

## ICT en eHealth

## Nieuwe uitdagingen voor de wetenschap

Bart De Moor

ESAT-SCD

Katholieke Universiteit Leuven

A: Kasteelpark Arenberg 10, B-3001 Leuven  
Belgium

T: +32(0)475 2 8 7052

W: [www.esat.kuleuven.be/~demoor](http://www.esat.kuleuven.be/~demoor)

E: [bart.demoor@esat.kuleuven.be](mailto:bart.demoor@esat.kuleuven.be)



# Outline

-Trends

-Context

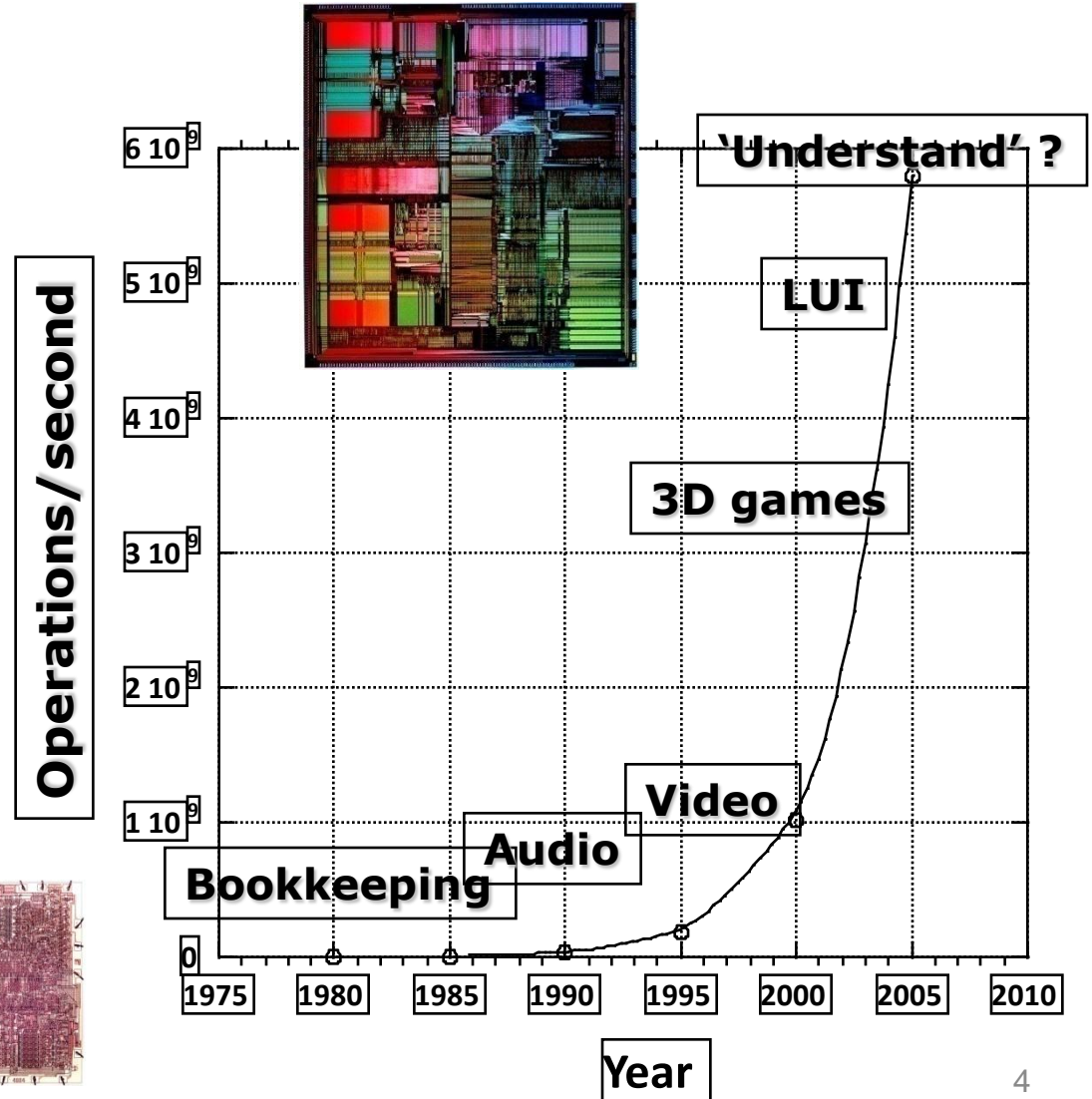
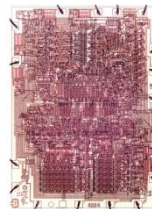
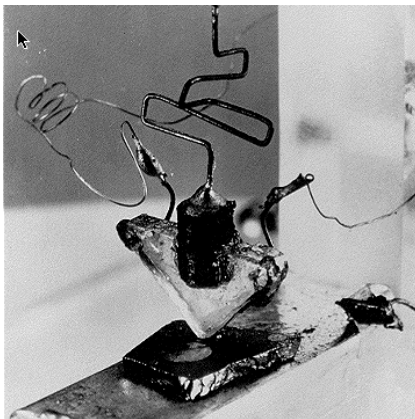
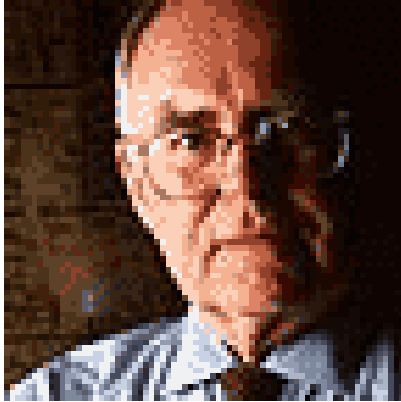
-Opportunities and challenges

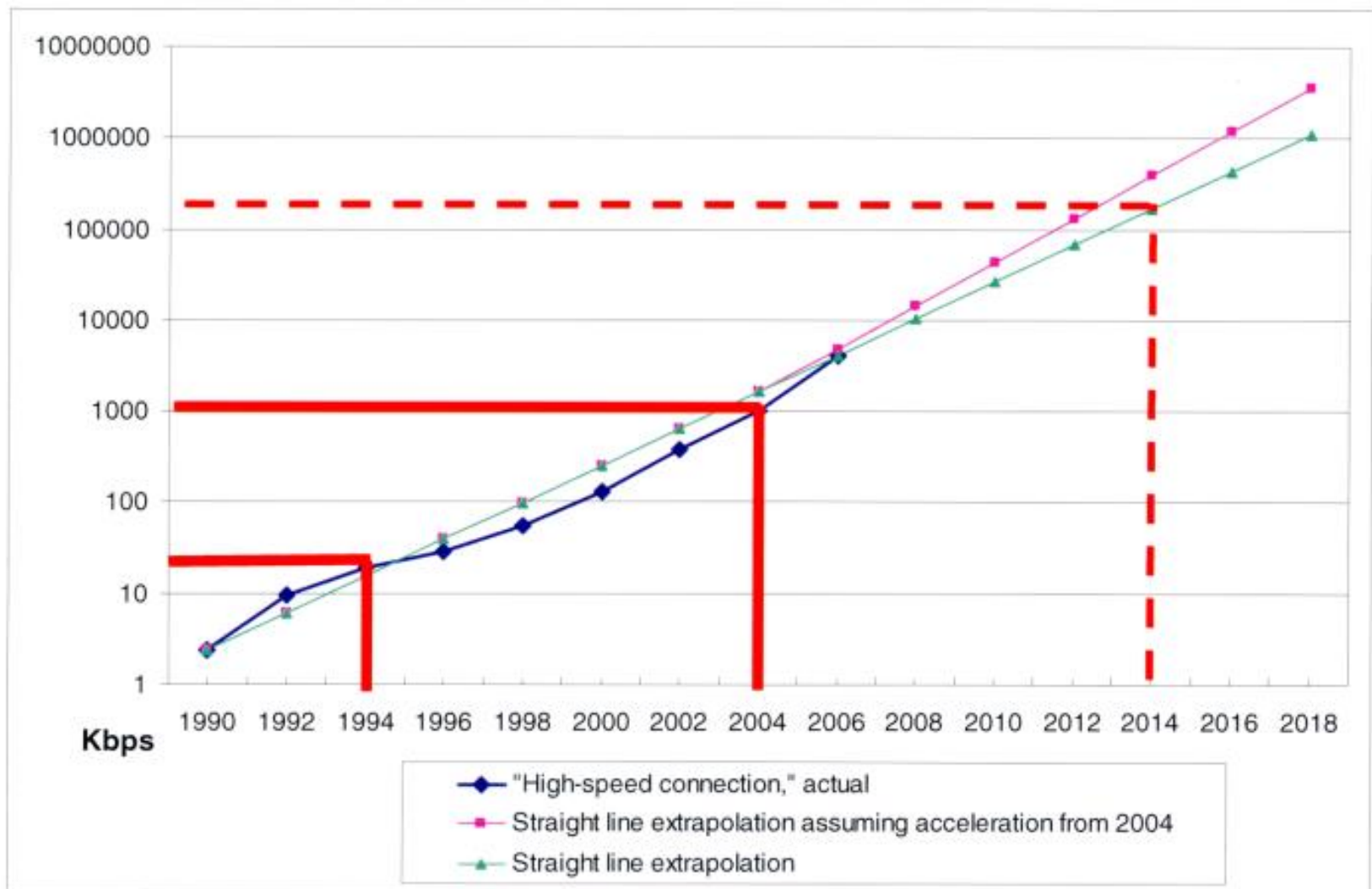
-What to do ?

# Trends

- I. Exponential evolution in ICT, medical and bio-technology
- II. Tsunami of data
- III. Inter-, cross-, and multi-disciplinarity
- IV. Societal demands
- V. Translational gap

# Gordon Moore's law

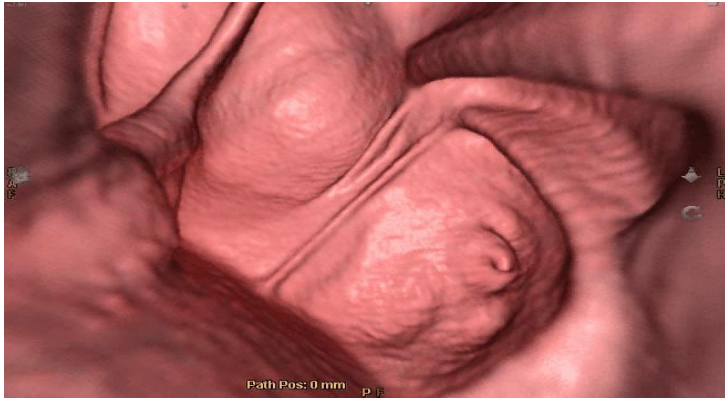




Source: Heavy Reading report "FTTH Worldwide Market & Technology Forecast, 2006-2011"

# Tsunami of data

- New technologies generate more data
- Increased spatial and temporal resolution
- More studies per patient, more datasets per study

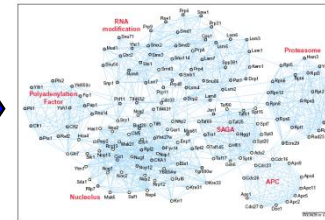
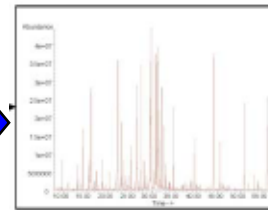
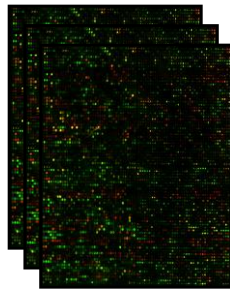
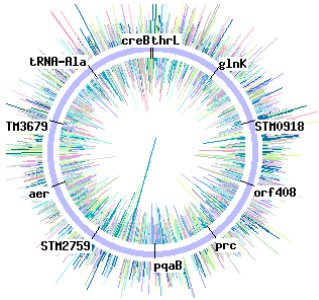
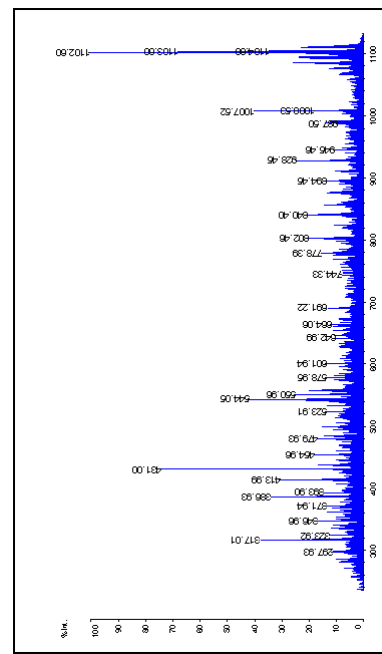
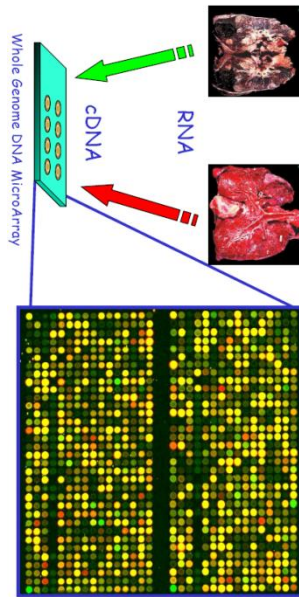


Virtual colonoscopy from CT  
images  
with automatically detected  
polyps



subtraction CT angiography

ACACATAAATCCTTATATGC  
 TAAAAGTGGTCTCGTTTTA  
 GGGATGTTTATAACCATCTT  
 TGAGATTATTGATGCATGGT  
 TATTGGTTAGAAAAAATATA  
 CGCTTGTTTTCTTTCCTAG  
 GTTGATTGACTCATAATGT  
 GTTTCATTGAGGAAGGAAC  
 TTAACAAAAGTCACTTTTT  
 TCAACGTACAGCTACTTTA  
 AAAGTGATCAAAGTATATCA  
 AGAAAAGCTTAATATAAAGAC  
 ATTTGTTTCAAGGTTTCGTA  
 AGTGCACAATCAAGAAG  
 ACAAAAATGACTAATTTTTGT  
 TTTTCAGGAAGCATATATATT  
 ACACGAACACAAATCTATTT  
 TTGTAATCAACACCGACCAT  
 GGTTTCGATTACACACATTA  
 ATCTTATATGCTAAAACCTAG  
 GTCTCGTTTTAGGGATGTTT  
 ATAACCATCTTTGAGATTAT  
 TGATGCATGTTATTGGTTA  
 GAAAAAATATACGCTTGTTT  
 TTCTTTCCTAGGTTGATTGA



**genome**

**transcriptome**

**proteome**

**metabolome**

**interactome**



GS-FLX Roche  
 Applied Science 454

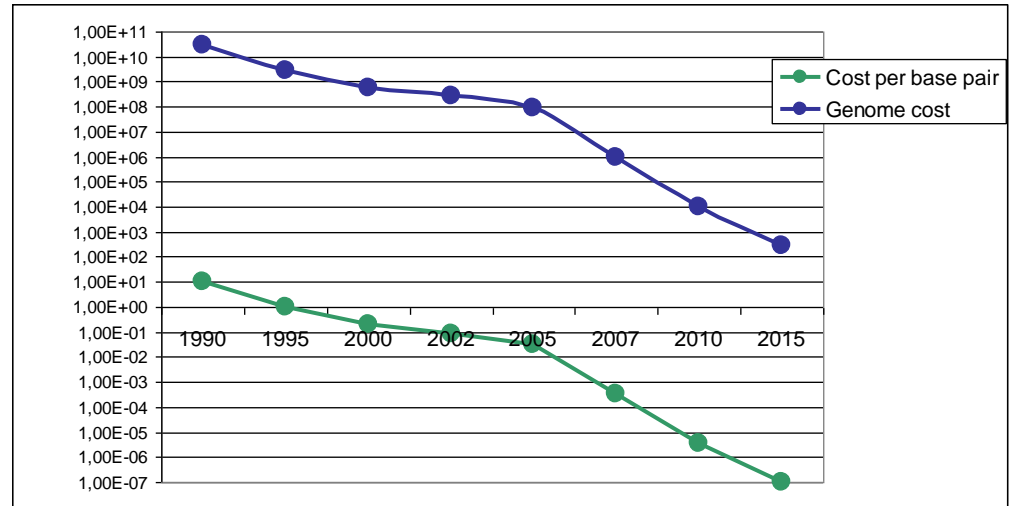


Prometa



# Making sense of the 1000 \$ genome ?

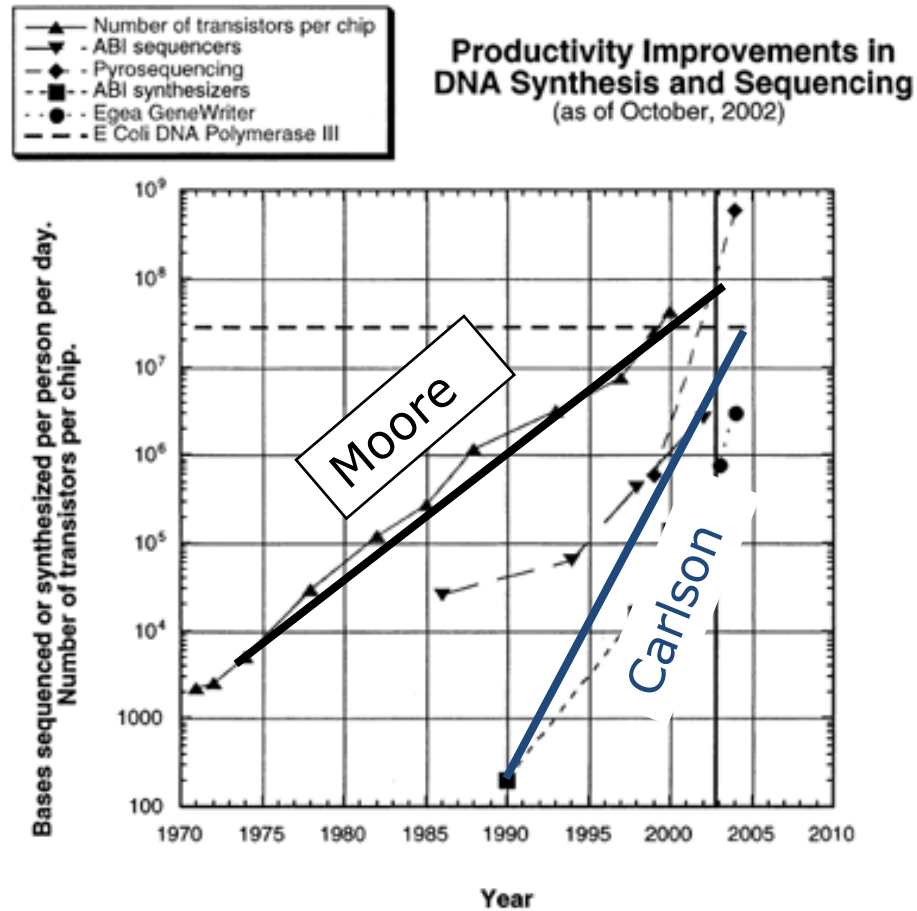
- Human genome project
  - Initial draft: June 2000
  - Final draft: April 2003
  - 13 year project
  - \$300 million value with 2002 technology
- Personal genome
  - June 1, 2007
  - Genome of James Watson, co-discoverer of DNA double helix, is sequenced
    - \$1.000.000
    - Two months
- €1000-genome
  - Expected 2012-2020



Year	Cost per base pair	Genome cost
1990	10	3E+10
1995	1	3.000.000.000
2000	0.2	600.000.000
2002	0.09	270.000.000
2005	0.03	90.000.000
2007	0.000333333	1.000.000
2010	3.33333E-06	10000
2015	0.0000001	300



# Moore versus Carlson



# Text mining

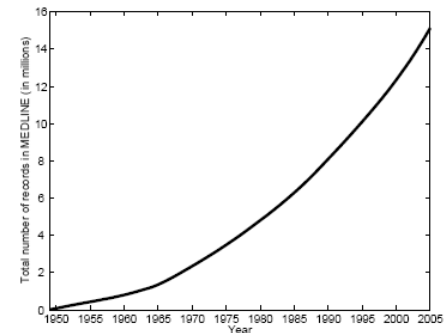
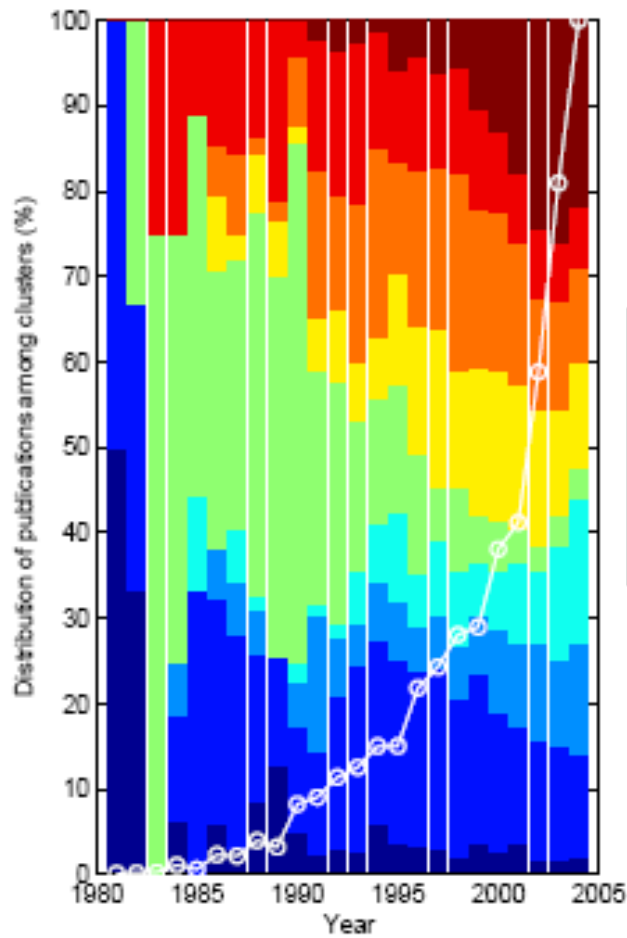
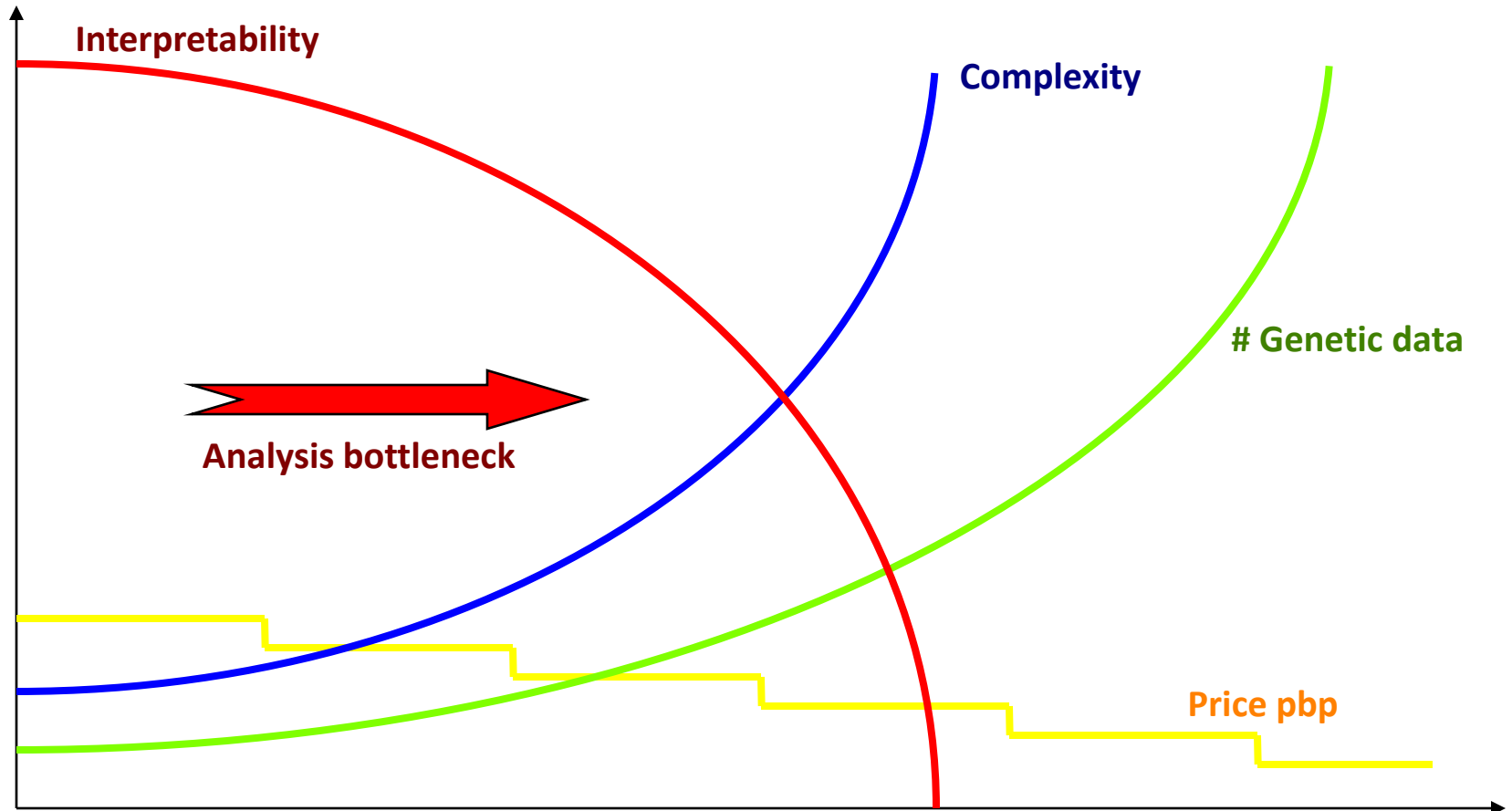


Figure 1.2: Growth of MEDLINE, the U.S. National Library of Medicine (NLM) premier bibliographic database covering the fields of medicine, nursing, dentistry, veterinary medicine, the health care system and preclinical sciences. The total number of scientific publications (in millions) is indicated for each year. Today, MEDLINE contains approximately 15 million unique records about journal articles in life sciences. This figure was constructed using data published by NLM [161].

By 2010, 1/3 of all world data bases will consist of biomedical data

# Analysis bottlenecks



# Outline

-Trends

-Context

-Opportunities and challenges

-What to do ?

# Context



- VRWB cluster analysis
  - Cluster 2: ICT and Health Care
  - Cluster 5: New business models
- VRWB, 2008: De uitbouw van het translationeel onderzoek in Vlaanderen
- VR 30/04/2009: Oprichting van een Centrum voor Translationele Biomedische Innovatie / m.i.v. 8 mio euro voor biobank
- VIB, IBBT, Universities
- eHealth platform

# Obama

But in order to lead in the global economy and to ensure that our businesses can grow and innovate, and our families can thrive, we're also going to have to address the shortcomings of our health care system.

The Recovery Act will support the long overdue step of ***computerizing America's medical records***, to reduce the duplication, waste and errors that cost billions of dollars and thousands of lives. But it's important to note, ***these records also hold the potential of offering patients the chance to be more active participants in the prevention and treatment of their diseases***. We must maintain patient control over these records and respect their privacy. At the same time, we have the opportunity to offer billions and ***billions of anonymous data points to medical researchers who may find in this information evidence that can help us better understand disease***.

History also teaches us the greatest advances in medicine have come from scientific breakthroughs, whether the discovery of antibiotics, or improved public health practices, vaccines for smallpox and polio and many other infectious diseases, antiretroviral drugs that can return AIDS patients to productive lives, pills that can control certain types of blood cancers, so many others.

Because of recent progress — ***not just in biology, genetics and medicine, but also in physics, chemistry, computer science, and engineering*** — ***we have the potential to make enormous progress against diseases in the coming decades***. And that's why my administration is committed to increasing funding for the National Institutes of Health, including \$6 billion to support cancer research -- part of a sustained, multi-year plan to double cancer research in our country. (Applause.)

<http://www.whitehouse.gov/blog/09/04/27/The-Necessity-of-Science/>

# Need for investments

- RIZIV: 23 bio euro / year
- Cumulative R&D funding Flanders (FWO, IWT, IBBT, VIB, IMEC,...)  
human health: 150 mio euro/year
- Need for new funding federal / communities / regions on  
Innovation in Health Care
- FOD Volksgezondheid: 16 a 17 mio euro / year for IT Hospitals

# Rationales for eHealth

## **-Improve quality performance of health decision/diagnosis systems**

- Support individual medical doctor
  - Avoid/decrease number of medical errors
  - Web portal for Evidence Based Medicine
    - Organised access to literature
    - Examples: UK, Norway, Sweden, Finland
- Information sharing among doctors
  - avoid/monitor patient (s)hopping behavior
  - Global Medical File per patient
  - Interoperability

## **-Deal with 'empowerment of the patient': Patient-centric health care**

- Medical care in 4P: personalized, preventive, predictive, participatory
- Increasing trend for 'customized'/'personalized' medicine
- Improve transparency and consistency
- Deal/cope with 'professional' (chronical) patients (heart, diabetes, cancer,...)
- Improve patient mobility

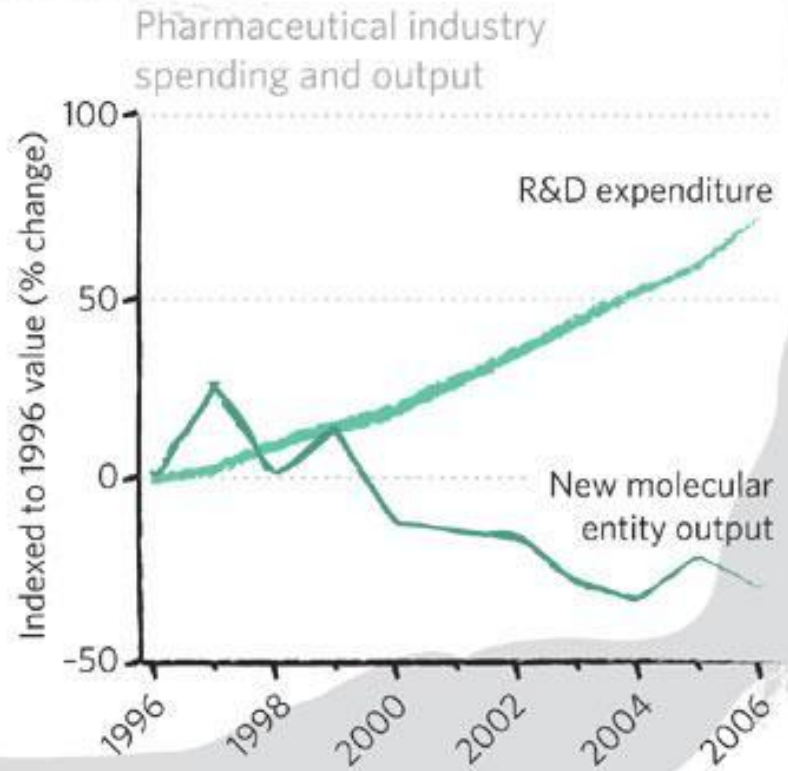
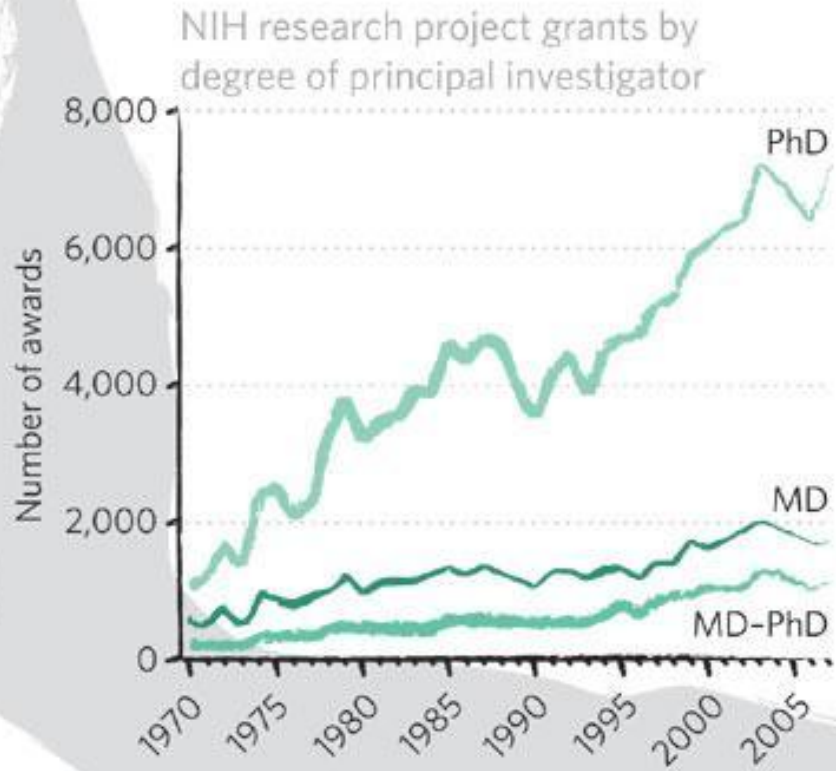
## **-Cost effectiveness of the health care system**

- Ageing population:
  - EU 2050: 65+ → +70%; 80+ → +180%
  - VI. 2012: 60+ → 25 % of VI.
- Monitor overconsumption
- Improve transparency
- Detect abnormalities in diagnosis/therapy/...

## **-Cope with tsunami of available information and data (clinical, population, ....)**



# THE TRANSLATION GAP

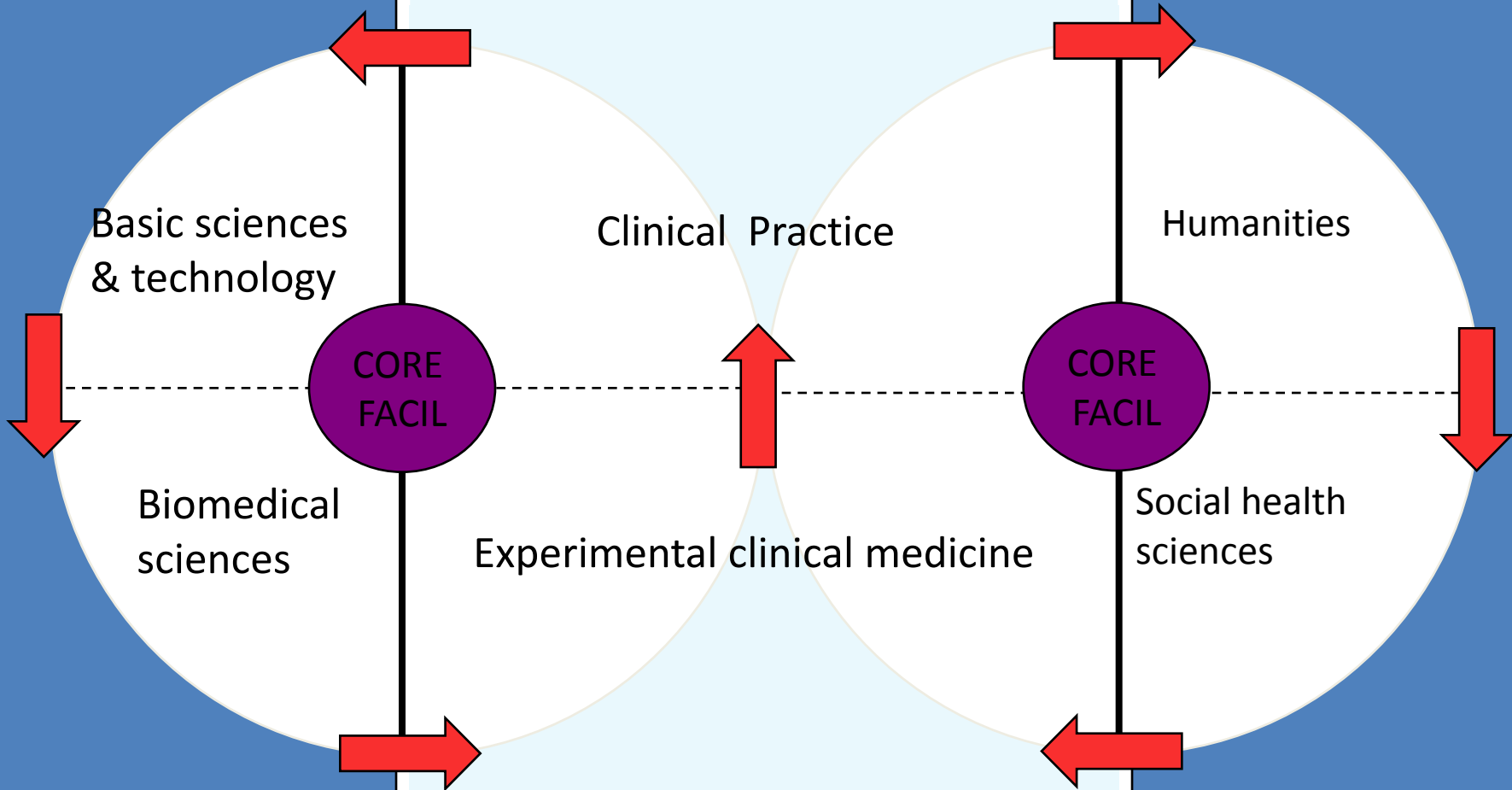


Source: NIH; CMR International & IMS Health

**Academia**

**Health care system**

**Academia**



**BASIC /  
PRECLINICAL**

**CLINICAL**

**BASIC /  
PRECLINICAL**

# Outline

-Trends

-Context

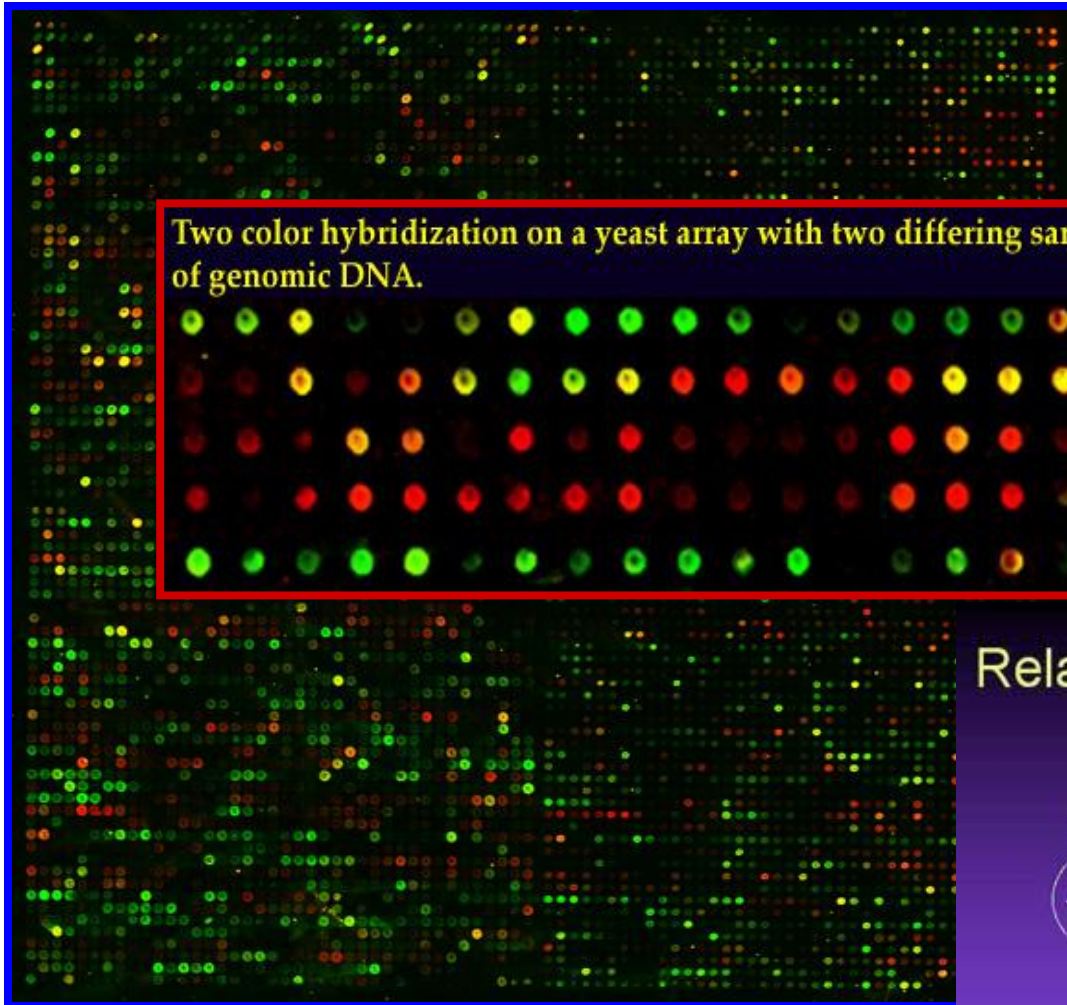
-Opportunities and challenges

-What to do ?

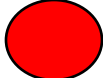



# Examples and cases

- Diagnosis via DNA-chips
- Gene prioritization via multiple sources
- International Ovarian Tumor Analysis

# Microarrays – DNA-chips



Two color hybridization on a yeast array with two differing samples of genomic DNA.

	Test	Ref.
	High	Low
	Low	High
	High	High
	Low	Low

## Relative Abundance Detection



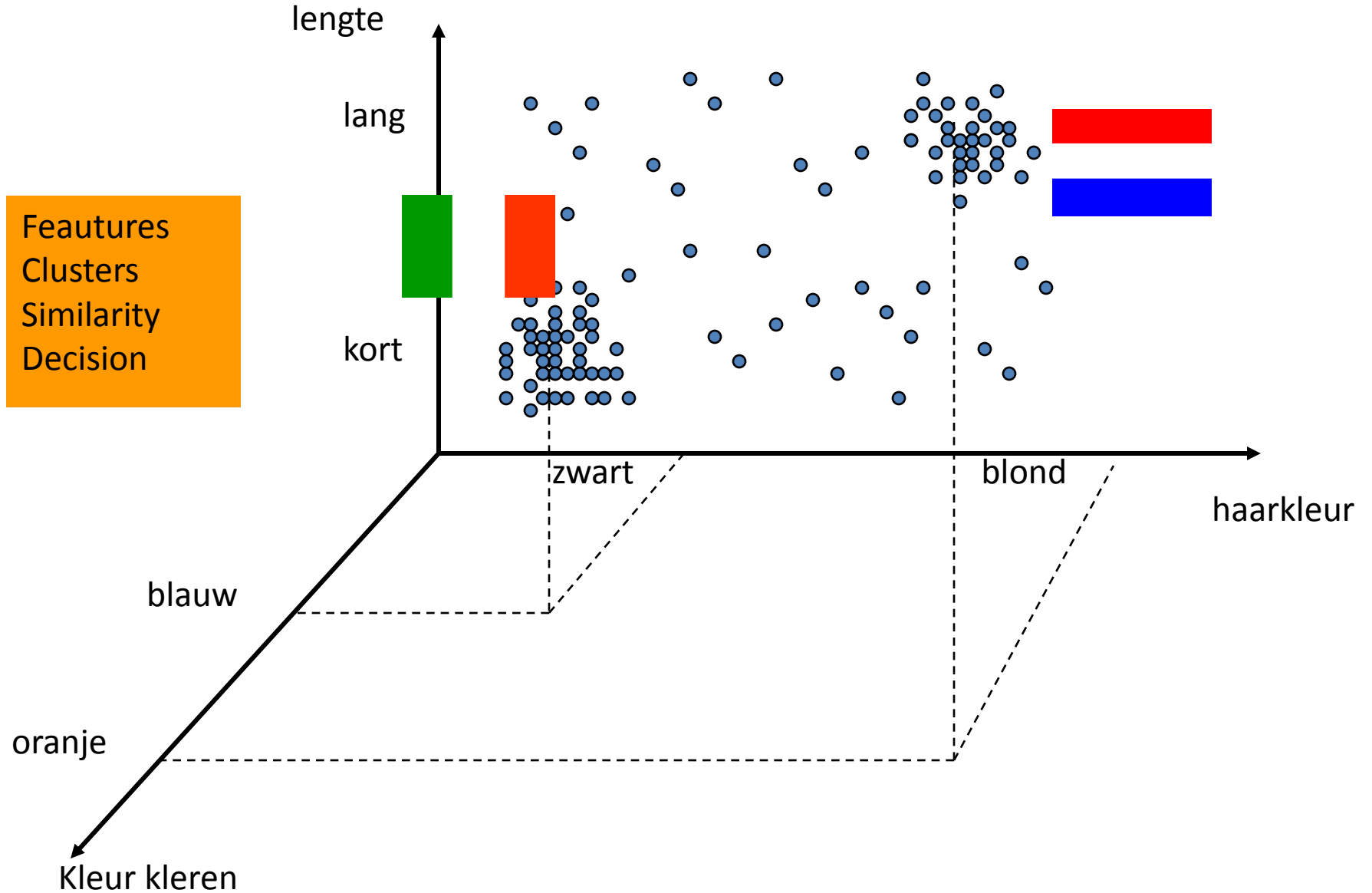
Mix and hybridize

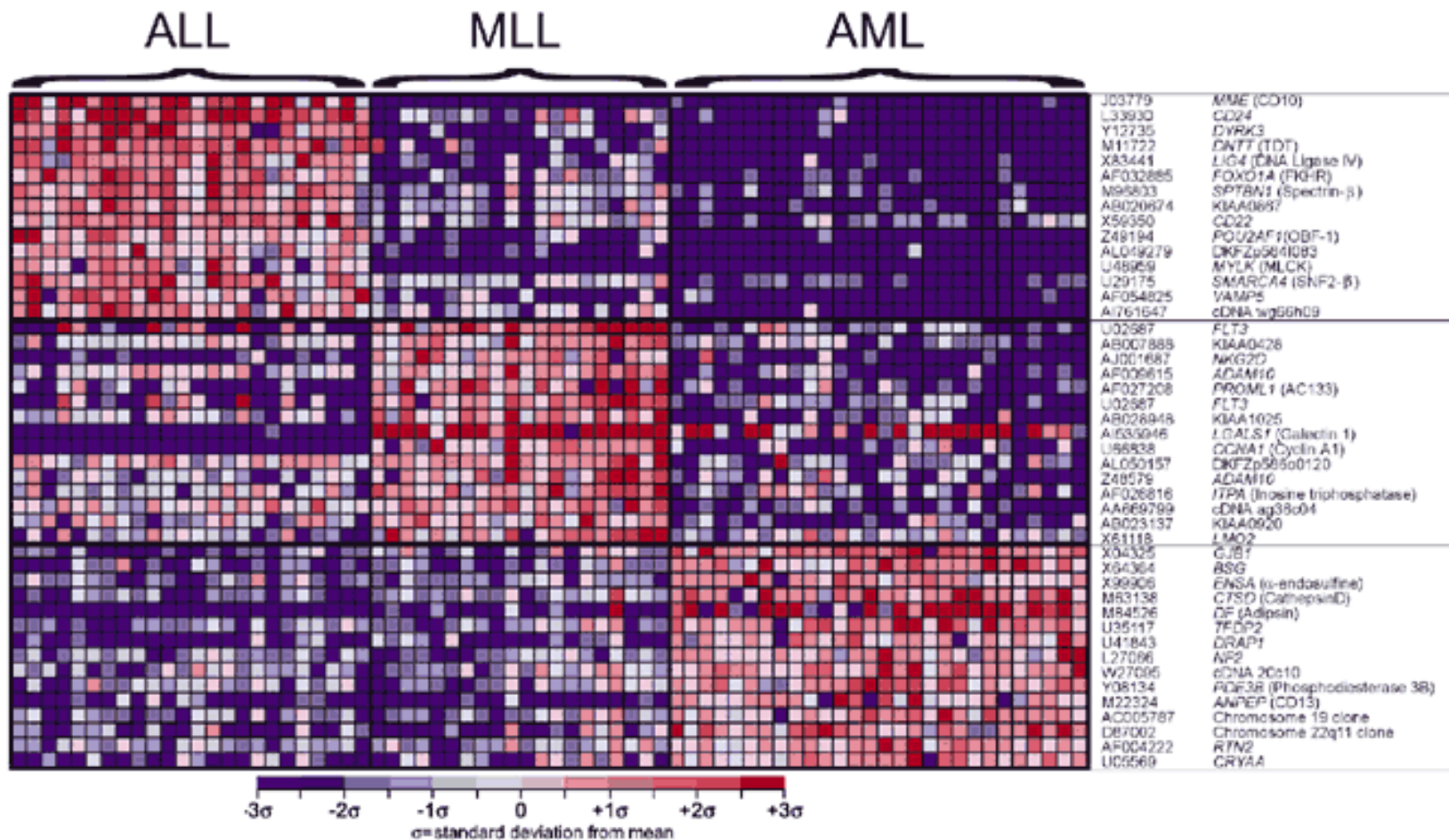


# Algorithm

- Abu Ja'far Muhammad ibn Musa al-Khwarizmi was born in Uzbekistan around 800 A.D
- His name persists in the word 'algorithm'.
- Main work: “De kunst van het overbrengen en het wegstrepen”  
“ Ilm aljabr wa'l muqabalah”, in which we recognize the root of the word “algebra”.
- al-Khwarizmi also enriched the Arabian number notation with the cipher zero.
- The calculus book by al-Khwarizmi lay hidden in the library of Bagdad before it was translated in Latin and found its way to Europe, where it was introduced by mathematicians such as Fibonacci (Sicily, 1200), Tartaglia (Venice, 1500), Cardano (Rome, 1500), Vieta (France, 1550), Descartes (France, 1625), before it got its ultimate position in analytic geometry.

# Clustering and classification algorithms









# International Ovarian Tumor Analysis Group (IOTA)

Making it easier to diagnose ovarian  
cancer

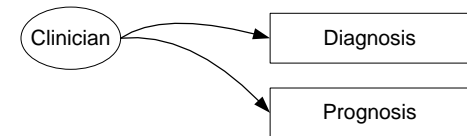
# Motivation

- Clinicians have to make many decisions concerning the therapy of their patients e.g.:
  - Diagnosis



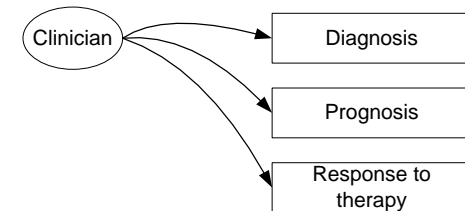
# Motivation

- Clinicians have to make many decisions concerning the therapy of their patients e.g.:
  - Diagnosis
  - Prognosis



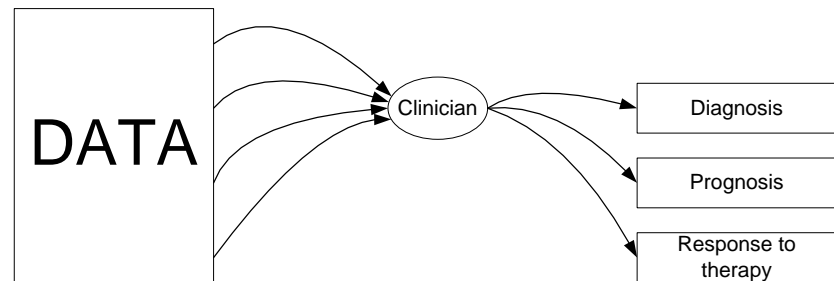
# Motivation

- Clinicians have to make many decisions concerning the therapy of their patients e.g.:
  - Diagnosis
  - Prognosis
  - Therapy response
- Based on **expertise**
- But often the clinician has



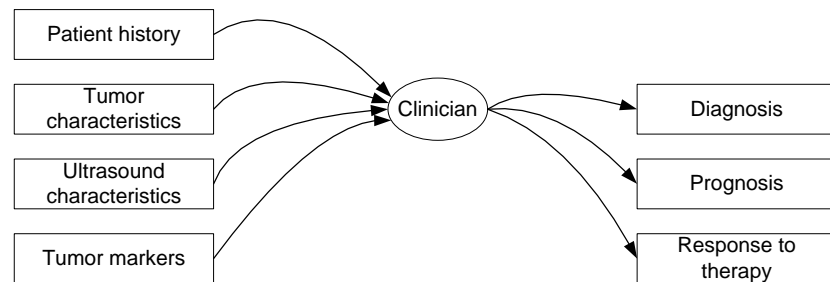
# Motivation

- Clinicians have to make many decisions concerning the therapy of their patients e.g.:
  - Diagnosis
  - Prognosis
  - Therapy response
- Based on **expertise**
- But often the clinician has
  - Patient Data



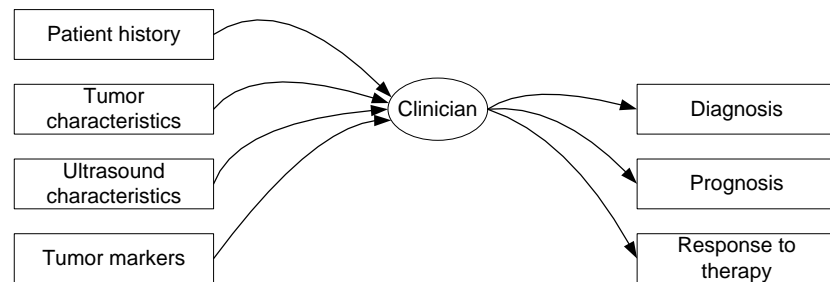
# Motivation

- Clinicians have to make many decisions concerning the therapy of their patients e.g.:
  - Diagnosis
  - Prognosis
  - Therapy response
- Based on **expertise**
- But often the clinician has
  - Patient Data
    - Patient history
    - Tumor characteristics
    - Ultrasound characteristics
    - Tumor markers



# Motivation

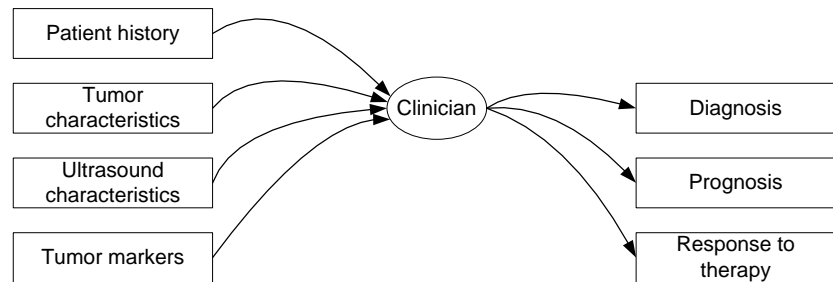
- Not all these data types are relevant for every disease
- But for example for the diagnosis of ovarian masses many data types are suspected to be relevant





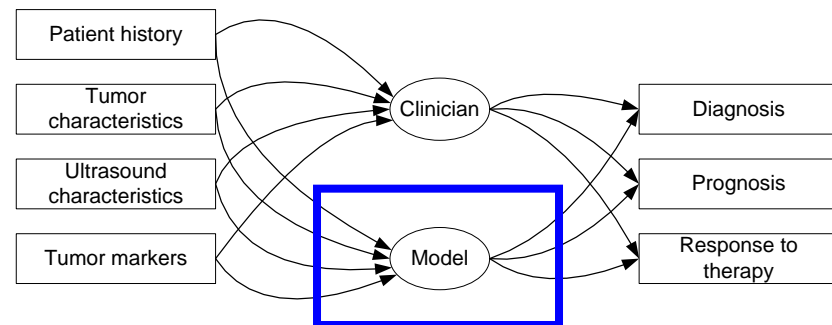
# Motivation

- Solution:



# Motivation

- Solution:
  - Clinical decision support modeling
  - Building a mathematical model on the data
  - Use this model to predict patient outcome
    - Diagnosis
    - Prognosis
    - Therapy response



# Standardization

- To make sure clinicians everywhere record the same data, they have agreed on definitions of features
- Standardization of data
- Protocol for data collection
- European Panel of Experts on Ovarian Neoplasms

*Ultrasound Obstet Gynecol* 2000; 16: 500–505.

Terms, definitions and measurements to describe the sonographic features of adnexal tumors: a consensus opinion from the International Ovarian Tumor Analysis (IOTA) group

D. TIMMERMAN, L. VALENTIN\*, T. H. BOURNE†, W. P. COLLINS‡, H. VERRELST§ and I. VERGOTE

*Department of Obstetrics and Gynaecology, University Hospitals KU Leuven, Leuven, Belgium, \*Department of Obstetrics and Gynaecology, University Hospital, Malmö, Sweden, †Department of Obstetrics and Gynaecology, St. George's Hospital Medical School, University of London, London, UK, ‡King's College, University of London, UK and §Department of Electrical Engineering, ESAT-SISTA, Katholieke Universiteit Leuven, Belgium*

**KEYWORDS:** Ultrasonography, Color Doppler imaging, Ovary, Definitions, Standardization

## INTRODUCTION

The lack of standardized terms and procedures to derive categorical and continuous variables in gynecological sonography is a general cause of concern<sup>1</sup>. The extent of the problem became more apparent to us during the planning stage of an international, multicenter study to characterize adnexal masses by ultrasonographic criteria using the histologic and surgical classification of each mass as the reference procedure. A detailed review of the literature had revealed considerable variation in the diagnostic accuracy of test procedures<sup>2</sup>. There had also been much discussion and more recently a report that the use of diagnostic algorithms derived from the retrospective analysis of data in a particular center<sup>3–5</sup> does not produce such good results when used prospectively in another center<sup>6</sup>. The possibility arose that both findings might be explained, at least in part, by differences in the interpre-

practices. We hope that the outcome of our deliberations will stimulate further debate, which will eventually lead to internationally agreed terms and definitions within our speciality.

## DEFINITIONS

### Lesion

An adnexal *lesion* is the part of an ovary or an adnexal mass that is judged from an assessment of ultrasound images to be inconsistent with normal physiologic function. This situation can arise from the presence of a persistent unilocular cyst, surrounded by normal looking ovarian stroma containing some follicles. In this case the whole ovary containing the cyst is the 'ovary', whereas the unilocular cyst is the 'lesion'. The size of both structures is measured independently, and the cyst is described as being

A

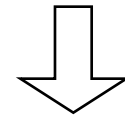
# Clinical Data

- Data gathered by IOTA group
  - Standardized multi-centric collection of clinical data
  - AIM: diagnose ovarian cancer
  - > 60 variables collected, 32 selected relevant for prediction
- Data gathered in two phases:
  - Phase 1: 1066 patients in 9 European centers
  - Phase 2: 1938 patients in 12 new International centers

# Data collection

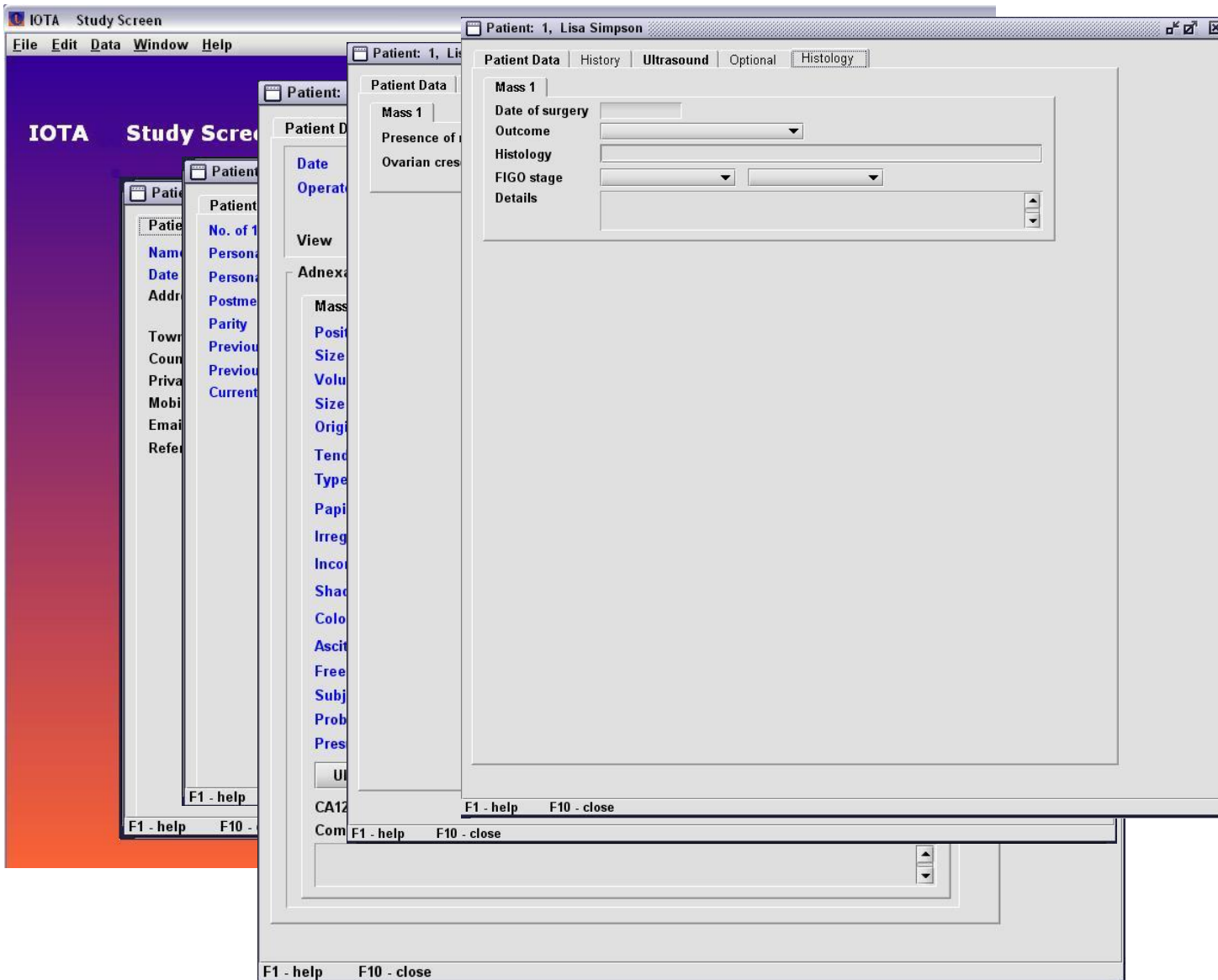
The screenshot shows a software window titled "IOTA Study Screen" with a menu bar (File, Edit, Data, Window, Help). The main area displays a patient data entry form for "Patient: 1, Lisa Simpson". The form has tabs for "Patient Data", "History", "Ultrasound", "Optional", and "Histology". The "Patient Data" tab is active, showing fields for Name (Lisa Simpson), Date of birth, Address, Town, Count(r)y, Private Tel., Mobile phone, Email, Referring doctor, Other names, Hospital no., Postcode, Work Tel., and Fax. A checkbox labeled "this is a test patient" is at the bottom. The status bar at the bottom left shows "F1 - help" and "F10 - close".

Privacy is ensured



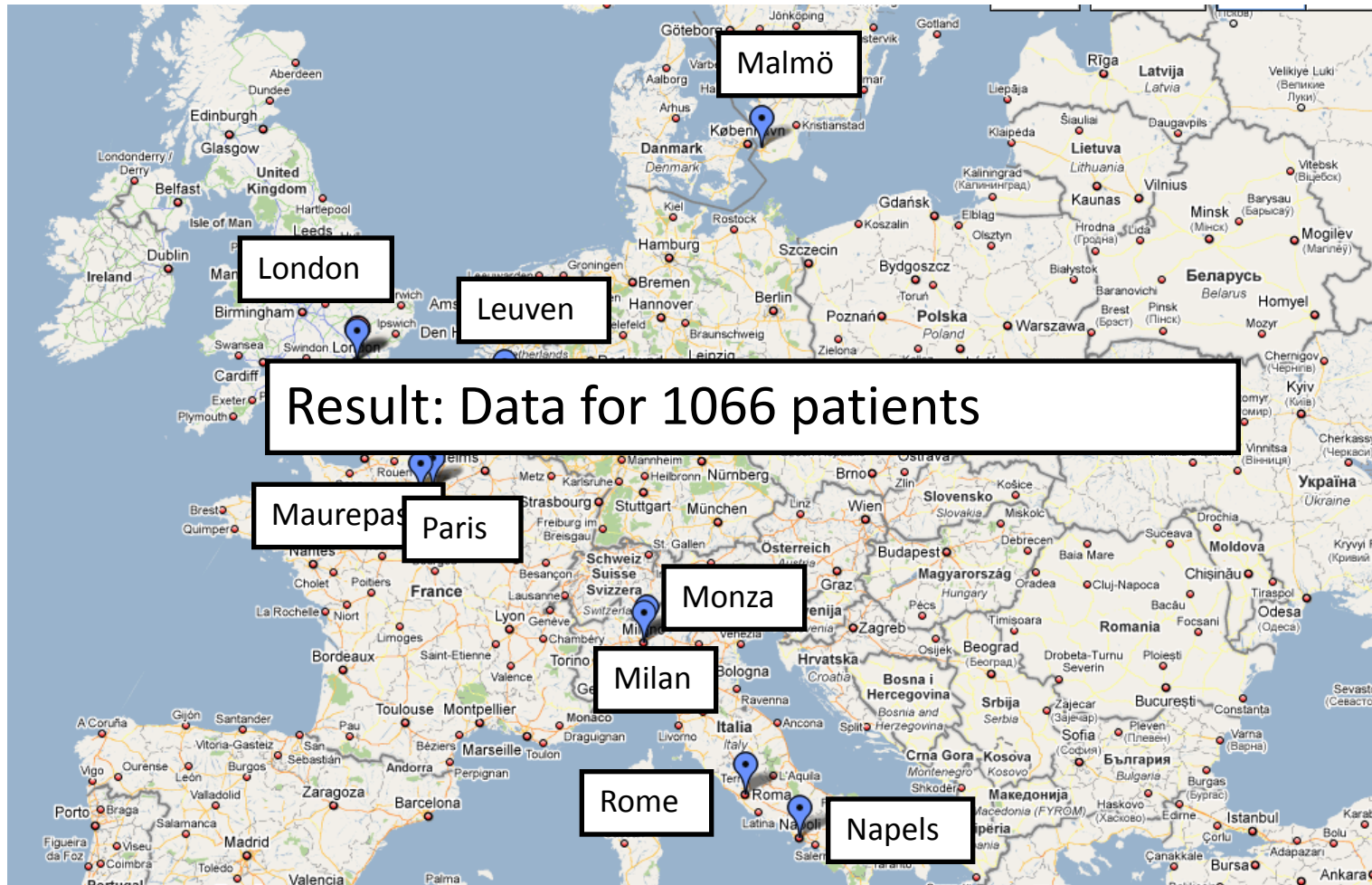
After input this data  
is anonymized and a  
unique code is given  
to each patient

# Data collection

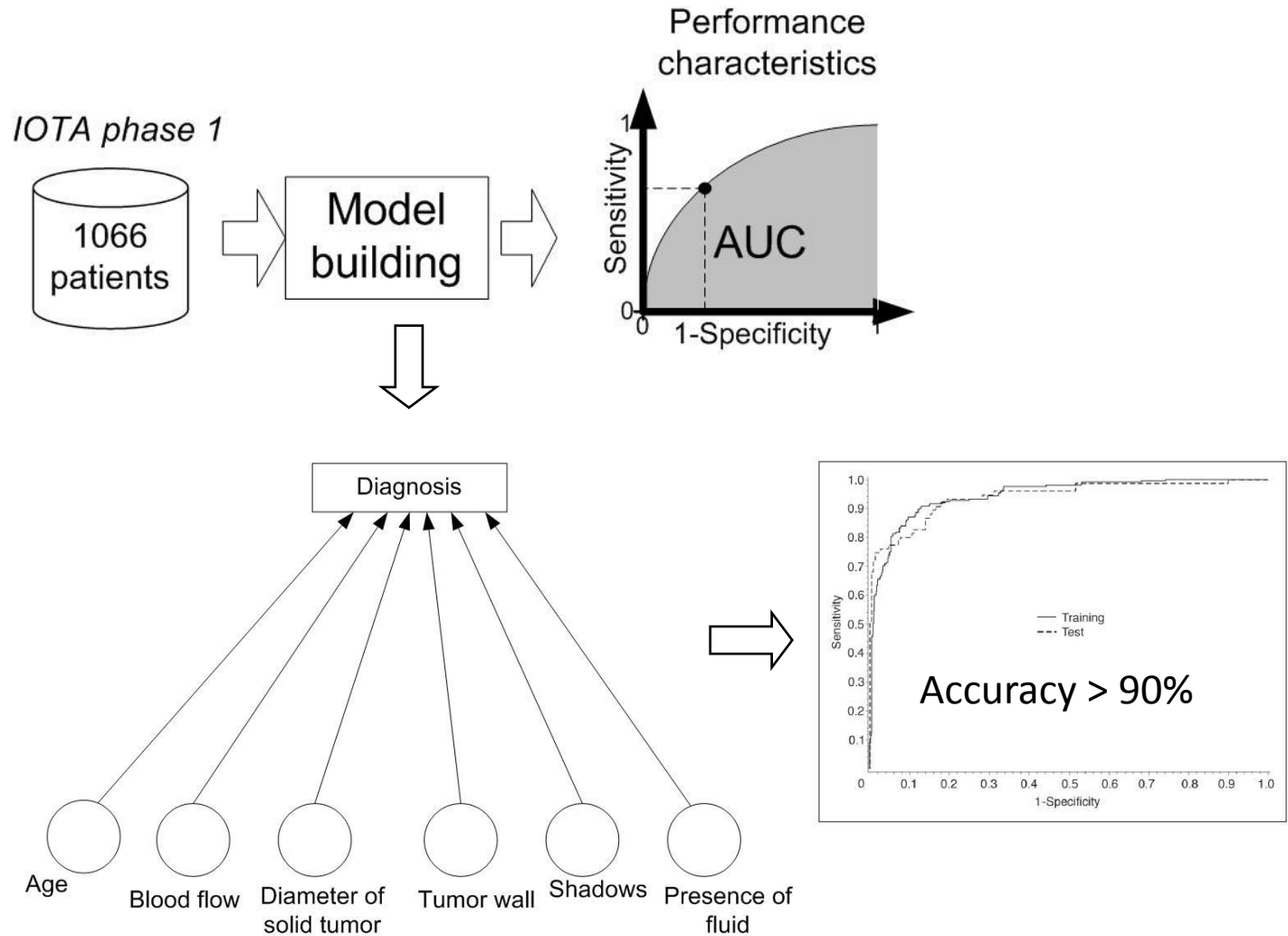


# IOTA phase 1 centers

## *9 centers*

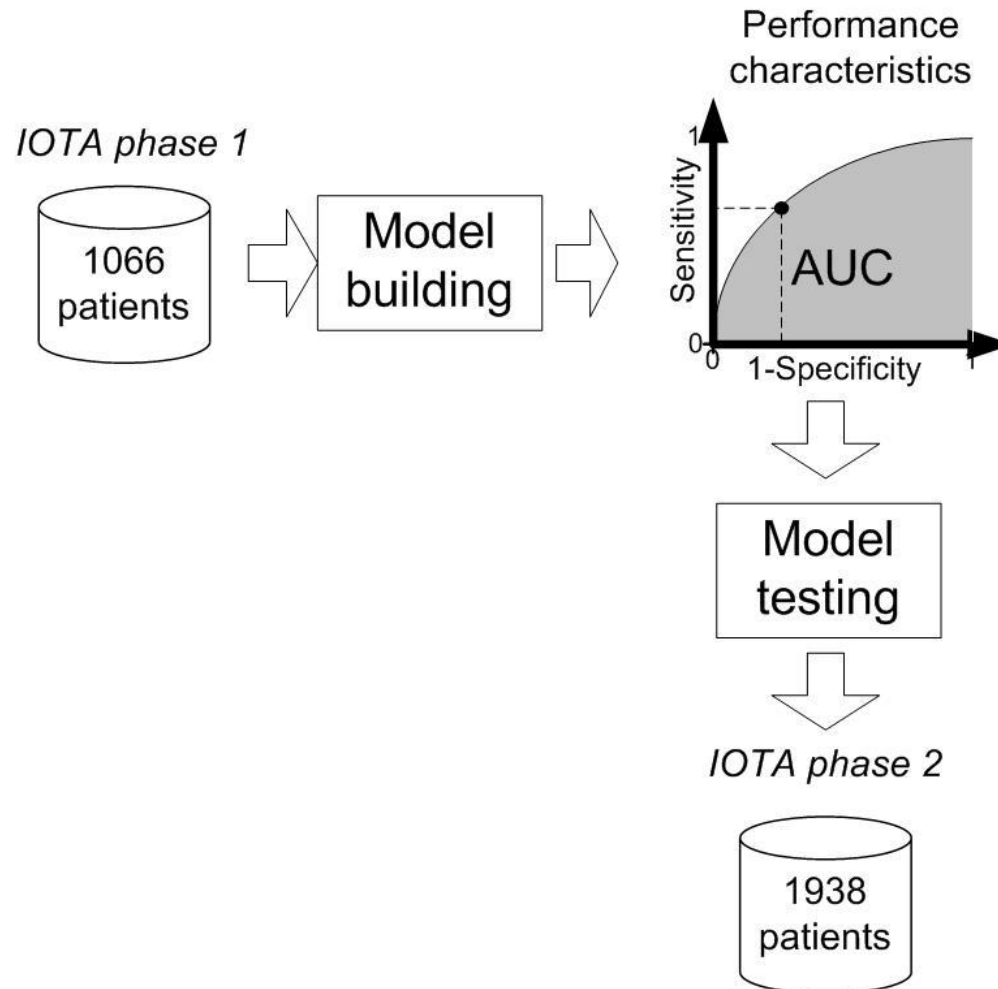


# Model building



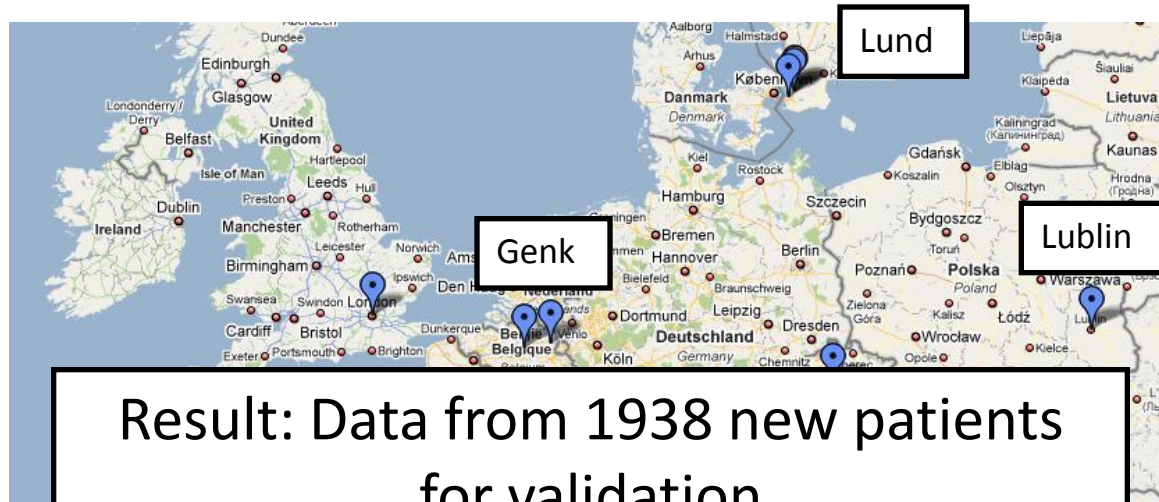


# Validation of the model



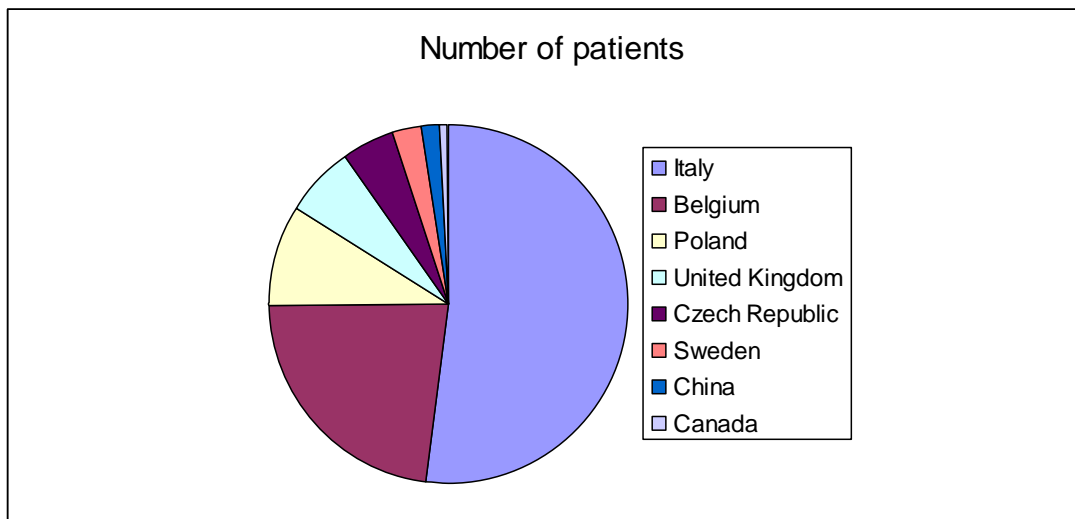
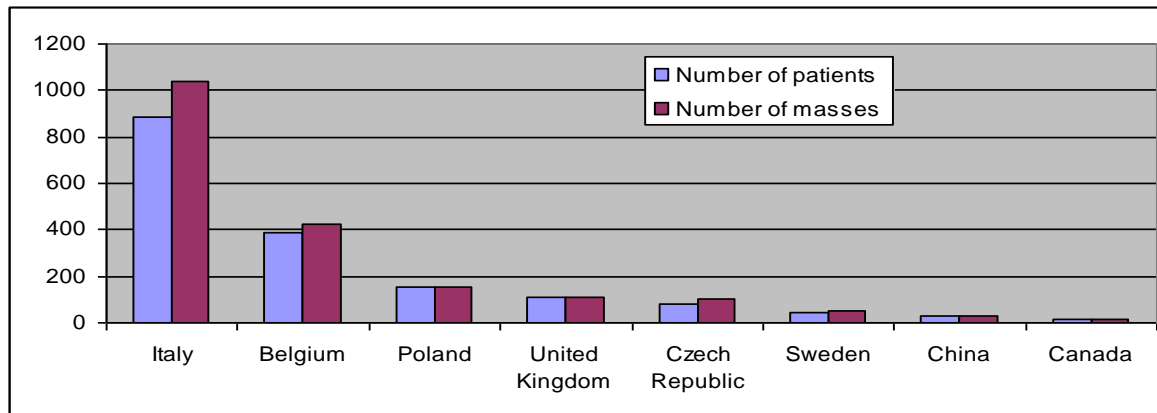
# IOTA phase 2 centers

*12 new centers*

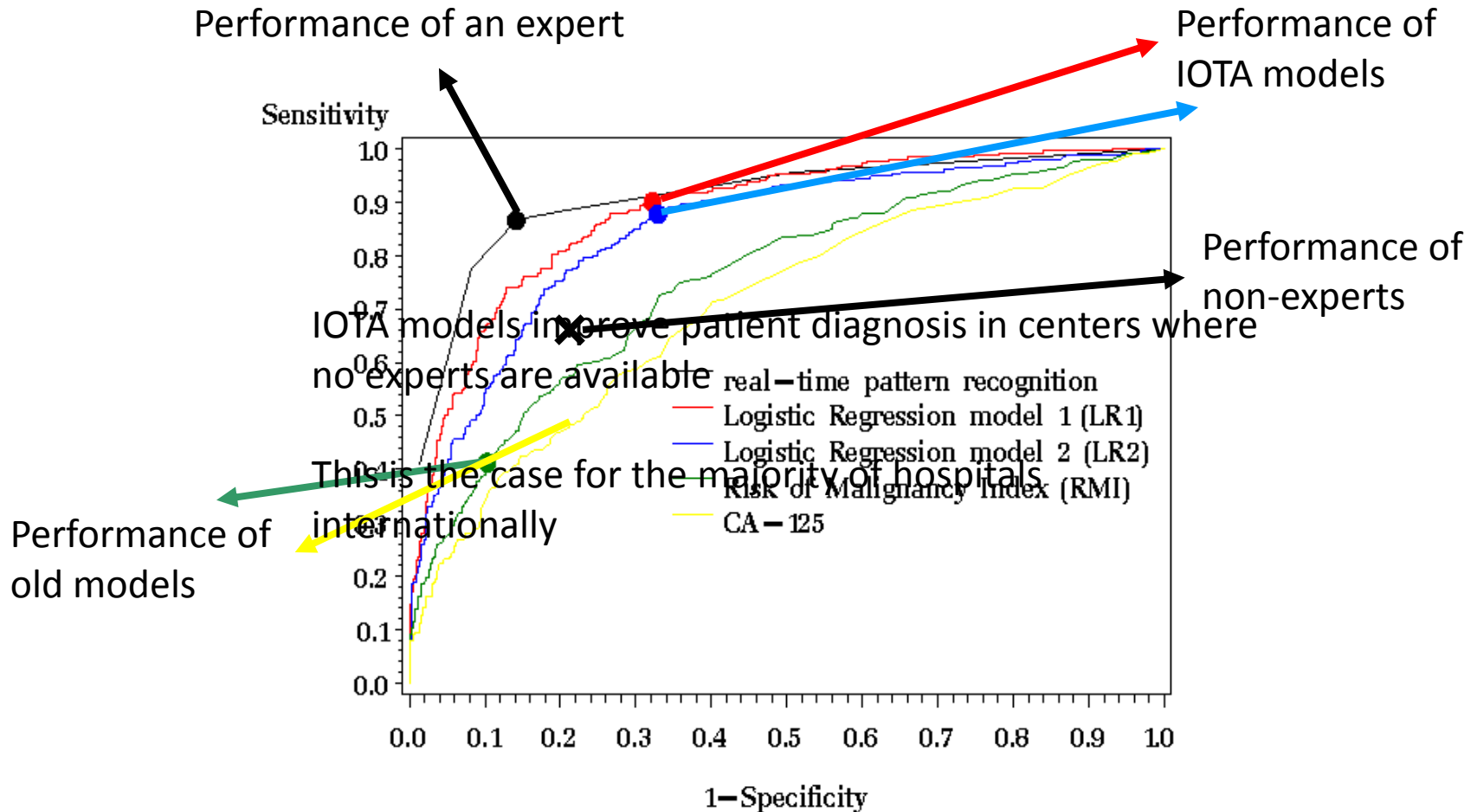


# IOTA phase 2

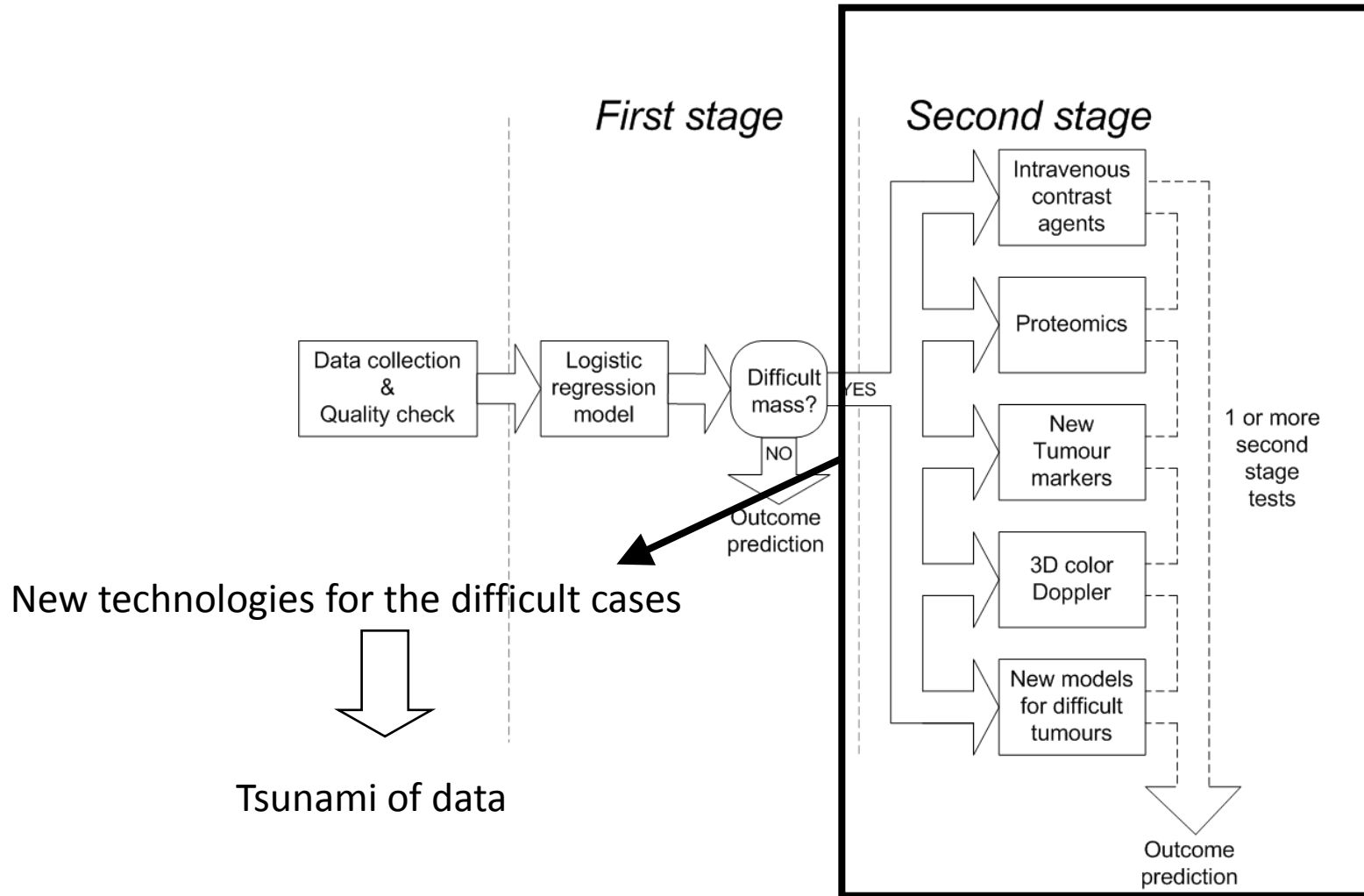
## *numbers*



# Performance comparison



# Future of IOTA



# Information security aspects

- Multilateral security for community-centric healthcare IT platforms
- System and software security of critical community (e-health) infrastructures
- Enabling technologies for collaborative work in the e-health sector
- Policy negotiation, enforcement and compliance
- Privacy preserving data-mining and statistical databases
- Body Area Networks (implanted devices, wearable devices,...) and Personal Area Networks
- E-government : identity management, delegation, controlled data exchange

**You share, we care !**

# Policy decision support

- Population based mining
  - Spatial-temporal modelling
    - geography, age clusters, consumption profiles, longitudinal time series
- Clustering, classification, modelling, prediction, trends, seasonalities
- Outlier detection
- Federaal Kenniscentrum Gezondheidszorg

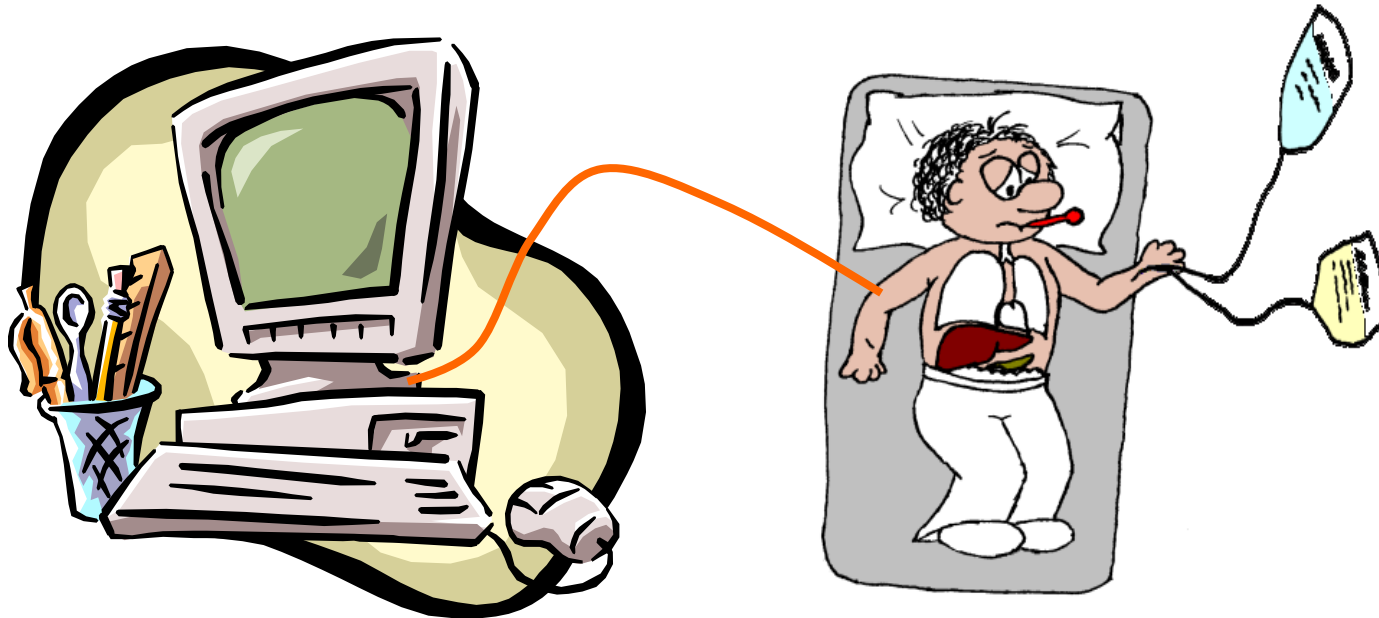
# Datamining van Intensieve Geneeskunde data



# Intensieve Geneeskunde :

## ”Patient Database Management System”:

- computer naast elk bed
- integratie van meer dan 300 variabelen die dagelijks gemeten worden



# Medische taal $\neq$ Ingenieurstaal

van medische vragen naar ingenieurstaal



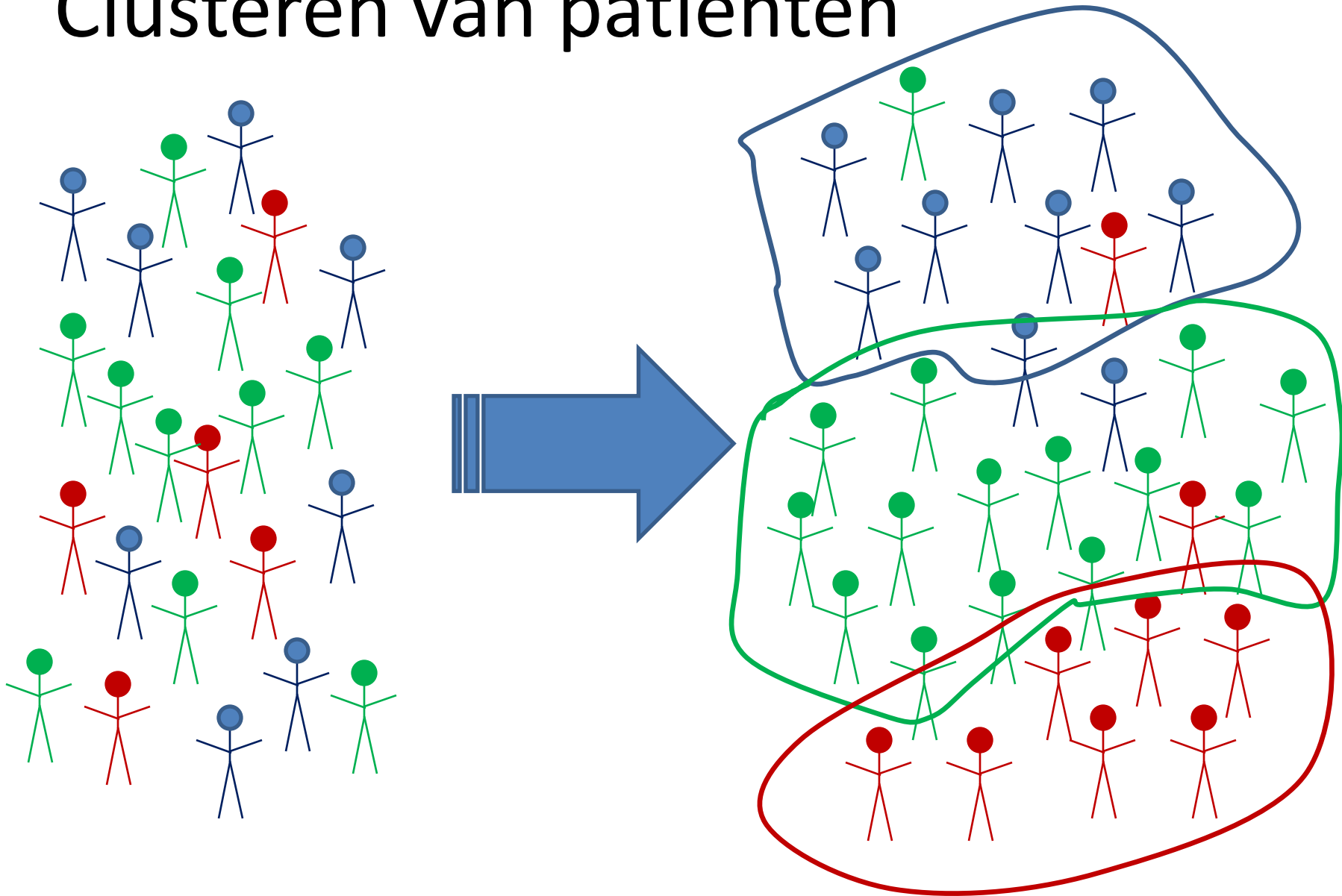
van ingenieursoplossingen naar medische implementatie

# Data management

- > 100 Gigabyte patiëntendata per jaar
- > 300 verschillende parameters
- Verschillende resoluties
- Correcte data? Complete data?

**Gepaste data management procedure vereist!**

# Clusteren van patiënten



# Voorspellen van variabelen

- klinisch relevante vraagstukken
- bv. voorspelling van nierfalen
- bv. voorspelling van ontslag patiënt
- ...

## **Doel:**

Efficiënt gebruik/integratie van de “tsunami”  
aan ICU data, met het oog op:

- Verbeterde zorg patiënt  
(minder complicaties, snellere genezing, enz.)
- Reductie van de medische kosten

# Embedded decision support systems

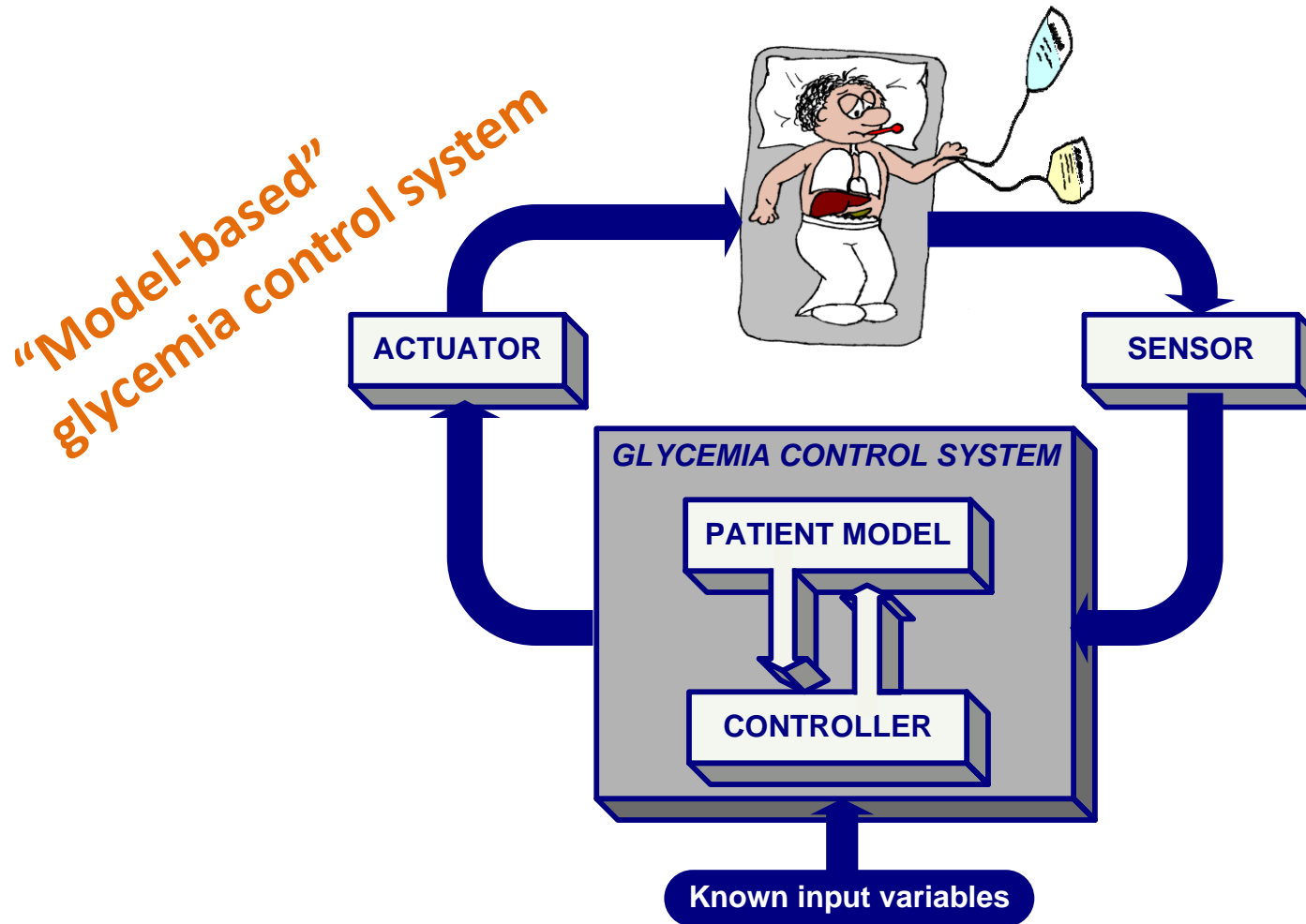
- Assistive health and wellness management systems
- Health telematics
- Intelligent environments, ambient intelligence, smart homes, home networks
- Home health monitoring and intervention
- Health vaults: personal medical data collection and processing
- Wearable sensor signal processing/wireless registration of physiological parameters

# Intensieve Geneeskunde: normalisatie bloedglucose



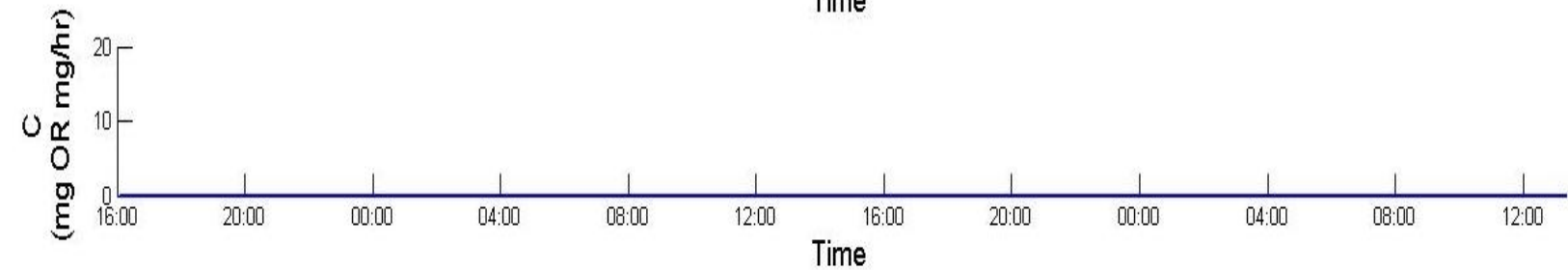
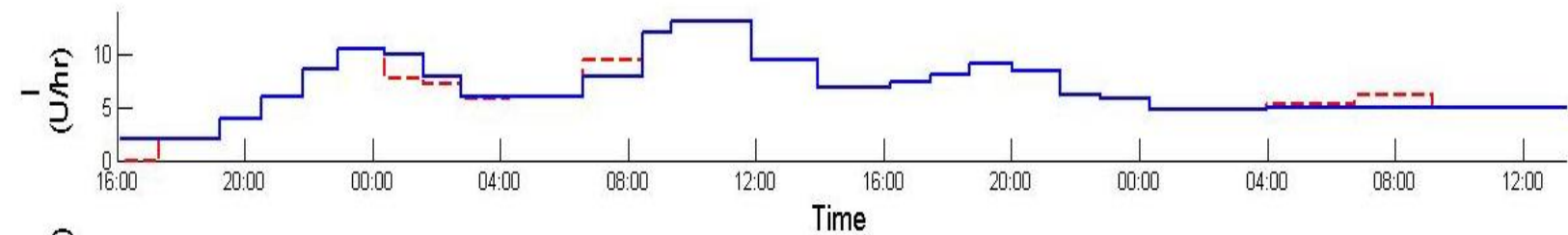
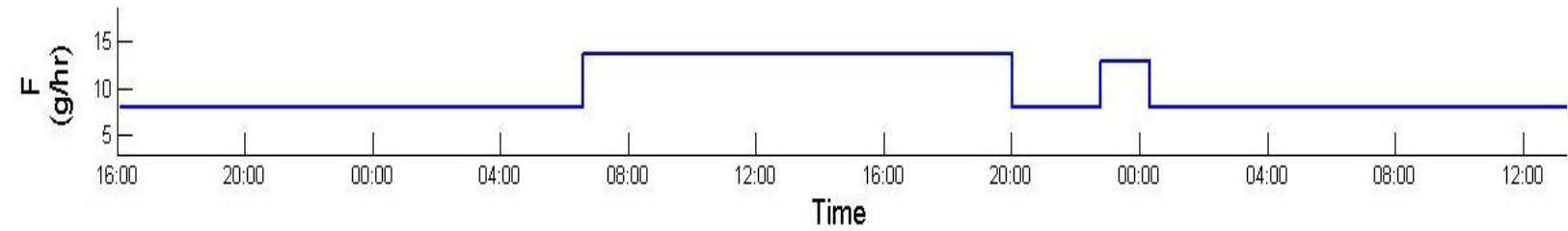
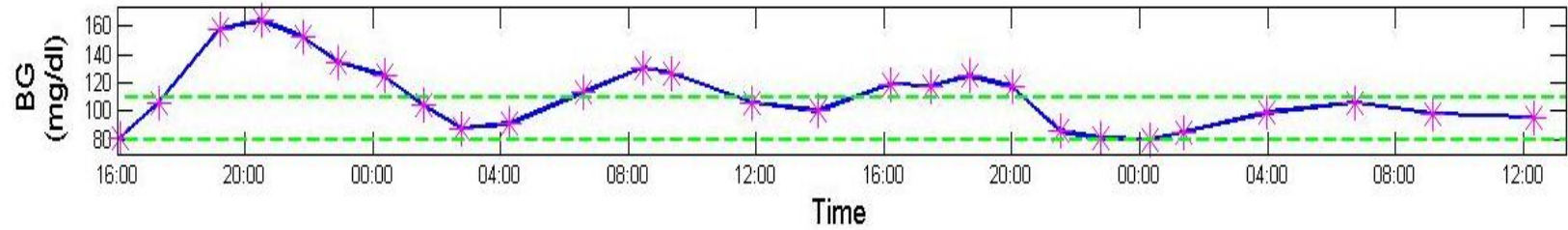
# Insulinedosering door verpleegkundigen: *arbeidsintensief*

- Kan dit proces geautomatiseerd worden?
- Kan dit proces geoptimaliseerd worden?

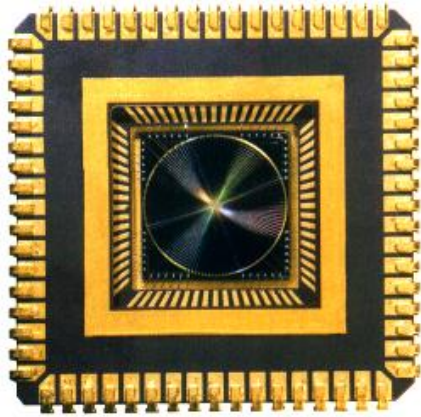




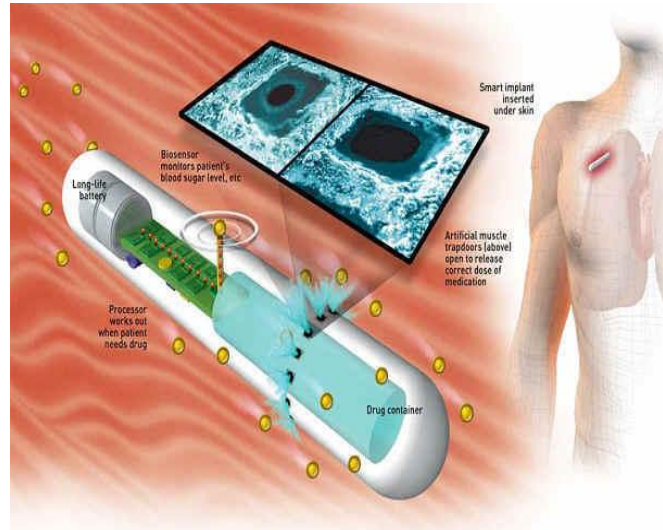
# Patiëntvoorbeeld



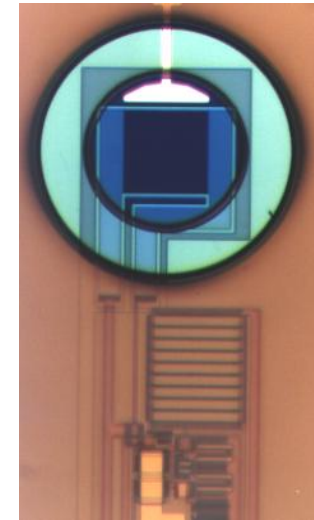
# Nano-Sensoren en Actuatoren



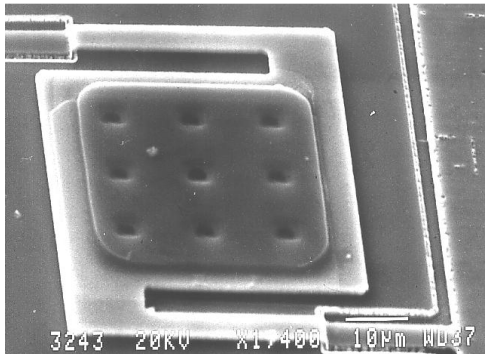
CMOS Imager



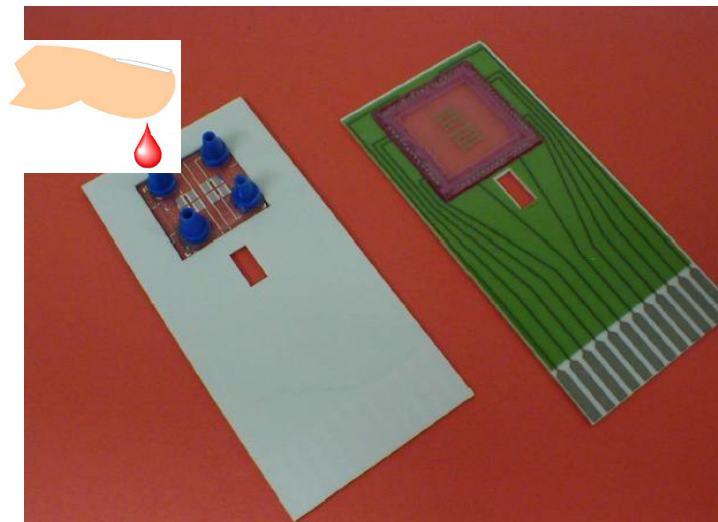
Smart Pill (Ohio State Univ)



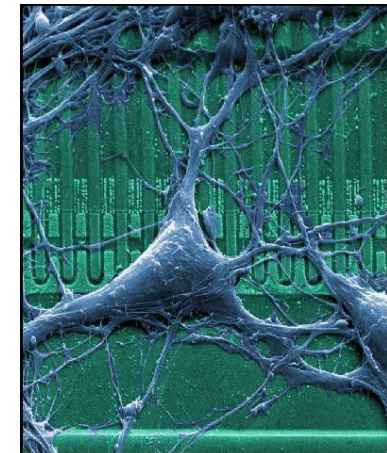
Blood gas sensor (IMEC)



IR Sensor (IMEC)

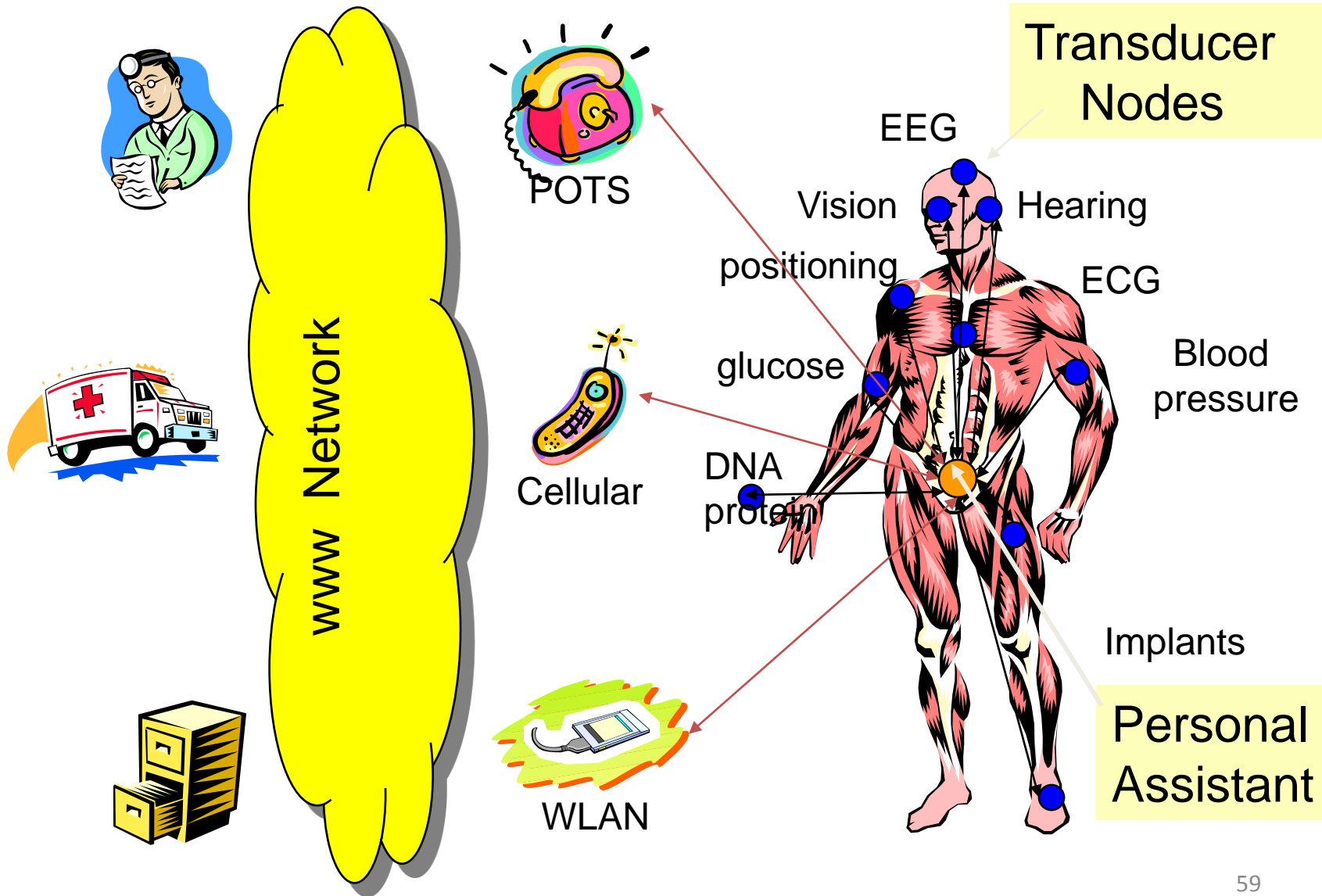


Prostate cancer diagnosis (IMEC)



NeuronSensor (KNS)

# Human++ programma IMEC



## Dr. Coli

The bacterial drug  
delivery system

Leuven - BELGIUM

Multidisciplinary team



Maarten



Antoine



Nick



Dries



Jan



Stefanie



Elke



Andim



Nathalie



Jonas



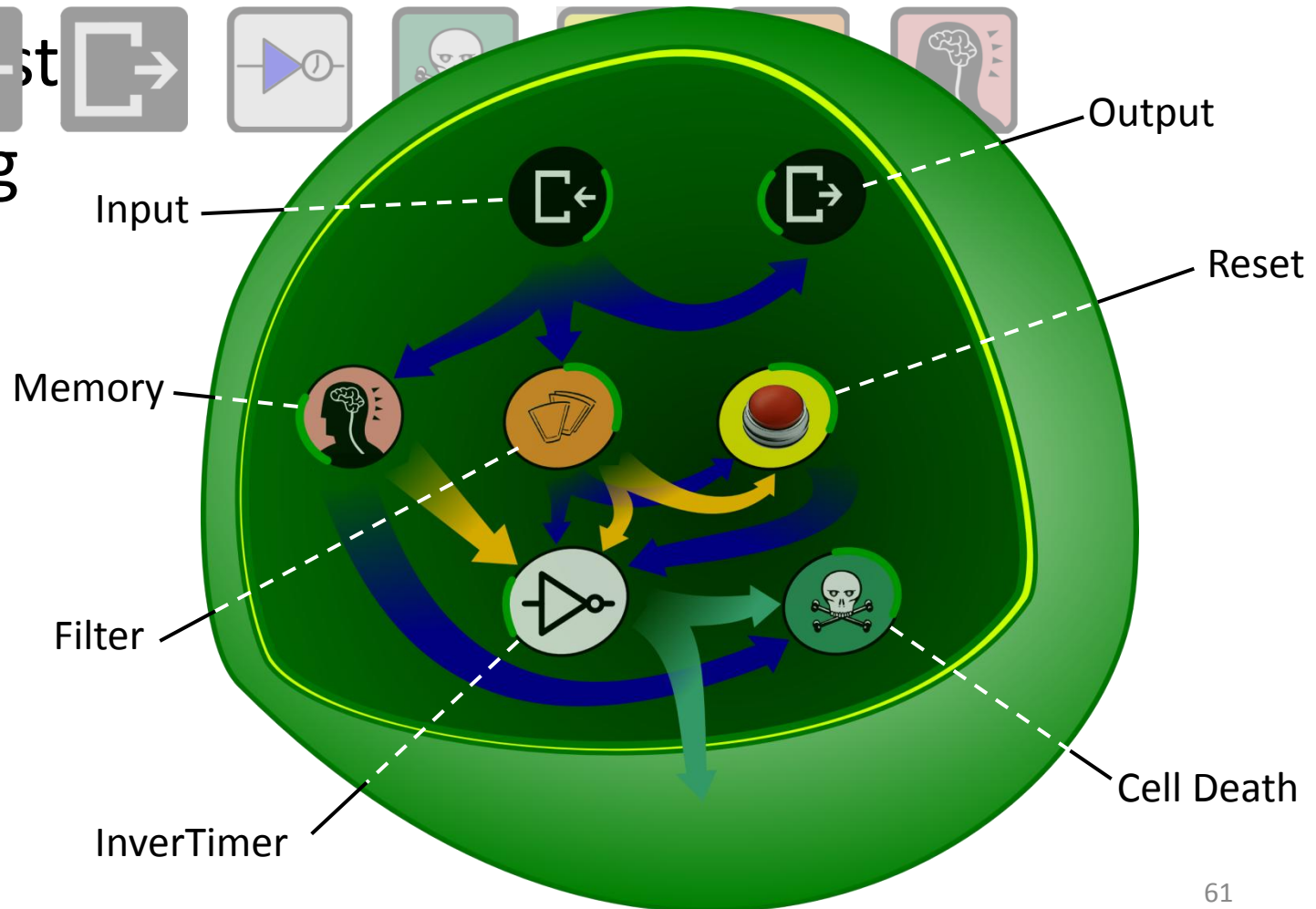
Benjamin



Hanne

# Overview

- 7 subsystems
- Global state
- Modeling



# Outline

-Trends

-Context

-Opportunities and challenges

-What to do ?

# What to do ?

