WHAT IS CLAIMED IS

1. A method for live imaging one or more bacterial spores in a sample, the method comprising:

contacting the sample with a probe having a formula $Ln[BD]_n$ wherein Ln is a member of the lanthanide series of elements, BD is a beta-diketone, and n is a whole number integer, to stain one or more bacterial spores in the sample; and

detecting a fluorescent signal from the one or more stained bacterial spores in the sample using a fluorescence microscope,

wherein the imaging comprises producing a video of the sample to observe changes in germination over time.

2. A method for distinguishing germination states of one or more bacterial spores *in situ*, the method comprising:

contacting a sample comprising one or more bacterial spores with a probe having a formula $Ln[BD]_n$, wherein Ln is a member of the lanthanide series of elements, BD is a beta-diketone, and n is a whole number integer, to stain one or more bacterial spores in the sample;

performing signal detection by live imaging fluorescent signal of the sample using a fluorescence microscope; and

distinguishing between dormant bacterial spores and germinating or germinated bacterial spores in the sample;

wherein dormant bacterial spores have a fluorescence signal characterized by a donut-shaped fluorescence profile with a central hollow, and

wherein germinating or germinated bacterial spores have a central core filled with fluorescence.

3. A method for real-time live imaging germination of bacterial spores, the method comprising:

contacting one or more bacterial spores with a germinant probe solution comprising one or more germinants and a probe having a formula $Ln[BD]_n$, wherein Ln is a member of the lanthanide series of elements, BD is a beta-diketone, and n is a whole number integer, to stain one or more bacterial spores in the sample to form a mixture;

mounting the mixture on a slide;
visualizing the morphology of the one or more bacterial spores on the slide using time-lapse phase-contrast microscopy over time; and
imaging fluorescent signals from the one or more bacterial spores on the slide using time-lapse fluoresce microscopy over time,
wherein the real-time live imaging of the germination of the one or more bacterial spores comprises three phase-contrast microscopy phases comprising: 1) a phase bright stage and a 2) phase gray stage of spore germination correlated with the most intense fluorescent signal being localized to regions exterior to the core of the spore, and 3) a phase dark stage of spore germination correlated with the most intense fluorescent signal being localized to the core region of the spore, wherein the phase dark stage indicates bacterial spore germination.

4. The method of claim 2, wherein the signal detection is performed using confocal microscopy,
wherein the optical plane slice images through dormant spores show a hollow region devoid of any fluorescent signal corresponding to the core region of the spore, and
wherein the optical plane slice images through germinated spores show a fluorescent signal in the center of the spore corresponding to the core region of the spore.

5. The method of claim 3, wherein the germinants are one or more of L-cysteine, hypoxanthine, oxyrase, sodium glycocholate, taurocholate, glycine, L-alanine, L-valine, D-valine, or D-cycloserine.

6. The method of any one of claims 1-3, wherein the Ln in the $Ln[BD]_n$ probe is Europium, Samarium, Dysprosium, or Terbium.

7. The method of any one of claims 1-3, wherein the BD in the $Ln[BD]_n$ probe is at least one selected from the group consisting of thenoyltrifluoroacetone (TTA), 1-(-2-Naphthoyl)-3,3,3-trifluoroacetone (NTFA), 4,4,4-Trifluoro-1-phenyl-1,3-butanedione (BTFA), Acetylacetone (AA), 1,1,1 Trifluoroacetylacetone (TriFAA), and 1,1,5,5 Tetrafluoroacetylacetone (TetraFAA).

8. The method of any one of claims 1-3, wherein n in the $Ln[BD]_n$ probe is 1 to 5.

9. The method of any one of claims 1-3, wherein the probe is at least one selected from the group consisting of $Eu[TTA]_3$, $Sm[TTA]_3$, $Dy[TTA]_3$, $Tb[TTA]_3$, $Eu[BTFA]_3$, $Eu[NTFA]_3$, $Eu[AA]_3$, $Eu[TriFAA]_3$, and $Eu[TetraFAA]_3$.

10. The method of any one of claims 1-3, wherein the probe binds to spores from at least one of the *Bacillus* genera, the *Clostridium* genera, or the *Clostridioides* genera.

11. The method of claim 12, where the probe binds spores from at least one of *B. subtilis*, *B. thuringiensis*, *B. cereus*, *C. novyi*-NT type A, *C. difficile*, or *C. septicum*.

12. The method of any one of claims 1-2, comprising performing signal detection using a USB powered microscope, a digital microscope, a confocal microscope, a Raman microscope, or a bright-field microscope.

13. The method of any one of claims 1-3, wherein treatment with the probe does not significantly affect spore viability, outgrowth, or colony-forming ability when compared to untreated spores, or wherein a change in colony forming units (CFU) of the bacterial spores before and after treatment with the probe is less than 0.5 log CFU, or wherein staining with the probe occurs instantaneously or near instantaneously.

14. The method of any one of claims 1-3, wherein the method further comprises contacting the sample with one or more additional probes or dyes and detecting one or more additional signals.

15. The method of any one of claims 1-3, wherein the ratio of Ln to BD in the $Ln[BD]_n$ probe is in the range of 9:1 to 1:9, or wherein the concentration of the probe is in the range of 0.7 mM to 10 mM.

16. The method of any one of claims 1-3, wherein the method does not include a step of spore permeabilization or a step of heating.

17. The method of any one of claims 1-3, wherein spore cortex hydrolysis precedes probe entry into the core.

18. The method of claim 2, comprising using Raman microscopy to distinguish dormant spores showing a double peak profile from germinated spores showing a single peak profile.

19. The method of claim 18, comprising detecting peaks in the double peak profile comprising an inner membrane region and a trough between the peaks coinciding with core region of the spore, and comprising detecting the single peak profile comprising the core of the spore, or wherein there is no statistically significant shift in the Raman profile of the Ln levels of the $Ln[BD]_n$ probe throughout germination, or comprising detecting Dipicolinic Acid (DPA) is not present when the single peak corresponding to the $Ln[BD]_n$ probe in the core region of the spore is present.

20. The method of any one of claims 1-19, wherein the probe is Europium (III) thenoyltrifluoroacetone ($Eu[TTA]_3$), or wherein the fluorescence microscope is equipped with a 4′,6-diamidino-2-phenylindole (DAPI) long-pass filter.

21. The method of any one of claims 1-20, further comprising adding one or more surfactants to the sample.

22. The method of claim 21, wherein the one or more surfactants are 2-[4-(2,4,4-trimethylpentan-2-yl)phenoxy]ethanol, a polysorbate, sodium dodecyl sulfate, or a combination thereof.

23. The method of any one of claims 1-22, further comprising co-staining bacterial spores with Nile Red, DAPI, fluorescein isothiocyanate (FITC)-dextran, or a combination thereof, or monitoring spore bioburden in food or pharmaceutical samples, monitoring spore bioburden in

the environment, or monitoring spore bioburden as a quality assurance step in an industrial process.

24. The method of any one of claims 2-23, wherein the imaging and/or monitoring comprises producing a video of the sample to observe changes in germination over time.

25. A composition comprising a germination probe having a formula $Ln[BD]_n$ wherein Ln is a member of the lanthanide series of elements, BD is a beta-diketone, and n is a whole number integer, and a germinant.

26. The composition of claim 46, wherein the germinant is L-cysteine, hypoxanthine, oxyrase, sodium glycocholate, taurocholate, glycine, L-alanine, L-valine, D-valine, or D-cycloserine.

27. Use of a method for live imaging one or more bacterial spores in a sample, the method comprising:

contacting the sample with a probe having a formula $Ln[BD]_n$ wherein Ln is a member of the lanthanide series of elements, BD is a beta-diketone, and n is a whole number integer, to stain one or more bacterial spores in the sample; and

detecting a fluorescent signal from the one or more stained bacterial spores in the sample using a fluorescence microscope, or the method of any one of claims 2-23, for producing a video of the sample to observe changes in germination over time.

28. Use of a kit comprising a germination probe having a formula $Ln[BD]_n$ wherein Ln is a member of the lanthanide series of elements, BD is a beta-diketone, and n is a whole number integer in a first container, and a germinant in a second container in a method for live imaging one or more bacterial spores in a sample, the method comprising:

contacting the sample with a probe having a formula $Ln[BD]_n$ wherein Ln is a member of the lanthanide series of elements, BD is a beta-diketone, and n is a whole number integer, to stain one or more bacterial spores in the sample; and

detecting a fluorescent signal from the one or more stained bacterial spores in the sample using a fluorescence microscope, or the method of any one of claims 2-23.

29. Use of the composition of any one of claims 46-47 in a method for live imaging one or more bacterial spores in a sample, the method comprising:

contacting the sample with a probe having a formula $Ln[BD]_n$ wherein Ln is a member of the lanthanide series of elements, BD is a beta-diketone, and n is a whole number integer, to stain one or more bacterial spores in the sample; and

detecting a fluorescent signal from the one or more stained bacterial spores in the sample using a fluorescence microscope, or the method of any one of claims 2-23.