



Rigshospitalet



PERSIMUNE
CENTRE OF EXCELLENCE FOR PERSONALISED MEDICINE
OF INFECTIOUS COMPLICATIONS IN IMMUNE DEFICIENCY



Integration of services in the personalized medicine agenda: integrating disease areas and settings

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Personalised medicine in testing & linkage to care for HepHIV

- HIV and viral hepatitis rare conditions in the population
- Significant “room for improvement” for testing strategies compared with status quo
- Linkage to care / drop-outs among linked
 - different sections of health system working together

Addressable questions

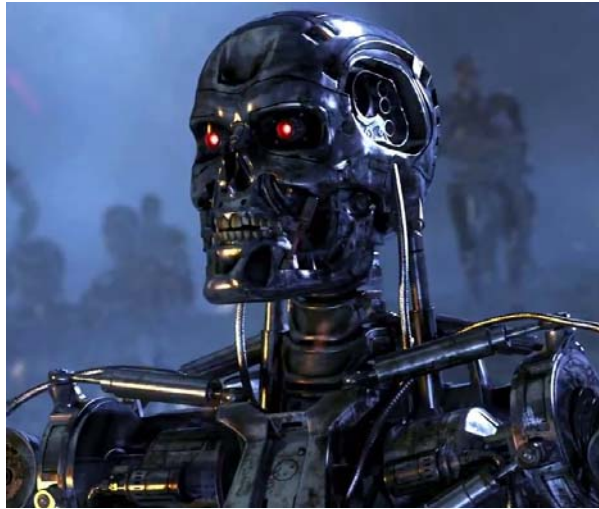
- Guidance of testing strategies so detection rate is optimised ?
- Lack of linkage to care / drop-outs from care – who are at risk ?
- What are potential benefits and harm from using modern computer science in answering these questions ?

COMPUTER SCIENCE:

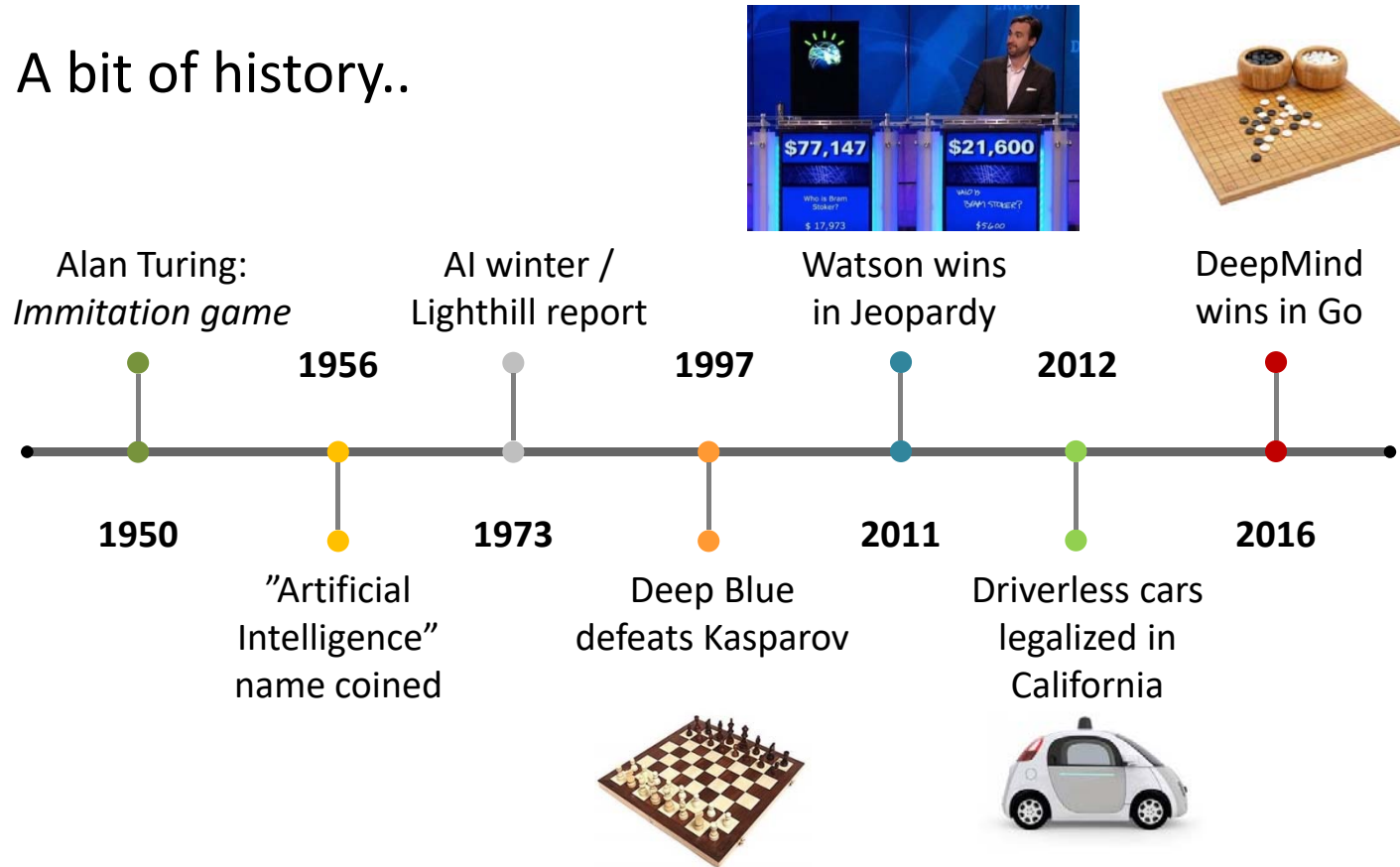
**1. STORE AND RETRIEVE – HUMAN
DIRECTED ANALYSIS**

2. THINK – ARTIFICIAL INTELLIGENCE

Artificial intelligence: When a machine mimics a human mind for problem solving or learning a task



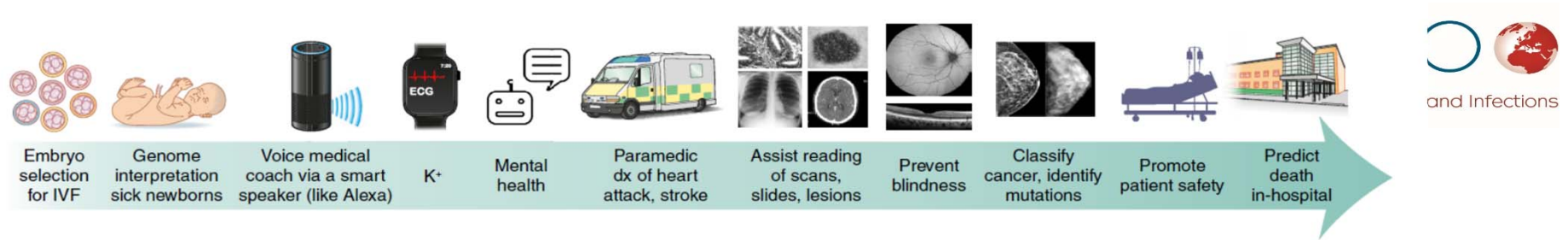
A bit of history..



MEDICAL AI WILL BE PART OF THE FUTURE HEALTH SYSTEM INFRASTRUCTURE

**1. IT CAN RESOLVE SOME HUMAN TASKS AS WELL AS
HUMANS**

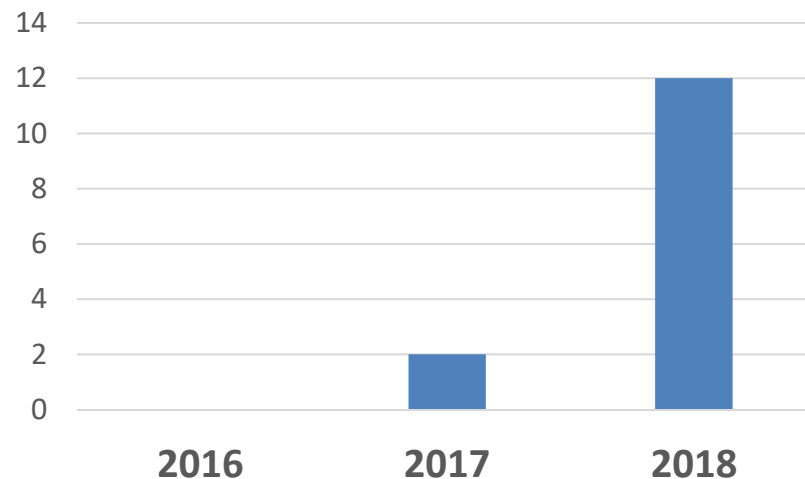
**2. THE VOLUME OF DATA GENERATED IN HEALTH SYSTEM IS
INCREASING EXPONENTIALLY – EXCEED HUMAN BRAIN
CAPACITY**



AI vs doctor – current state

- CT: acute neurological events, metastatic lung nodules, mammography
- Pathology – brain, breast and lung cancer
- Dermatology: skin cancer
- Ophthalmology: diabetes, retinal disease, macular degeneration
- Gastroenterology: polyps and colonoscopy
- Cardiology: Echocardiography

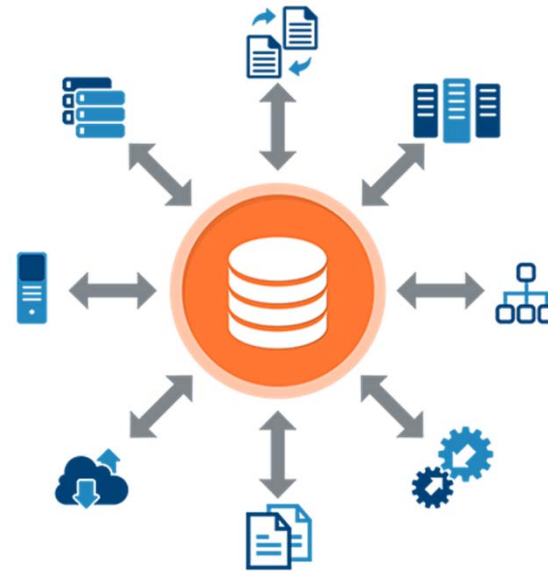
of FDA approved AI (including 3Q2018)



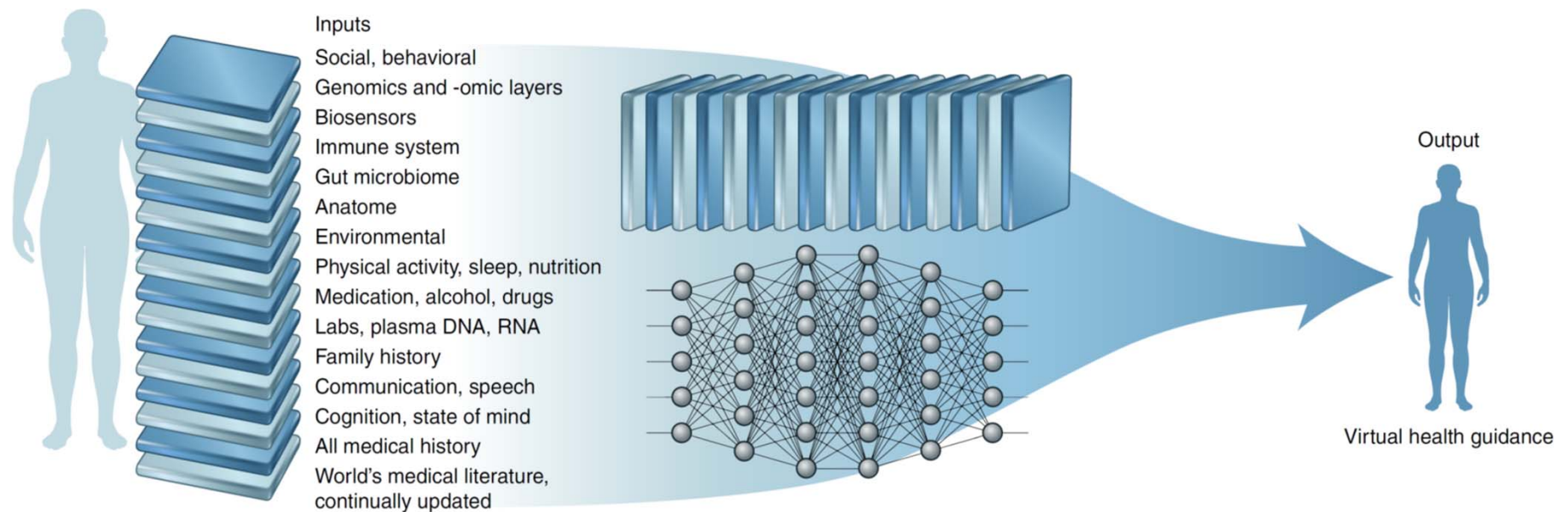
Topol. Nature Med 2019

Requires: Algorithms and a Data Lake

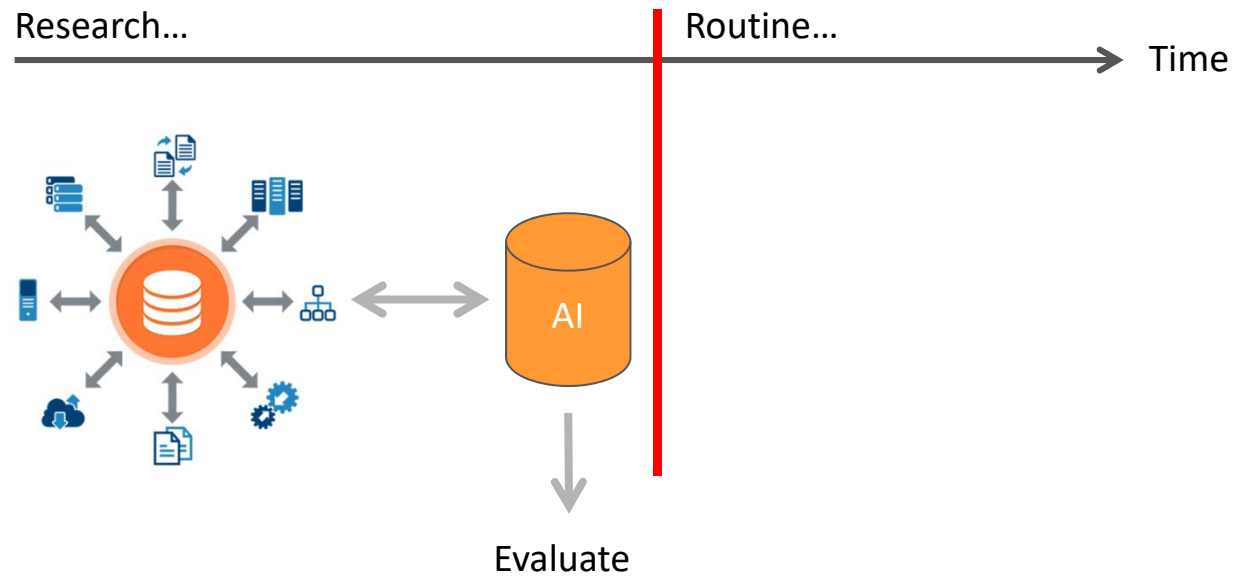
- Algorithm
 - Specifications on task to resolve
- Data-lake
 - Real-time, original, relevant data
 - Algorithm trained
 - A matrix is derived
 - Performance assessed
- Satisfactory
 - Algorithm can run "online"
 - On same datalake or
 - Other datalakes



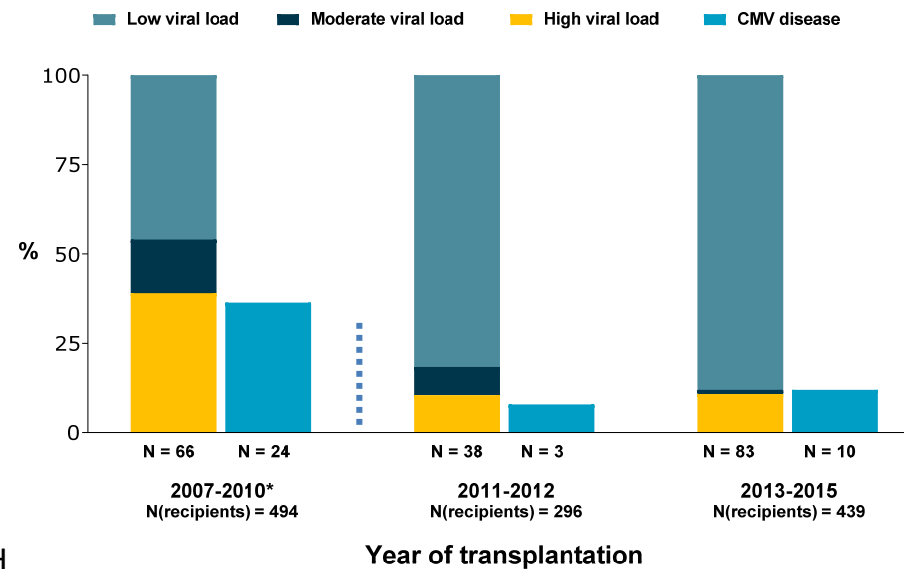
Virtual health advice – multiple data model inputs



Artificial intelligence in healthcare: development of "clinical applications"



CMV infection/disease in non-lung solid organ transplant recipients: before and after MATCH program*



Trent:

$$P_{\text{disease}} < 0.001$$

$$P_{\text{viral load}} < 0.001$$

Among those transplanted, risk of CMV disease also decreased over time ($P=0.005$)

--- MATCH started

*Due to inadequate data in the medical records we were unable to assess CMV disease in four patients with CMV infection in this time period.

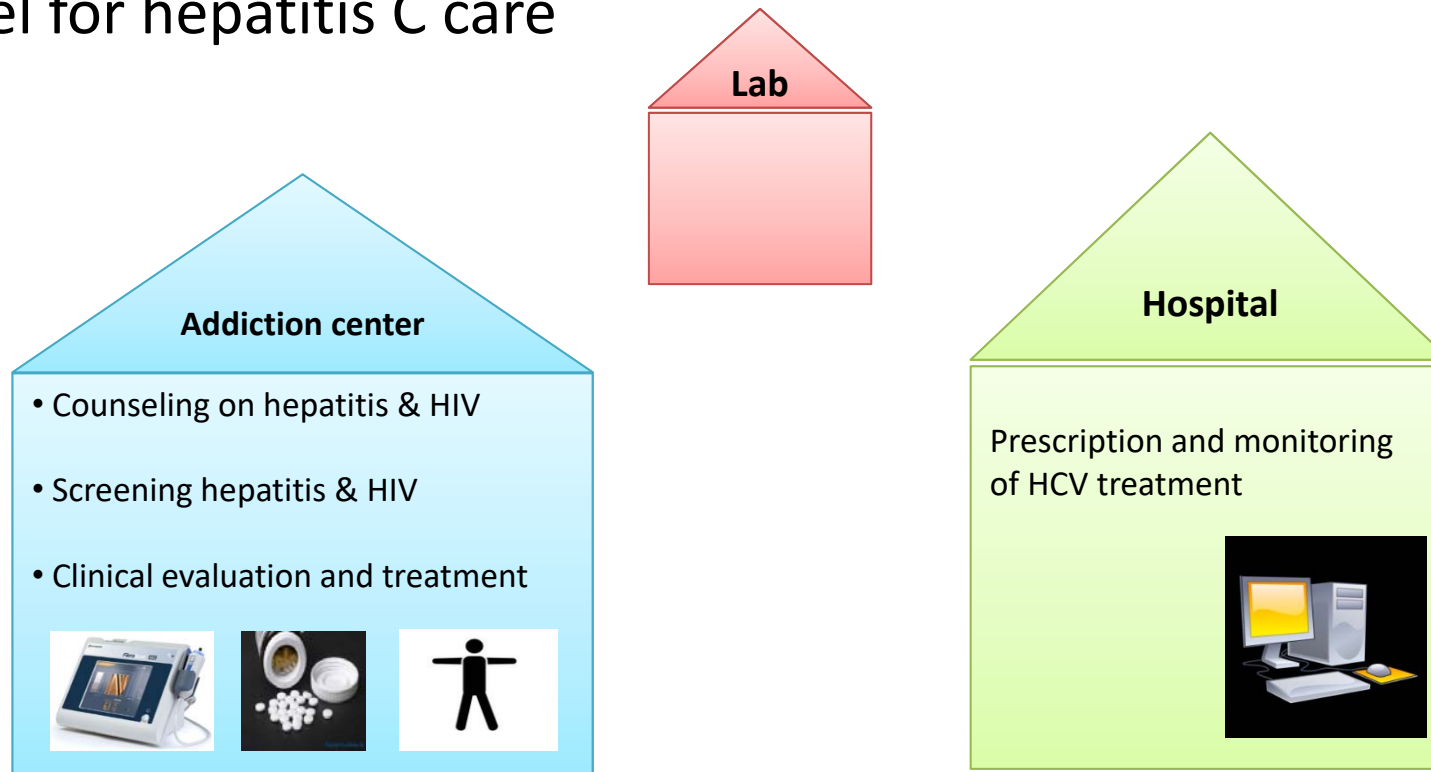
An artificial intelligence virtual health platform

Ekenberg & Cunha-Bang et al, IDWeek, 2018

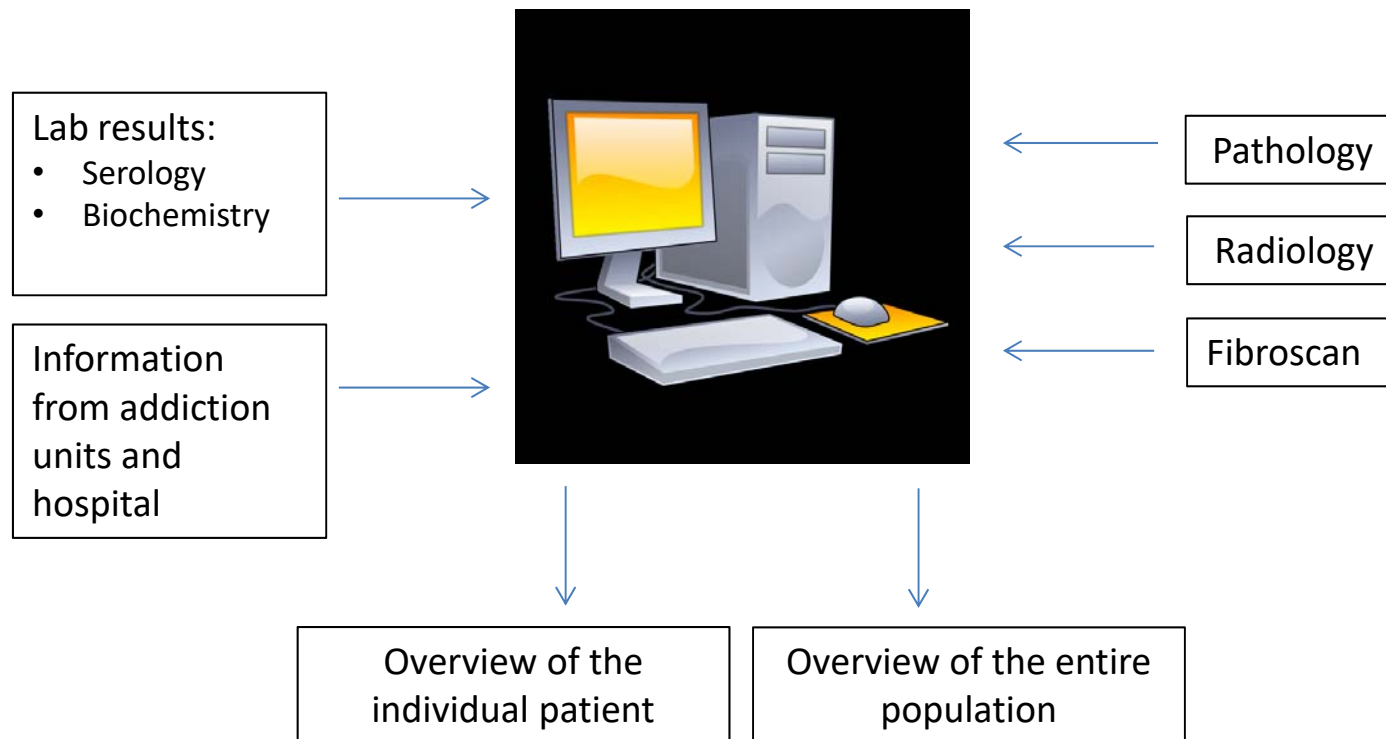
Key assets making MATCH successful (i.e. reducing risk of post-transplant CMV disease)

- Early treatment of emerging CMV infection prevents CMV disease (-pre-emptive strategy)
 - Window of opportunity before disease: 1-3 weeks
- Large variation in risk of contracting CMV infection
 - Everybody can't be tested all the time, but
 - Reliable predictive algorithm
 - A data lake with all required data elements accessed real-time
 - Centralization – few doctors+computer do what many doctors did - "virtual health"
- Output from algorithm
 - Intensity of testing for emerging CMV infection
 - The higher the risk – the more intense
 - Testing plan part of EMR + to patient directly (if requested)
 - If not adhered to – automated electronic reminder

Shared Addiction Care Copenhagen (SACC) model for hepatitis C care



The SACC database – combined EMR with AI



Patientdata:

Navn: Paula Sigrid Høj Doukkali
CPRNR: 231170TEST

Startdato: 06-01-2015

Forløb: TEST

LPET0031 (CHIP)

Logget ind d. 28-03-2017

Log ud

<p>Admin Patienter Borgerlisten</p> <p>(2388) Inklusionslister (0) Provesvar (72) Overskredet årskontrol (41) HBV positive (421) HCV-RNA positiv (110) Tidligere HCV-RNA positiv (95) HIV positiv (0) Kommunikation til KK (0) Kommunikation til Inf. med. (64) Inklusionslister (Enghavevej) (0) HBV Positive (Enghavevej) (2) HCV Positive (Enghavevej) (1) HIV Positive (Enghavevej) (132) Inklusionslister (Forchhammervej) (6) HBV positive (Forchhammervej)</p> <p>CPR Navn</p> <p>010101TEST - TEST 010160TEST - ConnieB 010160TEST - Jan Meyer 101010TEST - medcomtest 101010TEST - Patient 10 101010TEST - Torben Hansen 111065TEST - Hans Andersen</p>	<p>Patient stamdata Kontaktinformation Status Fibroskanning Vaccination Årskontrol EKG Radiologi</p> <p>Patobank Analyser Stratificering Behandlingsvurdering</p> <p>Patient stamdata</p> <p>CPR-NR: 231170TEST Navn: Paula Sigrid Høj Doukkali Kaldenavn: Sigrid Adresse: By: Post nr: Kontaktoplysning (Tlf. nr): 23562390gg Egen læge: Indskrivningsdato (CSC): Indskrivningsdato (SACC): 06-01-2015 Udskrivningsdato (SACC): 13-01-2015 Samtykke: <input checked="" type="checkbox"/> Sidst opdateret af 'TWEI0011 ' d.: 20-10-2016</p> <p>Kontaktinformation</p> <p>Enhedens navn:</p>	<p>Hepatitis / HIV Status</p> <table border="1"> <thead> <tr> <th>Statusbeskrivelse</th> <th>Dato</th> </tr> </thead> <tbody> <tr> <td>HAV: Tidligere smittet/vaccineret</td> <td></td> </tr> <tr> <td>HBV: Ikke vaccineret/smittet</td> <td></td> </tr> <tr> <td>HCV: Overstået infektion</td> <td></td> </tr> <tr> <td>HIV: Ikke smittet</td> <td></td> </tr> </tbody> </table> <p>Årskontrol</p> <table border="1"> <tbody> <tr> <td>Næste årskontrol skal foretages:</td> <td>23-02-2018</td> </tr> </tbody> </table> <p>Rådgivning & Vejledning</p> <table border="1"> <tbody> <tr> <td>Er senest givet:</td> <td>30-12-2015</td> </tr> </tbody> </table> <p>Vaccinationsplan</p> <table border="1"> <tbody> <tr> <td>1. Engerix givet</td> <td>02-08-2015</td> </tr> </tbody> </table> <p>Fibroskanning</p>	Statusbeskrivelse	Dato	HAV: Tidligere smittet/vaccineret		HBV: Ikke vaccineret/smittet		HCV: Overstået infektion		HIV: Ikke smittet		Næste årskontrol skal foretages:	23-02-2018	Er senest givet:	30-12-2015	1. Engerix givet	02-08-2015
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Suspicion of acute EBV infection (mononucleosis): indicator for HIV testing

- 2-7% are HIV+
- One of several conditions associated with excess risk of HIV+
- 1 in 5 were tested for HIV (Catalonia data)
- Prompt for HIV test / part of prediction

Region	N Total	N HIV+	Prevalence (95%CI)
Total	1569	85	5.4 (4.3 – 6.5)
East	994	67	6.7 (5.2 – 8.3)
West	61	2	3.3 (0 – 7.7)
South	84	6	7.1 (1.6 – 12.7)
North	430	10	2.3 (0.9 – 3.8)

Raben, Sullivan et al, HIDES

Virtual HIV treatment

- Datalake (e.g. data from patients cared for at one clinic)
 - Real-time, lab, medicines, vital signs, imaging, pathology
 - Legacy lab and diagnoses
- The task for the algorithm –
 - Predicting risk of clinical disease
 - Viral failure
 - Organ disease (CVD, CKD, cancer)
 - Output
 - Real-time prediction for individual patients (accessible to patient and provider)
 - Pro-active prompts as requested

Harm

- Performance of AI deviates because data from source changes over time
 - Requires continued supervision of data sources
- Data safety
 - Health data lakes in secure clouds
 - Compliant with national legislation
- Data governance – who have access ?
 - While data is in data lake, only computer has access
 - Meta-data – population-based data
 - Guide public health decisions
 - Individual person's data
 - person self
 - treating health professionals
 - Ensure avoidance of in-legitimate access

Medical AI - summary

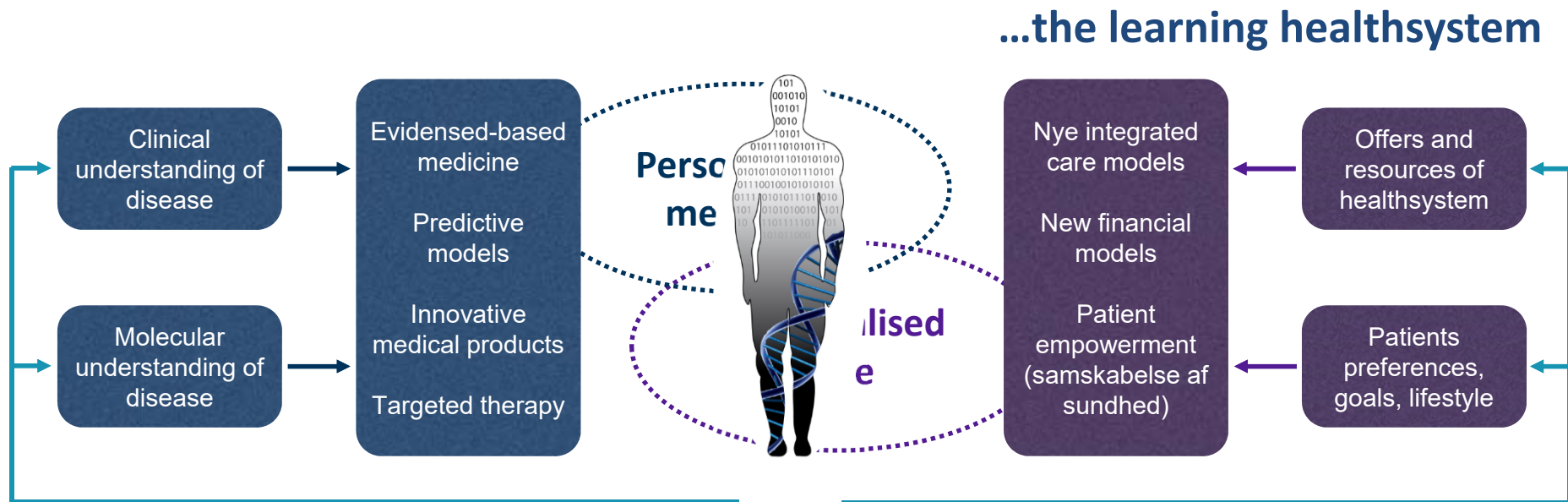
- Computer science to support (but not take over) health decision making
- Reality – question: extent
- Requires
 - Trained algorithm – i.e. a matrix
 - Data lake for relevant data on a given population
- User potentials
 - Guide testing intensity according to individual persons risk
 - Stratify activities re linkage to care per individual persons risk of missing out on linkage
 - Guide treatment
 - Laboratory monitoring
 - Done – if not, get it done
 - Optimal – if not, refer to expertise
- Misuse (and misperception) can be contra-acted if due diligence exerted

Thank you

- **Clinicians and diagnostic experts @ Rigshospitalet**
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Søren Brunak, Jessica Hu, Jesper Hastrup-Svendsen, Ulla Wever

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Personalised medicine & personalised care



...depends entirely on interoperative big data sharing!

A broad perspective on personalised medicine

- Personalised medicine is a medical procedure, able to tailor specified components of diagnosis, treatment and care, based on individual persons predicted risk of benefit and harm

WALL OF FAME PERSIMUNE DATA WAREHOUSE

Stocking a data warehouse with analyzable data is a huge task, requiring strong efforts of medical doctors and IT specialists. The service of the very dedicated men and women in CHIP, who performed this huge task since 2015, is acknowledged with gratitude on this list.

Version 1.0 - December 2017

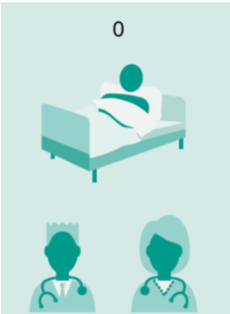

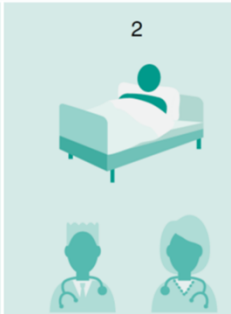


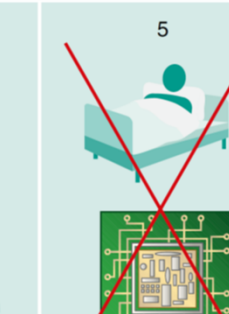


Analogy: self-driving car and computer doctor

Levels of self-driving car

Human driver monitors environment			System monitors environment		
0 No automation The absence of any assistive features such as adaptive cruise control.	1 Driver assistance Systems that help drivers maintain speed or stay in lane but leave the driver in control.	2 Partial automation The combination of automatic speed and steering control—for example, cruise control and lane keeping.	3 Conditional automation Automated systems that drive and monitor the environment but rely on a human driver for backup.	4 High automation Automated systems that do everything—no human backup required—but only in limited circumstances.	5 Full automation The true electronic chauffeur: retains full vehicle control, needs no human backup, and drives in all conditions.

Level of computer doctor

Humans and machine doctors					
0 	1 	2 	3 	4 	5 
Now				Unlikely	