20% doctor included

vinod khosla
@vkhosla

March 2019

khosla ventures

Things to reframe

AI based vs. “normal” improvements in healthcare

New enables vs. incremental medicine

List of key companies

khosla ventures

the problem

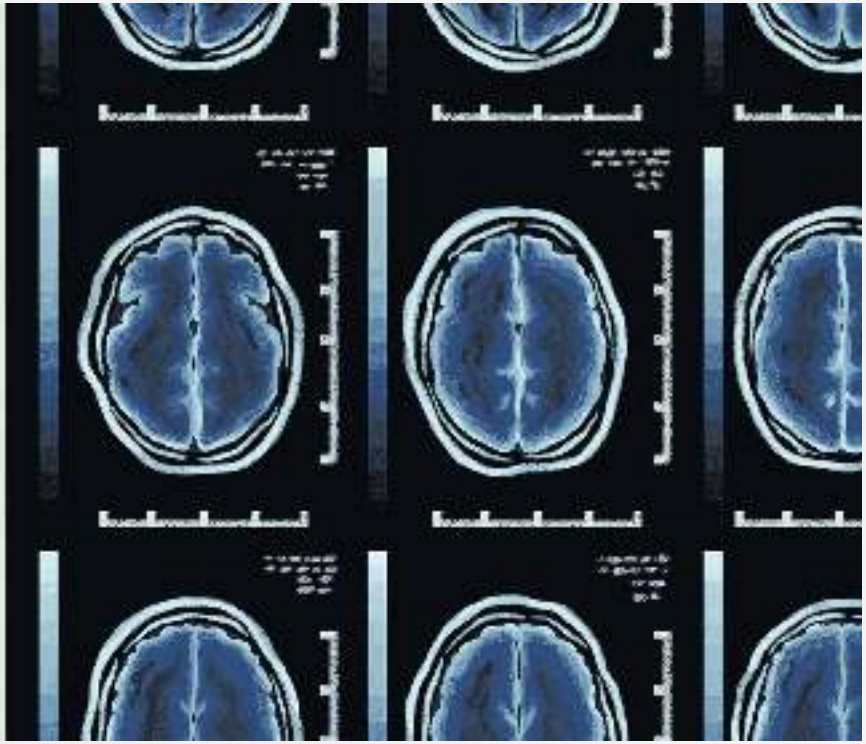
50% of MDs are below average (median)

40,000+ patients in u.s. icus may die from a misdiagnosis annually

winters, et al., bmj quality & safety (2012)
http://qualitysafety.bmj.com/content/21/11/894

What the tests don't show

Doctors are surprisingly bad at reading lab results. It's putting us all at risk.



https://www.washingtonpost.com/news/posteverything/wp/2018/10/05/feature/doctors-are-surprisingly-bad-at-reading-lab-results-its-putting-us-all-at-risk/

human doctors

cognitive limitations

cognitive biases

- http://www.jround.co.uk/error/reading/crosskerry1.pdf
- http://www.nejm.org/doi/full/10.1056/NEJMp1303712
- http://www.ncbi.nlm.nih.gov/pubmed/21392683
- http://www.ncbi.nlm.nih.gov/pubmed/16009864
- http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2219858/
- http://qualitysafety.bmj.com/content/22/12/1044.abstract
- http://www.sciencedaily.com/articles/l/list_of_cognitive_biases.htm
- http://evimedgroup.blogspot.com/2010/10/cognitive-biases-in-medicine.html

100 cases of diagnostic error involving internists…

cognitive factors in 74%...

…premature closure was most common cause

graber, et al., jama internal medicine (2005
http://archinte.jamanetwork.com/article.aspx?articleid=486642)

in many records of high-risk diagnosis, high-information clinical findings were present & ignored

feldman, et al., jamia (2012)
http://jamia.bmj.com/content/19/4/591

the AHA/ACC made 7,196 recommendations

…19% of recommendations of class I guidelines had level A evidence

…48% have level C evidence (the worst kind)…

tricoci, et al., jama (2009)
http://jama.jamanetwork.com/article.aspx?articleid=183453

40–50% of the recommendations made in guidelines are based on expert opinion, case studies, or standards of care rather than on more systematic trials and studies

chauhan, et al., american journal of obstetrics and gynecology (2006); institute of medicine (2008); tricoci, et al., jama (2009)
http://www.ajog.org/article/S0002-9378%2806%2900300-0/

surgeons were given detailed diagnoses & asked if patients should get surgery …

half said yes … the other half said no …

… 2 years later, 40% of the docs gave a different answer

eddy, jama (1990)
http://jama.jamanetwork.com/article.aspx?articleid=380215

fifty-eight experts' estimates of the chance of an outcome of an important procedure

0% 0.2% 0.5% 1% 1% 1% 1.5% 1.5% 2% 3% 3% 4%
5% 5% 5% 5% 5% 5% 5% 6% 6% 6% 8% 10% 10%
10% 10% 13% 13% 15% 15% 18% 20% 20% 20%
25% 25% 25% 30% 30% 40% 50% 50% 50% 62%
70% 73% 75 75% 75% 75% 80% 80% 80% 80%
80% 80% 100%

what does a consensus of a group whose perceptions might vary from 0% to 100% even mean?

eddy, jama (1990)
http://jama.jamanetwork.com/article.aspx?articleid=380215

the shift in stages: v0-v8

the practice of medicine

the science of medicine

machines will be better at
integrative medicine…

…across “all symptoms”, tests, imaging, demeanor, patient history, 1000s of data points, genomics, omics…

machines will …

…and learn across many good doctors, all research, all data and get better rapidly with time starting as “bionic assistants to humans”

we'll start with clumsy point innovations …

…"insighted" by machine learning…

…leading discoveries we never knew were right in front of us

dr. algorithm

v0 – 2017

v1 – 2020

v2 – 2023

v3 – 2024

v4 – 2027

v5 – 2030

v6 – 2033

v7 – 2036

…

3 years per generation?

technology will also upskill all medical professionals (nurses, technicians) and consumers

… leading to a complete shift to how we manage care

innovation axes

AI 24/7 “almost free” physicians…

data driven personalized care: 30k not 30 longitudinal biomarkers

“omics medicine” & imaging replacing symptom based medicine

new tools: CRISPR, DNA/RNA, microbiome

AI based Imaging, image diagnosis, enhancement, new imaging modalities

AI enhancement for tools (imaging, drug discovery, diagnosis, surgical robots…)

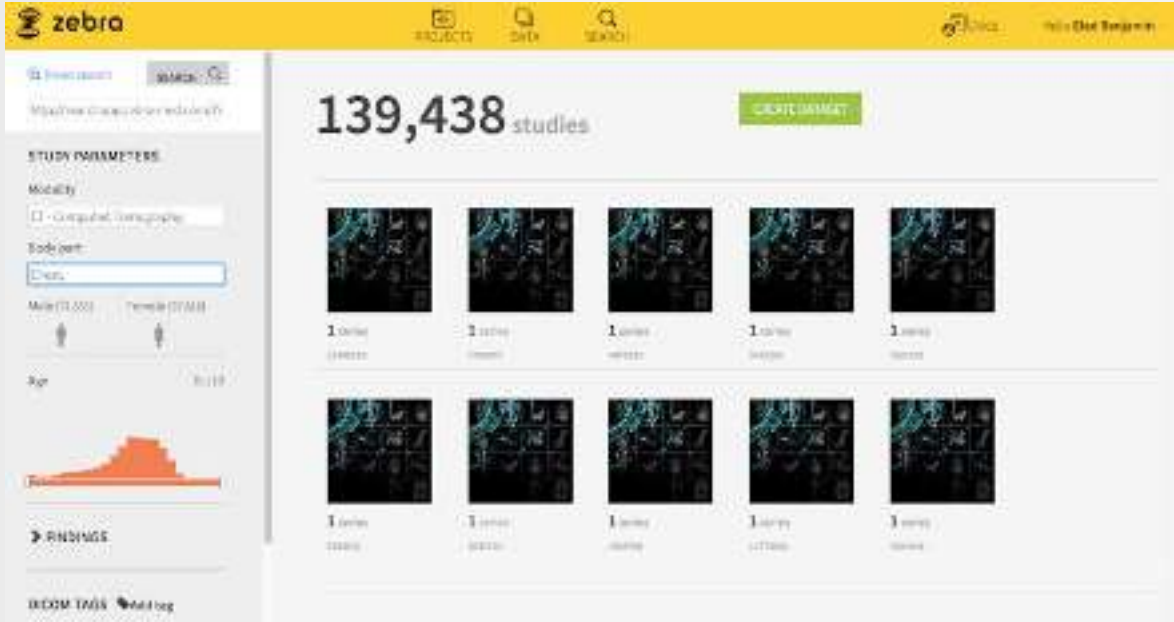
Accessibility, immediacy, affordability… the great equalizer

CRISPR organs, 3D printed organs/parts, microrobots

the shift: v1

data to insights: new radiology

algorithms interpreting images



… better than the average radiologist

mobile monitoring: from AFIB, Hyperkalemia

Novel Bloodless Potassium Determination Using a Signal-Processed Single-Lead ECG

Zachi I. Attia, BSc, [1,6] Christopher V. DeSimone, MD, PhD, [1] John J. Dillon, MD, [2] Yehu Sapir, BSc, [6] Virend K. Somers, MD, PhD, [1] Jennifer L. Dugan, CRC, [1] Charles J. Bruce, MD, [1] Michael J. Ackerman, MD, [1] Samuel J. Asirvatham, MD, [1] Bryan L. Striemer, BS, [3] Jan Bukartyk, MS, [1] Christopher G. Scott, MS, [4] Kevin E. Bennet, BS, MBA, [7] Dorothy J. Ladewig, BS, [5] Emily J. Gilles, MS, [5] Dan Sadot, PhD, [6] Amir B. Geva, PhD, [6] and Paul A. Friedman, MD[✉ 1]

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data to insights: statins

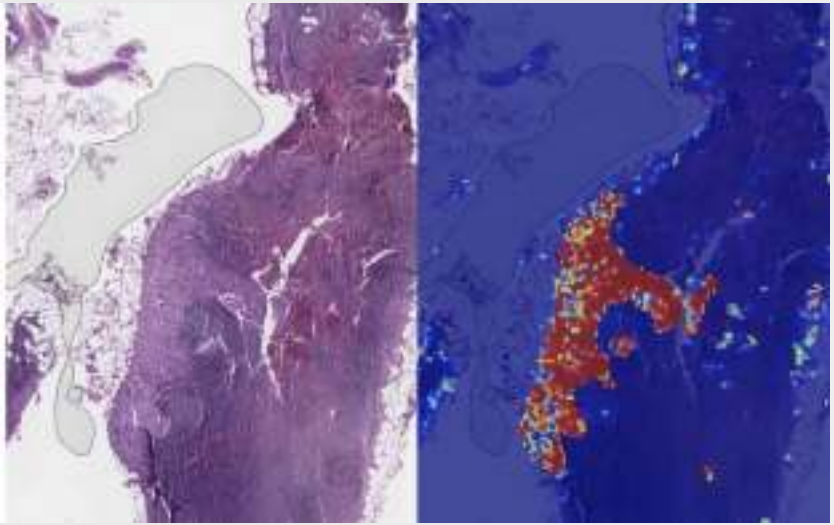
using new statin protocols for in-hospital stroke patients reduced the death rate by 40%

kaiser permanente
http://www.ncbi.nlm.nih.gov/pubmed/19228842

computer vision imaging/radiology

Google AI claims 99% accuracy in metastatic breast cancer detection

KYLE WIGGERS @KYLE_L_WIGGERS OCTOBER 12, 2018 9:00 AM



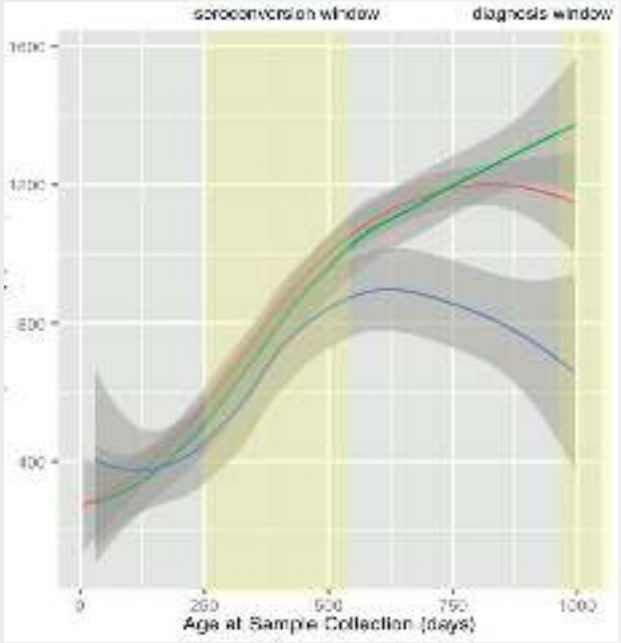
the shift: v2

technology handling doctor Q&A

research has progressed to show we can understand the relationships between diagnosis, disease, symptoms, and treatments such that we can ask questions, and get relevant and accurate clinical information on the fly

data to insights: microbiome

Microbiome complexity



Control

Seroconverted

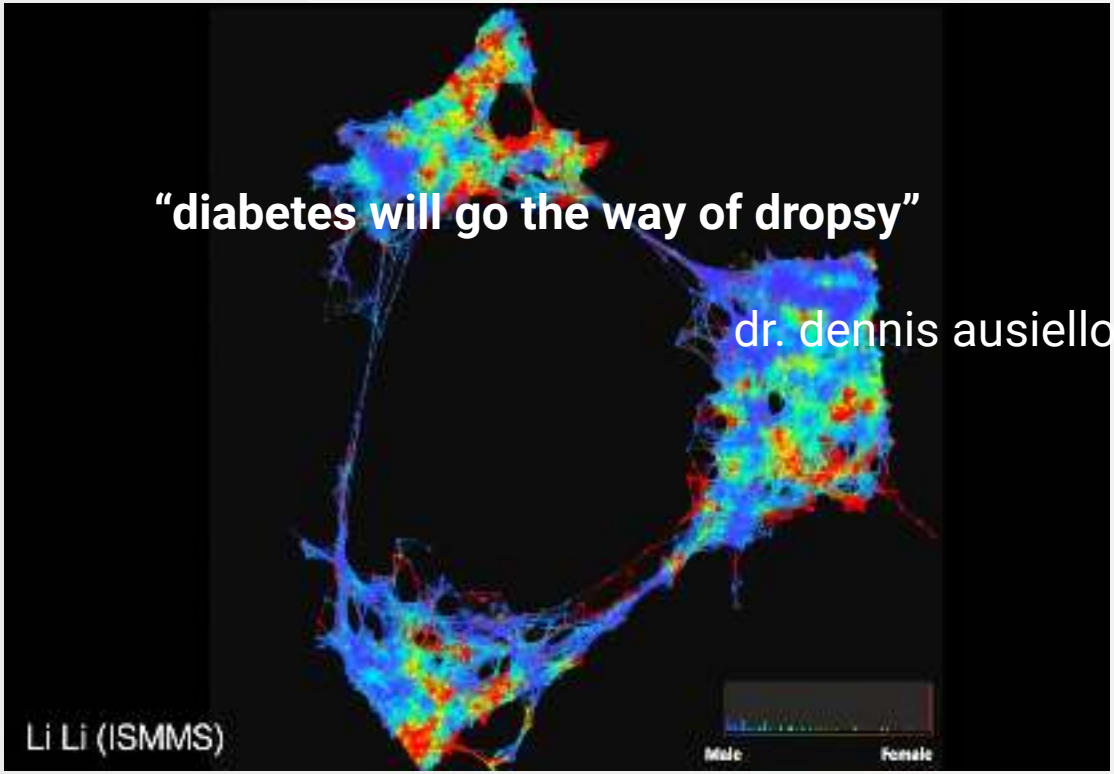
Type 1 diabetes Diagnosed

Birth

T1D

http://www.diapedia.org/type-1-diabetes-mellitus/microbiome-and-type-1-diabetes

type 2, type 3, type 4 diabetes



data to insights: mental health

use your phone to closely monitor behavioral patterns…

…with algorithms to predict mental health episodes and suggest software prescriptions

nurse and consumer upskilling

imagine a nurse coming to your home, with a full “health kit”: a portable ultrasound, EKG device, sensors that have remote monitoring, and a mobile phone which helps guide and direct them to do tasks normally done at the hospital

For not much more than the cost of Doordash delivery?

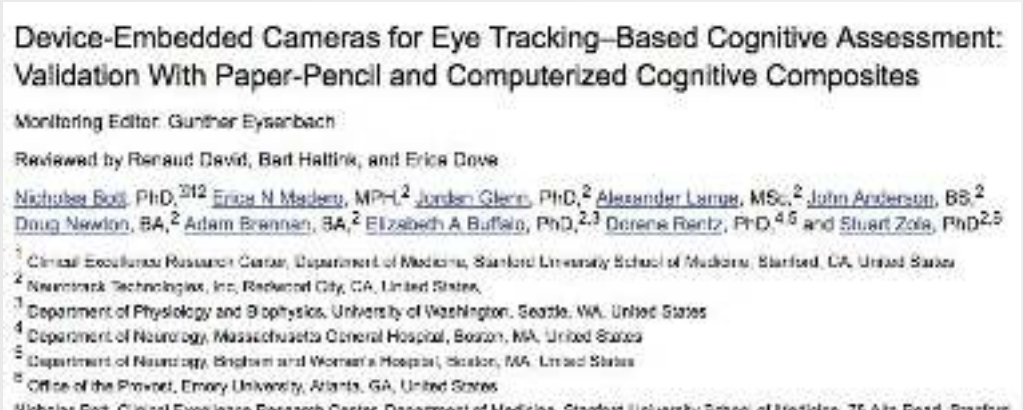
the shift: v3/4

data to insights to expertise:

AI starts to bionic assistant to psychiatrist, oncologists, cardiologist with triage up

data to insights to new medicine

… leads to insights driven by algorithms: Alzheimer's, cardiac



Device-Embedded Cameras for Eye Tracking–Based Cognitive Assessment: Validation With Paper-Pencil and Computerized Cognitive Composites

Monitoring Editor: Gunther Eysenbach

Reviewed by Renaud David, Bart Hallink, and Erica Dove

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[5] Department of Neurology, Brigham and Women's Hospital, Boston, MA, United States
[6] Office of the Provost, Emory University, Atlanta, GA, United States

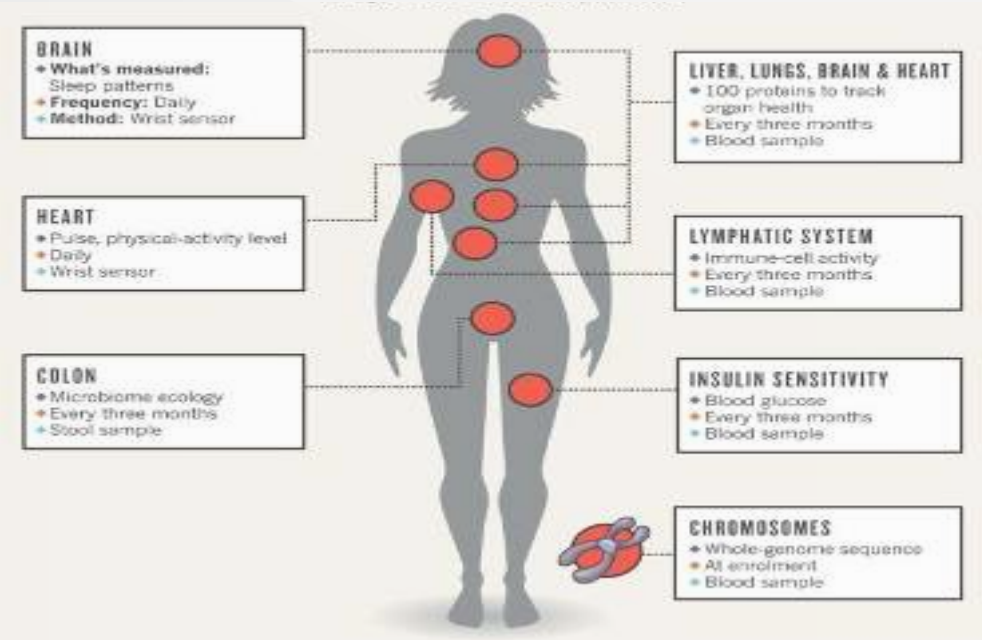
massively multiplexed biomarkers at home

lab on a chip, at your home, 1000’s of biomarkers

will lead to completely new forms of diagnosis

large-scale holistic studies

massive data collection …

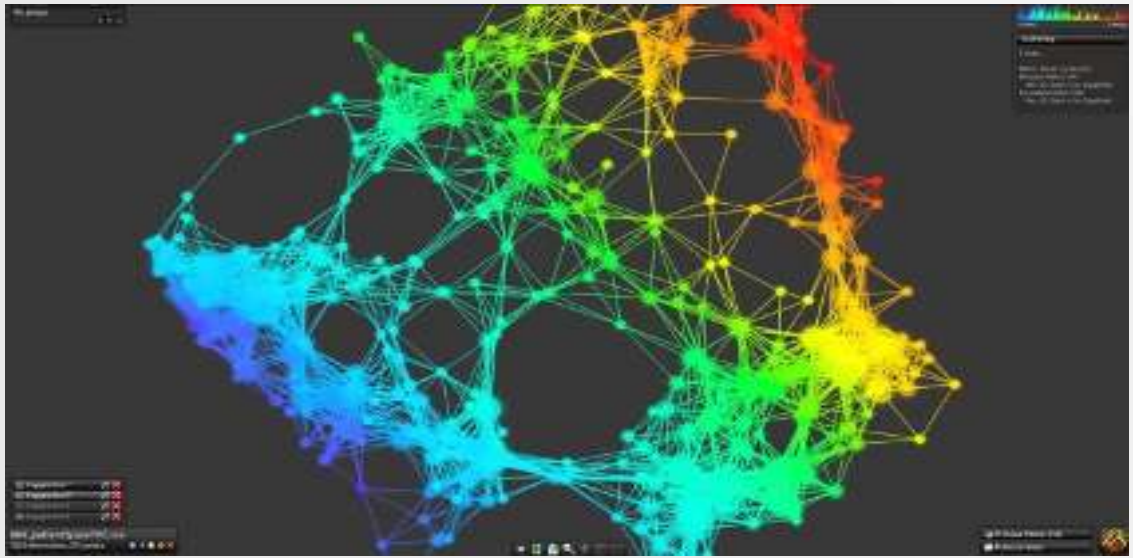


… leading to insights on illness

network medicine

SCIPHER Medicine

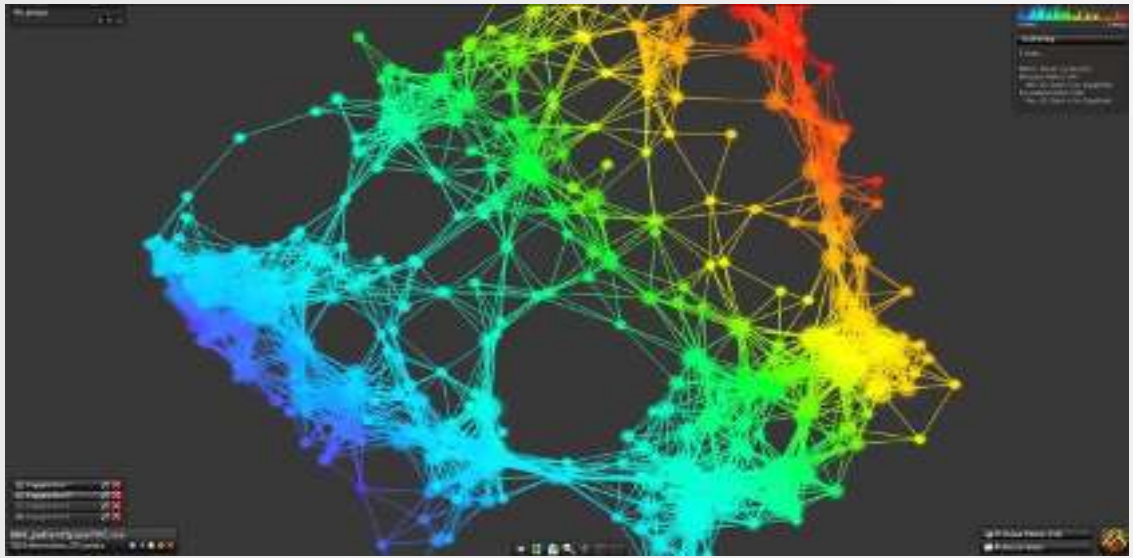
data to insights: new pharma



visualize 800 terabytes of raw data from breast and ovarian cancer patients…

…to drive novel drug discovery on genetic subpopulations

new biomarkers: blood, phenotypic, microbiome



New ways to diagnose, prescribe, monitor, dose, predict...

...healthcare not sickcare?

the shift: v5++

medicine will evolve

Imaging, testing and diagnostics primarily handled by algorithms

Consumer will have option to be CEO of their own health

New precise, personalized, predictive, participatory medicine

speculation: in the next 15-25 years…

…data science will do more for medicine than all biological sciences combined

….and traditional healthcare will keep improving ALSO

I will be wrong on the specifics but directionally right

5x5 speculation

5x reduction in doctor work

5x increase in research

5x lower error rate

5x faster diagnosis

5x cheaper?

role of the doctor

humans matter on the human element of care

… but 80% of diagnosis, prescription, monitoring doctors do today will be replaced by machines

the shift:

cautions on predictability & the need to make it happen outside of the system

let's not confuse “new medicine” with “better” traditional healthcare

Health v8 2050

Consumers as CEO's of their health!

Data, biomarkers, images frequently, quantitative physicals

Care fully personalized to "one", not for the "average", not population

Predict cancer or disease; predict food/supplement optimization

AI physicians: primary care, psychiatrist, oncologist, cardiologist,…

Obsolescence of symptom based diagnosis (except trauma?)

Healthcare more affordable, accessible, & better quality

kv portfolio

Risk bearing: Oscar, Lumiata

Consumer: Carrot, Color, Whole Biome, Viome, MD Algorithms

Clinical Care: Ginger.io, Alivecor, Forward, Curai, Totemic, Ellipsis, Flow

Diagnostics: Guardant, Genalyte, Two Pore, Karius, Inflammatix, Akna, Neurotrack

Imaging: Bay Labs, Heartvista, Zebra, Q.bio, Openwater

Microbiome: Siolta, Viome, Whole Biome

Food: Whole Biome, Impossible, Hampton, Ripple, Miraculex, Ukko

Medical Science: DiscernDX, Scipher, EDITAS, Ukko, eGenesis, Eligo

Other: Deep Genomics, Ultima, Apton, Loop, Vicarious, Atomwise, Healthtap, eGenesis...

questions?

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@vkhosla