

# Human Avatars, the Next Paradigm in Healthcare



Adrian M. Ionescu, EPFL, Switzerland @ SEMICON Europa 2019

# Outline

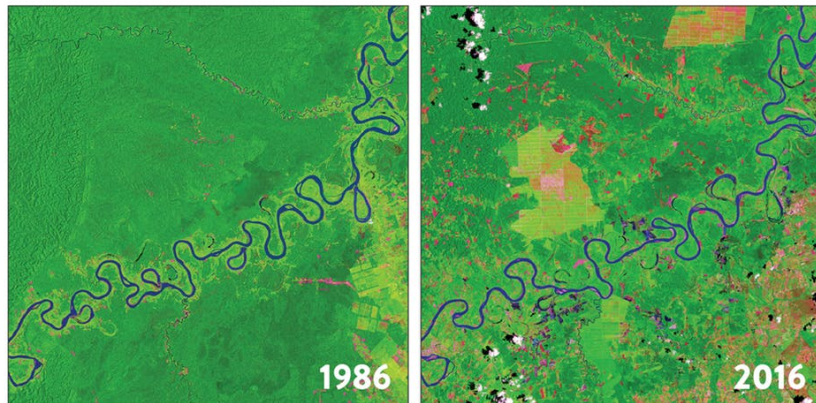
- Technologies for **Global Challenges**
- **Energy efficient** technologies for **Edge Artificial Intelligence & Verticals**
- **Health EU** initiative: a Revolutionary Integrative Technological Platform for P3 Healthcare to shape future missions in **Digital Healthcare**

# Global Challenges for Humanity in 21st Century

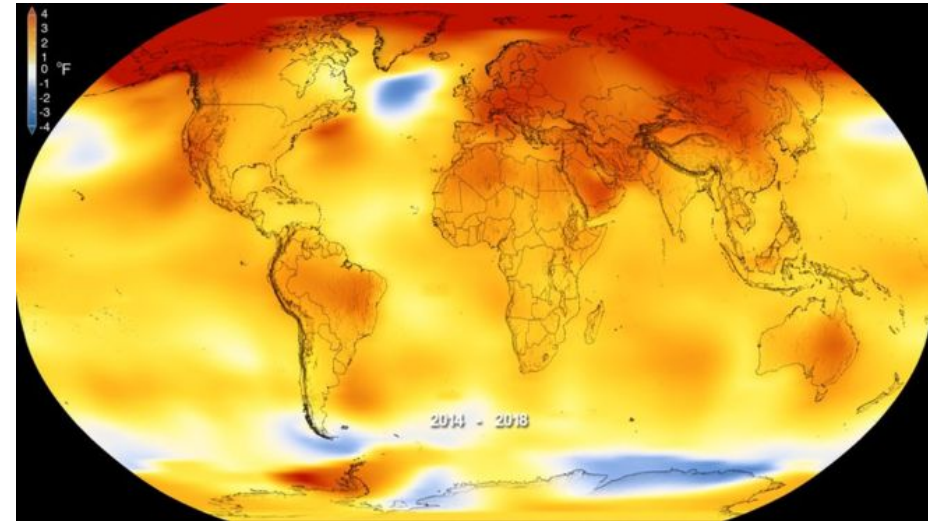
## 1. Climate Change

Greenhouse gas emissions must be drastically reduced within the next decades to stay within 1.5°C of warming above pre-industrial levels and avert the worst impacts of climate change.

**20** YEARS of deforestation near Pucallpa, Peruvian Amazon

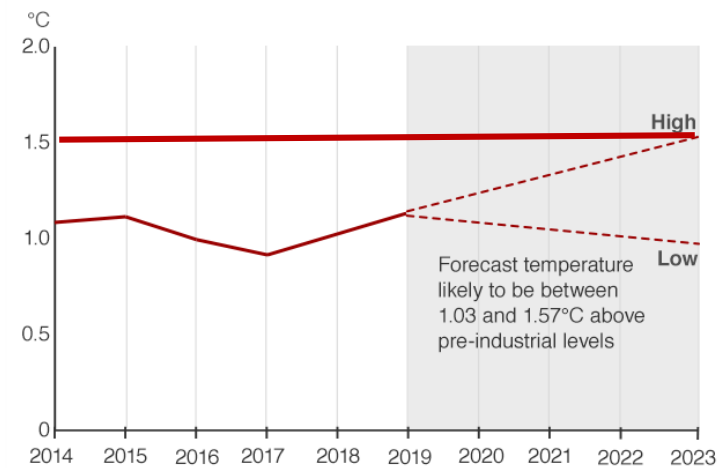


Source: NASA, Images of Change



Met Office predicts 2014-23 will be the warmest decade for 150 years

Temperatures average about 1°C above 1850-1900 levels



Confidence limit for 2015-2018 figs is 95%, confidence limit for 2019-23 is 90%

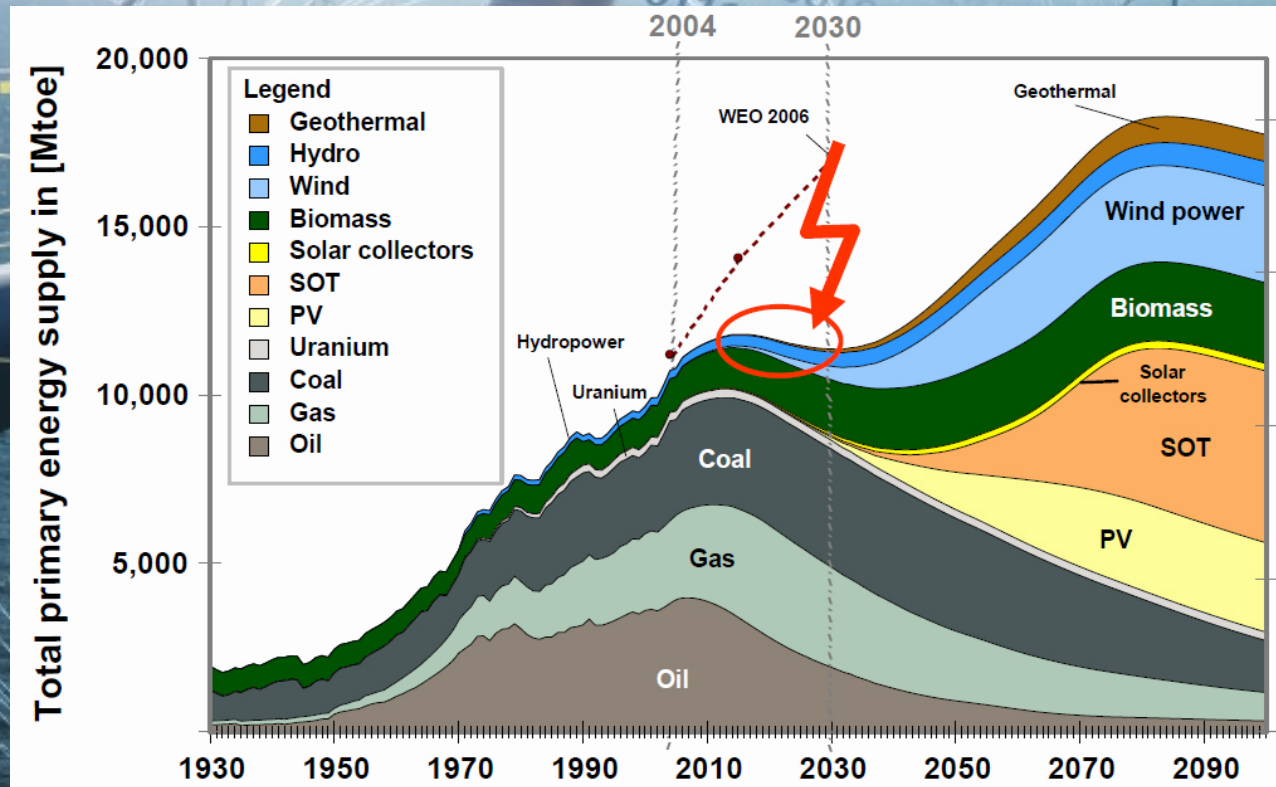
Source: Met Office

BBC

# Global Challenges for Humanity in 21st Century

## 2. Energy

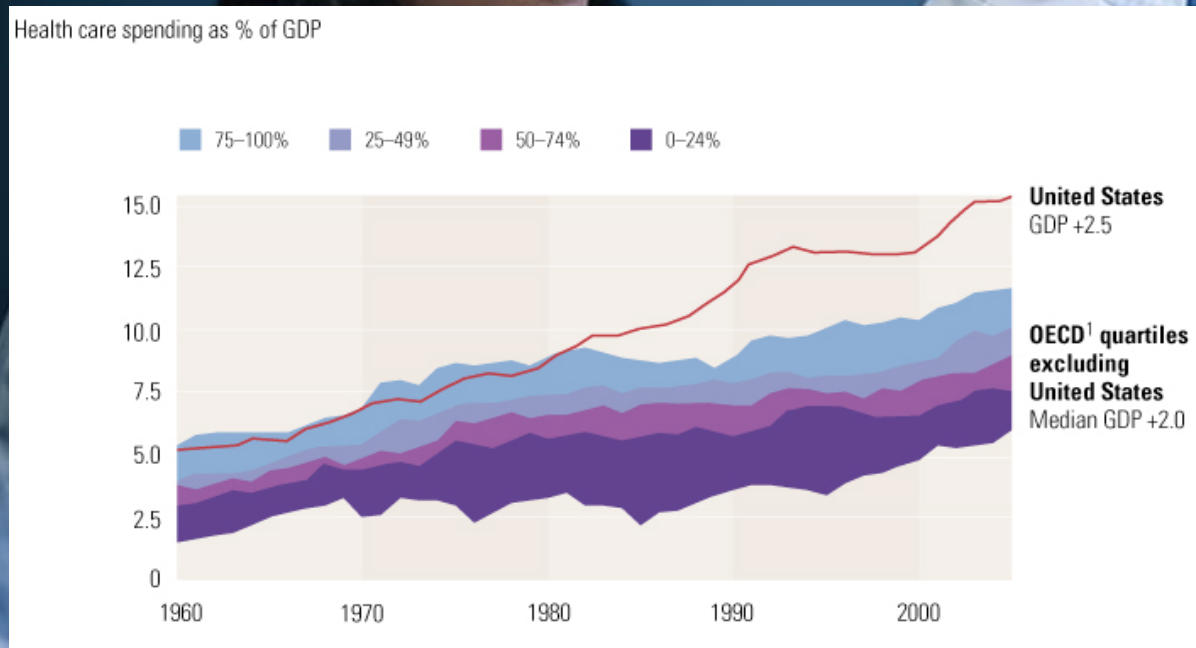
We are at a crucial point on how we make and use sustainable energy:



# Global Challenges for Humanity in 21st Century

## 3. Health

The 20<sup>th</sup> Century reactive healthcare model is unsustainable!



The median increase in health care spending has been 2% points above GDP for nearly 50 years in all OECD countries, with only minor fluctuations. Expectations:

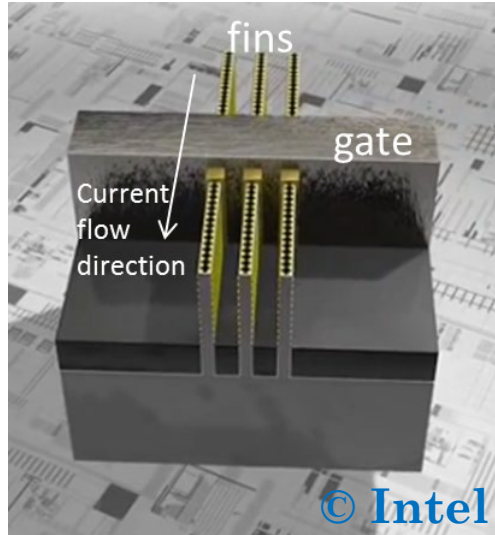
- **30% of GDP in the United States by 2040** (up to 97% in 2100)
- **30% of the median OECD GDP by 2070**

We need a paradigm change: a P3 Digital Healthcare revolution.  
**We are not yet almost there!**

# How technology can help?

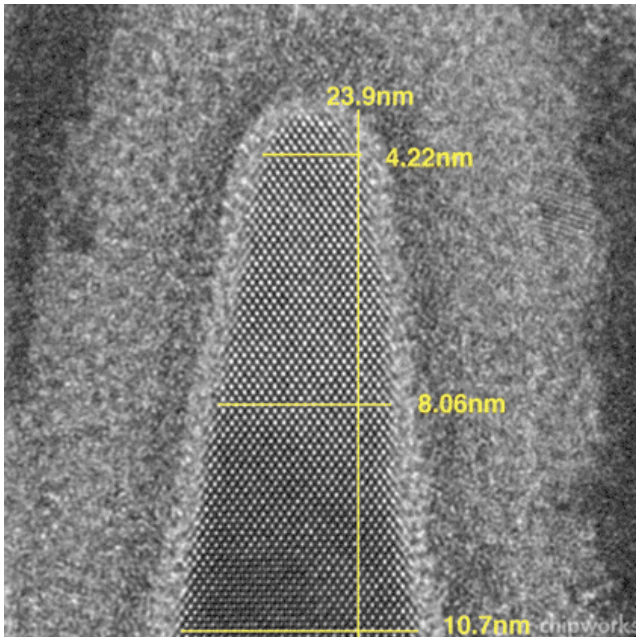
- Every day **new evidence of our unsustainable impact** on the environment is emerging.
- We have a **critical window of opportunity** to put in place commitments and actions to reverse the trend of nature loss.
- **Digital Technology** should play a crucial role in **decoupling development and environmental degradation**.

# Nanoelectronics: ~10nm 3D transistors

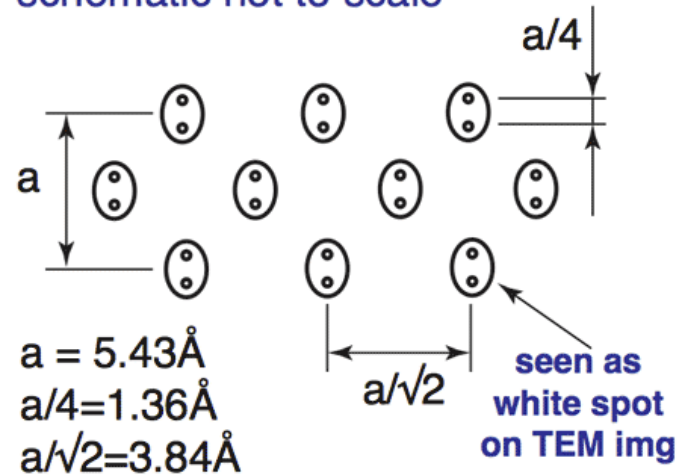


Today: **14 nm:**  
 40 millions transistors/mm<sup>2</sup>

2019-2020: **10 nm:**  
 100 millions transistors/mm<sup>2</sup>

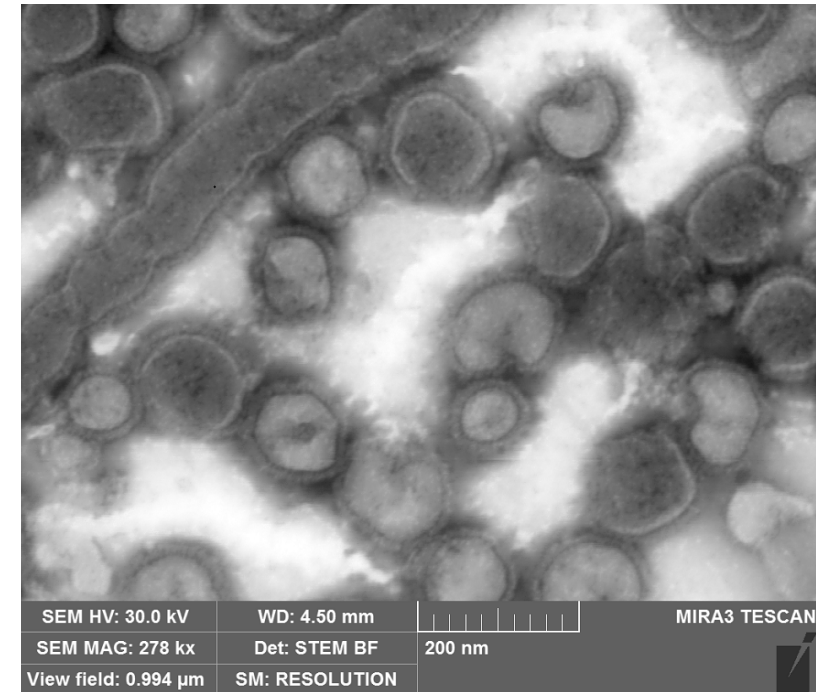


TEM image of Si(110), schematic not to scale



## Virus

Negatively stained Influenza Virus, usually spherical or ovoid in shape, 80 to 150 nm.

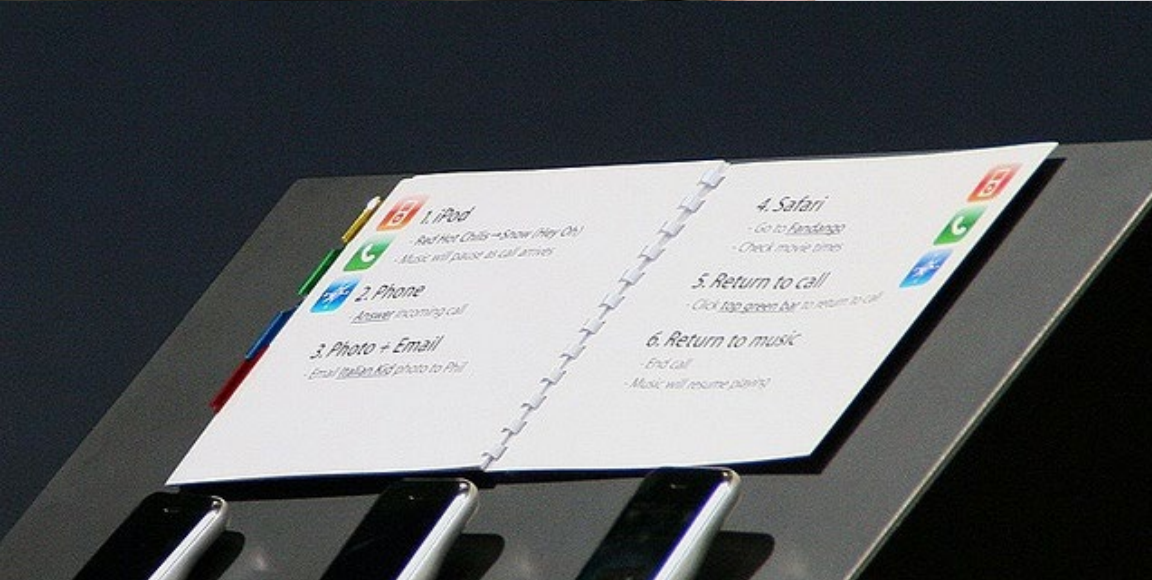


# Iphone & Guardian Angels

• First **wireless** computer with **sensors**

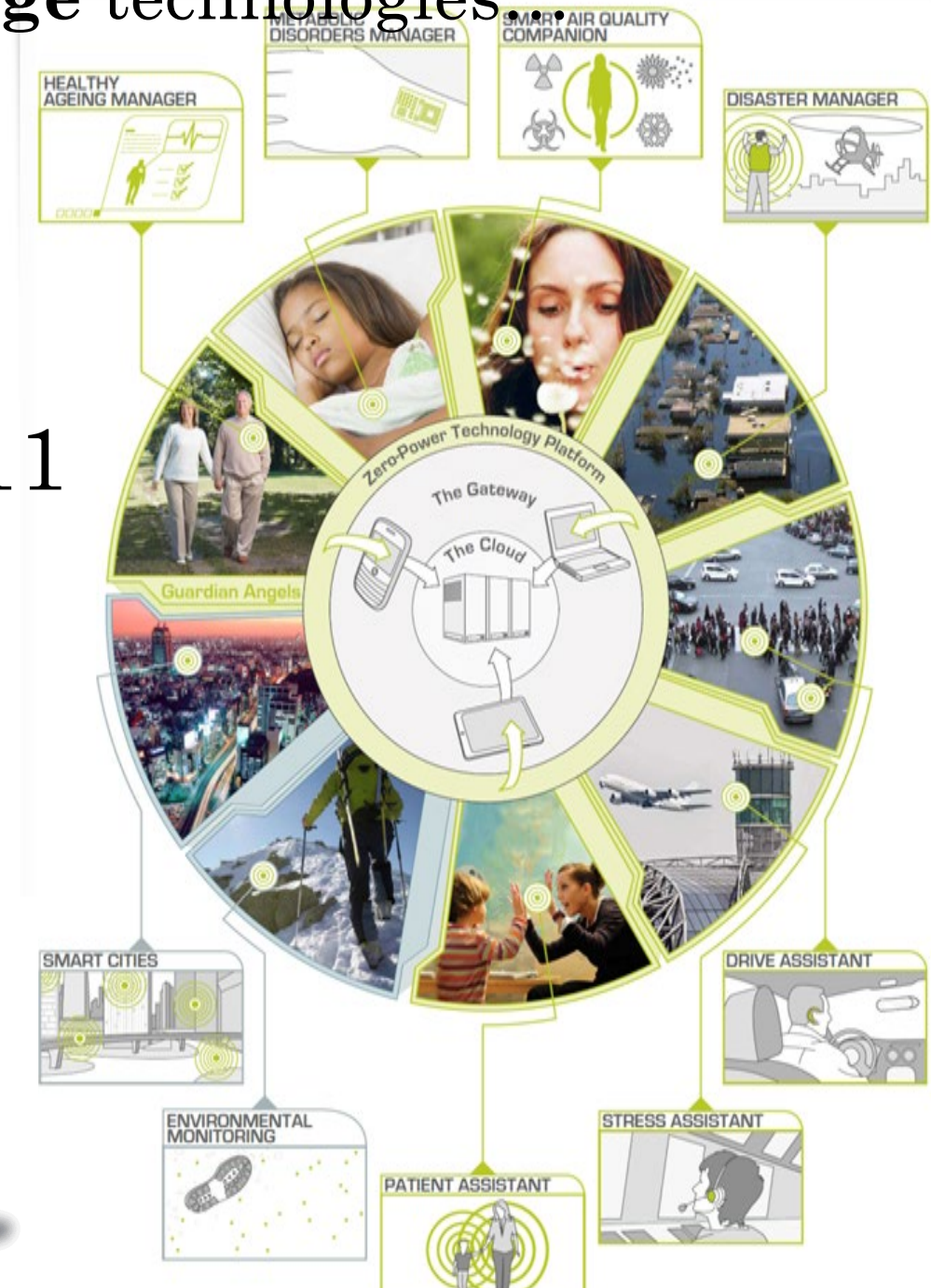


2007

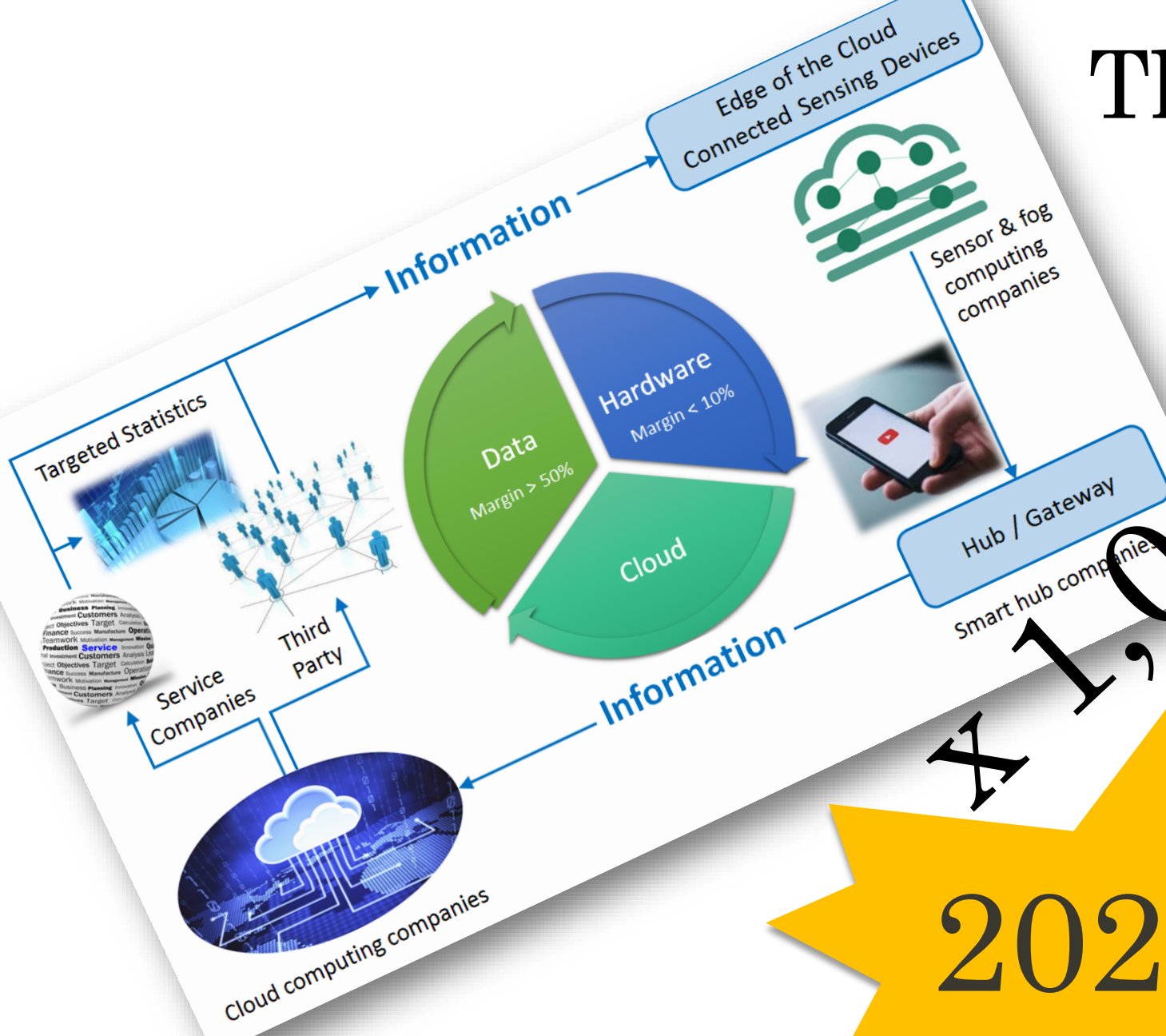


# • Edge technologies

2011



# The Zettabyte Era



**X 1,000,000**

1985 Storage 21PB  
Coms 59PB  
Comp 0.74PIPS

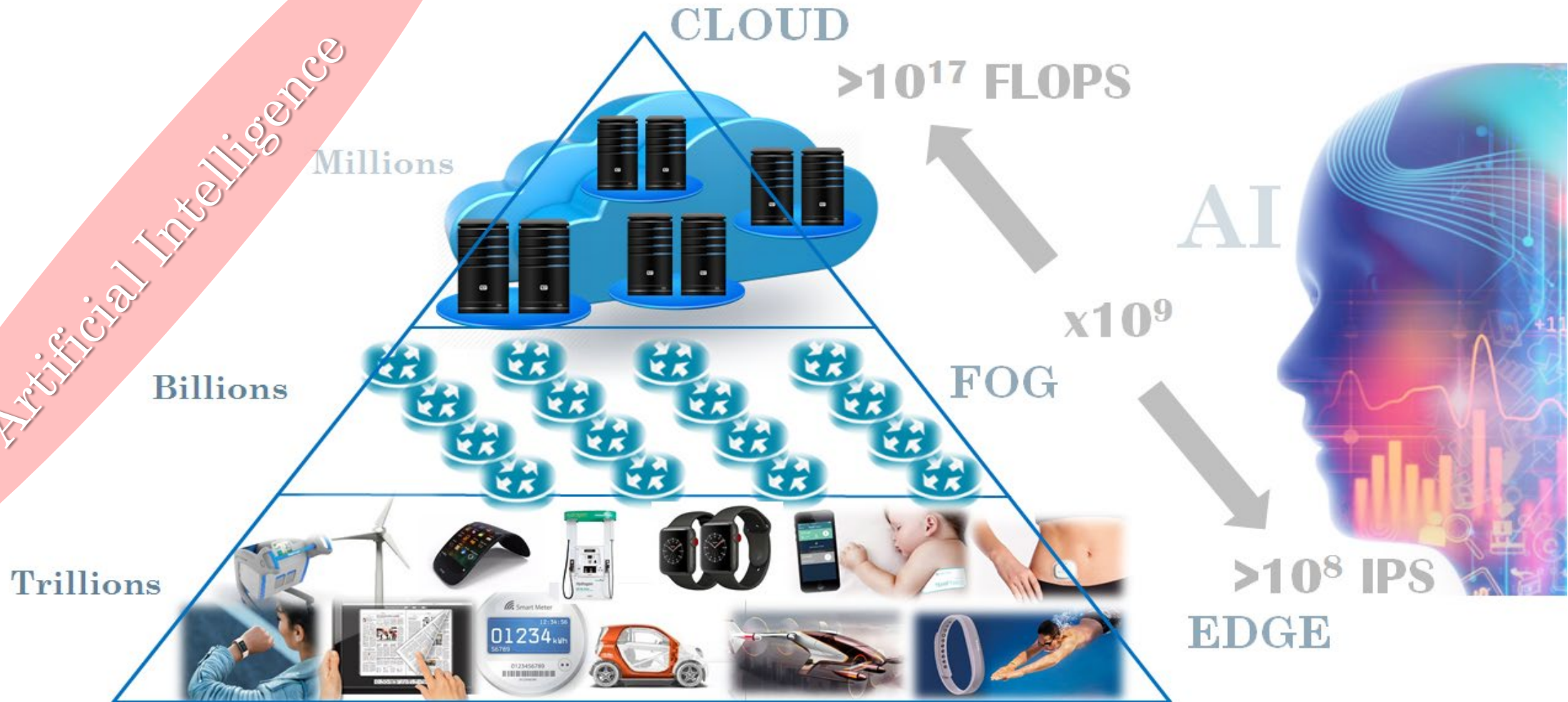
2007 Storage 277EB  
Coms 537EB1  
Comp 195PIPS

**2020** Storage 140 ZB  
Coms 272 ZB  
Comp 2'590 ZIPS  
Edge IoT >50 ZB

M. Hilbert, P. López, *Science*, 2011.  
Z.-W. Xu, *J. of Comp. Sci. and Tech.*, 2014.

# The Future of AI Computing?

Artificial Intelligence



2020:10% of the world's data (Source: IDC).



# What is **True AI**?

## Stretching the truth!?

- Many companies claim highly sophisticated automation software with some AI elements, none so far established **True AI** to replace the humans.
- What is **True AI @ Edge**?
  - ability of software to analyze and interpret that data in order to automate processes in a human-like intelligent way (ML = just the current status);
    - + **dedicated processing hardware**
    - + **deep & valid data generator technology**
    - + **Edge AI key attributes**: energy efficiency: computing, communication & sensing, data security, form factor, costs

# The Internet-of-Things makes healthcare accessible to all

- IoT technology bridges the gap between digital and physical data sources of data, by monitoring patient behavior in real time.
- Gradual transitioning from institution-centric care delivery to patient-centric care delivery practices.
- Internet of Things (IoT) Healthcare Market to Reach \$322.2 billion by 2025.

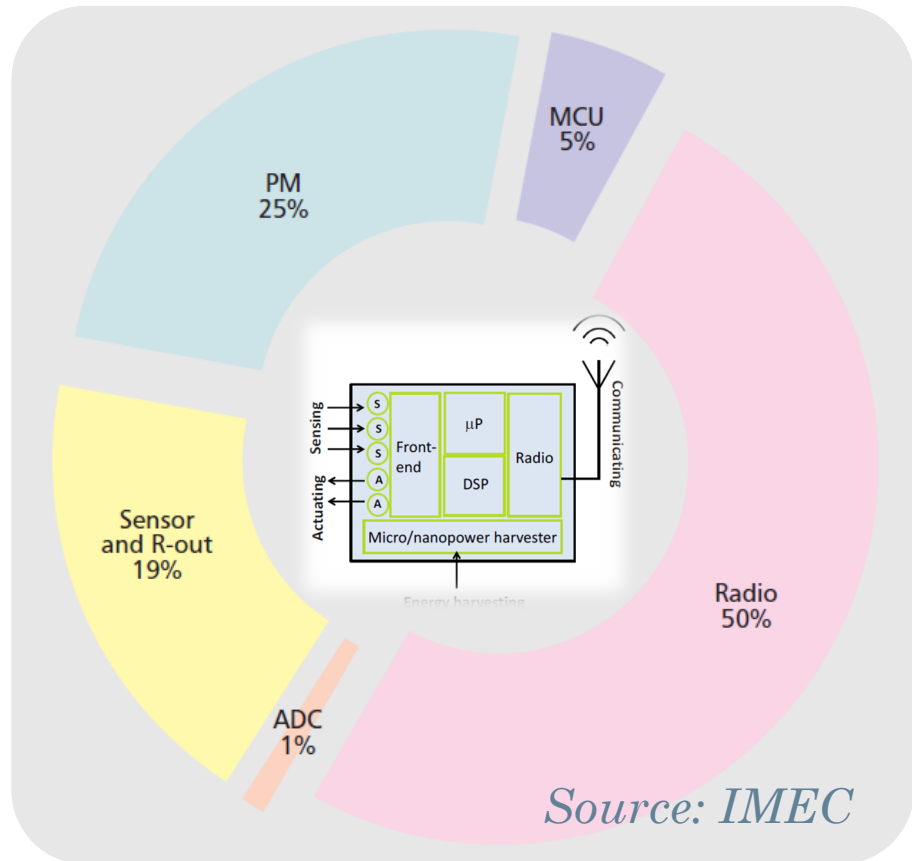
**Is IoT in healthcare the missing link in value-based care?**

**improve outcomes, reduce costs and ultimately provide greater access to high-quality care for more people across the globe.**

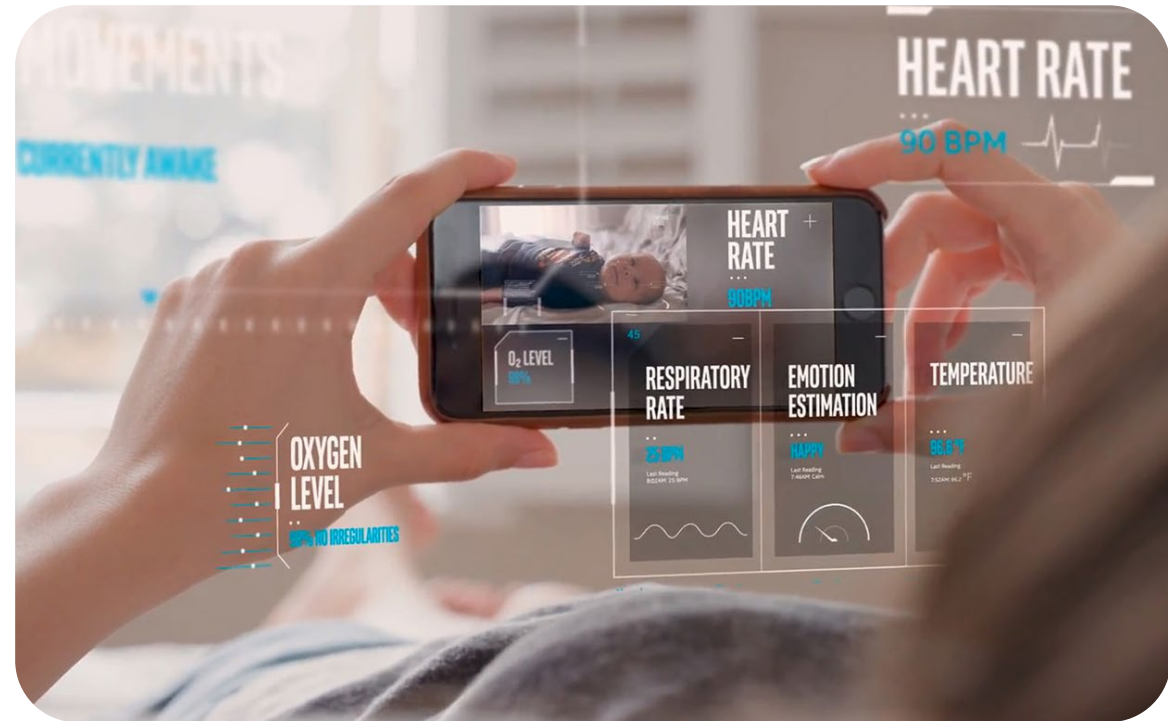


# Autonomous sensor nodes for IoT

100 microWatt – 10 mW  
*/ sensor node*



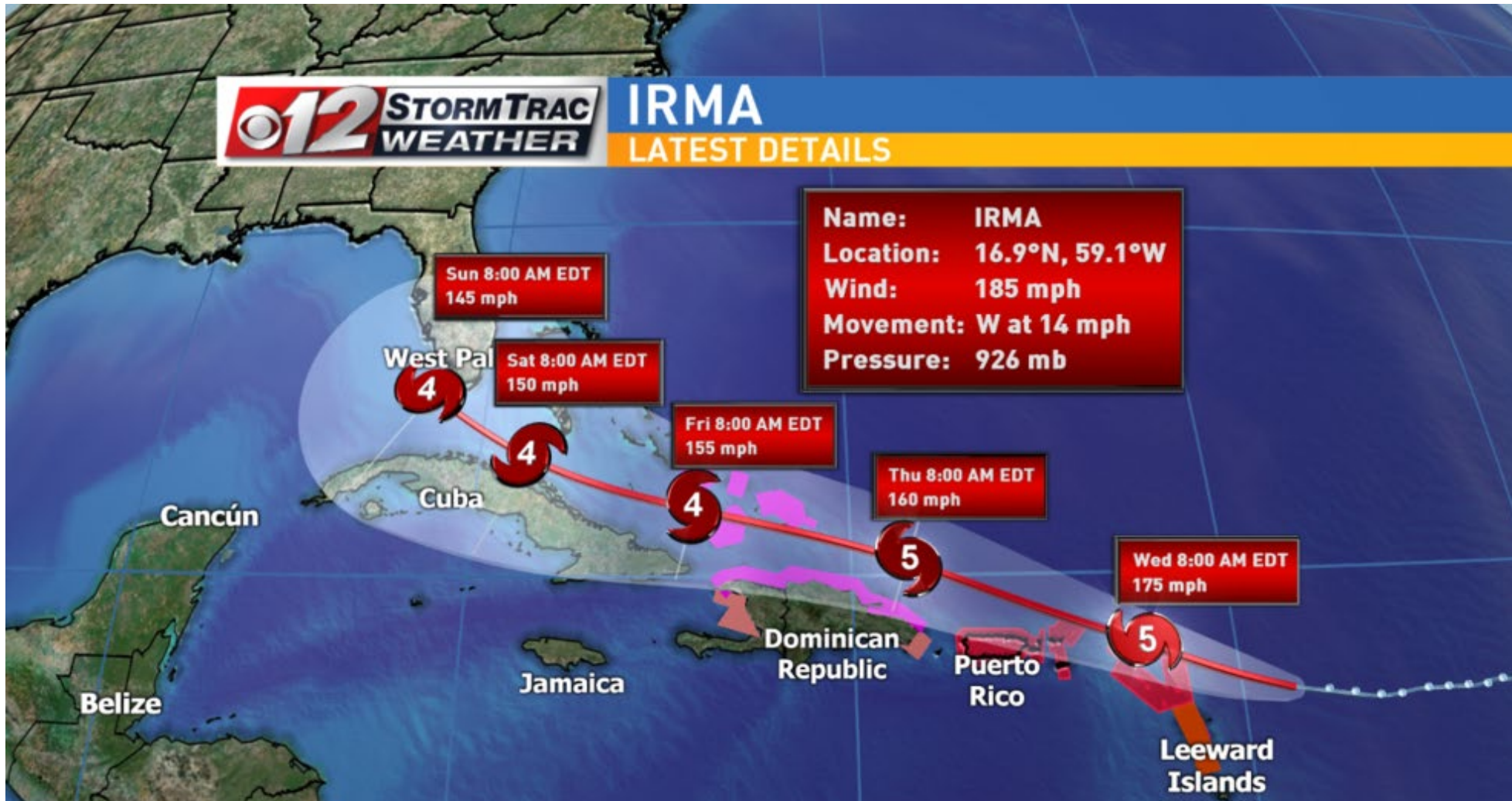
Smart hub: 100mW – 10W  
*(tens of sensors / hub)*



# What else?

# Today our technology can predict weather...

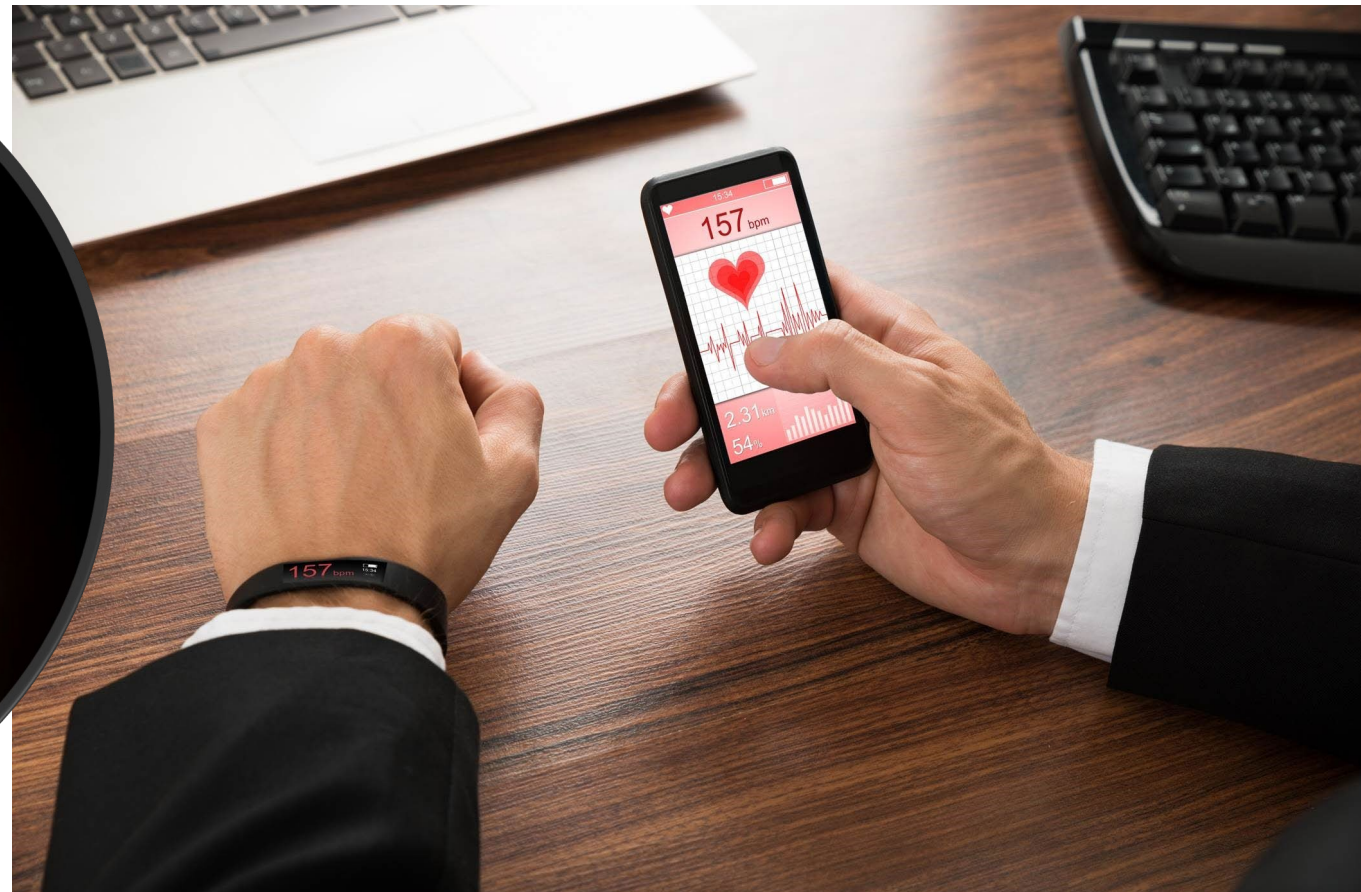
**SENSORS** → **BIG DATA** → **MODELS** → **COMPUTING** → **WEATHER FORECAST**



# ... but cannot predict health status

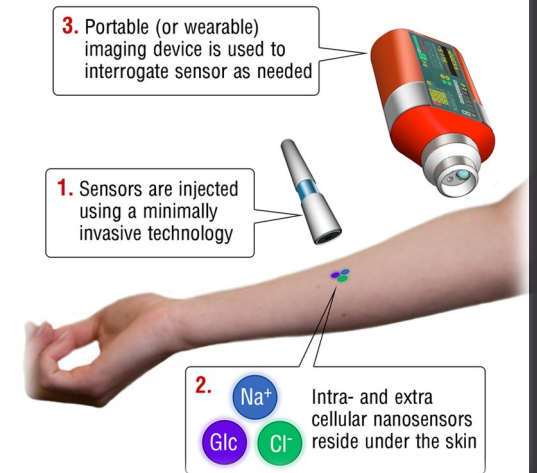
- Goal: turning a stream of information into predictions of outcomes
- **Can a Wearable Fitness Device Predict Your Heart Attack? Value chain!**

SENSORS → BIG DATA → MODELS → COMPUTING → HEALTH FORECAST



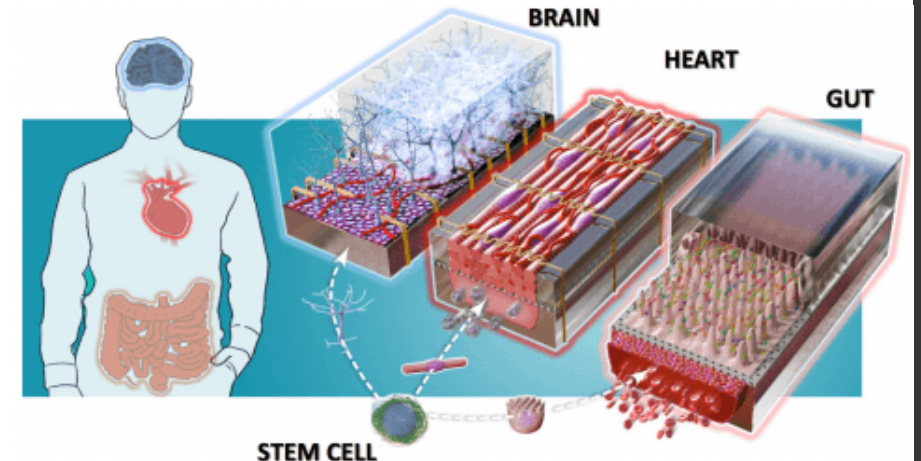
# Biosensing as enabler of revolutionary smart sensing & computational systems

- **Wearable** biosensors: ECG, EEG, EMG, SpO2, blood pressure, pH, glucose, various analytes/biomarkers in biofluids, ...
- **Implantable** sensors and transducers
- **Organs on Chip** with embedded biosensors!



## Requirements

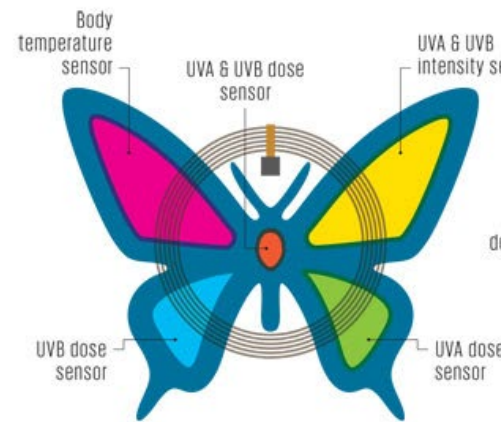
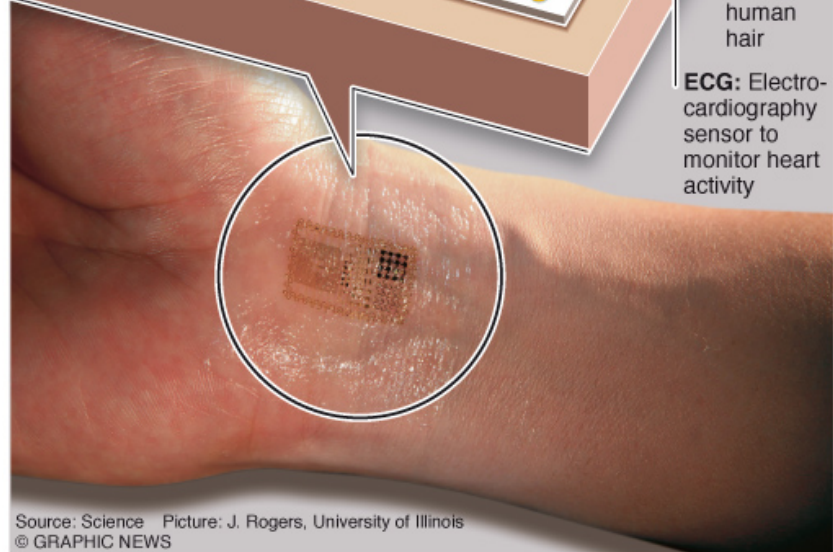
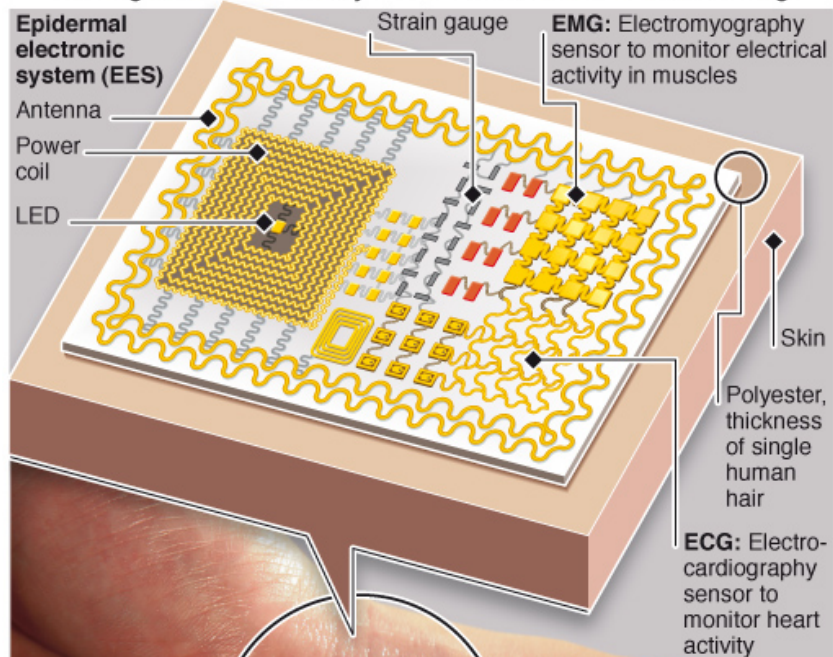
- High quality data - multi-parameter sensing
- Form factor - frictionless
- Autonomy - low power, energy efficiency
- User acceptance - data security, privacy
- Low cost systems – 3D, on foil integration



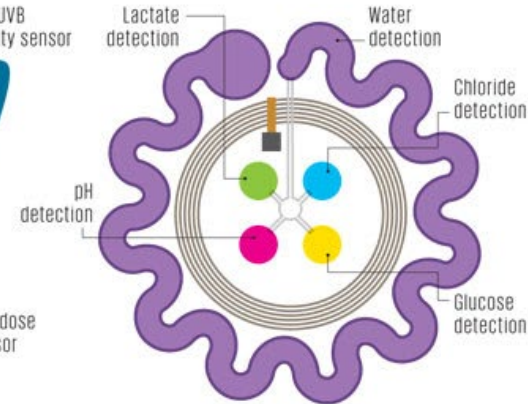
# Towards sensitive biostamps & tatoos

## Electronic "skin" can monitor heart

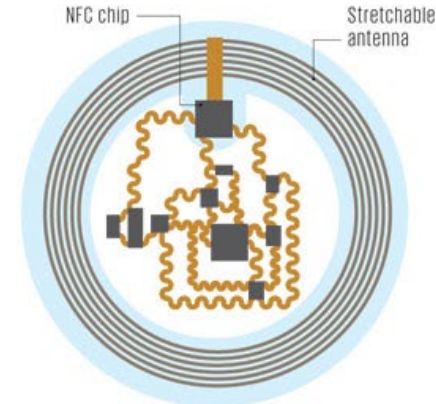
An ultra-thin electronic device that attaches to the skin like a stick-on tattoo can measure electrical activity of the heart, brain waves, and other vital signs without the bulky electrodes used in current monitoring



UV EXPOSURE & TEMPERATURE



PERSPIRATION & BIOCHEMISTRY

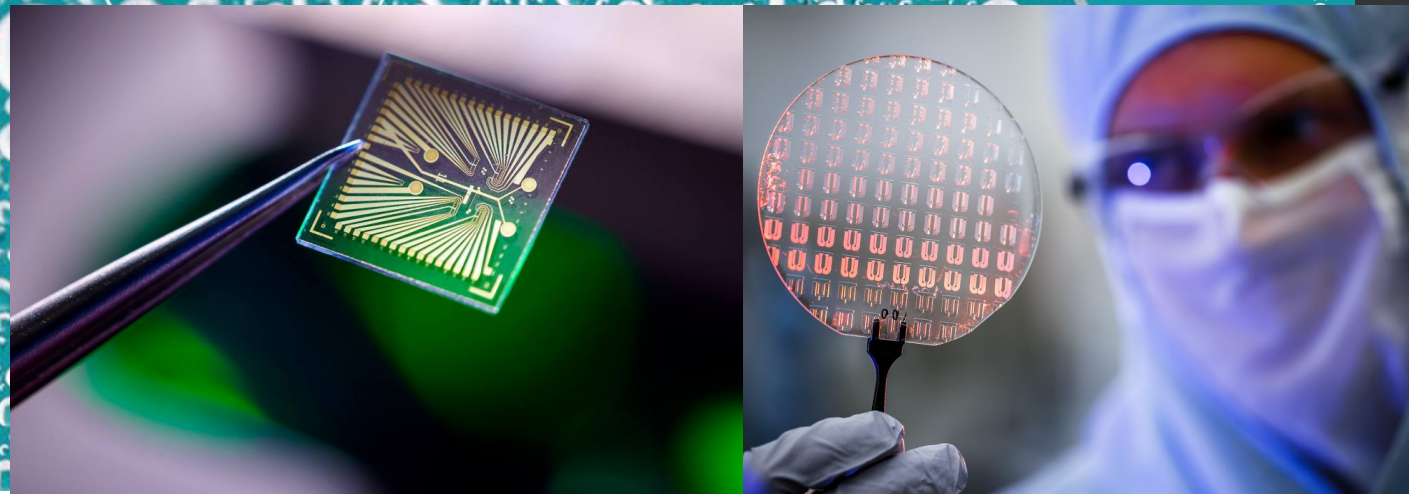
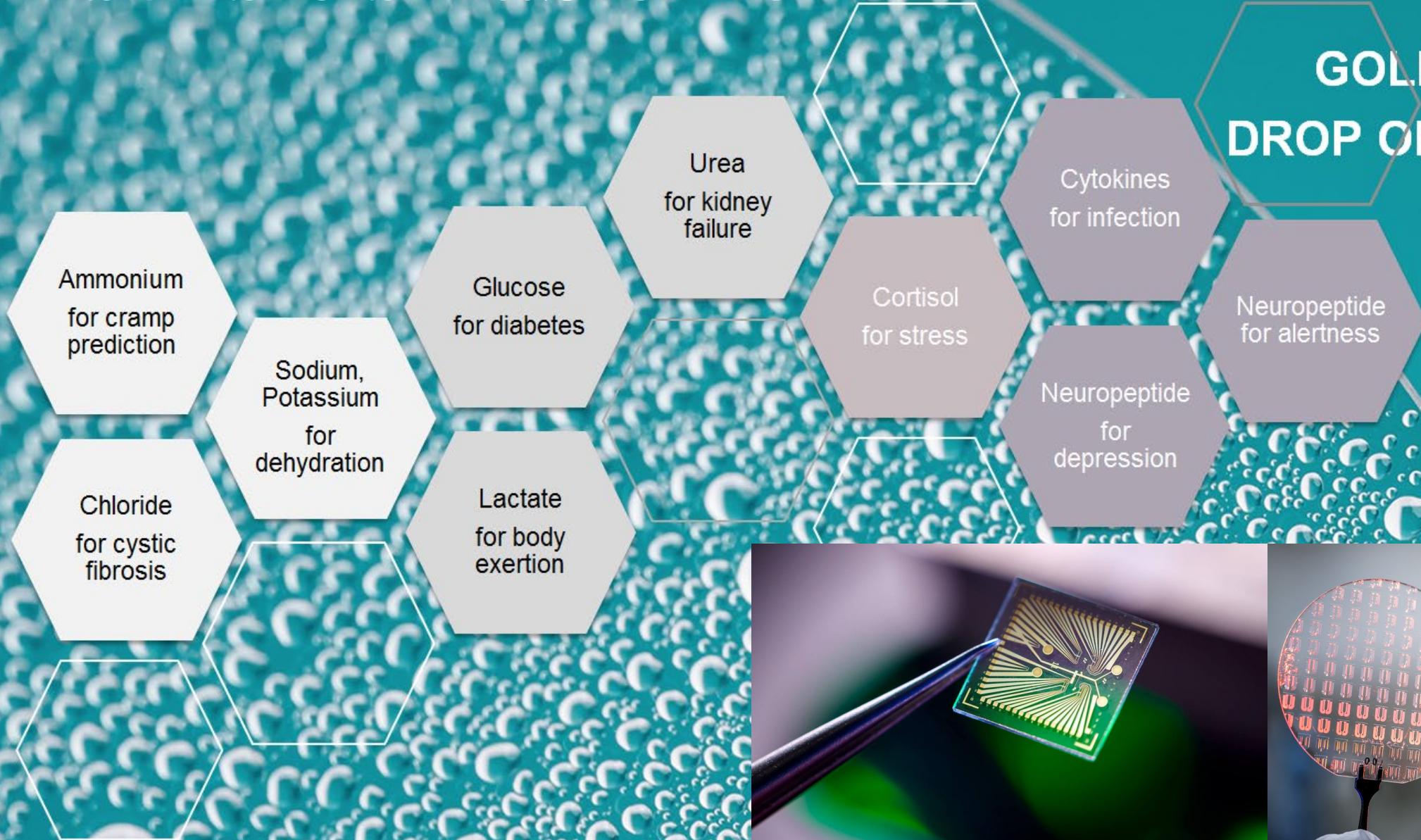


BLOOD PRESSURE

John A. Rogers, *Science*, 2011 & *IEEE Spectrum*, 2015.

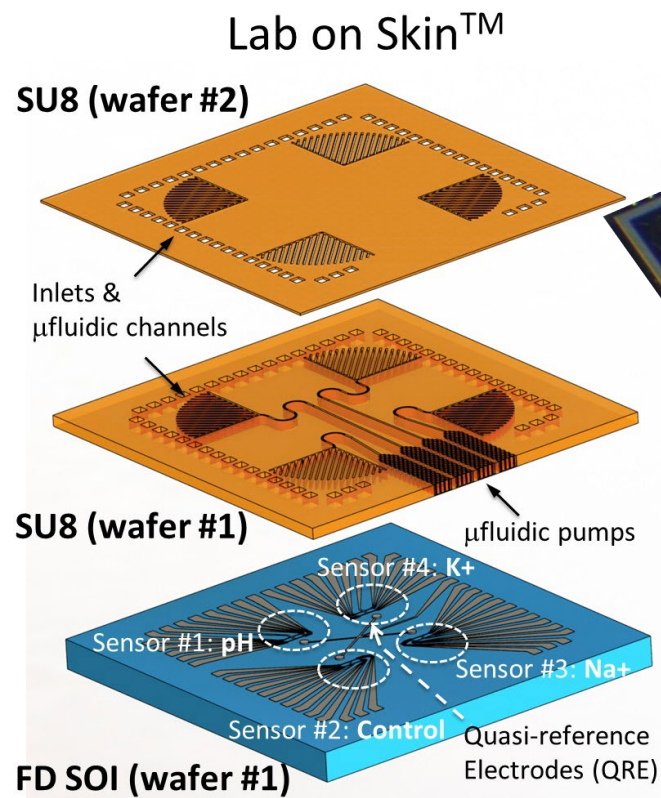
# Xsensio's Lab-on-Skin™

EXPLOITING  
THE DATA  
GOLDMINE IN A  
DROP OF BIOFLUID

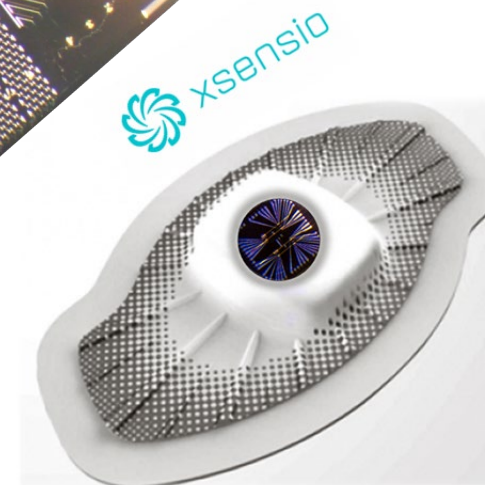


# Real-time sweat analysis with Lab On Skin™

- Embeddable unique Xsensio's **Lab-On-Skin™** electronic stamp technology: minute by minute non-invasive multi-biomarker sensing



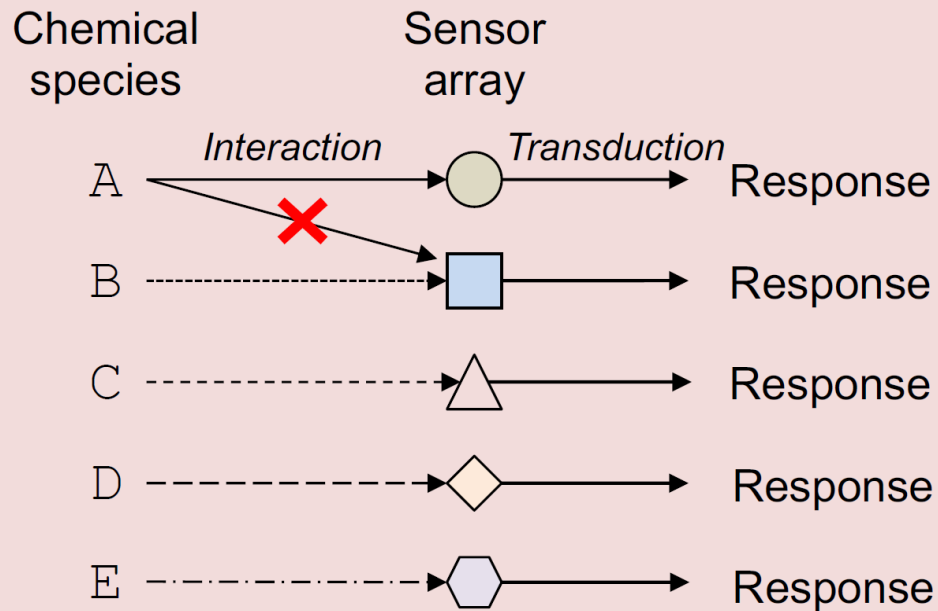
- Ultra-low power UTB SOI ISFETs: <math><50\text{nWatts/sensor}</math>
- Near Nernst limit sensitivity
- Selective
- Zero energy microfluidics



F. Bellando et al., IEDM 2017.

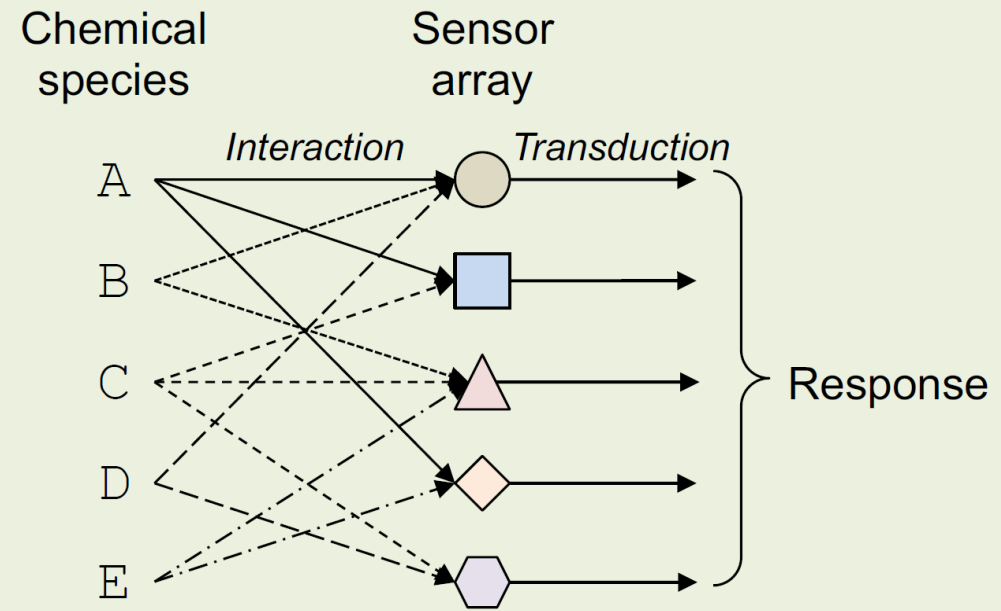
# Edge AI sensors: cross sensitive sensor arrays & dynamic signatures using Machine Learning

## Conventional chemical sensors



- 1:1 interaction between analyte and sensor
- Value lies in each specific sensor element
- Challenge: Sensor element development, cope with interfering analytes

## Cross-sensitive sensor array



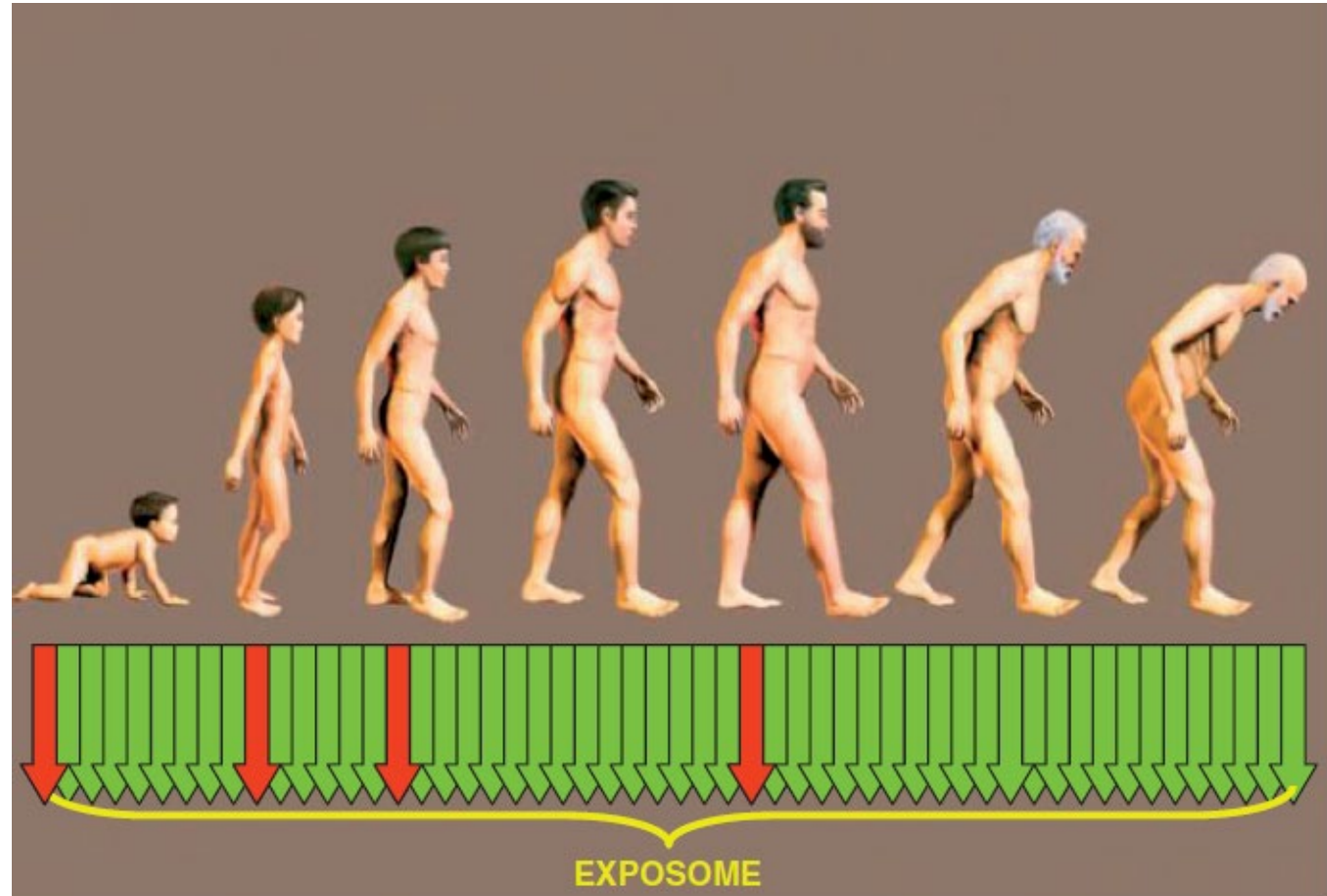
- Analyte interacts with multiple sensor elements
- Value lies in the dynamic response to chemicals
- Challenge: Design and training of sensor array, pattern recognition / machine learning

# The exposome: from concept to utility

- **The exposome would require measurements of exposures over time across the life course of an individual.**

**Table 1** Some examples of approaches and tools to measure the exposome

Approach	Tools
Biomarkers (omics)	
General	Genomics, transcriptomics, proteomics, metabolomics, epigenomics
Targeted	Adductomics, lipidomics, immunomics
Sensor technologies (including mobile phones)	Environmental pollutants, physical activity, stress, circadian rhythms, location [global positioning systems (GPS)]
Imaging (including mobile phones, video cameras)	Diet, environment, social interactions
Portable computerized devices (including palmtop computers)	Behaviour and experiences (ecological momentary assessment), stress, diet, physical activity
Improved conventional measurements (combined with environmental measures)	Job-exposure matrices; dietary recall (e.g. EPIC-Soft)

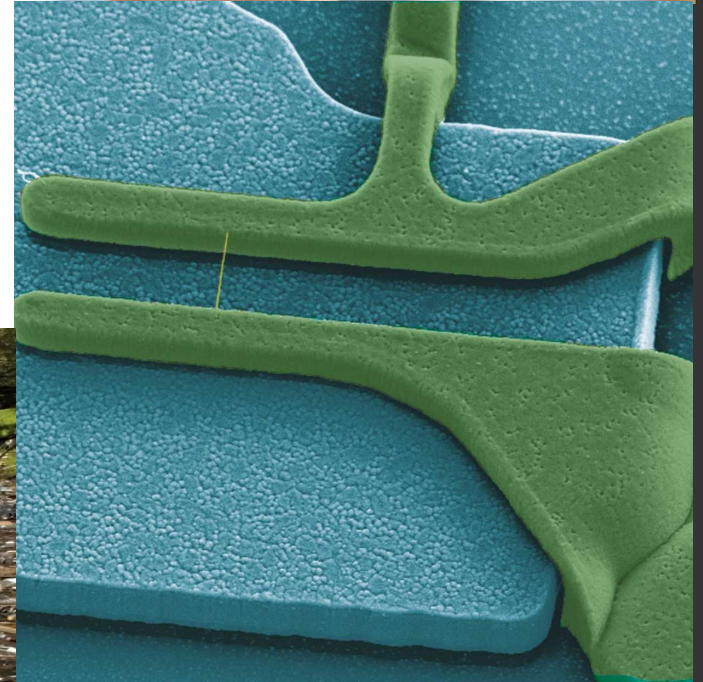


C.P. Wild, International Journal of Epidemiology, 2012.

# Human Exposome: bio and environmental co-monitoring for healthcare!

## Environmental related diseases:

- **RESPIRATORY INFECTIONS:** more than 1.5 million deaths annually from respiratory infections due to environment.
- **CANCER:** environmental accounts for an estimated 31% of global lung cancer burden.
- **CARDIOVASCULAR DISEASES:** 2.5 million people die every year from cardiovascular disease attributable to chemical and air pollution.
- **DIARRHOEA:** about 1.5 million deaths per year from diarrhoeal diseases; 88% of all cases of diarrhoea attributable to water, sanitation and hygiene.
- **MALARIA, INTESTINAL NEMATODE INFECTIONS, HEPATITIS B and C, TUBERCULOSIS, etc.**



# Thinking forward the healthcare...

What's the real opportunity for future Edge AI technology for Healthcare?



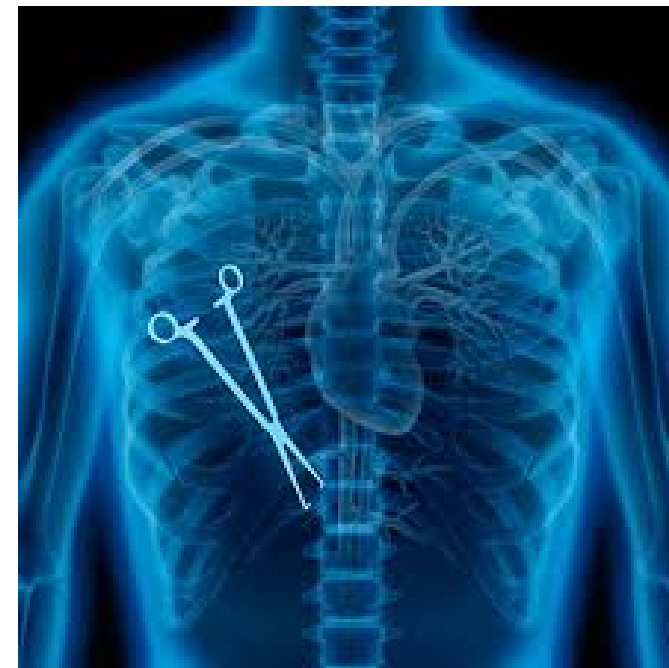
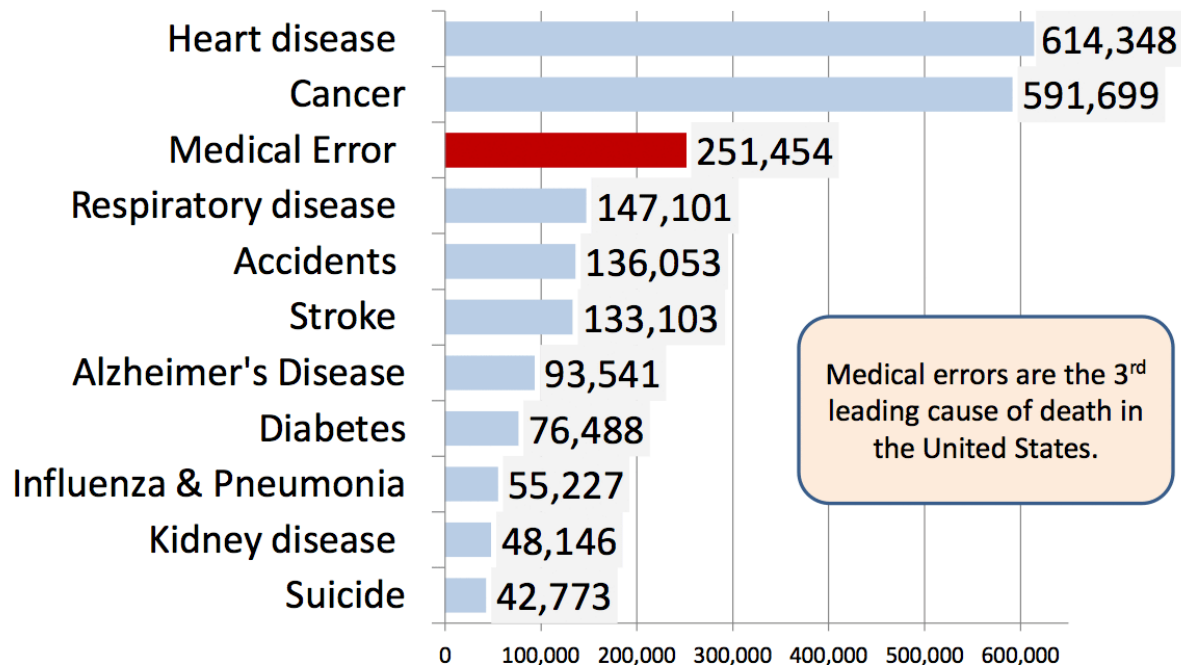
What's the value of NOT being sick = healthy?

The value of being sick!

# Leading Causes of death...

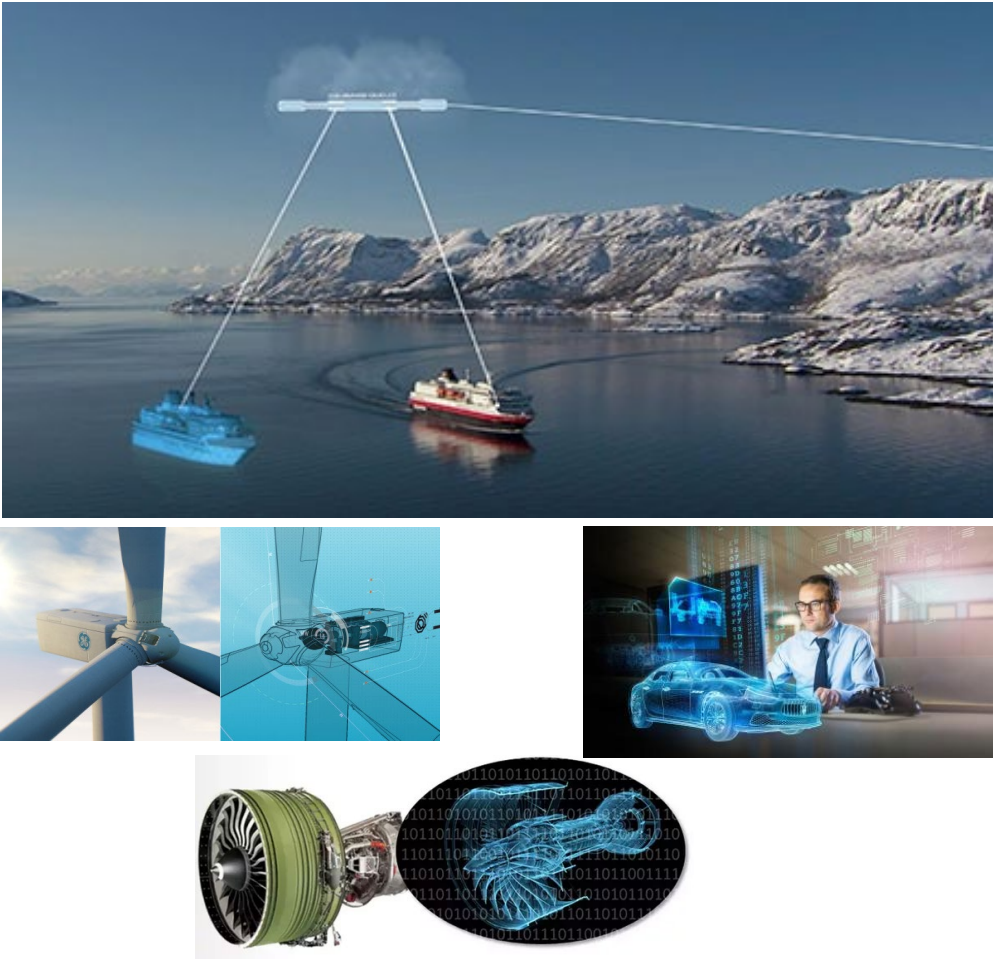
“an error in judgment, skill or coordination of care; a **diagnostic error**; a system defect resulting in death or a failure to rescue a patient from death; or a **preventable adverse event**.”

## Number of Deaths in the United States



# 2030: From Object to Human Digital Twins

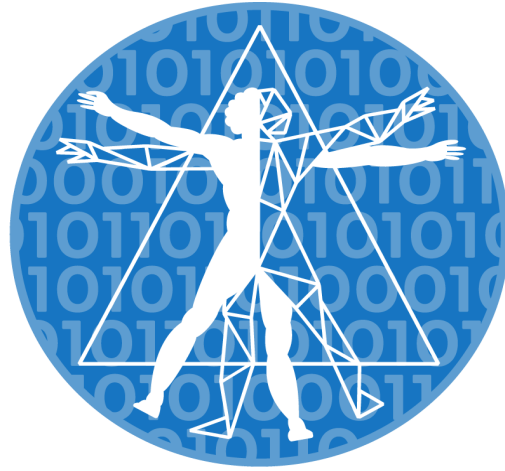
## Digital Twins of All Objects



## Digital Twins of All Humans



*A Truly Personalized and Preventive Healthcare System:*  
**SUSTAINABLE**



# Health EU

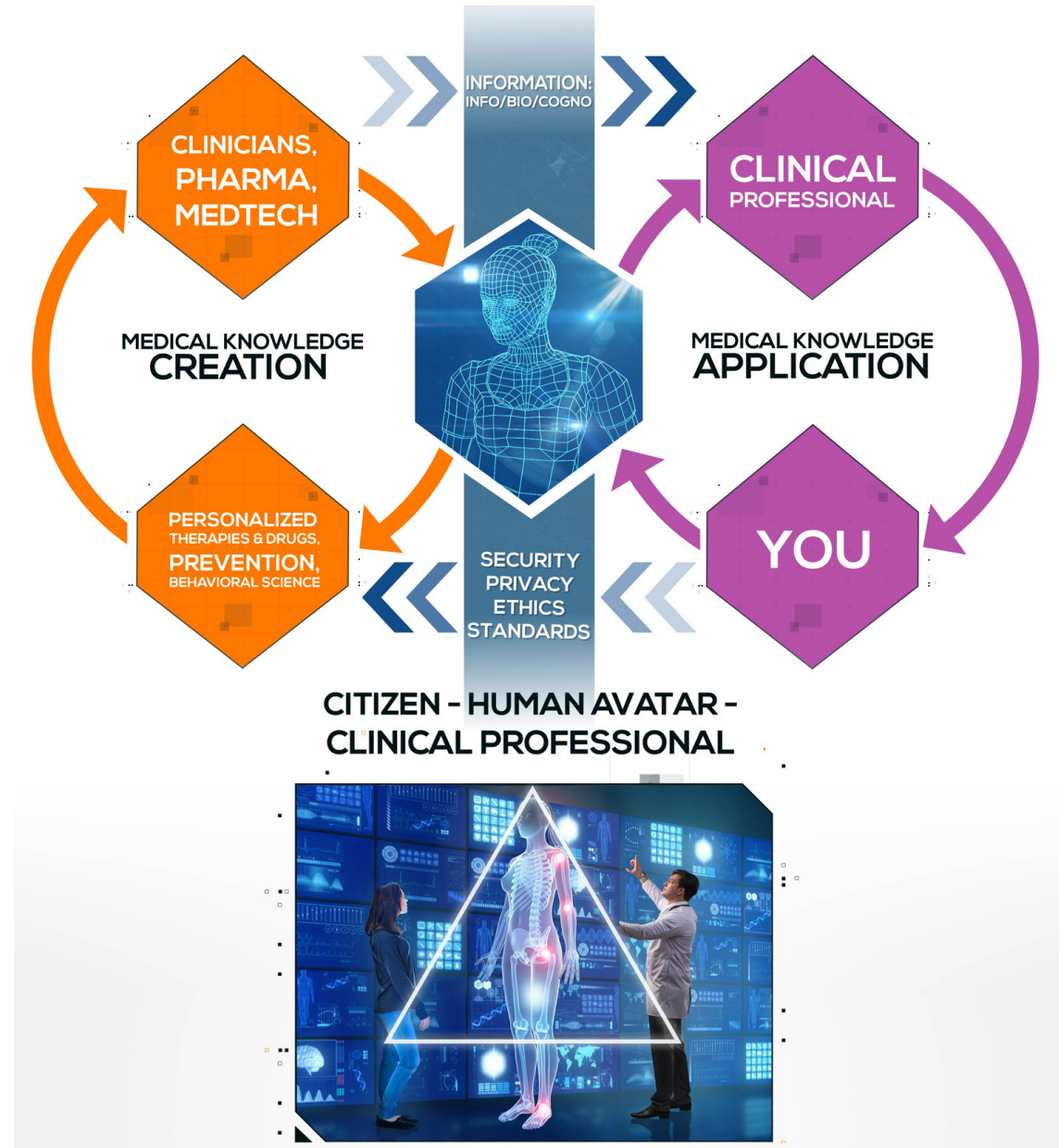
*Healthy You!*

Imagine a revolutionary healthcare and disease management system in Europe, built on human avatars aiming at:

**Empowering every citizen with a Human Avatar  
enabling access to comprehensive personalized  
healthcare, healthy lifestyle and disease  
prevention**

# Why Health EU is disruptive?

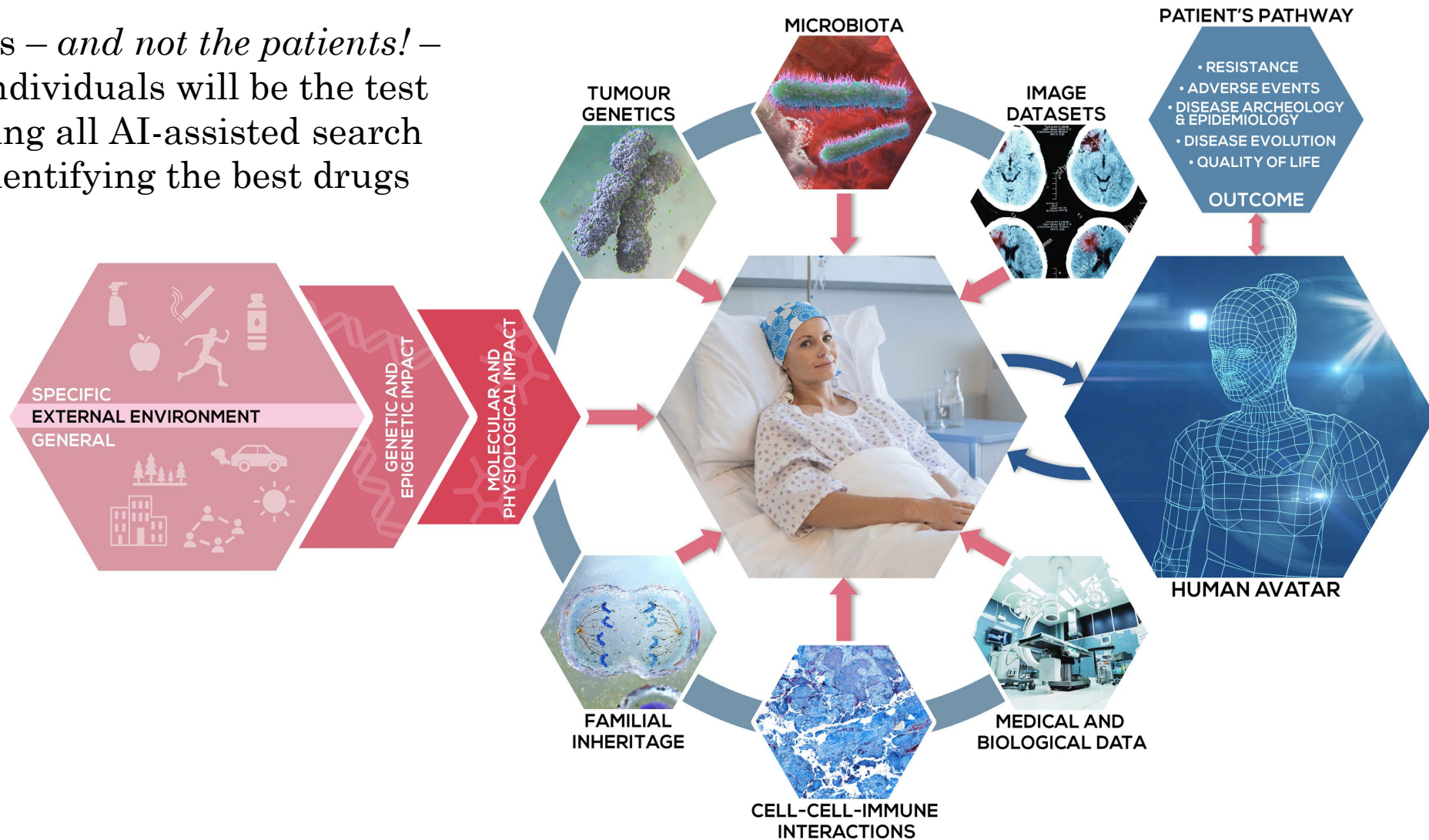
- The **missing link** of the 21st century for **breaking barriers** between Medical Knowledge Creation and Medical Knowledge Application
- Creates a P3 **Citizen – Human Avatar – Clinical Professional triangle**



© Health EU

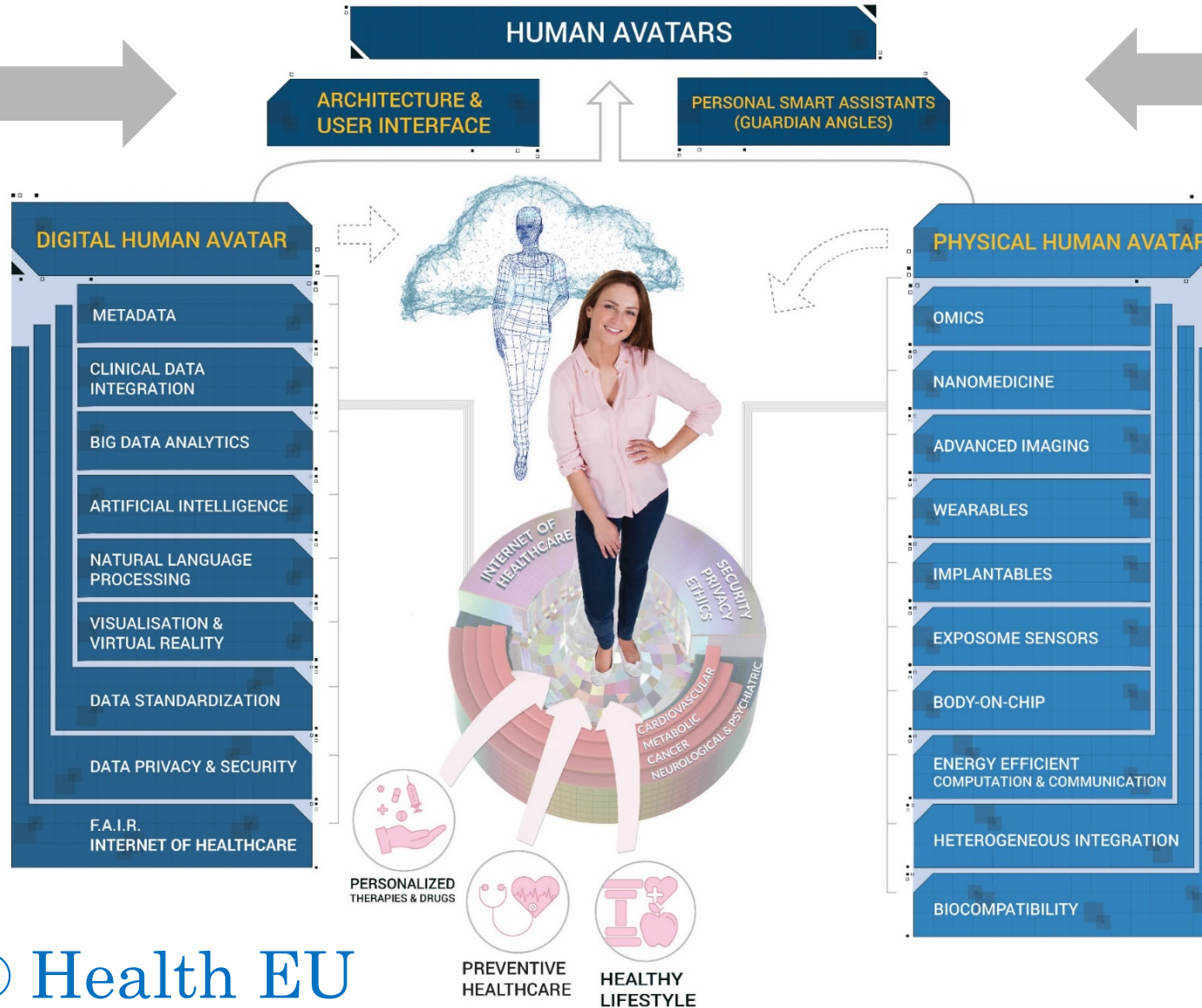
# Disease complexity in the 21st century with a focus on cancer and the role of a Human Avatar

Human Avatars – *and not the patients!* – calibrated on individuals will be the test vehicles, enabling all AI-assisted search processes for identifying the best drugs and therapies.



# Health EU Integrative Technology Platform: much more than a Digital Twin...

Big  
Data  
IoH  
AI



Data  
Generator  
Technology  
Body-On-  
Chip

# Health EU expectations

- Delivering on the promises of personalised and preventive medicine in **advancing towards affordable universal healthcare solutions**
- Taking medical sciences and practice to the next level **to promote well-being and improve life expectancy in good health**
- Providing future tools and infrastructure **to accelerate the generation of new data that can further enhance our knowledge** to support prevention and personalised treatment of diseases
- Creating **new business models, financing frameworks and incentive schemes**



## ➤ You, Your Human Avatar, Clinical Professional ➤ Up to 80 % of the costs associated to NCDs preventable with Health EU Human Avatars:

- Less chronic diseases (by prevention and monitored avatar-guide healthy living)
- Better Quality of Life
- Less adverse drug effects & medical errors (3<sup>rd</sup> leading cause of death)
- Cheaper medication by personalized repurposing
- Less need for organ transplantation by prevention
- Less (severe)surgical interventions and less misguided therapies
- Less need for animal testing by Organs on Chip

# Conclusions

- High expectations from novel technologies to sustainably solve Human Great Challenges: Climate Change, Energy and Health!
- Sustainable energy efficient IoT & AI will enable citizen-centric applications for a new Quality of Life in the zettabyte era.
- A revolution in P3 **Digital Healthcare** possible by IoT & AI:  
**Human Avatars for a Healthy YOU!**



Health EU Manifesto

<https://www.health-eu.eu/support/>

**Thank you!**  
Questions?