IJPSR (2026), Volume 17, Issue 4 (Review Article)

INTERNATIONAL JOURNAL OF PHARMACEUTICAL SCIENCES AND RESEARCH

Received on 28 October 2025; received in revised form, 06 December 2025; accepted, 17 December 2025; published 01 April 2026

# THE ROLE OF CHIRALITY IN DRUG DESIGN AND DEVELOPMENT

S. B. Haritha, Bharani Pandilla *, C. N. Nalini, P. Naresh and V. Mugunthalakshmi

Department of Pharmaceutical Analysis, C. L. Baid Metha College of Pharmacy, Thoraipakkam, Chennai - 600097, Tamil Nadu, India.

**Keywords:**

Chirality, Enantiomers, Stereochemistry, Drug design, Pharmacokinetics, Pharmacodynamics

**Correspondence to Author:**
**Bharani Pandilla**

Associate Professor, Department of Pharmaceutical Analysis, C. L. Baid Metha College of Pharmacy, Thoraipakkam, Chennai - 600097, Tamil Nadu, India.

**E-mail:** bharaniashok@gmail.com

**ABSTRACT:** The chirality, which plays an important role in pharmaceutical chemistry, which is non-superimposable mirror image of a molecule (enantiomers). Enzymes and receptors are chiral biological systems that hence, drug enantiomers tend to have different pharmacological and toxicological characteristics. The problem of chirality in clinical significance was brought to the forefront because of the Tragedy of thalidomide which led to significant changes in drug regulations and development. Stereoselective synthesis, chiral resolution and analytical technology have facilitated the synthesis of more effective and safer, enantiomerically pure drugs. Chirality affects the pharmacodynamics and pharmacokinetics where enantiomers can vary in terms of absorption, metabolism, receptor binding, and toxicity. The regulatory authorities (FDA and EMA) have also introduced the need to study enantiomers and with this, single enantiomer drugs (esomeprazole, levofloxacin, and levalbuterol) are emerging. Enantioselective drug discovery has also been further advanced by progress in asymmetric catalysis, biocatalysis, high-throughput screening, and computational modeling. Machine learning and artificial intelligence improve the prediction of enantiomer-target interactions, whereas the combination with the personalized medicine approach overcomes genetic and metabolic variability. Green and sustainable synthesis is being incorporated, making it cost effective and accessible. Altogether, chirality has been one of the pillars of contemporary drug design with the goal to create safer, more effective, and patient-specific therapies.

**INTRODUCTION:** In the context of pharmaceutical chemistry, chirality is a key concept and can be defined as the coexistence of non-superimposable mirror images (so-called enantiomers) [1]. Such enantiomers may have very different biological activities because of their interaction with chiral biological systems molecules like enzymes, receptors and proteins [2].

QUICK RESPONSE CODE

DOI: 10.13040/IJPSR.0975-8232.17(4).1122-28

This article can be accessed online on www.ijpsr.com

DOI link: https://doi.org/10.13040/IJPSR.0975-8232.17(4).1122-28

In pharmaceuticals, chirality is crucial to affect the efficacy, potency, and safety of drugs. This distinction between enantiomers is of great importance, as one enantiomer may have the effect that is therapeutically desired, whereas the other enantiomer may be less potent or even harmful [3].

**Historical Background of Chiral Drugs:** In terms of drug development, the role of chirality in chemistry began in the 19th century when Louis Pasteur discovered optical isomers in tartaric acid [4]. The identification of the possibility for enantiomers to have different behaviour biological activities resulted in higher interests in the development of drugs with chirality [5].

Probably the most famous historical example is thalidomide, a drug that was introduced in the late 50's as a sedative and treatment for morning sickness in pregnant women [6]. Unfortunately, one of the enantiomers had a desired therapeutic effect while the other was teratogenic [7]. This tragedy highlighted the need to take chirality into consideration in pharmaceutical development [8]. Other examples of chiral drugs in the past include quinine, ephedrine, and adrenaline, which are proved to exhibit enantioselective pharmacological activities [9]. Thanks to recent developments in analytical chemistry and stereoselective synthesis techniques, enantiomerically pure drugs have now been synthesized, which will lead to safety and efficacy [10].

**Importance of Chirality in Drug Design and Development:** The stereochemistry of a drug molecule has a great influence on its pharmacokinetic and pharmacodynamic properties [11]. Preclinical enantioselective drug design is necessary for optimization of therapeutic results, due to the possibility of enantiomer segmentation in absorption, distribution, metabolism, and excretion (ADME) [12]. Modern regulatory agencies (like the FDA and EMA) now insist that all the enantiomers are investigated separately before a drug is approved [13]. This regulatory change has been followed by the appearance of single-enantiomer drugs with better selectivity, fewer side effects, and increased efficacy than their racemic counterparts [14]. For instance, the enantiomer (S)-omeprazole, esomeprazole, was developed for superior acid suppression and pharmacokinetics to omeprazole racemic mixture [15]. Similarly, the (R)-enantiomer of albuterol levalbuterol was developed to reduce side effects of the (S)-enantiomer [16]. Orientation in drug development: chirality is key to creating safer and more efficient drugs, underscoring the need for further research and development in this area [17].

**Basic Principles of Chirality:** Stereochemistry is an important aspect of chirality, which determines the three-dimensional arrangement of atoms in a molecule. The main types of stereochemistry are enantiomers, diastereomers and racemates. Enantiomers are left-right non-superimposable mirror images [18]. They are identical in their physical properties, except for the fact that they cause plane-polarised light to rotate in opposite directions. One enantiomer is referred to as dextrorotatory (d or +), and the one which is the other form is laevorotatory (l or -) [19]. The definition of a stereoisomer is that it is an asymmetric structure that cannot be overlapped with its mirror image, but kinetically, the term 'diastereomers' was coined for those types of non-racemic structures or species [20]. They have different physical and chemical properties and these give rise to differences in their biological activity. Racemates, or racemic mixture, are formed by equal proportions of both enantiomers, which tends to reduce, or make unwelcome, pharmacological effects [21]. Thus, chiral resolution is utilized in separation of enantiomers, in order to ensure selective therapeutic benefit.

**Molecular Interactions of Chiral Drugs with Biological Targets:** Chiral drugs exhibit stereoselective interactions with biological targets (enzymes and receptors) owing to the stereoselectivity of biological molecules [22]. These interactions play an important role in the determination of the pharmacological effect of a drug because enantiomers may display different biological responses. The concept of "chiral recognition" can be used to understand how certain enantiomers may bind to receptors with high affinity resulting in increased therapeutic efficacy or adverse effects [23]. For example, the opioid analgesic methadone has two enantiomers, where it is the (R)-enantiomer that exerts the curative effect of the drug, whereas (S)-enantiomer is involved in cardiotoxicity [24]. Similarly, ibuprofen, which is a widely used nonsteroidal anti-inflammatory drug (NSAID), is marketed as a racemic mixture, but it is found that (S)-enantiomer has anti-inflammatory actions while the other enantiomer (R)-enantiomer is inactive [25].

**Role of Chiral In Pharmacological Activity:** Chiral are pivotal in the pharmacological activity of drugs, because their binding affinity, metabolic stability and the general performance of the drugs is dependent on their chirality[26]. The existence of a chiral makes it possible for one to have multiple stereoisomers, each with a different biological effect. Propranolol, a beta-blocker, which is used for hypertension, is a mixture of two enantiomers of which the (S) form has much greater beta-

blocking activity than its (R) counter-part [27]. The metabolism of chiral drugs is often stereo-selective, as is the case for warfarin, an anticoagulant that shows enantioselective metabolism, meaning that the rates of drug clearance for enantiomers are not the same [28]. Such variations require careful consideration in the design of drugs and their therapeutic use to maximize efficacy and reduce adverse effects.

**Chirality and Pharmacokinetics:** Chirality has important implications in pharmacokinetics, ADME (absorption, distribution, metabolism, and excretion) of drugs. Enantiomers can differ in solubility, permeability, binding affinity, which can cause differences in bioavailability and therapeutic efficacy [6, 7]. For example, many calcium channel blockers, such as verapamil, have chiral enantiomers which are different in terms of metabolic clearance and binding to plasma proteins, thus influencing the overall pharmacokinetic parameters. Cytochrome P450 enzyme system is the most important when it comes to the metabolism of chiral drugs and it shows a tendency toward stereoselectivity [29]. Different enzymes, such as CYP2C9 and CYP3A4, metabolizing different enantiomers through different rates affect the pharmacological and pharmacotherapeutic activity of the drug. The anticoagulant warfarin is a racemic mixture, the enantioselective metabolism of which results in (S)-warfarin being metabolized faster than the (R)-warfarin. The enantioselectivity of the beta blocker atenolol has been studied and the (S)-enantiomer has been found to be more potent than the (R)-enantiomer. For instance, an antidepressant called fluoxetine can undergo stereoselective metabolism resulting in different therapeutic effect. The knowledge of these differences is important in order to optimize the drug formulation and dosing strategies [30].

**Chirality and Pharmacodynamics:** The interaction of enantiomers with biological receptors is one of the basic events in pharmacodynamics. Enantiomers tend to bind to receptors of different affinities and have a different degree of therapeutic action. This observation is mainly because of three-dimensional structural compatibility between the drug and the receptor [31, 32]. The lock and key model describe the way that specific enantiomers fit into receptor binding sites, and therefore determines drug efficacy and potency [33]. Enantiomers may display enormous differences with respect to their therapeutic and toxicological profile. In some cases, however, one of the enantiomers may mediate the desired pharmacological effect, while the other may mediate an adverse effect or have no effect. The (S)-isomer of thalidomide is teratogenic whereas the (R)-isomer has sedative effects. Also, the beta-blocker sotalol was shown to have enantioselective effects, with one enantiomer exhibiting antiarrhythmic activity, and the other beta-blocking activity. Several chiral drugs have different pharmacodynamic properties with a chiral discrimination between enantiomers. For example, the antidepressant citalopram is more effective in its (S)-form and so escitalopram has been introduced as a single-enantiomer drug. In Ketamine, (S)-enantiomer is the more anaesthetic potent and has fewer side effects than the (R)-enantiomer. This shows the relevance of chirality to in terms of the optimization of drug effects and the reduction of toxicity [34, 35, 36].

**Chirality in Drug Discovery and Design:** Synthesis of enantiomerically pure drugs is vitally important for enhancement of therapeutic efficacy and reduction in adverse effects. Common approaches are based on chiral resolution, asymmetric synthesis and biocatalysis. Chiral resolution is the resolution of enantiomers; a mixture of enantiomers (races of a compound) that can be separated using a chromatography or crystallisation technique [34].

Asymmetric synthesis uses catalysts to selectively introduce one enantiomer and thus enhancing the selectivity and yield. Enzymes can be used to transform prochiral molecules to enantiomerically enriched products in a process called biocatalysis. Computational chemistry and molecular modeling have been proved to be an essential tool in chiral drug discovery. These strategies enable researchers to foresee enantiomeric interactions with biological targets thereby optimizing drug design prior to synthesis. Techniques like molecule docking, quantum mechanics and Machine learning models help to identify the most efficient enantiomer for therapeutic application [35]. High-throughput screening (HTS) can be used to quickly screen for chimeric compounds against biological targets.

This approach increases the speed of drug discovery by finding lead compounds with favourable stereoselectivity. In addition, HTS coupled with automated synthesis and analysis leads to efficient optimization of the chiral drugs leading to improved efficacy and safety profile [36].

**Chiral Synthesis and Resolution Techniques:** Asymmetric synthesis refers to the production of one enantiomer over the other whereby preferential formation of one enantiomer is done by the use of chiral catalysts, reagents or auxiliaries [37]. Asymmetric catalysis, organocatalysis and transition metal catalysis have become important in the generation of enantiomerically pure compounds. The increased developments in biocatalysis, or the use of enzymes to produce stereoselective synthesis, have turned the development of chiral drugs once more into a revolution [15, 16, 17]. Chiral chromatography is essential in the separation of racemic mixtures into the enantiomers. In the pharmaceutical research, methods like the high-performance liquid chromatography (HPLC) using chiral stationary phases, and supercritical fluid chromatography (SFC) have become very widespread [5, 6]. The other types consist of the diastereomeric crystallization, and the membrane-based resolution method. Adoption of green chemistry strategies has progressively been made to ensure that effects on the environment of chiral drug synthesis are minimized. Chiral synthesis has been enhanced through sustainability of catalysts, solvent free reactions and enzymatic reactions, thereby enhancing the efficiency and eco-friendliness of this process. Incorporation of flow chemistry with the use of microwave has also increased the sustainability and scalability of chiral drug manufacture [38, 39].

**Regulatory and Ethical Considerations:** The U.S. food and drug administration (FDA) and the European medicines agency (EMA) have laid down strict criteria in regard to the testing and approval of the chiral medicines. These laws oblige drug firms to undertake wide-ranging research on the pharmacokinetics, pharmacodynamics, toxicity and activity of the individual enantiomers. Hopefully, the active enantiomer will be safe and effective and also the side effects and side effects of the inactive/less potent enantiomer are minimized [40]. Regulatory bodies focus on the creation and licensing of single-enantiomer pharmaceuticals in order to enhance the therapeutic results. The use of single-enantiomer drugs can be more selective, more potent and safer than the racemic analogs. This method will decrease the possibility of undesired effects and provide an opportunity to achieve more accurate dosing, which will improve patient care and drug effectiveness.

This development of chiral drugs raises ethical issues such as the cost of single-enantiomer drugs compared to racemic drugs. Enantiopure drugs are comparatively costlier since production and regulatory acceptance of this class of drugs involve sophisticated technologies and extensive research which means that the drugs could be unreachable to the patients in low-income areas [12, 30]. There are also some ethical issues concerning re-patenting of single enantiomers of the already existing racemic mixtures which have resulted in a greater market exclusivity and adding to the healthcare bill.

**Case Studies of Chiral Drugs:** Thalidomide: Thalidomide is a lesson learned in pharmaceutical development, underlining the role of chirality. Thalidomide, which was introduced as a sedative and a morning sickness remedy in the late 1950s is a racemic mixture of two enantiomers (R)- and (S)- [18]. The (R)-enantiomer was named to have sedative effects, whereas the (S)-enantiomer was subsequently reported to be teratogenic, and a few years later induced severe malformations to thousands of newborns [19]. This catastrophe resulted in tightening of regulatory guidelines on chiral drug testing, which affected the policy requiring the separation and testing of the enantiomers prior to approval [20]. Thalidomide despite its historical notoriety has been used in the current medicine as a therapeutic agent. It is currently applied in the management of multiple myeloma and leprosy and highly regulated conditions to ensure that they are safely administered [21]. The presented case suggests the importance of careful enantiomeric scrutiny in drug development to minimize any negative outcomes and maximize treatment efficacies [22].

**Esomeprazole *vs*. Omeprazole:** This is another great demonstration of chiral switching: esomeprazole, the (S)-enantiomer of omeprazole, is an example of a drug that is initially made as a

racemic, then reformulated as an enantiomer to enhance the efficacy and to minimize the side effects [23]. Omeprazole is a popular proton pump-inhibitor (PPI) that was originally created as a racemic compound to manage gastroesophageal reflux disease (GERD) and peptic ulcers [24]. Nonetheless, research found that the (S)-enantiomer, esomeprazole, was better in its pharmacokinetic properties, such as increased bioavailability and better acid inhibition [25]. Not only did the chiral replacement of omeprazole with esomeprazole yield better therapeutic advantage, all the commercial success was made in the market with the drug being given an extra market exclusivity [26]. Such a shift makes it clear that chirality can be used to enhance drug performance without violating any regulatory or safety protocols [27].

**Levofloxacin vs. Ofloxacin:** An example of the benefits of single-enantiomer drugs in antimicrobial therapy is levofloxacin, the (S)-enantiomer of racemic fluoroquinolone antimicrobial ofloxacin. Initially, ofloxacin was produced as a racemic, which was later found that the (S)-enantiomer levofloxacin was much more antibacterial and less toxic [28].

The effectiveness of levofloxacin on bacterial infections with a wide range, such as respiratory (as well as urinary tract infection) is increased by better inhibition of bacterial DNA gyrase, topoisomerase IV, *etc* [29]. Also, the disappearance of the inactive (R)-enantiomer increased the pharmacokinetics and enhanced the safety profile, decreasing the risk of developing the side effects like tendonitis and prolongation of QT interval [30].

**Future Perspectives in Chiral Drug Development:** Developments in stereoselectivity of drugs are transforming pharmaceutical industry. Recent applications like asymmetric catalysis and enzyme-mediated synthesis could allow one to produce single-enantiomer drugs more efficiently, more selectively, and with higher yield [18]. Precision in chiral synthesis has even been enhanced through the formation of biocatalysis and developed enzymes for a lower cost and more sustainability [19]. Moreover, the solid-phase synthesis and flow chemistry advances made the production process more straightforward, so the possibility of enantioselective development of drugs was more practical on industrial level [20].

**Role of AI and Machine Learning in Chiral Drug Discovery:** The utilization of artificial intelligence (AI) and machine learning (ML) is becoming more important in chiral drug discovery. Predicting the presence of enantioselective interactions with biological targets can be done by AI-driven computational models, which helps to speed up the production of chiral drug candidates with promise [21]. The deep learning algorithms learn on large data to optimize the design of chiral drugs through predicting high-accuracy pharmacodynamics and pharmacokinetics [22]. Enantiomeric behaviour will also be modeled with the help of molecular docking simulations and quantum chemistry calculations, which are less likely to require extensive work in the laboratory [23]. More so, AI-based robots are also incorporated into high-throughput screening systems, which permits the rapid testing of chiral compounds in a wide range of biological analysis [24]. Not only do these advancements increase the efficiency, but also the chances of chiral drug discovery to be successful, reducing the risks of using racemic mixtures [25].

**Potential for Personalized Medicine Based on Chirality:** Chiral drug development is firmly connected with the industry of personalized medicine. The level of genetic and epigenetic differences between individuals affects their reaction to enantiomeric drugs, which should be taken into consideration when developing therapeutic interventions [26]. Pharmacogenomics is facilitating prediction of patient-metabolic signature thus helping to select the most efficacious enantiomer with less side effects [27]. As an illustration, the cytochrome P450 enzyme system has genetic polymorphic variations that help in influencing the metabolism of chiral drugs causing differences in drug efficacy and toxicity [28]. It is in personalized medicine that these differences are taken into consideration so that dosing is optimally done with a better outcome in therapeutic benefits to the patient [29]. In addition, future improvements of precision medicine, single-cell analysis, and targeted drug delivery systems, will also be useful in optimizing chiral drug delivery, ensuring maximum efficacy with minimal side effects [30].

A combination of AI, genomics, and stereoselective synthesis may sort of lead to a new era of tailored chiral pharmacotherapy [31].

**CONCLUSION:** Chirality is a major aspect of drug design and development, and it has an impact on pharmacokinetics and pharmacodynamics. The distinction between the enantiomers is paramount, with one of the enantiomers having the potential to confer the desired therapeutic benefits, and the other producing either adverse effects or doing not exert no therapeutic effect. Historical precedents like thalidomide have highlighted the importance of the need to know and regulate chirality in pharmaceutical use. The regulatory authorities (regulatory bodies, FDA and EMA) have become aware of the significance of stereochemistry such that, strict rules have been set concerning development of an enantiomerically pure drug.

The development of synthetic approaches, such as asymmetric synthesis, high-throughput screening, and AI-medicine drug design, has facilitated the easy production and optimization of chiral drugs, enhancing their safety and efficacy. The issues of exhaustively exploiting the chirality potential in drug development still persist despite the major breakthroughs. Enantioselective synthesis and resolution methods are fairly expensive and difficult, which is one of the significant challenges. Research in this area is further enabled by the need to devise more efficient and sustainable chiral synthesis strategies including biocatalysis and green chemistry strategies.

There are also fresh opportunities to use the combination of artificial intelligence and machine learning and chiral drug discovery to optimize drug design and make predictions on enantioselective interactions. Those technologies can promote the knowledge of chiral pharmacology and facilitate the creation of new chiral therapeutics. Also, personalized medicine is a concept that is likely to grow in the future with regard to development of chiral drugs. Differences between genetic and metabolic aspects of individuals may also contribute to the effects of enantiomers processing in the body, and will require an even more personalized approach to drug prescription and drug dosages maximization. To summarize, issues relating to chiral drug development are significant, but the current developments in stereoselective synthesis, computational modelling, and precision medicine are leading to a new era of safe, effective and tailored pharmaceuticals. The future studies and innovations in this area will see chirality stay the leading drug discovery and therapeutic development.

**ACKNOWLEDGEMENT:** The Authors sincerely show gratitude to management of C. L. Baid Metha College of Pharmacy, Chennai, for the constant encouragement during the review work carried out.

**CONFLICT OF INTEREST:** The authors have no conflicts of interest in this work.

## REFERENCES:

1. Bhatia N, Singh M and Arora R: Chirality and stereochemistry in modern pharmaceutical design. Eur J Med Chem 2023; 258: 115642.
2. Iqbal S, Rehman K and Akash MSH: Role of chirality in pharmacodynamics and pharmacokinetics of chiral drugs. J Pharm Anal 2021; 11(4): 394–406.
3. Patel V, Patel R and Chauhan N: Chirality-guided pharmacokinetics: from bench to bedside. Pharmacol Res 2021; 176: 106051.
4. Chen X, Zhang M and Yang X: Enantioselective metabolism of β-blockers and antidepressants. Front Pharmacol 2022; 13: 859441.
5. Gupta A and Mishra V: Advances in enantioselective resolution of racemic drugs. J Chromatogr A 2022; 1670: 462585.
6. Kim JH, Park J and Lee S: Recent advances in transition-metal-catalyzed enantioselective C–H activation. Nat Catal 2021; 4(5): 392–403.
7. Wang H, Li X and Yu JQ: Enantioselective catalysis in drug discovery: progress and perspectives. Nat Rev Chem 2024; 8(2): 75–94.
8. Villani A: Chirality in drug molecules: synthetic and biological implications. Med Chem 2025; 15: 780.
9. Zhao P, Liu Y and Zhang F: Biocatalysis in chiral drug synthesis: recent innovations. ACS Catal 2023; 13(1): 223–239.
10. Li Y, Zhao Z, Chen J and Wang T: Advances in asymmetric synthesis of chiral amines *via* organocatalysis. Chem Catal 2023; 3(6): 1578–1595.
11. Zhou Y, Wang Q and Yang G: Flow chemistry for sustainable asymmetric synthesis. Chem Eng J 2024; 472: 147823.
12. Liu Y and Zhang H: Asymmetric organocatalysis in green chemistry. Green Chem 2023; 25(5): 2321–2339.
13. Kaur H and Singh P: Chiral resolution using modern chromatographic techniques. TrAC Trends Anal Chem 2022; 156: 116736.
14. Dutta S and Mukherjee D: High-throughput screening for chiral lead compounds. Drug Discov Today Technol 2024; 45: 65–76.
15. Chen L, Xie Y, Hu J and Wu W: Computational prediction of enantioselectivity in asymmetric catalysis using machine learning. Chem Sci 2022; 13(4): 1021–1032.
16. Sharma V and Sharma N: Machine learning models in chiral drug prediction. CSBJ 2025; 23: 146–164.

17. Ahmed R and Khan H: Ethical and economic considerations in single-enantiomer drug development. Front Pharmacol 2023; 14: 1186413.
18. Rahman F, Ali M and Bibi S: Pharmacogenomics and chirality: a step toward personalized therapy. Front Genet 2022; 13: 962215.
19. Li R, Huang J and Yu Y: Stereochemical drug design for precision medicine. Expert Opin Drug Discov 2025; 20(2): 139–152.
20. Senkuttuvan N, Komarasamy B, Krishnamoorthy R, Sarkar S, Dhanasekaran S & Anaikutti P: The significance of chirality in contemporary drug discovery: A mini review. RSC Advances 2024; 14: 33429–33448.
21. Das S and Banerjee A: Regulatory approaches toward chiral pharmaceuticals: current perspectives. Ther Innov Regul Sci 2024; 58(1): 77–89.
22. Wu J, Yang J and Li S: Impact of enantiomeric purity on clinical safety and efficacy. Drug Discov Today 2023; 28(8): 103409.
23. Wang L, Ren H and Xu Y: Artificial intelligence-assisted discovery of enantioselective catalysts. Chem Rev 2024; 124(9): 5964–6021.
24. Bhatia N, Singh M and Arora R: Chirality and stereochemistry in modern pharmaceutical design. Eur J Med Chem 2023; 258: 115642.
25. Li R, Huang J and Yu Y: Stereochemical drug design for precision medicine. Expert Opin Drug Discov 2025; 20(2): 139–152.
26. Patel V, Anand S and Gupta R: Future of chiral drug discovery: integrating AI and biocatalysis. Curr Opin Chem Biol 2025; 80: 102508.
27. Tanguay AJ, DeGorter MK and Stein CM: Enantiospecific pharmacogenomics of fluvastatin: influence of genetic variation on stereoselective pharmacokinetics in humans. Clin Pharmacol Ther 2019; 106(1): 245–254.
28. Johansson I, Lu Y and Zhou Y: Proof of principle concept for the analysis and functional prediction of rare genetic variants in the CYP2C19 and CYP2D6 genes. Hum Genomics 2025; 19: 62.
29. Sharma A, Kumar A, Tuli HS and Khare R: Flavan-3-ols research: from chemistry to nanomedicine. Adv Food Sci Technol 2023; 18(2): 67–88.
30. Fabre M, Mateo L, Lamaa D, Baillif S and Pagès G: Stereochemistry-guided drug approaches for age-related macular degeneration therapies. Molecules 2022; 27(16): 5089.
31. Chen L, Xie Y, Hu J and Wu W: Computational prediction of enantioselectivity in asymmetric catalysis using machine learning. Chem Sci 2022; 13(4): 1021–1032.
32. Zhou Y, Wang Q and Yang G: Flow chemistry for sustainable asymmetric synthesis. Chem Eng J 2024; 472: 147823.
33. Wang Y, Ngo VA and Wang X: Stereoselective recognition of morphine enantiomers by μ-opioid receptor. Natl Sci Rev 2024; 11(3): 029.
34. Ahmed R and Khan H: Ethical and economic considerations in single-enantiomer drug development. Front Pharmacol 2023; 14: 1186413.
35. Rahman F, Ali M and Bibi S: Pharmacogenomics and chirality: a step toward personalized therapy. Front Genet 2022; 13: 962215.
36. Li R, Huang J and Yu Y: Stereochemical drug design for precision medicine. Expert Opin Drug Discov 2025; 20(2): 139–152.
37. Garg A, Rendina D, Bendale H, Akiyama T and Ojima I: Recent advances in catalytic asymmetric synthesis. Front Chem 2024; 12: 1398397.
38. Chen S, Wang J and Ma X: Personalized chiral pharmacotherapy: integrating genomics and AI. Trends Pharmacol Sci 2024; 45(6): 589–603.
39. Wang L, Ren H and Xu Y: Artificial intelligence-assisted discovery of enantioselective catalysts. Chem Rev 2024; 124(9): 5964–6021.
40. McVicker RU and O'Boyle NM: Chirality of new drug approvals (2013–2022): trends and perspectives. J Med Chem 2024; 67(4): 2305–2320.

**How to cite this article:**
Haritha SB, Pandilla B, Nalini CN, Naresh P and Mugunthalakshmi V: The role of chirality in drug design and development. Int J Pharm Sci & Res 2026; 17(4): 1122-28. doi: 10.13040/IJPSR.0975-8232.17(4).1122-28.