CLAIMS

What is claimed is:

1. A polymer, comprising:

(a) a plurality of hydrophobic repeat units;

(b) a plurality of a cationic repeat units; and

(c) a plurality of an anionic repeat units;

wherein the hydrophobic repeat units, cationic repeat units, and anionic repeat units are in random or statistical order; and/or

wherein the polymer is insoluble in water.

2. The polymer of claim 1, wherein the molar ratio of cationic repeat units to anionic repeat units is about 1.1:1 to about 1:1.1 or about 1:1.

3. The polymer of any one of claims 1- 3, wherein the net charge of the polymer is from -10 to +10.

4. The polymer of claim 1, wherein the molar ratio of cationic repeat units to anionic repeat units is greater than about 1:1, greater than about 1.5:1, or greater than about 2:1.

5. The polymer of claim 4, wherein the net charge of the polymer is positive.

6. The polymer of claim 1, wherein the molar ratio of cationic repeat units to anionic repeat units is less than about 1:1, less than about 0.67:1, or less than about 0.5:1.

7. The polymer of claim 6, wherein the net charge of the polymer is negative.

8. The polymer of any one of claims 1- 7, wherein the molecular weight of the polymer is greater than about 20,000 g/mol, greater than about 40,000 g/mol, greater than about 60,000 g/mol, greater than about 80,000 g/mol, greater than about 100,000 g/mol, or greater than about 120,000 g/mol.

9. The polymer of any one of claims 1- 8, wherein the plurality of hydrophilic repeat units constitutes at least about 30 wt%, at least about 35 wt%, at least about 40 wt%, at least about 45 wt%, at least about 50 wt%, at least about 60 wt%, at least about 65 wt%, at least about 70 wt%, at least about 75 wt%, at least about 80 wt%, at least about 85 wt%, or at least about 90 wt% of the polymer.

10. The polymer of any one of claims 1- 8, wherein the plurality of hydrophilic repeat units constitutes about 30 wt% to about 99 wt%, about 30 wt% to about 90 wt%, about 40 wt% to about 90 wt%, about 40 wt% to about 80 wt%, about 40 wt% to about 75 wt%, about 40 wt% to about 70 wt%, about 45 wt% to about 75 wt%, about 45 wt% to about 70 wt%, about 50 wt% to about 80 wt%, about 50 wt% to about 75 wt%, or about 50 wt% to about 70 wt% of the polymer.

11. The polymer of any one of claims 1- 10, wherein the plurality of cationic repeat units and the plurality of anionic repeat units each constitutes at least about 0.5 wt%, at least about 1 wt%, at least about 2.5 wt%, at least about 5 wt%, at least about 10 wt%, at least about 15 wt%, at least about 20 wt%, at least about 25 wt%, at least about 30 wt%, at least about 35 wt%, or at least about 40 wt% of the polymer.

12. The polymer of any one of claims 1- 11, wherein the plurality of cationic repeat units and the plurality of anionic repeat units each constitutes about 0.5 wt% to about 30 wt%, about 0.5 wt% to about 25 wt%, about 1 wt% to about 30 wt%, about 1 wt% to about 25 wt%, about 2 wt% to about 30 wt%, about 2 wt% to about 25 wt%, about 2.5 wt% to about 30 wt%, about 2.5 wt% to about 25 wt%, about 5 wt% to about 30 wt%, or about 5 wt% to about 25 wt% of the polymer.

13. The polymer of any one of claims 1- 12, wherein the hydrophobic repeat unit is independently selected from the group consisting of 2,2-trifluoroethyl methacrylate (TFEMA), fluorinated acrylates, methacrylates, pentafluoropropyl methacrylate, heptafluorobutyl methacrylate, pentafluorophenyl methacrylate, styrene, methyl methacrylate, and acrylonitrile.

14. The polymer of any one of claims 1- 13, wherein the hydrophobic repeat unit is the same, and is selected from the group consisting of 2,2-trifluoroethyl methacrylate (TFEMA), fluorinated acrylates, methacrylates, pentafluoropropyl methacrylate, heptafluorobutyl methacrylate, pentafluorophenyl methacrylate, styrene, methyl methacrylate, and acrylonitrile.

15. The polymer of any one of claims 1- 14, wherein each of the anionic repeat units is a methacrylate, acrylate, methacrylamide, acrylamide, styrene, or vinyl derivative comprising a carboxylic acid, sulfonate, phosphate, or other ionizable or charged group.

16. The polymer of any one of claims 1- 14, wherein the anionic repeat unit is independently selected from the group consisting of methacrylic acid (MAA), 2-sulfoethyl methacrylate (SEMA), L-tryptophan-methacrylamide (L-Try-MA), D-tryptophan-methacrylamide, L or D-tryptophan-acrylamide, L or D-alanine-methacrylamide, L or D-alanine-acrylamide, L or D-valine-methacrylamide, L or D-valine-acrylamide, L or D-isoleucine-methacrylamide, L or D-isoleucine-acrylamide, L or D-allo-isoleucine-methacrylamide, L or D-allo-isoleucine-acrylamide, L or D-methionine-methacrylamide, L or D-methionine-acrylamide, L or D-phenylalanine-methacrylamide, L or D-phenylalanine-acrylamide, L or D-tyrosine-methacrylamide, L or D-tyrosine-acrylamide, L or D-histadine-methacrylamide, L or D-histadine-acrylamide, L or D-glutamic acid-methacrylamide, L or D-glutamic acid-methacrylamide, L or D-aspartic acid-acrylamide, L or D-aspartic acid-methacrylamide, acrylic acid, 2-carboxyethyl acrylate, mono-2-(methacryloyloxy)ethyl succinate, mono-2-(methacryloyloxy)ethyl maleate, sodium 4-vinylbenzenesulfonate, 2-acrylamido-2-methylpropane sulfonic acid, 2-acrylamido-2-methyl-1-propanesulfonic acid sodium salt, 2-acrylamido-2-methyl-1-propanesulfonic acid, 3-sulfopropyl acrylate potassium salt, 3-sulfopropyl methacrylate potassium salt, 3-vinylbenzoic acid, 4-vinylbenzoic acid, 2-vinylbenzoic acid, 4-(2-propenyl)benzoic acid, 2-methyl-2-propene-1-sulfonic acid sodium salt, vinylsulfonic acid sodium salt, vinylphosphonic acid, and (4-ethenylphenyl)methylphosphonic acid.

17. The polymer of any one of claims 1-14, wherein the anionic repeat unit is the same, and is selected from the group consisting of methacrylic acid (MAA), 2-sulfoethyl methacrylate (SEMA), L-tryptophan-methacrylamide (L-Try-MA), D-tryptophan-methacrylamide, L or D-tryptophan-acrylamide, L or D-alanine-methacrylamide, L or D-alanine-acrylamide, L or D-valine-methacrylamide, L or D-valine-acrylamide, L or D-isoleucine-methacrylamide, L or D-isoleucine-acrylamide, L or D-allo-isoleucine-methacrylamide, L or D-allo-isoleucine-acrylamide, L or D-methionine-methacrylamide, L or D-methionine-acrylamide, L or D-phenylalanine-methacrylamide, L or D-phenylalanine-acrylamide, L or D-tyrosine-methacrylamide, L or D-tyrosine-acrylamide, L or D-histadine-methacrylamide, L or D-histadine-acrylamide, L or D-glutamic acid-methacrylamide, L or D-glutamic acid-methacrylamide, L or D-aspartic acid-acrylamide, L or D-aspartic acid-

methacrylamide, acrylic acid, 2-carboxyethyl acrylate, mono-2-(methacryloyloxy)ethyl succinate, mono-2-(methacryloyloxy)ethyl maleate, sodium 4-vinylbenzenesulfonate, 2-acrylamido-2-methylpropane sulfonic acid, 2-acrylamido-2-methyl-1-propanesulfonic acid sodium salt, 2-acrylamido-2-methyl-1-propanesulfonic acid, 3-sulfopropyl acrylate potassium salt, 3-sulfopropyl methacrylate potassium salt, 3-vinylbenzoic acid, 4-vinylbenzoic acid, 2-vinylbenzoic acid, 4-(2-propenyl)benzoic acid, 2-methyl-2-propene-1-sulfonic acid sodium salt, vinylsulfonic acid sodium salt, vinylphosphonic acid, and (4-ethenylphenyl)methylphosphonic acid.

18. The polymer of claim17, wherein the anionic repeat unit is selected from the group consisting of methacrylic acid (MAA), 2-sulfoethyl methacrylate (SEMA), and L-tryptophan-methacrylamide (L-Try-MA).

19. The polymer of claim 17, wherein the anionic repeat unit is methacrylic acid (MAA).

20. The polymer of claim 17, wherein the anionic repeat unit is 2-sulfoethyl methacrylate (SEMA).

21. The polymer of any one of claims 1- 20, wherein each of the cationic repeat units is a methacrylate, acrylate, methacrylamide, acrylamide, styrene, or vinyl derivative comprising an amine, ammonium, pyridinium, imidazolium, phosphonium, pyrrolidinium, or other ionizable or charged group.

22. The polymer of any one of claims 1- 20, wherein the cationic repeat unit is independently selected from the group consisting of [2-(methacryloyloxy)ethyl]trimethylammonium chloride (MAETA), [3-(methacryloylamino)propyl]trimethylammonium chloride, [2-(acryloyloxy)ethyl]trimethylammonium chloride, (3-acrylamidopropyl)trimethylammonium chloride, 4-vinylbenzyl(triphenyl)phosphonium chloride, (vinylbenzyl)trimethylammonium chloridemethacrylate, 3-vinylaniline, 4-vinylaniline, 2-isopropenylaniline, N-(3-aminopropyl)methacrylamide hydrochloride, N-vinylimidazolium salts, 1-allyl-3-vinylimidazolium salts, 1-allyl-2methyl-5-vinyl-pyridinium salt, 1-allyl-5-vinyl-pyridinium salt, and 1-methyl-1-(1-vinylcyclohexyl)pyrrolidinium iodide.

23. The polymer of any one of claims 1- 20, wherein each of the cationic repeat units is the same, and is selected from the group consisting of [2-(methacryloyloxy)ethyl]trimethylammonium chloride (MAETA), [3-(methacryloylamino)propyl]trimethylammonium chloride, [2-(acryloyloxy)ethyl]trimethylammonium chloride, (3-acrylamidopropyl)trimethylammonium chloride, 4-vinylbenzyl(triphenyl)phosphonium chloride, (vinylbenzyl)trimethylammonium chloridemethacrylate, 3-vinylaniline, 4-vinylaniline, 2-isopropenylaniline, N-(3-aminopropyl)methacrylamide hydrochloride, N-vinylimidazolium salts, 1-allyl-3-vinylimidazolium salts, 1-allyl-2methyl-5-vinyl-pyridinium salt, 1-allyl-5-vinyl-pyridinium salt, and 1-methyl-1-(1-vinylcyclohexyl)pyrrolidinium iodide.

24. The polymer of any one of claims 1- 23, wherein the cationic repeat unit comprises a quaternary ammonium group.

25. The polymer of claim 1, wherein the polymer consists essentially of or consists of:

(a) a plurality of hydrophobic repeat units;

(b) a plurality of a cationic repeat units; and

(c) a plurality of an anionic repeat units;

wherein the hydrophobic repeat units, cationic repeat units, and anionic repeat units are in random or statistical order.

26. A thin film composite membrane, comprising a porous substrate, and a selective layer comprising a polymer of any one of claims 1- 25, wherein an average effective pore size of the porous substrate is larger than an average effective pore size of the selective layer; and the selective layer is disposed on a surface of the porous substrate; and/or

wherein the selective layer has a thickness of about 10 nm to about 10 μm, about 10 nm to about 3 μm, or about 10 nm to about 1 μm.

27. The thin film composite membrane of claim 26, wherein the selective layer has the average effective pore size of about 0.1 nm to about 2.0 nm, about 0.1 nm to about 1.2 nm, or about 0.7 nm to about 1.2 nm.

28. The thin film composite membrane of any one of claims26-27, wherein the net charge of the polymer is positive, and the thin film composite membrane rejects positively charged solutes and salts.

29. The thin film composite membrane of any one of claims 26-27, wherein the net charge of the polymer is negative, and the thin film composite membrane rejects negatively charged solutes and salts.

30. The thin film composite membrane of any one of claims 26-27, wherein the net charge of the polymer is from -10 to +10; and the selective layer exhibits size-based selectivity between uncharged organic molecules.

31. The thin film composite membrane of claim 32, wherein the selective layer exhibits rejection of greater than or equal to about 95% or greater than or equal to about 99% for neutral molecule with hydrated diameter of about or greater than 1.5 nm.

32. The thin film composite membrane of any one of claims 26-31, wherein the selective layer exhibits antifouling properties, resistance to fouling by an oil emulsion, or resistance to fouling by adsorption of bioorganic macromolecules (e.g., proteins, alginate, organic matter).

33. A material with an anti-fouling coating, comprising a solid substrate, and a layer comprising a polymer of any one of claims 1-25, wherein the layer is disposed on a surface of the solid substrate.

34. The anti-fouling coating of claim 33, wherein the layer has a thickness of about 10 nm to about 10 μm, about 10 nm to about 3 μm, or about 10 nm to about 1 μm.

35. A method of purifying a peptide or protein, comprising:

contacting at a first flow rate the thin film composite membrane of any one of claims 26-32 with a mixture comprising one or more peptides or proteins, whereby a portion of the mixture is retained by the thin film composite membrane.

36. A method of removing an organic solute from water, comprising:

contacting at a first flow rate the thin film composite membrane of any one of claims

26-32 with an aqueous solution comprising an organic solute, whereby the organic solute is retained by the thin film composite membrane.

37. A method of decontaminating water, comprising:

contacting at a first flow rate the thin film composite membrane of any one of claims 26-32 with a mixture comprising water and one or more contaminants, whereby one or more contaminants are retained by the thin film composite membrane.

38. A method of size-selective separation, comprising:

contacting at a first flow rate the thin film composite membrane of any one of claims 26-32 with a mixture comprising one or more particles of differing sizes, whereby one or more particles of a particular size are retained by the thin film composite membrane.