CLAIMS

What is claimed is:

1. A method for separating a heterogeneous population of cells, the method comprising the steps of:

placing a microcapillary channel containing a sample of the heterogeneous population of cells in a magnetically-responsive medium into a levitation system, wherein the system comprises

a set of two magnets producing a magnetic field, wherein a space between the two magnets is sized to receive the microcapillary channel in a horizontal orientation relative to the direction of gravity, wherein the magnetic field is spatially constant over a distance of the microcapillary channel between the two magnets; and

a microscopy device having a stage between the set of two magnets on which the microcapillary channel is placed; and

levitating the heterogeneous population of cells in the magnetically-responsive medium by balancing a magnetic force applied to each of the cells by the magnetic field of the magnets with a corrected gravitational force of the cells in the magnetically-responsive medium, thereby separating the heterogeneous population of cells.

2. The method of claim 1, wherein the heterogeneous population of cells are differentiated from others in at least one of their magnetic susceptibility and cell density, and a cell variant creates this difference, wherein

the cell variant is selected from the group consisting of cell type, cell-cycle stage, malignancy, disease state, activation state, cellular age, infection state, cellular differentiation, apoptosis of the cell, and phagocytosis of the cell.

3. The method of claim 1, further comprising the step of separating individual cells to an equilibrium exhibiting a balance between gravitational forces and magnetic forces on the individual cell.

4. The method of claim 1, wherein the heterogeneous population of cells is selected from a group consisting of red blood cells, leukocytes, lymphocytes, phagocytes, platelets, and cancer cells.

5. The method of claim 1, wherein the levitation system comprises

a first mirror on a first open side of the microcapillary channel and a second mirror on a second open side of the microcapillary channel in which the mirrors are oriented at oblique angles relative to the path between the mirrors, and wherein

the method further comprises the step of reflecting light from a light source within the microscope with the first mirror through the sample of cells and towards the second mirror.

6. The method of claim 1, wherein the microscopy device is an upright fluorescence microscope leveled horizontally on its side, a side-viewing microscope, a cell phone camera, a lensless charged-coupled device (CCD) or complementary metal-oxide semiconductor (CMOS) system, or an inverted microscope.

7. The method of claim 1, wherein the magnetically-responsive medium is a paramagnetic medium and comprises gadolinium.

8. The method of claim 1, wherein the method is performed at the point of care, and wherein the magnetic field does not interfere with mobile devices.

9. The method of claim 1, wherein the magnetic field includes a magnetic field gradient created by electrical magnets using alternating currents.

10. The method of claim 1, wherein the set of two magnets are permanent magnets in an anti-Helmholtz configuration.

11. The method of claim 1, further comprising the step of observing the heterogeneous population of cells are in real time by the microscopy device, the microscopy device providing various images of the heterogeneous population of cells over a duration of time.

12. The method of claim 11, further comprising the steps of altering a physical environment of the heterogeneous population of cells and of observing a response of the heterogeneous population of cells as a result of the physical environment.

13. The method of claim 11, further comprising the steps of introducing a treatment agent into the heterogeneous population of cells and of observing a response of the heterogeneous population of cells as a result of the treatment agent.

14. The method of claim 13, wherein observing a response of the heterogeneous population of cells as a result of the treatment agent includes monitoring a continued response of the heterogeneous population of cells to establish the emergence of resistance of the heterogeneous population of cells to the treatment agent.

15. The method of claim 13, wherein the treatment agent is a drug.

16. The method of claim 13, wherein the treatment agent is an antibiotic.

17. The method of claim 11, wherein individual cells in the heterogeneous population of cells are individually monitored and tracked during the step of observation.

18. The method of claim 11, wherein the step of observation includes monitoring the heterogeneous population of cells during different phases of the cell life cycle.

19. The method of claim 1, wherein the heterogeneous population of cells includes some cells that are infected with a virus.

20. The method of claim 1, wherein the heterogeneous population of cells are levitated in a patient sample.

21. The method of claim 20, wherein the patient sample is blood.

22. The method of claim 20, wherein cancer cells are separated from healthy cells.

23. The method of claim 20, wherein red blood cells are levitated to detect the presence of type I diabetes.

24. The method of claim 1, wherein, during the levitation step, live cells in the heterogeneous population of cells are separated from dead cells.

25. The method of claim 24, wherein, the separation of live cells from dead cells in the heterogeneous population of cells are used to determine the efficacy of a treatment agent.

26. The method of claim 24, wherein, the separation of live cells from dead cells in the heterogeneous population of cells are used to determine the effect of a change in the physical environment on the cells.

27. The method of claim 1, wherein, during the step of separation, different microorganisms are separated from one another.

28. The method of claim 1, where a characteristic of at least some of the heterogeneous population of cells is determined by a measured height of the cells in the microcapillary channel.

29. A method for real-time interrogation of cells, the method comprising the steps of:

placing a microcapillary channel containing a sample of heterogeneous population of cells in a magnetically-responsive medium into a levitation system, wherein the system comprises

a set of two magnets producing a magnetic field, wherein a space between the two magnets is sized to receive the microcapillary channel in a horizontal orientation relative to the direction of gravity, wherein the magnetic field is spatially constant over a distance of the microcapillary channel between the two magnets; and

a microscopy device having a stage between the set of two magnets on which the microcapillary channel is placed; and

levitating the heterogeneous population of cells in the magnetically-responsive medium by balancing a magnetic force applied to each of the cells by the magnetic field of the magnets with a corrected gravitational force of the cells in the magnetically-responsive medium, thereby separating the heterogeneous population of cells; and

altering magnetic properties of the magnetically-responsive medium.

30. The method of claim 29, wherein the heterogeneous population of cells are differentiated from others in at least one of their magnetic susceptibility and cell density, and a cell variant creates this difference, wherein

the cell variant is selected from the group consisting of cell type, cell-cycle stage, malignancy, disease state, activation state, cellular age, infection state, cellular differentiation, apoptosis of the cell, and phagocytosis of the cell.

31. The method of claim 29, further comprising the step of separating individual cells to an equilibrium exhibiting a balance between gravitational forces and magnetic forces on the individual cell.

32. The method of claim 29, wherein the heterogeneous population of cells are selected from a group consisting of red blood cells, leukocytes, lymphocytes, phagocytes, platelets, and cancer cells.

33. The method of claim 29, wherein the levitation system further comprises a first mirror on a first open side of the microcapillary channel and a second mirror on a second open side of the microcapillary channel in which the mirrors are oriented at oblique angles relative to the path between the mirrors, and wherein the method further comprises the step of reflecting light from a light source within the microscope with the first mirror through the sample of cells and towards the second mirror.

34. The method of claim 29, wherein the microscopy device is an upright fluorescence microscope leveled horizontally on its side, a side-viewing microscope, a cell phone camera, a lensless charged-coupled device (CCD) or complementary metal-oxide semiconductor (CMOS) system, or an inverted microscope.

35. The method of claim 29, wherein the step of altering the magnetic properties of the magnetically-responsive medium is accomplished by exposing a paramagnetic medium to a low intensity laser beam.

36. The method of claim 29, wherein the magnetically-responsive medium is a paramagnetic medium and comprises gadolinium.

37. The method of claim 29, wherein the method is performed at the point of care, and wherein the magnetic field does not interfere with mobile devices.

38. The method of claim 29, wherein the magnetic field includes a magnetic field gradient created by electrical magnets using alternating currents.

39. The method of claim 29, wherein the set of two magnets are permanent magnets in an anti-Helmholtz configuration.

40. The method of claim 29, further comprising the step of observing the heterogeneous population of cells are in real time by the microscopy device, the microscopy device providing various images of the heterogeneous population of cells over a duration of time.

41. The method of claim 40, further comprising the steps of altering a physical environment of the heterogeneous population of cells and of observing a response of the heterogeneous population of cells as a result of the physical environment.

42. The method of claim 40, further comprising the steps of introducing a treatment agent into the heterogeneous population of cells and of observing a response of the heterogeneous population of cells as a result of the treatment agent.

43. The method of claim 42, wherein observing a response of the heterogeneous population of cells as a result of the treatment agent includes monitoring a continued response of the heterogeneous population of cells to establish the emergence of resistance of the heterogeneous population of cells to the treatment agent.

44. The method of claim 43, wherein the treatment agent is a drug.

45. The method of claim 43, wherein the treatment agent is an antibiotic.

46. The method of claim 40, wherein individual cells in the heterogeneous population of cells are individually monitored and tracked during the step of observation.

47. The method of claim 40, wherein the step of observation includes monitoring the heterogeneous population of cells during different phases of the cell life cycle.

48. The method of claim 29, wherein the heterogeneous population of cells includes some cells that are infected with a virus.

49. The method of claim 29, wherein the heterogeneous population of cells are levitated in a patient sample.

50. The method of claim 49, wherein the patient sample is blood.

51. The method of claim 49, wherein cancer cells are separated from healthy cells.

52. The method of claim 49, wherein red blood cells are levitated to detect the presence of type I diabetes.

53. The method of claim 29, wherein, during the levitation step, live cells in the heterogeneous population of cells are separated from dead cells.

54. The method of claim 53, wherein, the separation of live cells from dead cells in the heterogeneous population of cells are used to determine the efficacy of a treatment agent.

55. The method of claim 53, wherein, the separation of live cells from dead cells in the heterogeneous population of cells are used to determine the effect of a change in the physical environment on the cells.

56. The method of claim 29, wherein, during the step of separation, different microorganisms are separated from one another.

57. The method of claim 29, where a characteristic of at least some of the heterogeneous population of cells is determined by a measured height of the cells in the microcapillary channel.

58. A levitation system for separating a heterogeneous population of cells, wherein the variances in the cells are based on differences in magnetic susceptibility, the system comprising

a set of two magnets producing a magnetic field, wherein a space between the two magnets is sized to receive a microcapillary channel in a horizontal orientation relative to the direction of gravity, wherein the magnetic field is spatially constant over a distance of the microcapillary channel between the two magnets, and the two magnets are configured to levitate a heterogeneous population of cells in a magnetically responsive medium within a microcapillary channel by balancing a magnetic force applied by the magnetic field with a corrected gravitational force of the cells in the magnetically responsive medium; and

a microscopy device having a stage between the set of two magnets on which the microcapillary channel is placed.

59. The levitation system of claim 58, further comprising

a first gold-coated mirror on a first open side of the microcapillary channel; and

a second gold-coated mirror on a second open side of the microcapillary channel

wherein the gold-coated mirrors are oriented at oblique angles relative to the path between the mirrors.

60. The levitation system of claim 59, wherein the microscopy device is an upright fluorescence microscope leveled horizontally on its side, a side-viewing microscope, a cell phone camera, a lensless charged-coupled device (CCD) or complementary metal-oxide semiconductor (CMOS) system, or an inverted microscope.

61. The levitation system of claim 59, wherein the set of two magnets are electrical magnets.

62. The levitation system of claim 59, wherein the set of two magnets are permanent magnets in an anti-Helmholtz configuration.

63. A method for real-time interrogation of an individual cell, the method comprising the steps of:

placing a microcapillary channel containing a sample including the individual cell in a magnetically-responsive medium into a levitation system, wherein the system comprises

a set of two magnets producing a magnetic field, wherein a space between the two magnets is sized to receive the microcapillary channel in a horizontal orientation relative to the direction of gravity, wherein the magnetic field is spatially constant over a distance of the microcapillary channel between the two magnets; and

a microscopy device having a stage between the set of two magnets on which the microcapillary channel is placed; and

levitating the individual cell in the magnetically-responsive medium by balancing a magnetic force applied to the individual cell by the magnetic field of the magnets with a corrected gravitational force of the individual cell in the magnetically-responsive medium;

observing the individual cell in real time by the microscopy device, the microscopy device providing various images of the individual cell over a duration of time.

64. The method of claim 1, wherein the cell reaches its equilibrium levitation height within the microcapillary within 10 minutes.

65. The method of claim 1, wherein the cell reaches its equilibrium levitation height within the microcapillary within 15 minutes.

66. The method of claim 1, wherein the heterogeneous population of cells are present in a low concentration.

67. The method of claims 7 or 36, wherein the magnetically-responsive medium comprises a gadolinium-based medium wherein gadolinium is present at a concentration of 20 to 100 mM.

68. The levitation system of claim 58, wherein the two magnets are positioned relative to the microcapillary channel such that the magnetic field comprises a magnetic field strength distribution that is symmetric with respect to each axis of the microcapillary channel.