# How it started ......

Medicine is the exercise of the imagination—we enter another person's suffering to end it. If there can be no respite, then we stay with our patients until the end. Beyond this, there is no higher ideal. So read this book with one eye only: keep the other focused on more distant horizons, so when you meet impossible patients in impossible nights, under whatever moon, they will feel the twinkling of a kindly countenance begin to banish their fear.

OXFORD HANDBOOK OF CLINICAL MEDICINE

MURRAY LONGMORE
IAN WILKINSON
ESTÉE TOROK
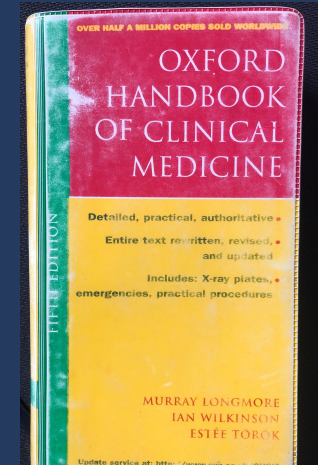
How it's going ......

"AI is technology's most important **priority**, and healthcare is its most **urgent application**."
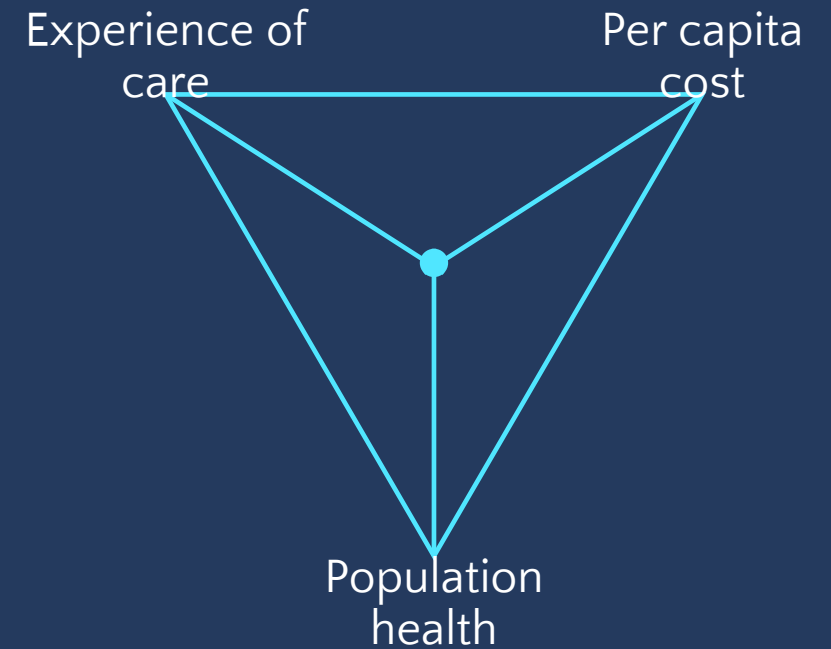
—Satya Nadella
2021

"The interest in humanity.... the secret of caring for the patient, is caring for the patient."

—Peabody
Harvard 1926

Macro: Context: every health system

Disease
20–25% $ Resources

5%

Pre-disease/disease
Sub-healthy

25–60
%

Healthy/
unknown

35–70%

Experience of
care

Per capita
cost

Population
health
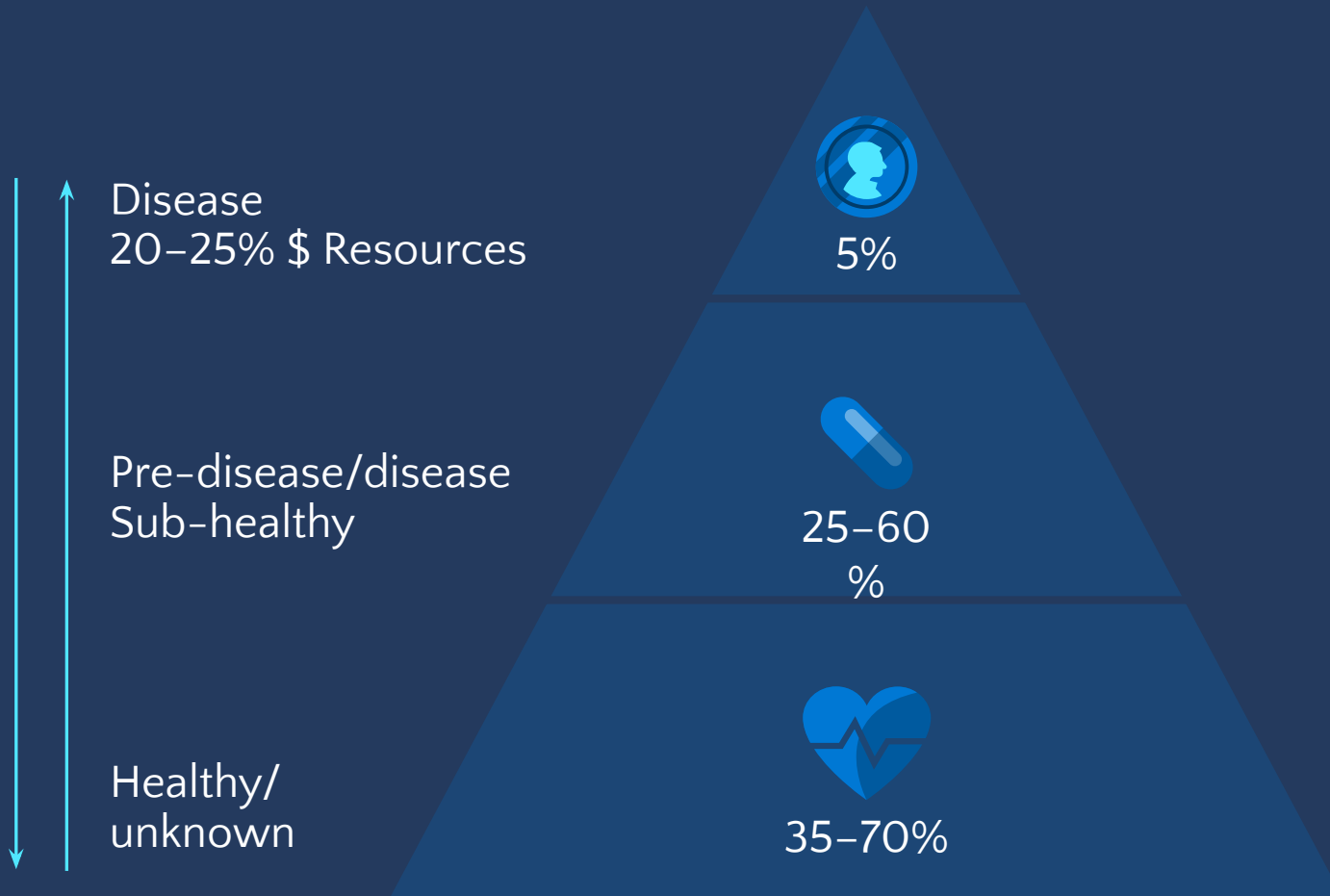
Macro: 6 factors are shaping global health systems
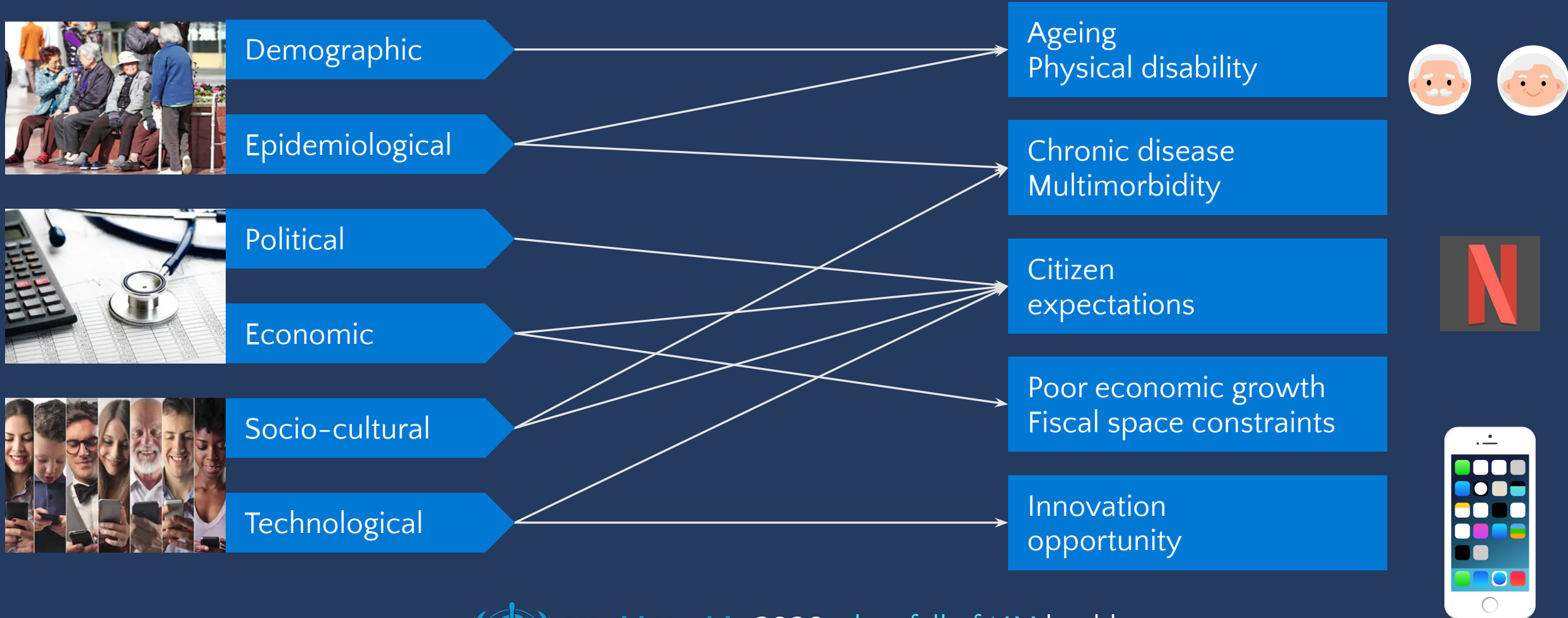
Demographic

Epidemiological

Political

Economic

Socio-cultural

Technological

Ageing
Physical disability

Chronic disease
Multimorbidity

Citizen
expectations

Poor economic growth
Fiscal space constraints

Innovation
opportunity

Macro-> Micro: The journey to personalization

MEDICAL CARE
11%

INDIVIDUAL BEHAVIOR
36%

ENVIRONMENTAL

GENETICS & BIOLOGY
22%

SOCIAL CIRCUMSTANCES
24%
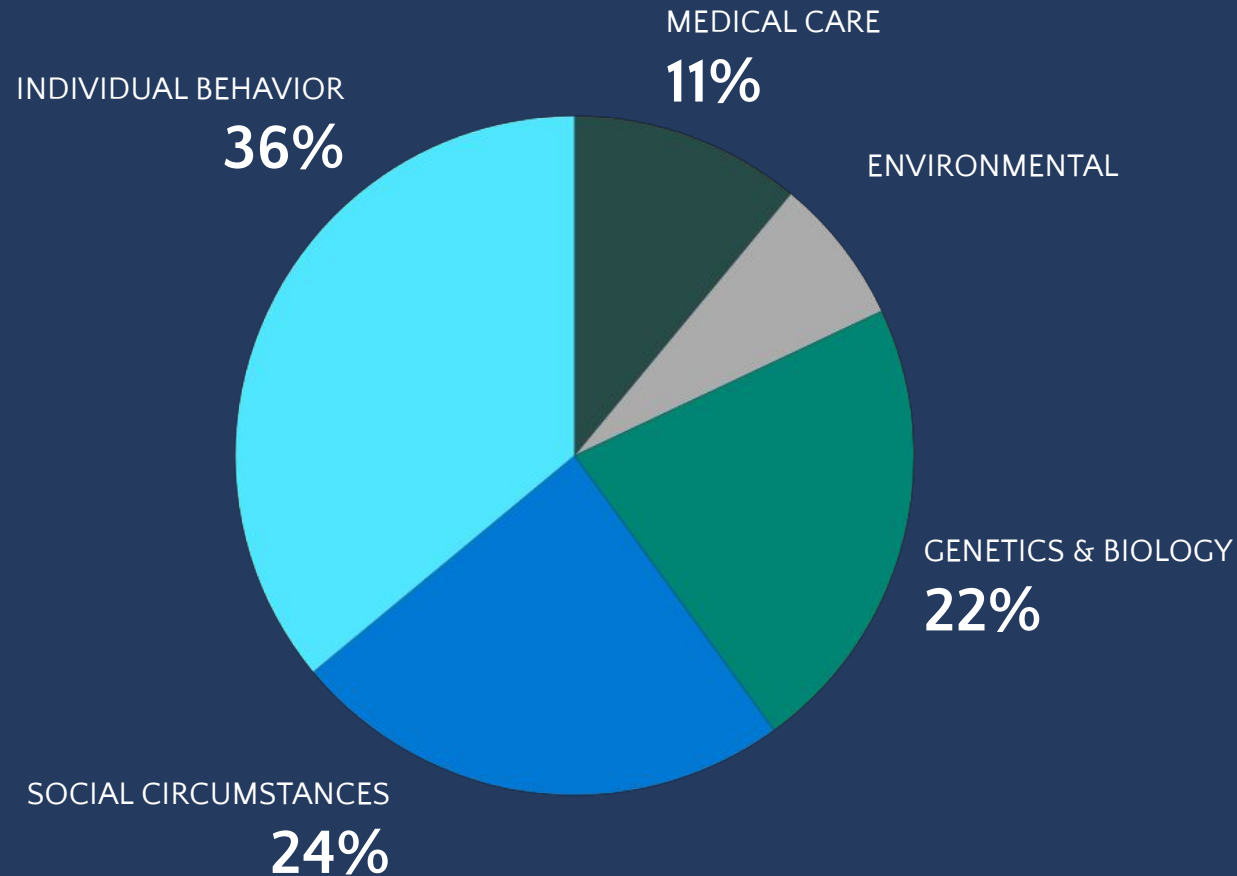
Source: determinantsofhealth.org

"What matters to you?"

vs

"What's the matter with you?"

Macro-> Micro: The journey to personalization

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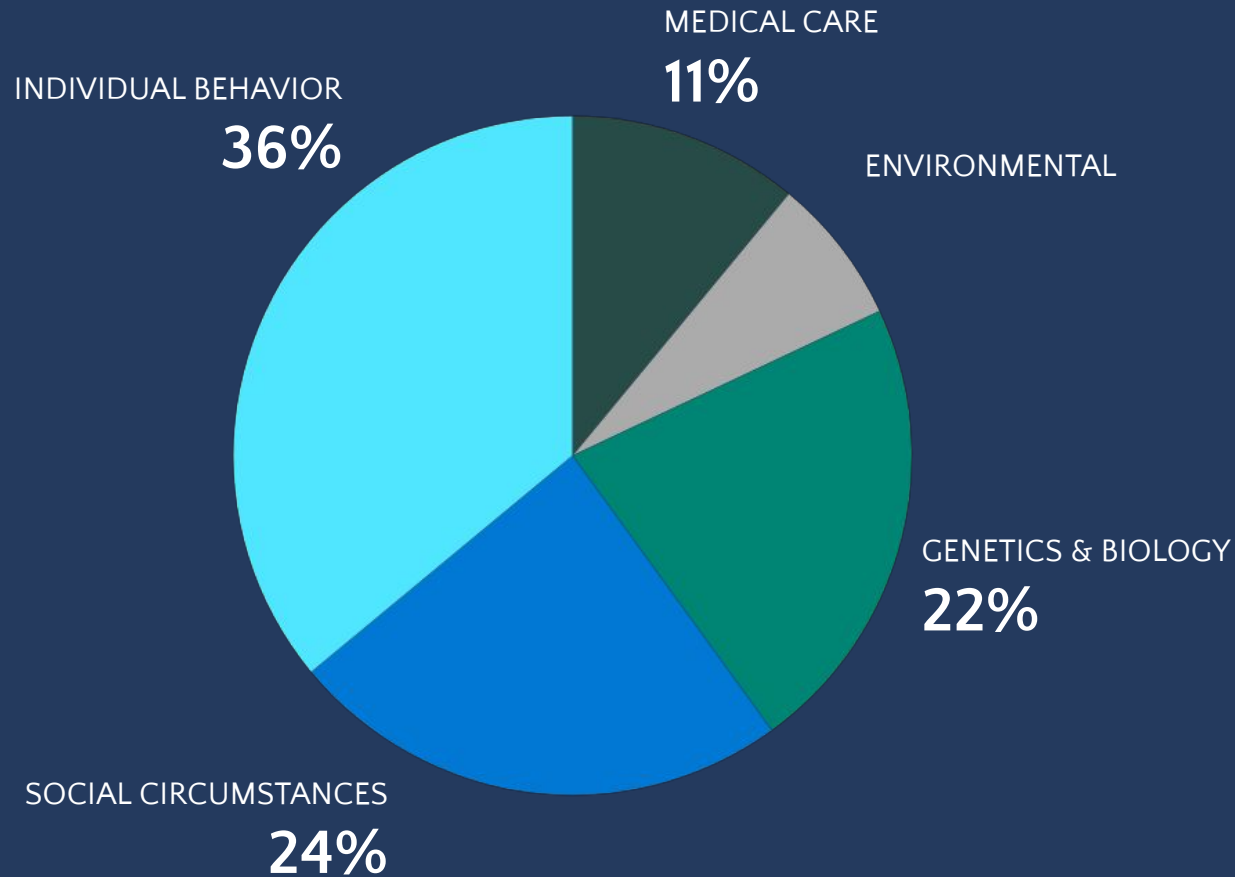
Diagnose and Treat

Recognize and Prevent

Source: determinantsofhealth.org

Macro–> Micro: The journey to personalization

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Connected care

Practice of Precision Medicine

Precision Dx

Precision Tx
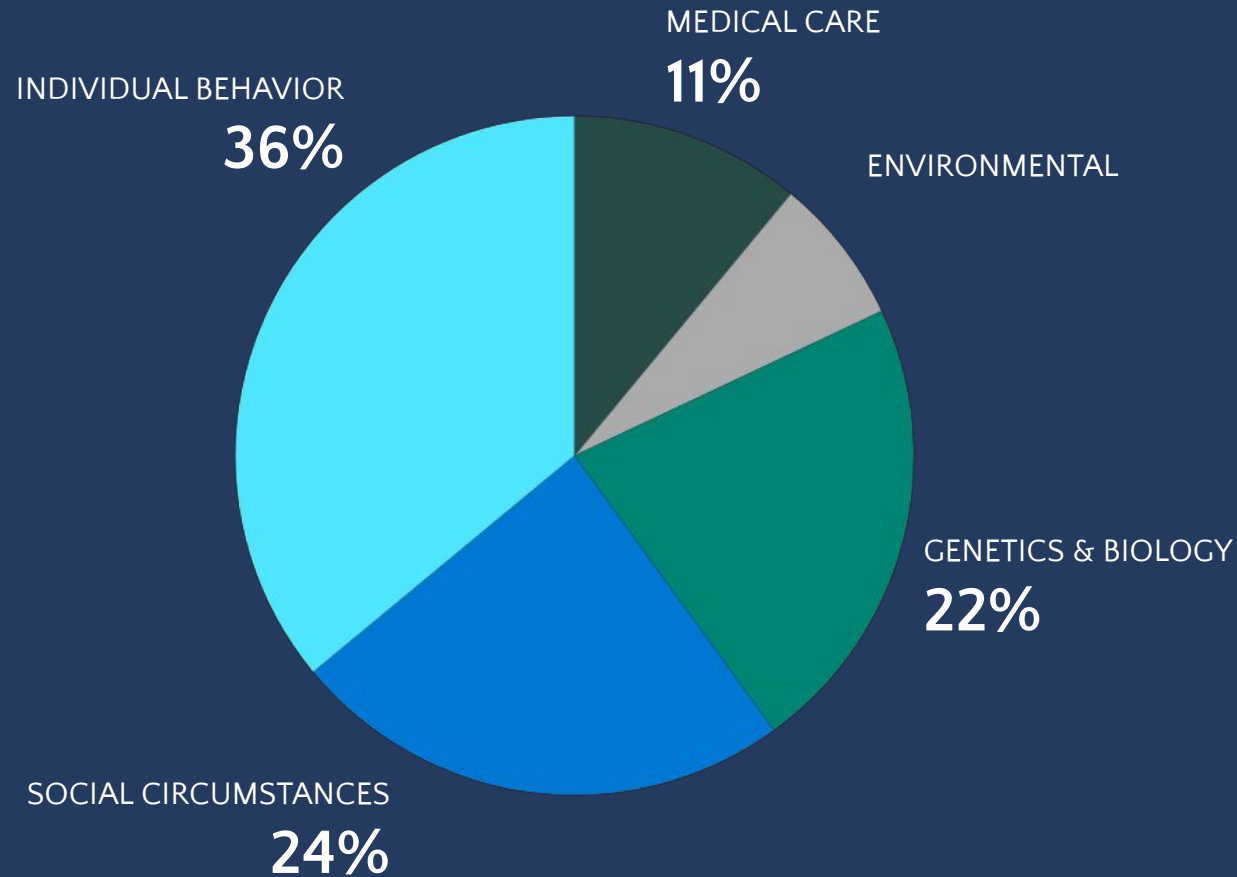
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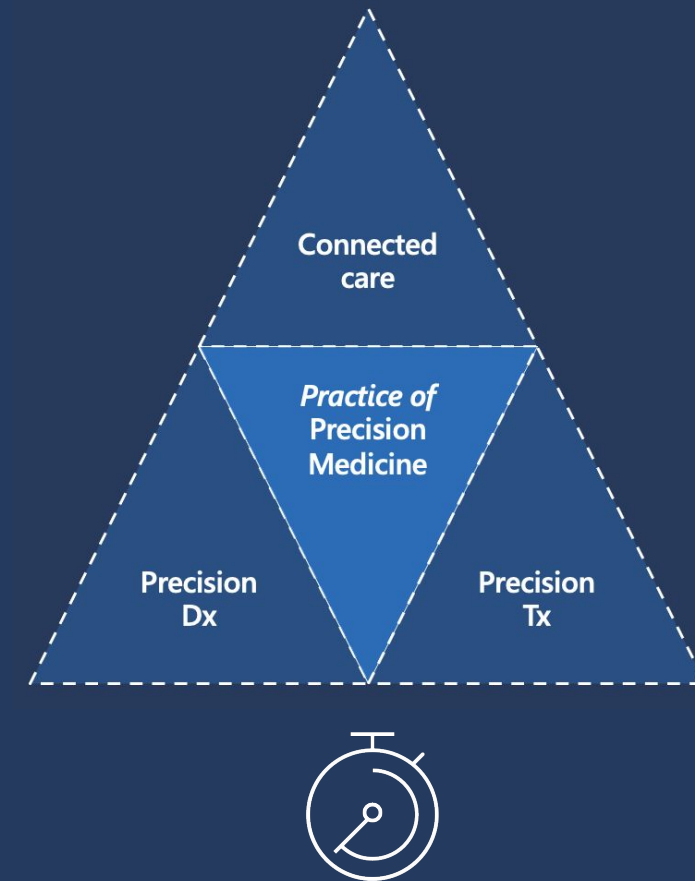
>40yrs of accelerated health technology innovation

1980's/90's	2000's	2010's	2010's	2020's	2020's	2020's

Evidence-based medicine
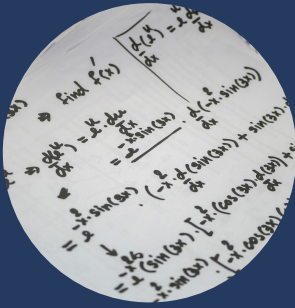
Hand-crafted models & scarce data
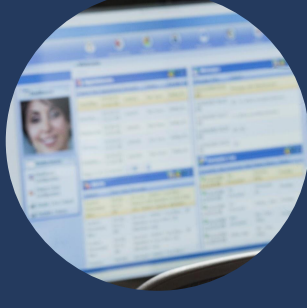
Electronic Health Records and Big Data

Models start to be learned from fuller data
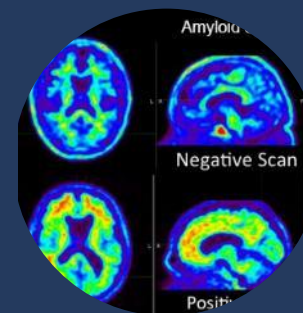
Multimodal AI (unstructured text + imaging)

Personalization & well-being

Privacy & bias

Population Health & Smart Cities

Clinical Audit/Governance
1-way: research → practice

Learning Health Systems
2-way: research <-> practice

Precision and Population Health Systems
360-degree view of the patient

The future of healthcare will be more data driven, accurate, predictive and precise.

Dataverse Innovation and Acceleration

Accelerating Growth in Technology (condensed)

Printing Press — Microscope — Telescope — Steam Engine — Telegraph — Light Bulb — Telephone — Car — Man on Moon — Microprocessor — Wordprecessor — MS-DOS — Apple Macintosh — Windows — WWW — Cell Phones — DVDs — Hybrid Cars — Google — Youtube — Facebook — iPad — Google Driverless Car — 3D Movies — First 3D Chip
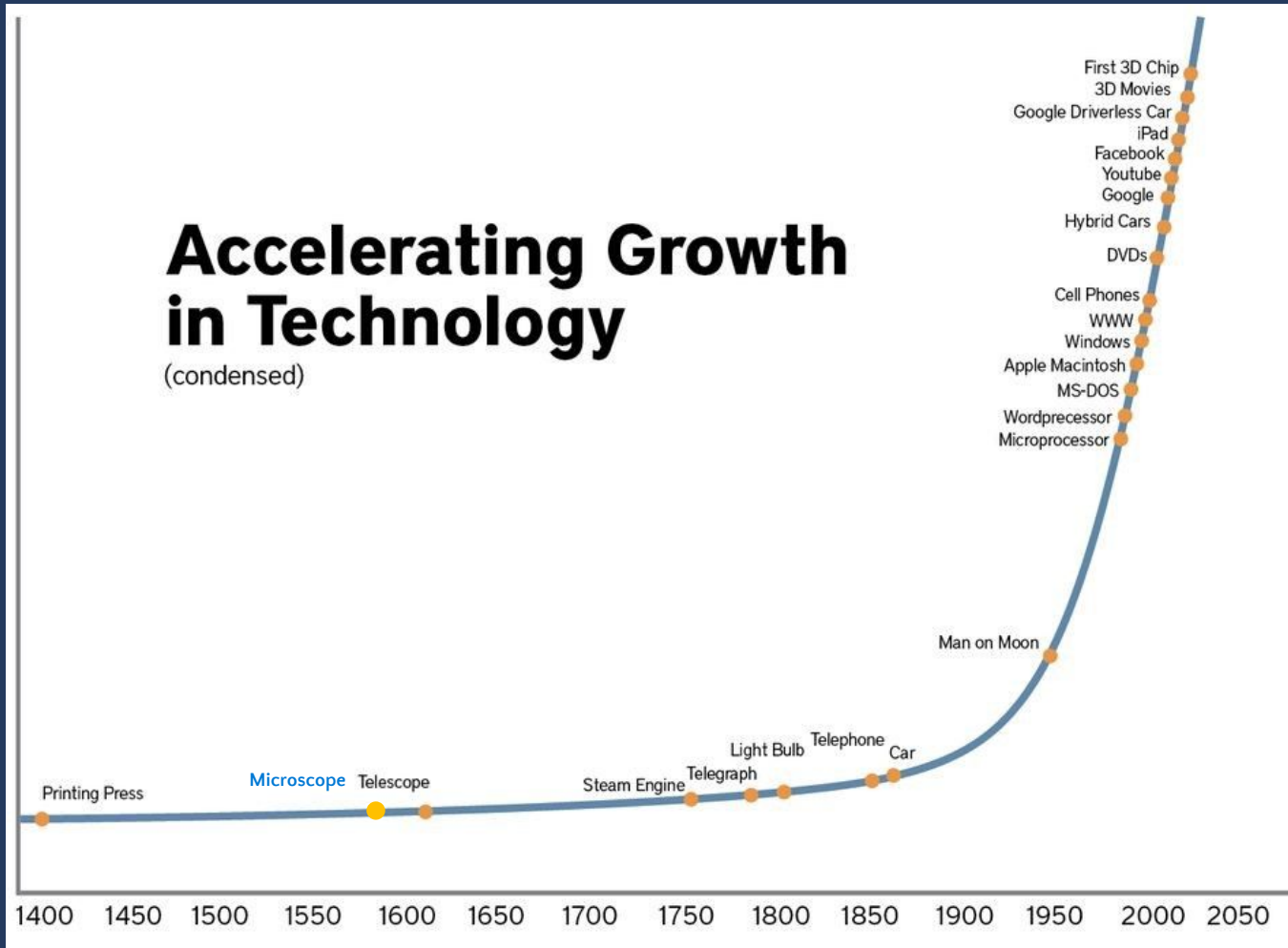
Game changers

Humana/ Nuance	Microsoft	Novartis/ Jax
PillPack Comprehend	amazon	Haven/ labs126
Verily / (Life Sciences)	Alphabet	DeepMind/GC (imaging)
Babylon/ wedoctor	Tencent 腾讯	Medopad (Parkinson's)
AliHealth	Alibaba.com	AI medical labs
Apple Watch EMR	(Apple logo)	ResearchKit CareKit

Future of Patient Data
(2017/18)
Locations and
key insights

London **14 DEC 2017**
- C Combining Data Sets
  Trust
  Linkability of Open Data
- O Embedded AI
  Getting Closer to the Patient
  Predictive Analysis
- E New Business Models
  Standardised Measures
  Inequality

Oslo **30 OCT 2017**
- C Combining Data Sets
  Getting Closer to the Patient
  Expanding Set of Data
- O Predictive Analysis
  Personalisation
  Artificial Intelligence
- E Standardised Measures
  Inequality
  Global Data Sharing

Mumbai **23 NOV 2017**
- C Data Quality
  Ulterior Motives
  Data Ownership
- O Data Marketplaces
  India Setting Standards
  Artificial Intelligence
- E Informed Consent
  New Models
  Inequality

San Francisco **19 JAN 2018**
- C Integration of Data
  Data Quality
  Unstructured Data
- O Individualized Medicine
  Artificial Intelligence
  Data Marketplace
- E Privatisation of Health data
  New Business Models
  Value of Health Data

Brussels **9 NOV 2017**
- C Ulterior Motives
  Resistance from HCPs
  Trust
- O Artificial Intelligence
  New Business Models
  Mental Health
- E Data Sovereignty
  Patient Empowerment
  Data Marketplaces

Dubai **27 SEPT 2017**
- C Data Gaps
  Infrastructure
  Digital Skills
- O Predictive Analysis
  Artificial Intelligence
  Genetic Profiling
- E Standardised Measures
  Mental Health
  Ulterior Motives

Toronto **16 JAN 2018**
- C Data Ownership
  Ulterior Motives
  Trust
- O Data Marketplaces
  Artificial Intelligence
  Personalisation
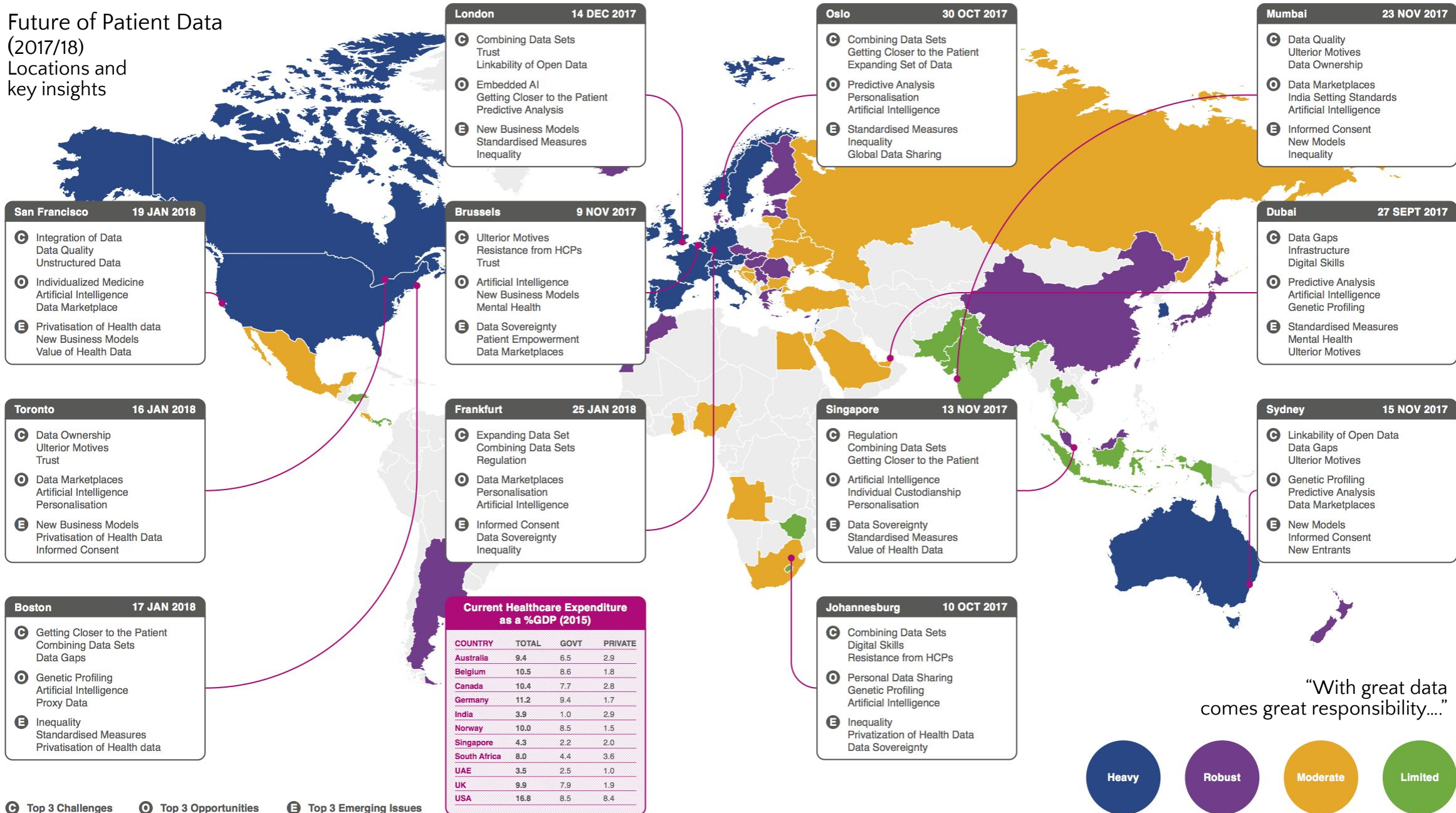- E New Business Models
  Privatisation of Health Data
  Informed Consent

Frankfurt **25 JAN 2018**
- C Expanding Data Set
  Combining Data Sets
  Regulation
- O Data Marketplaces
  Personalisation
  Artificial Intelligence
- E Informed Consent
  Data Sovereignty
  Inequality

Singapore **13 NOV 2017**
- C Regulation
  Combining Data Sets
  Getting Closer to the Patient
- O Artificial Intelligence
  Individual Custodianship
  Personalisation
- E Data Sovereignty
  Standardised Measures
  Value of Health Data

Sydney **15 NOV 2017**
- C Linkability of Open Data
  Data Gaps
  Ulterior Motives
- O Genetic Profiling
  Predictive Analysis
  Data Marketplaces
- E New Models
  Informed Consent
  New Entrants

Boston **17 JAN 2018**
- C Getting Closer to the Patient
  Combining Data Sets
  Data Gaps
- O Genetic Profiling
  Artificial Intelligence
  Proxy Data
- E Inequality
  Standardised Measures
  Privatisation of Health data

Johannesburg **10 OCT 2017**
- C Combining Data Sets
  Digital Skills
  Resistance from HCPs
- O Personal Data Sharing
  Genetic Profiling
  Artificial Intelligence
- E Inequality
  Privatization of Health Data
  Data Sovereignty

Current Healthcare Expenditure as a %GDP (2015)

COUNTRY	TOTAL	GOVT	PRIVATE
Australia	9.4	6.5	2.9
Belgium	10.5	8.6	1.8
Canada	10.4	7.7	2.8
Germany	11.2	9.4	1.7
India	3.9	1.0	2.9
Norway	10.0	8.5	1.5
Singapore	4.3	2.2	2.0
South Africa	8.0	4.4	3.6
UAE	3.5	2.5	1.0
UK	9.9	7.9	1.9
USA	16.8	8.5	8.4

"With great data
comes great responsibility...."

Heavy   Robust   Moderate   Limited

C Top 3 Challenges   O Top 3 Opportunities   E Top 3 Emerging Issues

Pharma: Time to development

Timeline and development stages for a pharmaceutical product (industry average)

Drug discovery	Pre-clinical testing	Clinical trials			Licensing approval
		Phase I	Phase II	Phase III	
5-10,000 candidates	10-20 candidates	5-10 candidates	2-5 candidates	1-2 candidates	1 medicine
4.5 years	5.5 years	7 years	8.5 years	11 years	12.5 years

Medicine available for patients

Source: ABPI

Disruptive Innovation on the horizon

Discovery

Mining data/ literature to identify drug targets

Understanding disease mechanism

Optimising drug selection/ generation

Development

Patient recruitment (trial optimization, decentralized trials)

Patient monitoring (metadata)

Biomarker identification (digital/ biological)

Manufacturing

Lab automation

Autonomous manufacturing plants

Managing supply/ demand

Optimising supply chain

Commercialisation

Physician decision support

Digital pharmacy/ delivery

Remote patient monitoring

Supporting self care, inc adherence

Demonstrating real world value, and partnering for outcomes

AI across the value chain: Automation, Aggregation, Analysis, AI..... repeat*
Potential to: generate novel hypotheses; unmask occult disease subtypes/ associations; reduce costs; support clinicians

Deep dive: Pharma's data and outcomes challenge
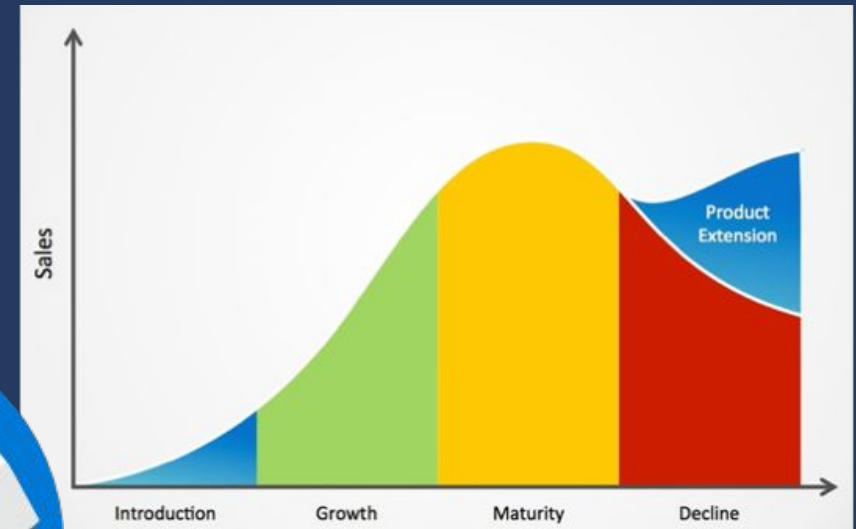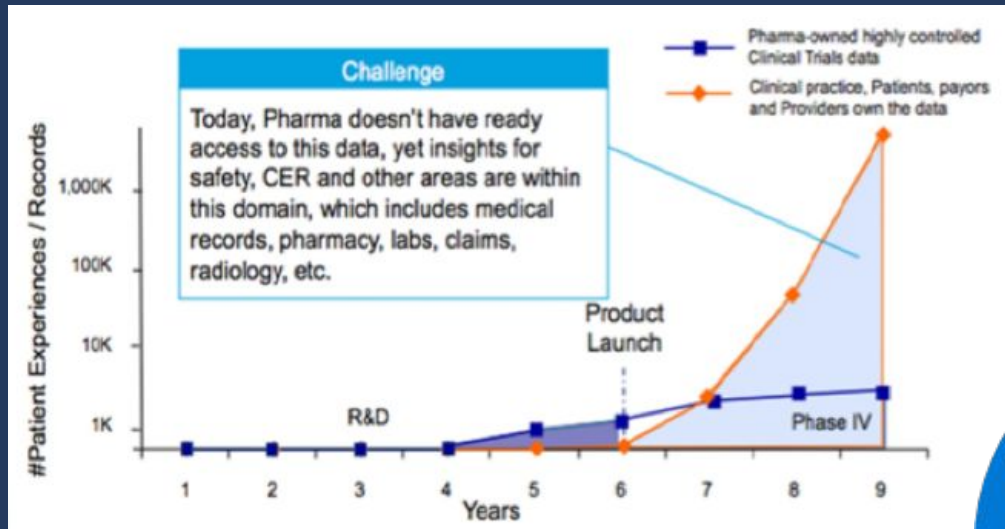
Context and problem statement:
Oncology patient journeys are becoming longer, leading to more complicated care coordination processes, which may lead to decreased Tx adherence

Case example: Non small cell lung cancer patient journey in the UK

SYMPTOMS
materialisation

DIAGNOSIS
and referrals

TREATMENT
and care experience

REHABILITATION
and resilience

SURVIVORSHIP
Coaching
Monitoring
Predictive analysis

PALLIATION
Coaching (e.g. Marie Curie, MacMillan)
Family support

Pathway overview
Patient concerned about symptoms (unexplained weight loss, cough, etc.)

Patient presents at GP clinic or A&E

Current pain points
Noticeable symptoms usually materialise at a later stage, once the cancer has spread through the lungs

Examination and tests (e.g. x-ray, CT scan, biopsy)

Cancer diagnosis confirmed

PDL1 test conducted

MDT for treatment options

Variation in time to treatment (current average 62 days— 28 day pathway published by NHS in April 2018

I/O alone or in combined (with radio chemo, surgery)

Administered as ~30min infusion every 3 weeks

Toxicity management

Therapy discontinued due to reactive toxicity management

Administrative burden (e.g. scheduling various treatments)

Discomfort / inconvenience of visiting hospital for treatment

Symptom monitoring—relapse prediction and prevention

Lifestyle coaching (e.g. diet, exercise)

Relapse potential heightened by reactive symptoms management

Ad-hoc / irregular support and coaching provided to patients

Assessing and referring adult cancers
by Will Stahl-Timmins

Possible cancers

Abdominal features (discomfort or pain)

Abdominal pain
- Rectal bleeding / Weight loss age 40+
- age 50+
- Weight loss age 60+ colorectal cancer excluded

Upper abdominal pain age 55+
- Weight loss
- Anaemia / Thrombocytosis / Nausea / Vomiting

Dyspepsia age 55+
- Weight loss treatment-resistant
- Thrombocytosis / Nausea / Vomiting

Abdominal features (distension or mass)

- Rectal or abdominal mass
- Upper abdominal mass, consistent with enlarged: Gall bladder / Liver / Stomach
- Hepatosplenomegaly
- Splenomegaly + Fever / Night sweats / Breathlessness / Pruritus / Weight loss
- Abdominal distension persistent / frequent / esp. age 50+
- Ascites +/ pelvic/abdominal mass not obviously uterine fibroids

Abdominal features (Bowel transit symptoms)

- Women: Irritable bowel syndrome symptoms in last 12 months age 50+
- Change in bowel habit unexplained age 50+
- Change in bowel habit: Rectal bleeding age 60+ / age under 60
- Diarrhoea / Constipation + Weight loss age 60+
- Nausea / Vomiting + Thrombocytosis / Weight loss / Reflux
- Dyspepsia / Upper abdominal pain age 55+
- Reflux + Weight loss age 55+
- Nausea / Vomiting + Weight loss age 60+

Respiratory

- Hoarseness unexplained / persistent age 45+
- Chest infection persistent / recurrent age 40+
- Chest pain / Cough / Breathlessness age 40+ unexplained / 2 or more of these symptoms / ever smoked / exposed to asbestos
- + Fatigue / Weight loss / Appetite loss
- age 40+ Chest signs consistent with: Lung cancer / Pleural disease / Finger clubbing

Lumps or masses

- Anal mass unexplained
- Axillary lump unexplained age 30+
- Breast lump age 30+ / unexplained age under 30
- Neck lump age 45+ / unexplained / persistent
- Lymphadenopathy generalised / supraclavicular / persistent cervical age 40+
- + Fever / Night sweats / Breathlessness / Pruritus / Weight loss / Alcohol-induced lymph node pain
- Soft tissue lump unexplained / increasing in size
- Thyroid lump unexplained
- Vaginal mass unexplained / palpable / in or at entrance to vagina
- Vulval mass

Primary care investigation

- non-urgent — Faecal occult blood testing
- within 2 weeks — CT scan / ultrasound
- within 2 weeks / non-urgent — Upper GI endoscopy direct access
- within 2 weeks — Ultrasound
- within 2 weeks — Ultrasound
- within 48 hours — Full Blood Count
- Measure serum CA125
- Measure serum CA126
- within 2 weeks / non-urgent — Chest X-ray

Possible cancers: Colorectal, Stomach, Ovarian, Pancreatic, Gall bladder, Liver, Oesophageal, Non-Hodgkin's lymphoma, Soft tissue sarcoma, Lymphoma, Leukaemia, Lung, Mesothelioma, Anal, Oral, Breast, Laryngeal, Thyroid, Vaginal, Vulval

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Bleeding

- Rectal bleeding age 40+ / unexplained
- + Abdominal pain / Change in bowel habit / Weight loss / Iron-deficiency anaemia
- Bruising / Bleeding / Petechiae unexplained
- Haemoptysis unexplained age 40+
- Haematemesis

Gynaecological (Women)

- Vulval bleeding unexplained
- Post-menopausal bleeding age 55+ / age under 55
- Vaginal discharge unexplained age 55+ +/ Thrombocytosis / Haematuria
- Appearance of cervix consistent with cervical cancer

Urological

- Haematuria visible age 45+ + Anaemia / Thrombocytosis / Vaginal discharge / non-visible age 60+ / Dysuria / Raised white blood cell count / visible age 45+ + No urinary tract infection / Recurrent / Persistent
- Urinary tract infection unexplained / recurrent / persistent age 60+
- Haematuria visible
- Erectile dysfunction
- Nocturia / Frequency / Hesitancy / Urgency / Retention (Men)
- Change in testis enlargement / change in shape / change in texture
- Testicular symptoms unexplained / persistent
- Penile mass or lesion ulcerated / STI excluded / persistent after STI treatment
- Penile symptoms affecting the foreskin or glans unexplained / persistent

Skin or surface

- Anal or vulval ulceration unexplained
- Skin lesion suspicious of a basal cell carcinoma
- Nipple changes one nipple only including: discharge / retraction age 50+
- Skin changes that suggest breast cancer
- Dermoscopy findings that suggest melanoma
- Skin lesion suspicious / pigmented + weighted 7-point checklist score of 3 or more / suggests nodular melanoma / suspicious of a squamous cell carcinoma

Oral lesions

- Ulceration in oral cavity unexplained lasting 3+ weeks
- Patch in oral cavity red / red and white consistent with: Erythroplakia / Erythroleukoplakia
- Lip or oral cavity lump

Musculoskeletal

- Back pain persistent / Bone pain persistent / Unexplained fracture age 60+ + Weight loss

Neurological

- Loss of central neurological function progressive / sub-acute

Non-specific features of cancer

- Fatigue persistent / Fever unexplained / Infection unexplained / persistent / recurrent / Pallor
- Fatigue / Weight loss / Appetite loss / Ever smoked / Exposed to asbestos + age 40+
- Infection unexplained / persistent / recurrent
- Weight loss unexplained
- Appetite loss unexplained
- Deep vein thrombosis
- Jaundice age 40+
- Weight loss age 60+ + Diarrhoea / Back pain / Abdominal pain / Nausea / Vomiting / Constipation / New-onset diabetes

Primary care investigation

- within 48 hours — Full Blood Count
- non-urgent — Upper GI endoscopy
- direct access — Ultrasound
- direct access — Ultrasound
- Prostate-specific antigen test + digital rectal examination
- urgent — Dental referral
- Full blood count + Blood tests: calcium / rate of erythrocyte sedimentation / plasma viscosity

Possible cancers: Colorectal, Lung, Vulval, Bladder, Leukaemia, Endometrial, Cervical, Stomach, Oesophageal, Prostate, Oral, Squamous cell carcinoma, Melanoma, Renal, Penile, Breast, Testicular, Basal cell carcinoma, Anal

suspected cancer referral for concerning lesion site or size

2.2 Miles
Oak Park Blvd

East way
Steenland
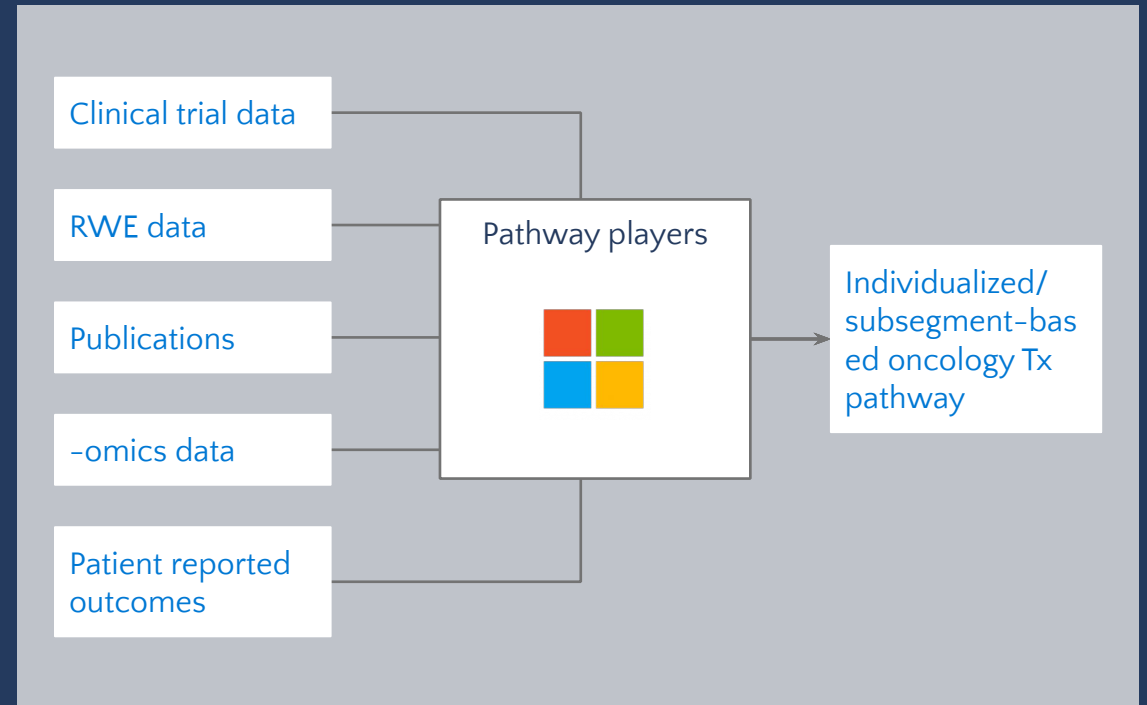Chestnut St.

10:06
25 min. 14 mi.

12:30

Complexity of oncology treatments: Personalizing outcomes paradox

Oncologists/tumor boards trying to to keep up with explosion of complexity of Tx paradigms and increasing speed of innovation…

…different players are taking ownership of shaping Tx pathways

Breakthrough new clinical trials

Label changes: New indications, Tx length adjustments

New research publications

New combination therapy approvals

Clinical trial data

RWE data

Publications

–omics data

Patient reported outcomes

Pathway players

Individualized/ subsegment–based oncology Tx pathway

- A medical article is published every 30s; **4000** new papers on PubMed **everyday** (experts can curate ~ 10)
- 50m medical publications in public databases (not all publications necessarily of the same quality/ inherent biases),
- Medical knowledge **doubles** every 73 days

…… What if healthcare and computing "spoke the same language" and this information could be democratized and lead to actionable insights?

Oncology treatment planning: Project Inner Eye [democratizing AI]
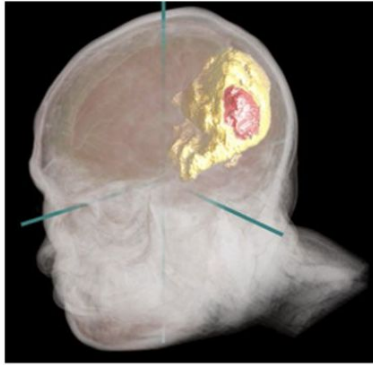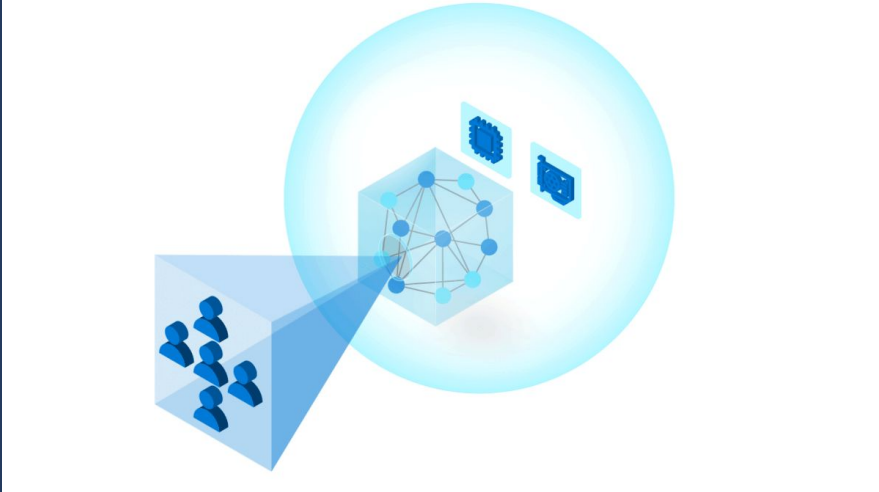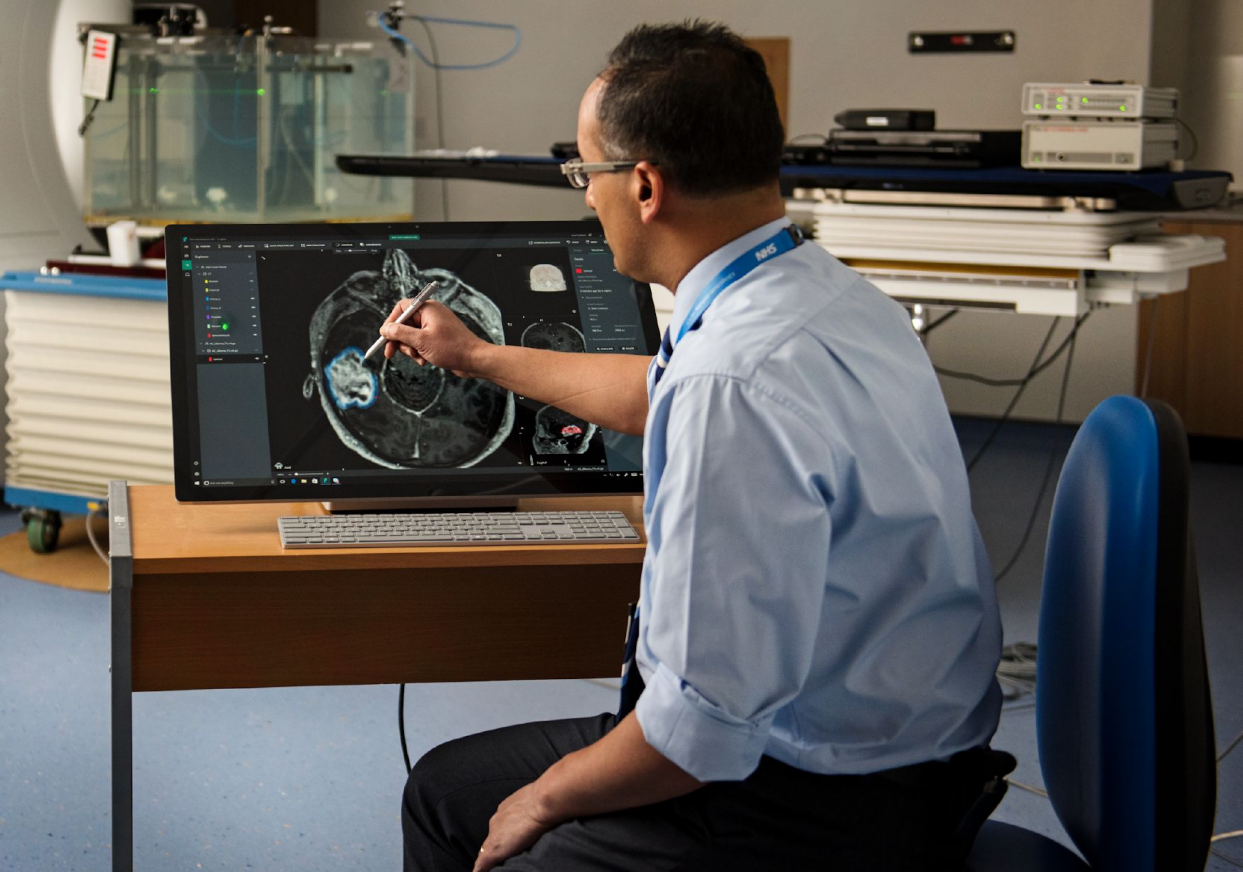
Quantitative radiology
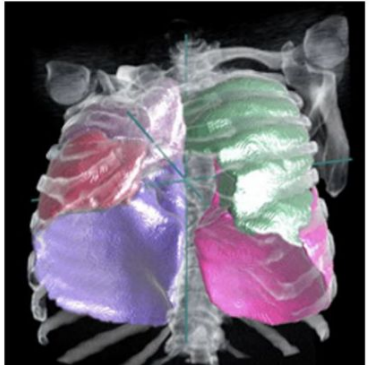
Radiation oncology
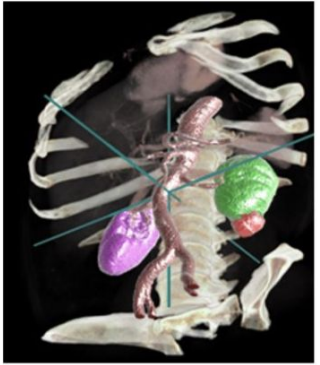
Surgical planning

Figure 1: Potential applications for the InnerEye Deep Learning Toolkit include quantitative radiology for monitoring tumor progression, planning for surgery, and radiotherapy planning.

Ambient Healthcare

Current & Future state: H1–H3

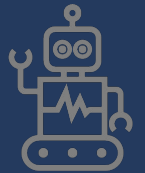**Horizon 3 (>10yrs)**: new technology: visionary/ transformative (*autonomous*)
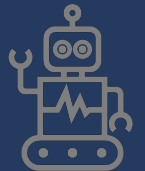
- Augmented Care: autonomous assistive tech, delivering anticipatory + predictive care
- Precision Diagnostics: Holographic/ hybrid medicine, holomics (genomic+ radiomic+ proteomic + clinical+++)
- Precision Therapeutics: Genomics Medicine, AI driven Drug Discovery (at scale)

Horizon 2 (5-10yrs) : emerging/ next gen products, services (*automation +AI*)

- Augmented Care: Ambient intelligence in healthcare
- Precision Diagnostics: Scale up of precision imaging technologies
- Precision Therapeutics: Synthetic biology, immunomics

Horizon 1: existing mature technology (*automation*)

- Augmented Care: Virtual assistants, IoT
- Precision Diagnostics: Precision Imaging
- Precision Therapeutics: e.g. CRISPR

Current & Future state: H1–H3

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'He who studies medicine without books sails an unchartered sea, but he who studies medicine without patients does not go to sea at all'

William Osler 1849–1919

The word 'patient' occurs frequently throughout this book.
Do not skim over it lightly.
Rather pause and doff your metaphorical cap, offering due respect to those who by the opening up of their lives to you, become your true teachers.
Without your patients, you are a technician with a useless skill.
With them, you are a doctor.

Microsoft

Thank you

Dr Junaid Bajwa
Email: junaid.bajwa@microsoft.com