Exploring Animal-Origin Drugs in Modern Pharmacology: A Review

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***Abstract*—Animal-origin pharmacological agents continue to influence modern drug development, shifting from empirical traditional use to highly characterised therapeutic molecules. Bioactive constituents derived from various animal taxa ranging from snakes and marine invertebrates to insects and mammals have inspired several notable pharmaceuticals. Advances in proteomics, molecular engineering, and in silico modelling now enable these compounds to be optimised and produced through recombinant or synthetic systems, reducing reliance on direct animal sourcing. Due to their structural diversity and significant target selectivity, animal-derived molecules remain essential in managing pain, cardiovascular disorders, endocrine dysfunctions, and immune-mediated diseases. In veterinary medicine, preparations like colostrum, eCG, and oxytocin maintain substantial clinical value, and antiserum-based interventions continue to support zoonotic disease control within the One Health framework. This review summarises the historical development, pharmacological features, therapeutic uses, and ethical concerns related to animal-origin drugs, and highlights emerging biotechnological methods aimed at improving sustainability and safety.**

I. INTRODUCTION

The use of animal-derived substances is among the earliest documented practices in pharmacology. Traditional medical systems, including Ayurveda, Traditional Chinese Medicine, and Unani, used materials such as honey, bile, musk, and venoms for healing purposes. The scientific understanding of these products, however, has only been clarified through recent advances in biochemistry, molecular biology, and analytical pharmacology.

In modern drug discovery, compounds derived from animals often serve as structural templates because of their high biological activity and specificity. Notable examples include peptides initially characterised from Bothrops jararaca venom that guided the development of ACE-inhibitory drugs; conotoxin derivatives that laid the groundwork for non-opioid analgesics; and GLP-1-mimetic agents modelled after peptides found in Gila monster saliva. These molecules frequently interact with specific molecular targets such as ion channels, G-protein coupled receptors, or important enzymatic pathways making them valuable tools for understanding physiology and treating disease (Calvete, 2020; King, 2019).

In veterinary pharmacology, animal-origin products are highly valuable. Colostrum remains key for neonatal passive immunity; eCG is broadly used for reproductive management; and oxytocin continues to aid obstetrical procedures. Additionally, hyperimmune antisera and biologics produced in animals are essential tools against zoonotic infections within One Health frameworks (Rahman et al., 2022).

Growing demand for these therapeutics raises concerns about animal welfare, sustainability, and biosecurity. These issues have sped up interest in alternatives such as recombinant proteins, monoclonal antibodies, and synthetic analogues that can mimic natural molecules while decreasing reliance on animal harvesting (Vázquez-Torres et al., 2024). This review consolidates recent knowledge on the evolution, mechanisms, classification, and therapeutic importance of animal-origin drugs, focusing on their use in both human and veterinary medicine.

II. HISTORICAL BACKGROUND OF ANIMAL-ORIGIN DRUGS

The therapeutic use of animal-derived materials dates back to early medical traditions, where animals played both symbolic and practical roles in disease treatment.

Over centuries, observations of their biological effects gradually developed into the modern understanding of animal-based therapeutics.

Ancient And Traditional Systems

Traditional Chinese Medicine (TCM) included a wide variety of animal-derived substances, such as bear bile, various venoms, and deer musk. The long-standing use of bear bile for biliary and hepatic disorders was later partly validated when ursodeoxycholic acid was identified as a major active component (Kong et al., 2016). Similarly, the use of snake venom preparations for neurological and musculoskeletal conditions anticipated later discoveries that venom-derived peptides affect ion-channel activity and neuromuscular transmission.

In Ayurveda, many animal-origin agents such as milk, ghee, horn derivatives, and certain animal fats were classified as restorative or tissue-supportive under the concept of Jeevaniya Dravyas and were used for treating chronic diseases and wound care (Mukherjee et al., 2019).

The Unani medical system documented the therapeutic use of musk, honey, egg components, and bezoars, attributing detoxifying, tonic, or protective properties to these materials (Suleman et al., 2021).

Early Biomedical Applications

During the Medieval and Renaissance periods, traditional practices began to intersect with early experimental physiology. Honey and milk were applied to wounds because of their antimicrobial properties, while medical leeching widely practised for circulatory disorders eventually led to the discovery of hirudin, a powerful inhibitor of thrombin (Markwardt, 1994).

Other examples include the use of silkworm-derived serrapeptase for inflammation management in Japan and the documented use of musk for cardiopulmonary symptoms. By the late 19th and early 20th centuries, researchers started isolating active compounds from animal tissues, marking the shift to standardised pharmaceuticals. This period led to key discoveries such as insulin from bovine and porcine pancreas (Banting & Best, 1922), thyroxine from thyroid glands, and gonadotropins from equine chorionic tissue.

III. TRANSITION TO MODERN PHARMACOLOGY

The latter half of the 20th century saw rapid growth in drug discovery from animal toxins and marine organisms. Venom-derived peptides inspired the development of ACE inhibitors, such as the Bothrops jararaca peptide analogue that became captopril (Ondetti et al., 1977). Conopeptide research led to ziconotide, a highly selective N-type calcium channel blocker used for severe chronic pain (Miljanich, 2004). At the same time, marine bioprospecting produced agents like trabectedin, a DNA-interacting compound first isolated from Ecteinascidia turbinata, which was later found to have clinical application in oncology (Demetri et al., 2009).

These examples show how traditional knowledge and natural toxins influenced modern pharmacology and spurred systematic bioprospecting efforts.

IV. CLASSIFICATION AND MECHANISMS OF ANIMAL-ORIGIN DRUGS

Animal-derived therapeutics include a wide range of compounds from both vertebrate and invertebrate species. For clarity, they can be categorised into:

(1) Hormones,
(2) Enzymes,
(3) Venom-derived peptides and toxins,
(4) Marine and exotic animal products, and
(5) Antisera and immunoglobulins.

Each category contributes distinct molecular templates and mechanisms relevant to both human and veterinary pharmacology.

Hormones

Historically central to metabolic and reproductive therapy, animal-derived hormones include early insulin preparations from porcine and bovine pancreas, natural thyroxine from desiccated thyroid tissue, and gonadotropins obtained from equine or human sources. Oxytocin was initially produced from pituitary extracts before synthetic forms became widely available. Salmon calcitonin, noted for its increased receptor affinity, offered a useful therapeutic option for metabolic bone disorders (Azria, 2002).

Mechanism:

Hormones operate via highly specific receptor-mediated pathways that control endocrine and reproductive functions, acting as physiological replacements or modulators.

Enzymes

Enzymatic preparations of animal origin remain clinically and industrially important. Trypsin, chymotrypsin, and pancreatin from pancreatic tissue are routinely used for digestion support and wound debridement. Hyaluronidase from bovine sources facilitates tissue permeability, enhancing local drug dispersion. Serratiopeptidase, obtained from silkworm bacteria, has demonstrated mucolytic and anti-inflammatory actions (Mazzone et al., 1990).

Mechanism:

These enzymes catalyse defined biochemical transformations that improve digestion, reduce inflammation, or modify tissue permeability.

Venom-Derived Peptides and Toxins

Animal venoms contain a rich repertoire of peptides targeting specific ion channels, enzymes, and receptors. Therapeutics inspired by these components include ACE-inhibitory peptides leading to captopril, conopeptides resulting in ziconotide, and serine proteases such as batroxobin used in hemostasis. Bee venom components (melittin, apamin) and scorpion toxins continue to be investigated for neurological and immunomodulatory applications (De la Vega et al., 2010; Park et al., 2022).

Mechanism:

Venom peptides generally exert their effects by selectively modulating voltage-gated channels or key enzymatic pathways, providing high potency with precise molecular specificity.

Marine and Exotic Animal Products

Marine species produce structurally unique metabolites with potential therapeutic uses. Trabectedin and eribulin showcase the usefulness of marine-derived cytotoxins in cancer treatment (Towle et al., 2001). EPA-derived icosapent ethyl lowers cardiovascular risk, while exenatide, modelled on a peptide from Gila monster saliva, is widely used for metabolic disease management (Kolterman et al., 2005).

Mechanism:

These agents interact with molecular targets such as DNA, microtubules, or metabolic pathways, often exhibiting unique modes of action compared to compounds derived from land-based sources.

Antisera and Immunoglobulins

Hyperimmunized livestock produce antisera and immunoglobulins essential for passive immunisation against toxins and infectious agents. Bovine colostrum provides IgG-rich preparations for neonatal immunity, while natural antimicrobial proteins such as lactoferrin and lysozyme demonstrate broad activity against microbial pathogens (Superti, 2020).

Mechanism:

Antisera provide passive immunity by neutralising pathogens or toxins, while immunoglobulin-derived proteins have direct antimicrobial effects.

Summary Table — Classification Overview

Category	Examples	Therapeutic Use	Key Mechanism
Hormones	Insulin, Oxytocin, Calcitonin	Diabetes, parturition, osteoporosis	Receptor activation
Enzymes	Trypsin, Hyaluronidase, Serratiopeptidase	Digestion, wound healing, and inflammation	Catalysis of biochemical reactions
Venom Peptides	Ziconotide, Captopril, Apitoxin	Pain, hypertension, arthritis	Ion channel/enzyme modulation
Marine/Exotic	Trabectedin, Eribulin, Exenatide	Cancer, diabetes	DNA binding, receptor agonism
Antisera/Ig	Rabies antiserum, Colostrum, Lactoferrin	Immunity, infection control	Passive immunisation, antimicrobial

V. PHARMACOLOGICAL APPLICATIONS OF ANIMAL-ORIGIN DRUGS

5.1 Animal-derived therapeutics have significantly advanced modern pharmacology by providing structurally diverse molecules with mechanisms that are difficult to replicate through synthetic chemistry. These agents have guided the treatment of neurological, endocrine, cardiovascular, immune-mediated, infectious, and neoplastic diseases. Their clinical importance is highlighted by the high selectivity and potency typical of many naturally evolved compounds.

Pain Management

Ziconotide

Ziconotide, a synthetic analogue of a conopeptide originally characterised from Conus magus, functions as a highly selective blocker of N-type voltage-gated calcium channels in dorsal horn neurons. Limiting presynaptic neurotransmitter release decreases transmission of nociceptive input.

- Indication: Severe chronic neuropathic pain unresponsive to conventional agents.
- Benefit: Provides analgesia without the dependence or tolerance associated with opioids (Miljanich, 2004).

Bee Venom–Based Preparations

Bee venom includes bioactive components such as melittin and apamin that affect inflammatory and immunoregulatory pathways.

- Indications: Investigated for rheumatoid arthritis, neuralgia, and neuroinflammatory disorders.
- Mechanism: Modulates cytokine production and may enhance endogenous glucocorticoid activity (Park et al., 2022).

Hirudin

Hirudin, isolated from Hirudo medicinalis, is a potent and specific inhibitor of thrombin.

- Clinical utility: Used in vascular surgery, microsurgical tissue salvage, and management of venous congestion.
- Mechanism: Reduces clot formation and improves microcirculatory flow (Markwardt, 1994).

5.2 Endocrine and Metabolic Disorders

Insulin

Early insulin preparations derived from bovine and porcine pancreas revolutionised diabetes therapy and formed the basis of modern endocrinology (Banting & Best, 1922).

- Mechanism: Promotes glucose uptake and metabolic regulation through insulin receptor signalling.

Exenatide

Exenatide is a peptide derived from the saliva of the Gila monster (Heloderma suspectum) and functions as a GLP-1 receptor agonist.

- Indication: Type 2 diabetes mellitus.
- Mechanism: Enhances insulin secretion, decreases glucagon output, and slows gastric emptying (Kolterman et al., 2005).

Salmon Calcitonin

A more potent analogue of human calcitonin is used in metabolic bone disease.

- Use: Osteoporosis and hypercalcaemia.
- Mechanism: Inhibits osteoclast activity, reducing bone resorption (Azria, 2002).

5.3 Cardiovascular Applications

Captopril

Captopril is a synthetic derivative inspired by peptides isolated from Bothrops jararaca venom.

- Mechanism: Inhibition of angiotensin-converting enzyme (ACE), decreasing vasoconstriction and aldosterone secretion.
- Indications: Hypertension and heart failure (Ondetti et al., 1977).

Batroxobin

A serine protease derived from Bothrops atrox venom.

- Use: Management of clotting abnormalities and certain bleeding disorders.
- Mechanism: Modifies fibrinogen to promote controlled clot degradation.

Marine-Derived Omega-3 Fatty Acids

Long-chain omega-3 fatty acids from marine fish oils contribute to cardiovascular risk reduction.

- Mechanism: Lower triglyceride levels, reduce inflammatory signalling, and stabilise vascular plaques (Bhatt et al., 2019).

5.4 Immune Modulation and Autoimmune Disorders

Bovine Colostrum

Rich in immunoglobulins, lactoferrin, and growth factors, bovine colostrum supports both innate and adaptive immune responses.

- Applications: Gastrointestinal inflammation, neonatal immunity, and immune-deficiency states (Playford et al., 2000).

Bee Venom in Autoimmune Regulation

Certain venom peptides may attenuate inflammatory mediators and influence regulatory T-cell function (Park et al., 2022).

Leech-Derived Molecules

Hirudin-containing preparations are used to support blood flow in ischemic tissues and to reduce inflammatory vascular responses.

5.5 Antimicrobial and Antiviral Applications

Antisera and Hyperimmune Immunoglobulins

Produced from immunised animals, these agents provide immediate passive immunity.

- Applications: Rabies, tetanus, diphtheria, and envenomation.
- Mechanism: Antibodies bind and neutralise toxins or infectious agents.

Lactoferrin

An iron-binding glycoprotein present in milk and colostrum with broad antimicrobial effects.

- Mechanisms: Restricts microbial access to iron, disrupts viral attachment, and modulates host immunity (Superti, 2020).

Lysozyme

A natural enzyme abundant in egg white and secretions such as tears.

- Use: Food protection, dental formulations, ophthalmic preparations.
- Mechanism: Cleaves peptidoglycan in bacterial cell walls.

Frog Skin Antimicrobial Peptides

Peptides from amphibian skin show promise as alternatives to antibiotics due to their broad-spectrum antimicrobial activity (Conlon, 2011).

5.6 Oncology and Emerging Therapeutics

Trabectedin

A marine-derived antitumor agent originally isolated from Ecteinascidia turbinata.

- Mechanism: Binds to DNA, disrupts transcription, and triggers apoptosis (Demetri et al., 2009).

Eribulin

Originating from the sea sponge Halichondria okadai, eribulin inhibits microtubule dynamics.

- Use: Metastatic breast cancer (Towle et al., 2001).

Squalamine

An aminosterol was first identified in sharks.

- Potential roles: Antimicrobial and antiviral applications; investigated in hepatic and ocular disease models (Zasloff, 2017).

5.7 Summary of Applications

Therapeutic Area	Example Drugs	Source	Mechanism / Key Action
Pain Management	Ziconotide, Apitoxin, Hirudin	Cone snail, Bee, Leech	Channel blockade, anti-inflammatory
Endocrine Disorders	Insulin, Exenatide, Calcitonin	Pig, Gila monster, Salmon	Hormone regulation
Cardiovascular	Captopril, Batroxobin, Omega-3	Snake, Fish	ACE inhibition, lipid modulation
Autoimmune & Immune Modulation	Colostrum, Bee venom, Hirudin	Cow, Bee, Leech	Immune regulation
Antimicrobial/Antiviral	Lactoferrin, Lysozyme, AMPs	Milk, Egg, Frog	Pathogen inhibition
Oncology	Trabectedin, Eribulin, Squalamine	Marine sources	DNA binding, microtubule inhibition

Technological Advances in Animal-Origin Drug Development

Advances in molecular biotechnology and computational science have reshaped the development of animal-origin therapeutics. Historically reliant on crude extraction, these products now benefit from platforms that allow controlled synthesis, structural optimisation, and enhanced safety. Contemporary approaches including recombinant protein expression, monoclonal antibody engineering, venomics, AI-assisted protein design, and nanotechnology have significantly reduced dependence on animal harvesting while improving clinical and veterinary utility.

VI. RECOMBINANT DNA TECHNOLOGY

Recombinant DNA systems permit the expression of animal proteins in microbial or mammalian hosts, enabling high-yield and ethically sustainable production. By inserting genes encoding specific therapeutic proteins into organisms such as E. coli, Saccharomyces cerevisiae, or engineered livestock, manufacturers can produce biologics identical to their native counterparts.

Examples:

- Human insulin, once obtained from porcine or bovine pancreas, is now synthesised using genetically modified microbial strains (Goeddel et al., 1979).
- Recombinant bovine somatotropin (rbST) is produced without requiring endocrine tissue extraction.
- Recombinant human antithrombin is efficiently generated in transgenic goat milk (Koles et al., 2004).

Advantages:

- High-purity products with consistent activity
- Reduced zoonotic risk
- Scalable biomanufacturing
- Minimal ethical impact through decreased animal usage

Monoclonal Antibody Technology

Monoclonal antibody (mAb) production began with the hybridoma method (Köhler & Milstein, 1975), in which an antibody-producing B lymphocyte is fused with a myeloma cell to create an immortal line capable of secreting uniform antibodies. Recombinant engineering now allows for chimeric, humanised, and fully human mAbs with applications in cancer, autoimmune diseases, and infectious conditions.

Veterinary relevance:

mAbs have been developed for parvovirus, canine distemper, and bovine respiratory pathogens, supporting precision immunotherapy in animals.

Venomics and Proteomics

Venomics combines high-throughput proteomic and genomic techniques to catalogue and analyse venom components at a molecular level.

Key methodologies:

- Mass spectrometry for peptide identification
- Transcriptomics to map toxin gene families
- Bioinformatic modelling to predict structure–function relationships

Outcomes:

This approach enabled the discovery and refinement of venom-derived drugs such as ziconotide and ACE-inhibitory peptides, and continues to generate candidates targeting ion channels, proteases, and signalling pathways (Calvete, 2020).

AI-Designed Antivenoms and Computational Drug Engineering

Artificial intelligence now plays a key role in modern toxicology. Deep-learning systems can create new protein structures that can bind to and neutralise specific venom toxins.

A notable example is the use of RFdiffusion to create synthetic antivenom molecules. Work by Vázquez-Torres et al. (2024) demonstrated that designed proteins can effectively bind elapid three-finger toxins, providing a scalable alternative to traditional equine antiserum production.

Impact:

- Reduced reliance on horse immunisation
- Improved molecular specificity
- Potential for rapid adaptation to regional venom variants

Cell Culture and Bioreactor Systems

Mammalian cell expression systems allow controlled, contamination-free production of therapeutic proteins.

Examples:

- CHO cell lines generate monoclonal antibodies and recombinant enzymes.
- Bioreactor-grown cells produce erythropoietin, interferons, and veterinary biologics.

Advantages:

Consistent product quality, reduced pathogen exposure, and a significant reduction in animal sacrifice.

Structural Modelling and Molecular Docking

Advances in structural biology provide atomic-level insights into how bioactive molecules interact with their targets. Computational docking and 3D modelling tools guide preclinical optimisation of animal-derived peptides.

Applications:

- Simulation of toxin–ACE interactions for improved ACE-inhibitor analogues
- Modelling bee venom peptides binding to inflammatory mediators
- Structural refinement of GLP-1 receptor agonists, including exenatide (Kumar et al., 2023)

These tools decrease experimental burden and accelerate candidate selection.

Nanotechnology-Enhanced Drug Delivery

Nanocarriers improve stability, targeting, and pharmacokinetic profiles of animal-origin drugs.

Examples:

- Liposomal bee venom formulations reduce cytotoxicity while sustaining anti-inflammatory activity (Lee et al., 2019).
- Nanoencapsulated lactoferrin enhances oral bioavailability and antiviral potency.
- PEGylated proteins exhibit prolonged circulation times and decreased immunogenicity.

Mechanism:

Nanoparticles enable tissue-selective delivery, controlled release, and reduced systemic exposure.

Summary of Technological Tools

Technology	Application	Outcome
Recombinant DNA	Hormones, enzymes	Ethical, scalable bioproduction
Monoclonal Antibody	Immune disorders, cancer	Specificity, reduced animal use
Venomics & Proteomics	Toxin profiling	Discovery of novel peptides
AI Modeling	Antivenom design	Precision, synthetic alternatives
Bioreactors	Protein synthesis	High yield, contamination control
Molecular Docking	Drug optimization	Mechanistic insights
Nanotechnology	Drug delivery	Enhanced targeting and safety

Animal-Origin Drugs in Veterinary Medicine and the One Health Framework

Animal-derived therapeutics continue to play an essential role in veterinary practice, supporting neonatal immunity, reproductive management, infectious-disease control, and metabolic health. Beyond their clinical utility within animal populations, these products contribute to the broader One Health vision by linking animal well-being, human health security, and environmental sustainability.

Veterinary Applications

Colostrum in Neonatal Care

Colostrum, the initial secretion produced after parturition, contains high concentrations of immunoglobulins predominantly IgG along with lactoferrin, lysozyme, cytokines, and bioactive peptides.

- Therapeutic role: Establishes passive immunity in calves, lambs, piglets, and other neonates, reducing susceptibility to early-life enteric and respiratory disease.
- Veterinary use: Prevention of neonatal diarrhoea, improved growth, and support for immunocompromised newborns.
- Industry relevance: Commercial colostrum replacers are widely applied in livestock and small-animal practice (Stelwagen et al., 2009).

Hormones in Reproductive Management

Animal-derived and biologically inspired hormones are central to reproductive pharmacology.

- Equine chorionic gonadotropin (eCG): Used to stimulate estrus and ovulation in small ruminants and cattle.
- Oxytocin: Facilitates parturition, uterine tone recovery, and milk letdown in dairy species.
- Prostaglandin $F_2\alpha$ ($PGF_2\alpha$): Initially characterized from porcine tissues; used for estrus synchronization and luteolysis.

These agents support fertility control, breeding efficiency, and herd productivity (Diskin et al., 2012).

Antisera and Veterinary Vaccinology

Hyperimmune sera remain indispensable where rapid passive immunity is required.

- Examples: Anti-rabies, anti-tetanus, and antivenom preparations.
- Mechanism: Antibodies bind and neutralise circulating toxins or infectious particles.

Such biologics are especially valuable in rural and high-risk regions with frequent snake envenomation or endemic rabies (WHO, 2021).

Enzyme Supplements

Digestive enzymes such as trypsin, lipase, and pancreatin are administered to animals with pancreatic insufficiency and are included in feed to improve nutrient utilisation in pigs and poultry.

Nutraceuticals and Functional Additives

- Omega-3 fatty acids: Support cardiovascular health, skin condition, and anti-inflammatory balance in dogs and horses.
- Colostrum and lactoferrin: Used as immune-modulating supplements in livestock.
- Probiotic–enzyme combinations: Improve gastrointestinal function and feed conversion efficiency.

Role of Animal-Origin Drugs in Zoonotic Disease Control

Animal-derived antibodies provide a fast and practical means of countering zoonotic pathogens when active vaccination is insufficient or unavailable.

- Rabies antiserum: Used in post-exposure prophylaxis for both animals and humans.
- Tetanus and diphtheria antisera: Produced mainly in horses and employed during outbreaks.
- Snake antivenoms: Polyvalent formulations from horses or sheep neutralise toxins from medically important snake species.

During emerging threats such as Ebola, H1N1, or COVID-19, antibody-based interventions from animal systems have offered provisional protective options (Rahman et al., 2022).

Integration into the One Health Framework

Animal-origin therapeutics contribute to One Health objectives in several ways:

1. Cross-species therapeutic relevance: Agents such as antisera, hormones, and enzymes are used in both veterinary and human medicine.
2. Outbreak preparedness: Rapid-acting passive immunotherapies help contain zoonotic spillover events.
3. Reduction of antimicrobial resistance: Immunoglobulins and natural antimicrobial proteins enhance host defences, reducing antibiotic dependence.
4. Environmental considerations: Ethical sourcing, sustainable harvesting, and recombinant alternatives reduce pressure on wildlife populations.

These interactions underscore the interconnectedness of ecological, animal, and human health (Destoumieux-Garzón et al., 2018).

Veterinary Public Health and Policy Considerations

Integrating animal-origin pharmacology into public health planning enhances:

- Emergency response capacity: Availability of antisera and immune biologics improves outbreak mitigation.
- Antibiotic stewardship: Immune-supportive agents lessen antimicrobial use in livestock systems.
- Food security: Improved reproductive efficiency and disease control contribute to stable livestock production.

Effective implementation requires coordinated policies between veterinary authorities, medical systems, and environmental agencies.

Future Prospects and Research Directions

Advances in biotechnology, computational sciences, and sustainable biomanufacturing are transforming the

future of animal-origin pharmacology. While these molecules hold significant therapeutic value due to their biological selectivity, future development must incorporate ethical stewardship, ecological responsibility, and precision engineering. The main goal is to preserve the pharmacological benefits of natural compounds while reducing or eliminating reliance on animal harvests.

Expansion of Recombinant and Synthetic Alternatives

A major direction in contemporary biopharmaceutical research is the replacement of extraction-based methods with recombinant or fully synthetic production platforms.

Examples include:

- Recombinant insulin, calcitonin, and antithrombin are produced in microbial or mammalian expression systems.
- Synthetic analogues of venom-derived peptides, such as ziconotide, are manufactured without sourcing cone snails.
- Recombinant antivenoms created through expression of engineered antibody fragments that selectively target venom epitopes (Laustsen et al., 2020).

Benefits:

Improved manufacturing consistency, enhanced biosafety, scalability, and substantial reductions in animal use.

AI-Enabled Drug Discovery and Protein Engineering

Artificial intelligence is accelerating the identification and optimisation of molecules originally derived from animals.

- Machine-learning models assist in predicting peptide–receptor interactions and identifying pharmacophoric regions within complex venoms.
- AI systems such as RFdiffusion can design novel binding proteins capable of neutralising specific toxins with high affinity (Vázquez-Torres et al., 2024).
- Computational frameworks optimise peptide stability, half-life, and target specificity, reducing in vivo testing requirements.

These tools shorten development timelines and expand the scope of feasible molecular designs.

Incorporating Ethnoveterinary and Traditional Knowledge

Ethnoveterinary medicine contains extensive documentation of animal-derived preparations used across diverse cultures.

- Traditional medical systems (Ayurveda, Siddha, Unani) describe numerous animal-origin products with potential pharmacological activity (Mukherjee et al., 2019).
- Scientific evaluation of such materials may provide affordable therapeutic options in resource-limited veterinary settings.
- Integration with analytical technologies (HPLC, LC-MS, metabolomics, and genomics) can validate efficacy and identify novel bioactive molecules.

Preservation and scientific engagement with traditional knowledge systems may yield sustainable innovations.

Ethical Innovation and Sustainable Sourcing

Future research will increasingly prioritise methods that minimise ecological and animal welfare impacts.

- Recombinant expression platforms, microbial fermentation, and tissue culture systems enable production of venom peptides and immunoglobulins without harming animals.
- Sustainable marine bioprospecting supported by aquaculture reduces pressure on wild populations.
- International policies such as CITES and the Convention on Biological Diversity (CBD) guide ethical resource management.

Sustainable biomanufacturing is essential for the long-term viability of natural-product drug development.

Strengthening the One Health and Translational Research Agenda

Cross-disciplinary collaboration will shape future therapeutic development.

- Comparative studies between species may reveal conserved molecular targets suited for shared interventions.
- Novel biologics antivenoms, antivirals, immunotherapies will increasingly serve dual roles in human and animal health.
- Preparedness for zoonotic threats will rely on rapidly deployable biologics, including recombinant antibodies and engineered peptides.

These efforts align with One Health priorities that integrate human, animal, and environmental well-being.

VII. OUTLOOK FOR THE COMING DECADES

Advances in biotechnology and computational design will drive the next generation of animal-origin therapeutics.

Priorities include:

- Fully synthetic or recombinant antivenoms to replace equine-derived sera.
- Environmentally certified production pipelines for biologics.
- AI-guided engineering of novel analgesics, anti-inflammatory peptides, and immunomodulators.
- Harmonisation of global regulatory frameworks for animal-origin and recombinant biologics.

In the long term, ethical biodesign will enable pharmacology to harness natural molecular diversity while safeguarding animals and ecosystems.

VIII. CONCLUSION

Animal-derived therapeutics have contributed profoundly to the evolution of pharmacology, linking early empirical practices with modern molecular science. Their applications span analgesia, endocrine regulation, cardiovascular therapy, immune modulation, infectious disease control, and oncology, demonstrating the functional diversity inherent in biological systems. In veterinary medicine, agents such as colostrum, reproductive hormones, and antisera remain indispensable for promoting animal health and productivity.

At the same time, ethical considerations and ecological constraints necessitate continued development of recombinant technologies, synthetic analogues, and AI-assisted drug design. These innovations provide pathways to maintain therapeutic availability while minimising reliance on animal harvesting.

Looking forward, interdisciplinary collaboration under the One Health paradigm will ensure that pharmacological advances benefit both humans and animals while supporting environmental stewardship. With the integration of biotechnology, computational modelling, and sustainable resource management, animal-origin pharmacology is poised to transition into a highly refined, ethical, and resilient scientific discipline.

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