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Nano Micelles: The Tiny Titans of Targeted Therapy

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Abstract: Nanomicelles is the class of nanoparticle-based drug delivery systems that have shown considerable promise, especially for hydrophobic drugs and may be able to defeat the restrictions of traditional drug delivery methods. Nanomicelles are usually 10 to 100 nm in size and made of amphiphilic molecules that self-assemble into a core shell structure. This permits lipophilic drugs to be enclosed inside the hydrophobic core, while the hydrophilic shell assurances stability and solubility in aqueous mediums. Progress in materials science and nanotechnology have led to a significant evolution of the notion of nanomicelles, which first appeared in surfactant research. Recent developments have focused on improving stability, increasing drug loading capacity, and targeting drug delivery through surface modifications. Among the many advantages that nanomicelles offer are improved solubility, regulated release, and the ability to cross biological barriers, such as the blood-brain barrier. Their versatility enables a wide range of applications, such as the treatment of neurological disorders, cancer, and gene delivery.

Keywords: nanomicelles, targeted drug delivery, nanotechnology, recent innovations, disease treatment, patents.

Introduction:

Nanomicelles are nanosized self-assembling colloidal dispersion with hydrophobic shell and hydrophobic core [1]. In the process of targeted drug delivery nanomicelles are used. They allow a greater depth of tissue penetration and increase the bioavailability of the drugs [2]. They are used for the encapsulation of poorly soluble drugs and hence they help in the solubility and hence the bioavailability of the drugs [3]. Hydrophilic medications, proteins like lysozymes, and solutes like fluorescein and trypan blue are all encapsulated and delivered using reverse micelles [4,5,6]. Sustained medication release is necessary for the treatment of infectious diseases, chronic illnesses, and cancer, which is a major concern nowadays. Strategies for long-term drug release from the micelles include prodrug production, the use of new polymers, layer-by-layer micellar assembly on solid support, reverse micelle formation, the creation of drug polymer conjugate micelles, and the creation of polymer films. Compared to bigger systems, the micelles' small size offers a higher benefit for drug targeting [7].

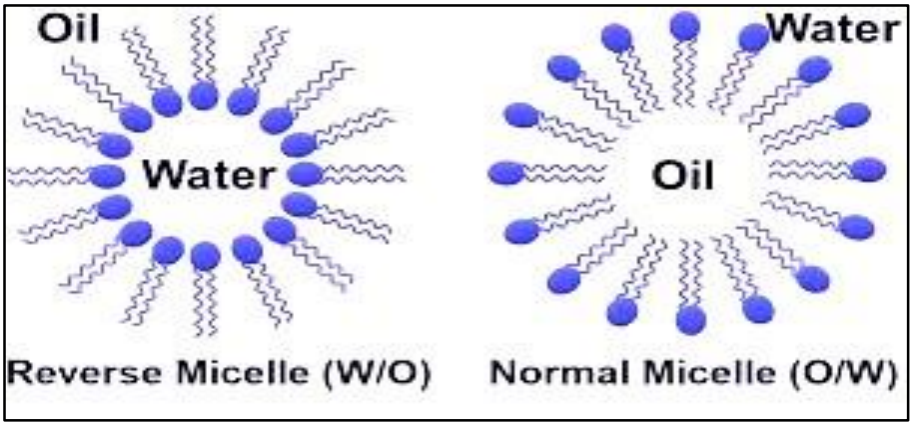


Figure 1. Diagrammatic view of micelle formation

Table 1. Structural Composition of Nanomicelles [8,9,10]

Region	Composition	Description
Core (Inner portion)	Hydrophobic region (typically lipids, hydrophobic surfactants, or hydrophobic polymers)	The inner part of the micelle is hydrophobic and often houses lipophilic drugs or other hydrophobic molecules.
Shell (Outer membrane)	Hydrophilic surfactants, hydrophilic block copolymers, or hydrophilic groups	The outer part of the micelle is hydrophilic, interacting with the surrounding aqueous environment, providing stability and preventing aggregation.
Water (Solvent)	Aqueous medium in which the micelles are dispersed	Surrounds the outer shell, stabilizing the micelle in solution.
Interfacial Region	Amphiphilic molecules (surfactants or block copolymers) at the interface	A thin layer where the hydrophilic outer part of the amphiphiles interacts with the hydrophobic core.

This shape enables micelles to work in aquatic situations by maintaining the exterior portion of the micelle hydrophilic to interact with water while stabilizing hydrophobic molecules within the core.

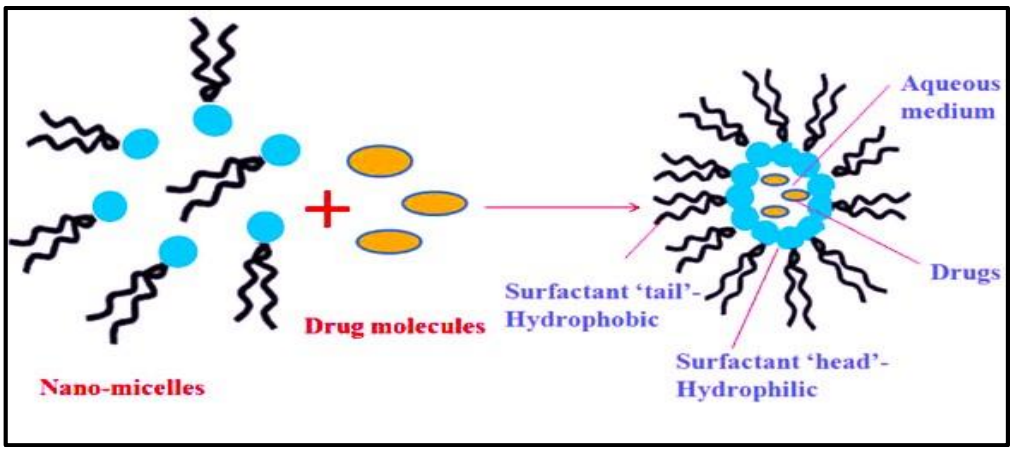


Figure 2. Structure of nanomicelles and its interaction with drugs

Table 2. From Discovery to Therapy: The Historical Development of Nanomicelles [11,12,13,14]

Time Period	Milestone	Key Developments
1960s	Early Studies on Surfactant Micelles	▪ The creation of micelles by surfactants, which are amphiphilic molecules, was discovered. ▪ Important research on micelle behaviour was done by J. M. H. L. G. Schmid (1961) and W. M. Rees (1960).
1980s	Polymeric Micelles and Block Copolymer Development	▪ Block copolymer micelles, which self-assemble from hydrophobic and hydrophilic blocks, are introduced. ▪ Polymeric micelles are being investigated for medication delivery by L. R. H. P. Kuo and associates.
1990s	Micelles in Drug Delivery	▪ It is being investigated to encapsulate hydrophobic medications in aqueous environments using nanocapsules. ▪ There is a growing interest in the functionalization of micelles for targeted medication delivery.
2000s	Optimization for Clinical Applications	▪ Improvements in nanomicelle size, stability, and drug-loading capabilities. ▪ Stimulus-responsive polymers are being introduced for regulated medication release. ▪ Formulations that have received FDA approval include Genexol-PM (paclitaxel-loaded micelles).
2010s	Advances in Biocompatibility, Functionalization, and Targeting	▪ Creation of biodegradable and biocompatible micelles (polymeric, lipid-based). ▪ Multifunctional nanomicelles are being introduced for combination therapy, such as cancer treatments. ▪ Targeting ligands for targeted tissue delivery is the main focus of customized medicine. ▪ Ongoing clinical trials and FDA-approved micelle-based therapies for cancer and other illnesses.

Unique Properties and Versatility of Nanomicelles in Targeted Drug Delivery Systems:

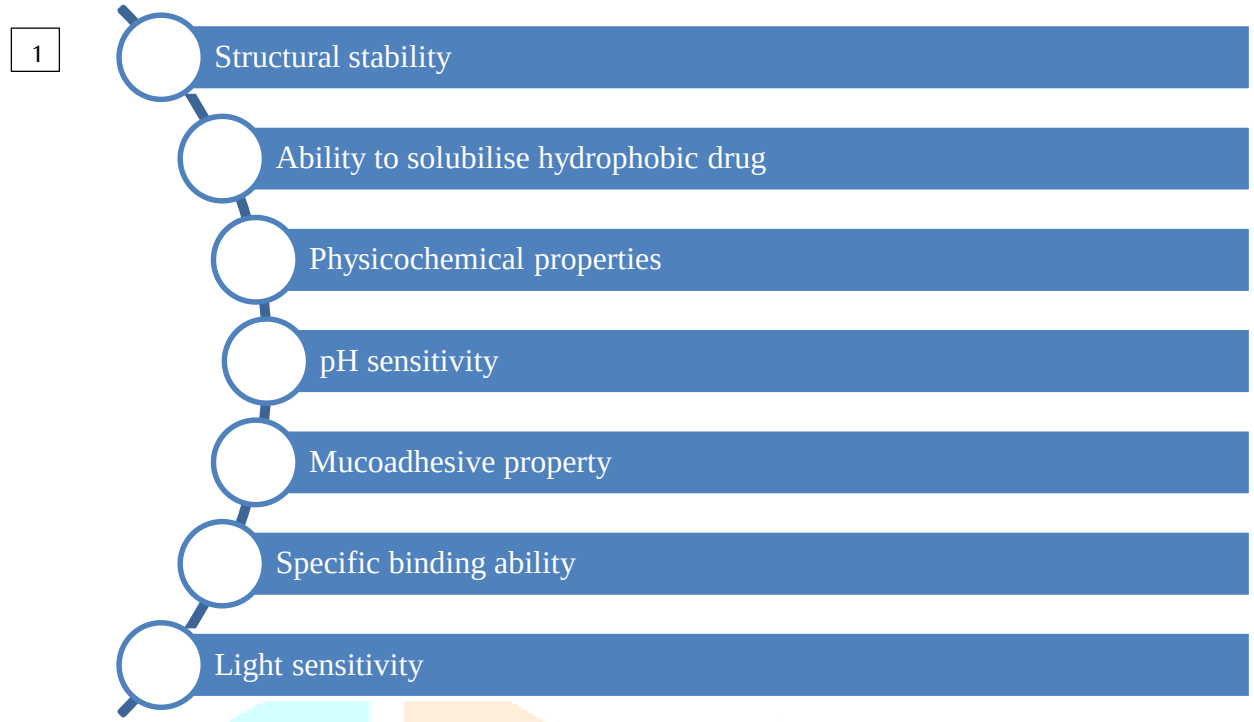


Table 3. Unique Properties of the Nanomicelles

Unique Properties	Description	References
Structural stability	Because of the entanglement of polymer chains in the micelle's inner core, nanomicelles have both thermodynamic and kinetic stability. When a nanomicelles copolymer concentration surpasses its CMC, thermodynamic stability is achieved. When medication delivery parameters are out of balance, kinetic stability becomes a more significant component. When the copolymeric concentration drops below its CMC, kinetic stability takes over.	15,16
Ability to solubilise hydrophobic drug	It is thought that the finest pharmacological carriers for solubilizing hydrophobic medicines are nanomicelles. Drugs that are hydrophobic can be dissolved by nanomicelles by trapping them in a mixed micellar hydrophobic core, while the shell is made up of hydrophilic chains that expand outward to produce a transparent watery solution.	17
Physicochemical properties	The amphiphilic copolymers known as nanomicelles are typically block copolymers. Both drug solubility and loading efficiency are improved by these configurations. The hydrophobic blocks that make up the inner core are stabilized by the hydrophobic interaction. As a result of its contact with the cells, the hydrophilic outer shell has steric stability and is crucial under in vivo conditions.	18,19,20

pH sensitivity	When drug release is dependent on intracellular signals, pH-responsive mechanisms are crucial. For the nanomicelle to develop, the pH must be higher than the protonable group's pKa. The ionization of the polymers causes hydrophilicity and electrostatic repulsion to rise as the pH drops below the pKa value. This destabilizes the micelle, which in turn results in regulated drug release.	21,22
Mucoadhesive property	Drug bioavailability is reduced when oral medicine nanoparticles stick to mucous and penetrate the mucosal membrane. High local concentrations of medicines are caused by mucoadhesive nonmicellar polymers that increase the effective surface area by swelling and filling the mucous membrane's cervixes. When particles come into touch with the mucosal surface, bio adhesion raises the medication concentration gradient.	23,24,25
Specific binding ability	It is possible to accomplish the desired medication delivery through the increased permeability and retention (EPR) effect. By adding particular targeted ligand molecules to the micelle surface or creating micelles of stimuli-responsive amphiphilic block copolymers, it is accomplished.	26
Light sensitivity	Research shows that exposure to light can change a substance's hydrophilicity and hydrophobicity. As a result, light can cause nanomicelles to break down and release the medication.	27,28

Table 4. Recent Advancements in Nanomicelle Development: From Drug Delivery to Diagnostics [29,30]

Advancement Area	Description	Year	Key Findings
Targeted Drug Delivery	Nanomicelles for more precisely delivering the drugs to the specific cells or organs	2023-2024	Improved treatment efficacy, less side effects, and increased bioavailability of cancer drugs.
Stimuli-Responsive Nanomicelles	Formulation of the drug-releasing nanomicelles that respond to alterations in pH, light, and temperature.	2023	Enhanced control over drug release, specifically in cancer therapy and localized treatment.
Improved Biocompatibility	Material optimization for nanomicelles (such as amphiphilic polymers) to decrease toxicity and increase biocompatibility.	2022-2024	Lower toxicity levels, improved circulation time, and better tissue compatibility for clinical applications.
Combination Therapy	Simultaneous delivery of several therapeutic treatments using nanomicelles (e.g.,	2023	Synergistic effects for cancer treatment, reducing drug resistance and

	chemotherapy + gene therapy).		enhancing effectiveness.
Nanomicelles for Immunotherapy	Investigation into the use of nanomicelles to deliver adjuvants or immune-modulating substances for immunotherapy.	2023	Decreased adverse effects of the immune system and improved immune reactions during cancer treatments.
Biosensing and Diagnostics	Development of the nanomicelles for applications in real-time biosensing, such as diagnosis of the diseases.	2022-2024	Functionalized nanomicelles enhances the early diagnosis of illnesses like cancer.
Personalized Medicine	Drug delivery that is tailored to an individual's genetic makeup and it is made possible by combination of nanomicelles with personalized medicine approaches.	2024	More individualized and effective therapies with fewer adverse events.
Biodegradable Nanomicelles	Emphasize toward formulating biodegradable and ecologically sound nanomicelles.	2023	Nanomedicines a safer environment profile and minimized impact on the environment.
Self-Assembly Nanomicelles	The applications involving stable nanomicelles made up of self-assembling molecules including the delivery of therapeutics.	2023	Streamlined manufacturing procedures and enhanced medication stability and encapsulation.
Enhanced Imaging	Development of nanomicelles to serve as carriers for contrast agents and enhance imaging techniques.	2024	Improved diagnostic imaging capabilities, particularly for the diagnosis of diseases in their early stages.

Advantages of Nanomicelles in Drug Delivery and Nanomedicine [31,32,33]:

a. Improved Drug Solubility
b. Targeted Drug Delivery
c. Reduced Toxicity
d. Enhanced Drug Stability
e. Biocompatibility & Biodegradability
f. Ability to Carry Multiple Drugs
g. Controlled & Sustained Release
h. Improved Penetration & Permeability
i. Non-Invasive Delivery
j. Reduced Protein Adsorption
k. Versatility
l. Enhanced Imaging

Disadvantages:

a. Potential toxicity of surfactants
b. Production challenges
c. Complexity in surface modification
d. Environmental Impact
e. Limited Stability in Biological Environments
f. Difficulties in Scaling up Production

Table 5. Types of Nanomicelles: Structure, Characteristics, and Applications

Type of Nanomicelle	Description	Key Characteristics	Applications	References
Polymeric Nanomicelles	composed of polymers containing both hydrophobic and hydrophilic segments, known as amphiphilic block copolymers.	Block copolymers in which the core is hydrophobic and the shell is hydrophilic.	Drug delivery, gene delivery, imaging, and diagnostics.	34,35
Lipid-Based Nanomicelles	Created by the aggregation of lipids or surfactants into micelles with hydrophilic heads and hydrophobic arms.	Structures made of lipid molecules (such as surfactants and phospholipids) can self-assemble.	Targeted drug delivery, vaccines, gene therapy.	36

Amphiphilic Surfactant Micelles	Composed of tiny, amphiphilic surfactant molecules that group together in watery conditions.	Hydrophobic and hydrophilic areas are present in simple surfactants.	Drug solubilization, detergency, cosmetic formulations.	37,38
Thermosensitive Nanomicelles	Drug-releasing nanomicelles that react to temperature variations.	Sensitive to temperature changes, often employing temperature-sensitive polymers.	Cancer therapy, controlled drug release.	39,40
pH-Sensitive Nanomicelles	pH-sensitive nanomicelles are commonly employed for targeted medication delivery in acidic tumour settings.	Groups that are sensitive to pH in the structures of polymers or surfactants.	Targeted drug delivery for cancer, gene delivery.	41
Stimuli-Responsive Nanomicelles	Nanomicelles designed to react to light, magnetic fields, or enzymes, among other external stimuli.	Vulnerability to outside influences (such as light and magnetic fields).	Controlled release systems, targeted therapies.	42,43
Reverse Micelles	Created with the hydrophilic heads facing inside and the hydrophobic tails facing outward in non-aqueous liquids (such as oil).	Its shell is hydrophobic, whereas its core is hydrophilic.	Drug encapsulation in oil, protein delivery.	44,45
Polymeric Mixed Micelles	Created by combining various amphiphilic polymers or surfactants in order to maximize medication release and loading.	A blend of surfactants and polymers for enhanced performance.	Enhanced drug loading, sustained release, gene delivery.	46,47,48

Nanomicelles for Gene Delivery	For use in gene therapy, specialized nanomicelles are made to transport genetic material (DNA, RNA) into cells.	Nucleic acid incorporation, frequently combined with cationic elements to improve DNA binding.	Gene therapy, RNA delivery, genetic vaccines.	49,50
Targeted Nanomicelles	Targeting ligands (such as peptides or antibodies) are added to nanomicelles to guide them to particular cells or tissues.	Modifying the surface using targeted moieties.	Cancer therapy, targeted drug delivery, imaging.	51,52,53

Synthesis of Nanomicelles Using Different Fabrication Techniques:

Dialysis Technique [54]:

Prepare Organic Solvent (e.g., chloroform)

↓

Dissolve Amphiphilic Compound in Organic Solvent

↓

Formation of Micelle Solution
(When dissolved in the solvent, the amphiphilic molecules create micelles.)

↓

Dialysis Against Aqueous Medium
(Dialysis removes the organic solvent by diffusion through the bag membrane)

↓

Continuous Monitoring of Dialysis Process
(Monitor the removal of organic solvent and micelle formation)

↓

Collection of Nanomicelles
(Following dialysis, the aqueous medium forms nanomicelles.)

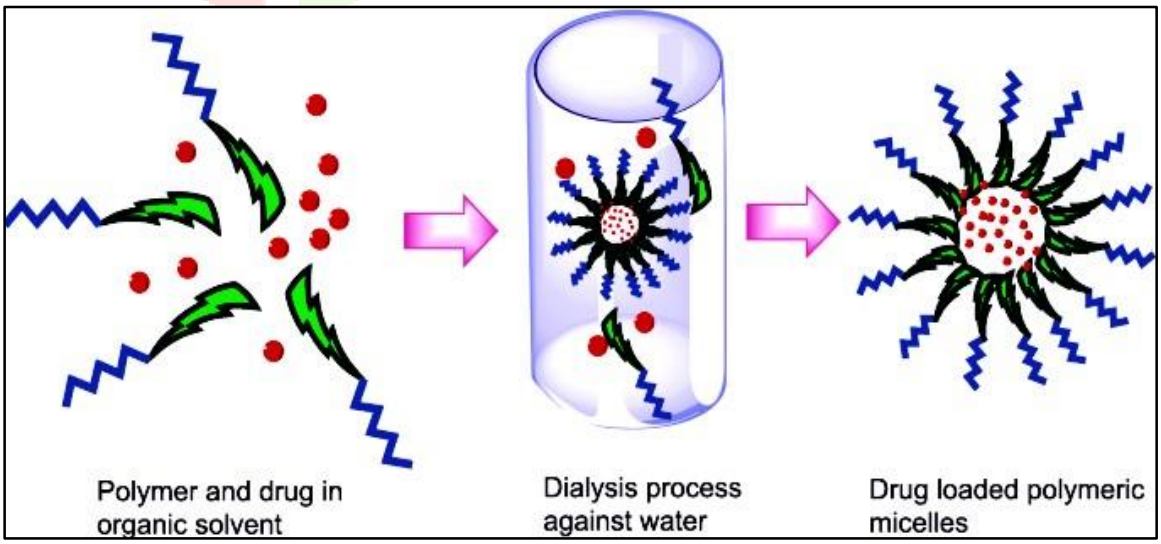


Fig 3. Preparation of nanomicelles by Dialysis Method

O/W Emulsion Technique:

Dissolve amphiphilic polymers
(such as polyvinyl alcohol and Pluronic F127)

↓

The amphiphilic polymer should be dissolved in an organic solvent, like acetone or chloroform, to create the organic phase.

↓

Prepare the Aqueous Phase
(either buffer solution or deionized water to prepare the aqueous phase; you can also add surfactants like Tween 80 or SDS for stability).

↓

Create the O/W Emulsion
(The O/W emulsion is created by sonicating or swirling the organic phase containing the polymer as it is added dropwise into the aqueous phase)

↓

Emulsification Process
(Use sonication or high-speed homogenization to break the oil phase into tiny droplets in order to generate an emulsion)

↓

Evaporate Organic Solvent: To create nanomicelles, use rotary evaporation or lower pressure to remove the organic solvent from the emulsion.

↓

Purification
(using centrifugation or dialysis to remove any leftover solvent or unencapsulated material)

↓

Nanomicelle collection
(After removing the solvent, gather the nanomicelle solution)

Simple Dissolution Method [55]:

Use an organic solvent to dissolve the amphiphilic block copolymer.

↓

The drug should be dissolved in the same organic solvent that was employed to dissolve the polymer.

↓

Combine the polymer and drug solutions in a suitable container.

↓

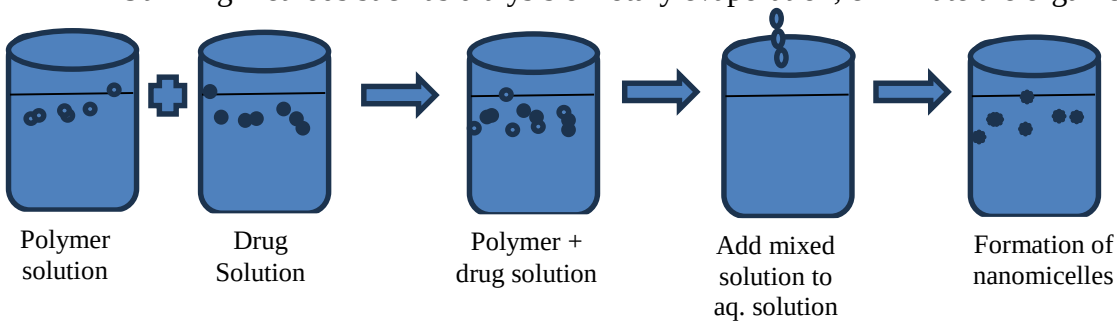
While gently stirring, add the combined solution dropwise to a large volume of aqueous solution.

↓

When the organic solvent diffuses into the aqueous phase, self-assembled nanomicelles are left behind.

↓

Utilizing methods such as dialysis or rotary evaporation, eliminate the organic solvent.



Solvent Evaporation Method [56]:

Amphiphilic block copolymer and medication should be dissolved in a typical organic solvent.

↓

To create an oil-in-water emulsion, add the organic solution dropwise to an aqueous phase while stirring.

↓

Reduce the pressure and remove the organic solvent.

↓

Amphiphilic compounds self-assembling into nanomicelles

lyophilization or Freeze Drying [57]:

Mix. of Water + Tertiary Butanol

⇩

Dissolve Drug + Polymer in mix. of H_2O & tert. butanol solution

⇩

Solution gets polymerized

⇩

Lyophilization/ Freeze drying

⇩

Redistributing the lyophilized product in an appropriate medium to produce drug-loaded nanomicelles

Techniques used for Characterization of Nanomicelles:

Dynamic Light Scattering (DLS) [58]:
The size distribution and hydrodynamic radius of the nanomicelles in the solution have been identified by the DLS. DLS analyses changes in the intensity of the scattered light as a nanomicelles diffuse in the solution. The data has been employed to calculate the size distribution. Provides data on average particle size, size distribution, and the polydispersity index (PDI), which indicates the degree of uniformity in micelle size.

Transmission Electron Microscopy (TEM) [58]:
TEM provides the information about size, shape, and morphology of nanomicelles visible through high-resolution pictures. The nanomicelles are seen in detail using electron beams in the TEM. Since the samples are processed on tiny grids, TEM allows for the direct visualization of micelle morphology at nanoscale. TEM provides details about the size, internal structure (core-shell arrangement), and shape (spherical, rod-like, etc.) of the micelle.

Scanning Electron Microscopy (SEM):
SEM is used to view nanomicelles and provide details on their surface morphology at magnifications lower than TEM. SEM creates fine-grained surface pictures by scanning the sample's surface with a concentrated electron beam and collecting secondary electrons. It gives info. on the surface's size, shape, and dispersion.

Small Angle X-ray Scattering (SAXS):
Information on internal structure and shape of nanomicelles at nanoscale can be obtained using the small angle X-ray scattering. SAXS analyses dispersion of X-rays when they interact with a material at tiny angles. The scattering pattern informs the size, shape, and structural order of the nanomicelles. Method gives the structural elements such as micelle size, inter-micelle spacing, and core-shell structure.

Fluorescence Spectroscopy [58]:
This technique is used to investigate the internal environment of nanomicelles as well as the solubility, polarity, and behavior of hydrophobic cores. Either micelles contain a fluorophore or it is employed to monitor their interaction. The surroundings and aggregation of nanomicelles are revealed via emission spectra. Comprehending micelle stability, dynamics, and interactions with medications or other compounds is aided by fluorescence emission and lifetime.

Nuclear Magnetic Resonance Spectroscopy (NMR):
Micelle structure and molecular dynamics are investigated using NMR. NMR may give the detailed data on the molecular structure inside the micelle in addition to identifying interactions between atomic nuclei in the micelle system. NMR provides the micelle morphology, surfactant molecule structural features, and micellar environment dynamics.

Cryo-Transmission Electron Microscopy (Cryo-TEM) [58]:
The Cryo-TEM gives high-resolution images of nanomicelles in their natural hydrated form without needing dehydration or staining. In cryo-TEM the sample is rapidly frozen in liquid nitrogen to maintain its structural

integrity. This makes it possible to observe the nanomicelles native state. It gives precise and thorough images of micelles and their structural behavior in a solvent environment.

Measurement of Zeta Potential:
Comprehending the nanomicelles stability and molecular interactions needs knowing their surface charge, which is determined by this method. Measuring the micelles electrophoretic mobility in an electric field yields the zeta potential. The magnitude of the micelles zeta potential indicates their stability. A high absolute zeta potential indicates more resistance to aggregation.

X-ray Diffraction (XRD) [58]:
XRD provides data about the crystalline structure or ordering of surfactant molecules in micelles, especially in solid-state formulations. When the sample is subjected to X-rays, the arrangement of molecules within the micelle is revealed by the diffraction pattern. The XRD describe the properties of the crystal lattice and the level of molecular structure in micelles.

Thermogravimetric Analysis (TGA):
The composition and thermal stability of nanomicelles are assessed using this technique. Through the measurement of a sample's mass change upon heating, TGA is able to ascertain the temperature at which the sample breaks down and the stability of the components within the micelles. TGA provides information on the thermal stability, solvent or surfactant loss, and decomposition temperatures.

Differential Scanning Calorimetry (DSC):
Phase transitions, stability, and other thermal properties of nanomicelles are investigated using the DSC. The DSC measures heat flux associated with phase transitions in the micelle structure, such as the shift from liquid to gel or solid. The DSC gives details on the melting and gelation temperatures as well as additional micelle thermodynamic properties.

Atomic Force Microscopy (AFM) [58]:
It provides high-resolution topography images of nanomicelles at the nanoscale. Using a sharp point, AFM scans the sample surface to provide three-dimensional surface pictures with atomic resolution. provides the micelle form, surface roughness, and nanoscale dimensions.

UV-Vis Spectroscopy:
UV-Vis Spectroscopy technique is often used to study the interactions between nanomicelles and medications or other substances that absorb UV-visible light. It measures the absorption of light at specific wavelengths to track changes in the micelle environment or the addition of bioactive compounds. Absorbance spectra produced by the UV-Vis Spectroscopy demonstrate the kind of material encapsulated and the efficiency of micelle encapsulation.

The Role of Nanomicelles in Targeted Drug Delivery for Disease Treatment:

In Cancer Therapy [59]:
Because of their severe toxicity and poor water solubility, the majority of anticancer drugs are pharmacologically effective but have restricted clinical use therefore, their altered biodistribution has significant consequences for both lowering toxicity and improving therapeutic effects. When compared to alternative drug administration methods, nanomicelles offer a number of benefits, including improved drug solubility, extended circulation half-life, tumor site accumulation, and reduced toxicity. Hydrophobic drugs such as doxorubicin and paclitaxel can be enclosed in nanomicelles to improve their absorption and more accurately target cancer cells, reduces the negative effects on healthy tissues. They can also build up in cancer tissues by taking advantage of the increased permeability and retention (EPR) effect. Furthermore, nanomicelles enable controlled drug release through external triggers, including changes in the pH of the tumor microenvironment.

In Eye Treatment [60]:
Due to the unique structure, physiology, and biochemistry of the eye, which render it nearly impervious to foreign substances, ocular medication delivery is one of the most difficult topics pharmaceutical researchers have to deal with. Nanomicelles helps to treat the diseases including glaucoma, macular degeneration, and

diabetic retinopathy because of their small size, which enhances the solubility, stability, and bioavailability of poorly soluble drugs.

- **Glaucoma**: Anti-glaucoma drugs which decreases intraocular pressure more effectively can be given by the use of nanomicelles and it lowers the chances of optic nerve damage.
- **Age Related Macular Degeneration (AMD)**: One of the main characteristics of Age-related macular degeneration is presence of anti-VEGF drugs which can be transported by nanomicelles and avoid abnormal blood vessel growth in the retina.
- **Diabetic Retinopathy**: The aberrant blood vessel growth and retinal inflammation related to diabetic retinopathy are the focus of the drug delivery systems employing the nanomicelles.

In Skin Treatment [61]:

Drug particulate carrier is a novel field of study that proposes the ability to operate at the molecular level, establishing delivery systems or devices with various features and capabilities. Among the many advantages of these carriers includes their capacity to deliver medications transdermally or intradermally to comparatively impermeable regions of the target tissue while avoiding adverse effects and build up at action sites. Nanomicelles can transport peptides, antioxidants, and other anti-aging substances that enhances skin suppleness and decrease wrinkles by promoting the formation of collagen. By delivering acne medications like benzoyl peroxide or salicylic acid directly to the hair follicles and sebaceous glands nanomicelles can more successfully treat the underlying causes of acne. Nanomicelles can provide individualized treatment for conditions like psoriasis and eczema by delivering immunomodulatory medications or anti-inflammatory corticosteroids to inflammatory areas. Growth hormones or antimicrobial medications can be delivered using nanomicelles to encourage tissue regeneration, improve wound healing, and prevent infection. Antibiotics or antifungal medications can be encapsulated in nanomicelles to improve their effectiveness in treating skin infections by enhancing penetration and reducing the bacterial resistance.

In Treatment of CNS Diseases [62]:

Currently, a wide range of brain illnesses are categorized as deficiencies in both neurological and psychiatric chapters, resulting in both temporary and permanent disability. Globally, 1.5 million people suffer from CNS illnesses, which account for 1% of fatalities. Numerous possible medications have been found to treat various neurological diseases. However, the existence of the blood-brain barrier (BBB) and blood-cerebrospinal fluid barrier (BCSFB) still limits the therapeutic efficacy of these medications. Diseases affecting the CNS may be efficiently treated with the novel class of nanocarriers known as nanomicelles. Because of their ability to transfer therapeutic compounds across blood-brain barrier, as well as their possibility for customized delivery and enhanced bioavailability they are particularly well-suited for CNS applications.

- **Blood-Brain Barrier (BBB) Penetration:** One of the main barriers to CNS drug delivery is the selective permeability of the blood-brain barrier, which prevents most therapeutic compounds from entering the brain. Nanomicelles can be engineered to penetrate the blood-brain barrier through active targeting or passive diffusion due to their minuscule size, typically ranging from 10 to 100 nm.
- **Blood-cerebrospinal fluid barrier (BCSFB):** The blood-cerebrospinal fluid barrier, a crucial physiological barrier in the central nervous system (CNS), regulates the movement of chemicals between the blood and the cerebrospinal fluid, that encircles and cushions the spinal cord and brain. Delivering therapeutic medications throughout the BCSFB presents unique challenges, especially for CNS illnesses and drug delivery devices. There are several ways that nanomicelles can move across the BCSFB, including endocytosis, carrier-mediated transport, and paracellular transport.

Table 6. Commercially Available Nanomicelle-Based Drug Products

Product Name	Company	Indication/Use
Genexol-PM	Samyang Biopharmaceuticals	Cancer treatment (breast cancer, non-small cell lung cancer, ovarian cancer)
Myocet	Teva Pharmaceuticals	Cancer treatment (e.g., breast cancer, ovarian cancer)
Marqibo	Spectrum Pharmaceuticals	Cancer treatment (leukemia, lymphoma)
Spiolto Respimat	Boehringer Ingelheim	Chronic obstructive pulmonary disease (COPD)
Onivyde	Ipsen Pharmaceuticals	Cancer treatment (metastatic pancreatic cancer)
Ambisome	Gilead Sciences	Fungal infections
Maraviroc (Selzentry)	ViiV Healthcare	HIV treatment
Doxil	Johnson & Johnson	Cancer treatment (e.g., ovarian cancer, Kaposi's sarcoma)
Vyxeos	Jazz Pharmaceuticals	Acute myeloid leukemia (AML)
Rapamune	Pfizer	Prevention of organ rejection in kidney transplant patients
Sivextro	Cubist Pharmaceuticals (Merck)	Bacterial infections (e.g., skin and soft tissue infections)
Eladys	AbbVie	Hepatitis C
Cometriq	Exelixis	Cancer (e.g., medullary thyroid cancer, renal cell carcinoma)

Salient Features of Nanomicelles: A Promising Drug Delivery System:

Because of the special qualities, drug delivery systems called nanomicelles which are based on nanoparticles are particularly successful in a range of use in medicine. Molecules having both hydrophobic and hydrophilic areas combine to create a core shell structure in amphiphilic nanomicelles. Nanomicelles size ranges between 10-100 nm. The hydrophobic core encloses drugs that are poorly soluble in water and hydrophilic shell enhances stability and solubility. Especially for hydrophobic drugs, nanomicelles' high drug loading capacity and ability to adjust their characteristics such as pH and temperature allow them for regulated drug release. Nanomicelles enhances the effectiveness of hydrophobic medications by improving their solubility and absorption. The nanomicelles are made up of biodegradable and biocompatible materials so that they can be used therapeutically. Their surfaces can be modified to employ passive targeting using the EPR effect or active targeting with specific ligands for targeted drug delivery. Neurological diseases can be treated using nanomicelles as they having the ability to cross the biological barriers such as the blood-brain barrier (BBB). Additionally, the site-specific drug release is made possible by their stimuli-responsive action. They are perfect for clinical use in infections, cancer, and other therapeutic fields because of their minimal toxicity.

Table 7. Issued Patents on Nanomicelle Formulations

Patent Name	Patent No.	Date of Patent	Inventors	Assignee
POLYMER CONJUGATED PROTEIN MCELLES	US 8,697,098 B2	Apr. 15, 2014	Omathanu P. Perumal, Brookings, SD (US); Satheesh K. Podaralla, Santa Clara, CA (US); Ranjith Kumar Averineni, Brookings, SD (US)	South Dakota State University, Brookings, SD (US)
POLYMERIC MICELLES FOR A POLYNUCLEOTDE ENCAPSULATION	US 8,747,904 B2	Jun. 10, 2014	Janni Mirosevich, Tampa, FL (US); Gregoire Cardoen, Tampa, FL (US); Kevin N. Sill, Tampa, FL (US); Habib Skaff, Tampa, FL (US)	Intezyne Technologies, Inc., Tampa, FL (US)
STABLE MICELLES OF MIXED FATTY ACDS	US 9,370,585 B2	Jun. 21, 2016	Frederick Sancilio, Palm Beach Gardens, FL (US); Peter Persicaner, Boca Raton, FL (US); Janice Cacace, St. Petersburg, FL (US); Mohand Dahim, Gaithersburg, MD (US)	Sancilio & Company, Inc., Riviera Beach, FL (US)
BLOCK COPOLYMER AND MICELLE COMPOSITIONS AND METHODS OF USE THEREOF	US 12,091,486 B2	Sep. 17, 2024	Jinming Gao, Plano, TX (US); David Boothman; Kejin Zhou, Dallas, TX (US); Xiaonan Huang, Beijing (CN); Yiguang Wang, Dallas, TX (US)	The Board of Regents of The University of Texas System, Austin, TX (US)
REVERSIBLY CROSSLINKED MICELLE SYSTEMS	US 11,192,978 B2	Dec. 7, 2021	Kit S. Lam, Davis, CA (US); Yuanpei Li, Davis, CA (US); Juntao Luo, Jamesville, NY (US); Kai Xiao, Sacramento, CA (US)	The Regents of the University of California, Oakland, CA (US)
Compositions comprising macromolecular assemblies of lipid and surfactant	AU 2007327054 B2	Nov. 29, 2007	Tonge, Stephen; Harper, Andrew	
Functional micelles for hard tissue targeted delivery of chemicals	AU 2009268528 B2	Jul. 9, 2009	Li, Xue; Liu, Xin-Ming; Wang, Dong; Reinhardt, Richard A.	

Poly(histidine)-based micelles for the complexation and delivery of proteins and nucleic acids	EP 3449004	Feb. 24, 2021	GHOROGHCHIAN, PAIMAN PETER; ROMERO URIBE, GABRIELA and OSTERTAG, ERIC	
MICELLE COMPOSITION OF POLYMER AND PASSENGER DRUG	US 9,107,814 B2	Aug. 18, 2015	Glen S. Kwon, Waunakee, WI (US); Marcus L. Forrest, Middleton, WI (US)	Wisconsin Alumni Research Foundation, Madison, WI (US)

Conclusion:

A highly adaptable class of nanocarriers i.e. nanomicelles has an amphiphilic core shell structure that enhances the solubility and bioavailability of hydrophobic drugs. Nanomicelles, which were first developed from surfactant research that are greatly evolved due to advancements in preparation methods, allowing for enhanced scalability and efficiency. Among it's the benefits of nanomicelles includes the enhanced drug stability, biocompatibility and the capacity to target specific tissues, even those that are immune to biological barriers. However, issues including possible toxicity and a restricted medication loading capacity are still exists. Number of nanomicelle types exhibit wide range of application including formulations based on lipids and polymers. Techniques for characterization are essential for determining their stability, size, and shape. In order of improving formulations and broaden their clinical uses across many therapeutic areas, more study is necessary even if their therapeutic promise is obvious.

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