

How science, technology and innovation will disrupt what we do



Keith Ison
Head of Medical Physics, Guy's and St Thomas'

Expectations and resources...

- All developed healthcare systems hitting resource problems*
- Difficult discussions on limits and rationing to come
- Growing global burden of non-communicable disease
- Growing global population
- Poverty and inequality
- Huge sustainability gap

* *'The world will be short of 12.9 million healthcare workers by 2035'* [WHO, 2013]





Death

War

Famine

Conquest

The Four Horsemen of Brexit

More of the same...





**Climate
change**

**Famine and
water shortages**

**Disease and
chronic illness**

**War and
conflict**



**Artificial
Intelligence**

... and a fifth ?

P



S



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SOCIAL

Population growth

Climate change

Ecological system collapse
Food and water shortages

War & conflict

More disease and
chronic illness

Inequality



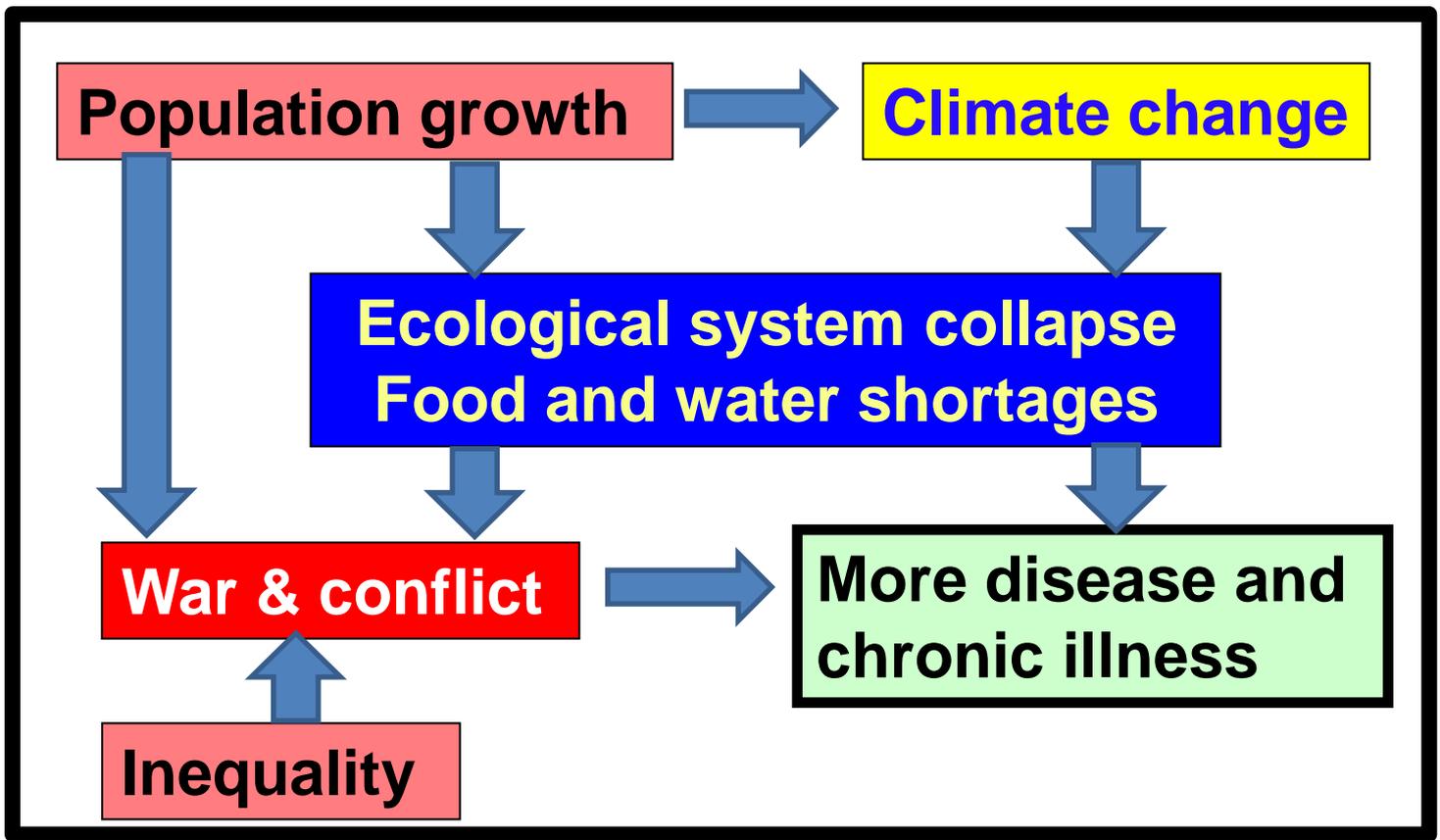
ENVIRONMENTAL



POLITICAL



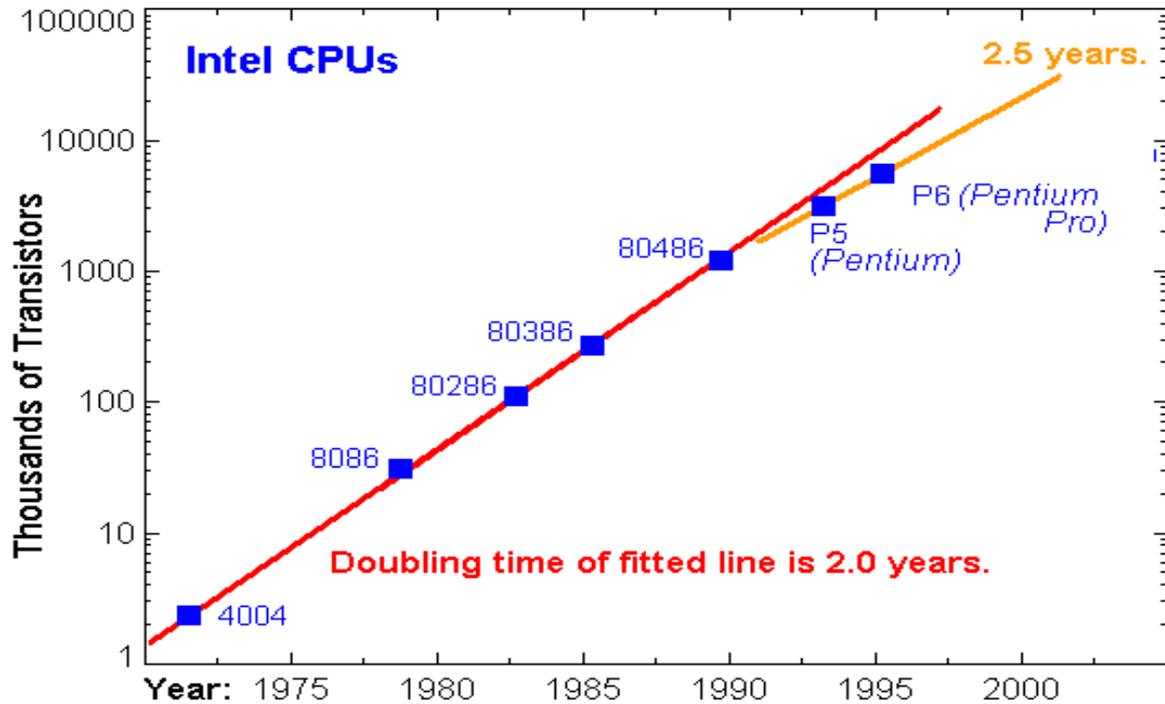
ECONOMIC



Technology

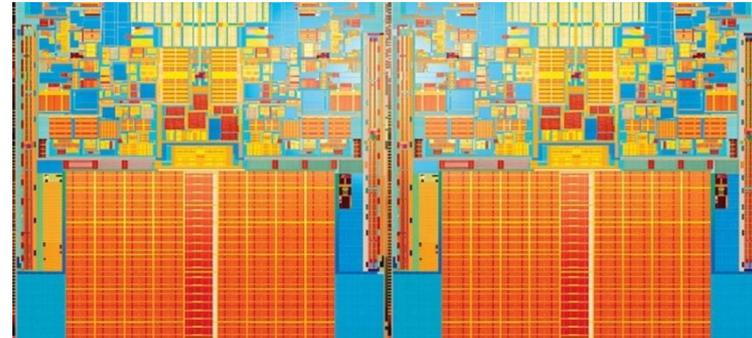


1. The pace of change



Moore's Law from 1975

Doubling of “capacity” every 2 years from 1965 to 2015 (exponential)





APPLE WATCH



2015

1973

1983

2000

2008

10 years

17 years

8 years

7 years

But Moore's Law no longer applies because of:



Global interconnections between people and organisations



Technology improves tools as well as outcomes



Greater accessibility of knowledge



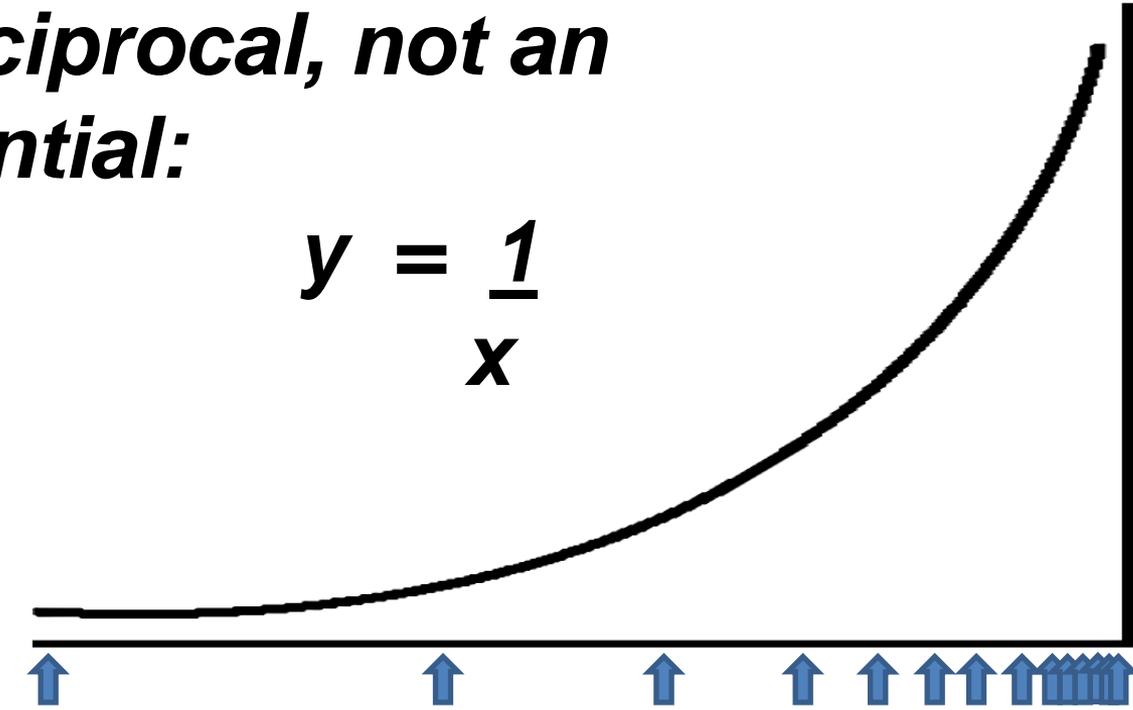
More scientists/engineers means more competition

***Rate of technological
change increasing
as a Reciprocal, not an
Exponential:***

$$y = \frac{1}{x}$$

2040-50

2000



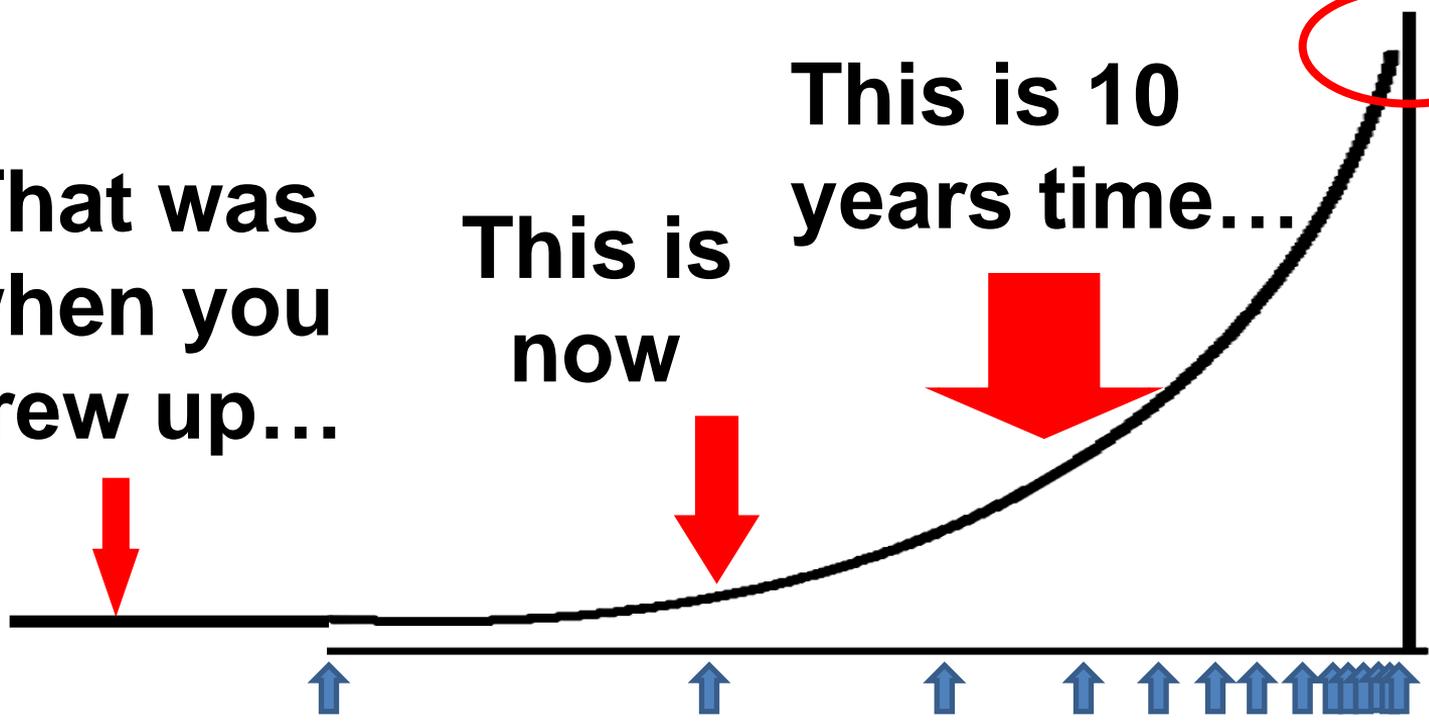
Doubling time...

That was
when you
grew up...

This is
now

This is 10
years time...

SINGULARITY



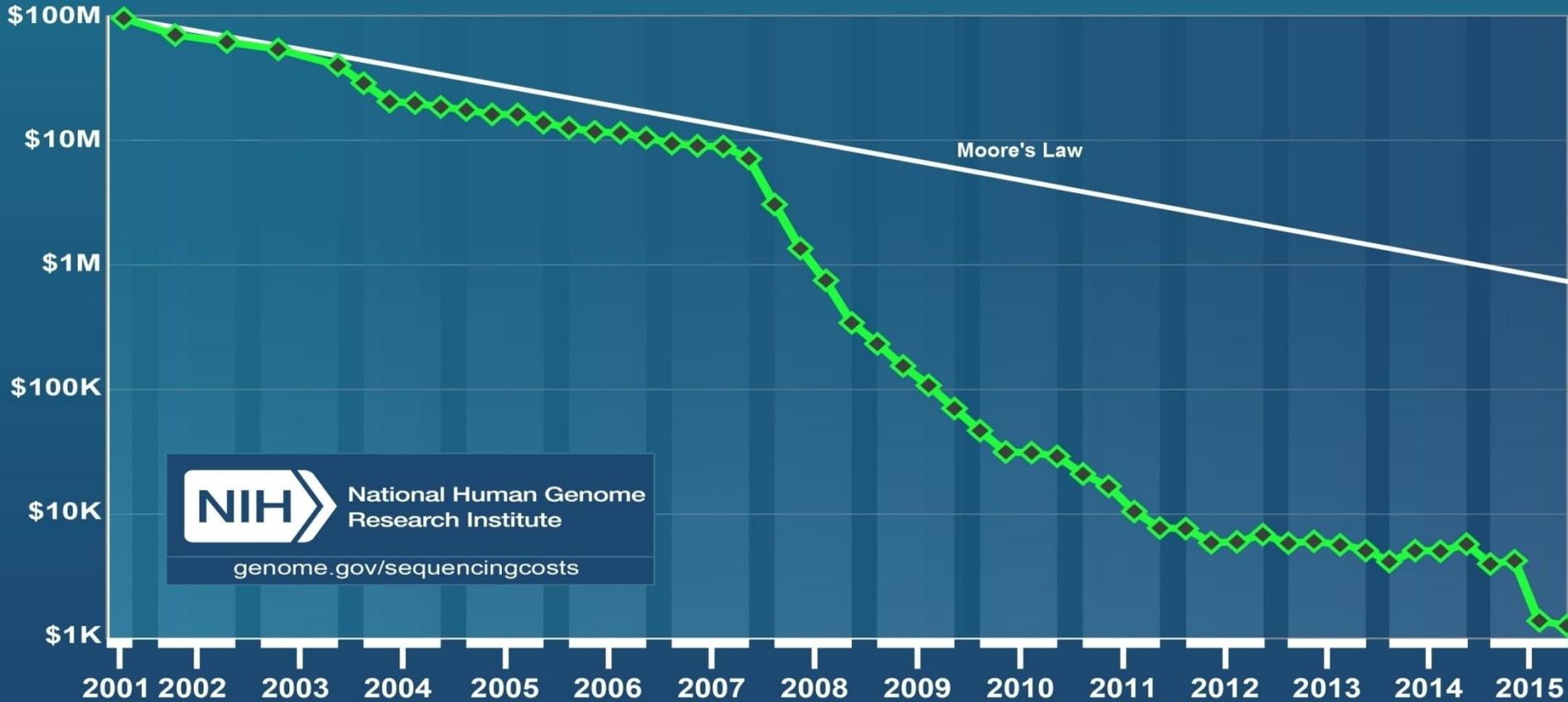
2000

2016

2040-50

Cost per Genome

accessed 15/5/2016



Wetterstrand KA. DNA Sequencing Costs: Data from the NHGRI Genome Sequencing Program (GSP)

Technology



2. Genomics

EXAMPLE: Genomic diagnosis guides clinical management

- mutations in >25 different genes cause neonatal diabetes
- genomic technology has found 5 new genetic subtypes



KCNJ11 p.V59M
Permanent diabetes
and developmental
delay

***Sulphonylurea
therapy***



EIF2AK3 p.E371*
Wolcott Rallison
Syndrome

***Liver
Transplant***



**FOXP3
c.227delT**
IPEX
syndrome

***Bone Marrow
Transplant***



GATA6 c.1448-1455del
Syndromic pancreatic
agenesis

***Insulin and
exocrine
supplements***



STAT3 p.T716M
Multi-organ
autoimmune
disease

***? STAT3
inhibitor***

Five babies – five different treatments

Siblings with the same genetic defect

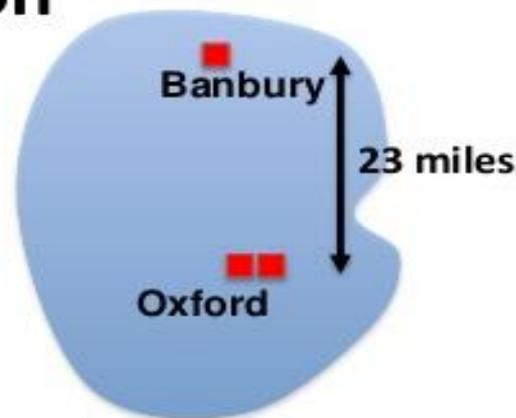


4 years to diagnose
genetic methionine
handling defect

Treated from birth with
a dietary supplement
costing 40p a day

Role of symptomatic patients in *C. difficile* transmission

- We sequenced 1223 of all 1251 hospital and community CDI cases (98%) in Oxfordshire, September 2007 – March 2011
- Hospital admission and ward movement data, and home postcode district and GP location available for each case



- 3 Hospitals
 - Typical CDI incidence
 - Infection control in line with published guidelines

Eyre: *N Engl J Med* 2013; 369:1195-1205

Outcome of study

- Only 20% of *C. difficile* infections are caught in the hospital from another case
- Most cases caught *C. difficile* from a very large reservoir
- Have developed software to monitor and track infection in the hospital and nationally

Rapid viral diagnosis

- DNA technology to diagnose viral infection from a nasal swab
- Machines the size of a microwave (already outdated 1yr on)
- Fast enough to guide nursing strategies and avoid infection of vulnerable patients
- Multiple further tests and miniaturisation in development
- How best to benefit from this technology and when and how to invest ?

1 hour



15 minutes



Technology



3. Personalised medicine

Precision & personalised medicine

Now



- 'One size fits all' treatment based on **symptoms** and **averaged responses** to drugs and procedures

'One size fits all'

Emerging



- Treat underlying **cause** & personal **response**

Individually-tailored approach

Precision & personalised medicine

...a fundamental revolution in medical practice...

2020s?

Now

- Organ/ **speciality** organisation of services and professions
- **Limited** use of genomic/molecular markers
- Diagnostic & other clinical **data not linked**

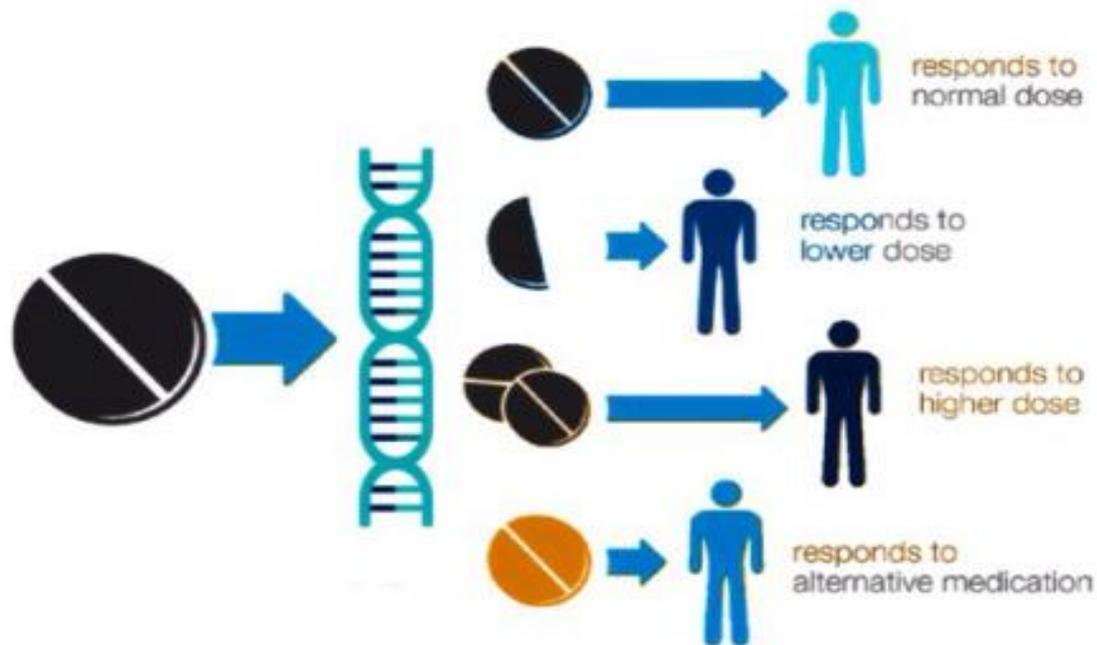
**'One size fits all'
treatments &
intervention**

- New taxonomy of medicine based on underlying **cause** & personal **response**
- Comprehensive **linked** diagnostics to give full picture
- **Tailored therapies** for better outcomes
- **Integrated** clinical services taking a '**whole body**' approach

**Individually-tailored
approach**

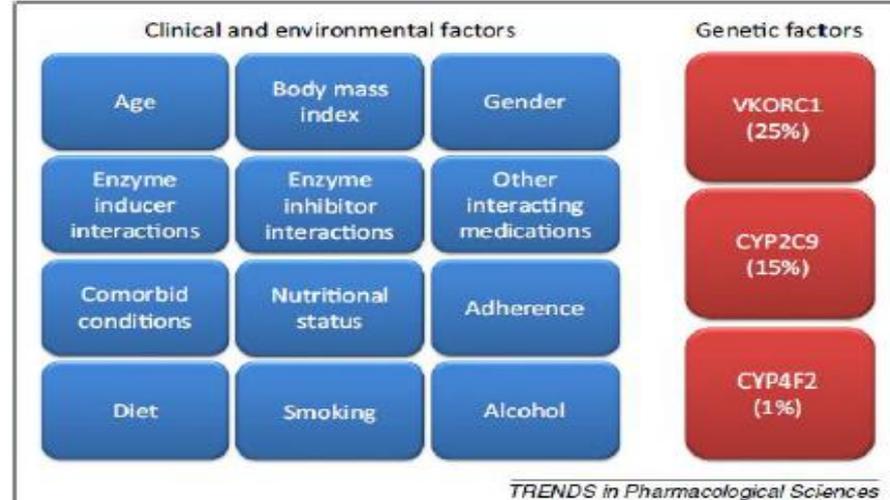
PERSONALIZED PRESCRIBING

Enables selection of the right drug and dose



Personalisation: Warfarin management

- 600,000 Warfarin users in UK
- Wide response range – 40x dose variability
- Major cause of adverse reactions
- Current ‘trial and error’ method in outpatient INR clinics
- Now understand the genetics behind significant element of variation
- Genotype-based protocols identify the right dose sooner, with fewer adverse effects
- Improves patient outcome and experience and reduces costs



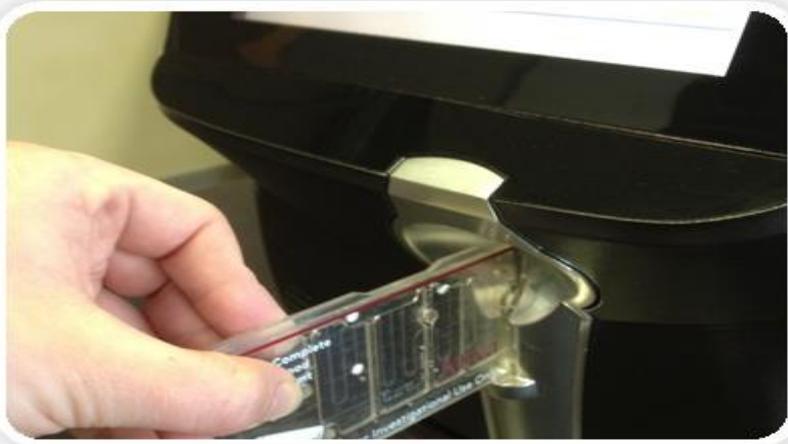
You feel ill...



You go to the doctor...



Who runs some tests...



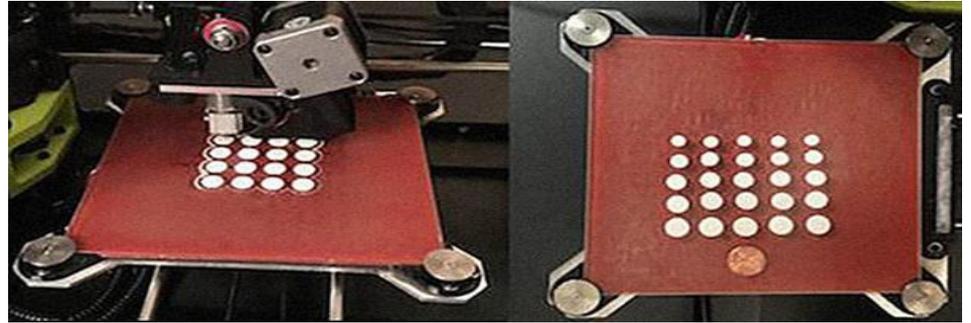
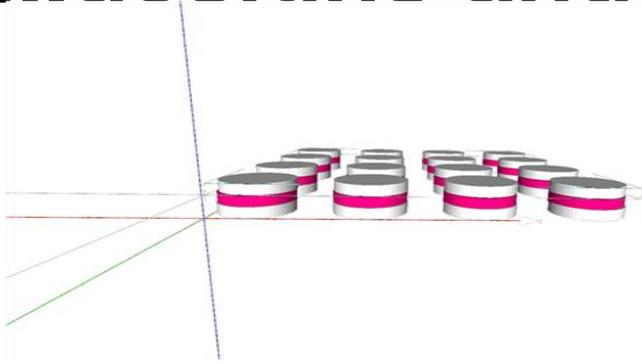
Which show you need some medicine...



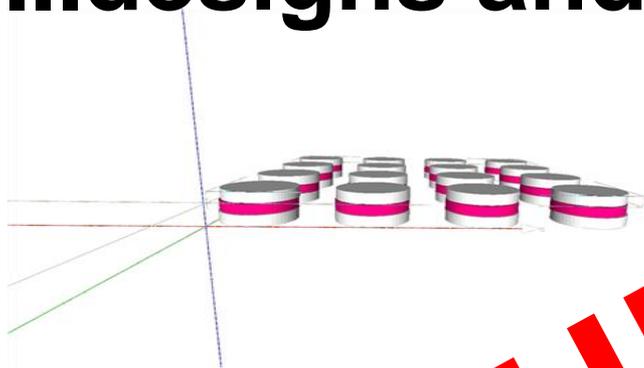
The pharmacist looks up your genomic and biological profile...



...designs and 3D prints a matching pill



...designs and 3D prints a matching pill



UNDER DEVELOPMENT

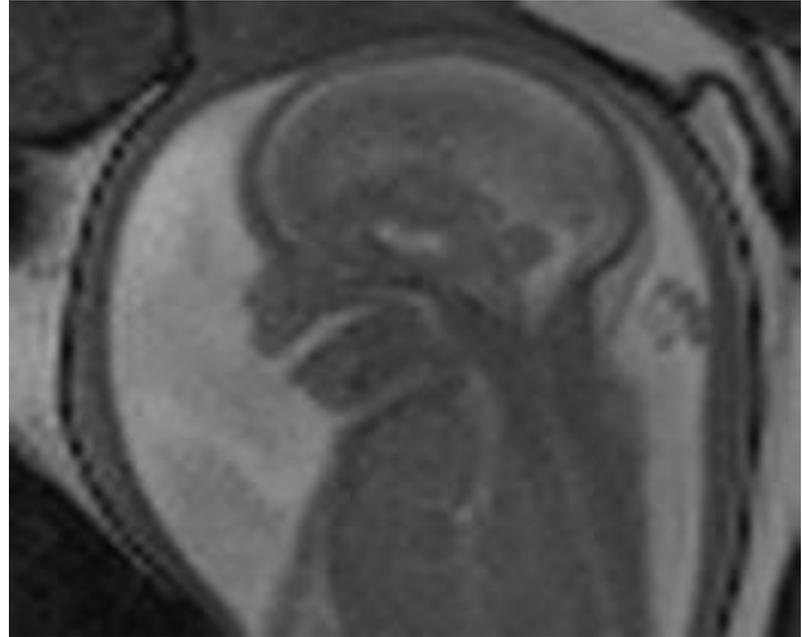
Technology



4. Imaging and visualisation

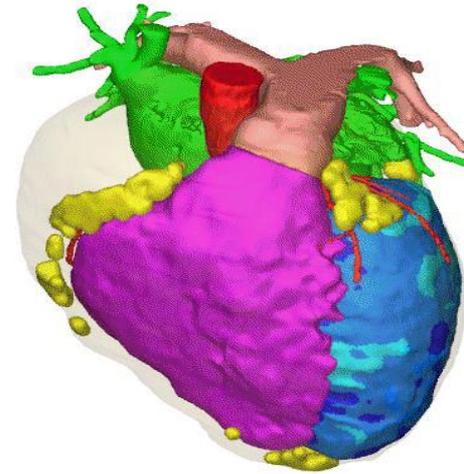
Development cine sequences for foetal MR imaging

Information aids
clinical and parental
decision making
when serious
problems are found



Interventional Example – Ventricular Tachycardia Ablation

- Detailed 3D models derived from imaging: CT, MR, PET etc
- Model used directly during the ablation procedure
- Anatomic/functional model can be fused to a catheter model
- Leads to more effective and safer ablation

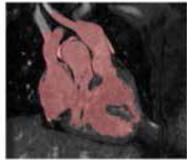


Model showing main cardiac structures including left ventricular wall thickness. These are used to guide the ablation procedure.

3D printing

Initial use for highly accurate surgical guides and true-to-life medical device prototypes

MR scan
of heart

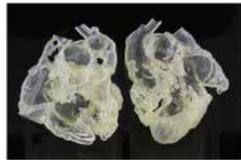


A

Image
Software

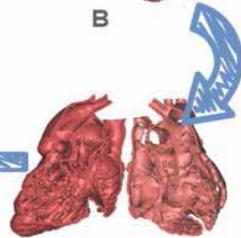


B



D

Print



C

Segment



**Other 3D technologies for
personalised implants, organs...**

Surgical Planning Example

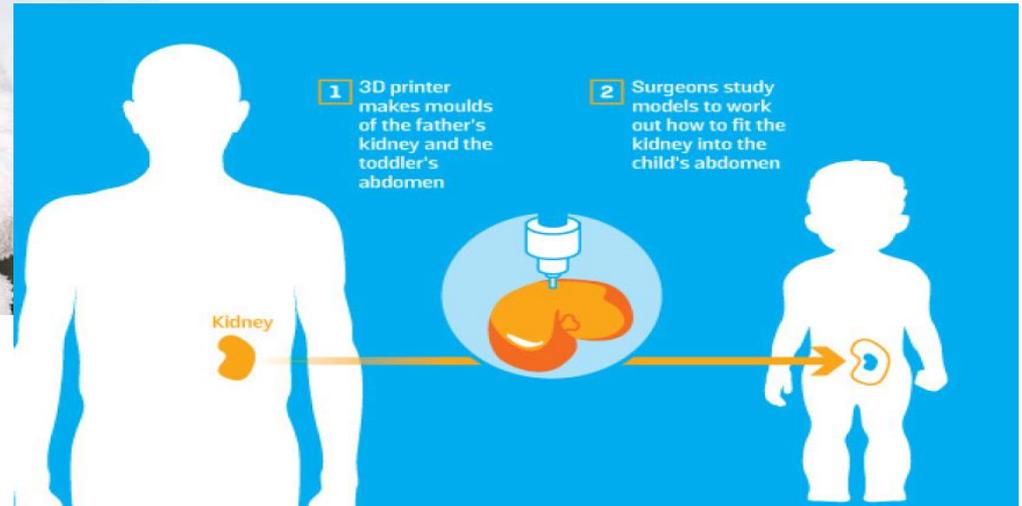
Surgeons' 3D prints give Lucy a new life

Sarah-Kate Templeton, Health Editor Published: 24 January 2016



Chris Boucher says he wondered how his kidney could fit inside daughter Lucy

**Pre-operative planning
makes more effective
use of time and skills**



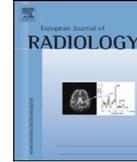
Imaging Genomics



Contents lists available at ScienceDirect

European Journal of Radiology

journal homepage: www.elsevier.com/locate/ejrad



Radiogenomics: Creating a link between molecular diagnostics and diagnostic imaging

Aaron M. Rutman^a, Michael D. Kuo^{a,b,*}

^a Department of Radiology, University of California San Diego Medical Center, San Diego, CA 92103, USA

^b Center for Translational Medical Systems, University of California San Diego Medical Center, San Diego, CA 92103, USA

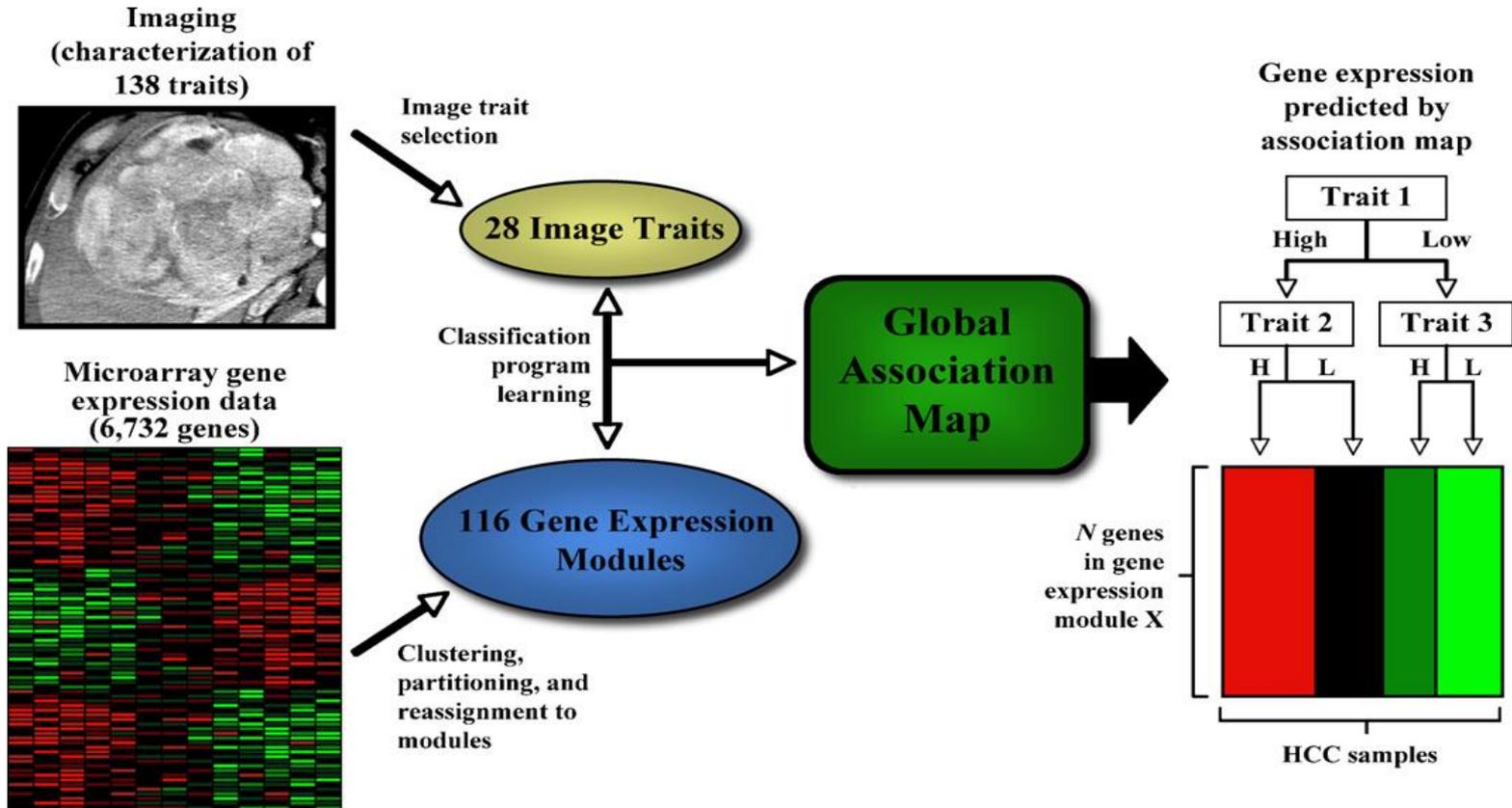
**nature
biotechnology**

Decoding global gene expression programs in liver cancer by noninvasive imaging

Eran Segal¹, Claude B. Sirlin², Chao Qiu⁴, Adam S. Adler⁵, Jeremy Gollub⁶, Xin Chen⁸, Bryan K. Chan², George R. Matcuk⁷, Christopher T. Barry³, Howard Y. Chang⁵ & Michael D. Kuo²



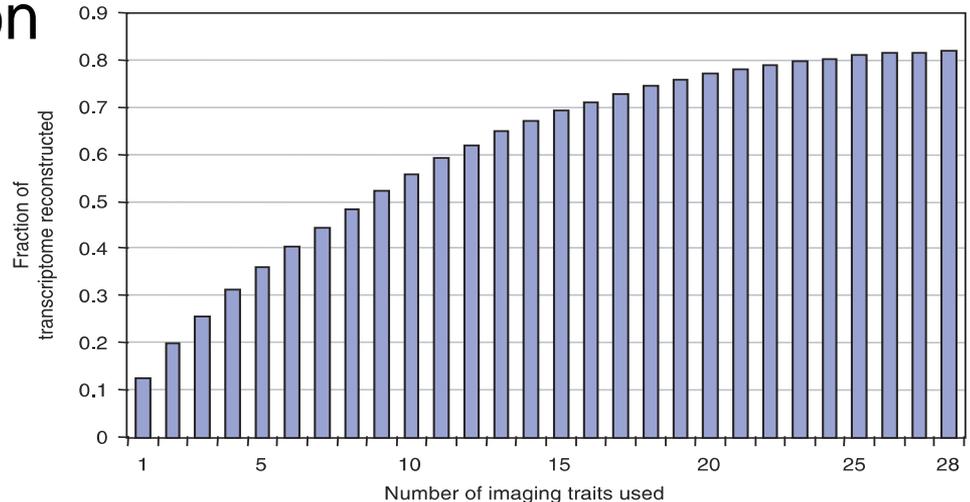
Linking imaging and gene expression data for primary liver tumors



Systematic relationship between imaging appearance and gene expression

- A large fraction of gene expression can be reconstructed from only a small number of imaging traits
- 9 traits account for 50% of tumour genetic variation
- For each gene, need on average three and no more than four traits to predict variation

Could reduce the need for invasive biopsies and use to monitor treatment progress



Technology



5. IT and 'Big Data'

Impact of Computing power

From dedicated models and **Expert Systems** trying to replicate human thinking...

.....to extracting evidence from massive data sets and machine learning...

Cognitive computing



Person AND machine > Person OR Machine

US Jeopardy game show 2011



Human



Human



IBM's Watson supercomputer

200 million digital pages
2,880 processors
80 teraflops

Computer

The power of predictive analytics

FEB 16, 2012 @ 11:02 AM 2,985,833 VIEWS

How Target Figured Out A Teen Girl Was Pregnant Before Her Father Did



Kashmir Hill, FORBES STAFF

Welcome to *The Not-So Private Parts* where technology & privacy collide [FULL BIO](#)

Every time you go shopping, you share intimate details about your consumption patterns with retailers. And many of those retailers are studying those details to figure out what you like, what you need, and which coupons are most likely to make you happy. [Target](#) TGT -2.28%, for example, has figured out how to data-mine its way into your womb, to figure out whether you have a baby on the way long before you need to start buying diapers.

Charles Duhigg outlines in the [New York Times](#) how Target tries to hook parents-to-be at that crucial moment before they turn into rampant — and loyal — buyers of all things pastel, plastic, and miniature. He talked to Target statistician Andrew Pole — before Target freaked out and cut off all communications — about the clues to a customer's impending bundle of joy. Target assigns every customer a Guest ID



TARGET

Target has got you in its aim



Watson Paths 2013 Cleveland Clinic

Integrating data and
inference to guide
complex diagnosis...

“When I look ahead into the era of cognitive computing, I see a revolution unfolding before my eyes. For the first time, computers will adapt to the way we want to do things, rather than vice versa. That will be a remarkable change.”

Michael Barborak, IBM Research



Scenario

Solution

“ A 73-year-old retired nurse...

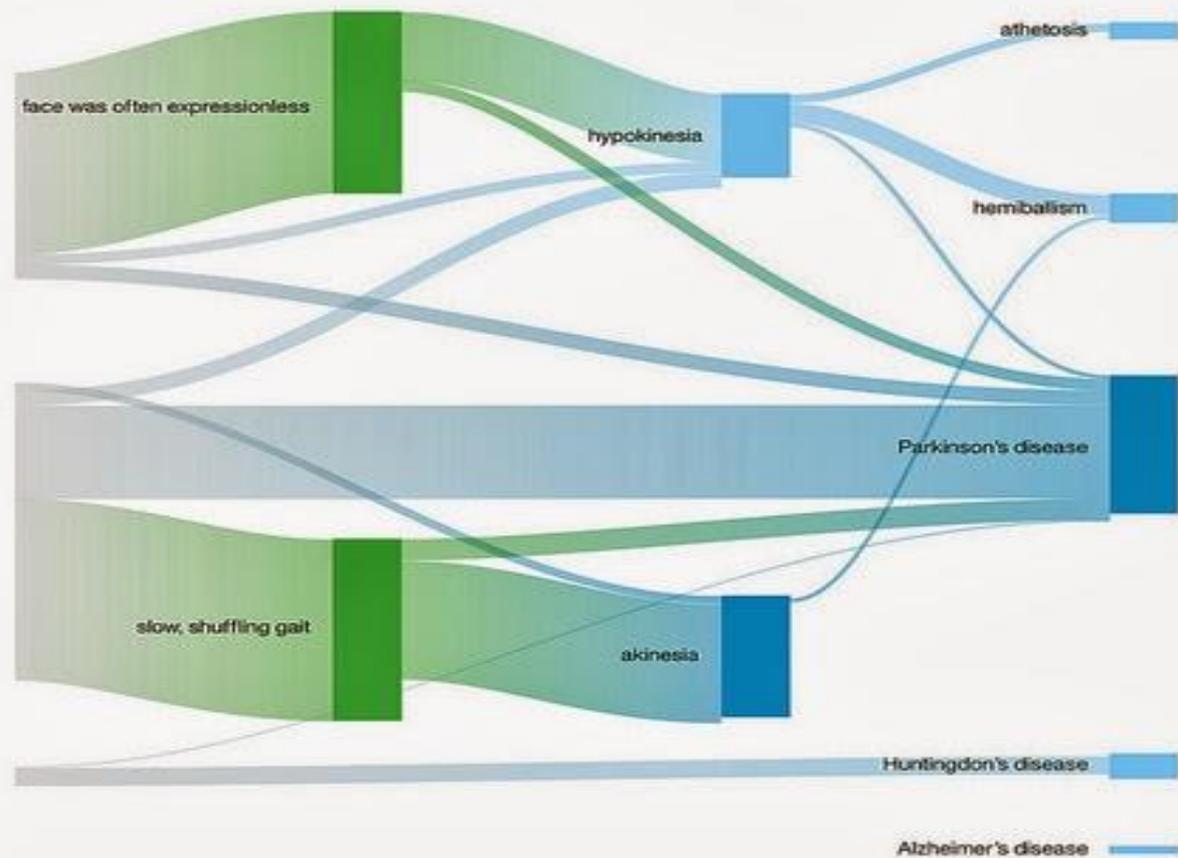
“ He now moved much more...

“ Upon examination, his phys...

“ Over the past several years,...

“ He immediately referred th...

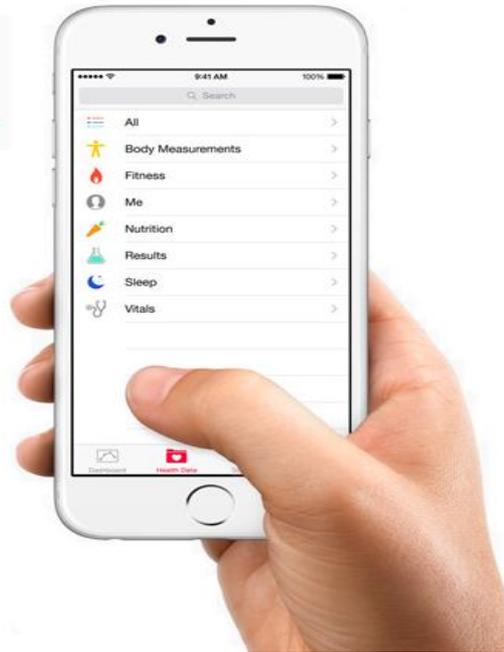
+ Add patient details



You're already carrying a powerful medical research tool.



ResearchKit



“What's unique about Apple's ResearchKit is that it works from the consumer-in. [An open source software framework], it empowers consumers rather than providers and in the process changes the healthcare research model.” March 2015

New algorithms and big data



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DeepMind Health

A dark blue background featuring medical equipment: a stethoscope, a smartphone displaying a patient record, and a medical device. The text 'CLINICIAN-LED TECHNOLOGY' is overlaid in white.

CLINICIAN-LED TECHNOLOGY

We are very excited to announce the launch of DeepMind Health

We founded DeepMind to solve intelligence and use it to make the world a better place by developing technologies that help address some of society's toughest challenges. It was clear to us that we should focus on healthcare because it's an area where we believe we can make a real difference to people's lives across the world.

We're starting in the UK, where the National Health Service is hugely important to our team. The NHS helped bring many of us into the world, and has looked after our loved ones when they've most needed help. We want to see the NHS thrive, and to ensure that its talented clinicians get the tools and support they need to continue providing world-class care.

What will doctors do when equipment and IT systems know more than they do?

Scientists and engineers will programme the new systems...

But will anyone know how they work?

And who is in control?



Technology



6. Putting it all together

Integrated diagnostic view

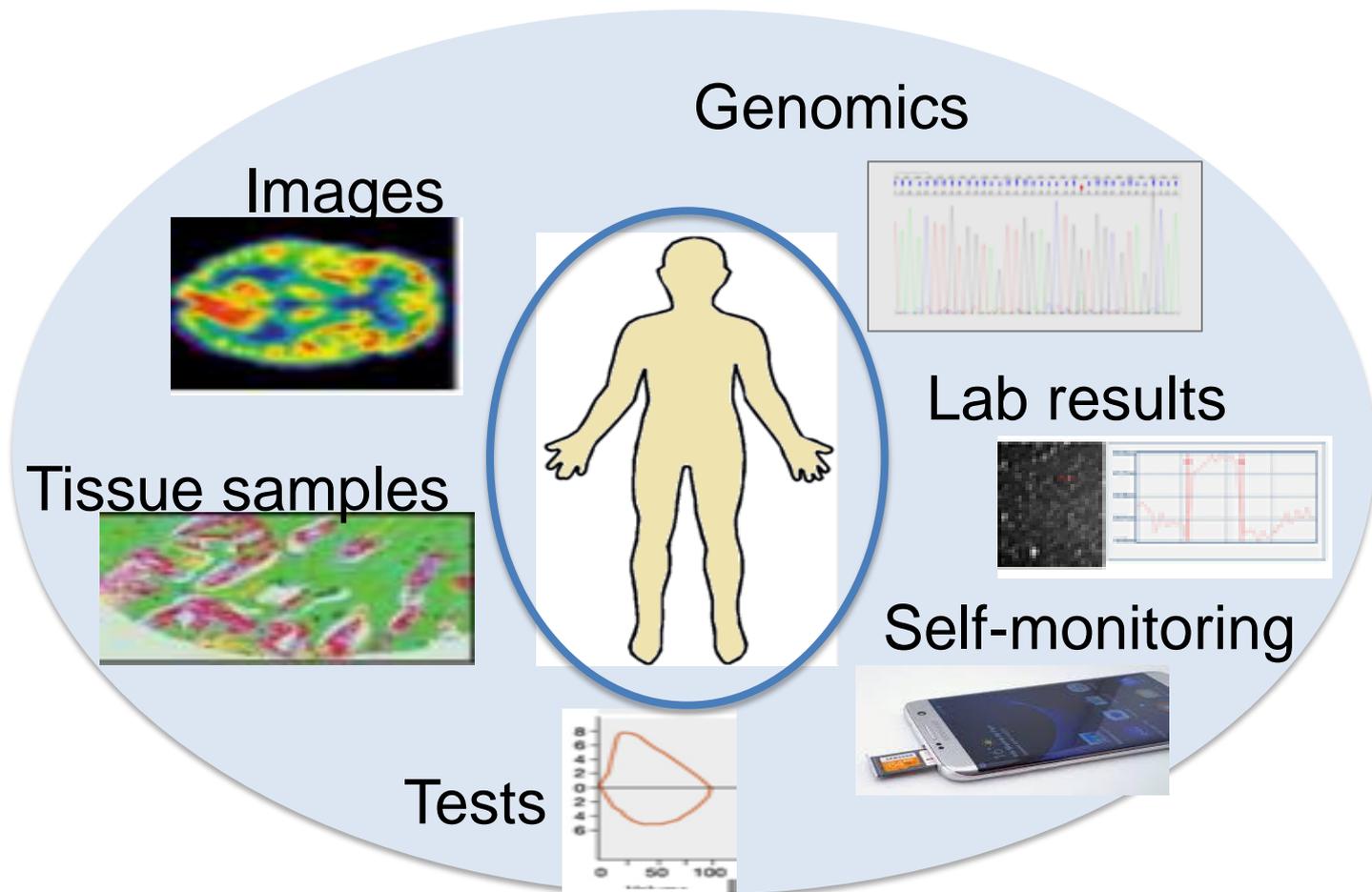
Individual
problem



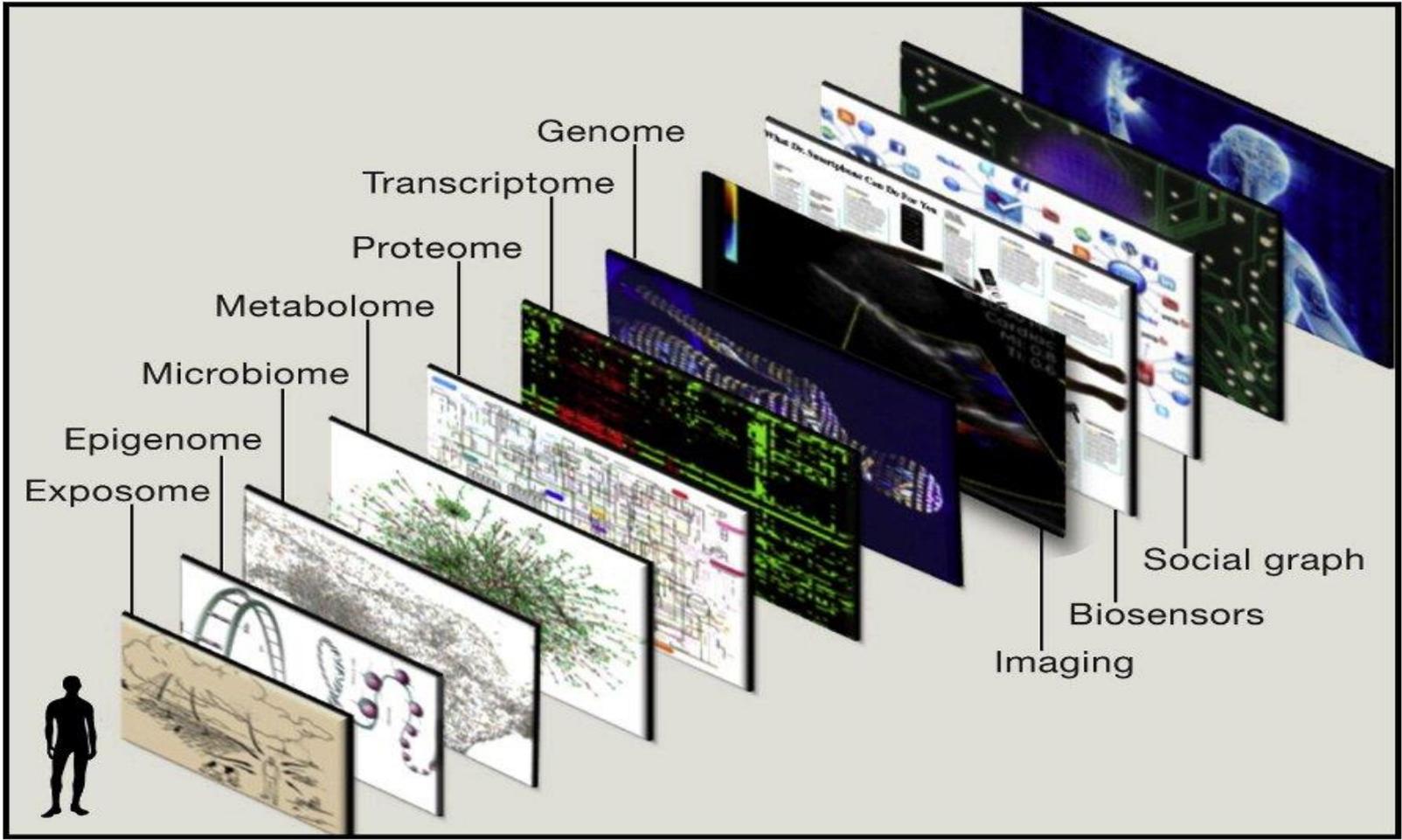
Person and
diagnosis:
genotype
to
phenotype



Targeted
treatment



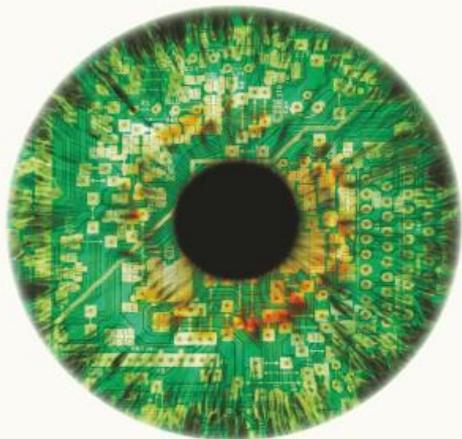
The Big Data Challenge – putting it all together





7. Behaviours, Expectations and Professional futures

RICHARD DANIEL
SUSSKIND SUSSKIND



THE FUTURE OF THE PROFESSIONS

HOW TECHNOLOGY WILL TRANSFORM
THE WORK OF HUMAN EXPERTS

The Creative Destruction of

MEDICINE



HOW THE DIGITAL REVOLUTION
WILL CREATE BETTER HEALTH CARE

ERIC TOPOL, M.D.

Behaviours: what connected humans do

- Communicate
- Research
- Share
- Co-operate
- Build Communities



Expectations: what connected humans want



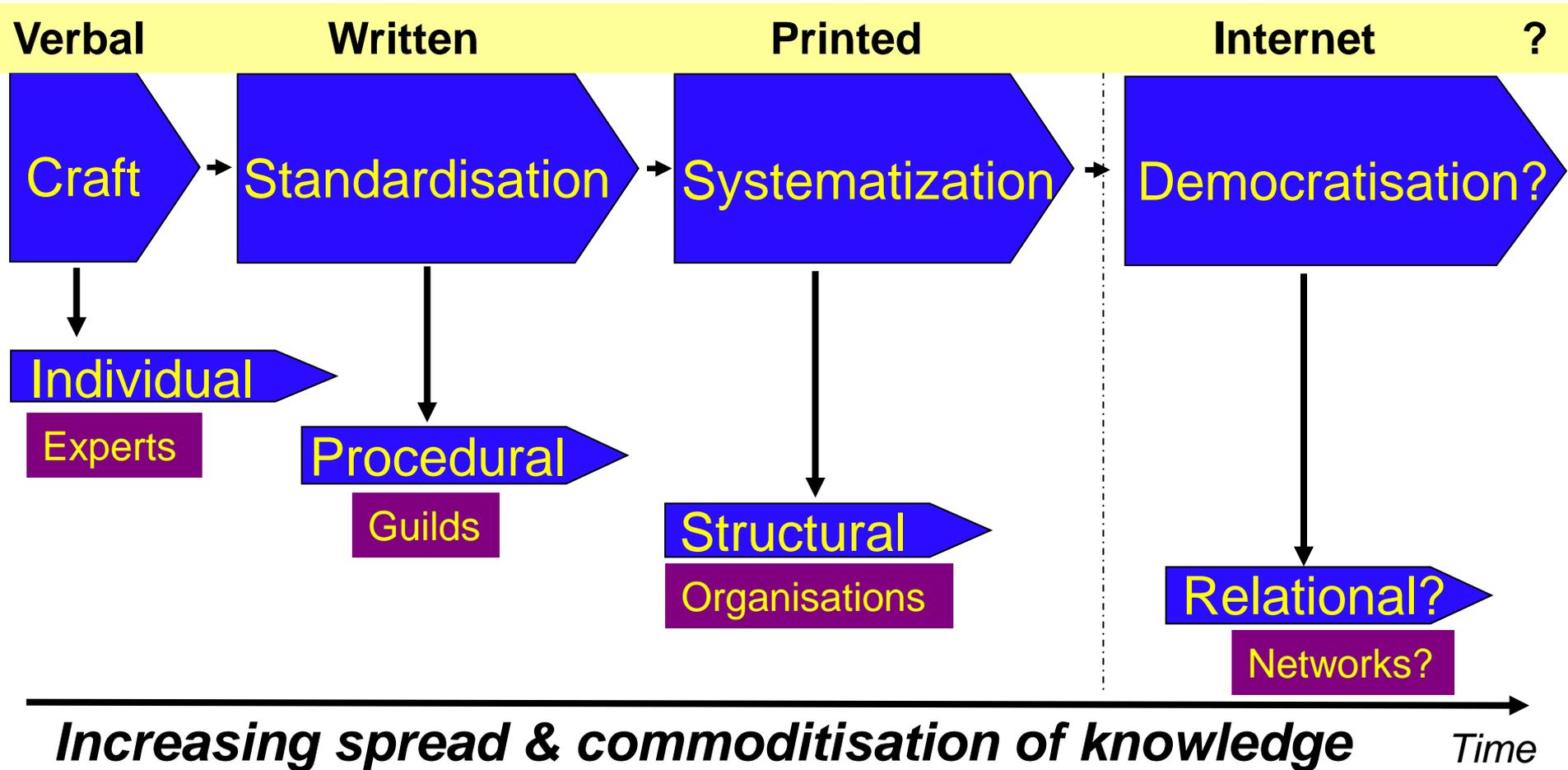
- Online help and access to knowledge
- Selection of the best expertise and techniques
- Personalisation and customisation of care
- Realisation of latent demand

Patterns and trends of change

- **The end of an era**
 - From reactive patients to proactive citizens
 - From treatment to improvement and prevention
 - The more-for-less challenge
- **Transformation by technology**
 - Smartphones and the internet
- **Demystification**
 - From exercise of a craft to operation of a system
 - Clarity of outcomes and effectiveness
- **Professional work reconfigured**
 - Routinised / Decomposed / Reallocated
 - New ways to access knowledge and care
 - New ways of working

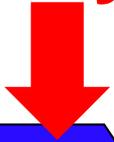


The evolution of professional knowledge



The evolution of professional knowledge

Medicine as a profession is very resistant to change...why?



Craft

Standardisation

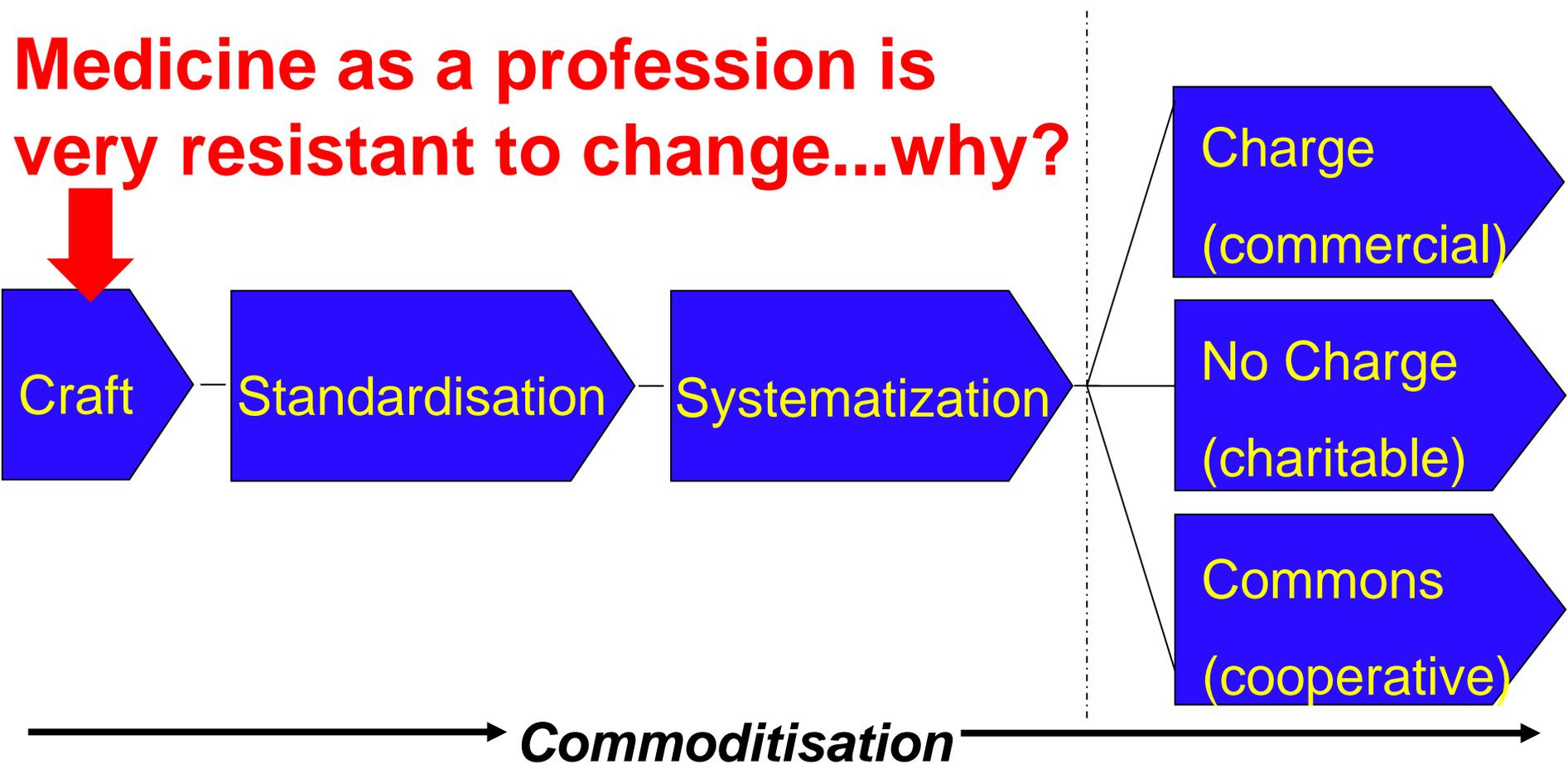
Systematization

Charge
(commercial)

No Charge
(charitable)

Commons
(cooperative)

Commoditisation



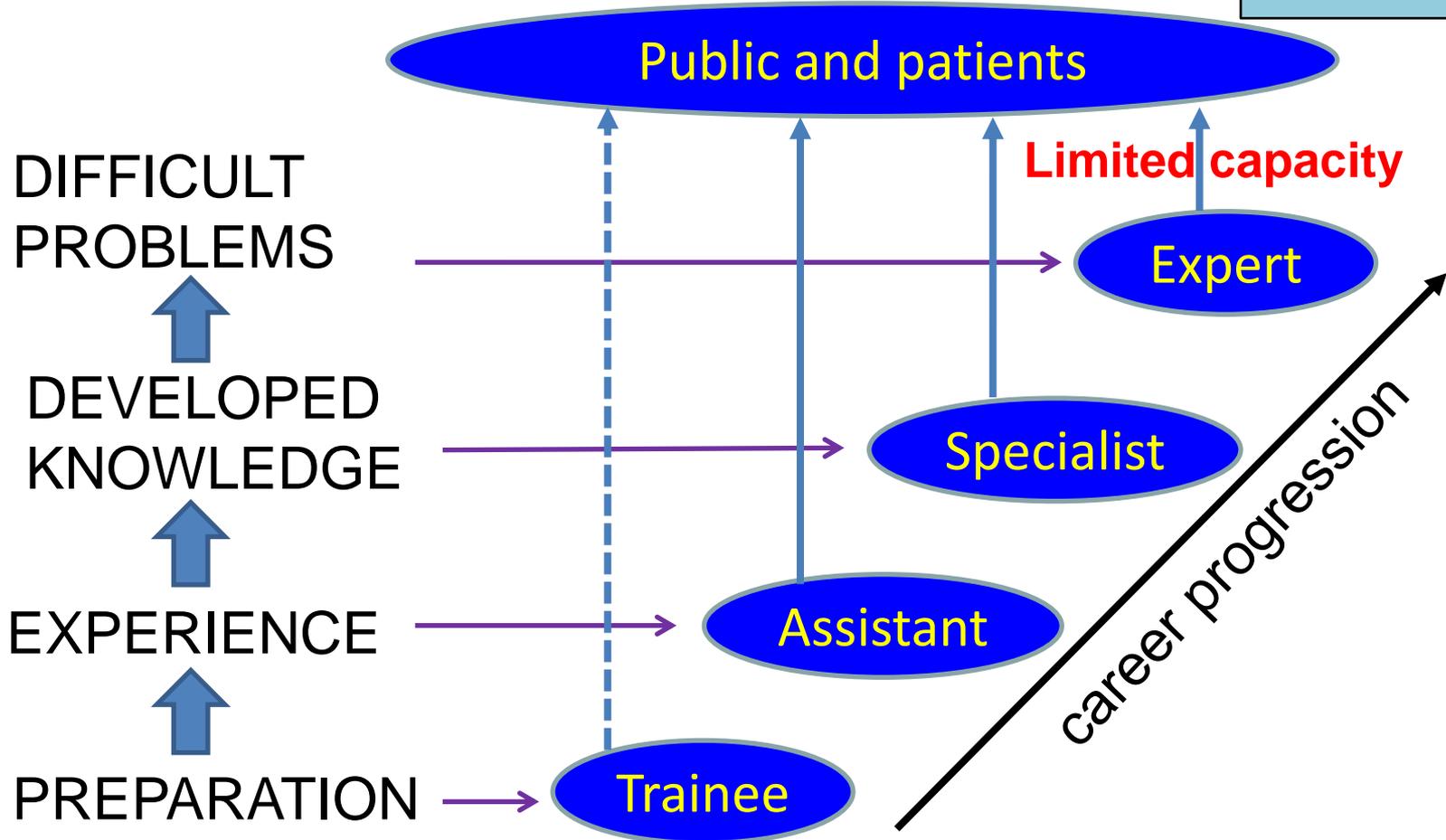
8. Changes by 2025 ?

**... in technologies and
roles**

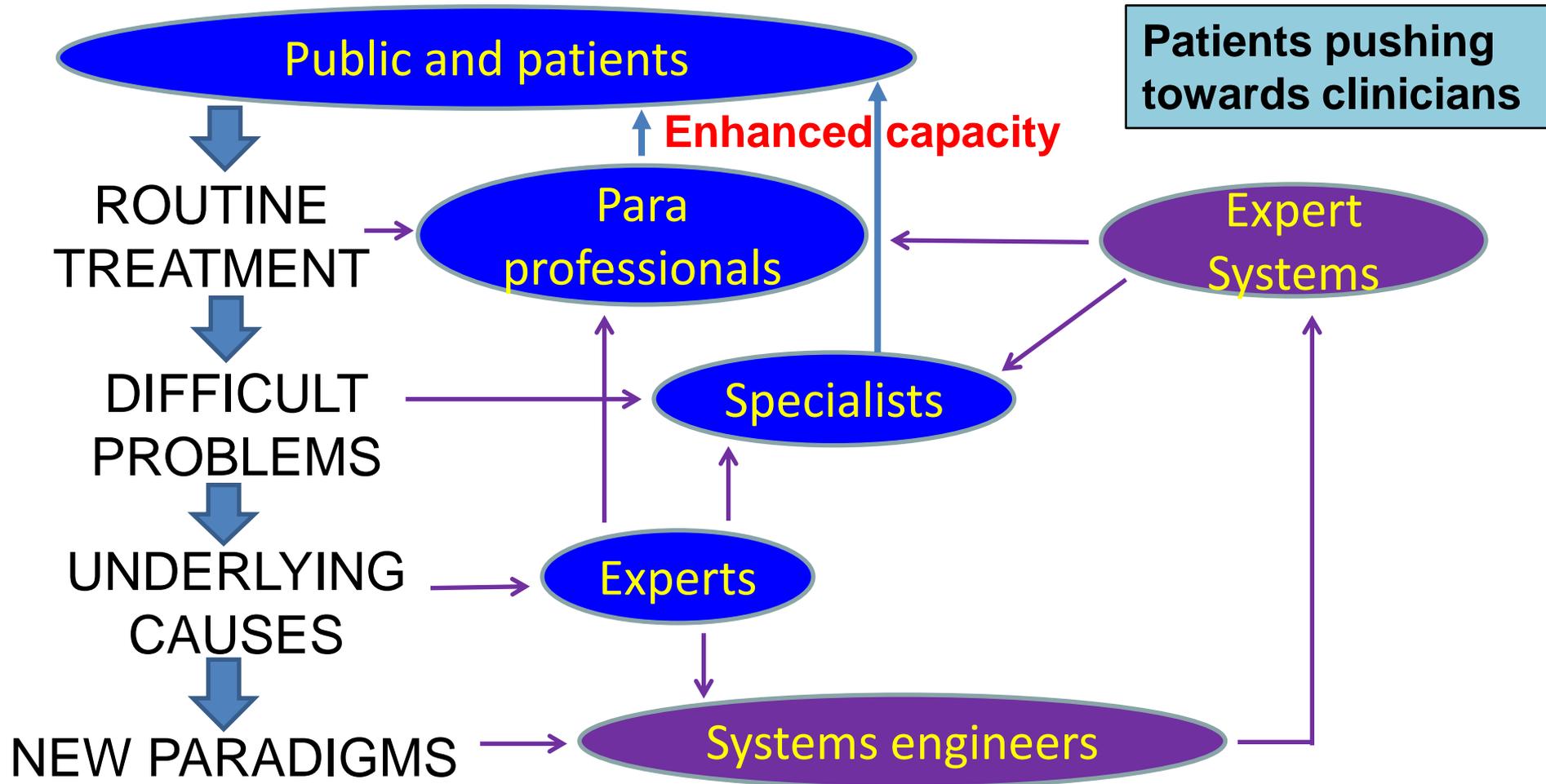


Professions and healthcare now...

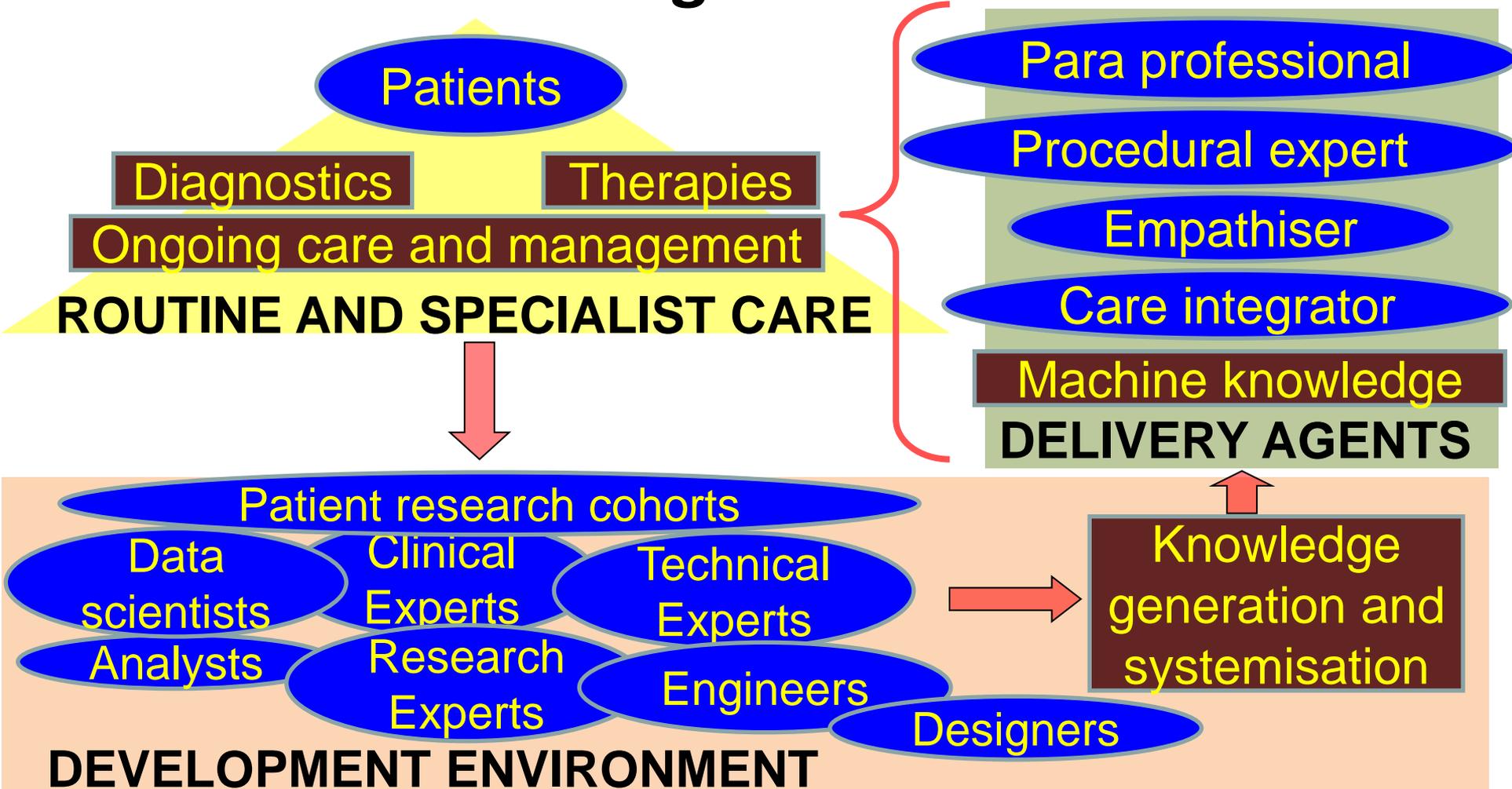
Care pushed towards patients



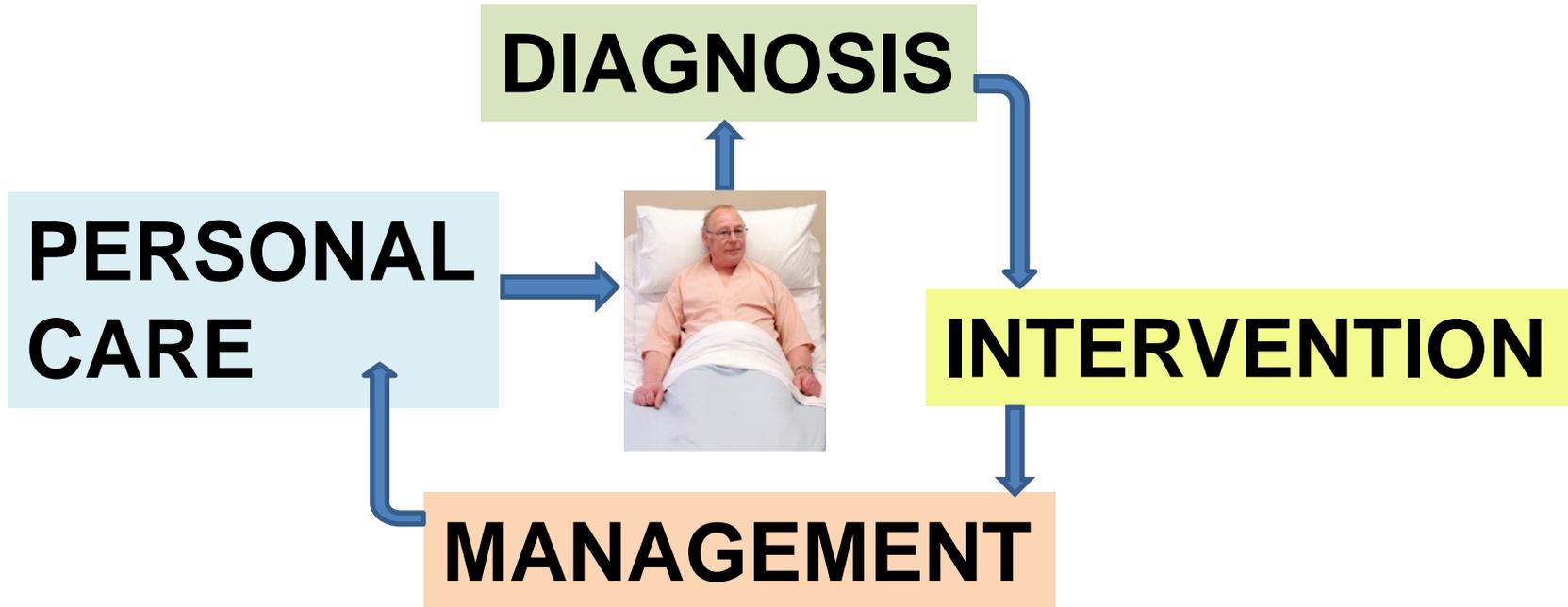
Professions and healthcare... in future



Future structuring of medical work ?



What goes on round the patient?



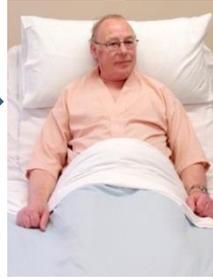
How does it improve?

1. Personalise care

2. Standardise procedures

DIAGNOSIS

PERSONAL CARE

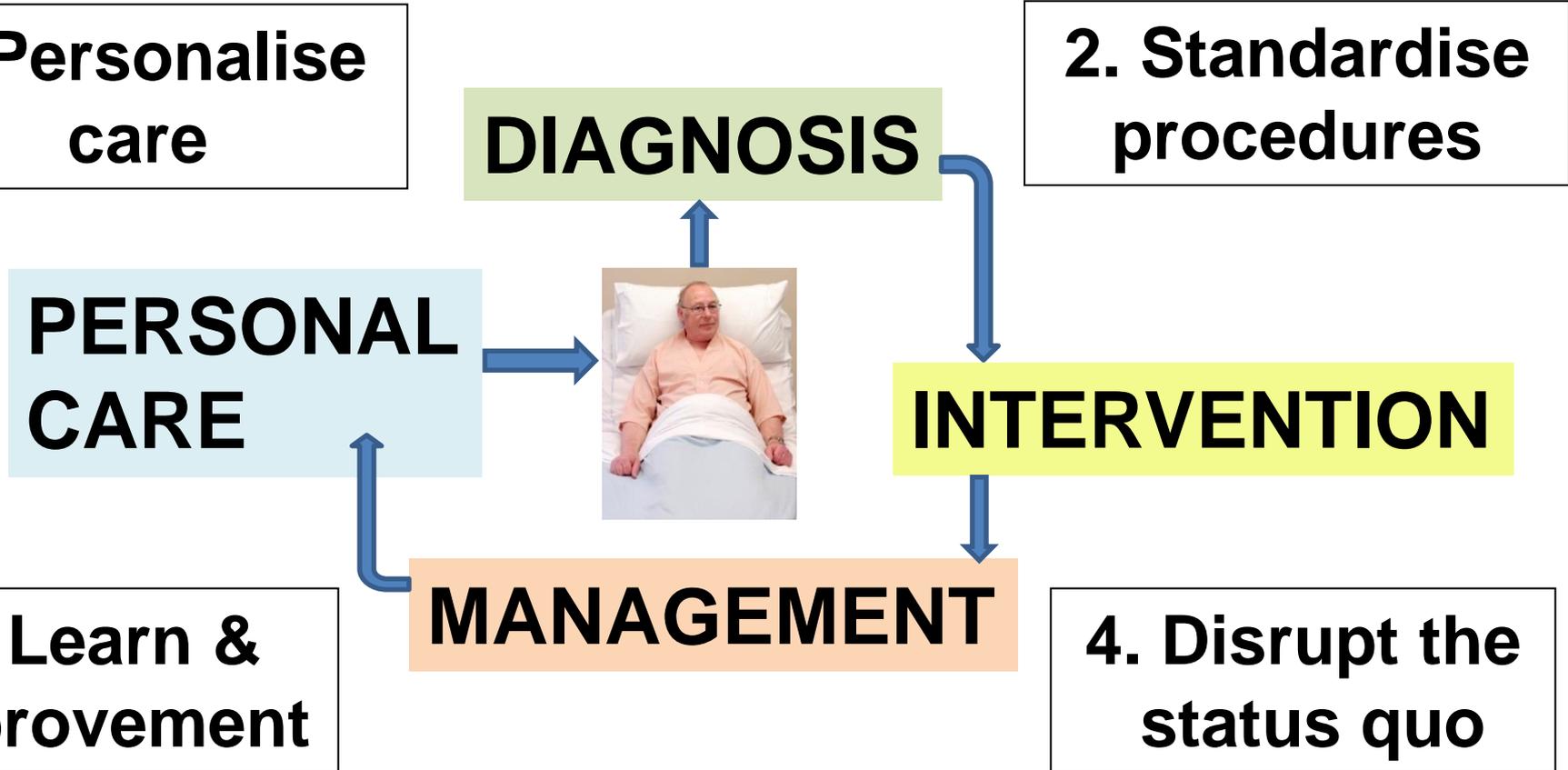


INTERVENTION

3. Learn & improvement

MANAGEMENT

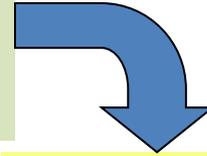
4. Disrupt the status quo



Who does it?



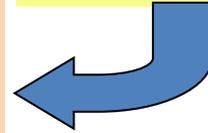
Expert diagnostic teams:
doctors, technicians, scientists



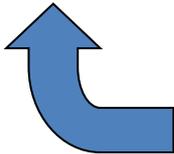
Personal carers:
nurses, therapists,
carers



Intervention experts:
doctors, technicians,
therapists, scientists



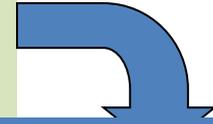
Management experts: doctors,
nurses, therapists, patients



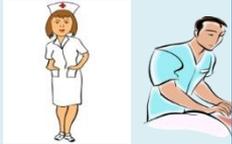
Who does it?



Expert diagnostic teams:
doctors, technicians, scientists



Supported by.....



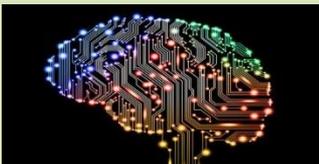
Personal
nurses, the
carers



erts:
ans,
ists

management experts, doctors,
nurses, therapists, patients

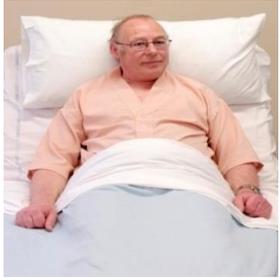
What supports it?



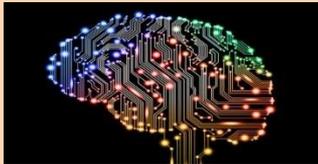
Diagnostic Expert systems



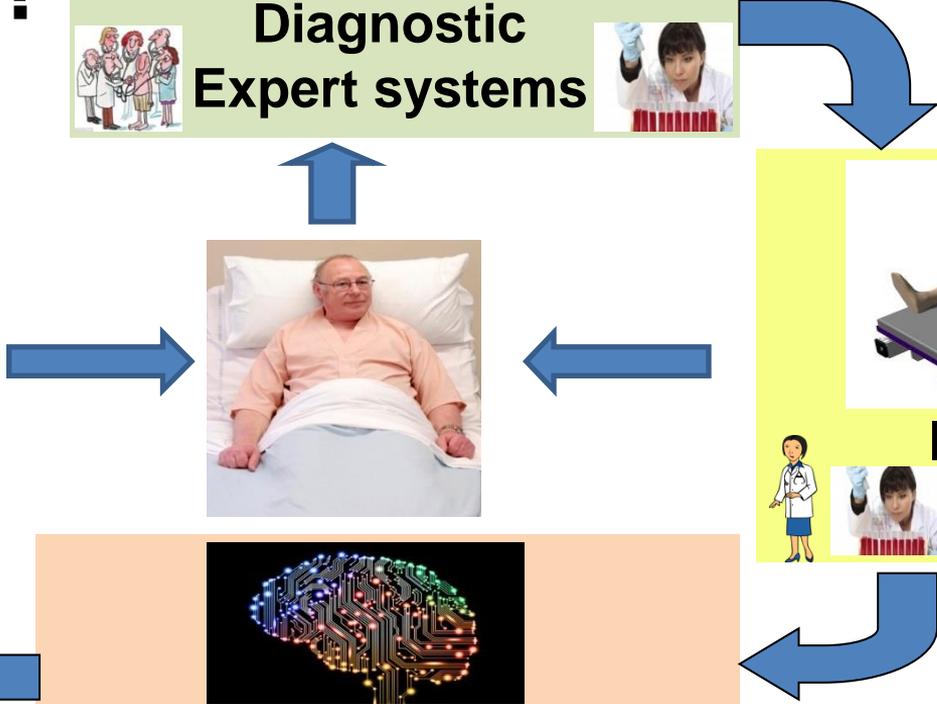
Rehabilitation robotics



Intervention robotics



Management Expert systems

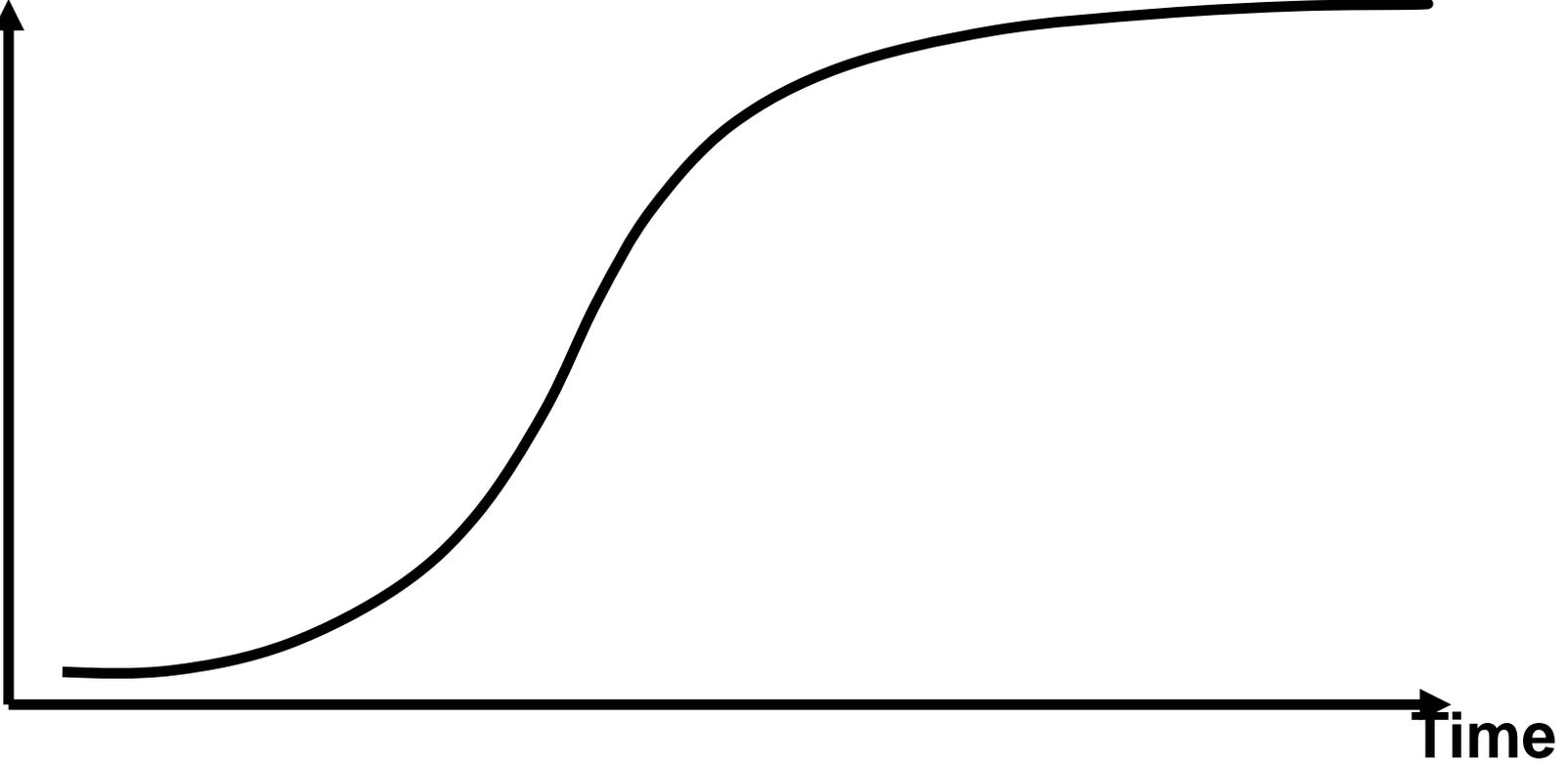




9. Some implications for NHS investment

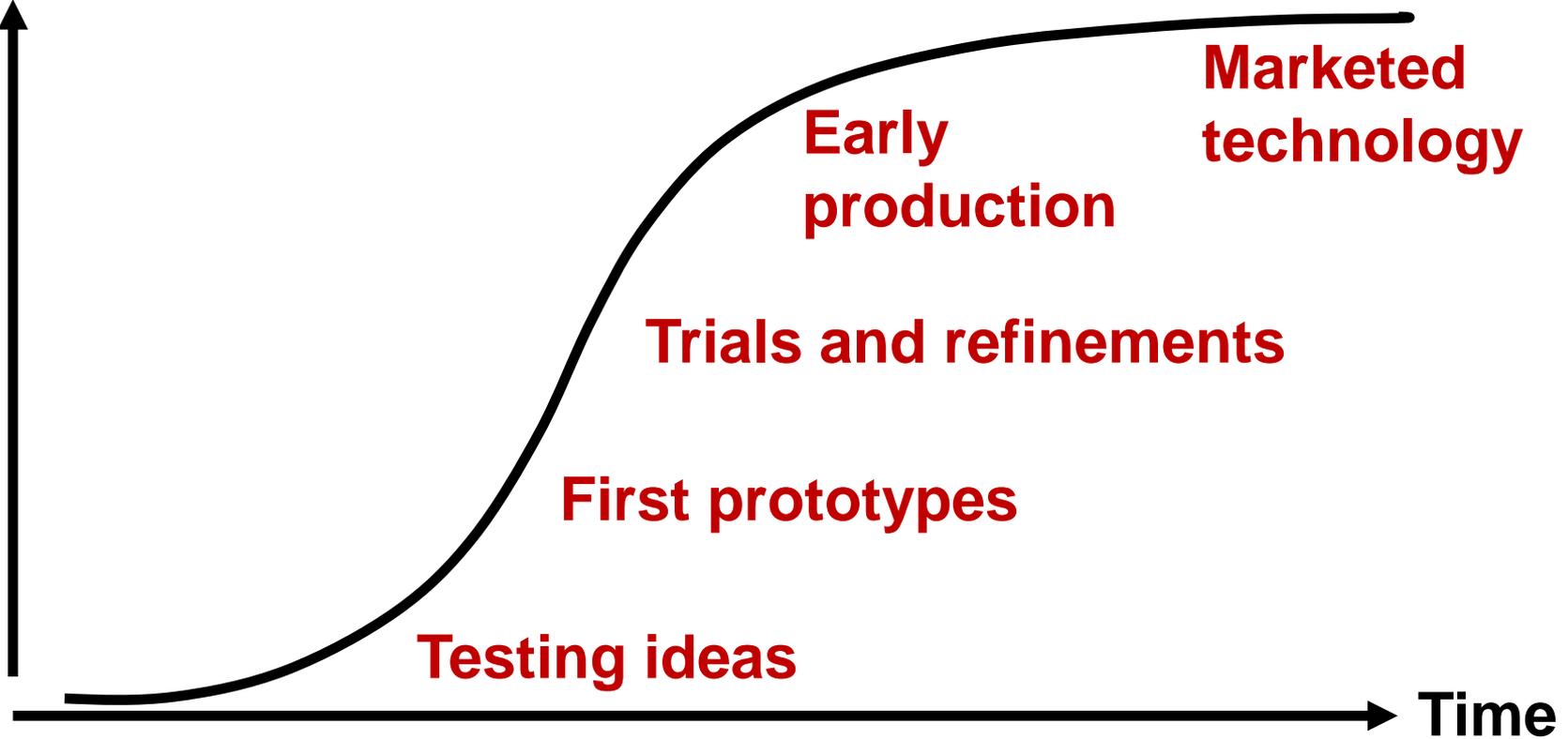
Innovation: the 'S' curve

Development
and Take Up
rate

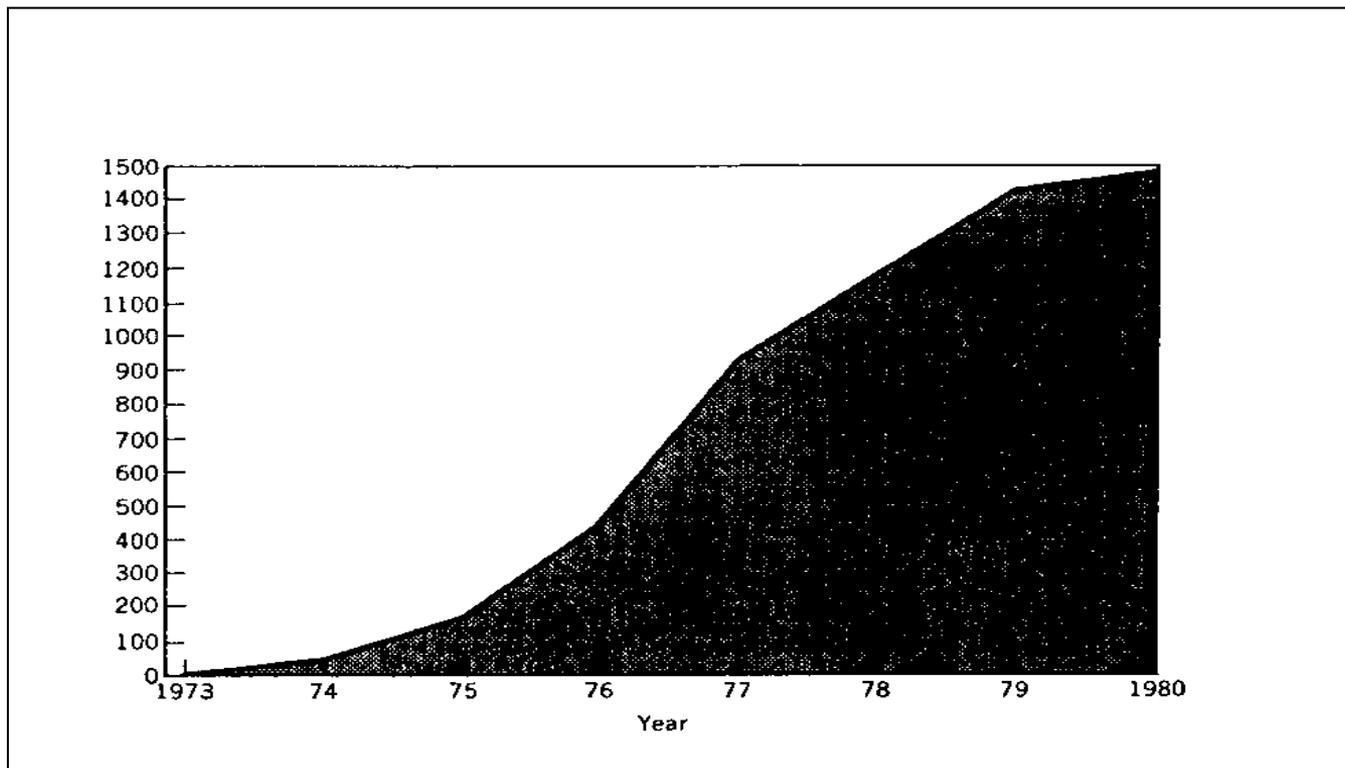


Innovation: the 'S' curve

Development
rate

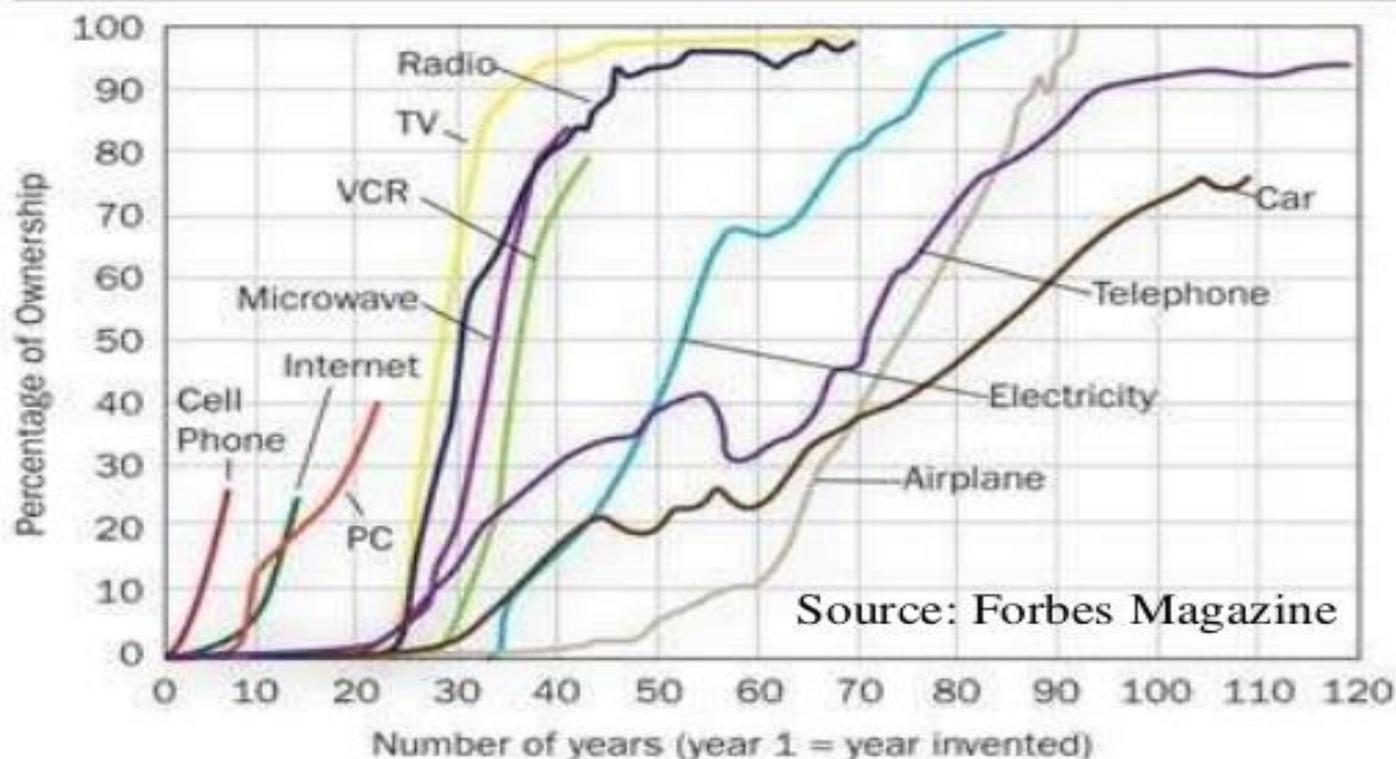


Number of CT scanners installed in the US between 1973 and 1980



Speed of Adoption

Technology Adoption



Investment example: patient monitors

When to invest?

Take Up
rate

Laggards

Late
adopters

Early
adopters

Pioneers



MD09X
ECG · SpO2 · PR · NIBP · RESP

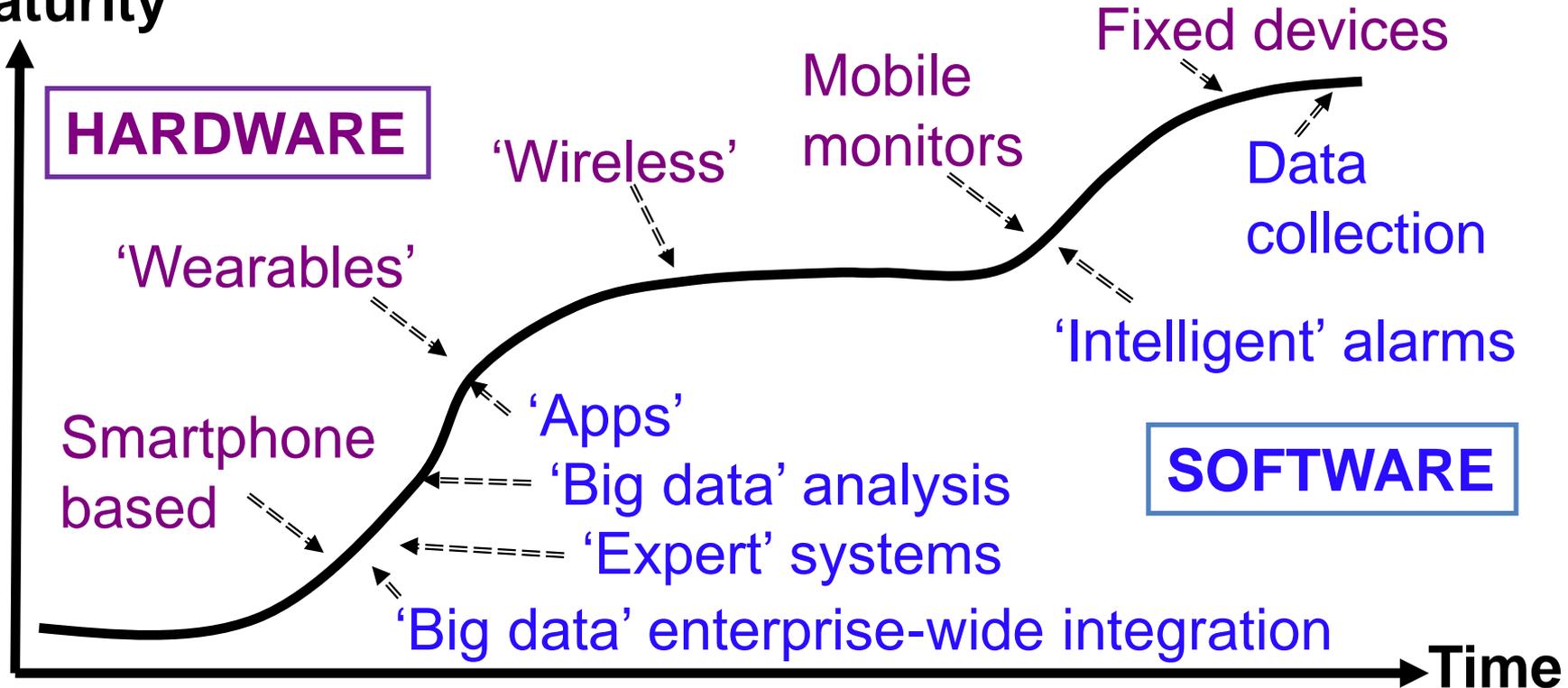


Time

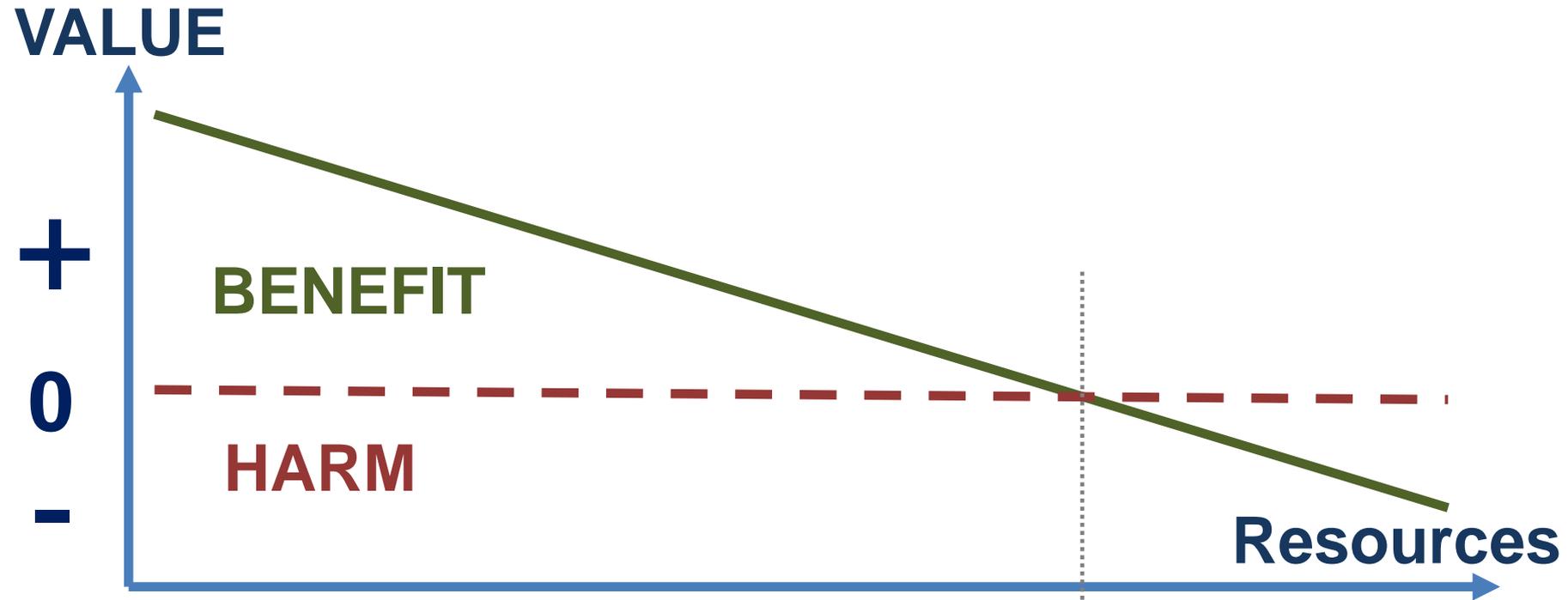
Innovation: patient monitoring

What to invest in?

Development
maturity

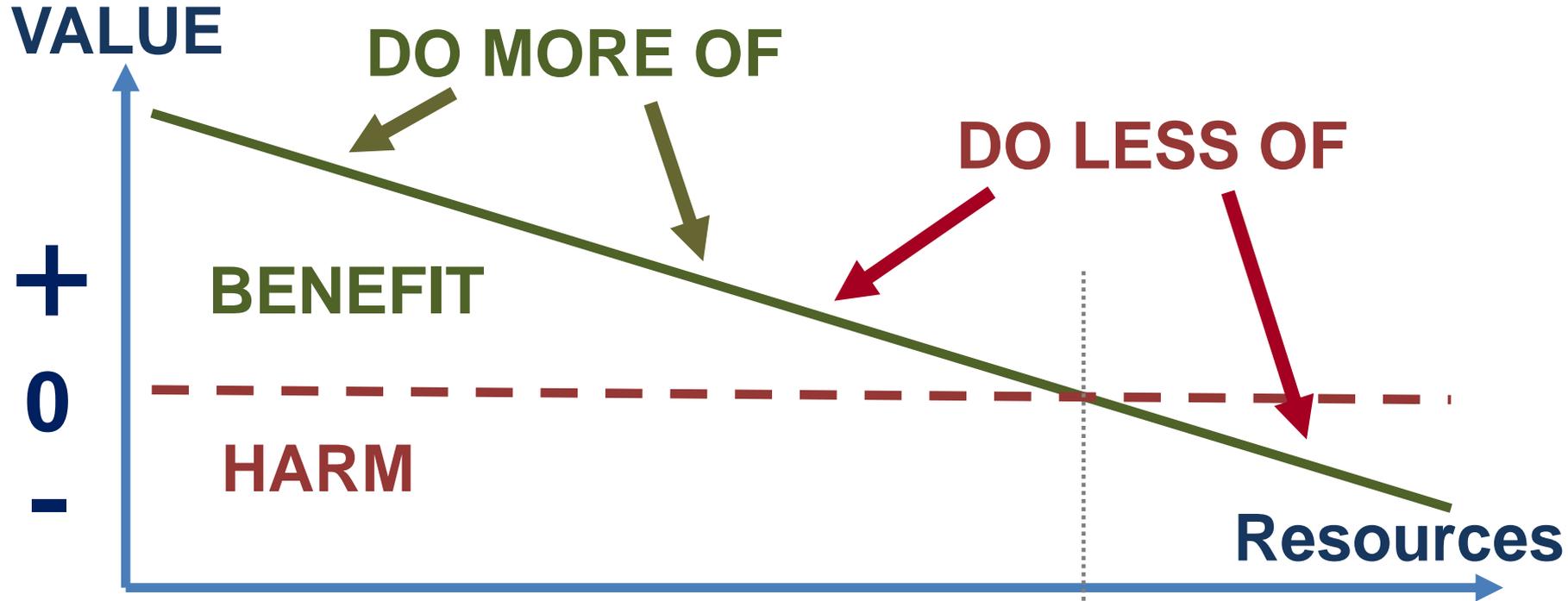


Measure balance of benefit and harm for each procedure, each patient and every population



CLINICAL:	Necessary	Appropriate	Inappropriate	Futile
ECONOMIC:	High	Low	Zero	Negative

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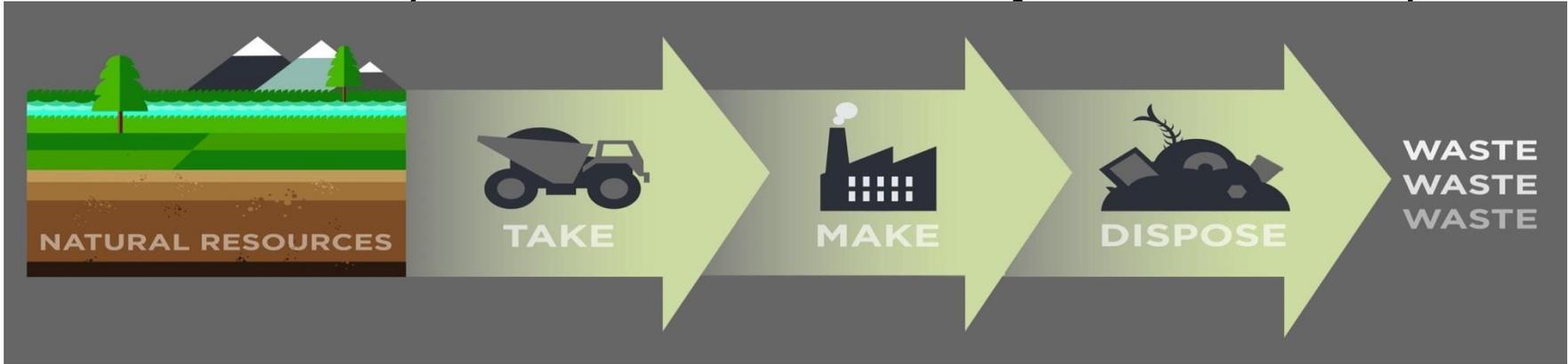
10. Some implications for future jobs

What will happen to jobs?



Current business is based on a Linear Economy

Linear economy is a **'take-make-dispose'** economy:



Take; get raw materials from the planet's natural resources

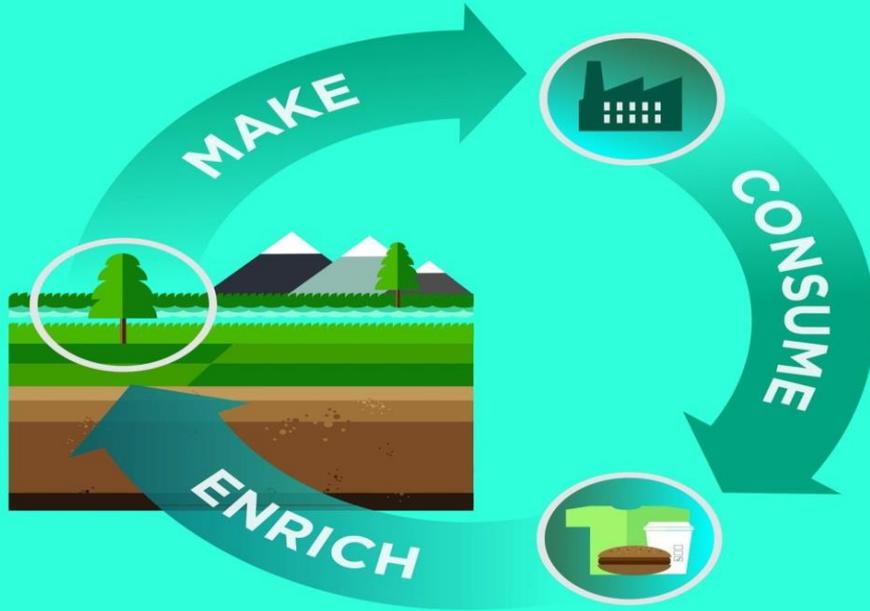
Make; create products to consume and use

Dispose; throw away the waste generated

Current recovery of consumer goods:

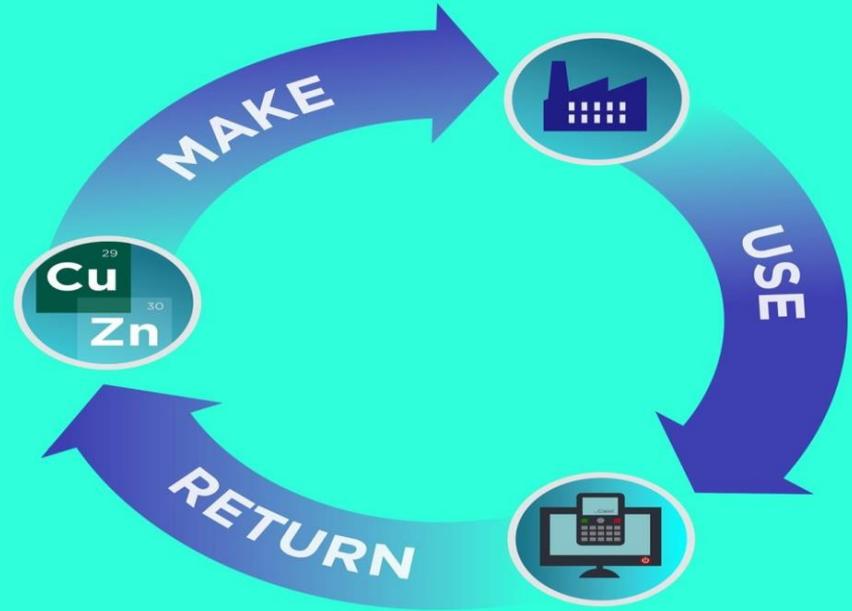
- **2% Recovered for reuse**
- **18% Recovered for decomposition**
- **80% not recovered**

The Circular Economy builds and retains value



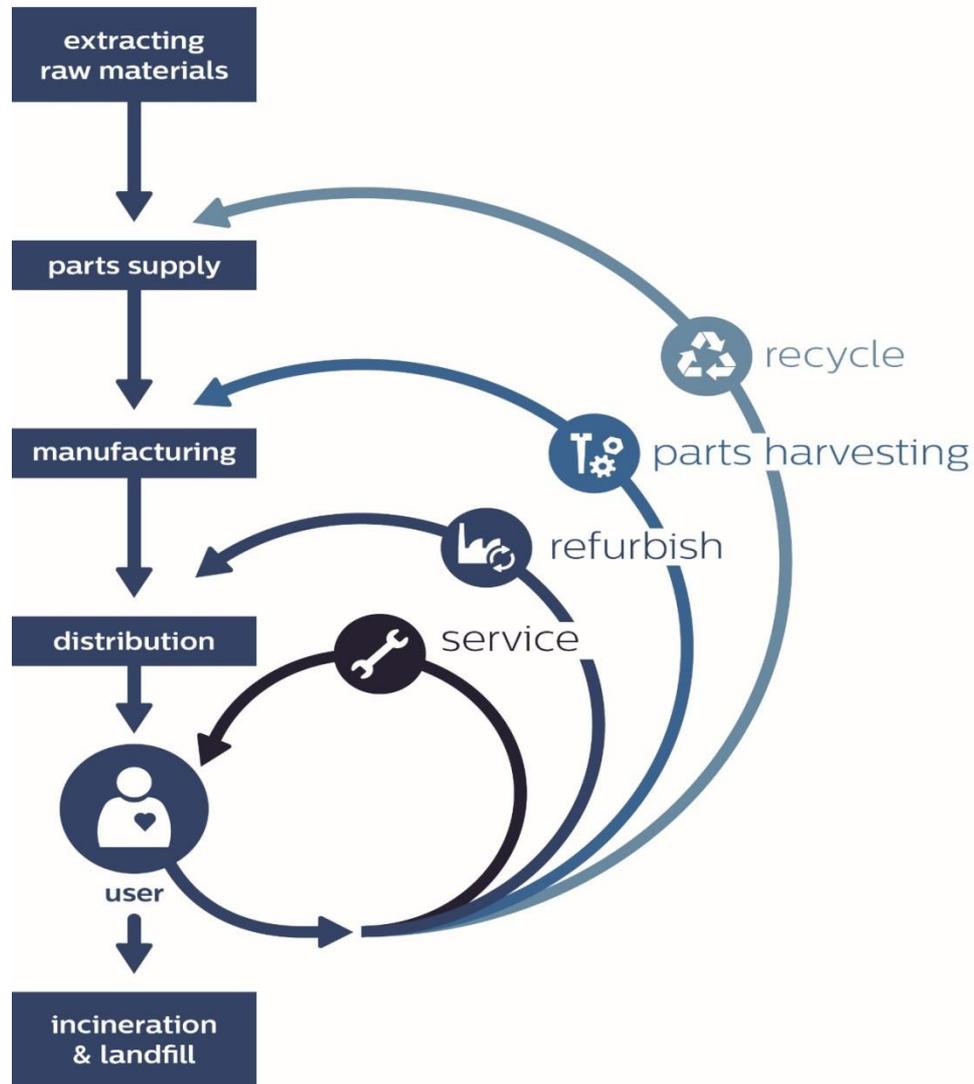
BIOLOGICAL MATERIALS

ENERGY FROM RENEWABLE SOURCES



TECHNICAL MATERIALS

- Refurbish
- Remanufacture
- Parts harvesting
- Materials collection & reuse



the circular economy

Enablers



Design



New Business Models



Collaboration



Reverse Logistics



PHONEBLOKS

A PHONE WORTH KEEPING

What will happen to jobs?

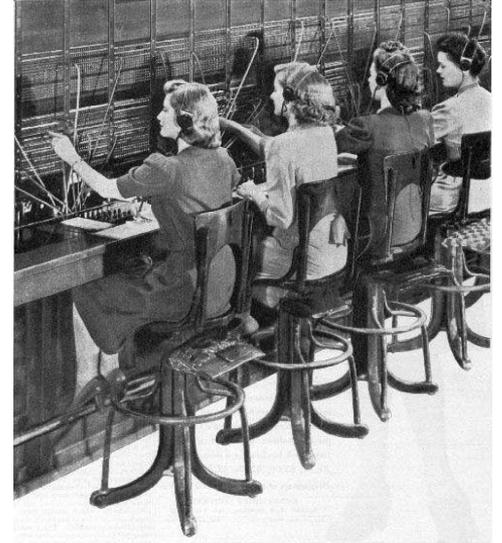
EXAMPLE: Switchboard operators

120,000 working for the Post Office
pre-automation, none afterwards

Where are these jobs now?

- Supporting telephone networks
- Making phones
- Selling mobile phones and services

Overall, more people than ever are
employed in this sector...



What will happen to jobs?

EXAMPLE: Self driving vehicles

- 750,000 drivers currently working in the UK
- There could be none in 20 years time
- Fewer vehicles needed – 20h operating day

Implications:

- Fewer manufacturing jobs
- No taxi drivers
- No parking attendants



Could remove 5 to 10% of jobs from the workforce

What will happen to jobs?

Strategy Directors...

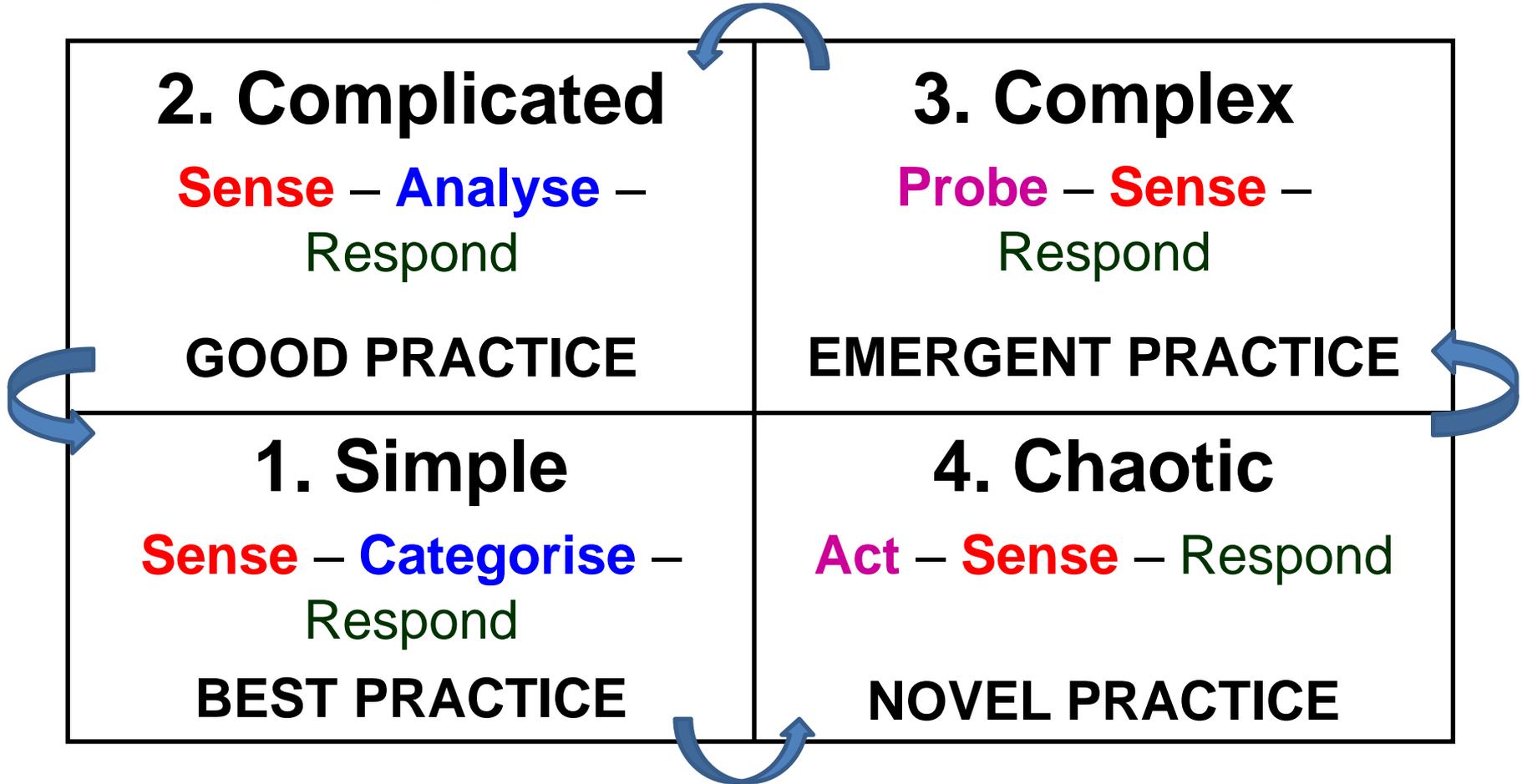
- More uncertainty
- Better technology forecasting
- Targeted investment
- Listen to patients and workforce
- Use systems thinking approaches

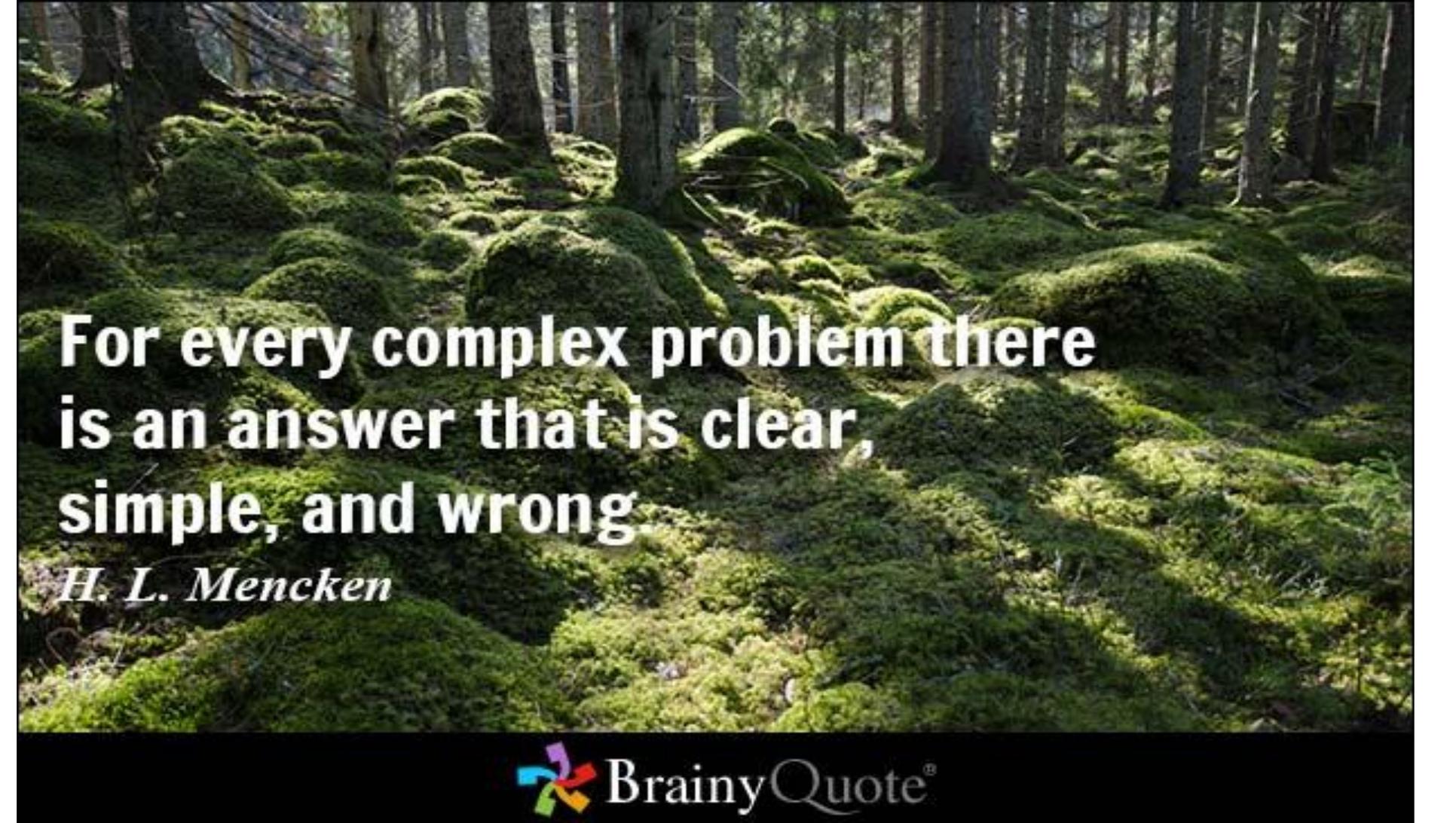


Key question:

- What is going to add value in the future?

Four categories of system behaviour





**For every complex problem there
is an answer that is clear,
simple, and wrong**

H. L. Mencken

Finally, some tactics to consider:

- Develop focus on rare conditions and domains of expertise
- Link research with knowledge generation & support systems
- Horizon scanning essential before making investments
- Investment and procedures guided by value analysis
- Standardise rigorously on best practice
- Radical changes coming in workforce roles and numbers
- Patient involvement will be demanded if not provided

Understanding impact of science and technology will be central to future success

