CLAIMS

1. A method of synthesizing a hydrolysate of a peptide-attached pillar[5]arene, the method comprising:

forming a pillar[5]arene substituted with carboxyl groups;

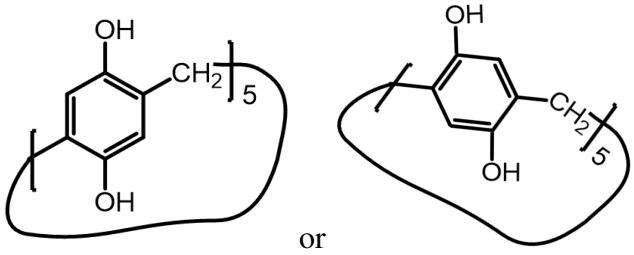
mixing the pillar[5]arene substituted with carboxyl groups and a tripeptide in an organic solvent to form the peptide-attached pillar[5]arene, wherein the tripeptide has a terminal -NH_2 group and a terminal ester, wherein the tripeptide comprises NH_2-L-Phe-L-Phe-L-Phe-O-methyl, NH_2-L-Phe-L-Phe-L-Phe-O-ethyl, or NH_2-L-Phe-L-Phe-L-Phe-O-propyl, wherein the peptide-attached pillar[5]arene comprises a diastereomeric mixture having a diastereomer pR of the peptide-attached pillar[5]arene and a diastereomer pS of the peptide-attached pillar[5]arene, wherein the diastereomer pR has a different solubility in acetone compared to the diastereomer pS;

isolating the diastereomer pR from the diastereomer pS based on the solubility difference in acetone; and

subjecting the diastereomer pR to hydrolysis in the presence of a base to obtain the hydrolysate of the peptide-attached pillar[5]arene, wherein the hydrolysate of the peptide-attached pillar[5]arene consists of a pR planar configuration.

2. The method of claim 1, wherein forming the pillar[5]arene substituted with carboxyl groups comprises mixing 1,4-dimethoxybenzene and a paraformaldehyde in the presence of trifluoroacetic acid to form 1,4-dimethoxypillar[5]arene.

3. The method of claim 1 or 2, wherein forming the pillar[5]arene substituted with carboxyl groups comprises forming a pillar[5]arene represented by the formula:

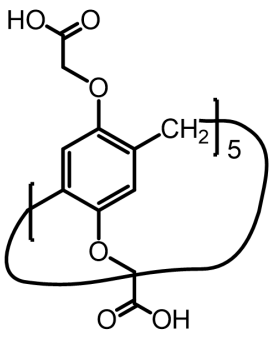


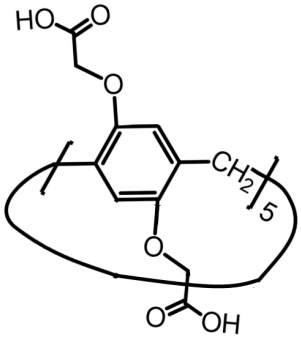
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4. The method of claim 3, wherein forming the pillar[5]arene substituted with carboxyl groups comprises mixing the pillar[5]arene and an ethyl bromoacetate in the presence of potassium iodide to form ethoxycarbonylmethoxy-substituted pillar[5]arene.

5. The method of claim 4, wherein forming the pillar[5]arene substituted with carboxyl groups comprises mixing the ethoxycarbonylmethoxy-substituted pillar[5]arene and a basic solution comprising sodium hydroxide to form the pillar[5]arene substituted with carboxyl groups.

6. The method of claim 1 or 2, wherein the pillar[5]arene substituted with carboxyl groups is represented by the formula:



or


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7. The method of any one of claims 1 to 6, wherein mixing the pillar[5]arene substituted with carboxyl groups and the tripeptide comprises mixing the pillar[5]arene substituted with carboxyl groups and the tripeptide at a temperature ranging from 45 to 70°C for 12 to 180 hours under an inert atmosphere.

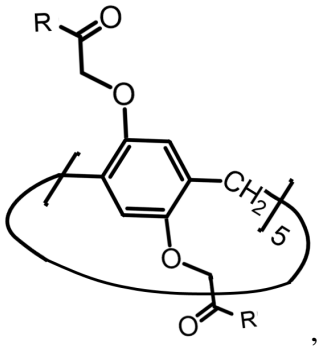
8. The method of any one of claims 1 to 7, wherein the organic solvent comprises anhydrous dimethylformamide, 4-dimethylaminopyridine and N-ethyl-N'-(3-dimethylaminopropyl)carbodiimide hydrochloride.

9. The method of any one of claims 1 to 8, further comprising subjecting the peptide-attached pillar[5]arene to column chromatography to produce a fraction comprising the diastereomeric mixture of the peptide-attached pillar[5]arene, and filtering the diastereomeric mixture after mixing the diastereomeric mixture with acetone to obtain a residue and a filtrate, wherein the residue comprises the diastereomer pR and the filtrate comprises the diastereomer pS.

10. The method of any one of claims 1 to 9, wherein subjecting the diastereomer pR to hydrolysis comprises mixing the diastereomer pR and the base for 8 to 40 hours.

11. The method of any one of claims 1 to 10, wherein the base comprises lithium hydroxide, potassium hydroxide, or sodium hydroxide.

12. A hydrolysate of a peptide-attached pillar[5]arene configured as a water channel in a liposomal membrane, wherein the hydrolysate of the peptide-attached pillar[5]arene is represented by the formula:



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wherein R represents a tripeptide having a terminal -NH- group and a terminal -COOH group, wherein the terminal -NH- group forms part of an amide linkage, wherein the terminal -COOH group extends away from the amide linkage, and wherein the tripeptide comprises -NH-L-Phe-L-Phe-L-Phe-COOH.

13. A method of synthesizing a liposomal membrane comprising a hydrolysate of a peptide-attached pillar[5]arene, the method comprising:

synthesizing a hydrolysate of a peptide-attached pillar[5]arene according to the method of any one of claims 1 to 11;

mixing the hydrolysate and a plurality of lipids to form a mixture;

forming a liposomal film from the mixture;

contacting the liposomal film with a buffer to form a suspension comprising the hydrolysate and the plurality of lipids; and

extruding the suspension through a membrane to form the liposomal membrane, wherein the hydrolysate of the peptide-attached pillar[5]arene consists of a pR planar configuration.

14. The method of claim 13, wherein mixing the hydrolysate and the plurality of lipids comprises dissolving the hydrolysate in one or more organic solvents.

15. The method of claim 14, wherein the one or more organic solvents comprise chloroform and/or methanol.

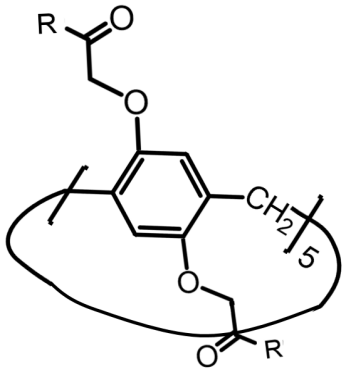
16. The method of any one of claims 13 to 15, wherein the plurality of lipids comprise phosphatidylcholine and/or phosphatidylserine.

17. The method of any one of claims 13 to 16, wherein mixing the hydrolysate and the plurality of lipids comprises mixing the hydrolysate and the plurality of lipids in a molar ratio of more than 0 and up to 0.02.

18. The method of any one of claims 13 to 17, wherein the buffer comprises (4-(2-hydroxyethyl)-1-piperazineethanesulfonic acid), sodium chloride, and sodium azide.

19. The method of any one of claims 13 to 18, wherein extruding the suspension comprises extruding the suspension for more than one time.

20. A liposomal membrane comprising a plurality of lipids and at least one hydrolysate of a peptide-attached pillar[5]arene, wherein the at least one hydrolysate of the peptide-attached pillar[5]arene is represented by the formula:



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wherein R represents a tripeptide having a terminal -NH- group and a terminal -COOH group, wherein the terminal -NH- group forms an amide linkage with the carbonyl carbon, wherein the terminal -COOH group extends away from the amide linkage, and wherein the tripeptide comprises -NH-L-Phe-L-Phe-L-Phe-COOH.

21. The liposomal membrane of claim 20, wherein the plurality of lipids comprise phosphatidylcholine and/or phosphatidylserine.

22. The liposomal membrane of claim 20 or 21, wherein the hydrolysate and the plurality of lipids are present in a molar ratio of more than 0 and up to 0.02.

23. The liposomal membrane of any one of claims 20 to 22, wherein the liposomal membrane comprises a unilamellar liposome.