Artificial Intelligence (AI) Enabled Drug Discovery and Development: Recent Advancement

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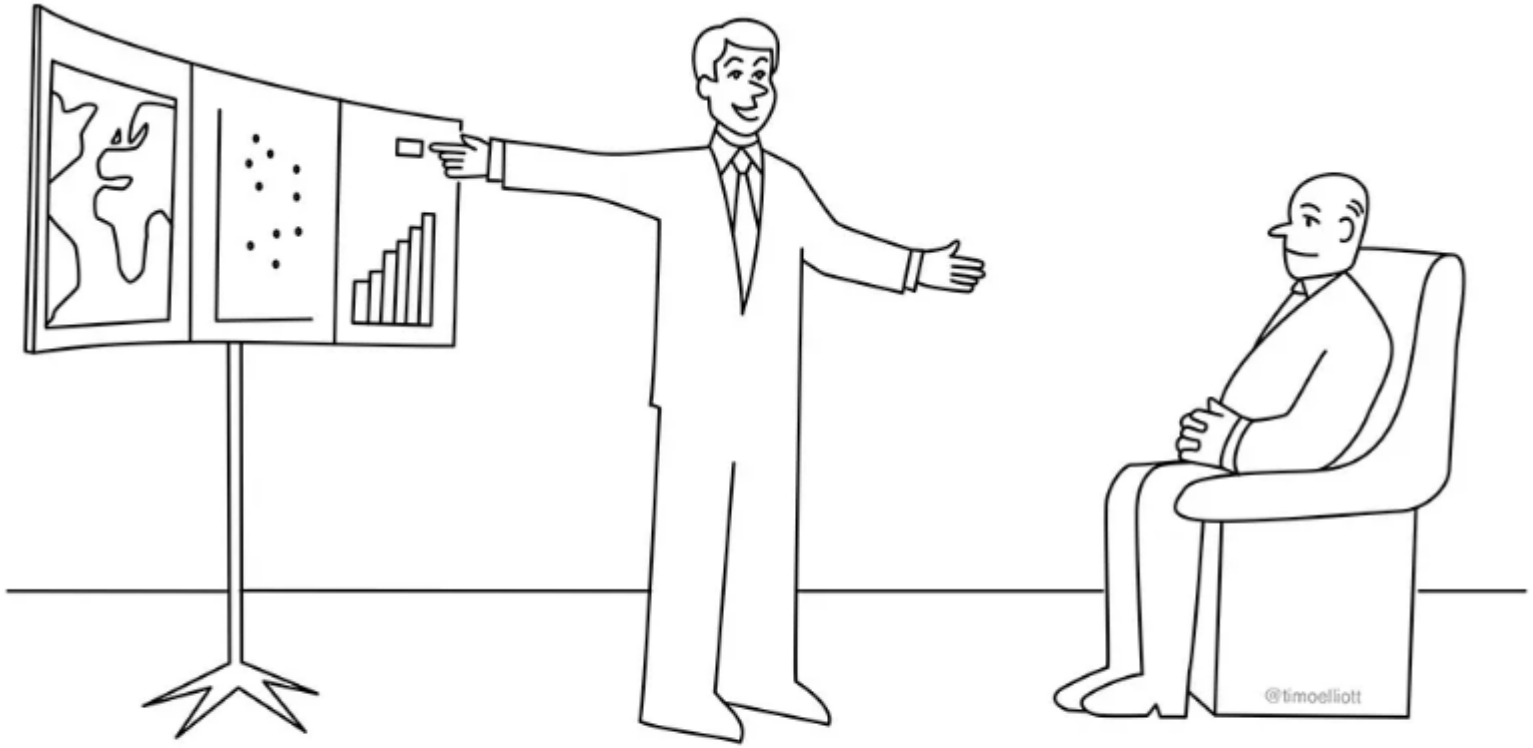
Research Director in Bioinformatics (as Advisory Professor), Institute of Skeletal Aging (ISA), Hallym University, South Korea

TATA Innovation Fellow (DBT, Government of India); Affiliate member of the Royal Society of Chemistry, Member, American Society of Microbiology and Sigma Xi, USA,

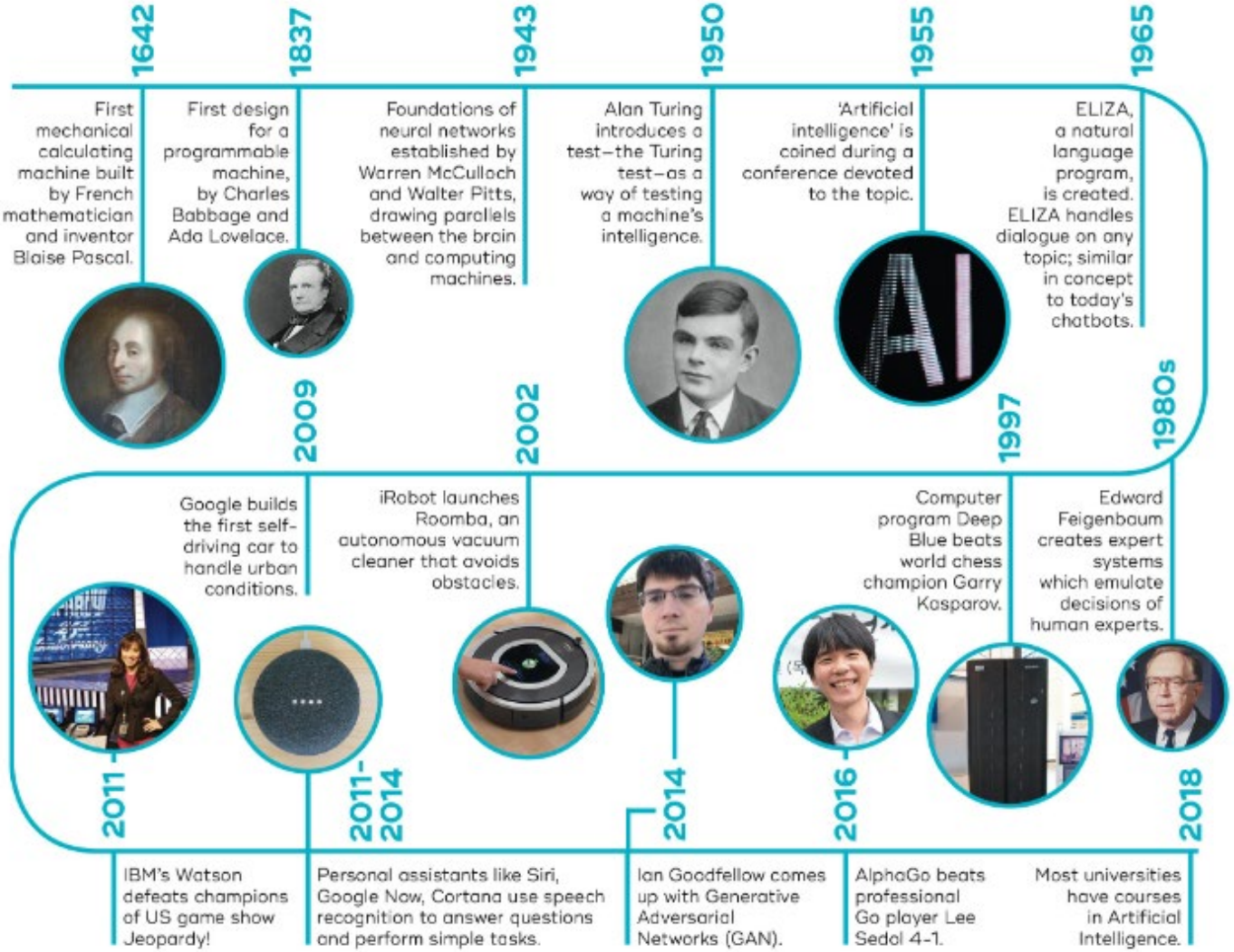
Everyone Talking About Artificial Intelligence



"And our unique JustifyIt™ feature uses deep learning to find data that agrees with your point of view!"

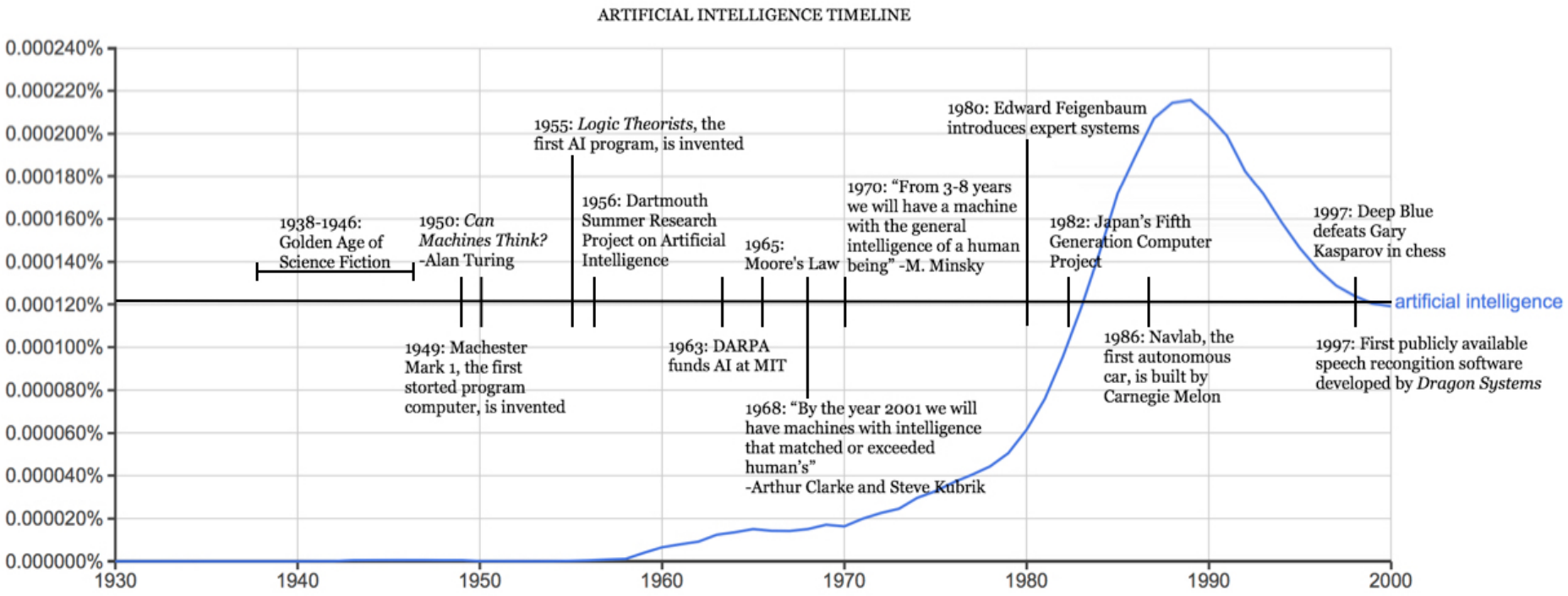
Source: https://timoelliott.com/

History of Artificial Intelligence



Source: Queensland Brain Institute

History of Artificial Intelligence

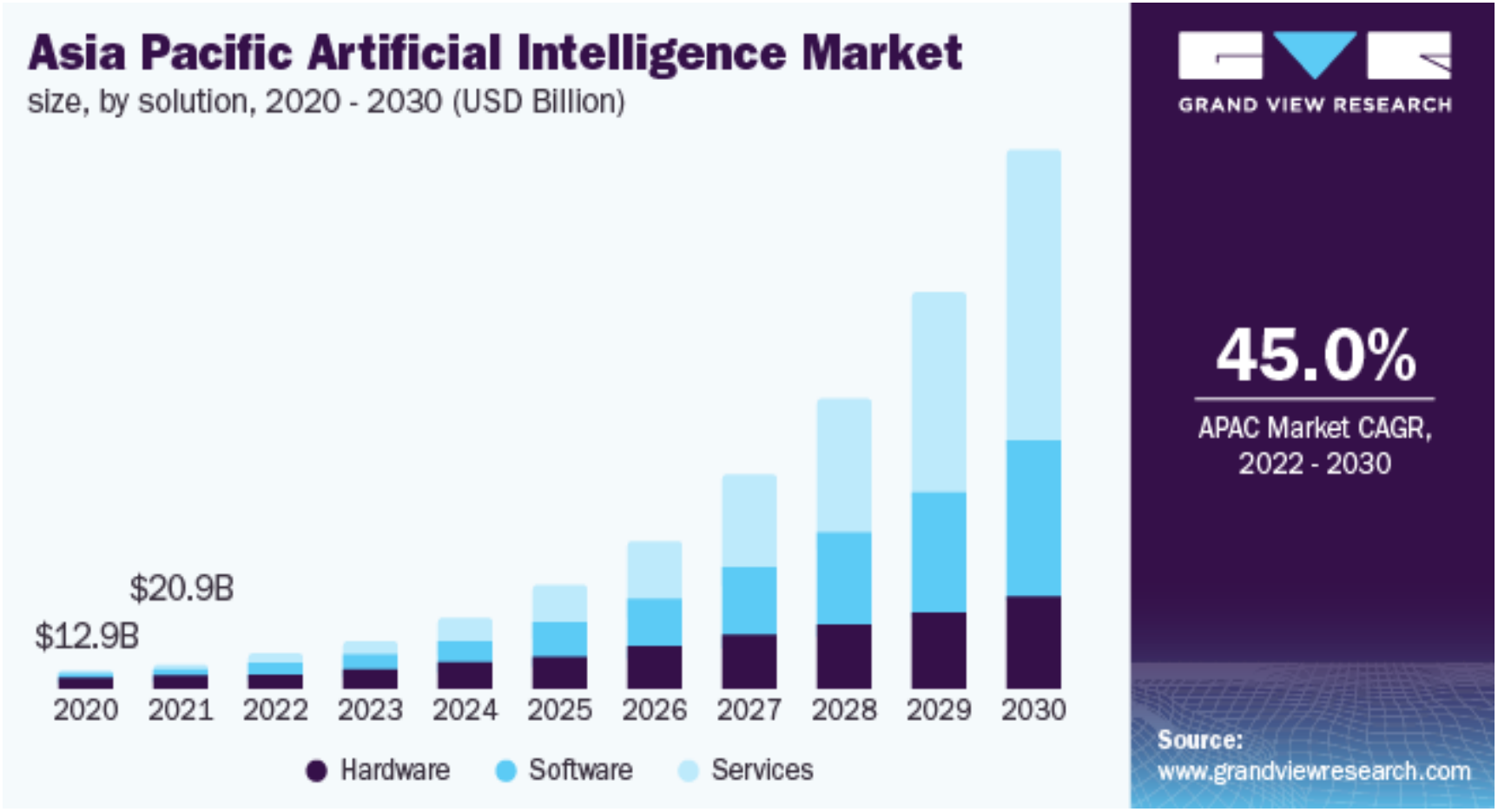


Source: *Rockwell Anyoha' Blog :* **The History of Artificial Intelligence. Harvard University**

Global artificial intelligence market size

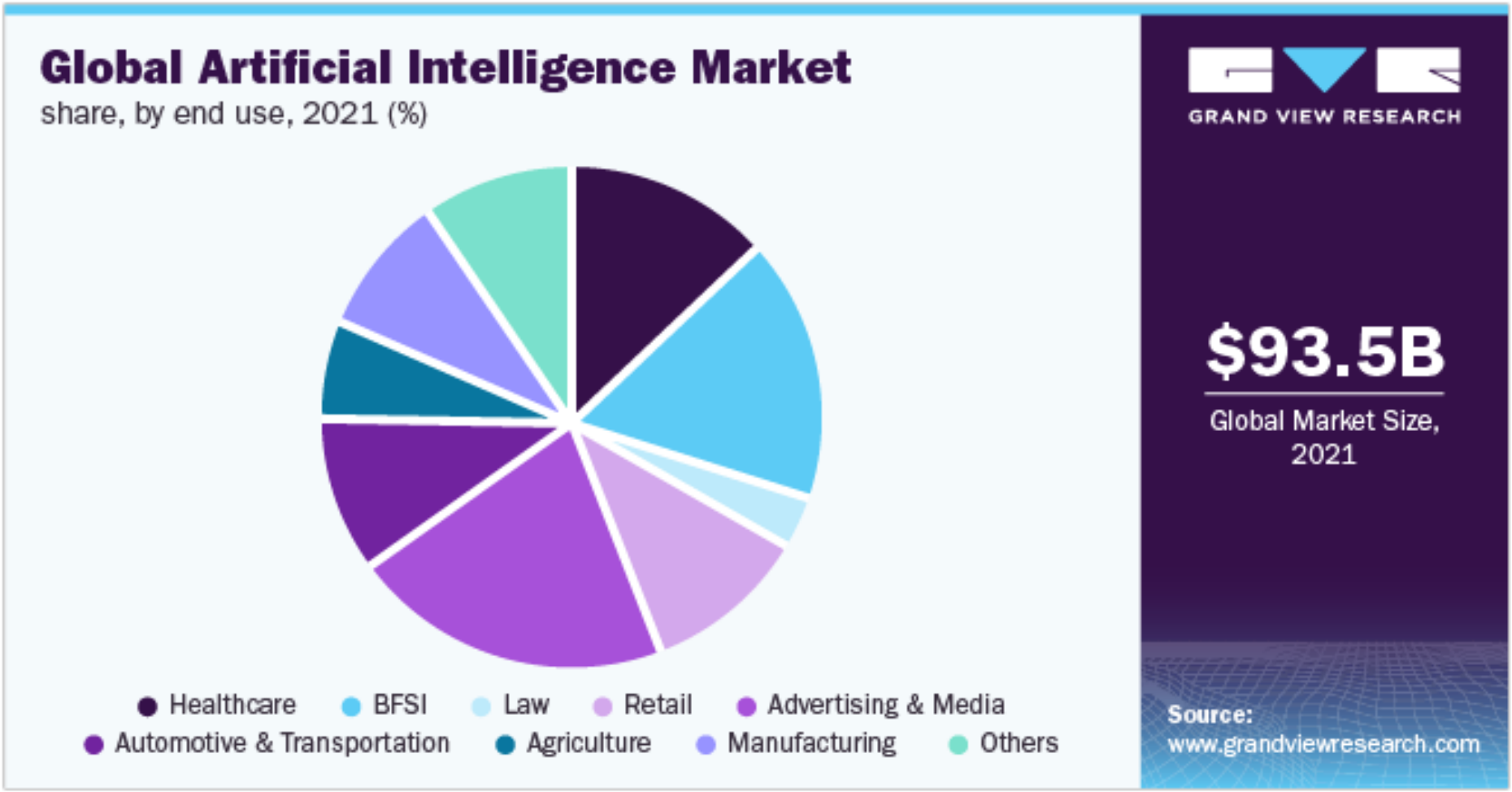
- Global artificial intelligence market size was valued at USD 94 billion in 2023 and is projected to expand at a compound annual growth rate (CAGR) of 38.1% from 2022 to 2030.
- AI is proven to be a significant revolutionary element of the upcoming digital era.
- Tech giants like Amazon.com, Inc.; Google LLC; Apple Inc.; Facebook, International Business Machines Corporation, and Microsoft are investing significantly in the research and development of AI.

Asia : AI Market size



Source: Artificial Intelligence Market Size, Share & Trends Analysis Report By Solution, By Technology (Deep Learning, Machine Learning, Natural Language Processing, Machine Vision), By End Use, By Region, And Segment Forecasts, 2022 - 2030

Global Market segment: AI



Source: Artificial Intelligence Market Size, Share & Trends Analysis Report By Solution, By Technology (Deep Learning, Machine Learning, Natural Language Processing, Machine Vision), By End Use, By Region, And Segment Forecasts, 2022 - 2030

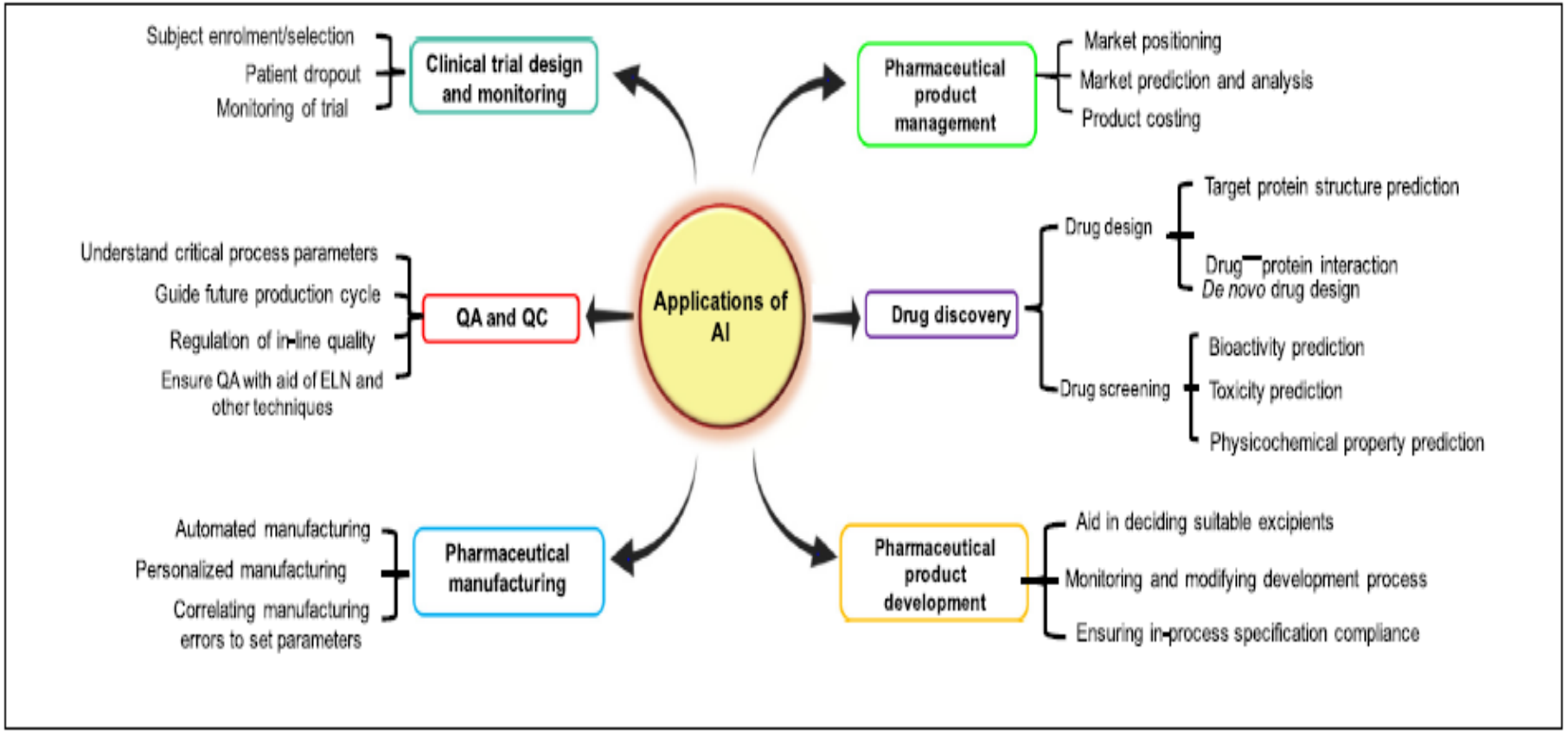
Main Revenue generated Areas

- **Solution Areas (2017 - 2030)**
  - Hardware
  - Software
  - Services
- **Technology Areas (2017 - 2030)**
- Deep Learning
- Machine Learning
- Natural Language Processing (NLP) Or Large Language Models or Gen AI

Main Revenue generated Areas: Healthcare

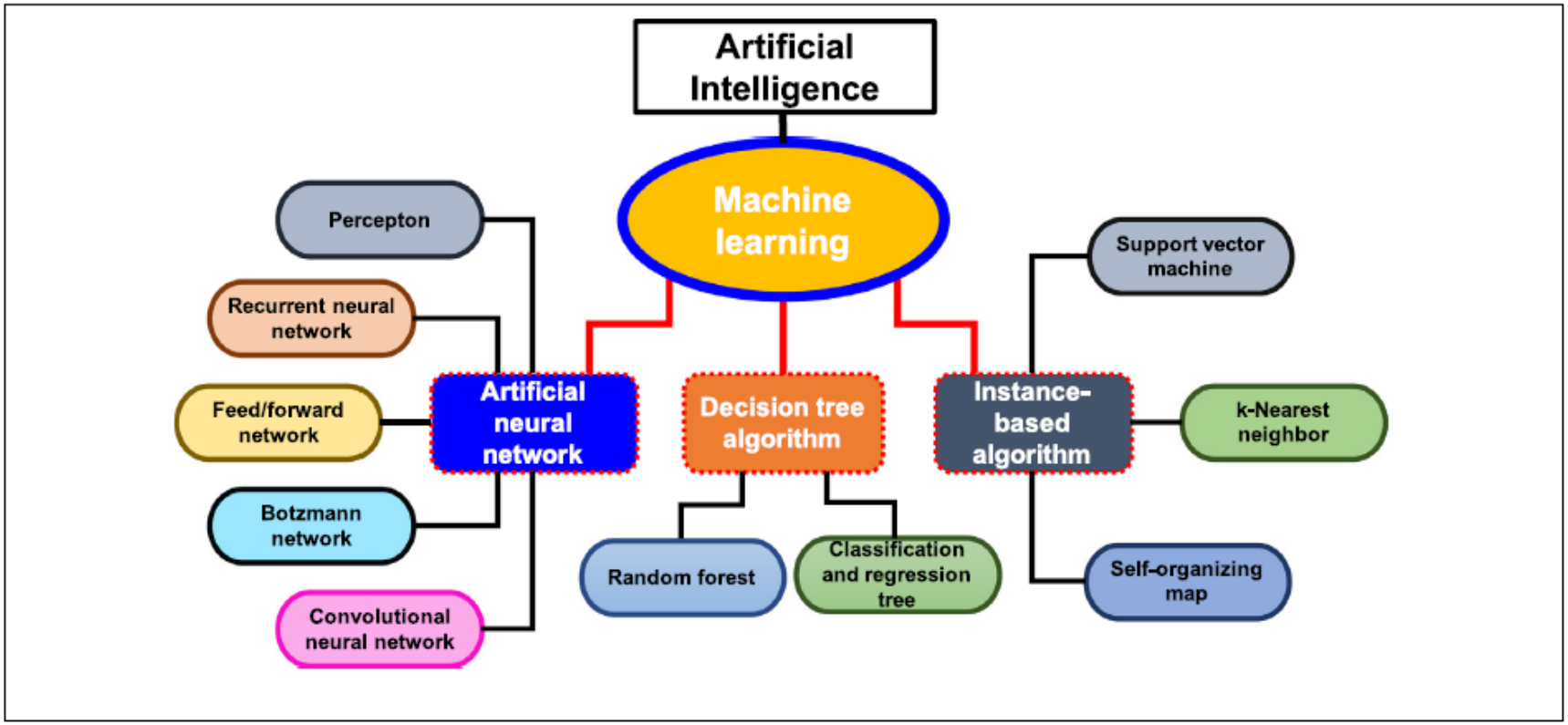
- **Healthcare Areas (2017 - 2030)**
  - Robot Assisted Surgery
  - Virtual Nursing Assistants
  - Hospital Workflow Management
  - Dosage Error Reduction
  - Clinical Trial Participant Identifier and Analysis of results
  - Preliminary Diagnosis
  - Automated Image Diagnosis
  - Drug target discovery
  - Small molecular Drug Discovery
  - Drug-Drug interaction studies

AI in Drug discovery



Source: Paul D, Sanap G, Shenoy S, Kalyane D, Kalia K, Tekade RK. Artificial intelligence in drug discovery and development. Drug Discov Today. 2021 Jan;26(1):80-93

Algorithms used



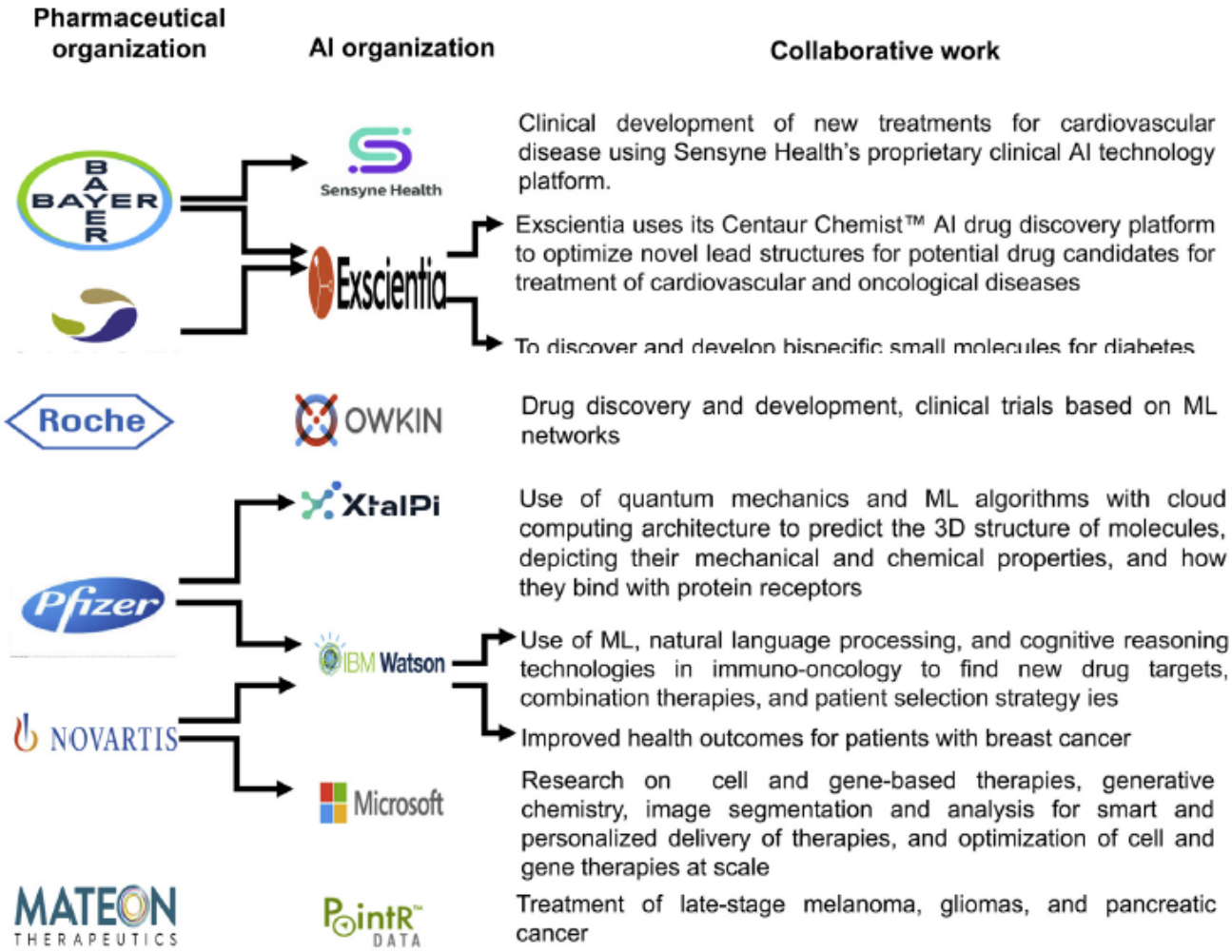
Source: Paul D, et al. Artificial intelligence in drug discovery and development. Drug Discov Today. 2021 Jan;26(1):80-93

AI-Based Computational Tools for Drug Discovery

Tools	Description	Websites
AlphaFold	Protein 3D structure prediction	https://deepmind.com/blog/alphafold
Chemputer	A more standardized format for reporting a chemical synthesis procedure	https://zenodo.org/record/1481731
DeepChem	A python-based AI tool for various drug discovery task predictions	https://github.com/deepchem/deepchem
DeepNeuralNet-QSAR	Molecular activity predictions	https://github.com/Merck/DeepNeuralNet-QSAR
DeepTox	Toxicity predictions	www.bioinf.jku.at/research/DeepTox
DeltaVina	A scoring function for rescoring protein–ligand binding affinity	https://github.com/chengwang88/deltavina
Hit Dexter	ML models for the prediction of molecules which might respond to biochemical assays	http://hitdexter2.zbh.uni-hamburg.de
Neural Graph Fingerprints	Property prediction of novel molecules	https://github.com/HIPS/neural-fingerprint

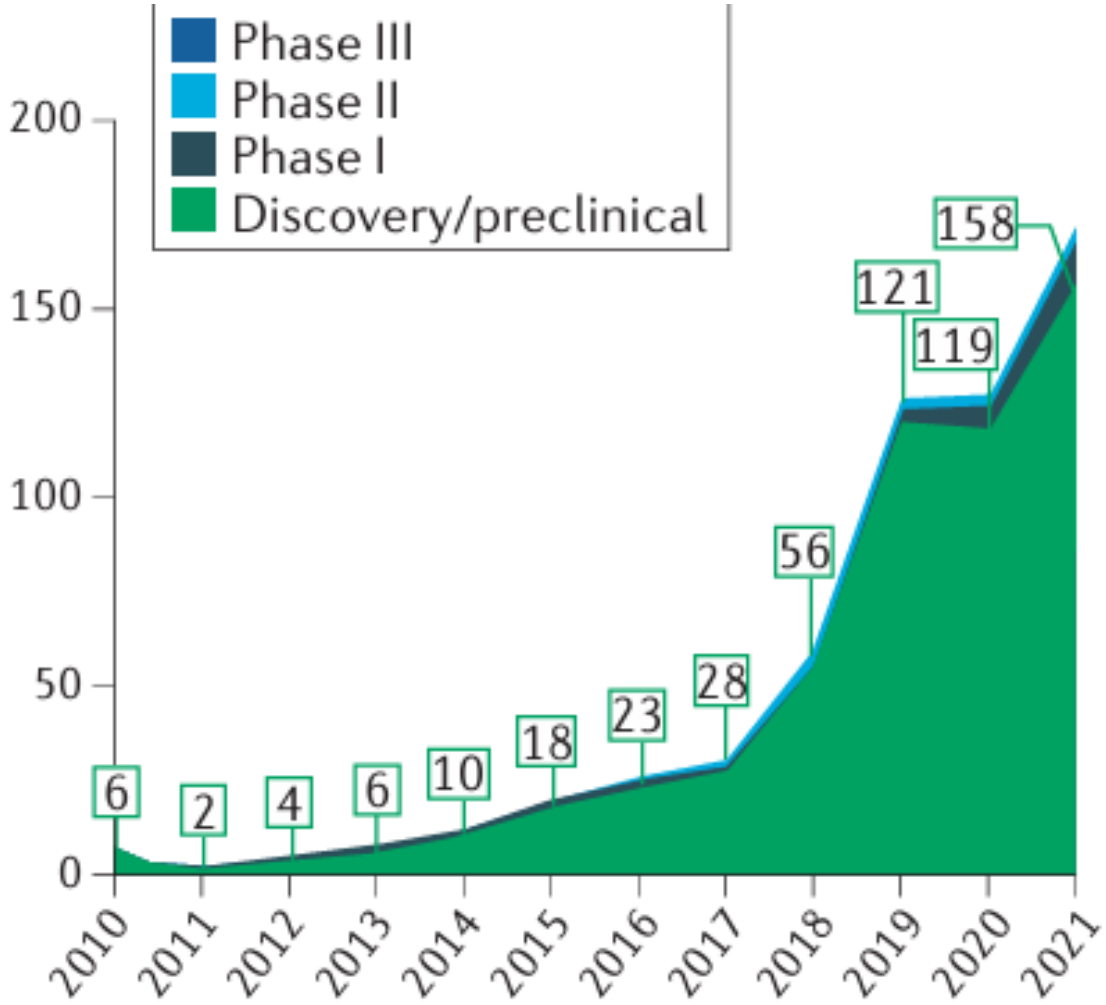
Source: Paul D, et al. Artificial intelligence in drug discovery and development. Drug Discov Today. 2021 Jan;26(1):80-93

Collaboration: Pharmaceutical Organization and AI Organization interface



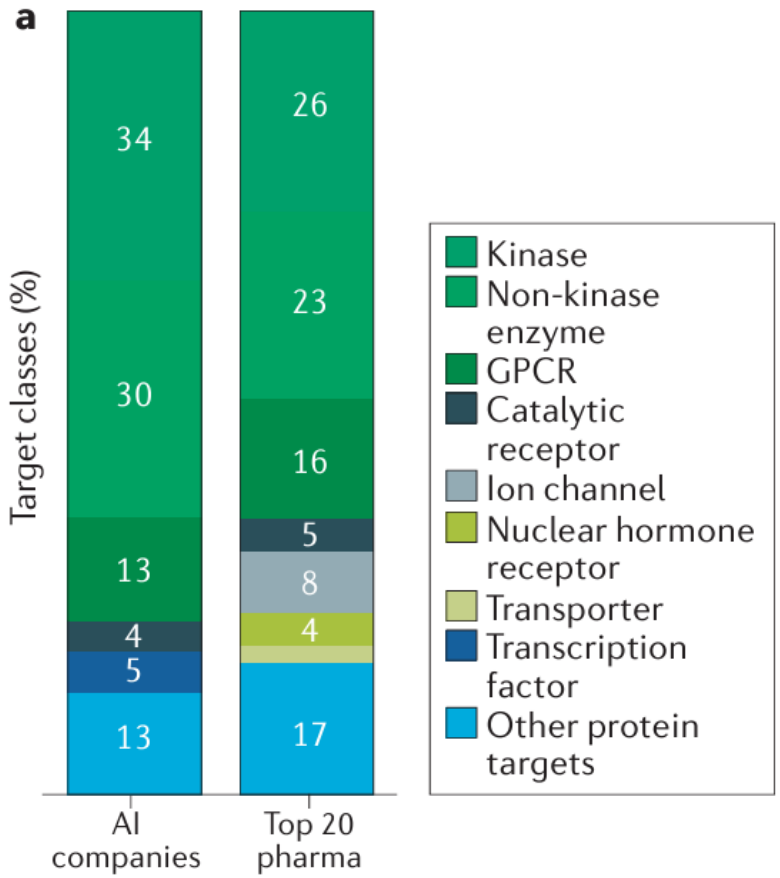
Source: Paul D, et al. Artificial intelligence in drug discovery and development. Drug Discov Today. 2021 Jan;26(1):80-93

AI-native drug discovery companies



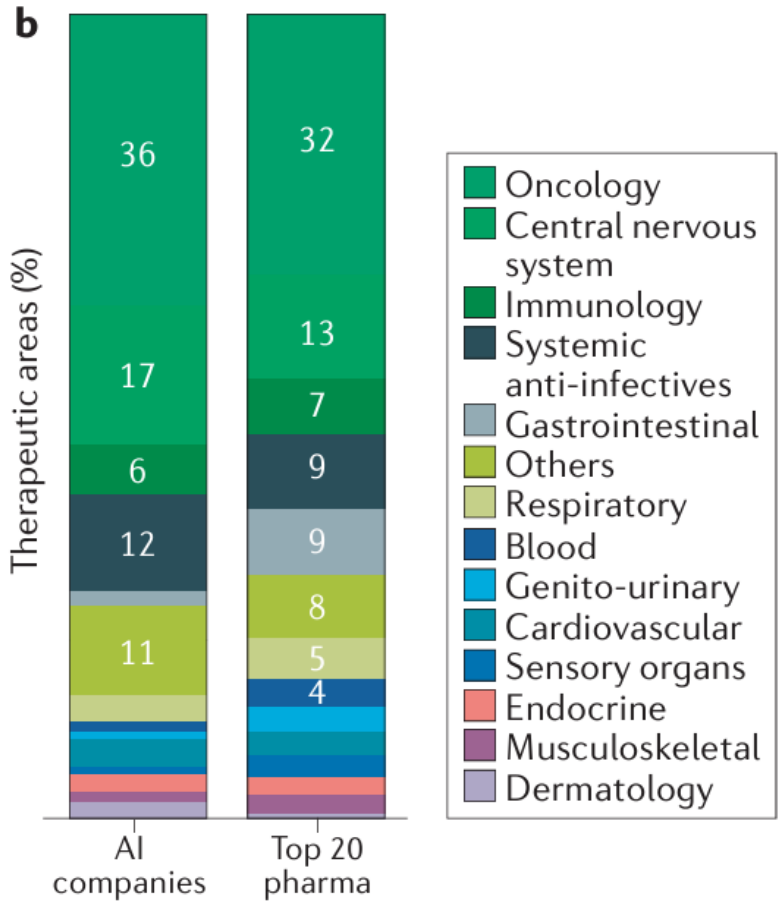
Jayatunga et al. AI in small-molecule drug discovery: a coming wave? Nat Rev Drug Discov. 2022 Mar;21(3):175-176.

AI drug discovery companies focus on well-established target classes



Jayatunga et al. AI in small-molecule drug discovery: a coming wave? Nat Rev Drug Discov. 2022 Mar;21(3):175-176.

AI drug discovery companies focus on well-established therapeutic areas



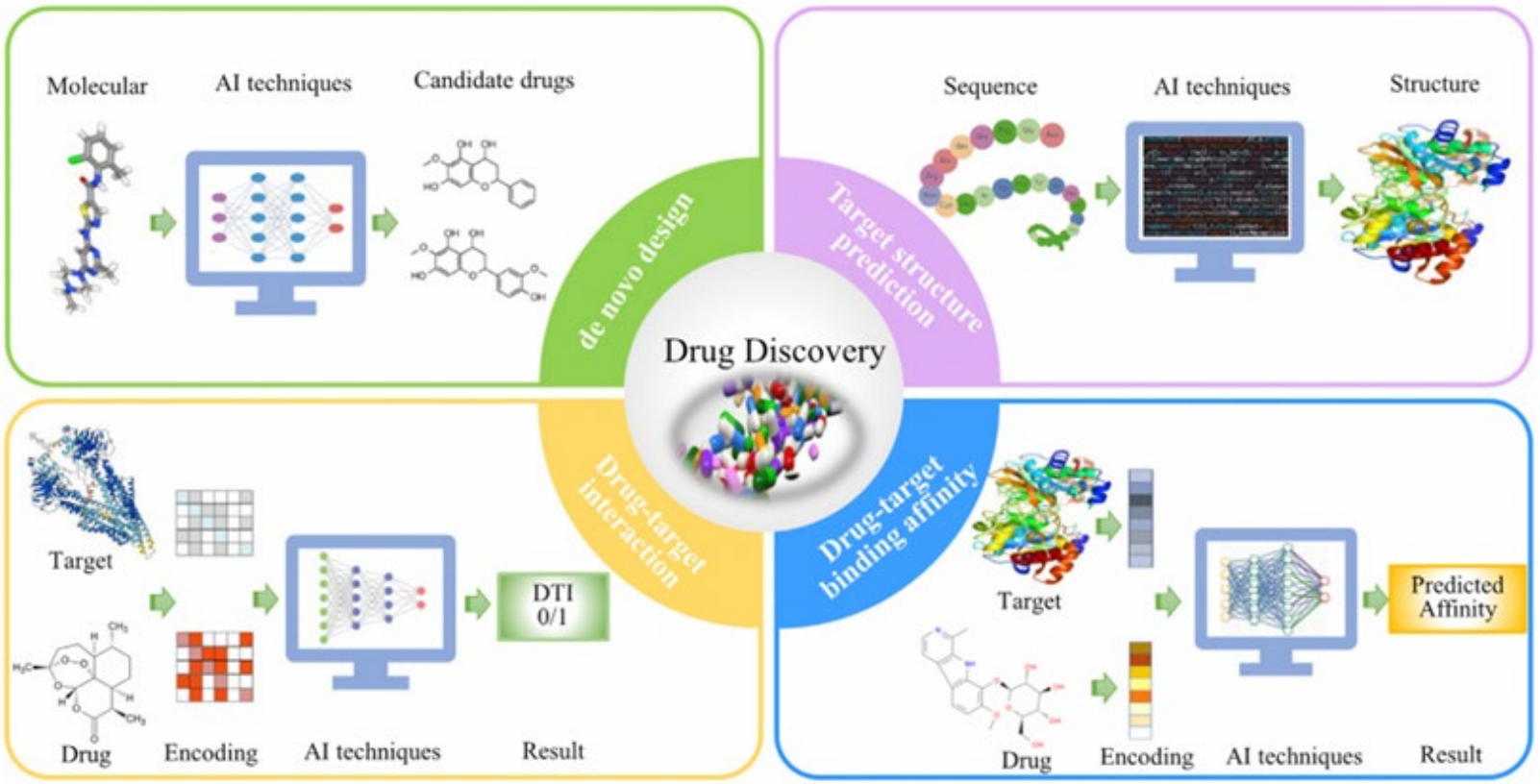
Jayatunga et al. AI in small-molecule drug discovery: a coming wave? Nat Rev Drug Discov. 2022 Mar;21(3):175-176.

Selected AI-designed drugs in or entering clinical trials

Treatment	Organization	Description	Phase	Lead indication
REC-2282	Recursion	Small molecule pan-HDAC inhibitor	2/3	Neurofibromatosis type 2
REC-994	Recursion	Small molecule superoxide scavenger	2	Cerebral cavernous malformation
REC-4881	Recursion	Small molecule inhibitor of MEK1 and MEK2	2	Familial adenomatous polyposis
INS018_055	InSilico Medicine	Small molecule inhibitor	2	Idiopathic pulmonary fibrosis
BEN-2293	BenevolentAI	Topical pan-tyrosine kinase inhibitor	2a	Atopic dermatitis
EXS-21546	Exscientia and Evotec	A_{2A} receptor antagonist	1b/2	Solid tumors carrying high adenosine signatures.
RLY-4008	Relay Therapeutics	Inhibitor of FGFR2	1/2	FGFR2-altered cholangiocarcinoma
EXS-4318	Exscientia	PKC-θ inhibitor	1/2	Inflammatory and autoimmune conditions
BEN-8744	BenevolentAI	Small molecule PDE10 inhibitor	1	Ulcerative colitis
Undisclosed	Recursion	Small molecular inhibitor of RBM39, a CDK12-associated protein	Pre-clinical	HRD-negative ovarian cancer

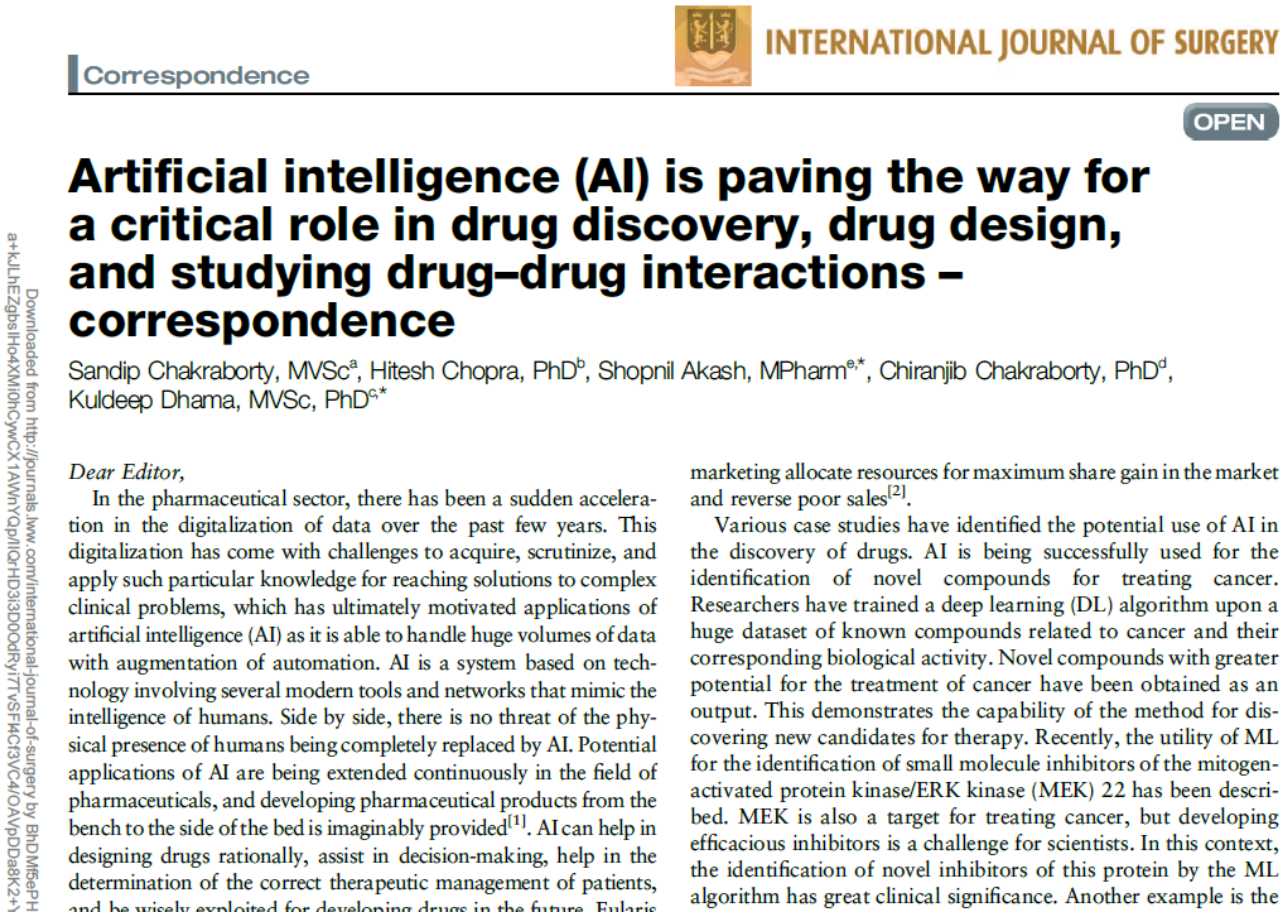
Arnold C. Inside the nascent industry of AI-designed drugs. Nat Med. 2023 Jun;29(6):1292-1295.

AI techniques for natural product-inspired drug discovery



Chen W, Liu X, Zhang S, Chen S. Artificial intelligence for drug discovery: Resources, methods, and applications. Mol Ther Nucleic Acids. 2023 Feb 18;31:691-702.

Our Publications in AI



Correspondence

INTERNATIONAL JOURNAL OF SURGERY

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Artificial intelligence (AI) is paving the way for a critical role in drug discovery, drug design, and studying drug–drug interactions – correspondence

Sandip Chakraborty, MVSc[a], Hitesh Chopra, PhD[b], Shopnil Akash, MPharm[e,*], Chiranjib Chakraborty, PhD[d], Kuldeep Dhama, MVSc, PhD[c,*]

Dear Editor,

In the pharmaceutical sector, there has been a sudden acceleration in the digitalization of data over the past few years. This digitalization has come with challenges to acquire, scrutinize, and apply such particular knowledge for reaching solutions to complex clinical problems, which has ultimately motivated applications of artificial intelligence (AI) as it is able to handle huge volumes of data with augmentation of automation. AI is a system based on technology involving several modern tools and networks that mimic the intelligence of humans. Side by side, there is no threat of the physical presence of humans being completely replaced by AI. Potential applications of AI are being extended continuously in the field of pharmaceuticals, and developing pharmaceutical products from the bench to the side of the bed is imaginably provided[1]. AI can help in designing drugs rationally, assist in decision-making, help in the determination of the correct therapeutic management of patients, and be wisely exploited for developing drugs in the future. Eularis marketing allocate resources for maximum share gain in the market and reverse poor sales[2].

Various case studies have identified the potential use of AI in the discovery of drugs. AI is being successfully used for the identification of novel compounds for treating cancer. Researchers have trained a deep learning (DL) algorithm upon a huge dataset of known compounds related to cancer and their corresponding biological activity. Novel compounds with greater potential for the treatment of cancer have been obtained as an output. This demonstrates the capability of the method for discovering new candidates for therapy. Recently, the utility of ML for the identification of small molecule inhibitors of the mitogen-activated protein kinase/ERK kinase (MEK) 22 has been described. MEK is also a target for treating cancer, but developing efficacious inhibitors is a challenge for scientists. In this context, the identification of novel inhibitors of this protein by the ML algorithm has great clinical significance. Another example is the

Chakraborty S, Chopra H, Akash S, **Chakraborty C**, Dhama K. Artificial intelligence (AI) is paving the way for a critical role in drug discovery, drug design, and studying drug-drug interactions - correspondence. Int J Surg. 2023 Oct 1;109(10):3242-3244. **IF: 15.3**

AI enabled ChatGPT and LLM in drug target discovery

Molecular Therapy
Nucleic Acids
Editorial

Artificial intelligence enabled ChatGPT and large language models in drug target discovery, drug discovery, and development

Drug discovery has been revolutionized recently by different computational approaches like artificial intelligence (AI), deep learning (DL), and quantum mechanical methods. Drug discovery and development was a prolonged process previously. Developing one small-molecular drug might take 15 years on average, costing around US $2 billion. A paradigm shift has recently been noted in drug discovery using computational technologies during the past few years.[1,2] Biotech-based drug discovery companies developed their new business models guided by molecular modeling techniques with AI and DL for "small-molecule hit generation" and "hit to lead generation."[3,4] In this direction, computational-guided ultra-large physics-based virtual screening techniques have been used in drug discovery.[2] All these computational approaches reduce the cost and time of early drug discovery stages. Therefore, biotech companies rely entirely on different computational approaches, especially AI, to search for new drugs. These companies look at this picky time for new algorithms to boost their drug discovery businesses. In this scenario, AI-enabled ChatGPT or large language models (LLMs) are the new addition to the drug discovery landscape.

(PK), and toxicity of the molecule (Figure 1B).[11] Such information using ChatGPT will be helpful for pharmaceutical companies for drug discovery and development. These ChatGPT-derived pieces of information will trigger the drug discovery and development process to move more quickly. At the same time, it will also help the pharmaceutical industry to develop more drugs that will benefit patients.

Sharma and Thakur have illustrated that ChatGPT can assist in the process of drug discovery, such as computing the assortment of a compound, converting smiles to structure, creating input files for Gaussian software, generating input files for docking, finding PDB files, etc. At the same time, ChatGPT can assist in understanding the absorption, distribution, metabolism, excretion, and toxicity (ADMET) properties of a drug. Similarly, it helps with optimizing drug properties and assessing drug toxicity. This tool is significant for early-stage drug discovery, although experimental validation is required.[12]

Serious consequences have been found from drug-drug interactions (DDIs) in patients. Therefore, DDI study is one of the significant pa-

Chakraborty C, Bhattacharya M, Lee SS. Artificial intelligence enabled ChatGPT and large language models in drug target discovery, drug discovery, and development. Mol Ther Nucleic Acids. 2023 Aug 28;33:866-868. IF: 8.8

AI enabled ChatGPT and LLM in drug target discovery

Correspondence

INTERNATIONAL JOURNAL OF SURGERY

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ChatGPT or LLM in next-generation drug discovery and development: pharmaceutical and biotechnology companies can make use of the artificial intelligence-based device for a faster way of drug discovery and development

Soumen Pal, PhD[a], Manojit Bhattacharya, PhD[b], Md. Aminul Islam, MSc[c,d,*], Chiranjib Chakraborty, PhD[e,*]

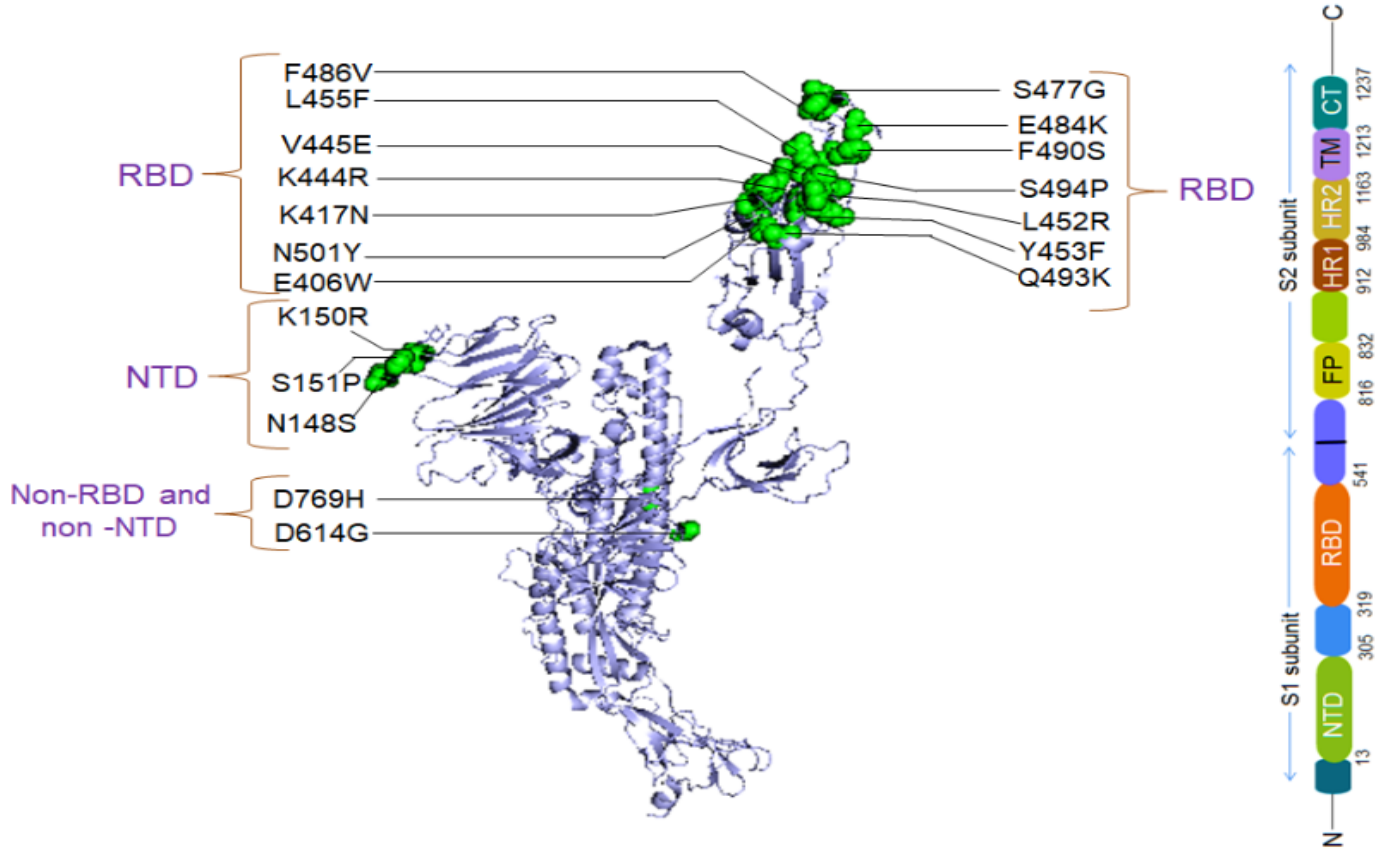
Dear Editor,

Two recent correspondence articles published in this journal about artificial intelligence (AI) in drug discovery and development are timely. The first article by Chakraborty C. *et al.* discussed AI in drug discovery and development, and the second article by Chakraborty C. illustrated AI in clinical trials[1,2]. These two articles elucidate the readers about the recent trend of AI in drug discovery and development. Recently, the increased application of AI has been observed in various sectors of society, including the healthcare sector. AI has been used in healthcare, from disease diagnosis to therapeutic discovery. AI-based drug discovery has played a significant role as a whole process of drug discovery and development. These two articles also provide significant information on AI-enabled drug discovery and development. However, one of the significant milestones of AI-based discovery was achieved by two companies, Exscientia and Sumitomo Dainippon Pharma, through the collaboration. Their discovered drug has entered into the clinical trial. Exscientia is a British start-up, and Sumitomo Dainippon Pharma is a Japanese pharmaceutical company. The drug molecule was developed using sophisticated AI methodologies, and the name of the molecule was DSP-1181[3]. Recently, AI-enabled ChatGPT has shown its application in other areas of medicine and healthcare, including drug discovery and development.

ChatGPT was popularized very fast after its first introduction in November 2022. It has been noted that more than one million users have utilized the AI-enabled device within 5 days after its release[4]. The ChatGPT's is a state-of-the-art natural language processing system ingeniously developed by OpenAI in 2022[5]. This cutting-edge system is endowed with the remarkable ability to generate human-like conversations by adroitly comprehending a conversation's context and producing appropriate responses. Using this characteristic, researchers and users have explored ChatGPT's several medical applications. Similarly, the AI-enabled ChatGPT application has been used in drug discovery and development. Recently, an article published in Nature Biotechnology has highlighted that he ChatGPT or large language models (LLM) are helping scientists to discover new drug targets. The article describes that AI-driven ChatGPT can map several potential drug targets, which helps drug discovery researchers from pharmaceutical companies in faster methods of drug discovery[6]. Therefore, there are immense possibilities that

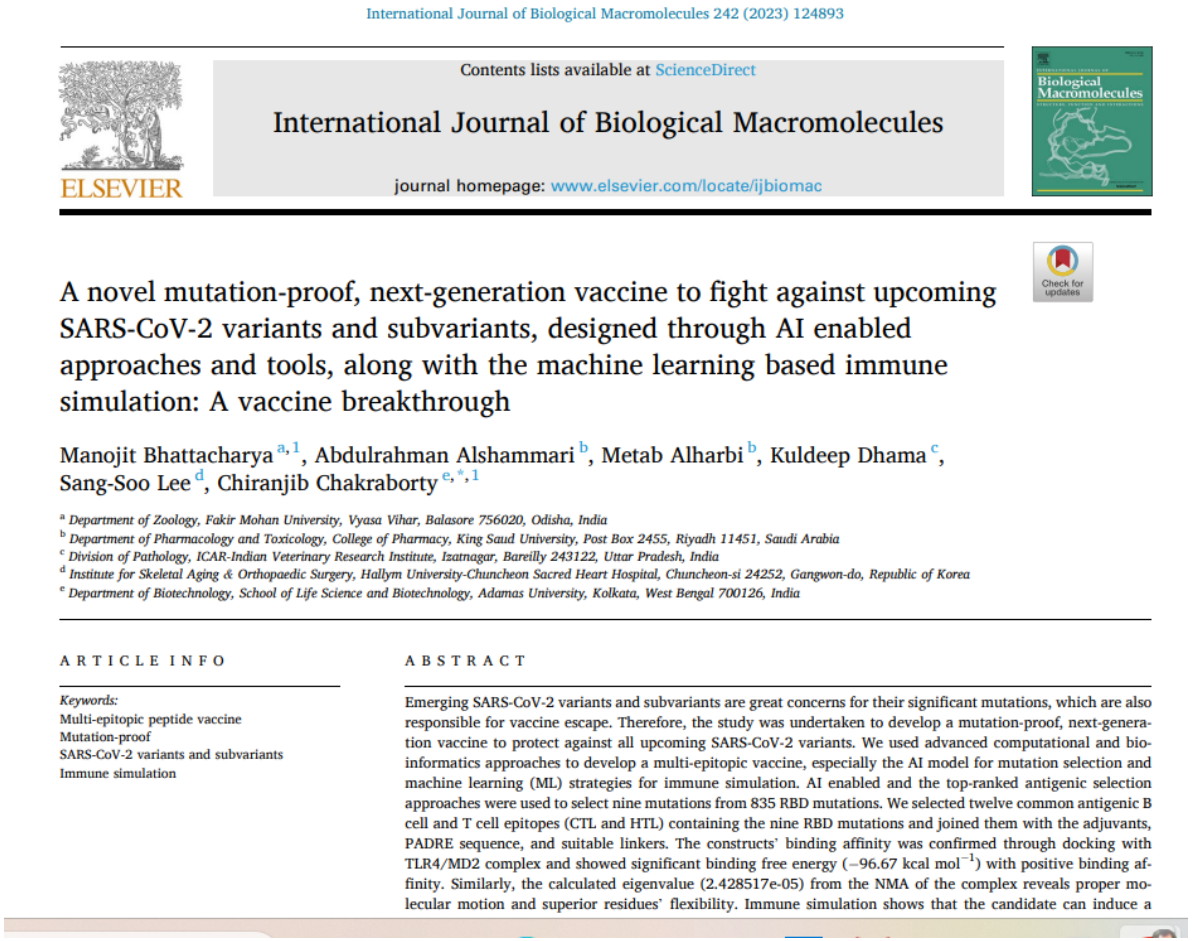
Pal S, Bhattacharya M, Islam MA, **Chakraborty C.** ChatGPT or LLM in next-generation drug discovery and development: pharmaceutical and biotechnology companies can make use of the artificial intelligence-based device for a faster way of drug discovery and development. Int J Surg. 2023 Dec 1;109(12):4382-4384. IF: **15.3**

Our Work: AI based mutation-proof vaccine to protect against current emerging Omicron sublineages and future SARS CoV-2 variants



Chakraborty C, Bhattacharya M, Sharma AR, Mohapatra RK, Chakraborty S, Pal S, Dhama K. Immediate need for next-generation and mutation-proof vaccine to protect against current emerging Omicron sublineages and future SARS-CoV-2 variants: An urgent call for researchers and vaccine companies - Correspondence. Int J Surg. 2022 Oct;106:106903. **IF: 15.3**

AI enabled approaches for Vaccine Development



International Journal of Biological Macromolecules 242 (2023) 124893

Contents lists available at ScienceDirect

International Journal of Biological Macromolecules

journal homepage: www.elsevier.com/locate/ijbiomac

A novel mutation-proof, next-generation vaccine to fight against upcoming SARS-CoV-2 variants and subvariants, designed through AI enabled approaches and tools, along with the machine learning based immune simulation: A vaccine breakthrough

Manojit Bhattacharya [a,1], Abdulrahman Alshammari [b], Metab Alharbi [b], Kuldeep Dhama [c], Sang-Soo Lee [d], Chiranjib Chakraborty [e,*,1]

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ARTICLE INFO

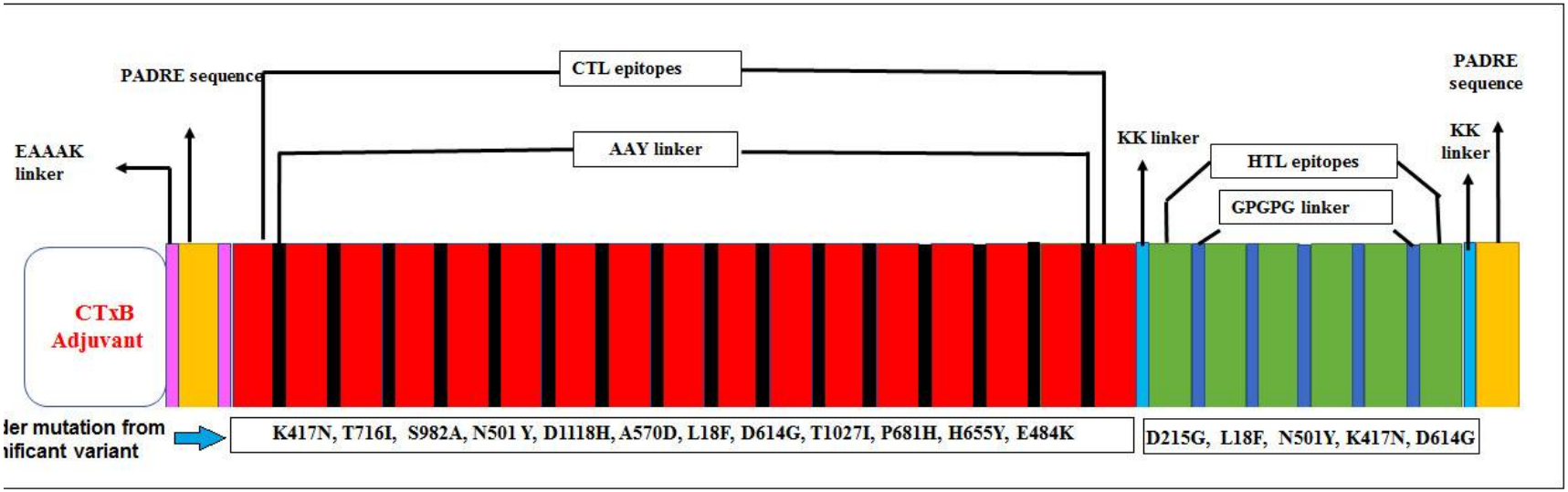
Keywords:
Multi-epitopic peptide vaccine
Mutation-proof
SARS-CoV-2 variants and subvariants
Immune simulation

ABSTRACT

Emerging SARS-CoV-2 variants and subvariants are great concerns for their significant mutations, which are also responsible for vaccine escape. Therefore, the study was undertaken to develop a mutation-proof, next-generation vaccine to protect against all upcoming SARS-CoV-2 variants. We used advanced computational and bioinformatics approaches to develop a multi-epitopic vaccine, especially the AI model for mutation selection and machine learning (ML) strategies for immune simulation. AI enabled and the top-ranked antigenic selection approaches were used to select nine mutations from 835 RBD mutations. We selected twelve common antigenic B cell and T cell epitopes (CTL and HTL) containing the nine RBD mutations and joined them with the adjuvants, PADRE sequence, and suitable linkers. The constructs' binding affinity was confirmed through docking with TLR4/MD2 complex and showed significant binding free energy (−96.67 kcal mol^{-1}) with positive binding affinity. Similarly, the calculated eigenvalue (2.428517e-05) from the NMA of the complex reveals proper molecular motion and superior residues' flexibility. Immune simulation shows that the candidate can induce a

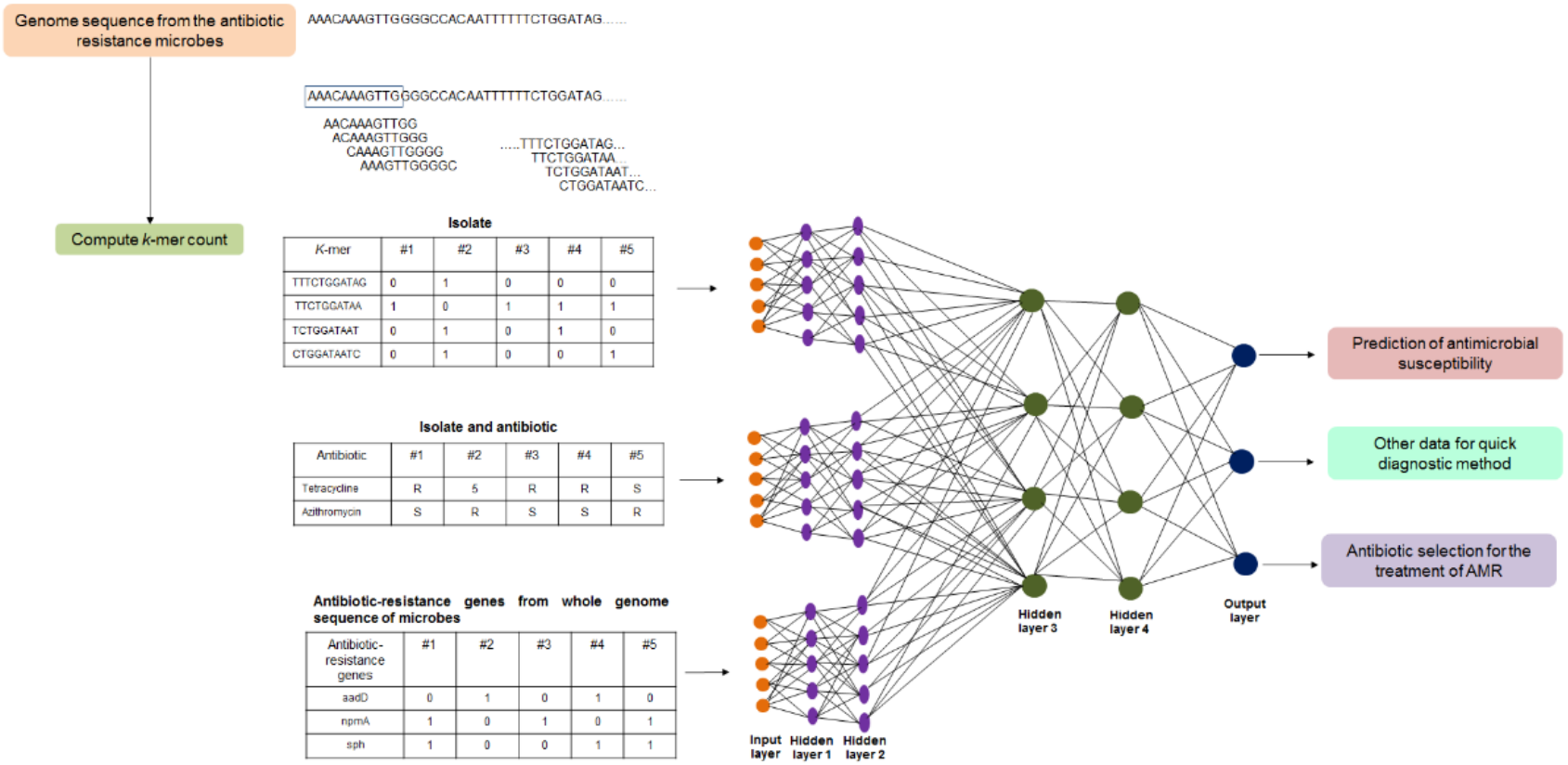
Bhattacharya M, Alshammari A, Alharbi M, Dhama K, Lee SS, **Chakraborty C.** A novel mutation-proof, next-generation vaccine to fight against upcoming SARS-CoV-2 variants and subvariants, designed through AI enabled approaches and tools, along with the machine learning based immune simulation: A vaccine breakthrough. Int J Biol Macromol. 2023 Jul 1;242(Pt 2):124893. **IF: 8.2**

mutation-proof vaccine to protect against current emerging Omicron sublineages and future SARS CoV-2 variants



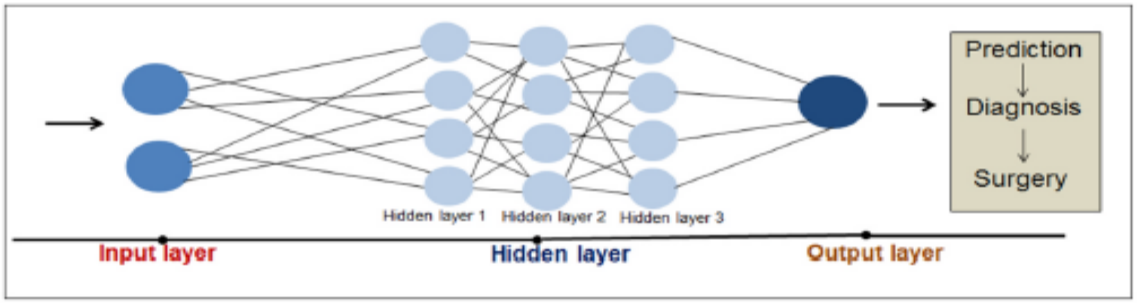
Source: Bhattacharya M, Sharma AR, Ghosh P, Lee SS**, Chakraborty C.** A Next-Generation Vaccine Candidate Using Alternative Epitopes to Protect against Wuhan and All Significant Mutant Variants of SARS-CoV-2: An Immunoinformatics Approach. Aging Dis. 2021 ;12(8):2173-2195. **IF: 7.4**

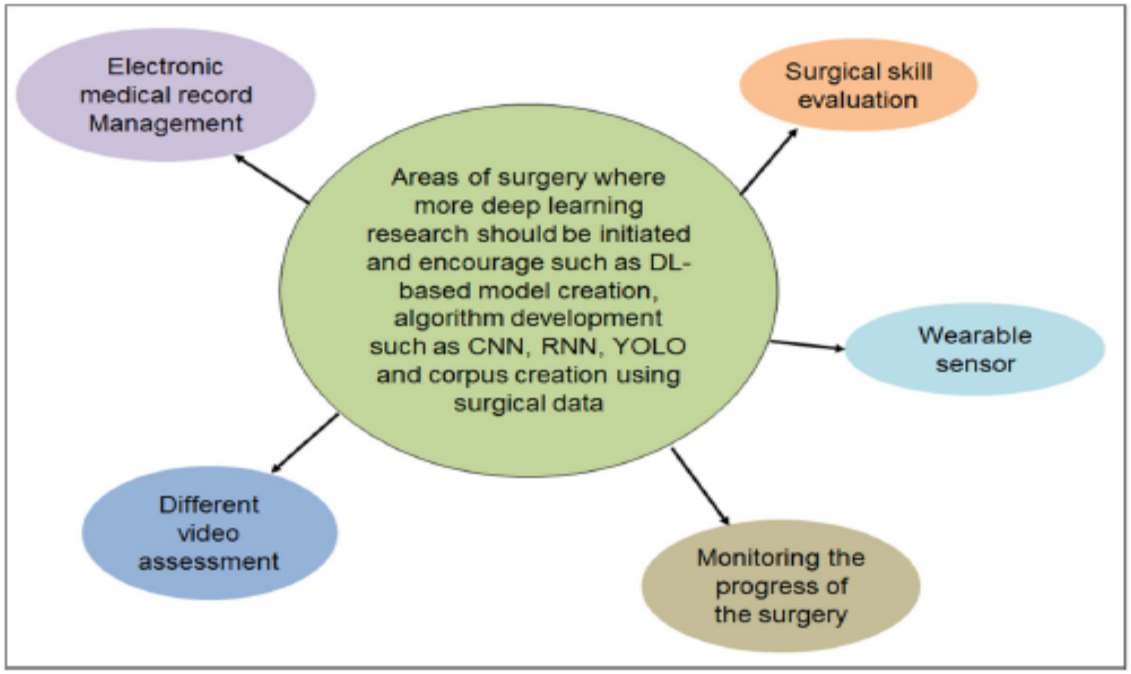
Our Work: Deep learning for diagnosis and treatment of antibiotic resistance of microbial infections



Chakraborty C, Bhattacharya M, Sharma AR**,** Roy SS, Islam MA, Chakraborty S, Nandi SS, Dhama K (2022) Deep learning research should be encouraged for diagnosis and treatment of antibiotic resistance of microbial infections in treatment associated emergencies in hospitals. International Journal of Surgery doi:10.1016/j.ijsu.2022.106857 IF: **15.3**

Our Work: Deep learning In surgery

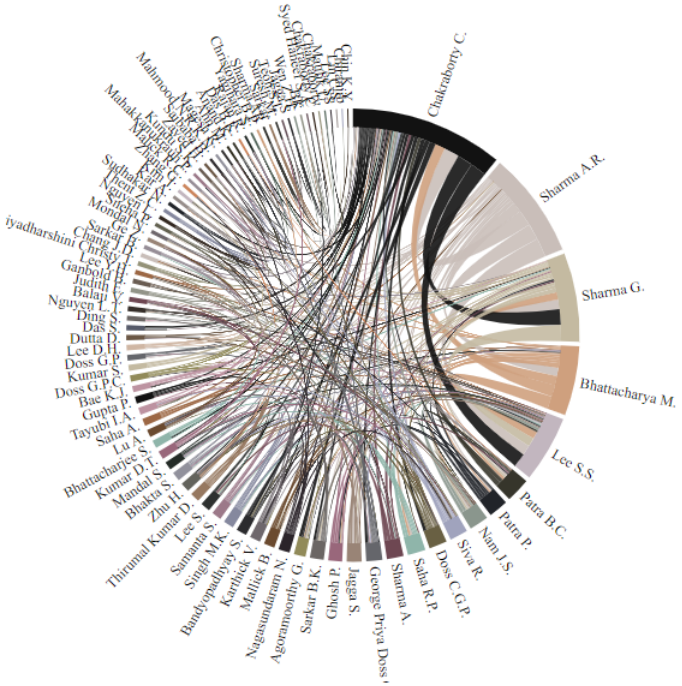




Chakraborty C*, Bhattacharya M, Sharma AR, Roy SS, Dhama K, Lee SS **(**2022) Deep learning research should be encouraged more and more in different domains of surgery: An open call . International Journal of Surgery 104:106749. doi: 10.1016/j.ijsu.2022.106749. **IF: 15.3**

Research Collaborations

- **International collaborations: 37**
- **National collaborations: 25**



Co-author Network (2013-2023); Data source: https://.irins.org/

Significant International Collaborators

**Professor Sang–Soo Lee,
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**Professor Prosun Bhattacharya,
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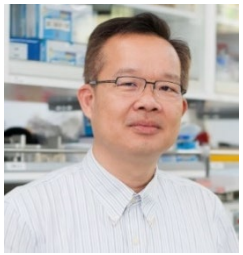
Sweden**

**Professor Siddappa N. Byrareddy,
University of Nebraska Medical Center
USA**

**Professor Alok Agrawal,
East Tennessee State
University,
USA**

**Professor Hsu, Minna J.,
National Sun Yat-sen University,
Taiwan**



**Professor Zhi-Hong Wen,
National Sun Yat-sen University,
Taiwan**

**Professor Hatem Zayed Ibrahim,
Qatar University,
Qatar**

Significant National Collaborators

Dr. Kuldeep Dhama,
Principal Scientist,
Indian Veterinary Research Institute,
Izatnagar- India

Professor Bidhan Chandra Patra,
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Professor Soumen Pal,
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Technology,
Tamil Nadu, India

Dr. George Priya Doss C,
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Tamil Nadu

Professor Sanjiban Sekhar Roy,
School of Computer Science and Engineering,
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Dr. Shyam Sundar Nandi
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ICMR-National Institute of
Virology Mumbai Unit

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Fakir Mohan University,
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My previous PhD students are now my collaborators

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Assistant Professor (Senior Grade)
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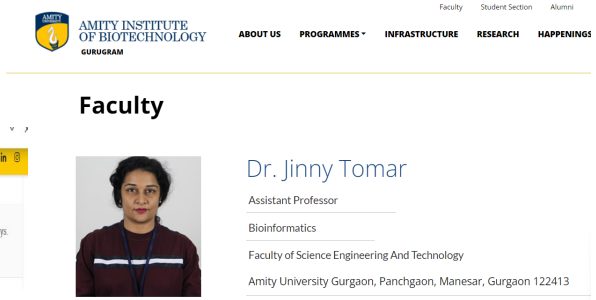
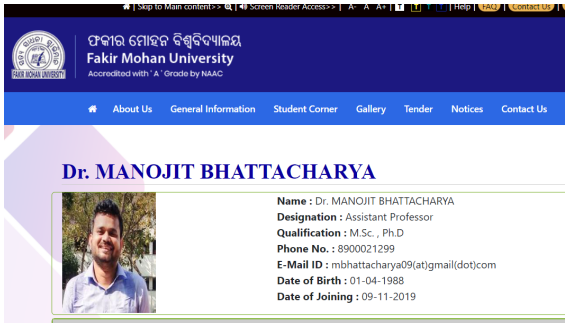
Amity University Gurgaon, Gurgaon

Dr. Manojit Bhattacharya
Assistant Professor,
Department of Zoology,
Fakir Mohan University, Odisha





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Laos eliminates lymphatic filariasis

Laos has become the 13th country in the WHO Western Pacific region to eliminate lymphatic filariasis. Sanjeet Bagcchi reports.

On Oct 16, 2023, WHO Western Pacific declared that the southeast Asian country Laos had eliminated lymphatic filariasis as a public health problem. WHO Director-General Tedros Adhanom Ghebreyesus applauded Laos for its achievement and presented a plaque and certificate to the country's Minister of Health Bounfeng Phoummalaysith at the 74th session of the WHO Regional Committee for the Western Pacific, which took place in Manila, Philippines, during Oct 16–20, 2023.

Acting WHO Regional Director for the Western Pacific Zsuzsanna Jakab credited Laos' success to the collective actions of health workers, communities, government, and partners. In the WHO Western Pacific region (which includes 37 countries and territories), Laos became the 13th country to eliminate lymphatic filariasis; the other 12 countries that have eliminated the disease since 2000 include, among others, South Korea, Vanuatu, Tonga, Viet Nam, and Cambodia.

Experts have commended Laos' initiatives and success in eliminating lymphatic filariasis. "[The country] could eliminate lymphatic filariasis as a result of its continuous efforts and successful strategies", said Chiranjib Chakraborty (School of Life Science and Biotechnology, Adamas University, Kolkata, India).

Achim Hoerauf (Institute of Medical Microbiology, Immunology and Parasitology, University Hospital Bonn, Bonn, Germany) commented, "Whereas elimination from Pacific Islands is somewhat easier because re-introduction of vectors carrying the infection can be controlled, this is a great success by yet another...country in [southeast] Asia".

Lymphatic filariasis is a neglected tropical disease caused by mosquito-borne nematodes—namely, *Wuchereria bancrofti*, *Brugia malayi*, and *Brugia timori*. The disease leads to damage of the lymphatic system, causing painful and disfiguring features (eg, lymphoedema, elephantiasis, and hydrocele), along with disability, stigma, and poverty. According to WHO, 882·5 million people in 44 countries in 2021 lived in areas that needed preventive drug treatment to stop lymphatic filariasis transmission. This is in spite of a 74% decrease in infections between 2000—the year that marked the beginning of WHO's Global Programme to Eliminate Lymphatic Filariasis—and 2018.

To eliminate lymphatic filariasis from Laos, health authorities and partners provided preventive medication to communities at risk of the infection. The elimination initiatives received a boost through activities to reduce dengue and malaria in the country, such as distribution of insecticide-treated bednets, and health education-related drives. Adding to that, partners and donors provided assistance in various activities—for example, administration of medicines and conducting a survey to evaluate the spread of the disease, among others.

Joseph Kamgno (University of Yaoundé 1, Yaoundé, Cameroon) told *The Lancet Infectious Diseases*, "The elimination of lymphatic filariasis in Laos is very welcome news for the entire community of researchers and public health practitioners working for decades for the elimination of lymphatic filariasis." Kamgno reflected on "the despair of a patient [in Cameroon] who had developed severe lymphoedema and was seeking for treatment or care", describing it as "a human tragedy, as it is for people all over the world who suffer from this disease".

Some of the countries in the WHO Western Pacific region where lymphatic filariasis is still endemic include Malaysia, the Philippines, French Polynesia, Brunei, and Fiji, among others. Hoerauf told *The Lancet Infectious Diseases*, "Elimination of [lymphatic filariasis] from Laos should spur the ambition of other endemic countries that [lymphatic filariasis] elimination, if consequently pursued, is feasible".

He commented, "I strongly believe that in addition to drug access for mass administration, as well as use of bednets, another key factor is a good population directory [record of population data], in order to achieve the necessary coverage when distributing drugs and not leave segments of the population treated less frequently".

Chakraborty said, "Countries [in the WHO Western Pacific region] that are yet to eliminate the disease should analyse their shortcomings, and rectify their strategies accordingly; for example, they might adopt appropriate measures in terms of disease awareness and health education".

For countries in the WHO Western Pacific region such as Laos that have eliminated lymphatic filariasis, it is important to maintain the status of elimination. According to WHO Laos representative Dr Ying-Ru Lo, it is necessary for the country to invest resources to "sustain and build on this momentum, by maintaining essential health services and continuing to stamp out more diseases".

Sanjeet Bagcchi

DNDi receives Dutch funding boost

The recent grant awarded by the Dutch government to The Drugs for Neglected Diseases Initiative will help to focus on research on neglected diseases in girls and women

The Drugs for Neglected Diseases initiative (DNDi)—a not-for-profit organization headquartered in Geneva, Switzerland, which works in the field of medical research—has been awarded a grant worth EUR 14 million by the Dutch Ministry of Foreign Affairs for a period of five years, from 2022 to 2027.

The funding will be provided to assist the aim of DNDi to develop 8–10 new treatments for poverty-related diseases, especially those that disproportionately affect and harm women of childbearing age. A February 2023 press statement by DNDi revealed that the diseases for which the grant has been announced include Chagas disease, mycetoma, leishmaniasis, sleeping sickness, and dengue, among others.

According to WHO, neglected tropical diseases (NTDs) refer to a varied group of diseases that are predominantly prevalent in tropical regions; these diseases are mainly observed in poverty-stricken communities. NTDs lead to disastrous health, social, and financial consequences for over one billion people, notes WHO.

A study conducted in Kenya and published in 2021 suggests that women and girls are disproportionately affected by NTDs owing to their gender related roles and responsibilities. They carry out heavy work for home and family and this increases their risk for NTDs including trachoma, visceral leishmaniasis, and schistosomiasis. The study also pointed out that as women take care of their children infected with NTDs, with time they become more likely to develop the same NTDs due to transmission.

Joelle Tanguy (DNDi, Geneva, Switzerland) told *The Lancet Infectious Diseases* that women and girls often have "less access to medical care. Meanwhile their specific medical needs are widely overlooked in traditional biomedical R&D [research and development]". "For example", said Tanguy, "women are often excluded from clinical trials, resulting in a lack of important data related to physiological differences—especially data concerning medicine safety and efficacy in pregnant or breastfeeding women".

According to Tanguy, there are disparities in women's access to treatments in contexts where gender barriers undermine their ability to get timely diagnosis and care, and this especially affects poor and rural women in resource-constrained healthcare environments. She said, "Let's take the example of dengue, a climate-sensitive disease now becoming a global threat: dengue infection leads to a three-fold increase in the risk of maternal death, and [there is] a 450-fold increase in the risk of maternal death with severe dengue".

Since 2006, the Dutch Ministry of Foreign Affairs has been collaborating with DNDi in terms of financial assistance, and thanks to such long-term support, DNDi could devise and ensure access to several new treatments for neglected diseases; it could also reinforce health care systems and boost the capacity to conduct research in resource-limited settings.

"We are working on identifying, developing, and delivering new, better, effective, safe, affordable, accessible, and easy-to-administer drugs", said Tanguy. "With the support from the Netherlands Ministry of Foreign Affairs, we will drive these activities with a gender-responsive lens: with careful attention to include women in clinical trials, to facilitate their access to treatment, and to promote women's leadership in science, including as lead investigators in trials and in scientific authorship," she pointed out.

The 2023–2030 Dutch Global Health Strategy aims to play a part in the betterment of public health across the world in a coordinated and targeted way. The strategy includes product development partnerships. The funding will enable DNDi to form a network of partners including low- and middle-income countries (LMICs) and reinforce LMICs' capacity for "discovery and clinical research".

Chiranjib Chakraborty (School of Life Science and Biotechnology, Adamas University, Kolkata, India) told *The Lancet Infectious Diseases* that "DNDi was developed as a non-profitable R&D organization for developing drugs for neglected diseases. To support the development of new drugs for NTDs, this organisation is working constantly. And the grant from the Dutch Ministry of Foreign Affairs will boost the development of more new treatments for NTDs through DNDi, and it will improve the NTDs situation in LMICs".

Tanguy added, "We are extremely grateful to the Netherlands Ministry of Foreign Affairs, and I would recommend funders to join the Netherlands and continue investing in science to find new treatments for neglected diseases, especially those that disproportionately affect women, and to integrate gender equity into all aspects of global health initiatives, including in research, to ensure that the specific and highly neglected needs of women are addressed."

DNDi carries out its activities through funding from various public and private donors, including Bill & Melinda Gates Foundation, Médecins Sans Frontières USA, Médecins Sans Frontières Brazil, and Medicor Foundation (UK).

Sanjeet Bagcchi

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UNICEF report reveals gender gaps persist in HIV

The *2023 Global Snapshot on HIV and AIDS* revealed that progress is stalling for children and adolescents with HIV, particularly among girls. Manjulika Das reports.

UNICEF's latest updates on HIV in children, adolescents, and pregnant women—described in the *2023 Global Snapshot on HIV and AIDS* report that was released ahead of World AIDS Day (Dec 1, 2023)—revealed that there were 98 000 new HIV infections among adolescent girls in 2022, making them more than twice as likely to contract HIV as boys. UNICEF estimated that every day in 2022, 356 children aged 0–14 years and 384 adolescent girls aged 10–19 years contracted HIV and 271 children and adolescents aged 0–19 years died from AIDS-related causes.

The report suggested that despite significant successes, the progress in combating HIV is stalling: "In 2022, half as many (47%) of adolescent girls and young women acquired HIV as in 2010. Even with this decline, we are not on track to meet our 2030 target to end new HIV infections among adolescent girls and young women". 71% of new HIV infections in adolescents aged 10–19 years in 2022 were among girls. In sub-Saharan Africa, prevalence of HIV among adolescent girls and young women aged 10–24 years was more than three times higher relative to their male counterparts.

A survey in South Africa that was published in 2022 suggested that a key factor for sustaining high HIV incidence among adolescent girls and young women is their male partners. According to the survey, adolescent girls and young women who are engaged in relationships with so-called Blessers (ie, male partner providing material needs to the female partner in return for sex) or age-disparate partners have an increased HIV risk.

Anurita Bains, UNICEF Associate Director of HIV/AIDS, told *The Lancet Infectious Diseases*: "We know gender inequalities, discrimination, violence, denial of rights, and poverty render adolescent girls at risk of HIV. A lack of basic knowledge about sex and sexuality and limited access to sexual and reproductive health services compound those vulnerabilities". She added, "There are still major gaps in basic HIV prevention programmes for adolescent girls and young women, and many have very little control over their sexual lives".

To combat this problem, Bains said that "programmes must do better at enabling girls and women to access quality HIV and sexual and reproductive health services, and to live healthy lives". She added, "We know there isn't one solution or quick fix. The evidence shows that adolescent girls need access to comprehensive services beyond health, to reduce their risk of HIV. This includes keeping all girls in school (including pregnant adolescents and young mothers), violence prevention, and linking adolescent girls exposed to violence to services".

Chiranjib Chakraborty (School of Life Science and Biotechnology, Adamas University, Kolkata, India) said: "Every nation [should] take immediate steps and prepare immediate and long-term strategies targeted at adolescent girls to fight against [HIV/AIDS]. And the strategies should be implemented quickly. The highest focus should be [on] HIV testing, especially [for] middle- and lower-income countries".

"At the same time, there is a need for HIV education in schools, which [should highlight] the prevalence of HIV among adolescent girls and women, along with topics such as HIV transmission, prevention, mortality, and how to live with HIV", Chakraborty added.

The report also revealed that the yearly number of new vertical HIV infections among children aged 0–14 years decreased by more than 75% between 2000 and 2022. However, almost one in five pregnant and breastfeeding women with HIV in 2022 did not receive antiretrovirals (ARVs) to protect their health and prevent vertical transmission of HIV. Additionally, in 2022, four in ten HIV-infected infants did not receive a timely diagnosis.

According to the report, children and adolescents with HIV face substantial problems compared with adults in accessing treatment. In 2022, nearly half of the 1·5 million children with HIV did not receive ARVs. An estimated 84 000 children died.

Bains said, "Globally, 77% of people living with HIV have access to treatment—this is a great achievement in global public health in the last two decades. But children and adolescents living with HIV are not benefitting from the treatment scale up. Only 57% of children and adolescents living with HIV have access to treatment. The treatment gap is unacceptable and we need to address this appalling inequity". She added, "We need to prioritise children and adolescents in funding proposals and decision making on how funds are allocated".

According to Bains, "Until recently, the absence of child-friendly, well tolerated and clinically optimal HIV treatment has been a major drawback for children living with HIV. Now we have dolutegravir-based ARV regimens for children, which is a breakthrough".

"We need additional strategies for case finding—working with community health workers to identify children and adolescents who may be living with HIV but are undiagnosed, and link them to treatment and care", Bains commented.

Manjulika Das

Matthew Oliphant/Science Photo Library

For the **report** see https://www.childrenandaids.org/sites/default/files/2023-11/2311130%20UNICEF_HIV_Global_Snapshot_2023UPDATED_0.pdf

For the **survey** see *BMC Public Health* 2022; **22**: 973

“Where the mind is without fear and the head is held high
Where knowledge is free
Where the world has not been broken up into fragments
By narrow domestic walls
Where words come out from the depth of truth
Where tireless striving stretches its arms towards perfection……..
……
Into that heaven of freedom, my Father, let my country awake.” Rabindranth tagore

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