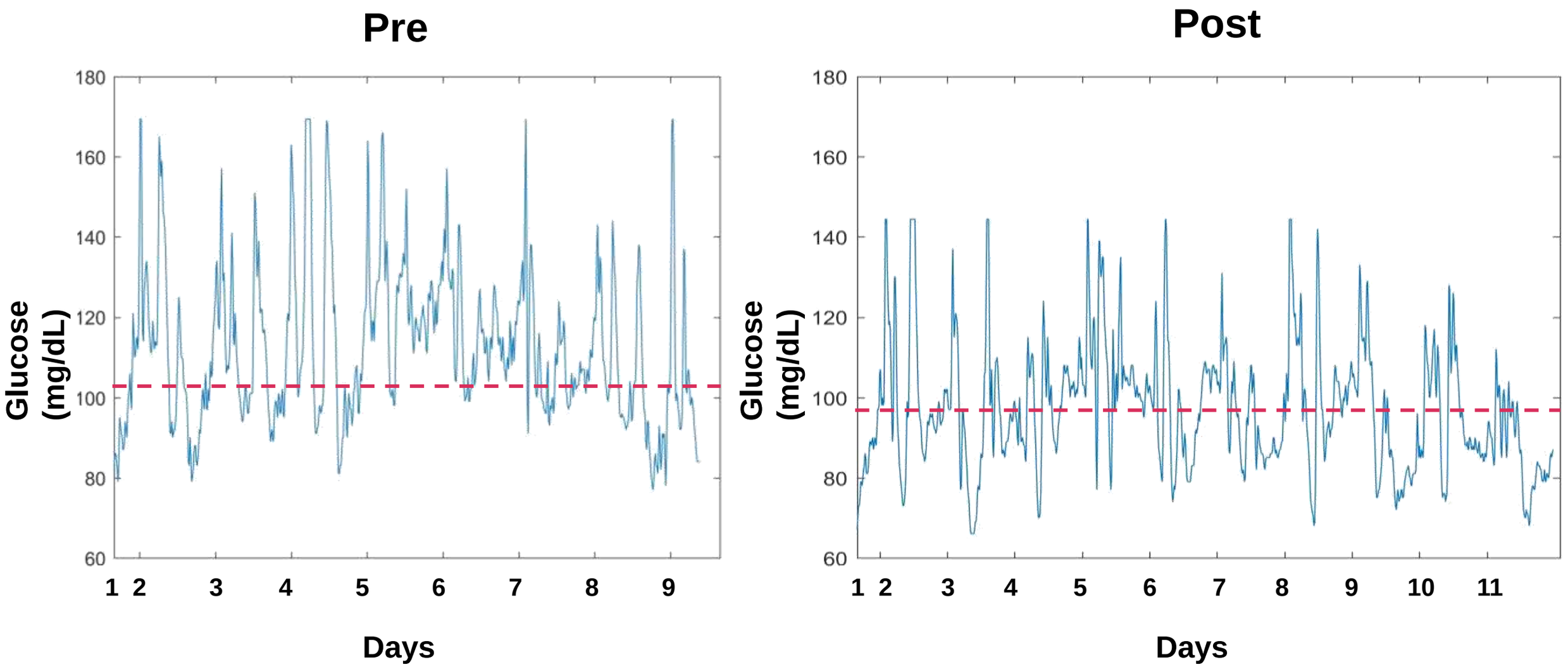


Satchin Panda, PhD
Circadian Biology

My Fasting Glucose Level Dropped Abruptly Into Normal Level During Time Restricted Diet

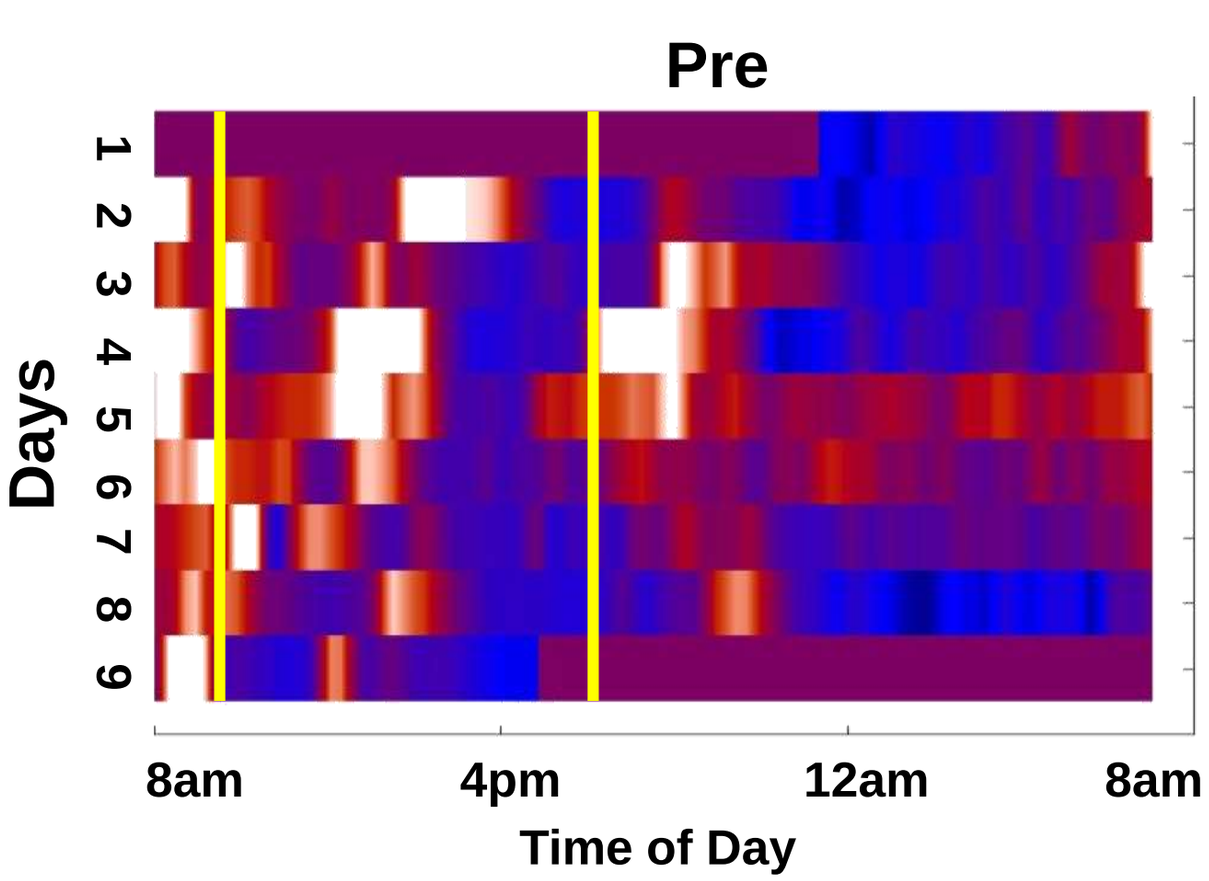


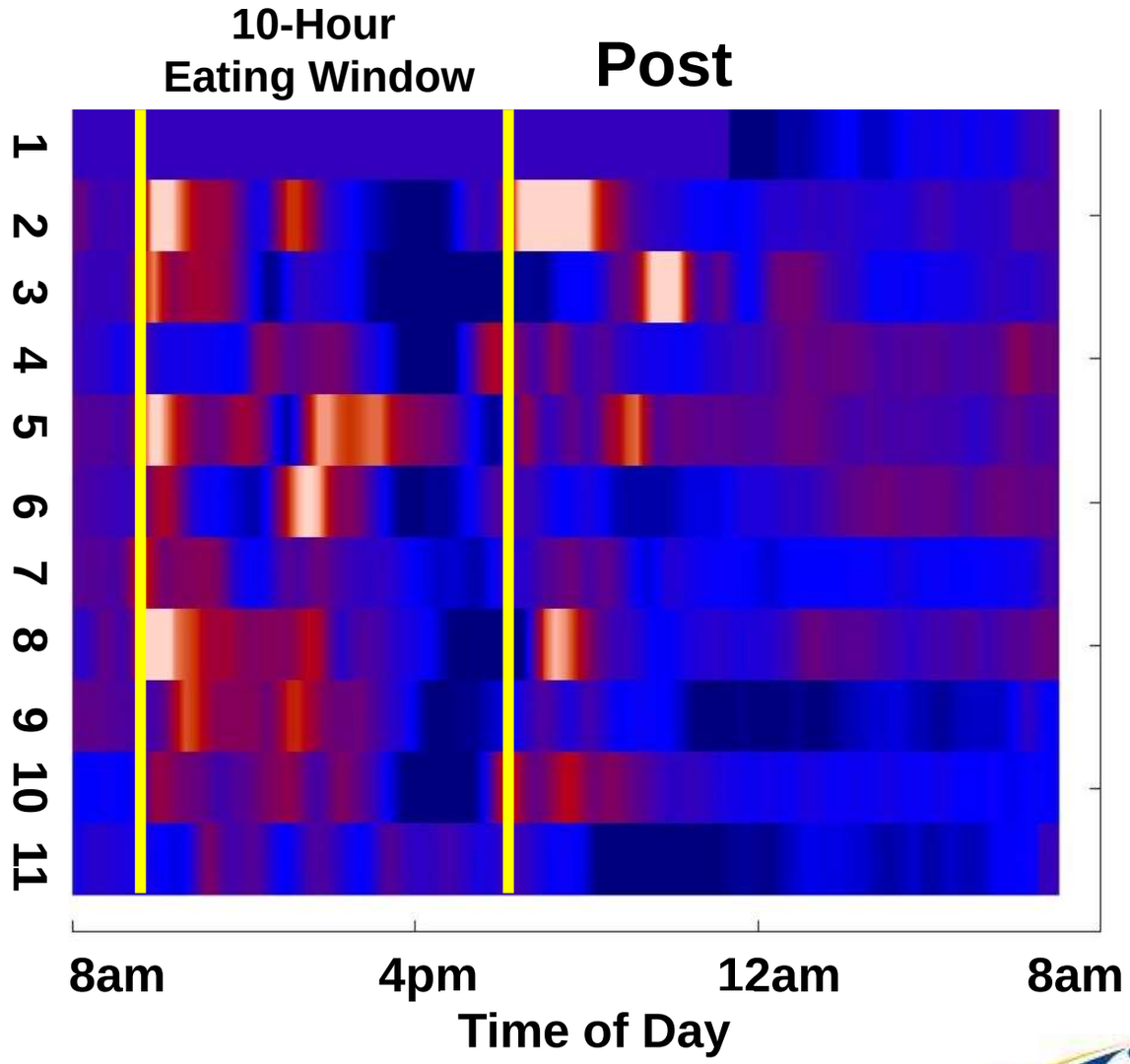
Time-Restricting My Food Intake to Ten Hours Improved My Glucose Spiking Without Changing Diet



Data from Taub/Panda Clinical Trial
Graphics by Azure Grant, UC Berkeley

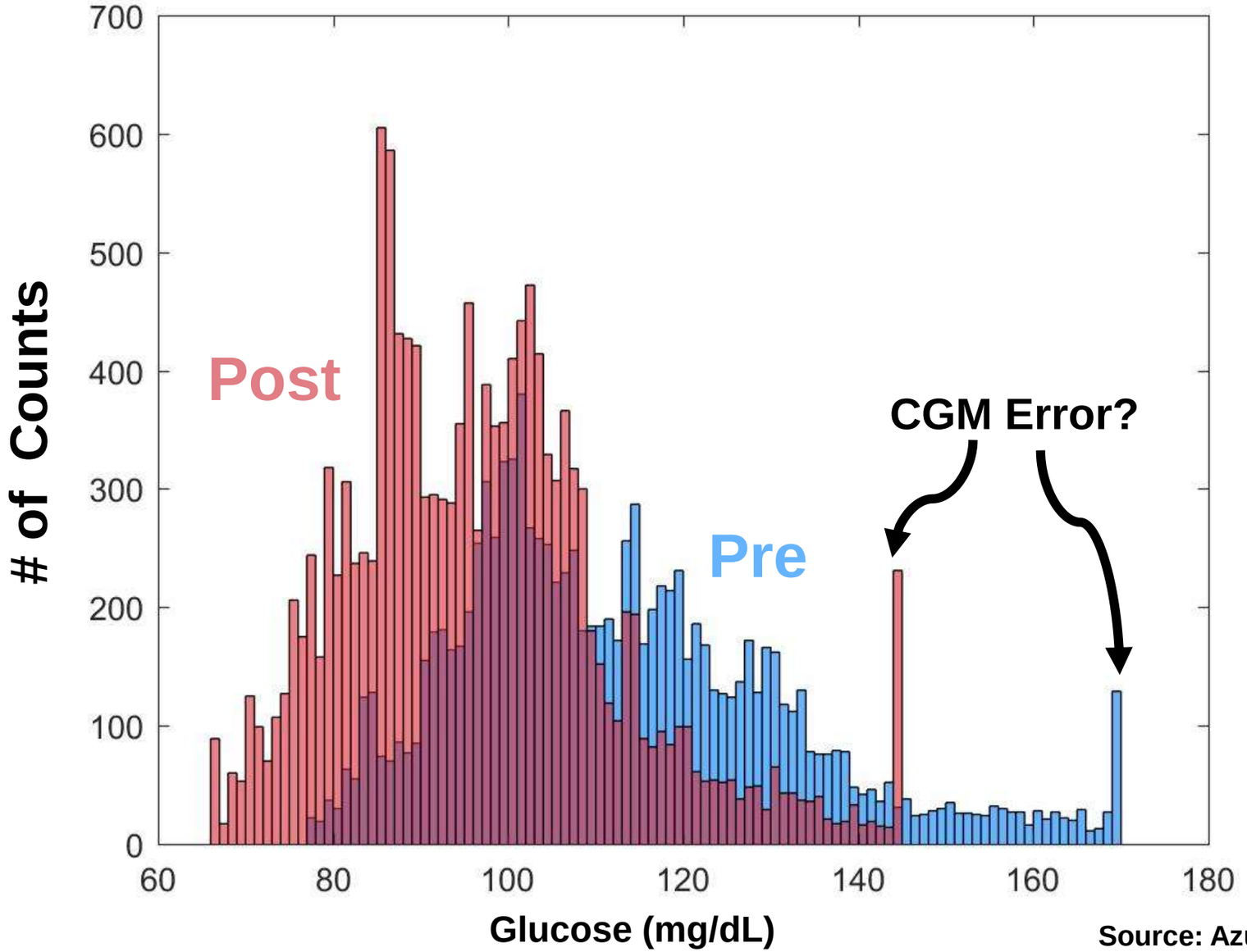
Heat Map of Continuous Glucose Monitor Every 15 Minutes Before and After 3 Months of Time-Restricted Eating





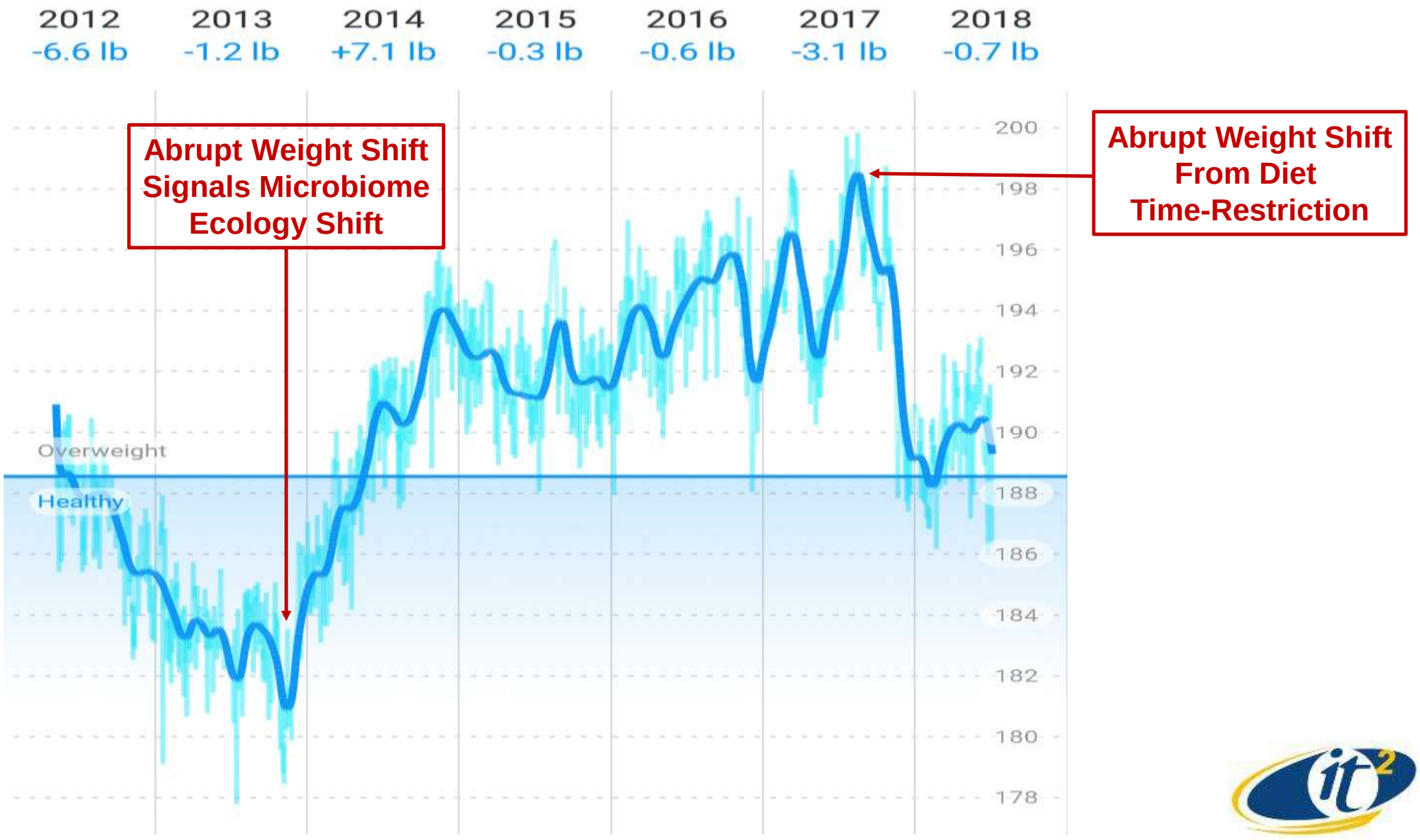
Data from Taub/Panda Clinical Trial
Graphics by Azure Grant, UC Berkeley

Major Changes in Glucose Profile
Before and After 3 Months of Time-Restricted Eating



Source: Azure Grant, UCB

Using My Daily Weight Time Series To Detect Internal Changes

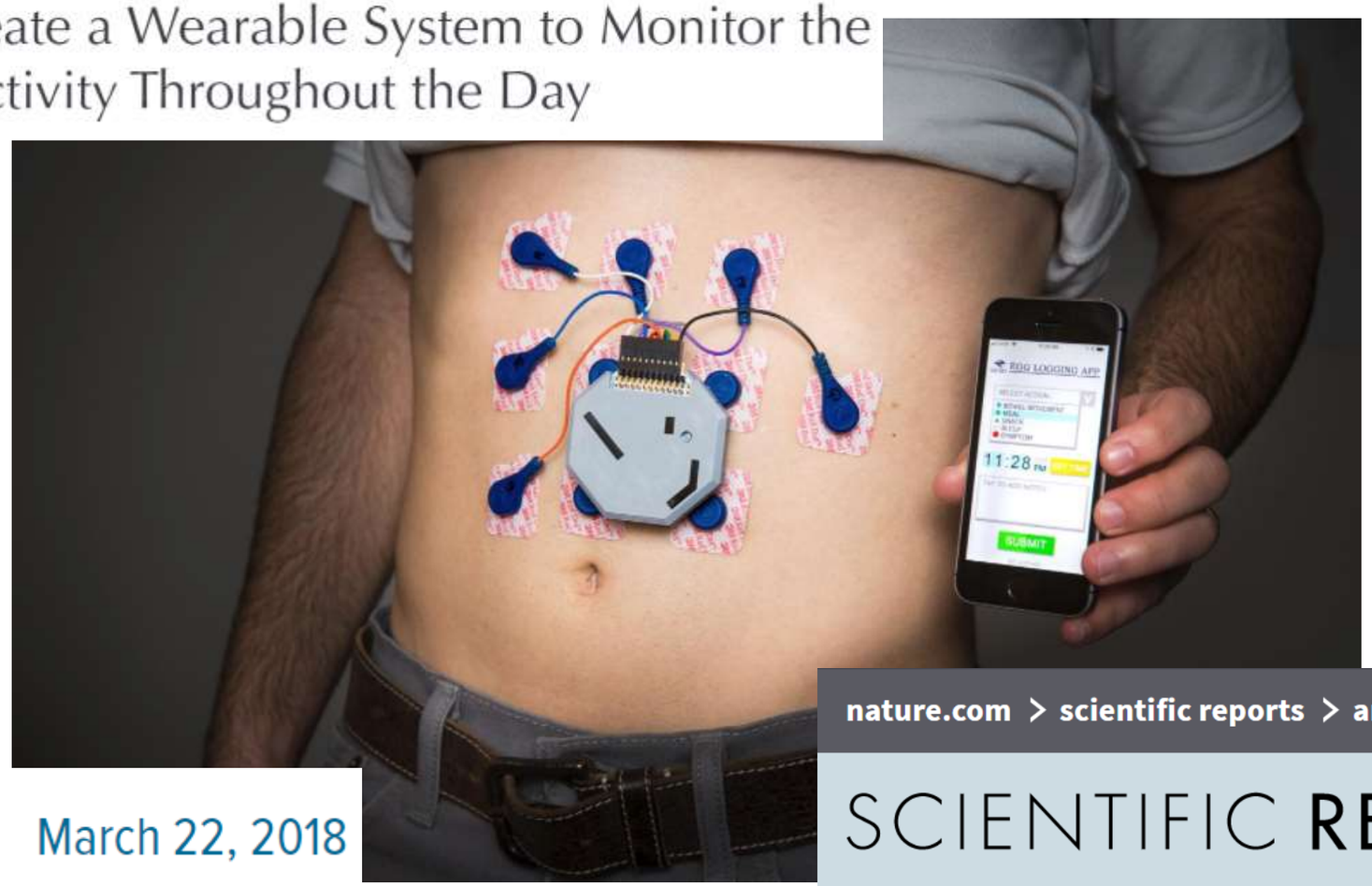


Data From Withings WiFi Bathroom Scale

Using Consumer Tech to Bring EKG Cardio Diagnostics to GI Medicine

UC San Diego

Scientists Create a Wearable System to Monitor the Stomach's Activity Throughout the Day



March 22, 2018

Scientific Reports **volume 8**, Article number: 5019 (2018)

nature.com > scientific reports > articles > article

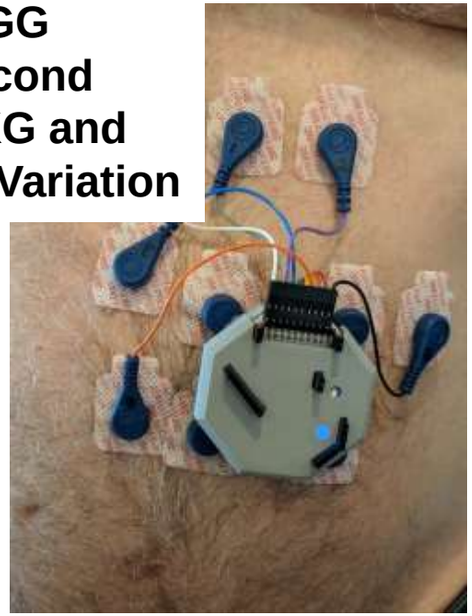
SCIENTIFIC REPORTS

Armen Gharibans, Benjamin Smarr, David Kunkel, Lance Kriegsfeld, Hayat Mousa & Todd Coleman

Multi-Variable Time Series
Wrist and Axial Temperature, CGM, EGG, Time-Stamped Food, Heartrate



GI EGG
250/Second
Heart EKG and
Heart Rate Variation





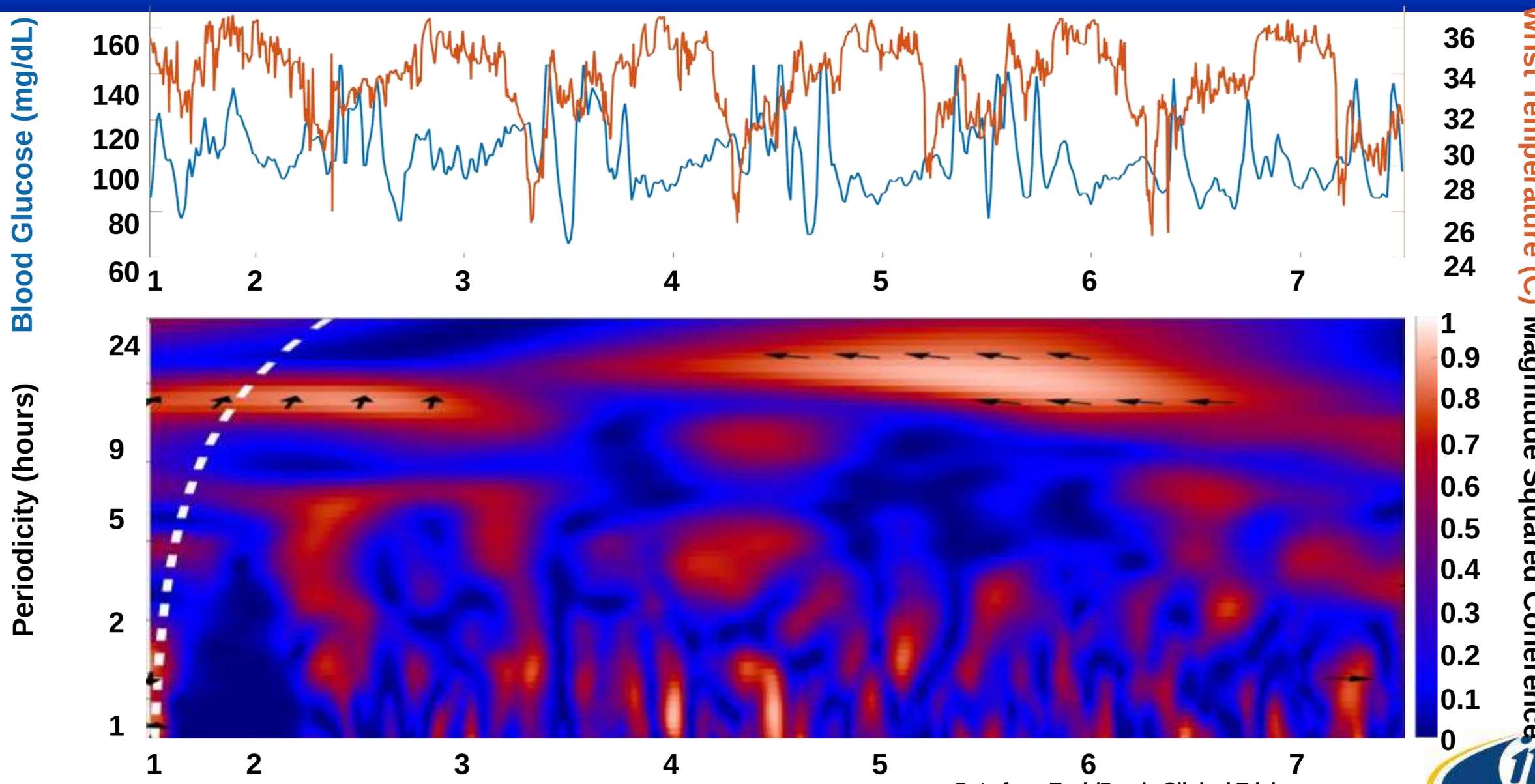
Temperature
Every 5 Minutes





Heart Rate, Steps,
Caloric Burn

Blood Glucose and Wrist Temperature: Linear and Wavelet Coherence



Data from Taub/Panda Clinical Trial
Graphics by Azure Grant, UC Berkeley

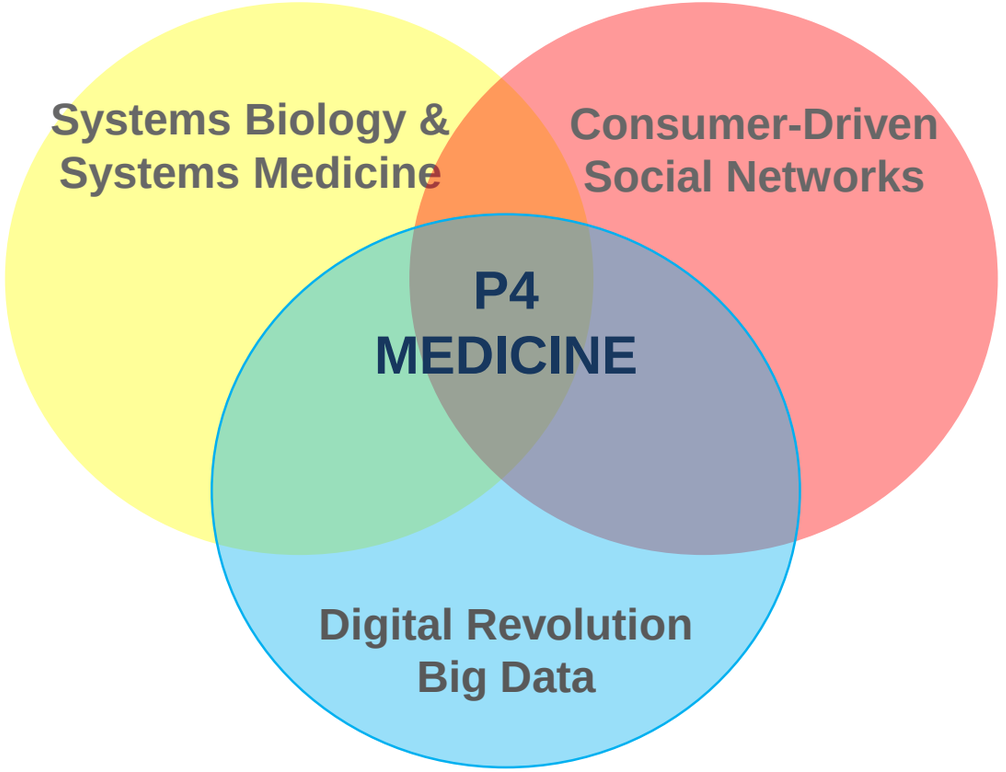
The Emergence of Precision or P4 Medicine -- Predictive, Preventive, Personalized, Participatory

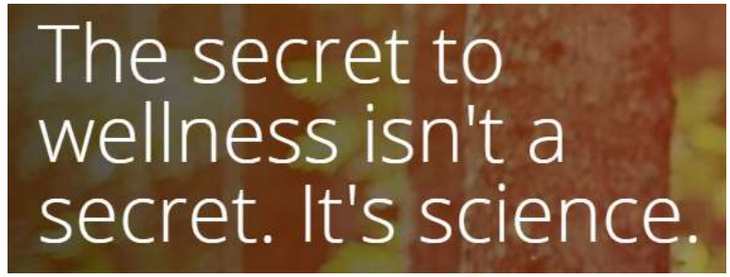
How Will the *Quantified Consumer* Be Integrated into Healthcare Systems?

100K WELLNESS PROJECT
Institute for Systems Biology



Lee Hood, Director ISB





The 100K Person Wellness Project: A Data-Rich Longitudinal Study for the Digital Age

Thanks to Our Great Team!

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