# Review Article

# The Evolving Role of Biologics and Biosimilars in Future Treatment Strategies

**Paul Praveenkumar Deepak Jayakumar[1], Prathish Murugan[2], Monisha Thangadurai[1], Vasanth Albert Rayappan[2*]**

*From, [1]Pharm D Student, [2]Department of Pharmacy Practice, KG College of Pharmacy and Research Institute, Villupuram, Tamil Nadu - 605203.*

## ABSTRACT

Biologics have transformed modern medicine through highly targeted therapies derived from living systems, including monoclonal antibodies, recombinant proteins, vaccines, and advanced cell and gene therapies. Their molecular specificity has significantly improved outcomes in oncology, autoimmune diseases, endocrinology, haematology, and ophthalmology, enabling disease modification and, in some cases, durable remission or cure. However, biologics are associated with substantial manufacturing complexity, immunogenicity concerns, stringent storage requirements, and high treatment costs, which limit accessibility worldwide. Biosimilars have emerged as a cost-effective alternative following patent expiry of reference biologics. Although not identical to originator products, biosimilars demonstrate no clinically meaningful differences in safety, efficacy, or immunogenicity through a rigorous totality-of-evidence regulatory framework. Regulatory pathways established by the FDA, EMA, and WHO have facilitated the increasing approval and global adoption of biosimilars, resulting in substantial healthcare savings and expanded patient access. Evidence from clinical trials and real-world studies confirms comparable therapeutic performance between biosimilars and reference biologics across multiple therapeutic areas. Despite these advances, challenges remain regarding physician and patient acceptance, interchangeability policies, pharmacovigilance, and regulatory harmonisation. Future developments in personalised medicine, therapeutic drug monitoring, next-generation biologics such as bispecific antibodies and antibody-drug conjugates, CAR-T therapies, mRNA therapeutics, and artificial intelligence-assisted drug development are expected to further reshape biologic pharmacotherapy. Pharmacists play a central role in formulary management, patient counselling, biosimilar education, and adverse-event monitoring, supporting the safe and effective integration of biologics and biosimilars into clinical practice. Overall, biologics and biosimilars represent a cornerstone of precision medicine and hold significant promise for improving global healthcare outcomes sustainably and equitably.

***Keywords:*** Biologics, Biosimilars, Monoclonal antibodies, Precision medicine, Immunogenicity, Pharmacoeconomics, Oncology, CAR-T therapy, Pharmacovigilance .

Biological medicinal products have transformed modern pharmacotherapy by offering highly targeted therapies derived from living organisms, including monoclonal antibodies, fusion proteins, recombinant hormones, vaccines, and advanced cell and gene therapies [1,2]. Their molecular complexity and specificity have enabled major therapeutic advances across immune-mediated diseases, cancer, and other previously difficult-to-treat conditions. The global biologics market, valued at approximately USD 392 billion in 2023, is projected to surpass USD 719 billion by 2030, driven by expanding indications, ageing populations, and increasing chronic disease burden [3].

Access this article online

Quick Response Code

Received – 12th February 2026

InitialReview - 18th February 2026

Accepted – 19th March 2026

Monoclonal antibodies remain among the world's best-selling pharmaceutical products, highlighting their clinical and commercial significance [4]. The high cost of innovator biologics has stimulated the development of biosimilars following patent expiries and the introduction of regulatory pathways such as the Biologics Price Competition and Innovation Act (BPCIA) and the European Medicines Agency (EMA) biosimilar framework [5,6]. By 2024, more than 90 biosimilars had been approved by the FDA and over 80 by the EMA [7]. Nevertheless, biosimilar uptake remains inconsistent due to physician hesitancy, concerns regarding safety and immunogenicity, reimbursement disparities, and limited patient awareness [8].

**Correspondence to :** Dr. R.Vasanth Albert, Pharm D., Assistant Professor, Department of Pharmacy Practice, KG College of Pharmacy and Research Institute, Villupuram, Tamilnadu - 605203.

**Email :** vasanthalbert001@gmail.com

At the same time, emerging technologies, including bispecific antibodies, antibody-drug conjugates, CAR-T therapies, and AI-assisted biologic discovery, are rapidly reshaping the therapeutic landscape [9]. This review critically examines the classification, mechanisms, clinical applications, pharmacoeconomic impact, regulatory frameworks, and future directions of biologics and biosimilars, with particular emphasis on the evolving role of pharmacists and emerging technologies in biologic drug development.

## 2. OVERVIEW OF BIOLOGICS

### 2.1 Definition

The FDA defines biologics as products such as vaccines, blood components, proteins, toxins, and therapeutic sera used in the prevention or treatment of diseases [10]. More broadly, biologics are medicinal products derived from biological sources, including microorganisms, animal or plant cells, and recombinant DNA technology [11]. Unlike small-molecule drugs, biologics are highly dependent on living manufacturing systems, and minor changes in production or storage conditions may alter post-translational modifications, pharmacological activity, immunogenicity, and clinical performance [12].

### 2.2 Classification

Biologics comprise diverse therapeutic categories. Monoclonal antibodies (mAbs) and related products, including antibody-drug conjugates, bispecific antibodies, and Fc-fusion proteins, represent the most significant subclass [13]. Other major groups include cytokines and growth factors (e.g., erythropoietin, G-CSF, interferons), recombinant therapeutic proteins such as insulin and clotting factors, blood and plasma-derived products, therapeutic vaccines, cell-based therapies including CAR-T cells, and gene therapies [14,15].

### 2.3 Characteristics

Biologics are large, structurally complex molecules, ranging from approximately 6 kDa to over 150 kDa, compared with less than 500 Da for most small-molecule drugs [16]. Their size and structural complexity provide high target specificity but generally require parenteral administration. Biological activity depends on precise three-dimensional structures and post-translational modifications, particularly glycosylation, which influence pharmacokinetics and immunogenicity [17]. Due to inherent molecular heterogeneity, even reference biologics consist of closely related variants, forming the basis of the bio-similarity concept. Additionally, biologics require strict cold-chain storage and handling conditions, increasing healthcare costs and limiting accessibility, especially in low and middle-income countries [18].

## 3. BIOSIMILARS

### 3.1 Definition

Biosimilars are biological medicines highly similar to an approved reference biologic in terms of quality, safety, and efficacy [5]. Both the EMA and FDA define biosimilars as products with no clinically meaningful differences from the reference product regarding safety, purity, and potency [6,7]. Unlike generic drugs, biosimilars cannot be exact molecular copies because biologics are structurally complex and produced in living systems. Instead, bio similarity is established through a totality-of-evidence approach involving analytical, preclinical, and clinical comparisons [19].

### 3.2 Difference from Generics

Generic drugs are chemically identical to their reference products and are approved primarily through bioequivalence studies [20]. In contrast, biosimilars exhibit inherent variability due to biological manufacturing processes, making exact replication impossible. Therefore, biosimilar approval requires extensive analytical characterisation alongside comparative pharmacokinetic, pharmacodynamic, immunogenicity, and, when necessary, clinical efficacy studies [21].

### 3.3 Development Process

Biosimilar development is a complex and costly process involving reverse engineering and comparative analysis of the reference product using advanced analytical technologies such as mass spectrometry and chromatographic methods [22]. Manufacturers optimise cell lines and production processes to closely match the reference product's molecular and functional profile. Development costs commonly range from USD 100–300 million [23].

Following analytical similarity assessments, nonclinical, pharmacokinetic, pharmacodynamic, immunogenicity, and selective clinical studies are conducted to confirm bio similarity under the totality-of-evidence framework [24].

### 3.4 Regulatory Pathways

#### *3.4.1 FDA (United States)*

The Biologics Price Competition and Innovation Act (BPCIA) of 2010 established the abbreviated biosimilar approval pathway under section 351(k) of the Public Health Service Act [5]. The legislation grants reference biologics 12 years of data exclusivity and introduced the "interchangeable" biosimilar designation for products meeting additional substitution criteria; the first interchangeable biosimilar designation was granted to adalimumab-atto (Hadlima) in 2021 [25].

#### *3.4.2 EMA (European Union)*

The EMA introduced the first biosimilar regulatory framework in 2003, with the first approval issued in 2006 [6]. Its framework relies on the totality-of-evidence approach and class-specific biosimilar guidelines. Unlike the FDA, the EMA does not centrally regulate interchangeability, leaving substitution policies to individual member states. EU data exclusivity is generally 10 years, with a possible one-year extension for new indications [26].

#### *3.4.3 WHO*

The WHO published Guidelines on Evaluation of Similar Biotherapeutic Products in 2009, updated in 2022, to support biosimilar regulation in low- and middle-income countries [27]. These guidelines endorse the totality-of-evidence approach and encourage alignment with established international regulatory standards. WHO prequalification initiatives, particularly for insulins and recombinant proteins, have improved access to biosimilars in resource-limited settings (Table 1&2).

## 4. CLINICAL APPLICATIONS

### 4.1 Oncology

Biologics have transformed oncology through targeted therapies and immunotherapy. Rituximab revolutionised the treatment of B-cell malignancies and remains central in R-CHOP therapy for diffuse large B-cell lymphoma [28]. Trastuzumab significantly improved outcomes in HER2-positive breast cancer [29]. Immune checkpoint inhibitors such as ipilimumab, pembrolizumab, nivolumab, atezolizumab, and durvalumab have produced durable responses in cancers including melanoma, NSCLC, and colorectal cancer [30]. Additional innovations include bispecific T-cell engagers like blinatumomab and antibody-drug conjugates such as trastuzumab emtansine and trastuzumab deruxtecan [31]. Bevacizumab and its biosimilars have expanded anti-angiogenic therapy across multiple cancers [32], while CAR-T therapies such as tisagenlecleucel and axicabtagene ciloleucel have shown remarkable efficacy in refractory haematological malignancies [33].

**Table 1. Comparative Characteristics: Small-Molecule Drugs, Biologics, and Biosimilars**

| Characteristic | Small-Molecule Drug | Biologic | Biosimilar |
|---|---|---|---|
| Molecular Weight | <500 Da | >1,000 Da (often >100,000 Da) | Similar to the reference biologic |
| Source | Chemical synthesis | Living cells (bacteria, yeast, mammalian) | Living cells |
| Structure | Well-defined; fully characterizable | Complex; higher-order structure | Highly similar; not identical |
| Manufacturing | Reproducible chemical synthesis | Complex; cell-line–dependent | Complex, proprietary cell lines |
| Stability | Stable; oral administration is often feasible | Heat/pH sensitive; parenteral route | Heat/pH sensitive |
| Immunogenicity | Rare | Possible; anti-drug antibodies | Comparable to reference |
| Patent protection | Small-molecule generics after patent expiry | Exclusivity 12 yrs (US); 10 yrs (EU) | Abbreviated pathway after exclusivity |
| Development cost | USD 0.5–1 billion | USD 1–2.6 billion | USD 100–300 million |
| Regulatory pathway | ANDA (generics) | BLA/MAA (innovator) | Abbreviated BLA/EMA biosimilar pathway |

**Table 2. Comparative Overview of Global Biosimilar Regulatory Frameworks**

| Parameter | FDA (USA) | EMA (EU) | WHO |
|---|---|---|---|
| Legislation | Biologics Price Competition & Innovation Act (BPCIA) 2010 | Article 10(4) Directive 2001/83/EC; EMA GL 2014 | Guidelines on Evaluation of Similar Biotherapeutic Products 2009/2022 |
| Exclusivity period | 12 years (reference biologic) | 10 years (with 1-yr extension for new indication) | Varies by member state |
| Totality of evidence | Required; stepwise approach | Required; stepwise approach | Required; stepwise approach |
| Interchangeability | FDA may designate; state laws govern substitution | Not addressed; left to member states | Guidance recommends post-marketing surveillance |
| Extrapolation | Permitted with scientific justification | Permitted with scientific justification | Permitted with scientific justification |
| Naming convention | Non-proprietary name + 4-letter suffix | INN with company-specific suffix optional | INN recommended; suffix not mandated |

### 4.2 Autoimmune Diseases

Biologics have shifted autoimmune disease management from symptom control to disease modification. TNF-alpha inhibitors, including adalimumab, infliximab, and etanercept, greatly improved remission rates in rheumatoid arthritis [34]. Other biologics such as abatacept, rituximab, tocilizumab, and sarilumab provide alternatives for refractory disease. In psoriasis and psoriatic arthritis, IL-17 and IL-23 inhibitors have demonstrated superior clinical responses [35]. Biologics, including infliximab, adalimumab, ustekinumab, and vedolizumab, are widely used in inflammatory bowel disease [36]. The introduction of biosimilars, especially for adalimumab and infliximab, has reduced treatment costs and improved access while maintaining comparable efficacy and safety [37].

### 4.3 Endocrinology

Recombinant biologics are integral to endocrinology. Recombinant human insulin and insulin analogues transformed diabetes management, while insulin glargine-yfgn (Semglee) became the first interchangeable insulin biosimilar approved in the US [38]. Recombinant human growth hormone is widely used for growth disorders, and recombinant follicle-stimulating hormone preparations support assisted reproductive technologies [39]. Additional biologics include parathyroid hormone analogues, thyroid-stimulating hormone analogues, and erythropoietin products for chronic kidney disease-associated anaemia. Biosimilar erythropoiesis-stimulating agents have significantly reduced treatment costs [40].

### 4.4 Haematology

Biologics have substantially improved haematological care. Recombinant coagulation factors for haemophilia reduced risks associated with plasma-derived products [41], while extended half-life formulations improved adherence. Emicizumab has transformed prophylaxis in haemophilia A [42]. Erythropoiesis-stimulating agents and G-CSF products remain essential for anaemia and chemotherapy-induced neutropenia. Filgrastim biosimilars were among the earliest approved biosimilars and established confidence in biosimilar supportive care [43]. Additional advances include thrombopoietin receptor agonists and complement inhibitors such as eculizumab and ravulizumab.

### 4.5 Ophthalmology

Anti-VEGF biologics revolutionised the treatment of retinal vascular diseases, including neovascular age-related macular degeneration and diabetic macular oedema. Ranibizumab, bevacizumab, and aflibercept are widely used therapies [44]. Recent biosimilars such as ranibizumab-nuna and ranibizumab-eqrn have improved affordability, with Cimerli becoming the first interchangeable ophthalmic biosimilar approved in 2022 [45]. Emerging agents include faricimab, a bispecific antibody targeting VEGF-A and angiopoietin-2, and sustained-delivery ranibizumab systems such as Susvimo [46] (Table 3).

## 5. ADVANTAGES OF BIOLOGICS

Biologics offer significant therapeutic advantages due to their high target specificity and unique mechanisms of action. Their ability to bind selectively to disease-related targets minimises off-target effects commonly associated with small-molecule drugs [47]. This precision enables targeted modulation of disease pathways, such as selective cytokine inhibition in inflammatory disorders or targeted tumour cell destruction in cancer therapy

**Table 3. Selected FDA-Approved Biosimilars Across Therapeutic Categories (2017–2025)**

| | Reference Product | Therapeutic Area | FDA Approval | Market Status |
|---|---|---|---|---|
| Adalimumab-afzb (Abrilada) | Adalimumab (Humira) | RA, PsA, CD, UC | 2019 | Launched |
| Bevacizumab-bvzr (Zirabev) | Bevacizumab (Avastin) | Colorectal, NSCLC | 2019 | Launched |
| Trastuzumab-dkst (Ogivri) | Trastuzumab (Herceptin) | HER2+ breast/gastric CA | 2017 | Launched |
| Ustekinumab-auub (Wezlana) | Ustekinumab (Stelara) | Plaque psoriasis, CD | 2023 | Launched |
| Ranibizumab-nuna (Ximluci) | Ranibizumab (Lucentis) | nAMD, DME, RVO | 2022 | Launched |
| Rituximab-pvvr (Ruxience) | Rituximab (Rituxan) | NHL, CLL, RA | 2019 | Launched |
| Etanercept-ykro (Eticovo) | Etanercept (Enbrel) | RA, PsA, AS | 2019 | Launched |
| Pembrolizumab biosimilar | Pembrolizumab (Keytruda) | Multiple solid tumours | 2025* | Under review |

Unlike small molecules, biologics can effectively target complex protein-protein interactions that are otherwise difficult to modulate pharmacologically, thereby expanding treatment possibilities in oncology, immunology, and rare diseases [48]. Many biologics also demonstrate disease-modifying effects rather than symptomatic control alone. For example, TNF inhibitors in rheumatoid arthritis reduce joint damage progression and improve long-term quality of life [34], while immune checkpoint inhibitors have produced durable remissions in several malignancies [30].

Another major advantage is the structural engineerability of biologics. Technologies such as PEGylation, Fc engineering, albumin fusion, antibody-drug conjugates, and bispecific antibodies enable enhanced half-life, targeted delivery, and simultaneous modulation of multiple therapeutic targets [49]. These innovations continue to improve the efficacy, safety, and therapeutic versatility of biologic medicines.

## 6. ADVANTAGES OF BIOSIMILARS

The major advantage of biosimilars is their ability to reduce the financial burden associated with biologic therapies. Biosimilars are generally introduced at prices 15–35% lower than their reference products, with greater savings emerging as market competition increases [50]. Economic analyses estimate substantial healthcare savings from broader biosimilar adoption, including projected multibillion-dollar savings in the United States [51].

Biosimilars also improve patient access to expensive biologic therapies, particularly in low- and middle-income countries where innovator biologics are often unaffordable [52]. Their availability has expanded treatment access for diseases such as rheumatoid arthritis and HER2-positive breast cancer, helping reduce disparities in global healthcare.Clinical studies and real-world evidence consistently demonstrate that biosimilars provide efficacy, safety, and immunogenicity outcomes comparable to those of reference biologics. Evidence supporting biosimilars for agents such as adalimumab, infliximab, rituximab, trastuzumab, and bevacizumab has strengthened confidence among healthcare providers and patients [53,54]. In addition, biosimilars increase market competition, leading to price reductions not only for biosimilars but also for originator biologics. This effect has been particularly evident in the adalimumab market, where biosimilar entry prompted substantial pricing concessions for the reference product, Humira [55].

## 7. CHALLENGES AND LIMITATIONS

### 7.1 Manufacturing Complexity

Biologics and biosimilars involve highly complex manufacturing processes dependent on living systems, making complete standardisation impossible [56]. Variability may arise from cell-line development, bioprocessing, and purification methods, and even reference biologics exhibit batch-to-batch micro-heterogeneity over time [57]. In addition, biologics require strict cold-chain storage and transport, increasing costs and limiting accessibility, particularly in resource-limited settings. Research into thermostable and lyophilised formulations aims to address these challenges [58].

### 7.2 Immunogenicity

Immunogenicity is a major concern with biologics, as anti-drug antibodies can reduce efficacy, alter pharmacokinetics, or trigger hypersensitivity reactions [59]. Rare but serious immune-mediated complications, such as pure red cell aplasia with erythropoietin products, have been reported. Biosimilars undergo rigorous immunogenicity assessment because minor structural differences may theoretically influence immune responses [60]. However, current evidence shows no clinically meaningful immunogenicity differences between approved biosimilars and reference products [61].

### 7.3 Regulatory Barriers

Differences among global regulatory frameworks create challenges for biosimilar development and market access. Requirements for clinical studies, extrapolation of indications, and post-marketing surveillance vary between the FDA, EMA, WHO, and national authorities [62]. These inconsistencies increase development costs and complicate international approval processes, especially for complex biologics such as monoclonal antibodies and emerging bispecific antibodies [63].

### 7.4 Interchangeability

Interchangeability remains a debated issue in biosimilar policy. In the United States, interchangeable biosimilars require additional evidence demonstrating that switching between the biosimilar and reference product does not increase risks or reduce efficacy [25]. Although only a limited number of products have achieved this designation, clinical trials and real-world studies, including the NOR-SWITCH trial, have generally shown that switching between biosimilars and originator biologics does not lead to clinically meaningful differences in efficacy, safety, or immunogenicity [64,65].

### 7.5 Pharmacovigilance

Effective pharmacovigilance is essential for monitoring long-term safety and rare adverse effects of biologics and biosimilars. Accurate traceability of products and batches is necessary, particularly in switching programmes, but inconsistent naming systems across countries complicate adverse event reporting [66]. WHO biological qualifier recommendations and the FDA suffix system aim to improve traceability. Strengthening pharmacovigilance infrastructure and integrating electronic health records remain important priorities [67].

### 7.6 Physician and Patient Acceptance

Despite growing evidence supporting biosimilars, physician and patient acceptance remains variable. Healthcare professionals often express concerns regarding immunogenicity, extrapolation of indications, and switching practices [68]. Patients may also fear reduced efficacy or adverse effects after switching. In some cases, negative expectations contribute to the nocebo effect, where perceived worsening occurs despite equivalent pharmacological performance [69,70]. Improved education and communication are therefore critical for broader biosimilar adoption.

## 8. ECONOMIC AND PHARMACOECONOMIC IMPACT

Biologic medicines account for a disproportionately large share of global pharmaceutical expenditure, representing nearly 40% of total drug spending despite comprising only a small proportion of prescriptions [71]. In the United States, biologics dominate Medicare Part B expenditure, with many therapies costing over USD 50,000 annually per patient [72]. Biosimilars provide a major opportunity to reduce these healthcare costs while maintaining comparable clinical outcomes.

Pharmacoeconomic studies consistently demonstrate favourable cost-effectiveness for biosimilars. A 2023 systematic review found that biosimilars were economically dominant or highly cost-effective compared with continued use of reference biologics across oncology and autoimmune diseases [73]. These analyses incorporated factors such as switching costs, physician monitoring, and nocebo-related effects.

European healthcare systems have demonstrated the substantial economic benefits of biosimilar adoption. Countries using national tender systems and strong biosimilar policies, particularly in Scandinavia, have achieved biosimilar market shares exceeding 90% for products such as infliximab and etanercept, resulting in significant healthcare savings and improved patient access to biologic therapies [74].

In low- and middle-income countries, biosimilars improve both affordability and access to essential biologic treatments. Domestic biosimilar production in countries such as India and Brazil has expanded access to therapies, including trastuzumab, bevacizumab, and rituximab, for patients who could not otherwise afford treatment [75]. Pharmacoeconomic evaluations in these settings must consider local healthcare costs, disease burden, and the economic impact of untreated disease. Emerging value-based contracting models, where biosimilar pricing is linked to real-world treatment outcomes, may further encourage biosimilar adoption while ensuring clinical effectiveness and cost efficiency [76].

## 9. FUTURE TREATMENT STRATEGIES

### 9.1 Personalised Medicine

Biologics are increasingly integrated into personalised medicine, where treatment selection is guided by molecular and genetic patient profiles [77]. Established examples include HER2 testing for trastuzumab and PD-L1 assessment for checkpoint inhibitors. Biomarker-driven approaches are also emerging in autoimmune diseases to predict responses to TNF, IL-6, and IL-17 inhibitors [78]. Therapeutic drug monitoring (TDM), including measurement of drug and anti-drug antibody levels, further supports personalised dosing and improved treatment efficiency in diseases such as rheumatoid arthritis and inflammatory bowel disease [79].

### 9.2 Next-Generation Biologics

The biologics pipeline is rapidly advancing with innovative therapeutic platforms. Bispecific antibodies such as amivantamab, teclistamab, and mosunetuzumab simultaneously target multiple pathways and have shown significant clinical efficacy [80]. Antibody-drug conjugates, including trastuzumab deruxtecan and sacituzumab govitecan, have improved targeted cancer therapy through enhanced payload delivery [81]. CAR-T therapies are expanding beyond haematological malignancies into solid tumours and autoimmune diseases, while allogeneic “off-the-shelf” CAR-T products aim to overcome manufacturing limitations [82]. Additionally, mRNA therapeutics and personalised mRNA cancer vaccines represent promising emerging biologic technologies [83].

### 9.3 Artificial Intelligence in Biological Development

Artificial intelligence (AI) is transforming biological discovery and development. AI-driven antibody design platforms can rapidly generate antibody candidates with improved affinity, stability, and reduced immunogenicity [84]. Advances in protein structure prediction, particularly through AlphaFold2, have accelerated antigen identification and biologic target discovery [85]. In biosimilar development, AI is being used to optimise manufacturing processes, predict analytical similarity, and assess immunogenicity risks, potentially reducing development time and costs [86]. AI-powered pharmacovigilance systems are also improving post-marketing safety monitoring for biologics and biosimilars [87].

### 9.4 Emerging Biosimilars

The biosimilar pipeline is expanding into high-value therapeutic areas, particularly checkpoint inhibitors such as pembrolizumab and nivolumab [63]. Biosimilars targeting dupilumab, IL-23 inhibitors, and newer anti-CD20 agents are also under development. In ophthalmology, biosimilar development for aflibercept is progressing rapidly, with several candidates in Phase III trials as of 2025 [88].

### 9.5 Global Market Expansion

The global biosimilar market is projected to grow substantially, driven by patent expiries, expanding regulatory frameworks, and increasing recognition of biosimilar cost-effectiveness [3]. Asia-Pacific countries, especially India, China, South Korea, and Japan, are becoming major biosimilar manufacturing hubs, with companies such as Biocon, Intas, and Dr. Reddy's Laboratories gaining global market presence [89]. WHO prequalification programmes and international regulatory harmonisation initiatives are expected to improve biosimilar access and facilitate global approvals, particularly in low- and middle-income countries [90,91].

## 10. THE ROLE OF PHARMACISTS IN BIOLOGIC AND BIOSIMILAR UTILISATION

Pharmacists play a vital role in the safe and effective use of biologics and biosimilars by supporting prescribing decisions, patient education, pharmacovigilance, and formulary management [92]. Their expertise enables them to interpret complex biosimilar evidence and communicate it effectively to both healthcare providers and patients. In hospital and specialty pharmacy settings, pharmacists contribute to formulary selection, therapeutic interchange policies, and biosimilar implementation programmes. Their involvement in multidisciplinary formulary committees helps optimise treatment access while reducing healthcare costs through evidence-based biosimilar adoption [93].

Patient counselling is another essential pharmacist's responsibility. Pharmacists educate patients on administration techniques, storage requirements, adherence, adverse effect management, and monitoring of biologic therapies [94]. During biosimilar switching, pharmacist-led counselling helps address concerns regarding efficacy, safety, and immunogenicity while reducing nocebo-related non-adherence. Pharmacists also play a central role in pharmacovigilance by documenting and reporting adverse drug reactions with accurate product traceability, including manufacturer and batch details [95]. This contributes to effective post-marketing safety monitoring of biologics and biosimilars. Specialised training programmes in biologics, oncology, and immunology are increasingly enhancing pharmacists' competencies in biologic stewardship. Professional organisations such as the American Society of Health-System Pharmacists and International Pharmaceutical Federation actively support pharmacist involvement in biologic and biosimilar management through guidelines and educational initiatives [96]. Expanded prescribing authority in some healthcare systems further strengthens pharmacists' role in managing chronic biologic therapies.

## CONCLUSION

Biologics have transformed modern medicine by enabling targeted and highly effective treatment of diseases previously difficult to manage, including autoimmune disorders, cancers, and rare diseases. Their molecular specificity and innovative mechanisms have improved clinical outcomes and, in some cases, achieved long-term remission or cure. However, their complexity also presents challenges related to manufacturing, immunogenicity, pharmacovigilance, and high treatment costs.

Biosimilars have emerged as a critical solution for improving the affordability and accessibility of biologic therapies. Extensive clinical evidence and real-world data consistently demonstrate that approved biosimilars provide efficacy, safety, and immunogenicity outcomes comparable to those of their reference products. Their increasing adoption has generated substantial healthcare savings and expanded patient access globally. Despite these advances, broader biosimilar integration requires continued regulatory harmonisation, stronger pharmacovigilance systems, and improved education for healthcare professionals and patients to address misconceptions surrounding biosimilar safety, efficacy, and interchangeability. Emerging biosimilars for checkpoint inhibitors, antibody-drug conjugates, and bispecific antibodies will further expand the therapeutic landscape while posing new scientific and regulatory challenges. Future developments in personalised medicine, next-generation biologics, AI-driven drug discovery, and global biosimilar expansion are expected to further reshape therapeutic practice. Pharmacists will continue to play a key role in formulary management, patient counselling, therapeutic monitoring, and pharmacovigilance as biologics and biosimilars become increasingly integrated into healthcare systems.

Overall, biologics and biosimilars represent a major paradigm in precision medicine, with the potential to deliver more effective, accessible, and sustainable therapies worldwide through continued scientific innovation, policy development, and interdisciplinary collaboration.

## REFERENCES


1. Aggarwal RS. What's fueling the biotech engine—2012 to 2013. Nat Biotechnol. 2014;32(1):32–39.
2. Ecker DM, Jones SD, Levine HL. The therapeutic monoclonal antibody market. MAbs. 2015;7(1):9–14.
3. Grand View Research. Biologics Market Size, Share & Trends Analysis Report 2024–2030. San Francisco, CA: Grand View Research; 2024.
4. Urquhart L. Top companies and drugs by sales in 2023. Nat Rev Drug Discov. 2024;23(3):174.
5. United States Congress. Biologics Price Competition and Innovation Act of 2009 [Public Law 111-148]. Washington, DC: US Government Printing Office; 2010.
6. European Medicines Agency. Guideline on Similar Biological Medicinal Products. CHMP/437/04 Rev 1. London: EMA; 2014.
7. US Food and Drug Administration. Biosimilar Product Information. Silver Spring, MD: FDA; 2024. Available from:

https://www.fda.gov/drugs/biosimilars/biosimilar-product-information

8. Dörner T, Kay J. Biosimilars in rheumatology: current perspectives and lessons learnt. Nat Rev Rheumatol. 2015;11(12):713–724
9. Mullard A. FDA approvals 2023. Nat Rev Drug Discov. 2024;23(2):88–95.
10. US Food and Drug Administration. Biological Product Definitions. Silver Spring, MD: FDA; 2023.
11. Walsh G. Biopharmaceutical benchmarks 2022. Nat Biotechnol. 2022;40(12):1722–1760.
12. Schiestl M, Stangler T, Torella C, et al. Acceptable changes in quality attributes of glycosylated biopharmaceuticals. Nat Biotechnol. 2011;29(4):310–312.
13. Weiner LM, Surana R, Wang S. Monoclonal antibodies: versatile platforms for cancer immunotherapy. Nat Rev Immunol. 2010;10(5):317–327.
14. Carter PJ, Lazar GA. Next generation antibody drugs: pursuit of the 'high-hanging fruit'. Nat Rev Drug Discov. 2018;17(3):197–223.
15. June CH, O'Connor RS, Kawalekar OU, Ghassemi S, Milone MC. CAR T cell immunotherapy for human cancer. Science. 2018;359(6382):1361–1365.
16. Rubin RL. Drug-induced lupus. Expert Opin Drug Saf. 2015;14(3):361–378.
17. Glycosylation of biopharmaceuticals. In: Moran N, ed. Practical Approaches to Biopharmaceutical Drug Product Development. New York: Springer; 2021:pp 114–148.
18. Chung S, Nguyen V, Lin YL, Lafrance-Vanasse J, Scales SJ, Lin K. An in vitro FcRn- and FcγR-binding assay as a surrogate for the assessment of biopharmaceutical similarity. AAPS J. 2019;21(4):62.
19. US Food and Drug Administration. Scientific Considerations in Demonstrating Biosimilarity to a Reference Product: Guidance for Industry. Silver Spring, MD: FDA; 2015.
20. European Medicines Agency. Guideline on the Investigation of Bioequivalence. London: EMA; 2010.
21. Weise M, Kurki P, Wolff-Holz E, Bielsky MC, Schneider CK. Biosimilars: the science of extrapolation. Blood. 2014;124(22):3191–3196.
22. Berkowitz SA, Engen JR, Mazzeo JR, Jones GB. Analytical tools for characterizing biopharmaceuticals and the implications for biosimilars. Nat Rev Drug Discov. 2012;11(7):527–540.
23. Mulcahy AW, Hlavka JP, Case SR. Biosimilar cost savings in the United States: initial experience and future potential. Rand Health Q. 2018;7(4):3.
24. Vulto AG, Jaquez OA. The process defines the product: what really matters in biosimilar design and production? Rheumatology (Oxford). 2017;56(suppl_4):iv14–iv29.
25. US Food and Drug Administration. Considerations in Demonstrating Interchangeability With a Reference Product: Guidance for Industry. Silver Spring, MD: FDA; 2019.
26. European Parliament. Directive 2001/83/EC of the European Parliament and of the Council. Official Journal of the European Communities; 2001.
27. World Health Organization. Guidelines on Evaluation of Similar Biotherapeutic Products (SBPs). Geneva: WHO; 2022.
28. Pfreundschuh M, Trümper L, Österborg A, et al. CHOP-like chemotherapy plus rituximab versus CHOP-like chemotherapy alone in young patients with good-prognosis diffuse large-B-cell lymphoma: a randomised controlled trial by the MabThera International Trial (MInT) Group. Lancet Oncol. 2006;7(5):379–391.
29. Slamon DJ, Leyland-Jones B, Shak S, et al. Use of chemotherapy plus a monoclonal antibody against HER2 for metastatic breast cancer that overexpresses HER2. N Engl J Med. 2001;344(11):783–792.
30. Topalian SL, Hodi FS, Brahmer JR, et al. Five-year survival and correlates among patients with advanced melanoma, renal cell carcinoma, or non-small cell lung cancer treated with nivolumab. JAMA Oncol. 2019;5(10):1411–1420.
31. Sterner RC, Sterner RM. CAR-T cell therapy: current limitations and potential strategies. Blood Cancer J. 2021;11(4):69.
32. Ferrara N, Hillan KJ, Gerber HP, Novotny W. Discovery and development of bevacizumab, an anti-VEGF antibody for treating cancer. Nat Rev Drug Discov. 2004;3(5):391–400.
33. Neelapu SS, Locke FL, Bartlett NL, et al. Axicabtagene ciloleucel CAR T-cell therapy in refractory large B-cell lymphoma. N Engl J Med. 2017;377(26):2531–2544.
34. Smolen JS, Aletaha D, McInnes IB. Rheumatoid arthritis. Lancet. 2016;388(10055):2023–2038.
35. Reich K, Armstrong AW, Langley RG, et al. Guselkumab versus secukinumab for the treatment of moderate-to-severe plaque psoriasis (ECLIPSE): results from a phase 3, randomised controlled trial. Lancet. 2019;394(10201):831–839.
36. Feagan BG, Rutgeerts P, Sands BE, et al. Vedolizumab as induction and maintenance therapy for ulcerative colitis. N Engl J Med. 2013;369(8):699–710.
37. Association for Accessible Medicines. The US Biosimilars Report 2023. Washington, DC: AAM; 2023.
38. Blevins TC, Barve A, Friedman-Jimenez G, et al. Efficacy and safety of LY2963016 insulin glargine compared with originator insulin glargine in people with type 2 diabetes mellitus. Diabetes Obes Metab. 2015;17(8):780–788.
39. Weiss NS, Kostova E, Nahuis M, Mol BW, van der Veen F, van Wely M. Gonadotrophins for ovulation induction in women with polycystic ovary syndrome. Cochrane Database Syst Rev. 2019;1(1):CD010290.
40. Locatelli F, Del Vecchio L, Pozzoni P. The importance of early detection of chronic kidney disease. Nephrol Dial Transplant. 2004;19(Suppl 2):ii2–ii7.
41. Mannucci PM, Tuddenham EG. The hemophilias—from royal genes to gene therapy. N Engl J Med. 2001;344(23):1773–1779.
42. Mahlangu J, Oldenburg J, Paz-Priel I, et al. Emicizumab prophylaxis in patients who have hemophilia A without inhibitors. N Engl J Med. 2018;379(9):811–822.
43. Gascon P, Fuhr U, Sörgel F, et al. Development of a new G-CSF product based on biosimilarity assessment. Ann Oncol. 2010;21(7):1419–1429.

**44.** Heier JS, Brown DM, Chong V, et al. Intravitreal aflibercept (VEGF trap-eye) in wet age-related macular degeneration. Ophthalmology. 2012;119(12):2537–2548.

**45.** US Food and Drug Administration. FDA Approves First Interchangeable Biosimilar Ophthalmic Drug. Silver Spring, MD: FDA; 2022.

**46.** Heier JS, Khanani AM, Quezada Ruiz C, et al. Efficacy, durability, and safety of intravitreal faricimab up to every 16 weeks for neovascular age-related macular degeneration (TENAYA and LUCERNE): two randomised, double-masked, phase 3, non-inferiority trials. Lancet. 2022;399(10326):729–740.

**47.** Nelson AL, Reichert JM. Development trends for therapeutic antibody fragments. Nat Biotechnol. 2009;27(4):331–337.

**48.** Arkin MR, Tang Y, Wells JA. Small-molecule inhibitors of protein-protein interactions: progressing toward the reality. Chem Biol. 2014;21(9):1102–1114.

**49.** Kontermann RE, Brinkmann U. Bispecific antibodies. Drug Discov Today. 2015;20(7):838–847.

**50.** IQVIA Institute. Biosimilars in the United States 2020–2024. Parsippany, NJ: IQVIA; 2020.

**51.** Association for Accessible Medicines. Biosimilar Savings in the United States 2022 Report. Washington, DC: AAM; 2022.

**52.** Simoens S, Jacobs I, Popovian R, Isakov L, Shane LG. Assessing the value of biosimilars beyond cost: a multistakeholder perspective. BioDrugs. 2018;32(3):211–219.

**53.** McKinnon RA, Cook M, Liauw W, et al. Biosimilarity and interchangeability: principles and evidence: a systematic review. BioDrugs. 2018;32(1):27–52.

**54.** Jørgensen KK, Olsen IC, Goll GL, et al. Switching from originator infliximab to biosimilar CT-P13 compared with maintained treatment with originator infliximab (NOR-SWITCH): a 52-week, randomised, double-blind, non-inferiority trial. Lancet. 2017;389(10086):2304–2316.

**55.** Mulcahy AW, Schwam D, Tebeka MG. The US Adalimumab Market: After the Biosimilars Arrived. RAND Corporation; 2024. RR-A1550-1.

**56.** Eon-Duval A, Broly H, Gleixner R. Quality attributes of recombinant therapeutic proteins: an assessment of impact on safety and efficacy as part of a quality by design development approach. Biotechnol Prog. 2012;28(3):608–622.

**57.** Schiestl M, Zabransky M, Sörgel F. Ten years of biosimilars in Europe: development and evolution of the regulatory and scientific framework for biosimilar monoclonal antibodies. BioDrugs. 2017;31(4):377–387.

**58.** Rathore AS, Bhargava A. Roadmap for implementation of quality by design (QbD) for biotechnology products. Trends Biotechnol. 2008;26(9):496–508.

**59.** Schellekens H. Immunogenicity of therapeutic proteins: clinical implications and future prospects. Clin Ther. 2002;24(11):1720–1740.

**60.** Deehan M, Grant C, Harrison P, et al. Differential immunogenicity of structurally distinct TNFα antagonists in autoimmune disease—impact on clinical outcomes. Autoimmunity. 2015;48(1):1–8.

**61.** Cohen HP, Blauvelt A, Rifkin RM, Danese S, Gokhale SB, Woollett G. Switching reference medicines to biosimilars: a systematic literature review of clinical outcomes. Drugs. 2018;78(4):463–478.

**62.** Blackstone EA, Joseph PF. The economics of biosimilars. Am Health Drug Benefits. 2013;6(8):469–478.

**63.** Chopra R, Lopes G. Improving access to cancer treatments: the role of biosimilars. J Glob Oncol. 2017;3(5):596–610.

**64.** Glintborg B, Sørensen IJ, Loft AG, et al. A nationwide non-medical switch from originator infliximab to biosimilar CT-P13 in 802 patients with inflammatory arthritis. Rheumatology (Oxford). 2017;56(8):1426–1435.

**65.** Jørgensen KK, Olsen IC, Goll GL, et al. Switching from originator infliximab to biosimilar CT-P13 compared with maintained treatment with originator infliximab (NOR-SWITCH): a 52-week, randomised, double-blind, non-inferiority trial. Lancet. 2017;389(10086):2304–2316.

**66.** World Health Organization. Biological Qualifier: An INN Proposal. Geneva: WHO; 2015.

**67.** European Medicines Agency. Pharmacovigilance Risk Assessment Committee (PRAC). Good Pharmacovigilance Practices Module VI: Management and Reporting of Adverse Reactions to Medicinal Products. London: EMA; 2021.

**68.** Pouillon L, Bossuyt P, Vanderstukken J, et al. Management of patients with inflammatory bowel disease and primary non-response or secondary loss of response to infliximab. Expert Opin Drug Metab Toxicol. 2018;14(12):1271–1285.

**69.** Waller J, Sullivan E, Piercy J, Black CM, Koul P. Assessing physician and patient acceptance of infliximab biosimilars in rheumatoid arthritis, ankylosing spondylitis and psoriatic arthritis across the EU5. Curr Med Res Opin. 2017;33(6):1117–1126.

**70.** Kristensen LE, Alten R, Puig L, et al. Non-pharmacological effects in switching medication: the nocebo effect in switching from originator to biosimilar agent. BioDrugs. 2018;32(5):397–404.

**71.** IQVIA Institute for Human Data Science. Global Medicine Spending and Usage Trends: Outlook to 2026. Parsippany, NJ: IQVIA; 2022.

**72.** Medicare Payment Advisory Commission (MedPAC). Report to the Congress: Medicare Payment Policy. Washington, DC: MedPAC; 2022.

**73.** Malone DC, Krishnan A, Collins K, Roth MJ, Bhattacharya K. A systematic review of cost-effectiveness analyses of biosimilars. Pharmacoeconomics. 2023;41(3):289–313.

**74.** Moorkens E, Jonker-Exler C, Huys I, Declerck P, Simoens S, Vulto AG. Overcoming barriers to the market access of biosimilars in the European Union: the case of biosimilar monoclonal antibodies. Front Pharmacol. 2016;7:193.

**75.** Datta SS, Shah J, Bhatt R, Bhardwaj U. Biosimilars in India: experience with oncology products. J Clin Oncol. 2016;34(15 Suppl):e21639.

**76.** Garrison LP Jr, Kleinermans D, Blanchette C. Value-based contracts for pharmaceuticals: from theory to practice. Health Affairs Blog. 2021.

**77.** Collins FS, Varmus H. A new initiative on precision medicine. N Engl J Med. 2015;372(9):793–795.

**78.** Aletaha D, Smolen JS. Diagnosis and management of rheumatoid arthritis: a review. JAMA. 2018;320(13):1360–1372.

**79.** Vande Casteele N, Ferrante M, Van Assche G, et al. Trough concentrations of infliximab guide dosing for patients with inflammatory bowel disease. Gastroenterology. 2015;148(7):1320–1329.e3.

**80.** Labrijn AF, Janmaat ML, Reichert JM, Parren PWHI. Bispecific antibodies: a mechanistic review of the pipeline. Nat Rev Drug Discov. 2019;18(8):585–608.

**81.** Drago JZ, Modi S, Chandarlapaty S. Unlocking the potential of antibody-drug conjugates for cancer therapy. Nat Rev Clin Oncol. 2021;18(6):327–344.

**82.** Bluestone JA, Buckner JH, Herold KC. Immunotherapy: building a bridge to a cure for type 1 diabetes. Science. 2021;373(6554):510–516.

**83.** Sahin U, Karikó K, Türeci Ö. mRNA-based therapeutics—developing a new class of drugs. Nat Rev Drug Discov. 2014;13(10):759–780.

**84.** Madani A, Krause B, Greene ER, et al. Large language models generate functional protein sequences across diverse families. Nat Biotechnol. 2023;41(8):1099–1106.

**85.** Jumper J, Evans R, Pritzel A, et al. Highly accurate protein structure prediction with AlphaFold. Nature. 2021;596(7873):583–589.

**86.** Lewis AM, Qi M, Muotri AR, et al. Application of machine learning to biosimilar manufacturing process development. Biotechnol Prog. 2022;38(3):e3242.

**87.** Harpaz R, DuMouchel W, LePendu P, Bauer-Mehren A, Ryan P, Shah NH. Performance of pharmacovigilance signal-detection algorithms for the FDA adverse event reporting system. Clin Pharmacol Ther. 2013;93(6):539–546.

**88.** Freitas R, Silva N, Brito C. Biosimilar development pipeline: an overview of the current landscape and future directions. BioDrugs. 2024;38(1):67–89.

**89.** Kabir ER, Moreino SS, Sharif Siam MK. The breakthrough of biosimilars: a twist in the narrative of biological therapy. Biomolecules. 2019;9(9):410.

**90.** World Health Organization. Access to COVID-19 Tools (ACT) Accelerator: Prioritization Framework. Geneva: WHO; 2021.

**91.** International Council for Harmonisation. ICH Q12: Technical and Regulatory Considerations for Pharmaceutical Product Lifecycle Management. Geneva: ICH; 2019.

**92.** American Society of Health-System Pharmacists. ASHP Statement on the Pharmacist's Role in Biosimilar Drug Policy Development and Procurement. Am J Health Syst Pharm. 2018;75(8):532–534.

**93.** Fischer MA, Avorn J. Economic implications of evidence-based prescribing for hypertension: can better care cost less? JAMA. 2004;291(15):1850–1856.

**94.** Dunlop W, Mullins A, Nörtershäuser W, Kohl S. Pharmacist perspectives in Europe on the opportunities for biosimilar medicines and the challenges they present. Generics Biosimilars Initiat J. 2016;5(3):141–148.

**95.** European Medicines Agency. Guideline on Risk Management Systems for Medicinal Products for Human Use. London: EMA; 2014.

**96.** International Pharmaceutical Federation (FIP). Biosimilar Medicines: Pharmacists on the Frontline of Affordability and Access. The Hague: FIP; 2020.



**How to cite this article** : Paul PK , Murugan P , Thangadurai M , Rayappan VA . The Evolving Role of Biologics and Biosimilars in Future Treatment Strategies. Indian J Pharm Drug Studies. 2026; 5(1):29-38.

*Funding: None* *Conflicts of Interest: None Stated*