# *New Technologies and the Fifth Industrial Revolution: Trajectories for Nutrition Science and Health Promotion*

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*Professor (adjunct), Department of Neurology*
*University of California at San Francisco*

*Fellow, American Institute for Medical and Biological Engineering (AIMBE)*

## *Disclaimers and Conflict of Interests*

*The opinions and assertions in this presentation are solely mine and do not necessarily represent the views or official policies of the US Army or any other federal agency or university*

*The use of any trade names does not imply any endorsement of a particular product or company*

*I receive licensing royalties from a patent associated with remote neurocognitive assessment technology*

# The Fifth Industrial Revolution

<u>Mechanical</u> (1760-1870). Steam power changes social economics of production; industrial revolution defined by Arnold Toynbee

<u>Electrical</u> (1870-1914). Steel, electricity, petroleum replaced iron, candles, steam engines; providing factory automation, mass employment

<u>Digital</u> (1969). Microprocessors and the home computer revolutionize the workplace; internet led to e-commerce and cloud computing

<u>Virtual</u> (2010). Personal electronics connect technology to humans; cyber-physical

***<u>Neural/Personalized</u>. Artificial intelligence and robotics change how we work; greater productivity and leisure time***

Source:  Gizmodo, 14 Nov 2012

**BLUF:**

**If you do not change direction,
you may end up where you are heading**

**Lao Tzu (604 BC - 531 BC)**

# "Convergence Revolution" in Biomedicine

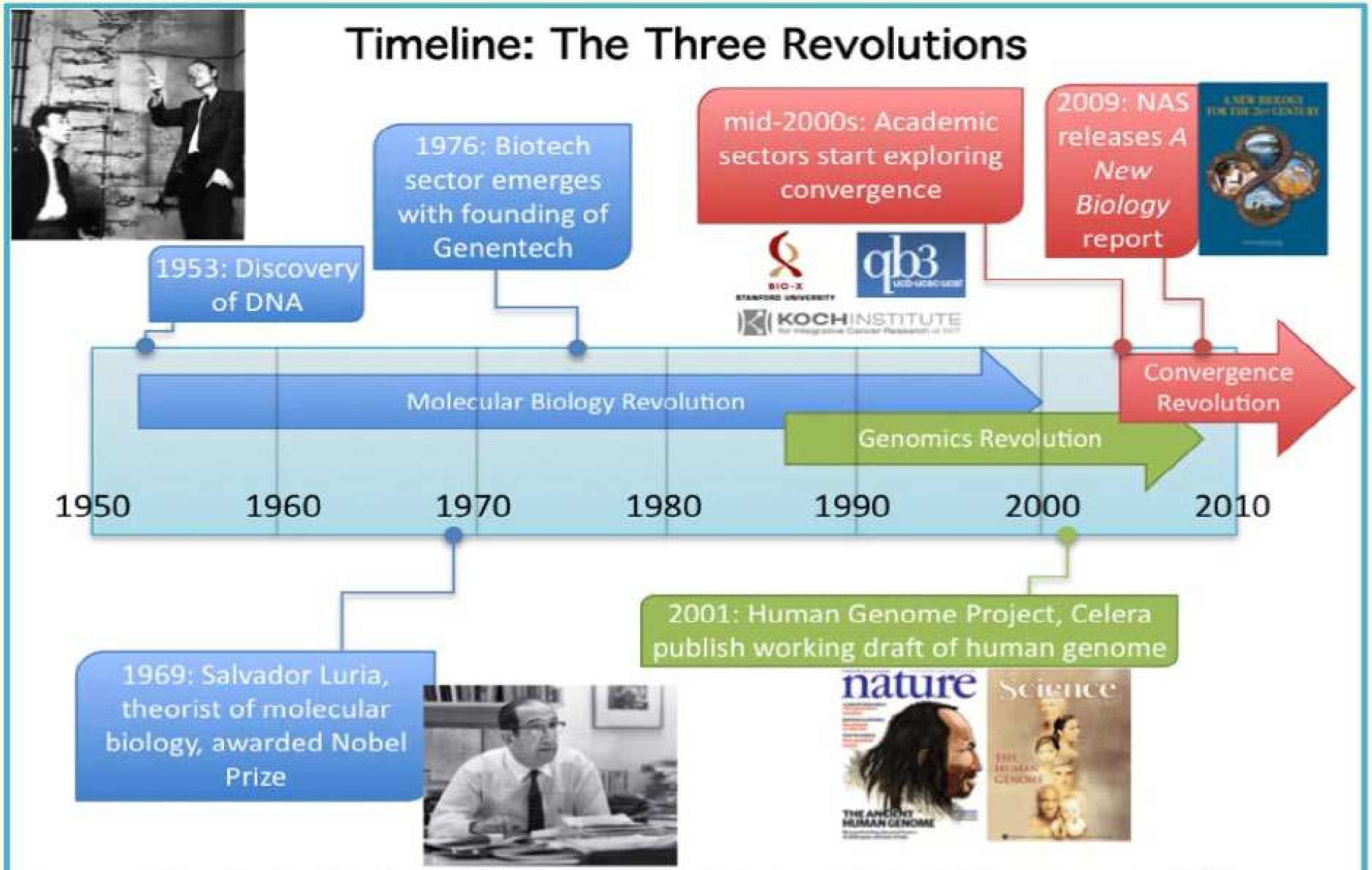


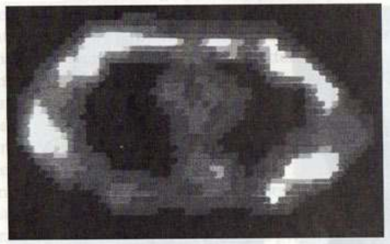

Image and info credits (clockwise from top-left): DNAmazing.com, Gene.com, BioX.stanford.edu, qb3.org, mit.edu/ki, nap.edu, sciencemag.org, nature.com, nlm.nih.gov

**Robert Langer**
**MIT**

- **Research driven by a specific and compelling problem**
- **Deep integration across disciplines**

***2009 MIT White Paper***

# How do we recognize useful new technology?



106 voxels took 4 hours to scan!

Damadian et. al. 1977


Fig. 1.
Cross-sectional line-scan NMR image through the abdomen at L2-3. Arrow indicates mid-line posterior. Left side lies to the left of the illustration. Bright zones correspond in general to high mobile proton content. See Fig. 2 for labelled details.

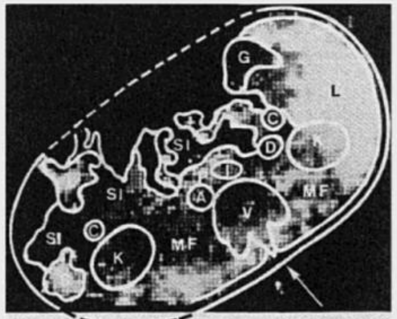
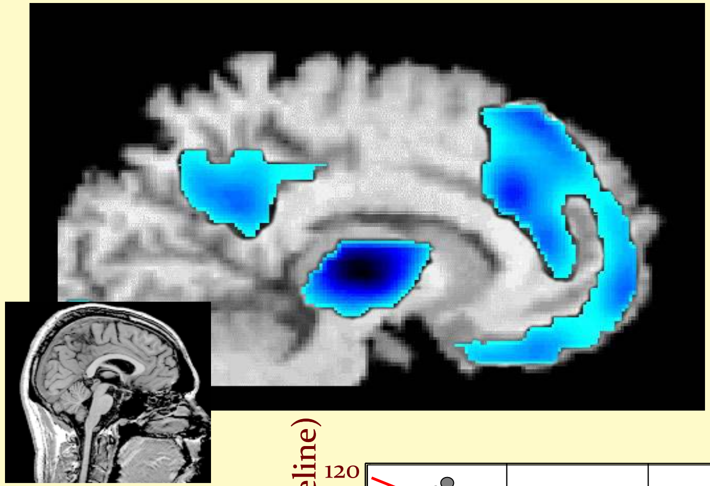
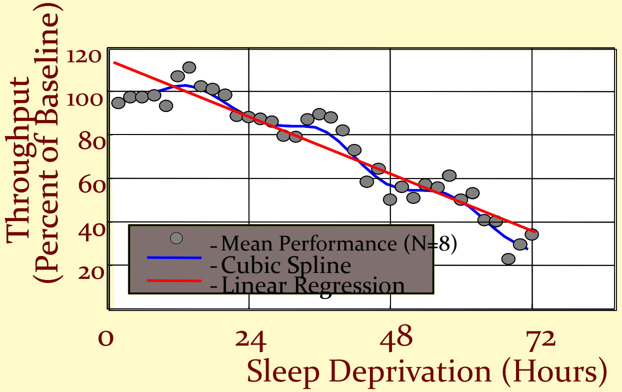



Fig. 2.
Labelled image of Fig. 1. A=aorta, C=colon, D=duodenum, G=gall-bladder, I=inferior vena cava, K=kidneys, L=liver, P=pancreas, S=spleen, SI=stomach and intestines, V=vertebra. Abdominal muscles and retro-peritoneal fat (MF) are seen adjacent to the vertebra.

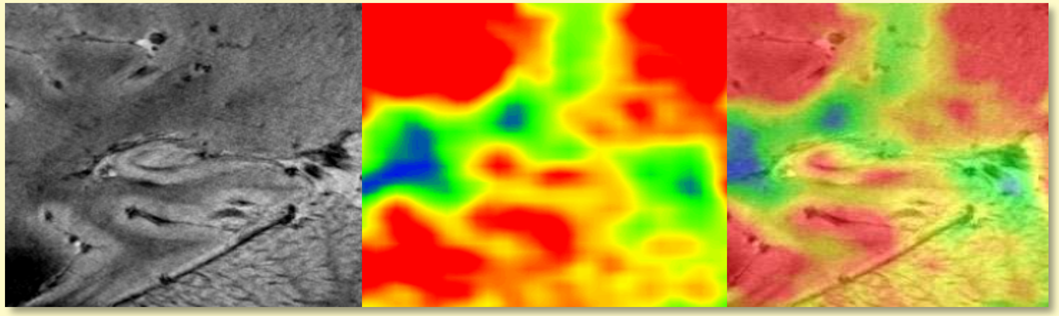
*Early magnetic resonance images were fuzzy*



Thomas Balkin
WRAIR



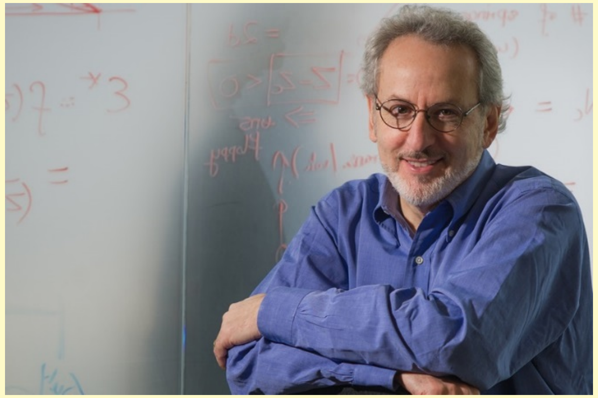

Michael Weiner
UCSF



7T MRI

High res PET

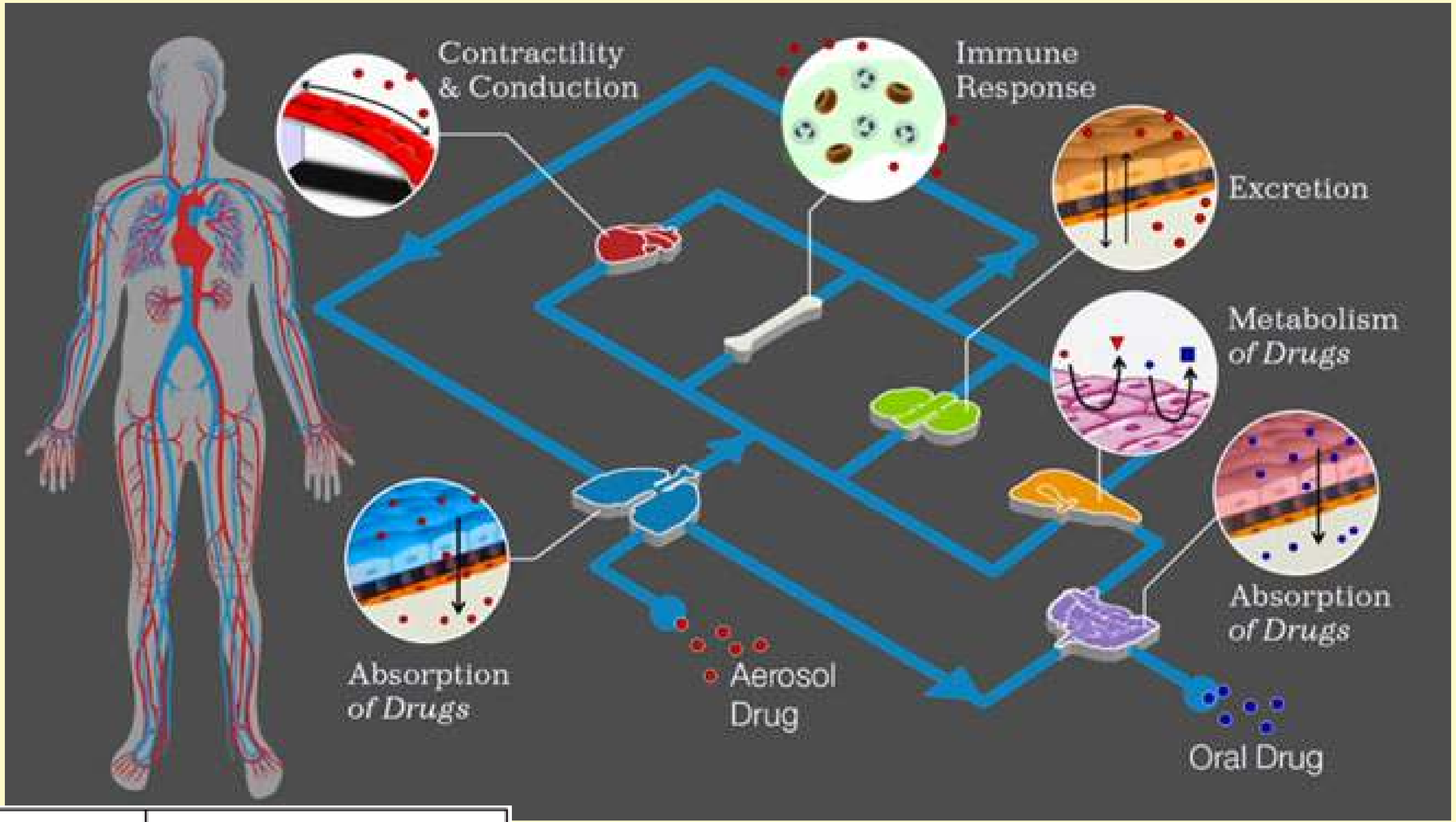
Fusion image

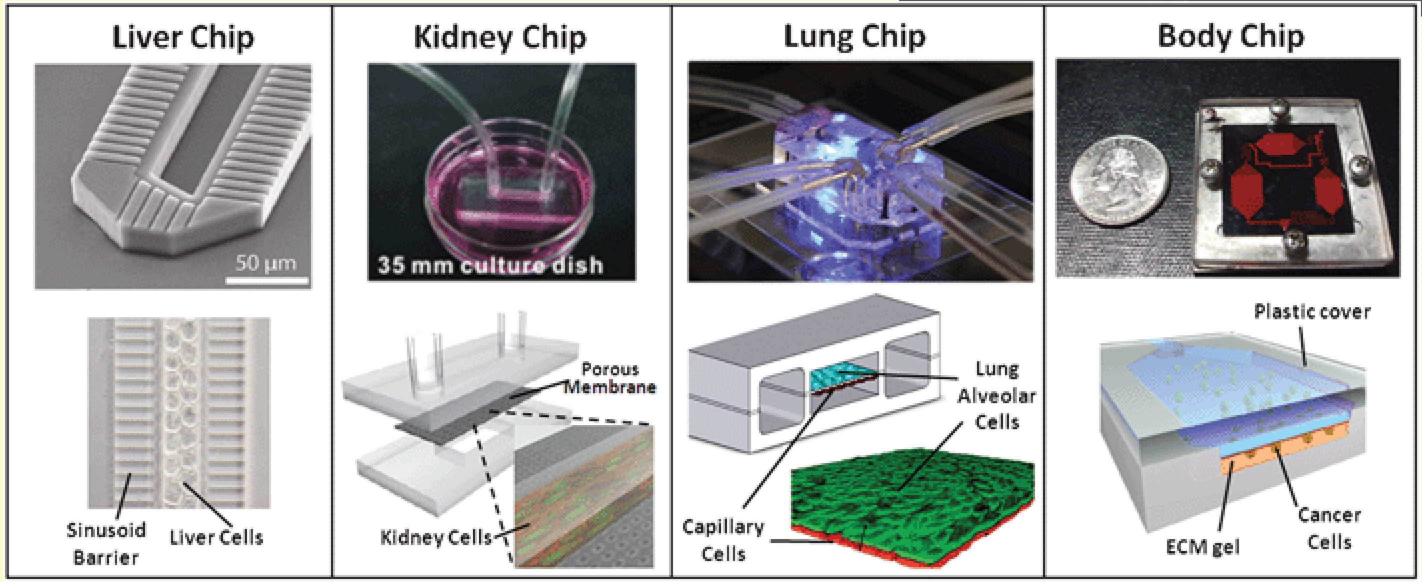


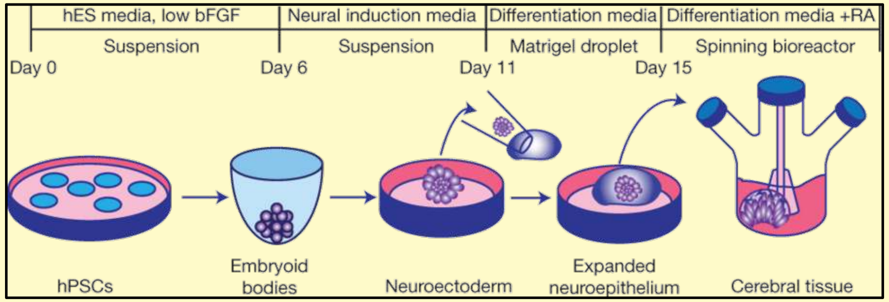
**Don Ingber**
**Wyss Institute**

# Human-on-a-chip

## test metabolic responses with personalized cell lines

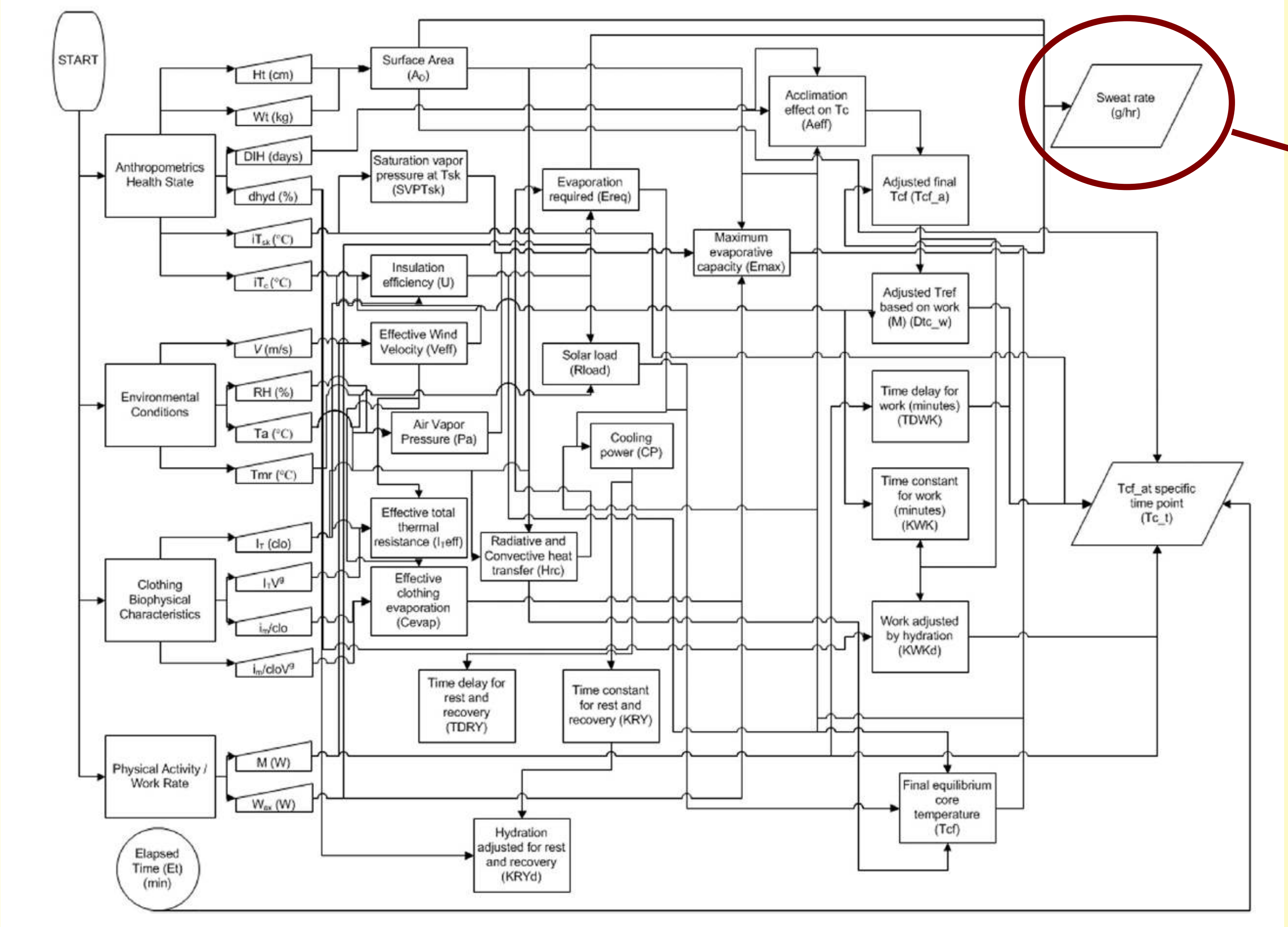


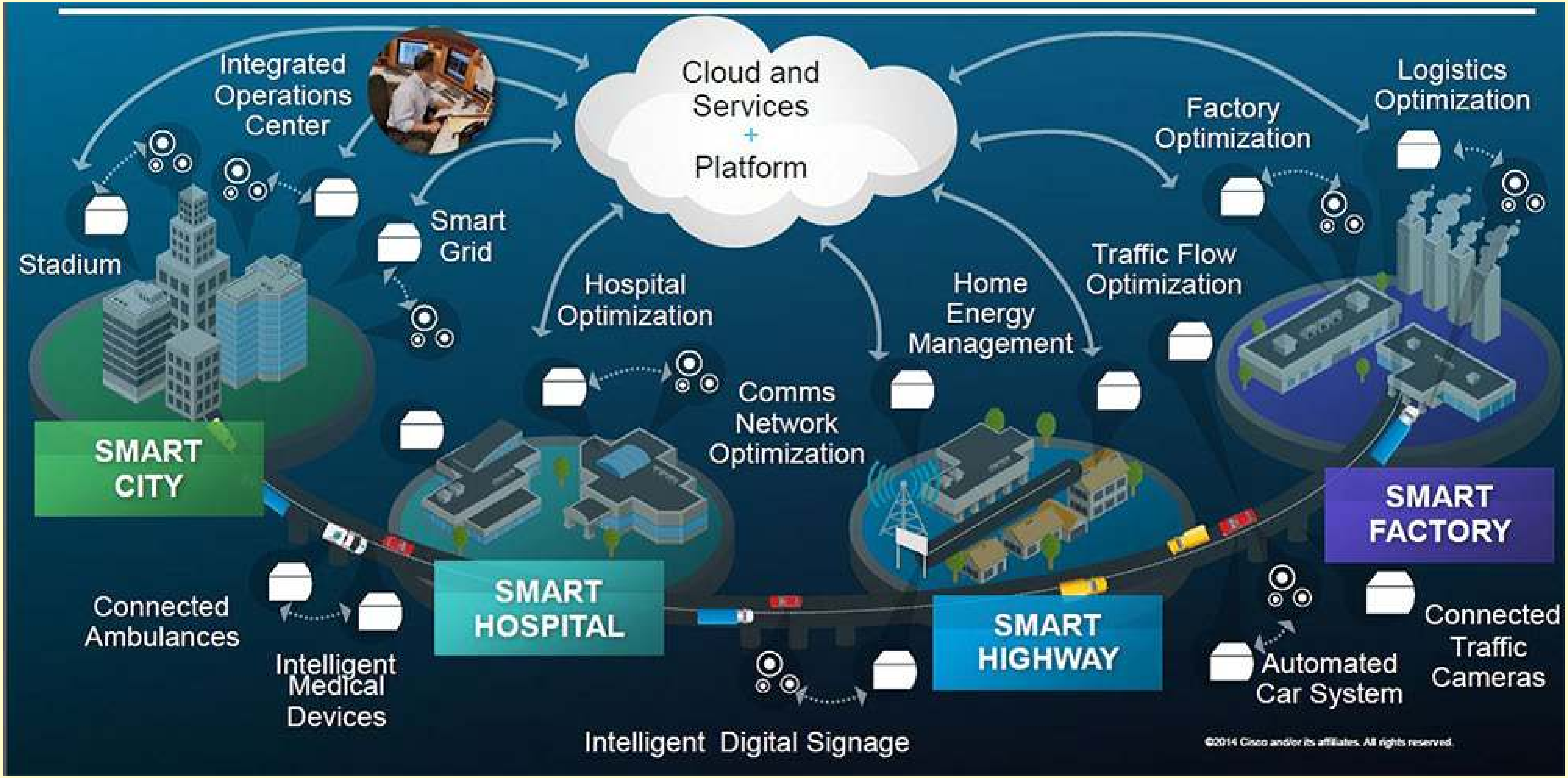

*Bhatia & Ingber, Microfluidic organs-on-chips. Nature Biotechnol 2014;32:760*

# AI Predictive Models: Heat Strain Decision Aid (HSDA)




*Potter et al. J Therm Biol 2017;64:78-85*

# Internet of Things



# Artificial Intelligence (AI) can draw on massive amounts of data to rapidly expand our understanding of important relationships

J Neurol Sci. 2017 April 15; 375: 355–359. doi:10.1016/j.jns.2017.02.032.

### Caffeine, creatine, *GRIN2A* and Parkinson's disease progression

**David K. Simon, MD PhD[1,*], Cai Wu, MS[2], Barbara C. Tilley, PhD[2], Katja Lohmann, PhD[3], Christine Klein, MD[3], Haydeh Payami, PhD[4], Anne-Marie Wills, MD, MPH[5], Michael J. Aminoff, MD, DSc[6], Jacquelyn Bainbridge, BSPharm, PharmD[7], Richard Dewey, MD[8], Robert A. Hauser, MD, MBA[9], Susen Schaake, BSc[3], Jay S. Schneider, PhD[10], Saloni Sharma, MBBS[11], Carlos Singer, MD[12], Caroline M. Tanner, MD, PhD[13], Daniel Truong, MD[14], Peng Wei, PhD[2], Pei Shieen Wong, PharmD[7,15], and Tianzhong Yang, MPH[2]**

[1]Department of Neurology, Beth Israel Deaconess Medical Center and Harvard Medical School; 330 Brookline Avenue; Boston, MA 02215; USA

## Abstract

Caffeine is neuroprotective in animal models of PD and caffeine intake is inversely associated with the risk of Parkinson's disease (PD). This association may be influenced by the genotype of *GRIN2A*, which encodes an NMDA-glutamate-receptor subunit. In two placebo-controlled studies, we detected no association of caffeine intake with the rate of clinical progression of PD, except among subjects taking creatine, for whom higher caffeine intake was associated with more rapid progression. We now have analyzed data from 420 subjects for whom DNA samples and caffeine intake data were available from a placebo-controlled study of creatine in PD. The *GRIN2A* genotype was not associated with the rate of clinical progression of PD in the placebo group. However, there was a 4-way interaction between *GRIN2A* genotype, caffeine, creatine and the time since baseline. Among subjects in the creatine group with high levels of caffeine intake, but not among those with low caffeine intake, the *GRIN2A* T allele was associated with more rapid progression ($p = 0.03$). These data indicate that the deleterious interaction between caffeine and creatine with respect to rate of progression of PD is influenced by *GRIN2A* genotype. This example of a genetic factor interacting with environmental factors illustrates the complexity of gene-environment interactions in the progression of PD.

[13]Parkinson's Disease Research Education and Clinical Center, San Francisco Veteran's Affairs

**Decipher complex gene-environment interactions**

PLOS | MEDICINE

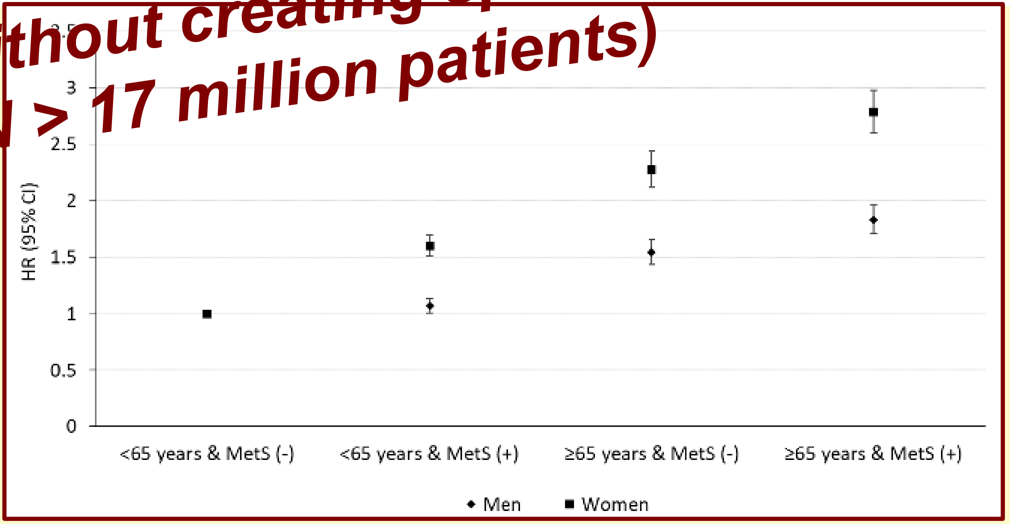
RESEARCH ARTICLE

### Metabolic syndrome and risk of Parkinson disease: A nationwide cohort study

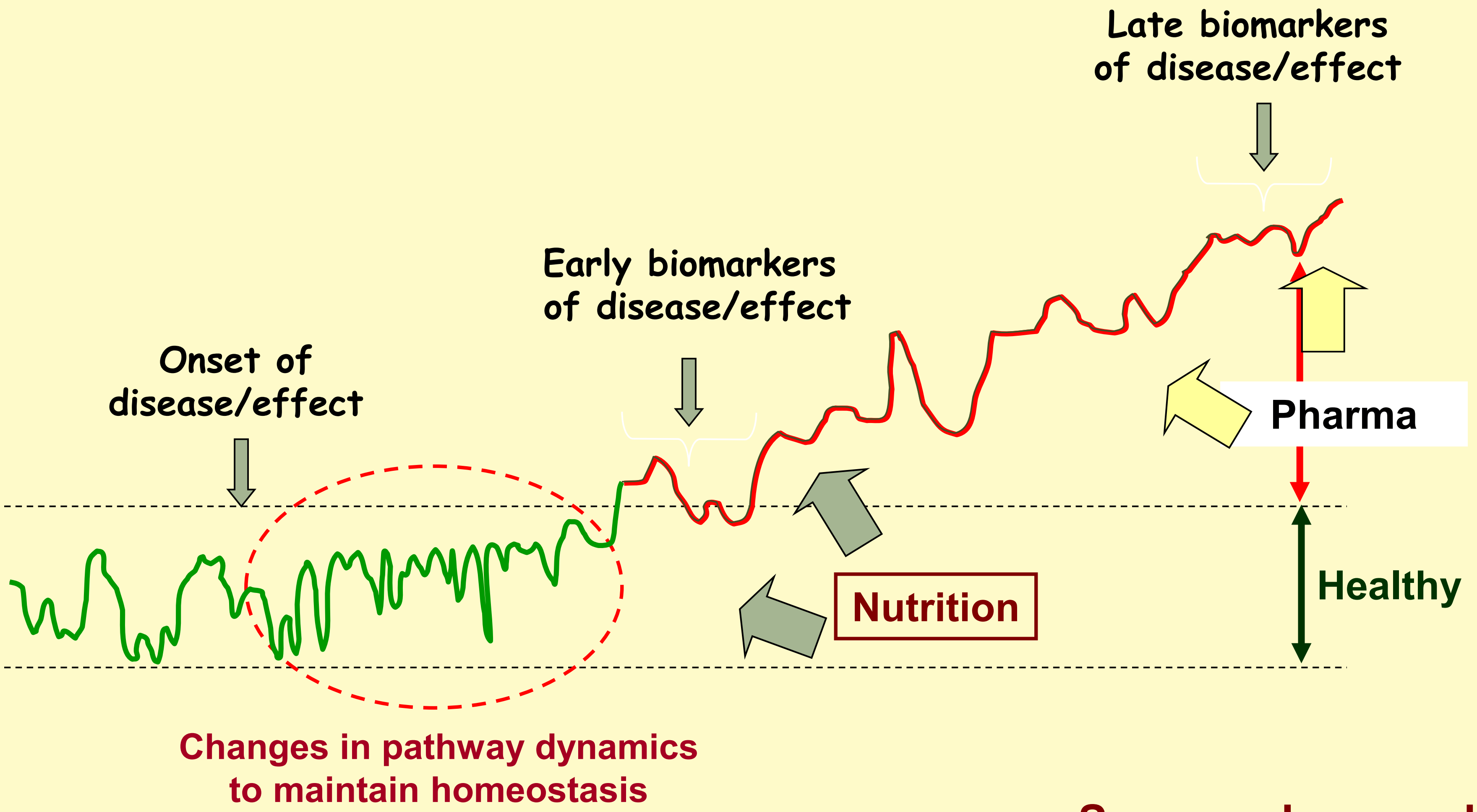
**Ga Eun Nam[1], Seon Mee Kim[2*], Kyungdo Han[3], Nan Hee Kim[4], Hye Soo Chung[4], Jin Wook Kim[2], Byoungduck Han[1], Sung Jung Cho[1], Ji Hee Yu[4], Yong Gyu Park[3], Kyung Mook Choi[4*]**

1 Department of Family Medicine, Sahmyook Medical Center, Seoul, Republic of Korea, 2 Department of Family Medicine, Korea University Guro Hospital, College of Medicine, Korea University, Seoul, Republic of Korea, 3 Department of Medical Statistics, College of Medicine, The Catholic University of Korea, Seoul, Republic of Korea, 4 Division of Endocrinology and Metabolism, Department of Internal Medicine, College of Medicine, Korea University, Seoul, Republic of Korea

**Examine medical data associations without creating special registries (N > 17 million patients)**

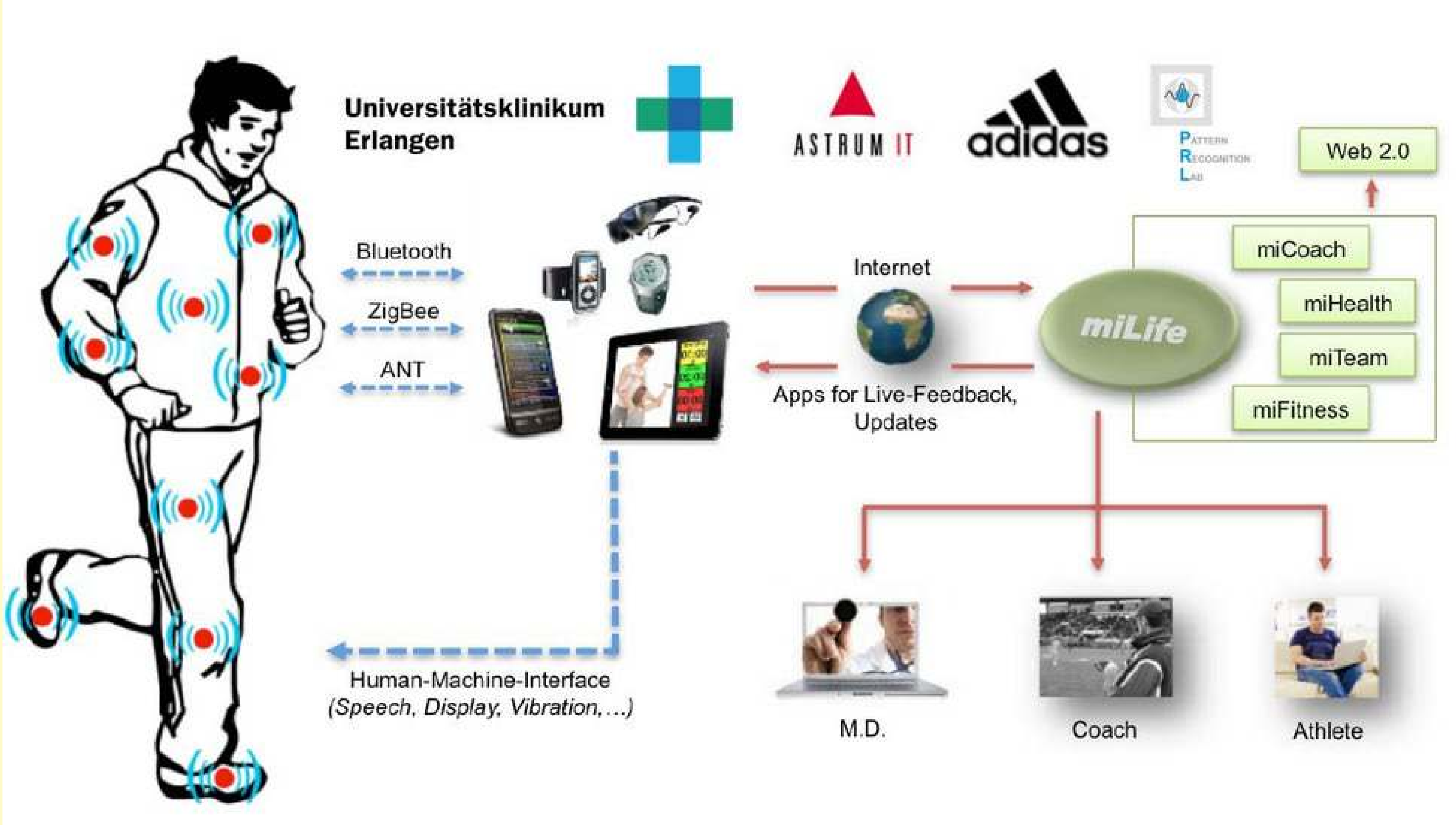


# Conceptual model of continuous monitoring and behavioural adjustment to optimize individual health and performance




Source: Jan van der Greef

# Monitoring behavior by accelerometry: with life there is motion




International Society for the Measurement of Physical Behavior (ISMPB)

ICAMPAM

MAASTRICHT, NETHERLANDS 2019

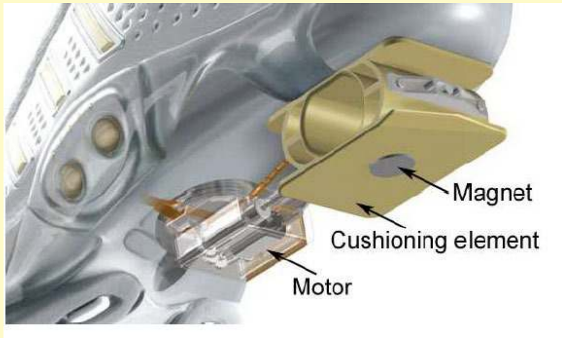
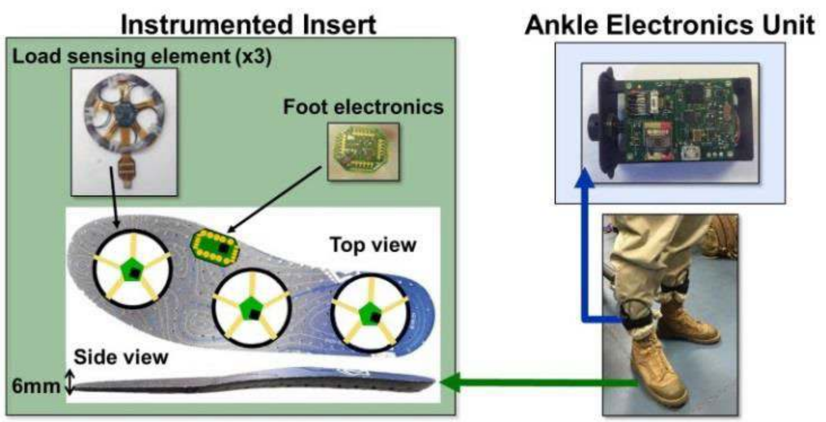



Figure 1. The "adidas_1" shoe, its cushioning element, magnet and motor unit.

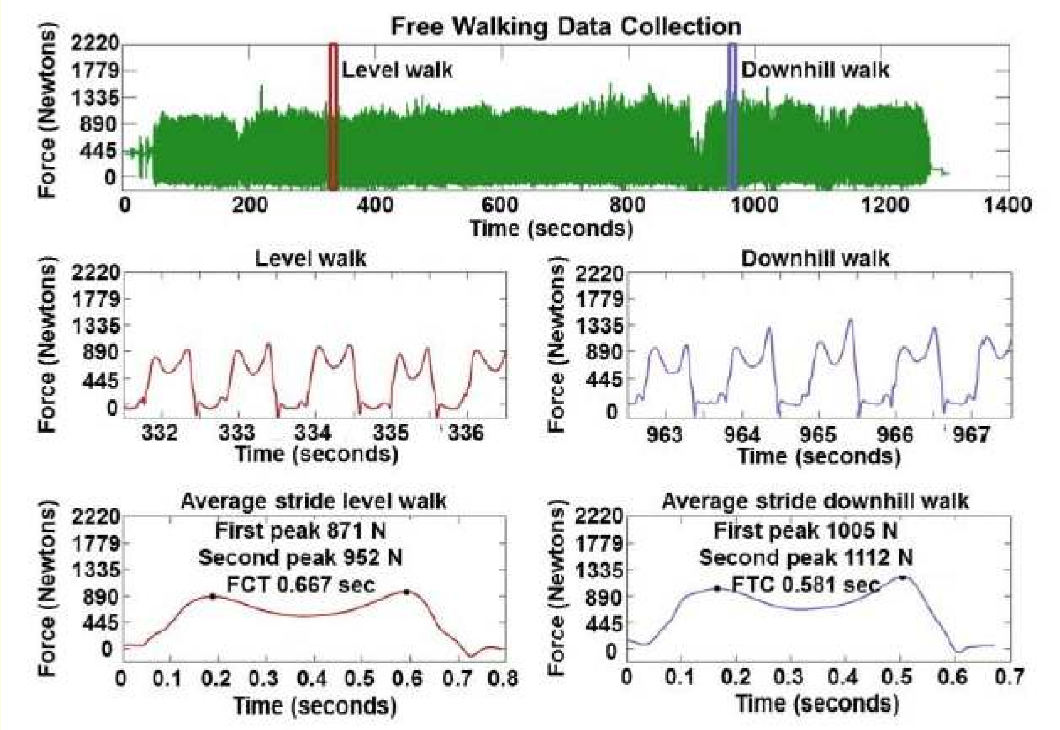
Bjoern Eskofier
FAU/Erlangen

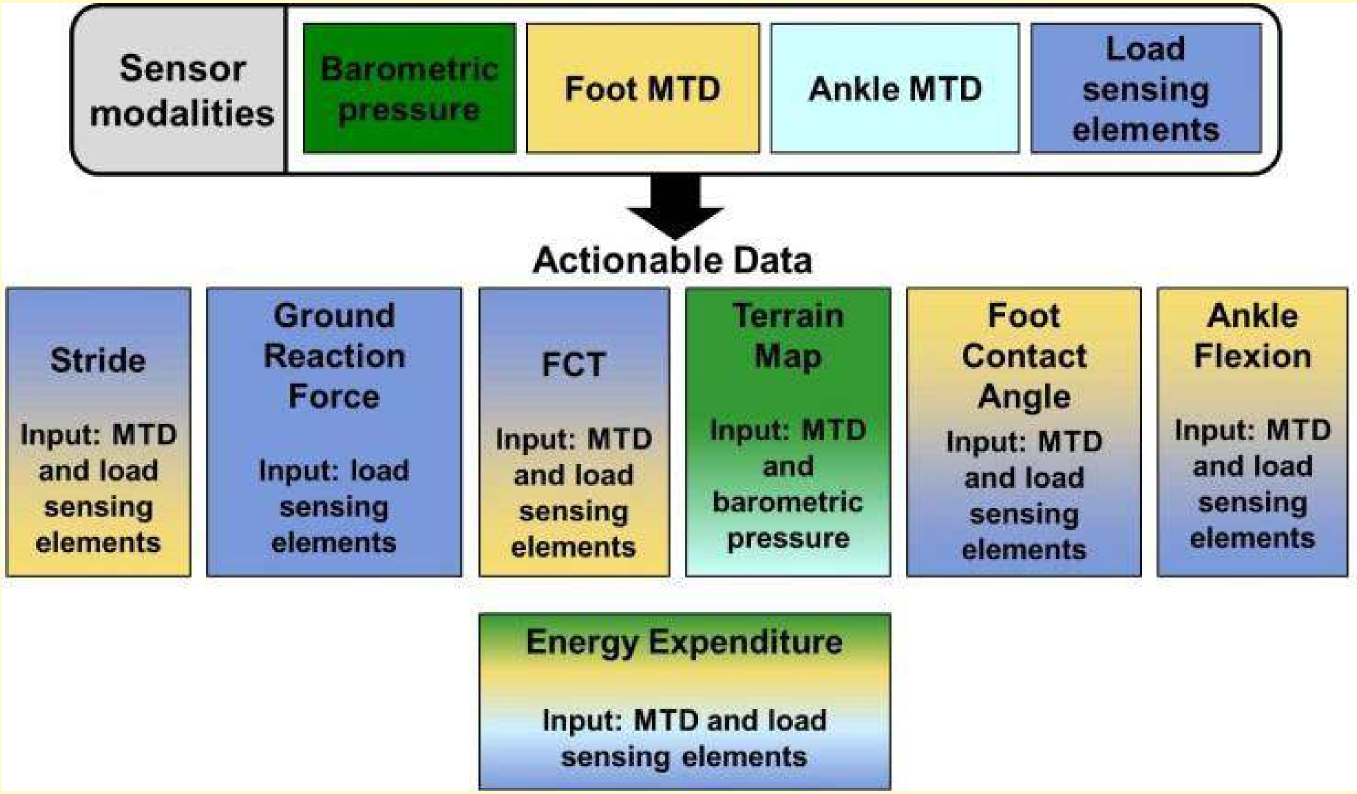
# Smart shoe concepts




**Instrumented Footwear Inserts: A New Tool For Measuring Forces and Biomechanical State Changes During Dynamic Movements***

Joseph Lacirignola, Christine Weston, Kate Byrd, Erik Metzger, Ninoshka Singh, Shakti Davis, David Maurer, Whitney Young, Paula Collins, James Balcius, Mark Richter, Jeff Palmer, *Member, IEEE*




*IEEE Body Sensor Networks 2017*

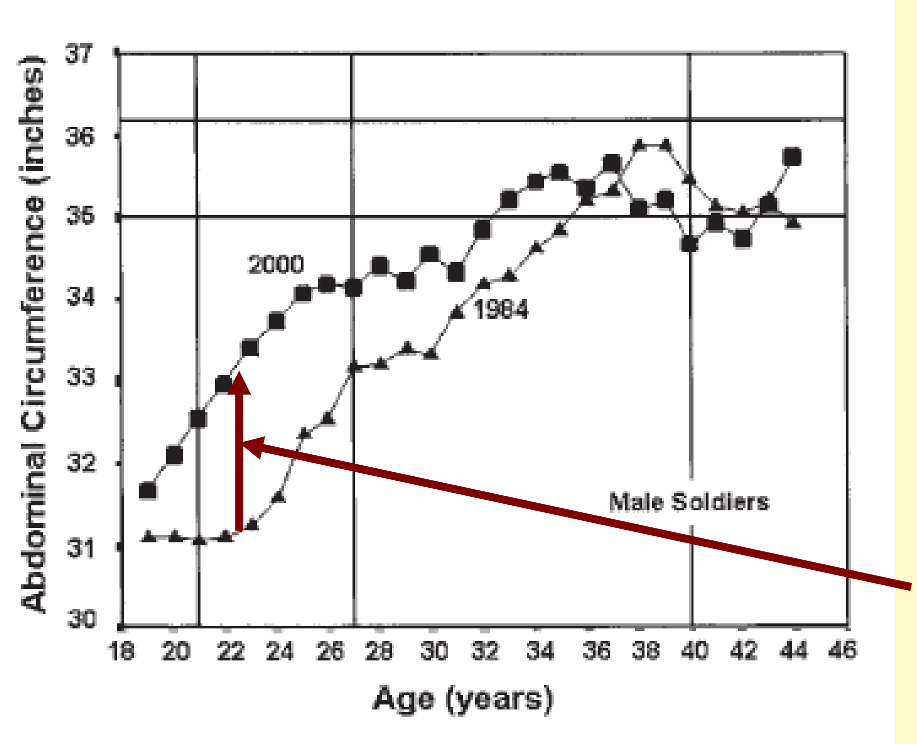
# Effects of Technology

TABLE 1. AVERAGE BODY COMPOSITION ESTIMATES OF MALE SOLDIERS IN FIVE ERAS

| | Year | | | | |
|---|---|---|---|---|---|
| *Variable* | *1864* | *1919* | *1946* | *1984* | *2000* |
| Sample size | 23,624 | 99,449 | 85,000 | 869 | 966 |
| Age (years) | 25.7 | 24.9 | 24.3 | 26.3 | 26.3 |
| Height (in) | 67.2 | 67.7 | 68.4 | 68.6 | 69.6 |
| Body weight (lbs) | 141 | 145 | 155 | 167 | 178 |
| Abdominal circumference (in) | 31.5 | 31.4 | 31.3 | 32.7 | 33.7 |
| Body fat (%) | 16.9 | 15.7 | 14.4 | 17.3 | 17.0 |
| Fat-free mass (lbs) | 117 | 122 | 133 | 138 | 148 |

Adapted from Friedl[4] with new data from Leu and Friedl.[5]

**Advances in medicine and nutrition have produced a 30 pound gain in FFM**




**In the first 15 years of the Army Weight Control Program average male soldier body weight increased by 10 lbs; waist circumference of young male soldiers increased by 2"**

# SCIENCE

FRIDAY, MAY 24, 1918

CONTENTS



## SOME PROBLEMS OF NUTRITION IN THE ARMY[1]

FOOD has been defined as a well-tasting mixture of materials, which, when taken in proper quantity into the stomach, is capable of maintaining the body in any desired
he choice of these mixtures in the
menus, their preparation for the
eir digestion and fate in the body,

*American Journal of Public Health*

Official Monthly Publication of the American Public Health Association
169 Massachusetts Ave., Boston, Mass.

*Subscription price, $4 per year. American Public Health Association membership, including subscription, $5 per year.*

Vol. IX JUNE, 1919 No. 6

## PRELIMINARY RESULTS OF NUTRITIONAL SURVEYS IN UNITED STATES ARMY CAMPS.

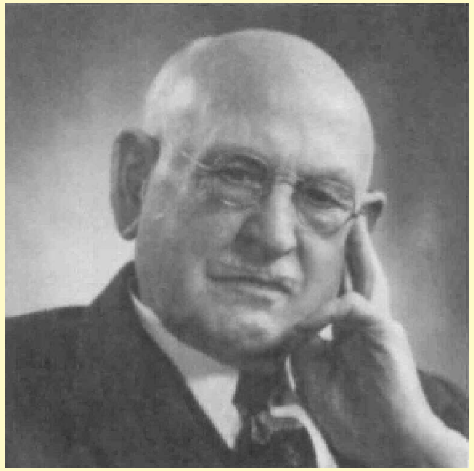
JOHN R. MURLIN, *Lieut.-Colonel, Sanitary Corps,*
and
CASPAR W. MILLER, *Major, Medical Corps,*
*Office of Surgeon-General, Washington, D. C.*

Abstract of paper read before Food and Drugs Section, American Public Health Association, at Chicago, Ill., December 9, 1918.

Before the war there had never been presented to food experts in this country an opportunity for the extended study of nutrition comparable to that afforded these investigators. Their report sets forth details of observations which support the "training ration," which is appetizing and secures a proper distribution of the nutrients.

THE Food Division of the Surgeon-General's Office,* organized early in September, 1917, for the pur-

Alonzo E. Taylor on behalf of Mr. Herbert Hoover, food administrator, at the Food Administration Headquarters in



John R. Murlin, AIN Founder

**Food wastage during a time of austerity with rations providing >5000 kcal/d**

**Key finding: TDEE= 4,000 kcal/d for healthy young men in training**

# Energy Expenditure Studies Using Doubly-Labelled Water Measurements in Militarily-Relevant Environments

*Important differences in fat metabolism*

| | TDEE (MJ/d) | | TDEE/kg (MJ/kg/d) | |
|---|---|---|---|---|
| Activity | Women | Men | Women | Men |
| Norwegian Ranger cadet training | 21.9 (2.0) n=6 | 26.6 (2.0) n=10 | 0.34 | 0.35 |
| US Marine recruit crucible exercise | 19.8 (0.6) n=20 | 25.7 (0.8) n=29 | 0.34 | 0.35 |
| Smoke jumpers | 14.8 (3.0) n=9 | 20.3 (3.0) n=7 | 0.23 | 0.28 |
| US Marine recruit training | 9.9 (1.6) n=20 | 16.9 (4.0) n=10 | 0.17 | 0.23** |
| US Army mass casualty training | 12.1 (1.0) n=10 | 16.4 (3.7) n=6 | 0.20 | 0.19 |
| U S Navy sailors at sea | 11.6 (1.8) n=16 | 14.4 (3.6) n=9 | 0.17 | 0.18 |

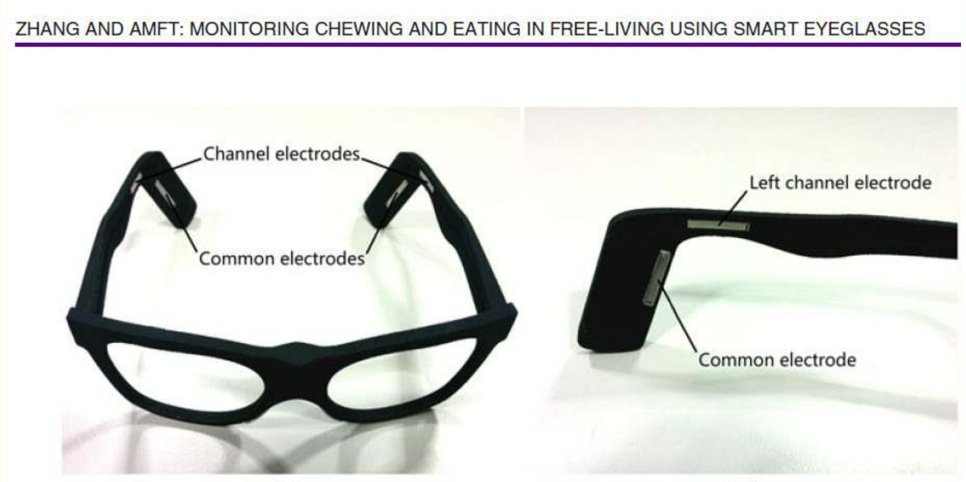
James Delany, PBRC

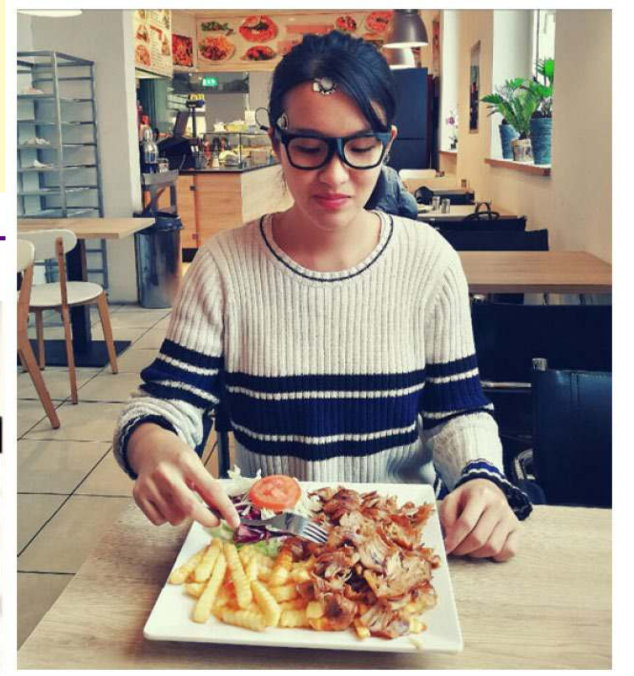
Reed Hoyt, USARIEM

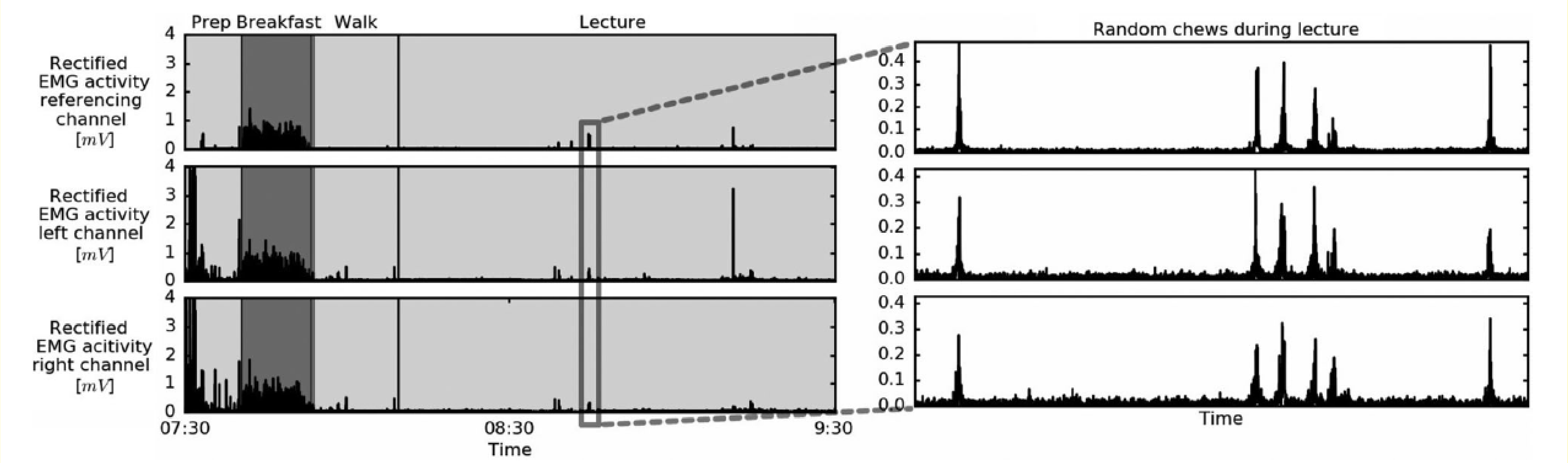
# Smart eyeglasses for food intake monitoring

*Oliver Amft*
*ACTLab*
*Univ of Passau*

- Chewing cycle recognition
- Distinguish food texture (banana, cucumber, carrot)
- 3D printed glasses personalized to user



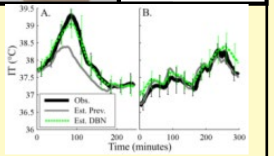
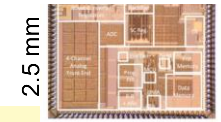


# Real Time Physiological Status Monitor (RT-PSM)

## *Technology Development*

*Reed Hoyt*

*Jeff Palmer*

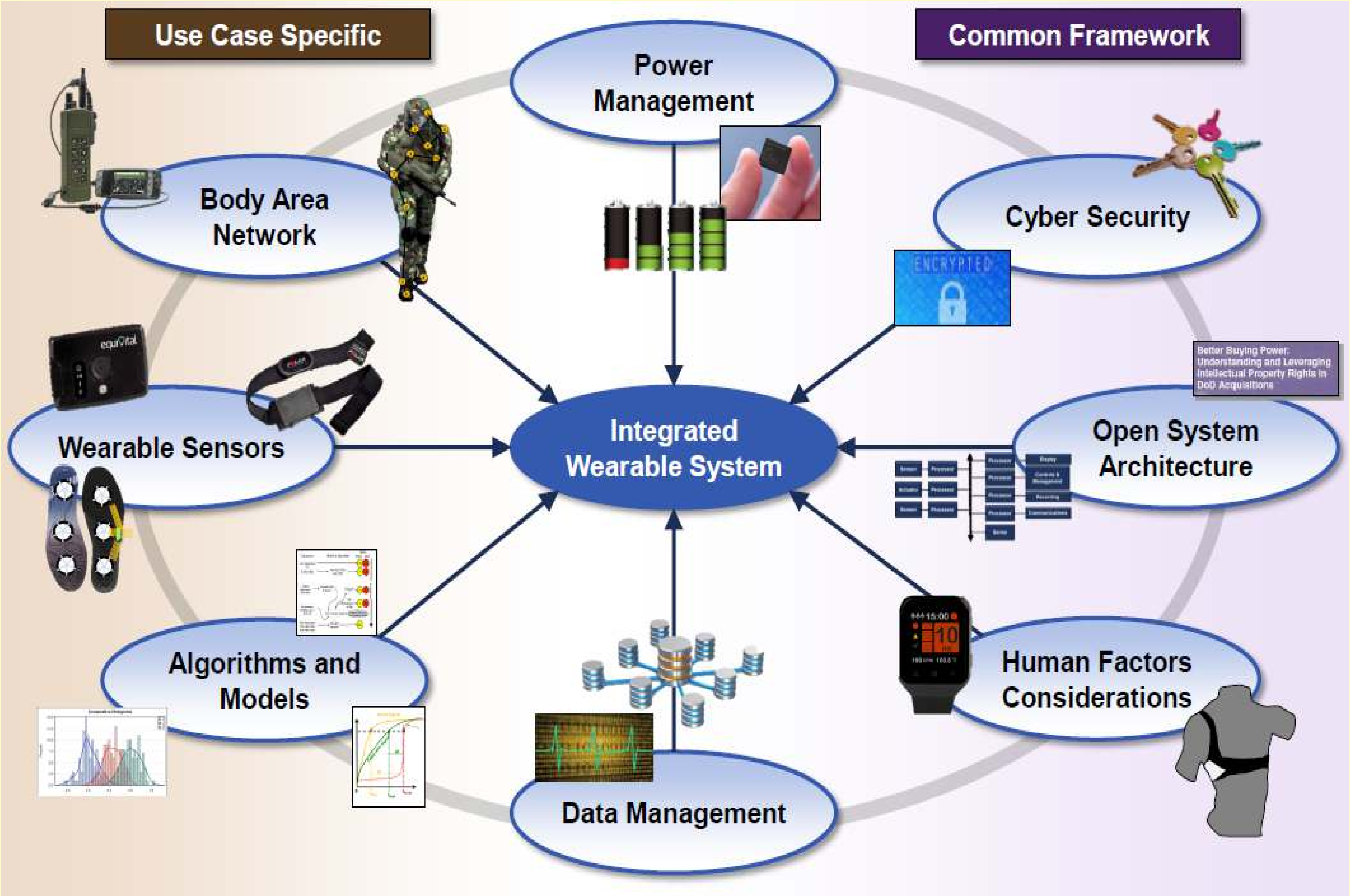

| | Baseline | Near-term | Mid-term |
|---|---|---|---|
| Technology | **Hidalgo/Zephyr**   | **RT-PSM**<br>Low SWaP<br>GOTS/mod COTS<br>Tunable Narrow Band (TNB)(low data rate)<br>Ti11xx   | **ULPW-SoC PSM**<br>Batteryless, power harvesting, integrated sense/process/ communicate (UWB/TNB)   |
| **TRL (current/planned)** | **TRL 7-8 (COTS)** | **TRL 4-6** | **TRL 3-6** |
| **Applications**<br>1. Specialized<br>2. Training<br>3. Operational |  |  |  |

*TBD

*Specialized* *Training* *Operational*

*Joel Fink*

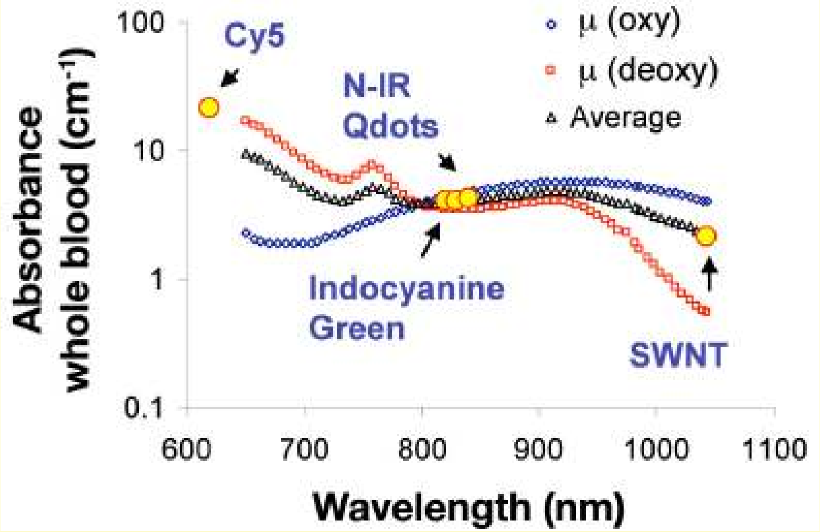
# Components of a physiological status monitoring system

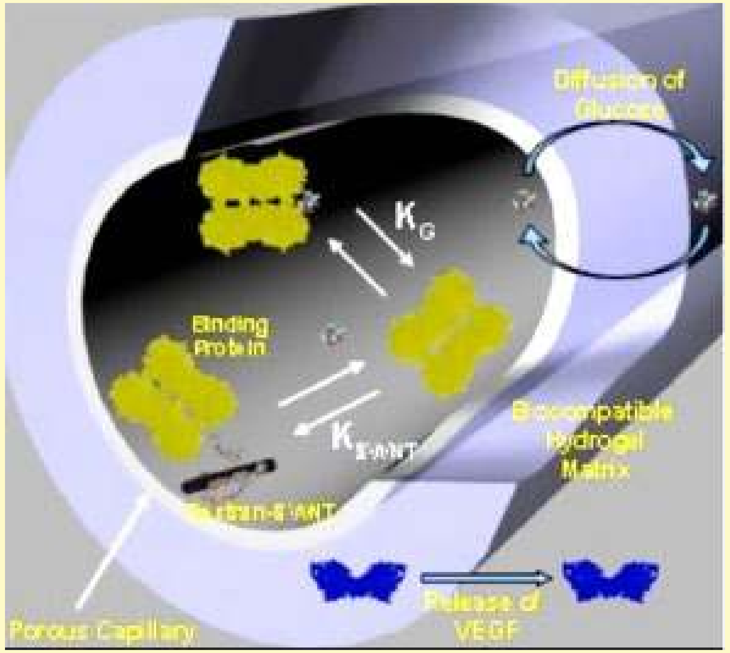


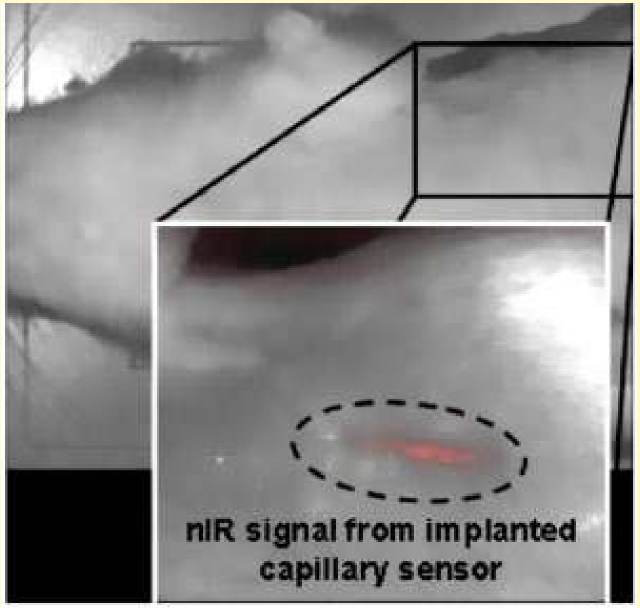

*Source: Reed Hoyt (USARIEM) and Jeffrey Palmer (MIT Lincoln Labs)*

# Concepts for implantable continuous glucose monitoring

Measure changes in a subcutaneous "tattoo"



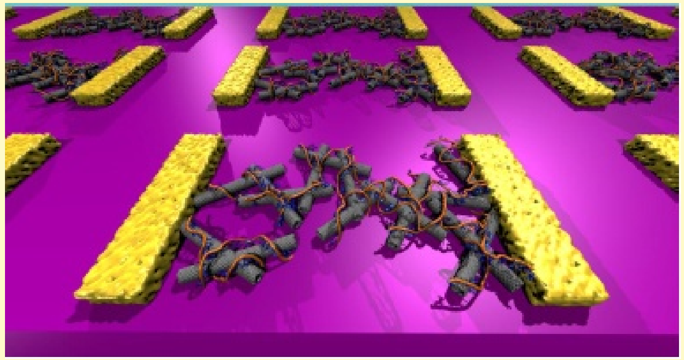

## Single wall nanotube (SWNT) glucose sensors

Barone & Strano
J Diabetes Sci Technol 2009;3:242

**Michael Strano**
**MIT**

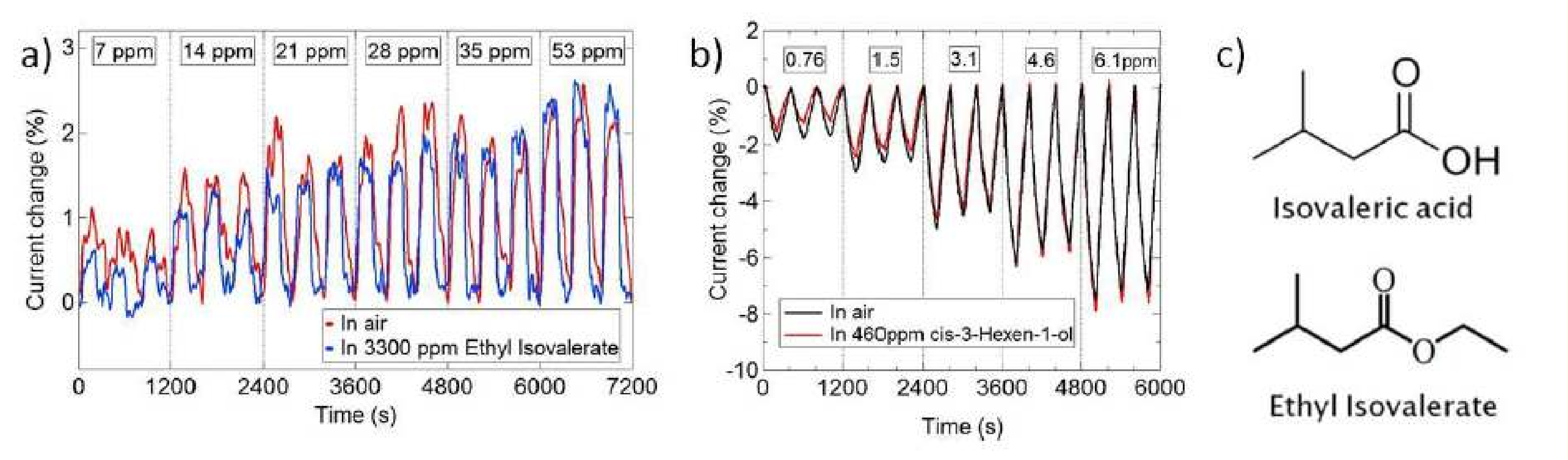
# Biosensing human odor signals

- Single stranded DNA coated nanotubes
- Field effect transistor (FET) arrays



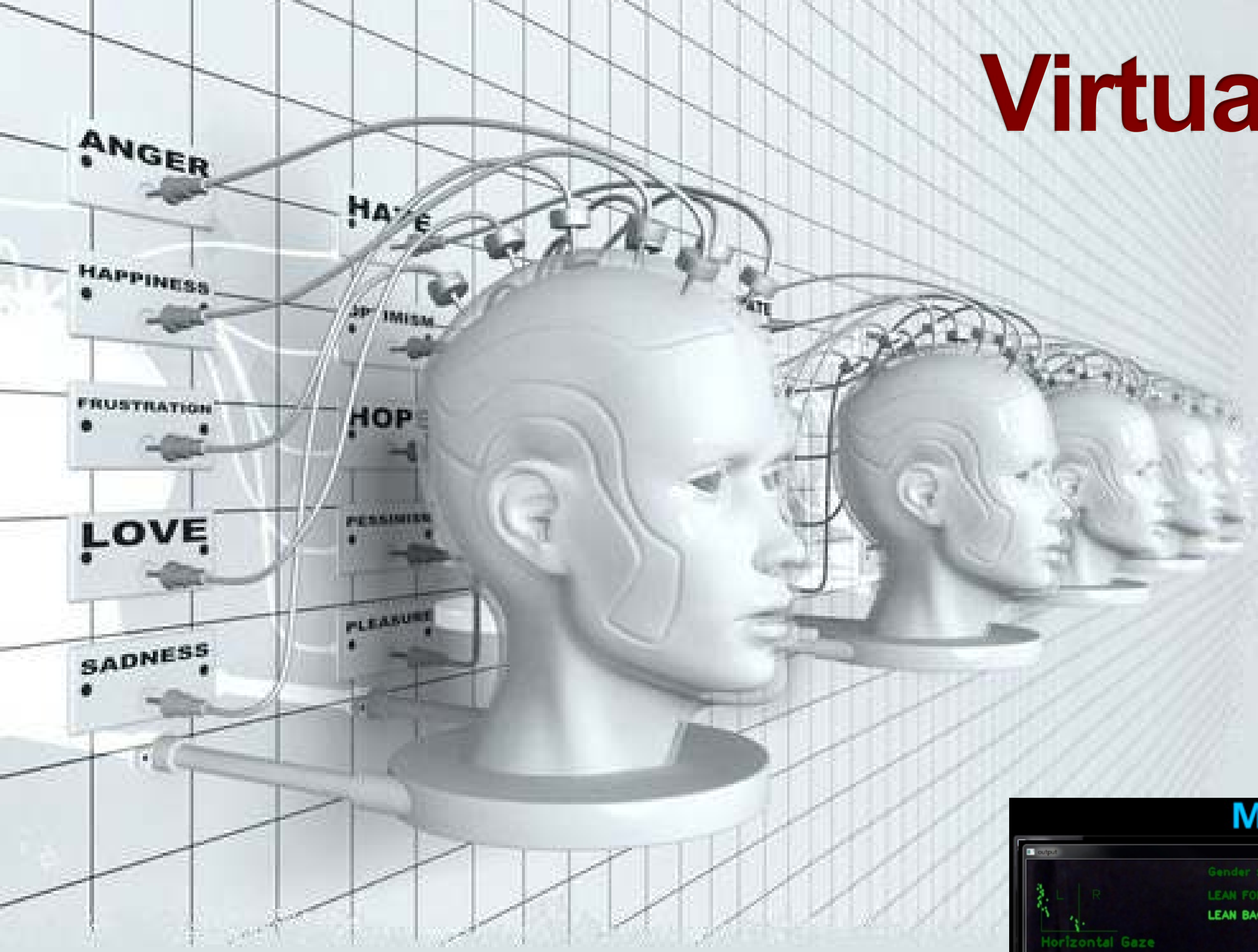

Differentiation of complex vapor mixtures using carbon nanotube chemical sensors

(ACS Nano 2013;7:2800-7)



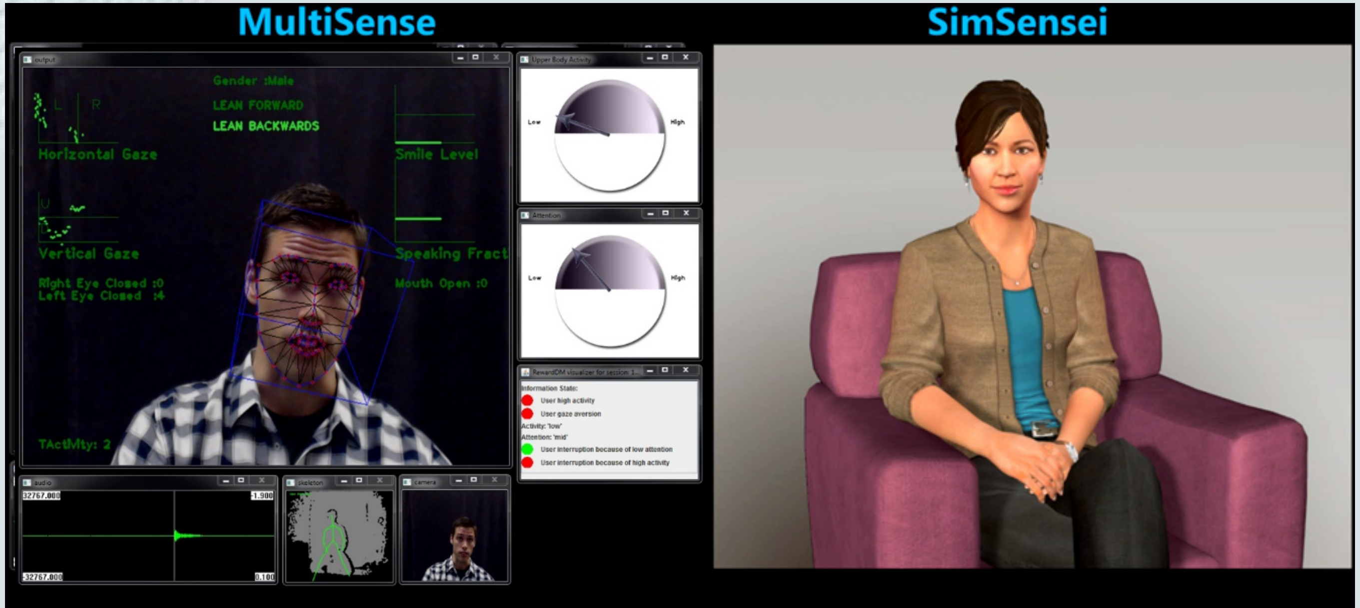

MONELL CENTER
ADVANCING DISCOVERY IN TASTE AND SMELL

# Virtual Humans



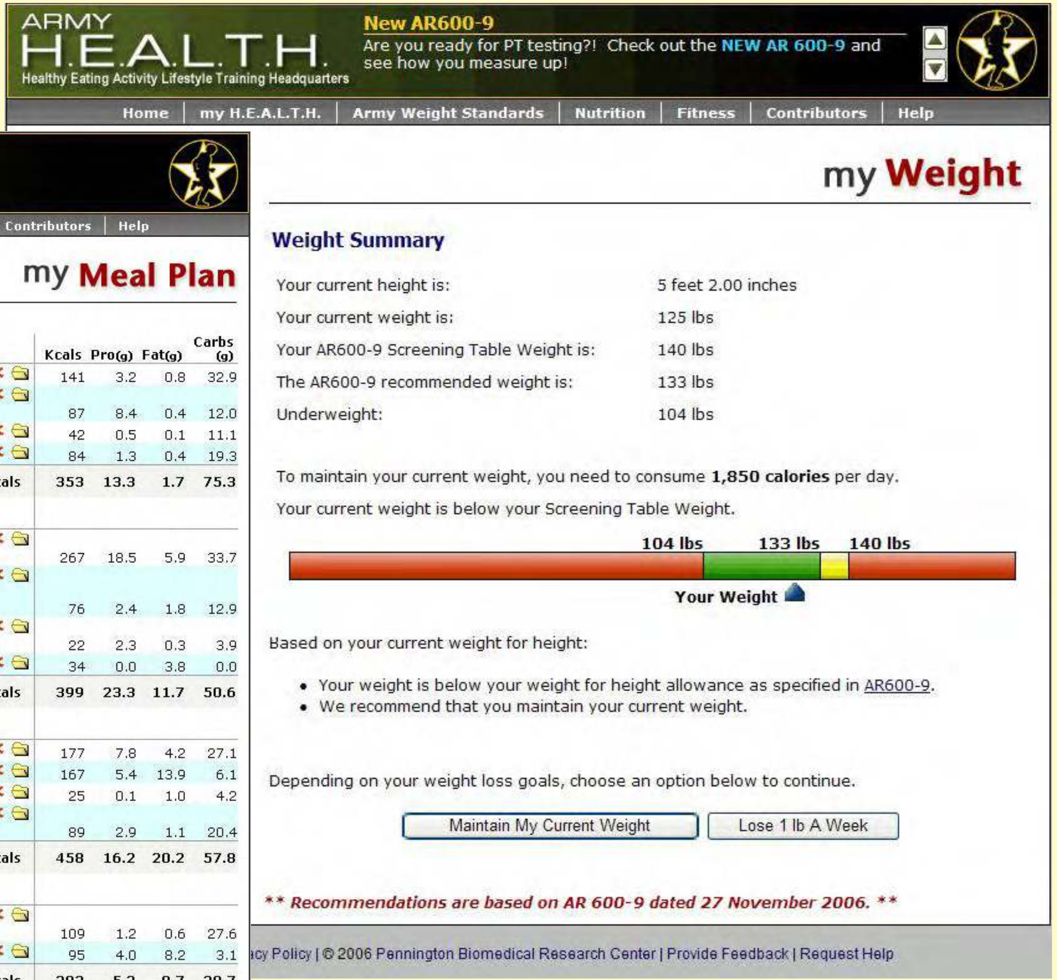

**Autonomous virtual characters that can have meaningful interactions with human users**

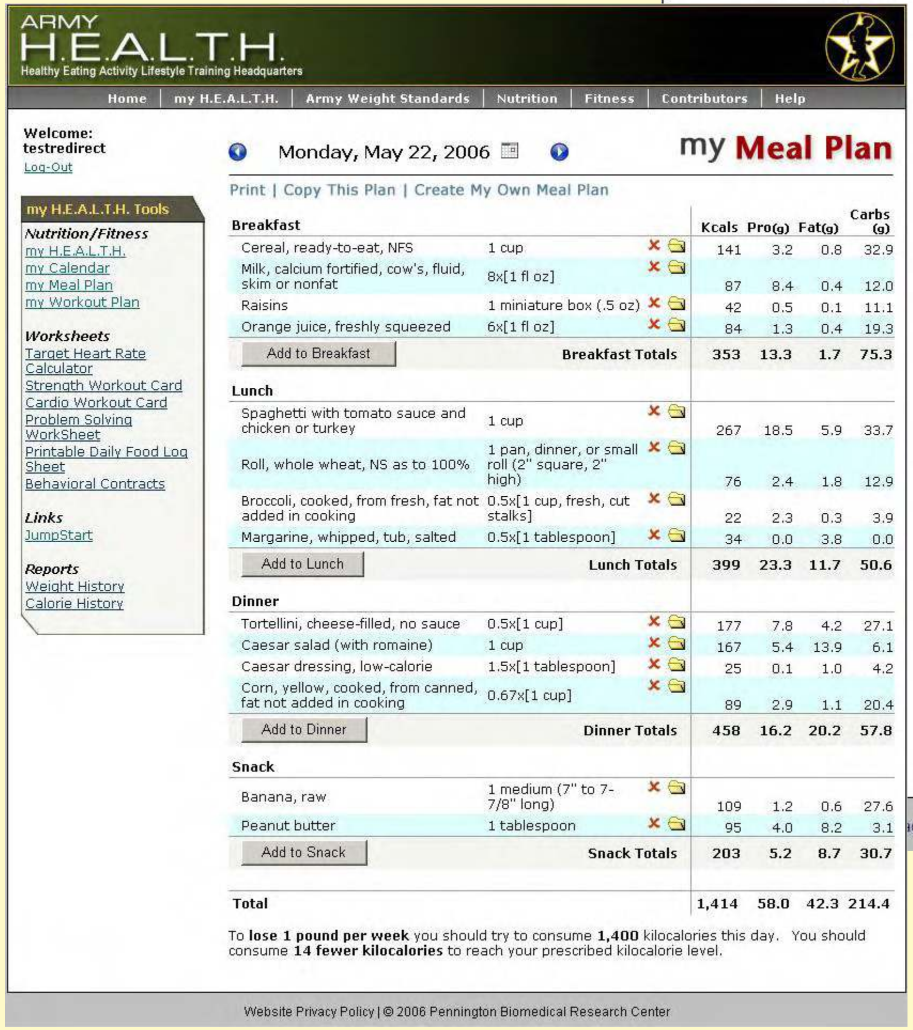
- Reason about environment
- Understand and express emotion
- Communicate through speech & gesture
- Play the role of teachers, peers, adversaries




"Skip" Rizzo

# Internet-based weight and fitness intervention and support




**Three major database and study efforts:**

**94th Regional Readiness Command**

**Fort Bragg**


**Louisiana Army National Guard**

**Tiffany Stewart & Don Williamson**

PENNINGTON BIOMEDICAL RESEARCH CENTER LSU | 30 YEARS OF DISCOVERY

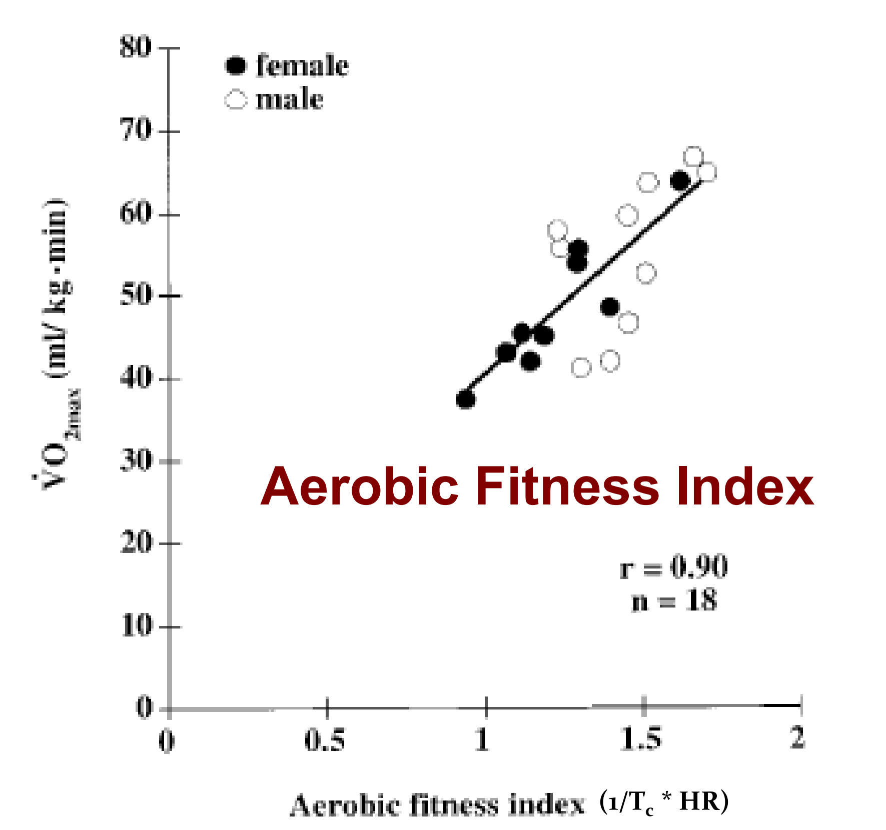
# Early concepts for continuous fitness monitoring

+


$$VO_{2max} = -5.075 + 44.98 * (1/T_c * HR)$$

**Peter Weyand**
**SMU**

*"Heartbeats per running step"*




**Elegant biological relationships can provide useful physiological information from simple measurements**

Table 3. *Techniques for estimating $\dot{V}O_{2max}$*

| | Accuracy | Convenience | Exertion Required |
|---|---|---|---|
| Åstrand-Rhyming | Good | Average | Intermediate |
| Harvard step test | Average | Good | Intermediate |
| Cooper 12-min run | Fair | Average | Maximal |
| Shuttle run | Good | Fair | Maximal |
| AFI | Good | Good | Modest |

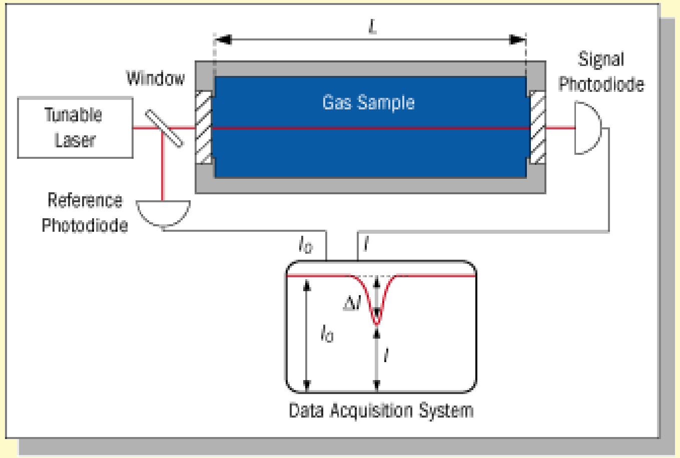
Accuracy and convenience rankings are based on a 5-category scale (poor, fair, average, good, excellent). Convenience rankings incorporate time and equipment required to obtain estimates.

*J Appl Physiol 2001;91:451*

# Military metabolic technologies

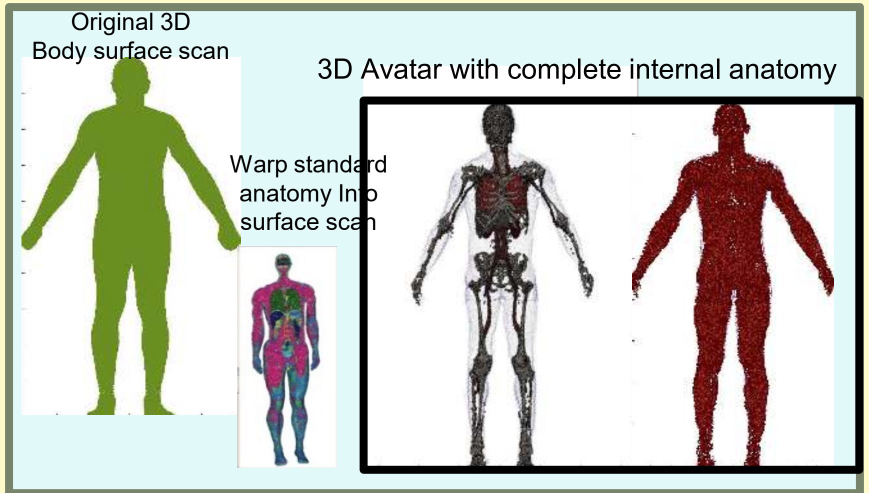
***My RQ, portable metabolic monitor***
***Gary Shaw & Holly McClung***

***C-13 labelled macronutrient studies***

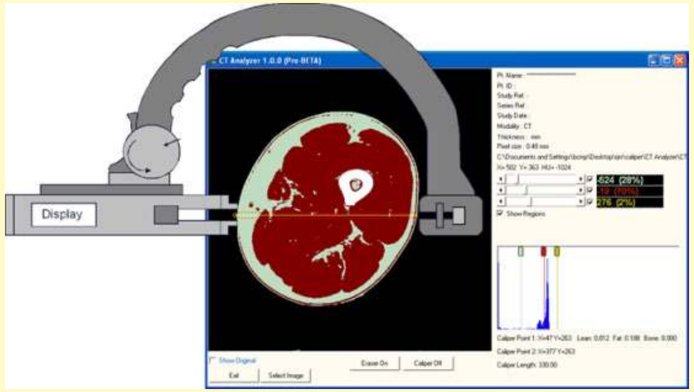



***Virtual metabolic coach***

***Personalized body composition avatars***
***Gary Zientara***

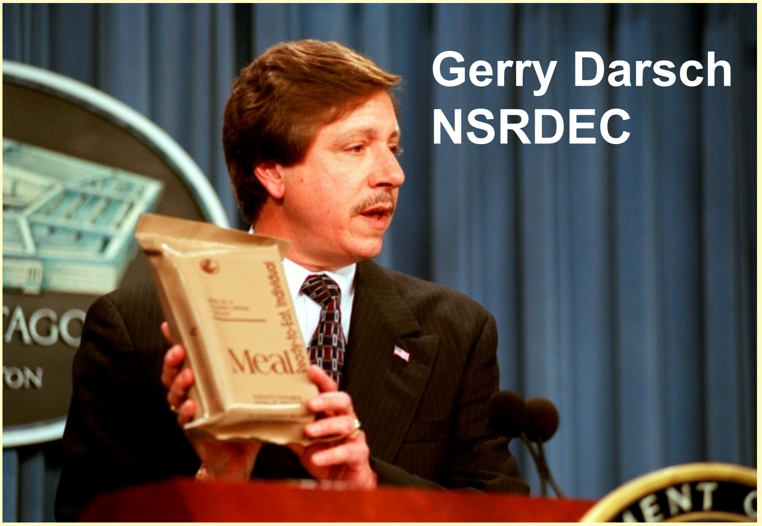



***Hand held DXA, Joseph Kehayias***





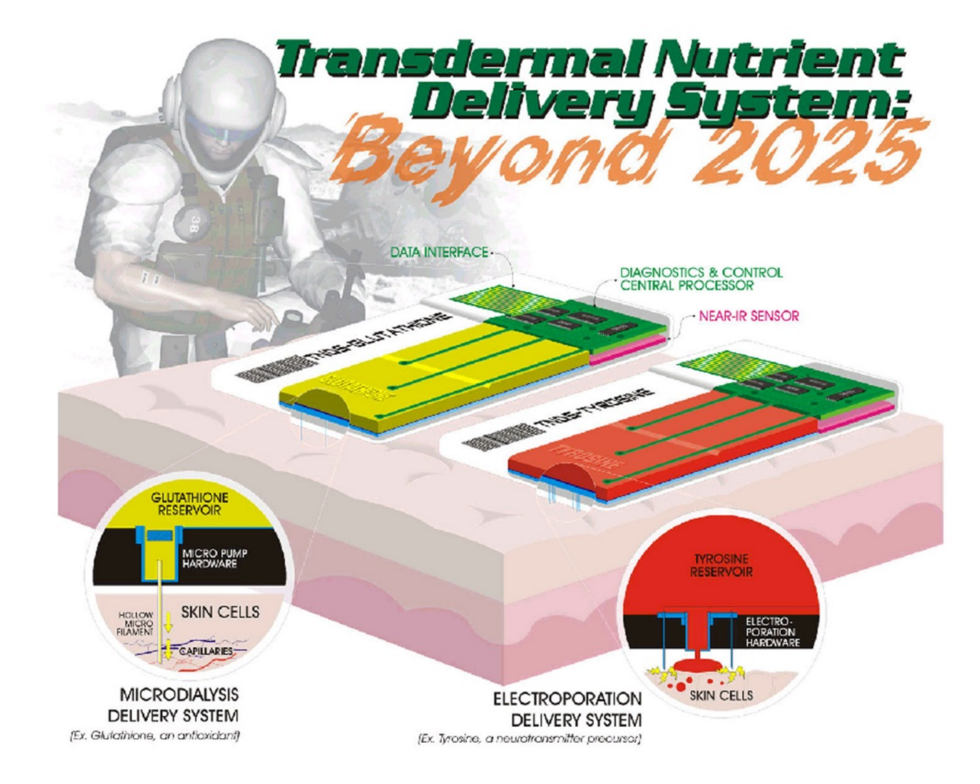
# Technologically enhanced rations






**Why can’t we just get all our nutrients in a pill and skip the trouble of meal preparation?**


K ration




*“Dr. Ancel Keys had preceded us in the desert. He reported favorably on K rations. But we followed the path of a maneuvering unit by the trail of discarded K biscuits. Even small desert rodents avoided them.”*

*William Bean, MD*

## *Flavor memories: umami and the fats of life*

# Technology must consider neurobiology

Pastrami, Katz's Deli

Smoked eel, Zuiderzee

Peking Duck

Hamachi cheek, Narita

Pork belly, Gordon Ramsey's, London

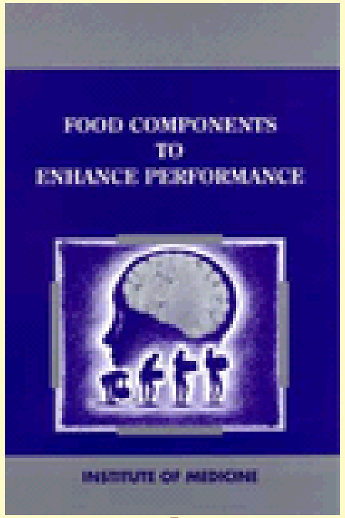
Black cod, Kyo Ya, NYC

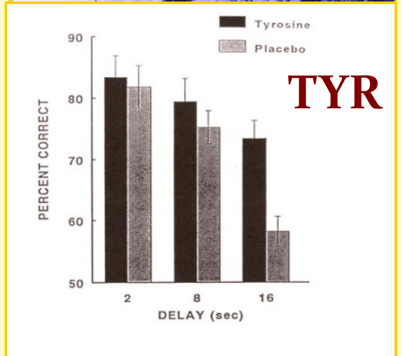
Pork buns, Hakata Ippudo, NYC

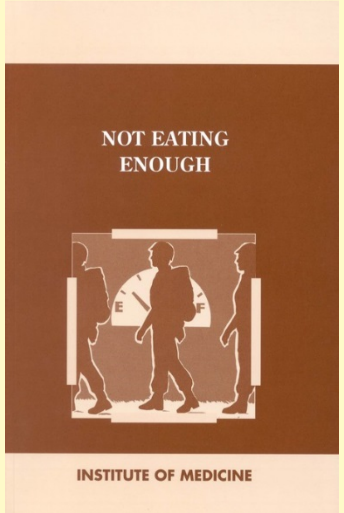
Toro, Akiko's
San Francisco

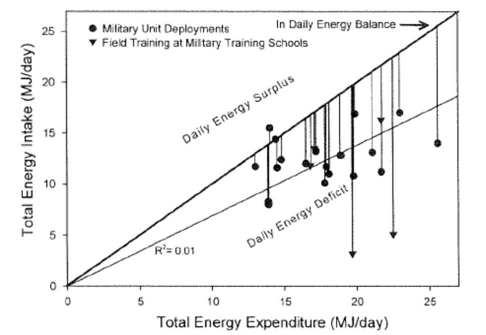
| RATION | NSN | PURPOSE | WEIGHT/ UNIT | VOLUME | NUTRITION |
|---|---|---|---|---|---|
| MRE™ | 8970-00-149-1094 | General Purpose | 1.5 lbs (.68 kg)/meal | .08 $ft^3$ (2.27 $dm^3$)/meal | 1300 Cal |
| FSR™ | 8970-01-543-3458 | Assault | 2.5 lbs (1.14 kg)/ration | .11 $ft^3$ (3.1 $dm^3$)/ration | 2900 Cal |
| MORE™ | Multiple | Nutritional Enhancement | .75 lbs (.34 kg)/pack | Varies | 1100 Cal |
| MCW | 8970-01-467-1753 | Cold Weather | 1 lbs (.45 kg)/meal | .04 $ft^3$ (1.1 $dm^3$)/meal | 1450 Cal |
| LRP | 8970-01-467-1749 | Assault | 1 lbs (.45 kg)/meal | .04 $ft^3$ (1.1 $dm^3$)/meal | 1450 Cal |
| UGR-E™ | Multiple | Group, Self-Heating | 43 lbs (19.5 kg)/module | 1.9 $ft^3$ (53.8 $dm^3$)/module | 1300 Cal |
| UGR-H&S™ | Multiple | Group | 124.5 lbs (56.6 kg)/module | 5.25 $ft^3$ (148.7 $dm^3$)/ module | 1450 Cal |
| UGR-B™ | Multiple | Group | 124.5 lbs (56.6 kg)/module | 5.25 $ft^3$ (148.7 $dm^3$)/ module | 1300 Cal |
| UGR-A™ | Multiple | Group (Perishable) | 100 lbs (45.5 kg)/module | 5.25 $ft^3$ (148.7 $dm^3$)/ module | 1450 Cal |
| Arctic Supplement | 8970-01-470-5075 | Nutritional Enhancement | 60 lbs (27.3 kg)/module | 5 $ft^3$ (141.6 $dm^3$)/module | 914 Cal |

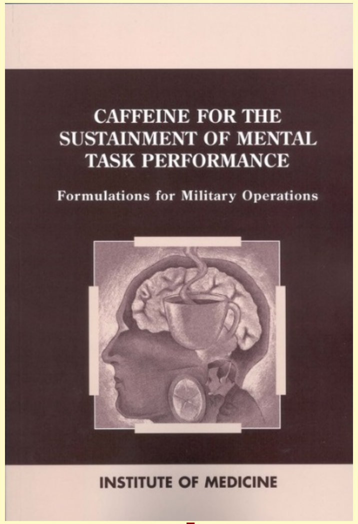
# Science-based ration components for soldier health & performance

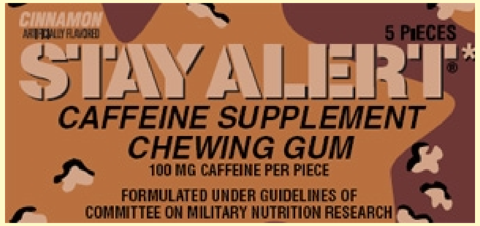


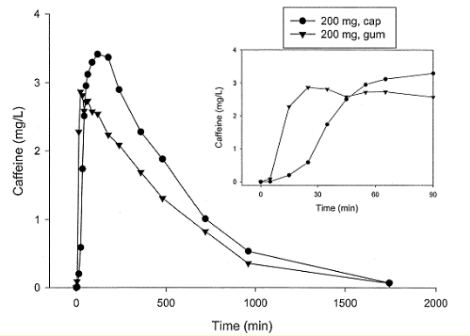



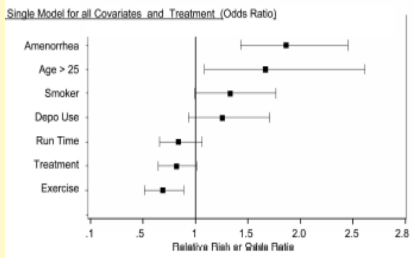






pocket sandwiches, energy bars, carbohydrate enhanced applesauce, high energy drinks, pouches of tuna, chunk chicken and caffeine gum


*Most Americans are NOT deficient for Vitamin D*

*One group tends to be deficient – young women (18-25 yrs)*

*"Mediterranean diet"*

**Extra virgin olive oil (oleocanthal)**
**Fish (omega-3 fatty acids)**
**Red wine (resveratrol)**
**Onion (quercetin)**
**Garlic (allicin)**
**Legumes and nuts**
**Whole grains: bread and macaroni**


# Relative comparison of obesity


**Cultures that "respect" food and food variety**

***Healthy food choices: a <u>varied diet</u> including fruits and vegetables and low-salt intake, a diet generally <u>believed</u> to help reduce the incidence of obesity and cardiovascular disease***

*Report*

## Report of an EU–US Symposium on Understanding Nutrition-Related Consumer Behavior: Strategies to Promote a Lifetime of Healthy Food Choices

Karl E. Friedl, PhD[1]; Sylvia Rowe, MA[2]; Laura L. Bellows, PhD, MPH, RD[3]; Susan L. Johnson, PhD[4]; Marion M. Hetherington, DPhil[5]; Isabelle de Froidmont-Görtz, MSc[6]; Veerle Lammens, MSc[6]; Van S. Hubbard, MD, PhD[1]

ABSTRACT

This report summarizes an EU–US Task Force on Biotechnology Research symposium on healthy food choices and nutrition-related purchasing behaviors. This meeting was unique in its transdisciplinary approach to obesity and in bringing together scientists from academia, government, and industry. Discussion relevant to funders and researchers centered on (1) increased use of public–private partnerships, (2) the complexity of food behaviors and obesity risk and multilevel aspects that must be considered, and (3) the importance of transatlantic cooperation and collaboration that could accelerate advances in this field. A call to action stressed these points along with a commitment to enhanced communication strategies.

Accepted May 5, 2014.

### INTRODUCTION

Obesity prevention and nutritional sciences have been a focus within the European Union (EU)–US Task Force on Biotechnology Research[1] since the addition of this topic in 2005. It was important to achieve additional transatlantic cooperation of public and private sectors on this topic through dialogue and collaboration and these efforts were not limited particularly from public–private partnerships involving 3 key scientific sectors: academia, government, and the food and beverage industry (key participants are listed as Supplementary Data). It was the stated aim of the organizers that by convening an innovative transdisciplinary group of scientists, new ideas would emerge, both in prevention and management strategies and in directions for future obesity research. This report provides expressly defined in this meeting but were expressed in terms of a varied diet including fruits and vegetables and low-salt intake, a diet generally believed to help reduce the incidence of obesity and cardiovascular disease.

### DISCUSSION OF STATE OF THE SCIENCE

Complexity of the Problem

# Low Tech Policies

“Metabo Law” 2008


## Toward Society 5.0

**Society 4.0**
**Information society**

Individual optimization through application of ICT

Efficient use of natural resources

World bound by various constraints (temporal, spatial, etc.)

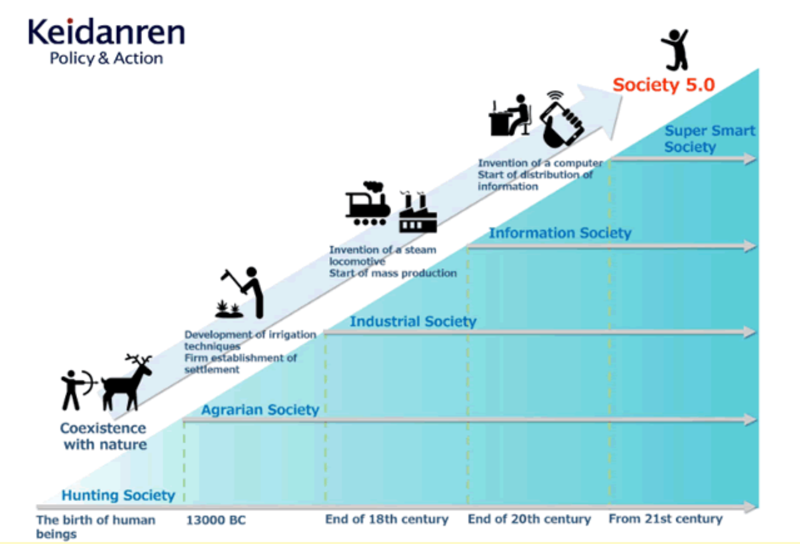
Seeking solutions to individual problems Making individual industries more efficient

**Society 5.0**
**Super-smart society**

Optimizing society as a whole through integration of cyberspace and physical space

Use of new resources (data)

World released from various constraints




Using remote sensing and oceanographic data for monitoring and management of water quality, forests, land degradation, biodiversity, etc.

Resolving climate change issues with the simulation based on the analysis of meteorological and other observation data by using High Performance Computing

Creating smart cities where convenience, safety and economic efficiency are made compatible

Building global innovation ecosystems by connecting industries, academic institutions and other related stakeholders

Building resilient infrastructure and promoting sustainable industrialization by using i-Construction


Boosting food production by smart agriculture utilizing IoT, AI and Big Data
Improving nutritional status with smart food produced by cutting-edge biotechnology

Developing early warning alert system for the prevention of infectious diseases by combining different types of monitoring data

Make high quality education affordable for everyone on the earth with e-learning systems utilizing state-of-the-art technologies

Empowering women with access to education and information through the Internet
Providing women with opportunities for startups by utilizing ICT

Managing electric power supply and demand in a sustainable way by constructing smart grid systems

# Progress since the "decade of the brain"

- New technological era provides benefits and risks - risks of overnutrition and underexercise are now major public health (and national security) concerns

- New technologies such as metabolic sensing, virtual environments, and AI decision support tools may be directed to help humans effectively self-regulate

- The head is connected to the body, and an integrated view of brain and behavior with human metabolic regulation is critical to advancing nutrition science