Section II

Novel Technologies & Trends (Industry Forecast 2019-2020)

Section II: Novel Technologies & Trends (Industry Forecast 2019-2020) is devoted to in-depth coverage of the science and technology behind the industry, and to analysis of emerging subsectors within the industry, including an in-depth look at one of the forms of AI making the largest impact on enhancing drug discovery (Deep Learning), an analysis of the intersection of the AI for Drug Discovery sector with the Longevity Industry, and the convergence of next-generation AI for drug discovery with Blockchain and Digital Medicine.

- **Chapter VIII: Deep Learning in Drug Discovery** gives an in-depth overview of topics, trends and advancements occuring in deep learning for drug discovery, one of the specific forms of AI which has now emerged as the leading technology delivering practical and tangible results in the industry, and pays particular attention to the emergence of Generative Adversarial Networks (GANs) as a highly disruptive sub-class of deep learning that may come to dominate industry progress in the years to come.

- **Chapter IX: Longevity Research (AI and Advanced R&D)** is devoted to the use of AI in Drug Discovery for Longevity research, which can be considered to have started in mid-2017 with an event held at the Buck Institute for Research on Aging, at which Atomwise, BioAge and Insilico Medicine held a workshop, and which has just recently been formally solidified through Insilico Medicine being awarded the 2018 North American Artificial Intelligence for Aging Research and Drug Development Technology Innovation Award by leading business consulting firm Frost & Sullivan.

- **Chapter X: Next Generation AI, Convergence with Blockchain and Digital Medicine** charts the ongoing convergence of AI for Drug Discovery with other advanced technologies inclusion blockchain, personalised medicine and digital medicine, illustrating how these technologies and industries are being synergistically integrated so as to expedite the dynamic of progress in the AI for Drug Discovery sphere.

Chapter VIII

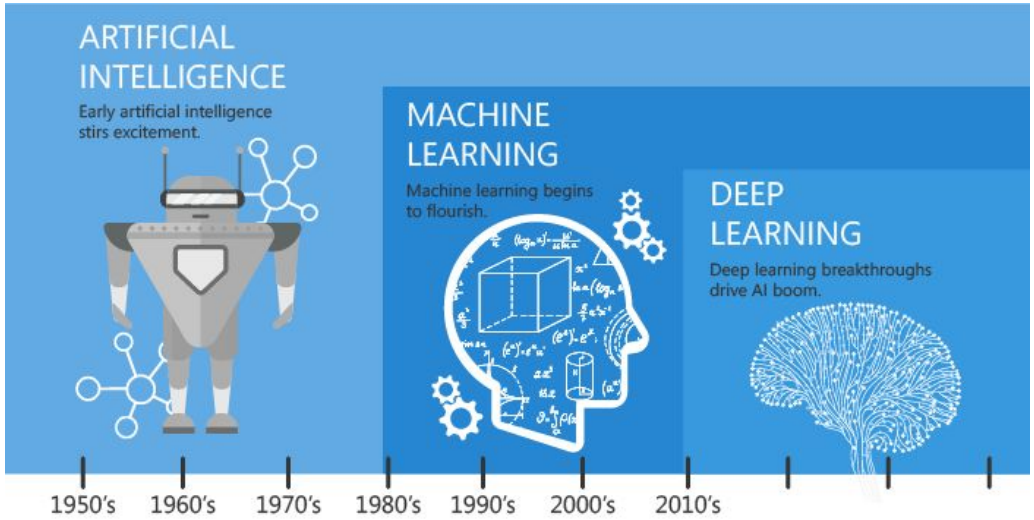
Deep Learning in Drug Discovery

Deep Learning in Drug Discovery

Deep learning is a subset of machine learning consisting of artificial neural networks, famous for its capacity to learn in an unsupervised manner by being “trained on” unstructured and/or unlabelled data.

Its distinction with respect to traditional machine learning can be best thought of as its depth - i.e., deep learning uses “deeper” layers of artificial neural networks with are layered on top of each other.

Machine learning has been in use for almost two decades in the process of in drug discovery.



Since an early flush of optimism in the 1950's, smaller subsets of artificial intelligence - first machine learning, then deep learning, a subset of machine learning - have created ever larger disruptions.

Since the inception of deep learning as a field, it has progressed by leaps and bounds, and has become famous in the public eye for replicating many functions which previously were once thought of as the exclusive domain of humans.

For instance, over the past few years deep learning algorithms have allowed computers to see, read, and write, in ways that are less error-prone than older, more traditional methods of AI, such as decision trees.

For instance, the use of deep learning algorithms trained to analyze and interpret medical images with an error rate of just 6%, which some experts claim to be less error-prone than human doctors. Deep learning has a place in a wide variety of healthcare niches, including medical image analysis, medical device data evaluation, sequencing data analysis, virtual drug screening, drug adherence analysis, drug efficacy analysis, metabolomic profiling, sequencing, molecule profiling, biomarker identification, and drug lead identification, virtual testing and optimization.

Source: https://www.rootsanalysis.com/reports/view_document/deep-learning-in-drug-discovery-and-diagnostics-2017-2035/156.htm

Deep Learning in Drug Discovery

Importantly, deep learning algorithms have show substantial capacities in significantly reducing the time and cost required to bring a drug to market.

Bringing the average drug to market has been known to cost as much as $2.5B over a period of 12 years, and deep learning algorithms have in some cases been shown to reduce the cost of bringing a drug to market by as much as 50%.

Some experts predict that the annual cost savings associated with the development and deployment of deep learning-based solutions to drug discovery could result in cost savings nearing $100B, with nearly $35B projected savings in the diagnostics niche alone.

One of the most ripe commercial opportunities for the picking with regards to deep learning for healthcare is the AI-supported diagnostic imaging subsector, due to the abundance of data available, as well as the consistency of how such data is organized across different databases.

One of the starkest examples of the power of deep learning is in AlphaGo, popularly known to have bet the world champion in the game Go in a remarkably short amount of time. By emulating the computational patterns of human thought in a much more naturalistic manner than, for example, traditional, brute-force decision trees, it required less computational steps in order to arrive at the decisions it needed go make, and managed to win 100 out of 100 games after training on Go data for just three days.

Remarkably, more than 55% of deep learning companies focusing on the image recognition sector are applying their efforts to diagnostic imaging. Of these 55%, a remarkable 78% focus on medical imaging. Meanwhile, out of all deep learning companies, 35% are focusing their efforts on drug discovery, and 57% of those 35% aim to provide deep learning based drug discovery platforms.

Source: http://www.gbm.hsbc.com/solutions/global-research

Deep Learning in Drug Discovery

Medical data can be used to build knowledge maps and then be applied to applications like AIassisted diagnosis and diagnostic imaging. A good example of this is Watson, IBM's collection of artificial-intelligence technologies used to interpret, analyze and predict data patterns. Its global medical database includes 100m patient records, 30m images and 200m insurance records.

According to Chinabgao.com and other research institutes, 10-20% of Chinese hospital revenue comes from medical imaging, the visualisation of body parts, tissues, and organs for use in clinical diagnosis and treatment.

HSBC Research Report assume that by 2021 the charge for single-patient AI-assisted diagnosis reaches RMB3,000 and the number of diagnosis accounts for one in a thousand of the 3bn hospital visits, the size of this market size would be around RMB9bn. Industry Research Institute estimates that sales of medical robots can reach USD4.8bn by 2021 and the overall market of AI healthcare applications is likely to total RMB100bn within five years.

The current revenue model for image diagnosis and AI-assisted diagnosis is similar to that of traditional medical informatisation companies. They both generate revenue from selling software and hardware products and undertaking informatisation projects for hospitals. The application of AI technologies can increase the value of products by improving doctors' efficiency and diagnosis accuracy. Government investment in medical and healthcare generates most of the revenue.

Deep learning technology, together with cloud computing and big data, are expected to trigger a new round of technological innovation. Software companies are usually asset-light and they focus on continuous innovations and technological upgrades. Their real value lies in the quality of their research teams and the ability of the management to turn R&D into products and sales. AI drug discovery platforms have the potential to have a real impact on the pharmaceutical industry. Over just the past year, many of the big drug makers seriously examine the potential of the technology via numerous tests, official collaborations of different sizes, and licensing agreements.

Source: https://www.techemergence.com/machine-learning-drug-discovery-applications-pfizer-roche-gsk/

Deep Learning in Drug Discovery

Deep learning has been proven capable of achieving lower error rates in image and voice recognition and natural language processing compared to traditional machine learning algorithms. Famous in the eyes of the public for things like self-driving cars, natural language processing and image/voice recognition, its impacts on the drug discovery process have only recently begun to accumulate. So, if deep learning is supposed to be a closer approximation to the kinds of information processing occurring in the human brain, then how does it differ? One of the starkest differences is that, whereas humans require relatively little data in order to extrapolate trends and patterns, deep learning algorithms are famous for their dependence on very little data. Consider the example of a human seeing a pattern one time, and extrapolating it to other instances.

This, in deep learning, is referred to as one-shot learning. Research has shown that deep learning algorithms perform better when the datasets they are trained on are large. While work on specific architectures that allow for deep learning-based classifiers and predictors to be built that operate according to one-shot and even zero-shot learning, for now, the performance deep learning algorithms are somewhat limited to the available size of the datasets used to train them. Deep learning algorithms have proven highly effective in modeling the chemical reactions between candidate drugs and their molecular targets, through which they exert their mechanisms of action. This has allowed researchers to hone in on a much more precise suite of candidate molecules in silico, prior to in vitro validation.

While much work in the real of deep learning for drug discovery is happening in the US, such as through the work of Insilico Medicine, a Baltimore-based AI for age-related drug discovery and biomarker development company, important work in this arena is also occurring abroad as well.In the UK for example, researchers from Warwick's School of Engineering have developed a deep learning algorithm capable of predicting whether or not a candidate drug molecule will bind to its target protein with 99% accuracy. Take, for instance, the case of Chuna, which recently launched a next-generation AI development plan which includes such AI platforms as Baidu's self-driving car algorithms, AliCloud's "city brain", Tencent's medical imaging algorithms and iFlytek's natural language processing algorithms. The Chinese healthcare system is ripe for the development of deep learning algorithms, because China's network of hospitals and healthcare institutions generated vast swatches of data regularly, so much so that the digitisation, classification and processing of such data was baluated at RMB30b in 2016

Source: https://www.sciencedirect.com/science/article/pii/S1359644617303598; https://www.sciencedaily.com/releases/2017/12/171214144442.htm

Deep Learning in Drug Discovery

Furthermore, the use of AI and Big Data Analysis has also made great strides in predicting the safety and predicting possible toxic side-effects of new drugs as well. In a July 2018 paper published in Toxological Sciences, a team of US researchers created a machine-readable database of 10,000 chemicals based on 800,000 animal tests. Through big data analysis, the team was able to compare new chemicals (e.g. drugs) to existing chemicals in the database, and estimate the probability of toxic effects by comparing it to its degree of similarity to chemicals in the database. It essentially performs the work of a human toxicologist in an automatic fashion.

One of the strongest results of the teams study is that their big data-based analysis is actually more accurate than animal tests for certain types of toxicity, because it compares a new drug's probability of toxic side effects to data on the effects of a chemically similar drug derived from more animal models than could ever be feasibly conducted in a study.

This study is a very strong source of validation for the AI for Drug Discovery industry because it effectively demonstrated that AI and Big Data analysis can assess the safety profile of new drugs not only faster than humans, but with greater accuracy as well.


MENU

nature
International journal of science

NEWS · 11 JULY 2018

Software beats animal tests at predicting toxicity of chemicals

Machine learning on mountain of safety data improves automated assessments.

Source: https://academic.oup.com/toxsci/advance-article/doi/10.1093/toxsci/kfy152/5043469; https://www.nature.com/articles/d41586-018-05664-2#ref-CR1

Computer toxicity test to put an end to animal testing

On 12th July 2018 Clive Cookson wrote for the Financial Times that Scientists in the US have developed the first computer system that can predict instantly the toxicity of any new chemical, more accurately than expensive, contentious and time-consuming animal tests.

On 11th July 2018 in a paper published in Toxicological Sciences, the authors reported that its algorithm can accurately predict toxicity for tens of thousands of chemicals, a range much broader than other published models achieve, across nine kinds of test, from inhalation damage to harm to aquatic ecosystems.

To improve the software, Thomas Hartung (a toxicologist at Johns Hopkins University in Baltimore, Maryland) and his team created a giant database with information on roughly 10,000 chemicals based on some 800,000 animal tests. These data were originally collected by the European Chemicals Agency (ECHA) in Helsinki as part of a 2007 law known as REACH (registration, evaluation, authorization and restriction of chemicals), which requires companies to register safety information for most chemicals marketed in the European Union. As of May 2018, the closing date for registrations, the agency had received information on more than 20,000 substances.

The next steps for the project include strengthening the database, by including more forms of toxicity and persuading holders of proprietary data such as drug companies to contribute information in an anonymised form that preserves corporate confidentiality.

According to Nature, other researchers and firms are developing machine-learning algorithms, too, although they have not published papers about their work. Mike Rasenberg, head of computational assessment at the European Chemicals Agency (ECHA), said that in the EU, the ECHA has also encouraged companies to avoid animal tests by using read-across and methods based on analysis of lab cells where possible.

Sources: https://www.ft.com/content/4be6617e-85dd-11e8-96dd-fa565ec55929
https://www.nature.com/articles/d41586-018-05664-2

Chapter IX

AI and Advanced R&D for Longevity Research

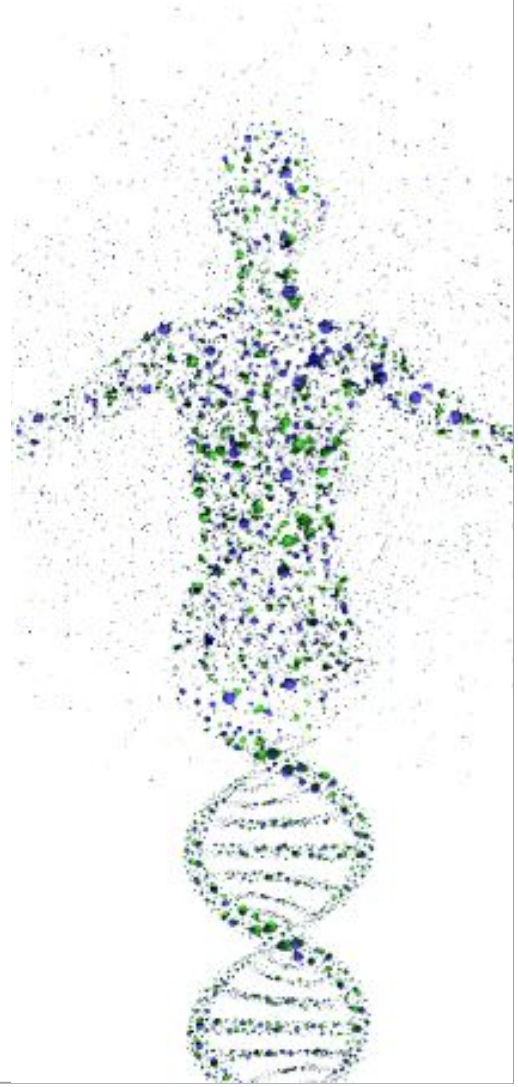
“ We have the means right now to live long enough to live forever. ”
~Ray Kurzweil

The following chapter describes the manner in which these technologies combine to form an industry.

But any industry worthy of the Industrial Revolution title must have some form of automation or technological optimisation, and a system of finance behind it.

This chapters examines how AI and blockchain technology form the engine of the future industry, and touches upon some novel financial systems.

“I see a bright future for the biotechnology industry when it follows the path of the computer industry, the path that von Neumann failed to foresee, becoming small and domesticated rather than big and centralized. “ ~Freeman Dyson



AI Companies in Longevity

Atomwise

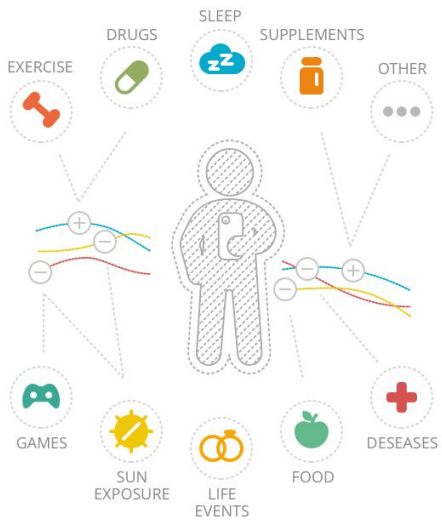
BioAge

Insilico Medicine
Aging.AI 2.0

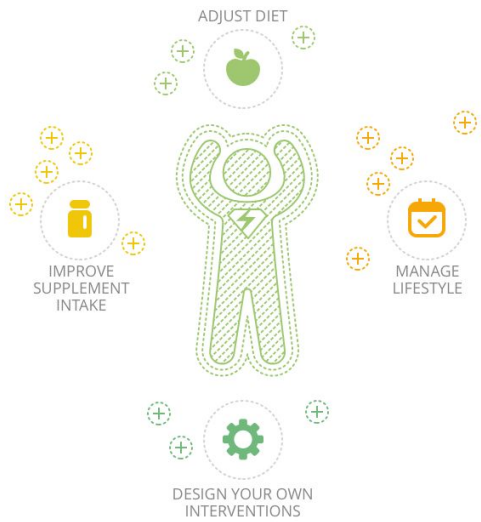
One of the most promising projects developed by Insilico Medicine is called Aging.AI 2.0, which is an AI-empowered platform integrating multiple predictors of clints age and used to track changes of health over time and optimize clints lifestyle.

http://young.ai/

Track your age at every level!



See what makes you younger or older!



Stay young!

Insilico Medicine

Insilico Medicine's mission is to extend healthy longevity through innovative AI solutions for drug discovery and aging research. Insilico Medicine is committed to transforming the pharmaceutical industry with next-generation artificial intelligence. They are developing new tools for drug discovery and repurposing, biomarker development and pursuing novel strategies for rapid validation. Their projects combine advances in genomics, big-data analysis, deep learning and reinforcement learning.

Insilico Medicine and Biotime announced in 2016 the launch of a beta version of Embryonic.AI, an artificially intelligent system for analyzing the embryonic state of human cell samples using gene expression data.

Insilico established in 2017 a collaboration with GSK to discover novel biological targets and molecules. As a first stage of the collaboration, GSK will evaluate Insilico's technology in the identification of novel biological targets and pathways of interest to GSK.

In 2018 a collaboration occurred between Insilico Medicine and Juvenescence AI Limited, which is a drug development and artificial intelligence company focused on ageing and age-related diseases. Juvenescence AI combines advances in artificial intelligence with classical development expertise in order to prioritize and develop compounds from Insilico Medicine, Inc.'s end-to-end automated drug discovery pipeline through to clinical proof of concept.

By using AI and deep learning, the company can analyze how different compounds will affect certain cells, determine what drugs can be used to treat the symptoms, and any possible side effects that may occur.

Even though it's only been around a few years, Insilico has already been named by NVIDIA as one of the 5 top AI companies. With R & D resources spread out across the globe in the UK, Russia, and Belgium and a backing of $14 million behind it.

Sources: https://www.eurekalert.org/pub_releases/2017-08/imi-iec081417.php
https://www.businesswire.com/news/home/20180205005024/en/Insilico-Medicine-Juvenescence-Announce-Drug-Candidate-Joint

Atomwise

Atomwise is the creator of AtomNet, the first Deep Learning technology for novel small molecule discovery, characterized by its unprecedented speed, accuracy, and diversity.

Today, drug-resistant bacteria and pandemic viruses threaten to send us back to the time of plague and smallpox. Persistent, neglected diseases remain a dark spot on our collective conscience. And while we're all living longer, diseases of aging like Alzheimer's still have no cure. Atomwise has the unique ability to research hundreds of millions of potential medicines rapidly, making it fundamentally easier to tackle these big problems.

Atomwise's AtomNet platform uses structural information to predict binding between molecular targets and small molecules by processing millions of data points regarding successful and unsuccessful ligand-binding interactions. The company has more than 50 molecular discovery programs, including confidential projects with AbbVie Inc. and Merck & Co. Inc.

In April 2017, Atomwise started a program to motivate academic scientists to explore the drug-hunting potential of its technology. Researchers can apply to the company's Artificial Intelligence Molecular Screen (AIMS) awards program by identifying the disorder they hope to treat, and the disease-causing biomolecules they want to defeat with a drug. Successful applicants will receive 72 compounds that Atomwise predicts are most likely to work as that drug.

Atomwise has been partnering up with big pharmaceutical firms, biotechnology companies, and university research labs in an effort to speed up the discovery of new drug candidates for neurodegenerative diseases, cancer, and other disorders. In June, the startup also announced a collaboration with Monsanto to find compounds that might protect crops against pest infestations and diseases.

Source: http://www.chematria.com/
http://www.4-traders.com/ABBVIE-12136589/news/AbbVie-AI-drug-discovery-company-Atomwise-raises-51M-series-A-26122374/
https://www.xconomy.com/san-francisco/2018/03/07/atomwise-raises-45m-to-grow-ai-driven-drug-discovery-business/

BioAge

BioAge is committed to contribute to and support the evidence-based medical approach to a healthy lifestyle, accomplished through diet, exercise, supplementation and the use of integrative medicine.

The overall aim of the proposed staff exchange programme is to build, extend and strengthen sustainable international collaborations between the partners so as to create a knowledge base for biomarker based research related to aging, sampling techniques in the elderly and biomonitoring studies.

BioAge develop biomarkers and drugs that impact human aging by coupling genomic data with machine learning. BioAge is building a platform that doesn't require waiting for its subjects to actually age. Instead, it wants to measure biological age using signals floating in a drop of blood.

BioAge Labs raised $10.9M in Series A financing to accelerate drug discovery for aging in 2017. BioAge is betting on the power of high-throughput human data, coupled with innovative machine learning, to substantially accelerate drug discovery for aging. The company take a hybrid experimental and computational approach to identifying the molecular signatures that drive aging, working with multiple partners in academia and industry. The funding will enable BioAge to build their team, refine and test their signatures of aging, and begin in vivo evaluation of drug candidates. Their initial targets for drug development will be specific diseases where aging is causal; however, their ultimate goal is more ambitious — to combat the suffering and disability caused by all aging-related diseases, and to restore both the quality and quantity of life that is so often lacking in old age.

Sources: https://medium.com/@BioAge/bioage-labs-raises-10-9m-in-series-a-financing-to-accelerate-drug-discovery-for-aging-31974fcb3229
http://bioage.com/about.html
https://a16z.com/2017/07/28/bioage/

Biomarkers of Aging

While many anti-aging interventions have demonstrated life-extending or other geroprotective effects in model organisms, practical limitations continue to hamper translation to the clinic. One problem is that the evaluation of aging changes and possible anti-aging remedies requires a comprehensive set of robust biomarkers.

Large-scale longitudinal programs like MARK-AGE have been launched to analyze changes in multiple biomarkers during aging and correlation between biological and chronological age. Several “aging clocks” able to predict human chronological age using various biomarkers have already been proposed. Methylation-based markers such as epigenetic aging clocks are currently the most accurate, while transcriptomics and metabolomics have shown to be less so.

Recent studies show that biomarkers of age-related pathologies could be used to evaluate senescence modifications based on the connection between age-related pathologies at the signaling pathway level. However, most of these biomarkers are not representative of the health state of the entire organism or individual systems and are not easily measured or targeted with known interventions.

Machine learning (ML) techniques, such as support vector machines (SVM), are routinely used in biomarker development and rapid increases in labeled data are enabling deep neural networks (DNNs). Methods based on deep architectures have outperformed classical approaches not only in image analysis, but also in solving a wide range of genomics, transcriptomics and proteomics problems.

Using Artificial Intelligence (AI), **Insilico Medicine** has developed a system that measures the biological age using readings found in a common blood test. Insilico Medicine calls it the Aging Clock, and it is based on biomarkers of aging found in our blood chemistry. Insilico Medicine says its number-crunching has yielded the most precise measure of a person’s biological age. To develop their algorithm, the company used AI techniques to analyze the blood tests of an international group of 130,000 people.

Sources: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4931851/
http://longevityfacts.com/ai-based-app-measures-bodys-aging-clock/

Biomarkers of Aging

Vadim Gladyshev, Professor of Medicine at Brigham and Women's Hospital, Harvard Medical School:

"*The use of the new tool to track human biological age may enable discovery of drugs and other interventions that target the fundamental process of aging, thereby delaying the onset of all chronic diseases at once, instead of targeting one disease at a time. The project has parallels with MouseAge, a tool for assessing biological age in mice, which we develop jointly with In Silico Medicine*."

Insilico Medicine, Inc., a Baltimore-based company specializing in the application of artificial intelligence for drug discovery, biomarker development and aging research, announced in 2018 a publication of a research paper titled "Population-specific biomarkers of human aging: a big data study using South Korean, Canadian and Eastern-European patient populations" in The Journal of Gerontology. Insilico believe AI will transform biomarker development and drug discovery much sooner than most pharmaceutical companies and regulators expect.

In the paper, the authors present a novel deep-learning based hematological human aging clock, a biomarker that predicts the biological age of individual patients.

In 2017 the company announced the launch of the Beta 1.0 version of YOUNG.AI. The first version was publicly unveiled on September 12th, 2017 at the 4th Aging Research for Drug Discovery Forum and the Artificial Intelligence and Blockchain for Healthcare Forum in Basel, Switzerland, 11-13 of September. The beta 1.0 version features deep learned photographic and basic blood biochemistry-based predictors of age as well as the ability to track drug and supplement intake.

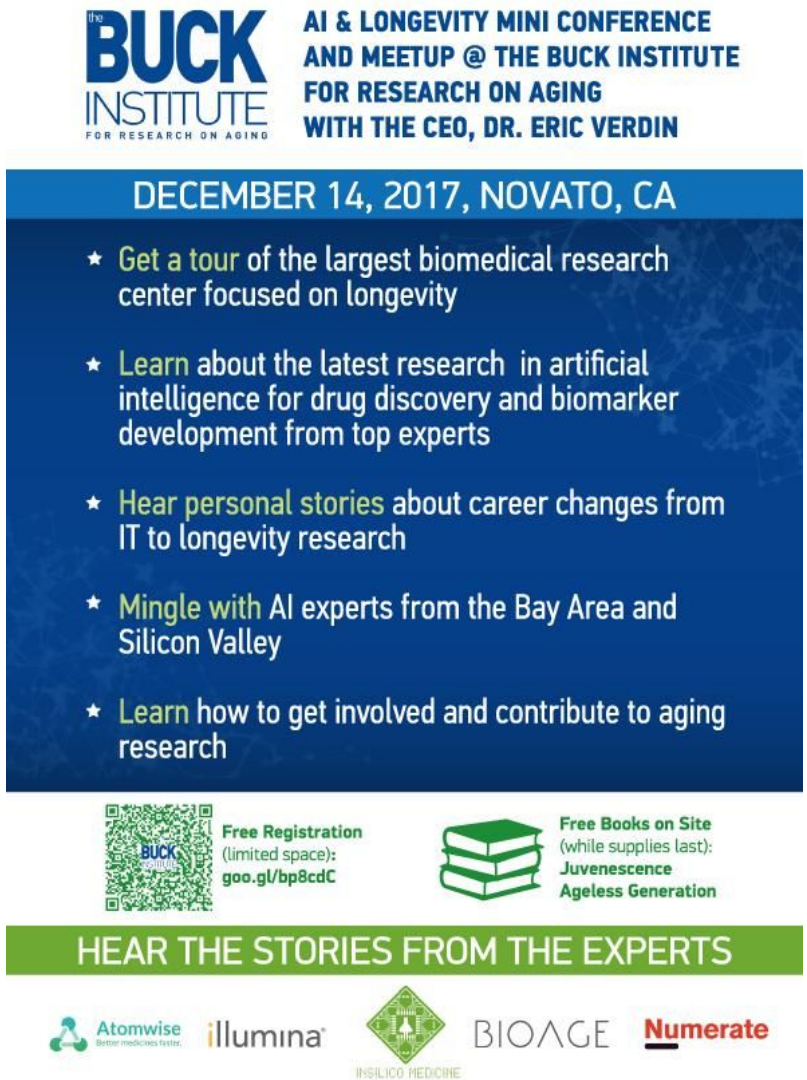
Sources: https://www.eurekalert.org/pub_releases/2018-01/imi-apd011118.php
https://www.eurekalert.org/pub_releases/2017-09/imi-ant091117.php

AI for Drug Discovery is Now Recognized as an Official Niche within the Longevity Research & Geroscience Community

While work being done by the companies discussed above has been progressing now for several years, the inauguration of AI for Drug Discovery and biomarker development as a legitimate niche within the broader longevity research, recognized as such by thought leaders and major players within geroscience, can be considered to have occurred in Q4 of 2017, when several leading AI for Drug Discovery companies focused on longevity research held a mini-conference at the Buck Institute for Research on Aging, the United State's most well-funded non-profit research institution devoted to aging research and the development of healthspan-extending interventions.

In a press release associated with the conference, Buck Institute CEO Eric Verdin stated: "The Buck Institute for Research on Aging generates an enormous amount of biological data, which has intriguing possibilities for combining with AI. We would like to explore synergies and invite the AI community from the Bay Area and all over the world to learn about our progress and contribute."

The min-conference featured talks by researchers from Insilico Medicine, Atomwise, Numerate, BioAge and Illumina.



Buck Institute Brings Insilico Medicine CEO on as Adjunct Professor to Spearhead their AI for Longevity Research Activities

Following this mini-conference, the Buck Institute also acquired Insilico Medicine's CEO Alex Zhavoronkov as an Adjunct Professor, in order to spearhead the Buck's activities in utilizing the latest advanced in AI and deep learning for longevity research.

The fact that the leading aging research foundation in the United States is devoting their time and resources towards the use of AI and deep learning for geroscience research is yet another indication that AI, machine learning and deep learning is now recognized as a legitimate niche within the broader geroscience community.

In a press release associated with the announcement, Buck Institute CEO Eric Verdin stated:

"We are incredibly excited about the potential of AI to accelerate aging research.The Buck has been at the forefront of asking the most important questions in the field. Now, with the latest in bioinformatics and artificial intelligence, and with the involvement of world-class experts like Dr. Zhavoronkov, we will finally have the tools to answer them. Fully utilizing these powerful technologies, we will dramatically increase our understanding of how aging works, and what we can do about it."

Buck

IN SILICO MEDICINE

AI for Drug Discovery in Longevity Research Reaches a New Degree of Credibility Through Frost & Sullivan's Best Practices Award

Meanwhile, in 2018, AI for Drug Discovery as a legitimate and official subsector within the broader longevity research landscape, and longevity research as a legitimate niche within the broader drug discovery landscape, attained a new degree of recognition.

This occurred when leadining business consulting firm Frost & Sullivan awarded Insilico Medicine the North American Artificial Intelligence for Aging Research & Drug Development Technology Innovation Award, as part of their 2018 Best Practices Awards.

More than this, the fact that a highly respected business consulting firm like Frost & Sullivan created a specific category of award for this specific area of research and development is highly indicative of the increasing level of repute that AI in Drug Discovery for aging research is garnering from both the broader geroscience community as well as the wider drug development communities.

This new development may also serve to highlight the high degree of synergy that is possible through the convergent integration of two cutting-edge and highly innovative classes of R&D.

Insilico Medicine Earns Accolades from Frost & Sullivan

FROST & SULLIVAN

2018 North American Artificial Intelligence for Aging Research and Drug Development Technology Innovation Award

Insilico Medicine Technology Innovation Score

FROST & SULLIVAN

BEST PRACTICES RESEARCH

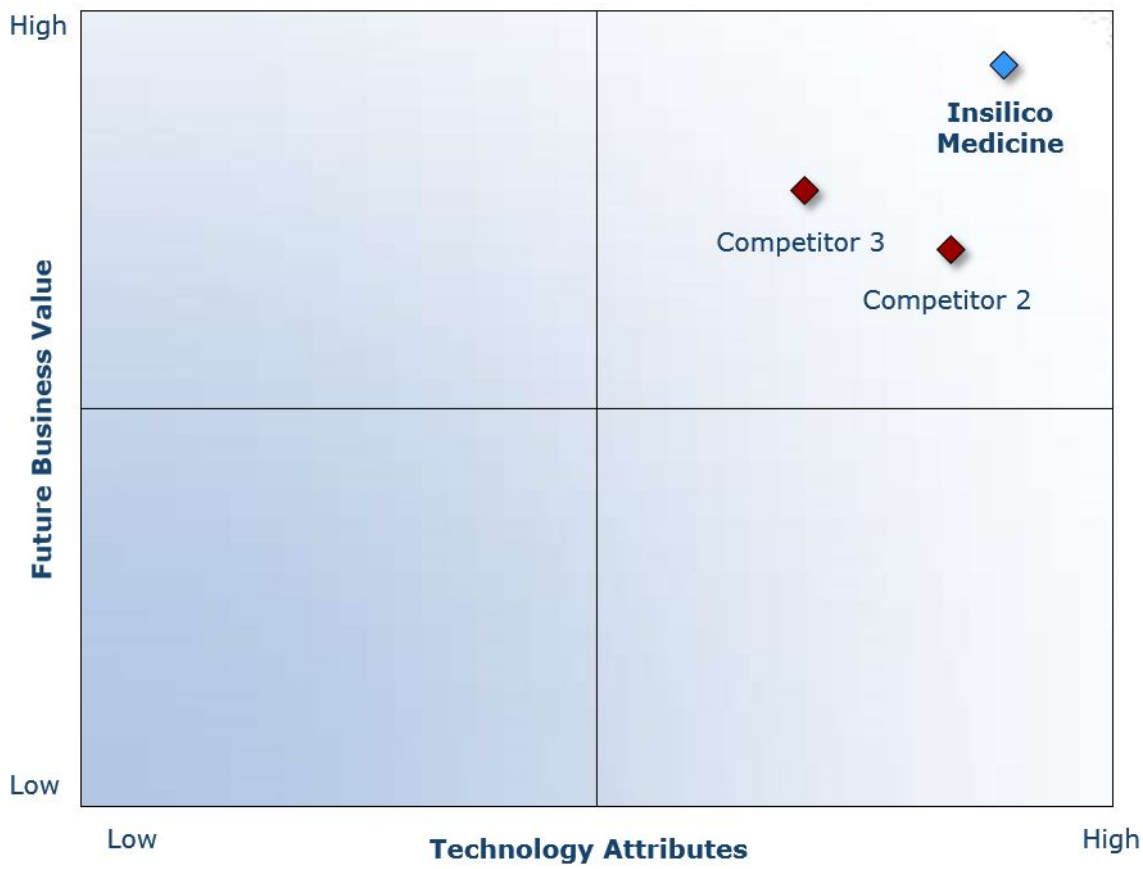
The results of this analysis are shown below. To remain unbiased and to protect the interests of all organizations reviewed, we have chosen to refer to the other key participants as Competitor 2 and Competitor 3.

Measurement of 1–10 (1 = poor; 10 = excellent)			
Technology Innovation	Technology Attributes	Future Business Value	**Average Rating**
Insilico Medicine	**9.0**	**9.0**	**9.0**
Competitor 2	8.0	7.0	7.5
Competitor 3	7.0	8.0	7.5

Insilico Medicine's Future Business Value & Technology Attributes Ranking in Comparison to Top 2 Competitors

The analysis performed by Frost & Sullivan included an estimation of the winning business' future value and technology attributes. Assessing the company's technology attributes involved analyzing its industry impact, product impact, scalability, visionary innovation and application diversity, while assessing the company's future business value involved analyzing its financial performance, customer acquisition, technology licencing, brand loyalty and human capital.

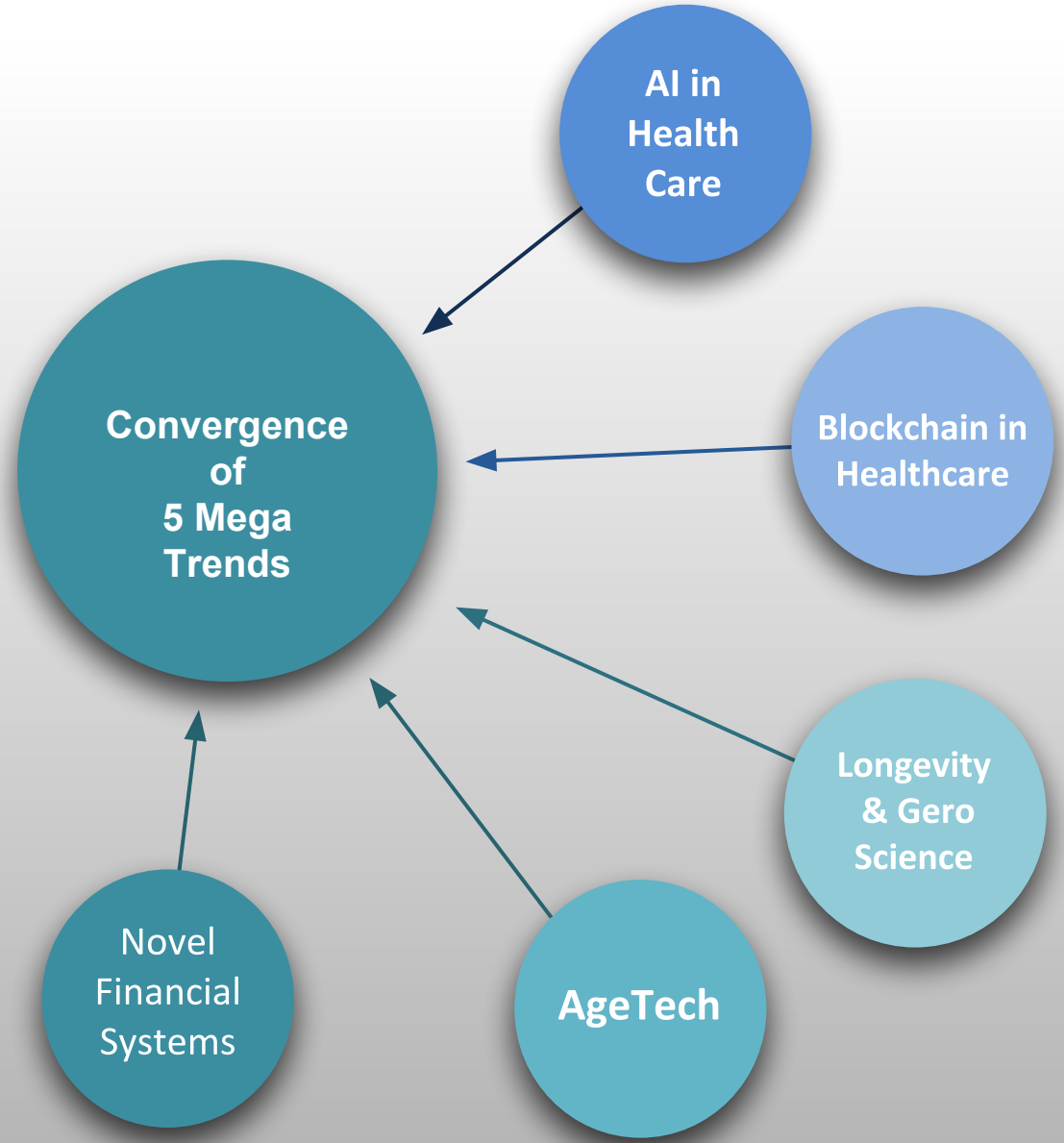
As Frost & Sullivan explain in their report: "Technology innovation begins with a spark of creativity that is systematically pursued, developed, and commercialized. That spark can result from a successful partnership, a productive in-house innovation group, or a bright-minded individual. Regardless of the source, the success of any new technology is ultimately determined by its innovativeness and its impact on the business as a whole"



Chapter X

Next Generation AI for Drug Discovery and Biomarker Development: Convergence with Blockchain and Digital Medicine

5 Mega Trends to Disrupt the BioTech & BioMedicine Industries in the next 5 Years



I AI in Healthcare

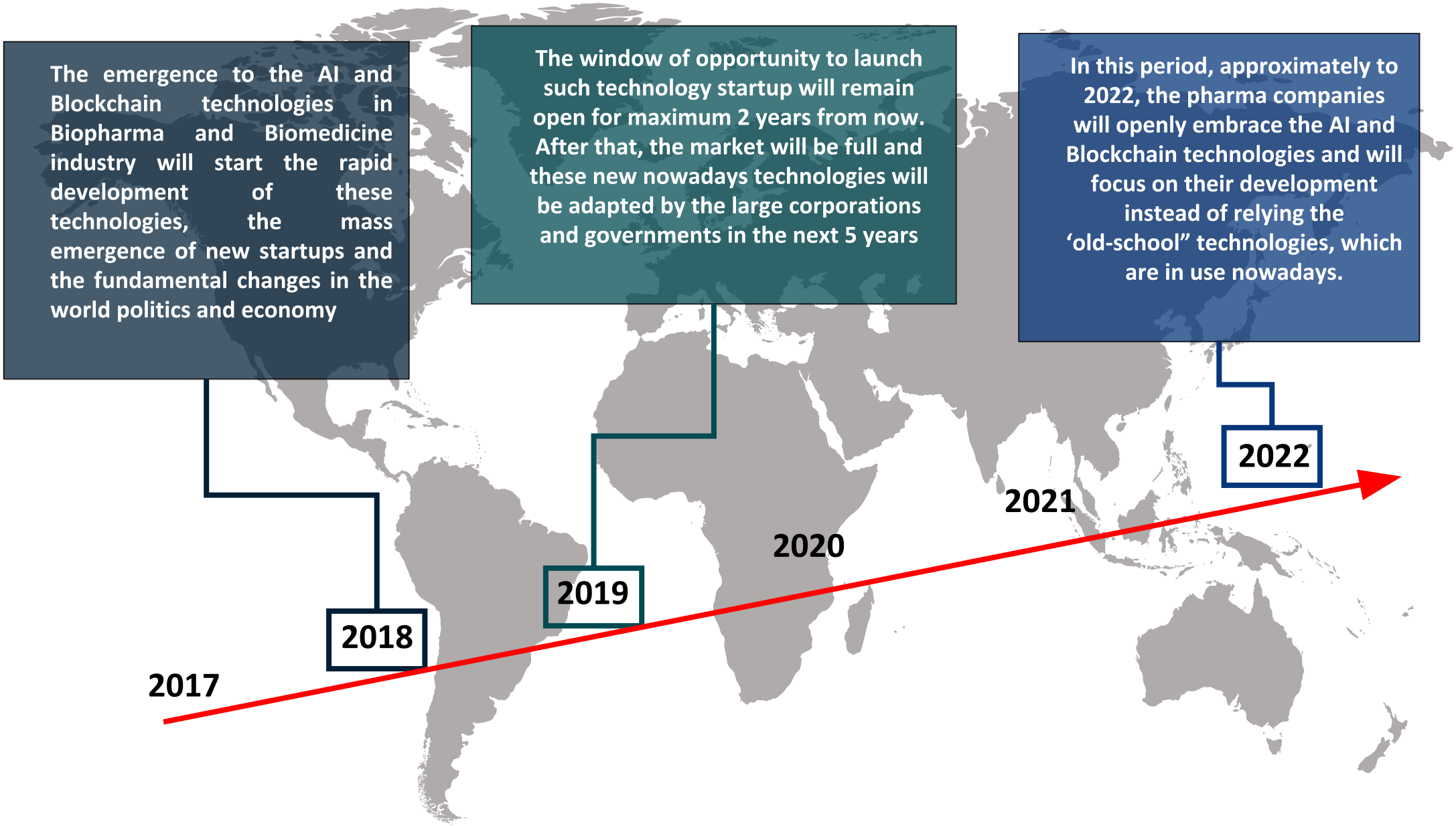
II Blockchain in Healthcare

III Longevity & Geroscience

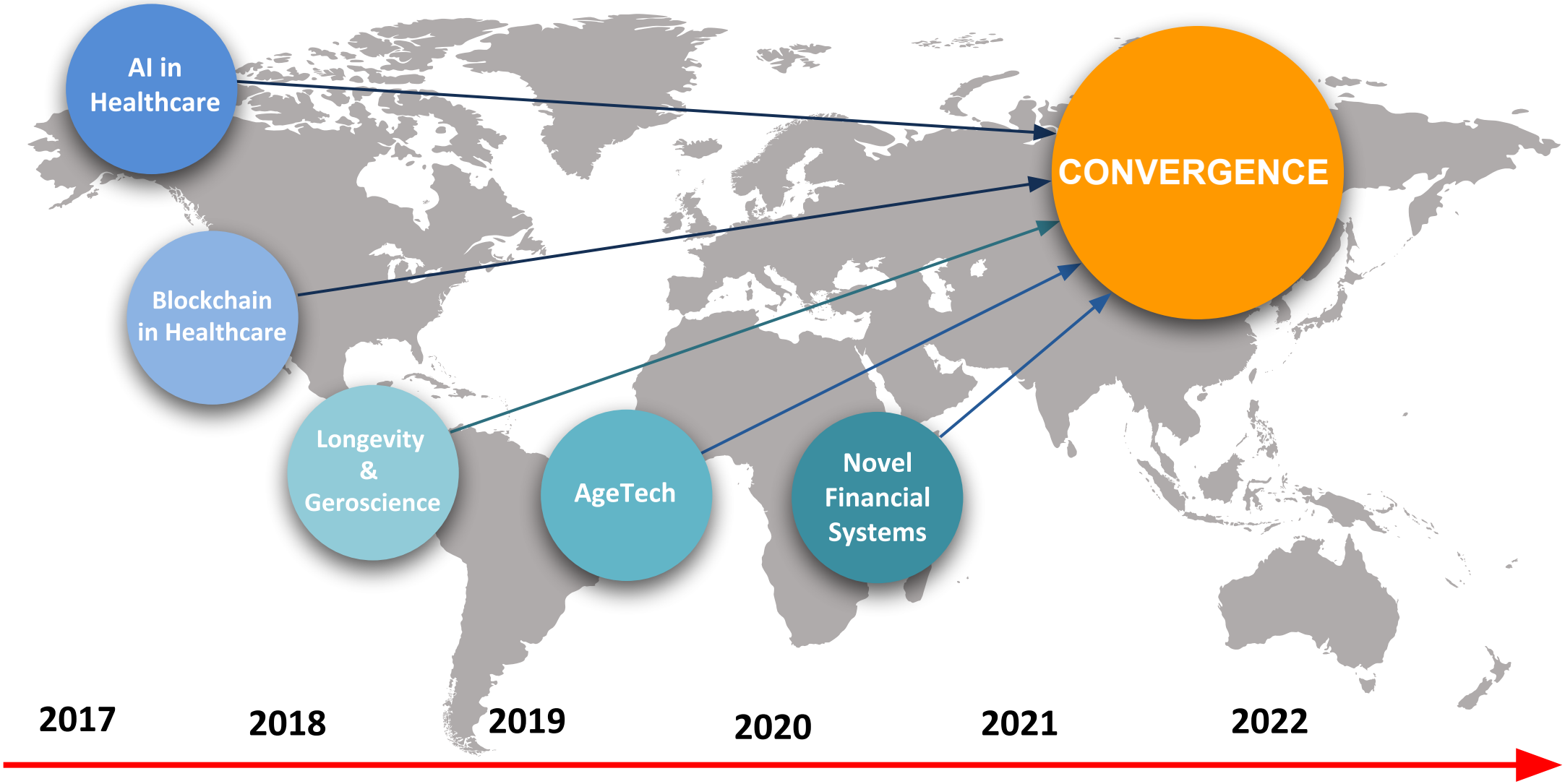
IV AgeTech

V Novel Financial Systems

Consequence:
The Major Shift in the BioMedicine Industry



Convergence of 5 Mega Trends



Convergence of Technological MegaTrends

5 Mega Trends to Disrupt the BioTech & Venture Capital Industry in 5 Years

Major Disruption on the Horizon

The BioPharma and BioMedicine industry is now on the edge of a major shift which will happen in 2018-2019.

There is clear evidence of this today, but due to the significant inertia pervading the BioPharma industry relating to the traditional business model of pharmaceutical companies and heavy government regulations, the capacity for the industry to translate novel trends into actual practice is significantly lacking.

We have major evidence for these emerging trends all around us, but for several specific reasons they are only recognized by a few top executives in the industry. Those executives that don't begin to recognize these trends and act accordingly will be responsible for colossal industry failures in the next 5 years.

The window of opportunity to board this departing train is 1, maximum 2 years from now and in the next 5 years the first pharma company to openly embrace AI at the C suite and board level focusing on their own development instead of relying on the "old-school" technology companies, will see its stock skyrocket.

Major Disruptive Trends:

I. **AI in BioPharma and Healthcare**
II. **Blockchain and Next Generation IT in Healthcare**
III. **Longevity & Gero Science**
IV. **Broken VC and BioPharma Business Model and Novel Financial Systems**
V. **AgeTech**

Convergence of Technological MegaTrends

I. Artificial Intelligence

- AI in Healthcare is rising very fast. There have been several deals worth tens to hundreds of millions of dollars in just the past few months alone
- As this trend continues it will mostly be applied by existing IT corporations, with the exception of areas such as electronic health records and digital pathology where these do not have access to the data
- These advances will occur much faster than even the most optimistic scenarios, outperforming even the speed of AI development demonstrated by the big IT corporations of today - Google, Facebook, NVIDIA, Baidu, etc.
- The continuous development of software, the rise of the sharing economy, the distribution and processing power and AI, along with the convergence of all these niches causes transformation at a global scale making the right forecasting for healthcare and BioPharma in particular, needed, and where key players should switch from thinking of niche areas to a much more holistic and inclusive approach
- One of the most important patterns in this emerging area is AI in Drug Discovery, and it holds the greatest disruptive potential. It has begun to penetrate into Big Pharma's drug discovery departments at a rapid pace

II. Blockchain in Healthcare

- This will take the form of blockchain integration into healthcare governance systems, into telemedicine mobile apps for securing and transmitting personal medical information, and into systems for analyzing and optimizing healthcare business processes, among others
- The overarching trend will be blockchain as healthcare's backend
- Its speed of penetration is enormous and on the rise, and its speed of penetration into new fields that could benefit significantly from enhanced protection of data and enhanced logistical optimization, like the healthcare industry, is huge

Convergence of Technological MegaTrends

III. Longevity & Healthcare

- Longevity is another major trend, but is much more complicated that the above 2 trends
- With AI, this window of opportunity is very short. For longevity it is much longer - around 5 years
- The window of opportunity is longer for longevity, but its potential to disrupt the field is also much larger
- Because the window of opportunity is larger, there is much more time and opportunity for Pharma to begin activities within this emerging trend

IV. A Broken VC and BioPharma Business Model

- During recent years we have seen significant stagnation in the VC industry, not only in biotech but many other industries
- The industries most affected are those with big requirements for DeepTech, advanced R&D
- This stagnation is due to the outdated model of typical VC funds, which made sense 5-10 years ago, but not so much nowadays
- There is an emerging phenomenon already disrupting the typical VC industry, known as Initial Coin Offerings and Crypto Liquid Venture Funds, applying advances in blockchain and cryptocurrencies to create radically progressive and dynamic investment models
- VC funds, in the US in particular, are also beginning to recognize the disruptive potential of this new investment model
- These new investment models and instruments are in a sense like the merger of VC funds and Hedge Funds, with all their advantages and fewer of their disadvantages

Convergence of Technological MegaTrends

- VC funds sometimes have very high profits but very low liquidity. Hedge funds typically have lower profits but very high liquidity
- These new investment models have both - high profits and very high liquidity
- We can predict that 2018 will be the threshold moment when many promising biotech startups will begin receiving substantial investments in the form of angel financing and crypto fundraising

V. AgeTech

- A fifth major trend will be what can be called AgeTech - the integration of FinTech and HealthTech
- Financial services designed for the aging demographic that integrates cutting-edge FinTech services with emerging geoscience and P3 (personalized, precision and preventive) medicine therapies to deliver optimized financial and healthcare services for elderly citizens
- The aging demographic is rising rapidly and will witness enormous growth over the next 20 years.
- AgeTech services will serve to extend the healthy, productive and functional years of elderly citizens' lives and will promote them to remain in or re-enter the workforce, enhancing their lives and the economy simultaneously

> "It's vital that individuals and businesses recognize the tremendous potential of this longevity revolution. Our aging population could generate the most significant opportunity of our lifetime."[216]
>
> – Andy Sieg, Head of Merrill Lynch Wealth Management

-Milken Institute, *Silver to Gold*

Convergence of Technological MegaTrends

VI. Conclusions

- Keep an eye on these 5 rapidly emerging trends - AI in Healthcare and Drug Discovery, Blockchain in Healthcare, Geroscience and Longevity, AgeTech and Crypto Liquid Venture Funds

- In 5 years these 5 areas will disrupt the BioMedicine and BioPharma industry nearly beyond recognition to what it is today as well as many other industries

- It is well known that professionals are unable to see these trends on a grand scale, the real transformation will happen because of convergence between all these 5 trends in combination. This convergence will further influence the acceleration at an unforeseen rate that requires deep forecasting

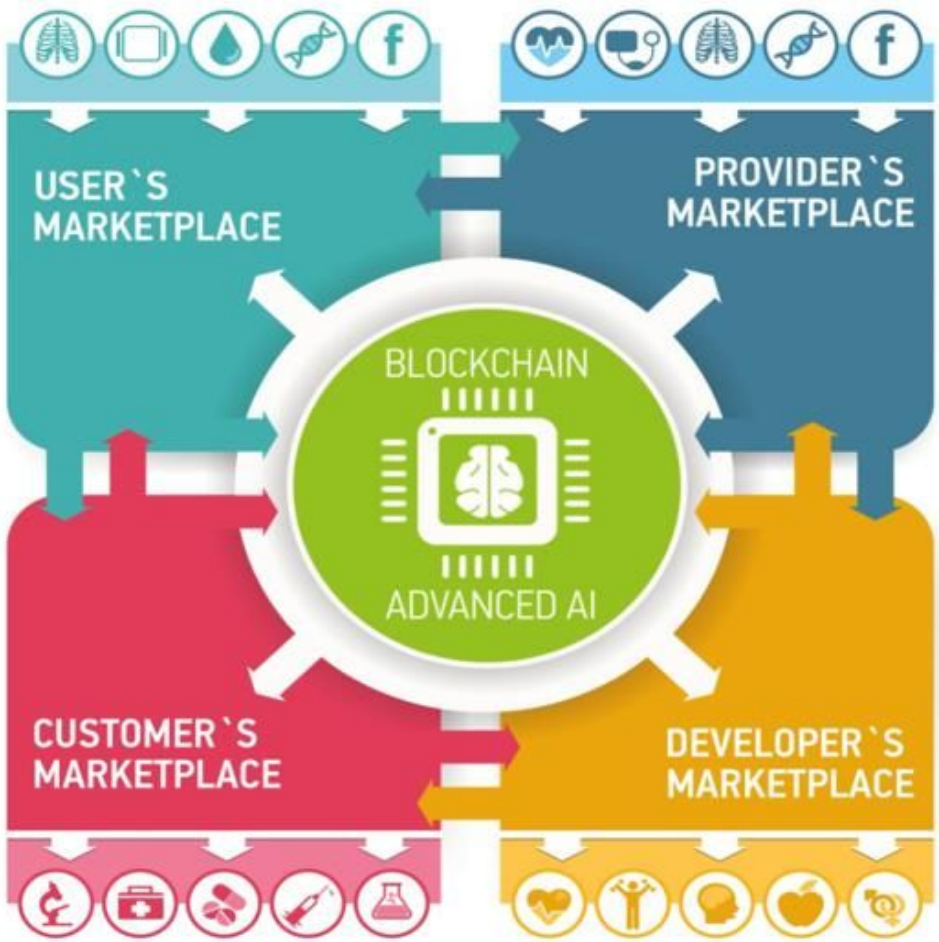
- The era of venture capital and unadaptable BioMedicine and BioPharma companies in this industry is coming to a close with ample opportunity for them to adapt or die making way for up and coming R&D groups and startups that take advantage of these new technologies and financing mechanisms.

- Development of the BioMedicine and BioPharma industries will be faster than anyone can imagine including the pessimists and optimists because of the convergence of these trends, the more the number of dimensions, the greater the acceleration as the industry leapfrogs into a new era.

- These megatrends will become much clearer in the next two years and we will make adjustments to these megatrends in 2018 when the picture becomes clearer and we can forecast the synergy between the rate of acceleration of these trends and of their convergence

Next Generation AI for Drug Discovery and Biomarker Development Convergence with Blockchain and Digital Medicine

- In 2018, even more extreme challengers and disruptors will arrive with the convergence of next generation AI, blockchain and precision medicine.
- Longenesis is a revolutionary blockchain-based personalized medicine Data Marketplace platform built by Insilico Medicine and Bitfury that provides modular toolsets coupled with integrated advanced
- Artificial Intelligence systems to store, manage, and trade life data: social network data, health data and medical records.
- Longenesis will redefine the relationships between healthcare companies and patients. By facilitating a fast and easy way to contribute or purchase data along with an integrated deep learning AI, enterprises can save much money on R&D while users will for the first time be compensated for their Life data efficiently and ethically.



Digital Health

Digital health covers a broad range of applications and areas. This includes mobile health, health information technology, wearable devices, telehealth and telemedicine, and personalized medicine.

The digital and genomic revolutions in particular hold great potential for digital health: while it took 10 months to sequence a genome in 2007, today it takes as little as just one hour.

Digital health concerns itself with the following goals:

- Reducing inefficiencies and costs
- Increasing quality of care
- Improving access
- Making medicine more personalized

Over $16 billion have been invested in 800+ digital health companies since 2014; $3.5 billion in the first half of 2017 alone, but no unicorns so far. Healthcare is an old industry with traditional institutions that struggle to innovate; hence the high interest in investing in up and coming, innovative startups.

This means that digital health startups need early funding for a relatively extended period of time - compared to the average apps and platforms - before they can start reaping the benefits of their work in contrast to apps and platforms.

Data also represents another challenge for these companies. The metrics of success for healthcare companies are harder to come by and usually take a long time to come by.

Digital Health

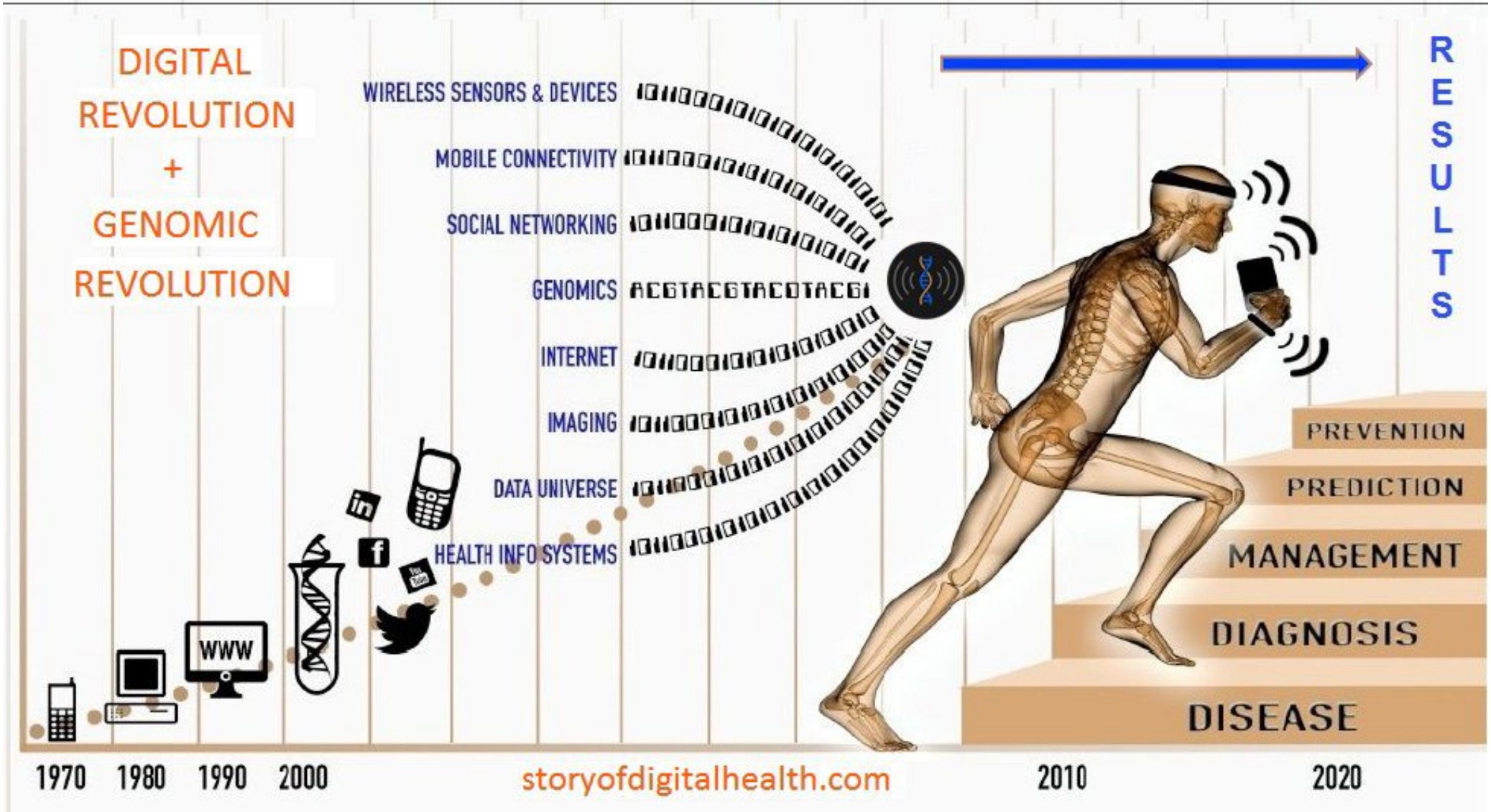
1. Digital Health Interventions:
Interventions delivered through digital technologies, such as smartphones, website, text messaging hold great potential to healthcare delivery making it more efficient, effective, accessible, and personalized. This is an area of interest particularly to insurance companies, since it can improve success rates for treatments and reduce patient readmissions.

2. Doctor-Patient Interaction:
Documentation requirements have taken over the patient encounter in many specialities. Digital solutions that streamline the documentation workload and allow doctors to give their full attention to the patient are currently being developed. Some of solutions being tested include head mounted displays that stream the doctor-patient interaction to a remote transcription center.

3. Big Data:
Companies have so much data that they can model the risk factors associated with a given patient or procedure, i.e. assume the likelihood of someone being readmitted or the recovery time. In another instance, looking at thousands of cases, and taking the patient's own history in context, companies can draw conclusions on whether a certain procedure might be riskier for a given patient.

THE DIGITAL HEALTH REVOLUTION

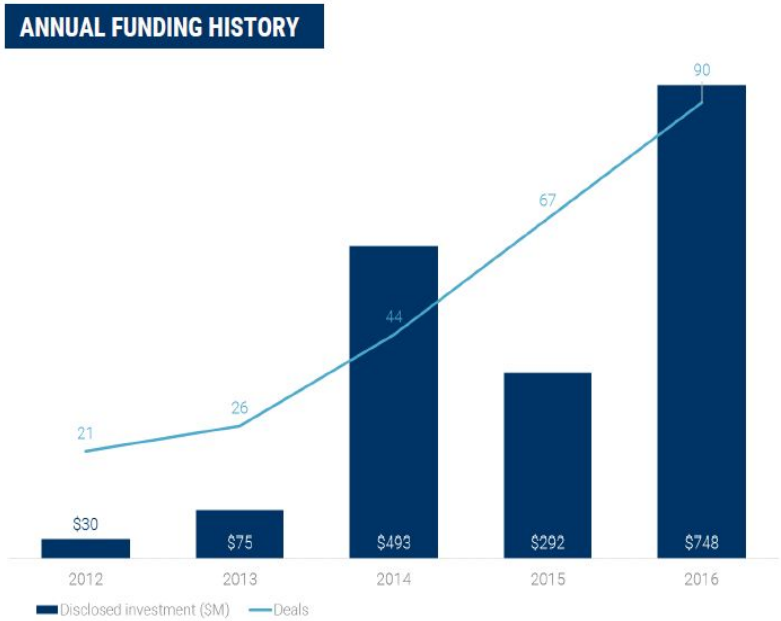
Infographic by Paul Sonnier



Artificial Intelligence

Much of the current commercial applications of AI concern what is known as weak artificial intelligence, aka narrow AI; think Google, Apple, or Amazon's personal assistants that use natural language processing to understand a query then do a relatively simple search, taking into consideration a few factors from your history and behavior. A truly artificially intelligent system is one that learns on its own, is capable of processing very large amounts of data and digging up associations, and imitates human behavior. We are just beginning to scratch the surface of AI in healthcare.

When talking about Artificial Intelligence in healthcare, more often than not, Big Data is the first topic that comes into discussion. Digital data is growing at an exponential rate - by 2020, the data created annually will reach 44 trillion gigabytes. Tech titans such as Google or IBM, are trying to tap the potential of patient data mining using their AI tech. It is worth noting that IDC predicts that the worldwide spend on AI and cognitive computing will reach $46 billion by 2020.



Alphabet, the parent company of Google, recently launched the Google Deepmind Health project. Deepmind Health is able to process hundreds of thousands of medical information entries within minutes. This will enable providers to provide better and faster health services. Google also aims to employ the same algorithms that power its search engine to genetic data in the hopes of understanding what makes people healthy.

IBM on its part, is using Watson technology to power WatsonPaths. The aim is to help physicians make informed and accurate decisions, faster, and to glean insights from electronic medical records.

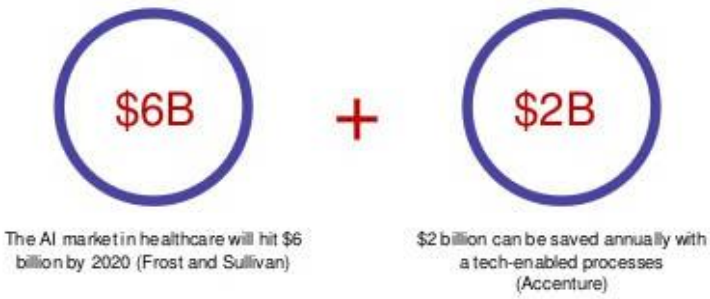
AI in healthcare dominates all other industrial applications of AI in terms of equity deals, raising $1.8B across 270 deals since 2012.

Artificial Intelligence

Real artificial intelligence is already being used to detect diseases. According to the American Cancer Society, a large number of mammograms yield false results - as much as half of healthy women are wrongly diagnosed with cancer. AI, on the other hand, is able to review and translate mammograms 30 times faster, and with a 99% accuracy rate.

This is possible because we are able to train algorithms to tell the difference between groups of pixels that represent cancer versus groups that don't. The algorithms constantly learn. Software is able to process millions of those images, or others, in a day.

Gartner predicts that by 2025, half of the population will rely on "virtual personal health assistants" powered by AI. These personal assistants would be cognizant of a user's unique medical conditions, history, and genetic makeup and able to incorporate them in its decision making. Automating primary care needs is also a great boon to the elderly demographic in particular, who typically lacks mobility. These assistants will help seniors remain independent for longer, and reduce the need for hospitalization or staying in nursing homes. Overall the progress of AI implementation in healthcare will carry great reduction in costs and time.



AI for instance will be able to accelerate drug development and make it more cost effective; by contrast, the costs of developing pharmaceuticals through clinical trials can reach billions of dollars and can take more than a decade.

Banks have embraced machine learning quickly, looking more like IT firms with each passing day, but the executives of pharma have been less agile. Top managers are avoiding risk rather than showing results. They don't want to be the executive who reduced earnings by engaging in advances IT capex. However, in neglecting disruptive technological risk, they are failing to hedge properly. The same is true of countries, including the United Kingdom.

Blockchain

We have already discussed the power and importance of Blockchain technology in creating trust in the ecosystem.

Trust to share health data, which is paramount to harnessing the power of biological science and research.

We also went over the value that blockchain can offer when it comes to logistical matters, such as maintaining and unifying health records, establishing a log of accountability and transparency, as well as fighting counterfeit drugs.

All of those advances are a great boon to the longevity industry.

But to delve deeper into the effects of blockchain on longevity, there has been accumulating evidence that suggests that aging is linked to genetic and epigenetic alterations.

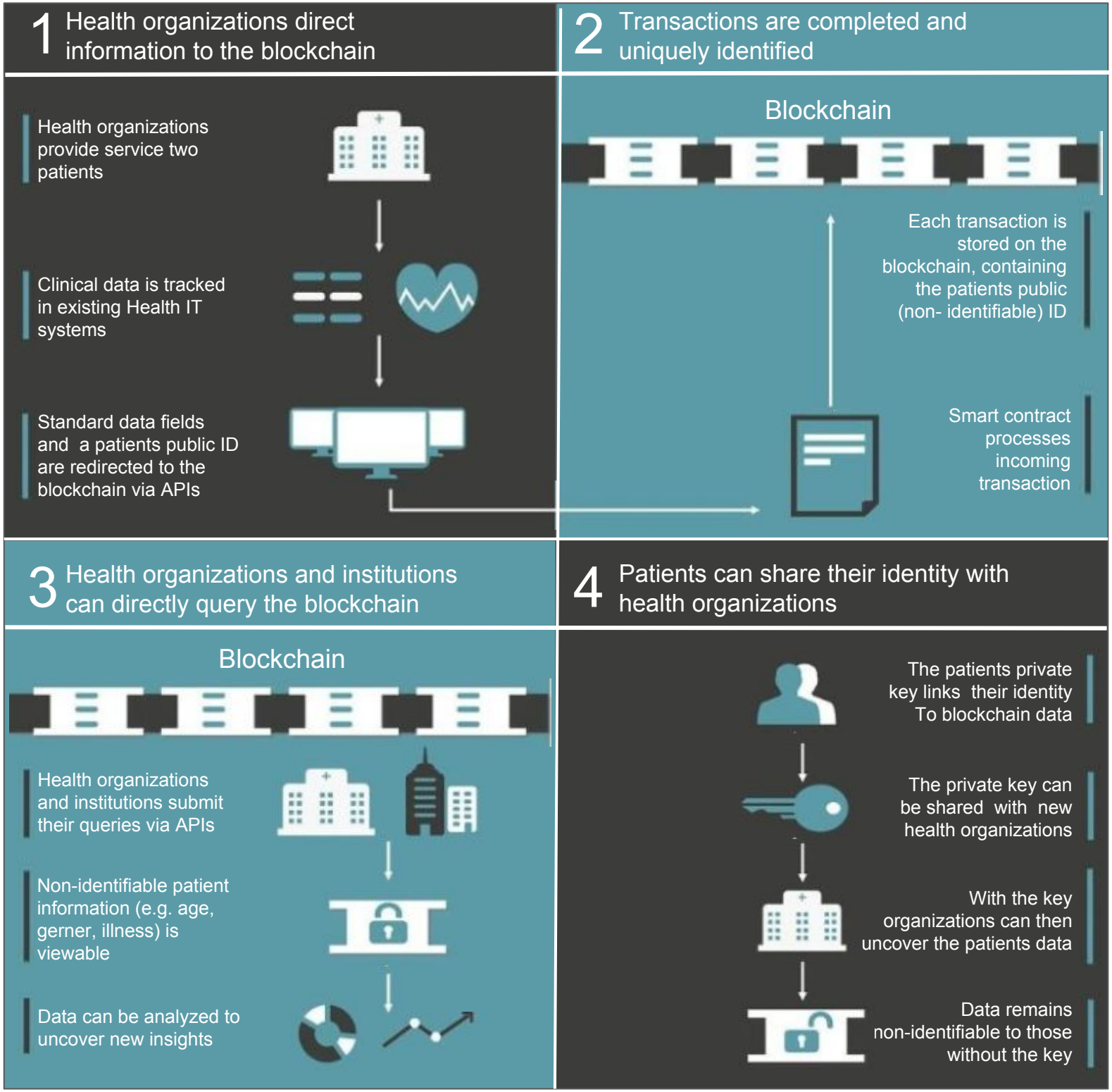
Epigenetic, by definition, describes the study of changes in gene expression that do not involve changes to the underlying DNA sequence, instead arising from nongenetic influences on gene expression.

Given the reversible nature of epigenetic mechanisms, they provide promising avenues for therapeutics against age-related decline and disease.

Looking at epigenetic data, deep learning algorithms can predict the risk of a disease in time to prevent it.

However, ensuring security and privacy in transmitting and storing personal epigenetic profiles will require building a new and open data ecosystem.

Blockchain has the potential to do just that.

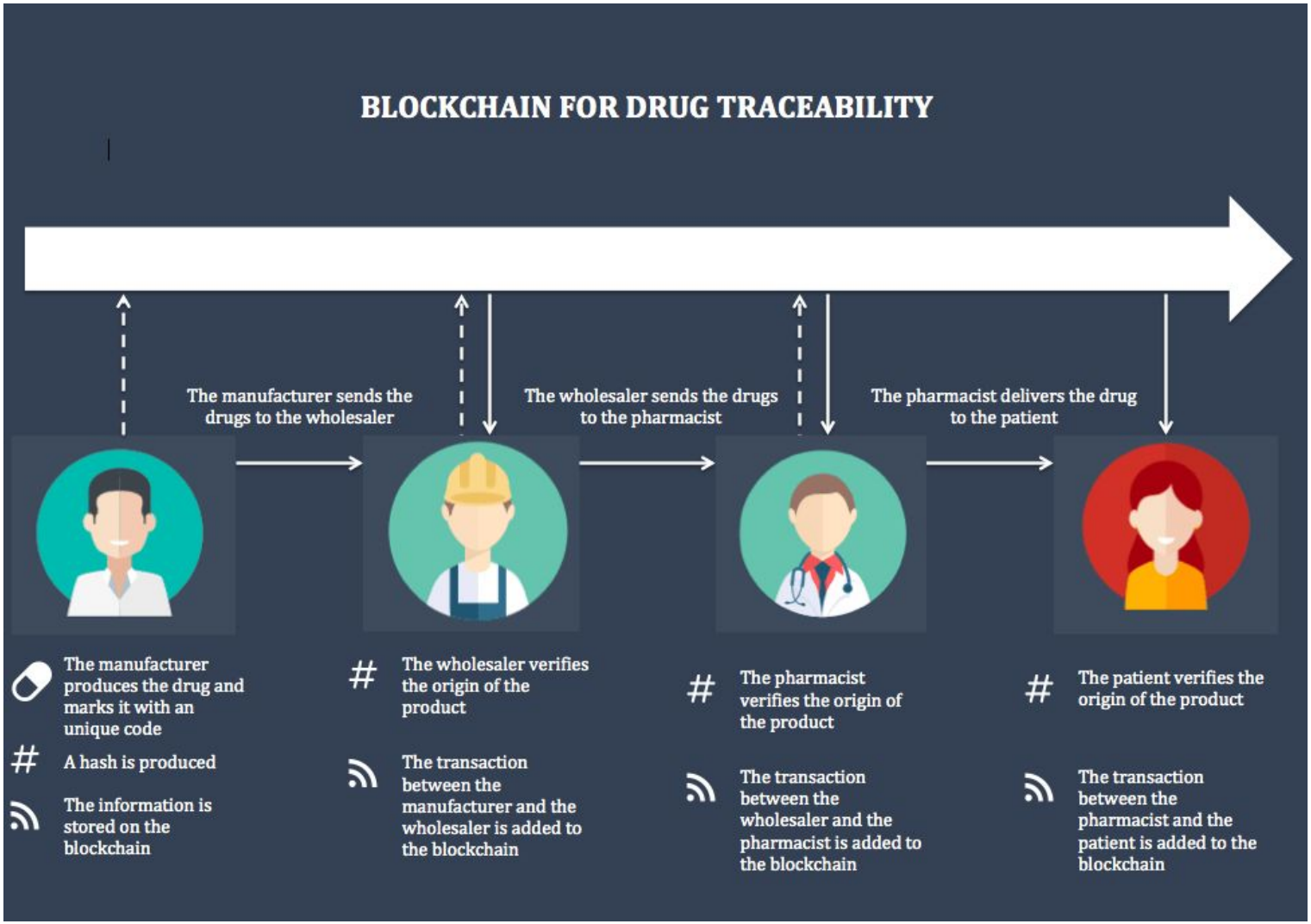


Blockchain will enable secure and verifiable sensitive data storage and sharing, while allowing patients to choose to share their individual data with relevant parties such as doctors and researchers, as well as for clinics to access non-identifiable patient data through queries via APIs.

Each patient is assigned their **private key** to enable sharing of their data which remains unidentifiable to anyone from the outside without the key.

Source: https://innovatemedtec.com/digital-health/blockchain

Blockchain



Another interesting use-case for blockchain in the BioPharma industry is utilizing distributed ledgers to record where a drug has come from and where it has been received as an immutable and transparent mechanism for ensuring drug traceability so as to avoid fraud.

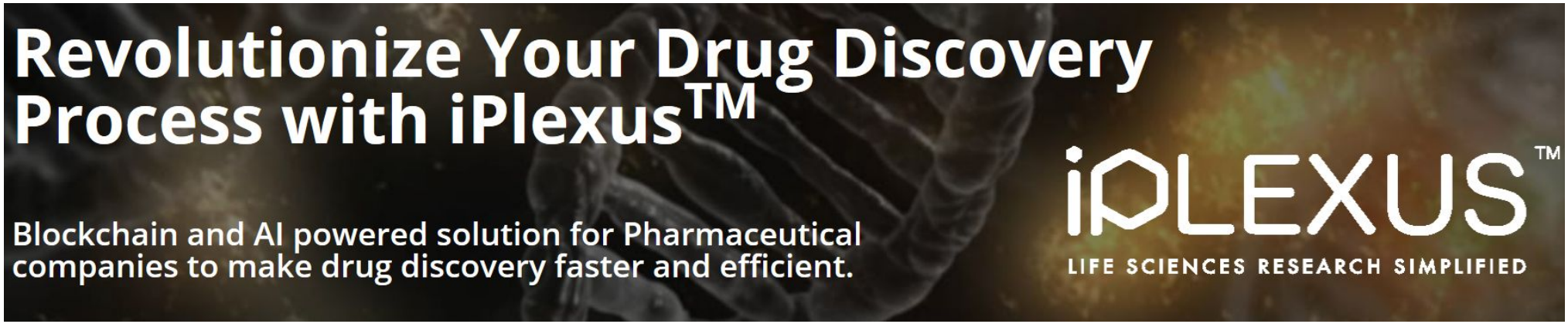
Source:https://www.intelligenthq.com/innovation-management/blockchain-use-cases-in-healthcare/

Blockchain: Combined AI & Blockchain Platforms for Drug Discovery are on the Horizon

In May 2018, Innoplexus announced the launc of iPlexus, an AI and blockchain-based platform to democratize drug discovery. The project aims to give researchers a blockchain and AI-driven platform for posting and using unpublished data from both successful and failed experiments, with IP being secured on the blockchain so as to be immutable and transparent. Meanwhile, AI will perform analysis of the data uploaded to the blockchain in order to rank it in terms of its value for drug development R&D.

In an associated press release Gunjan Bhardwaj, CEO of Innoplexus AG, stated:

"Our mission at Innoplexus is to democratize the drug discovery process. We believe that cutting-edge technologies like AI and blockchain are the key to making this possible. After over 6 months of research, we believe that the new iPlexus is a major step forward for the preclinical trial industry and will solve many of the problems that are slowing the industry down. By overcoming these challenges, we will make drug discovery more efficient and bring down the consumer price of drugs."



Source: https://www.prnewswire.com/news-releases/new-blockchain-and-ai-based-platform-to-revolutionize-drug-discovery-300654106.html

83% of Surveyed Pharma Executives Expect Blockchain to be Adopted in the BioPharma Industry within Next 5 Years

A 2017 survey conducted by The Pistoia Alliance, an international nonprofit that works to lower barriers to innovation in life sciences R&D, among senior pharmaceutical executives found that industry interest in blockchain has increased dramatically in reent years, with 83% of respondants stating that they expected blockchain to be widely adopted in the pharmaceutical and life sciences industry in the next five years.

In an associated press release, Pistoia Alliance President Steve Arlington stated:

"We are entering a future where individuals have cheap and ready access to their genomic profile or ancestral history, for as little as $100. The potential of this data to advance research and development efforts is huge. But this potential will only be realised if the industry can work out how to safely and securely store and share sensitive data. Right now, blockchain is a technology originally created for use in the financial services industry, but by working together, the life sciences industry can take advantage of its secure attributes. The Pistoia Alliance was formed to foster collaboration between the life sciences industry and its stakeholders in other sectors – our aim is to support our members' blockchain initiatives and provide a forum for such partnership."

Pistoia Alliance consultant Nick Lynch added:

"The dynamics of power are changing and patients today have become more empowered – we are seeing a shift to a transformative age of 'the patient will see you now'. In the future, patients will even have the possibility of monetising access to their personal data, giving individual companies access to 'blocks' of their data for research purposes. This shift – where patients have access to and control over how their data is used – is changing the entire model of healthcare from early R&D all the way to frontline delivery. Ultimately, patients will want to manage their personal data the way they manage their bank accounts. The life sciences industry must collaboratively explore solutions that enable patients to do this, while ensuring they retain access to data for their own R&D efforts."

Source:
http://www.drugdiscoverytoday.com/view/46077/83-of-life-science-leaders-believe-blockchain-will-be-adopted-within-five-years-finds-survey-from-the-pistoia-alliance/

P3 medicine

Precision, preventive, and personalized medicine, **also known as P3 medicine**, represents the next evolutionary step from reactive disease care. In contrast to the latter, P3 covers three functions: the early detection of factors responsible for diseases (predictive), reducing the likelihood of diseases (preventive), and therapy that focuses uniquely on each patient (personalized).

P3 medicine is made possible thanks to the convergence of three trends:

One is the advances in systems medicine - a field of study that looks at the systems of the human body as part of an integrated whole that are affected by biochemical, physiological, and environment factors - particularly its increased ability to understand the complexity of diseases.

Two is our increased ability to collect, store, and analyze data.

And three, an ever easier access to information afforded to consumers about their own health data, leading to a rise in their active interest in managing their health.

The human genome is made up of about 25,000 genes, but some genes may not be fully expressed, some genes share multiple responsibilities, and each gene encodes multiple proteins, all of which produces very complex interactions. This is where supercomputers come in.

They are able to model biological networks and simulate the functioning of these networks to identify any perturbation, or disease, and the therapies most likely to ‘fix’ the network.

P3 medicine is much more effective than the medicine we know today. While the current status is marked by increasing healthcare costs, the promise of P3 is that it could lead to better health for consumers and an industry that is more efficient financially.

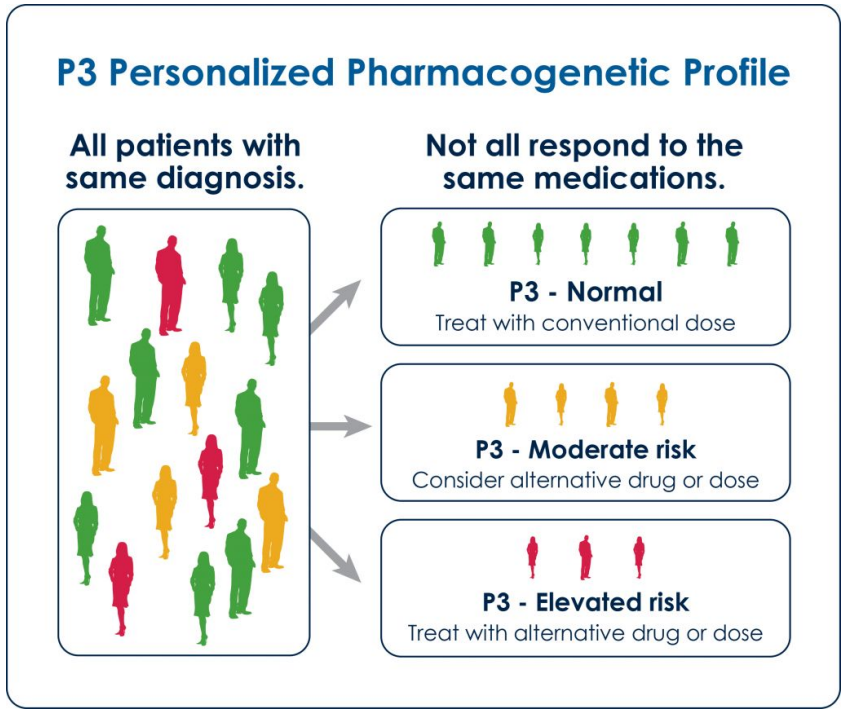
P3 Medicine

Personalized medicine is an interdisciplinary field that is entering the market with a promise to revolutionize the industry. Personalized medicine can be defined as an approach in healthcare that creates therapies based on individual characteristics of the patients.

Personalized medicine is used in conjunction with the precision and preventive medicine to form the P3 Medicine. The core ideas of the P3 approach are:

- Take **personal** traits of the patient into the consideration
- **Predict** diseases before they do any substantial damage
- **Prevent** diseases when possible, rather than to treat them

P3 Medicine stands as a key enabler in the longevity technology framework that ties multiple innovations in a single industry,



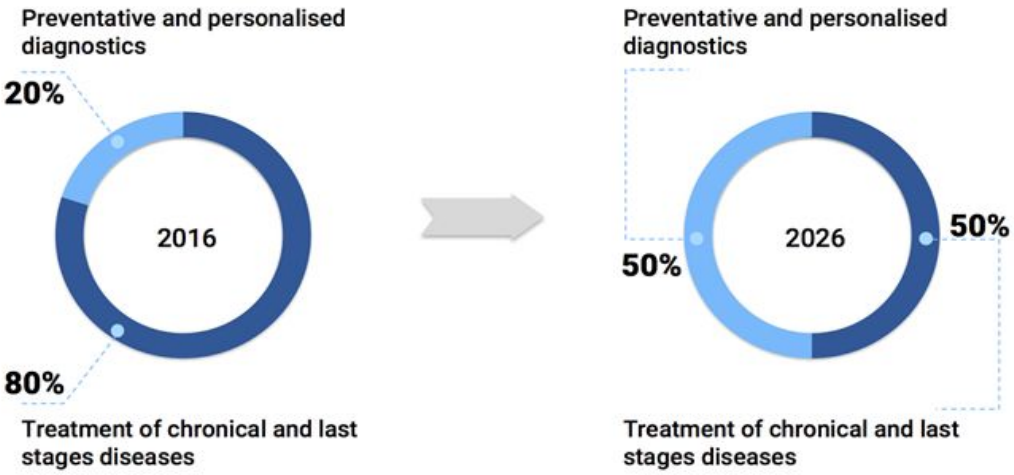
Source: http://arcpointos.com/pharmacogenetics-testing/

P3 Medicine mirrors another notable trend in modern healthcare, gene therapy. While the latter is using advancements in genetics and related fields in order to treat diseases by altering patient's genome, P3 looks to learn from one's genetics instead of altering it. This approach can be seen as a safer and less invasive one.

The strongest point of P3 medicine from the longevity perspective is the fact that it is **already being partially implemented** while having enormous potential for further development.

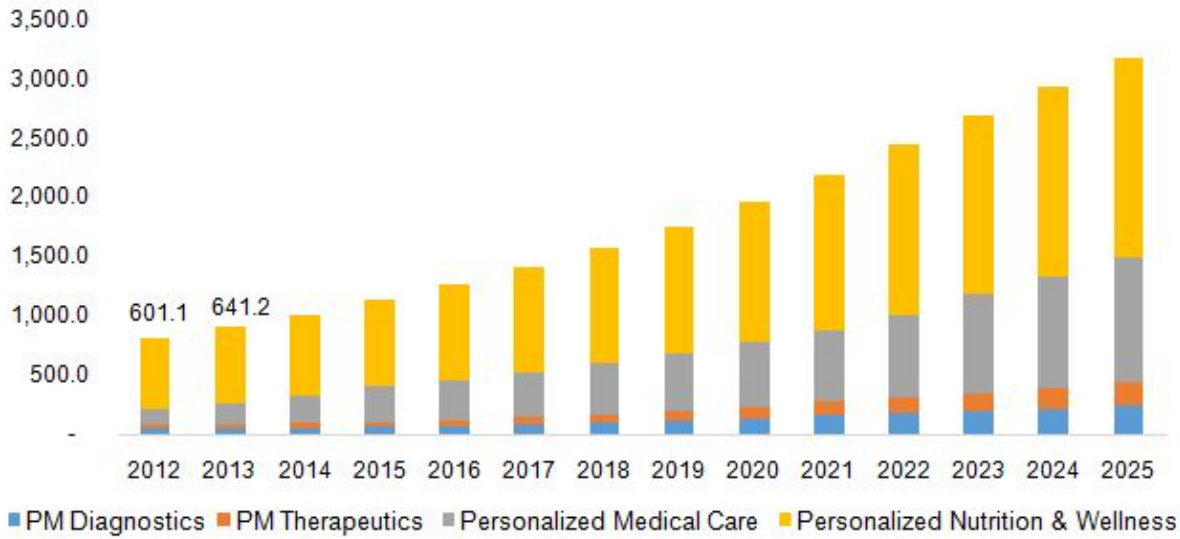
P3 market is expected to develop significantly over the course of the next ten years. This is because P3 Medicine is a complex structural change for the healthcare industry that heavily relies on other **emerging technologies** that are also expected to be fully developed in ten years.

P3 medicine



It is expected that personalized and preventive approaches in the treatment of chronic diseases will become the prevalent one by 2026.

The changes in healthcare systems together with emerging technologies will double the P3 medicine market by 2022.



Source:
https://www.grandviewresearch.com/industry-analysis/personalized-medicine-market

AgeTech

“We need a seismic shift from collective responsibility for retirement to individual responsibility.”
~ Laurence D. Fink

AgeTech is the amalgamation of Fintech and Healthtech. Age-friendly banks use technology to attract and protect vulnerable older customers.

A person’s financial decision-making ability peaks roughly in their mid-50s, and begins to deteriorate afterwards. Elderly people in general struggle with day-to-day banking activities, are more susceptible to poor investment choices and financial fraud; the average age of victims of mass-marketing scams is 75.

Barclays for instance uses voice recognition to help customers who have trouble with passwords. Other fintech solutions for the elderly focus on mobile technology: the devices currently found on the market aren’t friendly to the elderly populations. A revolution in AgeTech then is very much dependant on the spread of mobile devices that are easy to use for old people. Only then will banks be able to unlock mobile banking for that demographic.

More significantly, algorithms are helping banks spot any alarming changes in behavior - such as spending patterns - which could signal trouble.

Managing people’s money can shed light on their health

A much more intriguing pattern is emerging: banks are well placed to spot elderly individuals who are at risk. A decline in financial management skills can be an early sign of health problems, dementia for example. Banks will be able to refer a person to a doctor. In addition to spotting financial abuse, some banks are currently training their staff to spot dementia.

AgeTech and the Shifting Retirement Landscape

Commenting on the changing retirement landscape in a 2013 speech to NYU Stern MBA students entitled *Longevity in the Age of Twitter,* Laurence D. Fink, CEO of BlackRock and an NYU Trustee raised the spectre of the Silver Tsunami:

"When I was growing up, the U.S. was launching the Great Society, which sought to summon the resources of government to wipe out poverty. Today, the generation that came of age with the Great Society is headed for retirement and giving you a Grey Society – where we will need to summon up even greater resources just to meet their needs."

Turning to the role of technology in managing senior finances:

" We need a seismic shift from collective responsibility for retirement to ***individual*** *responsibility. "*

By adapting to the changing biological reality of each individual's as they age, the growth of AgeTech hands back to old people their former individual decision making capacity, putting the wisdom of individual life experience back behind the grey pound.

Objective forecasting for 2018 - 2022 (applying TRLs)

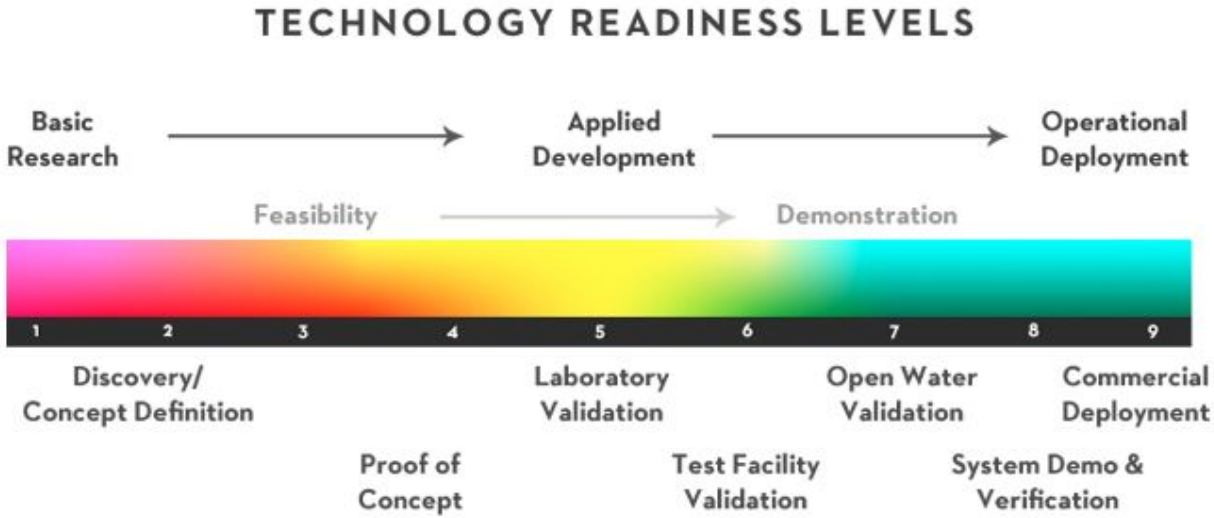
Technology readiness levels (TRLs) enable the gauging of the maturity of Critical Technology Elements (CTEs) determined during a Technology Readiness Assessment (TRA) that examines program concepts, technology requirements, and demonstrated technology capabilities.

TRL use a ranking 1 - 9, with 9 being the most mature technology, with specific TRL levels being assigned to specific technologies by a group of scientific experts familiar with each specific technology. The use of TRLs enables consistent, uniform discussions of technical maturity across different types of technology.

In the coming years, TRLs can underpin efforts to shed light on the most important technologies, but also those that are at present furthest away from their practical application; therefore enabling the right timing and focus to ensure the accomplishment of specific endpoints with regard to each emerging technology, and the interactions that are possible between technologies that are currently at different points on the TRL scale, but can be expected to merge in level over the coming few years.

Using TRLs can expedite progress in the coming 5 years by employing TRLs to provide an objective lens through which various technologies are viewed.

In the same way that using this scale has benefited the aerospace industry, it can bolster the efforts of the life sciences industry in the coming years.



Exponential acceleration of further progress

We have barely scratched the surface when it comes to the applications of technology in healthcare.

Technology grows exponentially: according to Moore's Law, computer processing speed doubles every 18 months. Although the healthcare industry is typically slow to progress, the growth driven by innovative tech should accelerate the progress exponentially.

Another factor enabling this acceleration is the growth of outside players: big and small companies looking to capitalize on gaps in the market will drive advances in diagnostics and treatments faster than traditional medical institutions. According Mary Meeker's latest report, venture capitalists in Silicon Valley are increasingly hiring bio experts to help guide their investments.

Artificial Intelligence, for instance, is expected to reach $6.6 billion in 2021, at a compound annual growth rate of 42%. By 2020, it is expected that conditions such as cancer and diabetes will be diagnosed in minutes using cognitive systems. By 2025, AI systems are expected to be implemented in 90% of the U.S., and 60% of the global hospitals and insurance companies will have implemented AI systems, which will be able to deliver quality care to 70% of patients at a reduced cost.

Innovation in immunotherapy, such as checkpoint inhibitors - a type of drug that boosts the immune response against cancer cells - is growing at 139% CAGR. Scientists are still trying to nail down an algorithm for its effective use. Once realized, the market for checkpoint inhibitors could reach $21.1 billion by 2020.

Now that the media hype dust has settled, 3D Printing for organ or tissue repair carries huge potential in healthcare. The 3D printing business for healthcare is expected to reach approximately $6 billion in 2025.

Conclusion

The whole will become bigger than the sum of its parts when the following 5 technology megatrends converge:

- AI in biomedicine
- The adoption of blockchain
- Progress in longevity and geroscience
- New financial systems and AgeTech.

These megatrends are going to converge **very fast** in the coming 5 years. Therefore the window for startups to enter this new market will be closing swiftly over the course of the next few years. By 2022, the big companies will openly begin to embrace these new trends, whereupon the leaders of the AI for Drug Discovery race (whether they are startups, BioPharma corporations or IT/Tech corporations) will adapt to work with the transformed industries.

"Given the increasing cost of drug discovery, development and clinical evaluation, it is clear that the clinical translation of geroprotective interventions will be increasingly led by the private sector, and by parties who have the resources to sustain the increasing financial burden of bringing truly effective longevity therapeutics to market." **- Dmitry Kaminskiy, Managing Partner of Deep Knowledge Ventures**