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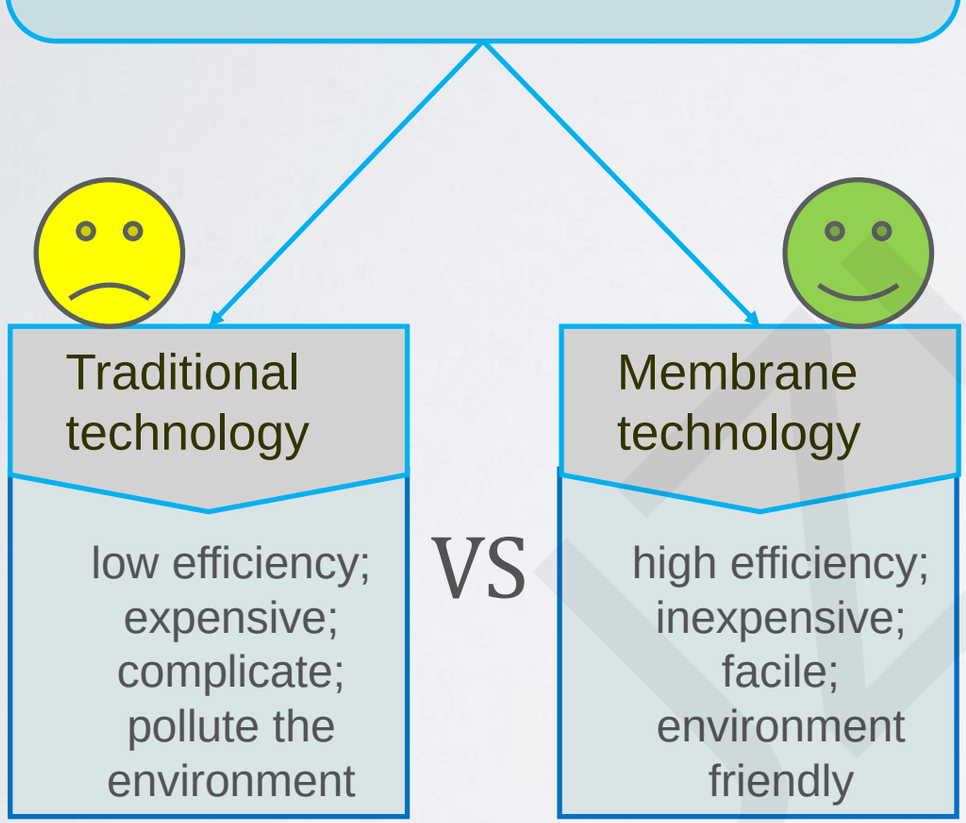
Recent advances in chiral drug separation membranes: design, mechanisms, challenges, and prospects

Key words:

Chiral drugs; Chiral separation; Separation mechanisms; Membrane separation

Why we need chiral drug separation membranes (CDSM)?

Effective separation of chiral drugs are crucial because the left-handed and right-handed enantiomers exhibit different pharmacological activities and side effects.



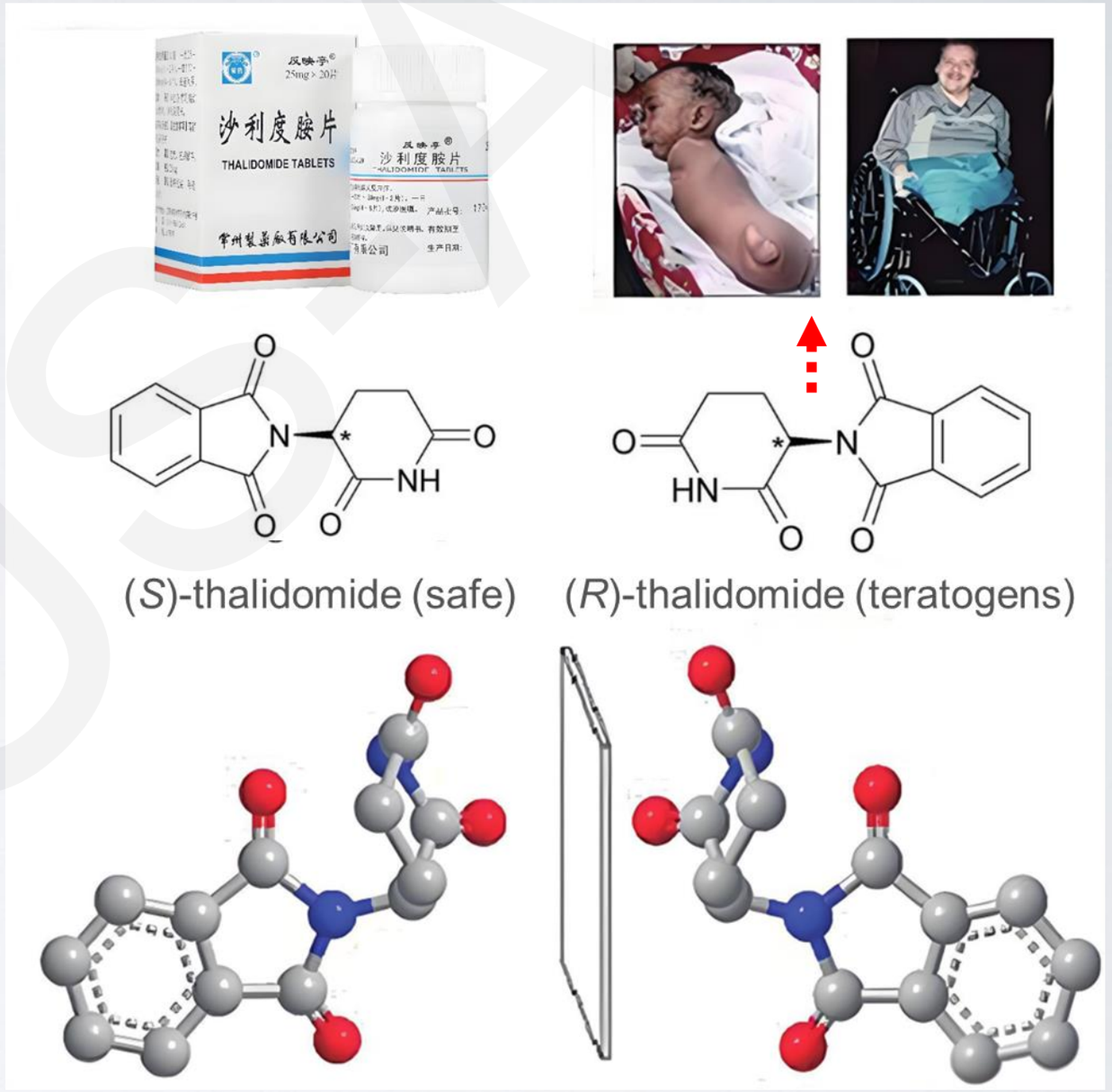


Fig.1 The famous chiral drug named thalidomide has *S*-enantiomer and *R*-enantiomer, the former one is safe while the later one is teratogens.

How to fabricate CDSM?

As shown in Fig.2, CDSM can be fabricated by using various materials such as polymer martials, metal-organic frameworks, carbon nanomaterials, and other inorganic materials etc., the fabrication methods including phase transformation, interfacial polymerization, surface modification, secondary growth and so on.

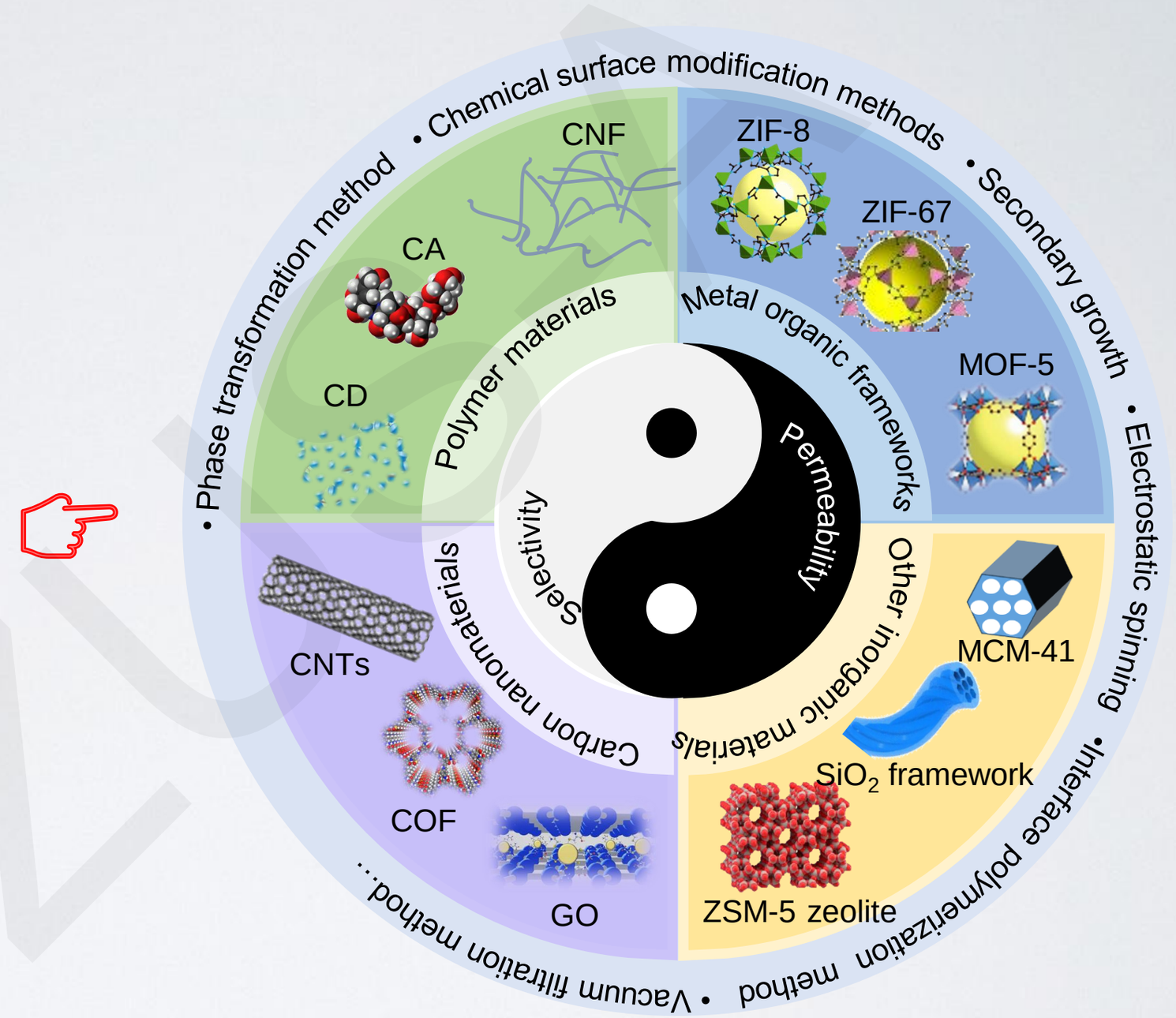


Fig.2 Chemical structures of different chiral drug separation membranes, and related construction methods.

How CDSM work in the chiral separation processes?

Separation mechanism of CDSM

1. Facilitating transport mechanism

CDSM is equipped with chiral recognition sites, exhibiting strong attraction toward one of the enantiomers and can accelerate its transportation through membrane, by this mechanism, the CDSM can selectively separate different enantiomers.

2. Retarded transport mechanism

In this mechanism, the chiral recognition site has a strong binding affinity for an enantiomer, resulting in the enantiomer staying on the membrane for a long time. For another enantiomer, it has a relatively weak bond to the chiral recognition site and therefore a faster transmission rate.

Challenges and prospects

Challenges

- Achieving high selectivity while maintaining high flux remains a huge challenge (trade-off effective).
- The membranes can be affected by contaminants, deposits, and gases, leading to decreased separation efficiency and stability.
- Factors such as dehydration, deformation, and membrane-material aging during long-term use can also impact the performance and lifespan of the CDSM.

Prospects

- The use of new technologies such as machine learning and high-throughput screening can accelerate the discovery and optimization of novel separation membranes, with the potential to further improve chiral selectivity.
- Through interdisciplinary cooperation, it may be possible to promote the development of new membrane materials and achieve a balance of membrane properties.
- To tackle pollution-related issues, it is advisable to explore surface-modification techniques that would enable self-cleaning functions.