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Snakes as Biological Assets in the World (Reptilia: Ophidia): A Pictorial Essay

Ashraful Kabir[1*], Mamata Rani Das[2], Ahsan Habib[3]

[1] Department of Biology, Cantonment Public College, Saidpur Cantonment—5311, Nilphamari, Bangladesh

[2] Department of Natural History, Bangladesh National Museum, Shahbag, Dhaka, Bangladesh

[3] Department of Zoology, Boro Solua New Model Degree College, Chuadanga Sadar—7200, Chuadanga, Bangladesh

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*__Corresponding author:__ Ashraful Kabir

Abstract

Snakes serve as indispensable assets to global ecosystems, human medicine, and sustainable industries. As highly effective biological control agents, they regulate destructive rodent populations to naturally mitigate zoonotic diseases and protect agricultural productivity. They support food webs by serving as prey for raptorial birds and other predators while facilitating secondary seed dispersal. Snake genomes and physiological adaptations provide valuable models for evolutionary and biomedical research, while their complex venoms constitute an important biochemical resource for developing life saving drugs targeting hypertension, thrombosis, chronic pain, and cancer. Snakes supply the global luxury leather and textile trades, while their profound anthropological heritage continues to enrich cross-cultural art and history. Ultimately, snakes represent a vital ecological, economic, and medical resource essential to environmental stability.

***Keywords:** Snakes, positive impact, biological asset, ecosystem services, biological control, snake venom, biodiversity conservation.*

Introduction

Snakes are vital contributors to global ecosystems and human well-being, playing a crucial role as highly efficient natural pest controllers. By hunting rodents, amphibians, and insects, they protect agricultural crops from destruction and significantly curb the spread of dangerous rodent borne diseases to humans. Additionally, snake venom is a complex mixture of biologically active proteins and peptides from which compounds have been isolated to develop life-saving treatments for hypertension, cardiovascular diseases, stroke, and chronic pain. As highly adapted predators and an important food source for larger birds and mammals, snakes maintain the delicate balance of biodiversity across diverse global habitats. In agricultural sectors, the presence of snakes acts as an eco-friendly biological control agent that safeguards food security. Rodents reproduce at remarkably rapid rates, capable of decimating grain stores, chewing through farm infrastructure, and contaminating harvests with their waste.

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Chemical rodenticides often introduce toxic heavy metals into the soil and water, creating secondary poisoning hazards for livestock and native wildlife. A single snake can consume dozens of rodents each year, actively suppressing pest populations. Beyond crop protection, this hunting behavior breaks the transmission cycle of dangerous zoonotic infections. Snakes represent an invaluable frontier for pharmaceutical research and biotechnology. Venom fractions are utilized to design fast-acting anticoagulants that dissolve blockages in stroke patients, effectively minimizing permanent brain damage. Snakes function as both predators and prey within food webs. While they regulate populations of rodents, amphibians, reptiles, and other small animals, they also serve as important prey for raptors, owls, foxes, badgers, herons, and numerous mammalian carnivores. Without snakes to regulate the abundance of small mammals, insects, and amphibians, these lower-level prey populations would quickly explode. Sudden collapse in snake populations would directly threaten the survival of the apex predators that rely on them for sustenance during breeding seasons. By maintaining this equilibrium, snakes ensure that energy flows smoothly through diverse global habitats, supporting the long-term resilience and health of forests, wetlands, grasslands, and deserts. Snakes are among the most evolutionarily successful vertebrates, having adapted to an extraordinary diversity of terrestrial, freshwater, and marine habitats worldwide. More than 4,200 species have been described and are distributed across all continents except Antarctica, with new species continuing to be discovered each year (Uetz *et al.*, 2025). Approximately 600 species are venomous, of which nearly 200 are considered medically important because they can cause severe envenoming in humans. This remarkable diversity reflects the evolutionary success of snakes and underscores their ecological significance as key predators, regulators of food webs, and contributors to ecosystem stability (Greene, 1997; Uetz *et al.*, 2025). The objective of this pictorial essay is to highlight the ecological, medical, economic, educational, and cultural importance of snakes while helping to correct common misconceptions regarding these reptiles.

Table 1. Major groups of snakes of the world

Group	Representative genera/species (examples)	Major roles
Cobras	*Naja* spp., King cobra (*Ophiophagus hannah*)	Mesopredator to apex predator
Kraits	*Bungarus* spp.	Apex predator
Vipers	Russell's viper (*Daboia russelii*), Bamboo pit vipers (*Trimeresurus* spp.)	Ambush predator
Sea snakes	*Hydrophis* spp., *Aipysurus* spp., *Enhydrina* spp.	Regulate marine fish populations
Coral snakes	*Micrurus* spp., *Calliophis* spp.	Predator of reptiles and amphibians
Pythons and Boas	*Python* spp., *Boa constrictor*, *Eunectes* spp.	Regulate mammal and bird populations
Wolf snakes	*Lycodon* spp.	Control small vertebrate pests
Cat snakes	*Boiga* spp.	Arboreal predator of birds, lizards, and frogs
Pipe snakes/Shield snakes	*Cylindrophis* spp.	Predator of eels and caecilians
Kukri snakes	*Oligodon* spp.	Regulate bird and reptile eggs
Rat snakes	*Ptyas* spp., *Pantherophis* spp.	Control rodent populations
Gliding snakes	*Chrysopelea* spp.	Arboreal predator
Vine snakes/Bronzebacks	*Ahaetulla* spp.	Arboreal ambush predator
Rattlesnakes	*Crotalus* spp.	Ambush predator
Keelbacks	*Xenochropis* spp., *Fowlea* spp.	Predator of fishes and amphibians
Blind snakes/Thread snakes	*Indotyphlops* spp., *Typhlops* spp.	Control ants and termites

Table 2. Major snake families and their approximate numbers of species

Family	Approximate numbers (%)
Elapidae	~410 (~10%)
Viperidae	~350 (~9%)
Colubridae	~1900 (~50–55%)
Dipsadidae (New World colubrids)	~800 (~20%)
Pythonidae	~45 (~1%)
Boidae	~70 (~2%)
Typhlopidae	~280 (~7%)
Other families	~300 (~7%)

Table 3. Top five countries with the highest snake diversity

Country	Approximate number of species
Mexico	~438
Brazil	~420
Indonesia	~376
India	~305
Colombia	~301

Source (Tables 1–3): Taxonomic classification and species numbers are based on *The Reptile Database* (Uetz *et al.*, 2025).

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Major positive issues of snakes

Biological control: Snakes are deployed for biological control primarily to manage destructive rodent populations in agricultural fields and grain storage facilities. They are highly effective biological control agents. This natural predation helps maintain ecological balance, prevents crop damage, and eliminates the risk of secondary poisoning in non-target wildlife.

Snakes in agriculture: Snakes provide considerable economic benefits to agriculture by reducing populations of rodents that consume crops before and after harvest. Natural snake predation decreases grain losses, minimizes damage to irrigation systems, and reduces dependence on chemical rodenticides. This ecosystem service supports sustainable agriculture and environmentally friendly pest management.

Snake museum: The Museum of Zoology at the University of Michigan houses one of the world's largest scientific snake collections, containing approximately 70,000 preserved specimens used for taxonomy, systematics, ecology, and evolutionary research. A snake museum, often called a serpentarium, serves as a specialized facility for the public exhibition, conservation, and scientific study of various snake species. These institutions play a vital role in biodiversity education by dispelling common myths, and promoting the ecological importance of reptiles. Additionally, many snake museums double as critical research centers where scientists harvest venom to manufacture life-saving antivenoms.

Ecological balance: Since snakes do not act as pollinators but it has impact on secondary seed dispersal by consuming seed-eating prey. This process, known as secondary seed dispersal, successfully moves intact seeds to new locations for germination. Beyond myths and misconceptions, snakes play a vital role in maintaining ecological balance (Amuzu, 2026).

Ecosystem engineering: Although snakes are not ecosystem engineers in the traditional sense, they indirectly influence ecosystem processes by regulating prey populations and maintaining food web stability. Their predatory activities prevent rodent outbreaks that can alter vegetation structure, soil characteristics, and nutrient dynamics. Through these indirect ecological interactions, snakes contribute to ecosystem resilience and biodiversity conservation.

Ecosystem services of snakes: Snakes provide essential ecosystem services that support environmental stability and human well-being. As important predators, they regulate rodent and other small vertebrate populations, maintaining trophic balance and reducing crop losses and food contamination. Their natural pest control also lowers the spread of rodent-borne diseases and decreases reliance on chemical pesticides. By sustaining balanced predator–prey interactions, snakes enhance ecosystem resilience to environmental change. Moreover, their sensitivity to habitat degradation and pollution makes them valuable bioindicators for biodiversity conservation and long-term ecosystem monitoring.

Role in nutrient cycling: Snakes contribute to nutrient cycling by transferring energy through food webs and returning nutrients to ecosystems. Their feces enrich soils with organic matter and nutrients, while dead snakes become food for insects, fungi, and scavengers, supporting decomposition and nutrient recycling. These processes enhance soil fertility and promote healthy ecosystem functioning.

Control other snakes: Certain snake species play a critical role in ecological balance by actively hunting and consuming other snakes (e.g., king cobras, king snakes, and mussuranas). By preying on both venomous and non-venomous reptiles, these specialized hunters naturally regulate snake populations and regulate populations of other snake species.

Prevent rat-borne diseases: Snakes serve as an essential natural barrier against rat-borne diseases especially plague. Rats and mice act as primary reservoirs for severe illnesses, including hantavirus, leptospirosis (Amuzu, 2026), and salmonellosis, which they transmit to humans through ectoparasites, urine, or feces. By

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preying on these rodents, snakes reduce the abundance of disease reservoirs. By hunting in narrow burrows, barns, and crawl spaces where mechanical traps cannot reach, snakes suppress rodent infestations in both rural and residential areas.

Genetic resource: Snakes represent a unique and valuable genetic resource due to their highly specialized evolutionary adaptations. Their genomes contain specific regulatory elements and structural variations like rapid metabolic shifting and complete limb loss, extreme axial skeleton elongation, and advanced skull kinesics. Most notably, the diverse multi-gene families responsible for snake venom composition serve as an invaluable library for drug discovery. Furthermore, mapping their unique genetic blueprints provides insights into vertebrate developmental biology, tissue regeneration, and complex DNA repair mechanisms that can deepen our understanding of human gene evolution.

Evolutionary research: Snakes are exceptional model organisms for evolutionary research because of their unique anatomical and genetic adaptations. Their evolution provides valuable insights into limb loss, skull modification, venom evolution, thermal adaptation, and specialized locomotion. Advances in snake genomics have further improved our understanding of genome evolution, vertebrate development, and adaptive evolution. Consequently, snakes have become indispensable models in evolutionary biology, comparative anatomy, and biomedical research.

Snakes as bioindicators: Snakes are valuable bioindicators because they occupy high trophic levels and accumulate environmental contaminants through their prey. Changes in their abundance, reproduction, and distribution often reflect habitat degradation, pollution, and climate change. Monitoring snake populations provides important information on ecosystem health and biodiversity status. Their sensitivity to environmental change makes them useful indicators for long-term ecological monitoring and conservation.

Support horse for antivenom production: Snakes and horses play essential roles in the production of life-saving medical antivenom. The process involves the collection of venom from specific snake species, which is carefully processed and diluted for medical use. Small, controlled amounts of these antigens are introduced to a host horse under strict veterinary supervision. Horses are well-suited for this role because their large body mass and robust immune systems allow them to generate high concentrations of neutralizing antibodies.

Medical issues: Snake venom serves as a highly versatile modern medicine and forensic science (Murphy and Xanten, 2007). In cardiovascular care, venom enzymes are engineered into vital anti-clotting medications (Amuzu, 2026). For neurological therapy, specialized neurotoxins are modified to cross the blood-brain barrier to target brain tumors, manage chronic pain, and treat degenerative strokes. Dermatological research utilizes antimicrobial peptides like cathelicidins for antibiotic skin applications and enhanced wound healing. Medicine Department of Chittagong Medical College of Bangladesh has launched a snake venom center in order to manufacture antivenom locally (Kabir, 2025).

Venom-based pharmaceuticals: Snake venoms are complex mixtures of biologically active proteins, peptides, and enzymes that have become invaluable resources for modern drug discovery and pharmaceutical development. Over the past several decades, detailed studies of venom components have led to the development of several clinically important drugs for the treatment of cardiovascular diseases, blood-clotting disorders, and other medical conditions. Venom-derived compounds have served as templates for antihypertensive agents, antiplatelet drugs, anticoagulants, and defibrinogenating agents, while ongoing research continues to explore their potential in cancer therapy, pain management, antimicrobial treatments, and neurological disorders. Some of the major drugs developed from snake venom and their principal medical applications (Casewell *et al.*, 2020; Calvete, 2023) (Table 4).

Table 4. Major venom-derived drugs developed from snake venom

Drug	Snake venom source	Medical application
Captopril	*Bothrops jararaca*	Hypertension and heart failure
Eptifibatide	Southeastern pygmy rattlesnake (*Sistrurus miliarius barbouri*)	Acute coronary syndrome
Tirofiban	Saw-scaled viper (*Echis carinatus*)	Prevention of thrombosis
Batroxobin	*Bothrops atrox*	Defibrinogenating agent
Ancrod	Malayan pit viper (*Calloselasma rhodostoma*)	Anticoagulant (research/ clinical use)

Venom research: Snake venom is a rich source of bioactive molecules with diverse biomedical applications beyond antivenom production. Venom-derived compounds have contributed to the development of antihypertensive drugs such as captopril, anticoagulants, and novel analgesics for pain management. They also show great potential as anticancer and antimicrobial peptides, diagnostic reagents, and nanotechnology-based drug delivery systems. Continued venomics research is expected to accelerate the discovery of innovative therapeutics for human diseases.

Importance in biotechnology: Modern biotechnology increasingly utilizes snake venom proteins to develop biosensors, diagnostic kits, recombinant therapeutic proteins, and drug-delivery systems. Venomics and proteomics have opened new avenues for pharmaceutical innovation and molecular medicine.

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Education and research: Their unique physiology provides critical insights into vertebrate development, metabolic regulation, and the mechanics of extreme tissue regeneration. By studying and showcasing these reptiles, academic institutions can successfully dispel deep-rooted cultural myths, and train future herpetologists in wildlife management. Reptilian taxidermy in a museum could play a different testament to the students for learning (Das *et al.,* 2024). Snakes are widely used in universities, museums, and zoological collections for teaching anatomy, physiology, ecology, taxonomy, evolution, and conservation biology. Their remarkable adaptations provide excellent educational models for students studying vertebrate biology.

Conservation importance: Despite their immense ecological, economic, and biomedical importance, snake populations are increasingly threatened by habitat destruction, road mortality, illegal wildlife trade, pollution, climate change, and widespread human persecution driven by fear and misunderstanding. Recent global assessments indicate that approximately one-fifth of snake species are threatened with extinction. Conserving snake populations is essential for maintaining ecosystem stability, sustaining natural pest control, safeguarding agricultural productivity, and preserving valuable genetic and venom resources for future biomedical research. Effective conservation strategies should include habitat protection and restoration, enforcement of wildlife protection laws, public awareness campaigns, mitigation of road mortality, and scientific monitoring to ensure the long-term survival of snake diversity and the ecosystem services they provide. Recent assessments indicate that nearly one-fifth of the world's snake species face varying levels of extinction risk due to habitat destruction, persecution, invasive species, pollution, and climate change. Global cooperation is therefore essential for snake conservation.

Minor positive issues of snakes

Snake meat: Meat from snake farms can be an alternative of eating wild snakes. Snakes serve as an important source of animal protein and a culinary tradition in various cultures worldwide, particularly across parts of Southeast Asia, East Asia, and the Americas. The meat is valued for being low in fat and high in protein. In regions like southern China and Viet Nam, snake meat is consumed in traditional dishes like snake soup, which is culturally believed to improve circulation, warm the body, and offer medicinal benefits.

Skin for leather and design: Snake skin is a highly prized material in the luxury leather industry and an aesthetic inspiration in textile design. In the leather trade, skins from pythons, cobras, and water snakes are processed into exotic leathers valued for shoes, bags, and belts. To satisfy these visual trends sustainably, the textile industry utilizes digital printing, and weaving techniques to replicate camouflage patterns onto synthetic and natural fabrics.

Economic value beyond leather: Beyond the luxury leather industry, snakes generate substantial economic benefits through ecotourism, wildlife photography, nature education, zoological collections, and wildlife documentaries. Protected areas and reptile parks in countries such as India, Costa Rica, Australia, and South Africa attract thousands of visitors annually who are interested in observing snakes in their natural habitats, thereby supporting local economies through tourism and conservation-related employment (Tisdell and Wilson, 2002; Ballantyne *et al.,* 2007). Snakes are also featured in museums, zoos, and educational institutions, where they promote biodiversity awareness, environmental education, and public appreciation of reptiles (Patrick *et al.,* 2007). Furthermore, their striking appearance and fascinating behavior make them popular subjects for professional wildlife photography and nature documentaries, generating income for researchers, conservation organizations, photographers, and the ecotourism industry while fostering greater public support for wildlife conservation (Mossaz *et al.,* 2015).

Snake farming: Snake farming is the commercial breeding and rearing of snakes in controlled environments to supply the international leather, pharmaceutical, and culinary industries. These specialized facilities primarily target pythons, cobras, and rat snakes to systematically harvest their skins, collect meat for regional food markets, and milk venom for life-saving antivenom production. Compared to traditional livestock, snake farming requires significantly less land, water, and food. The industry faces strict regulatory scrutiny, requiring close compliance with global conservation frameworks like CITES to prevent the laundering of illegally poached wild snakes and to enforce mandatory animal welfare and biosecurity standards.

Support raptors: Snakes support raptorial birds by serving as a vital and abundant food source within terrestrial food webs. Birds of prey, such as hawks, eagles, falcons, and owls-rely heavily on snakes to meet their high protein, particularly during the nesting season. Certain specialized raptors, like the secretary bird and various snake eagles, have evolved specific hunting techniques and physical adaptations solely to target these reptiles.

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Aesthetic value of snakes: Snakes are celebrated as some of the most visually stunning creatures in the natural world due to their extraordinary variety of colors, and complex patterns. Their scales can exhibit intense coloration ranging from iridescent, shimmering blues and greens to vibrant, warning reds, which they use for camouflage, thermoregulation, or mate selection. The mesmerizing geometric symmetries found in their skin patterns have inspired human art, architecture, and luxury fashion for centuries.

Camouflage (mimicry): Snakes demonstrate remarkable mimicry through highly evolved morphological and behavioral traits designed to deceive predators and prey. The most prominent example is Batesian mimicry, where non-venomous species like milk snakes copy the distinct red, yellow, and black banding patterns of highly venomous coral snakes to deter potential attackers. Additionally, many species employ behavioral mimicry, such as harmless rat snakes vibrating their tails in dry leaves to imitate the warning sound of a rattlesnake. Some snakes even use aggressive mimicry, utilizing specialized tail tips that resemble insects or worms to lure unsuspecting frogs and birds within striking distance.

Cultural issues: Snakes hold a profoundly complex and dualistic position across global religion, history, and anthropology. In many ancient traditions, their ability to shed their skin led to universal associations with rebirth, immortality, and healing (Bauchot, 1994). They are venerated as powerful deities, such as the Mesoamerican feathered serpent, the protective Hindu Nagas, and the Australian Aboriginal Rainbow Serpent, all representing fertility, water, and earth (Bauchot, 1994; Coborn, 1995).

Role in aquatic ecosystems: Semi aquatic and marine snakes help regulate the populations of fish, amphibians, crustaceans, and invasive aquatic species. By consuming injured, weak, or diseased aquatic organisms, they actively suppress the transmission of pathogens through water systems, preserving overall wildlife health.

Conclusions

Snakes are vital pillars of ecological balance, medical innovation, and sustainable economic value. Deconstructing the historical stigma surrounding these reptiles reveals their indispensable roles in stabilizing food webs, improving soil dynamics, and mitigating public health crises through natural pest control. The immense pharmaceutical breakthroughs derived from snake venom underscore their status as a critical genetic library for human medicine. Protecting and sustainably managing snake populations is therefore a non-negotiable priority. Embracing their ecological, scientific, and cultural significance is essential for preserving global biodiversity. Additionally, everyone should acquire practical knowledge about snakes to promote safe coexistence, reduce unnecessary killing, and improve community-based conservation efforts. Public education and awareness programs are crucial for correcting misconceptions and highlighting the ecological importance of snakes. Collaborative efforts among researchers, conservation organizations, policymakers, and local communities will be essential to ensure the long-term survival of snake diversity worldwide. By valuing snakes as ecological partners rather than threats, humanity can ensure the persistence of these remarkable reptiles and the vital services they provide for generations to come.

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