Navigating The Technological Future or Star Trek's Tricorder: Science Fiction or Future Science?

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21st Congress of the EAHP, Vienna, Austria, 2016

Disclosure

Relevant Financial Relationships NONE

Off-Label Investigational Uses NONE

Fasten Your Seatbelts

Machines That Sent Man To The Moon ('60s)

Smartwatch Vision ('80s)

Today…

Your Phone Is More Powerful Than The Computer In The Spaceship NASA Launched This Week

Matt Rosoff
Dec. 6, 2014, 3:01 PM 316

FACEBOOK LINKEDIN TWITTER EMAIL PRINT

- These 12 Thing Will Happen When You Make...
- Sparta : The Strategy Game Phenomenon of 2015
- Miracle Blood Sugar Level Reducing Foods Yo...
- The Most Exciting MMORPG You've Ever Playe...

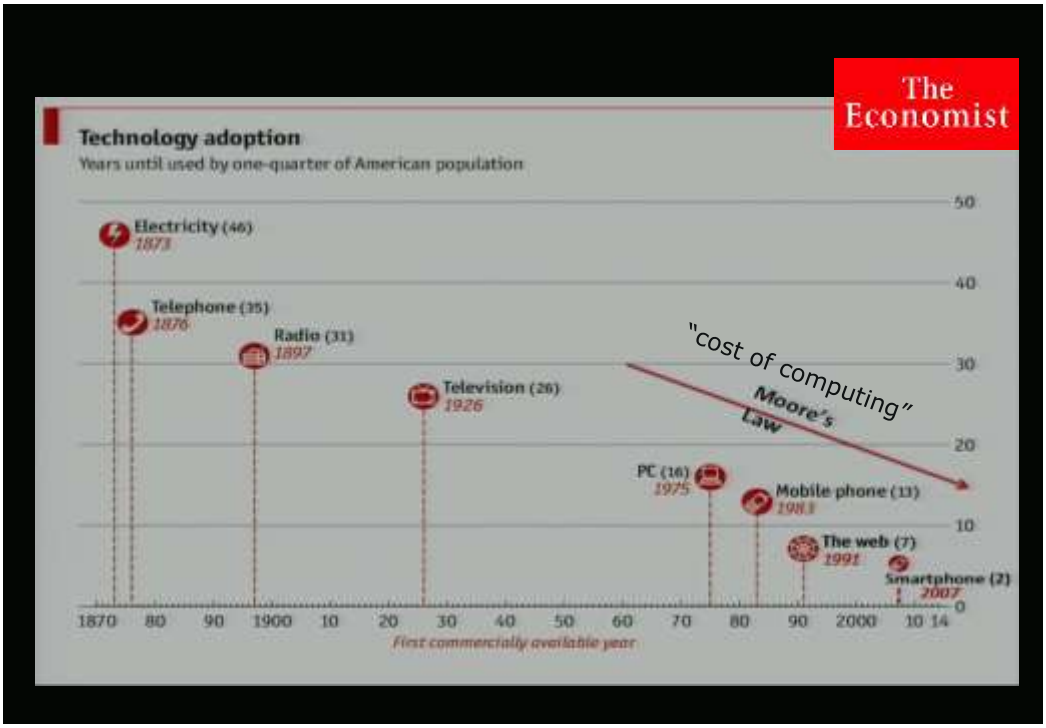
The Orion spaceship, which NASA launched this week as a first step on a mission to take astronauts to Mars, has a less powerful computer than your smartphone.

It's widely known that today's smartphones have more computing power than all of NASA did when it started sending astronauts to the moon.

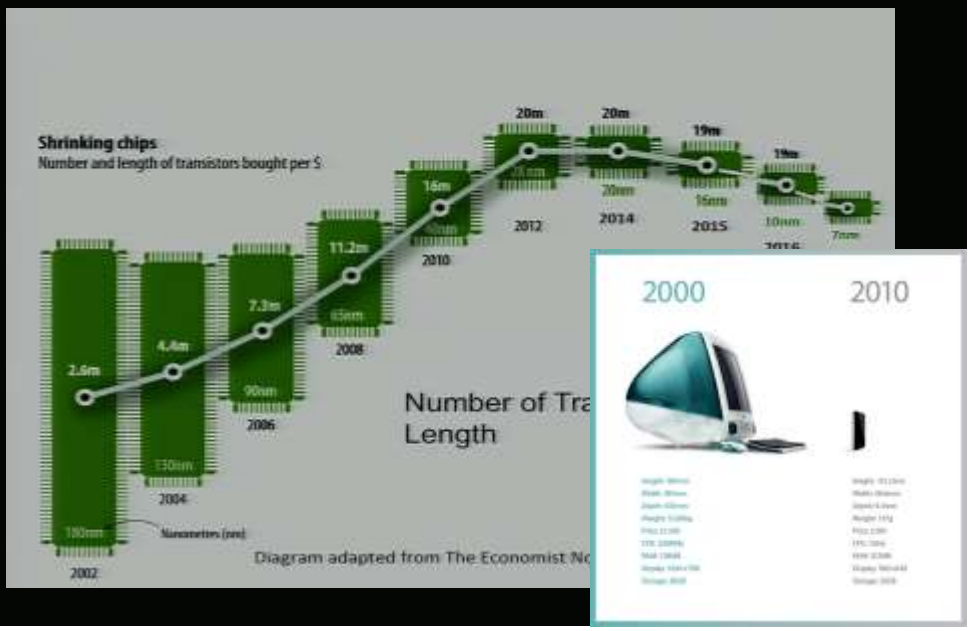
ears ago!
y have
it?

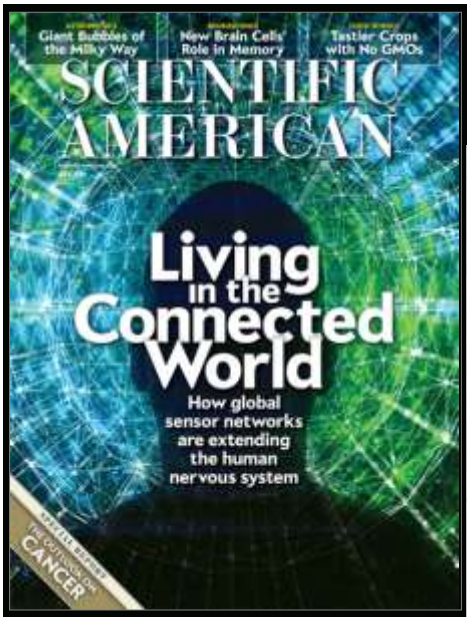
Most smartphones have more computing power than The Orion spaceship.

BUSINESS INSIDER UK



2 Billion Transistors in Your iPhone 6





Almost 200 Million Google Searches By The End Of My Talk

The Downside: Homo-Distractus

It keeps me from looking at my phone every 30 seconds…

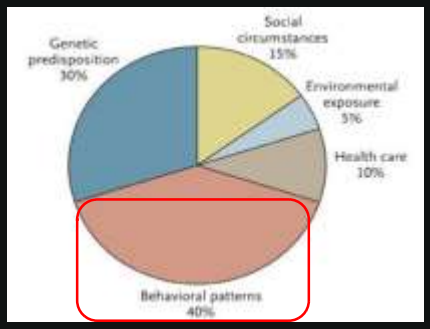
Back to Health…

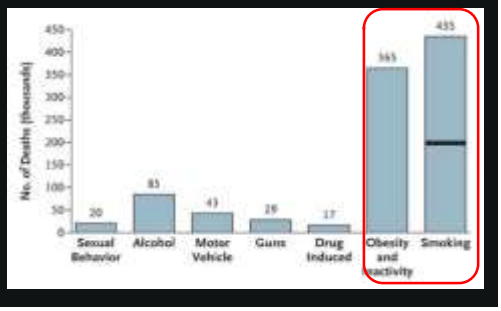
Actual Causes of Death in the United States, 2000

ABSTRACT

ABSTRACT | METHODS | RESULTS | COMMENT | REFERENCES

JAMA
The Journal of the American Medical Association





Challenge Today

Imprecision medicine = *Population health* & *average patient*


Personalized medicine: Time for one-person trials

Nicholas J. Schork

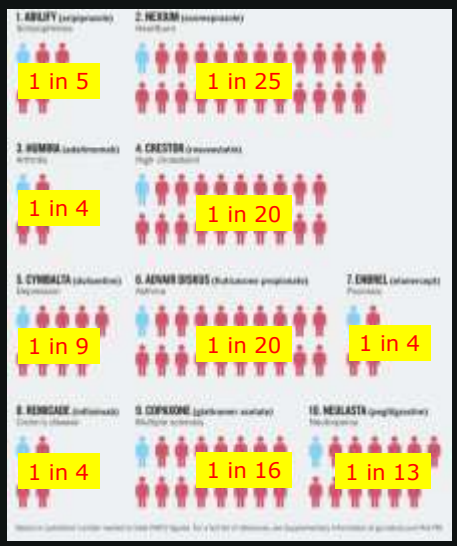
29 April 2015

Precision medicine requires a different type of clinical trial that focuses on individual, not average, responses to therapy, says Nicholas J. Schork.

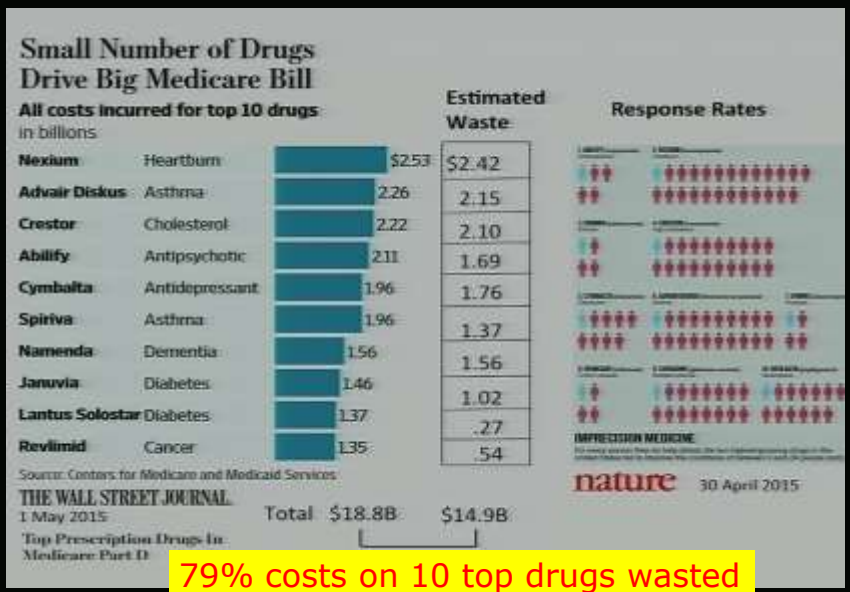
PDF Rights & Permissions

Subject terms: Cancer · Drug discovery · Medical research · Health care

Top 10 Drugs Our Patients Do Not Respond To (US)



Wasted Efforts (US-based Numbers, by E. Topol)



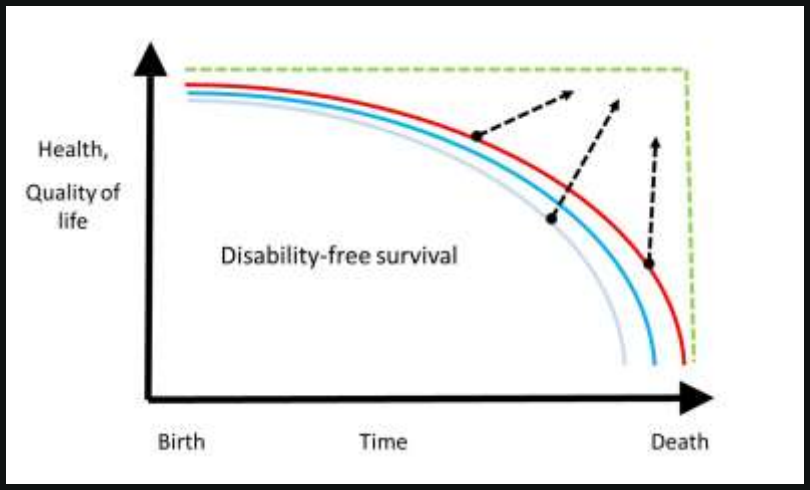
79% costs on 10 top drugs wasted

~~Im~~precision medicine

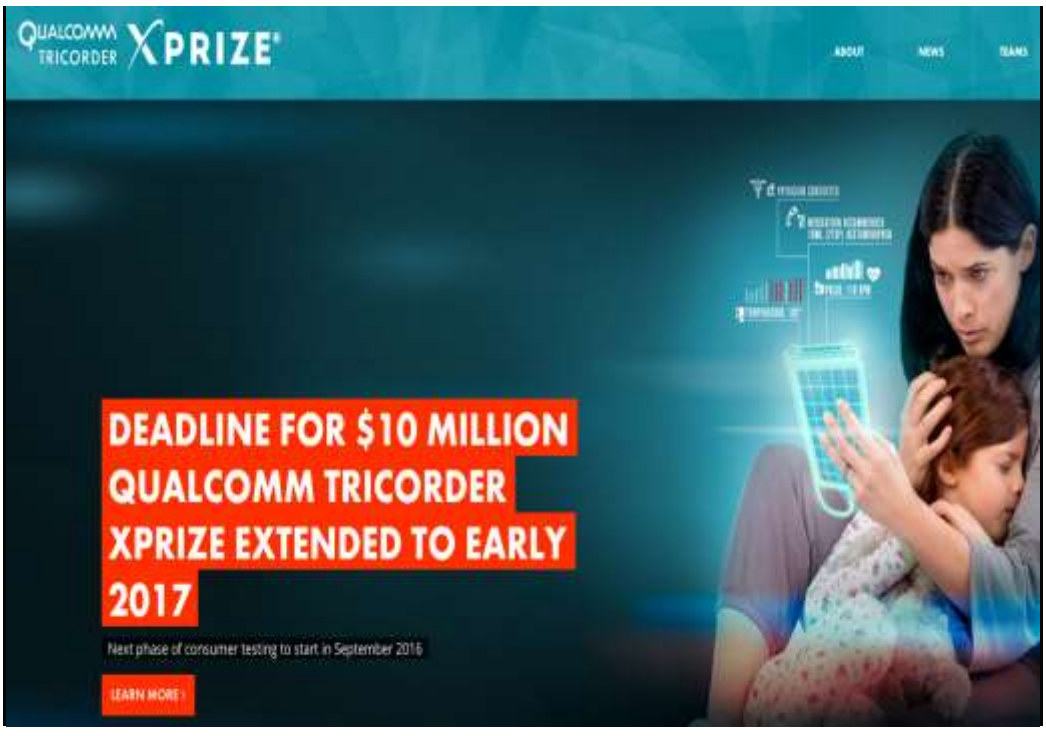
~~*Population,*~~

~~*average*~~ *patient¡*

Squaring The Curve




COMPETITION #2 TEAMS
DMI
UNITED STATES
TEAM LEADER:
EUGENE CHAN
BIOVOTION
SWITZERLAND
TEAM LEADER:
ANDREAS CAZLEY
BIOEN LIFESCIENCE
UNITED STATES
TEAM LEADER:
SHAN WANG
ENDOTRONIX
WIRELESS HEALTH
MONITORING
UNITED STATES
TEAM LEADER:
HARRY ROWLAND
GOLDEN GOPHER
MAGNETIC
BIOSENSING
UNITED STATES
TEAM LEADER: JIAN-
PING WANG
GUES
UNITED KINGDOM
TEAM LEADER:
ESTHER
RODRIGUEZ
VILLEGAS
NOKIA
SENSING
XCHALLENGE

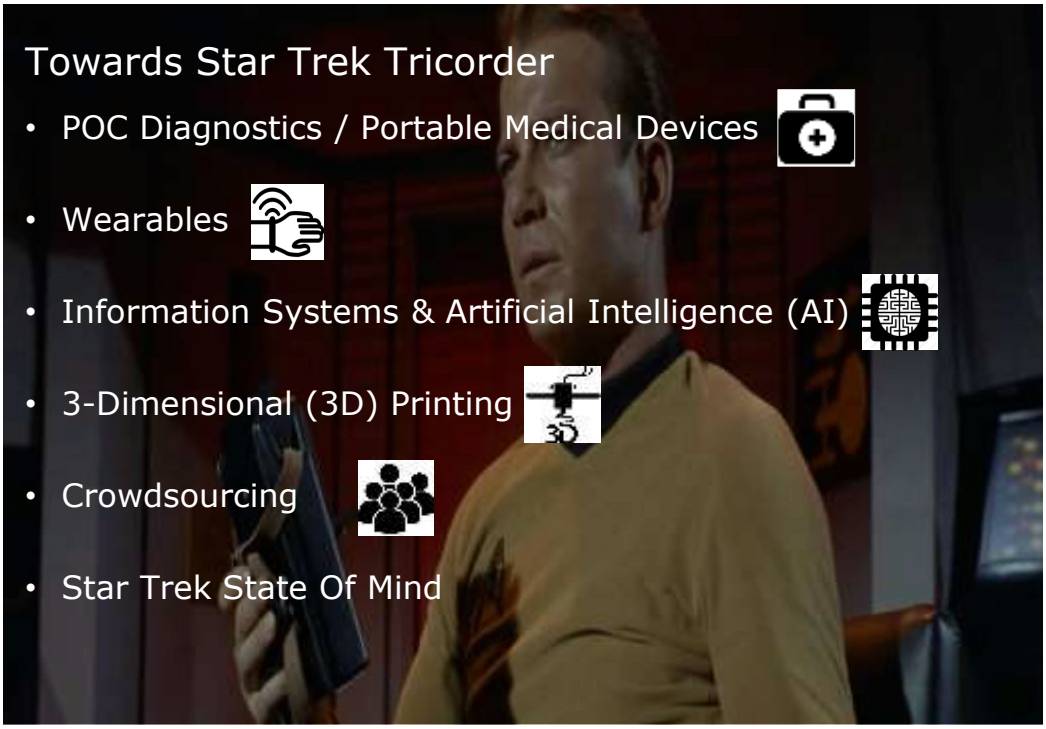

QUALCOMM
TRICORDER
XPRIZE
ABOUT
NEWS
TEAMS
DEADLINE FOR $10 MILLION QUALCOMM TRICORDER XPRIZE EXTENDED TO EARLY 2017
Next phase of consumer testing to start in September 2016
LEARN MORE

Ultimate Tricorder (Elysium Movie)

Precision medicine

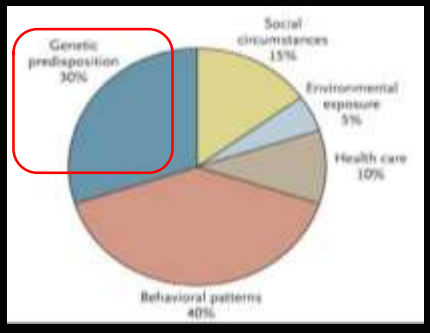
[Personalized, Preventative, Proactive, Participatory]

- ***Average is over: patient$_i$***
- ***POC is where the patient is***
- ***Toolbox is expanded beyond a stethoscope and a pill***
- ***Approach to health is holistic***


Towards Star Trek Tricorder
• POC Diagnostics / Portable Medical Devices
• Wearables
• Information Systems & Artificial Intelligence (AI)
• 3-Dimensional (3D) Printing
• Crowdsourcing
• Star Trek State Of Mind

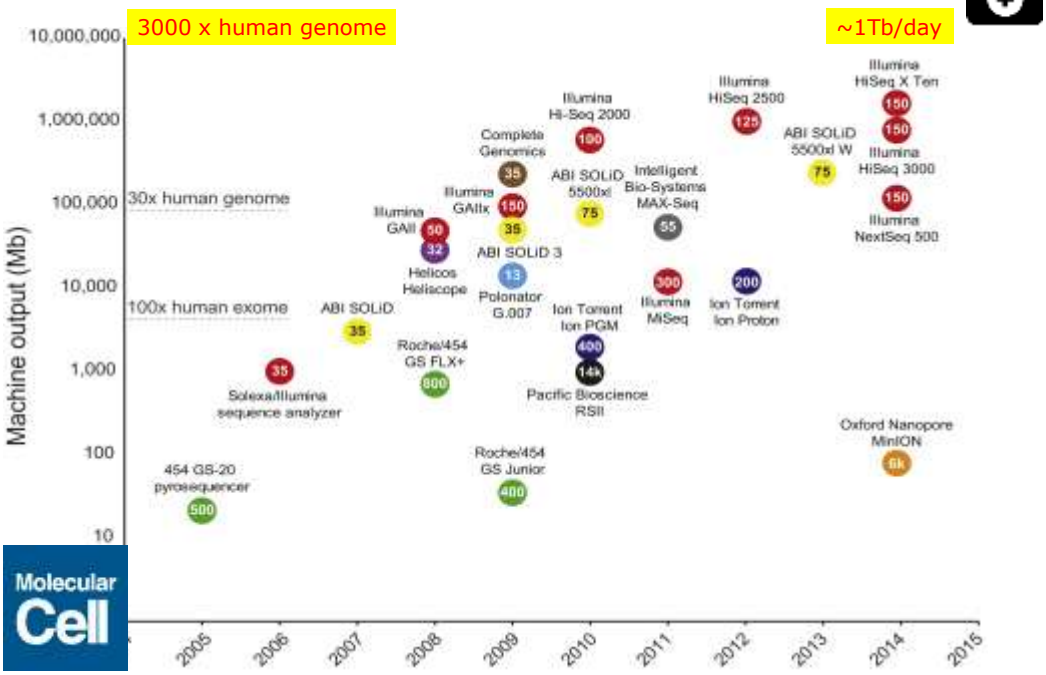

point of care diagnostics
portable medical devices

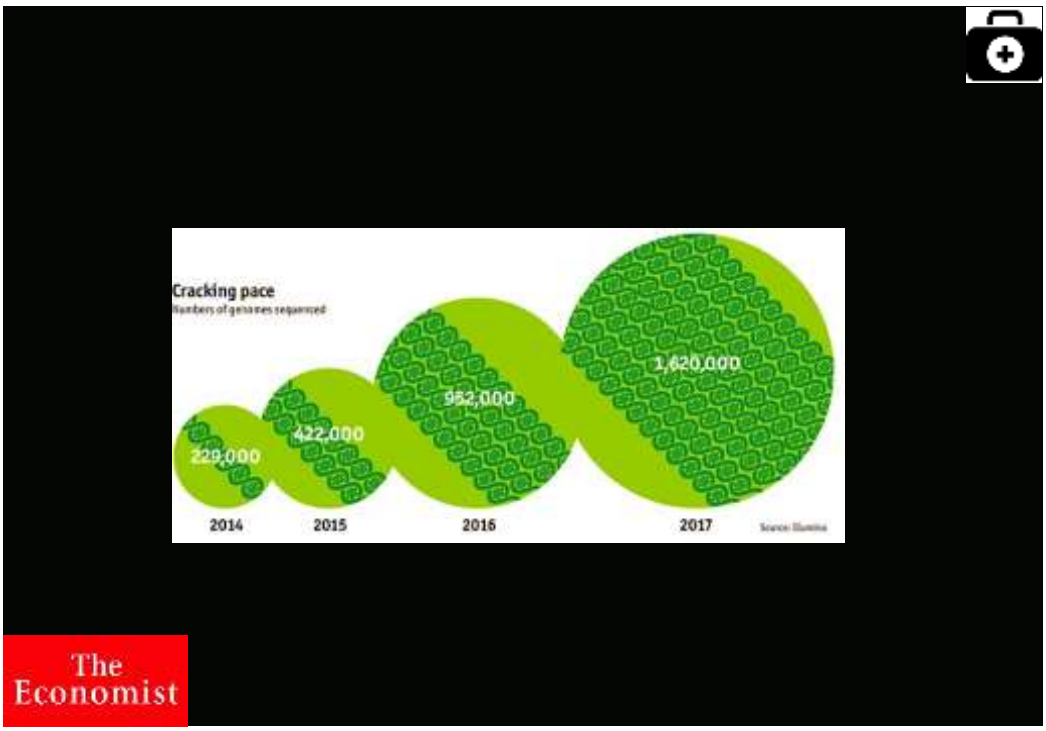
Contributors To Premature Death



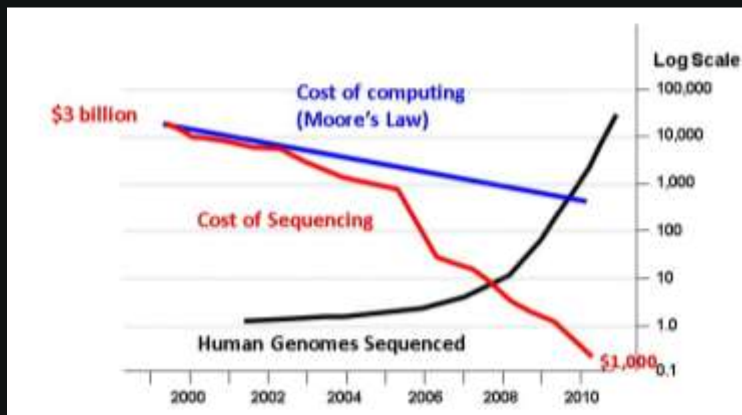
JAMA
The Journal of the American Medical Association

Timeline of Commercial High-Throughput Sequencing Platforms (speed/day)





Decreasing Cost



The Economist

Screen Newborns for Certain Treatable Conditions

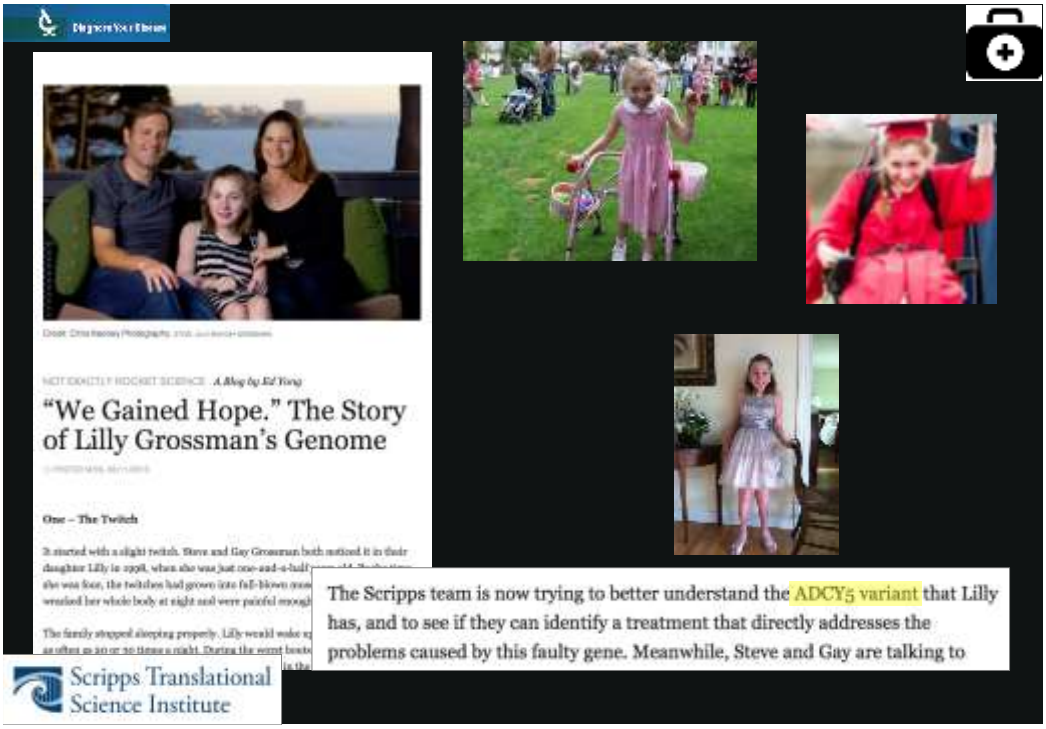
NIH Studies Explore Promise of Sequencing Babies' Genomes

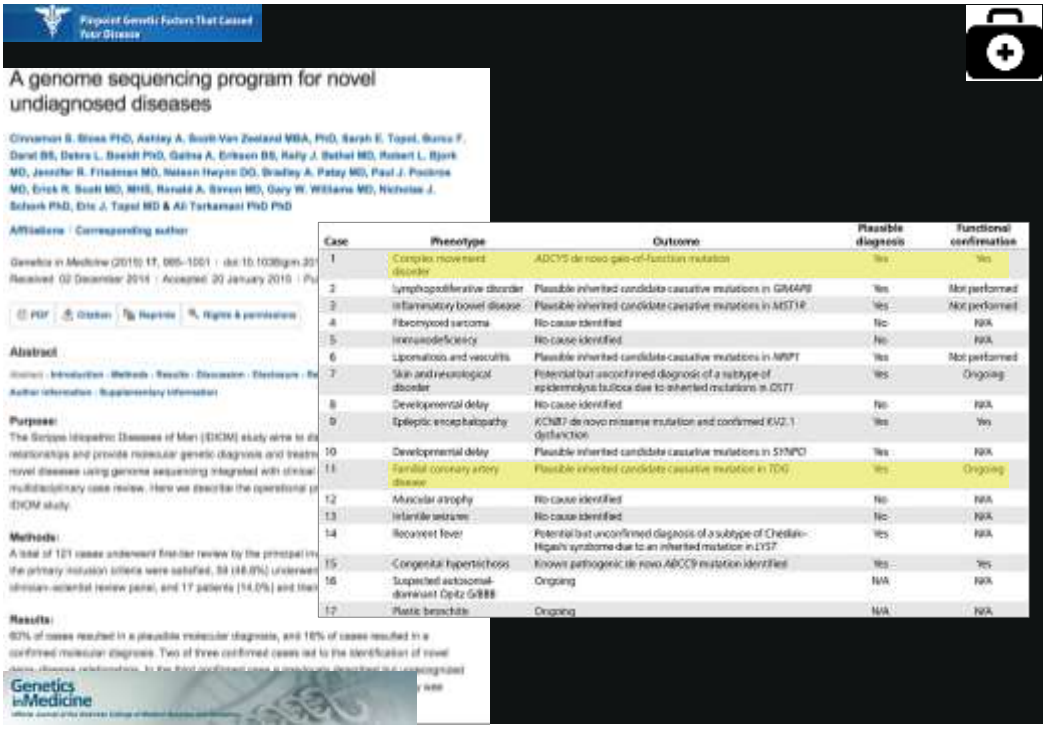
Fast sequencing saves newborns

Science

AAAS

nature





Case	Phenotype	Outcome	Plausible diagnosis	Functional confirmation
1	Complex movement disorder	ADCY5 de novo gain-of-function mutation	Yes	Yes
2	Lymphoproliferative disorder	Plausible inherited candidate causative mutations in GINS4P8	Yes	Not performed
3	Inflammatory bowel disease	Plausible inherited candidate causative mutations in MST1P	Yes	Not performed
4	Fibromyxoid sarcoma	No cause identified	No	N/A
5	Immunodeficiency	No cause identified	No	N/A
6	Lipomatosis and vasculitis	Plausible inherited candidate causative mutations in NPEPT	Yes	Not performed
7	Skin and neurological disorder	Potential but unconfirmed diagnosis of a subtype of epidermolysis bullosa due to inherited mutations in DST1	Yes	Ongoing
8	Developmental delay	No cause identified	No	N/A
9	Epileptic encephalopathy	KCNB7 de novo missense mutation and confirmed Kv2.1 dysfunction	Yes	Yes
10	Developmental delay	Plausible inherited candidate causative mutations in SYNPO	Yes	N/A
11	Familial coronary artery disease	Plausible inherited candidate causative mutation in TDG	Yes	Ongoing
12	Muscular atrophy	No cause identified	No	N/A
13	Infantile seizures	No cause identified	No	N/A
14	Recurrent fever	Potential but unconfirmed diagnosis of a subtype of Chediak–Higashi syndrome due to an inherited mutation in LYST	Yes	N/A
15	Congenital hypertrichosis	Known pathogenic de novo ABCC9 mutation identified	Yes	Yes
16	Suspected autosomal-dominant Opitz G/BBB	Ongoing	N/A	N/A
17	Plastic bronchitis	Ongoing	N/A	N/A

Where is Your Tricorder?

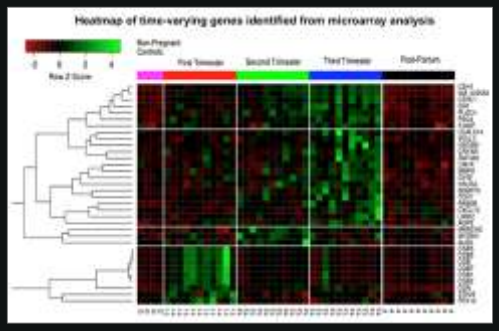
Noninvasive in vivo monitoring of tissue-specific global gene expression in humans

Significance

Abstract

PNAS

The Molecular Stethoscope



Choose the Best Medicine and Correct Dose

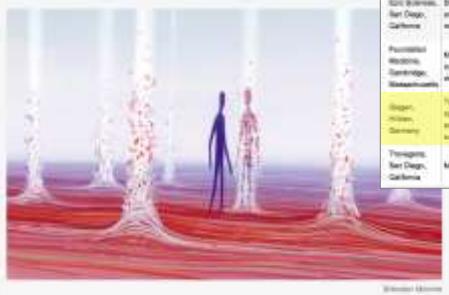
Therapy: This time it's personal

Lauren Gravitz

Nature 509, S52–S54 (29 May 2014) | doi:10.1038/509S52a
Published online 28 May 2014

Tailoring cancer treatment to individual and evolving tumours in the way of t… scientists are still hashing out the details.

Subject terms: Cancer therapy · Drug development · Targeted therapies · Chronic myeloid leukaemia · Leukaemia · Cancer genetics · Personalized medicine



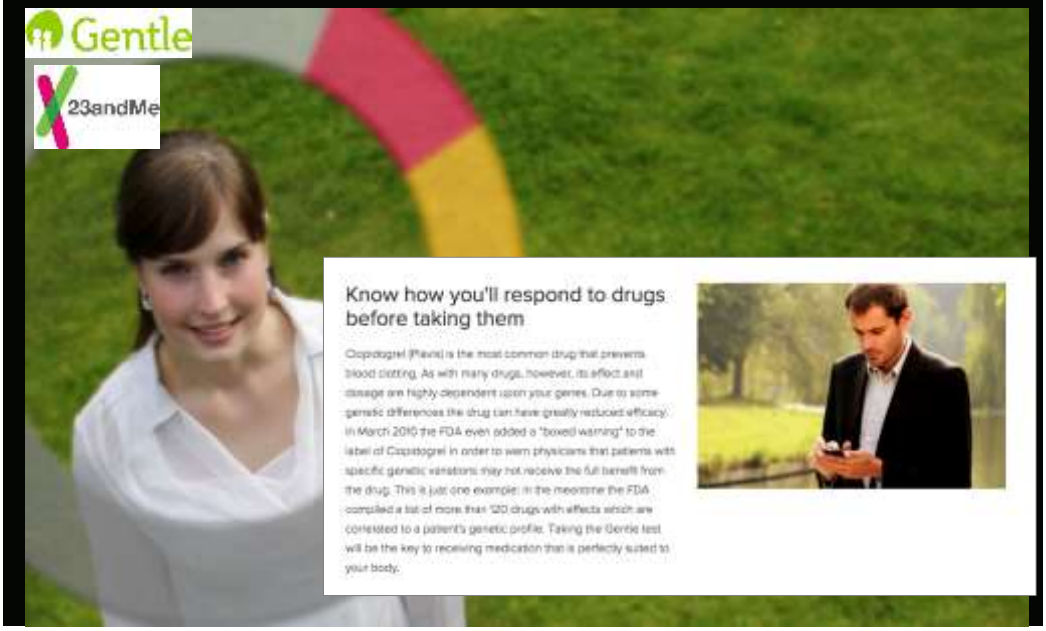
Elaine Mardis and her colleagues first encountered 39-year-old Lucy (not her real name) in 2010 … Missouri. Lucy had been referred … it she had a subtype of the … he most treatable forms — which … d up, or translocated, triggering …

nature

Company	Goal	Technology	Developmental stage
Genomic Health, Redwood City, California	Risk assessment	Assesses molecular markers in tumours. Predicts whether chemotherapy will be beneficial, as well as likelihood of recurrence.	Launched oncotype DX test for breast cancer in 2004. Tests now also available for colon and prostate cancers.
Epic Sciences, San Diego, California	Diagnosis and monitoring	Isolates tumour cells circulating in blood, and tests them for receptors and enzymes that indicate effectiveness of therapeutics.	Partnering with pharmaceutical and biotechnology companies and cancer centres. Tests are currently in clinical trials and not yet commercially available.
Foundation Medicine, Cambridge, Massachusetts	Match patient to drug	Screens biopsies for alterations in 228 cancer-related genes for solid tumours and 405 genes for haematological cancers. Then matches mutations to drugs that are either approved by the US Food and Drug Administration or in clinical trials.	Two clinical products are available to oncologists: FoundationOne for solid tumours, launched in 2013, and FoundationOne Heme for haematological cancers, launched in 2012.
Qiagen, Hilden, Germany	Targeting appropriate patient subgroups	Uses the polymerase chain reaction analysis to detect mutations in epidermal growth factor receptor and determine whether the drug afatinib is the appropriate treatment.	Approved by US Food and Drug Administration for testing in conjunction with afatinib in patient metastatic non-small-cell lung cancer patients for first-line treatment with afatinib.
Theragen, San Diego, California	Monitoring	Analysis cell-free cancer DNA in urine to … monitor disease progression, recurrence and … response.	

Drug /Condition	Gene	O.R.	Comment
Lithium for Bipolar Disorder	GADL1	120X	Efficacy in Han Chinese
Interferon-α for Hepatitis C	IL28B	3X	Efficacy in core viral infection
Carbamazepine for Multiple Neurologic Conditions	HLA-A*3101	26X	Stevens-Johnson Syndrome
Simvastatin for LDL Cholesterol Lowering	SLCO1B1	17X	Severe muscle inflammation
Flucloxacillin for infections	HLA-B*5701	91X	Liver toxicity
Abacavir for seizures	CYP3A5*3	14X	Stevens-Johnson Syn
Azathioprine for autoimmune diseases	NUDT15 HLA-DQA1	36X 2X	Leukopenia Pancreatitis

Consumers: Genetics & Drug Response



Story of Joshua Osborne Infection

Actionable Diagnosis of Neuroleptospirosis by Next-Generation Sequencing

Joshua Osborn, 14, lay in a coma at American Family Children's Hospital in Madison, Wis. For weeks his brain had been swelling with fluid, and a battery of tests had failed to reveal the cause.

but a spinal tap turned up no pathogens. Even a biopsy of his brain tissue told the doctors nothing.

After only 96 minutes, the results appeared on a computer monitor. Joshua's cerebrospinal fluid contained DNA from a potentially lethal type of bacteria called Leptospira. As dangerous as Leptospira can be, it is readily treated with penicillin.

THE NEW ENGLAND JOURNAL of MEDICINE

Where is Your Tricorder?

Health care: Bring microbial sequencing to hospitals

Sharon Peacock

22 May 2014

Analysing bacterial and viral DNA can help doctors to pick effective drugs quickly, says Sharon Peacock.

Subject terms: Genomics · Microbiology · Health care · Infection

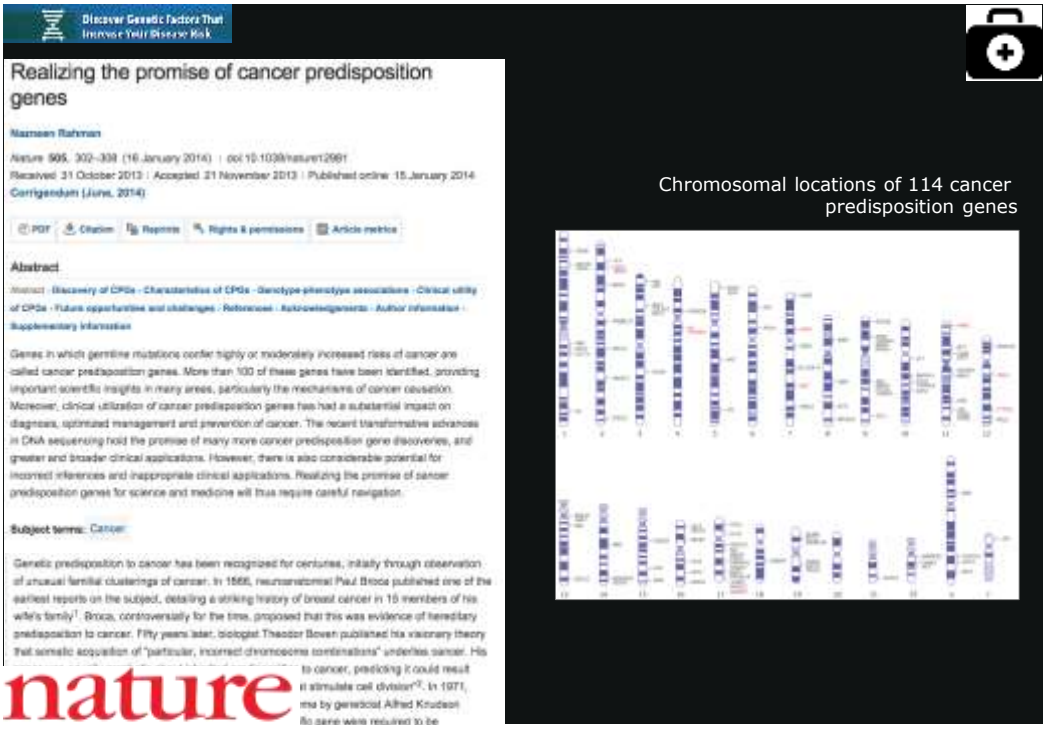
A patient goes to her doctor with fever, cough and night sweats. Rapid tests confirm the diagnosis of tuberculosis and hint at multidrug resistance. But to suggest the optimum drug combination, as many as eight weeks of laboratory testing are required — a timescale dictated by the slow growth rate of the pathogen (*Mycobacterium tuberculosis*). In the meantime, the doctor must make an educated guess about which medicines to prescribe, increasing the risk of ineffective treatment and spread of infection.

Yet it would take less than a week to sequence a culture of *M. tuberculosis* and to detect mutations that indicate which drugs the bacteria are resistant to. My colleagues and I demonstrated[1] this in a research setting last year using a sputum culture from a tuberculosis patient. We have also shown that whole-genome sequencing can detect resistance of other pathogens to carbapenem antibiotics, drugs reserved to treat the most serious infections. Although a range of genetic mechanisms can confer resistance, sequencing is informative in all species tested so far, including *Acinetobacter baumannii* and *Klebsiella pneumoniae*, which can infect the most vulnerable hospital patients[2]. Sequence information can also be used to confirm outbreaks and help to bring them to a close.

Although technology for microbial sequencing has existed for years, it is yet to help patients on a routine basis. Now that pathogen genomes can be completed in less than a day, the time is right is, at least in the developed world. This will nto local diagnostic laboratories and the d genomes. Both are more a matter of wil

nature


cancer
point of care diagnostics
portable medical devices


Discover Genetic Factors That Increase Your Disease Risk
Realizing the promise of cancer predisposition genes
Nazneen Rahman
Nature 505, 302–308 (16 January 2014) | doi:10.1038/nature12981
Received 31 October 2013 | Accepted 21 November 2013 | Published online 15 January 2014
Corrigendum (June, 2014)
PDF
Citation
Reprints
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Article metrics
Abstract
Genes in which germline mutations confer highly or moderately increased risks of cancer are called cancer predisposition genes. More than 100 of these genes have been identified, providing important scientific insights in many areas, particularly the mechanisms of cancer causation. Moreover, clinical utilization of cancer predisposition genes has had a substantial impact on diagnosis, optimized management and prevention of cancer. The recent transformative advances in DNA sequencing hold the promise of many more cancer predisposition gene discoveries, and greater and broader clinical applications. However, there is also considerable potential for incorrect inferences and inappropriate clinical applications. Realizing the promise of cancer predisposition genes for science and medicine will thus require careful navigation.
Subject terms: Cancer
Genetic predisposition to cancer has been recognized for centuries, initially through observation of unusual familial clusterings of cancer. In 1866, neuroanatomist Paul Broca published one of the earliest reports on the subject, detailing a striking history of breast cancer in 16 members of his wife's family[1]. Broca, controversially for the time, proposed that this was evidence of hereditary predisposition to cancer. Fifty years later, biologist Theodor Boveri published his visionary theory that somatic acquisition of "particular, incorrect chromosome combinations" underlies cancer. His
to cancer, predicting it could result
n stimulate cell division"[2]. In 1971,
ma by geneticist Alfred Knudson
ts gene were required to be
nature
Chromosomal locations of 114 cancer predisposition genes

Discovery and saturation analysis of cancer genes across 21 tumour types

Michael S. Lawrence, Petar Stojanov, Craig H. Mermel, James T. Robinson, Levi A. Garraway, Todd R. Golub, Matthew Meyerson, Stacey B. Gabriel, Eric S. Lander & Gad Getz

Affiliations | Contributions | Corresponding authors

Nature 505, 495–501 (23 January 2014) | doi:10.10
Received 12 September 2013 | Accepted 27 Novemb
2014

Abstract

Abstract · Introduction · Cancer-genome data · Cancer-genes
21 tumour types · Coverage of known cancer genes · Analys
Saturation analysis · Power analysis · Discussion · Methods
information · Supplementary information

Although a few cancer genes are mutated in a high pro
most are mutated at intermediate frequencies (2–20%)
comprehensive catalogue of cancer genes, we analyse
sequences from 6,742 human cancers and their match
cancer types. We found that large-scale genomic analy
genes in these tumour types. Our analysis also identifi
known to be significantly mutated in cancer, including
genome stability, chromatin regulation, immune evasio
homeostasis. Down-sampling analysis indicates that ta
genes mutated at clinically important frequencies. We
achieved with 600–5,000 samples per tumour type, depending on background mutation
frequency. The results may help to guide the next stage of cancer genomics.

nature

Where is Your Tricorder?

The Cancer Genome Atlas Pan-Cancer analysis project

The Cancer Genome Atlas Research Network, John N Weinstein, Eric A Collisson, Gordon B Mills, Kenna R Mills Shaw, Brad A Ozenberger, Kyle Ellrott, Ilya Shmulevich, Chris Sander & Joshua M Stuart

Affiliations | Corresponding author

Nature Genetics 45, 1113–1120 (2013) | doi:10.1038/ng.2764
Published online 26 September 2013

Abstract

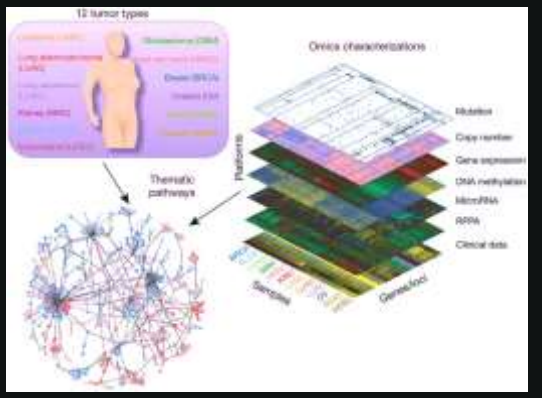
Abstract · References · Acknowledgments · Author information

The Cancer Genome Atlas (TCGA) Research Network has profiled and analyzed large numbers of human tumors to discover molecular aberrations at the DNA, RNA, protein and epigenetic levels. The resulting rich data provide a major opportunity to develop an integrated picture of commonalities, differences and emergent themes across tumor lineages. The Pan-Cancer initiative compares the first 12 tumor types profiled by TCGA. Analysis of the molecular aberrations and their functional roles across tumor types will teach us how to extend therapies effective in one cancer type to others with a similar genomic profile.

Subject terms: Cancer · Genomics

At a glance

Figures



Discover Genetic Factors That Increase Your Disease Risk

Consumers: Genetics & Cancer


New Genetic Tests for Breast Cancer Hold Promise

The New York Times

color Genomics

VeritasGenetics

genomeweb

23andMe

First Tricorder: Stethoscope (1816)

Zargis Medical

Eko Devices

Thinklabs

Where is Your Tricorder? All Around.

An ICU Monitor That Fits On Your Wrist

A new medical device wants to make patient vitals more portable and networked, but designing devices for the medical field is nothing like consumer electronics sector.

Anyone who's been unfortunate enough to spend time in an ICU e. Even for patients who are y're often so tethered to tubes and ones bedbound.

FAST COMPANY

Blood Pressure (Withings), $Sp0_2$ (iChoice), ECG (Alivecor)

'Sticker' Based Diagnostic (RDS)

ECG (1 lead)
Heart Rare (HR)
HR variability (Hrvar)
Respiratory Rate
Respiratory Depth
Oxygen Saturation ($Sp0_2$)
Temperature
Physical Activity

Wearable, Wireless, Waterproof

Review

Seizure reporting technologies for epilepsy treatment: A review of clinical information needs and supporting technologies

Highlights

- Limited recording and annotation tools are available for characterizing patient motion during seizures.
- Existing seizure detection systems tend to have high false positives rates.
- Inertial, wrist worn seizure detection systems coupled with video capture systems may offer promise for addressing both problems.

Abstract

This review surveys current seizure detection a... relate to aiding clinical decision-making during e... collected from neurologists and a literature revie... distinguishing between patients exhibiting gene... as achieving more accurate seizure counts. Tha... neurologists to select the correct class of antiep... evaluating AED efficiency during long-term trea... neurologists reported they would like to have vi... AED during an initial consultation. Presently, on... technology review we identified that only a subs... patient self-reporting performance due to high f... detection devices coupled with video capture fo... to address collecting seizure counts that are mo... reporting during day and night time use.

Keywords

Epilepsy, Seizure reporting, Accelerometry, Non-EEG seizure detection, ECG-based seizure detection, Automated seizure detection

seizure
European Journal of Epilepsy

epilepsy action

E4 wristband

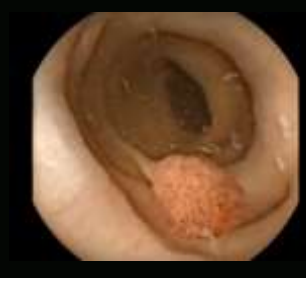
Ear (CellScope), Eye (PEEK, eyeNetra), Oral Health (OScan)

Portable Ultrasound (Philips, Toshiba)

Where is Your Tricorder? In Your Pocket.

Colon Check Via a Pill (PillCam)

polyp

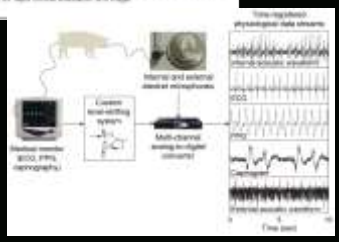


Intra-body: Vital Signs or Gases via A Pill


Physiologic Status Monitoring via the Gastrointestinal Tract

Abstract

ECG
Resp. Rate
Acoustics



PLOS ONE


Intestinal Gas Capsules: A Proof-of-Concept Demonstration

Abbreviations used in this paper

GI, gastrointestinal

Description of Technology

Gastroenterology

Multiplexed volumetric bar-chart chip for point-of-care diagnostics

Yujun Song, Yuanqing Zhang, Paul E. Bernard, James M. Reuben, Naoto T. Ueno, Ralph B. Arlinghaus, Youli Zu & Lidong Qin

Affiliations | Contributions | Corresponding author

Nature Communications 3, Article number: 1283 | doi:10.1038/ncomms2292
Received 27 July 2012 | Accepted 14 November 2012 | Published 18 December 2012

PDF | Citation | Reprints | Rights & permissions | Article metrics

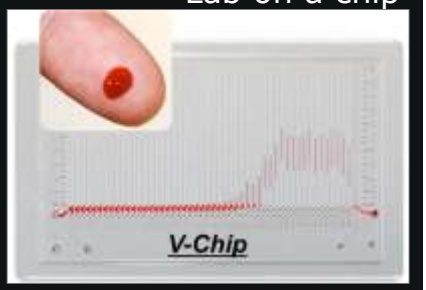
Abstract

Abstract - Introduction - Results - Discussion - Methods - Additional information - References - Acknowledgements - Author information - Supplementary information

Microfluidics have become an enabling technology for point-of-care and personalized diagnostics. Desirable capabilities of microfluidics-based diagnostic devices include simplicity, portability, low cost and the performance of multiplexed and quantitative measurements, ideally in a high-throughput format. Here we present the multiplexed volumetric bar-chart chip (V-Chip), which integrates all these capabilities in one device. A key feature of the V-Chip is that quantitative results are displayed as bar charts directly on the device—without the need for optical instruments or any data processing or plotting steps. This is achieved by directly linking oxygen production by catalase, which is proportional to the concentration of the analyte, with the displacement of ink along channels on the device. We demonstrate the rapid quantification of protein biomarkers in diverse clinical samples with the V-Chip. The development of the V-Chip thus opens up the

nature COMMUNICATIONS

'Lab on a chip'



RESEARCH ARTICLE

Comprehensive serological profiling of human populations using a synthetic human virome

George J. Xu[1,2,3,4,*], Tomasz Kula[1,4,5,*], Qikai Xu[3,4], Mamie Z. Li[3,4], Suzanne D. Vernon[5], Thumbi Ndung'u[7,8,9,10], Kiat Ruxrungtham[11], Jorge Sanchez[12], Christian Brander[12], Raymond T. Chung[13], Kevin C. O'Connor[14], Bruce Walker[8,9], H. Benjamin Larman[3], Stephen J. Elledge[1,4,6,†]

Science 09 Jun 2015:
Vol. 348, Issue 6239, pp.
DOI: 10.1126/science.aaa0698

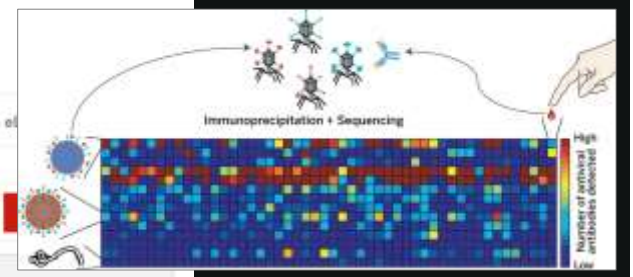
Article | Figures & Data | Info & Metrics

You are currently viewing the abstract.

Viral exposure—the complete history

In addition to causing illness, viruses leave indelible footprints beh
permanently alters the immune system. Blood tests that detect ar
provide information about both past and present viral exposures.
measure only one virus at a time. Using a synthetic representation
peptides, Xu *et al.* developed a blood test that identifies antibodies
d blood samples from nearly 600 peop
ound that most had been exposed to ab
ences in the rates of exposure to specif
is targeted the same viral epitopes.

science.aaa0698



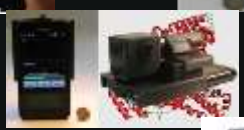
Science
AAAS

Where is Your Tricorder? Attached To Your Phone.

Cholesterol (Cornell)

STD/HIV, syphilis (Columbia)

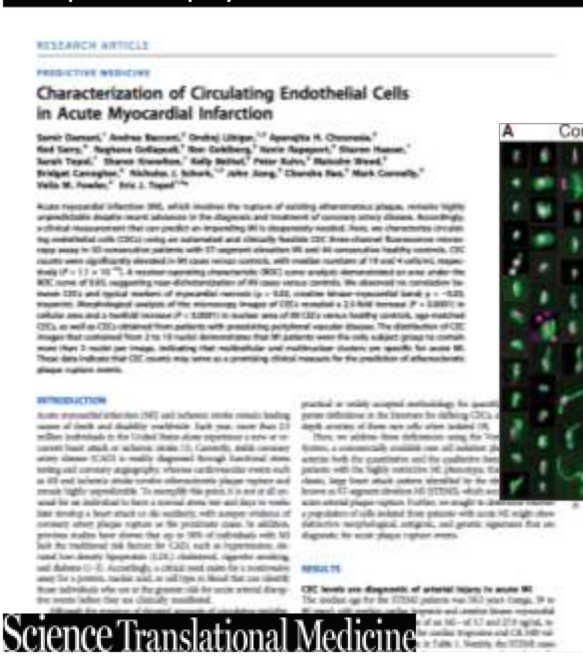
BP, blood glucose, lipids, incl. bleeding (Qloudlab)



Blood, allergens in food, urine analysis mercury in water (holomic/cellmic)

Vit. D, fertility, influenza inflammation, testosterone (Cue)

Liquid Biopsy: Heart Attack


RESEARCH ARTICLE

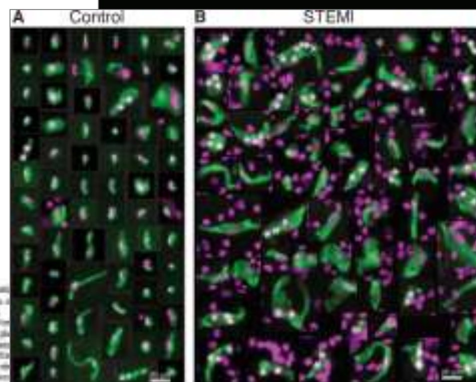
PREDICTIVE MEDICINE

Characterization of Circulating Endothelial Cells in Acute Myocardial Infarction

INTRODUCTION

RESULTS

Science Translational Medicine



Liquid Biopsy: Cancer

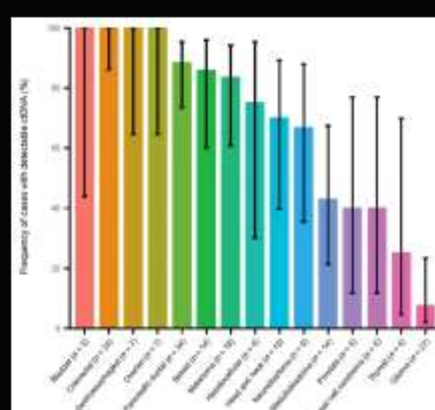

Detection of Circulating Tumor DNA in Early- and Late-Stage Human Malignancies

Article | Figures & Data | Info & Metrics | eLetters | PDF

View Full Text

Abstract

Science Translational Medicine



Where is Your Tricorder? Coming Soon To Your Lab.

BOREAL GENOMICS

GUARDANT HEALTH

OnTarget

Consumers: Blood Tests (incl. drug-induced nutrient depletion)

HemoLink

Talking20

Consumers: Cancer

Get these Screenings

Cervical cancer

RATINGS
- for women age 21 to 65
- for women of all other ages

WHAT'S INVOLVED: A Pap smear (a microscopic analysis of cervical tissue sample) and a human papillomavirus (HPV) test, which looks for the virus that can cause the cancer.

WHO NEEDS IT: Women age 21 to 30 should have a Pap smear every three years. Those 30 to 65 can go five years between Pap smears if they have had HPV testing. High-risk women may need to be screened more often; women 66 and older don't need to be tested as long as they've had regular screenings when they were younger. Women under 21 don't need to be screened because the cancer is uncommon before then and the tests are not accurate for them.

RISK FACTORS: A family history of the disease, a history of HPV infection, using birth-control pills for five or more years, having three or more children, and having weakened immunity because of HIV infection or other causes.

Colon cancer

RATINGS
- for people age 50 to 75
- for people 76 to 85
- for people 86 and older
- for people 49 and younger

WHAT'S INVOLVED: Colonoscopy (exam of the entire colon with a flexible scope) every 10 years, sigmoidoscopy (exam of the lower third of the colon) every five years plus a stool test every three years, or a stool test every year.

WHO NEEDS IT: People age 50 to 75 should be regularly screened. Older people should talk with their doctor about the benefits and harms of the test based on their health and risk factors. Younger people should consider testing only if they are at high risk, because the cancer is uncommon before age 50.

RISK FACTORS: A family history of the disease or a personal history of precancerous polyps, inflammatory bowel disease, obesity, smoking, type 2 diabetes, excessive alcohol consumption, and a diet high in red or processed meats.

Breast cancer

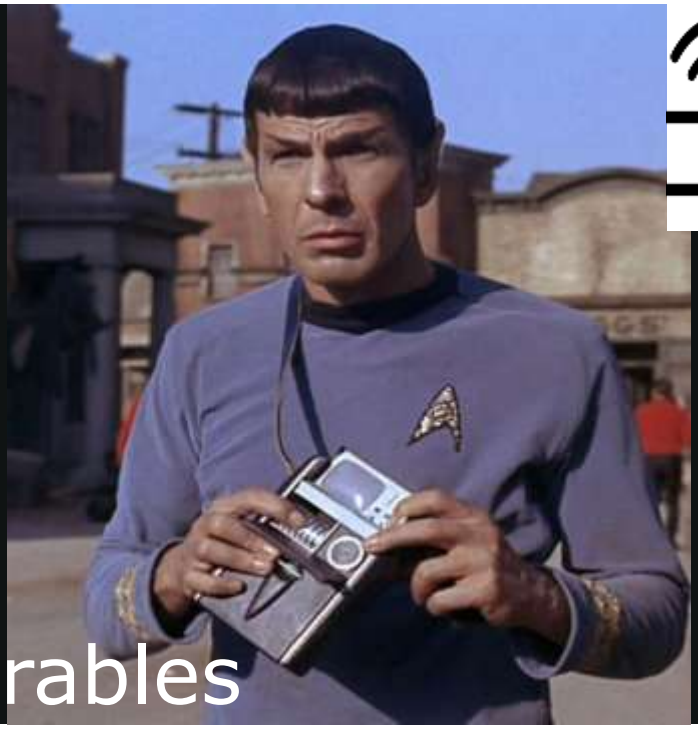
RATINGS
- for women age 50 to 74
- for women 40 to 49
- for women 75 and older
- for women 39 and younger

WHAT'S INVOLVED: Mammogram (an X-ray of the breast).

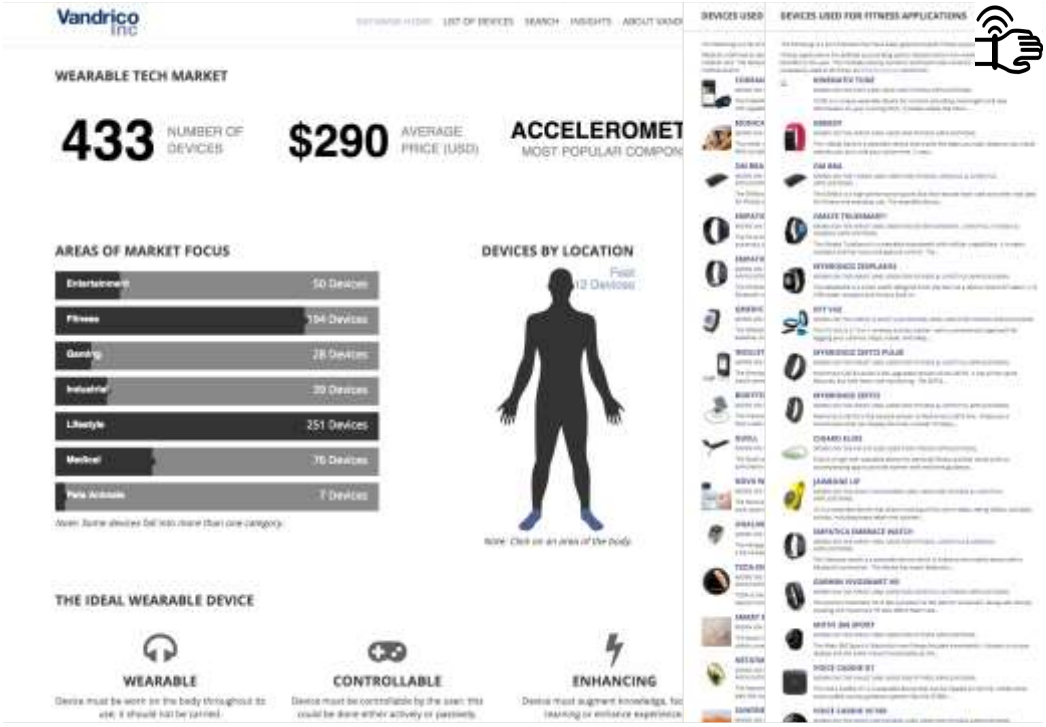
WHO NEEDS IT: Women age 50 to 74 should have mammograms every two years. Women in their 40s or those 75 and older should talk with their

Cancer screening remains stuck in a 1960s view of the disease.

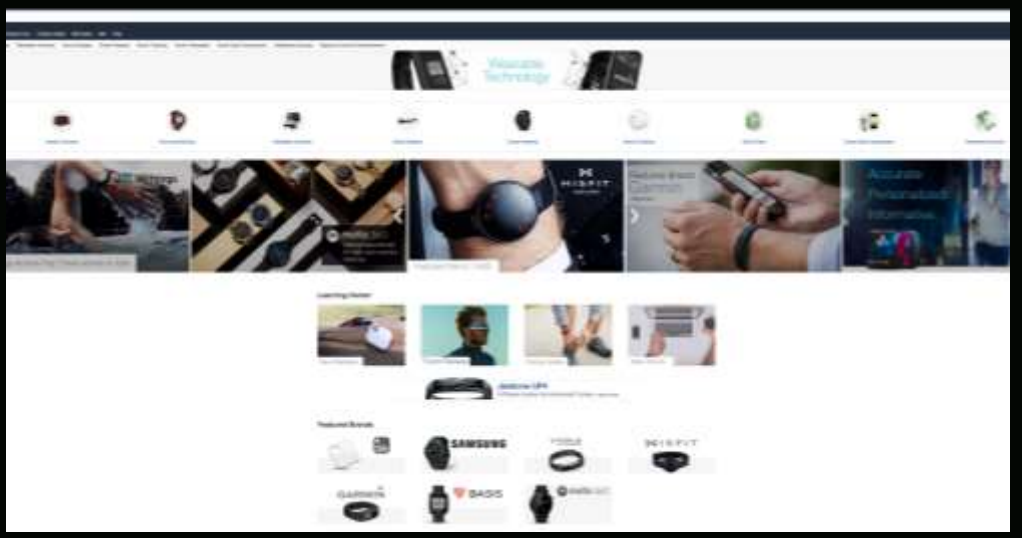
Consumers: Self-diagnosis (Scanadou)



wearables



Marketplaces (Amazon)



Bracelets, Bands, Smart Watches (And Weight Scales)

Steps (kcal)
Activities
Sleep
HR, Temp, GSR

Phone notifications

Diabetes Control (Dexcom Sensor, Multiple Watches)

Medication Reminder (WebMD, PillPack)

Medication Reminder (Google)

Fully integrated wearable sensor arrays for multiplexed *in situ* perspiration analysis

Wei Gao, Sam Emaminejad, Hnin Yin Yin Nyein, Samyuktha Challa, Kevin Chen, Austin Peck, Hossain M. Fahad, Hiroki Ota, Hiroshi Shiraki, Daisuke Kiriya, Der-Hsien Lien, George A. Brooks, Ronald W. Davis & Ali Javey

Affiliations | Contributions | Corresponding author

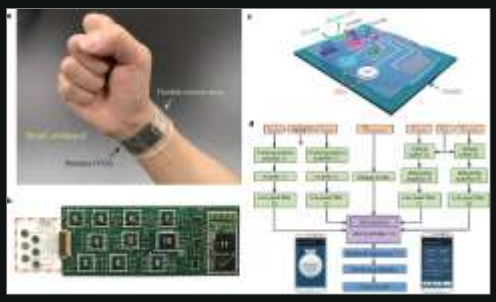
Nature **529**, 509–514 (28 January 2016) | doi:10.1038/nature16521
Received 26 June 2015 | Accepted 23 November 2015 | Published online 27 January 2016

Wearable sensor technologies are essential to the realization of personalized medicine through continuously monitoring an individual's state of health[1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12]. Sampling human sweat, which is rich in physiological information[13], could enable non-invasive monitoring. Previously reported sweat-based and other non-invasive biosensors either can only monitor a single analyte at a time or lack on-site signal processing circuitry and sensor calibration mechanisms for accurate analysis of the physiological state[14, 15, 16, 17, 18]. Given the complexity of sweat secretion, simultaneous and multiplexed screening of target biomarkers is critical and requires full system integration to ensure the accuracy of measurements. Here we present a mechanically flexible and fully integrated (that is, no external analysis is needed) sensor array for multiplexed *in situ* perspiration analysis, which simultaneously and selectively measures sweat metabolites (such as glucose and lactate) and electrolytes (such as sodium and potassium ions), as well as the skin temperature (to calibrate the response of the sensors). Our work bridges the technological gap between signal transduction, conditioning (amplification and filtering), processing and wireless transmission in wearable biosensors by merging plastic-based sensors that interface with the skin with silicon integrated circuits consolidated on a flexible circuit board for complex signal processing. This application could not have been realized using either of these technologies alone owing to their respective inherent limitations. The wearable system is used to measure the detailed sweat profile of human subjects engaged in prolonged indoor and outdoor physical activities, and to make a real-time assessment of the physiological state of the subjects. This platform enables a wide range of personalized diagnostic and physiological monitoring applications.

nature trials for devices -

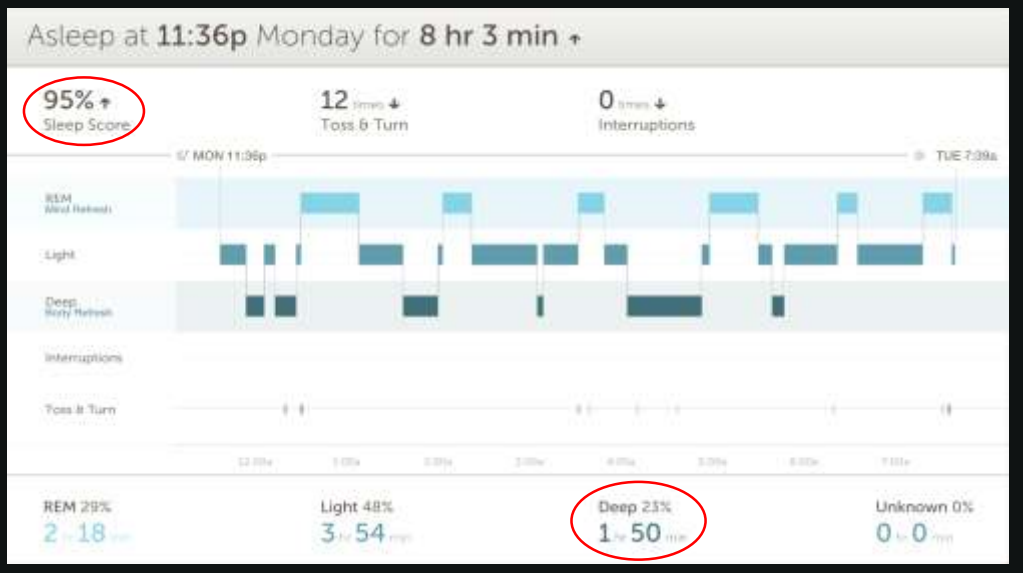
Sweat Analysis

Sweat metabolites (glucose and lactate)
Electrolytes (sodium and potassium ions)
Skin temperature

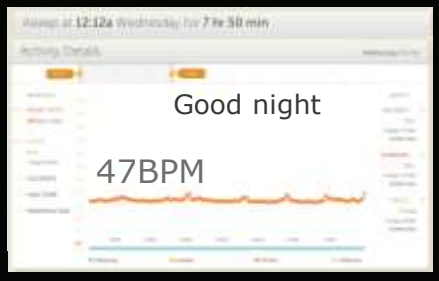


Sleep Quality (BASIS PEAK)

Sleep Quality (BASIS PEAK)



Sleep Quality (BASIS PEAK)



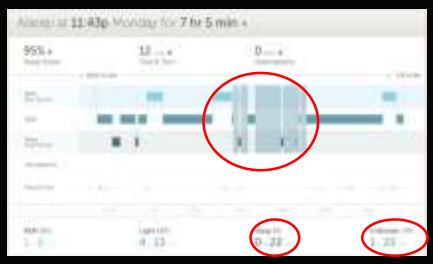
Sleep Quality (BASIS PEAK)

Good Night

Stressful (Job Talk the Next Day)

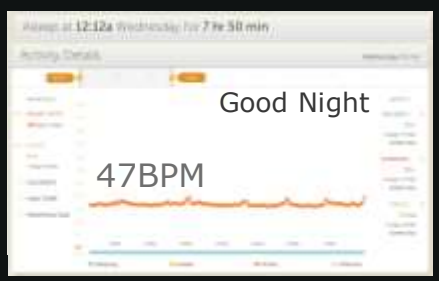
Vivid Dream

No Dinner – Nighttime Hypoglycemia



Sleep Quality (BASIS PEAK)

Stressful (Job Talk the Next Day)



Vivid Dreams

No Dinner – Nighttime Hypoglycemia

Smart Textiles (Myontec, Hexoskin, Athos)

Excess Fluid in CVD (Edema.dk)

Excess Fluid in Heart Failure (toSense)

Heart Rate
Resp Rate

Thoracic Fluid
Stroke Volume
Cardiac Output
Physical Activity

Smart Lenses Measuring Glucose Level (Google)

Tattoo-Based Noninvasive Glucose Monitoring: A Proof-of-Concept Study

Amay J. Bandodkar,† Wenzhao Jia,† Ceren Yardımcı,† Xuan Wang, Julian Ramirez, and Joseph Wang*

Department of NanoEngineering, University of California, San Diego, La Jolla, California 92093, United States

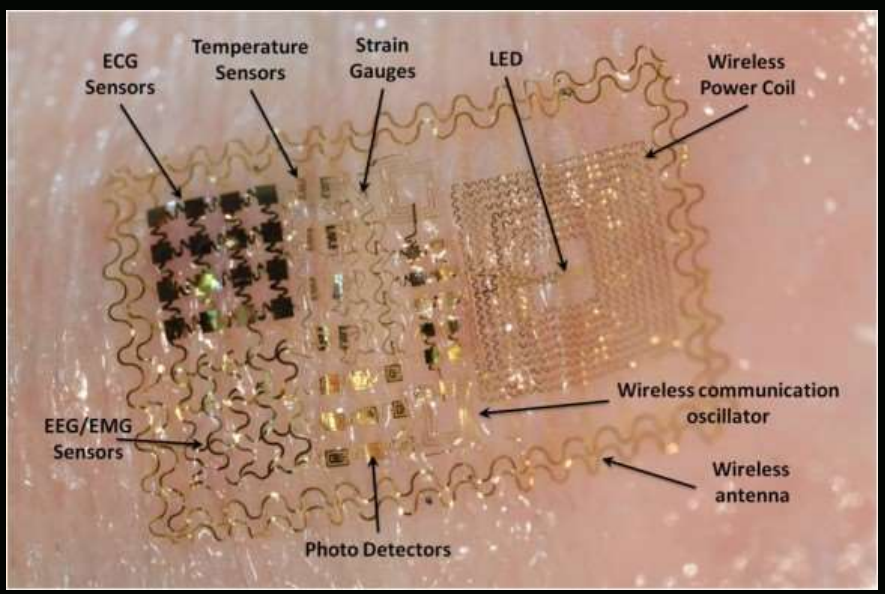
Supporting Information

ABSTRACT: We present a proof-of-concept demonstration of an all-printed temporary tattoo-based glucose sensor for noninvasive glycemic monitoring. The sensor represents the first example of an easy-to-wear flexible tattoo-based epidermal diagnostic device combining reverse iontophoretic extraction of interstitial glucose and an enzyme-based amperometric biosensor. In-vitro studies reveal the tattoo sensor's linear response toward physiologically relevant glucose levels with negligible interferences from common coexisting electroactive species. The iontophoretic biosensing tattoo platform is reduced to practice by applying the device on human subjects and monitoring variations in glycemic levels due to food consumption. Correlation of the sensor response with that of a commercial glucose meter underscores the promise of the tattoo sensor to detect glucose levels in a noninvasive fashion. Control on-body experiments demonstrate the importance of the reverse iontophoresis operation and validate the sensor specificity. This preliminary investigation indicates that the tattoo-based iontophoresis-sensor platform holds considerable promise for efficient diabetes management and can be extended toward noninvasive monitoring of other physiologically relevant analytes present in the interstitial fluid.

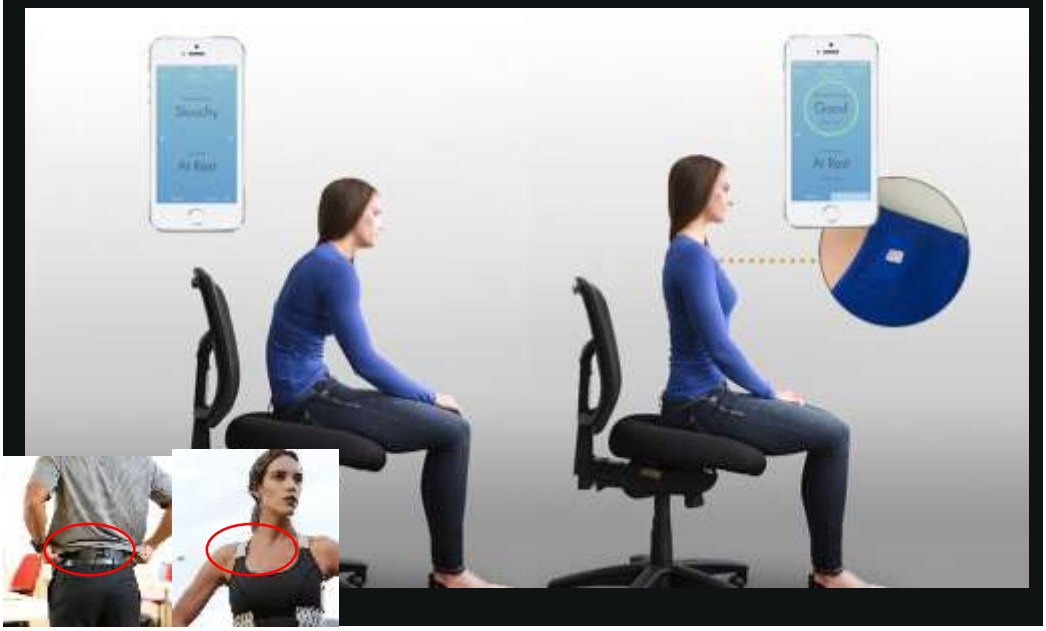
Diabetes is one of the most widely spread modern lifestyle diseases affecting hundreds of millions of people and is among the leading causes of deaths globally.[1,2] Frequent monitoring of glucose is essential for optimal management of the disease and avoiding its associated problems.[3] Extensive research has led to the introduction and widespread use of self-testing blood glucose meters.[4] However, such self-testing methods rely on inconvenient and painful blood sampling from the finger tip that compromises the patient's compliance. Efforts aimed at addressing this drawback have resulted in several commercial continuous glucose monitoring systems. These enzyme-based microneedle sensors are inserted under the skin to measure glucose levels in the skin interstitial fluid (ISF) fluid.[5,6] Such minimally invasive sensing methods are based on the correlation between glucose levels in the ISF and glucose sensor. Reverse iontophoresis involves applying a mild current to the epidermis causing ions to migrate across the skin and toward the electrodes.[11] Sodium ions are the major charge carriers due to the negative charge of the human skin at neutral pH. The migration of sodium ions from across the cathode leads to electro-osmotic flow of the ISF cathode. During this ISF flow, glucose is also towed the cathode. Thus, this technique can noninvasive monitoring of ISF glucose levels.[11] H device was later discontinued as patients exper irritation. This limitation has been addressed employing a lower current density for the glucose connection to new noninvasive reverse iontopho sensors.[12−14] However, these protocols have either not under in vitro conditions[14,15] or require off-

analytical chemistry

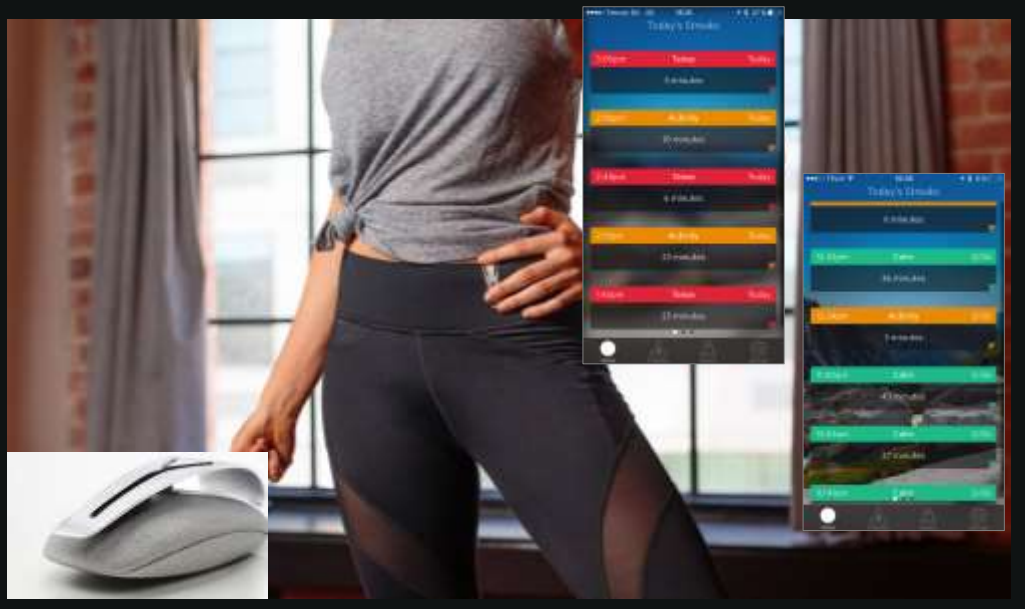
Tattoos incl. ECG, EMG, …, Temp, Hydration Level (MC10)



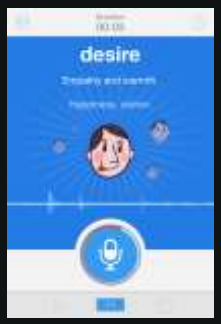
Posture (Lumo Lift)

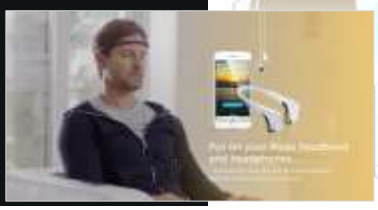


Brain & Mind (Resp Rate by SPIRE)



Brain & Mind (GSR by PIP, voice by BeyondVerbal, EEG by MUSE, NeuroPro)





Brain decoding: Reading minds

By scanning blobs of brain activity, scientists may be able to decode people's thoughts, their dreams and even their intentions.

Kerri Smith

23 October 2013

Jack Gallant perches on the edge of a swivel chair in his lab at the University of California, Berkeley, fixated on the screen of a computer that is trying to decode someone's thoughts.

On the left-hand side of the screen is a reel of film clips that Gallant showed to a study participant during a brain scan. And on the right side of the screen, the computer program uses only the details of that scan to guess what the participant was watching at the time.

Anne Hathaway's face appears in a clip from the film *Bride Wars*, engaged in heated conversation with Kate Hudson. The algorithm confidently labels them with the words 'woman' and 'talk', in large type. Another clip appears — an underwater scene from a wildlife documentary. The program struggles, and eventually offers 'whale' and 'swim' in a small, tentative font.

"This is a mandrill, but it doesn't know what that is," says Gallant, talking about the program as one might a recalcitrant student. They had trained the program, he explains, by showing it patterns of brain activity elicited by a range of images and film clips. His program had encountered large aquatic mammals before, but never a mandrill.

Listen

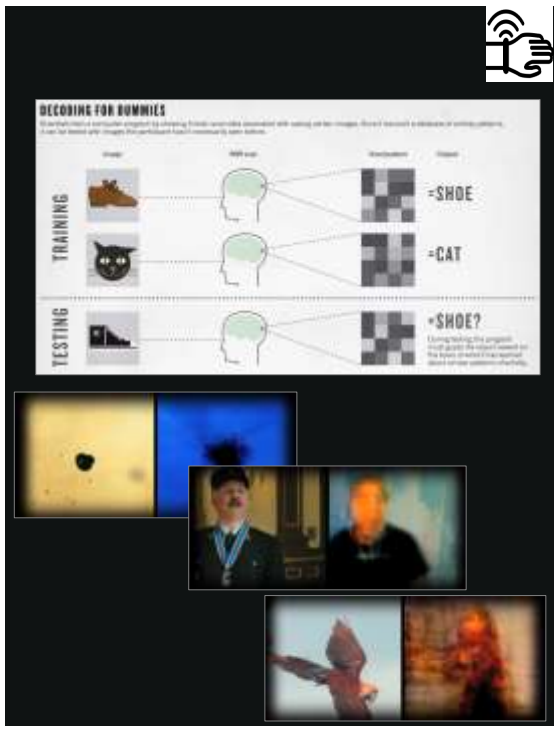
Neuroscientists can predict what a person is seeing or dreaming by looking at their brain activity.

Go to full podcast

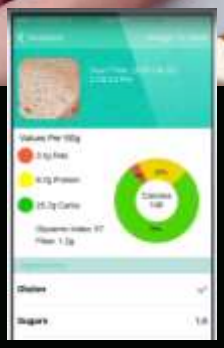
Media reports have suggested that such techniques bring mind-reading "from the realms of fantasy to fact", and "could influence the way we do just about everything". *The Economist* in London even cautioned its readers to "be afraid", and speculated on how long it will be until scientists promise telepathy through brain scans.

Although companies are starting to pursue brain decoding for a few applications, such as market research and lie detection, scientists are far more interested in using this process to learn about the brain itself. Gallant's group and others are trying to find out what underlies those different brain ... brain uses to make sense of the world ... ut the basic principles governing ... and emotion (see 'Decoding for

nature



Food Scanner (TellSpec, MyScio)



Environment: Air Quality (atmotube, sensaris, TZOA)

Blow (on) Your Phone: Lung Performance (SpiroSmart)

Tracking Lung Health With a Cell Phone

Breathe in, breathe out. Dial and repeat.

January 15, 2013

Today, a deep sigh at your smartphone could reveal a well-developed emotional connection with your gadget. But one day those sighs could tip off your doctor to a latent or worsening lung condition.

A group at the University of Washington, in collaboration with Seattle Children's Hospital, is developing a way to check how healthy your lungs are when you breathe out at your smartphone.

For patients with conditions like asthma, chronic bronchitis, or cystic fibrosis doctors sound out their pipes using a spirometer, a device that measures volumes of air breathed in and out. The exhaled volume indicates if the patient's air passages are clogged and leading to difficulty breathing.

Recently, a group at Shwetak Patel's lab at the University of Washington figured out how to measure exhaled breaths using the microphone on a smartphone.

The SpiroSmart app estimates the volume of air exhaled by the sound waves recorded as you breathe out. The goal was to create a home lung

Patel explained in a press

48, the system seemed reliable

s. The group presented that at

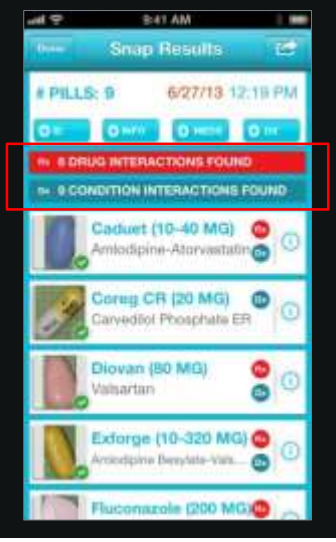
ther last year.

reading lung function from

MIT Technology Review

Where? GPS For Asthma Inhalers (PropellerHealth)

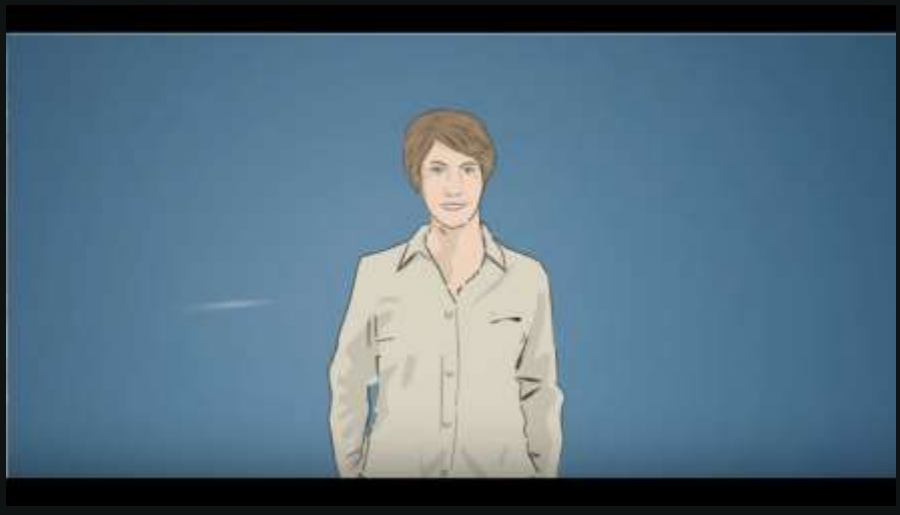
Medication: Which is Which? (MedSnap)



Medication Reminder: Smart PillBox (GlowCap)

Medication Adherence: Pill & Sensor & 'Sticker' (Proteus)

Medication Adherence: Pill & Sensor & 'Sticker' (Proteus)



Cancer Therapies Use a Little Help From Microbial Friends

Elizabeth Pennisi

Article | Figures & Data | Info & Metrics | eLetters | PDF

Outnumbering our own cells more than 10 to one, the microbes thriving peacefully in the human body do more than make up for the warmth and shelter we provide. They make us healthy, helping to tune up our immune systems and keep our digestive systems humming. Now, in two papers on pages 1157 and 1171, investigators show that our microbial guests may also aid in the treatment of disease.

The studies show that in mice, gut bacteria bolster the effects of three anticancer regimens. In each case, when a mouse's microbial residents are missing, the treatments are far less effective. "The bacteria are demonstrated to be critical," says Matthew Redinbo, a structural biologist at the University of North Carolina, Chapel Hill, who in 2010 showed a bacterial enzyme could limit the toxicity of a cancer drug. "[These are] insights that further deepen our appreciation of mammalian-microbial symbiosis."

They could ultimately affect clinical practice, as many cancer patients get antibiotics for infections due to weakened immune systems. "Antibiotic treatments may have adverse effects that weren't predicted previously," suggests Lora Hooper, an immunologist at the University of Texas Southwestern Medical Center in Dallas. Investigators are cautious about applying the mice findings to people, however. The mouse gut bacteria are not the same as those in our own intestines, and the details of how the bacteria collaborate in the destruction of cancer cells are still mysterious.

Science | AAAS

HUMAN MICROBIOME PROJECT

american gut

μBiome

Where is Your Tricorder? In the Patient's Pocket.

Wearable
Wireless
Waterproof
Multipurpose
Unobtrusive
Fashionable
Long battery lifetime

Further: Non-contact, Ingestible, Bio-degradable, Injectable

You can't list your iPhone as your primary-care physician


information systems & AI


Opinion | Biomedical | Diagnostics
Big Data Is Transforming Medicine
New self-monitoring devices will help collect our vi
stats into powerful databases, allowing us to preve
predict health problems as well as treatment suces
failure
By Susan Hassler
Posted 28 May 2015 | 15:00 GMT
Illustration: Bryan Christie Design
What's the next big thing in big data? Bigger data.
The digital world is exploding with data that has yet to be analyzed. Businesses are just starting to wake up to the possibilities.
With more Internet-connected devices, machines, and
Spot in Time, John Jerome detailed the pu
f excellent execution over time. How do supe
spectrum
FORTUNE

Brain scan

Medicine by numbers

Susan Ellenberg is a biostatistician trying to avoid mistakes in an era of Big Data and high-tech personalised medicine

"IF WE didn't take any risks, we wouldn't approve any drugs," says Susan Ellenberg, a professor of biostatistics at the University of Pennsylvania. "Some people will always want a new drug sooner and say they're willing to take a chance. Others will ask, why didn't you study it longer and find out about this horrible side-effect?"

During her long career, Dr Ellenberg has used data to quantify and communicate those risks. Along the way she has helped to shape a discipline that owes as much to ethics and philosophy as it does to pure mathematics. Now medicine is entering a new digital age, one of Big Data and high-tech personalised treatments that are tailored to an individual's genetic make-up. But more data does not necessarily mean better data, so amid the increasing complexity it will be as important as ever to measure correctly which treatments work and which do not.

It is a job Dr Ellenberg is well suited to. She has already played a big part in improving the data-monitoring committees that now oversee virtually all clinical trials; she has helped establish standard practices for tracking dangerous treatments; and she has encouraged patient lobbies to find a voice in clinical testing.

The Economist

Without the right analytical methods, more data just gives a more precise estimate of the wrong thing

Smarter Care (Google, Dell, IBM)

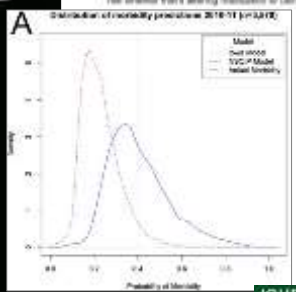
Smart care: how Google DeepMind is working with NHS hospitals

Google DeepMind, the tech giant's London-based company most famous for its groundbreaking use of artificial intelligence, is developing software in partnership with NHS hospitals to alert staff to patients at risk of deterioration and death through kidney failure.

DeepMind Health

CLINICIAN-LED TECHNOLOGY

Analytics Predict Which Patients Will Suffer Post-Surgical Infections



THE WALL STREET JOURNAL.

JOURNAL OF GASTROINTESTINAL SURGERY

Smarter Care (Google, Dell, IBM)

IBM's Watson is better at diagnosing cancer than human doctors

knowledge relating to oncology. That's just lung, prostate and breast cancers to begin with, but with others to come in the next few years). Watson's ingestion of more than 600,000 pieces of medical evidence, more than two million pages from medical journals and the further ability to search through up to 1.5 million patient records for further information gives it a breadth of knowledge no human doctor can match.

claimed that, in tests, Watson's successful diagnosis rate for lung cancer is 90 percent, compared to 50 percent for human doctors.

WIRED

Smarter Care (Google, Dell, IBM)

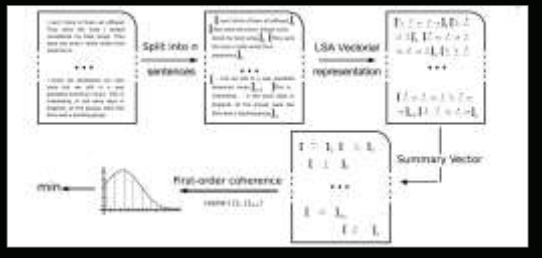
Computers Can Predict Schizophrenia Based on How a Person Talks

A new study finds an algorithmic word analysis is flawless at determining whether a person will have a psychotic episode.

Although the language of thinking is deliberate—*let me think, I have to do some thinking*—the actual experience of having thoughts is often passive. Ideas pop up like dandelions; thoughts occur suddenly and escape without warning. People swim in and out of pools of thought in a way that can feel, paradoxically, mindless.

Most of the time, people don't actively track the way one thought flows into the next. But in psychiatry, much attention is paid to such intricacies of thinking. For instance, disorganized thought, evidenced by disjointed patterns in speech, is considered a hallmark characteristic of schizophrenia. Several studies of at-risk youths have found that doctors are able to guess with impressive accuracy—the best predictive models hover around 79 percent—whether a person will develop psychosis based on tracking that person's speech patterns in interviews.

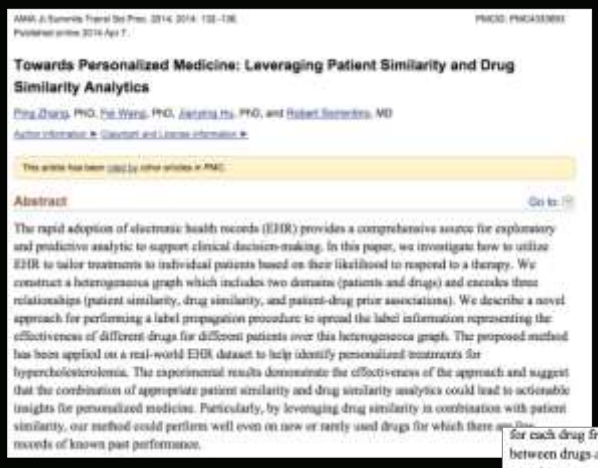
A computer, it seems, can do better.



the Atlantic

npj | Schizophrenia

Smarter Care (Google, Dell, IBM)

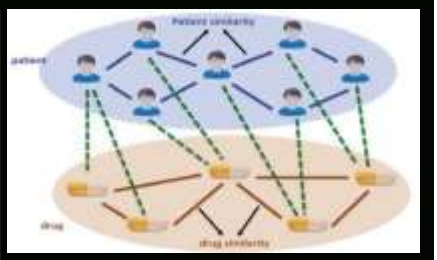


Towards Personalized Medicine: Leveraging Patient Similarity and Drug Similarity Analytics

Ping Zhang, PhD, Fei Wang, PhD, Jianying Hu, PhD, and Robert Sorrentino, MD

Abstract

The rapid adoption of electronic health records (EHR) provides a comprehensive source for exploratory and predictive analytic to support clinical decision-making. In this paper, we investigate how to utilize EHR to tailor treatments to individual patients based on their likelihood to respond to a therapy. We construct a heterogeneous graph which includes two domains (patients and drugs) and encodes three relationships (patient similarity, drug similarity, and patient-drug prior associations). We describe a novel approach for performing a label propagation procedure to spread the label information representing the effectiveness of different drugs for different patients over this heterogeneous graph. The proposed method has been applied on a real-world EHR dataset to help identify personalized treatments for hypercholesterolemia. The experimental results demonstrate the effectiveness of the approach and suggest that the combination of appropriate patient similarity and drug similarity analytics could lead to actionable insights for personalized medicine. Particularly, by leveraging drug similarity in combination with patient similarity, our method could perform well even on new or rarely used drugs for which there are few records of known past performance.



for each drug from DrugBank[20]. Then we calculated the pairwise drug target similarity between drugs d_x and d_y based on the average of sequence similarities of their target protein sets:

$$sim_{target}\left(d_x, d_y\right) = \frac{1}{\left|P\left(d_x\right) \| P\left(d_y\right)\right|} \sum_{i=1}^{|P(d_x)\|P(d_y)|} \sum_{j=1} SW\left(P_i\left(d_x\right), P_j\left(d_y\right)\right)$$

Proceedings — AMIA Joint Summits on Translational Science

AMIA

AI: From Good to Bad (2009-2013 by Google)

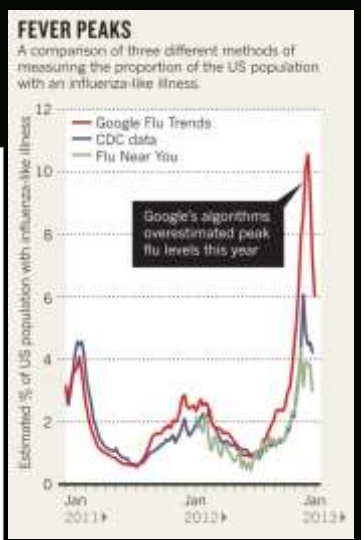
Assessing Google Flu Trends Performance in the United States during the 2009 Influenza Virus A (H1N1) Pandemic

Abstract

Background

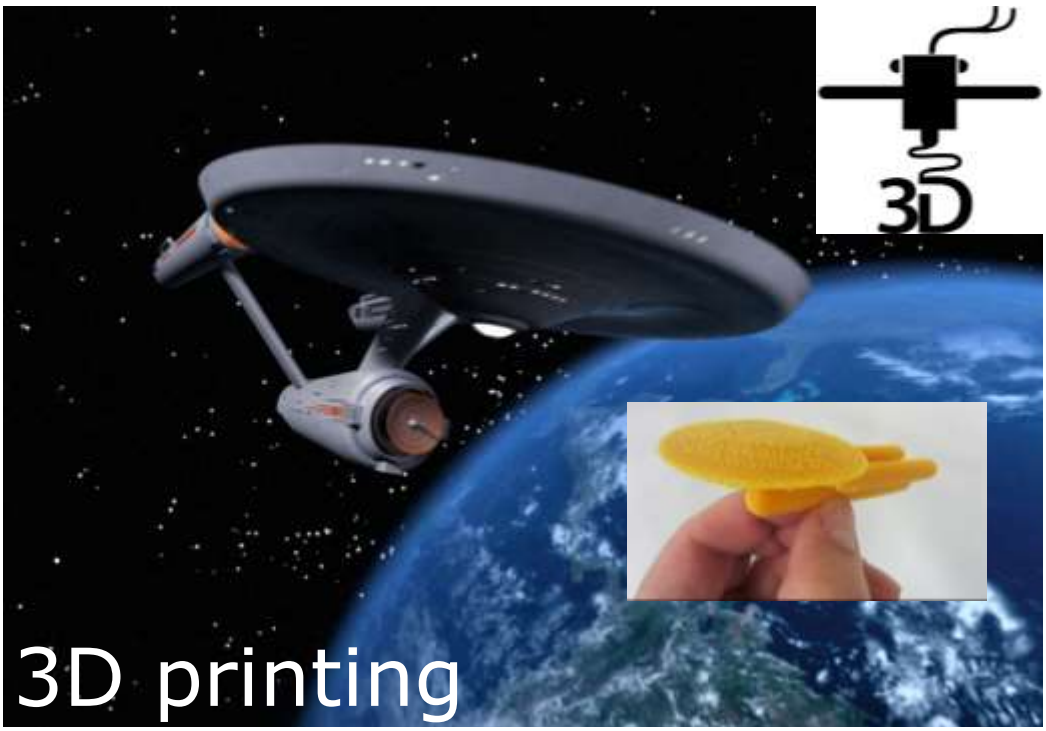
When Google got flu wrong

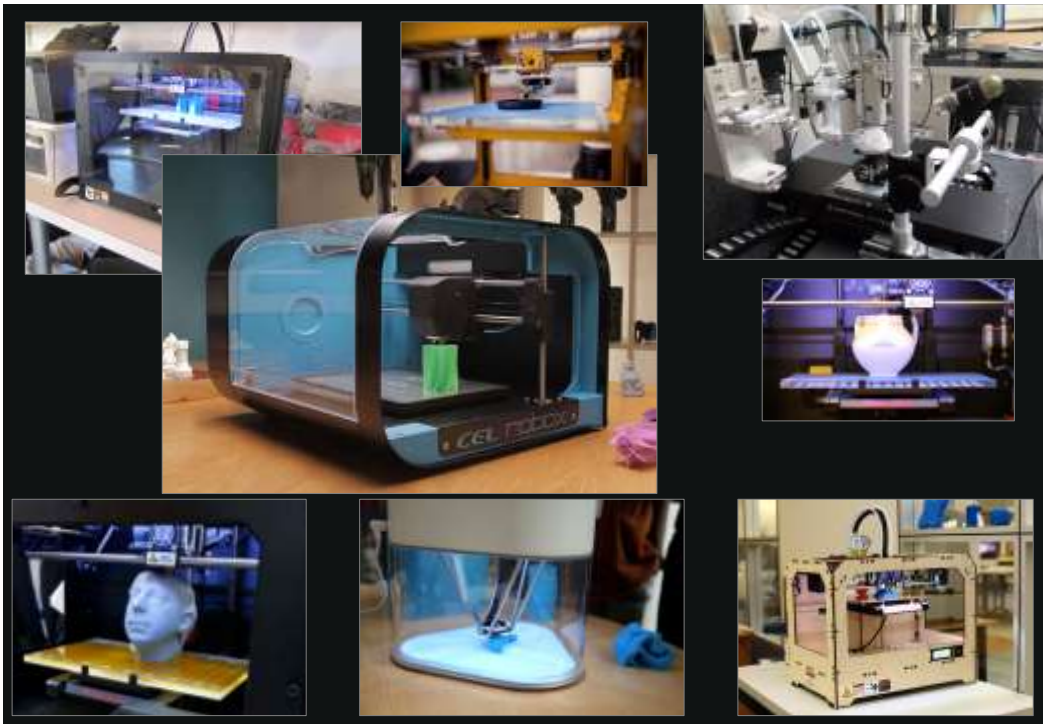
US outbreak foxes a leading web-based method for tracking seasonal flu.



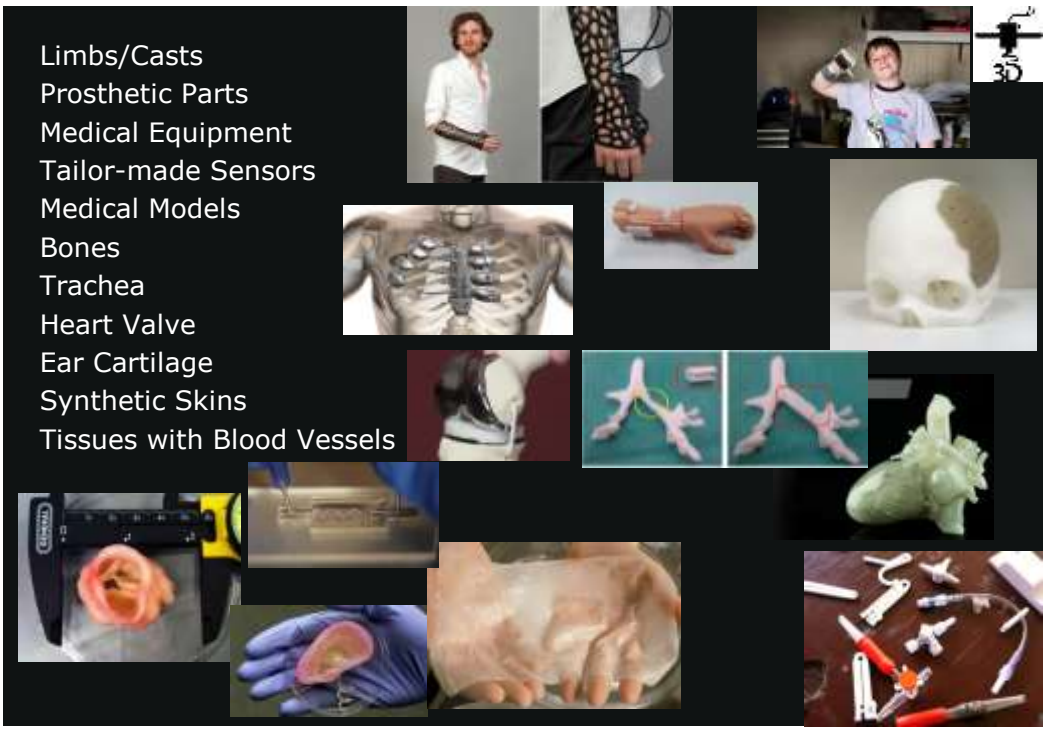
PLOS ONE | nature

My 'check gallbladder' light came on

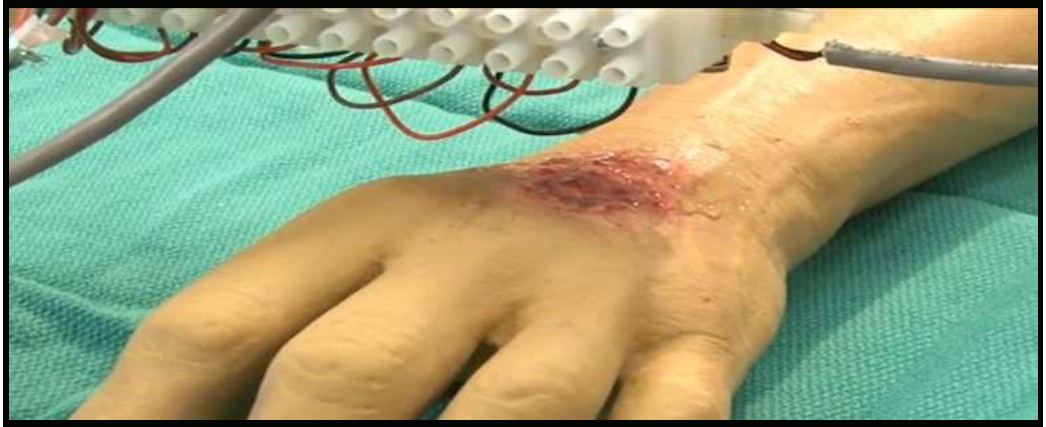




Limbs/Casts
Prosthetic Parts
Medical Equipment
Tailor-made Sensors
Medical Models
Bones
Trachea
Heart Valve
Ear Cartilage
Synthetic Skins
Tissues with Blood Vessels



3D Printing In-vivo (biopen by Cegene Therapeutics)



HUG
Hôpitaux Universitaires de Genève

Where is Your Tricorder? Inside 3D Printed Drugs.

Innovations

Why it matters that the FDA just approved the first 3D-printed drug

A | Save for Later | Reading List

By Dominic Basulto

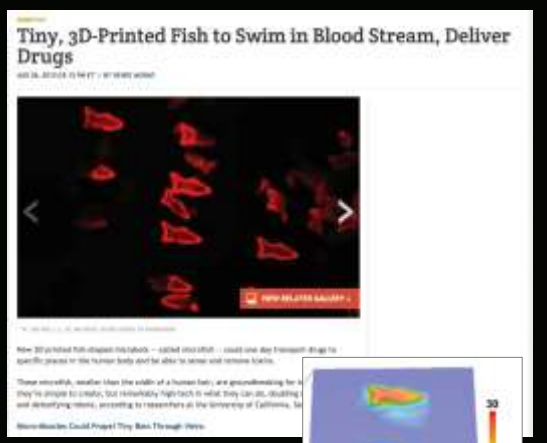
For the first time ever, the FDA has approved a 3D-printed prescription pill for consumer use. This 3D-printed pill, which will sold by Aprecia Pharmaceuticals under the name Spritam, could be used by the more than 3 [illegible] who suffer from certain types of [illegible] printing innovation could have far-

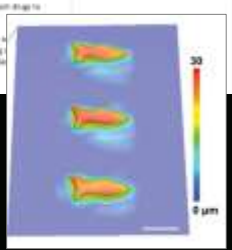
The Washington Post

Where is Your Tricorder? Inside 3D Printed Drugs.

Where is Your Tricorder? Inside 3D Printed Fish Delivering Drugs.


3D-Printed Artificial Microfish


Tiny, 3D-Printed Fish to Swim in Blood Stream, Deliver Drugs



ADVANCED MATERIALS

WIRED

3d Printed Tissue to Test Drugs (Liver, Kidney by Organovo)

Now Printing: Micro-Livers

A La Jolla biotech boosts drug testing with human organs made on demand.

BY JOSH BAXT

Published: 2010.08.24 08:45 AM

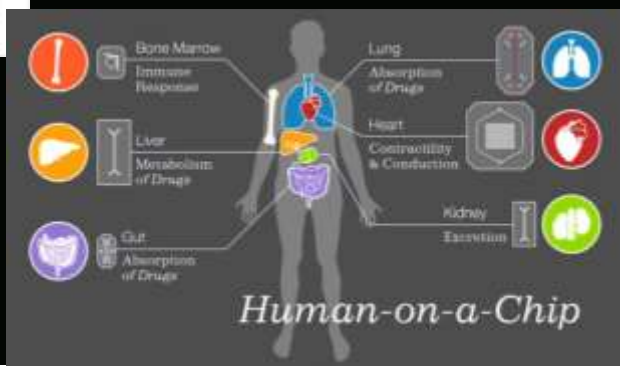
Once novel, 3-D printing is making a big splash, produ
limbs. But those applications merely scratch the surfa
and

SanDiego MAGAZINE

"Multiple drugs have shown toxicity in late-stage trials. This is an opportunity to understand how a drug will work in humans."

Printing Full Organs (Kidney, Liver)

Human on a Chip (Wyss Institute, Harvard)



KIDNEY RESEARCH AND CLINICAL PRACTICE

crowdsourcing

Laurie Becklund dies at 66; former L.A. Times reporter, author

Op-Ed **As I lay dying**

By Laurie Becklund

I am dying, literally, at my home in Hollywood, of metastatic breast cancer, the only kind of breast cancer that kills. For six years I've known I was going to die. I just didn't know when.

Then, a couple of weeks before Christmas, a new, deadly diagnosis gave me a deadline. No doctor would promise me I'd make it to 2015.

Promise me, I told my friends and family, that you'll never say that I died after "fighting a courageous battle with breast cancer." This tired, trite line dishonors the dead and the dying by suggesting that we, the victims, are responsible for our deaths or that the fight we were in was ever fair.

Promise me you'll never wear a pink ribbon in my name or drop a dollar into a bucket that goes to breast cancer "awareness" for "early detection for a cure," the mantra of fund-raising juggernaut Susan G. Komen, which has propagated a distorted message about breast cancer and how to "cure" it.

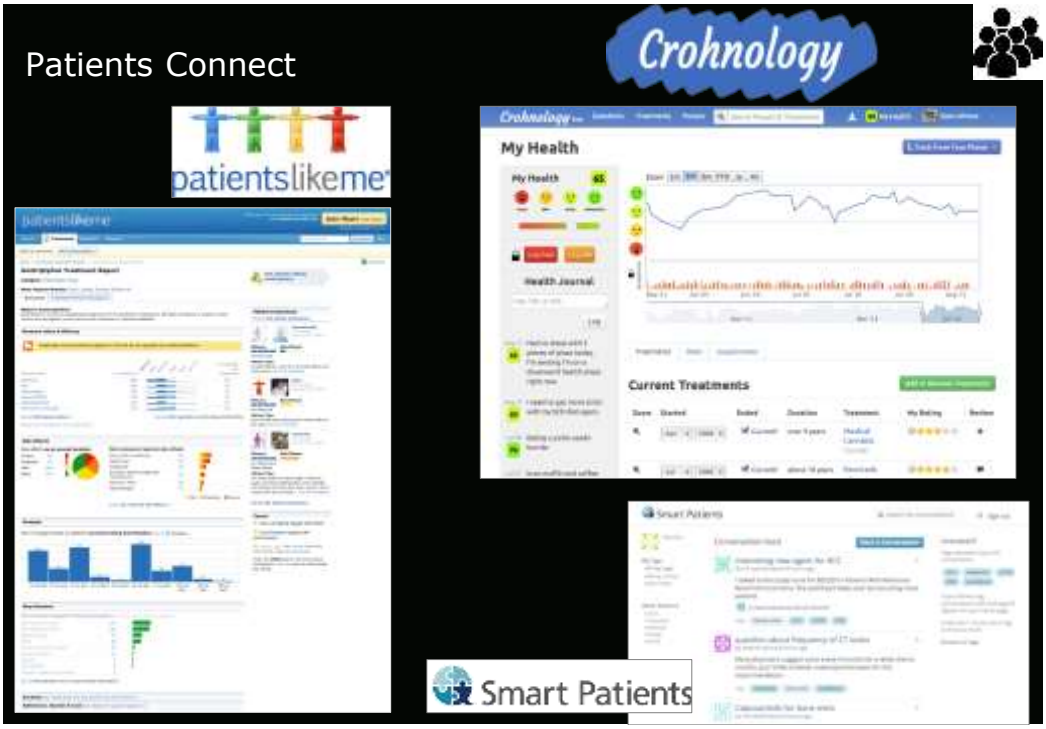
I'm proud that early detection doesn't cure cancer. I had more than 20 mammograms, and none of them caught my disease. In fact, we now have significant studies showing that routine mammogram screening, which may result in misdiagnoses, unnecessary treatment and radiation overexposure, can leave more people than it helps.

In 1996, during a self-exam, I found a peanut-sized lump in one breast that turned out to be stage one breast cancer. I had the "best," most common, kind of breast cancer, found it early, got a lumpectomy and short dose of radiation. Five years out, my doctor told me there was little chance of recurrence and said, "Have a great life!"

In the Big Data era, this void is criminal. Consider what Wall Street does. Even the tiniest companies can see how much stock they sell, compare themselves to cohorts, review history, predict trends. Why can't we create such a database for cancer patients, so we can all learn from patient experiences and make more educated decisions on what treatments will extend and improve lives?

Los Angeles Times

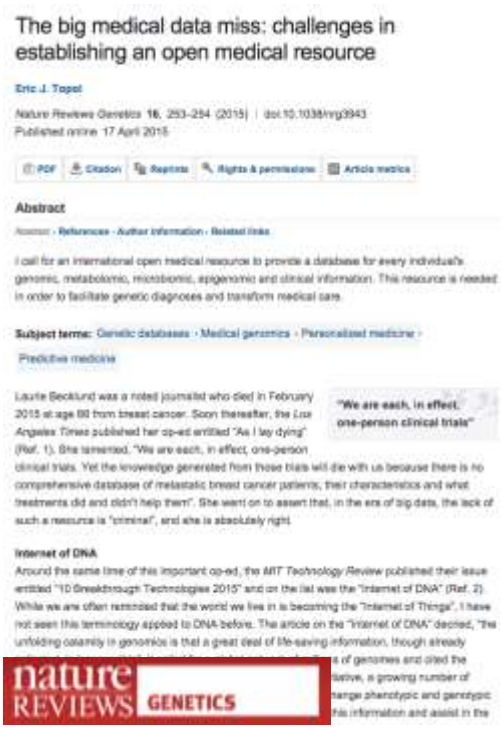
Patients Connect



effect of lithium on disease progression. Although observational studies using unblinded data are not a substitute for double-blind randomized control trials, this study reached the same conclusion as subsequent randomized trials, suggesting that data reported by patients over the internet may be useful for accelerating clinical discovery and evaluating the effectiveness of drugs already in use.

Medical Investigation for Patients by Crowds

The big medical data miss: challenges in establishing an open medical resource



"We are each, in effect, one-person clinical trials"

"a massive, open, online medicine resource … would help to quickly identify the genetic cause of the disorder"

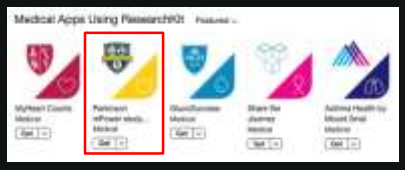
Projects & Initiatives

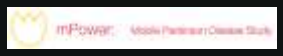
Open Humans

Where is Your Tricorder? Online. In the App Store.

Apps to Track Exercise, Sleep Help Patients Participate in Clinical Trials

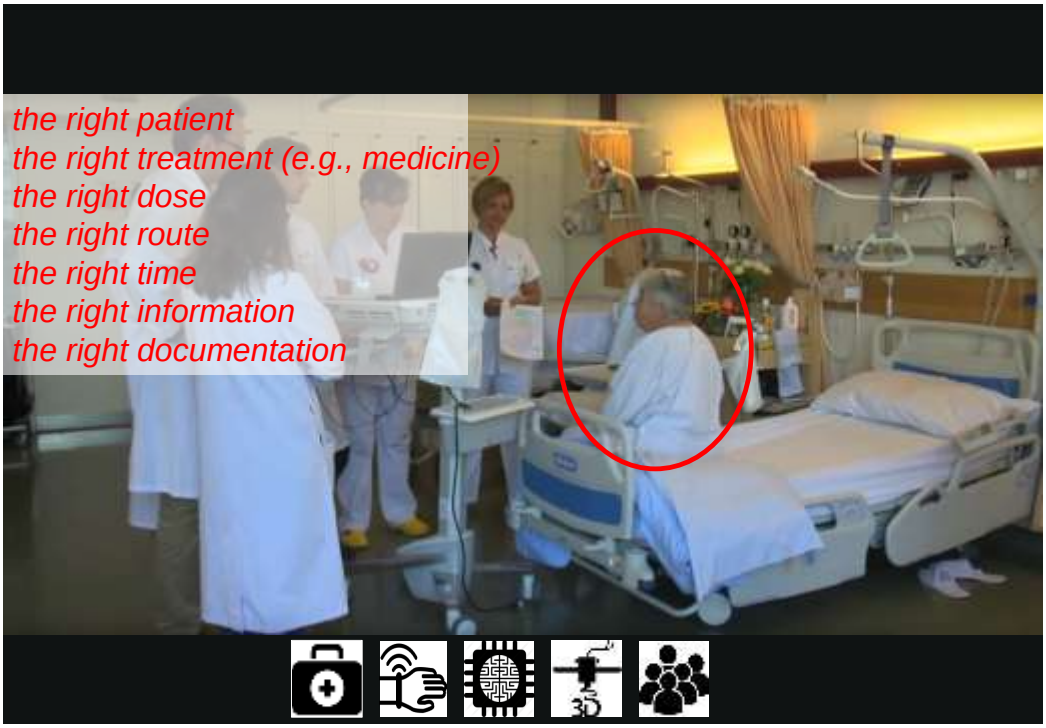
THE WALL STREET JOURNAL.



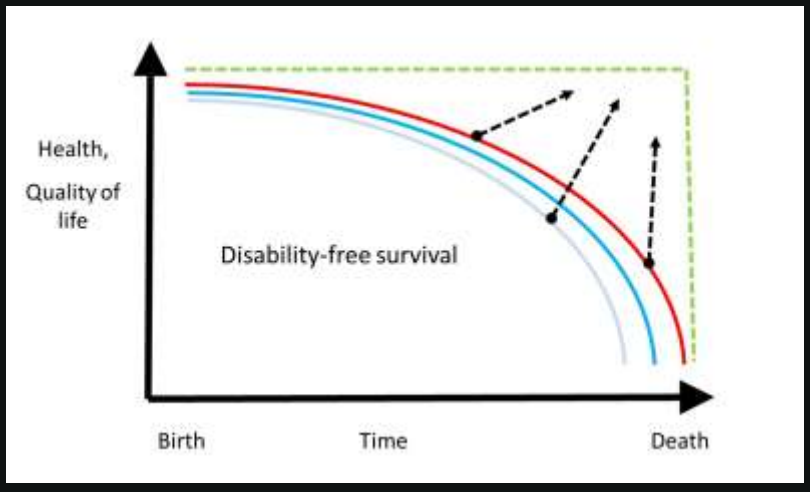


Since the apps were launched March 9, some 60,000 patients have enrolled in five studies just by downloading the apps from the app store, answering a few questions about the disease and clicking through a consent form. None of the patients had to see a doctor to sign up.

Academic researchers doing similar trials might need several years to enroll only a few hundred patients. Pharmaceutical companies need scores of research sites and hundreds of millions of dollars to find 20,000 patients for a major drug trial.



Squaring The Curve



The Challenge (One of Many)

News

Anonymizing patient records for genomics

New method for concealing identity could open up more data for science.

Daniel Cressey

Combining genetic information with existing medical records could allow researchers to rapidly identify genes linked to diseases. But bringing together diagnostic and genetic information in one place risks compromising the confidentiality of patients.

Diagnostic data held in medical records could be very useful to geneticists.

DNYSS/iStockphoto

Now a team from Vanderbilt University in Nashville, Tennessee, has developed a method they say can anonymize electronic medical records, eliminating the risk of individual patients being identified while preserving the ability of researchers to do such work.

There is a huge push under way in the United States and elsewhere to create and exploit electronic medical records (see 'Clinical epidemiology: Archived answers'). Combining the diagnosis codes that list a patient's conditions in these records with genetic information from the patient could save time and money in genome-wide association studies, which seek to link genetic variations with diseases.

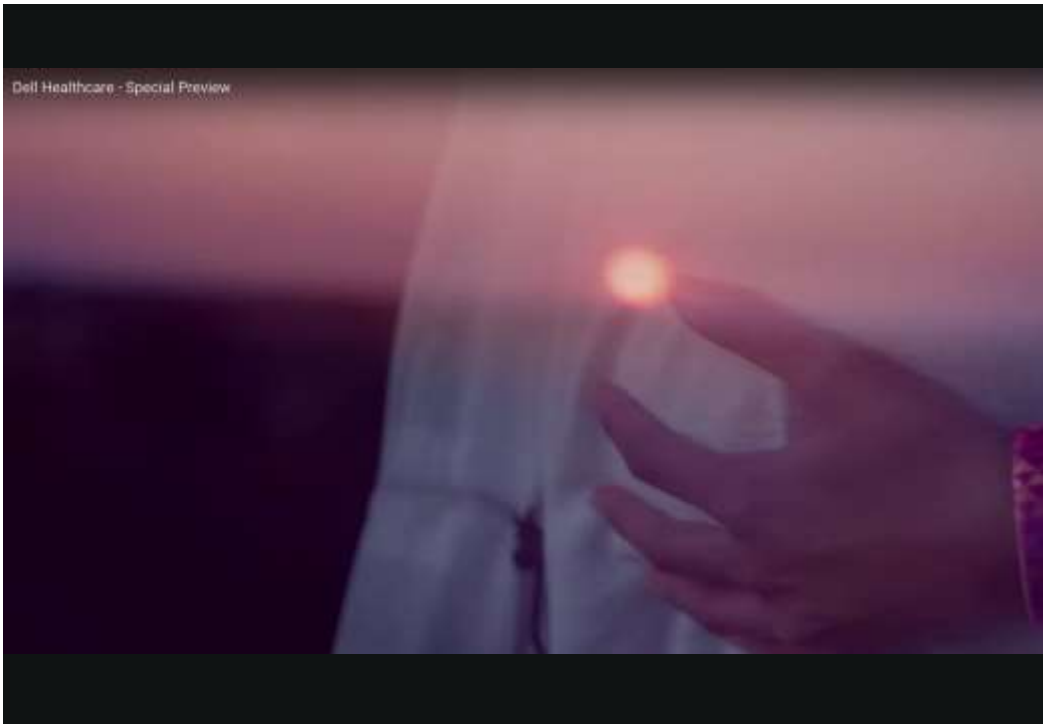
If their new approach is adopted it could open up vast new amounts of data for researchers to crunch while keeping patient data anonymous, the team say.

"There are lots of different types of information that exist within medical records. In the past it has been shown that demographic information is readily linkable to public information that could lead to

nature

demonstrates is that
es — are also
ymatics researcher
the study. Malin

The Challenge (One of Many) → We Are Working On It!



Precision medicine

[Personalized, Preventative, Proactive, Participatory]

- ***Average is over: patient$_i$***
- ***POC is where the patient is***
- ***Toolbox is expanded beyond a stethoscope and a pill***
- ***Approach to health is holistic***

Connect with Me to Design *Your* Next Tricorder!

Prof. Katarzyna Wac [1,2] **& QoL Team & Funding Agencies Supporting The Research**

[1] Human-Centric Computing, University of Copenhagen, Denmark
[2] Quality of Life Technologies lab, University of Geneva, Switzerland

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TWITTER: @katewac
LINKEDIN and SLIDESHARE: /KatarzynaWac

21st Congress of the EAHP, Vienna, Austria, 2016

You have been pretty sedentary for 60 minutes…
Time to stretch your legs?