REVIEW ARTICLE

Pharmaco-Cybernetics: A New Frontier in Personalized Medicine

Koppula Jyothi[1], Koppula Sirisha[1], Rajagiri Triveni[1], Reehana Shaik[2], Himaja Rama Tulasi Kanakamedala[1], Gnana Triveni Darisa[1], Mounika Derangula[1], Gnana Nitya Kambham[1], Suneetha Achanti[1]

[1]Department of Pharmaceutical Analysis, KVSR Siddhartha College of Pharmaceutical Sciences, Vijayawada, Andhra Pradesh, India, [2]Department of Pharmacy, KL University, Koneru Lakshmaiah Education Foundation, Vaddeswaram, Andhra Pradesh, India

Abstract

Pharmaco-cybernetics, also referred to as pharma-cybernetics, cybernetic pharmacy, and cyberpharmacy, is an emerging field that describes the science of assisting in the use of drugs and medications by applying and assessing informatics and internet technologies to enhance patient pharmaceutical care. To design, develop, apply, and assess technological innovations that enhance drug and medication management as well as prevent or resolve drug-related issues, this interdisciplinary field integrates the fields of medicine, pharmacy, and computer sciences (informatics, cybernetics, interactive digital media, and human–computer–environment interactions), and psychological sciences. The designs of these technology advancements are typically activity-centered, experience-centered, and user-centered. The conceptual background, utilization, obstacles, and future prospects of the discipline of pharmaco-cybernetics are all thoroughly discussed in this review paper. The potential advantages of pharmaco-cybernetics include improving treatment results, lessening side effects, and boosting patient safety. This review highlights the importance of addressing the limitations and downsides of pharmaco-cybernetics, such as obstacles related to regulations, integration of systems, and safeguarding information and safety. The potential applications in the field of development of new drug moieties, individualized medicine, safety surveillance, and monitoring means drug safety are discussed. To promote new research avenues and partnerships that will spur innovation and advancement in medication therapy and patient care, this review attempts to give a thorough overview of this quickly expanding field. In the end, pharmaco-cybernetics is an alarming and quickly developing topic that merits more research and funding since it has the potential to improve healthcare outcomes and change the angle of perception of people toward pharmaceutical therapy. To fully exploit pharmaco-cybernetics and revolutionize healthcare delivery, the information acquired in this review article ends with a need for additional study and development.

Key words: Artificial intelligence, pharmaco-cybernetics, pharmacology, real time data analysis

INTRODUCTION

Pharmaco-cybernetics, one of the more modern disciplines that includes systems theory, cybernetics, and computational modeling into pharmacology, allows for a deeper comprehension of drug interactions, the intricate connections between biological systems, and external consequences. This approach's ability to predict and describe the dynamic behavior of drug-biological systems is its main benefit. It simulates non-linear interactions and feedback loops in addition to pharmacokinetics (PK) and pharmacodynamics (PD). Pharmaco-cybernetics[1] allows for a far more thorough examination of treatment results by modeling and analyzing how medications respond to whole-organ systems from molecular targets using computational tools and algorithms.

Because of this, pharmacology's knowledge of how drugs function has entirely evolved, moving away from linear

Address for correspondence:
Dr. Reehana Shaik, Department of Pharmacy, KL University, Koneru Lakshmaiah Education Foundation, Vaddeswaram, 522302, Andhra Pradesh, India.
E-mail: drskreehana@gmail.com

Received: 20-02-2026
Revised: 23-03-2026
Accepted: 29-03-2026

models and toward more dynamic systems models. This change is especially important in the age of customized medicine, where individual differences in drug sensitivities are a major problem. Using pharmaco-cybernetics, these problems can be resolved. Individual differences in medication ADME, receptor binding, signal transduction, and eventually overall pharmacological effects can be modeled using cybernetic principles.[2] Pharmaco-cybernetics has excellent potential for enhancing drug dosage regimes. The growing use of internet technologies and informatics in the field has led to the development of a wide range of software, tools, and applications for patients and healthcare professionals to enhance pharmaceutical care and health-related outcomes. Informatics and internet technologies are used to address drug-related issues in pharmacoinformatics, also known as pharmacy informatics,[3] a subfield of e-health. By combining the study of technology with the relationships between people, computers, and the environment, pharmaco-cybernetics takes things a step further. This makes it possible for technological advancements to be planned, developed, put into practice, and evaluated in relation to encouraging drug and pharmaceutical use and reducing or avoiding drug-related issues.

CONCEPTUAL FRAMEWORK OF PHARMACO-CYBERNETICS

Integrating pharmacology with systems control theory to maximize drug delivery and therapeutic results is the foundation of the pharmaco-cybernetics[4] conceptual framework. To make sure that medication administration is in line with changing physiological reactions, it makes use of modeling, feedback, and adaptive control mechanisms.

This is an organized explanation of its conceptual foundation:

The fundamentals of pharmaco-cybernetics

Biological target or pharmacological system

The organ or body system of the patient (e.g., the blood glucose system in diabetes). It contains information on medication PD and PK.[5] Models include disease progression models, target–receptor interactions, and compartmental PK/PD models**.**

Regulatory system cybernetic controller

The device uses sensor data analysis to make decisions and control drug dosage. Systems with sliding scale insulin, proportional-integral-derivative controllers with model predictive control, and adaptive learning systems (artificial intelligence [AI]/machine learning [ML]-based controllers) are examples of these types of systems.

Mechanisms for sensors and feedback

Real-time physiological variable measurements, such as blood pressure, blood glucose, and plasma medication concentration, make it possible for the controller to receive ongoing monitoring and feedback. Wearable sensors, lab-on-a-chip systems, and implantable biosensors are examples of technologies.

Feedback control loop (model cybernetic)

The cybernetic-based feedback control loop starts with the ongoing measurement of a physiological parameter, such as blood sugar levels. Any variation is then found by comparing this sensed data to the set-point, or planned therapeutic target. This divergence is used by the controller to calculate the dosage of medication needed to rectify the imbalance. After this calculation, the system gives the patient the recommended dosage of the drug.[6]

The medication's action causes a change in the physiological parameter, which is then sensed again. This continuous sensing and modification creates a closed-loop framework that maintains its physiological state within the targeted therapeutic range.

Complementary concepts and technologies

As a result of the growing combination of complementary concepts and technologies, the concern and safety for patients is becoming more personalized, effective, and data-driven. To better understand and predict the complicated interactions within human body systems, it is essential to use mathematical modeling. PK and PD[7] mathematical models illustrate in what manner drugs impact the body and are absorbed, transported, digested, and eliminated. These models are essential for better treatment outcomes and pharmaceutical dosage management. AI, which is accomplished through autonomous control and pattern recognition, improves these models. These AI systems can analyze larger volumes of data to find trends and predict patient responses, which results in more customized treatment regimens. For example, by examining data from continuous glucose monitors, AI can predict hypoglycemia episodes in diabetic patients, enabling prompt therapies and individualized care. The Internet of Things (IoT) and telemedicine,[8] which offer data transfer and remote monitoring, further improve these technologies. Medical professionals receive physiological data continuously collected by wearable sensors and other IoT devices through telemedicine systems. Real-time patient health status monitoring is made possible by this connectivity, which makes it easier to identify possible problems early and take prompt[9] action.

EVOLUTION OF PHARMACO-CYBERNETICS

Pharmaco-cybernetics, also known as pharmacological cybernetics or pharmacoinformatics, is a multidisciplinary

field that integrates information technology, cybernetics, and pharmacology concepts to optimize drug therapy through the use of computational tools and models. The following pivotal moments shed light on its historical beginnings and evolution.

Initial pharmacology

The ancient discipline of pharmacology, which examines drugs and their effects on living organisms, is where pharmaco-cybernetics got its start. Ancient societies such as the Greeks, Chinese, and Egyptians documented[10] the use of many natural substances for medicinal purposes.

Introduction of computers

Modern computing technology emerged in the middle of the 20th century, creating new opportunities for pharmaceutical data storage and analysis. The ability to swiftly process enormous amounts of data allowed for more sophisticated approaches to drug development and discovery.

Cybernetics

The goal of this field, which emerged in the 1940s and 1950s, was to understand the feedback and control mechanisms present in both machines and biological systems. Cybernetic ideas such as feedback loops[11] and system optimization have become crucial for studying complex biological systems, particularly pharmaceutical procedures.

Early computational pharmacology

In the 1960s and 1970s, researchers began using computers to mimic PK and PD processes. These early computational models helped scientists understand how drugs interact with biological targets to produce therapeutic effects as well as how they are absorbed, transported,[12] digested, and removed by the body.

Information technology advances

The rapid advancement of information technology in the second half of the 20th century accelerated the development of pharmaco-cybernetics. The availability of powerful computers, sophisticated software, and large datasets enabled the effectiveness of virtual screening, molecular modeling,[13] and other computational techniques to identify potential drug candidates.

Integration of omics data

Proteomics, metabolomics, and genomics are examples of high-throughput technologies that have revolutionized pharmacological research by making a vast amount of biological data accessible. Pharmaco-cybernetics has been crucial in integrating and assessing omics data to identify biomarkers, elucidate drug mechanisms of action, and customize medicine therapy based on individual genetic profiles.

Systems pharmacology's development

Systems pharmacology, an interdisciplinary technique that combines computational modeling and experimental methodologies to study medication effects at the systems level, has become a crucial part of pharmaco-cybernetics in recent years. Systems pharmacology considers the complex interactions between drugs, biological processes, and disease networks to optimize treatment efficacy and minimize side effects.

TECHNOLOGIES ENABLING

Pharmaco-cybernetics is a new multidisciplinary field that combines pharmacology, cybernetics, systems biology, and computational modeling to improve pharmaceutical therapy and personalized care. It improves patient safety, drug research, and discovery by utilizing technologies such as AI, ML, and IoT.

Systems biology and computational modeling and simulation

Includes ML, AI, and computational fluid dynamics.

Personalized medicine

Smart inhalers, insulin pens, wearable sensors, and reproductive genomics for patient monitoring.

Patient participation and empowerment

Telemedicine and remote consultations, real-time support and feedback, and interactive patient education.

Neural networks, deep learning, and ML are some of the technologies that define the modern field of AI.[14] An important turning point in the development of AI was the phrase "Artificial Intelligence" (Wilks, 2023), which was coined by John McCarthy. AI's widespread use in fields including robotics, computer vision, natural language processing, and more defines its current state. AI and cybernetics combine to create intelligent,[15] adaptable systems. AI-driven control systems in self-driving cars, smart city development, and groundbreaking developments in medical diagnostics are a few notable examples (Yang *et al*., 2017). Social and ethical issues, such as the appropriate creation and implementation

of these interconnected systems, continue to be central to conversations (Tzimas, 2021). However, the possibility of brain-machine interfaces, neural interfaces, and human enhancement creates new opportunities for study and development.

Integration with Internet of Medical Things (IoMT)

The IoMT creates a sophisticated health-tech ecosystem that improves real-time diagnosis and increases healthcare quality and efficiency by fusing wireless connectivity with medical equipment. IoMT equipment, such as smartphone-based point-of-care systems, enables remote monitoring and diagnostics using non-invasive samples such as sweat and saliva, making healthcare more accessible and economical, especially in remote areas. AI and IoMT devices can be integrated to provide individualized treatment regimens and powerful data analytics, which can help forecast and manage complicated diseases such as diabetes and cancer. IoMT technology covers a range of wearable gadgets and sensors that monitor physical activity and vital signs, helping to collect data and monitor patients continuously for improved healthcare results.

"Electronic health records (EHRs) are becoming more and more common and are useful for both drug development and patient treatment since they may uncover patterns of drug use and illness correlations. Electronic management solutions are required due to the increasing amount of chemical data, and there are several databases available for drug discovery. By employing signals to notify doctors, clinical event monitors assist in identifying adverse drug responses in intensive care units.

AI and ML

Pharmacy Education Using Augmented and Virtual Reality Medical students at Australia's Bond University in Queensland have access to state-of-the-art learning resources. Among these are augmented reality systems that allow the manipulation of 3D anatomical models and virtual settings for investigating interior organs.

To fully immerse oneself in virtual reality events, consumers must feel as though they are physically present. This "presence," in Slater's opinion,[16] depends on two essential elements: How strongly people feel physically situated within the virtual environment, which is known as the place illusion. In essence, this indicates their level of immersion.

Automation

Pharmaceutical operations automation is a technology that is essential to improving efficiency, accuracy, and consistency at different phases of medication discovery, manufacture, and distribution. Because it lowers human error, automation is crucial to pharmaceutical operations. Without a question, quality assurance workers now have it simpler than they did in the past. To stay up with the automated systems, staff members[17] need to acquire new abilities. These are some of the new skills: Managing and analyzing digital data. Employees need to be properly trained to handle and comprehend data because it is all digital in the automated world.

ETHICAL, LEGAL, AND REGULATORY CONSIDERATIONS OF PHARMACO-CYBERNETICS

Ethical considerations

Self-reliance and informed consent

Patients need to be completely aware of how cybernetic tools influence their medication regimes; explicit, transparent agreement is required for decisions made or supported by algorithms. It is crucial to respect mental privacy and identity, particularly when systems have an impact on judgment or thought processes.

Non-maleficence versus beneficence

These systems need to improve outcomes without turning dangerous. It is crucial to always look for errors or biases. To avoid harm, cybernetic[18] technologies must appropriately prioritize instances and forward complex cases to individuals.

Equity and justice

There is a problem with fair access. Inequalities could worsen if advanced technology primarily benefits wealthier patients. Preventing socioeconomic or demographic biases in system design or deployment is essential.

Accountability and openness

Establishing clear lines of accountability between institutions, medical professionals, and instrument manufacturers is essential. Legal deficiencies can be filled with the use of frameworks for ethical governance.

Legal and regulatory considerations

Approval and classification of devices

Many cybernetic systems are subject to FDA 510(k) and Class II or III regulations, which govern medical devices. Systems with greater autonomy might need longer review periods and more stringent control.

Standards for risk management

Risks are recognized, reduced, and regularly assessed[19] when frameworks such as ISO 14971 are followed.

Data privacy and security

HIPAA (USA), GDPR (EU), APPI (Japan), and other laws govern the handling of private and sensitive pharmaceutical data; these laws call[20] for robust encryption, access restriction, and anonymization. Cybersecurity precautions are essential to stop sensitive data or dosing algorithms from being tampered with.

AI regulation and upcoming laws

The Cyber Resilience Act and the EU AI Act are two proposals that would place further restrictions on medical cybernetic systems. Pre-market evaluation[21] is necessary for software-as-a-medical-device technologies used in pharmacotherapy.

Insurance and liability

There are regulatory loopholes about who has liability for mistakes – the institution, the developer, or the clinician? Regulations (such as tort and profession-specific laws) must change to make it clear who is liable when automation results in certain outcomes.

International harmonization and cross-border

International development and deployment are complicated by regulatory differences (FDA vs. EMA vs. PMDA, etc.). Mutual acceptance and harmonized standards can expedite worldwide implementation.

APPLICATIONS OF PHARMACO-CYBERNETICS

A developing multidisciplinary[22] field called pharmaco-cybernetics blends systems biology, cybernetics, computational modeling, and pharmacology. Its primary goals are to enhance medication therapy, enhance patient outcomes, and promote personalized medicine using technology to comprehend and treat drug-related issues. These are some important pharmaco-cybernetics applications.

Optimized dosing and personalized medicine

Predictive modeling

This technique uses AI, ML, and big data analytics to forecast how each person will react to medications while taking into account variables including disease condition, metabolism, and genetics (pharmacogenomics).

Customized Dosage Plans: Creating dynamic models that can forecast the duration of a drug's effects and include physiological feedback systems to modify dosages for specific patients to minimize side effects and maximize therapeutic benefits.

Drug behavior simulation

To comprehend how pharmaceuticals[23] function on molecular targets and whole-organ systems, PK (what the body does to the drug) and PD (what the drug does to the body) are modeled using feedback loops and non-linear interactions.

Drug development and discovery

Effective Drug Design: This uses computational tools and algorithms to simulate and analyze drug interactions at different biological levels, which speeds up the drug development process.

Determining drug-drug interactions

Creating sophisticated models that might help understand mechanisms and predict potential adverse effects by illuminating complex interactions between various drugs. This includes specialized databases for complex drug combinations, such as those used in chemotherapy.

Adverse drug reaction (ADR) prediction

Early management and prevention are made possible using ML techniques (such as principal component analysis and multiple correspondence analysis) to identify clinically relevant predictors of ADRs. This has been used to treat conditions including nausea and vomiting caused by chemotherapy.

Enhancing patient safety and pharmaceutical care

Speaking about drug-related issues at every step of the digital healthcare innovation cycle, from problem knowing to technology design, development, application, and evaluation, is known as the "Digital Health Innovation Cycle." Clinicians and researchers[24] can easily obtain detailed information about drugs, their activities, sources, and possible interactions through the creation and use of massive computerized databases known as computerized electronic drug information records.

CHALLENGES AND LIMITATIONS

Data safety and security

Pharmaco-cybernetics requires appropriate data privacy and security measures because it depends so heavily on confidential patient data. These hazards include the possibility of worse results, a decline in public trust, and violations of patient identity and privacy.[25] Reducing risks such as these requires putting in place robust defenses against cybercrime, using cutting-edge encryption techniques, and abiding by regulations such as GDPR and HIPAA.

Connectivity with existing systems

Healthcare systems differ greatly in terms of their capabilities, technology, and design. Integrating cybernetic solutions[26] into such diverse ecosystems is fraught with difficulties. Compatibility problems, a lack of defined protocols, and the presence of outdated systems that might not be able to handle new technology can all hinder integration. To ensure successful implementation, large expenditures in infrastructure upgrades and comprehensive staff training are required.

Clinical evaluation

Pharmaco-cybernetic systems must undergo a rigorous clinical validation[27] procedure to guarantee their reliability, safety, and efficacy before being widely used. These systems' inherent complexity, which involves biological and computational components, makes validation extremely difficult. Furthermore, to assess these systems' performance in real-world scenarios, strong frameworks are required.

User acceptability

The effectiveness of pharmaco-cybernetic solutions depends on patient and medical professional acceptance. Adoption can be severely hampered by usability problems, resistance to change, and a lack of faith in technology. Strong training programs, a user-centric design approach, and a clear demonstration of the real benefits of these systems are required to address these problems.

Ethical concerns

Among the major ethical[28] challenges raised by the development of pharmaco-cybernetics are ensuring fair access, reducing algorithmic bias, and maintaining decision-making transparency. To overcome these obstacles, clear ethical norms must be established, and open communication among interested parties – including ethicists, physicians, and legislators – must be encouraged.

Barriers imposed by regulations: Pharmaco-cybernetics' regulatory framework[29] is currently being developed. The unique features of cybernetic systems, such as real-time data processing and ML algorithms, might not be adequately covered by current legislation. Comprehensive policies that protect patient safety and promote innovation are crucial.

Financial concerns

The development, installation, and upkeep of pharmaco-cybernetic systems are costly. Continuous upgrades, employee training, system integration, and technology purchases are some of these expenses. It is still very difficult to balance cost and quality, particularly in environments with few resources.

Preserve technological parties

Pharmaco-cybernetics systems are greatly impacted by the quick development of technologies such as wearables, data analytics, and AI. Continued research and development expenditures are required to take advantage of the most recent developments in order for these systems to stay up to date and efficient.

FUTURE DIRECTIONS

Cybernetics (systems theory, feedback, control systems, and automation) and pharmacology (the study of medications and their effects) are combined in the new multidisciplinary discipline of pharmaco-cybernetics. Through intelligent systems, digital modeling, AI, and real-time feedback mechanisms, it seeks to optimize pharmacological therapy.

Digital therapeutics and cyber-medication management

Apps and digital platforms that guide drug adherence and timing. Smart pill dispensers with reminder systems and dosage tracking. Virtual assistants and chatbots for drug counseling and monitoring.

Cybersecurity in drug administration

Secure data transmission for intelligent medical devices. Patients' drug information will be protected using blockchain technology and encryption. Real-time notifications and fault/tamper protection.

Telepharmacy and remote pharmacovigilance

AI solutions for early side effect detection using EHRs;[30] integration with wearable technologies for real-time reporting; and remote monitoring of adverse medication reactions.

Cognitive cybernetic interfaces

Brain-computer interfaces for neuropharmacological applications. Closed-loop systems for neurostimulation and psychopharmacology.

Robotic and automated drug dispensing systems

Pharmacy automation through the application of cybernetic concepts.reducing human error in the dispensing and manufacturing of medications.

CONCLUSION

Pharmaco-cybernetics is a cutting-edge fusion of cybernetic and pharmacological technology that makes medication administration safer, more intelligent, and more individualized. Pharmacotherapy is growing more accurate and flexible as ML, AI, and digital monitoring tools are integrated. Although there are many potential advantages, such as better treatment results and fewer negative medication reactions, strong regulatory frameworks are required to address ethical, legal, and data privacy issues. Pharmaco-cybernetics has the potential to transform healthcare delivery and enhance patient care by bridging the gap between traditional pharmacology and the digital era. Pharmacologists can now use highly tailored treatment regimens that are specifically matched to each patient's unique features and genetic profile, starting to affect the way decisions are made in drug therapy. Before pharmaco-cybernetics can become extensively employed, a few barriers must be addressed despite its potential. To realize its full potential, more study, advancements in technology, and the adoption of exact regulations would be necessary. It is about improving the accuracy, effectiveness, and patient-centeredness of healthcare delivery. If experts in the field work together to create a new medical universe where patients are truly at the center, all of this is achievable.

REFERENCES

1. Yap KY, Chuang X, Lee AJ, Lee RZ, Lim L, Lim JJ, *et al*. Pharmaco-cybernetics as an interactive component of pharma-culture: Empowering drug knowledge through user-, experience- and activity-centered designs. Int J Comput Sci Issues 2009;3:1-13.
2. Yap KY. A pharmaco-cybernetics approach to patient safety: Identifying adverse drug reactions through unsupervised machine learning. In: Handbook of Research on Patient Safety and Quality Care through Health Informatics. United States: IGI Global Scientific Publishing; 2014. p. 179-97.
3. Aslam MS. The Impact of Pharmacybernetic in Reducing Medication Error [arXiv Preprint]; 2012.
4. Vanitha KG, Viknesh AM, Alahmadi TA, Salmen SH, Sudhakar N. Scientific validation of traditional detoxification process and evaluation of its impact on anti-microbial potency, phytochemical and heavy metals in *Nigella sativa*. Indian J Pharm Educ Res 2024;58:s668-82.
5. Grinin L, Grinin AL. The Cybernetic Revolution and the Forthcoming Epoch of Self-Regulating Systems. Волгоград: ООО Издательство Учитель; 2016.
6. Senćanski D, Marinković V, Milošević-Georgiev A, Tadić I. Emotional intelligence and perceived stress in pharmacists completing post-graduate specialization programs: A cross-sectional study. Indian J Pharm Educ Res 2024;58:671-8.
7. Novikov DA. Cybernetics: From Past to Future. Berlin: Springer; 2015.
8. Preciado PB. Pharmaco-pornographic regime: Sex, gender, and subjectivity in the age of punk capitalism. In: The Transgender Studies Reader Remix. England: Routledge; 2022. p. 404-13.
9. Tilak S, Glassman M, Kuznetcova I, Pelfrey GL. Applications of cybernetics to psychological theory: Historical and conceptual explorations. Theory Psychol 2022;32:298-325.
10. Wu CH. Order out of chaos: The pharmacology of cybernetics in the posthuman comedy. Ex Pos 2025;53:27-50.
11. Yap KY, Lim KJ. Merging the old with the new: A cybermedicine marriage for oncology interactions with traditional herbal therapies and complementary medicines. CellMed 2012;2:18.1-16.
12. Preciado B. Pharmaco-pornographic politics: Towards a new gender ecology. Parallax 2008;14:105-17.
13. Wiener N, Schade JP. Cybernetics of the Nervous System. Netherlands: Elsevier; 1965.
14. Warwick K, Gasson M, Hutt B, Goodhew I, Kyberd P, Andrews B, *et al*. The application of implant technology for cybernetic systems. Arch Neurol 2003;60:1369-73.
15. Falliers CJ. Asthma and cybernetics: (Or why doesn't everyone have asthma). J Allergy 1966;38:254-7.
16. Stiegler B, Roberts B, Gilbert J, Hayward M. Bernard stiegler: 'A rational theory of miracles: On pharmacology and transindividuation'. New Form 2012;77:164-84.
17. Corning P. Holistic Darwinism: Synergy, Cybernetics, and the Bioeconomics of Evolution. United States: University of Chicago Press; 2010.
18. Brilliant M. Type One Cybernetics: Biotechnical Embodiment as a Crip/Queer Site of Feminist Knowledge Production [Doctoral Dissertation].
19. Krivý M. Towards a critique of cybernetic urbanism: The smart city and the society of control. Plan Theory 2018;17:8-30.
20. Cope B, Kalantzis M. The cybernetics of learning. Educ Philos Theory 2022;54:2352-88.
21. Geroulanos S, Weatherby L. Cybernetics and the human sciences. Hist Hum Sci 2020;33:3-11.
22. August V. Network concepts in social theory: Foucault and cybernetics. Eur J Soc Theory 2022;25:271-91.
23. Dhande SR, Mahadik J, Gujja AR. Study of interactions between monoherbal formulation of *Arjuna* and *Aloe vera* in isoproterenol induced cardiotoxicity rat model. Indian J Pharm Educ Res 2024;58:480-6.
24. Shrivastava A, Gupta JK. Enlightening pharmacological mechanisms of cannabidiol in epilepsy: A comprehensive review on their neuroprotective potential. Indian J Pharm Educ Res 2023;58:15-20.
25. Alothaim AS. Anti-cancer potential of sinensetin, a bioactive compound against human cervical carcinoma cells via its molecular mechanism of apoptosis. Indian J Pharm Educ Res 2024;58:154-61.
26. Polat O, Yaman T, Kömüroğlu AU. Histopathological and biochemical investigation of the effect of Shepherd's

purse (*Capsella bursa-pastoris* L.) on ethanol-induced liver damage. Indian J Pharm Educ Res 2024;58:198-203.
27. Arjun HR, Halagali P, Tausi YM, Paramakrishnan N, Rakshith UR. Role of stem cells in the management of type-I diabetes mellitus. Indian J Pharm Educ Res 2023;57:951-5.
28. Wang H, Tang B, Shi J, Wang Y, Wang Q. Effect of a herbal formulation on infection prevention and immune regulation in children with frequent relapse nephrotic syndrome. Indian J Pharm Educ Res 2023;57:1251-7.
29. Narayanan RR, Durga N, Nagalakshmi S. Impact of artificial intelligence (AI) on drug discovery and product development. Indian J Pharm Educ Res 2022; 56:S387-97.
30. Ramesh P, Jain A, Karuppasamy R, Veerappapillai S. Exploring machine learning models for recurrence prediction in lung cancer patients. Indian J Pharm Educ Res 2022;56:s398-406.

Source of Support: Nil. **Conflicts of Interest:** None declared.