

**BASIC DIAGNOSTIC TESTING
PROTOCOLS FOR LEVEL A LABORATORIES**

FOR THE PRESUMPTIVE
IDENTIFICATION OF

Bacillus anthracis

CDC

Centers for Disease Control
and Prevention

ASM

American Society for Microbiology

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Association of Public Health Laboratories

Credits: *Bacillus anthracis*

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I. General information

A. Description of organism

Bacillus anthracis is an aerobic, spore-forming, nonmotile, large, gram-positive rod.

B. History

The first recorded description of anthrax is in the Book of *Genesis*, wherein the disease was referred to as the fifth plague (1491 BC) and was responsible for killing Egyptian cattle. Additional descriptions of anthrax affecting both animals and humans have been recorded in the early literature of Hindus, Greeks, and Romans. A pandemic, referred to as the “black bane,” swept through Europe in the 17th century and was responsible for many animal and human deaths. The human form of disease was later referred to as the “malignant pustule.”

During the 19th century, several distinguished microbiologists characterized the pathologic basis of the disease and attempted to develop a vaccine to combat the problem of anthrax in the livestock industry. The first field-tested vaccine, developed by Pasteur in 1881 as an attenuated spore vaccine, was followed in 1939 by Stern’s development of a vaccine consisting of a spore suspension of an avirulent, nonencapsulated live strain of *B. anthracis*. The vaccine remains in use today for the vaccination of livestock.

The first reports of outbreaks associated with occupational cutaneous and respiratory anthrax occurred in the mid-1800s in the industrialized parts of Europe, namely England and Germany. Cutaneous forms of the disease resulted from handling hides, wool, and hair; aerosol-creating activities such as carding wool (“wool sorter’s disease”) or handling contaminated sacks of dried bones in the production of bonemeal were responsible for the respiratory form of the disease. Early in the 20th century, in the United States, anthrax occurred in individuals who handled materials that had been woven from contaminated animal fibers. Since that time, the number of reported cases in developed countries has steadily declined. This decline can be attributed to the administration of a cell-free anthrax vaccine in individuals who work in a high-risk industry, a decrease in importation of potentially contaminated animal products, improved animal husbandry, and the emphasis placed on the practice of hygiene in industry.

C. Geographic distribution

Although anthrax can be found globally in temperate zones, it is more often a risk in countries with less standardized and less effective public health programs. Areas currently listed as high risk are South and Central America, Southern and Eastern Europe, Asia, Africa, the Caribbean, and the Middle East. Anthrax infrequently occurs in livestock and wildlife in North America; however, anthrax outbreaks have been reported among deer from Texas and among wood buffalo in the Northwest Territory in Canada. Animal infections in the United States are reported most often in Texas and North and South Dakota.

D. Clinical presentation

Humans can become infected with *B. anthracis* by handling products or consuming undercooked meat from infected animals. Infection may also result from inhalation of *B. anthracis* spores from contaminated animal products, such as wool, or the intentional release of spores. Human-to-human transmission has not been reported. Three forms of anthrax occur in humans: cutaneous, gastrointestinal, and inhalational.

- 1. Cutaneous anthrax:** Cutaneous infections occur when the bacterium or spore enters a cut or abrasion on the skin. Skin infection begins as a raised itchy bump or papule that resembles an insect bite. Within 1 to 2 days, the bump develops into a fluid-filled vesicle, which ruptures to form a painless ulcer (called an eschar), usually 1 to 3 cm in diameter, with a characteristic black necrotic (dying) area in the center. Pronounced edema is often associated with the lesions because of the release of edema toxin by *B. anthracis*. Lymph glands in the adjacent area may also swell. Approximately 20% of untreated cases of cutaneous anthrax result in death either because the infection becomes systemic or because of respiratory distress caused by edema in the cervical and upper thoracic regions. Deaths are rare following appropriate antibiotic therapy, with lesions becoming sterile within 24 h and resolving within several weeks.
- 2. Gastrointestinal anthrax:** The gastrointestinal form of anthrax may follow the consumption of contaminated meat from infected animals and is characterized by an acute inflammation of the intestinal tract. Initial signs of nausea, loss of appetite, vomiting, and fever are followed by abdominal pain, vomiting of blood, and severe bloody diarrhea. The mortality rate is difficult to determine for gastrointestinal anthrax, but is estimated to be 25 to 60% if not treated.
- 3. Inhalational anthrax:** Inhalational anthrax results from inhaling *B. anthracis* spores and is most likely following an intentional aerosol release of *B. anthracis*. After an incubation period of 1 to 6 days (depending on the number of inhaled spores), disease onset is gradual and nonspecific. Fever, malaise, and fatigue may be present initially, sometimes in association with a nonproductive cough and mild chest discomfort. These initial symptoms are often followed by a short period of improvement (ranging from several hours to days), followed by the abrupt development of severe respiratory distress with dyspnea (labored breathing), diaphoresis (perspiration), stridor (high-pitched whistling respiration), and cyanosis (bluish skin color). Shock and death usually occur within 24 to 36 h after the onset of respiratory distress, and in later stages, mortality approaches 100% despite aggressive treatment. Physical findings are usually nonspecific. The chest X-ray is often pathognomonic (disease -specific), revealing a widened mediastinum with pleural effusions, but typically without infiltrates.

II. Procedures: *B. anthracis*

A. General: The procedures described below function to rule out or presumptively identify *B. anthracis* from clinical specimens or isolates.

B. Precautions: These procedures should be performed in microbiology laboratories that use Biological Safety Level-2 (BSL-2) practices.

C. Specimens

1. Acceptable specimens: Collect other specimens if/as clinically indicated (e.g., cerebrospinal fluid [CSF], lymph node biopsy)

a. Cutaneous anthrax

- (1) Vesicular stage: Aseptically collect vesicular fluid on sterile swabs from previously unopened vesicles. Note: The anthrax bacilli are most likely to be seen by Gram stain in the vesicular stage.
- (2) Eschar stage: Collect eschar material by carefully lifting the eschar's outer edge; insert a sterile swab, then slowly rotate for 2-3 sec beneath the edge of the eschar without removing it.

b. Gastrointestinal anthrax

- (1) Blood cultures: Collect appropriate blood volume and number of sets per laboratory protocol. In later stages of disease (2-8 days post-exposure) blood cultures may yield the organism, especially if obtained before antibiotic treatment.
- (2) Stool: Transfer ≥ 5 g of stool directly into a clean, dry, sterile, wide-mouth, leak-proof container.
- (3) Rectal swab: For patients unable to pass a specimen, obtain a rectal swab by carefully inserting a swab 1 inch beyond the anal sphincter.

c. Inhalational anthrax

- (1) Blood cultures: Collect appropriate blood volume and number of sets per laboratory protocol.
- (2) Sputum: Collect >1 ml of a lower respiratory specimen into a sterile container. Inhalational anthrax usually does not result in sputum formation.

2. Rejection criteria: Use standard laboratory criteria.

3. Specimen transport and storage: Refer to Shipping Procedure.

- a. Swabs: Transport directly to laboratory at room temperature. For transport time >1 h, transport at 2-8°C.
- b. Stool: Transport unpreserved stool to laboratory within 1 h. For transport time >1 h, transport at 2-8°C.
- c. Sputum: Transport in sterile, screw-capped container at room temperature when transport time is <1 h. For transport time >1 h, transport at 2-8°C.
- d. Blood culture: Transport directly to laboratory at room temperature.

D. Materials

1. Reagents

- a. Gram stain reagents
- b. Catalase reagent (3% hydrogen peroxide)
- c. Motility media (or slide, coverslips, saline for wet mount)
- d. Distilled or deionized water
- e. Sterile saline
- f. India ink (an optional test, refer to Appendix)

2. Media

- a. 5% sheep blood agar (SBA) or equivalent
- b. Chocolate agar (CA)
- c. MacConkey agar (MAC)
- d. Phenyl ethyl alcohol agar (PEA)
- e. Blood culture bottles
- f. Tubed motility media
- g. Thioglycolate broth or equivalent

3. Equipment/miscellaneous

- a. Blood culture instrument (optional)
- b. Light microscope with 10X, 40X and 100X objectives and 10X eyepiece
- c. Microscope slides and coverslips
- d. Disposable bacteriologic inoculating loops
- e. Incubator, 35-37°C, ambient preferred (CO₂ enriched is acceptable)

E. Quality control: Document all quality control results for the following tests per standard laboratory procedure/protocol.

F. Stains and smears: Gram stain

1. Procedure: Perform Gram stain procedure/QC per standard laboratory protocol.

2. Interpretation

- a. *B. anthracis* is a large gram-positive rod (1-1.5 X 3-5 μm).
- b. Blood and impression smears: Vegetative cells seen on Gram stain of blood and impression smears are in short chains of 2-4 cells that are encapsulated, which may be seen on the Gram stain as clear zones around the bacilli. Spores are not present in clinical samples unless exposed to low CO₂ levels, such as those found in ambient atmosphere; higher CO₂ levels within the body inhibit sporulation. The presence of large encapsulated gram-positive rods in the blood is strongly presumptive for *B. anthracis* identification. Refer to Fig. A2.
- c. Growth on SBA or equivalent medium: *B. anthracis* forms oval, central-to-subterminal spores (1 X 1.5 μm) on SBA that do not cause significant swelling of the cell. However, cells from growth on SBA regardless of the incubation conditions (ambient atmosphere or CO₂ enriched) are not encapsulated and occur as long chains of bacilli. Refer to Fig. A3a and Fig. A3b.

G. Cultures

- 1. Inoculation and plating procedure:** Inoculate and streak the following media for isolation of the respective specimen types. Note: Standard media should be used according to normal laboratory procedures.
 - a. Blood cultures: Process following routine laboratory protocol.
 - b. Cutaneous swab specimens: Plate directly on media used routinely for surface wounds such as SBA, MAC, and broth enrichment, and prepare smears for staining. Note: *B. anthracis* does not grow on MAC.
 - c. Stool: Plate directly on appropriate media, such as PEA, SBA, and MAC.
 - d. Sputum specimens: Plate directly on media used routinely, such as SBA, MAC, and CA, and prepare smears for staining.

- 2. Incubation**
 - a. Temperature: 35-37°C
 - b. Atmosphere: Ambient preferred, CO₂ is acceptable.
 - c. Length of incubation: Hold primary plates for at least 3 days; read daily. Examine plates within 18-24 h of incubation. Growth of *B. anthracis* may be observed as early as 8 h after incubation.

- 3. Colony characteristics of *B. anthracis***
 - a. After incubation of SBA plates for 15-24 h at 35-37°C, well isolated colonies of *B. anthracis* are 2-5 mm in diameter. The flat or slightly convex colonies are irregularly round, with edges that are slightly undulate (irregular, wavy border), and have a ground-glass appearance. There may be often comma-shaped projections from the colony edge, producing the "Medusa-head" colony. Refer to Fig. A4.
 - b. *B. anthracis* colonies on SBA usually have a tenacious consistency. When teased with a loop, the growth will stand up like beaten egg white; refer to Fig. A5. In contrast to colonies of *B. cereus* and *B. thuringiensis*, colonies of *B. anthracis* are not β -hemolytic; refer to Fig. A6. However, weak hemolysis may be observed under areas of confluent growth in aging cultures and should not be confused with β -hemolysis.
 - c. When examining primary growth media, it is important to compare the extent of growth on SBA plates with that on MAC. *B. anthracis* grows well on SBA but does not grow on MAC.
 - d. *B. anthracis* grows rapidly; heavily inoculated areas may show growth within 6-8 h and individual colonies may be detected within 12-15 h. This trait can be used to isolate *B. anthracis* from mixed cultures containing slower-growing organisms.

H. Motility test: Wet mount or motility medium

- 1. Purpose:** Used to determine motility of suspected isolates. *B. anthracis* is nonmotile. Two methods are given, the wet mount and the motility medium test.

- 2. Wet mount procedure**
 - a. Deliver 2 drops (approximately 0.1 ml) of sterile distilled water into a sterile glass tube. Using an inoculating loop, transfer a portion of the suspect colony from a 12-20 h culture and suspend the growth in the water.

- b. Alternatively, a loopful of medium from a fresh broth culture can be used.
- c. Transfer 10 µl of the suspension to a microscope slide and overlay with a coverslip.
- d. Examine slide under a microscope using the 40X objective (total magnification 400X; may also be viewed at 1000X with oil objective).
- e. Discard slide(s) following standard laboratory procedures, such as into 0.5% hypochlorite solution.

3. Motility medium test procedure

- a. Using a sterile inoculating needle, remove a portion of growth from an isolated, suspect colony after 18-24 h incubation.
- b. Inoculate the motility medium by carefully stabbing the needle 3-4 cm into the medium and then drawing the needle directly back out so that a single line of inoculum can be observed.
- c. Incubate the tube at 35-37°C in ambient atmosphere for 18-24 h.

4. Interpretation of motility results: Lack of motility is unusual among *Bacillus* spp. and is therefore useful in the preliminary identification of *B. anthracis* isolates.

- a. Wet mount
 - (1) Positive result: Motile organisms will be observed moving throughout the suspension. Observe that the movement may be sluggish/slower than that of the positive controls .
 - (2) Negative result: Nonmotile organisms either do not move or move with Brownian motion.
- b. Motility test
 - (1) Positive result: Motile organisms will form a diffuse growth zone around the inoculum stab.
 - (2) Negative result: Nonmotile organisms, such as *B. anthracis*, will form a single line of growth that does not deviate from the original inoculum stab.

5. Quality control

- a. Positive control strain: *Pseudomonas aeruginosa* ATCC 35032 or laboratory-validated equivalent will demonstrate motility.
- b. Negative control strain: *Acinetobacter* spp. ATCC 49139 or laboratory-validated equivalent will show no motility
- c. Method controls: Perform the test with fresh cultures of the control strains using the same method as with unknowns. Control strains should be assayed on each day of testing.

6. Resolving out-of-control results

- a. Check media, reagents, controls and equipment; replace or correct as appropriate. Document corrective actions and repeat test.
- b. Check purity and identity of control strains and repeat testing.

I. Interpretation and reporting

1. Presumptive identification criteria: Refer to Table A1.

- a. Direct smears from clinical samples, such as blood, CSF, or skin lesion (eschar) material: Encapsulated gram-positive rods
- b. From growth on SBA or equivalent media: Large gram-positive rods (may stain gram-variable after 72 h of culture). Spores may be found in culture, under non-CO₂ atmosphere (but not on direct examination). Spores do not swell the cell and are oval-shaped.
- c. Rapid, aerobic growth, and tenacious colonies on sheep blood agar.
- d. Catalase positive
- e. Nonmotile: In addition to *B. anthracis*, *B. cereus* var. *mycoides* is nonmotile.
- f. Nonhemolytic on SBA, ground-glass appearance of colonies

2. Reporting/action

- a. Consult with state public health laboratory director (or designate) if *B. anthracis* is suspected.
- b. General instruction and information
 - (1) Preserve original specimens pursuant to a potential criminal investigation and possible transfer to an appropriate LRN laboratory.
 - (2) Environmental/nonclinical samples and samples from announced events are not processed by Level A Laboratory; submitter should contact the state public health laboratory directly.
 - (3) The state public health laboratory/state public health department will coordinate notification of local FBI agents as appropriate.
 - (4) Assist local law enforcement efforts in conjunction with guidance received from the state public health laboratory.
 - (5) The state public health laboratory/state public health department may request transfer of suspicious specimens prior to presumptive testing.
 - (g) FBI and state public health laboratory/state public health department will coordinate the transfer of isolates/specimens to a higher-level LRN laboratory as appropriate; refer to Shipping Procedure.
- c. Immediately notify state public health laboratory director (or designate) and state public health department epidemiologist/health officer if *B. anthracis* cannot be ruled out and a bioterrorist event is suspected.
- d. Immediately notify physician/infection control according to internal policies if *B. anthracis* cannot be ruled.
- e. If *B. anthracis* is ruled out, proceed with efforts to identify using established procedures.

III. References

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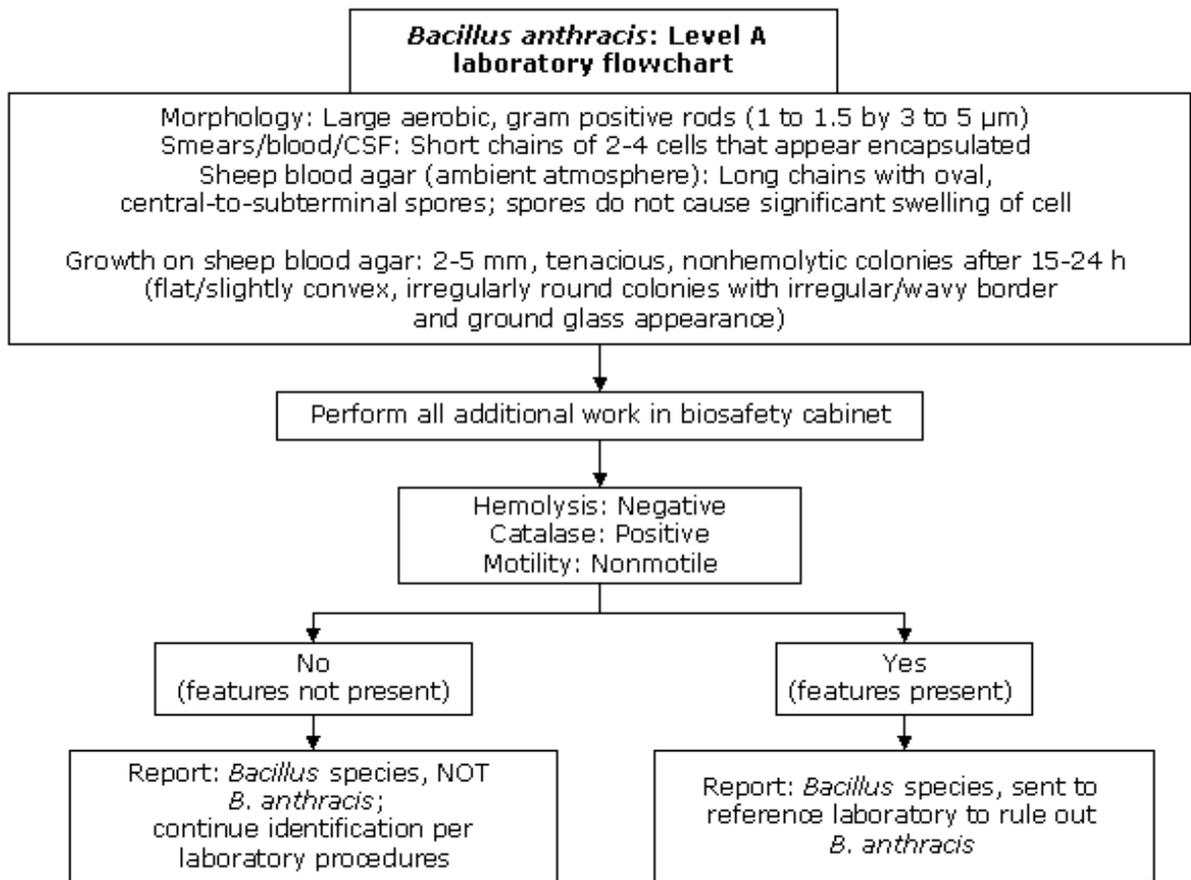


Figure A1: Level A flowchart for *Bacillus anthracis*

Figure A2. Gram stain of *B. anthracis* in rhesus monkey blood, magnification 1000X



Figure A3a. Gram stain of *B. anthracis* from SBA, magnification 1000X



Figure A3b. Gram stain of *B. anthracis* with spores, magnification 1000X

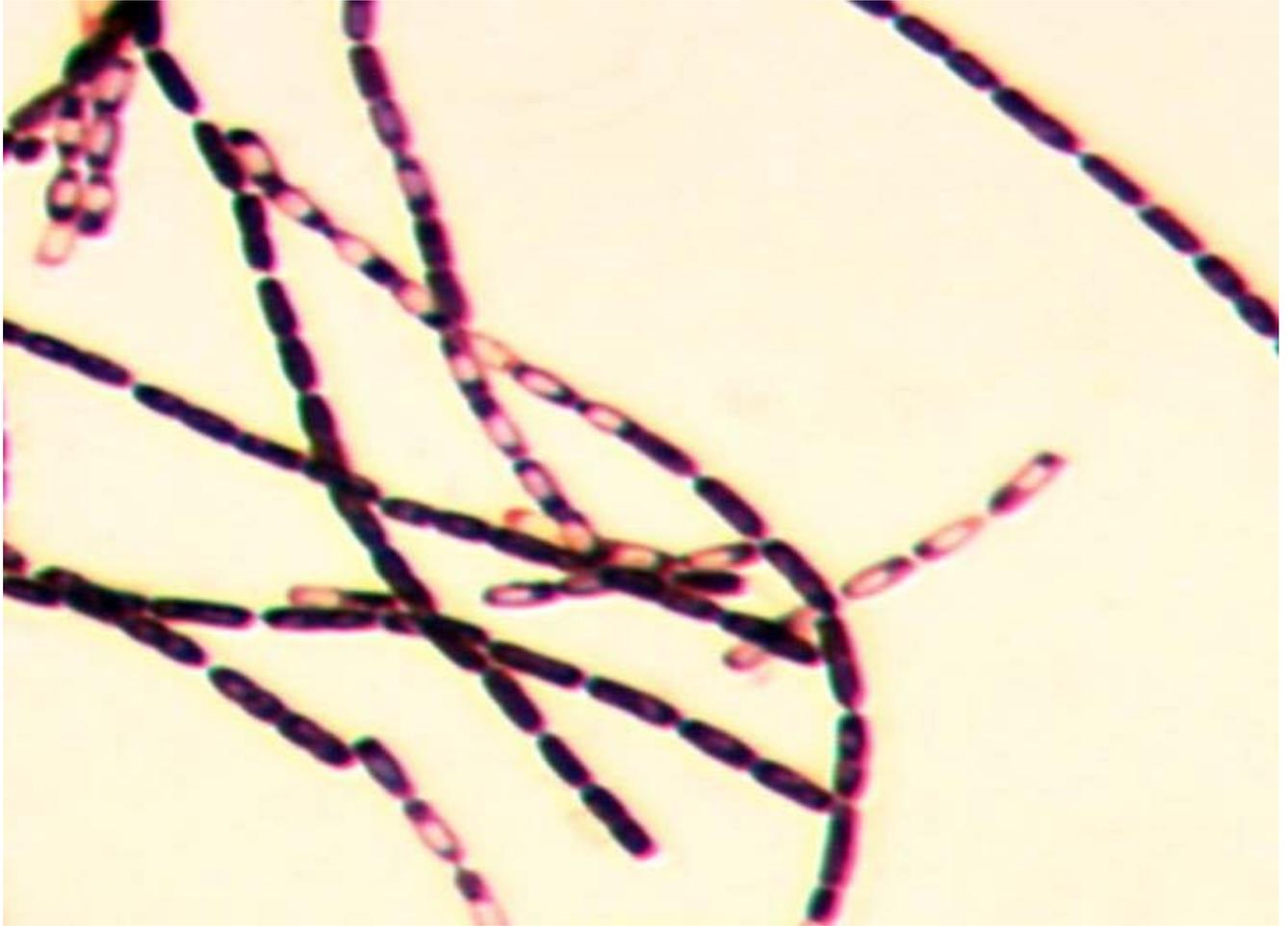


Figure A4. *B. anthracis* colony morphology; overnight cultures on SBA



Figure A5. Tenacious colonies of *B. anthracis* on SBA



Figure A6. *B. anthracis* and *B. cereus* colony morphology; overnight cultures of *B. cereus* (left side of plate) and *B. anthracis* (right side) on SBA.

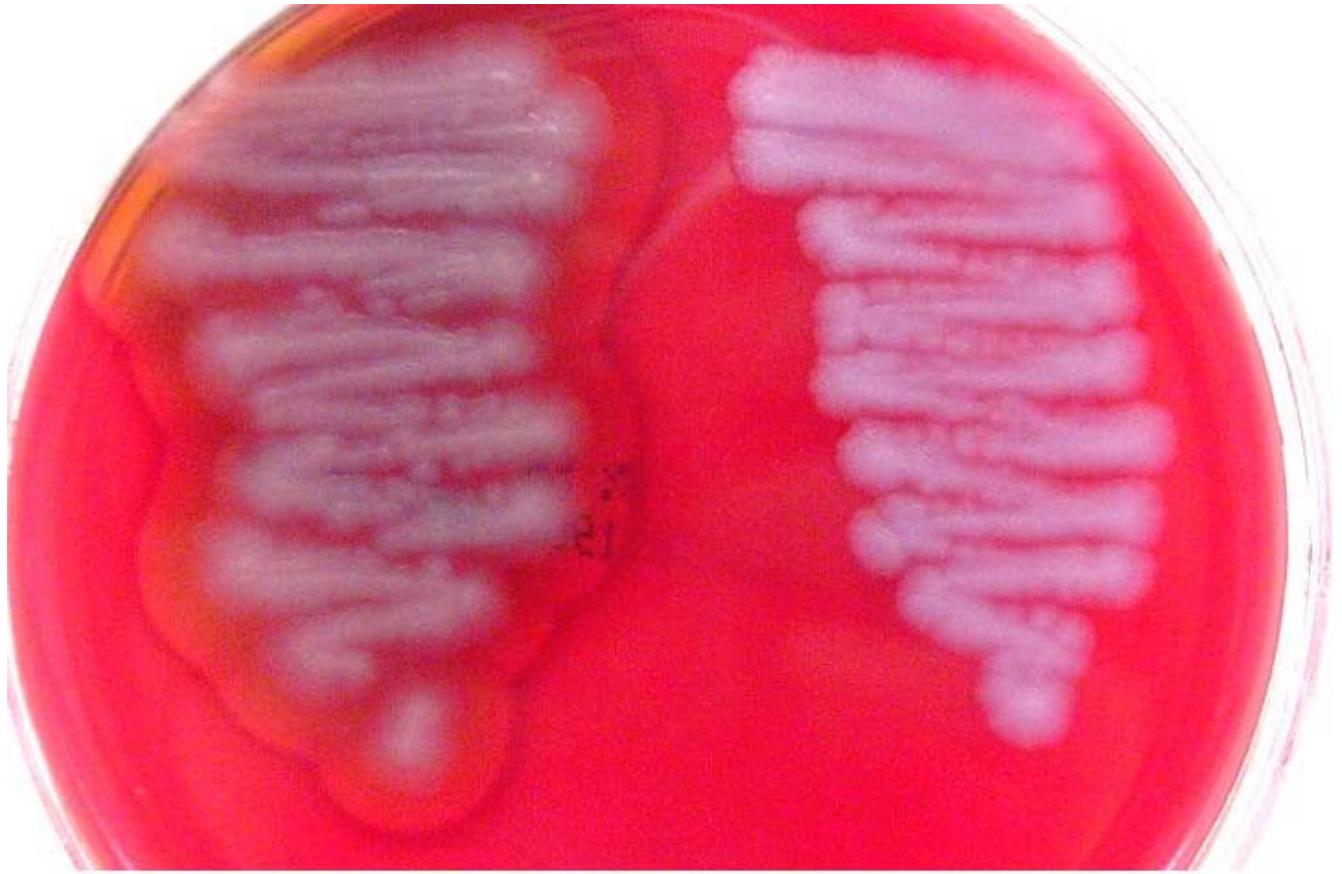


Table A1. Presumptive identification of *Bacillus anthracis*

Lab Level	Type of sample	Presumptive identification	
		Characteristic	Method
A	Clinical sample	1. Gram-positive rods AND 2. Capsule	Gram stain India ink stain
A	Isolate	1 Spore-former AND 2. Colony morphology AND 3. Nonhemolytic AND 4. Nonmotile	Gram stain Observation on SBA Observation on SBA Motility medium or Wet mount

IV. Appendix: India ink stain

A. Purpose: This optional test is used to improve visualization of encapsulated *B. anthracis* in clinical samples such as blood, blood culture bottles, or cerebrospinal fluid (CSF). This is not an ASM recommended procedure; performance of the test requires staff that are trained/experienced with this procedure .

B. Quality control

1. Positive control strain: *Klebsiella pneumoniae* (or laboratory validated equivalent) will demonstrate a well-defined clear zone on SBA.
2. Negative control strain: *E. coli* ATCC 25922 (or laboratory validated equivalent) will demonstrate no clear zone.
3. Method controls: Perform the test with suspensions of fresh cultures of the control strains. Control strains should be assayed on each day of testing.
4. Resolving out-of-control results: Check media, reagents, controls and equipment; replace or correct as appropriate. Document corrective actions and repeat test.

C. Procedure

1. For the controls, transfer a small amount of growth (1 mm diameter) from each control SBA plate (positive control = *Klebsiella pneumoniae*; negative control = *Escherichia coli* ATCC 25922) into 0.5 ml saline and mix.
2. For the unknowns, take 100 µl of sample (blood, CSF). Transfer 5-10 µl of unknown sample or control to a slide. Place a coverslip on the drop, and then add 5-10 µl of India ink to the edge of the coverslip. After the ink diffuses across the slide, view the cells using 100X oil immersion objective with oil on top of the coverslip.

D. Interpretation

1. Positive result: The capsule will appear as a well-defined clear zone around the cells.
2. Negative result: No zone will be present.

E. Reporting/actions

1. Clinical specimens with encapsulated (visualized with India Ink), gram-positive rods provide a presumptive identification of *B. anthracis*; it does not confirm *B. anthracis*.
2. Every effort should be made to obtain an isolate for continued testing and referral to state public health laboratory.

F. Limitations

1. Interpretation of results requires trained/experienced staff.
2. A negative test result should not be used to rule out *B. anthracis*.