CLAIMS

1. A non-naturally occurring microbial organism having carbon monoxide dehydrogenase or hydrogenase activity and a reductive tricarboxylic acid (rTCA) pathway, wherein said microbial organism comprises at least one exogenous nucleic acid encoding a rTCA pathway enzyme expressed in a sufficient amount to convert CO, CO_2 or H_2 to acetyl-CoA, wherein said rTCA enzyme is selected from the group consisting of an ATP citrate-lyase, a citrate lyase, an aconitase, an isocitrate dehydrogenase, an alpha-ketoglutarate:ferredoxin oxidoreductase, a succinyl-CoA synthetase, a succinyl-CoA transferase, a fumarate reductase, a fumarase, and a malate dehydrogenase.

2. A non-naturally occurring microbial organism comprising at least one exogenous nucleic acid encoding an enzyme expressed in a sufficient amount to produce reducing equivalents from carbon monoxide or hydrogen, thereby fixing CO_2 via a rTCA cycle, wherein said at least one exogenous nucleic acid is selected from a carbon monoxide dehydrogenase, a hydrogenase, and an NAD(P)H:ferredoxin oxidoreductase.

3. A non-naturally occurring microbial organism comprising

   a rTCA pathway comprising at least one exogenous nucleic acid encoding a rTCA pathway enzyme expressed in a sufficient amount to convert (i) CO, (ii) CO_2 and H_2, (iii) CO and CO_2, (iv) synthesis gas comprising CO and H_2, or (v) synthesis gas comprising CO, CO_2, and H_2; to acetyl-CoA; wherein said at rTCA pathway enzyme is selected from the group consisting of an ATP citrate-lyase, a citrate lyase, an aconitase, an isocitrate dehydrogenase, an alpha-ketoglutarate:ferredoxin oxidoreductase, a succinyl-CoA synthetase, a succinyl-CoA transferase, a fumarate reductase, a fumarase and a malate dehydrogenase; and

   a reducing equivalent producing pathway comprising at least one exogenous nucleic acid encoding a reducing equivalent producing enzyme selected from the group consisting of a carbon monoxide dehydrogenase, a hydrogenase and a NAD(P)H:ferredoxin oxidoreductase.

4. The non-naturally occurring microbial organism of claim 2 or 3, wherein said microbial organism further comprises a ferredoxin.

5. The non-naturally occurring microbial organism of claim 1 or 3, wherein said rTCA pathway enzyme is selected from the group consisting of an ATP citrate lyase, a citrate lyase, an alpha-ketoglutarate:ferredoxin oxidoreductase, and a fumarate reductase.

6. The non-naturally occurring microbial organism of claim 1 or 3, wherein said rTCA pathway enzyme is an aconitase or an isocitrate dehydrogenase.

7. A non-naturally occurring microbial organism having a (2-hydroxy-3-methyl-4-oxobutoxy)phosphonate pathway, wherein said microbial organism comprises at least one exogenous nucleic acid encoding a (2-hydroxy-3-methyl-4-oxobutoxy)phosphonate pathway enzyme expressed in a sufficient amount to produce (2-hydroxy-3-methyl-4-oxobutoxy)phosphonate, said (2-hydroxy-3-methyl-4-oxobutoxy)phosphonate pathway comprising a 2-C-methyl-D-erythritol-4-phosphate dehydratase.

8. The non-naturally occurring microbial organism of claim 7, wherein

   (i) said (2-hydroxy-3-methyl-4-oxobutoxy)phosphonate pathway further comprises a 1-deoxyxylulose-5-phosphate synthase and/or a 1-deoxy-D-xylulose-5-phosphate reductoisomerase;

   (ii) said microbial organism comprises three exogenous nucleic acids each encoding a (2-hydroxy-3-methyl-4-oxobutoxy)phosphonate pathway enzyme;

   (iii) said microbial organism comprises three exogenous nucleic acids, each encoding a 2-C-methyl-D-erythritol-4-phosphate dehydratase, a 1-deoxyxylulose-5-phosphate synthase and a 1-deoxy-D-xylulose-5-phosphate reductoisomerase;

   (iv) said at least one exogenous nucleic acid is a heterologous nucleic acid; or

   (v) said non-naturally occurring microbial organism is in a substantially anaerobic culture medium.

9. A method for producing (2-hydroxy-3-methyl-4-oxobutoxy)phosphonate, comprising culturing the non-naturally occurring microbial organism of claim 7 or 8 under conditions and for a sufficient period of time to produce (2-hydroxy-3-methyl-4-oxobutoxy)phosphonate.

10. A non-naturally occurring microbial organism having a p-toluate pathway, wherein said microbial organism comprises at least one exogenous nucleic acid encoding a p-toluate pathway enzyme expressed in a sufficient amount to produce p-toluate, said p-toluate pathway comprising a 2-dehydro-3-deoxyphosphoheptonate synthase; a 3-dehydroquinate synthase; a 3-dehydroquinate dehydratase; a shikimate dehydrogenase; a shikimate kinase; a 3-phosphoshikimate-2-carboxyvinyltransferase; chorismate synthase; or a chorismate lyase.

11. The non-naturally occurring microbial organism of claim 10, wherein

(i) said microbial organism comprises two, three, four, five, six, seven or eight exogenous nucleic acids each encoding a p-toluate pathway enzyme;

(ii) said microbial organism comprises eight exogenous nucleic acids, each encoding a 2-dehydro-3-deoxyphosphoheptonate synthase; a 3-dehydroquinate synthase; a 3-dehydroquinate dehydratase; a shikimate dehydrogenase; a shikimate kinase; a 3-phosphoshikimate-2-carboxyvinyltransferase; a chorismate synthase; and a chorismate lyase;

(iii) said microbial organism further comprises a (2-hydroxy-3-methyl-4-oxobutoxy)phosphonate pathway;

(iv) said at least one exogenous nucleic acid is a heterologous nucleic acid; or

(v) said non-naturally occurring microbial organism is in a substantially anaerobic culture medium.

12. The non-naturally occurring microbial organism of claim 11, wherein the (2-hydroxy-3-methyl-4-oxobutoxy)phosphonate pathway comprises a 2-C-methyl-D-erythritol-4-

phosphate dehydratase, a 1-deoxyxylulose-5-phosphate synthase and/or a 1-deoxy-D-xylulose-5-phosphate reductoisomerase.

13. A method for producing p-toluate, comprising culturing the non-naturally occurring microbial organism of any one of claims 10 to 12 under conditions and for a sufficient period of time to produce p-toluate.

14. A non-naturally occurring microbial organism having a terephthalate pathway, wherein said microbial organism comprises at least one exogenous nucleic acid encoding a terephthalate pathway enzyme expressed in a sufficient amount to produce terephthalate, said terephthalate pathway comprising a p-toluate methyl-monooxygenase reductase; a 4-carboxybenzyl alcohol dehydrogenase; or a 4-carboxybenzyl aldehyde dehydrogenase;

and wherein said microbial organism further comprises a p-toluate pathway, wherein said p-toluate pathway comprises a 2-dehydro-3-deoxyphosphoheptonate synthase; a 3-dehydroquinate synthase; a 3-dehydroquinate dehydratase; a shikimate dehydrogenase; a shikimate kinase; a 3-phosphoshikimate-2-carboxyvinyltransferase; and a chorismate synthase; or chorismate lyase.

15. The non-naturally occurring microbial organism of claim 14, wherein

(i) said microbial organism comprises two or three exogenous nucleic acids each encoding a terephthalate pathway enzyme;

(ii) said microbial organism comprises three exogenous nucleic acids, each encoding a p-toluate methyl-monooxygenase reductase; a 4-carboxybenzyl alcohol dehydrogenase; and a 4-carboxybenzyl aldehyde dehydrogenase;

(iii) said p-toluate pathway comprises a 2-dehydro-3-deoxyphosphoheptonate synthase; a 3-dehydroquinate synthase; a 3-dehydroquinate dehydratase; a shikimate dehydrogenase; a shikimate kinase; a 3-phosphoshikimate-2-carboxyvinyltransferase; a chorismate synthase; and a chorismate lyase;

(iv) said microbial organism further comprises a (2-hydroxy-3-methyl-4-oxobutoxy)phosphonate pathway;

(v) said at least one exogenous nucleic acid is a heterologous nucleic acid; or

(vi) said non-naturally occurring microbial organism is in a substantially anaerobic culture medium.

16. The non-naturally occurring microbial organism of claim 15, wherein the (2-hydroxy-3-methyl-4-oxobutoxy)phosphonate pathway comprises a 2-C-methyl-D-erythritol-4-phosphate dehydratase, a 1-deoxyxylulose-5-phosphate synthase and/or a 1-deoxy-D-xylulose-5-phosphate reductoisomerase.

17. A method for producing terephthalate, comprising culturing the non-naturally occurring microbial organism of any one of claims 14 to 16 under conditions and for a sufficient period of time to produce terephthalate.

18. The non-naturally occurring microbial organism of any one of claims 1 to 8, 10 to 12 or 14 to 16, wherein said microbial organism is a species of bacteria, yeast or fungus.

19. A culture medium comprising (2-hydroxy-3-methyl-4-oxobutoxy)phosphonate, wherein said (2-hydroxy-3-methyl-4-oxobutoxy)phosphonate is produced by the non-naturally occurring microbial organism of any one of claims 1 to 8.

20. A biosynthesized (2-hydroxy-3-methyl-4-oxobutoxy)phosphonate.

21. A biosynthesized (2-hydroxy-3-methyl-4-oxobutoxy)phosphonate, wherein said (2-hydroxy-3-methyl-4-oxobutoxy)phosphonate is produced according to the method of claim 9.

22. A chemical compound, polymer, or other product comprising the biosynthesized (2-hydroxy-3-methyl-4-oxobutoxy)phosphonate of claim 20 or 21.

23. Use of the biosynthesized (2-hydroxy-3-methyl-4-oxobutoxy)phosphonate of claim 20 or 21 in the manufacture of a chemical compound, polymer, or other product.

24. The use of claim 23, wherein the manufacture comprises a chemical conversion of the (2-hydroxy-3-methyl-4-oxobutoxy)phosphonate.

25. The use of claim 23, wherein the chemical compound, polymer, or other product is p-toluate or terephthalate.

26. The use of claim 23, wherein the chemical compound, polymer, or other product is a polyethylene terephthalate.

27. The use of claim 23, wherein the chemical compound, polymer, or other product is a clothing, resin, plastic bottle, poultry feed additive, polymer stabilizer, pesticide, light sensitive compound, animal feed supplement or organic chemical.

28. A culture medium comprising p-toluate, wherein said p-toluate is produced by the non-naturally occurring microbial organism of any one of claims 10 to 12.

29. A biosynthesized p-toluate.

30. A biosynthesized p-toluate, wherein said p-toluate is produced according to the method of claim 13.

31. A chemical compound, polymer, or other product comprising the biosynthesized p-toluate of claim 29 or 30.

32. Use of the biosynthesized p-toluate of claim 29 or 30 in the manufacture of a chemical compound, polymer, or other product.

33. The use of claim 32, wherein the manufacture comprises a chemical conversion of the p-toluate.

34. The use of claim 32, wherein the chemical compound, polymer, or other product is terephthalate.

35. The use of claim 32, wherein the chemical compound, polymer, or other product is a polyethylene terephthalate.

36. The use of claim 32, wherein the chemical compound, polymer, or other product is a clothing, resin, plastic bottle, poultry feed additive, polymer stabilizer, pesticide, light sensitive compound, animal feed supplement or organic chemical.

37. A culture medium comprising terephthalate, wherein said terephthalate is produced by the non-naturally occurring microbial organism of any one of claims 14 to 16.

38. A biosynthesized terephthalate.

39. A biosynthesized terephthalate, wherein said terephthalate is produced according to the method of claim 17.

40. A chemical compound, polymer, or other product comprising the biosynthesized terephthalate of claim 38 or 39.

41. Use of the biosynthesized terephthalate of claim 38 or 39 in the manufacture of a chemical compound, polymer, or other product.

42. The use of claim 41, wherein the manufacture comprises a chemical conversion of the terephthalate.

43. The use of claim 41, wherein the chemical compound, polymer, or other product is a polyethylene terephthalate.

44. The use of claim 41, wherein the chemical compound, polymer, or other product is a clothing, resin, plastic bottle, poultry feed additive, polymer stabilizer, pesticide, light sensitive compound, animal feed supplement or organic chemical.

CLAIMS

1. A non-naturally occurring microbial organism having carbon monoxide dehydrogenase or hydrogenase activity and a reductive tricarboxylic acid (rTCA) pathway, wherein said microbial organism comprises (1) at least one exogenous nucleic acid encoding a rTCA pathway enzyme expressed in a sufficient amount to convert CO, CO_2 or H_2 to acetyl-CoA, wherein said rTCA enzyme is selected from the group consisting of an ATP citrate-lyase, a citrate lyase, an aconitase, an isocitrate dehydrogenase, an alpha-ketoglutarate:ferredoxin oxidoreductase, a succinyl-CoA synthetase, a succinyl-CoA transferase, a fumarate reductase, a fumarase, and a malate dehydrogenase; and (2) at least one exogenous nucleic acid encoding a biosynthetic product pathway enzyme expressed in a sufficient amount to produce said biosynthetic product, wherein the microbial organism does not require light for growth.

2. A non-naturally occurring microbial organism comprising

a rTCA pathway comprising at least one exogenous nucleic acid encoding a rTCA pathway enzyme expressed in a sufficient amount to convert (i) CO, (ii) CO_2 and H_2, (iii) CO and CO_2, (iv) synthesis gas comprising CO and H_2, or (v) synthesis gas comprising CO, CO_2, and H_2; to acetyl-CoA; wherein said at rTCA pathway enzyme is selected from the group consisting of an ATP citrate-lyase, a citrate lyase, an aconitase, an isocitrate dehydrogenase, an alpha-ketoglutarate:ferredoxin oxidoreductase, a succinyl-CoA synthetase, a succinyl-CoA transferase, a fumarate reductase, a fumarase and a malate dehydrogenase;

a reducing equivalent producing pathway comprising at least one exogenous nucleic acid encoding a reducing equivalent producing enzyme selected from the group consisting of a carbon monoxide dehydrogenase, a hydrogenase and a NAD(P)H:ferredoxin oxidoreductase; and

at least one exogenous nucleic acid encoding a biosynthetic product pathway enzyme expressed in a sufficient amount to produce a biosynthetic product, wherein the microbial organism does not require acetyl-CoA synthase.

3. The non-naturally occurring microbial organism of claim 1 or 2, wherein said microbial organism further comprises a ferredoxin.

4. The non-naturally occurring microbial organism of claim 1 or 2, wherein said rTCA pathway enzyme is selected from the group consisting of an ATP citrate-lyase, a citrate lyase, an alpha-ketoglutarate:ferredoxin oxidoreductase, and a fumarate reductase.

5. The non-naturally occurring microbial organism of claim 1 or 2, wherein said rTCA pathway enzyme is an aconitase or an isocitrate dehydrogenase.

6. The non-naturally occurring microbial organism of any one of claims 1 to 5, wherein said microbial organism is a species of bacteria, yeast or fungus.

7. A non-naturally occurring microbial organism comprising a reducing equivalent producing pathway comprising at least one exogenous nucleic acid encoding a reducing equivalent producing enzyme selected from the group consisting of a carbon monoxide dehydrogenase, a hydrogenase and a NAD(P)H:ferredoxin oxidoreductase; and

at least one exogenous nucleic acid encoding a biosynthetic product pathway enzyme expressed in a sufficient amount to produce said biosynthetic product, wherein the microbial organism does not require acetyl-CoA synthase.

8. The non-naturally occurring microbial organism of any one of claims 2 to 7 comprising at least one exogenous nucleic acid encoding a reducing equivalent producing enzyme carbon monoxide dehydrogenase.

9. The non-naturally occurring microbial organism of any one of claims 2 to 8 comprising at least one exogenous nucleic acid encoding a reducing equivalent producing enzyme carbon monoxide dehydrogenase and a ferredoxin.