 ISSN-2583-2581

SYNTHETIC BIOLOGICAL INTELLIGENCE: A HUMANE ALTERNATIVE TO ANIMAL TESTING IN CLINICAL TRIALS

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Abstract

Clinical trials are the essential bridge between scientific discovery and safe medical treatments for humans. For decades, animal testing has served as a mandatory first step to reduce risks to people. However, ethical concerns, species differences, and high failure rates have long questioned this approach. This paper explores the evolution of ethical safeguards in biomedical research from the Nuremberg Code and Declaration of Helsinki to India's own guidelines and examines how emerging Synthetic Biological Intelligence (SBI), particularly systems like Cortical Labs' CL1 that use living human neurons, could offer a more humane, accurate, and efficient alternative for preclinical drug testing, especially for neurological disorders. It highlights the urgent need for India to update its legal and regulatory framework to responsibly embrace this bio-digital technology while protecting human dignity, data privacy, and biosecurity.

Introduction

Every new medicine that reaches patients must first prove it is safe and effective. This journey begins with clinical trials carefully regulated studies that test drugs on humans only after extensive preliminary research. Historically, animals have been used as the primary "buffer" to protect human volunteers from unknown dangers. While this practice helped establish modern ethical standards such as informed consent, autonomy, and the principles of beneficence and justice, it has also raised serious moral questions about animal suffering and scientific limitations due to differences between species. Today, groundbreaking advances in Synthetic Biological Intelligence (SBI) are challenging this traditional model. By growing living human

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neurons in the lab and connecting them to digital systems, scientists can now create biological computing platforms that more closely mimic the human brain. These systems promise faster, cheaper, and more personalized drug testing with significantly reduced reliance on animal experimentation. This paper discusses the ethical foundations of clinical research, the potential of SBI as a compassionate and superior alternative, and the critical legal and regulatory gaps that India must address to safely adopt this emerging technology.

What are clinical trials?

Use of animals in clinical trials for strong scientific evidence can traced back to gruesome ethical failures in 20th century. The Tuskegee Syphilis Study (1932-1972) by US public health service where they withheld treatment of hundreds of African American Men infected with syphilis even after penicillin was available another inhumane experiments done by nazi doctors during World War 2, these gave birth to the Nuremberg Code 1947, first instrument to declare "Inform consent of human subject is important and essential" and established principal of autonomy and right to bodily and mental self-determination as non-negotiable, This assertion and Nuremberg Code gave jurisprudential basis for subsequent international development, such as Declaration of Helsinki 1964 both of them stressed of inform consent as essential, that humans shall not be treated as test objects and for that purpose research must be based on prior animal trials to prove scientific evidence. It was first instrument to declare "Inform consent of human subject is important and essential" and established principal of autonomy and right to bodily and mental self-determination as non-negotiable. Justice Benjamin Cordozo interpreted this idea in ***Schloendorff v. Society of New York Hospital (1914)***[1], he said "Every human being of adult years and sound mind has a legal right to determine what shall be done with his own body." This assertion and Nuremberg Code gave jurisprudential basis for subsequent international development, such as Declaration of Helsinki 1964 including The Belmont Report 1979, both of them stressed of inform consent as essential. Beauchamp and Childress in their book Principles of Bio-Medical Ethics 1979, gave four basic principle's **Autonomy**, **Beneficence**, **Non-maleficence** and **Justice**[2].

[1] Schloendorff v. Soc'y of N.Y. Hosp., 105 N.E. 92 (N.Y. 1914).
[2] Jyoti Bhakare & Vipasha Chirmulay, Interface Between Ancient Indian and Western Jurisprudence with Reference to Medical Ethics, 4 ICREP J. Interdisciplinary Stud. 1 (2025).

Later UNESCO Universal Declaration on Bioethics and Human Rights 2005 to Article 7 of ICCPR, all of these supported and elevated autonomy from a basic moral principle to binding norm prohibiting non-consensual interference with human body.

In India, the Indian Council of Medical Research (ICMR) turned these norms into national framework through ethical guidelines from 1980 to recent National Ethical Guidelines for Biomedical and Health Research Involving Human Participants 2017 it ensures that every human shall be treated as independent decision maker with dignity and rights.

The Indian legal framework governing biomedical research reflects care adaptation of these global principles into legally enforceable rules. Statutes such as the Prevention of Cruelty to Animals Act, 1960 which regulates the use of animals in clinical trials and experimentation, it does not promote this practice but seeks to restricts and minimize the cruelty. Under this act we have, the Committee for the Purpose of Control and Supervision of Experiments on Animals which supervise experiments, protocols to ensure that research is legally justified, here pain is minimized and better alternatives are considered in order to keep up with 3Rs principles which are REPLACEMENT, REDUCTION and REFINEMENT. In drugs and cosmetics act 1940 and rules under it mandate that generation of preclinical data before human trials, which includes toxicity and pharmacological studies which again conducted on animals. Complementing this, Indian Council of Medical Research (ICMR) Guidelines influenced by international norms such as the Declaration of Helsinki, which says requirement of prior laboratory and animal studies, alongside ethical review and risk minimization, before human participation is permitted.

Once this preclinical requirement is met, the legal and ethical focus shift from animals to humans, permitting carefully regulated human participation in research. In India, this process is governed by Drugs and Cosmetics Act, 1940 along with ICMR Guidelines which inspired form principles of Declaration of Helsinki and the Nuremberg Code. Now human trials are not permitted openly with arbitrary processes it has structured system of clinical trial phases, each designed to incrementally asses safety, dosage, efficacy, and side effects.

So, this is how animals' functions as initial buffer to reduce the risk, uncertainty and then eventually humans become the participants of these experiments under the framework of autonomy, dignity and protection.

Clinical Trial Framework

The process is primarily under Drugs and Cosmetics Act, 1940 and overseen by the Central Drugs Standards Control Organisation (CDSCO) India.

1. **Preclinical Stage:** involves extensive studies on animals to asses toxicity, pharmacokinetics, pharmacodynamics and efficacy. Animal subjects are used because they provide whole-organism responses. Sometimes, species differences often lead to poor translation to human's, majority of drugs that succeed animal trials somehow fail in human clinical trials.[3]

2. **Clinical Trial Phases[4]:**

a) **Phase 1:** safety and dosage testing on small group of healthy human volunteers.

b) **Phase 2:** effectiveness and side-effect evaluation on large patient group.

c) **Phase 3:** large scale verifying trails for comparing drugs against standard treatment.

d) **Phase 4:** post approval and marketing surveillance.

Major limitations in clinical trial process are inter-species differences which result in poor predictive accuracy for human outcomes, then ethical concerns regarding animal suffering and moral justification of using sentient beings for experimentation. This traditional clinical trial process is extremely costly and time-consuming.[5] This can be improved and solved through Synthetic Biological Intelligence for clinical trials of drugs made for neurological disorders.

Synthetic Biological Intelligence

Synthetical biological intelligence (SBI) is next-gen emerging field, an In-Vitro testing platform which uses living human neurons as core biological sensors and processor to perform computational task. Instead of using silicon chips like traditional AI, SBI grows biological neural network which mainly made from stem-cells in lab and connect them electronic devices. These lab grown neurons can learn, adapt and also respond to stimuli which resembles natural human brain function. CL1 biological computer which is developed by Cortical Labs, is the leading commercial example of this technology.

The CL1 system integrates approx. 8000000 human-induced pluripotent stem cell (iPSC) derived neurons onto a silicon chip with high density multi-electrode arrays (MEAs). These

[3] Gail A. Van Norman, Limitations of Animal Studies for Predicting Toxicity in Clinical Trials, 4 JACC BASIC TRANSL SCI 845 (2019), https://pmc.ncbi.nlm.nih.gov/articles/PMC6978558/.
[4] Venkataramana Kandi & Sabitha Vadakedath, Clinical Trials and Clinical Research: A Comprehensive Review, 15 CUREUS e35077, https://pmc.ncbi.nlm.nih.gov/articles/PMC10023071/ (last visited Apr. 8, 2026).
[5] *Id.*

electrodes which allow real-time two-way communication. The platform operates through a biological operating system (biOS) that enables continuous, bidirectional feedback between biological and digital components. Advanced AI tools can be integrated to analyse large volumes of electrophysiological data, predict experimental outcomes, and dynamically optimise parameters in real time.[6]

Technical advantages of SBI

One of the biggest advantages of the CL1 system is that it uses real human neurons which carries patient own genetic background and it helps create disease-specific models by reprogramming cells taken from patients which can help in rare neurological, oncology and other rare diseases such as Alzheimer's, epilepsy, Parkinsons etc. CL1 also provide significant improvement in traditional preclinical methods. It also enables continuous, real-time monitoring of neuronal activity, including firing patterns, network behaviour, and synaptic interactions. When multiple CL1 systems are used together, it becomes possible to test many compounds simultaneously, greatly increasing throughput. It contrasts with 3R principles (replacement, reduction, refinement) and stands as practical alternative for animal use in neuro-related studies, drug trials which reduces animals needed by enabling early-stage screening on human neurons.

SBIs (CL1) major benefit is speed and cost-effectiveness, traditional preclinical research takes long time, taking months to produce meaningful results. It has precision/personalised medicine making potential, the neurons can be derived from the particular patient cell's it is more efficient to test what kind drug works best for specific DNA profile and this real human neurons when combined with artificial intelligence this synergy allows AI-driven optimization of drugs, predictive modelling of long term effects and automated detection of toxicity signals or side effects much earlier than conventional methods. Synthetic biological intelligence is very energy efficient for example CL1 consumes 30 watts for single unit and this allows it to large scale screening very sustainable; it learns thing faster than traditional AI it can provide continuous rich data on neuronal network dynamics, synaptic plasticity and functional connectivity.

Legal and regulatory challenges in India

[6] Md Sayed Tanveer et al., Starting a Synthetic Biological Intelligence Lab from Scratch, 6 PATTERNS 101232 (2025), http://www.sciencedirect.com/science/article/pii/S2666389925000807.

The replacement and supplementing this synthetic biological intelligence for clinical trials expose vacuum of legal and regulatory system. The current legal framework governs traditional digital systems and traditional biomedical research, struggles to address the unique hybrid bio-digital nature of SBI.

Information Technology Act 2000[7], is the foundational statute for cyber law in India, it has foundational deficiency of definition, the SBI which is combined with living neurons does not fit within definitions such as "computer", "computer resource", "computer system" under section 2 of the act. It Rules 2021[8] including amendments of 2026 on synthetic content impose due diligence obligation on platforms, which does not include platforms offering cloud-based access to SBI systems for clinical research, creating ambiguity regarding liability for incorrect biological outputs or poor-quality neuronal data. The Digital Personal Data Protection Act 2023[9], here the "sensitive personal data" does not explicitly address this hybrid biological-digital data, Donor consent for using iPSC-derived neurons in long-term computing systems is problematic. Neurons remain biologically active for up to six months and generate continuously evolving data. Current consent frameworks do not adequately address re-consent requirements or the use of derived neural activity patterns.

Similarly, Drugs and Cosmetics Act 1940 and rules thereunder here the preclinical data generated from SBI may not be readily accepted by the CDSCO for Investigational New Drug applications, as current guidelines currently recognise animal and conventional In-vitro data. The use of human-derived neurons in computing platforms falls under dual oversight of DBT (Department of Biotechnology) and ICMR, yet there are no clear guidelines for cyber-secured biological computing facilities.

Cyber security and Biosecurity Risk

Malicious actors could interfere with the electrical signals used to communicate with neuron cultures, altering their behaviour and distorting experimental outcomes. Such manipulation could lead to inaccurate results or even trigger unintended toxic responses during drug testing, then the Neuron cultures depend on tightly controlled environmental conditions to survive. Cyberattacks such as ransomware or DDoS targeting these control systems could disrupt

[7] The Information Technology Act, 2000, § 2, No. 21, Acts of Parliament, 2000 (India).
[8] Information Technology (Intermediary Guidelines and Digital Media Ethics Code) Rules, 2021, G.S.R. 139(E) (Feb. 25, 2021), Gazette of India.
[9] Digital Personal Data Protection Act, 2023, No. 22 of 2023, Gazette of India, Aug. 11, 2023.

temperature, nutrients, or oxygen levels, potentially destroy valuable biological material and halt ongoing research. Unauthorized access to sensitive data such as neuronal activity patterns or patient-derived disease models could result in intellectual property theft and the misuse of confidential genetic information, raising both security and ethical concerns.

Comparative International Perspective

1. United States

Us has taken significant steps to modernise preclinical test by reducing participation of animals in clinical trails FDA Modernization Act 2.0[10] is landmark legislation which allows drug developers to use alternatives to animal testing, which includes organoids, organ-on-a-chip systems and computational models, for establishing drug efficacy and safety. The FDA's Centre for Drug Evaluation and Research (CDER)[11] has issued guidance documents encouraging the use of "fit-for-purpose" alternative methods. Human iPSC-derived neuron cultures and bio-hybrid systems like SBI are increasingly viewed as valid components of preclinical packages.

2. European Union

EU artificial intelligence act 2024, says that SBI system in drug discovery or clinical trials may be classified as "high-risk AI" because of its potential impact on human health and use of sensitive biological data. This causing strict requirement for transparency, risk-assessment etc[12]. GDPR applications can be seen such as genetic data, health data and electrophysiological recordings from neuron cultures are treated as special category of sensitive personal data under article 9 of the GDPR. Yet right to be forgotten creates practical challenges when dealing with long-term neuron cultures that continuously generate new data.[13]

Global Neuro-ethics and International Initiatives

The **Baltimore Declaration on Organoid Intelligence (2023)**, backed by prominent neuroscientists and ethicists, highlights the urgent need for clearer terminology and stronger

[10] Peter-James H. Zushin, Souhrid Mukherjee & Joseph C. Wu, FDA Modernization Act 2.0: Transitioning beyond Animal Models with Human Cells, Organoids, and AI/ML-Based Approaches, 133 J CLIN INVEST e175824, https://pmc.ncbi.nlm.nih.gov/articles/PMC10617761/ (last visited Apr. 9, 2026).
[11] Center for Drug Evaluation and Research (CDER) | FDA, https://www.fda.gov/about-fda/fda-organization/center-drug-evaluation-and-research-cder (last visited Apr. 9, 2026).
[12] Regulation (EU) 2024/1689 of the European Parliament and of the Council of 13 June 2024 Laying down Harmonised Rules on Artificial Intelligence (Artificial Intelligence Act), 2024 O.J. (L 1689).
[13] Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the Protection of Natural Persons with Regard to the Processing of Personal Data and on the Free Movement of Such Data (General Data Protection Regulation), 2016 O.J. (L 119) 1.

oversight in this emerging field. It emphasizes collaboration across disciplines and calls for forward-looking governance, while also stressing that biological intelligence should not be confused with conventional AI systems.[14]

At the global level, organizations like **UNESCO** and the **WHO** have taken important steps. UNESCO's ***Recommendation on the Ethics of Artificial Intelligence (2021)*** and the WHO's ongoing discussions on neurotechnology offer valuable ethical guidance. However, these frameworks remain largely advisory and do not yet provide enforceable rules for bio-hybrid computing systems, especially in clinical research contexts.[15]

Similarly, the **OECD** has started addressing governance challenges through its work on ***New Approach Methodologies (NAMs)*** in areas like chemical safety and drug testing. It encourages countries to recognize and adopt data derived from advanced human-based models, though a comprehensive regulatory structure is still evolving.[16]

Proposed Policy Recommendations

The integration of Synthetic Biological Intelligence (SBI) and CL1-type biological computing systems into drug discovery and preclinical research presents significant scientific and ethical advantages. However, these benefits cannot be fully realised without targeted reforms in India's legal and regulatory framework. The following recommendations aim to address existing gaps across cyber law, data protection, and biomedical governance.

The Information Technology Act, 2000 must evolve to recognise emerging bio-digital systems. A new definition under Section 2 should formally introduce "biological computing systems," encompassing hybrid platforms that utilise living neurons particularly those derived from human induced pluripotent stem cells as computational substrates in applications such as drug discovery and disease modelling.

[14] Thomas Hartung et al., The Baltimore Declaration Toward the Exploration of Organoid Intelligence, 1 Frontiers in Science 1068159 (2023).
[15] UNESCO, Recommendation on the Ethics of Artificial Intelligence, U.N. Doc. SHS/BIO/PI/2021/1 (Nov. 23, 2021).
[16] Fiona Sewell et al., New Approach Methodologies (NAMs): Identifying and Overcoming Hurdles to Accelerated Adoption, 13 TOXICOL RES (CAMB) tfae044 (2024), https://pmc.ncbi.nlm.nih.gov/articles/PMC10964841/.

To address novel forms of harm, a dedicated provision (e.g., Section 43B) should classify unauthorised manipulation of neuron cultures through electrical or chemical stimuli as damage to a biological computing resource, attracting both civil and criminal liability.

Further, the Information Technology (Intermediary Guidelines and Digital Media Ethics Code) Rules, 2021 should be amended to introduce "Significant Biological Computing Intermediaries" (SBCIs). Such entities must adhere to heightened due diligence obligations, including real-time monitoring of neuronal stimuli, robust cybersecurity safeguards for life-support systems, and mandatory reporting of bio-digital security incidents to Indian Computer Emergency Response Team.

The Digital Personal Data Protection Act, 2023 should explicitly recognise "neuro-biological data" as a category of sensitive personal data. This includes genetic material from donor-derived cells, electrophysiological recordings, neural activity patterns, and derived functional outputs of biological computing systems.

Consent frameworks must be recalibrated to reflect the dynamic nature of SBI research. A tiered model distinguishing between cell donation, long-term culture, and computational use should be adopted, alongside periodic re-consent mechanisms aligned with the lifecycle of neuron cultures or changes in research purpose. Donors must also be informed of emerging risks, including potential bio-digital interface vulnerabilities.

Additionally, Data Protection Impact Assessments (DPIAs) should be made mandatory for entities handling such data, with specific emphasis on neuroethical risks, biosecurity, and long-term privacy implications.

Amendments to the Drugs and Cosmetics Rules should empower the Central Drugs Standard Control Organization to recognise data generated from validated SBI platforms as admissible preclinical evidence in Investigational New Drug applications, subject to defined validation and quality standards.

The Indian Council of Medical Research National Ethical Guidelines should be revised to include a dedicated framework for biological computing systems. This should address the use of human iPSC-derived neurons, ethical review of hybrid AI–SBI research protocols, and standards for safe decommissioning and disposal of biological materials.

A coordinated institutional approach is essential. The establishment of a National Bio-Computing Regulatory Authority under the Ministry of Health and Family Welfare, in collaboration with Ministry of Electronics and Information Technology and Department of Biotechnology would provide centralised oversight. Its mandate should include certification of SBI platforms, development of technical standards, and enforcement of ethical and cybersecurity compliance.

Existing institutions should also be strengthened. The mandate of CERT-In should extend to incident response for biological computing systems, while the National Critical Information Infrastructure Protection Centre should include large-scale biological data infrastructures within its protective ambit. Coordinated guideline development between CDSCO and ICMR is also necessary for the regulatory acceptance of SBI-derived data.

Conclusion

The future of drug development lies in moving beyond outdated animal models toward more human-relevant, ethical, and precise methods. Synthetic Biological Intelligence represents a promising step in this direction offering real human neurons as living sensors that can learn, adapt, and provide richer data for neurological drug testing while aligning with the 3Rs principle of Replacement, Reduction, and Refinement. However, realizing this potential requires more than scientific innovation. India must proactively reform its legal framework updating the Information Technology Act, Drugs and Cosmetics Act, and data protection laws to recognize bio-digital systems, strengthen consent and privacy protections, and ensure robust cybersecurity and biosecurity. By establishing clear, forward-looking regulations and ethical guidelines, India can lead in responsible innovation, protect human dignity, and accelerate the discovery of safer, more effective treatments for patients worldwide.