
بسم الله الرحمن الرحیم

The Digital Twin in Clinical Endocrinology

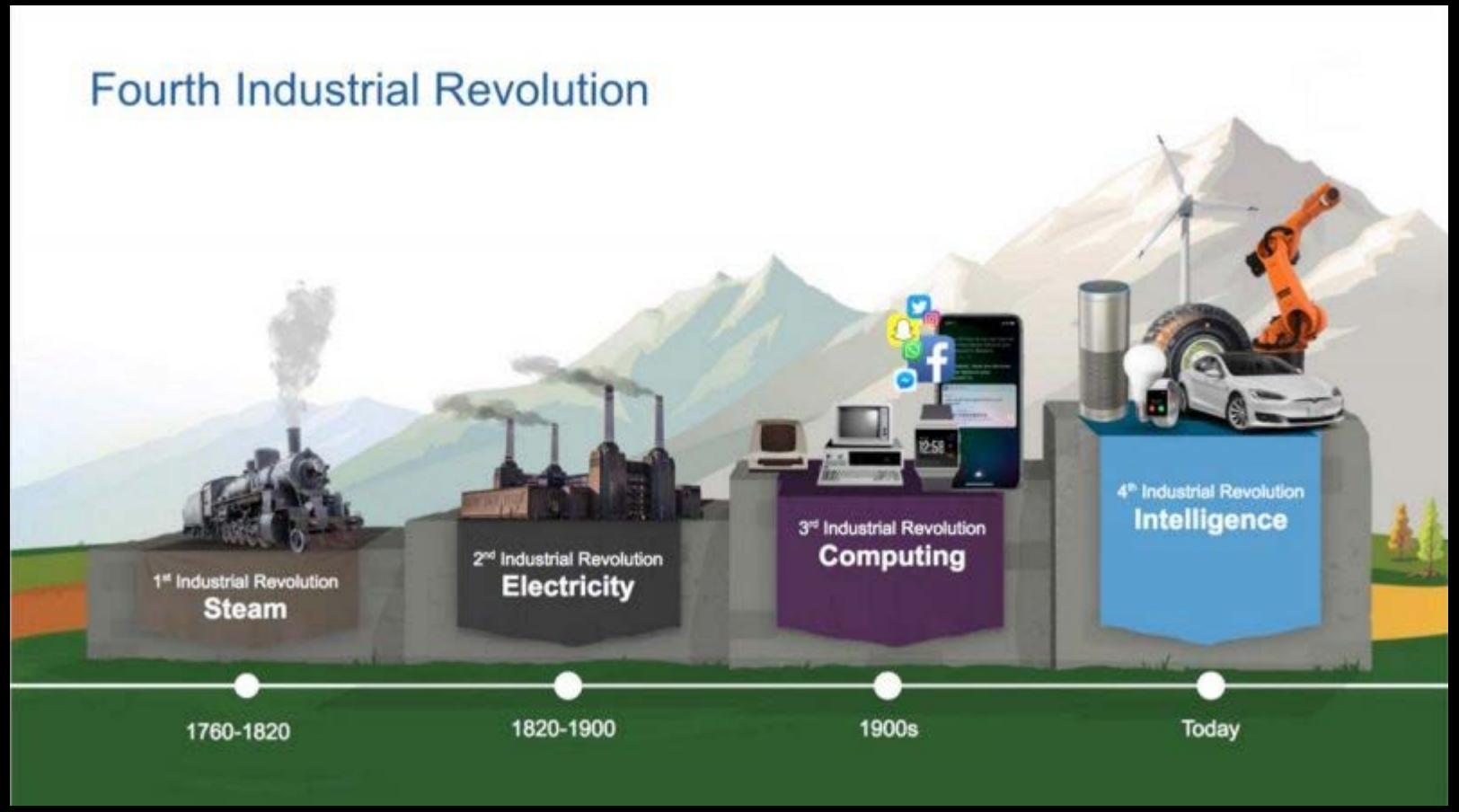
Iraj Nabipour, MD

Bushehr University of Medical Sciences

DIGITAL TWIN

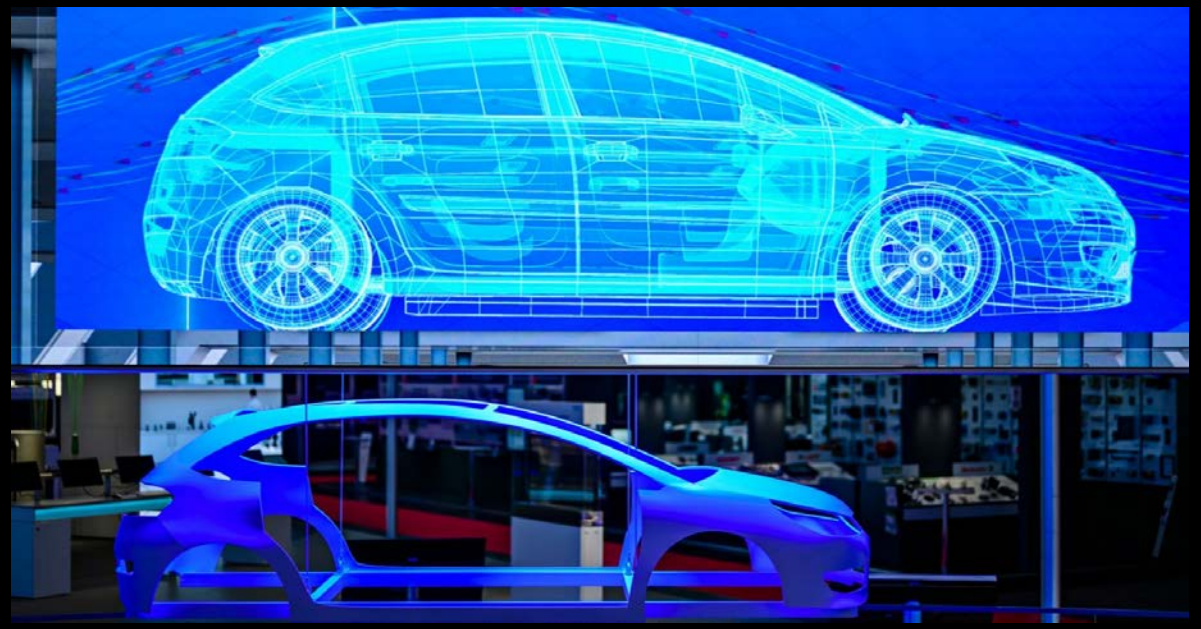
A REVOLUTION IN MEDICINE

Dr. Iraj Nabipour

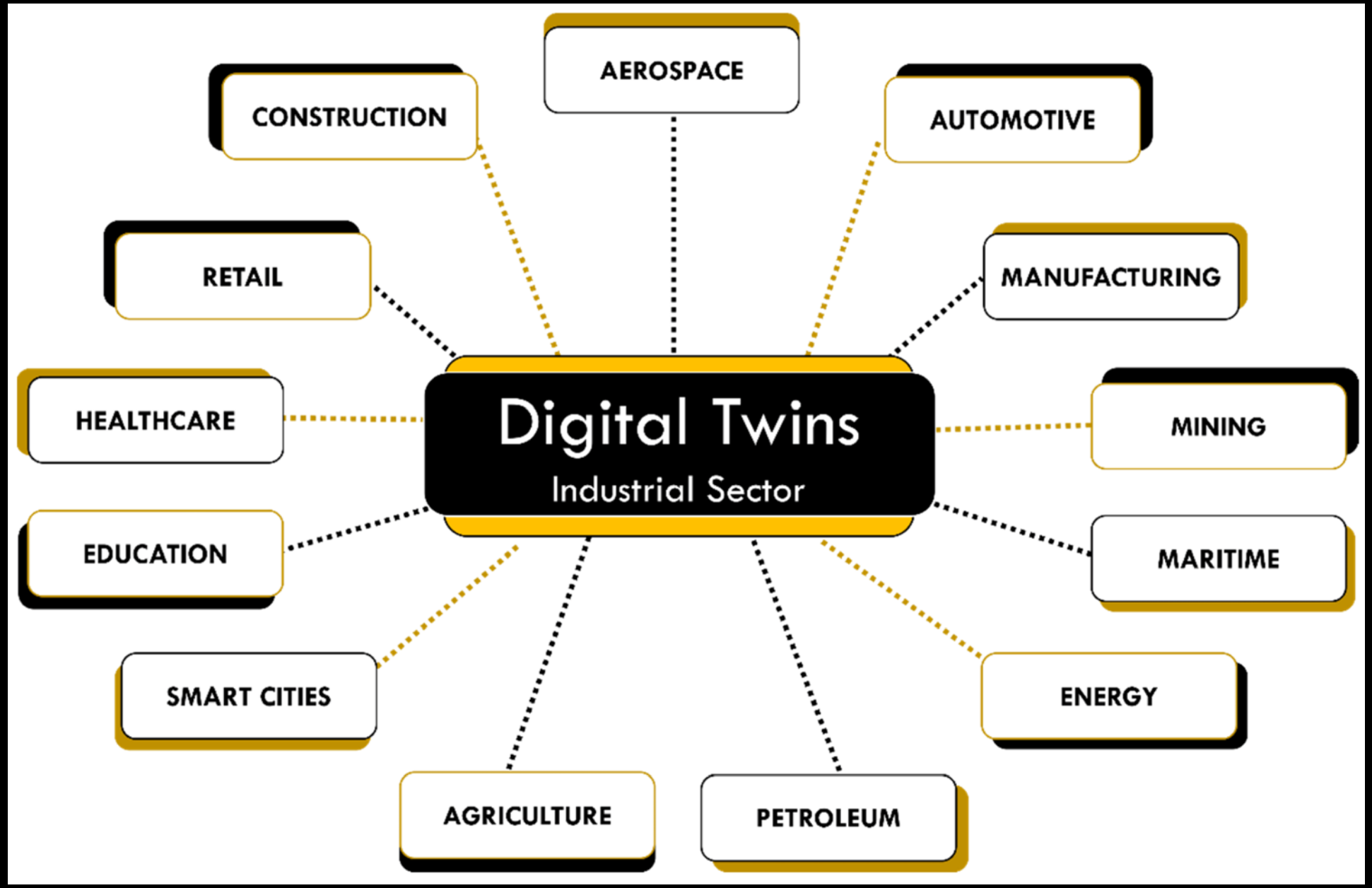


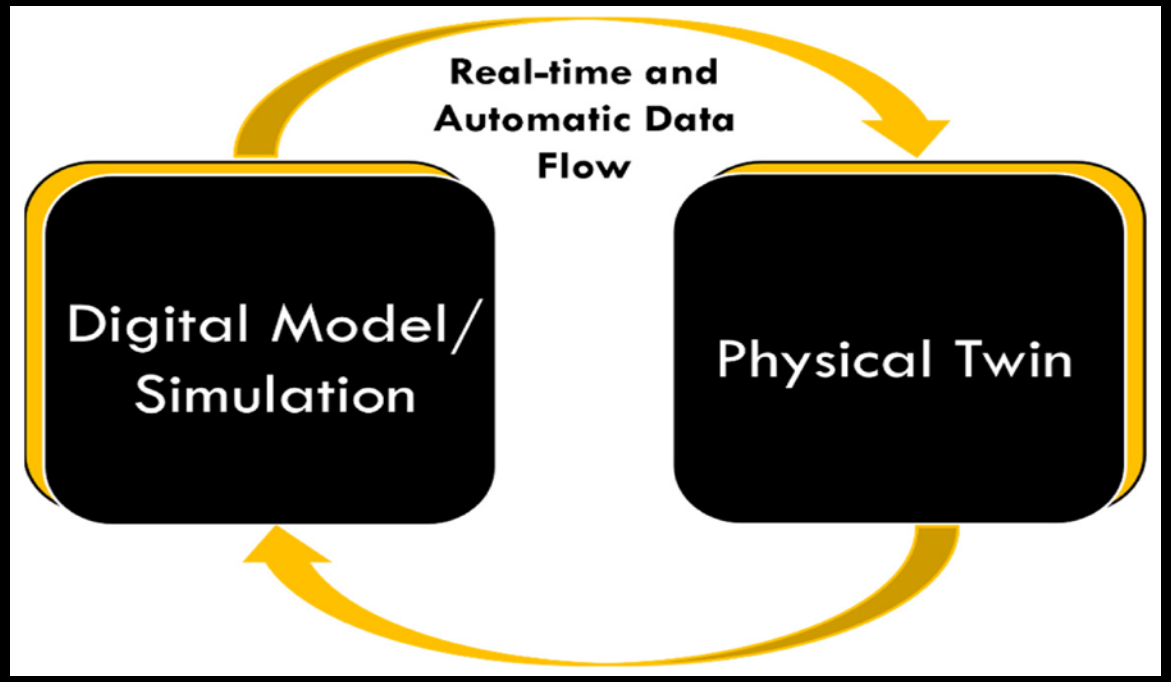
These advances are merging the physical, digital and biological worlds in ways that create both huge promise and potential peril.

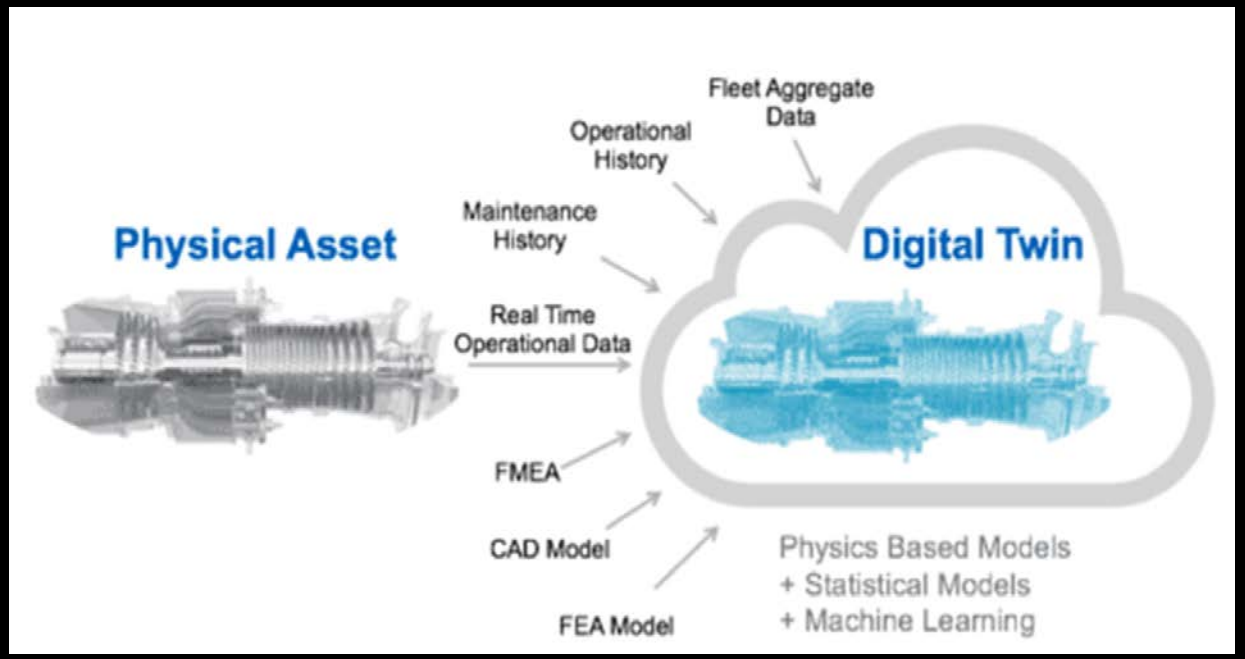
The concept of a physical twin, a precursor to Digital twin, is rather old and dates to NASA’s Apollo program.




DIGITAL TWIN


Digital Twins
Industrial Sector
AEROSPACE
CONSTRUCTION
AUTOMOTIVE
RETAIL
MANUFACTURING
HEALTHCARE
MINING
EDUCATION
MARITIME
SMART CITIES
ENERGY
AGRICULTURE
PETROLEUM





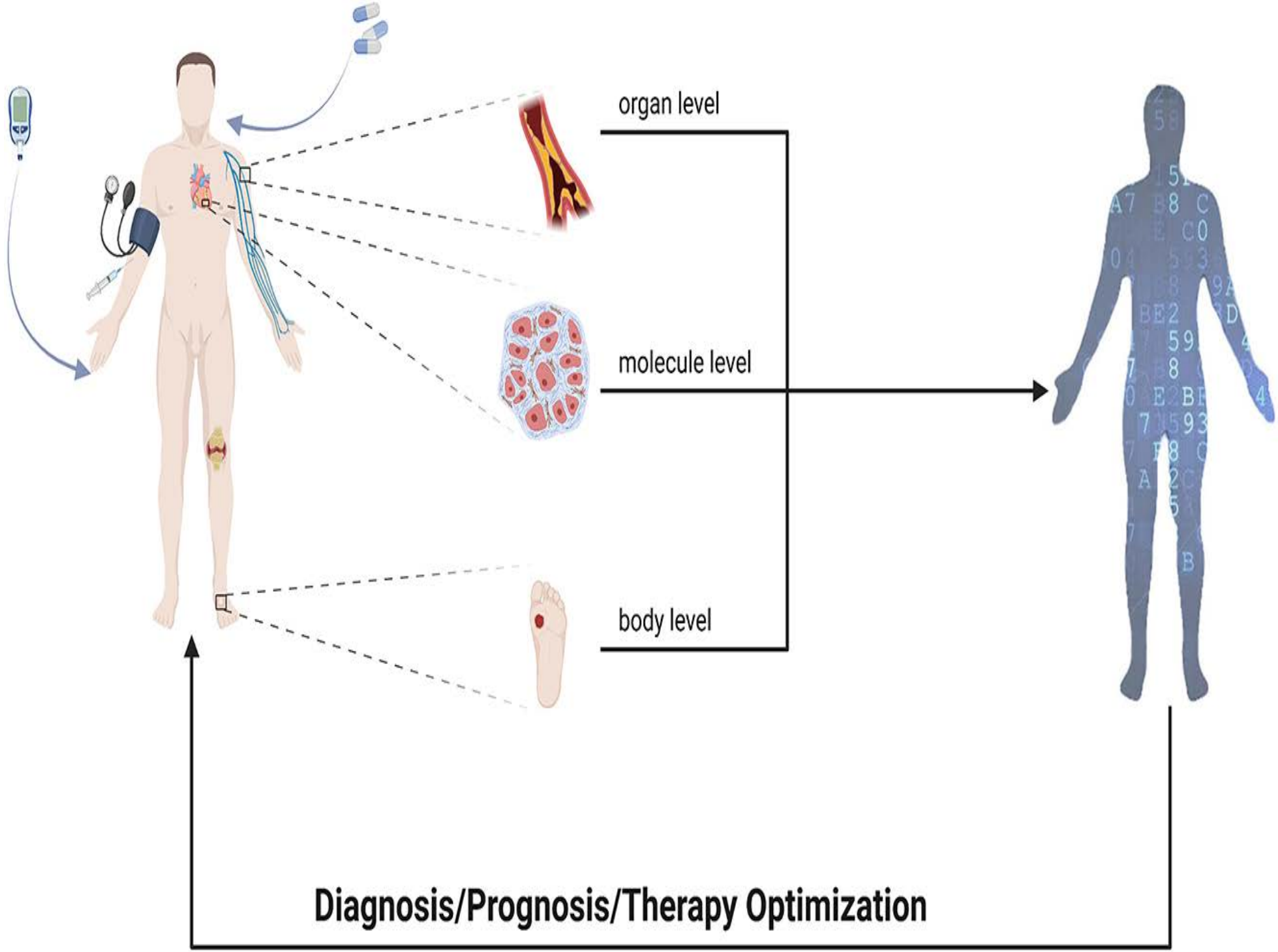
1. Physical twin: A real-world entity (living/non-living) such as part/product, machine, process, organization, or human, etc.

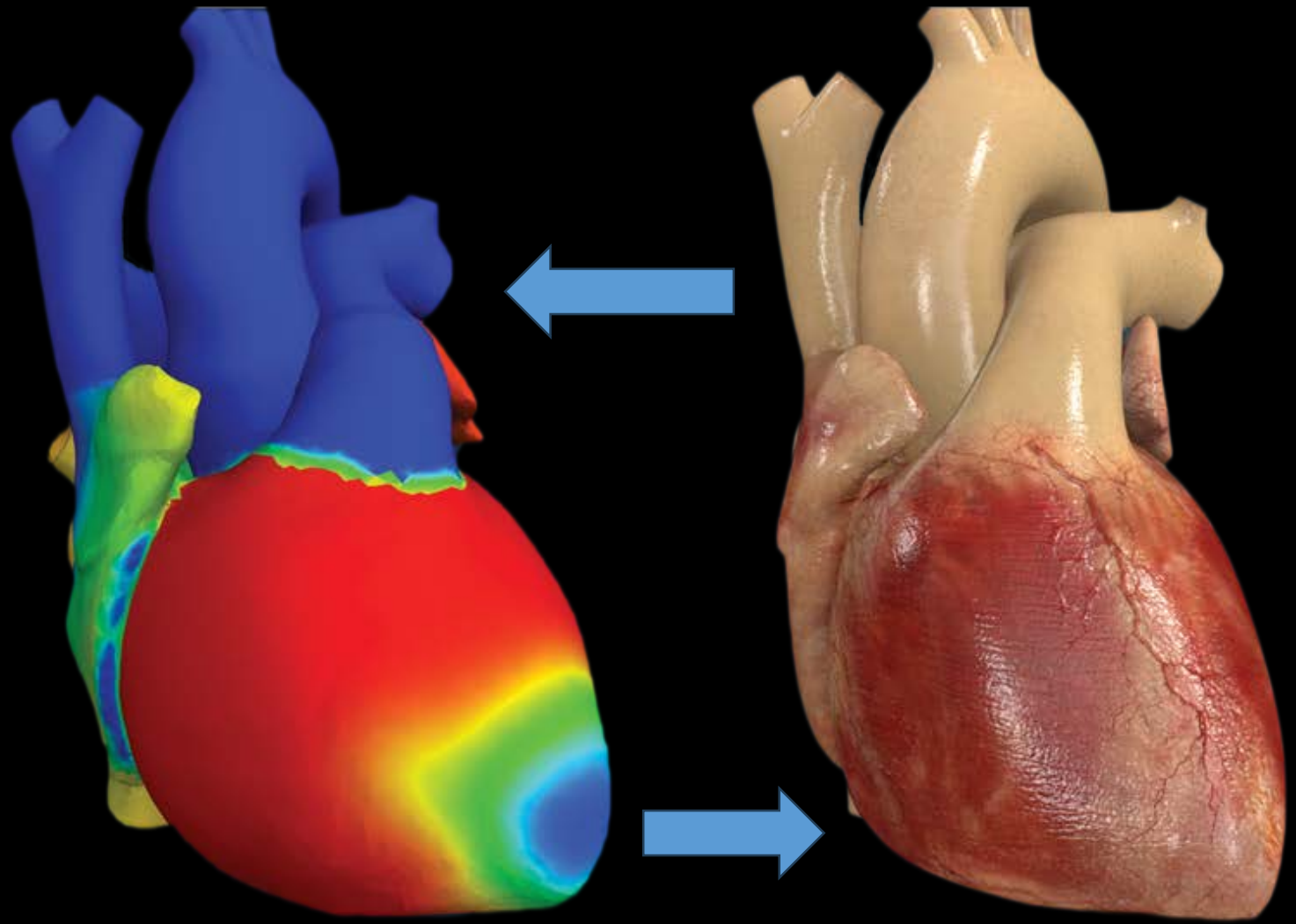
(ii)

2. Digital twin: The digital representation of the physical twin with the capability to mimic/mirror its physical counterpart in real time.

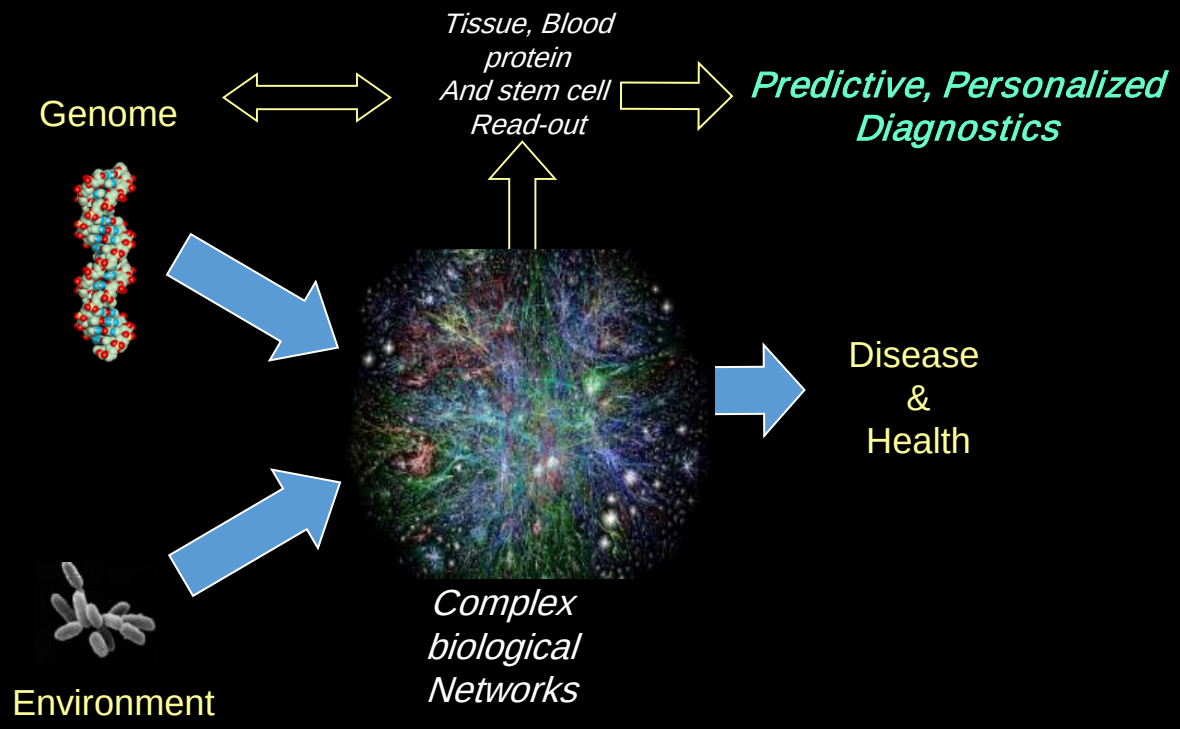
(iii)

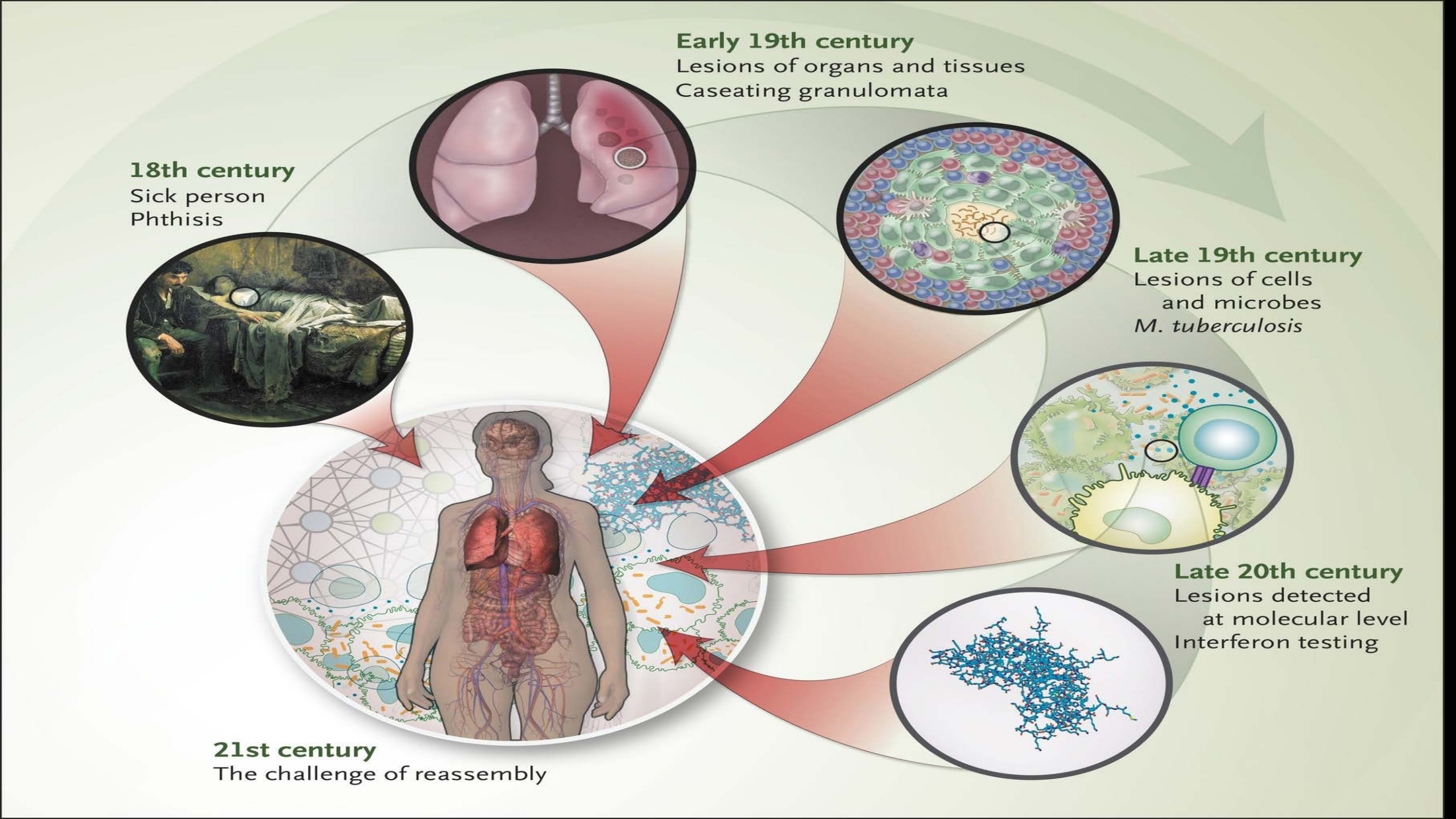
3. Linking mechanism: The bidirectional flow of data between the two which operates automatically in real-time.

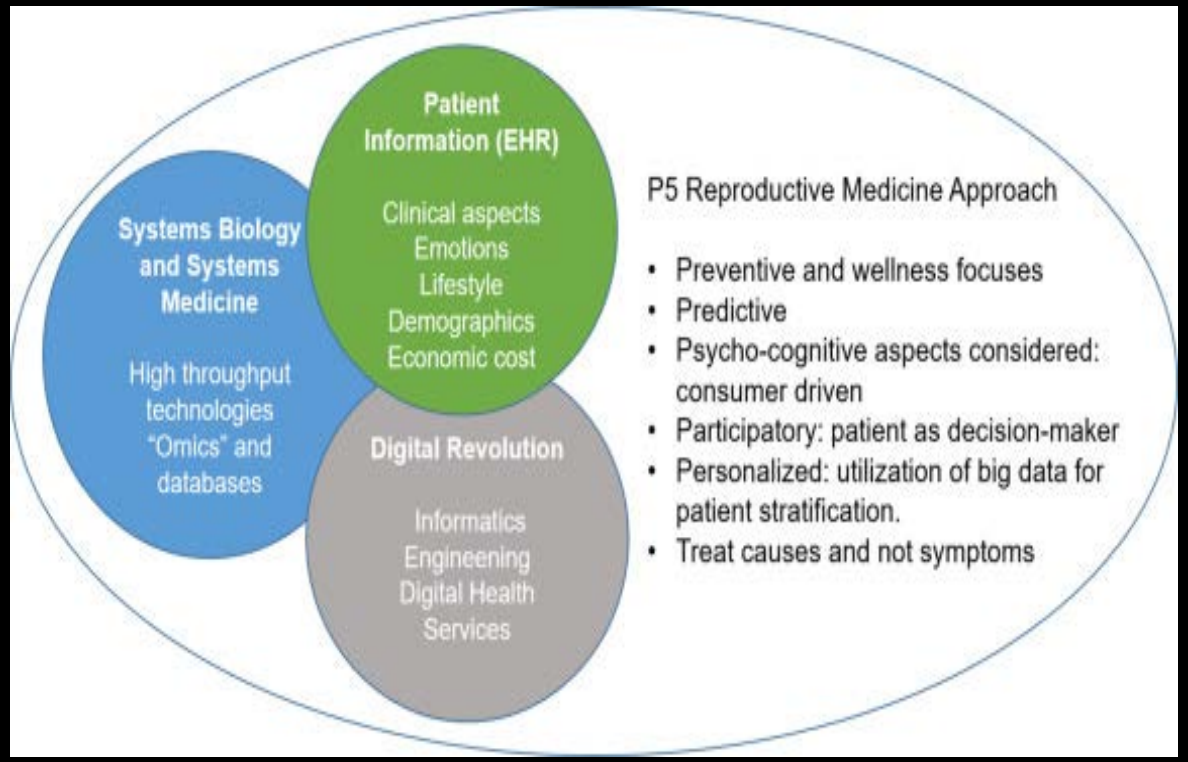

organ level
molecule level
body level
Diagnosis/Prognosis/Therapy Optimization

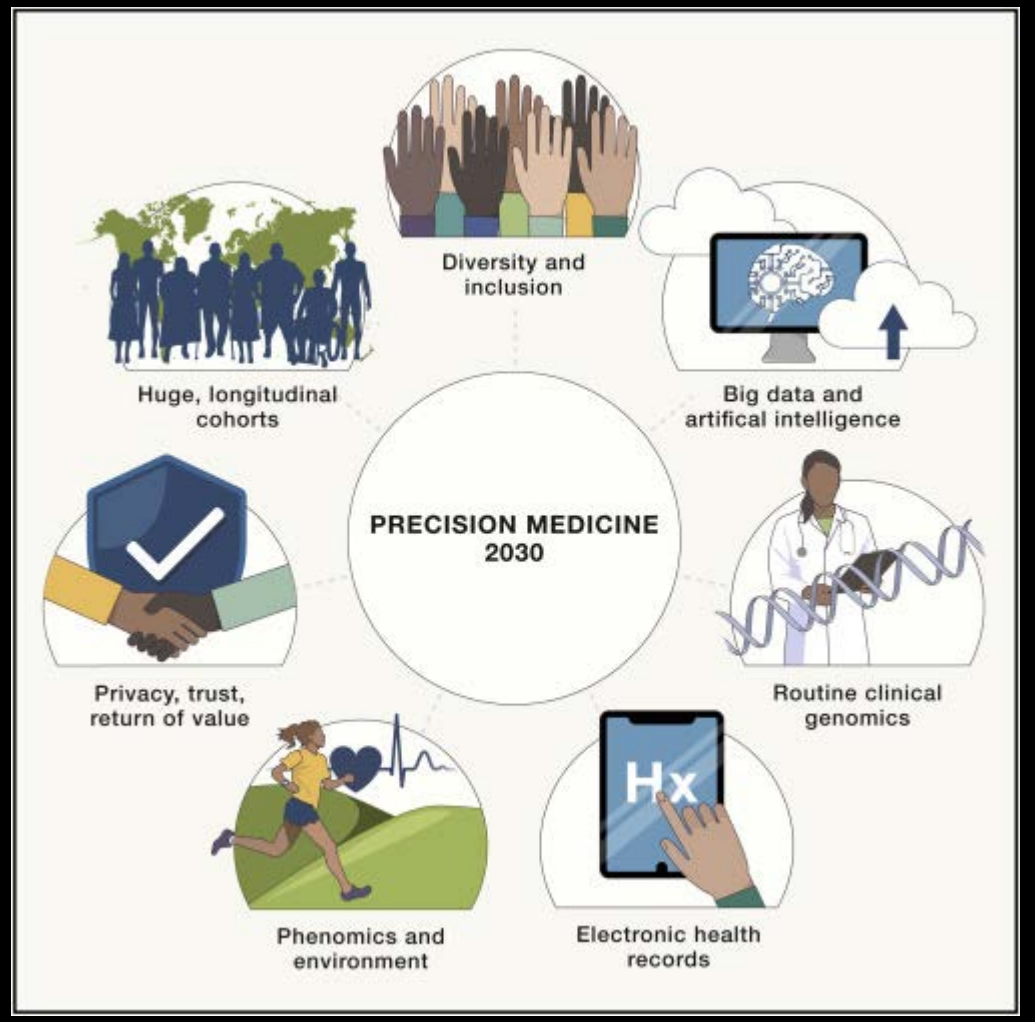


There are two types of Biological Information

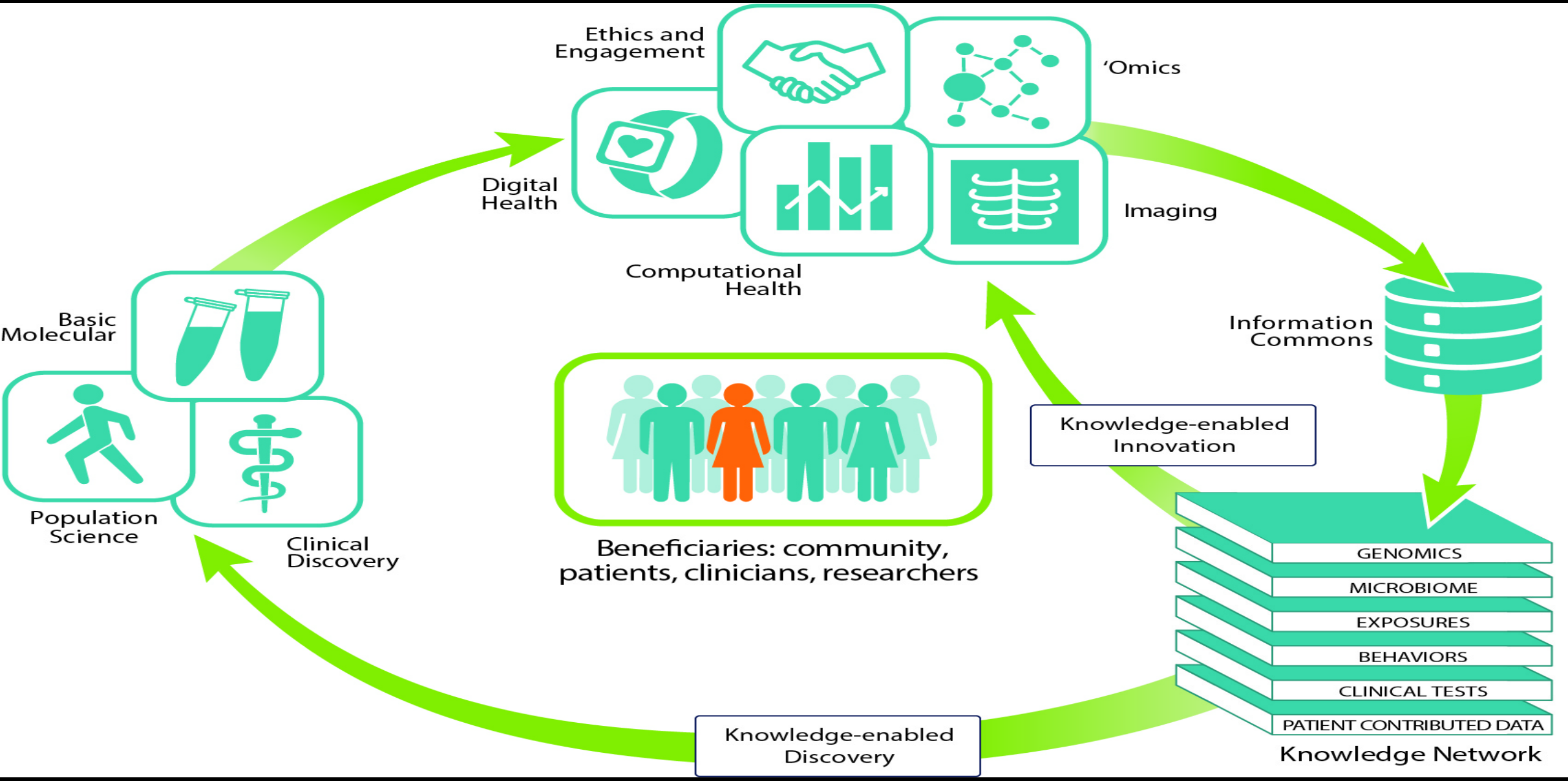



Early 19th century
Lesions of organs and tissues
Caseating granulomata
18th century
Sick person
Phthisis
Late 19th century
Lesions of cells
and microbes
M. tuberculosis
Late 20th century
Lesions detected
at molecular level
Interferon testing
21st century
The challenge of reassembly



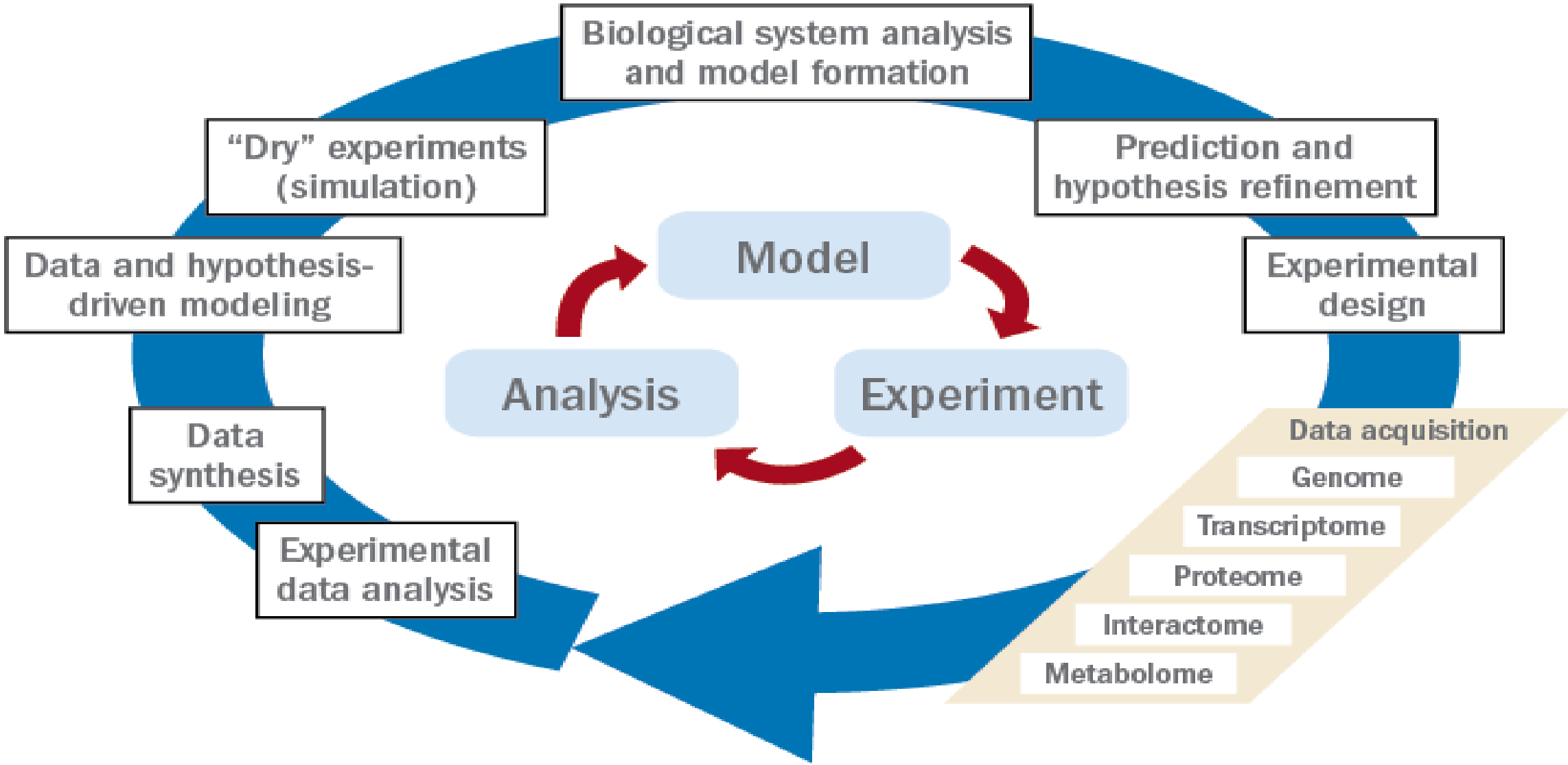


Systems medicine is defined as the application of the systems approach to the prevention of, understanding and modulation of, and recovery from developmental disorders and pathological processes in human health (Clermont et al. 2009).

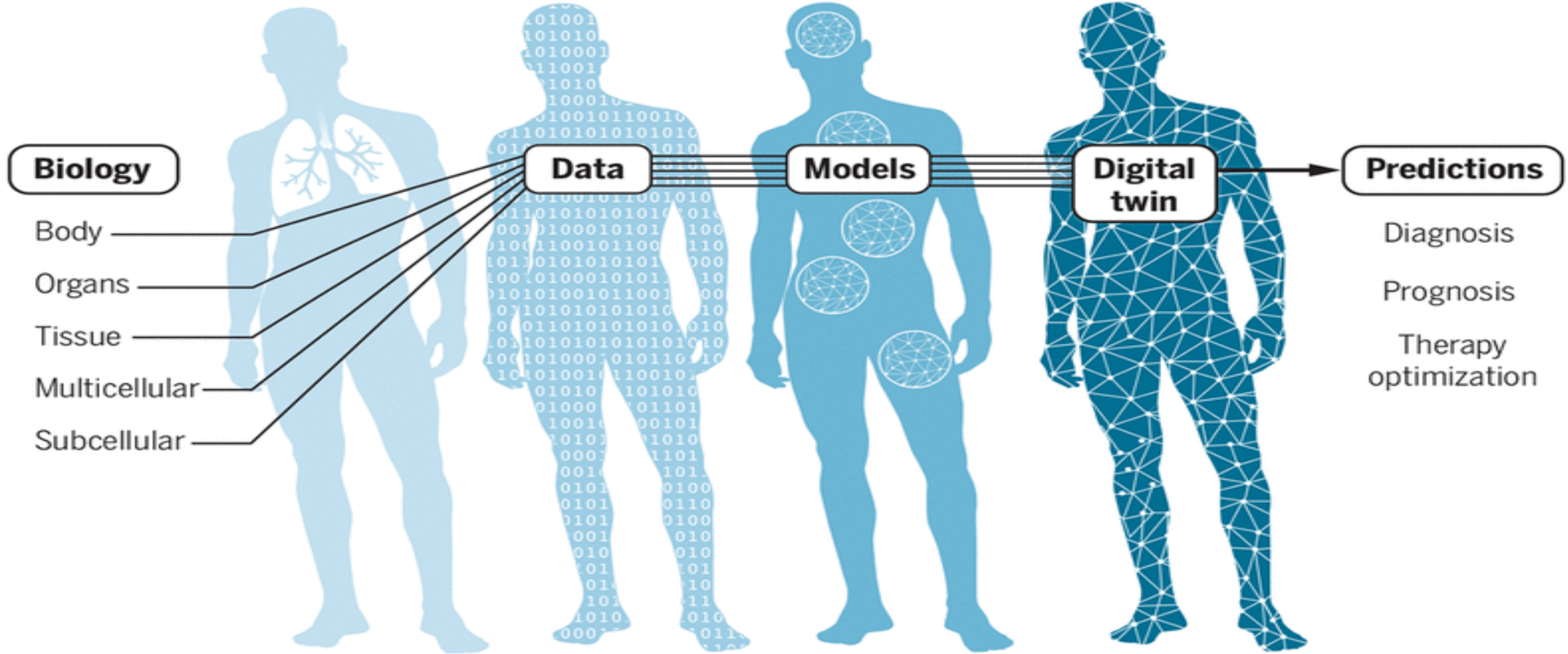


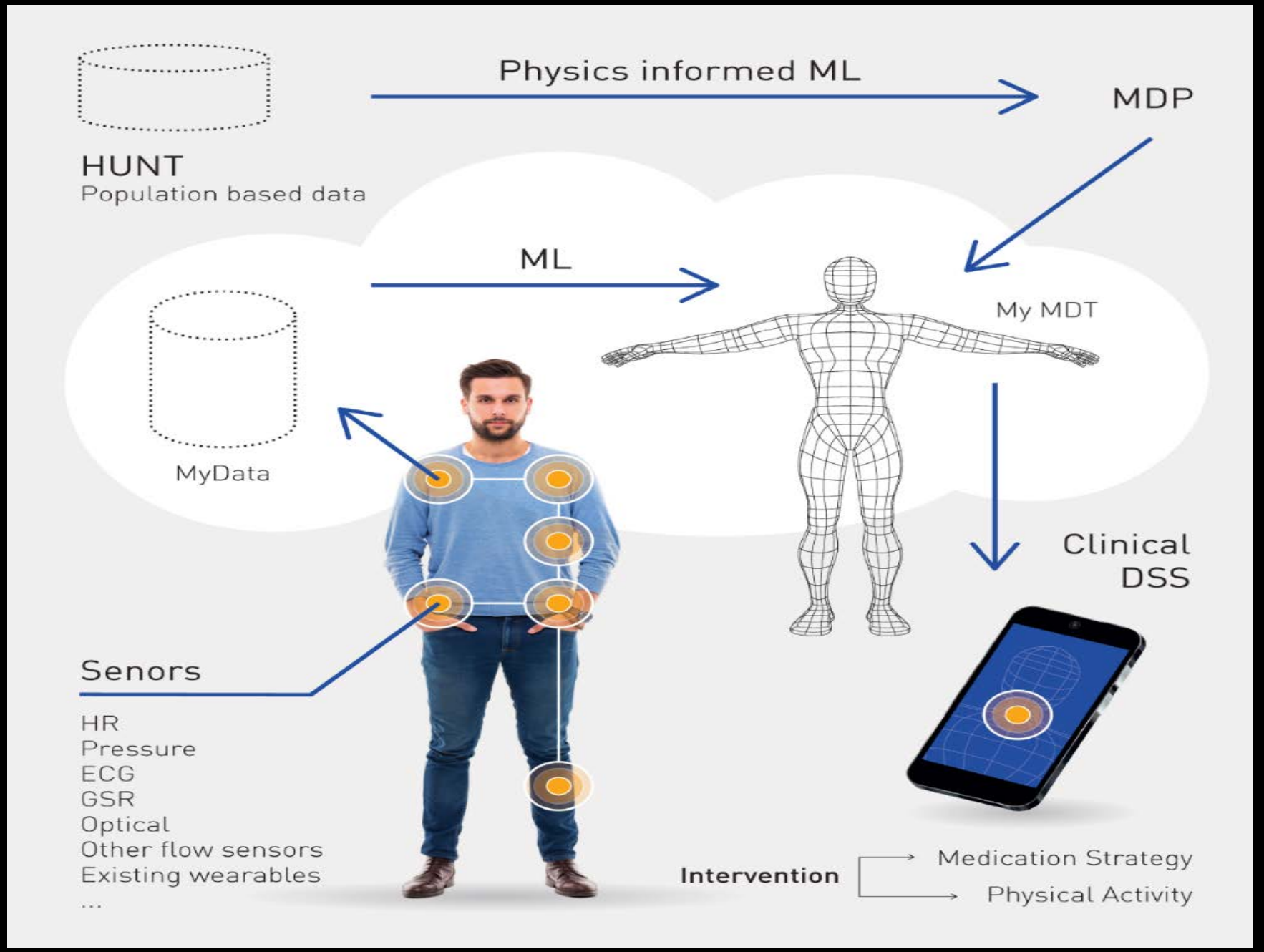
"Precision medicine is an emerging approach for disease treatment and prevention that takes into account individual variability in genes, environment, and lifestyle for each person."

The process of systems biology research



Source: Agilent Technologies


Biology
Body
Organs
Tissue
Multicellular
Subcellular
Data
Models
Digital twin
Predictions
Diagnosis
Prognosis
Therapy optimization


Physics informed ML
MDP
HUNT
Population based data
ML
My MDT
MyData
Clinical
DSS
Senors
HR
Pressure
ECG
GSR
Optical
Other flow sensors
Existing wearables
...
Intervention
Medication Strategy
Physical Activity


Trends
SYNC
TRENDS
OVERLAY
1WK
2WK
1MO
3MO
YR
BG
76%
In Range
126 mg/dL
Average
Blood Glucose Avg
Mon, Mar 27
116 mg/dL
Insulin
Mon, Mar 27
39.2 units
Home
History
Trends


Carrier
8:08 AM
100%
Hi, John
Rescue Medication
3
times this week
View Details
Daily Schedule
Dulera
Dulera


2:09

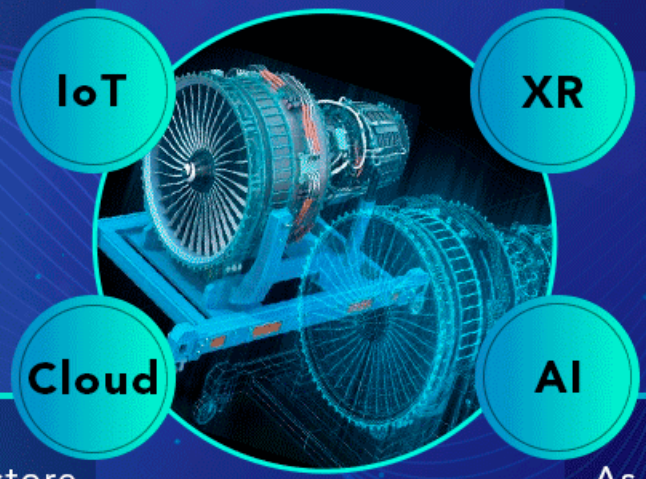

Metagenics
MetaBiome™
MICROBIOME SAMPLING KIT
MICROBA


DEMO
DAY TWO
TRUST YOUR GUT™

TECHNOLOGIES USED IN DIGITAL TWINS

IoT sensors enable constant data transmission, which is used to create a digital duplicate of the physical object

Due to its visualization capabilities, XR allows to digitally model physical objects



Cloud computing allows to store gained data in the virtual cloud and easily access them from any location

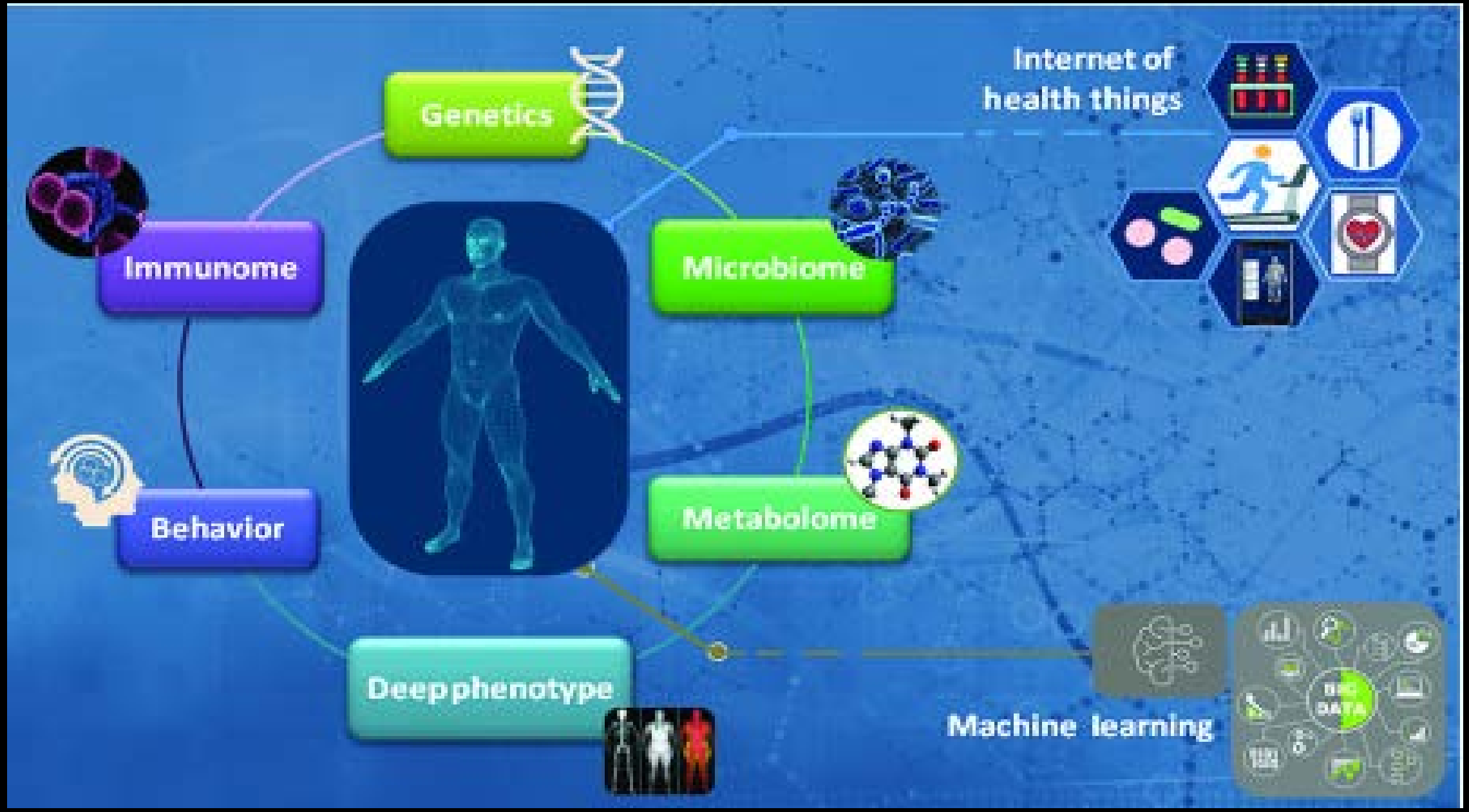
As an advanced analytical tool, AI automatically analyze obtained data, provide valuable insights and make predictions

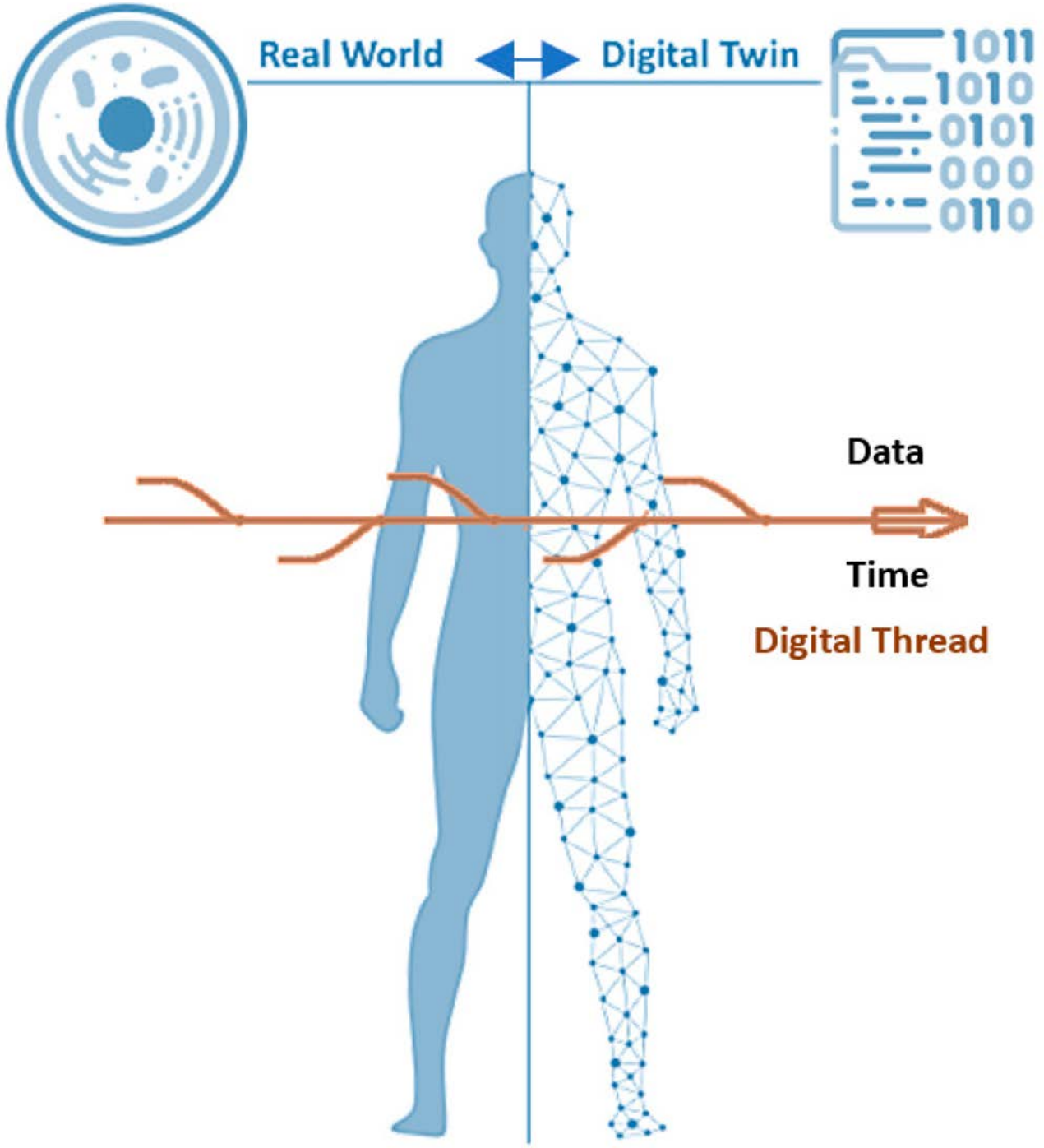
DEEP MEDICINE

HOW ARTIFICIAL INTELLIGENCE CAN MAKE HEALTHCARE HUMAN AGAIN

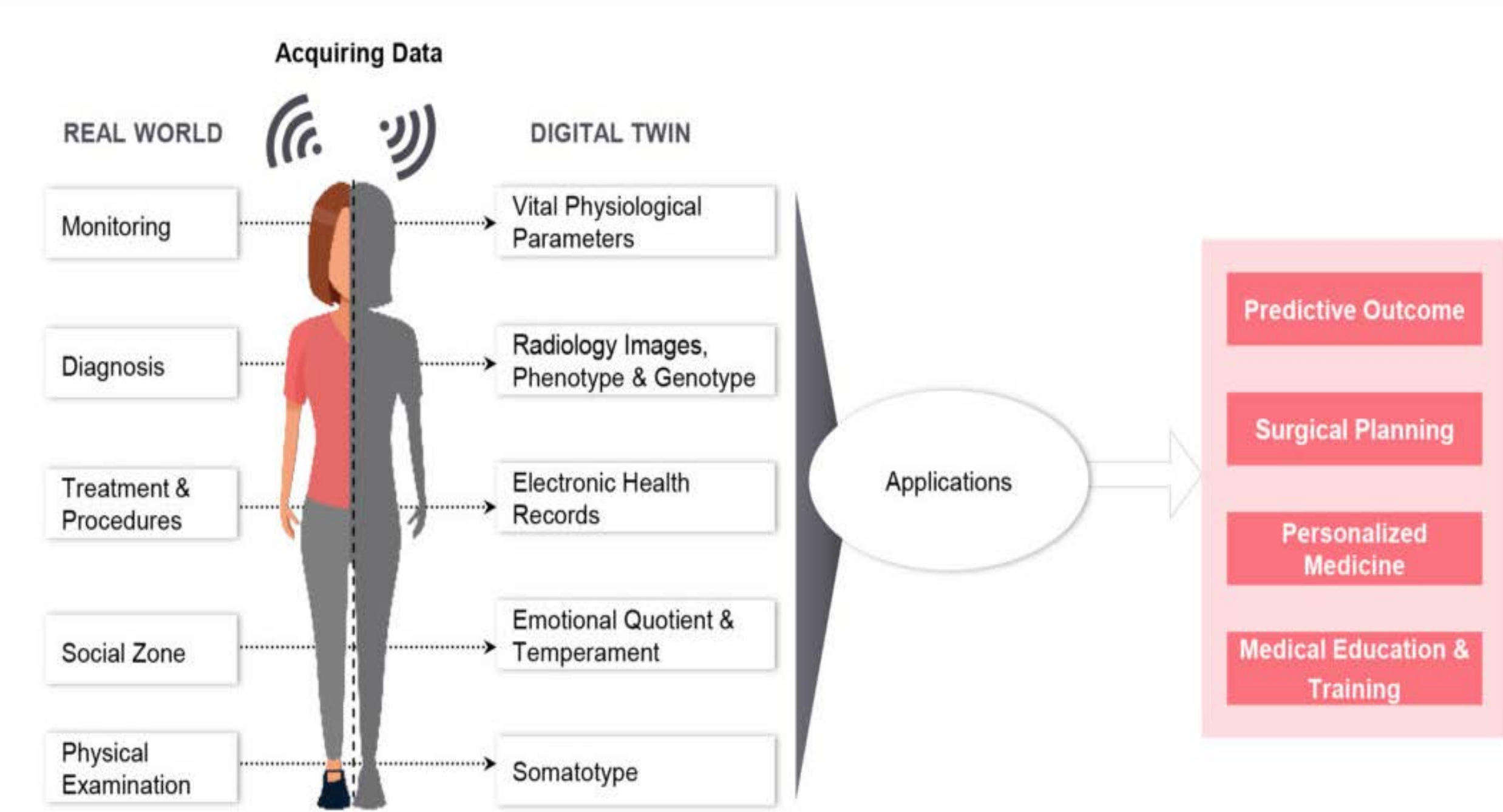
ERIC TOPOL, MD

With a foreword by
ABRAHAM VERGHESE,
author of *Cutting for Stone*

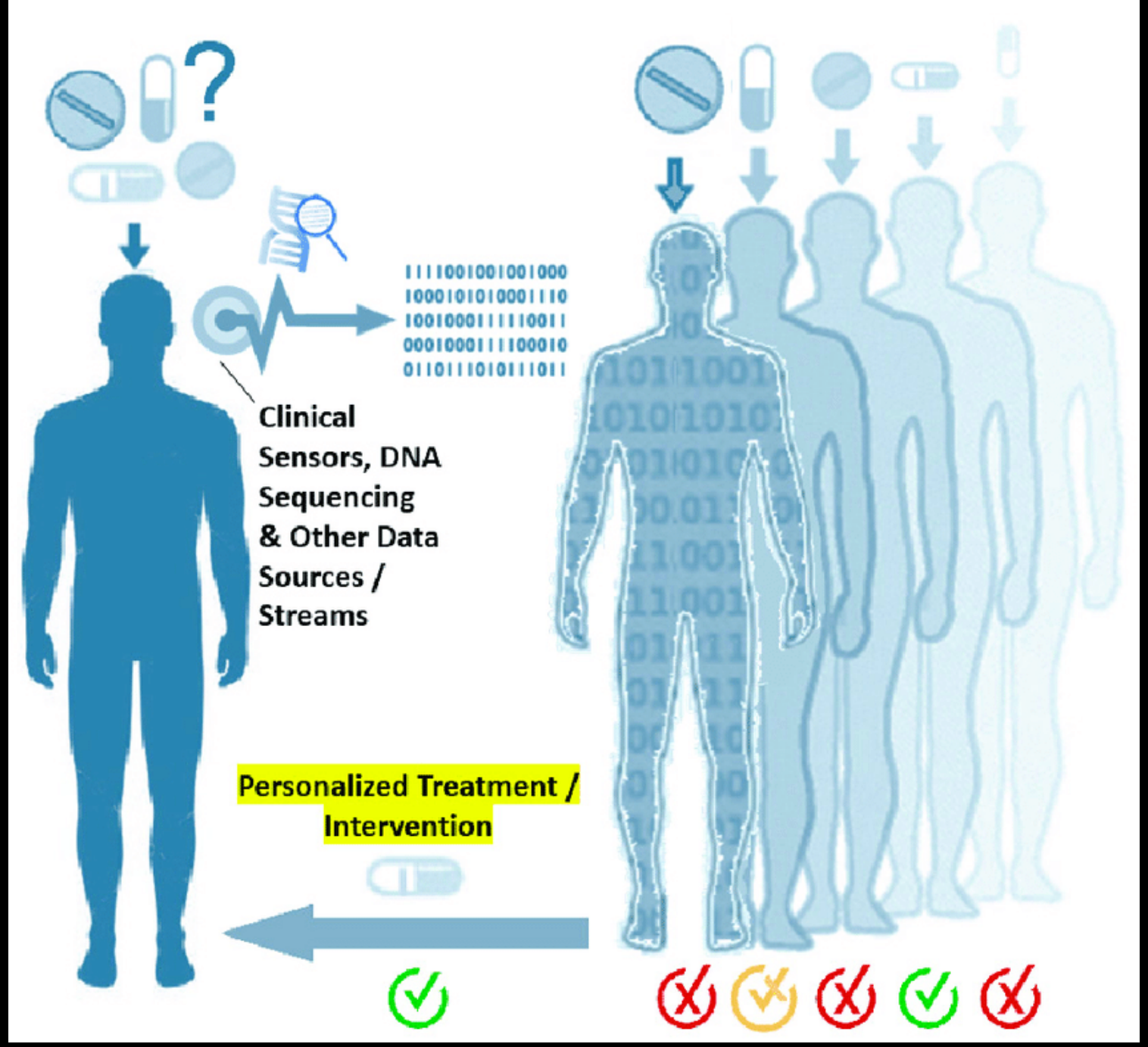

Genetics
Internet of health things
Immunome
Microbiome
Behavior
Metabolome
Deep phenotype
Machine learning
BIG DATA


Real World
Digital Twin
1011
1010
0101
000
0110
Data
Time
Digital Thread

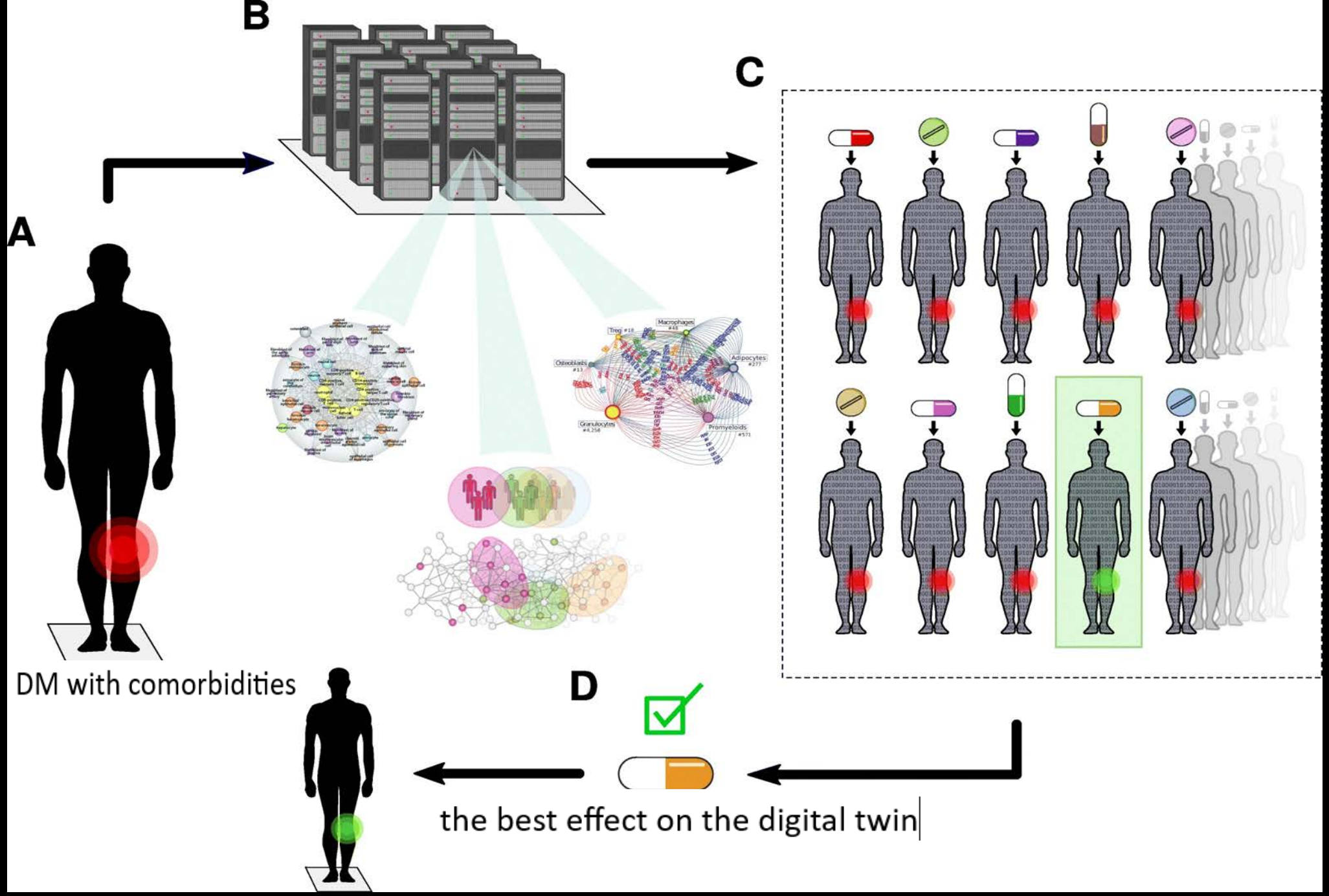

SDTC
Swedish Digital Twin Consortium
Digital Twins
The Concept
The Consortium
Links / Media
News
Publications
Swedish Digital Twin Consortium
Contact Us



Source: FutureBridge Analysis



The digital twin concept for personalized medicine.



The digital twin concept for personalized medicine.

داده‌های اندازه‌گیری شده

بیولوژی/
فیزیولوژی/ فیزیک/
پاسخ مکانیکی

مدل‌ها/ ریاضیات

همزاد
دیجیتالی

Digital Twin

بازتاب/ پیش‌بینی

پزشک

مراقبت بهینه

بیمار ICU

Endocrine emergencies

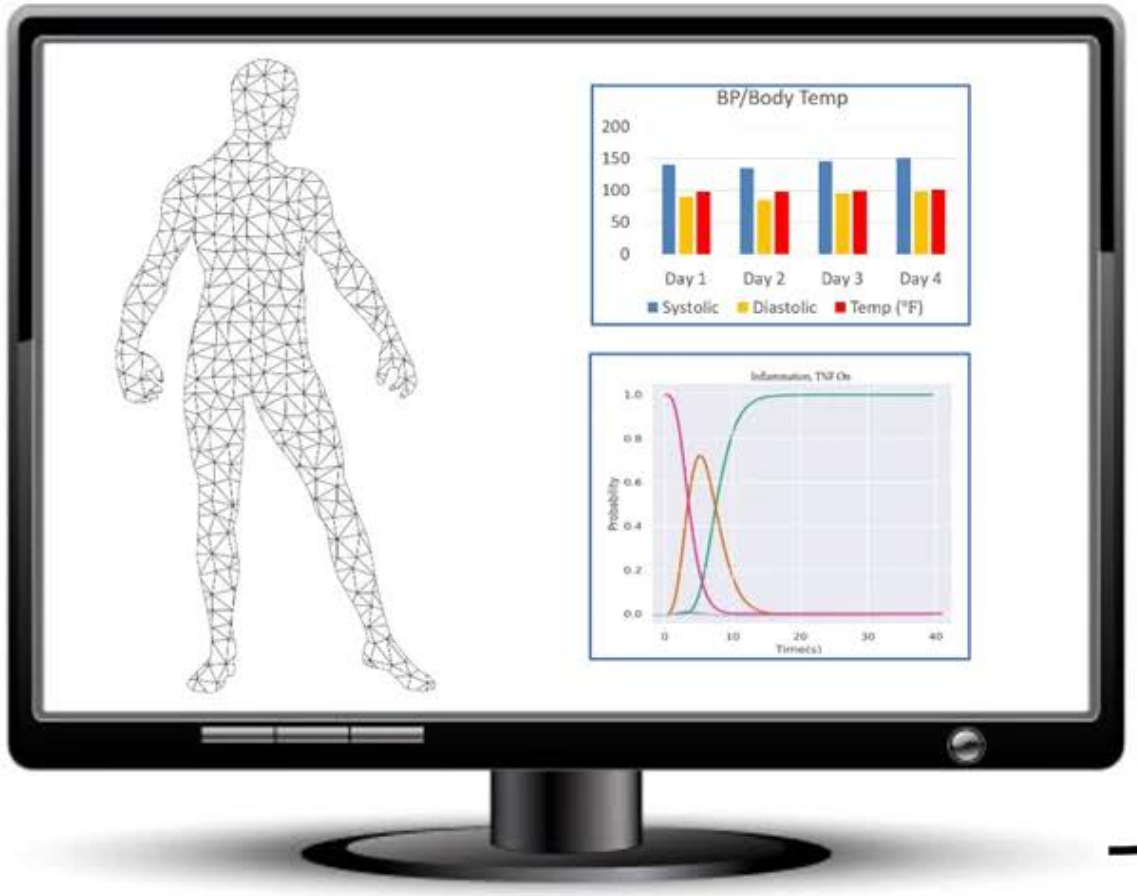
The Endocrine Digital Twin

Multi-scale biological data

- Body level
- Organ level
- Tissue level
- Cellular level
- Molecular level

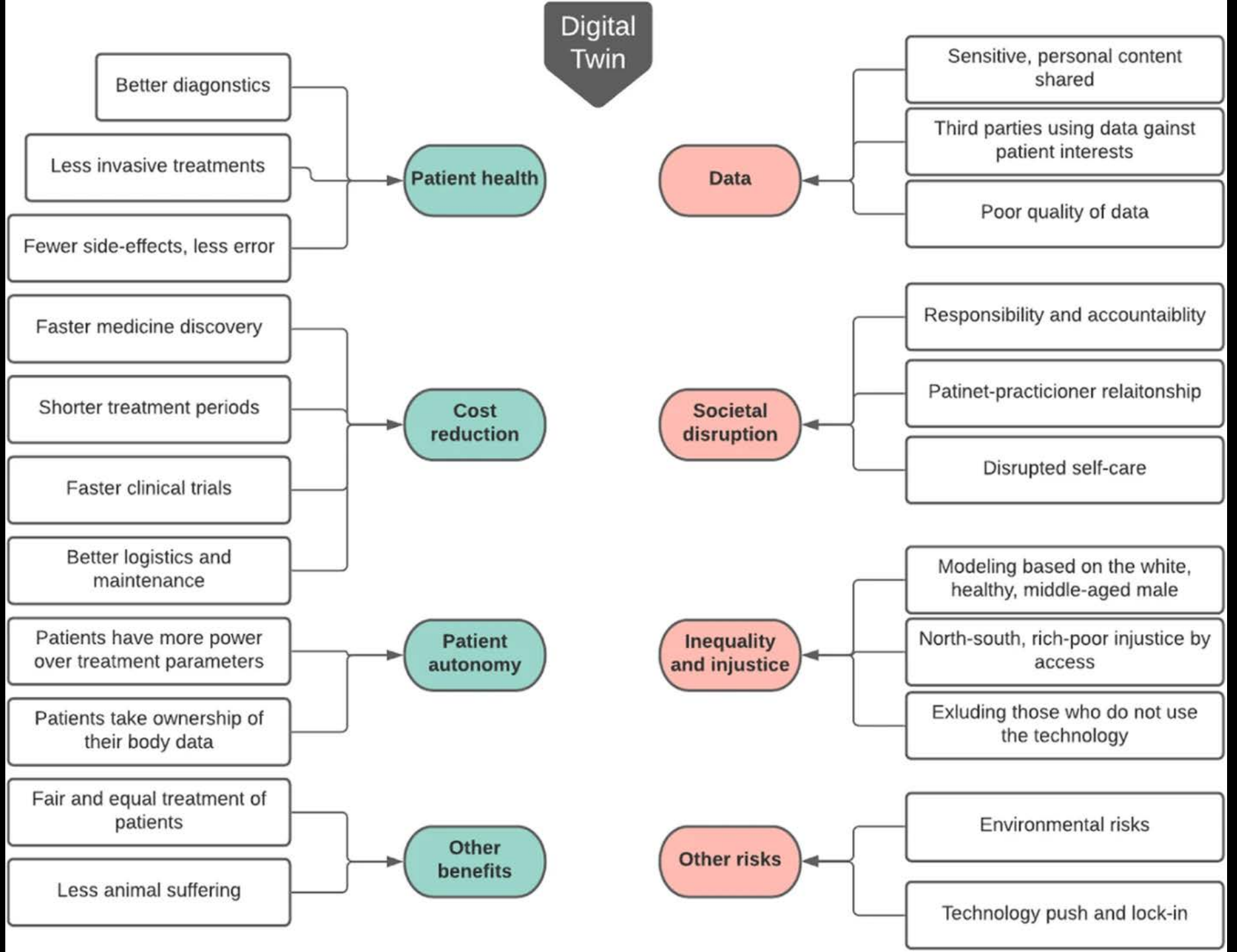
Data Integration & Analysis

Modelling & in silico simulations

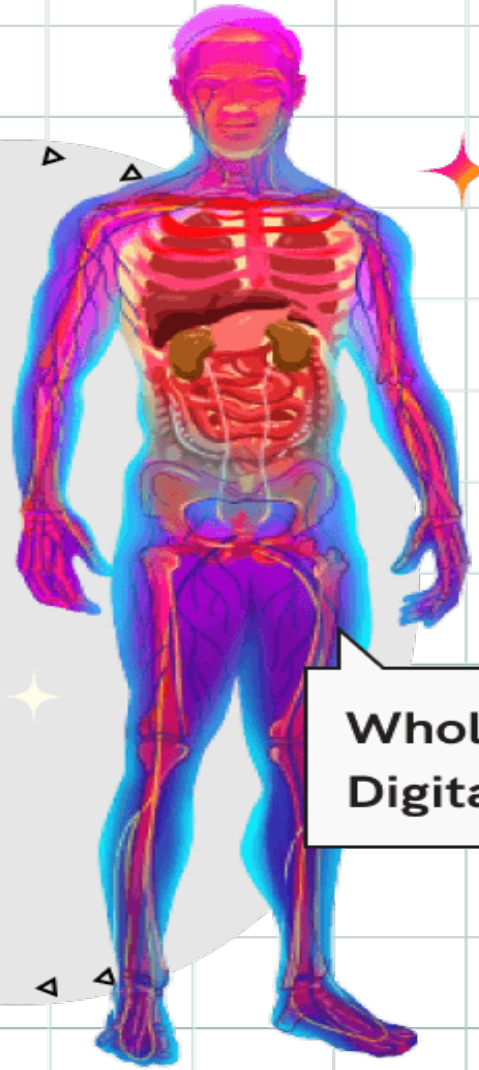


Personalized care

- Diagnosis
- Prognosis
- Therapy Optimization


Digital Twin
Better diagonstics
Less invasive treatments
Fewer side-effects, less error
Patient health
Faster medicine discovery
Shorter treatment periods
Faster clinical trials
Better logistics and maintenance
Cost reduction
Patients have more power over treatment parameters
Patients take ownership of their body data
Patient autonomy
Fair and equal treatment of patients
Less animal suffering
Other benefits
Data
Sensitive, personal content shared
Third parties using data gainst patient interests
Poor quality of data
Societal disruption
Responsibility and accountaiblity
Patinet-practicioner relaitonship
Disrupted self-care
Inequality and injustice
Modeling based on the white, healthy, middle-aged male
North-south, rich-poor injustice by access
Exluding those who do not use the technology
Other risks
Environmental risks
Technology push and lock-in

3000+ health signals / day are
send through our body sensors

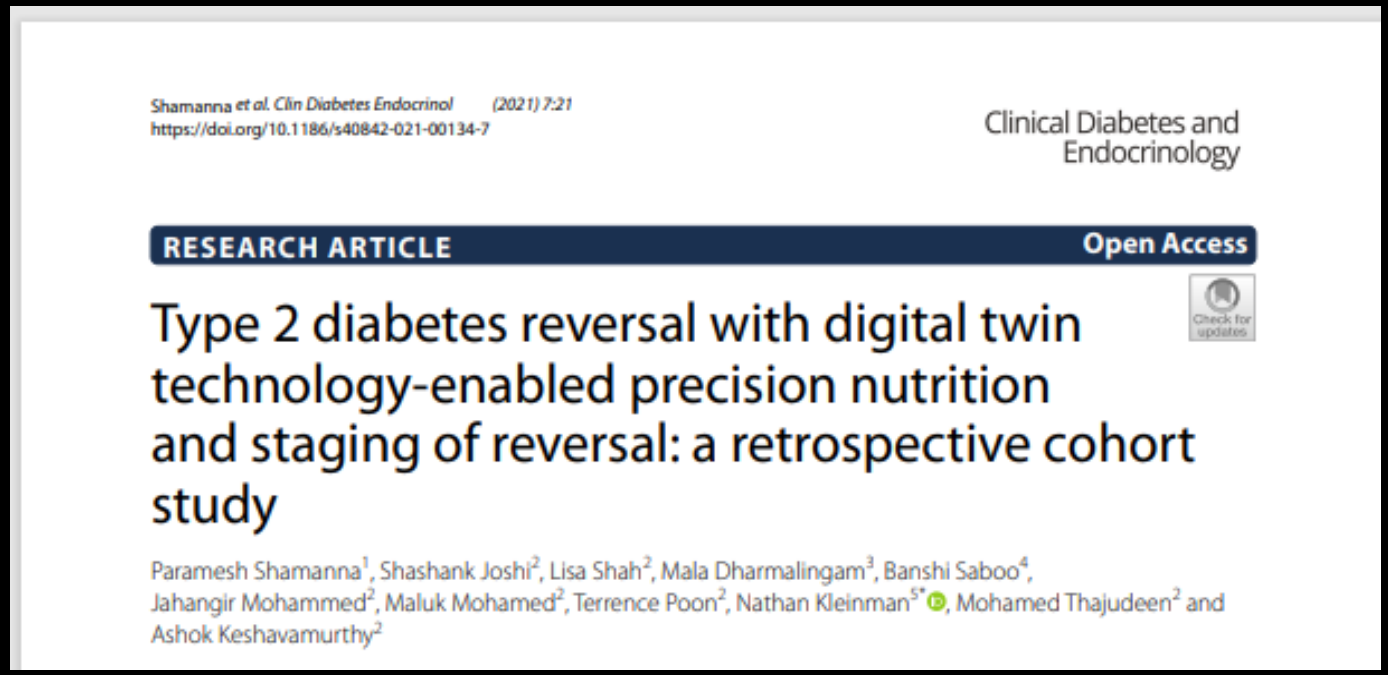


Whole Body
Digital Twin

In return, you get ‘precision treatment’
for your body to heal its metabolism

The Artificial Intelligence-based Whole Digital Twin for diabetes remission

- A more recent 2021 ADA consensus statement defined diabetes remission as HbA1c<6.5% at least 3 months after stopping glucose-lowering pharmacotherapy.



Shamanna et al. Clin Diabetes Endocrinol (2021) 7:21
https://doi.org/10.1186/s40842-021-00134-7

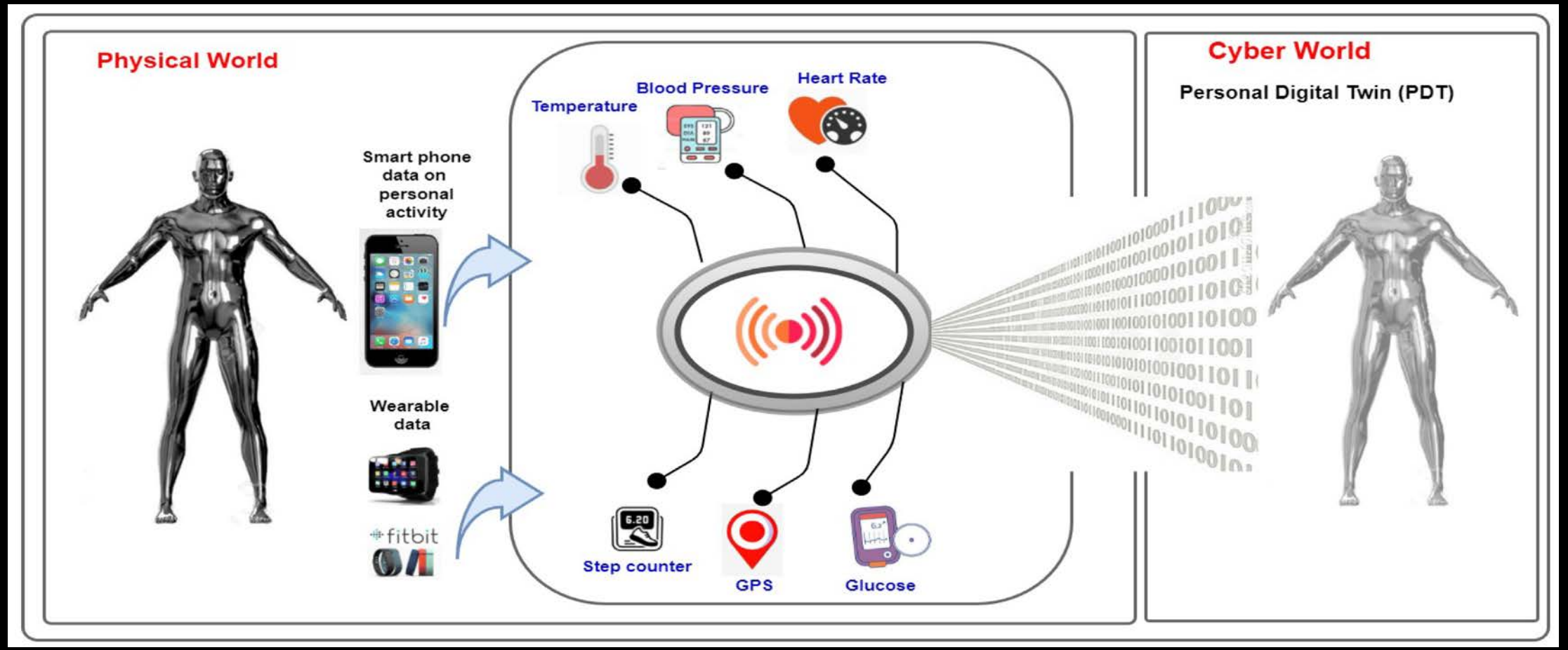
Clinical Diabetes and Endocrinology

RESEARCH ARTICLE Open Access

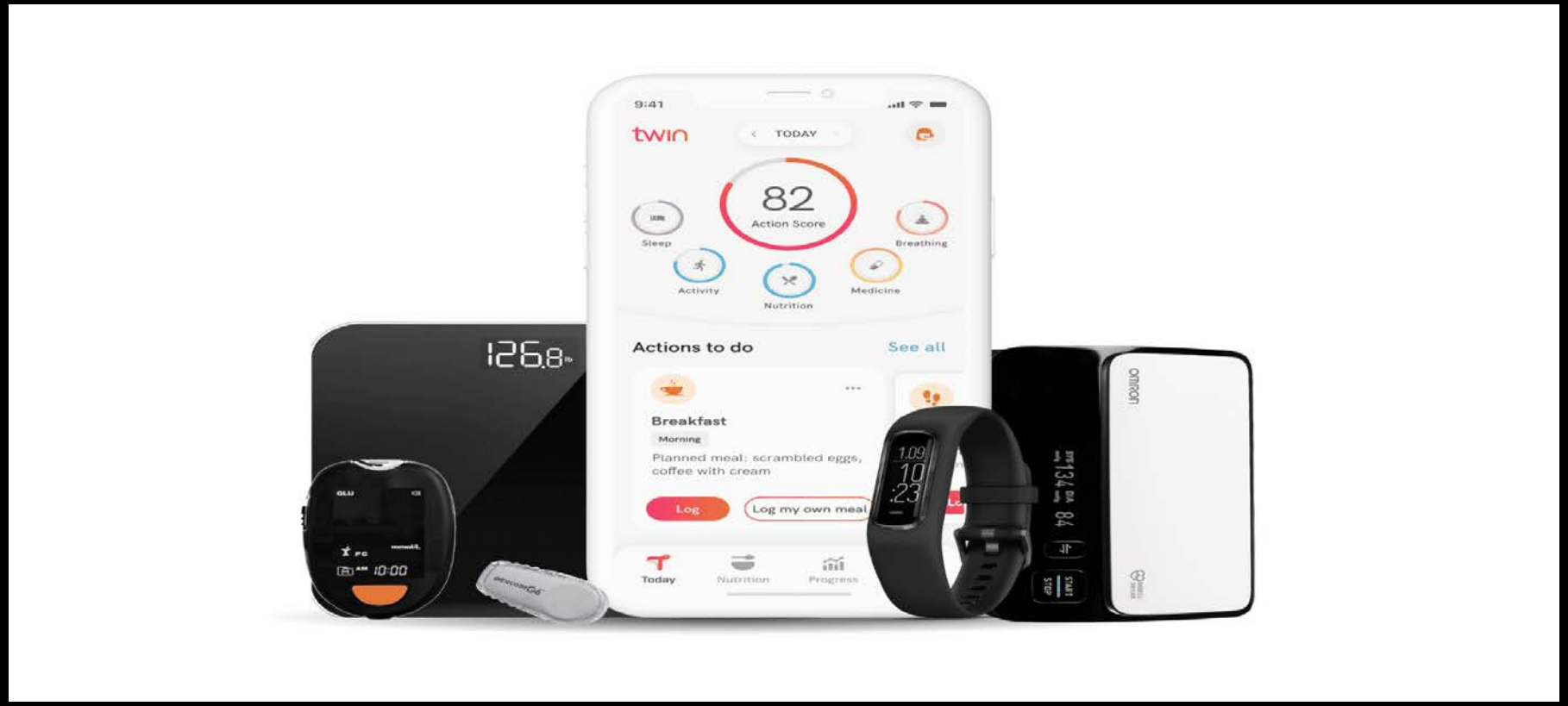
Type 2 diabetes reversal with digital twin technology-enabled precision nutrition and staging of reversal: a retrospective cohort study

Paramesh Shamanna[1], Shashank Joshi[2], Lisa Shah[2], Mala Dharmalingam[3], Banshi Saboo[4], Jahangir Mohammed[2], Maluk Mohamed[2], Terrence Poon[2], Nathan Kleinman[5*], Mohamed Thajudeen[2] and Ashok Keshavamurthy[2]

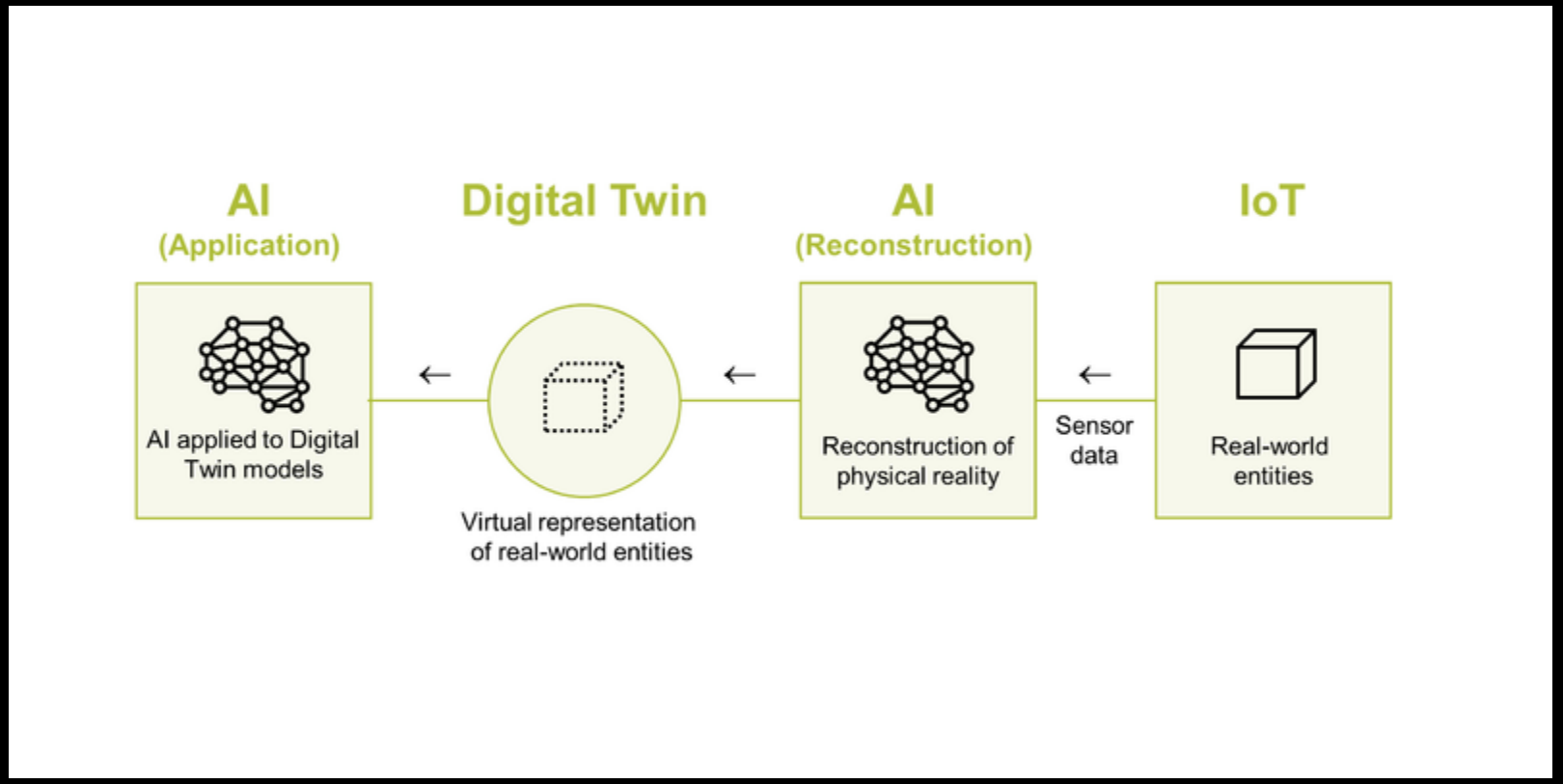
A randomized controlled trial of the tech was conducted on individuals with type-2 diabetes, to use the Whole Body Digital Twin platform (n = 199) or receive standard of care (n = 63) for 180 days.



The platform collects daily data from continuous glucose monitors (CGM), sensor watches, blood pressure meters, smart scales, detailed patient food intake information, and a mobile app to track and analyze the body's health signals in order to personalize the patient's treatment and provide daily precision nutrition guidance to the patient.

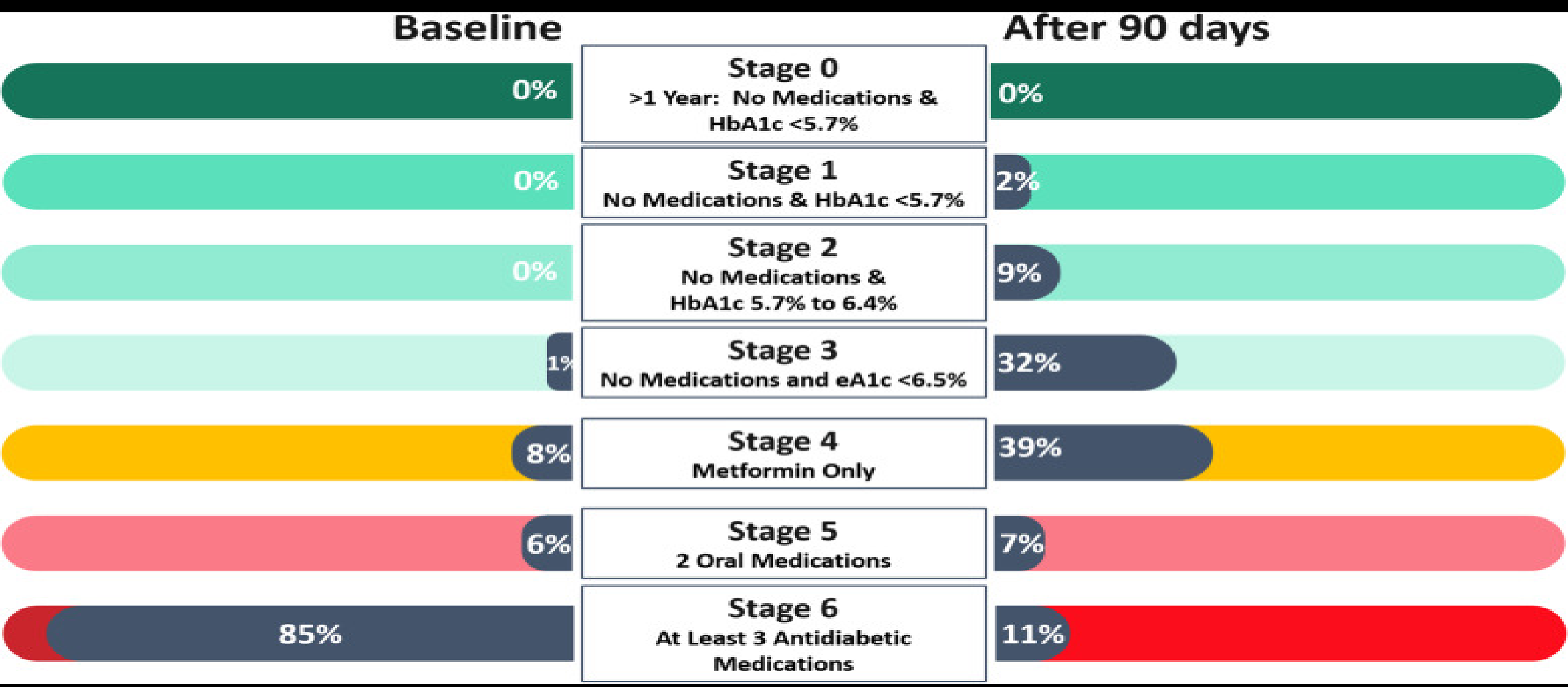


The program employs a machine learning predictive model using data from food logs and multiple sensors, including continuous glucose monitoring fitness watches and comprehensive blood tests. The technology provides individualized and timely recommendations through a mobile app to users and their care teams.



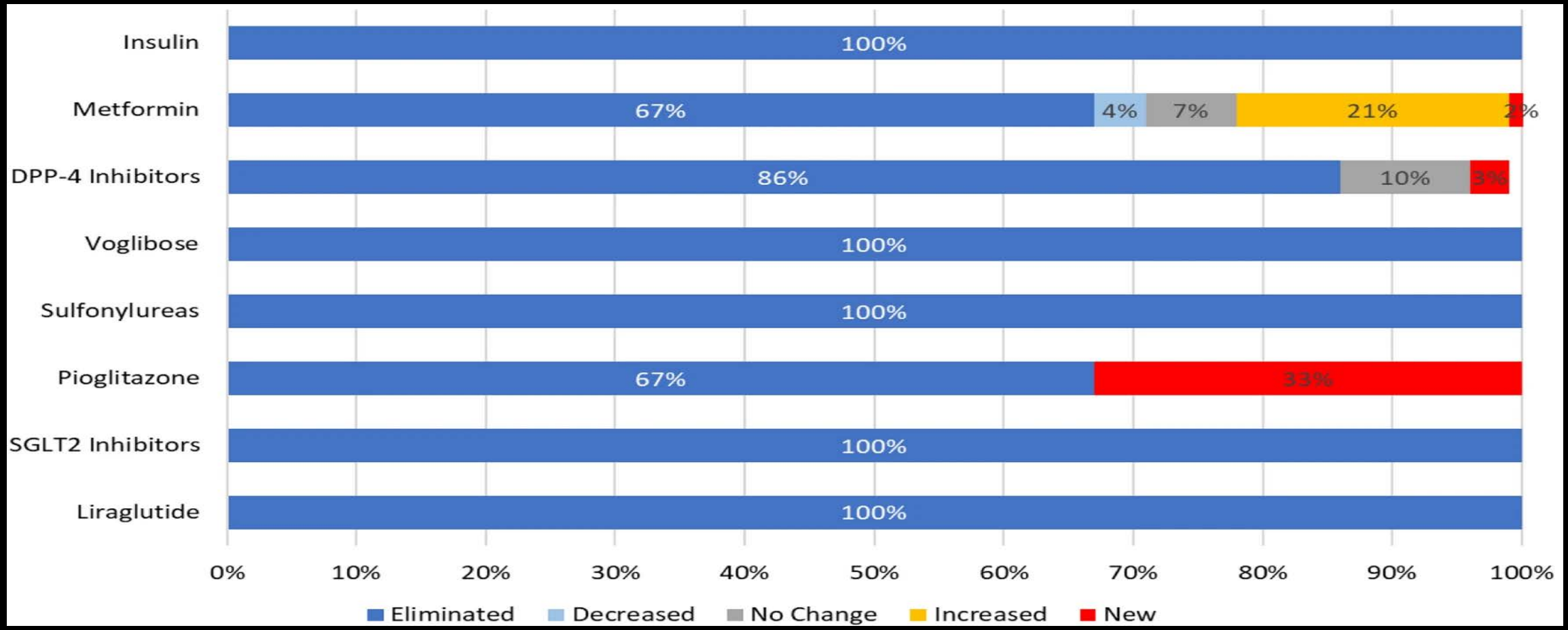
Machine learning algorithms analyzed the patient's macronutrients, micronutrients, and biota nutrients to measure and predict glucose response to specific foods. Participants were provided with specific daily food recommendations to avoid glucose spikes.

Change in HbA1c from baseline to 180 days and the percentage of participants achieving type 2 diabetes remission were the primary outcomes.

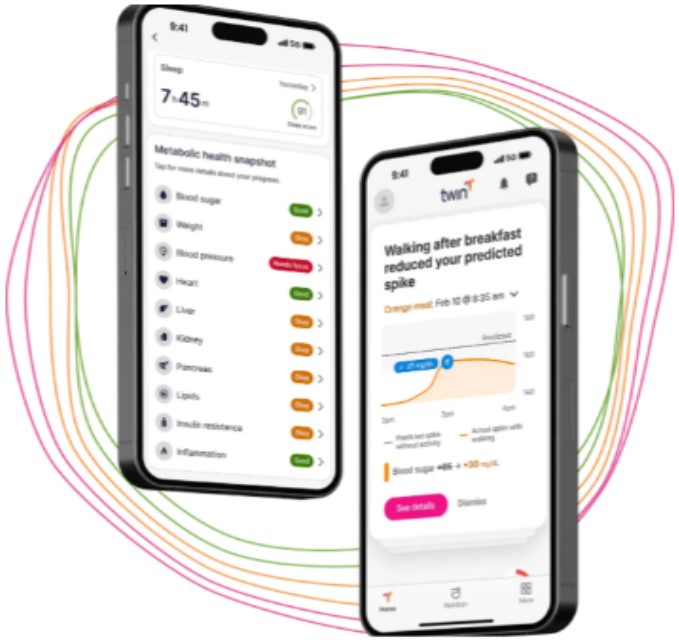


In interim analysis, majority of participants in the intervention group reached an HbA1c <6.5% at 180 days using no medications or metformin only

The remission was independent of the level of weight loss.



All nine participants in the intervention group who used insulin at baseline stopped using insulin prior to 90 days.



Reduce medication, lose weight, and recover from metabolic diseases

"In total, nearly 84% of the group who followed their digital twin's guidance for six months were determined to be in remission by the end of that period, per the ADA's standards—meaning they maintained normal blood glucose levels for at least three months without taking diabetes medication."

– American Diabetes Association (ADA)*

The Whole Body Digital Twin™ is a digital representation of your unique metabolism and delivers precise, personalized guidance about foods, sleep, activity, and breathing through the easy-to-use app.

Twin Health's program combines the Whole Body Digital Twin™ with a dedicated care team that monitors your sensor data, offers personalized recommendations, and supports you on your health journey.

*Artificial Intelligence Offers Significant Rate of Remission for Type 2 Diabetes Compared to Standard Care. American Diabetes Association (2022, June 4).

"We were pleased to see the magnitude of remission of diabetes achieved in our study, validating the power of understanding the distinctions of each individual's unique metabolism to provide personalized recommendations," Shamanna said.

Shamanna :"*Our results demonstrate the potential of Whole Body Digital Twin technology to change the conventional, medication-driven management of type 2 diabetes to achieving remission of type 2 diabetes with a life free of medication in a large proportion of people. Precision lifestyle changes implemented by continued inputs delivered digitally by artificial intelligence has the potential to deliver both glycemic and extra glycemic benefits.*"


YOUR BODY CAN
TELL YOU HOW TO
REVERSE
DIABETES
SAFELY


HERE'S THE
TECHNOLOGY
TO LISTEN
twin
ASK YOUR DOCTOR ABOUT
TWIN DIABETES REVERSAL
TECHNOLOGY.
T&C Apply.


twin
REMISSION
of your chronic metabolism conditions
Like Prediabetes & Obesity
with Whole Body Digital Twin™

Heal your metabolism to help normalize your blood sugar

Reduce costly medications including insulin

Increase energy, improve mood, and decrease symptoms

Newsroom

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OVERVIEW > NEWS

OPTOMICS: Digital twin technology improving type-2 diabetes healthcare

The EU Horizon 2020 OPTOMICS project will develop and validate a digital-twin model, which aims at developing non-invasive and inexpensive prognostic and treatment planning methods for type-2 diabetes patients.

date: 18/02/2021

This so-called digital-twin model aims to improve prediction and early detection of individuals likely to develop the disease, which will improve the overall possibility for prevention. Simultaneously, the method will reveal potential risks for developing disease complications, all while personalizing patient treatment.

The project involves in-depth molecular phenotyping of individuals at the DNA, protein and metabolite level.

www.nature.com/scientificreports

scientific reports

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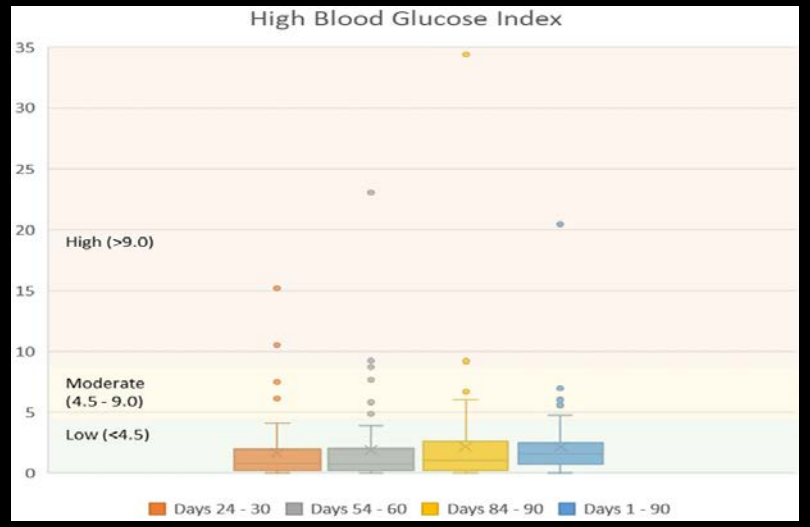
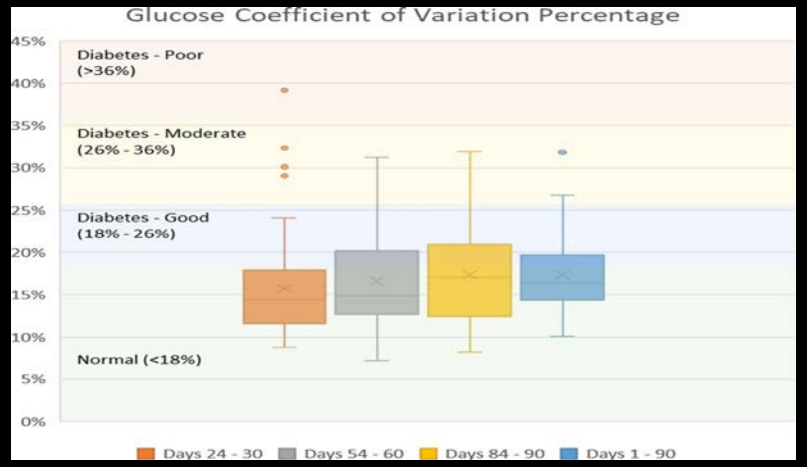
OPEN

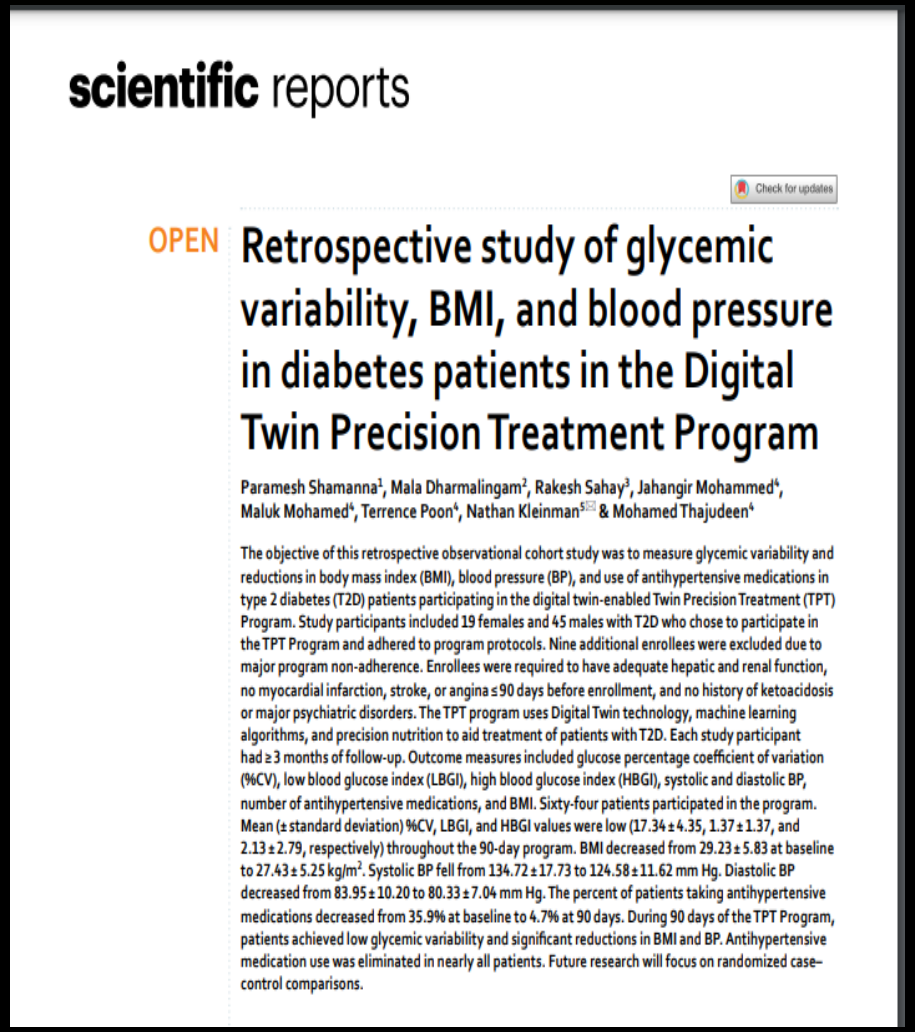
Retrospective study of glycemic variability, BMI, and blood pressure in diabetes patients in the Digital Twin Precision Treatment Program

Paramesh Shamanna[1], Mala Dharmalingam[2], Rakesh Sahay[3], Jahangir Mohammed[4], Maluk Mohamed[4], Terrence Poon[4], Nathan Kleinman[5]✉ & Mohamed Thajudeen[4]

The objective of this retrospective observational cohort study was to measure glycemic variability and reductions in body mass index (BMI), blood pressure (BP), and use of antihypertensive medications in type 2 diabetes (T2D) patients participating in the digital twin-enabled Twin Precision Treatment (TPT) Program. Study participants included 19 females and 45 males with T2D who chose to participate in the TPT Program and adhered to program protocols. Nine additional enrollees were excluded due to major program non-adherence. Enrollees were required to have adequate hepatic and renal function, no myocardial infarction, stroke, or angina ≤ 90 days before enrollment, and no history of ketoacidosis or major psychiatric disorders. The TPT program uses Digital Twin technology, machine learning algorithms, and precision nutrition to aid treatment of patients with T2D. Each study participant had ≥ 3 months of follow-up. Outcome measures included glucose percentage coefficient of variation (%CV), low blood glucose index (LBGI), high blood glucose index (HBGI), systolic and diastolic BP, number of antihypertensive medications, and BMI. Sixty-four patients participated in the program. Mean (± standard deviation) %CV, LBGI, and HBGI values were low (17.34 ± 4.35, 1.37 ± 1.37, and 2.13 ± 2.79, respectively) throughout the 90-day program. BMI decreased from 29.23 ± 5.83 at baseline







scientific reports

Check for updates

OPEN

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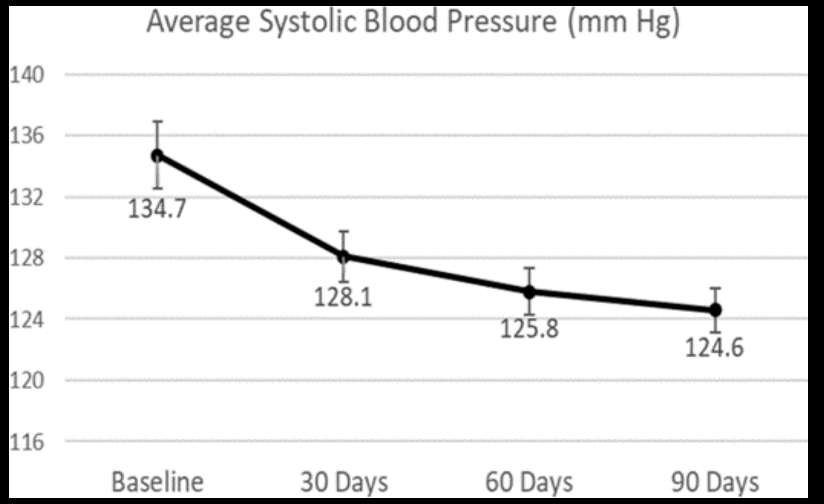
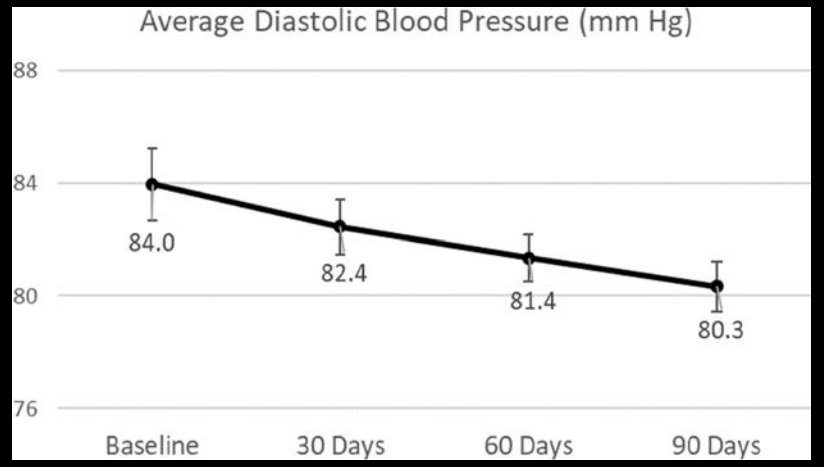
Paramesh Shamanna[1], Mala Dharmalingam[2], Rakesh Sahay[3], Jahangir Mohammed[4], Maluk Mohamed[4], Terrence Poon[4], Nathan Kleinman[5✉] & Mohamed Thajudeen[4]

The objective of this retrospective observational cohort study was to measure glycemic variability and reductions in body mass index (BMI), blood pressure (BP), and use of antihypertensive medications in type 2 diabetes (T2D) patients participating in the digital twin-enabled Twin Precision Treatment (TPT) Program. Study participants included 19 females and 45 males with T2D who chose to participate in the TPT Program and adhered to program protocols. Nine additional enrollees were excluded due to major program non-adherence. Enrollees were required to have adequate hepatic and renal function, no myocardial infarction, stroke, or angina ≤ 90 days before enrollment, and no history of ketoacidosis or major psychiatric disorders. The TPT program uses Digital Twin technology, machine learning algorithms, and precision nutrition to aid treatment of patients with T2D. Each study participant had ≥ 3 months of follow-up. Outcome measures included glucose percentage coefficient of variation (%CV), low blood glucose index (LBGI), high blood glucose index (HBGI), systolic and diastolic BP, number of antihypertensive medications, and BMI. Sixty-four patients participated in the program. Mean (± standard deviation) %CV, LBGI, and HBGI values were low (17.34 ± 4.35, 1.37 ± 1.37, and 2.13 ± 2.79, respectively) throughout the 90-day program. BMI decreased from 29.23 ± 5.83 at baseline to 27.43 ± 5.25 kg/m^2. Systolic BP fell from 134.72 ± 17.73 to 124.58 ± 11.62 mm Hg. Diastolic BP decreased from 83.95 ± 10.20 to 80.33 ± 7.04 mm Hg. The percent of patients taking antihypertensive medications decreased from 35.9% at baseline to 4.7% at 90 days. During 90 days of the TPT Program, patients achieved low glycemic variability and significant reductions in BMI and BP. Antihypertensive medication use was eliminated in nearly all patients. Future research will focus on randomized case–control comparisons.





During 90 days of the TPT Program, patients achieved low glycemic variability and significant reductions in BMI and BP.

Antihypertensive medication use was eliminated in nearly all patients.

Journal of
Clinical Medicine

MDPI

Article

Human Digital Twin for Personalized Elderly Type 2 Diabetes Management

Padmapritha Thamotharan [1], Seshadhri Srinivasan [1,2,*], Jothydev Kesavadev [3], Gopika Krishnan [3], Viswanathan Mohan [4], Subathra Seshadhri [1], Korkut Bekiroglu [5] and Chiara Toffanin [6]

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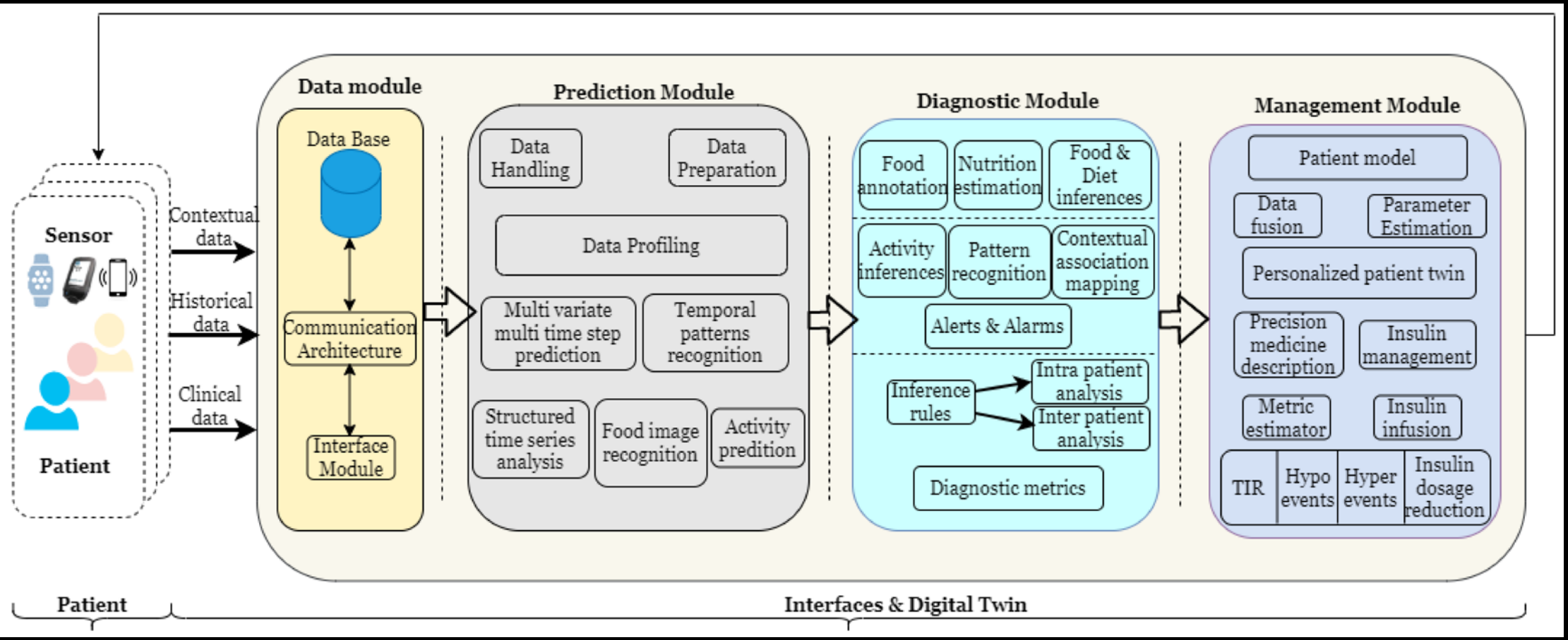
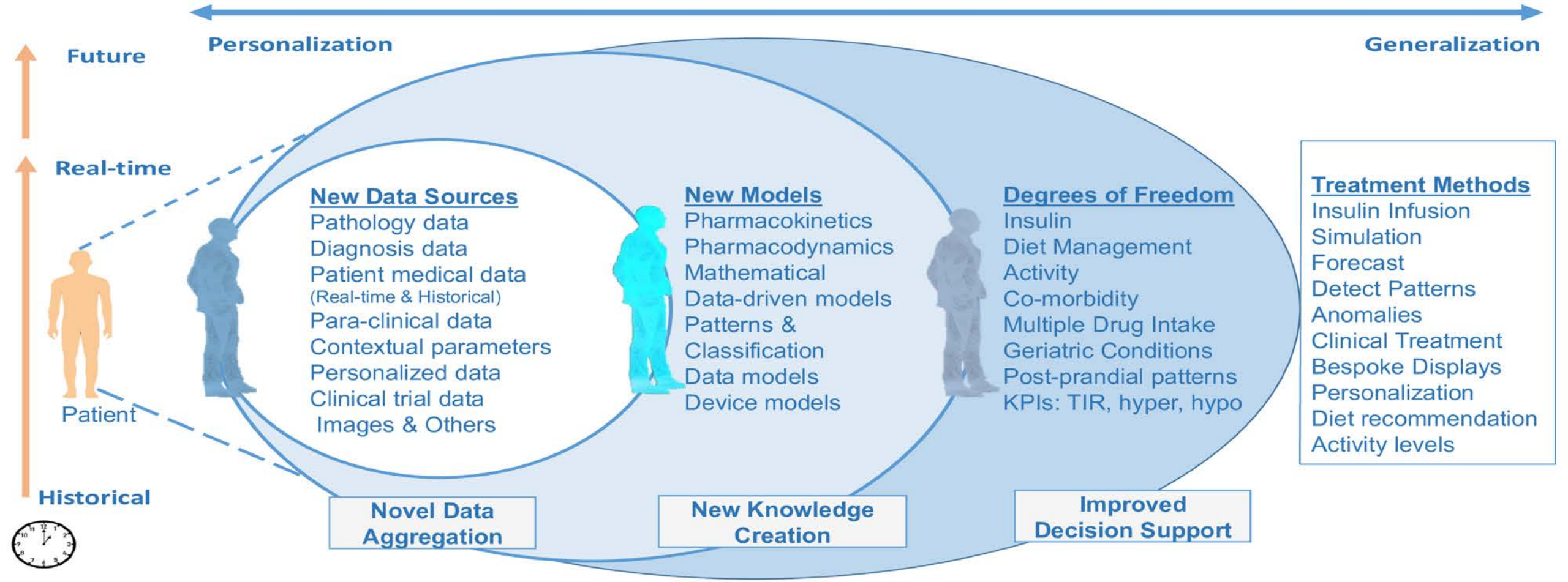
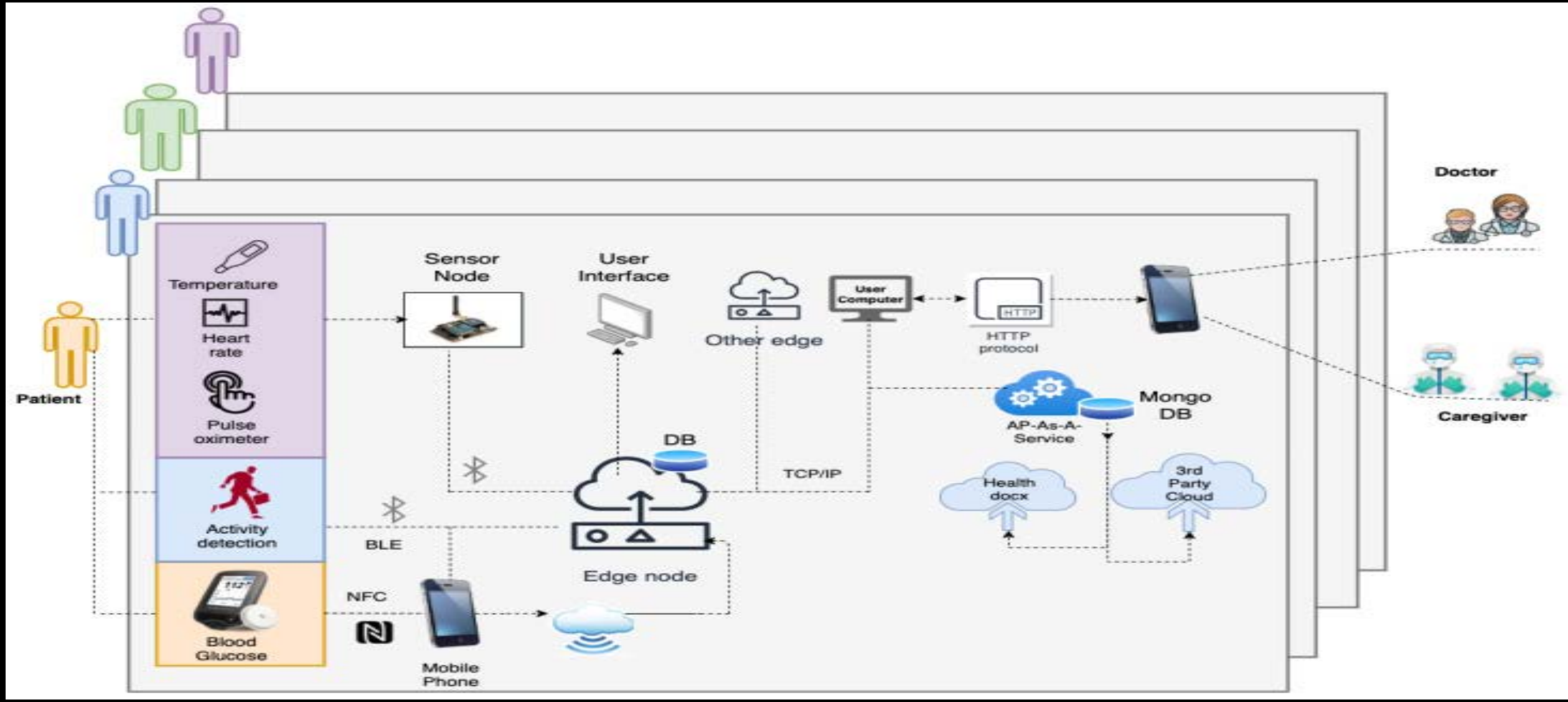
Abstract: Managing Elderly type 2 diabetes (E-T2D) is challenging due to geriatric conditions (e.g., co-morbidity, multiple drug intake, etc.), and personalization becomes paramount for precision medicine. This paper presents a human digital twin (HDT) framework to manage E-T2D that exploits various patient-specific data and builds a suite of models exploiting the data for prediction and management to personalize diabetes treatment in E-T2D patients. These models include mathematical and deep-learning ones that capture different patient aspects. Consequently, the HDT virtualizes the patient from different viewpoints using an HDT that mimics the patient and has interfaces to update the virtual models simultaneously from measurements. Using these models the HDT obtains deeper



The human digital twin framework architecture



Precision Treatment Methods Through framework leads to new data, novel models that create additional knowledge, and improved decision support through new degrees of freedom.



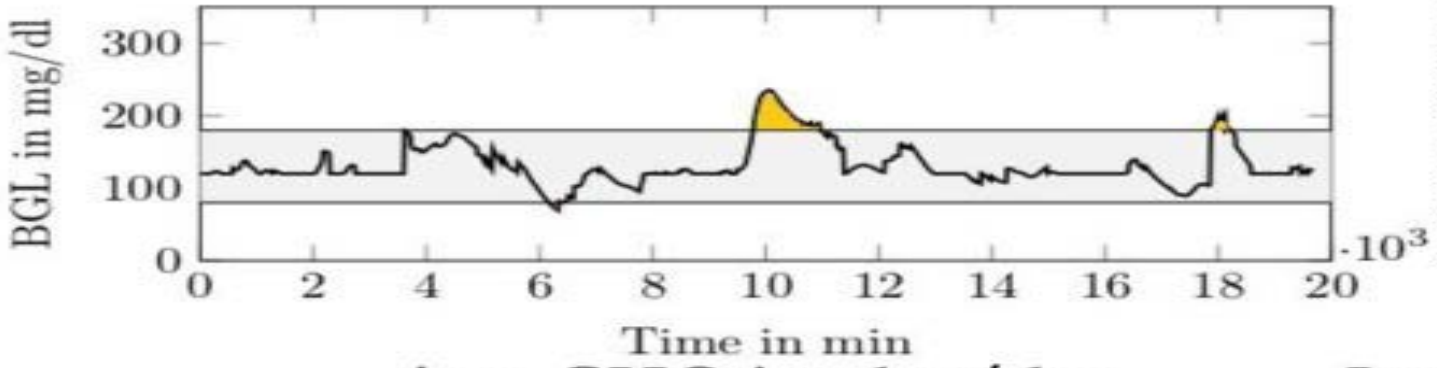
IoMT Architecture—Data transfer using IoT sensor devices from patients' (left), mounted devices to edge nodes (center) to the HDT architecture and finally to medical personnel and caretakers using a mobile app.

Personalized Insulin Recommender

jothydev's DIABETES & RESEARCH CENTRE

Patient Id: JDC 30569 – P1
Status: on Insulin pump
Diabetes: T2D

Controlled BGL

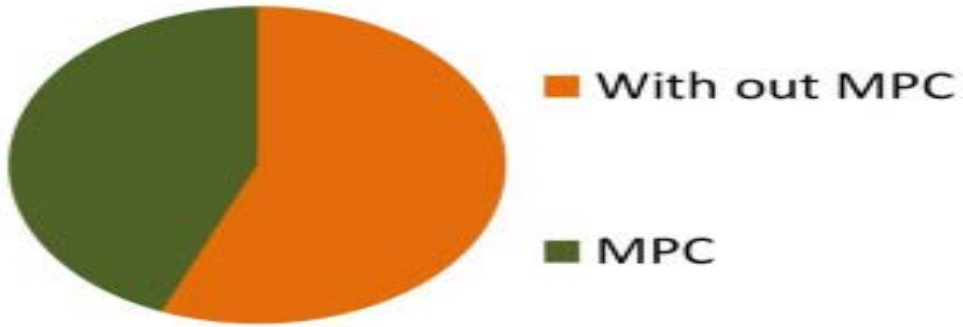


Metrics

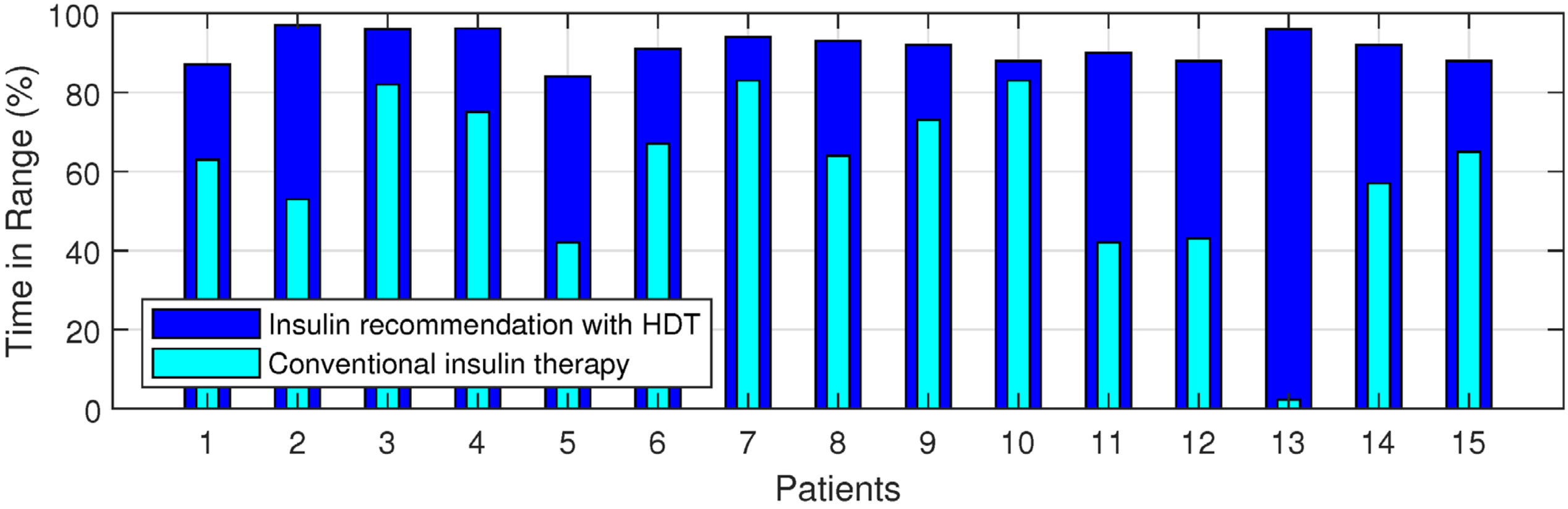
Avg BGL	Target Range	Time in Hyper	Time in Hypo
130 mg/dl	83 %	15 %	2 %

Avg. CHO intake /day

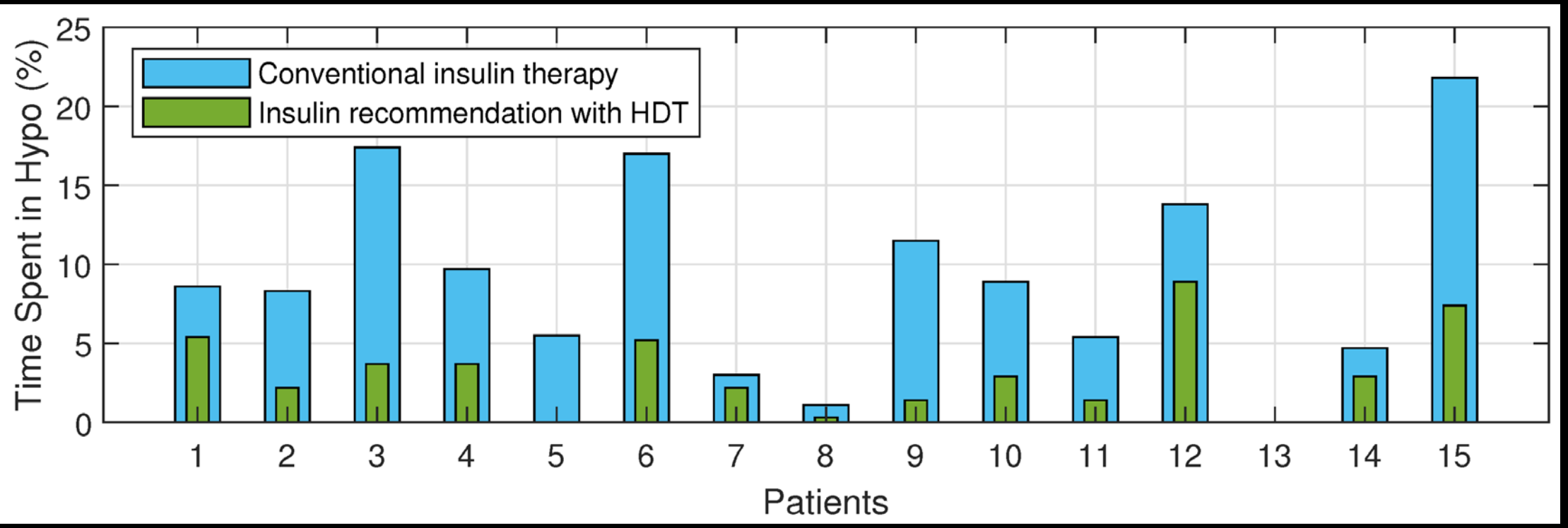
Insulin infusion (U) 15 days



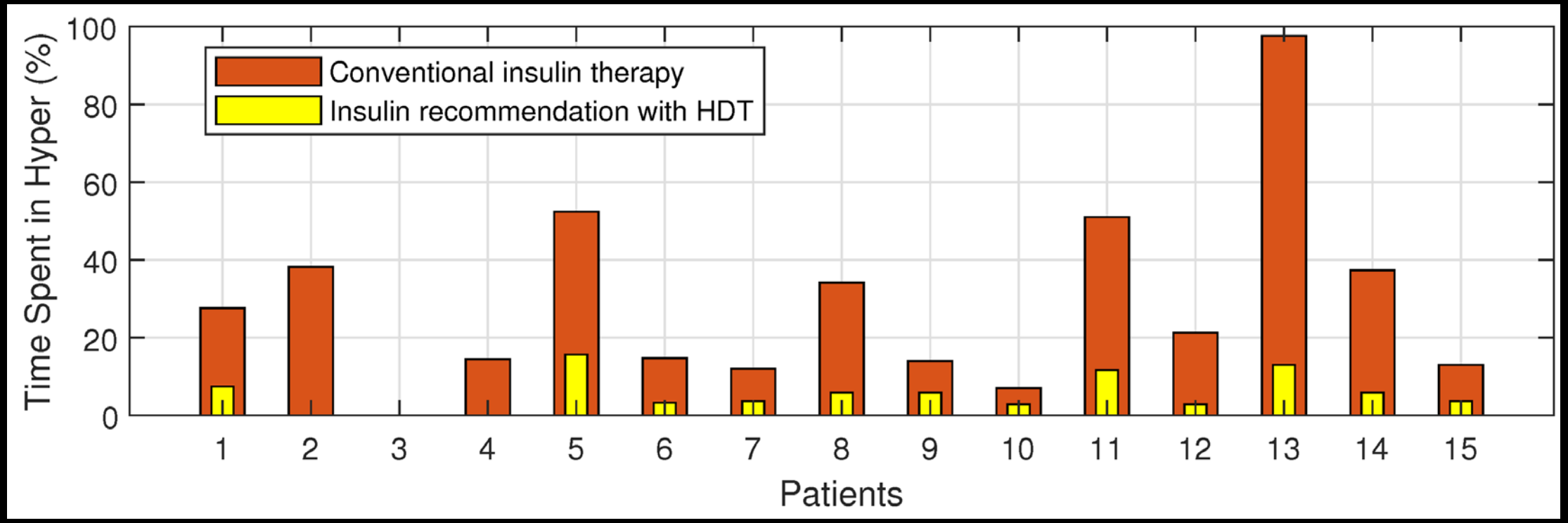
Simulated web page view of the patient's data.



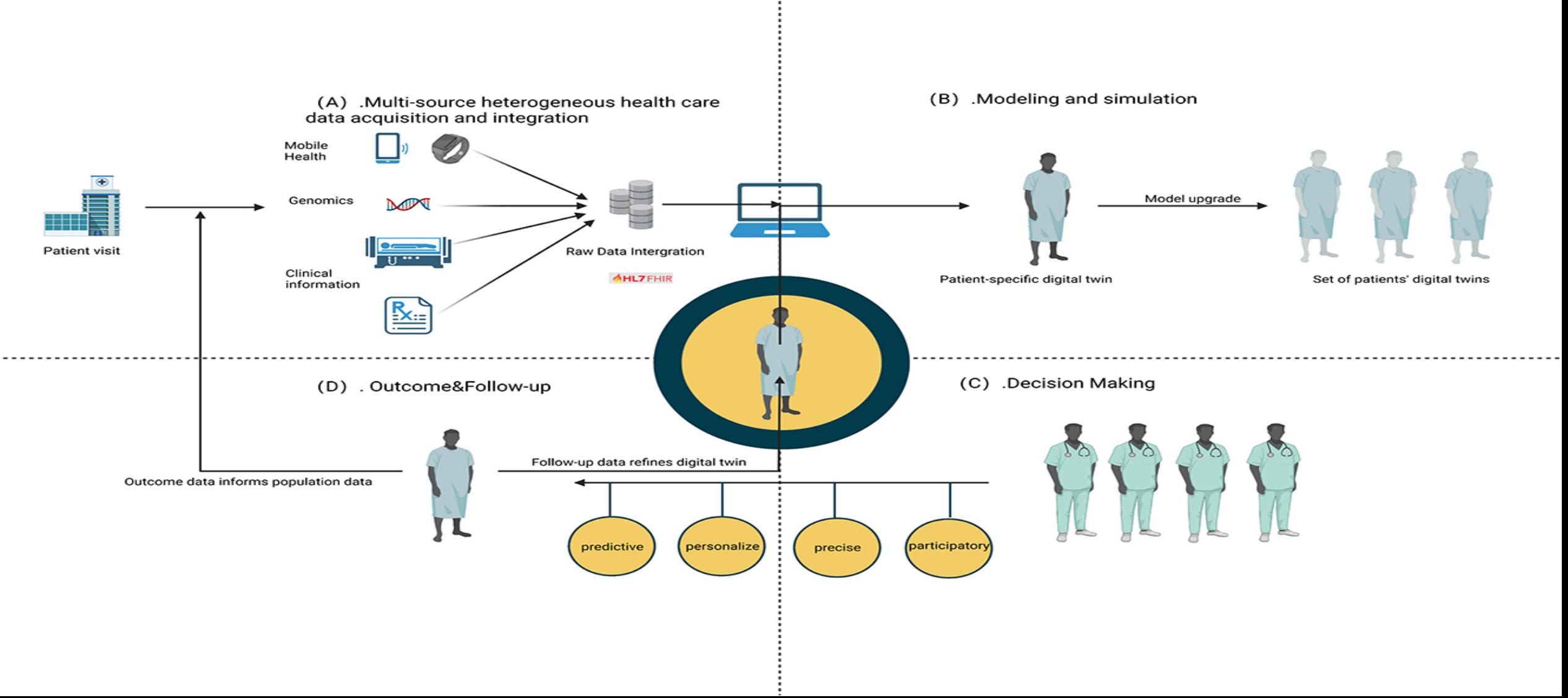
This shows that the TIR is increased from 3–75% to 86–97%.



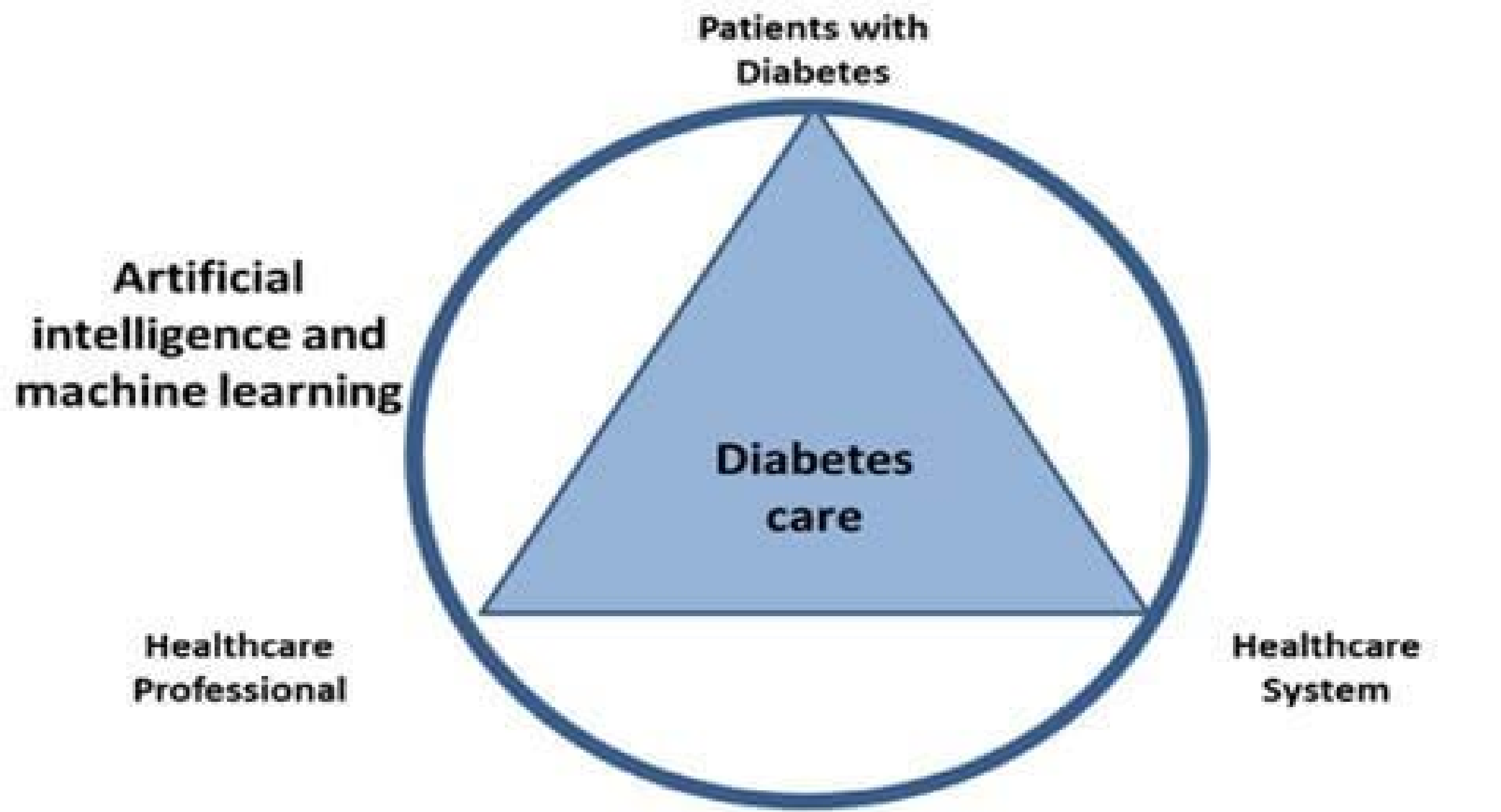
This shows that HDT-based personalized BGL management can reduce the time spent in hypo from 0–22% to 0–9%,



This shows that HDT-based personalized BGL management can reduce percentage of time spent in hyper from 0–98 % to 0–12%.



This paper presented a Human Digital Twin (HDT) framework for Elderly Type-2 Diabetes (E-T2D). The HDT enables personalization and precise insulin infusion considering.


Patients with Diabetes
Artificial intelligence and machine learning
Diabetes care
Healthcare Professional
Healthcare System

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WILEY

BASIC RESEARCH

Toward an artificial intelligence-assisted framework for reconstructing the digital twin of vertebra and predicting its fracture response

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Abstract

This article presents an effort toward building an artificial intelligence (AI) assisted framework, coined ReconGAN, for creating a realistic digital twin of the human vertebra and predicting the risk of vertebral fracture (VF). ReconGAN consists of a deep convolutional generative adversarial network (DCGAN), image-processing steps, and finite element (FE) based shape optimization to reconstruct the vertebra model. This DCGAN model is trained using a set of quantitative micro-computed tomography (micro-QCT) images of the trabecular bone obtained from cadaveric samples. The quality of synthetic trabecular models generated using DCGAN are verified by comparing a set of its statistical microstructural descriptors with those of the imaging data. The synthesized trabecular microstructure is then infused into the vertebra cortical shell extracted from the patient's diagnostic CT scans using an FE-based shape optimization approach to achieve a smooth transition between trabecular to cortical regions. The final geometrical model of the vertebra is converted into a high-fidelity FE model to simulate the VF response using a continuum damage model under compression and flexion loading conditions. A feasibility study is presented to demonstrate the applicability of digital twins

Medical & healthcare

AI-assisted digital twin could predict spinal column fractures in cancer patients

News | 2 min read

06 May 2022

An AI-assisted digital twin of human vertebrae could predict how cancer affects the probability of spinal column fractures, a study from Ohio State University has found.

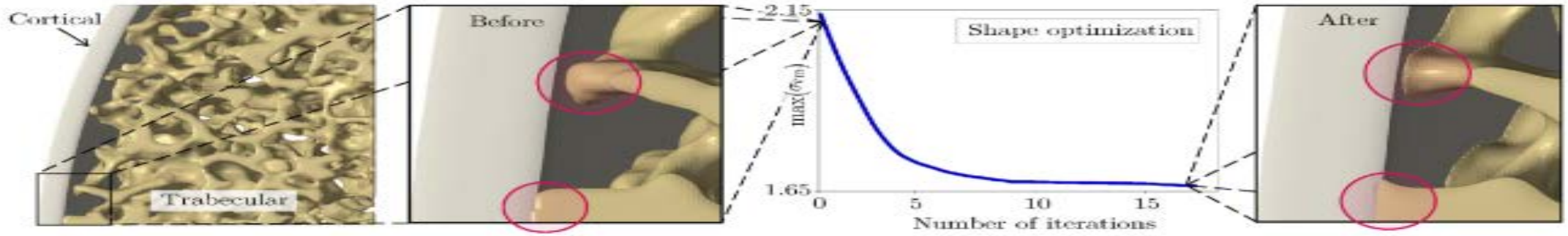


FIGURE 8 Performing finite element-based shape optimization to obtain a tapered transition from cortical to trabecular bone in the virtual vertebra model, which avoid unrealistic stress concentrations in these regions during Vertebral Compression Fracture (VCF) simulations

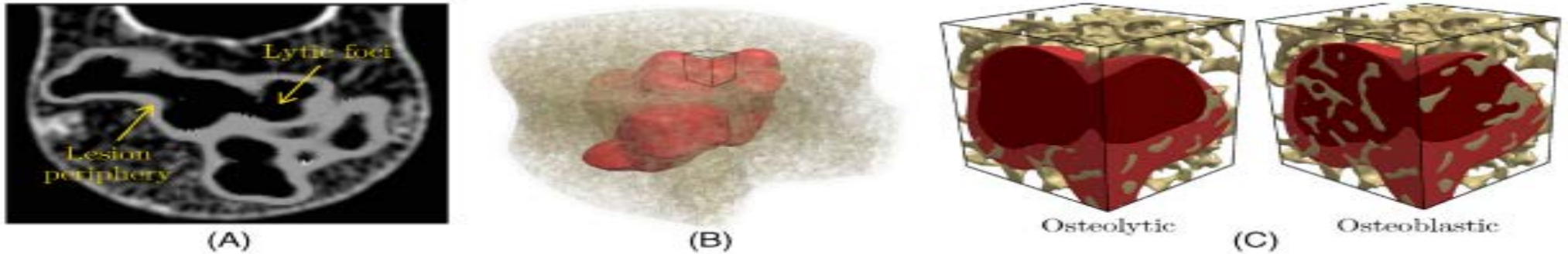


FIGURE 9 (A) Co-registered CT-MRI scan of a vertebra with a metastatic tumor; (B) 3D reconstruction of tumor morphology added to the virtual vertebral model generated using ReconGAN; (C) comparing lytic and blastic tumors in a small portion of the trabecular bone

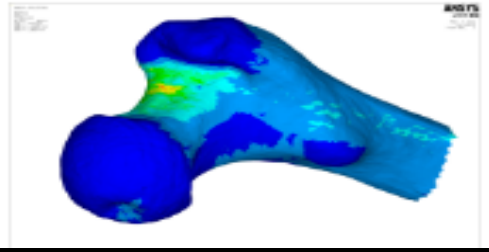
An AI-assisted framework, coined ReconGAN, was developed for synthesizing realistic digital twins of the human vertebra and predicting its fracture response.

ReconGAN enables integrating diagnostic imaging data (e.g., CT scans) with virtual microstructural models of the trabecular bone, to create realistic geometrical models of the whole vertebra.

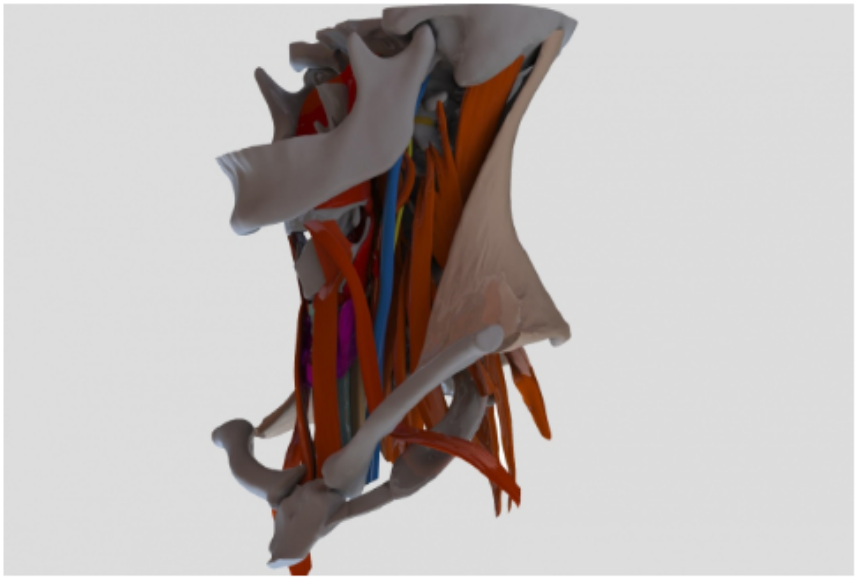
CoE European Excellence in HPC Applications

CompBioMed

- To develop an efficient digital twin solution for the estimation of long bone fracture risk in elderly patients (CT2S solution)
- To not only be able to evaluate the bone strength at present, but also predict the changes in the next 10 years (ARF10 solution)
- To extend the digital twin solution to predict other types of fracture, such as the vertebral
- To enable the running of large scale in silico clinical trials (BoneStrength solution, with a current target for bone treatments)
- To port these solutions on multiple HPC platforms across Europe and solve potential scalability issues



LETI Scientists Developed a Digital Twin of a Neck for Effective Thyroid Surgery Planning



The model will also allow studying the effect of surgical intervention on the biomechanics of the patient's neck.

10.10.2022 290

DeepLife
deeplife.co

DeepLife.

How digital twins of human cells are accelerating drug discovery

Designed to reshape drug discovery and drug repositioning, systems biology company DeepLife has created a data-driven technology platform that creates digital twins of human cells, to evaluate response to new drug candidates.

The rapid proliferation of omics data, which provides essential information regarding bio-molecular activity within cells, is transforming drug discovery. Equipped with this data, DeepLife, a next generation systems biology company, has established a platform for creating digital twins of human cells, enabling scientists to rapidly evaluate how unhealthy cells respond to drug candidates in silico. DeepLife has deployed and established proof-of-concept for its platform, and is now actively seeking partners for target identification and drug repositioning projects enabled by its digital twin technology.

All diseases, and efforts to treat them, start at the cellular level. Small changes in the trillions of chemical interactions that make up human cells, which can be triggered by mutations or external forces, can cause cells to enter pathological states that ultimately manifest in diseases. The massive scale and complexity of the inner workings of cells has traditionally impeded efforts to identify the drivers of diseases through the iterative reconstruction of cell mechanisms, but science is now taming the challenge.

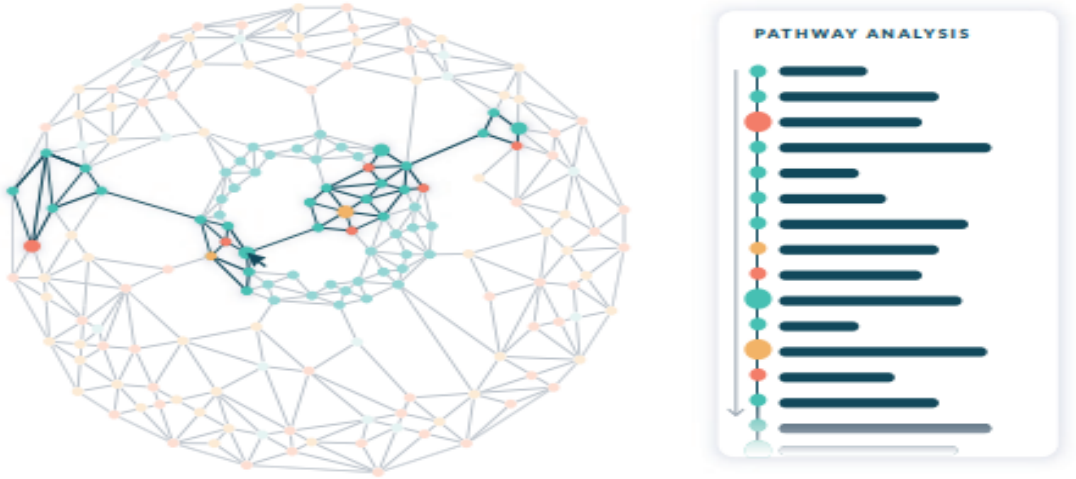
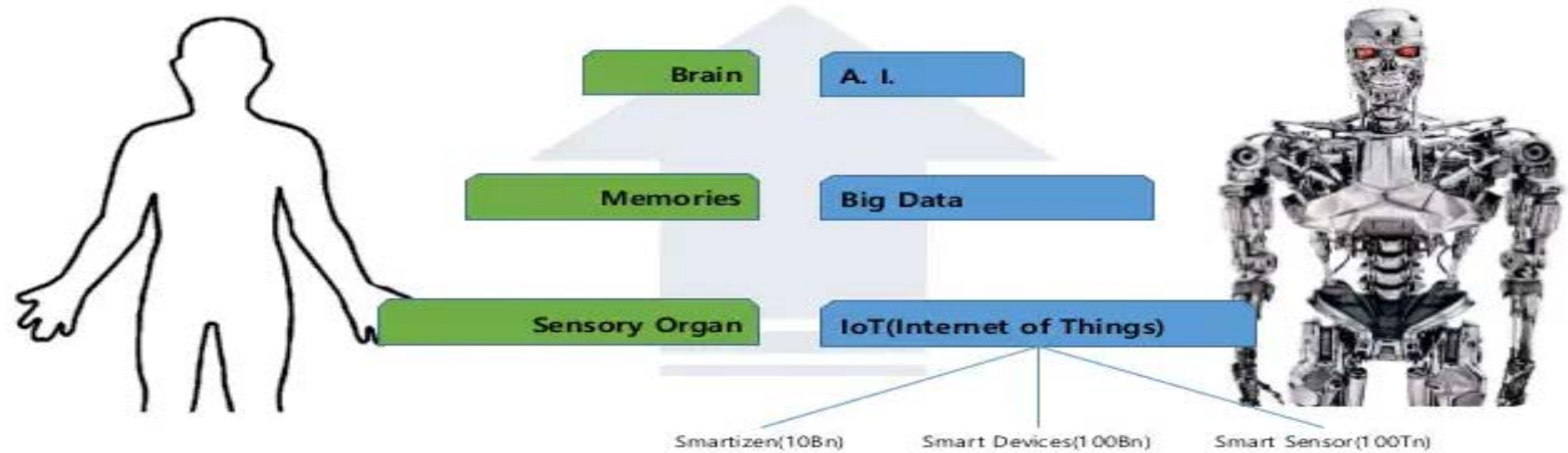


Fig. 1 | The DeepLife Digital Cell technology platform. With the digital cell technology developed by DeepLife, biologists can access interpretable representation of cell mechanisms highlighting pathways and most probable druggable targets.

DeepLife has mapped more than 30 atlases with more than 20 million single. The atlases span brain, blood, liver, lung, intestines, and other tissues and organs, and DeepLife updates them monthly using more than 20 qualified data repositories.


Brain
A. I.
Memories
Big Data
Sensory Organ
IoT(Internet of Things)
Smartizen(10Bn)
Smart Devices(100Bn)
Smart Sensor(100Tn)

همزاد دیجیتالی

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کتابخانه

در این صفحه شما می‌توانید به کتاب‌هایی با موضوع آینده‌پژوهشی و یا آینده‌نگاری پزشکی دسترسی داشته باشید.

علوم پایه برای توسعه پایدار

نویسنده: ایرج نبی‌پور

همزاد دیجیتالی: انقلابی در پزشکی

نویسنده: ایرج نبی‌پور

آینده پزشکی ایران

بر پایه یک مدل سناریونویسی

نویسندگان: دکتر معصومه جرجانی، دکتر مجید اسدی، دکتر سید حسن مقدم نیا، دکتر مجید فصیحی هرندی، دکتر ایرج نبی‌پور

علوم غدد آینده و فناوری‌های همگرا

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زیست‌شناسی کوانتومی

فناوری‌های همگرا و آینده داروسازی