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LIPOSOMES IN REGENERATIVE COSMETICS: REVOLUTIONIZING SKIN CARE THROUGH ADVANCED NANOTECHNOLOGY

Fawzia SHAAT[1], Ramona-Daniela PAVALOIU[1], Ciprian FODOR[2], Emilian ROMAN[2], Mariana FODOR[2]

[1]National Institute for Chemical-Pharmaceutical Research & Development – ICCF Bucharest, 112 Vitan Avenue, District 3, 031299, Bucharest, Romania
[2]SC PURE LIFE SRL, 13 Veronica Micle Street, 720217, Suceava, Romania

Corresponding author email: pavaloiu_daniella@yahoo.com

Abstract

Liposomes play a vital role in the advancement of regenerative cosmetics due to their capacity to encapsulate, protect, and effectively deliver active ingredients deep within the skin. These versatile carriers mimic biological membranes, enhancing the stability and bioavailability of sensitive compounds such as peptides, growth factors, vitamins, and plant-derived bioactives. Regenerative cosmetics leverage liposomal systems to promote skin repair, boost collagen synthesis, and combat signs of aging by targeting cellular pathways with precision. This review explores the state-of-the-art advancements in liposome technology for cosmetic applications, emphasizing their role in addressing challenges such as poor solubility, rapid degradation, and limited penetration of active agents. Additionally, we examine the economic viability, scalability, and regulatory considerations associated with integrating liposome-based products into the commercial cosmetic market. Despite their transformative potential, challenges remain in ensuring formulation stability, achieving cost-effective production, and verifying long-term safety. By providing a comprehensive overview, this review underscores the potential of liposome technology to revolutionize regenerative cosmetics, paving the way for next-generation skincare innovations that restore, rejuvenate, and protect the skin.

Key words: *liposomes, regenerative cosmetics, natural ingredients, skin carre.*

INTRODUCTION

The field of regenerative cosmetics has witnessed significant advancements in recent years, with liposome technology emerging as a key innovation in the delivery of active ingredients for enhanced skin health (Dubey et al., 2022; Huang et al., 2024). Liposomes, vesicles composed of phospholipid bilayers, serve as highly efficient carriers that encapsulate and transport bioactive compounds deep into the skin. Their structural similarity to biological membranes allows for improved biocompatibility and enhanced absorption of otherwise poorly soluble or unstable molecules (Aziz et al., 2019; Dymek & Sikora, 2022; Giordani et al., 2023; Lee, 2020; Khater et al., 2021; Nsairat et al., 2022; Obeid et al., 2017).

One of the primary challenges in skincare formulations is ensuring the effective penetration of active ingredients, such as peptides, growth factors, vitamins, and botanical extracts, into the deeper layers of the skin. Traditional topical applications often suffer from limitations, including rapid degradation, insufficient bioavailability, and inefficient targeting of cellular pathways (Antimisiaris et al., 2021; Ashfaq et al., 2023; Aqil et al., 2013; Li et al., 2019; Musielak & Krajka-Kuźniak, 2024). Liposomal carriers overcome these challenges by providing controlled and sustained release, protecting sensitive compounds from environmental degradation, and optimizing their bioavailability.

Regenerative cosmetics, which focus on skin repair, rejuvenation, and protection, have greatly benefited from liposomal advancements. By facilitating targeted delivery of essential biomolecules, liposomes contribute to enhanced collagen synthesis, reduction of fine lines and wrinkles, and overall skin renewal. This cutting-edge approach is particularly relevant for anti-aging treatments, hydration therapies, and formulations designed to combat oxidative stress and inflammation (Huang et al., 2024; Lee et al., 2024; Pleguezuelos-Beltrán et al., 2024). Additionally, the ability of liposomes to encapsulate both hydrophilic and lipophilic molecules has broadened their application scope, enabling the development of multifunctional cosmetic formulations that address a wide range of dermatological concerns.

Despite the promising benefits of liposomal technology in cosmetics, several hurdles remain in its widespread adoption. The high cost of production, challenges in ensuring long-term formulation stability, and the need for rigorous regulatory approvals pose significant barriers to commercial scalability (Agrawal et al., 2025; Liu et al., 2022; Sameer Khan et al., 2024). Moreover, the physicochemical properties of liposomes, including their size, charge, and composition, must be carefully optimized to ensure consistent performance in skincare applications (Gatto et al., 2024; Tran et al., 2022). Advanced techniques such as nanoliposomes, ethosomes, and deformable liposomes have emerged to further refine delivery efficiency, but their full potential is yet to be realized in mainstream cosmetic formulations (Ricci et al., 2024; Sapkota & Dash, 2021). This review explores the current state of liposomal technology in regenerative cosmetics, highlighting its transformative potential in overcoming traditional skincare limitations.

Additionally, we examine the economic viability, scalability, and regulatory considerations associated with integrating liposome-based products into the commercial cosmetic market. Despite their transformative potential, challenges remain in ensuring formulation stability, achieving cost-effective production, and verifying long-term safety. By providing a comprehensive analysis, this review underscores the role of liposomes in revolutionizing modern skincare, paving the way for next-generation cosmetic innovations that restore, rejuvenate, and protect the skin.

MATERIALS AND METHODS

This mini-review was conducted through an extensive literature search and analysis of various types of papers like reviews, books, research articles, etc. related to liposomal technology in regenerative cosmetics. A systematic search was performed in March 2025 using databases such as PubMed, Scopus, Web of Science, ScienceDirect, etc. to collect peer-reviewed journal articles, using keywords, such as ‘liposomes’, ‘regenerative cosmetics’, ‘nanocarriers in skincare’, ‘liposomal drug delivery’, ‘cosmetic formulations’ and ‘biocompatible nanoparticles’. Articles were selected based on their relevance, credibility, and impact on the field, prioritizing studies discussing the physicochemical properties, stability, efficacy, and safety of liposomal formulations in cosmetic applications.

Studies were included if they focused on the development, characterization, stability, and effectiveness of liposomal formulations in cosmetic applications, along with regulatory and economic considerations, while articles lacking experimental or clinical data, those centered exclusively on pharmaceutical applications, or reports with insufficient methodological details were excluded. Also, Regulatory guidelines for cosmetic liposomal formulations were reviewed, focusing on the European Union (Regulation EC No. 1223/2009) and FDA regulations.

RESULTS AND DISCUSSIONS

Liposomes in regenerative cosmetics

Liposomes are nanoscale vesicles composed of one or more concentric phospholipid bilayers enclosing an aqueous core, making them highly effective carriers for both hydrophilic and lipophilic molecules (Gregoriadis, 2017). Their amphipathic nature allows them to self-assemble in aqueous environments, forming stable bilayer structures known as lamellae, which can be classified as unilamellar (single bilayer) or multilamellar (multiple bilayers) vesicles (Aman Mohammadi et al., 2023). This unique architecture not only protects encapsulated compounds from environmental degradation but also enhances their stability and bioavailability in cosmetic formulations (Giordani et al., 2023; Musielak & Krajka-Kuźniak, 2024).

The composition of liposomes plays a crucial role in their structural integrity and performance. Typically, they are formed using natural or synthetic phospholipids, such as phosphatidylcholine, phosphatidylethanolamine, and cholesterol, which influence their stability, charge, and permeability (Santonocito & Puglia, 2025). Cholesterol, in particular, is often incorporated to enhance membrane rigidity and reduce permeability, thereby increasing the shelf life of liposomal formulations (Ohishi et al., 2024).

The size and surface charge of liposomes also impact their ability to penetrate the stratum corneum, the outermost layer of the skin. Liposomes ranging from 50 to 200 nm in diameter have been shown to exhibit improved skin permeability, allowing for deeper penetration of active ingredients (Nayak et al., 2024). Additionally, surface modifications, such as PEGylation or functionalization with ligands, can enhance the targeting efficiency and stability of liposomes in cosmetic applications (Gatto et al., 2024).

Beyond their structural advantages, liposomes offer significant benefits in skincare by improving the bioavailability and controlled release of active compounds. They have been used to encapsulate a wide range of bioactive ingredients, including vitamins (e.g., vitamin C and E), antioxidants (e.g., resveratrol and coenzyme Q10), peptides, and botanical extracts (Tran et al., 2022). The encapsulation process protects these sensitive compounds from oxidation, UV degradation, and enzymatic breakdown, ensuring prolonged efficacy upon application (Agrawal et al., 2025; Sameer Khan et al., 2024; Pires et al., 2019).

Various techniques, including sonication, extrusion, and freeze-thaw cycles, are employed to reduce liposome size and improve their ability to penetrate the skin barrier (Lombardo & Kiselev, 2022; Santonocito & Puglia, 2025; Taouzinet et al., 2023). Sonication utilizes ultrasonic waves to break down liposomes into smaller vesicles, whereas extrusion forces liposomal suspensions through membranes of defined pore sizes, yielding uniform nano-sized vesicles (Martel-Estrada et al., 2022). The freeze-thaw method, which involves repeated cycles of freezing and thawing, enhances liposomal stability and encapsulation efficiency (Huang et al., 2005).

Liposomes offer multiple advantages as delivery systems for cosmetics. They protect bioactive compounds from degradation caused by light, oxidation, and environmental factors, thereby extending product shelf life and ensuring sustained release (Huang et al., 2024; Khorasani et al., 2018). Furthermore, liposomes improve ingredient bioavailability, enhance skin absorption, and allow for targeted delivery of both hydrophilic and lipophilic active agents (Musielak & Krajka-Kuźniak, 2024; Ricci et al., 2021).

Several encapsulation techniques, including emulsion, spray drying, extrusion, electrospinning, and coacervation, can be utilized to achieve efficient liposomal formulations (Dejeu et al., 2024; Filipczak et al., 2020). Among these, extrusion is regarded as the most efficient nanosizing method due to its ability to produce homogeneous liposomal structures with controlled particle sizes (Kaul et al., 2018; Mozafari et al., 2020).

To ensure successful encapsulation, several critical factors must be considered: (i) forming a stable liposomal shell around the active ingredient, (ii) preventing leakage of encapsulated compounds, and (iii) maintaining the exclusion of undesired external materials (Giordani et al., 2023; Huang et al., 2024). These characteristics contribute to improved product stability, extended efficacy, and enhanced bioavailability (Huang et al., 2024). Additionally, liposomes' physicochemical properties, such as size, lamellarity, and membrane rigidity, can be tailored to optimize solubility, pharmacokinetics, and biodistribution of active ingredients (Kaul et al., 2018; Allen & Cullis, 2013; Santonocito & Puglia, 2025).

Despite their numerous advantages, several challenges hinder the widespread adoption of liposomes in cosmetics. High production costs, potential leakage of encapsulated compounds, phospholipid oxidation or hydrolysis, fusion of active ingredients, low solubility, and short half-life present significant obstacles (Huang et al., 2024; Khorasani et al., 2018). The inherent instability of liposomal formulations can lead to aggregation, fusion, or precipitation, reducing their effectiveness in delivering active ingredients (Giordani et al., 2023). Furthermore, the interaction of liposomes with skin enzymes and external environmental factors, such as temperature and humidity, can degrade phospholipids, diminishing the overall bioavailability of encapsulated agents (Puri et al., 2020).

Another major concern is the structural integrity of liposomes upon skin application. The skin's stratum corneum acts as a formidable barrier, limiting the penetration of larger or unstable liposomal structures (Gupta et al., 2012; Musielak & Krajka-Kuźniak, 2024). While nanosized vesicles improve absorption, uncontrolled liposome fusion or premature release of active ingredients can reduce their targeted effectiveness (Nayak et al., 2024).

Additionally, the physicochemical properties of the liposomal membrane, including its charge, rigidity, and lamellarity, significantly influence its interaction with the skin surface and subsequent permeability (Cheng et al., 2022; Martel-Estrada et al., 2022).

Overcoming these limitations requires advancements in formulation techniques, cost-effective manufacturing strategies, and improved stabilization methods. Strategies such as polymer coating, cholesterol incorporation, and hybrid nanosystem development have shown promise in enhancing liposomal stability and prolonging their shelf life (Carita et al., 2018; Ferraris et al., 2021; Patra et al., 2018). Modified liposomal systems, such as ethosomes, transfersomes, and niosomes, have emerged as superior alternatives due to their enhanced flexibility, deeper skin penetration, and higher encapsulation efficiency (Lane, 2013; Santonocito & Puglia, 2025). With ongoing research and development, liposomes are poised to become a cornerstone in regenerative cosmetics, offering consumers high-performance skincare solutions with improved efficacy and safety (Kaul et al., 2018). Advances in nanotechnology continue to drive the evolution of liposomal formulations, incorporating stimuli-responsive vesicles that release active compounds based on pH, temperature, or enzymatic activity (Gupta et al., 2012). These innovations not only extend product longevity but also provide personalized skincare solutions tailored to individual skin needs. As the field progresses, liposome-based formulations will likely dominate the next generation of cosmeceuticals, setting new benchmarks in cosmetic science and dermatological care (Dejeu et al., 2024; Ferraris et al., 2021; Mozafari et al., 2020).

Economic viability, scalability, and regulatory considerations of cosmetic liposome-based products

Economic viability

The economic viability of liposome-based cosmetic products hinges on several key factors, including production costs, consumer demand, market potential, and scalability. The formulation and manufacturing of liposome-based products are inherently more complex than standard cosmetic products, as they require advanced techniques, specialized equipment, and precise control over physicochemical properties to maintain liposomal stability and encapsulation efficiency (Lombardo & Kiselev, 2022; Taouzinet et al., 2023).

One of the major cost drivers is the selection of high-purity phospholipids and stabilizers essential for preventing degradation, oxidation, and leakage of active compounds. Additionally, processing methods such as high-pressure homogenization, microfluidization, and freeze-drying further increase production costs (Cheng et al., 2022; Izadiyan et al., 2025). Despite these challenges, innovations in large-scale liposome production, such as continuous flow microfluidics and spray-drying techniques, have the potential to reduce costs while improving batch-to-batch consistency and scalability (Shah et al., 2020).

Consumer demand is another crucial economic aspect. With increasing awareness of advanced skincare technologies, there is growing interest in products that offer superior efficacy, such as liposome-based formulations (Assali & Zaid et al., 2022; Kaul et al., 2018). The global shift toward science-driven beauty solutions, particularly in the anti-aging, hydration, and dermatological skincare sectors, is expected to drive demand for liposomal skincare products. Additionally, the rise of personalized skincare – where formulations are tailored to individual needs – has further positioned liposome-based products as a preferred choice among consumers willing to invest in innovative solutions (Tran et al., 2022). Liposome-based cosmetics predominantly target the high-end skincare market, offering luxury formulations with clinically backed benefits.

The willingness of consumers to pay a premium for advanced skincare, particularly those that provide visible and long-term results, is a strong indicator of economic viability (Ferraris et al., 2021; Giordani et al., 2023). Furthermore, the clean beauty movement and demand for natural, bioavailable ingredients have created a niche for liposome-based products that utilize plant-derived phospholipids and encapsulated botanical extracts (Cheng et al., 2022). Although high production costs remain a concern, companies can mitigate these expenses through cost-effective formulation strategies, outsourcing specialized liposome manufacturing, and leveraging economies of scale. Strategic partnerships with biotechnology firms and research institutions can also facilitate access to novel liposomal encapsulation methods that enhance cost efficiency (Raszewska-Famielec & Flieger, 2022). Moreover, as production technologies continue to evolve, the cost gap between conventional and liposome-based cosmetic formulations is expected to narrow, making these products more accessible to a broader consumer base (Izadiyan et al., 2025).

Scalability

Scalability is a critical consideration when introducing liposome-based products into the market, as manufacturers must balance quality, cost, and volume.

The production of liposomal products requires specialized techniques, such as thin-film hydration, reverse-phase evaporation, or the hydration method (Dhawan et al., 2020). These methods, while effective, are more labor- and resource-intensive than conventional production processes.

Scaling up without compromising the quality and integrity of the liposomes can be challenging. Sourcing raw materials for liposome production, such as phospholipids and other bioactive ingredients, must be consistent and reliable. While these materials are available globally, fluctuations in their prices or availability could impact production scalability. Developing long-term supplier relationships and ensuring stability in the supply chain is essential for long-term success (Dhawan et al., 2020; Giordani et al., 2023; Patel et al., 2023).

Regulatory considerations

In the European Union, cosmetic products, including liposomal skincare products, are regulated under Regulation (EC) No. 1223/2009, which ensures that products are safe for consumers. Any new cosmetic product must be thoroughly tested for safety and efficacy before being marketed. Liposome formulations, due to their complex structure and the inclusion of active compounds, may require additional clinical testing to demonstrate their safety and efficacy. In addition to cosmetic product safety, individual ingredients must be compliant with EU regulations. Any novel ingredients encapsulated within liposomes must be assessed for safety, and certain ingredients may require approval or safety assessments by the European Medicines Agency (EMA) or other relevant bodies if they are used in therapeutic skin products (Ferraris et al., 2021).

The market for liposome-based regenerative cosmetics

Liposome-based formulations have been widely adopted in the cosmetic industry, enhancing the performance of various products. These formulations can be categorized into key areas of skin care: i) anti-aging and wrinkle reduction; ii) skin hydration and moisturization; iii) skin protection and regeneration; and iv) specialized treatments. Anti-aging and wrinkle reduction formulations assist in smoothing wrinkles, improving skin tone, and enhancing hydration, leading to a youthful appearance. Liposome-based formulations play a crucial role in reducing signs of aging by enhancing the delivery of bioactive compounds. Encapsulated ingredients such as antioxidants, peptides, retinol, and botanical extracts help combat oxidative stress, improve skin elasticity, and promote collagen synthesis. Skin hydration and moisturization focused formulations incorporate essential lipids, ceramides, hyaluronic acid, and botanical extracts to restore the skin's moisture barrier. Liposomal encapsulation improves the penetration of these ingredients, ensuring deeper and longer-lasting hydration. These formulations aid in revitalizing fatigued skin, reversing dullness, and protecting against environmental stressors that contribute to dryness and dehydration.

Liposomes enhance the efficacy of sunscreens, anti-pigmentation, and skin-repair treatments by facilitating the delivery of UV-blocking agents, antioxidants, and regenerative compounds such as vitamins C and E (Huang et al., 2024; Shaw et al., 2022). These formulations help shield the skin from environmental aggressors, reduce the appearance of dark spots, and accelerate skin renewal (Raza et al., 2013). Encapsulated polyphenols, ferulic acid, and plant-derived anthocyanins contribute to strengthening the skin's defense mechanisms while promoting a smooth, even complexion. Advanced liposomal systems are used in targeted treatments such as acne control, oil regulation, and skin nourishment. Active compounds like salicylic acid, tea tree oil, vitamins A and E, and plant-derived saponins are encapsulated for improved efficacy and controlled release (Lohani & Verma, 2017). These formulations help soothe inflammation, and enhance the absorption of nutrients, leading to healthier skin. In Table 1 are summarized the main cosmetic liposomal products available on market. Romania's skin care market is expanding, driven by a growing demand for anti-aging and dermatological products. Liposomal technology, being associated with high-quality, efficient skincare, fits well into the premium segment, which has seen growth in the past few years (De Leeuw et al., 2009; Huang et al., 2024; Shaw et al., 2022). In Romania, liposomal skin care products are likely to be available in high-end cosmetic stores, pharmacies, and online platforms. E-commerce is particularly growing, with more Romanian consumers purchasing beauty products online, often seeking products with a high scientific basis like liposome-based formulations. As Romania follows EU regulations for cosmetics, manufacturers will need to ensure compliance with all necessary safety tests and certification for liposomal skin care products before entering the market.

Table 1. Main cosmetic liposomal products

Cosmetic application	Product name	Manufacturer	Key ingredients
Anti-aging	Capture Totale	Dior	Longoza flower extract, niacinamide, lactiflora Root Extract, *Lilium candidum* Bulb Extract, Jasmine flower extract etc.
Anti-aging	Ageless Facelift Cream	I-Wen Naturals	Coenzyme Q10, tetrahexyldecyl ascorbate, glycan booster peptide, matrix peptide, hydrolyzed oat proteins, cranberry seed oil etc.
Anti-aging	Royal Jelly Lift Concentrate	Jafra Cosmetics	Extracts of winter cherry, lotus flower, sunflower etc.
Anti-aging	Derma Stemness Reviving Serum	Kaya Skin Clinic	Argan plant stem cell extract, hyaluronic acid etc.
Anti-aging	Isocell MAP	Lucas Meyer	Hydrogenated lecithin, magnesium, ascorbyl phosphate etc.
Anti-aging	Daeses Lifting Cream	Sesderma	Silicone, jojoba oil, vitamin e, dimethyl mae, liposomal organic silicon, immediate tensile complex (*Caesalpinia spinosa* fruit extract, *Kappaphycus alvarezii* extract) etc.
Anti-aging	Liposome Concentrate	Russell Organics	Vegetable oils & organic floral water, superoxide dismutase, beta glucan from oats etc.
Anti-aging and skin repair	Liposome Face and Neck Lotion	Clinicians Complex	Sunflower oil, squalane, sodium hylauronate, super oxide dismutase, Vit E etc.
Anti-aging and skin repair	Rovisome ACE Plus	Evonik	Ascorbyl palmitate, lecithin, retinol, tocopherol etc.
	Bio Performance Liposome	Dead Sea Premier	Dead Sea minerals,Vit A & E, Dunaliella seaweed extracts and Aloe vera
Anti-aging and skin repair	Acglicolic Classic Crema Hidratante SPF 15	Sesderma	8% liposomal glycolic acid, Vit C+E, Aloe vera, *Eryngium maritimum* stem cells, hyaluronic acid, milk proteins, bisabolol, ergothioneine, ceramides etc.
Anti-wrinkle and anti-	Rovisome® Q10 NG	Evonik	Coenzyme Q10, Vit A, C and E and *Camellia*

Cosmetic application	Product name	Manufacturer	Key ingredients
oxidant			*sinensis* extract
Anti-aging skin brightening	C-Vit	Sesderma	Vitamin C, extracts of mulberry and hyaluronic acid
Anti-aging, hydration, anti-wrinkle	Ferulac Liposomal Serum	*Sesderma*	Ferulic acid from Apple polyphenol extract
Anti-aging, anti-wrinkle	Resveraderm Antiox Serum	*Sesderma*	Resveratrol, quercetin and EGCG from Red grape extract
Anti-wrinkle	Lumessence EyeCream	AubreyOrganics	*Rosa Mosqueta* seed oil, *Camellia sinensis* leaf oil, evening primrose oil, *Laminaria digitata* extract, rye seed extract etc.
Anti-pigmentation	Azelac Ru Serum	Sesderma	*Bellis perennis* flower extract, pummelos fruit extract, lecithin etc.
Moisturizer	Rehydrating Liposome Day Creme	Kerstin Florian	Vitamin E, shea butter & horse chestnut
Moisturizer	Moisture Liposome: Eye Cream/Face Cream	Decorte	Ginkgo biloba leaf extract, *Lagerstroemia speciosa* leaf extract, oyster extract, Panax ginseng root extract, polyglutamic acid etc.
Skin repair	Advanced Night Repair Protective Recovery Complex	Estee Lauder	Tripeptide-32, hyaluronic acid
Skin repair	Skin rejuvenate cream	*Mythos*	*Punica granatum* (pomegranate) extract
Skin repair	Holistic Age Defense Eye Cream	*Apivita*	Greek royal jelly extract liposomes
Anti-acne and oil control	Clearly It!® Complexion Mist	Kara Vita	Vit A & E, Lecithin, Complex Origanum, Lyphazomes.
Anti-acne	Acnel Lotion N	Dermaviduals	Natural oils and Vit F

CONCLUSIONS

Liposomes have emerged as a transformative technology in regenerative cosmetics, offering enhanced stability, bioavailability, and targeted delivery of active ingredients. Their unique phospholipid bilayer structure mimics biological membranes, enabling deeper penetration of bioactive compounds such as peptides, antioxidants, and vitamins. This capability translates into improved skin repair, collagen synthesis, hydration, and protection against environmental stressors, making liposomes a powerful tool in modern skincare formulations. Despite their numerous benefits, challenges persist in the widespread adoption of liposomal formulations, including high production costs, formulation stability, and regulatory requirements. Advances in nanotechnology, such as ethosomes and deformable liposomes, continue to refine their efficiency, while scalable production methods and strategic collaborations may help mitigate economic barriers. Furthermore, compliance with regulatory frameworks remains essential to ensuring product safety and consumer confidence. As scientific advancements drive the evolution of liposomal formulations, their integration into regenerative cosmetics is expected to expand, setting new benchmarks in skincare innovation. With ongoing research and development, liposomes have the potential to revolutionize the cosmetics industry, offering more effective, long-lasting, and scientifically driven skincare solutions that cater to the growing demand for high-performance beauty products.

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