NEUROPROTECTIVE EFFECTS OF MEDICINAL PLANTS IN ALZHEIMER'S DISEASE AND PARKINSON'S DISEASE

Prof. Dr. V. Mahalakshmi[1], Chirag M. Modi[2], Dr. Namdeo Bhagwan Admuthe[3], Dr. Yahya Khan[4], Dr. Shailendra .S.Choudhari[4*]

[1]Professor, Head of the Department, Department of Siddhar Yoga Maruthuvam, National Institute of Siddha, Chennai-47, Tamil Nadu, India

[2]Assistant Professor Department of Veterinary Pharmacology and Toxicology, College of Veterinary Science and A. H., Kamdhenu University, Sardarkrushinagar

[3]Assistant Professor, Department of Botany, Annasaheb Awate Arts, Commerce and Hutatma Babu Genu Science College, Manchar, Dist. Pune, Maharashtra

[4]Assistant Professor and Head Department of Botany, J.A.T. Arts science and commerce College (for women) Malegaon Dist-Nashik , Maharashtra Affiliated to savitribai phule pune University pune, Maharashtra

[5]Associate Professor,Department of Botany Balbhim Arts,Science and Commerce College,Beed Dist. .Beed. Pin Code – 431122 Maharashtra -INDIA

Abstract – Neurodegenerative diseases such as Alzheimer's disease (AD) and Parkinson's disease (PD) are characterized by progressive neuronal loss, cognitive decline, and motor dysfunction. Current therapeutic strategies primarily focus on symptom management rather than disease modification. Medicinal plants have gained significant attention due to their neuroprotective properties, which include antioxidative, anti-inflammatory, anti-amyloidogenic, and cholinesterase-inhibitory effects. Various phytochemicals, including flavonoids, alkaloids, and polyphenols, have shown potential in mitigating neurodegenerative processes by targeting oxidative stress, mitochondrial dysfunction, and neuroinflammation. This review explores the molecular mechanisms underlying the neuroprotective effects of medicinal plants, with a focus on key herbs such as *Ginkgo biloba*, *Curcuma longa*, *Withania somnifera*, *Bacopa monnieri*, and *Camellia sinensis*. Furthermore, it discusses preclinical and clinical studies supporting their efficacy, limitations, and future research directions in neurodegenerative therapy.

*Keywords:*Neurodegeneration, Alzheimer's disease, Parkinson's disease, medicinal plants, phytochemicals, oxidative stress, neuroinflammation, cholinesterase inhibitors, cognitive decline, neuroprotection

I. INTRODUCTION

Neurodegenerative disorders, particularly Alzheimer's disease (AD) and Parkinson's disease (PD), are among the leading causes of cognitive and motor impairments worldwide (Agnihotri et al., 2020). These conditions are marked by progressive neuronal degeneration, resulting in memory loss, cognitive decline, motor dysfunction, and a reduced quality of life. The prevalence of AD and PD is increasing with the aging global population, making them a major public health challenge (Chang et al., 2019; Luo et al., 2025). Current treatment options, such as cholinesterase inhibitors for AD and dopamine-replacement therapies for PD, only provide symptomatic relief but do not slow or reverse disease progression (Khan et al., 2023). As a result, there is a growing interest in alternative and complementary approaches, particularly the use of medicinal plants, which have been historically employed in traditional medicine systems like Ayurveda, Traditional Chinese Medicine (TCM), and Unani medicine. These plants contain a variety of bioactive compounds with antioxidant, anti-inflammatory, and neuroprotective properties that can target the molecular mechanisms of AD and PD (Shoaib et al., 2023). This review aims to provide a comprehensive analysis of the neuroprotective effects of medicinal plants in AD and PD, focusing on their mechanisms of action and the evidence supporting their therapeutic potential.

Table: Medicinal Plants and Their Neuroprotective Mechanisms in AD and PD

Medicinal Plant	**Active Compounds**	**Mechanism of Action**	**Neurodegenerative Disease**	**References**
Curcuma longa (Turmeric)	Curcumin	Antioxidant, anti-inflammatory, anti-amyloid	AD, PD	Bássoli et al., 2023
Withania somnifera (Ashwagandha)	Withanolides	NGF upregulation, anti-inflammatory, mitochondrial protection	AD, PD	Dar et al., 2020; Lerose et al., 2024
Bacopa	Bacosides	Cholinesterase	AD	Thakor et

monnieri (Brahmi)		inhibition, neurogenesis, synaptic enhancement		al., 2023
Panax ginseng (Ginseng)	Ginsenosides	Mitochondrial protection, anti-inflammatory, neurogenesis	AD, PD	Shin et al., 2019
Camellia sinensis (Green Tea)	EGCG	Antioxidant, anti-amyloid, synaptic plasticity	AD, PD	Payne et al., 2022
Ginkgo biloba	Ginkgolides, flavonoids	Anti-inflammatory, improves cerebral blood flow	AD	Pagotto et al., 2024
Centella asiatica (Gotu Kola)	Triterpenoids	Enhances neuroplasticity, promotes cognitive function	AD	Kim et al., 2016
Resveratrol (Grapes, Berries)	Polyphenols	Anti-amyloid, mitochondrial function, synaptic enhancement	AD, PD	Grabska-Kobyłecka et al., 2023

2. Pathophysiology of Alzheimer's and Parkinson's Diseases

2.1 Alzheimer's Disease (AD)

Alzheimer's disease is the most prevalent neurodegenerative condition and the leading cause of dementia globally. It is defined by worsening cognitive impairment, memory loss, and behavioral symptoms. The pathological substrate of AD consists of extracellular amyloid-beta (Aβ) plaques, intracellular neurofibrillary tangles (NFTs) made of hyperphosphorylated tau protein, synaptic loss, and ongoing neuroinflammation (Ju et al., 2022). The build-up of Aβ peptides is caused by the pathological cleavage of the amyloid precursor protein (APP) by β- and γ-secretases, which generates neurotoxic Aβ oligomers that abolish synaptic signaling and cause neuronal apoptosis (Yu et al., 2024). NFTs, by contrast, are generated as a result of tau protein hyperphosphorylation, resulting in destabilization of microtubules and disruption of axonal transport. In addition, oxidative stress and mitochondrial dysfunction also add to the neuronal injury by enhancing the generation of reactive oxygen species (ROS), deranging energy metabolism, and initiating apoptotic signaling pathways. Neuroinflammation, which is mediated through activated microglia and astrocytes, contributes importantly towards AD pathology through the release of pro-inflammatory cytokines IL-1β, IL-6, and TNF-α, leading to neuronal death. With these complex pathological mechanisms, it is crucial to target oxidative stress, neuroinflammation, and protein aggregation in developing therapeutic interventions against AD (Sharifi-Rad et al., 2022).

2.2 Parkinson's Disease (PD)

Parkinson's disease is the second most prevalent neurodegenerative condition, with its primary impact on motor function because of the selective degeneration of dopaminergic neurons within the substantia nigra pars compacta (SNpc) (Goloborshcheva et al., 2022). The pathology involves bradykinesia, tremor, muscle rigidity, and postural instability, which worsen with time. The pathological signature of PD is the deposition of misfolded alpha-synuclein within Lewy bodies, causing mitochondrial dysfunction, oxidative stress, and neuroinflammation (Calabresi, et al., 2023). Degeneration of dopaminergic neurons causes reduced dopamine levels in the striatum, resulting in dysfunctional motor control and coordination. Mitochondrial impairment is responsible for PD progression through decreased ATP generation, elevated levels of ROS, and activation of apoptotic processes in dopaminergic neurons. Moreover, chronic neuroinflammation, which is mediated by activated astrocytes and microglia, results in neuronal degeneration by

releasing pro-inflammatory cytokines and nitric oxide. Although symptomatic relief can be achieved with dopamine-replacement therapies such as levodopa, they cannot retard disease progression. Thus, neuroprotective interventions directed against oxidative stress, inflammation, and mitochondrial dysfunction are essential for finding effective PD therapies (Bej et al., 2024).

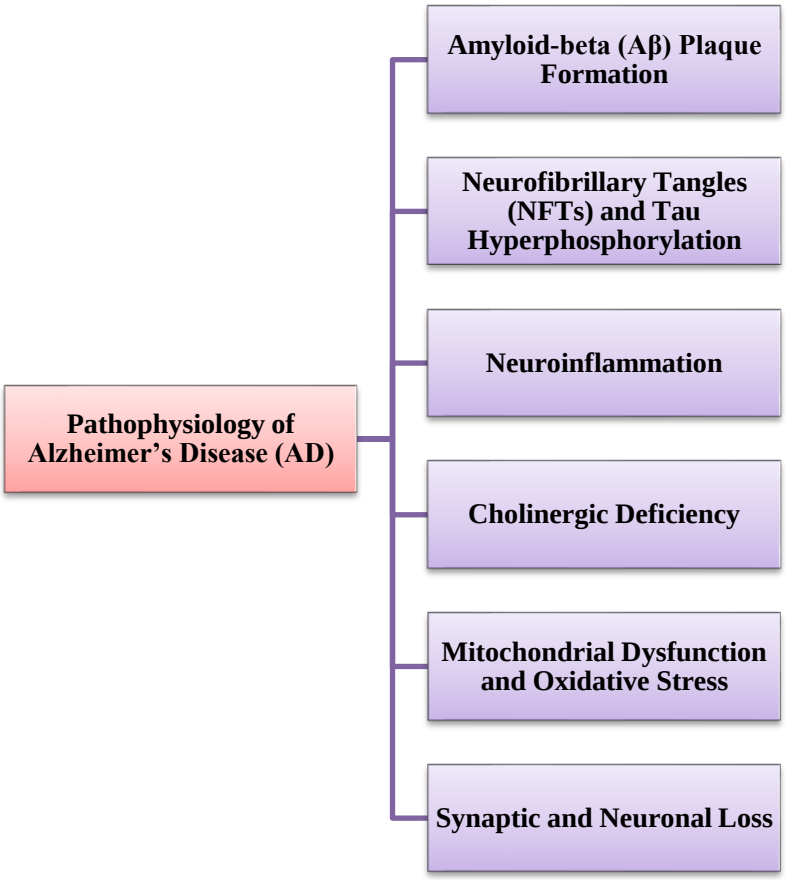

Figure 1: Pathophysiology of Alzheimer's Disease (AD)

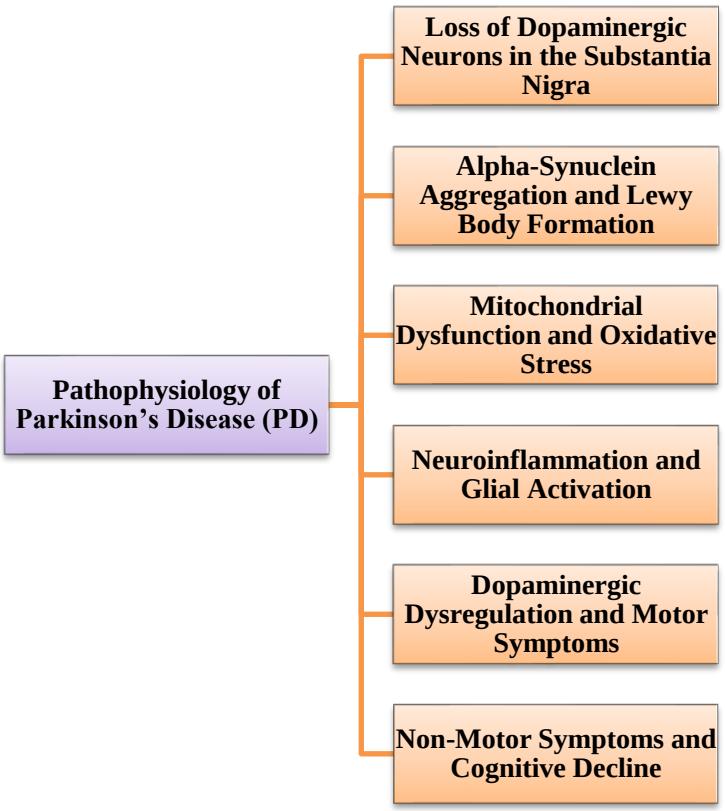

Figure 2: Pathophysiology of Parkinson's Disease (PD)

3. Neuroprotective Mechanisms of Medicinal Plants

3.1 Antioxidant Activity

Oxidative stress is among the key causes of neurodegeneration in AD and PD. The overproduction of ROS results in lipid peroxidation, protein oxidation, and DNA damage, triggering neuronal apoptosis and synaptic dysfunction. Most medicinal plants have strong antioxidant activities because they contain high levels of flavonoids, polyphenols, and carotenoids. For instance, *Curcuma longa (turmeric)* has curcumin, a widely recognized antioxidant that scavenges ROS, suppresses lipid peroxidation, and improves mitochondrial function (Bássoli et al., 2023). Curcumin has been found to attenuate Aβ-induced oxidative damage in AD as well as dopaminergic neuron loss in PD models. In like manner, Camellia sinensis (green tea) has epigallocatechin gallate (EGCG), a highly active polyphenol that quenches free radicals and inhibits oxidative stress-induced neuronal damage (Li et al., 2024). These antioxidant compounds help restore cellular redox balance, protecting neurons from oxidative injury and slowing disease progression.

3.2 Anti-Inflammatory Effects

Chronic neuroinflammation plays a significant role in the pathogenesis of AD and PD by activating microglia, promoting cytokine release, and exacerbating neuronal loss. Medicinal plants with anti-inflammatory properties can mitigate neuroinflammation by inhibiting key inflammatory pathways. *Withania somnifera (Ashwagandha),* an Ayurvedic plant, inhibits inflammation by down-regulating nuclear factor-kappa B (NF-κB) and inhibiting the synthesis of pro-inflammatory cytokines like TNF-α and IL-6. An example is the ginkgolides of Ginkgo biloba that inhibit microglial activation and attenuate neuroinflammation in AD and PD models. Through the regulation of inflammatory cascades, such plants conserve the integrity of the neurons and increase cognitive and motor functions in neurodegenerative disorders.

3.3 Cholinesterase Inhibition

In AD, decreased levels of acetylcholine are responsible for cognitive dysfunction and memory loss. Acetylcholinesterase (AChE) inhibitors are usually prescribed to improve cholinergic neurotransmission but may be associated with side effects. A number of medicinal plants exhibit natural cholinesterase inhibitory activity and can serve as a safer substitute. Bacopa monnieri (Brahmi), an established nootropic herb, is rich in bacosides, which are known to inhibit AChE and enhance synaptic plasticity (Dar et al., 2020; Lerose et al., 2024). Ginkgo biloba also increases acetylcholine levels by inhibiting AChE, thus enhancing memory and cognitive function in AD patients. Such cholinergic-enhancing activities render medicinal plants promising candidates for cognitive support in AD.

3.4 Anti-Amyloid and Anti-Synuclein Effects

Amyloid-beta (Aβ) aggregation in AD and alpha-synuclein in PD is a significant cause of neuronal toxicity (Sengupta et al., 2022). A number of plant-derived polyphenols have been reported to disrupt protein aggregation and enhance protein clearance. Green tea polyphenols, especially EGCG, inhibit Aβ fibril formation and promote Aβ clearance through autophagy. Likewise, resveratrol, a grape polyphenol, blocks alpha-synuclein aggregation and rescues dopaminergic neurons in PD models. Such anti-amyloid and anti-synuclein activities underscore the therapeutic potential of medicinal plants against proteinopathy-induced neurotoxicity (Sengupta et al., 2022).

3.5 Mitochondrial Protection

Mitochondrial impairment is a primary pathological characteristic of AD and PD, resulting in energy deficits and neuronal apoptosis. There are some medicinal plants that promote mitochondrial well-being through increased ATP synthesis, lowering of oxidative stress, and

induction of mitochondrial biogenesis. Panax ginseng has ginsenosides which enhance mitochondrial functioning and safeguard neurons against apoptotic death. Quercetin, a flavonoid present in onions and apples, increases mitochondrial respiration and lowers oxidative stress-induced damage. These mitochondrial-preserving effects contribute to the useful role of medicinal plants in maintaining neuronal energy metabolism and avoiding neurodegeneration.

3.6 Enhancement of Neurogenesis and Synaptic Plasticity

Neurogenesis, the generation of new neurons, and synaptic plasticity, which allows synapses to strengthen and weaken with passage of time, are essential to learning, memory, and global brain function. In neurodegenerative disease states such as AD and PD, compromised neurogenesis and dysfunction of synapses play a profound role in both cognitive and motor impairment. Select medicinal plants were discovered to encourage neurogenesis and synaptic plasticity through the modulating of neurotrophic factors, neurotransmitter concentrations, and connectivity between neurons(Payne et al., 2022; Pagotto et al., 2024; Kim et al., 2016;, Grabska-Kobyłecka et al., 2023).

Among the principal regulators of neurogenesis are brain-derived neurotrophic factor (BDNF), which protects neurons, aids differentiation, and maintains synaptic plasticity. BDNF expression is increased in a number of medicinal herbs including Bacopa monnieri and Panax ginseng. Bacopa monnieri harbors bacosides that activate dendritic sprouting and synaptogenesis with the consequent enhancement of memory and learning. Panax ginseng evokes neurogenesis within the hippocampus, one of the primary brain regions damaged in AD (Payne et al., 2022; Pagotto et al., 2024; Kim et al., 2016;, Grabska-Kobyłecka et al., 2023).

Another significant factor is nerve growth factor (NGF), which has a key function in the support of cholinergic neurons. Withania somnifera (Ashwagandha) has been found to raise NGF levels, supporting neuronal survival and growth(Dar et al., 2020; Lerose et al., 2024).. Centella asiatica (Gotu Kola) also supports synaptic plasticity by augmenting dendritic complexity and increasing synaptic transmission, which counteracts the synaptic loss seen in AD.

In addition, some polyphenols like resveratrol found in grapes and epigallocatechin gallate (EGCG) found in green tea augment long-term potentiation (LTP), a cellular process that supports learning and memory. These phytochemicals evoke signaling cascades like the cAMP response element-binding protein (CREB) cascade important for memory formation. Through stimulation of neurogenesis and synaptic plasticity, medicinal plants restore cognitive capacity and retard neurodegenerative disease progression.

4. Conclusion

Neurodegenerative diseases such as Alzheimer's disease and Parkinson's disease place a heavy burden on public health, with few therapeutic options to prevent disease progression. Medicinal plants provide a promising source of neuroprotection because they contain a wide range of bioactive compounds that target various pathological mechanisms, such as oxidative stress, neuroinflammation, mitochondrial dysfunction, protein aggregation, cholinergic dysfunction, and disrupted neurogenesis.

The neuroprotective activities of medicinal plants like Curcuma longa, Withania somnifera, Bacopa monnieri, and Panax ginseng demonstrate their potential as complementary therapies for AD and PD. Their capacity to augment antioxidant defenses, suppress inflammatory pathways, enhance neurotrophic support, and enhance synaptic plasticity renders them useful candidates for additional research and clinical use.

Subsequent research must include thorough clinical trials for the verification of efficacy and safety of these phytochemicals from plants. Further, nanotechnology and drug delivery systems will be able to raise the bioavailability of these phytochemicals so that they can exert more therapeutic potential. With the combination of medicinal plants and traditional therapies, a more holistic form of neurodegenerative disease treatment is possible, with hope of enhanced cognitive and motor function in patients.

REFERENCES

Agnihotri, A., & Aruoma, O. I. (2020). Alzheimer's disease and Parkinson's disease: a nutritional toxicology perspective of the impact of oxidative stress, mitochondrial dysfunction, nutrigenomics and environmental chemicals. *Journal of the American College of Nutrition*, *39*(1), 16-27.

Bássoli, R. M. F., Audi, D., Ramalho, B. J., Audi, M., Quesada, K. R., & Barbalho, S. M. (2023). The effects of curcumin on neurodegenerative diseases: A systematic review. *Journal of Herbal Medicine*, *42*, 100771.

Bej, E., Cesare, P., Volpe, A. R., d'Angelo, M., & Castelli, V. (2024). Oxidative stress and neurodegeneration: insights and therapeutic strategies for Parkinson's disease. *Neurology International*, *16*(3), 502-517.

Calabresi, P., Mechelli, A., Natale, G., Volpicelli-Daley, L., Di Lazzaro, G., & Ghiglieri, V. (2023). Alpha-synuclein in Parkinson's disease and other synucleinopathies: from overt neurodegeneration back to early synaptic dysfunction. *Cell death & disease*, *14*(3), 176.

Chang, A. Y., Skirbekk, V. F., Tyrovolas, S., Kassebaum, N. J., & Dieleman, J. L. (2019). Measuring population ageing: an analysis of the Global Burden of Disease Study 2017. *The Lancet Public Health*, *4*(3), e159-e167.

Dar, N. J., & Ahmad, M. (2020). Neurodegenerative diseases and Withania somnifera (L.): An update. *Journal of ethnopharmacology*, *256*, 112769.

Goloborshcheva, V. V., Kucheryanu, V. G., Voronina, N. A., Teterina, E. V., Ustyugov, A. A., & Morozov, S. G. (2022). Synuclein proteins in MPTP-induced death of Substantia Nigra pars compacta dopaminergic neurons. *Biomedicines*, *10*(9), 2278.

Grabska-Kobyłecka, I., Szpakowski, P., Król, A., Książek-Winiarek, D., Kobyłecki, A., Głąbiński, A., & Nowak, D. (2023). Polyphenols and their impact on the prevention of neurodegenerative diseases and development. *Nutrients*, *15*(15), 3454.

Ju, Y., & Tam, K. Y. (2022). Pathological mechanisms and therapeutic strategies for Alzheimer's disease. *Neural regeneration research*, *17*(3), 543-549.

Khan, S. S., Khatik, G. L., & Datusalia, A. K. (2023). Strategies for treatment of disease-associated dementia beyond Alzheimer's disease: an update. *Current Neuropharmacology*, *21*(2), 309-339.

Kim, M. S., Bang, J. H., Lee, J., Han, J. S., Baik, T. G., & Jeon, W. K. (2016). Ginkgo biloba L. extract protects against chronic cerebral hypoperfusion by modulating neuroinflammation and the cholinergic system. *Phytomedicine*, *23*(12), 1356-1364.

Lerose, V., Ponticelli, M., Benedetto, N., Carlucci, V., Lela, L., Tzvetkov, N. T., & Milella, L. (2024). Withania somnifera (L.) Dunal, a potential source of phytochemicals for treating neurodegenerative diseases: A systematic review. *Plants*, *13*(6), 771.

Li, S., Wang, Z., Liu, G., & Chen, M. (2024). Neurodegenerative diseases and catechins:(−)-epigallocatechin-3-gallate is a modulator of chronic neuroinflammation and oxidative stress. *Frontiers in Nutrition*, *11*, 1425839.

Luo, Y., Qiao, L., Li, M., Wen, X., Zhang, W., & Li, X. (2025). Global, regional, national epidemiology and trends of Parkinson's disease from 1990 to 2021: findings from the Global Burden of Disease Study 2021. *Frontiers in Aging Neuroscience*, *16*, 1498756.

Pagotto, G. L. D. O., Santos, L. M. O. D., Osman, N., Lamas, C. B., Laurindo, L. F., Pomini, K. T., ... & Barbalho, S. M. (2024). Ginkgo biloba: a leaf of hope in the fight against Alzheimer's dementia: clinical trial systematic review. *Antioxidants*, *13*(6), 651.

Payne, A., Nahashon, S., Taka, E., Adinew, G. M., & Soliman, K. F. (2022). Epigallocatechin-3-

Gallate (EGCG): New therapeutic perspectives for neuroprotection, aging, and neuroinflammation for the modern age. *Biomolecules*, *12*(3), 371.

Sengupta, U., & Kayed, R. (2022). Amyloid β, Tau, and α-Synuclein aggregates in the pathogenesis, prognosis, and therapeutics for neurodegenerative diseases. *Progress in neurobiology*, *214*, 102270.

Sharifi-Rad, J., Rapposelli, S., Sestito, S., Herrera-Bravo, J., Arancibia-Diaz, A., Salazar, L. A., ... & Calina, D. (2022). Multi-target mechanisms of phytochemicals in Alzheimer's disease: Effects on oxidative stress, neuroinflammation and protein aggregation. *Journal of Personalized Medicine*, *12*(9), 1515.

Shin, S. J., Jeon, S. G., Kim, J. I., Jeong, Y. O., Kim, S., Park, Y. H., ... & Moon, M. (2019). Red ginseng attenuates Aβ-induced mitochondrial dysfunction and Aβ-mediated pathology in an animal model of Alzheimer's disease. *International Journal of Molecular Sciences*, *20*(12), 3030.

Shoaib, S., Ansari, M. A., Fatease, A. A., Safhi, A. Y., Hani, U., Jahan, R., ... & Islam, N. (2023). Plant-derived bioactive compounds in the management of neurodegenerative disorders: challenges, future directions and molecular mechanisms involved in neuroprotection. *Pharmaceutics*, *15*(3), 749.

Thakor, A. (2023). *Protective Effect of Memantine and Bacopa Monnieri on LPS-Induced SHSY5Y Cells Via Amyloidosis, Anti-Inflammatory and Intrinsic Apoptotic Pathways* (Master's thesis, Long Island University, Brooklyn).

Yu, Y., Yu, S., Battaglia, G., & Tian, X. (2024). Amyloid-β in Alzheimer's disease: Structure, toxicity, distribution, treatment, and prospects. *ibrain*, *10*(3), 266-289.