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Review Article

LECTINS AS BIOACTIVE MOLECULES: EMERGING APPLICATIONS AND THERAPEUTIC INSIGHTS-A REVIEW

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ABSTRACT

Lectins are a broad group of carbohydrate-binding proteins that have attracted significant attention due to their therapeutic potential. This review focuses on four major types of lectins: plant, animal, fungal, and marine, and examines their unique properties and promising applications in medicine. Plant lectins are known for their ability to modulate immune responses and exhibit a range of biological activities, including anticancer, antiviral, and antibacterial effects. These properties make them strong candidates for the development of novel therapeutic agents. Animal lectins, found in both mammals and insects, play critical roles in innate immunity, and their potential in treating infections and inflammatory diseases has been a subject of extensive research. Marine lectins, derived from marine organisms, represent an underexplored yet promising source of bioactive compounds with unique binding specificities. Their potent biological activities suggest they may serve as effective tools for future drug development. Fungal lectins, which are less studied but no less important, also show potential in therapeutic applications, particularly in immune modulation and antimicrobial activity. This review highlights the current state of knowledge on the therapeutic potential of lectins across various biological sources and emphasizes the need for further research. Exploring the full range of lectin properties could lead to groundbreaking advancements in medicine, opening new avenues for treatments of infectious diseases, cancer, and other health conditions.

Keywords: Lectin, Anticancer, Antimicrobial, Antiviral, Anti-inflammatory, Antioxidant

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INTRODUCTION

Lectins are proteins with varied molecular arrangements that can bind to carbohydrate structures specifically and reversibly without changing the carbohydrate moiety [1]. Theterm "lectin" was coined by William Boyd from the Latin verb "legere," meaning "to choose" or "to select" [2]. Lectins are a diverse group of proteins that are essential in various biological processes [3]. Lectins exhibiting specific carbohydrate-binding affinities have been isolated from various plant tissues and other organisms. They are commonly classified according to their carbohydrate specificity [4]. Over the years, numerous lectins have been isolated from plants, microorganisms, and animals. In the past two decades alone, the structures of hundreds of these lectins have been successfully characterized [5]. They can cause hemagglutination and specifically bind to carbohydrates, playing roles in cell adhesion, immune responses, and signaling pathways. Lectins are known for their potential in fighting viral diseases, regulating blood sugar, defending against pathogens, and inhibiting cancer progression, making them promising therapeutic agents [6]. In recent years, plant lectins have been utilized in the development of lectin microarrays to identify malignant tumor cells, contributing to improved cancer diagnosis and prognosis [7]. Fungal lectins from mushrooms, microfungi, and yeasts show unique carbohydrate specificity and offer promising biomedical and biotechnological applications [8]. Animal lectins are widely involved in pathogen defense and the regulation of immune responses [9]. Marine lectins, particularly from algae and cyanobacteria, are gaining attention for their antiviral properties. These high mannose-binding lectins show potential as drugs to prevent the transmission of enveloped viruses by inhibiting viral entry, unlike traditional antivirals that target the virus lifecycle [10]. The full range of functions and applications of lectins may not yet be fully discovered. Their abundant presence, high thermal stability, and specific carbohydrate-binding capabilities make them valuable resources in glycoscience, immunology, biotechnology, healthcare, and the pharmaceutical industry for a variety of research and applications [11].

This review investigates the therapeutic potential of diverse lectins, emphasizing their anti-cancer, antifungal, anti-inflammatory, antidiabetic, antioxidant, and antiviral properties. Information was compiled from leading scientific databases such as Google Scholar, ResearchGate, Web of Science, Scopus, and ScienceDirect. The review provides an in-depth look at the role of lectins in diagnostics and therapeutics, detailing their mechanisms of action and future medical applications.

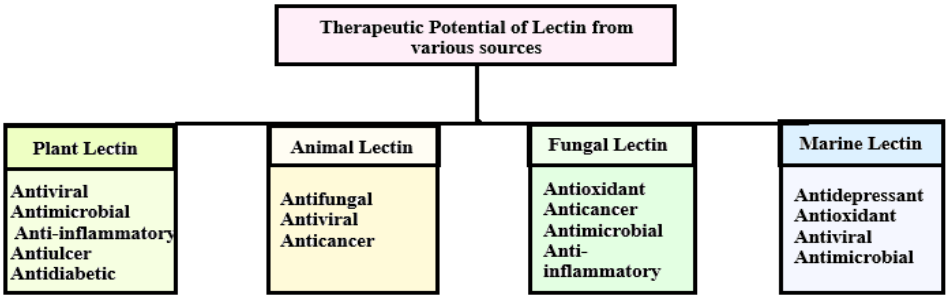

Fig. 1: Therapeutic potential of lectin from various sources

Therapeutic potential of plant lectins

Plant lectins represent a diverse group of proteins characterized by the presence of at least one non-catalytic domain that specifically binds carbohydrates [12]. Plant lectins are predominantly found in seed cotyledons, where they are located in the cytoplasm or within protein bodies. They have also been identified in other plant parts, including leaves, roots, and stems [13]. Stillmark is credited with isolating the first lectin, ricin, from castor bean seeds (*Ricinus communis L.*) in 1888 [14]. Seeds contain higher levels of lectins compared to the bark, leaves, roots, and stems of leguminous plants. Plant lectins have been widely utilized as molecular tools across multiple fields of biology and medicine [15]. Plant lectins are recognized for their therapeutic potential, including antiviral, anticancer, and immunomodulatory activities [5]. Silva, 2021 highlights the antibacterial potential of plant lectins, noting their ability to bind specific carbohydrates and modulate immune responses, such as cytokine and nitric oxide production. Found abundantly in seeds, roots, and rhizomes, lectins present a promising alternative to traditional antibiotics amid growing resistance [16]. Yau *et al.,* 2015 reviewed plant and animal lectins that induce apoptosis and autophagy in cancer cells, highlighting their potential as anticancer drugs. Examples include galectins, annexins, concanavalin A, and mistletoe lectin [17]. Soliman *et al.,* 2024 developed plant lectin-conjugated chitosan nanoparticles using phytohemagglutinin (PHA), soybean agglutinin (SBA), and peanut agglutinin (PNA), demonstrating strong antibacterial and anticancer effects. PHA-chitosan nanoparticles showed the highest antibacterial activity and reduced cancer cell viability by up to 66.92%, suggesting their potential as therapeutic agents for infections and cancer [18]. Konozy *et al.*, 2022 explore the therapeutic potential of plant lectins, which are carbohydrate-binding proteins with various biological activities. Lectins are recognized for their ability to target viral envelope sugars, making them potential candidates in the fight against coronaviruses, including SARS-CoV-2, by blocking viral attachment to host cells. Additionally, plant lectins have demonstrated antinociceptive, anti-inflammatory, and antiulcer properties, with their mechanisms often linked to their carbohydrate-binding sites. These properties suggest that plant lectins could be developed for use in treating infections, inflammation, and digestive disorders, highlighting their promising therapeutic potential [19]. Gong *et al.,* 2017 demonstrated that plant-derived dietary lectins can activate the NLRP3 inflammasome, leading to caspase-1 activation and IL-1β secretion. Their study showed that lectins induce Ca2+release, mitochondrial damage, and subsequent inflammasome activation, contributing to inflammation in diseases like inflammatory bowel disease, diabetes, and rheumatoid arthritis [20]. El-Araby *et al.* 2020 characterized lectins from Egyptian leguminous seeds (fava bean, lentil, and pea), which exhibited notable antimicrobial and antifungal properties. Lentil lectins showed strong activity against *Staphylococcus aureus*, while pea lectins inhibited *Pseudomonas aeruginosa*. Fava bean lectins were the first legume lectins to show antifungal effects on *Candida albicans*, and SEM images revealed microbial agglutination [21]. Agrawal *et al.* 2020 studied the effects of *Bauhinia purpurea* and *Wisteria floribunda* lectins on MCF-7 breast cancer cells. The lectins caused significant cell death through mechanisms involving cell cycle arrest, ROS generation, and caspase-3 activation. These findings underline the potential of plant lectins as therapeutic agents for cancer treatment [22]. Podder *et al.,* 2024 purified a seed lectin from *Manilkara zapota* (MZSL) and evaluated its antimicrobial, antioxidant, and anticancer activities. MZSL had a molecular weight of 33.0±1 kDa, with a minimum hemagglutination concentration of 15.625 µg/ml and neutral sugar content of 6.32%. The lectin was stable at 30–50 °C and pH 7.0–8.0, and exhibited mild toxicity with an LC50 of 107.93 µg/ml. It showed bacteriostatic activity against *Staphylococcus aureus* and *Shigella dysenteriae* and fungistatic activity against *Aspergillus niger*. MZSL also inhibited biofilm formation by *E. coli*, demonstrated antioxidant activity with an IC50 of 96.42 µg/ml, and exhibited antiproliferative effects against *Ehrlich ascites carcinoma* (21.64% growth inhibition) and cancer cell lines MCF-7 (IC50: 70.66 µg/ml) and A-549 (IC50: 107.64 µg/ml) [23]. Devi *et al.,* 2021 isolated lectins from *Bryophyllumpinnatum* leaves and evaluated their antioxidant activity using DPPH and ABTS assays, highlighting their potential as natural antioxidants [24]. Srinivas *et al.*, 2019 explored the lectin and anticancer activities of phloem exudates from ethnomedicinal plants. The study found that *Musa acuminata* and *Euphorbia geniculate* exudates exhibited potent lectin activity and inhibited cancer cell viability. The samples also induced apoptosis and reduced angiogenesis *in vitro*. These findings highlight the potential of plant-derived lectins in cancer therapy, suggesting the need for further purification and characterization of active compounds [25]. Estrada-Martínez *et al.,* 2017 highlight the potential of plant lectins in diagnosing and treating digestive system cancers, which often go undetected until advanced stages. Due to their carbohydrate-binding properties, plant lectins exhibit selective anticancer activity, offering promise as diagnostic and therapeutic tools for gastrointestinal malignancies [26]. According to Sridhara*et al.,* 2024, lectin isolated from *Entada rheedii* showed selective cytotoxicity toward HCT 116 cells, with an IC_{50} of 188.72 µg/ml. The protein exhibited stable hemagglutination and carbohydrate-binding properties, supporting its role as a natural antiproliferative agent [27]. González De Mejía and Prisecaru, 2005 explored the therapeutic potential of dietary plant lectins, emphasizing their ability to target and kill cancer cells. These lectins interfere with protein synthesis, cell division, and angiogenesis while also influencing immune signaling. Their stability and bioactivity post-digestion underscore their relevance in cancer treatment research [28]. Lectin from *Lepidium sativum* seeds, as studied by Bashir, 2024 exhibited dual functionality antibacterial effects against *E. coli*, *S. aureus*, and *S. pyogenes*, and anticancer activity against HepG2 cells emphasizing its biomedical relevance [29]. Enoma *et al.,* 2023 analyzed the antimicrobial activity of *Erythrina senegalensis* seed lectin (ESL) and its phylogenetic relationship to other legume lectins. The study found that ESL exhibited strong antimicrobial effects against several pathogens, including *Klebsiella pneumoniae* and *Staphylococcus aureus*, with inhibition zones ranging from 18 to 24 mm. The minimum inhibitory concentrations ranged from 50 to 400 µg/ml. Phylogenetic analysis showed that ESL shares high genetic similarity with lectins from other *Erythrina* species, underscoring its potential for developing new antimicrobial agents in health and agriculture [30]. Sawant *et al.*, 2017 evaluated the antidiabetic and antihyperlipidemic effects of lectins purified from *Abrusprecatorius* seeds (ABA). In alloxan-induced diabetic rats, oral administration of ABA (150 and 200 mg/kg) for 14 days led to significant reductions in blood glucose, improved lipid profiles, and increased liver glycogen levels. Acute toxicity testing (OECD 425) showed no adverse effects at doses up to 2000 mg/kg. These results highlight the potential of *A. precatorius* lectins as a safe, natural adjunct therapy for diabetes management [31].

Exploring the therapeutic power of animal lectins

Animal lectins are classified based on several interrelated factors, including the complexity of their carbohydrate ligands, the biological processes they are involved in, their expression patterns, and their dependence on divalent cations [32]. Animal lectins are key to processes like endocytosis, glycoprotein transport, and glycoconjugate binding. They also aid in apoptosis, pathogen defense, cell adhesion, migration, and bacterial attachment to epithelial tissues [33]. Liu *et al.*, 2015 explore the critical roles of animal lectins in both antiviral immunity and viral pathogenesis. They discuss how lectins can either activate immune responses to eliminate viruses or enhance viral entry and replication by recognizing specific carbohydrates on viral surfaces. The review also highlights how certain arthropod lectins act as viral susceptibility factors, facilitating infection. This insight is valuable for developing antiviral treatments and vaccines [34]. Loh *et al.,* 2015 review the immunomodulatory properties of ginseng polysaccharides (GPs), emphasizing their unknown receptors and signaling pathways. Animal lectins, carbohydrate-binding proteins involved in immune recognition, are proposed as potential receptors for GPs, providing new avenues for developing GPs as therapeutic materials for immune diseases [35]. Liu *et al.*, 2012 review the roles of animal lectins, such as galectins, C-type lectins, and annexins, in apoptosis pathways, highlighting their potential as anti-cancer drug targets. The article provides a comprehensive overview of how these lectins influence cancer-related cell death and discusses their therapeutic potential in drug discovery [36]. Rabinovich, 1999 reviews galectins, a family of animal lectins involved in various biological processes like cell adhesion, growth regulation, immune modulation, and cancer metastasis. The review explores their potential as therapeutic targets for autoimmune diseases, inflammation, allergies, and cancer [37]. Cao *et al.*, 2010 purified a lectin (MLL-2, 38 kDa) from *Musca domestica* larvae, which inhibited MCF-7 breast cancer cell proliferation and induced apoptosis in a dose-dependent manner. MLL-2 caused G2/M arrest, increased intracellular calcium, and activated mitochondrial apoptosis pathways, with a significant rise in caspase-3 activity and antitumor activity [38]. Nie *et al.,* 2012 discovered Lectin from *Muscadomesticapupae* that suppresses tumor cell proliferation. In HepG2 cells, MPL triggered

apoptosis and caused cell cycle arrest at the S phase. It prevented IκB-α degradation and inhibited NF-κB/p65 translocation to the nucleus, leading to downregulation of the FLIP gene. This resulted in the activation of caspase-8 and caspase-3, which induced apoptosis, suggesting MPL initiates caspase-dependent cell death through the NF-κB/p65 pathway [39]. Sreeramulu *et al.*, 2018 purified a β-galactoside-binding lectin from *Stenopsyche kodaikanalen sis* larvae, which displayed significant antibacterial activity. The lectin agglutinated *Bacillus subtilis* and lysed *Bacillus flexus*. It was heat-labile, calcium-independent, and had a molecular weight of 360 kDa with five subunits. These findings highlight its potential role in insect immunity [40].

Fungal lectins: natural therapeutics for health

Fungal lectins, found in fungi, have diverse carbohydrate-binding specificities. They play crucial roles in various biological processes, including host-pathogen interactions, fungal growth, and cell adhesion [41]. Lectins are widespread proteins that play key roles in cellular recognition, binding carbohydrates in a specific, reversible, and non-catalytic way. Fungi, such as mushrooms, yeasts, and microfungi, are emerging as valuable sources of novel lectins with unique specificities for potential biomedical and biotechnological applications [42]. Žurga *et al.,* 2017 showed that fungal lectin MpL facilitates targeted drug delivery to cancer cells by binding to overexpressed glycoproteins, CD13 and integrin α3β1. MpL is endocytosed in a clathrin-dependent manner, directing drugs to the Golgi apparatus and lysosomes. Fusion of MpL with peptidase inhibitors inhibited cancer cell invasiveness, demonstrating MpL's potential for drug delivery [43]. Sabotič *et al.,* 2025 highlight that glycosylation patterns serve as a key signature of cancer cells, which can be decoded by glycan-binding proteins, including fungal lectins. In this study, 22 fungal lectins, such as *Marasmiusoreades agglutinin* (MOA), *Laetiporussulphureus lectin* (LSL), *Agrocybeaegerita galectin* (AAG), *Aleuria aurantia lectin* (AAL), *Xerocomuschrysenteron lectin* (XCL), *Sordariamacrospora transcript associated with perithecial development* (TAP1), and *Agaricusbisporus lectin* (ABL), were tested on nine cancer cell lines. Eight lectins showed antiproliferative activity linked to glycan binding and varying effects on cell phenotypes. The β-galactoside-binding lectins MOA and LSL displayed broad antiproliferative effects, while AAG showed more specific activity. Fucose-binding lectins, especially AAL, exhibited strong antiproliferative effects. Other lectins, like XCL, TAP1, and ABL, also demonstrated weaker but differential effects. These results underscore the potential of fungal lectins in targeting cancer cells through diverse mechanisms, offering valuable insights for therapeutic development [44]. Ghufran *et al.*, 2017 identified a fucose-specific lectin (FFL) from *Aspergillus flavus* that induces IL-8 expression in human cells via the p38 MAPK pathway. FFL activates the transcription factor c-Jun, and inhibition of p38 MAPK reduces this effect, highlighting a lectin-mediated mechanism in host immune response modulation [45]. Audfray *et al.,* 2015 developed a recombinant GlcNAc-specific lectin (rPVL) from *Psathyrellavelutina* to detect truncated glycans associated with cancer. rPVL showed strong affinity for terminal GlcNAc residues, rare in healthy tissues, and specifically labeled cancer cells from lung, breast, and colon tissues. Structural analysis confirmed its glycan-binding specificity, making rPVL a promising marker for distinguishing cancerous from healthy tissues based on glycan alterations [46]. Nagre*et al.,* 2010 purified a mitogenic lectin (CSL) from *Cephalosporium*, a fungus linked to mycotic keratitis. CSL is a tetrameric protein (14 kDa subunits) that agglutinates human erythrocytes and binds strongly to mucin but not to simple sugars, indicating complex carbohydrate specificity. It also binds to peripheral blood mononuclear cells (PBMCs) and induces mitogenic activity, suggesting a role in host cell adhesion and fungal pathogenesis during eye infections [47]. Leal *et al.*, 2012 used lectin histochemistry to analyze carbohydrate expression on the cell walls of *Aspergillus* species in brain and lung tissues from patients with invasive aspergillosis. Using HRP-conjugated lectinsCon A, WGA, UEA-I, and PNA they identified strong binding of N-acetyl-D-glucosamine and methyl-α-D-mannoside across all species, while L-fucose and D-galactose showed variable expression. WGA and Con A effectively labeled fungal structures such as hyphae, conidial heads, and conidia, making them useful tools for detecting *Aspergillus* in tissue samples [48]. Belur, 2019A fucose-specific lectin (ANL) from *Aspergillus niger*, isolated from a keratitis patient, was purified and shown to have a molecular mass of 30 kDa. ANL binds to L-fucose, galactose, lactose, and glycoproteins, and exhibits antibacterial activity against *Klebsiella pneumoniae*, *Staphylococcus aureus*, *Pseudomonas aeruginosa*, and *Escherichia coli*. It inhibits biofilm formation and strongly binds to human pancreatic cancer PANC-1 cells, with blocking by L-fucose and mucin reducing binding by 76.2% and 84.2%, respectively. ANL showed dose-dependent growth inhibition on PANC-1 cells with an IC50 of 1.25 µg/ml at 48h, suggesting promising therapeutic potential [49]. Ismaya *et al.*, 2020 discuss the therapeutic potential of lectins from *Agaricusbisporus*, particularly ABL and Abmb. These lectins show anti-cancer and immune-stimulating properties. While ABL has been extensively studied, its commercial use remains limited. The *A. bisporus* genome suggests other lectins with similar therapeutic potential, highlighting future research opportunities [50]. Liu, 2023 identified a lectin gene, Polec2, from *Pleurotusostreatus* mycelia that enhances fungal resistance to the storage mite *Tyrophagusputrescentiae*. Polec2, a galectin-like lectin, triggers the ROS/MAPK signaling pathway and boosts the production of salicylic acid (SA) and jasmonates (JA, JA-Ile, MeJA). Overexpressing Polec2 in *P. ostreatus* increased antioxidant activity and reduced mite feeding, suppressing its population. This study provides insights into the molecular mechanisms of fungal defense against mite predation and offers potential for pest-resistance gene discovery [51]. Moradi *et al.*, 2021 expressed *Coprinopsis cinerea* lectin 2 (CCL2) in *Arabidopsis* to evaluate its protective effects. CCL2 enhanced resistance to plant-parasitic nematodes, fungal pathogens (*Botrytis cinerea*), and bacteria (*Pseudomonas syringae*), while promoting plant growth. The protective effect relied on CCL2's fucoside-binding ability, as a mutant version (CCL2-Y92A) failed to confer resistance. CCL2 boosted plant defense gene expression during infection, showing potential as a tool for plant protection [52]. Al-Obaydi, 2023. Lectins, proteins found in many foods, are immune-boosting and antioxidant agents. They pass through the digestive system undigested, binding to sugars to enhance immunity. In this study, lectins were extracted from 1 kg of mushrooms using cell disruption, ammonia sulfate precipitation, and dialysis. The purified lectin exhibited antibiotic properties, indicating its potential for therapeutic use [53]. He *et al.,* 2017 investigated the potential of *Pleurotusostreatus* (POL) lectin as a treatment for chronic hepatitis B virus (HBV) infection. While the HBV vaccine induces high antibody levels, it does not effectively stimulate innate or cellular immunity for chronic infection. POL activated the Toll-like receptor 6 signaling pathway in dendritic cells, boosting the innate immune response. This led to increased HBV-specific antibody levels and enhanced follicular helper T cell responses, overcoming HBV tolerance in transgenic mice. The findings suggest that POL could offer a new therapeutic approach for HBV [54]. Seliman *et al.*, 2024 studied a novel lectin from *Pleurotuseryngii* var. *ferulae* (PEFL) was purified and showed significant anti-inflammatory effects. It reduced pro-inflammatory cytokines and prostaglandin production, while increasing anti-inflammatory IL-10. PEFL also inhibited COX-2 and iNOS expression, suggesting its potential as a therapeutic agent for inflammation [55].

Marine lectins: promising therapeutics from the sea

Lectins from marine organisms are structurally varied and distinct from those found in terrestrial organisms, showing significant promise for therapeutic applications and the development of new bioactive compounds [10]. Buriak, and Kumeiko, 2024. Glycosylation is a key post-translational modification that influences protein structure, with abnormal glycosylation patterns observed in brain tumors. This study explores marine-derived lectins and lectin-like proteins as potential tools for identifying these aberrant glycosylation signatures, offering prospects for precision diagnostics and personalized therapies in brain tumor treatment [56]. Catanzaro *et al.*, 2020 studied marine and freshwater lectins show considerable anticancer promise due to their ability to target specific sugar patterns on cancer cell surfaces. These proteins induce controlled cell death and inhibit tumor cell growth with minimal toxicity. The rich biodiversity of marine environments offers a vast reservoir of lectins that could pave the way for new cancer treatments in clinical settings [57]. The 2023 study by Arruda *et al.*, highlights that marine algae-derived lectins exhibit notable antitumor activity by inhibiting cell proliferation, inducing cell cycle arrest, and triggering apoptosis. These lectins primarily enter cancer cells through carbohydrate moieties and have shown effectiveness against various cancers, with a particular focus on breast cancer. Additionally, their immunomodulatory effects enhance their potential as therapeutic agents [58]. Hung *et al.*, 2018 study focused on SFL, a lectin derived from the

marine sponge *Stylissaflexibilis*, which was found to be a 64 kDa glycoprotein. SFL caused agglutination of human a erythrocytes and inhibited the growth of *Vibrio alginolyticus* and *Vibrio parahaemolyticus* in a dose-dependent manner. Its calcium-dependent activity, inhibited by d-galactose, points to its promising therapeutic potential in antibacterial applications [59]. Singh and Walia's, 2018 study focuses on lectins from red algae, proteins that bind specifically to carbohydrates and initiate biochemical reactions. These lectins have antiviral potential against viruses such as HIV, hepatitis, and influenza, and also show anti-cancer, anti-microbial, and anti-inflammatory properties, making them valuable for biomedical research [60]. Fernández Romero *et al.*, 2021 explore lectins from marine and freshwater organisms, such as algae and cyanobacteria, discussing their structure, function, and antimicrobial properties. The study emphasizes their potential for treating diseases like HIV, influenza, and coronavirus, with a focus on their preclinical and clinical evaluation [61]. The 2024 study by Carneiro investigated the synergistic effect of marine lectins and antibiotics against resistant bacteria. Lectins alone had no antibacterial activity, but when combined with tetracycline, they enhanced its effectiveness, particularly lectins from the *Bryothamnium* genus, which reduced the MIC of tetracycline significantly [62]. Abreu *et al.,* 2022 investigated the antidepressant effects of *Solieriafiliformis* lectin (SfL) in a mouse model of LPS-induced depression. The study revealed that SfL could prevent and reverse depressive behaviors and neurochemical changes, providing strong evidence for its potential as a natural antidepressant therapy [63]. Lima*et al.,* 2005 purified a lectin from *Gracilaria cornea* (GCL) demonstrated potential therapeutic properties, including hemagglutination activity unaffected by simple sugars but inhibited by complex glycoproteins. GCL also significantly reduced the weight and survival rates of *Boophilusmicroplus* ticks, suggesting its potential as an anti-tick agent. These findings highlight GCL as a promising candidate for further exploration in therapeutic applications, particularly in controlling tick infestations [64]. Ahmmed *et al.*, 2022 focused on marine lectins with diverse functions, including immune system modulation and pathogen recognition. Their bioactive properties and pharmaceutical potential make them valuable candidates for developing treatments in various industries, including biomedical and pharmaceutical [65]. Rogers and Hori, 1993 explored methods for extracting and purifying lectins from marine algae, emphasizing their biochemical characterization. They identified three types of red algal lectins, each with different carbohydrate binding properties and cation requirements. These findings highlight the potential of marine algal lectins for clinical applications, particularly in immune modulation and therapeutic development [66]. Almeida *et al.,* 2023 isolated a novel lectin, IsL, from the marine sponge *Irciniastrobilina*. IsL exhibited significant hem agglutinating activity, which was inhibited by galactosides, and was stable at neutral to alkaline pH. Although non-toxic to *Artemia nauplii* and lacking antimicrobial activity, IsL effectively inhibited biofilm formation of *Staphylococcus aureus* and *Staphylococcus epidermidis*. These properties suggest IsL's potential for clinical applications, particularly in combating bacterial infections and biofilm-related diseases [67]. Roopashri and Janakiraman 2022 identified lectins in 40 freshwater microalgae isolates, demonstrating their potential as bioactive compounds. These lectins showed hem agglutination activity with various animal erythrocytes, especially after enzyme treatment, and their activity was inhibited by specific oligosaccharides and glycoproteins. The findings highlight the therapeutic potential of these microalgal lectins in disease diagnostics and their possible applications in biotechnology and therapeutic development [68]. Gondim *et al.* 2019 discovered that lectins from Brazilian flora, particularly from species like ConBr and DSclerL, exhibited powerful antiviral effects, particularly against HIV and influenza. These promising results suggest that these lectins could be utilized as therapeutic agents for viral diseases [69].

Table 1: Lectins and their therapeutic potential

Lectin name	Source	Therapeutic potential	Reference
Soybean agglutinin (SBA) and Peanut agglutinin (PNA),	Seeds	Antibacterial and Anticancer	[18]
Plant lectins	Plant	Antiviral, Antinociceptive, Anti-inflammatory and Antiulcer	[19]
Fava bean, Lentil, and Pea lectins	Egyptian leguminous seeds	Antimicrobial and Antifungal	[21]
Wisteria and *floribunda* lectins	Seeds	Anticancer	[22]
Manilkara zapota lectin	Seeds	Antimicrobial, Antioxidant, and Anticancer	[23]
*Bryophyllumpinnatum*Lectin	Leaves	Antioxidant	[24]
Musa acuminata and *Euphorbia geniculate* lectin	Phloem	Anticancer	[25]
*Entada rheedii*lectin	Seeds	Antiproliferative	[27]
Lepidium sativum lectin	Seeds	Antibacterial and Anticancer	[29]
Abrusprecatorius lectin	Seeds	Antidiabetic and Antihyperlipidemic	[31]
Musca domestica lectin (MLL)	Larvae	Anticancer	[38]
*Agaricusbisporus*lectin (ABL)	Fungi	Anticancer, Immune-Stimulating	[50]
*Pleurotusostreatus*lectin	Fungi	Antiviral	[54]
Pleurotuseryngii var. ferulae (PEFL) lectin	Fungi	Anti-inflammatory	[55]
Red algae lectin	Marine	Antiviral, Anticancer, Antimicrobial, and Anti-inflammatory	[60]
olieriafiliformis lectin (SfL)	Marine organism	Antidepressant	[63]
*Irciniastrobilina*lectin (ISL)	Marine sponge	Antimicrobial	[67]
Brazilian flora lectin	Marine organism	Antiviral	[69]

This table 1 summarizes various lectins and their sources, and therapeutic potentials.

CONCLUSION

Lectins, as carbohydrate-binding proteins, present a vast and largely untapped therapeutic potential across multiple biological sources, including plants, animals, fungi, and marine organisms. Each type of lectin offers unique properties and biological activities that make them valuable candidates for the development of new therapeutic agents. However, despite the exciting prospects, further research is essential to fully understand the mechanisms of action of lectins and optimize their application in clinical settings. Challenges such as sourcing, isolation, and stability need to be addressed to maximize their therapeutic efficacy. Overall, the diverse range of lectins from various organisms offers immense opportunities for advancing medicine, and ongoing studies are crucial to unlocking their full potential for treating a variety of diseases and improving human health.

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AUTHORS CONTRIBUTIONS

All authors have contributed equally

CONFLICT OF INTERESTS

Authors declare no conflict of interest

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