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**Review Article**

# Comprehensive Study of Liposome

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## ABSTRACT

Liposomes are spherical vesicular drug delivery systems made up of an aqueous core surrounded by one or more phospholipid bilayers. They can improve the solubility, stability, and bioavailability of therapeutic agents by encasing both hydrophilic and lipophilic drugs. The structure, classification, preparation techniques, and drug delivery mechanism of liposomes are all thoroughly examined in this short project. Their role in controlled, targeted, and less toxic drug delivery is highlighted. The clinical significance of liposomes is demonstrated by their use in vaccines, anticancer therapy, and innovative drug delivery methods. All things considered, liposomes are a flexible and efficient carrier system in contemporary pharmaceutical research and development.

## INTRODUCTION

Liposomes are lipid-soluble vesicles that are mostly composed of phospholipids and are created when amphipathic molecules self-assemble into a spheric bilayer. Phospholipids consist of two hydrocarbon chains and a hydrophilic head that form a membrane, with the hydrocarbon chains facing the hydrophobic interior and the hydrophilic head groups facing the external aqueous environment [1]. In watery media, polar heads of the lipids stabilize a uniform structure. These vesicles encapsulate any additional hydrophobic or hydrophilic molecules that are present throughout the self-assembly process. depicts the structure of a typical liposome containing a charged active ingredient. There are various kinds of drug- carrying liposomes with various starting ingredients and drug delivery methods in addition to the main characteristics mentioned [2,3]. Three methods can be used to encapsulate drugs: hydrophilic drugs are encapsulated in liposomes in aqueous solutions, whereas lipophilic drugs are entrapped between lipid bilayers and passively loaded. Active loading is demonstrated by loading through the pH gradient and the difference in electrical potential [4,5]. Drug entrapment occurs during the stages of liposome synthesis and assembly in the passive-loading process. Using transmembrane chemical gradients to entrap amphipathic chemicals from aqueous media into premade liposomes, the

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active-loading procedure is an alternative drug encapsulation technique that typically depends on a concentration gradient . The size and quantity of medication injected into liposomes can be influenced by the liposome production techniques. Liposomes are generally classified according to their structure (lamellarity and particle size), composition (phospholipids and cholesterol), application (conventional, charged, stealth stable, actively targeted, stimulatory, and bubble liposomes), and preparation techniques (classical, mechanical, drying-based, and advanced) [6,7]. Liposomes are categorized as unilamellar vesicles (ULVs), oligolamellar vesicles (OLVs), multilamellar vesicles (MLVs), and multivesicular liposomes (MVLs) based on compartment structure and lamellarity, and as small unilamellar vesicles (SUVs), large unilamellar vesicles (LUVs), and giant unilamellar vesicles (GUVs) based on particle size.

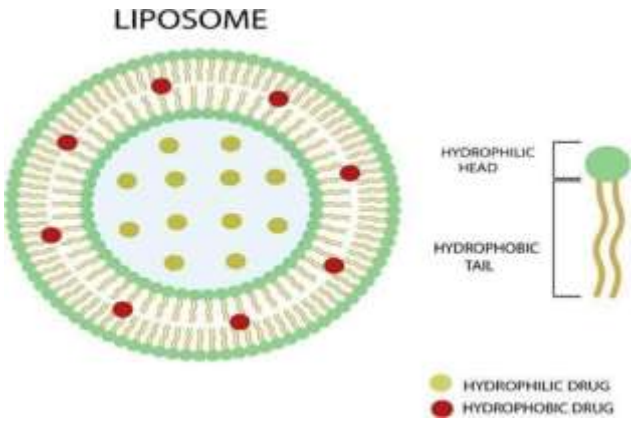


**Fig 1 – Liposome structure**

Liposomes can be produced using a variety of techniques. Thin-film hydration is arguably the most popular technique. In this process, the drug and lipid components of the liposomes are combined in an organic solvent, which is gradually eliminated by rotating evaporation. The components are rehydrated in an aqueous medium at a temperature higher than the lipids' phase transition temperature once a dried thin layer has developed atop the flask. Although liposomes are now created, their size and lamellarity can be further homogenized using additional processing methods such freeze-thaw cycles, sonication, or extrusion [8] . In REV, the drugcontaining aqueous phase is added after the lipid components are combined in an organic solvent to create a water-in-oil emulsion [10]. The therapeutic liposomes are present in the leftover aqueous solution after the organic phase is eliminated by rotary evaporation. Once more, the size might be homogenized through additional processing. Although the two main techniques for liposome preparation are thin-film hydration and REV, a number of nontraditional procedures are also employed. In microfluidics, dissolved lipids flow laminarly into a flowing aqueous phase, causing the liposome to self-assemble. A desired size distribution can be attained by adjusting the flow rates of each phase [11]. Although it is wonderful that there is no need for additional homogenization, the procedure is sadly not scalable. The supercritical anti-solvent (SAS) approach is another non-traditional preparation technique. A drugcontaining aqueous phase hydrates lipids dissolved in a supercritical fluid, often carbon dioxide. Liposomes will form with remarkably high encapsulation efficiencies when the pressure is lowered [10]. Unfortunately, this method's exorbitant cost prevents it from gaining traction. While there are other preparation techniques, like the heating method [12]. and the freeze-drying method [13]. none are as popular as thin-film hydration or REV.

The characteristics of liposomes can also be influenced by a number of formulation elements in addition to the preparation technique. For instance, adding cholesterol to the lipid membrane at ratios of 30 to 50% can enhance membrane ordering and give the nanoparticle more stability [14,15]

Additionally, it has been demonstrated that adding cholesterol to the membrane increases cellular absorption [16]. In addition to cholesterol, the hydration medium used to house liposomes is crucial. Liposomes are usually stored in aqueous solutions such water, phosphate-buffered saline, or 5–10% sugar solutions. The composition and application of the liposomal mixture will typically determine the hydration medium. For instance, when hydrated in solutions with low ionic strength, liposomes made of strongly charged phospholipids may form a viscous gel [17]. As a result, the hydration medium should include a larger concentration of salts. The use of surfactants is a third formulation issue to take into account. A smaller liposome size has been found to be correlated with higher surfactant concentrations during formulation [18]. Reduced vesicle aggregation, which is essential for efficient nanoparticle storage, could be the cause of this. For the delivery of drugs, liposomes offer numerous benefits. They are compatible with both hydrophilic and hydrophobic medications due to their amphiphilic nature (Figure 1) [19]. Higher dosages of the medication can be given without sacrificing safety due to their low toxicity [20, 21]. As a matter of fact, liposomes are among the least hazardous nanoparticles that can be used in clinical settings [22]. Extended-release dose formulations are possible due to their longer half-life compared to the free medication [23,24]. Because of all these benefits, liposomes are a worthwhile investment during drug development to prevent in vivo failures in subsequent clinical trials.[25]

## CLASSIFICATION OF LIPOSOME(23)

Liposomes are classified on the basis of:

- Structure.
- Method of preparation.
- Composition and application.
- Conventional liposome.
- Specialty liposome

### 1. Classification Based on Structure (Table 1)

**Table-1. Vesicle Types with their Size and Number of Lipid Layers**

| Vesicle Type | Abbreviation | Diameter Size | No of Lipid Bilayer |
|---|---|---|---|
| Unilamellar vesicle | UV | All size range | One |
| Small Unilamellar vesicle | SUV | 20-100 nm | One |
| Medium Unilamellar vesicle | MUV | More than 100nm | One |
| Large Unilamellar vesicle | LUV | More than 100nm | One |
| Giant Unilamellar vesicle | GUV | More than 1 micro meter | One |
| Oligolamellar vesicle | OLV | 0.1-1 micro meter | Approx. 5 |
| Multilamellar vesicle | MLV | More than 0.5 | 5-25 |
| Multi vesicular vesicle | MV | More than 1 micro meter | Multi compartmental structure |

**Table-2. Different Preparation Methods and the Vesicles Formed by these Methods**

| Preparation Method | Vesicle Type |
|---|---|
| Single or oligo lamellar vesicle made by reverse phase evaporation method | REV |
| Multi lamellar vesicle made by reverse phase evaporation method | MLV-REV |
| Stable pluri lamellar vesicle | SPLV |
| Frozen and thawed multi lamellar vesicle | FATMLV |
| Vesicle prepared by extrusion technique | VET |
| Dehydration- Rehydration method | DR V |

### 3. Based on Composition and Application (Table 3)

**Table-3. Different Liposome with their Compositions**

| Type of Liposome | Abbreviation | Composition |
|---|---|---|
| Conventional liposome | CL | Neutral or negatively charge phospholipids and cholesterol |
| Fusogenic liposome | RSVE | Reconstituted sendai virus envelops |
| PH sensitive liposomes | - | Phospholipids such as PER or DOPE with either CHEMS or OA |
| Cationic liposome | - | Cationic lipid with DOPE |

## EVALUATION PARAMETER FOR LIPOSOME

- Particle size & size distribution – by DLS, microscopy
- Zeta potential – indicates surface charge and stability
- Morphology / shape – TEM, SEM, optical microscopy
- Entrapment efficiency (%EE) – amount of drug entrapped Drug loading capacity
- In-vitro drug release study
- Stability studies – physical and chemical stability
- pH of formulation
- Lamellarity (uni-/multilamellar vesicles)

## POLYMER USED IN LIPOSOME FORMULATION

- Chitosan – improves mucoadhesion and stability
- Polyethylene glycol (PEG) – increases circulation time (stealth liposomes)
- Polyvinyl alcohol (PVA) – stabilizer and coating polymer Carbopol (Carbomer) – used in topical liposomal gels
- Alginate – controlled release and coating polymer Gelatin – biocompatible stabilizer
- Dextran – surface modification and stabilization
- PLGA – used in hybrid liposome–polymer systems
- Cellulose derivatives (HPMC, CMC) – viscosity enhancer, topical formulations

**TABLE: -1 METHOD AND LIPOSOME**

| SN. | LIPOSOME | METHOD | TYPES OF LIPOSOMES |
|---|---|---|---|
| 1) | Doxil | Remote loading | PEGylated liposome |
| 2) | DaunoXome | Thin Film Hydration + Extrusion | Small unilamellar liposome |
| 3) | AmBisome | Sequential detergent removal method | Small unilamellar liposome |
| 4) | Arikayce | Spray-drying + thin film hydration + extrusion | Inhalable liposome |
| 5) | Visudyne | Thin Film Hydration + Sonication | Liposomal injection |

## WRINKLES

## INTRODUCTION

Clinical signs of skin aging include wrinkles, dermal atrophy, and decreased elasticity due to a variety of molecular processes triggered by both intrinsic and extrinsic sources, which result in degenerative changes and a reduction in the quantity of functional components of the skin [23, 24] . Despite the fact that skin aging is a normal process brought on by the body's chronological aging, photoaging caused by UV radiation is shown to be the most significant extrinsic factor that speeds up the process due to the impacts of the produced reactive oxygen species [25–27]. The retinoid family includes both manufactured and naturally occurring retinol (vitamin A) analogs. The promotion of keratinocyte proliferation and

collagen synthesis, enhancement of the epidermal barrier, inhibition of collagen degradation, transdermal water loss (TEWL), and metalloproteinase activity are the basis for the anti-wrinkle effects of topically applied formulations containing retinoids [28, 29]. Retinoic acid (RARa, -b, -c) and retinoid-X receptors (RXR-a, -b, -c) are how retinoids work [23].Retinoids are divided into four generations based on their chemical structure and receptor specificity, as seen in Table Following topical administration, retinyl esters are hydrolyzed to retinol, which is then transformed into physiologically active retinoic acid (tretinoin) via retinaldehyde by dehydrogenases in a twostep oxidation process [30, 31]. The first-generation representatives' retinoid activity rises in the following sequence based on their metabolic pathway: retinyl esters, retinol, retinaldehyde, and retinoic acid, however the tolerance ordering is reversed: retinoic acid (Fig. 1) [31]. retinyl esters [retinol = retinaldehyde]. Consequently, while other retinoids are active substances in their particular form, retinol, retinaldehyde, and retinol esters must be transformed into the physiologically active form of retinoin when administered topically [32]. Retinol, retinaldehyde, or retinyl esters are typically found in commercial cosmetics (cosmeceuticals). Cosmeceuticals are a subset of topical prescription medications and cosmetic products that contain active chemicals that are said to have "drug-like" effects on the structure and function of the skin [33].

## LITERATURE REVIEW

Peruš M et.al, (2025) the scientists systematically analyzed and summarized existing research on liposome-based nanoparticle drug delivery systems. They reviewed conventional and advanced liposome production methods, including thin film hydration, reverse phase evaporation, solvent injection and microfluidic techniques, and compared their advantages and limitations in terms of encapsulation efficiency, stability and in vivo performance. The authors collected and categorized a wide range of active pharmaceutical ingredients that have been successfully encapsulated in liposomes, such as anticancer drugs, antibiotics, NSAIDs, vaccines, diagnostic agents and gene therapy vectors. They also evaluated challenges associated with liposome degradation, opsonization and rapid clearance, and discussed formulation modifications developed to overcome these limitations. Furthermore, the review examined recent technological advancements, including artificial intelligence, microfluidics and 3D printing, highlighting their role in improving liposome design, scalability and personalized drug delivery. Overall, the scientists integrated experimental and technological findings to assess the current status and future potential of liposome-based drug delivery systems in medicine .[39]

Rahim M .Abdul et.al, (2025) Scientists working on liposomal encapsulation in food systems focus on understanding how liposomes can be designed and processed to safely protect and deliver sensitive food ingredients. They study the structure of liposomes, such as unilamellar and multilamellar vesicles, to determine how much and how efficiently bioactive compounds can be encapsulated. Researchers analyze the effect of lipid composition, including the type of phospholipids, degree of fatty acid saturation, and the presence of sterols like cholesterol, to control membrane rigidity, flexibility, and permeability. They also investigate thermodynamic factors, especially temperature-induced phase transitions, to understand how heating, cooling, and storage conditions influence liposome stability. In addition, scientists evaluate rheological and mechanical properties such as viscosity and

viscoelastic behavior to predict how liposomes behave during food processing. Various processing techniques, including spray-drying, freezedrying, and fluidized bed coating, are optimized to convert liposomes into stable, food-grade powders, often using cryoprotectants like trehalose to prevent vesicle fusion and leakage. Researchers further study enzyme encapsulation to preserve enzymatic activity in applications such as cheese making and fermentation. Finally, they assess liposome performance in real food matrices and identify challenges related to scalability, long-term stability, cost, and regulatory approval, guiding future research and industrial application.[40]

IzadiyanZahra et.al,(2025),Scientists in the field of liposomal nanomedicine focus on developing advanced drug delivery systems to treat diseases such as cancer, infectious diseases, and other medical conditions. They study the composition and structure of liposomes to optimize drug loading, stability, and targeted delivery to specific cells or tissues. Researchers design targeted and "smart" liposomes that can respond to environmental triggers like pH, temperature, or enzymes, enabling controlled and precise drug release. A major focus is on enhancing biodistribution while minimizing rapid clearance, organ toxicity, and side effects. Scientists also integrate immunotherapeutic agents into liposomes to create platforms that can modulate immune responses, effectively combining therapy and diagnostics (theranostics).

Recent work has accelerated due to applications in COVID-19 vaccines and antiviral therapies, highlighting the need for efficient and safe delivery mechanisms. Additionally, researchers are increasingly using artificial intelligence and machine learning to optimize liposome design, predict therapeutic outcomes, and advance personalized medicine. Overall, scientists aim to improve treatment precision, efficacy, and safety through innovative liposomal formulations, bridging nanotechnology, immunology, and clinical medicine for better patient outcomes.[41]

PateL.D Tarika et.al, (2025) Scientists conducted a scoping review of the literature to evaluate the safety and efficacy of liposomal bupivacaine (LB) in paediatric postoperative pain management. They searched three electronic databases and selected 26 studies involving 1,496 pediatric patients, including 2 randomized controlled trials, 15 retrospective cohort studies, and 9 case series/reports. They extracted data on postoperative pain, opioid use, adverse events, length of hospital stay, and hospital costs. The scientists analysed trends across different surgery types and administration methods, assessed the incidence of adverse events such as local anesthetic systemic toxicity, and evaluated potential biases in the studies. Their work highlighted the limitations in current research and identified the need for high- quality, independent studies to establish LB's clinical effectiveness in children.[42]

Hamad Islam et.al, (2024) This study provides a comprehensive bibliometric analysis of research on liposome-based drug delivery systems in cancer therapy over the past 20 years. Using data from the Scopus database and analytical tools such as VOSviewer and Biblioshiny, the scientists analyzed 14,873 peer-reviewed publications to identify research trends, key themes, and hotspots. The findings show that liposomes are widely used to enhance targeted drug delivery, improve bioavailability, and reduce toxicity of anticancer drugs. Major research areas include nanomedicine, chemotherapy strategies, pharmacokinetics, gene delivery, and cytotoxicity studies. Overall, the study highlights the growing importance of

liposomes in oncology and emphasizes the need for continued research, collaboration, and clinical translation to improve cancer treatment outcomes.[43]

Agrawal S.Surenda et.al,(2024) The scientists reviewed and analyzed recent advances in liposome-based drug delivery systems to overcome the limitations of conventional liposomes. They developed and evaluated new lipid compositions to improve drug loading and stability, and applied surface modification techniques such as PEGylation and ligand conjugation to achieve targeted delivery. Researchers designed stimuli-responsive liposomes that release drugs in response to pH, temperature, magnetic fields, or ultrasound for controlled and ondemand drug release. They also explored multifunctional liposomes, including prodrug- and RNA-loaded systems, and assessed their performance through preclinical and clinical studies across cancer, infectious, neurological, and inflammatory diseases. Finally, the scientists identified key challenges in scalability, manufacturing, regulation, and long-term safety, highlighting areas for future research and clinical translation.[44]

Wang Shile et.al, (2023) The scientists reviewed and analyzed advances in liposome-based nanocarriers used for drug delivery, with a particular focus on cancer therapy. They examined the composition, types, and preparation methods of liposomes and evaluated how different lipid components and surface modifications influence drug delivery performance. The researchers studied various functionalized liposomes, including PEGylated, ligand- targeted, stimuliresponsive, and cell membrane–coated systems, to understand their targeting mechanisms and drug release behavior at tumor sites. They also assessed current tumor- targeting strategies under clinical evaluation, highlighted the evolution of liposomes into multifunctional nanocarriers, and identified key challenges, especially related to physical and chemical stability, that must be addressed to improve clinical translation[45]

Aloss Kenan et.al,(2023) The scientists systematically reviewed and evaluated advanced liposomal formulations of doxorubicin (DOX) to improve tumor targeting while preserving the safety advantages of existing liposomal products. Their work focused on understanding why FDA-approved liposomal DOX formulations (Doxil and Myocet) improve safety but fail to show superior clinical efficacy, and on identifying strategies to overcome this limitation.First, they analyzed functionalized (targeted) PEGylated liposomal DOX (PLD) systems. The scientists assessed liposomes modified with antibodies, peptides, aptamers, carbohydrates, and cell-penetrating enhancers (CPEs) to enhance tumor-specific delivery. They evaluated how ligand type, size, and surface density influence tumor penetration, circulation time, and clearance. Antibody-conjugated liposomes such as MM-302 and C225-IL-DOX were reviewed for their progression into clinical trials, while also noting limitations related to antibody size and rapid clearance.[46]

Pasarin Diana et.al,(2023) The scientists reviewed and analyzed liposome stability and surface-modification strategies used across the pharmaceutical, food, and cosmetic fields. Their main objective was to understand why liposomes show low stability at the industrial level and how this limitation can be overcome to ensure effective delivery of encapsulated compounds.First, they examined how liposomes are used to encapsulate, protect, and release sensitive compounds, focusing on different routes of administration such as parenteral, oral, and transdermal delivery. They evaluated how liposomal encapsulation helps

preserve compound properties, extend shelf life, and maintain functional benefits.[47]

Abbasi Haneich et.al,(2023) Scientists in the field of liposome research focus on designing and optimizing liposomal formulations to improve their stability, drug-loading capacity, and therapeutic efficacy. They systematically explore different lipid compositions, cholesterol ratios, and surface modifications to control membrane rigidity, permeability, and circulation time in biological fluids. Various preparation methods, including thin-film hydration, ethanol injection, microfluidics, and supercritical fluid (SCF) techniques, are investigated to achieve liposomes with precise size, lamellarity, and reproducibility, while also enabling scalable production for clinical applications. Researchers study both passive and active drug-loading strategies to maximize encapsulation efficiency and minimize premature drug release. Surface functionalization, such as PEGylation and ligand attachment, is employed to reduce rapid clearance by the reticuloendothelial system and to enhance targeted delivery to specific tissues or disease sites. Additionally, stimuli-responsive liposomes that release drugs in response to pH, temperature, enzymes, or external triggers are developed to achieve controlled and sitespecific drug release. Scientists also evaluate the biological performance of liposomes through in vitro and in vivo studies, examining parameters such as cellular uptake, cytotoxicity, pharmacokinetics, biodistribution, and therapeutic outcomes.[48]

Quan Taihao et.al,(2023) Scientists examined age-related structural and molecular changes in human skin by analyzing alterations in both the epidermis and dermis associated with aging. They investigated the decline in epidermal stem cell populations and the reduction of collagen content to understand their roles in skin atrophy and functional impairment. Researchers explored how these age-induced changes disrupt skin architecture, compromise barrier function, delay wound healing, and increase susceptibility to skin cancer. Additionally, scientists reviewed recent molecular discoveries underlying skin aging pathways and evaluated preventive strategies, with a particular focus on topical retinoids. Through experimental and clinical studies, they assessed the effects of retinoids on skin texture, wrinkle formation, and epidermal and dermal thickness, highlighting their potential to counteract aging-related skin deterioration.[49]

Tseu Wei yi Gloria et.al,(2022) The scientists reviewed and analyzed non-viral liposomal gene delivery systems as safer alternatives to chemotherapy and viral vectors for breast cancer gene therapy. Recognizing the severe physical and psychological side effects of chemotherapy and the immunogenic risks associated with viral vectors, they focused on liposomes as lipidbased nanoparticle carriers for therapeutic genes.They systematically compared cationic, anionic, and neutral liposomes based on key parameters relevant to gene therapy, including stability, cytotoxicity, nucleic acid encapsulation capacity, cellular uptake, and transfection efficiency. The scientists evaluated how surface charge influences electrostatic interactions with negatively charged nucleic acids and cancer cell membranes, which directly affects intracellular delivery.Their analysis showed that cationic liposomes are the most promising carriers for breast cancer gene therapy due to their strong electrostatic binding with nucleic acids, enhanced cellular uptake, and higher transfection efficiency. They also assessed the limitations of anionic and neutral liposomes, noting that these systems often require additional complex modifications—such as polymers, ligands, or targeting moieties—to achieve comparable gene delivery performance[50].

Nikolova P. Maria et.al,(2022) The scientists carried out a detailed review of recent advances in smart, stimuli-responsive liposomal drug delivery systems for cancer therapy, focusing on how modern nanotechnology has improved the performance of liposomes compared with conventional formulations and free anticancer drugs. They examined the fundamental advantages of liposomes, including their non-toxic nature, biocompatibility, biodegradability, and ability to simultaneously encapsulate both hydrophilic and hydrophobic drugs, which makes them highly suitable for anticancer drug delivery. The review analysed how emerging liposomal technologies have led to higher drug loading capacity, improved protection of encapsulated drugs, enhanced bioavailability, and better intracellular delivery, resulting in superior therapeutic outcomes and reduced systemic toxicity. Furthermore, the scientists evaluated the development of stimuli-responsive ("smart") liposomes, which are engineered to release their drug payload in response to specific endogenous stimuli (such as pH changes, enzymes, or redox conditions in tumor tissues) or exogenous stimuli (such as temperature, light, or magnetic fields). They discussed how deliberate changes in the physicochemical and morphological properties of liposomes enable controlled and site-specific drug release, improving drug accumulation in tumors while sparing healthy tissues. The review also emphasized that while ligand-mediated targeting alone is often insufficient for complete tumor eradication, combining targeting ligands with stimuli-responsive mechanisms greatly enhances localized drug release and therapeutic efficacy[51].

Sriwidodo et.al,(2022) The scientists conducted a comprehensive review of polymer– liposome complexes to address the major limitations of conventional liposomes, particularly their rapid biodegradation and clearance, which restrict their effectiveness in oral and systemic drug delivery. They analyzed how complexation of liposomes with natural and synthetic polymers improves stability against pH variations, chemical degradation, enzymatic attack, and immune system recognition. The review systematically examined different modes of polymer– liposome interaction, including polymer adsorption on the liposome surface, polymer incorporation into lipid bilayers, and polymer encapsulation within liposomes, along with the types of bonds and crosslinking mechanisms involved. The scientists evaluated how these parameters—such as polymer type, interaction strength, bonding nature, and formulation conditions—affect key properties like liposome stability, controlled drug release, targeting ability, and pharmacokinetic behavior. They also reviewed evaluation methods and analytical techniques used to characterize liposome complexes and assess their performance in drug and vaccine delivery. By comparing findings across multiple studies, the scientists concluded that polymer-modified liposome complexes represent an optimal and versatile delivery system, capable of enhancing targeted delivery, regulating drug release, and stabilizing sensitive drugs and vaccines, while emphasizing the importance of rational polymer selection and interaction design for developing effective liposomal delivery platforms[52].

Liu Peng et.al,(2022) , scientists systematically analyzed liposomal drug products approved by the FDA and EMA by examining publicly available regulatory documents, including FDA approval packages and EMA European Public Assessment Reports (EPARs). They evaluated the formulation composition, particularly the selection of lipid excipients, and critically assessed established manufacturing processes such as vesicle formation methods, nanosizing techniques, and drug-loading

approaches. The researchers also identified and discussed critical quality attributes (CQAs) essential for ensuring product safety, efficacy, and consistency. Furthermore, they reviewed existing regulatory frameworks governing liposomal products and highlighted future challenges and opportunities in liposome development. Overall, the study bridges regulatory science and pharmaceutical technology, offering practical insights for the development of liposomal drug candidates from laboratory research to industrial-scale production.[53]

Lew De Vincenzo et.al,(2021) Scientists investigated liposomes as biomimetic nanocarriers for drug and bioactive molecule delivery, focusing on their structural versatility for topical and systemic applications. They evaluated the limitations of first-generation phospholipid vesicles, including physical instability, short circulation time, limited drug loading, uncontrolled release, and poor targeting efficiency. To overcome these challenges, researchers explored the integration of natural and synthetic polymers into liposomal systems. They synthesized polymers with controlled molecular weights and tunable physicochemical properties and examined their use as surface coatings, bilayer-intercalating agents, or components of hybrid polymer–liposome structures. Scientists also studied advanced liposomal architectures, including second- and third-generation vesicles, to improve stability, payload capacity, stimulus responsiveness, and active targeting capabilities. Additionally, they assessed strategies in which liposomes are embedded within polymeric matrices to act as drug reservoirs or stimuli-responsive delivery systems. Through a comprehensive review of recent literature, researchers highlighted advances in polymer synthesis, supramolecular organization, and manufacturing techniques to expand the functional potential of polymer– liposome assemblies in drug delivery.[54]

Cipollaro Lucio et.al,(2020) scientists are responsible for designing, developing, and evaluating liposomal drug delivery systems intended for orthopedic applications. They select appropriate phospholipids and active pharmaceutical ingredients, optimize formulation parameters, and apply conventional or advanced production techniques—such as high- pressure homogenization and SuperLip technology—to obtain nanometric, stable liposomes. Scientists systematically characterize these vesicles by assessing particle size, lamellarity, surface charge, encapsulation efficiency, and drug release kinetics. They also investigate the biological performance of liposomes through in vitro and in vivo studies, focusing on anti- inflammatory efficacy, biocompatibility, pharmacokinetics, and toxicity reduction. In addition, researchers critically analyze existing literature using standardized methodologies such as PRISMA guidelines to compare production techniques, identify limitations of traditional methods, and evaluate clinical relevance, cost-effectiveness, and translational potential. Through these activities, scientists aim to improve therapeutic outcomes in orthopedic conditions such as osteoarthritis by developing safer, more efficient, and controlled drug delivery[55].

Drescher Simon et.al,(2020) Scientists working in phospholipid-based drug delivery research investigate how phospholipids can be used to design safe, effective, and versatile drug delivery systems. They begin by studying the physicochemical properties of phospholipids, such as amphiphilicity, phase behavior, and self-assembly, to understand how these molecules form structures like liposomes, mixed micelles, emulsions, and extrudates. Based on this

knowledge, scientists formulate drug carriers tailored for different routes of administration, including parenteral, oral, and topical delivery.Researchers optimize formulation parameters such as lipid composition, drug loading, particle size, stability, and release profiles to improve bioavailability and therapeutic efficacy while minimizing toxicity. They apply both conventional and advanced production techniques and systematically characterize the resulting systems using analytical and biological methods. Scientists also conduct in vitro and in vivo studies to evaluate safety, pharmacokinetics, and clinical performance.[56]

Almeida Bethany et.al,(2020) scientists focus on designing and optimizing liposome systems to improve drug loading, targeting, and therapeutic efficacy. They investigate the physicochemical properties and biocompatibility of liposomes and develop bioconjugation strategies—such as surface modification with ligands, antibodies, peptides, or polymers—to enhance selective delivery to diseased tissues while minimizing off-target effects. Researchers systematically study methods for incorporating small molecules, biologics, and nucleic acids into liposomes and evaluate how these modifications influence stability, circulation time, cellular uptake, and drug release. Scientists also assess the performance of bioconjugated liposomes through in vitro and in vivo models, examining pharmacokinetics, biodistribution, safety, and therapeutic outcomes[57].

## RATIONALE OF RESEARCH

- Many drugs have poor solubility and low bioavailability in conventional dosage forms.
- Many drugs have poor solubility and low bioavailability in conventional dosage forms.
- Liposomal systems improve drug stability and protect drugs from degradation.
- Liposomes reduce toxicity by controlled and targeted drug delivery.
- Sustained release from liposomes improves therapeutic efficacy and patient compliance.
- Liposomes enhance bioavailability and prolong drug circulation time.
- Liposomes have wide applications in cancer therapy, vaccines, gene delivery, and diagnostics.
- Challenges such as stability and large-scale production still exist.
- comprehensive study of liposomes is necessary for effective pharmaceutical development.
- Useful in cancer therapy, vaccines, gene delivery, and diagnostics

## AIM AND OBJECTIVE

**Aim**- To study the comprehensive study of liposome

### Objectives

- To carry out benefits liposome in different diseas
- To execute positive effect of liposome in skin diseas
- To conduct the importance of liposome in pharmaceutical field

## DRUG PROFILE:- RETINOL

Generic name: Retinol Chemical name: All trans retinol

Category: vitamin A derivative(retinoid)

Therapeutic class: anti- Aging agent, keratolytic anti-acne agent

## CHEMICAL INFORMATION

Molecular Formula: C20 H30 O Molecular weight :286.45g/mol

**TABLE: -API AND EXICIPIENT IN QUANTITY**

| INGREDIENT | QUANTITY | FUNCTION |
|---|---|---|
| RETINOL | 50mg | Anti aging |
| CETYL ALCOHAL | 200mg | Emollient, stieffining agent |
| STERIC ACID | 500mg | Emulsifier |
| Isopropyl myristate | 300mg | Penetration enhancer |
| Liquid paraffin | 500mg | Emollient |
| Glycerin | 500mg | Humectant |
| Methyl parabean | 20mg | Presevatives |
| BHT | 5mg | Anti oxidant |
| PURIFIED WATER | 7ml | Vehicles |
| POLYSORBATE 60 | 100mg | Emulsifying agent |

## METHODOLOGY

## THIN FILM HYDRATION METHOD

By evaporating a solvent from a lipid solution, this traditional approach creates a thin lipid film, which is subsequently hydrated with an aqueous buffer to produce multilamellar vesicles . This approach is straightforward and frequently used, suited for a broad range of lipids. However, it often yields multilamellar liposomes with limited encapsulation efficiency for hydrophilic medicines and requires further size reduction procedures (such as extrusion or sonication) to make small unilamellar vesicles. The thin film approach is not easily scalable, as ensuring uniform hydration and effective mixing at high volumes is problematic, contributing to batch variability and very low throughput [60].

## REVERSE PHASE EVAPORATION

REV includes emulsifying an aqueous phase in a lipid-containing organic phase to make a water-in-oil emulsion, then withdrawing the solvent under decreased pressure to form a gel like phase that yields enormous unilamellar vesicles upon hydration [67]. Because the interior aqueous phase is initially effectively preserved, this approach provides excellent encapsulation efficiencies, especially for hydrophilic pharmaceuticals. huge macromolecules can be successfully encapsulated using the REV approach, but it requires huge amounts of organic solvents and a more complicated process (emulsion generation and solvent removal) that can be challenging to scale and repeat reliably. Scalability and regulatory issues are also brought up by residual solvent and the requirement for intensive post-processing.

Each preparation process has unique advantages and limits. The quality of the liposomes generated and simplicity of use are frequently balanced when choosing a procedure at the laboratory scale. Comparative studies have shown, for example, that thin film hydration tends to produce larger, multilamellar liposomes requiring downstream size reduction, whereas solvent injection methods like ethanol injection yield smaller vesicles with a narrower size distribution under optimized conditions [10]. Such discrepancies in initial vesicle features can influence the subsequent scale-up approach and end product attributes. While new techniques (such as microfluidic hydrodynamic focusing and freeze-drying/rehydration procedures) are constantly being created at the lab scale as research progresses, the aforementioned three remain fundamental to laboratory practice[61].

## ETHANOL ENJECTION METHOD

This technique involves quickly injecting an ethanolic lipid solution into an aqueous phase, which causes the solvent to disperse and spontaneously form liposomes [67].Small unilamellar vesicles can be directly produced by ethanol injection, which is a somewhat quick and repeatable procedure. Because it may be modified

for continuous processes (e.g., utilizing microfluidic mixers or in-line solvent injection equipment), this approach is more scalable than simple hydration. However, ethanol injection frequently delivers inferior encapsulation effectiveness for hydrophilic chemicals compared to thin film hydration, and an extra solvent removal step (to eliminate leftover ethanol) is necessary. In an industrial setting, microfluidic based production techniques that enable exact control over mixing have implemented solvent injection principles, producing liposome populations with restricted size distributions.[62]

## HOMOGENIZERS AND EXTRUCTION

High-pressure homogenizers break up multilamellar liposomes into smaller vesicles by forcing lipid solutions through tight valves at pressures frequently more than 100 MPa. This method (e.g., Microfluidizer®) is frequently utilized in industrial production due to its scalability and consistency. Membrane extruders, on the other hand, push liposome dispersions through polycarbonate membranes of preset pore diameters. While industrial extruders use enormous filter cartridges and pumps to process tens of liters, lab-scale extruders (handheld or bench-top machines) usually handle a few milliliters to liters. Both techniques can be repeated to achieve the desired size and necessitate temperature control (extrusion is frequently carried out at 50– 60 °C for lipid membranes)[61]

## MICROFLUIDIC MIXING DEVICE

For the generation of liposomes, microfluidic mixers such T-junction microfluidic chips and staggered herringbone have become more popular. In these devices, streams of lipid-insolvent and aqueous buffer meet in microchannels, and the fast mixing leads to nucleation of liposomes. Because of their small size, liposome populations are homogeneous due to the quick and even mixing. To increase throughput on an industrial scale, numbering-up techniques (many chips or parallel channels) are employed. These gadgets show how precise engineering at a small scale can be applied to big scale manufacturing by parallelization.

## FREEZE DRYER

To address stability difficulties, liposomal formulations are frequently freeze-dried with cryoprotectants (e.g., sucrose or trehalose) to make a dry product that is reconstituted before use. Industrial lyophilizers with shelf volumes capable of processing large batch vials are deployed for approved items (for example, AmBisome® is supplied as a lyophilized powder). To prevent liposome structure damage and to guarantee that the cryoprotectant sufficiently maintains liposome integrity throughout drying, the freezing and drying cycles must be carefully optimized.[62]

## CONCLUSION

liposomes can encapsulate both hydrophilic and lipophilic drugs, they have become a significant and adaptable drug delivery system. Through targeted and controlled drug release, they increase therapeutic efficacy, decrease toxicity, and improve drug bioavailability. Designing liposomes with the appropriate size, composition, and release characteristics is made possible by a variety of preparation techniques. In clinical applications like gene delivery, vaccines, and anticancer therapy, liposomal formulations have demonstrated notable success. Many limitations have been addressed by recent technological advancements, despite difficulties with stability and large-scale production. All things considered, liposomes are still essential to the development of innovative and efficient pharmaceutical drug delivery systems.

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