

Standard Safety Practices in the Microbiology Laboratory

Laboratorians working with infectious agents are subject to laboratory-acquired infections as a result of accidents or unrecognized incidents. The degree of hazard depends upon the virulence of the biological agent concerned and host resistance. Laboratory-acquired infections occur when microorganisms are inadvertently ingested, inhaled, or introduced into the tissues. Laboratorians are relatively safe when working with *Haemophilus influenzae* and *Streptococcus pneumoniae*; however, persons who work with aerosolized *Neisseria meningitidis* are at increased risk of acquiring a meningococcal infection. The primary laboratory hazard associated with enteric pathogens such as *Shigella*, *Vibrio* or *Salmonella* is accidental ingestion. Biosafety Level 2 (BSL-2) practices are suitable for work involving these agents that present a moderate potential hazard to personnel and the environment. The following requirements have been established for laboratorians working in BSL-2 facilities.

- Laboratory personnel must receive specific training in handling pathogenic agents and be directed by competent scientists.
- Access to the laboratory must be limited when work is being conducted.
- Extreme precautions must be taken with contaminated sharp items.
- Certain procedures involving the creation of infectious aerosols or splashes must be conducted by personnel who are wearing protective clothing and equipment.

Standard microbiological safety practices

The following safety guidelines listed below apply to all microbiology laboratories, regardless of biosafety level.

Limiting access to laboratory

Sometimes, people who do not work in the laboratory attempt to enter the laboratory to look for test results they desire. Although this occurs more frequently in clinical laboratories, access to the laboratory should be limited, regardless of the setting.

Biohazard signs or stickers should be posted near all laboratory doors and on all equipment used for laboratory work (e.g., incubators, hoods, refrigerators, and freezers). Children under 12 years of age and pets are not allowed in laboratory areas. All laboratories should be locked when not in use. In addition, all freezers and refrigerators located in corridors should be locked.

Handwashing

Each laboratory should contain a sink for handwashing. Hands should be washed for at least one minute. Frequent handwashing is one of the most effective procedures for avoiding laboratory-acquired infections. Hands should be washed with an appropriate germicidal soap before exiting the laboratory and after infectious materials are handled. (Laboratorians working with gram-positive organisms should use alcohol (70%) to cleanse their hands if germicidal soap is unavailable.)

Eating

Eating, drinking, and smoking are not permitted in laboratory work areas. Food must be stored and eaten outside of the work area in designated areas used for that purpose only. Personal articles (e.g., handbags, eyeglasses, or wallets) should not be placed on the workstations.

Mouth pipetting

Mouth pipetting is **strictly prohibited** in the laboratory. Rubber bulbs or mechanical devices should be used.

Sharps

A high degree of precaution must always be taken with any contaminated sharp items, including needles and syringes, slides, pipettes, capillary tubes, and scalpels. Dispose of sharps in designated containers. To minimize finger sticks, used disposable needles must not be bent, sheared, broken, recapped, removed from disposable syringes, or otherwise manipulated by hand before disposal. Non-disposable sharps, including syringes, should be placed in a labeled discard pan for decontamination before cleaning. Broken glassware should not be handled directly by hand but should be removed by mechanical means (e.g., a brush and dustpan, tongs, or forceps).

Aerosols

All procedures must be carefully performed to minimize splashes or aerosolization. Techniques that tend to produce aerosols should be avoided. Inoculating wires and

loops should be cooled by holding them still in the air for 5 – 10 seconds before they touch colonies or clinical material. Loops containing infectious material should be dried in the hot air above a burner before flaming. Vortexing and centrifugation should be done in closed containers. (If safety capped tubes are not available, sealed tubes should be used.) Gauze should be used to remove the tops on blood specimens and should be placed around the top of blood culture bottles to minimize aerosol production during removal of the needle. Needles should never be cut or removed from the syringe before autoclaving. All body fluids should be centrifuged in carriers with safety caps only.

When procedures with a high potential for creating infectious aerosols are conducted or when a procedure is used that can result in splashing or spraying of the face with infectious or other hazardous materials, laboratory work should be conducted in a safety cabinet or by laboratorians wearing the appropriate face-protection equipment (e.g., goggles, mask, face shield, or other splatter guards). Procedures that pose a risk may include centrifuging, grinding, blending, vigorous shaking or mixing, sonic disruption, opening containers of infectious materials whose internal pressures may be different from ambient pressures, inoculating animals intranasally, and harvesting infected tissues from animals or eggs. Face protection should also be used when working with high concentrations or large volumes of infectious agents.

Decontaminating bench tops and other surfaces

Bench tops should be wiped with a disinfectant (a phenolic disinfectant, 1% sodium hypochlorite [bleach], or 70% isopropyl alcohol) routinely after working with infectious agents or clinical specimens or after spills, splashes, or other contamination by infectious materials. Solutions of disinfectants should be maintained at the work station (see *Disinfectants*).

Disposal of contaminated materials

All discarded plates, tubes, clinical samples, and other contaminated materials should be placed in disposal containers at each bench. Special disposal boxes must be used for sharps (e.g., syringes or broken glass) to minimize the risk of injury. Avoid overfilling such containers. Containers of contaminated material should be carefully transported to the autoclave room and autoclaved before disposal.

Autoclaving

An autoclave must be available for the BSL-2/3 laboratory and must be operated only by personnel who have been properly trained in its use. To verify that each autoclave is working properly, spore strips or other biological indicators designed to test for efficiency of sterilization should be included in autoclave loads on a

regular basis. Each autoclave load should be monitored with temperature-sensitive tape, thermograph, or by other means (e.g., biological indicators).

General laboratory policies

All areas of the laboratory must be kept clean and orderly. Dirt, dust, crowding, or clutter is a safety hazard and is not consistent with acceptable biological research. Floors should be kept clean and free of unnecessary clutter. They should be washed with a germicidal solution on a regular basis and after any spill of infectious material has occurred.

Refrigerators and freezers

Refrigerators and freezers should be regularly inspected for the presence of broken vials or tubes containing infectious agents. When removing and discarding broken material, laboratorians should wear gloves and proper protective attire (e.g., laboratory coat, goggles, or face-shield). Refrigerators and freezers should be regularly cleaned with a disinfectant and defrosted to prevent possible contamination and temperature failure.

Fire prevention

Burners should be used away from lamps and flammable materials. Bulk flammable material must be stored in the safety cabinet. Small amounts of these flammable materials (e.g., ethyl acetate, ethyl alcohol, and methanol) can be stored in safety containers. Burners must be turned off when not in use. All laboratorians must know the location of fire extinguishers, fire blankets, and showers, and fire safety instructions and evacuation routes should be posted.

Special practices

Transport of biohazardous materials

Transport of biohazardous materials from one building to another increases the risk of breakage and spills. If transport is necessary, the primary infectious agent container (regardless of size) must be placed in an unbreakable second container that can be sealed (e.g., using a screw-top tube or a plastic bag).

Disinfectants

Organisms may have different susceptibilities to various disinfectants. As a surface disinfectant, 70% alcohol is generally effective for the *Enterobacteriaceae*, but other organisms are more resistant. However, 70% isopropyl alcohol is not the

disinfectant of choice for decontaminating spills. Phenolic disinfectants, although expensive, are usually effective against many organisms. Always read disinfectant labels for manufacturers' recommendations for dilution and for exposure times for efficacy, especially before use on BSL-3 organisms (e.g., *Mycobacterium tuberculosis*). **A effective general disinfectant is a 1:100 (1%) dilution of household bleach (sodium hypochlorite) in water; at this dilution, bleach can be used for wiping surfaces of benches, hoods and other equipment.** A 1:10 (10%) dilution of bleach is corrosive and will pit stainless steel and should not be used routinely; however, the 10% bleach solution may be used to clean up spills of cultured or concentrated infectious material where heavy contamination has occurred. If sodium hypochlorite is used as a disinfectant, the standard 1% dilutions should be made **daily** from a stock solution.

Decontamination of spills

The following procedure is recommended for decontaminating spills.

- Isolate the area to prevent anyone from entering.
- Wear gloves and protective clothing (e.g., a gown or lab coat, shoes, and a mask [if the spill may contain a respiratory agent or if the agent is unknown]).
- Absorb or cover the spill with disposable towels.
- Saturate the towels with an appropriately diluted intermediate or high-level disinfectant (e.g., a phenolic formulation or household bleach).
- Place disinfectant-soaked towels over the area and leave them in place for at least 15 minutes before removing and discarding them.
- Wipe area using clean disinfectant-soaked towels and allow area to air dry.
- Place all disposable materials used to decontaminate the spill into a biohazard container.
- Handle the material in the same manner as other infectious waste.

Accidents

All injuries or unusual incidents should be reported immediately to the supervisor. When cuts or puncture wounds from potentially infected needles or glassware occur, the affected area should be promptly washed with disinfectant soap and water for 15 minutes. In the event of a centrifuge accident in which safety carriers have not been used, other personnel in the area should be warned immediately and the area isolated to prevent anyone from entering.

Protective clothing and equipment

Laboratory coats

Protective coats, gowns, smocks, or uniforms designated for laboratory use must be worn while working in the laboratory. Laboratory coats should fit properly and should cover arms to the wrist. This protective clothing should be removed and left in the laboratory before leaving for non-laboratory areas. All protective clothing is either disposed of in the laboratory or laundered by the institution; it should never be taken home by personnel.

Gloves

Regardless of the type of infectious material, gloves should be worn when performing potentially hazardous procedures (e.g., slide agglutination) in which there is a risk of splashing or skin contamination or when the laboratory worker has cuts or broken skin on his or her hands. Gloves should always be worn when handling clinical specimens, body fluids, and tissues from humans and animals. These tissues should be assumed to be positive for hepatitis B virus, human immunodeficiency virus (HIV), other bloodborne pathogens, and *M. tuberculosis*. Gloves must be removed when contaminated by splashing or spills or when work with infectious materials is completed. Gloves should not be worn outside the laboratory. Personnel should not use the telephone or open doors with gloves that have been used in laboratory procedures. All used gloves should be disposed of by discarding them with other disposable materials and autoclaving. **Hands should be washed immediately after removing gloves.**

Barrier precautions

Clinical specimens, body fluids, and tissues from humans and animals should be assumed to be positive for hepatitis B virus, HIV, other bloodborne pathogens, and *M. tuberculosis*. These materials should be handled in a safety cabinet or using other barrier precautions (e.g., goggles, mask, face shield, or other splatter guards) whenever a procedure is performed that can potentially create an aerosol.

Useful biosafety references for the laboratory

- Centers for Disease Control and Prevention, National Institutes of Health. *Biosafety in microbiological and biomedical laboratories*. Washington, DC: U.S. Government Printing Office; 1999: stock no. 017-040-00547-4.
- World Health Organization. *Laboratory Biosafety Manual*, 2nd edition. Geneva: WHO; 1993: ISBN 92 4 154450 3.

Media, Reagents, and Quality Control

Each laboratory must ensure adequate control of the media and reagents it uses. Quality control (QC) includes the selection of satisfactory reagents, the preparation of media according to approved formulations or specific manufacturer's instructions, and the use of well-characterized reference strains to check prepared media. The World Health Organization (WHO) encourages central public health laboratories to participate in at least three external quality assessment surveys per year; for reference laboratories, this may involve an international testing scheme. National central laboratories (reference laboratories) should work to standardize procedures of regional and local laboratories to their own, so that observations can be interpreted in the same manner across sites.

Quality control of media

A summary of considerations for quality control of media, methods, and sources of quality control strains follows:

1) Considerations for quality control of media

Each batch of medium prepared from individual ingredients or each different manufacturer's lot number of dehydrated medium should be tested for sterility, the ability to support growth of the target organism(s), and/or the ability to produce appropriate biochemical reactions, as appropriate.

Sterility

- Incubate one tube or plate from each autoclaved or filter-sterilized batch of medium overnight at 35°–37°C and examine it for contaminants.

Ability to support growth of the target organism(s)

- Use at least one strain to test for ability of selective media to support growth of the target pathogen (e.g., for MacConkey agar, a *Shigella* strain such as *S. flexneri*). Documentation should be made regarding whether this strain produces the appropriate biochemical reactions / color on the test medium.

(Discussions of specific biochemical reactions are included in the media section of this appendix.)

Ability to produce appropriate biochemical reactions

- **For selective media:** Use at least one organism that will grow on the medium and at least one organism that will not grow on the selective medium to test for the medium's ability to differentiate target organisms from competitors. If the medium is both selective and differential, it may be useful to include two organisms that will grow on the medium and produce different reactions (e.g., for MacConkey agar: a lactose-nonfermenting organism such as *S. flexneri*; a lactose-fermenting organism such as *E. coli*; and, *S. aureus*, which should not grow).
- **For biochemical media:** Use at least one organism that will produce a positive reaction and at least one organism that will produce a negative reaction (e.g., for urea medium, a urease-positive organism such as *Proteus* and a urease-negative organism such as *E. coli*).

2) Methods for quality control of media

When testing for ability of a medium to support growth, a small inoculum will give greater assurance that the medium is adequate for recovery of a small number of organisms from a clinical specimen; therefore, use a dilute suspension of control organisms to inoculate the medium for QC. An example of a protocol for quality control of media follows here:

- a) Inoculate the control strain to nonselective broth (e.g., a tryptone-based soy broth [TSB]) and incubate / grow overnight.
- b) Prepare a standardized inoculum for testing the medium. The appropriate standard dilution differs for selective and nonselective media.
 - **If testing selective or inhibitory media:** To prepare a standardized inoculum for testing selective and inhibitory media, make a 1:10 dilution of the overnight nonselective broth culture.
 - **If testing nonselective media:** To prepare a standardized inoculum for testing nonselective media, make a 1:100 dilution of the nonselective broth culture.
- c) Using a calibrated loop, if available, inoculate one tube or plate of each medium with a loopful of the standardized inoculum of the control strain(s). (If performing QC of plating medium, streak for isolation.) The same loop should be used for all QC of all media; it is more important to have the consistency of the same inoculating loop every time than it is to use a calibrated loop.

- **If testing selective or inhibitory media:** A nonselective plating medium (e.g., heart infusion agar [HIA]) should be inoculated at the same time as the selective medium for comparison purposes.

3) Sources of quality control strains

Suitable QC strains may be obtained in the following ways.

- A laboratory may use strains isolated from clinical specimens or quality assurance specimens, provided the strains have been well characterized by all available methods (e.g., biochemical, morphologic, serologic, and molecular).
- Many laboratories purchase QC strains from official culture collections (e.g., the American Type Culture Collection [ATCC] and the National Collection of Type Cultures [NCTC]).³⁴ (Addresses for ATCC and NCTC are included in Appendix 13.)

Quality control strains appropriate for antimicrobial susceptibility testing as included in this manual

The following ATCC numbers can be used to identify the appropriate antimicrobial susceptibility testing QC organisms included in this laboratory manual.

<i>Haemophilus influenzae</i>	<i>H. influenzae</i> ATCC 49247 * (* for testing of the antimicrobial agents included in this laboratory manual)
<i>Neisseria meningitidis</i>	<i>S. pneumoniae</i> ATCC 49619
<i>Streptococcus pneumoniae</i>	<i>S. pneumoniae</i> ATCC 49619
<i>Neisseria gonorrhoeae</i>	<i>N. gonorrhoeae</i> ATCC 49226 (other reference strains, available from CDC, may be used when testing antimicrobial agents not included in NCCLS criteria)
<i>Salmonella</i> serotype Typhi	<i>E. coli</i> ATCC 25922
<i>Shigella</i>	<i>E. coli</i> ATCC 25922
<i>Vibrio cholerae</i>	<i>E. coli</i> ATCC 25922

³⁴ This manual presents the ATCC numbers for quality control organisms, but these ATCC strains may also be obtained from the NCTC.

Quality control of reagents

As with all other products used in testing, reagents (whether purchased or prepared in the laboratory) should be clearly marked to indicate the date on which they were first opened and the expiration date, if appropriate. Each reagent should be tested to make sure the expected reactions are obtained.

If the reagent is a rare, expensive, or difficult-to-obtain product (e.g., diagnostic antiserum) it does not necessarily have to be discarded on the expiration date. If satisfactory sensitivity and specificity can still be verified by normal QC procedures, the laboratory may indicate on the vial label the date of verification of quality of the reagent. All reagents should be tested for quality at intervals established by each laboratory to ensure that no deterioration has occurred; if the quality of the reagent is being verified after the expiration date, testing should be performed more frequently.

Slide agglutination method for quality control of antisera

For QC of antiserum, two or more control strains (one positive and one negative) should be used to test the agglutination characteristics of the antiserum. The results of all reactions should be recorded. Following is an example of a typical QC procedure.

- Place a drop (about 0.05 ml, though as little as 10 µl can be used) of each antiserum on a slide or plate. Also, place a drop of 0.85% saline on each slide or plate to test each antigen for roughness or autoagglutination.
- Prepare a densely turbid suspension (2 or 3 McFarland turbidity standard, see Table 21) of each control isolate in 0.85% saline with growth aseptically harvested from an 18- to 24-hour culture from nonselective agar (e.g., HIA or tryptone soy agar [TSA]).
- Add one drop of the antigen suspension to the antiserum and the saline. Mix thoroughly with an applicator stick, glass rod, or inoculating loop. Rock the slide back and forth for 1 minute.
- Read the agglutination reaction over a light box or an indirect light source with a dark background. The saline control must be negative for agglutination for the test to be valid.

The degree of agglutination should be read and recorded as follows:

Percentage of agglutination:	Record reaction as:
100%	4+
75%	3+
50%	2+
25%	1+
0%	negative

Advantages of centralized acquisition of media and reagents

Centralizing acquisition of media and reagents in the national reference laboratory or Ministry of Health can provide several benefits:

- Large amounts of a single lot of medium or reagent can be purchased and subsequently divided into smaller aliquots for distribution to provincial/district laboratories. This may be more cost effective because of, *e.g.*, discounts for larger orders, lower shipping costs, less waste because of product going past expiration date, etc.
- Quality control can be performed in the central laboratory, avoiding duplication of effort among provincial and district laboratories. An unsatisfactory medium or reagent can then be returned to the manufacturer before the lot is distributed to other laboratories.
- The standardization of methods among laboratories at all levels is facilitated by use of single lots of media.

Preparation of media and reagents

Each manufacturer's lot number of commercial dehydrated medium and each batch of medium prepared from individual ingredients should be quality controlled before use. Immediately after preparation, each medium should be tested, as appropriate, with a reference strain of *H. influenzae*, *N. meningitidis*, *S. pneumoniae*, *N. gonorrhoeae*, *S. Typhi*, *Shigella*, and/or *V. cholerae* O1/O139 for proper growth characteristics as described for each medium.

A record of all media preparation or purchase dates and quality control test results should be kept, and any unusual characteristic (*e.g.*, the color of the medium or slow growth of test bacteria) should be noted.

Many media call for the use of defibrinated blood. Defibrinated blood can be prepared mechanically by swirling 30 ml blood and (*e.g.*) sterile glass beads or a wooden-stick device in a 125–250 ml Erlenmeyer flask at approximately 90 rpm for 7–9 minutes. (Sterile paper clips in a flask can also serve to assist in defibrination.) Blood is defibrinated when clotting factors have been removed; they will be visible in the flask as a translucent, fibrous “web.” (A useful reference for “low-technology” methods to defibrinate blood is in a publication by Kay *et al.* [1986], and is included in Appendix 15.)

Agar media should be dispensed into 15 x 100-mm or 15 x 150-mm Petri dishes to a uniform depth of 3–4 mm; approximately 20-ml of liquid agar medium will achieve this depth in a 15 x 100-mm plate. If agar is cooled to 50°C prior to pouring, condensation is minimized. After pouring, the plates should be kept at

room temperature for several hours to prevent excess condensation from forming on the covers of the dishes. Another means by which condensation will be reduced is if plates are stacked so that they cool more slowly. Alternatively, if when preparing **selective** media (e.g., MacConkey [MAC], xylose lysine desoxycholate [XLD], thiosulfate citrate bile salts [TCBS] agar, etc.), conditions are such that there is little chance that the cooling media will be contaminated, after the agar is poured into the plates, the lids can be placed on the dish so that a small opening is left to let the heat out, resulting in the formation of less condensation on the upper lid; the lid should remain slightly open like this for approximately 30 minutes, while the agar solidifies. If, however, it is likely that the agar will be contaminated if the lid is left partly open, the agar should be allowed to solidify with the lid closed.

Note: Covering the agar while it is still hot will allow for the formation of a substantial amount of condensation on the upper lid. If the plates contain condensation, the plates should be covered at room temperature for 24 hours to allow the condensation to evaporate. After condensation has evaporated, the plates should be placed in an inverted position and stored in a plastic bag in an inverted position at 4°C.

Media for enrichment, identification, and antimicrobial susceptibility testing

Some of the culture media included in this manual are commonly referred to by their abbreviations rather than their full names. Therefore, when these media are mentioned in the methods for the preparation or quality control of other media in this section, they are referred to by their abbreviations.

Name of commonly abbreviated culture medium	Abbreviation
Alkaline peptone water	APW
Bismuth sulfite agar	BS
Cystine trypticase agar	CTA
Desoxycholate citrate agar	DCA
Gram-negative broth	GN
Hektoen enteric agar	HE
Heart infusion agar	HIA
<i>Haemophilus</i> test medium	HTM
Kligler iron agar	KIA
Lysine iron agar	LIA
MacConkey agar	MAC
Martin-Lewis agar	ML
Modified Thayer-Martin agar	MTM

Name of commonly abbreviated culture medium, continued Abbreviation

Phosphate buffered saline	PBS
Selenite broth	SEL
Sulfide-indole-motility medium	SIM
<i>Salmonella-Shigella</i> agar	SS
Thiosulfate citrate bile salts sucrose agar	TCBS
Tryptone (Trypticase) soy agar	TSA
Tryptone (Trypticase) soy broth	TSB
Triple sugar iron agar	TSI
Xylose lysine desoxycholate agar	XLD

Methods for the preparation of media (from individual ingredients or commercially available preparations) follow, in alphabetical order.

Acidometric agar

This agar may be used to test *H. influenzae* for β -lactamase if nitrocefin is not available.

Distilled water	100 ml
Agar	1.5 g
0.5% phenol red solution	0.2 ml
NaOH (1 Normal)	
Penicillin G powder (to prepare a 5000 unit/ml concentration)	

Combine distilled water, agar, and phenol red solution and boil until the agar dissolves. Adjust the pH of the solution with NaOH until the pH is in the range of 8.5 – 9.0. Dispense into 20-ml tubes and cool in a water bath to 50°–55°C. Add penicillin G powder (to yield a concentration of 5000 unit/ml) to the tube and vortex (or mix well). Re-check the pH for the proper range, pour the contents of the tube into a Petri plate and allow it to solidify.

Quality control:

- The acidometric agar surrounding β -lactamase-positive colonies will be yellow in color after incubation for one hour at 35°C.
- The acidometric agar surrounding β -lactamase-negative colonies will exhibit no color change after incubation for one hour at 35°C.

Alkaline peptone water (APW)

Alkaline peptone water (APW) can be used to enhance the recovery of *V. cholerae* when there are few organisms present. [**Note:** There are several different published formulations for this medium.]

Peptone	10.0 g
NaCl	10.0 g
Distilled water	1000.0 ml

Add ingredients to the water and adjust to pH 8.5 with 3 M NaOH solution. Distribute into jars, bottles, or tubes, and autoclave at 121°C for 15 minutes. Store at 4°C for up to 6 months, making sure containers' caps are tightly closed to prevent a drop in pH or evaporation.

- **Peptone water** differs from APW in that it does not have added salt, nor is the pH adjusted to 8.5. Add 10 g of peptone to 1000 ml of distilled water; distribute, autoclave and store as previously described for APW.

Quality control: When inoculated into alkaline peptone water for quality control, *V. cholerae* O1 should show good growth at 6–8 hours.

Bismuth sulfite agar (BS)

Bismuth sulfite agar (BS), which is highly selective, is the preferred medium for isolation of *S. Typhi*. However, **bismuth sulfite agar should not be used for isolation of *S. Typhi* if it has been stored for more than 24–36 hours**. BS has been reported to inhibit *Salmonella* serotypes other than *S. Typhi* unless it is refrigerated at 4°C for at least 24 hours before use. When culturing fecal specimens from suspected typhoid carriers, the use of a BS pour plate may enhance isolation.

Prepare according to manufacturer's instructions. [**Note:** Several commercial brands of bismuth sulfite agar are available. This medium can also be prepared from individual ingredients, but results may be much more variable than with a commercial dehydrated formulation.] Heat to boiling to dissolve, but avoid overheating (*i.e.*, once dissolved, remove from heat). Do not autoclave.

For preparation of BS streak plates:

When cool enough to pour, dispense the BS medium into plates. Plates can be stored at 4°C for up to 1 week if BS will not be used to isolate *S. Typhi*.

For preparation of BS pour plates:

For pour plates, the BS agar must be boiled and cooled to 50°C in a water bath. A 5-ml quantity of fecal suspension is added to a Petri plate, after which approximately 20 ml of cooled BS is immediately poured into the plate. The plate is swirled to mix the fecal suspension and the BS agar, and the plate is left to harden.

Quality control: The following organisms should be adequate for quality control of BS agar:

- *S. Typhi* should produce excellent growth of black colonies with a metallic sheen;

- *E. coli* should grow poorly, if at all, and will appear as brown to green colonies.

Blood agar: TSA with 5% sheep blood

Sheep blood agar is used as a general blood agar medium, and consists of TSA plus 5% sheep's blood. The sheep blood agar plate should appear a bright red color. If the plates appear dark red, the blood has been added when the agar was too hot; if this happens, the medium should be discarded and a new batch prepared.

- Prepare TSA according to the instructions given on the label of the dehydrated powder. For convenience, 500 ml of molten agar can be prepared in a 1-liter flask. Add 20 g of agar into 500 ml of water. Heat to dissolve.
- Autoclave at 121°C for 20 minutes. Cool to 60°C.
- Add 5% sterile, defibrinated sheep blood (*i.e.*, add 25 ml sheep blood to 500 ml of agar). If a different volume of basal medium is prepared, the amount of blood added must be adjusted accordingly to 5% (*e.g.*, 50 ml of blood per liter of medium).
- Dispense 20 ml into 15 x 100-mm Petri dishes. Allow the medium to solidify and dry out, place in a plastic bag, and store at 4°C.

Quality control: Test each new, freshly prepared or purchased batch of blood agar plates for growth and hemolytic reaction with a strain of *S. pneumoniae*. The colonies are small and should appear grey to grey-green surrounded by a distinct greenish halo in the agar (Figure 56).

Blood culture broth

Blood culture broth contains TSB and sodium polyanetholesulfonate (SPS).

- Follow the instructions of the manufacturer on the label of each bottle of dehydrated trypticase soy broth.
- Add 0.25 g SPS per liter of medium. SPS is especially important for recovery of *H. influenzae* since it prevents the inoculated blood from clotting.
- Dispense in 20-ml (pediatric blood culture bottle) and 50-ml (adult blood culture bottle) amounts into suitable containers (*e.g.*, tubes or bottles) with screw-caps with rubber diaphragms. The amount of liquid in the containers should comprise at least two-thirds of the total volume of the container.
- Sterilize by autoclaving at 121°C for 15 minutes. Cool and store medium at room temperature.

Quality control: Each new batch of freshly prepared or purchased blood culture medium should be tested for supporting the growth of a variety of pathogens

including, e.g., *H. influenzae*, *N. meningitidis*, *S. pneumoniae*, and *S. Typhi*. Add 1–3 ml of sterile rabbit, horse, or human blood to three bottles of freshly prepared blood culture medium. A fresh culture of each of the three bacteria should be inoculated into separate blood culture bottles. Make a dilute suspension of growth from an agar plate in broth by collecting a loopful of the growth and suspending it in 1–2 ml of broth. Inoculate this suspension into the blood culture broth to be tested. Incubate the broths at 35°C for 7 days; observe for growth and subculture at 14 hours and 48 hours. All four bacteria mentioned above should be recovered on subculture after 14 and 48 hours.

Chocolate agar with TSA base and growth supplement

Chocolate agar with growth supplements is a medium that supports the special growth requirements needed for the isolation of fastidious organisms (when incubated in a 5% CO₂ atmosphere). Chocolate agar contains a reduced concentration of agar, which increases the moisture content of the medium.

Supplemented chocolate agar should support the growth of *H. influenzae*.

Chocolate agar slants for transport and short-term storage can be prepared in the same manner as that described for agar plates, except that the medium is dispensed in 16 x 125-mm screw-cap tubes and slanted before solidifying.

- a) Use TSA as the basal medium. Prepare double strength (i.e., 20 g in 250 ml distilled water). Autoclave, and then cool to 50°C. Use the thermometer to verify the cooling temperature.
- b) Prepare a solution of 2% hemoglobin (i.e., 5 g in 250 ml distilled water). Mix the hemoglobin in 5–6 ml of the distilled water to form a smooth paste. Continue mixing as the rest of the water is added. Autoclave, and cool to 50°C.
- c) Add the hemoglobin solution to the double-strength TSA and continue to hold at 50°C.
 - **Alternative to steps a-c:** If a hemoglobin solution is unavailable, an alternative is to add 5% sterile defibrinated sheep, rabbit, guinea pig, or horse blood (i.e., 5 ml blood per 100-ml agar) to full-strength TSA (i.e., 20 g in 500 ml distilled water). **DO NOT use human blood.** After the base medium has been autoclaved and cooled to 50°C, add the blood and place in a hot water bath at no more than 80°C for 15 minutes or until a chocolate color is achieved. Then cool to 50°C.
- d) After the hemoglobin solution or the defibrinated blood has been added to the base medium and the medium has cooled to 50°C, add growth supplement (e.g., IsoVitaleX or Vitox) to a final concentration of 1%. Mix the ingredients by gently swirling the flask; avoid forming bubbles.
- e) Dispense 15–20 ml in each 15 x 100-mm Petri dish.

Quality control: All freshly prepared or purchased chocolate agar media should be tested to determine the medium's capacity to support growth of the bacteria to be isolated, particularly *H. influenzae*. If the medium does not support the growth of one or all of the bacteria, the medium should be discarded, and a new batch of medium should be prepared or purchased.

- Chocolate agar should look brown to brownish-red in color. *N. meningitidis* and *H. influenzae* should appear as a greyish, almost translucent film on the slant's surface with no discoloring of the medium after 24 hours of incubation; *S. pneumoniae* should appear as small grey to grey-green colonies with a very distinct greenish discoloring of the medium (see Figures 61 and 62).

If *H. influenzae* does not grow, the growth supplement (IsoVitaleX or its equivalent) may have been inadvertently omitted.

Chocolate agar with bacitracin

This medium is used for primary isolation of *H. influenzae* from respiratory sources. **Bacitracin-chocolate agar should not be used for subcultures.**

A stock solution of bacitracin can be made by suspending 3 g of bacitracin in 20 ml of distilled water. The solution should be sterilized by filtration. Dispense in 1-ml amounts and store in a -20°C to -70°C freezer.

- a) Prepare chocolate agar suspension according to the instructions for the preparation of chocolate agar outlined above (in steps a–d).
- b) After adding the hemoglobin and growth supplement to the TSA base medium, cool the medium to 50°C, and add 1.0 ml of stock solution of bacitracin per 500 ml of chocolate agar.
- c) Dispense 15–20 ml in each 15 x 100-mm Petri dish (so that agar is a uniform 3–4 mm); this volume makes 25 to 30 bacitracin-chocolate agar plates.
- d) After quality control testing, the plates should be placed in plastic bags and stored at 4°C.

The final concentration of bacitracin in the chocolate agar is 300 µg/ml. The bacitracin does not change the color of the medium, and it should appear brown like standard supplemented chocolate agar (similar to the medium shown in Figure 58).

Quality control: For quality control of bacitracin-chocolate agar, a strain of *H. influenzae* (e.g., ATCC 49247) should be tested for proper growth characteristics.

Cystine trypticase agar (CTA) with 1% carbohydrate

CTA medium is a semi-solid medium presented in this manual for the biochemical testing of *N. meningitidis* with glucose, maltose, lactose, and sucrose. It can be purchased as a ready-made medium or prepared from dehydrated media with the

addition of sugars. (Follow the manufacturer's instructions when using dehydrated medium.)

- a) Suspend 28.0 g of cystine trypticase agar medium in 900 ml of distilled water. Mix thoroughly, heat with frequent agitation, and bring to a boil for 1 minute to completely dissolve the powder.
- b) Autoclave the flask at 121°C for 15 minutes. Cool to 50°C.
- c) Prepare a 10% glucose solution using 10 g of glucose in 100 ml of distilled water. Filter-sterilize the solution using a 0.22-micron filter.
- d) Aseptically add this entire solution (100 ml of 10% glucose solution) to the 900 ml of the CTA medium to obtain a final 1% concentration of the glucose.
- e) Dispense 7 ml into each 16 x 125-mm glass screw-capped tube.
- f) Store at 4°C.
- g) Repeat this procedure for the remaining three carbohydrates (in place of glucose in step c): maltose, lactose, and sucrose.

Quality control: Testing of CTA agar with a reference strain of *N. meningitidis* will yield an acid reaction (indicated by a color change from red to yellow) in glucose and maltose (but not in lactose or sucrose). Reactions typical of other organisms are included in Table 3. It should be noted that because *N. gonorrhoeae* typically has a weak glucose reaction difficult to detect in CTA media, this laboratory manual suggests using a rapid acid-detection test (in place of CTA) for presumptive *N. gonorrhoeae*.

Desoxycholate citrate agar (DCA)

Desoxycholate citrate agar (DCA) is a differential selective plating medium for the isolation of enteric pathogens, particularly *Shigella* and *Salmonella*. Lactose-fermenting organisms produce pink colonies surrounded by a zone of bile precipitation. Colonies of lactose-nonfermenting strains are colorless. Several formulations of DCA, which may vary in selectivity, are available from different manufacturers.

Prepare according to manufacturer's instructions. [**Note:** DCA may also be prepared from individual ingredients, but doing so can result in much greater lot-to-lot variation than when prepared from commercial dehydrated preparations.] DCA medium is very heat-sensitive, and overheating during boiling should be avoided; **do not autoclave DCA medium**. Plates can be stored at 4°C for up to a week.

Quality control: For quality control of DCA, the following organisms should be adequate for confirmation of selective and inhibitory growth characteristics:

- *E. coli* may be somewhat inhibited, depending on the particular formulation used, but will produce pink colonies surrounded by a zone of precipitated bile; and,
- *S. flexneri* and *S. dysenteriae* 1 will produce fair-to-good growth of colorless colonies.

Formalinized physiological saline

(Refer to “Physiological saline,” listed later in this Appendix.)

GC-Chocolate agar (gonococcus agar medium [GC] base plus hemoglobin and 1% defined growth supplement)

GC-chocolate agar is a nonselective medium used to grow pure cultures of *Neisseria gonorrhoeae*. Although chocolate agar is often made with fresh sheep blood, it is **not** recommended that fresh blood products be used in gonococcal medium because they vary in their ability to support the growth of *N. gonorrhoeae*. Hemoglobin powder must therefore be used to prepare a standardized GC-chocolate agar medium.

The following methods allow for the production of 100 ml of medium (five 15 x 100-mm diameter plates); adjust quantities proportionately for the production of larger volumes of media. It is suggested that laboratorians should prepare no more than 500 ml of media per individual container, because it is difficult to properly mix larger amounts of media.

- Suspend 7.2 g of GC agar base in 100 ml of distilled water. Mix thoroughly, heat with frequent agitation, bring to a boil, and gently swirl to completely suspend the powder (approximately 1 minute). Autoclave the medium at 121° C for 15 minutes. Cool in a water bath set to 50° C.
- Add 2 g of soluble hemoglobin powder to 5–10 ml of warm distilled water in a screw-cap bottle. Gradually add warm distilled water (to a total volume of 100 ml) and gently agitate the bottle until a smooth suspension is achieved. (This process is made easier if the solution can be stirred using a magnetic stirrer.) Autoclave the hemoglobin solution at 121°C for 15 minutes. Cool in a water bath set to 50°C.
 - If ready-made sterile hemoglobin solution is available, instead of following the methods described here in step b, use 100 ml of ready-made 2% sterile hemoglobin solution warmed in a water bath set at 50°C.
- Reconstitute the growth supplement (e.g., IsoVitaleX).
- Aseptically open the vial containing the lyophilized growth supplement.
- Use a sterile needle and syringe to aseptically transfer 10 ml of the accompanying diluent to the vial.

- f) Shake to ensure complete solution. After reconstitution, use growth supplement immediately, or store at 4°C and use within 2 weeks.
- g) Aseptically add 100 ml sterile hemoglobin solution and 2 ml of reconstituted growth supplement to 100 ml of GC agar base medium. Mix gently, but thoroughly, to avoid the formation of air bubbles in the agar (*i.e.*, foam). Holding the bottle in an upright position, bottle neck in the hand, and gently swirling it three times in one direction (*e.g.*, clockwise) and then three times in the other direction (*e.g.*, counter-clockwise) is a good, gentle mixing technique.
- h) Dispense 15–20 ml volumes of medium into each sterile 15 x 100-mm Petri dish to achieve a uniform depth of 3–4 mm in the plate.
- i) Replace the lid on the plate, and allow the medium to stay at room temperature for several hours. Place plates in a plastic bag and store at 4°C.

Quality control: Inoculated GC-chocolate agar should support the growth of *N. gonorrhoeae* (*e.g.*, the fastidious strain 14AHU [available from CDC, see Appendix 14] as well as ATCC 49226) after incubation at 35°–36.5°C in a 5% CO₂, humid atmosphere for 18–24 hours. QC strains may be inoculated onto either whole- or half-plates.

GC- susceptibility test medium (GC-agar base medium plus 1% defined growth supplement)

Mueller-Hinton agar does not support growth of *N. gonorrhoeae*, and therefore must not be used for antimicrobial susceptibility testing of this organism.

Antimicrobial susceptibility testing of *N. gonorrhoeae* is performed on a GC-susceptibility test medium, a simple nonselective medium of GC agar base plus 1% defined supplement (*e.g.*, IsoVitaleX). GC-susceptibility test medium does not contain hemoglobin (*i.e.*, it is not a chocolate medium), unlike other GC test media.

GC-susceptibility test medium is similar to but simpler than the standard GC-chocolate medium; it is prepared in the same manner with the exception of the exclusion of hemoglobin from the GC-susceptibility testing medium. The methods described here allow for the production of 100 ml of medium (five 15 x 100-mm diameter plates); adjust quantities proportionately for the production of larger volumes of media. If a large number of plates is required, prepare no more than 500 ml of media per individual container (because it is difficult to mix larger quantities of the ingredients properly).

- a) Suspend 7.2 g of GC agar base in 100 ml of distilled water. Mix thoroughly, heat with frequent agitation, bring to a boil, and gently swirl to completely suspend the powder (approximately 1 minute). Autoclave the medium at 121° C for 15 minutes. Cool in a water bath set to 50° C.

b) Reconstitute the growth supplement (e.g., IsoVitaleX).

- 1) Aseptically open the vial containing the lyophilized growth supplement.
- 2) Use a sterile needle and syringe to aseptically transfer 10 ml of the accompanying diluent to the vial.
- 3) Shake to assure complete solution. After reconstitution, use growth supplement immediately, or store at 4°C and use within 2 weeks.

c) Aseptically add 2 ml of reconstituted growth supplement to 100 ml of GC agar base medium. Mix gently, but thoroughly, to avoid the formation of air bubbles in the agar (i.e., foam). Holding the bottle in an upright position, bottle neck in the hand, and gently swirling it three times in one direction (e.g., clockwise) and then three times in the other direction (e.g., counter-clockwise) is a good, gentle mixing technique.

d) Dispense 15–20 ml volumes of medium into each sterile 15x100-mm Petri dish to achieve a uniform depth of 3–4 mm in the plate.

e) Replace the lid on the plate, and allow the medium to stay at room temperature for several hours. Place plates in a plastic bag and store at 4°C.

Quality control: Each new lot of GC-susceptibility test medium should be quality controlled by testing both the NCCLS-recommended *N. gonorrhoeae* strain (ATCC 49226) and the other reference strains to be used when performing antimicrobial susceptibility testing of *N. gonorrhoeae*. Appropriate ranges of antimicrobial susceptibility test values for these QC strains are listed in Tables 9 and 10.

Gonococcal selective media

Gonococcal selective media support adequate growth of *N. gonorrhoeae* from clinical specimens while inhibiting commensal species and fungi. A variety of media share the same supplemented GC-chocolate base and antibacterial agents (vancomycin and colistin), and vary by antifungal agents (e.g., anisomycin or nystatin) and additional antibacterial agents (e.g., amphotericin B or trimethoprim lactate). *N. gonorrhoeae*, *N. meningitidis*, *N. lactamica*, and *K. denitrificans* are routinely able to grow on gonococcal selective media whereas strains of most commensal species cannot. Two commonly used selective gonococcal media mentioned in this manual are Modified Thayer-Martin and Martin-Lewis.

Modified Thayer-Martin (MTM) is GC-chocolate agar containing 3 µg/ml vancomycin, 7.5 µg/ml colistin, 12.5 units/ml nystatin and sometimes also 5 µg/ml trimethoprim lactate. Similarly, **Martin-Lewis (ML)** is GC-chocolate agar containing 4 µg/ml vancomycin, 7.5 µg/ml colistin, 20 µg/ml anisomycin and sometimes 5 µg/ml trimethoprim lactate. The antimicrobial/antifungal agents are commercially available as combined inhibitory supplements (e.g., “VCA”, “VCN”, “VCNT”, and GC-supplement).

Laboratories able to access inhibitory supplements can prepare their own gonococcal selective media by following the instructions included in this manual for the supplemented GC-chocolate base and following the manufacturer's instructions for the addition of the inhibitory supplement to the base medium. Alternatively, laboratories can purchase prepared gonococcal selective media from commercial suppliers.

Quality control: Gonococcal selective media should support the growth of *N. gonorrhoeae* (e.g., ATCC 49226) after incubation at 35°–36.5°C in a 5% CO₂, humid atmosphere for 18–24 hours. *N. cinerea* is colistin-susceptible and should **not** grow on gonococcal selective media. Additional QC strains may be suggested on the manufacturer's package insert.

- **Note:** Because some gonococcal strains are vancomycin-sensitive, part of the quality assurance program should include comparing the rate of positive culture results with the rate of observation of gram-negative diplococci in urethral smears from the corresponding men with uncomplicated symptomatic gonorrhea. If a discrepancy is observed between these rates, laboratorians should culture the next (approximately) 50 specimens first on nonselective GC-chocolate agar and then on the selective medium. If cultures grow on the nonselective medium and exhibit poor growth or no growth on the selective medium, laboratorians should suspect that isolates are susceptible to vancomycin and consider sending strains to a reference lab for confirmation.

Gram-negative (GN) broth

Gram-negative (GN) broth is a selective / inhibitory medium for isolation of gram-negative organisms. It may be used for the enrichment of fecal specimens suspected to contain *Salmonella* serotype. Prepare GN broth according to manufacturer's instructions. [**Note:** GN broth may also be prepared from individual ingredients, but doing so can result in much greater lot-to-lot variation than when prepared from commercial dehydrated preparations.]

Quality control: After overnight enrichment in GN broth, *S. Typhi* should produce good growth of colorless colonies on MacConkey agar.

Haemophilus test medium (HTM)

The unsupplemented Mueller-Hinton agar used for antimicrobial susceptibility testing of many bacteria included in this manual does not support growth of *H. influenzae* and therefore must not be used for the antimicrobial susceptibility testing of this organism. **Antimicrobial susceptibility testing of *H. influenzae* is performed on *Haemophilus* test medium (HTM).**

HTM can be prepared by supplementing thymidine-free Mueller-Hinton agar with 15 µg/ml β-NAD (β- nicotinamide adenine dinucleotide), 15 µg/ml bovine haematin and 5 mg/ml yeast extract. However, to decrease lot-to-lot variation, **it is suggested that laboratories prepare HTM from commercially available dehydrated preparations when possible** (or purchase ready-made plated media).

Prepare HTM according to manufacturer's instructions.

Quality control: Incubate HTM for 48 hours at 35°C, and then for 120 hours at room temperature to ensure purity in the closed medium container. Each new lot of HTM should also be quality controlled by testing the NCCLS-recommended *H. influenzae* strain (ATCC 49247). Appropriate ranges of antimicrobial susceptibility test values for this QC strain are listed in Table 2.

Heart infusion agar (HIA)

Heart infusion agar (HIA) is a general-purpose medium used with or without blood for isolating and cultivating a number of microorganisms. The medium should appear straw colored (a yellowish to gold coloring). HIA can also be used for determining the X- and V-factor requirements of *H. influenzae*.

- a) Prepare the HIA according to the instructions on the label of the dehydrated medium. Prepare the volume needed in flasks. These media should be fully dissolved with no powder on the walls of the vessel before autoclaving; stirring over heat may help the powder dissolve more rapidly.
- b) Autoclave at 121°C for 20 minutes.
- c) Cool to 50°C and pour into 15 x 100-mm Petri dishes.
- d) Allow medium to solidify and condensation to dry out before placing plates in plastic bags and storing at 4°C until used.

Quality control: Each freshly prepared or purchased batch of HIA should be quality control tested by determining the X and V requirements of *H. influenzae*. Inoculate a fresh plate of HIA with a control strain, such as *H. influenzae* ATCC 49247 (which should be readily available in laboratories performing antimicrobial susceptibility testing of *H. influenzae*); X, V, and XV disks should be placed on the inoculated plate identical to that shown in Figure 3. *H. influenzae* should grow only around the XV disk.

Heart infusion rabbit blood agar (HIA-Rabbit blood)

HIA-rabbit blood is used for determining the hemolytic reaction of *Haemophilus* species. This medium should appear bright red and look very similar to blood agar plates. (Be sure to label the prepared medium carefully.) If the medium is dark red, discard and prepare a new batch. (Horse blood may be substituted for rabbit blood

in this medium; the preparation is exactly the same, with the exception of the blood source.)

- a) Prepare the HIA according to the instructions on the label of the dehydrated medium. Prepare the volume needed in flasks and autoclave at 121°C for 20 minutes. Cool to 50°C in a water bath.
- b) Add 5% sterile, defibrinated rabbit blood (5 ml/100 ml of medium) and dispense into 15x100-mm Petri dishes. Allow to solidify and dry for a few hours. Then, place in a plastic bag and store at 4°C.

Quality control: A strain of *H. haemolyticus* should be used to quality control the proper growth and hemolytic reactions of the HIA-rabbit blood medium. *H. haemolyticus* should grow well and be surrounded by a distinct zone of complete hemolysis that appears as a clear halo surrounding the colonies.

Hektoen enteric agar (HE)

Hektoen enteric (HE) agar is a differential selective agar that is useful for isolation of *Salmonella* and *Shigella*. It has an H₂S-indicator system for selecting H₂S-producing *Salmonella*, which produce blue-green colonies with a black center. *Shigella* colonies are green whereas rapid lactose-fermenters (e.g., *E. coli*) are pink to orange with a zone of bile precipitation.

Prepare HE according to manufacturer's instructions. [**Note:** Several commercial brands of Hektoen enteric agar are available. This medium can also be prepared from individual ingredients, but results may be much more variable when the medium is prepared in this manner than with a commercial dehydrated formulation.] Heat to boiling to dissolve, but avoid overheating (i.e., remove from heat after the powder has dissolved); do not autoclave. When cool enough to pour, dispense the HE into plates. Plates can be stored at 4°C for up to 1 week.

Quality control: For quality control of Hektoen enteric agar, the following organisms should be adequate for confirmation of selective and inhibitory growth characteristics:

- *E. coli* should produce colonies that are pink to orange surrounded by a bile precipitate; and,
- *S. flexneri* should produce fair to good growth of green colonies, but *S. dysenteriae* 1 colonies should be smaller.

Horse blood agar (blood agar base)

Horse blood agar is a highly nutritive medium that may be used for the primary isolation of *H. influenzae* and for the determination of the hemolysis with *H. haemolyticus* or other bacteria.

- a) Prepare blood agar base according to the instructions on the label of the dehydrated medium. Oxoid number 2 base is best, but other blood agar bases may be substituted.
- b) Autoclave at 121°C for 15 minutes, and cool to 50°C in a water bath.
- c) Add horse blood (5 ml per 100 ml of medium).
- d) Mix well, dispense in 15 x 100-mm Petri dishes. Allow to solidify and dry out excess moisture before placing in plastic bags and storing at 4°C.

Quality control: The quality control testing of this medium is the same as that described for HIA-rabbit blood: a strain of *H. haemolyticus* should be used to quality control the proper growth and hemolytic reactions of horse blood agar medium. *H. haemolyticus* should grow well and be surrounded by a distinct zone of complete hemolysis that appears as a clear halo surrounding the colonies.

Kligler iron agar and triple sugar iron agar

Kligler iron agar (KIA) and triple sugar iron (TSI) agar are carbohydrate-containing screening media widely used for identification of enteric pathogens. Both media differentiate lactose fermenters from nonfermenters and have a hydrogen sulfide indicator. H₂S-producing organisms will cause blackening of the medium in both KIA and TSI.

KIA contains glucose and lactose. Organisms that ferment glucose cause the butt of the tube to become acid (yellow); some also produce gas. Lactose-fermenting organisms will produce an acid (yellow) slant; lactose-nonfermenting organisms will have an alkaline (red) slant.

TSI contains sucrose in addition to the ingredients in KIA. Organisms that ferment either lactose or sucrose will produce an acid (yellow) slant while organisms that ferment neither carbohydrate will have an alkaline (red) slant. As in KIA, in TSI glucose-fermenters produce an acid (yellow) reaction in the butt (sometimes with gas produced).

- a) Prepare according to manufacturer's instructions. [**Note:** There are several commercially available dehydrated formulations of KIA and TSI. These media can also be prepared from individual ingredients, but doing so may result in lot-to-lot variation.]
- b) Dispense a quantity of medium in appropriate tubes with a sufficient volume to give a deep butt and a long slant (e.g., dispense 6.5 ml of medium into 16 x 125-mm screw-cap tubes).
- c) Leave screw-caps loose, and autoclave the medium.
- d) After autoclaving, allow the slants to solidify in a manner such that the medium in the butt of the tube is about 3.5-cm deep and the slant is about 2.5-cm long.

- e) Tighten the screw-cap tops of the tubes and store at 4°C for up to 6 months.

Quality control: For quality control of KIA or TSI, the following organisms should be adequate for confirmation of biochemical response characteristics:

- *E. coli* should give an acid slant and butt, with the production of gas but no H₂S;
- *S. flexneri* should give an alkaline slant, acid butt, without production of gas or H₂S (as shown in Figure 38);
- an H₂S-producing *Salmonella* may be used to control this reaction, which would appear as blackening of the medium in a positive reaction.

Lysine iron agar (LIA)

Organisms that produce lysine decarboxylase in lysine iron agar (LIA) cause an alkaline reaction (purple color) in the butt of the medium and also on the slant (Figure 40). H₂S production is indicated by a blackening of the medium. Organisms lacking lysine decarboxylase (*e.g.*, *Shigella*) typically produce an alkaline slant (purple), an acid butt (yellow), no gas, and no H₂S (see Table 13). *Proteus* and *Providencia* species will often produce a red slant caused by deamination of the lysine. LIA must be prepared so that the volume of medium in the tube is sufficient to give a deep butt. LIA tubes must have a deep butt because the decarboxylation reaction occurs only in anaerobic conditions.

- a) Prepare LIA medium according to manufacturer's instructions on the bottle.
[**Note:** There are several commercially available formulations of dehydrated LIA. LIA may also be prepared from individual ingredients, but doing so may result in lot-to-lot variation.]
- b) Dispense a quantity of medium in appropriate containers such that the volume of medium is sufficient to give a deep butt and a long slant (*e.g.*, dispense 6.5 ml of medium into 16 x 125-mm screw-cap tubes).
- c) Leave the screw-caps loose), and autoclave the medium.
- d) After autoclaving, allow the slants to solidify in a manner such that the medium in the butt of the tube is approximately 3.5-cm deep and the slant is approximately 2.5-cm long.
- e) Tighten the screw-top caps and store at 4°C for up to 6 months.

Quality control: For quality control of LIA, the following organisms should be adequate to confirm the biochemical response properties of the medium:

- *S. flexneri* should produce an alkaline slant and an acid butt without production of H₂S;

- an H₂S-producing *Salmonella* strain may be used to control the H₂S reaction. *Salmonella* strains will most likely be lysine-positive and give an alkaline reaction in the butt of the tube.

MacConkey agar (MAC)

MacConkey agar (MAC) is a differential plating medium recommended for use in the isolation and differentiation of lactose-nonfermenting, gram-negative enteric bacteria from lactose-fermenting organisms. Colonies of *Shigella* on MAC appear as convex, colorless colonies about 2–3 mm in diameter. *S. dysenteriae* 1 colonies may be smaller. *S. Typhi* colonies are flat, colorless and usually 2–3 mm in diameter.

Several commercial brands of MAC are available. Most manufacturers prepare several formulations of MAC, which may vary in selectivity and thereby affect the isolation of *Shigella*. For example, some formulations of MAC do not contain crystal violet, a selective agent; these types are not as selective and should not be used for isolation of *Shigella*. Oxoid MacConkey Agar No. 3, Difco Bacto MacConkey Agar, and BBL MacConkey Agar are all suitable.

- Prepare MAC according to manufacturer's instructions. [**Note:** MAC can also be prepared from individual ingredients, but this produces more lot-to-lot variation than preparation of a commercially available dehydrated formulation.]
- Sterilize the medium by autoclaving at 121°C for 15 minutes.
- Cool to 50°C and pour into Petri plates (to a uniform depth of 3–4 mm).
- Leave lids ajar for about 20 minutes so that the surface of the agar will dry. Close lids and store at 4°C for up to 1 month. If plates are to be stored for more than a few days, put them in a sealed plastic bag to prevent drying.

Quality control: For quality control of MAC, the following organisms should be adequate for confirmation of selective and inhibitory growth characteristics:

- *E. coli* should produce pink to red colonies with good to excellent growth; and,
- *S. flexneri* should produce colorless colonies with fair to good growth, but *S. dysenteriae* 1 colonies may be smaller.

Martin-Lewis (ML) agar medium

(Refer to "Gonococcal Selective Media," listed earlier in this Appendix.)

Modified Thayer-Martin (MTM) agar medium

(Refer to "Gonococcal Selective Media," listed earlier in this Appendix.)

Motility medium

Because *Shigella* are always nonmotile, motility medium is a useful biochemical screening test. Motility is indicated by the presence of diffuse growth (appearing as clouding of the medium) away from the line of inoculation (Figure 39).

Nonmotile organisms do not grow out from the line of inoculation.

- a) Follow manufacturer's instructions to weigh out and suspend the dehydrated medium. [**Note:** Several commercial dehydrated formulations of motility agar are available. This medium can also be prepared from individual ingredients, but this results in more lot-to-lot variation than commercial preparations.]
- b) Heat to boiling to make sure medium is completely dissolved.
- c) Dispense into tubes with screw-caps (or other types of containers), leaving the caps loose, and sterilize at 121°C for 15 minutes.
- d) Allow the medium to solidify upright, forming a deep butt with no slant (e.g., about 4–5 ml of medium per 13 x 100-mm screw-cap tube). When the medium is solidified and cooled, leave caps loose until the surface of the medium has dried.
- e) Tighten caps and store at 4°C for up to 6 months.

Quality control: For quality control of motility medium, the following organisms should be adequate:

- *E. coli* is motile;
- *Shigella* spp. are nonmotile.

The surface of the medium should be dry when used. If moisture has accumulated in the tube, carefully pour it out before the tube is inoculated. Moisture can cause a nonmotile organism to grow down the sides of the agar, creating a haze of growth and making it appear to be motile.

Mueller-Hinton agar

Mueller-Hinton agar is the NCCLS-recommended medium used for standardized antimicrobial susceptibility testing of certain bacteria; the organisms in this document for which it is appropriate to use this formulation of Mueller-Hinton medium (i.e., unsupplemented Mueller-Hinton) are *S. Typhi*, *Shigella* spp., and *V. cholerae*.

[**Note:** Several formulations of Mueller-Hinton agar are commercially available. This laboratory manual suggests that Mueller-Hinton agar medium should not be prepared from individual ingredients because this can diminish the quality. Commercial dehydrated Mueller-Hinton is carefully quality controlled before being released for sale.]

- a) Follow manufacturer's instructions to prepare medium.
- b) After autoclaving, cool medium to 50°C in a water bath.
- c) Measure 60–70 ml of medium per plate into 15 x 150-mm plates, or measure 25–30 ml per plate into 15 x 100-mm plates. Agar should be poured into flat-bottom glass or plastic Petri dishes on a level pouring surface to a **uniform depth of 3–4 mm**. Using more or less agar will affect the susceptibility results. Agar deeper than 4 mm may cause false-resistance results, whereas agar less than 4 mm deep may be associated with a false-susceptibility report.
- d) Freshly prepared plates may be used the same day or stored in a refrigerator (at 2°–8°C) for up to 2 weeks. If plates are not used within 7 days of preparation, they should be wrapped in plastic to minimize evaporation. Just before use, if excess moisture is on the surface, plates should be placed in an incubator (35°–37°C) until the moisture evaporates (usually 10–30 min).
Do not leave lids ajar because the medium is easily contaminated.

Quality control: Each new lot of Mueller-Hinton agar should be quality controlled before use by testing the *E. coli* ATCC 25922 standard strain for antimicrobial susceptibility testing. (This formulation of Mueller-Hinton agar can also be used for testing of gram-positive aerobes, in which case *S. aureus* ATCC 25923 can be used as a quality control strain.) **The pH of each new lot of Mueller-Hinton should be between 7.2 and 7.4; if the pH is outside this range, the pH of the medium should not be adjusted by the addition of acid or base, i.e., the batch of Mueller-Hinton plates should be discarded and a new batch of plates prepared.** If the pH for every batch is too high or low, the entire lot of dehydrated medium may have to be returned to the manufacturer as unsatisfactory. Inhibition zone sizes / minimal inhibitory concentration (MIC) values for quality control are included in the antimicrobial susceptibility testing section of each pathogen-specific chapter.

Mueller-Hinton agar plus 5% sheep (or horse) blood

Mueller-Hinton agar plus 5% sheep (or horse) blood is the NCCLS-recommended medium used for standardized antimicrobial susceptibility testing of certain bacteria; the organisms in this document for which it is appropriate to use this formulation of Mueller-Hinton medium supplemented with sheep (or horse) blood are *S. pneumoniae* and *N. meningitidis*.

[**Note:** Several commercial formulations of Mueller-Hinton agar are available. This medium should not be prepared from individual ingredients because this can diminish the quality and result in increased lot-to-lot variation. Commercial dehydrated Mueller-Hinton is carefully quality controlled before being released for sale.]

- a) Follow manufacturer's instructions to prepare medium.

- b) After autoclaving, cool medium to 50°C in a water bath.
- c) Add 5% sterile, defibrinated sheep (or horse) blood, *i.e.*, 50 ml of blood per liter of medium. (If a different volume of base medium is prepared, the amount of blood must be adjusted accordingly to 5%, *e.g.*, 25 ml of blood would be added to 500 ml of base medium.)
- d) Measure 60–70 ml of medium per plate into 15 x 150-mm plates, or measure 25–30 ml per plate into 15 x 100-mm plates. Agar should be poured into flat-bottom glass or plastic Petri dishes on a level pouring surface to a uniform depth of 3–4 mm. Using more or less agar will affect the susceptibility results. Agar deeper than 4 mm may cause false-resistance results, whereas agar less than 4 mm deep may be associated with a false-susceptibility report.
- e) Freshly prepared plates may be used the same day or stored in a refrigerator (2°–8°C) for up to 2 weeks. If plates are not used within 7 days of preparation, they should be wrapped in plastic to minimize evaporation. Just before use, if excess moisture is on the surface, plates should be placed in an incubator (35°–37°C) until the moisture evaporates (usually 10–30 minutes). **Do not leave lids ajar because the medium is easily contaminated.**

Quality control: Each new lot of Mueller-Hinton plus sheep blood agar (or horse blood, if preparing Mueller-Hinton for antimicrobial susceptibility testing of *S. pneumoniae* with trimethoprim-sulfamethoxazole [cotrimoxazole]) should be quality controlled before use by testing the *S. pneumoniae* standard strain (for quality control of *S. pneumoniae* and *N. meningitidis*). **The pH of each new lot of Mueller-Hinton should be between 7.2 and 7.4; if outside this range, the pH of the medium should not be adjusted by the addition of acid or base; the batch of plates should be discarded and a new batch of plates prepared.** If the pH for every batch is too high or low, the entire lot of dehydrated medium may have to be returned to the manufacturer as unsatisfactory. Inhibition zone sizes and MIC values for quality control are included in the antimicrobial susceptibility testing section of each pathogen-chapter.

Phosphate buffered saline (PBS)

The formula for this medium is:

Sodium dihydrogen phosphate	7.0 g
Disodium hydrogen phosphate	7.0 g
Distilled water	1000.0 ml

To prepare 0.1 M PBS, pH 7.2: Dissolve ingredients in distilled water. Adjust pH to 7.2 with 1 N acid or base. Dispense buffer in 500-ml bottles, and autoclave at 121°C for 15 minutes. Label bottles with the reagent name, date prepared, and the expiration date.

PBS has a shelf-life of one year if stored at room temperature (25°C).

Physiological saline

(0.85% saline, also referred to as “Physiologic” saline or “Normal” saline)

Physiological saline is used in many different microbiological techniques. The formula for this saline is:

NaCl	8.5 g
Distilled water	1 liter

Dissolve the NaCl in water, heating if necessary. Physiological saline may be sterilized by autoclaving or membrane filtration. Store physiological saline at ambient temperature for up to 6 months with caps tightened to prevent evaporation.

Formalinized physiological saline is physiological saline with the addition of formalin (formaldehyde). Follow the instructions above for preparation of physiological saline, and **after autoclaving** add 5 ml of 36% – 38% formaldehyde solution. Do not autoclave after the addition of formaldehyde to the saline.

Polysaccharide medium

Polysaccharide medium is used to detect the production of polysaccharide from sucrose, and consists of TSA with 1% sucrose. The medium is included in this laboratory manual to assist in the identification of *N. gonorrhoeae*, which has a negative reaction. The formula for this medium is:

Tryptone soy agar (TSA)	40 grams
Distilled water (endotoxin-free; ETF)	1000.0 ml
Reagent-grade sucrose	(10% solution, preferably in distilled water)

If reagent-grade sucrose is not available, white table sugar may be an acceptable substitute, but brown sugar is not appropriate for preparation of this medium.

- Suspend TSA in the distilled, ETF water.
- Autoclave at 121°C for 15 minutes. Cool to 50°C.
- Prepare a 10% sucrose solution using the reagent-grade sucrose, and filter-sterilize it using a 0.45-micron filter.
- Aseptically add sucrose solution to agar to give a final concentration of 1% (wt/vol).
- Dispense 20–25 ml volumes in 100-mm Petri dishes.

Store medium refrigerated (at 4°–10°C) until used. Pre-warm the medium to room temperature prior to inoculation.

Quality control: For quality control of polysaccharide medium, the following organisms may be used:

- *N. gonorrhoeae* and *N. meningitidis* are two examples of organisms that do not produce polysaccharide from sucrose, and therefore exhibit a negative reaction (no color change) with the addition of Gram's iodine to the incubated inoculated medium.
- *N. polysaccharea* and *N. mucosa* are two examples of polysaccharide-positive organisms, and will exhibit a color change to dark brown to blue-black with the addition of Gram's iodine to the incubated inoculated medium.

***Salmonella-Shigella* agar (SS agar)**

SS agar is a highly selective medium for isolation of *Salmonella* and *Shigella*, although **it should not be used for isolation of *Shigella dysenteriae* type 1 because some strains are inhibited**. *S. Typhi*, which is lactose-negative, produces smooth, colorless, transparent or translucent colonies that may or may not have black centers indicating production of H₂S. Lactose-positive colonies are pink surrounded by a zone of bile precipitation.

Quality control: To quality control SS agar, *Salmonella* should produce good growth of colorless colonies that may have black centers, whereas *E. coli* should grow poorly and appear as pink colonies.

Selenite broth (SEL)

Selenite broth (SEL) is a frequently used as an enrichment broth for *Salmonella*, including *S. Typhi*. It may be advantageous for a laboratory to use SEL because it can also be used for enrichment for *Shigella*. SEL should only be incubated for 14–16 hours at 35°–37°C. After incubation, selenite broth should be streaked to selective agar (e.g., HE or XLD).

Quality control: After overnight enrichment in SEL, *Salmonella* spp. typically produce good to excellent growth when streaked on MacConkey agar.

Sulfide-indole-motility medium (SIM)

Sulfide-indole-motility medium (SIM) is a commercially available combination medium that combines three tests in a single tube: hydrogen sulfide (H₂S) production, indole production, and motility. The indole reaction is not useful for screening suspected *Shigella* isolates because strains vary in their reactions in this test. SIM is inoculated in the same way as motility agar (*i.e.*, by using a needle to stab about 1–2 cm down into the medium, and is incubated overnight at 35°–37°C). The motility reaction in SIM is read the same as for motility medium. As in Kligler iron agar or triple sugar iron agar, H₂S production is indicated by blackening of the medium. Indole production can be tested by either the filter paper method or by adding Kovac's reagent to the tube.

- a) Follow manufacturer's instructions to weigh out and suspend dehydrated SIM medium.
- b) Heat to boiling to make sure the medium is completely dissolved.
- c) Dispense into tubes and sterilize by autoclaving for 15 minutes at 121°C.

Quality control: For quality control of SIM medium, the following organisms may be used:

- *E. coli* is indole positive, H₂S-negative, and motility positive;
- an H₂S-producing *Salmonella* strain may be used to control the H₂S reaction and will most likely be motile and indole negative;
- *Shigella* are motility negative and H₂S-negative but are variable for the indole reaction.

Thiosulfate citrate bile salts sucrose agar (TCBS)

TCBS is a selective medium used to isolate *V. cholerae* from fecal specimens.

- a) Follow manufacturer's instructions to weigh out and suspend the dehydrated medium. [**Note:** Several commercial brands of thiosulfate citrate bile salts sucrose agar (TCBS) agar are available. This medium can also be prepared from individual ingredients, but results may be much more variable than with a commercial dehydrated formulation.]
- b) Heat with agitation, until the medium is completely dissolved.
- c) Cool agar in a water-bath until cool enough to pour (50°–55°C).
- d) Pour into Petri plates, leaving lids ajar about 20 minutes so that the surface of the agar will dry. Close lids and store at 4°C for up to 1 week.

Quality control: Each new lot should be quality controlled before use because TCBS is subject to lot-to-lot and brand-to-brand variations in selectivity.

- *V. cholerae* O1 should show good growth of yellow colonies; and,
- *E. coli* should have none to poor growth of translucent colonies.

Todd-Hewitt broth

Todd-Hewitt broth is used (in the context of this laboratory manual) to incubate *S. pneumoniae* before re-testing when a Quellung reaction is not observed with growth in cell suspension from a blood agar plate. It is suggested that laboratories use a commercially available dehydrated formulation to prepare Todd-Hewitt broth, when possible.

- a) Prepare the Todd-Hewitt broth according to the instructions on the label of the dehydrated medium.

- b) Dispense 1 ml into 15 x 125-mm tubes, autoclave at 121°C for 20 minutes, cool, and store at 4°C.

Quality control: For quality control of Todd-Hewitt broth, inoculate a tube of medium with a loop of freshly growing strain of *S. pneumoniae*; incubate overnight at 35°C; the broth should be turbid the next day. Subculture the broth onto a blood agar plate to test for proper growth characteristics of *S. pneumoniae*.

Triple sugar iron agar (TSI)

(Refer to “Kligler iron agar and triple sugar iron agar,” listed earlier in this Appendix.)

Tryptone-based soy agar (TSA)

TSA is a general-purpose tryptone-based agar medium (also commonly referred to as Trypticase soy agar or Tryptic soy agar) used with or without blood for isolating and cultivating a number of microorganisms. The medium should appear straw colored (*i.e.*, a yellowish to gold coloring). TSA is also used for determining the X- and V-factor requirements of *H. influenzae* (as is HIA).

- a) Prepare the TSA according to the instructions on the label of the dehydrated medium. Prepare the volume needed in flasks. The medium should be fully dissolved with no powder on the walls of the vessel before autoclaving; stirring over heat may help the powder dissolve more rapidly.
- b) Autoclave at 121°C for 20 minutes.
- c) Cool to 50°C and pour into 15x100-mm Petri dishes.
- d) Allow medium to solidify and condensation to evaporate before placing plates in plastic bags and storing at 4°C until they are used.

Quality control: Each freshly prepared or purchased batch of TSA should undergo quality control testing; follow instructions provided by the manufacturer.

- In general, *E. coli* is an organism that should show good growth on TSA.
- If a laboratory is using TSA to test suspect *H. influenzae* for growth factor requirements, it is suggested that the quality control include testing of a known *H. influenzae* isolate for X and V- factor requirements. To test the X and V requirements, inoculate a fresh plate of TSA with a control strain of *H. influenzae* (*e.g.*, ATCC 49247, which should be in stock for laboratories performing antimicrobial susceptibility testing); X, V, and XV disks should be placed on the inoculated plate identical to that shown in Figure 3. *H. influenzae* should grow only around the XV disk.

Tryptone soy broth (TSB)

TSB (also commonly referred to as Trypticase soy broth or Tryptic soy broth) is used for making suspensions of *H. influenzae* prior to testing for X- and V- factor requirements. (HIA, sterile saline or phosphate-buffered saline [PBS] may be substituted for TSB when making the *H. influenzae* suspension for X and V factor testing.)

- a) Prepare the TSB according to the instructions on the label of the dehydrated medium.
- b) Dispense 5 ml into 15 x 125-mm tubes, autoclave at 121° C for 20 minutes, cool, and store at 4° C.

Quality control: Inoculate a tube of medium with a loop of freshly growing strain of *S. pneumoniae*; incubate overnight at 35°C; the broth should be turbid the next day. Use a blood agar plate to subculture the broth to test for proper growth characteristics of *S. pneumoniae*. [**Note:** *H. influenzae* is not an appropriate organism for quality control of TSB because TSB lacks the X and V factors *H. influenzae* requires to grow.]

Tryptone soy sheep blood agar with gentamicin

Sheep blood agar with gentamicin is used for the primary isolation of *S. pneumoniae* from nasopharyngeal swabs.

Prepare a stock solution of gentamicin by adding 80 mg of gentamicin in 32 ml of distilled water; the stock solution contains 2.5 mg of gentamicin/ml. Sterilize by filtration and dispense in 1.0-ml amounts, store at -20°C to -70°C.

To prepare sheep blood agar with gentamicin:

- a) Add 1 ml of the stock solution of gentamicin to 500 ml of molten agar (prepared according to manufacturer directions). Add the gentamicin at the same time the defibrinated sheep blood is added.
- b) Place the plates in plastic bags and store them at 4°C after they solidify. The agar should appear only slightly darker than the medium without gentamicin. If the agar is not bright red, discard and prepare a new batch.

Quality control: The quality control testing of freshly prepared or purchased gentamicin-blood medium is the same as for the (TSA-sheep) blood agar without gentamicin.

Urea medium

Urease-positive cultures produce an alkaline reaction in the medium, evidenced by a pinkish-red color (Figure 40). Urease-negative organisms do not change the color

of the medium, which is a pale yellowish-pink. *Shigella* are always urease-negative (Table 15).

- a) Follow manufacturer's instructions for preparation of urea medium. [**Note:** Several commercial brands of urea medium are available, some of which require the preparation of a sterile broth that is added to an autoclaved agar base. Some manufacturers have sterile prepared urea concentrate available for purchase.] Prepare urea agar base as directed on the bottle.
- b) Sterilize at 121°C for 15 min.
- c) Cool to 50°–55°C, then add urea concentrate according to manufacturer's directions. (Before adding the urea to the agar base, make sure the agar base is cool since the urea is heat labile.)
- d) Mix and distribute in sterile tubes. Slant the medium during cooling so that a deep butt is formed.

Quality control: For quality control of urea medium, the following organisms are adequate:

- *Proteus* species produce urease;
- *E. coli* is urease negative.

Xylose lysine desoxycholate agar (XLD)

Xylose lysine desoxycholate agar (XLD) is a selective differential medium suitable for isolation of *Shigella* and *Salmonella* from stool specimens. Differentiation of these two species from non-pathogenic bacteria is accomplished by xylose and lactose fermentation, lysine decarboxylation, and hydrogen sulfide production. *Shigella* colonies on XLD agar are transparent pink or red smooth colonies 1–2-mm in diameter (Figure 86). *S. dysenteriae* 1 colonies on XLD agar are frequently very tiny, unlike other *Shigella* species (Figure 85). Coliforms appear yellow (Figure 87). *Salmonella* colonies are usually red with black centers but can also be yellow with black centers.

- a) Prepare according to manufacturer's instructions. [**Note:** Several commercial brands of XLD agar are available. This medium can also be prepared from individual ingredients, but results exhibit more lot-to-lot variation than a commercially available dehydrated formulation.]
- b) Mix thoroughly.
- c) Heat with agitation just until the medium boils. Do not overheat; overheating when boiling XLD or allowing the medium to cool too long may cause the medium to precipitate.
- d) Cool flask under running water until just cool enough to pour; avoid cooling the medium too long.

- e) Pour the XLD into Petri plates, leaving the lids ajar for about 20 minutes so that the surface of the agar will dry.
- f) Plates can be stored at 4°C for up to a week.

Quality control: For quality control of XLD, the following organisms should be adequate for confirmation of selective and inhibitory growth characteristics:

- *S. flexneri* should produce fair to good growth of transparent pink or red smooth colonies that are 1–2 mm in diameter;
- *S. dysenteriae* 1 may produce very small transparent or red colonies;
- *E. coli* should produce poor to fair growth of yellow colonies.

Transport and storage media

Cary-Blair medium, Amies medium, and Stuarts medium

Prepare each of these transport media according to the manufacturer's instructions. [**Note:** Several dehydrated formulations of Cary-Blair are commercially available; some require the addition of calcium chloride and some do not.] These media can also be prepared from individual ingredients; however, it is very difficult to make a well quality-controlled batch and so this manual recommends purchasing them from a manufacturer.

When the Cary-Blair medium is prepared, it should be dispensed into containers in sufficient volume so that swabs will be covered by at least 4 cm of medium. For example, 5- to 6-ml amounts may be dispensed into 13 x 100-mm screw cap tubes. With the caps loosened, sterilize the medium by steaming (**not** by autoclave) at 100°C for 15 minutes. Tighten the caps after sterilization, and store the medium at 15°–30°C.

These media are quite stable if stored in tightly sealed containers in a cool dark place so that the medium does not dry out. Each may be used for up to 1 year as long as no loss of volume, visible contamination (e.g., foreign objects or bacterial growth), or color change is observed. Prepared Amies medium that has been stored for longer than 9 months, however, should be freshly steamed and the charcoal re-suspended before use.

Dorset egg medium

Dorset egg medium (DE) is a good choice for the long-term survival of *S. pneumoniae* isolates (up to 44 days), *H. influenzae* isolates (up to 21 days) and *N. meningitidis* isolates (up to 21 days) at room temperature. The formula for this medium includes physiologic (normal) saline and whole hen's eggs.

- a) Combine sterile 0.85% (normal) saline solution with beaten whole hen's eggs in a 1:3 ratio.

- b) Inspissate (*i.e.*, thicken) the mixture in an electric inspissator at 80°C for 60 minutes.

Greaves solution

Greaves solution can be used in the process of preparation of isolates for frozen storage, as described in Appendix XI of this manual. The formula for this medium is:

Albumin, bovine, fraction V	10.0 g
L-glutamic acid, sodium salt (Fluka, Buchs, Switzerland, 49621)	10.0 g
Glycerol	20.0 ml
Distilled water	200.0 ml

- a) Mix all ingredients and let them dissolve for 2–3 hours.
- b) Filter-sterilize the solution.
- c) Transfer the solution to a sterile tube.
- d) Incubate for 2 days at 35°–37°C (to control the sterility of the medium).
 - If contamination is observed, discard the solution and prepare a new batch.
- e) Store at 4°C.

JEMBEC® Plates

Jembec® plates are commercially available kits containing a CO₂-generating system and a medium that will support the growth of gonococcus.

Skim-milk tryptone glucose glycerol (STGG) transport medium

STGG medium is used for transport (and sometime storage) of nasopharyngeal secretions on swabs. The formula for this medium is:

Skim milk powder (from grocery or, <i>e.g.</i> , Difco)	2 g
TSB (from, <i>e.g.</i> , Oxoid)	3 g
Glucose	0.5 g
Glycerol	10 ml
Distilled water	100 ml

- a) Mix to dissolve all ingredients.
- b) Dispense in 1.0 ml amounts in screw-capped 1.5-ml vials.
- c) Loosen the screw-cap tops and autoclave for 10 minutes (at 15 pounds).
- d) Tighten caps after autoclaving.

- e) Store STGG frozen at -20°C or refrigerate until use.
- Use STGG medium within 6 months of preparation.

Transgrow medium

Transgrow medium is a selective medium for the transport and isolation of *N. gonorrhoeae*. It should be prepared according to manufacturer's instructions. [Note: Transgrow medium is a chocolate agar plus three antibiotics and may also be prepared from individual ingredients, but doing so can result in much greater lot-to-lot variation than when the medium prepared from commercially available dehydrated preparations.]

Trans-Isolate (T-I) Medium

T-I medium is a biphasic medium that is useful for the primary culture of *N. meningitidis*, *S. pneumoniae*, and *H. influenzae* from cerebrospinal fluid (CSF) samples. It can be used as a growth medium as well as a holding and transport medium.

When preparing T-I medium, use glass serum bottles with flange-type, slotted rubber plugs and aluminum crimp seals. Any size serum bottle that has at least a 20-ml capacity can be used, provided that the combined volume of solid and liquid phases equals approximately one-half the capacity of the bottle.

T-I medium includes solid and liquid phases; 0.1 M MOPS buffer (*i.e.*, 3-(N-morpholino) propanesulfonic acid buffer) with a pH of 7.2 is used in the preparation of both the solid and liquid phases of T-I medium. NaOH can be used to adjust the pH, and distilled water should be used to create the appropriate volume of 0.1 M solution (approximately 21 g MOPS: 1000 ml distilled water).

a) Solid phase:

Activated charcoal	2.0 g
Soluble starch	2.5 g
Agar agar (<i>e.g.</i> , from Difco)	10.0 g
0.1 M MOPS buffer, pH 7.2	500 ml

1. Suspend the activated charcoal, the soluble starch and the agar agar in 500 ml of MOPS buffer and add a magnetic bar to the flask.
2. Heat on a magnetic stirrer-heater to dissolve the starch and the agar.
3. With continued mechanical stirring to keep the charcoal in suspension, dispense 5.0 ml to each 20-ml serum bottle.
4. Cap each bottle with a piece of aluminum foil and autoclave in metal baskets at 121°C for 20 minutes.
5. Remove from the autoclave and slant the baskets until the bottles cool, so that the apex of the agar reaches the shoulder of each bottle.

b) Liquid phase:

TSB	30.0 g
Gelatin (e.g., from Difco)	10.0 g
MOPS buffer [0.1 M, pH 7.2]	500.0 ml

1. Heat the medium to dissolve the gelatin and avoid coagulation.
2. Autoclave at 121°C for 15 minutes.
3. *Optional:* the addition of growth supplement (e.g., IsoVitaleX or Vitox) to the liquid phase of T-I medium can help support the growth of *H. influenzae*.
 - To add growth supplement to the entire batch of liquid phase medium, use aseptic technique to add a total of 10 ml of the growth supplement to the cooled liquid medium.
 - To add growth supplement to individual bottles, add 0.1 ml of the supplement to the liquid phase contained in an individual T-I bottle (1% of the volume of both phases) or to a limited number of bottles, as needed.

c) Addition of the liquid phase to the solid phase

1. Dispense 5 ml of the broth aseptically into each of the bottles containing the solid-phase slants.
2. Seal with sterile rubber stoppers and aluminum caps.
 - Use a hand-crimping tool to fasten the aluminum caps if an automated system is not available.

T-I bottles can be stored and used for at least 2 years if tightly capped and stored at 4°C. In the refrigerator, the liquid phase becomes gelatinous but re-liquefies at room temperature.

Before use, perform quality control of the T-I medium: check several uninoculated bottles for sterility at 35°C. Inoculate several bottles with *N. meningitidis* and check their ability to support meningococcal growth at 35°C.

Before inoculation, the bottles should be pre-warmed in the incubator (at 35°–37°C) or allowed to reach room temperature (i.e., 25°–30°C).

Miscellaneous reagents

Gram stain (Hucker Modification) reagents

The Gram stain (Hucker modification) requires the use of two stains (e.g., crystal violet and safranin or carbol-fuchsin), Gram's iodine, and a decolorizing agent (e.g., ethyl alcohol). Individual reagents and Gram stain kits are available commercially from several laboratory supply sources. Alternatively, follow the

methods for preparation of the individual reagents (as presented in steps a–d below).

- a) **Ammonium oxalate-crystal violet** contains two solutions (solution a and solution b).

Solution a

Crystal violet (certified)	2.0 g
Dissolve in 95% ethyl alcohol	20.0 ml

Solution b

Ammonium oxalate	0.8 g
Distilled water	80.0 ml

1. Mix solutions a and b.
2. Let stand overnight.
3. Filter through coarse filter paper before use.

- b) **Gram's iodine** must be protected from light.

Iodine (crystalline)	1.0 g
Potassium	2.0 g
Distilled water	300.0 ml

1. Combine the crystalline iodine, potassium, and distilled water to prepare an iodine solution.
 - Grinding the dry chemicals in a mortar with small additions of distilled water may be helpful in preparing the iodine solution.
2. Store the Gram's iodine solution in a dark bottle and protected from light so it does not degrade.

- c) **Decolorizer** is commonly ethyl alcohol. (Some kits use acetone or an acetone-alcohol combination.)

95% ethyl alcohol

- d) **Counterstain** is commonly either safranin or carbol-fuchsin. Ziehl-Nielsen carbol-fuchsin is considered by many to be a more effective counter-stain than carbol-fuchsin.

1. **Safranin**

Stock solution:

Safranin-O (certified)	2.5 g
95% ethyl alcohol	100.0 ml

Working solution:

Safranin stock solution	10.0 ml
Distilled water	90.0 ml

a. Prepare the stock safranin solution by combining the Safranin-O with the 95% ethyl alcohol.

b. Combine 10-ml of the stock solution with 90-ml of distilled water.

OR

2. Ziehl-Nielsen carbol-fuchsin

Basic fuchsin	0.3 g
95% ethyl alcohol	10.0 ml
Phenol crystals, melted	5.0 ml
Distilled water	95.0 ml

a. Dissolve fuchsin in alcohol.

b. Add the 5% phenol solution.

c. Let stand overnight.

d. Filter through coarse filter paper.

- This solution can be used as described or diluted 1:10.

When limited by resource availability, counterstain can be prepared as a 0.3–0.5 aqueous solution of the basic fuchsin.

Loeffler's methylene blue stain

Loeffler's methylene blue provides a simple staining method for visualize the shape of bacterial cells; it does not determine whether bacteria are gram-positive or gram-negative. If determining whether an organism is gram-positive or gram-negative is essential, smears must be stained by Gram's method (*i.e.*, using reagents as described in "Gram stain", earlier in this Appendix). Because of the characteristic shape and arrangement of cells in *Neisseria* species, the methylene blue stain may provide an inexpensive, rapid method for detecting diplococci. (This laboratory manual recommends use of Loeffler's methylene blue stain in place of Gram stain for staining of suspect *N. gonorrhoeae* from specimens or cultures of non-sterile sites, but not for staining of *N. meningitidis* from sterile-site specimens.)

To prepare the Loeffler's methylene blue stain, add the components in the order presented in the following two steps to first prepare saturated ethanolic methylene blue and then the staining solution.

a) Saturated ethanolic methylene blue

Methylene blue powder	1.0 g
Ethanol (95%)	100 ml

b) Staining solution

KOH (1% aqueous solution)	1 ml
Distilled water	99 ml
Ethanolc methylene blue solution (<i>step 1</i>)	30 ml

Loeffler's methylene blue reagent must be 'ripened by oxidation,' and the ripened reagent is called polychrome methylene blue. Normally, oxidation takes several months, but it can be hastened by aerating the reagent: Place the reagent in bottles filled no more than half-full and shake the bottle frequently.

Loeffler's methylene blue stain improves with age, and the shelf-life of this reagent is 5–10 years; thus, the reagent can be prepared in batches large enough to last for this time period.

Nitrate reduction test reagents

These media and reagents are used to perform the nitrate reduction test for the confirmation of an isolate as *N. gonorrhoeae*. The test is performed in a nitrate broth composed of heart infusion broth containing 0.2% potassium nitrate.

The formula for the nitrate reduction test medium is:

Heart infusion broth	25.0 g
Potassium nitrate	2.0 g
Distilled water	1000.0 ml

Reagents for developing the nitrate reduction tests are as follows:

Nitrate Reagent A (Sulfanilic acid solution): 0.8% in 5 N acetic acid*

4-aminobenzene sulfonic acid	0.5 g
Acetic acid, glacial	20 ml
Distilled water	100 ml

- 1) Dissolve 0.5 g of 4-aminobenzene sulfonic acid in 30 ml of glacial acetic acid.
- 2) Add 100 ml of distilled water and filter.

Store Nitrate Reagent A at room temperature (15°–30°C) in the dark. Reagents may be stored in dark brown glass bottles or in clear bottles wrapped in aluminum foil to ensure darkness. **Nitrate Reagent A is stable for one month.**

Nitrate Reagent B (alpha-naphthylamine solution): 0.6% in 5 N acetic acid*

N,N-dimethyl-1 naphthylamine	0.1 g
Distilled water, boiling	100 ml
Acetic acid, glacial	30 ml

- 1) Dissolve 0.1 g of N,N-dimethyl-1 naphthylamine in 100 ml of boiling distilled water. Cool to room temperature.

2) Add 30 ml of glacial acetic acid.

3) Filter.

Store Nitrate Reagent B at room temperature (15°–30°C). Reagents may be stored in dark brown glass bottles or in clear bottles wrapped in aluminum foil to ensure darkness. **Nitrate Reagent B is stable for up to one week (7 days).**

Zinc powder: reagent grade. Store at room temperature.

* **Warning:** 5 Normal (glacial) acetic acid is corrosive. Contact with skin may cause blisters and burns. In case of contact, flush eyes and skin immediately with plenty of water for at least 15 minutes.

Nitrocefin reagent for β -lactamase (penicillinase) test

The nitrocefin test is used to detect β -lactamase. Reagents should be warmed to room temperature prior to use. There are two formulations of the liquid reagent for the nitrocefin test: one has a nitrocefin powder concentration of 500- μ g/ml, and the other has a nitrocefin powder concentration of 25- μ g/ml. The reagent used for the plate test contains 500 μ g of nitrocefin powder/ml and is dropped directly onto colonies on culture medium; in contrast, the reagent used for the tube test (in which bacterial cells are suspended in the reagent) contains only 25 μ g of nitrocefin/ml. Nitrocefin disks are also commercially available.

Because the nitrocefin reagent is expensive, this laboratory manual suggests that a commercially available nitrocefin disk be used because it is a more cost-effective means of performing the test than use of the liquid reagent (unless a laboratory is conducting surveillance for penicillin resistance in *N. gonorrhoeae* and will be performing the nitrocefin test on large numbers of isolates). If, however, a laboratory wants to prepare its own liquid nitrocefin reagent, instructions are below. (Methods for performing the nitrocefin test with liquid reagent are included in the *N. gonorrhoeae* chapter of this manual.) Because the reagent used for the tube method is more dilute than that used for the plate test, performing the nitrocefin test by the tube method using the liquid reagent is more cost-effective than the plate or disk method for testing large numbers of isolates.

Note that preparation of the nitrocefin solution requires dimethyl sulfoxide (DMSO; CH_2SO_4), and because of the hazardous nature of DMSO some suppliers may require a letter of justification for its purchase.

Materials for preparation of nitrocefin solution include:

Nitrocefin powder	(0.5 g for stock solution of 100 ml)
0.1 M phosphate buffer, pH 7.2	(100 ml for stock solution; 1:20 dilution for tube test)

DMSO (dimethyl sulfoxide)
Graduated cylinder (50 ml)
Screw-cap/snap-capped tubes (5 ml capacity)
Pasteur pipets (sterile)

Nitrocefin solution for plate test (“stock solution”; 500 µg/ml)

- Weigh 0.5 g nitrocefin powder in a weigh boat or beaker. Transfer nitrocefin powder to graduated cylinder.
- Using a sterile glass pipette, add a few drops of DMSO to the nitrocefin powder. Swirl until the powder dissolves.
- Make volume up to 100 ml with 0.1 M phosphate buffer, pH 7.2.
- Dispense nitrocefin reagent in 5 ml volume into screw-cap/snap-capped tubes.
- Label tubes with the following information: Reagent name, date prepared, the expiration date when moved to storage at 4°–10°C, and hazard code for DMSO. (*This information should also be logged in the QC log.*)

Nitrocefin solution for tube test (25 µg/ml) (*Growth suspended in nitrocefin reagent contained in tubes / microtiter plate wells*)

- Prepare the stock nitrocefin solution (500 µg nitrocefin/ml) as described in the “Plate test nitrocefin solution, stock solution” section above.
- Dilute the stock solution 1:20 with 0.1 M phosphate buffer, pH 7.2.
- Dispense 3-ml volumes of the diluted nitrocefin solution into screw-cap or snap-capped tubes.
- Label tubes with the following information: reagent name, date prepared, the expiration date, and hazard code for DMSO. (*This information should also be logged in the work record.*)

Nitrocefin reagents may be prepared in bulk, dispensed in small aliquots (1–2 ml), and stored at -20°C or -70°C indefinitely if no color change (from colorless/yellow to pink) is observed. If a tube of the reagent is ‘in-use,’ the reagent may be stored for up to one year at 4°–10°C if no color change is observed.

Quality control: Perform quality control with each newly prepared batch of nitrocefin reagent or each newly purchased batch of nitrocefin disks.

- An example of a β-lactamase negative control strain is *N. gonorrhoeae* ATCC 49226.
- Examples of β-lactamase positive control strain are *H. influenzae* ATCC 49247 and *N. gonorrhoeae* P681E (available from the CDC’s Gonorrhea Research Laboratory, see Appendix 14).

Oxidase reagent (Kovac's oxidase)

Kovac's oxidase reagent is used to test for the presence of cytochrome oxidase; *N. gonorrhoeae*, *N. meningitidis*, and *V. cholerae* are all oxidase-positive and exhibit a purple reaction when exposed to this reagent. The formula for Kovac's oxidase follows:

<i>N,N,N',N'</i> -Tetramethyl- <i>p</i> -phenylenediamine dihydrochloride	0.05 g
Distilled water	5.0 ml

Dissolve the reagent in purified water. (Do not heat to dissolve.)

Preparation of 1% Kovac's oxidase reagent from powder

To prevent deterioration of stock oxidase-reagent powder, store in a tightly closed bottle in a desiccator kept in a cool dark area. Prepare 10 ml of a 1.0% tetramethyl-*p*-phenylenediamine hydrochloride solution in distilled water. Dispense the reagent in 1-ml aliquots and store frozen at -20°C.

For use, thaw a 1-ml vial and either use the liquid reagent to moisten filter paper or a swab or prepare dried strips of filter paper.

- To prepare dried treated filter paper, immediately after the vial is thawed, wet as many strips of filter paper as possible on a nonporous surface (*i.e.*, Petri dish, glass plate). Let the strips dry in air or in the incubator. When the strips are completely dry, place them in a tightly capped tube/bottle and refrigerate at 4°C. The strips can then be used as needed.

Note: Oxidase reagent is intended only for *in vitro* diagnostic use; avoid contact with the eyes and skin because it can cause irritation. In case of contact, immediately flush eyes or skin with plenty of water for at least 15 minutes.

Instead of Kovac's oxidase reagent (described above), some laboratories may use Gordon and McLeod's reagent. Gordon and McLeod's reagent is prepared to a 1% solution (as is Kovac's oxidase), but instead of the tetramethyl- reagent used for Kovac's reagent, Gordon and McLeod's reagent uses dimethyl-*p*-phenylenediamine dihydrochloride. Gordon and McLeod's oxidase is a more stable reagent but oxidase reactions take up to 30 minutes to occur, instead of 5 minutes; it should also be noted that oxidase-positive reactions with Gordon and McLeod's reagent are blue (not purple). This laboratory manual suggests using Kovac's oxidase reagent if it is available.

Quality control: Positive and negative controls should be tested every time the reagent is prepared.

- *V. cholerae*, *N. meningitidis*, and *N. gonorrhoeae* are oxidase-positive
- *E. coli* and *S. pneumoniae* are oxidase negative.

Sodium desoxycholate reagent (0.5%) for string test

The string test is used to help identify *V. cholerae*. The formula for this reagent follows:

Sodium desoxycholate (also seen as “deoxycholate”)	0.5 g
Sterile distilled water	100.0 ml

Add sterile distilled water to sodium desoxycholate and mix well. Store at room temperature for up to 6 months.

Quality control: Each new batch of sodium desoxycholate should be quality controlled before use.

- Use a *V. cholerae* O1 strain as a positive control.
- *E. coli* may be used as a negative control.

Preparation of turbidity standards

Turbidity standards (McFarland turbidity standards)

Commercially prepared 0.5 McFarland turbidity standards are available from various manufacturers. Alternately, the 0.5 McFarland turbidity standard may be prepared by adding 0.5 ml of a 1.175% (wt/vol) barium chloride dihydrate ($\text{BaCl}_2 \cdot 2\text{H}_2\text{O}$) solution to 99.5 ml of 1% (vol/vol) sulfuric acid (H_2SO_4). The turbidity standard is then aliquoted into test tubes identical to those used to prepare the inoculum suspension. Seal the McFarland turbidity standard tubes with wax, Parafilm, or some other means to prevent evaporation. McFarland turbidity standards may be stored for up to 6 months in the dark at room temperature (*i.e.*, 22°–25°C); discard after 6 months or sooner if any volume is lost. (Mark the tube to indicate the level of liquid, and check before use to be sure that evaporation has not occurred; if it has, a fresh turbidity standard should be prepared.) Before each use, shake the tube containing the turbidity standard well, so that the fine white precipitate of barium sulfate is mixed in the tube.

The composition of McFarland turbidity standards and the corresponding densities of bacteria (/ml) are presented in Table 23.

The accuracy of the density of a prepared McFarland turbidity standard should be checked by using a spectrophotometer with a 1-cm light path; for the 0.5 McFarland turbidity standard, the absorbance at a wavelength of 625 nm should be 0.08–0.1. Alternately, the accuracy of the McFarland turbidity standard may be verified by adjusting a suspension of a control strain (*e.g.*, *E. coli* ATCC 25922) to the same turbidity, preparing serial 10-fold dilutions, and then performing plate counts of colonies (Figure 50). The adjusted suspension should give a count of 108 colony forming units/ml. Figures 51 and 52 are helpful guides for how to read and compare the McFarland turbidity standard to a newly prepared cell suspension.

FIGURE 50: Flowchart procedure for preparation and quality control of the 0.5 McFarland turbidity standard

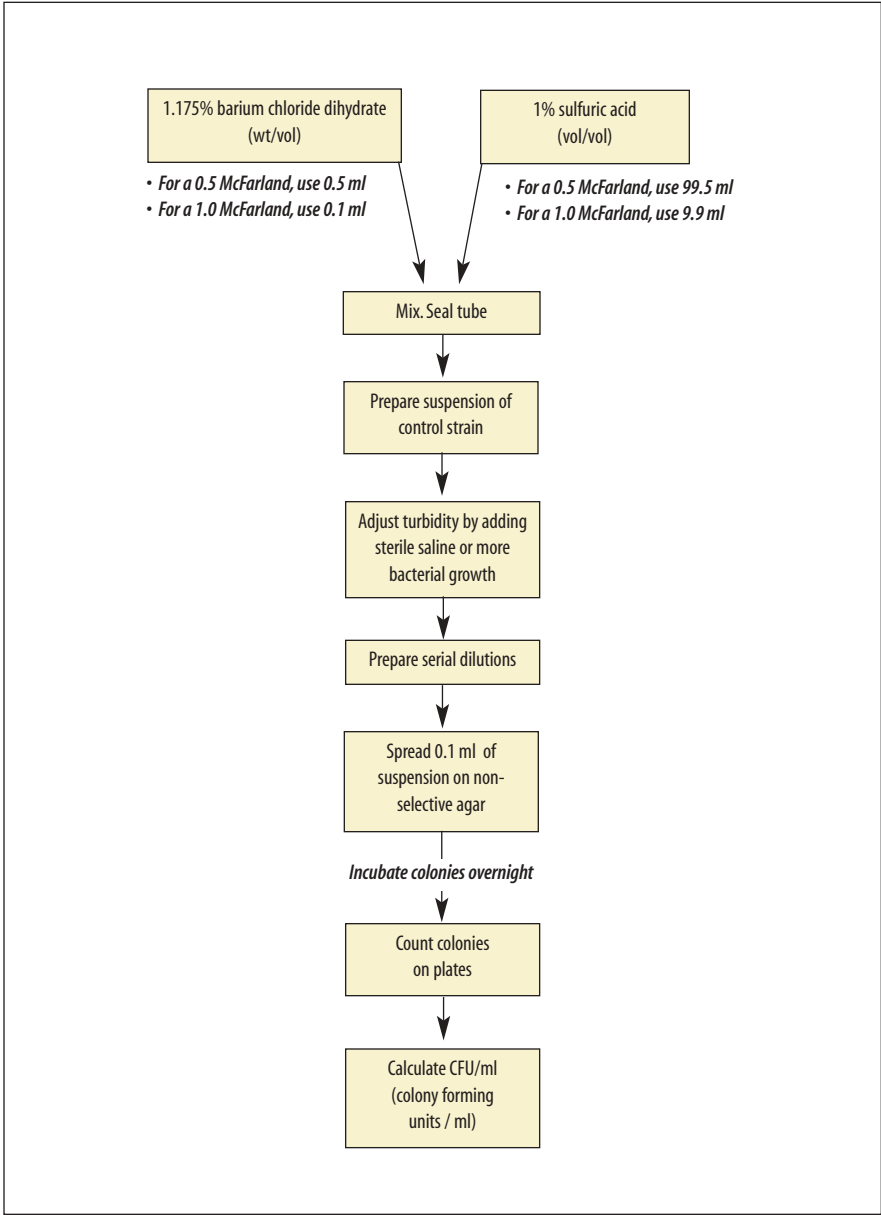


TABLE 23: Composition of McFarland turbidity standards

Turbidity standard number	Barium chloride dihydrate (1.175%)	Sulfuric acid (1%)	Corresponding approximate density of bacteria
0.5	0.5 ml	99.5 ml	1×10^8
1	0.1 ml	9.9 ml	3×10^8
2	0.2 ml	9.8 ml	6×10^8
3	0.3 ml	9.7 ml	9×10^8
4	0.4 ml	9.6 ml	12×10^8
5	0.5 ml	9.5 ml	15×10^8
6	0.6 ml	9.4 ml	18×10^8
7	0.7 ml	9.3 ml	21×10^8
8	0.8 ml	9.2 ml	24×10^8
9	0.9 ml	9.1 ml	27×10^8
10	1.0 ml	9.0 ml	30×10^8

FIGURE 51: Comparison of the 0.5 McFarland turbidity standard with inoculum suspension



FIGURE 52: Background lines for viewing turbidity of a suspension in comparison to a turbidity standard

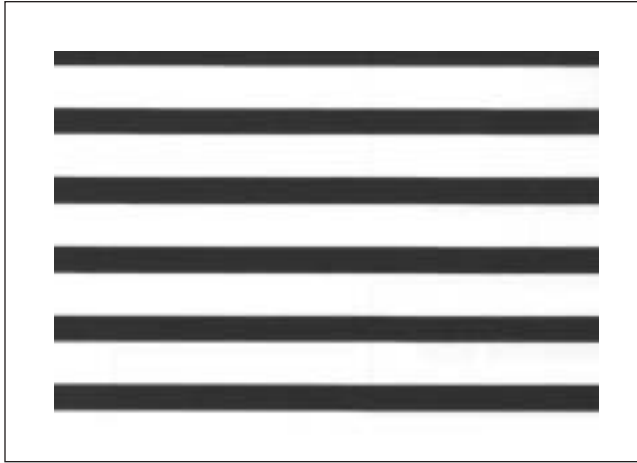


Plate count method for testing a 0.5 McFarland turbidity standard

The goal of this procedure is to determine the number of bacteria per ml of fluid. A bacterial suspension equivalent in turbidity to a 0.5 McFarland turbidity standard contains approximately 10^8 bacteria per ml.

- 1) Prepare 0.5 McFarland turbidity standard, as described above.
- 2) Prepare a suspension of a test organism (*e.g.*, *E. coli* ATCC 25922) to match the density of the McFarland turbidity standard.
- 3) Make serial, 10-fold dilutions of the bacterial suspension in a suitable broth medium. (Examples of suitable broth media include Mueller Hinton broth, TSB, or PBS.) The following steps *a – i* describe the procedure for making the serial dilutions.

Materials necessary for testing of the 0.5 McFarland turbidity standard include: seven sterile screw-capped tubes, seven agar plates (with medium to support growth of the organism you're testing), and pipettes capable of measuring out 4.5 ml and 0.5 ml, respectively. In addition, a vortex machine is useful for vigorous mixing in tubes.

- a) Make sure you have seven screw-capped tubes, each capable of holding at least 10 ml of fluid. Prepare dilution tubes by adding 4.5 ml of sterile broth to each of the seven 10-ml tubes.
- b) Label the tubes from 1 to 7, indicating the dilution the tube will hold. Also label agar plates of the appropriate medium from 1 to 7.
- c) Add 0.5 ml of the bacterial suspension made up to 0.5 McFarland turbidity standard to the tube labeled 7 and mix vigorously.

- d) **Using the same pipette as in step C**, draw up and release the suspension several times into the pipette and then transfer 0.5 ml from tube 7 to tube 6 and mix vigorously.
- e) Continue this process of transferring 0.5 ml to each successive tube, **using the same pipette**, until you have completed the dilutions with tube 1. After vigorously mixing tube 1, use the pipette to draw up and release the suspension in the tube several times.
- f) Using the same pipette, transfer 0.1 ml from tube 1 to the plate labeled 1.
- g) Using the same pipette, transfer 0.1 ml from tube 2 to the plate labeled 2. Continue this process for tube 3 to plate 3, and tube 4 to plate 4. (If laboratorians unfamiliar with making bacterial suspensions to match a McFarland turbidity standard are responsible for the procedure, the process may be continued through tube 7. However, plating out the tubes with a higher concentrations of medium is not mandatory, because doing so would result in too many colonies to count when they grow.)
- h) Using a bent rod and starting with plate 1, spread the fluid on each plate over the entire surface of the plate. A bent rod can be made by using heat to bend a 2–5 mm diameter glass rod to an approximately 60°-angle, with the short end measuring approximately 5 cm. A bent, stainless steel metal rod of similar size can be used as an alternative to a glass rod. (The fluid can also be spread with a wire inoculating loop or needle bent to a 60°-angle, but spreading the fluid evenly is more difficult using these methods.)
- i) Incubate the plates overnight and count the number of colonies on each plate. It may be difficult to count the colonies on plates 4 through 7, and if there are more than 300 colonies per plate it should not be counted.

Interpretation of plate count results

A 0.5 McFarland turbidity standard is equivalent to approximately 10^8 bacteria per ml. The original bacterial suspension that resembles the 0.5 McFarland turbidity standard could have a range of 1.0×10^8 bacteria/ml to 9.0×10^8 bacteria/ml. Within this range, the 0.5 turbidity standard is accurate; the difference will be evident in the number of bacteria that grow out on the plates.

After 0.5 ml of the original bacterial suspension (*i.e.*, which is equivalent to the 0.5 McFarland turbidity standard) is added to the 4.5 ml of broth in tube 7, a suspension of bacteria is produced that contains approximately 10^7 bacteria per ml. Then 0.1 ml of this suspension has been transferred to the plate marked 7, which translates to approximately 10^6 (1,000,000–9,000,000) bacteria present on that plate. If the bacteria were diluted correctly: approximately 10^5 (or 100,000 –

³⁴ All lists are limited and incomplete. Note that inclusion of a company or specific product does not imply endorsement by CDC or WHO.

900,000) bacteria should be present on the plate labeled 6; approximately 10,000–90,000 bacteria on the plate labeled 5; approximately 1,000–9,000 bacteria present on plate 4; approximately 100 to 900 bacteria present on plate 3; approximately 10 to 90 bacteria on plate 2; and, approximately 1 to 9 bacterial colonies would be present on plate 1. Each plate should have one-tenth the bacteria as the plate with the next higher number. Generally, the plate labeled 3 will be the plate that is counted; however, if there are more than 300 colonies present on plate 3, then plate 2 should be counted.

Sources of prepared media and reagents

Although commercially prepared media and reagents are more expensive than media or reagents that can be prepared locally, commercially available items can be used (and may be preferable) in certain situations. Dehydrated media, for example, are often preferable to media prepared from individual components because of reduced lot-to-lot variation. It may also be desirable to purchase the supply of media and reagents to perform short-term studies rather than attempt formulation. The following media and reagents are available in most parts of the world from suppliers including, but **not limited to**: BBL (available from Becton, Dickinson and Company), bioMérieux, Difco (available from Becton, Dickinson and Company), Merck, Oxoid, and Quélab (Table 24); a partial listing of manufacturers, suppliers, and distributors with contact information is included in Appendix 13.³⁵ (The listing of supplies, media and reagents in this laboratory manual is not exhaustive, and availability of products from specific companies or suppliers may change. Inclusion of a company or product does not imply endorsement by CDC or WHO.) It is essential that each lot of materials has a satisfactory expiration date and that the date of expiration and lot number for commercial media are recorded in the laboratory.

In addition to media and reagents, laboratories must maintain their supplies (e.g., glassware) and equipment; Developing Health Technology is a company that provides low-cost laboratory equipment for developing countries, nongovernmental organizations (NGOs) and aid agencies. Furthermore, as noted elsewhere in this document, the manufacturer of the Etest® (AB Biodisk) may make materials available at a reduced price to laboratories in developing country settings. Contact information for these companies is available in Appendix 13.

³⁵ All lists are limited and incomplete. Note that inclusion of a company or specific product does not imply endorsement by CDC or WHO.

TABLE 24: Partial listing of materials and suppliers / manufacturers

Description of item ^a <i>^a This is not intended to be comprehensive catalog of materials and suppliers.</i>	Sample listing of manufacturers ^b <i>^b Inclusion does not imply endorsement of commercial products or suppliers by CDC or WHO.</i>
Acetone-alcohol (decolorizing agent)	Remel; Difco (BD); BBL (BD)
Agar agar	Remel; Oxoid; BBL (BD)
Ampicillin disks	Remel; Oxoid; BBL (BD)
Azithromycin disks	Remel; Oxoid; BBL (BD)
Bile salts	Quélab; Remel; Oxoid; BBL (BD)
Bismuth sulfite (BS) agar	Quélab; Difco (BD); Oxoid; BBL (BD)
Blood culture medium - <i>prepared</i>	bioMérieux; Oxoid
Bovine hematin	Quélab; BBL (BD)
Brain-heart infusion (BHI)	Quélab; Difco (BD); Oxoid; BBL (BD); Remel
Cary-Blair medium	Quélab; Difco (BD); Oxoid; BBL (BD)
Cefixime disks	Remel; Oxoid; BBL (BD)
Ceftriaxone disks	Remel; Oxoid; BBL (BD)
Chloramphenicol disks	Remel; Oxoid; BBL (BD)
Chocolate blood agar - <i>prepared</i>	bioMérieux; Remel; BBL (BD)
Chocolate blood agar + bacitracin - <i>prepared</i>	Remel; BBL (BD)
Ciprofloxacin disks	Remel; Oxoid; BBL (BD)
CO ₂ -generating systems	Oxoid; Remel
Colistin disks	Quélab; Remel; Oxoid; BBL (BD)
Crystal violet	Quélab; Difco (BD); Remel; BBL (BD)
Cystine trypticase agar (CTA)	Quélab; Difco (BD); BBL (BD)
Defined growth supplement (e.g., IsoVitalEx, Vitox, VX Supplement)	BBL (BD); Oxoid; Difco (BD)
Desoxycholate	Quélab; Remel
Desoxycholate citrate agar (DCA)	Quélab; Difco (BD); BBL (BD)
Etest® antimicrobial gradient strips	AB Biodisk; Remel; Fisher Scientific
Ethanol	Remel; Merck
Formalin (formaldehyde)	Remel; Merck
Furazolidone disks	Remel; Oxoid; BBL (BD)
Gonochek II® (enzyme substrate test)	TCS Microbiology
Gonococcus (GC) agar base medium	Quélab; Difco (BD); Oxoid; BBL (BD)
Gram stain kit	bioMérieux; Difco (BD); Remel; BBL (BD)
Gram-negative broth	Difco (BD); BBL (BD); Renek
Gram's iodine	Quélab; Difco (BD); Remel; BBL (BD)
<i>H. influenzae</i> serotyping antisera	Difco (BD); Remel

continued

TABLE 24: Partial listing of materials and suppliers / manufacturers, *continued*

Description of item ^a ^a This is not intended to be comprehensive catalog of materials and suppliers.	Sample listing of manufacturers ^b ^b Inclusion does not imply endorsement of commercial products or suppliers by CDC or WHO.
<i>Haemophilus</i> test medium (HTM)	Oxoid; BBL (BD)
Heart infusion agar / broth	Quélab; Difco (BD); BBL (BD)
Hektoen enteric (HE) agar	Quélab; Difco (BD); Oxoid; BBL (BD)
Hemoglobin powder	Quélab; Difco (BD); Oxoid; BBL (BD)
Horse blood	Difco (BD); Oxoid
Jembec® plates	BBL (BD); Quélab
Kligler iron agar (KIA)	Quélab; Difco (BD); Oxoid; BBL (BD)
Kovac's oxidase reagent (<i>N,N,N',N'</i> -tetramethyl- <i>p</i> -phenylenediamine dihydrochloride)	Quélab; Merck
Lysine iron agar (LIA)	Quélab; Difco (BD); Oxoid; BBL (BD)
MacConkey agar (MAC)	Quélab; Difco (BD); Oxoid; BBL (BD)
Martin-Lewis medium - <i>prepared</i>	Quélab; BBL (BD)
Methylene blue	Quélab; Remel
Modified Thayer-Martin medium - <i>prepared</i>	Quélab; Remel; BBL (BD)
Motility medium	Quélab; Difco (BD); BBL (BD)
Mueller-Hinton agar - <i>prepared</i>	bioMérieux; Remel; BBL (BD)
Mueller-Hinton agar plus 5% sheep blood - <i>prepared</i>	bioMérieux; Remel; BBL (BD)
Mueller-Hinton agar/broth	Quélab; Difco (BD); Oxoid; Remel
<i>N. meningitidis</i> serogrouping antisera	Difco (BD); Remel
Nalidixic acid disks	Oxoid; BBL (BD)
Nicotinamide adenine dinucleotide (NAD; V factor)	Quélab; Merck
Nitrate broth	Quélab; Difco (BD)
Nitrate Reagents A and B	Remel; BBL (BD)
Nitrocefin (beta-lactamase)	Remel; Difco (BD); Oxoid; BBL (BD)
Optochin (p-disks)	Oxoid; BBL (BD)
Oxacillin disks	Oxoid; BBL (BD)
Penicillin disks	Oxoid; BBL (BD)
Peptone	Difco (BD); Oxoid
Permeable membrane screw-caps (for short-term storage of <i>N. meningitidis</i> at 4 °C)	(Biomedical Polymers, Inc., via) Fisher Scientific; VWR International
Phosphate buffered saline (PBS)	Quélab; Oxoid
Quad ID plate	Quélab; BBL (BD)
Quality control strains (type cultures)	American Type Culture Collection (ATCC); National Culture Type Collection (NCTC)
<i>S. pneumoniae</i> serotyping antisera	Omniserum; Remel; Difco (BD)

continued

TABLE 24: Partial listing of materials and suppliers / manufacturers, *continued*

Description of item ^a ^a This is not intended to be comprehensive catalog of materials and suppliers.	Sample listing of manufacturers ^b ^b Inclusion does not imply endorsement of commercial products or suppliers by CDC or WHO.
Safranin	Quélab; Difco (BD); Remel; BBL (BD)
<i>Salmonella</i> (ser. Typhi) serotyping antisera	Remel; Difco (BD)
<i>Salmonella-Shigella</i> (SS) agar	Quélab; Difco (BD); Oxoid; BBL (BD)
Selenite broth (SEL)	Quélab; Difco (BD); Oxoid; BBL (BD)
Sheep blood	Remel; Quélab
Sheep blood agar (TSA + 5% sheep blood) - <i>prepared</i>	bioMérieux; BBL (BD)
Sheep blood agar + gentamicin - <i>prepared</i>	Quélab; BBL (BD)
<i>Shigella</i> antisera	Remel; Difco (BD)
Silica gel packets (for transport and short-term storage of some pathogens)	Scientific Device Laboratory, Inc.
Skim milk powder	Quélab; Difco (BD); BBL (BD)
Sodium polyanethol sulfonate (SPS)	Quélab; Oxoid
Spectinomycin disks	Oxoid; BBL (BD)
Sucrose (reagent-grade)	Quélab; BBL (BD)
Sulfide-indole-motility medium (SIM)	Remel; Oxoid; BBL (BD)
Superoxol reagent (30% H ₂ O ₂)	Quélab; Merck
Tetracycline disks	Remel; Oxoid; BBL (BD)
Thiosulfate citrate bile salts sucrose agar (TCBS)	Quélab; Oxoid; BBL (BD)
Todd-Hewitt broth	Difco (BD); Oxoid; BBL (BD)
Trimethoprim-sulfamethoxazole (cotrimoxazole) disks	Remel; Oxoid; BBL (BD)
Triple sugar iron agar (TSI)	Quélab; Difco (BD); BBL (BD)
Tryptone (Trypticase) soy agar/broth	Quélab; Difco (BD); Oxoid; BBL (BD); bioMérieux
Tryptone (Trypticase) soy agar - <i>prepared</i>	BBL (BD); bioMérieux
Urea medium	Quélab; Difco (BD); Oxoid; BBL (BD)
<i>V. cholerae</i> antisera	Remel; Difco (BD)
VCA(T) supplement (to prepare Martin-Lewis medium)	Quélab; Oxoid; BBL (BD)
VCN(T) supplement (to prepare Modified Thayer-Martin)	Quélab; Oxoid; BBL (BD)
V-factor disks (NAD)	Remel; Oxoid
X-factor disks (haemin)	Remel; Oxoid; Quélab
XV-factor disks	Remel; Oxoid; Quélab
Xylose lysine desoxycholate agar (XLD)	Quélab; Difco (BD); Oxoid; BBL (BD); Remel
Zinc dust	Quélab; BBL (BD)

Collection and Transport of Sterile-Site Specimens

Blood

Blood specimens may be obtained from patients with pneumonia, meningitis, or fever of unknown origin, among other syndromes.

Pneumonia

Blood cultures will be positive for a bacterial pathogen in approximately 10% – 35% of children with chest x-ray confirmed pneumonia. Because of the time and resources required to collect and process specimens, blood cultures should be obtained from children likely to have bacteremic pneumonia. Pneumonia should be diagnosed using criteria established by the World Health Organization (WHO): if several family members present with the same pneumonic symptoms and / or if wheezing is a major symptom, the etiology is likely to be viral and not bacterial; if the patient is a child under two years of age or a child with fever $>39^{\circ}\text{C}$, bacteremia may be easier to detect.

Meningitis

Blood cultures may be collected from a patient with meningitis when the performance of a spinal tap is contraindicated or when it is not technically feasible.

Fever of unknown origin

Blood cultures collected early after the onset of sustained fever (*i.e.*, suspected typhoid fever) may be positive for *Salmonella* serotype Typhi, a gram-negative bacillus.

Collection of blood specimens

Reference laboratories should usually receive isolates, rather than clinical specimens, but blood is a commonly collected clinical specimen, and one with which laboratorians should be familiar working.

Infection can be transmitted from patient to staff and from staff to patient during the blood-taking procedure. Viral agents pose the greatest hazard and in some instances are potentially lethal. Of particular importance are the hepatitis viruses and the human immunodeficiency virus (HIV; the virus causing acquired immunodeficiency syndrome [AIDS]). **To decrease the risk of transmission of these viral agents**, the following recommendations should be practiced.

- a) Wear latex or vinyl gloves impermeable to liquids.
- b) Change gloves between patients.
- c) Inoculate blood into blood-culture media immediately to prevent the blood from clotting in the syringe. Syringes and needles should be disposed of in a puncture-resistant, autoclavable container. No attempt should be made to recap the needle. **A new syringe and needle must be used for each patient.**
- d) Wipe the surface of the blood-culture bottle and the gloves with a disinfectant.
- e) Label the bottle.
- f) For the transport to the microbiology laboratory, place the blood-culture medium in a container that can be securely sealed.
- g) Specimen containers should be individually and conspicuously labeled. Any containers with blood on the outside should be wiped thoroughly. Such containers should be transported in individual, sealed plastic envelopes.
- h) Remove gloves and discard in an autoclavable container.
- i) Wash hands with soap and water immediately after removing gloves.
- j) Transport the specimen to the microbiology laboratory or, if that facility is closed, store the specimen in an approved location.
- k) In the event of a needle-stick injury or other skin puncture or wound, wash the wound thoroughly with soap and water, encouraging bleeding.

Report any contamination of the hands or body with blood, or any puncture wound, or any cut to the supervisor and the health service for treatment, as appropriate.

Venipuncture

An outline of the proper method for collecting blood from the arm is shown in Figure 52.

- a) Gather everything needed to complete the blood collection process: gloves, syringe, needle, tourniquet, gauze squares, cotton balls, adhesive bandage, puncture resistant container, culture medium and antiseptic; iodine tincture (100 ml of 70% isopropyl alcohol to 1 g of iodine) or povidone-iodine is

preferred, but 70% alcohol is an acceptable alternative.³⁶ The size of the needle will depend on the collection site and the size of the vein. A 23-gauge needle that is 20 – 25 mm in length or a butterfly needle is generally used for children.

Collecting a large amount of blood from a child can be difficult: 1 – 3 ml is usually sufficient, but volume of blood is directly related to culture yield. Blood cultures from young children should be diluted to 1 – 2 ml of blood in 20 ml of broth (1:10 to 1:20). Blood cultures from adults should be diluted to 5 – 10 ml of blood in 50 ml of broth (1:5 to 1:10).

- b) Select an arm and apply a tourniquet to restrict the flow of venous blood. The large veins of the forearm are illustrated in Figure 53; the most prominent vein is usually chosen for venipuncture.
- c) Vigorously wipe the skin with the 70% alcohol, and swab with the iodine tincture or povidone-iodine. Rub over the selected area. Allow to dry. **If the vein is palpated again, repeat the skin disinfection.**
- d) After the disinfectant has dried, insert the needle into the vein with the bevel of the needle face-up. Once the vein is entered, withdraw the blood by pulling back the barrel of the syringe in a slow, steady manner. Air must not be pumped into a vein. After the desired amount of blood is obtained, release the tourniquet and place a sterile cotton ball over the insertion site while holding the needle in place. Withdraw the needle and have the patient hold the cotton ball firmly in place until the wound has stopped bleeding. Inoculate the culture medium. Put the adhesive bandage on the wound.
- e) Use vacutainer tubes for blood collection, if they are available.

Specimens should be put into a blood-culture bottle immediately and placed in an incubator as soon as possible; if incubation is not feasible, the blood culture bottle can be kept at room temperature (20° – 25°C) for up to 8 hours. Ideally, the blood samples should be processed in a bacteriology laboratory as soon as possible after collection (*i.e.*, within 2 hours).

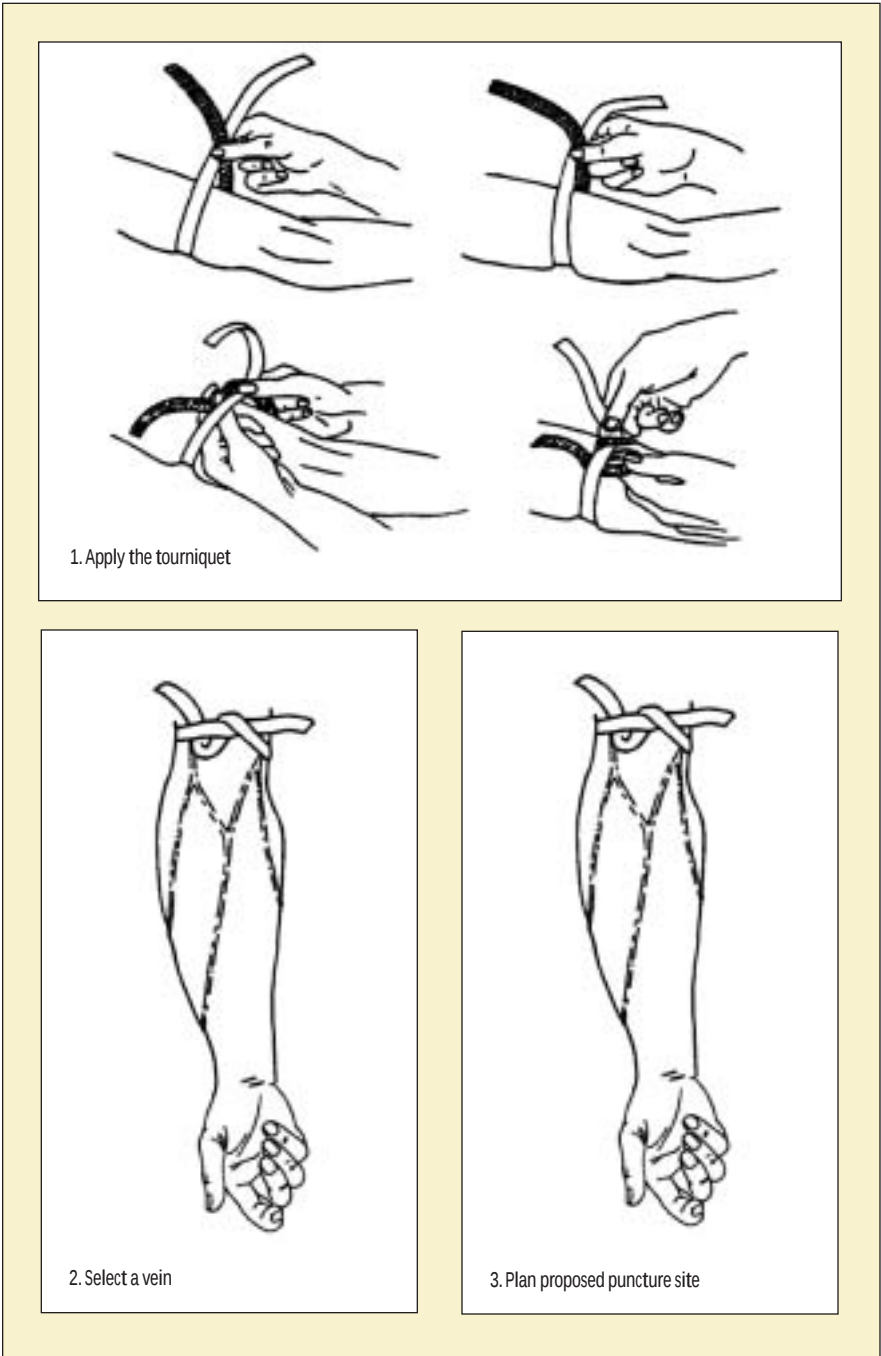
For the diagnosis of bacterial meningitis, blood should be collected when a spinal tap is contraindicated or cannot be performed for technical reasons.

Transport of blood specimens

Blood cannot be transported before being placed in broth because the collection procedure does not use an anticoagulant. If the blood-culture bottle contains a diaphragm, clean the diaphragm with 70% alcohol and povidone-iodine before inoculating the broth medium.

³⁶ Alcohol with concentrations greater than 70% has decreased bactericidal activity and should not be used.

FIGURE 53: Collection of blood from an arm



- a) Inject the blood into the broth culture medium within 1 minute of collection. The broth culture medium should contain supplemental SPS or haematin to promote survival of any organisms. Swirl the bottle several times. Discard the needle and syringe in a puncture-resistant container. Do not re-cap the needle. Clean the diaphragm of the blood-culture bottle, if necessary. Then label it appropriately with patient identification and the date and time of blood collection. The preparation of blood culture media is described in Appendix 2.
- b) The inoculated medium can be kept at room temperature (20°–25°C) for 4 – 6 hours before incubation at 35°C. **Inoculated or uninoculated blood-culture medium must not be placed in a refrigerator.** A portable incubator can be used (temperature range 25°– 35°C).
- c) Immediately transport the inoculated media to the laboratory. **All inoculated blood-culture media should be received by the laboratory within 12 – 18 hours for subculture and should be protected from temperature extremes (<18°C or >37°C)** by using a transport carrier made of, *e.g.*, polystyrene (*e.g.*, Styrofoam), which can keep the samples at moderate temperature.

Cerebrospinal fluid (CSF)

If meningitis is suspected, cerebrospinal fluid (CSF) is the best clinical specimen to use for isolation and identification of the etiologic agent. Suspected agents should include *N. meningitidis*, *S. pneumoniae* and *H. influenzae*. The collection of CSF should only be performed for diagnosis, by experienced personnel, and under aseptic conditions.

Cerebrospinal fluid (CSF) collection

Usually, three tubes of CSF are collected for chemistry, microbiology, and cytology. If only one tube of fluid is available, it should be given to the microbiology laboratory. If more than one tube (1-ml each) is available, the second or third tube should go to the microbiology laboratory (Table 25).³⁷

TABLE 25: Submission of tubes of cerebrospinal fluid (CSF) to laboratories based on the number of tubes collected from the patient

Number of tubes of CSF collected from patient	Microbiology laboratory	Chemistry laboratory	Cytology laboratory
1	Send tube 1	~	~
2	Send tube 2	Send tube 1	~
3	Send tube 2 or 3	Send tube 1	Send tube 2 or 3

³⁷ Because the presence of blood can affect cultures of CSF, it is suggested that **if more than one tube of CSF is collected from a patient**, the first tube collected (which could contain contaminating blood from the lumbar puncture) **not** be the tube sent to the microbiology laboratory.

Lumbar puncture and cerebrospinal fluid (CSF) transport

The kit for collection of CSF (Figure 54) should contain the following items:

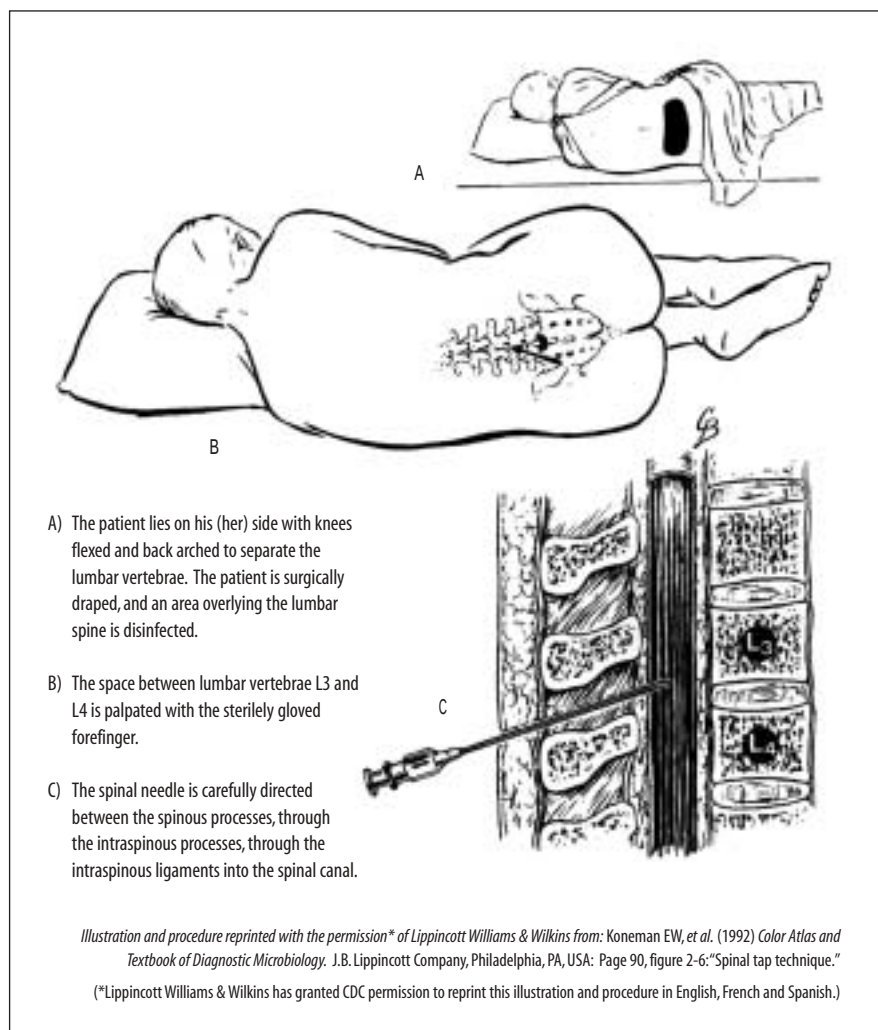
- skin disinfectant
- sterile gauze and adhesive bandages
- lumbar puncture needles: 22 gauge/3.5" for adults; 23 gauge/2.5" for children
- sterile screw-cap tubes
- syringe and needle
- transport container
- Trans-Isolate (T-I) medium (*if CSF cannot be analyzed in the microbiology laboratory immediately*)

Patients should be kept motionless for the lumbar puncture, either sitting up or laying on the side, with the back arched forward so that the head almost touches the knees during the procedure (Figure 55). Disinfect the skin along a line drawn between the crests of the two ilia with 70% alcohol to clean the surface and remove debris and oils, then apply a tincture of iodine or povidone-iodine and let it dry. Introduce the needle is introduced, and collect the drops of fluid (1 ml minimum; 3–4 ml, if possible) into sterile, screw-cap tubes. Label the specimen with patient identification and the date and time of CSF collection.

FIGURE 54: Kit for collection of cerebrospinal fluid (CSF)



FIGURE 55: Collection of cerebrospinal fluid (CSF) by lumbar puncture



Transport of CSF specimens

As soon as the CSF has been collected, it should be transported to the microbiology laboratory, where it should be examined as soon as possible (preferably within 1 hour from the time of collection); hand-carry the specimen to the laboratory whenever feasible. **Do not refrigerate the CSF specimen or expose it to extreme cold, and do not expose it to excessive heat or sunlight.** If *N. meningitidis* is suspected to be the cause of the illness and a delay of several hours in processing specimens is anticipated, incubating the CSF (with screw-caps

loosened) at 35°C in a 5% CO₂ atmosphere (*i.e.*, in a CO₂-incubator or a candle-jar) may improve bacterial survival.

If same-day transport to the laboratory is not possible, CSF should be inoculated aseptically into a Trans-Isolate (T-I) medium with a syringe and then held overnight at 35°C. T-I medium is a biphasic medium that is useful for the primary culture of meningococci and other etiological agents of bacterial meningitis from CSF (Figure 75); it can be used as a growth medium as well as a holding and transport medium. The preparation of the T-I medium is described in Appendix 2.

Isolation and Presumptive Identification of Bacterial Agents from Normally Sterile Sites

General laboratories commonly receive blood samples or cerebrospinal fluid from patients with pneumonia, meningitis, or unexplained febrile illness. Laboratories may also receive urine, joint fluid, pleural fluid, or other sterile site specimens from these patients. This section of the laboratory manual provides methods for the isolation and presumptive identification of agents from these normally sterile sites. Pathogens included in this laboratory manual that could be isolated from normally sterile sites are *Haemophilus influenzae*, *Neisseria meningitidis*, *Salmonella* serotype Typhi, and *Streptococcus pneumoniae*.

Personnel who are at risk for the routine exposure to aerosolized *N. meningitidis* should strongly consider vaccination. The risk of infection when working in the laboratory with *H. influenzae* and *S. pneumoniae* is very low, and it is not required that laboratorians receive vaccination against these organisms. However, least two good vaccines (oral and injection) are available for *S. Typhi*, and laboratorians should ensure that their vaccination status remains current. Additional information on laboratory safety is included in Appendix 1.

After bacteria are recovered from normally sterile sites, the isolates require confirmatory identification; isolates received by a reference laboratory (e.g., for antimicrobial susceptibility testing) must also undergo confirmatory testing. Methods for confirmatory identification and antimicrobial susceptibility testing of *H. influenzae*, *N. meningitidis*, *S. pneumoniae*, and *S. Typhi* are presented earlier in this laboratory manual (in Chapters III, IV, V, and VII, respectively).

Blood cultures

Laboratory personnel handling blood culture specimens must be able to identify culture bottles that may have bacterial growth, isolate bacteria on solid media, and subculture isolates. Provisional identification of an isolate will often be possible on the basis of colony morphology and the microscopic appearance of a Gram-stained specimen. (Methodology for the preparation and collection of blood specimens is presented in Appendix 3.)

Several variables affect the sensitivity of blood cultures: the number of collections, the volume of each collection, and the steps taken to inhibit or neutralize

bactericidal properties of blood may vary with the age of the patient. As stated in the section on specimen collection, blood cultures from young children should be diluted to 1–2 ml of blood in 20 ml of broth (1:10 to 1:20), whereas blood cultures from adults should be diluted to 5–10 ml of blood in 50 ml of broth (1:5 to 1:10). Ideally, the blood samples should be processed in a bacteriology laboratory as soon as possible after collection (*i.e.*, within 2 hours).

Inoculation of primary culture media

Blood should be cultured in a tryptone-based soy broth (commonly referred to as “Trypticase” or “tryptic” soy broth [TSB]) or brain heart infusion with a supplement, such as haematin or sodium polyanetholesulfonate (SPS). If only one blood-culture bottle is used, it should contain TSB. Neutralization of normal bactericidal properties of blood and potential antimicrobial agents is accomplished by adding chemical inhibitors such as 0.025% SPS to culture media and by diluting the blood. SPS, which has anticoagulant, antiphagocytic, anticomplementary, and antilysozymal activity, **may be inhibitory if used in higher concentrations**, but it is important to use. The blood-culture bottles should be inoculated directly with blood and should be vented before incubation at 35°–37°C. Venting is accomplished by inserting a sterile cotton-plugged needle into the diaphragm (*i.e.*, rubber part) of the blood-culture bottle.

Adding growth supplements, such as IsoVitalX or Vitox, to blood culture bottles to help support the growth of *H. influenzae* is appropriate; however, if resources are limited, a laboratory would benefit more by using this costly resource to supplement chocolate agar medium.

Identifying positive blood culture bottles

Blood-culture bottles should be examined at 14–17 hours and then every day for up to 7 days. Any turbidity or lysis of erythrocytes may be indicative of growth, and subcultures should be made immediately. Because *H. influenzae*, *N. meningitidis*, and *S. pneumoniae* are fragile organisms, **subcultures should be routinely performed after 14–17 hours of incubation, again at 48 hours, and again at day 7, regardless of the appearance of the blood-culture bottles** because the absence of turbidity does not always correlate with the absence of bacterial growth. Before subculturing, swirl the bottle to mix the contents.

Subculture

Subcultures are made by first disinfecting the surface of the blood-culture bottle diaphragm with alcohol and a povidone-iodine swab, and then aspirating a small volume (*i.e.*, 0.5 ml) with a syringe and needle from the blood-culture bottle and inoculating the agar media with the fluid. If the bottle has a screw-cap, open the

bottle and take the fluid using sterile technique (*i.e.*, flaming the bottle mouth upon opening and closing the cap).

Ordinarily, both chocolate agar plates and blood agar plates are used for subculture. **When only one agar plate is used, it should be chocolate agar, because chocolate agar contains the X and V growth factors needed for *H. influenzae*, whereas blood agar does not.** If a blood specimen is received from a patient with a primary diagnosis of fever of unknown origin, if typhoid is suspected symptomatically, or if a Gram stain of blood-culture broth reveals gram-negative bacilli (Figure 69), add a total of 3–4 loopfuls of the blood culture onto MacConkey agar (MAC) in addition to chocolate agar and/or blood agar. Incubate the media with suspect pathogens at 35°–37°C in a 5% CO₂ atmosphere (incubator or candle-extinction jar). Because *N. meningitidis* grows well in a humid atmosphere, if an infection with *N. meningitidis* is suspected, laboratorians may choose to add a shallow pan of water to the bottom of the incubator or add a dampened paper towel to the candle-extinction jar; the moisture source should be changed regularly (*e.g.*, daily) to prevent contamination with molds.

If the laboratory has the resources to support the use of a third plate for subculture, MacConkey agar should be used, particularly when the specimen was obtained from a patient with fever of unknown origin (when typhoid fever [*S. Typhi*] or blood stream infection by gram-negative rods of other species [*e.g.*, *E. coli*, *Klebsiella*, etc.] may be suspected).

Chocolate agar should be periodically confirmed to support growth of *H. influenzae*. The agar plates should be streaked (Figures 56, 57, 58, 59a, and 59b), and incubated for up to 48 hours. The MAC and blood plates for *S. Typhi* should be incubated for 18–24 hours at 35°–37°C.

When bacterial growth has been confirmed by subculture of the blood-culture bottle, the bottle no longer requires incubation. The bottle should be disposed of according to safety procedures.

Presumptive identification of isolates from sterile-site specimens

Because the primary purpose of this section of the manual is to aid in the identification of *N. meningitidis*, *S. pneumoniae*, *H. influenzae*, and *S. Typhi* from sterile-site specimens, the methods described here will not apply to the identification of other bacterial agents (of pneumonia and meningitis) of clinical importance that are more rarely encountered. Microbiologists should refer to clinical microbiology manuals (*e.g.*, the American Society for Microbiology's *Manual of Clinical Microbiology*, the WHO's *Manual for the Laboratory Investigations of Acute Enteric Infections*, the *Clinical Microbiology Procedures Manual*, *Basic Laboratory Procedures in Clinical Microbiology* [WHO 2001]) or a medical microbiology manual or textbook for procedures to identify other bacteria.

FIGURE 56: Proper streaking and growth of *Neisseria meningitidis* on blood agar

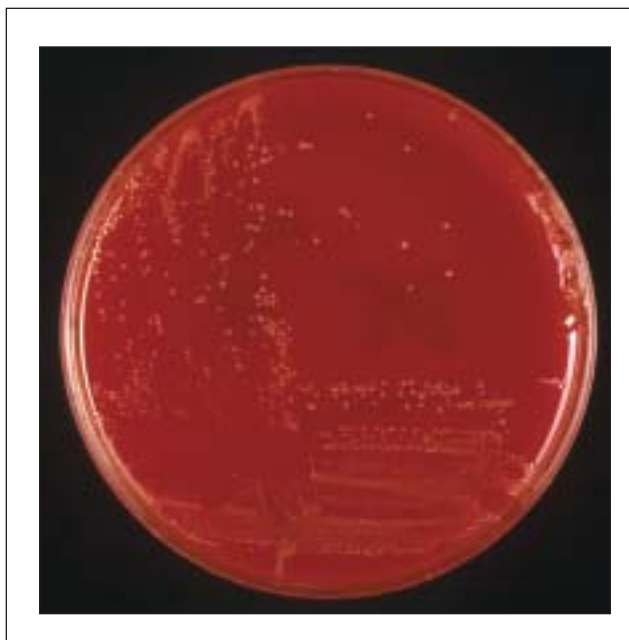


FIGURE 57: Proper streaking and growth of *Streptococcus pneumoniae* on blood agar

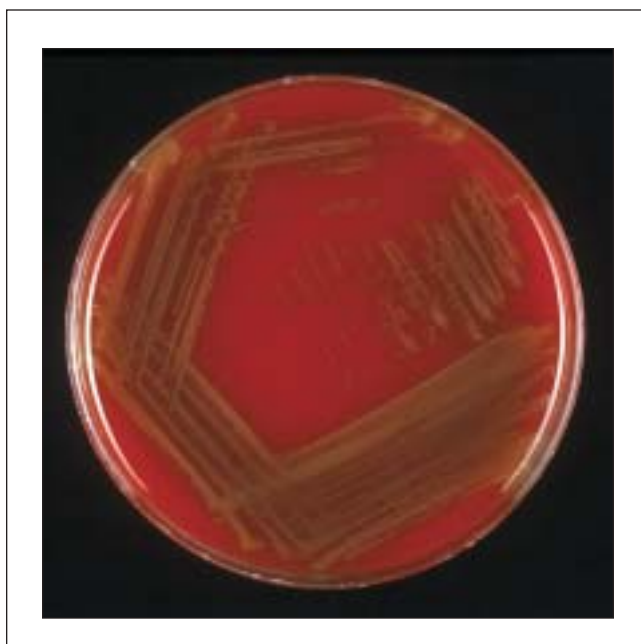


FIGURE 58: Proper streaking and growth of *Haemophilus influenzae* on chocolate agar



FIGURE 59a: Growth of *Salmonella* ser. Typhi on MacConkey agar



FIGURE 59b: Growth of *Salmonella* ser. Typhi on blood agar



Presumptive identification of *N. meningitidis*, *H. influenzae*, and *S. pneumoniae* can be made on the basis of the growth on blood agar and chocolate agar and on the basis of the microscopic morphology of the organisms (Figures 60, 61, and 62). Figure 63 provides a sample worksheet for the presumptive diagnosis of bacterial agents of meningitis and pneumonia isolated from normally sterile sites. Images comparing alpha(α)-hemolysis, alpha-prime(α')-hemolysis and beta(β)-hemolysis on sheep blood agar are shown in Figure 64.

N. meningitidis grows on blood agar, whereas *H. influenzae* will not grow without supplements (found in chocolate agar). When grown on chocolate agar, *H. influenzae* and *N. meningitidis* look similar; the two organisms can be distinguished on the agar plate by the pungent smell of indol from *H. influenzae*.

The following procedures should be followed to prepare a dried smear for Gram stain of pure culture.

- a) Place one drop of physiological saline or distilled water on an alcohol-rinsed and dried slide.
- b) With a flamed and cooled, sterile inoculating needle or loop, touch the center of the bacterial colony.
- c) Prepare a smear from the colony by adding the bacteria from the inoculating loop to the physiological saline or distilled water drop with a gentle tap. Use the loop to mix the organisms into suspension.
- d) Spread the suspension and allow it to dry, either by air (approximately ten minutes) or incubator.

Continue the Gram stain procedure with steps (c - l) from the Gram stain methodology outlined later in this appendix. Upon microscopic examination, organisms that are gram-positive will appear violet, while gram-negative organisms will appear pink. The staining further enables the laboratorian to see morphology of the bacteria.

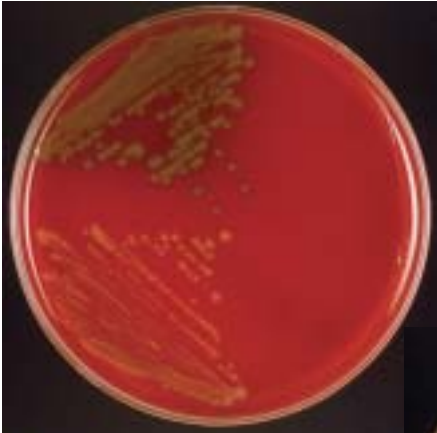
- **Presumptive identification of *H. influenzae***

H. influenzae appears as large, flat, colorless-to-grey opaque colonies on chocolate agar (Figure 65). No hemolysis or discoloration of the medium is apparent. Encapsulated strains appear more mucoidal than non-encapsulated strains, which appear as compact greyish colonies. Gram staining will yield small, gram-negative bacilli or coccobacilli (Figure 74). Methods for confirmatory identification and antimicrobial susceptibility testing of *H. influenzae* are included in Chapter III.

FIGURE 60: Presumptive identification of *Haemophilus influenzae*, *Neisseria meningitidis*, and *Streptococcus pneumoniae*

Growth on		Gram stain morphology	Presumptive identification
Chocolate agar	Sheep blood agar		
+	+	gram-negative diplococci	<i>N. meningitidis</i>
+	+	gram-positive cocci or diplococci	<i>S. pneumoniae</i>
+	–	small, gram-negative pleomorphic coccobacilli	<i>H. influenzae</i>

FIGURE 61: Growth of *Haemophilus influenzae*, *Neisseria meningitidis*, and *Streptococcus pneumoniae* on sectioned blood agar and chocolate agar plates



Growth on sheep blood agar plate (BAP)



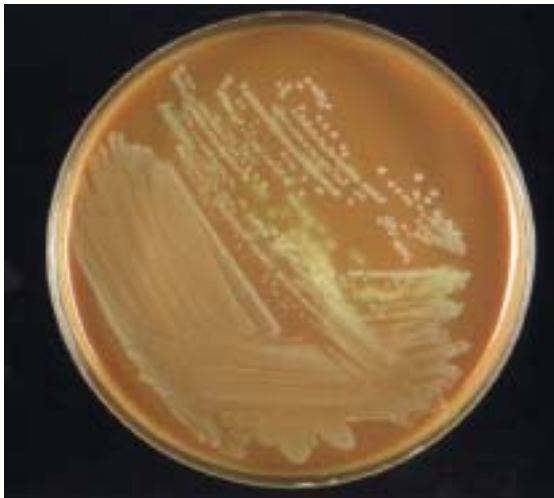
Growth on chocolate agar plate (CAP)

• *H. influenzae* was inoculated on the right third of each plate; it grows on CAP but not BAP.

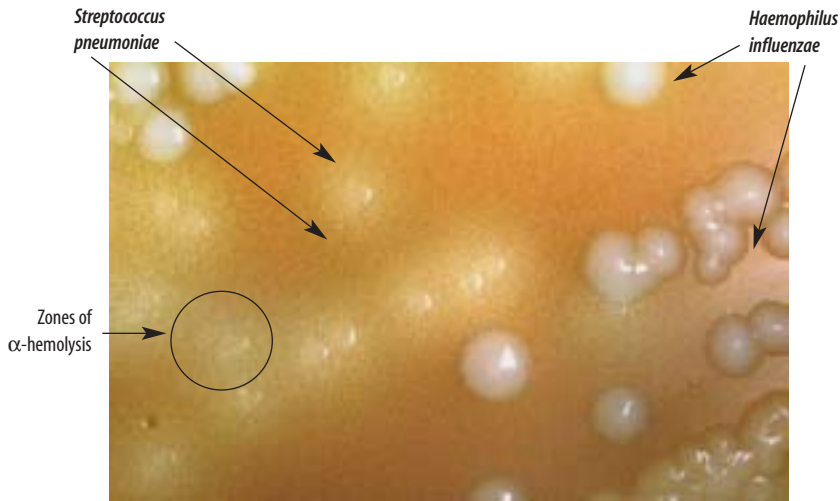
• *S. pneumoniae* was inoculated on the top of each plate; it hemolyzes the blood. Note the greenish α -hemolysis in the blood agar.

• *N. meningitidis* colonies (bottom left of each place) appear grayish and have good growth on both media like *S. pneumoniae* does, but no hemolysis occurs.

FIGURE 62: *Haemophilus influenzae* and *Streptococcus pneumoniae* colonies growing on the same chocolate agar plate



Hemolysis is apparent around the pneumococcal colonies.

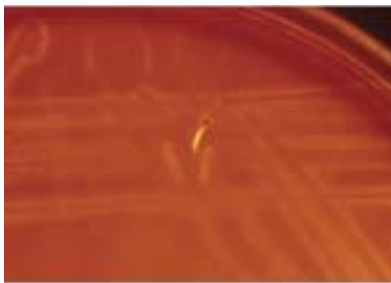


In this magnified picture, the different morphology of the colonies is easily observed. The *H. influenzae* colonies are larger and grayer than the *S. pneumoniae* colonies, which exhibit α -hemolysis.

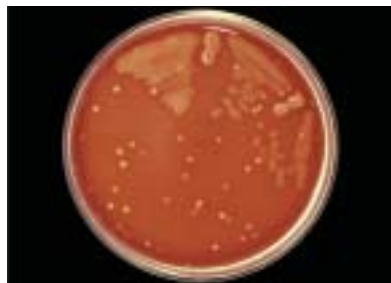
FIGURE 63: Sample worksheet for the presumptive laboratory identification of bacterial agents of pneumonia and meningitis

Specimen number, (type), date	Medium	Appearance of each colony type	Hemolysis (α , β , none)	Gram stain & arrangement	(If Gram + cocci) Optochin ?	(If Gram + cocci) Bile soluble ?	(If G — bacilli & growth on CAP only) X and V Factors?	(If Gram — diplococcus) Oxidase test	(If Gram — diplococcus, Oxidase +) Carbo-hydrate utilization	(H. influenzae, N. meningitidis) Slide serology	Identification
MQP4-30 (blood culture) 22-04-01	Blood agar (BAP)	BAP 1 Small, grayish Flat center	α ha	G + cocci in chains	8 mm (resistant)	N/A	N/A	N/A	N/A	N/A	Possible viridans strep
		BAP 2 (only 1 type)	-	-	-	-	-	-	-	-	-
		BAP 3									
	Chocolate agar (CAP)	CAP 1 Large, flat, mucoid	No	Small G — bacilli	N/A	N/A	Both X & V	N/A	N/A	(polyvalent +) type b	H. influenzae
		CAP 2 Small, grayish flat center	α ha	G + cocci in chains	8 mm (resistant)	N/A	N/A	N/A	N/A	N/A	Possible viridans strep
		CAP 3 (only 2 types)	-	-	-	-	-	-	-	-	-
	Blood agar (BAP)	BAP 1									
		BAP 2									
		BAP 3									
	Chocolate agar (CAP)	CAP 1									
		CAP 2									
		CAP 3									

FIGURE 64: Alpha (α), alpha-prime (α') and beta (β) hemolysis on sheep blood agar



α -hemolysis on a streak and stab plate.
Note the light yellow-green clearing in the streaks and the stab.



β -hemolysis on a pour, streak and stab plate.
Note the clearing in the agar surrounding the colonies.



α -hemolysis surrounding a colony in a pour plate.
Note the light color surrounding the subsurface colony in the center of the image.



α' -prime hemolysis surrounding a subsurface colony in a pour plate.
Note the cells inside the clear zone of hemolysis and around the subsurface colony; a magnifying glass may assist with the visualization of α' -prime (α') hemolysis.

- Presumptive identification of *N. meningitidis*

On blood agar plates, young colonies of *N. meningitidis* are round, smooth, moist, glistening and convex, with a clearly defined edge. Some colonies appear to coalesce with other nearby colonies. Growth of *N. meningitidis* on blood agar is greyish and unpigmented; older cultures become more opaquely grey and sometimes cause the underlying agar to turn dark. Well-separated colonies can grow from about 1 mm in diameter in 18 hours to as large as 4 mm, with a somewhat undulating edge, after several days (Figure 66). Gram staining will yield a gram negative, coffee-bean-shaped diplococcus (Figure 72). Methods for confirmatory identification and antimicrobial susceptibility testing of *N. meningitidis* are included in Chapter IV.

FIGURE 65: *Haemophilus influenzae* colonies on chocolate agar (magnified 10x)



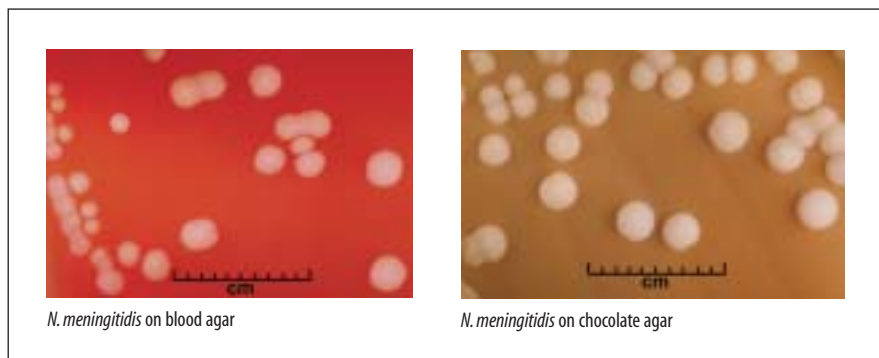
- Presumptive identification of *S. pneumoniae*

S. pneumoniae appears as small, greyish, moist (sometimes mucoid), watery colonies with a greenish zone of α -hemolysis surrounding them on blood agar (Figure 67) and chocolate agar. The degree of mucoidness of *S. pneumoniae* colonies is dependent on the freshness of the medium and the incubation atmosphere. Some serotypes appear more mucoid than others, and the fresher the medium, the more mucoid the cultures appear.

Young pneumococcal colonies appear raised, similar to viridans streptococci. Differentiating pneumococci from viridans streptococci on chocolate agar is difficult. However, a hand lens or microscope (30X-50X) is a useful aid in differentiating pneumococci from α -hemolytic viridans streptococci, which also produce a greenish zone of hemolysis on a blood- or chocolate agar plate. However, as the culture ages 24-48 hours, the colonies become flattened and the central part of each colony becomes depressed. This does not occur with the viridans streptococci (Figure 14).

Another type of colony that might appear on the culture plate along with *S. pneumoniae* is *Staphylococcus aureus* (or another *Staphylococcus* species). Figure 68 shows the two types of colonies are growing on the 5% sheep blood trypticase soy agar medium: the dull gray flat colony surrounded by a greenish zone of hemolysis is *S. pneumoniae* and the yellowish colony with no hemolytic action is *S. aureus*. Gram staining of *S. pneumoniae* will reveal a gram positive

FIGURE 66: Overnight growth of *Neisseria meningitidis* on blood agar and chocolate agar



diplococci or chain of cocci (Figure 73). Methods for confirmatory identification and antimicrobial susceptibility testing of *S. pneumoniae* are included in Chapter V.

- Presumptive identification of *Salmonella* ser. Typhi

Salmonella ser. Typhi grows on both blood agar and chocolate agar; on these media, *S. Typhi* colonies are grayish, transparent to opaque, glistening (shiny) and usually >1 mm in diameter. On MacConkey agar (MAC), *S. Typhi* colonies appear as colorless nonfermenters. (Colonies of *S. Paratyphi* A, *S. Paratyphi* B, and *S. Paratyphi* C and most other *Salmonella* serotypes look similar to those of *S. Typhi* on these media.) Gram staining of *Salmonella* serotypes will reveal gram-negative bacilli (Figure 69). Methods for identification and antimicrobial susceptibility testing for *S. Typhi* are included in Chapter VII.

Cerebrospinal fluid (CSF) specimens

The collection of cerebrospinal fluid (CSF) is an invasive technique and should be performed by experienced personnel under aseptic conditions. If meningitis is suspected, CSF is the best clinical specimen to use of isolating and identifying the etiologic agents. The collection of CSF should be performed for diagnosis only. Clinical specimens should be obtained before antimicrobial therapy is begun to avoid loss of viability of the etiological agents. Treatment of the patient, however, should not be delayed while awaiting collection of specimens.

The CSF section of this manual includes only those procedures pertaining to the isolation of *H. influenzae*, *N. meningitidis*, and *S. pneumoniae* (and *S. Typhi*). Other procedures appropriate for the clinical setting and common pathogens in

FIGURE 67: *Streptococcus pneumoniae* colonies on blood agar (magnified 10x)

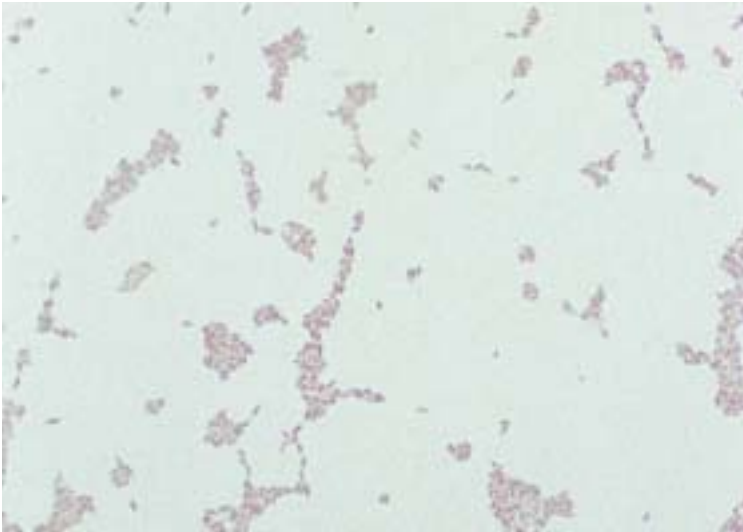


FIGURE 68: *Streptococcus pneumoniae* and *Staphylococcus aureus* growing together on the same blood agar plate



The small gray, flat colony surrounded by a greenish zone of alpha-hemolysis is *S. pneumoniae*; the gray-white-yellowish colony with no hemolytic action is *S. aureus*.

FIGURE 69: Gram stain of *Salmonella* ser. Typhi



Like all other members of the *Enterobacteriaceae*, *S. Typhi* is a gram-negative bacillus (rod).

the region may be performed on the CSF as well. These might include, but are not limited to: cell count; acid fast staining and culture for *Mycobacterium tuberculosis*; antigen detection, India ink / negative stain, or culture for cryptococcal meningitis; or others.

The contents of a kit for lumbar puncture and the procedure for collection of CSF are shown in Appendix 3. Usually, three tubes (1-ml each) of CSF are collected for chemistry, microbiology, and cytology. If only one tube of fluid is available, it should be given to the microbiology laboratory; if more than one tube is available, the second or third tube should go to the microbiology laboratory (Table 25).

Primary laboratory procedures for isolation of *H. influenzae*, *N. meningitidis*, and *S. pneumoniae* from cerebrospinal fluid (CSF)

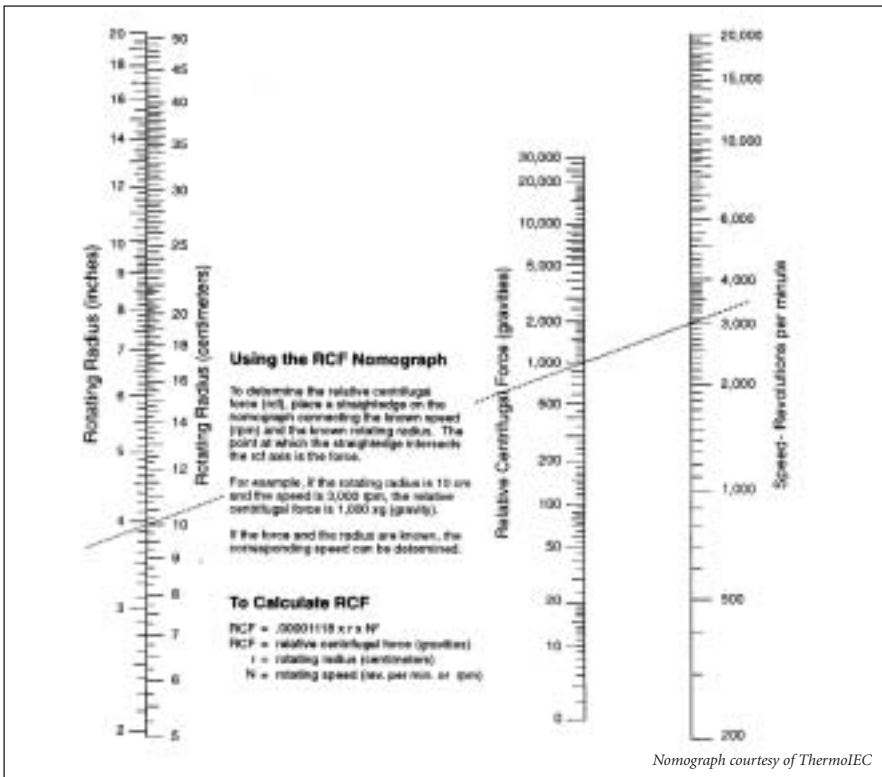
Once the CSF has arrived at the microbiology laboratory, note whether there is more than 1 ml available for analysis. **If less than 1 ml of CSF is available, it should not be centrifuged; instead, the CSF should be plated directly for the Gram stain.**

If there is >1 ml of CSF (*i.e.*, if the sample is ample for centrifugation), it must be centrifuged at a force sufficient to sediment most bacteria within 10–15 minutes; a relative centrifugal force (RCF, measured in “xg” is usually sufficient to sediment

bacteria within 10–15 minutes).³⁸ Refer to Figure 70 for a nomograph to assist in the calculation of RCF.

An algorithm for the processing of CSF specimens is presented in Figure 71. After the sample has been centrifuged, draw off the supernatant with a Pasteur pipette. (When antigen detection by latex agglutination is planned, save the supernatant.) Vigorously mix the sediment (e.g., with a vortex machine); once it is well-mixed, use one or two drops of sediment to prepare the Gram stain and use one drop to streak the primary culture media.

FIGURE 70: Nomograph for calculation of relative centrifugal force (RCF)



Presumptive diagnosis by Gram stain or latex agglutination of cerebrospinal fluid (CSF)

A presumptive diagnosis of bacterial meningitis caused by *H. influenzae*, *S. pneumoniae*, and *N. meningitidis* can be made by Gram stain of the CSF sediment

³⁸ Because centrifuges vary from laboratory to laboratory, the revolutions per minute (rpm) required should be calculated on the basis of a desired relative centrifugal force (RCF) of 1000 to sediment the bacteria within 10–15 minutes. To calculate the RCF (measured in xg), the radius of the centrifuge (radius = r) and the revolutions per minute (rpm = n) must be known: $RCF = [11.17 (r)] \times [(n / 1000)^2]$. For example, a typical bench-top centrifuge with a radius of 10.5 cm and run at 2800 rpm has a RCF of 920 xg; this RCF is sufficient to sediment bacteria in CSF in 10–15 minutes. See Figure 70 for a nomograph to assist with these calculations.

or by detection of specific antigens in the CSF by a latex agglutination test. (**Note:** Counter immunoelectrophoresis may also be used for direct antigen detection in CSF.) Positive results of either or both tests can provide evidence of infection, even if cultures fail to grow.

The Gram stain procedure for CSF (Hucker Modification)

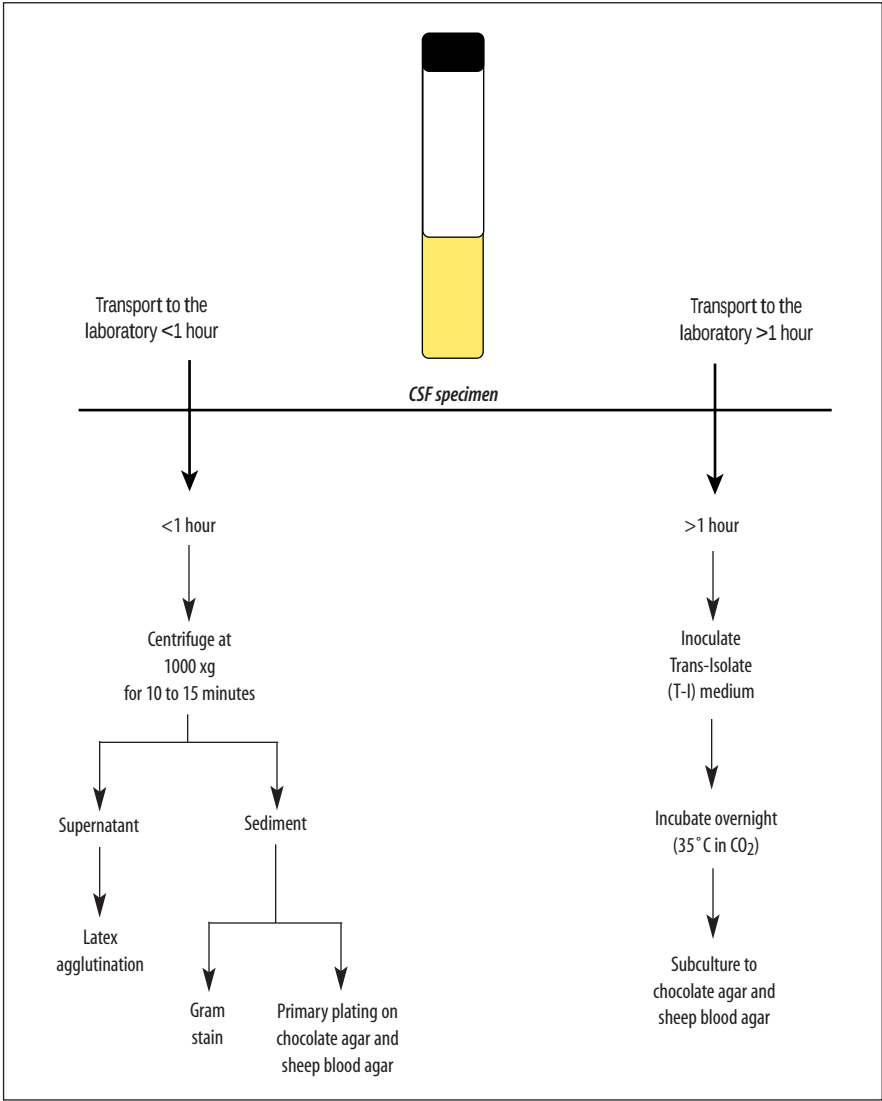
After the CSF has been centrifuged and the sediment well-mixed, a portion of the sediment is Gram stained.

- a) Centrifuge the CSF for 10–15 minutes at an RCF of approximately 1000 xg. (See footnote 38 for an explanation of this formula, and the nomograph in Figure 70 for assistance in calculating the RCF.)
 - For example, a centrifuge with a radius of 10.5cm running at 2800 rpm would yield a RCF of 920 xg. This force is sufficient to sediment out bacteria in approximately 15 minutes.
- b) Mix the sediment well, and prepare a smear by placing one or two drops of sediment on an alcohol-rinsed and dried slide, allowing drop(s) to form one large drop. Do not spread fluid nor use too heavy a concentration of sediment.
- c) Air-dry the slide in a biosafety cabinet, if available.
- d) After the smear is thoroughly dry, pass the slide quickly through a flame three times to fix the smear. At this time, the slide will be slightly warm (not hot) when the back of the hand touches the bottom of the slide. Alternatively, fixation by methanol (95% – 100%) can be used for 1 minute.
- e) Flood the smear with ammonium oxalate-crystal violet and let stand for 1 minute.
- f) Rinse gently with tap water. Drain off excess water.
- g) Flood the smear with Gram's iodine solution and let stand for 1 minute.
- h) Rinse gently with tap water and drain.
- i) Decolorize with 95% ethyl alcohol (5–10 seconds may be enough).
- j) **Note:** Alternatives to ethyl alcohol in this step include acetone or an ethanol-acetone mixture. If using acetone or ethanol-acetone, rinse the slide gently with water and drain.
- k) Counterstain with safranin for 20–30 seconds, or with carbol-fuchsin for 10–15 seconds.
- l) Rinse the slide with tap water. Gently blot dry with clean, absorbent tissue or paper or allow to air-dry. If using tissue or paper, it is important to blot (*i.e.*, do not rub the slide).

m) Examine the stained smear with a microscope, using a bright-field condenser and an oil-immersion lens.

Note: Some commercial Gram stain kits may have slightly different staining instructions. **It is important to use the manufacturer's instructions included with a commercial kit.**

FIGURE 71: Processing of cerebrospinal fluid (CSF)



Upon microscopic examination, organisms that are gram-positive will appear violet to blue, whereas gram-negative organisms will appear pink to red. The staining further enables the laboratorian to see morphology of the bacteria.

When examining the Gram-stained slide under a microscope, *N. meningitidis* may occur extra-cellularly or intra-cellularly in the polymorphonuclear leukocytes and will appear as gram-negative, coffee-bean-shaped (or kidney-bean-shaped) diplococci (Figure 72). *S. pneumoniae* are gram-positive diplococci sometimes occurring in short chains (Figure 73). *H. influenzae* are small, pleomorphic gram-negative rods or coccobacilli with random arrangements (Figure 74). Other manuals should be consulted for Gram stain reactions of other bacteria.

The general method for performing latex agglutination tests

Several commercial latex agglutination kits are available. For best results, test the supernatant of the centrifuged CSF sample as soon as possible. If immediate testing is not possible, the sample can be refrigerated (at 2°– 8°C) up to several hours, or frozen at -20°C for longer periods. Reagents should be kept refrigerated at 2°– 8°C when not in use. **Product deterioration occurs at higher temperatures, especially in tropical climates, and test results may become unreliable before the expiration date of the kit.** Latex suspensions should never be frozen. General recommendations and instructions typical for the detection of soluble bacterial antigens are provided in this manual, but **follow the manufacturer's instructions precisely when using these tests.**

- a) Heat the supernatant of the CSF in a boiling water bath for 5 minutes.
- b) Shake the latex suspension gently until homogenous.
- c) Place one drop of each latex suspension on a ringed glass slide or a disposable card.
- d) Add 30–50 µl of the CSF to each suspension.
- e) Rotate by hand for 2–10 minutes.

The test should be read under a bright light, without magnification. The test is read as **negative** if the suspension remains homogenous and slightly milky in appearance. In contrast, the reaction is **positive** if visible clumping (*i.e.*, agglutination) of the latex particles occurs within 2–10 minutes.

Note: It is important to appreciate that false positive and **false negative reactions can and do occur with latex agglutination tests.** For example, certain proteins from *E. coli* may cross-react with *N. meningitidis* proteins in the latex agglutination test, yielding a false positive result. **Culture is therefore preferable.**

Culturing of cerebrospinal fluid (CSF)

CSF should be processed in a bacteriology laboratory as soon as possible, within 1 hour of collection. CSF should be inoculated directly onto both a supplemented

FIGURE 72: Gram stain of cerebrospinal fluid (CSF) with *Neisseria meningitidis*

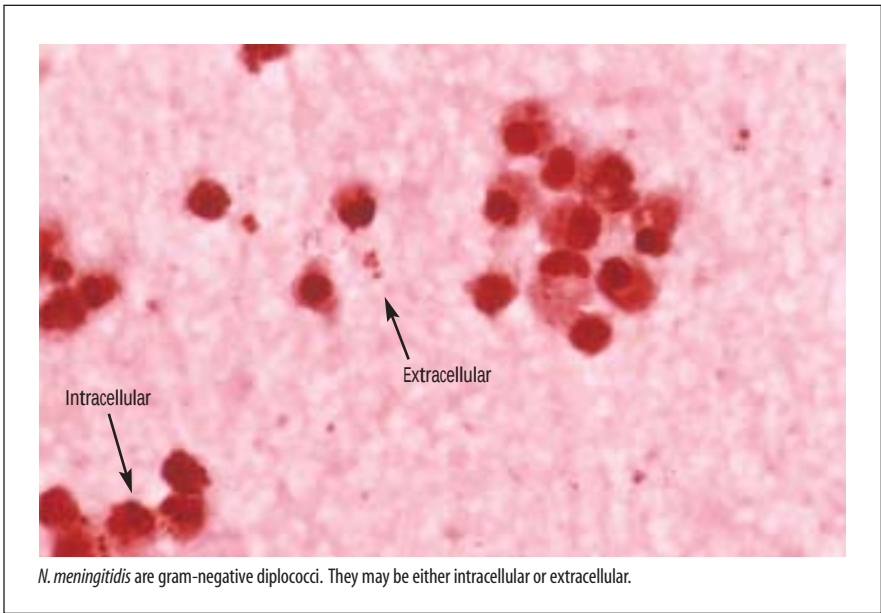


FIGURE 73: Gram stain of cerebrospinal fluid (CSF) with *Streptococcus pneumoniae*

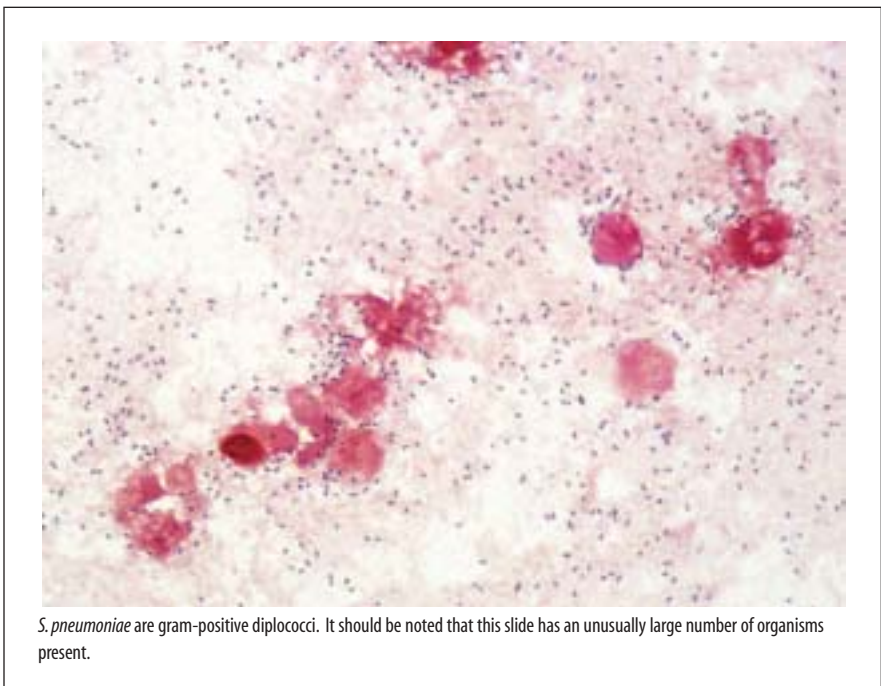
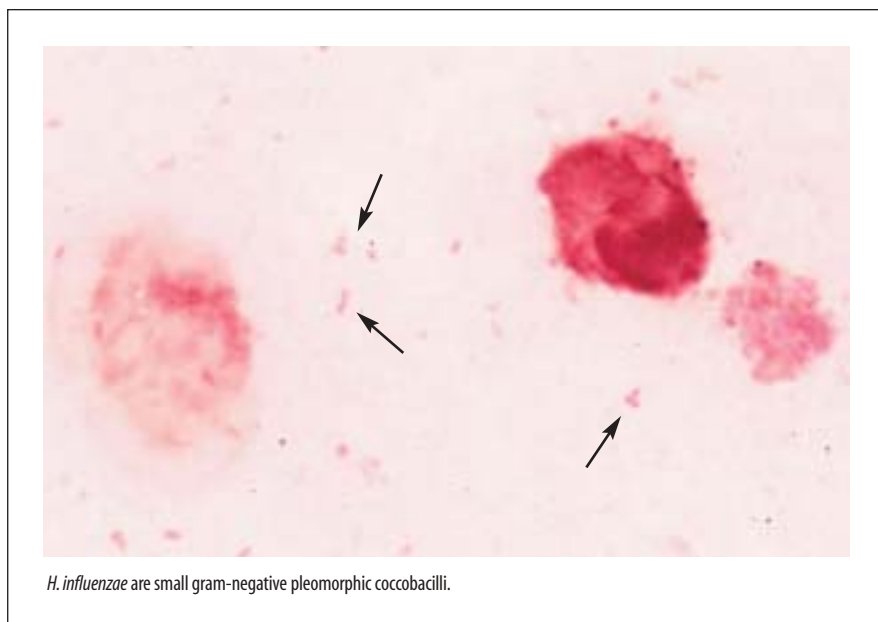


FIGURE 74: Gram stain of cerebrospinal fluid (CSF) with *Haemophilus influenzae*



chocolate agar plate and a blood agar plate. Use a sterile bacteriological loop to streak or thin the bacteria into single colonies; **the loop must be sterilized prior to each step** of the plate-streaking process.

Blood agar that has been properly streaked is shown in Figures 55, 56, and 57. The agar plates should be incubated in a 5% CO₂-incubator or candle-jar. A back-up broth (e.g., brain-heart infusion broth) should be inoculated with some of the sediment pellet and also incubated. Agar plates inoculated with CSF should be incubated in a 5% CO₂-incubator or candle-extinction jar at 35°–37°C.

The best medium for growth of *S. pneumoniae* is a blood agar plate, which is a tryptone soy agar (TSA) plate containing 5% sheep or horse blood. **Human blood is not an acceptable substitute** for the blood in the agar because the antibodies contained in human blood may inhibit bacterial growth. *S. pneumoniae* will also grow on chocolate agar.

For *H. influenzae*, a chocolate agar plate supplemented with haemin and a growth supplement (e.g., IsoVitaleX, supplement B, or Vitox) should be used. (When supplemented chocolate agar is not available, an acceptable alternative to achieve growth of *H. influenzae* on blood agar plates is achieved by cross-streaking the medium with *S. aureus*, or by applying a filter paper [or disks] saturated with X and V factors to the surface of the medium **after** the medium has been inoculated; *H. influenzae* forms satellite colonies along the length of the staphylococcal growth or produces a halo of growth around the XV strip/disk.)

N. meningitidis grows on both blood agar and chocolate agar.

If only one type of plate is available, (supplemented) chocolate agar should be used, because all three of these suspected etiological agents of pneumonia and meningitis can grow on this medium.

Appropriate utilization of Trans-Isolate medium for transport and culture of cerebrospinal fluid (CSF)

If the CSF cannot be analyzed in the microbiological laboratory immediately, Trans-Isolate (T-I) medium should be used. T-I is a biphasic medium that is useful for the primary culture of meningococci from CSF samples (Figure 75). It can be used as a growth or enrichment medium as well as a holding and transport medium for *Neisseria meningitidis*. The preparation of the T-I medium is described in Appendix 2.

The T-I bottle septum should be disinfected with alcohol and iodine and allowed to dry before inoculation. Inoculate 1 ml of CSF into the T-I medium, which has either been pre-warmed in the incubator (35°C – 37°C) or kept at room temperature (25° C). Keep the remaining CSF in the container or syringe in which it was collected. The CSF should not be refrigerated but **held at room temperature before Gram staining**.

FIGURE 75: Trans-Isolate (T-I) medium



The T-I bottles must be labeled appropriately with the patient identification and the date and time of CSF inoculation. After inoculation, incubate the T-I bottles overnight at 35°C; alternatively, the T-I medium can be incubated at 35°C for up to 7 days. Venting the bottle with a venting needle, or a sterile cotton-plugged hypodermic needle after the initial 24-hour incubation (or as soon as possible after transportation has been completed) encourages growth and survival. If transport is delayed, vented bottles can be held for days at moderate to warm room temperatures (25°–30°C). The vents must be removed before shipment. **It is essential to obtain specimens using aseptic technique and to avoid contamination when inoculating or sampling the bottles.**

When T-I medium is used for transport of CSF, after 24 hours of incubation, use a sterile needle and syringe to transfer 100 µl of the liquid portion of T-I onto the blood- and chocolate agar plates. Usually 50–100 µl is used to streak each plate, so to streak two plates draw either 100 µl or 200 µl with the syringe at one time (so that it is only necessary to go into the bottle once). Streak the plate for isolation and incubate at 35°C in a CO₂ atmosphere for up to 48 hours. (If no growth occurs, subculture the T-I medium at 3 days and again at 7 days.) Check for purity of growth by performing a Gram stain of the culture.

Presumptive identification of *H. influenzae*, *N. meningitidis*, *S. pneumoniae*, and *S. Typhi* on the basis of macroscopic examination of colonies on blood agar and chocolate agar plates is presented earlier in this chapter (see “Presumptive Identification”).

Isolation of bacterial agents from other sterile site specimens

Isolation and identification of agents in fluids from sterile site specimens can be critical in guiding patient care. When collected and processed under proper conditions, these body fluids can be good sources of some of the pathogens included in this laboratory manual, not to mention others beyond its scope.

Bone marrow

Bone marrow should be inoculated onto commercially available nutrient broth, (e.g., brain heart infusion broth or TSB). Consult a clinical laboratory manual for further, specific instructions.

Pleural fluid

Pleural fluid should be inoculated directly onto both chocolate agar and trypticase soy blood agar rather than being diluted in a broth as with blood cultures. Consult a clinical laboratory manual for further, specific instructions.

Urine

Urine is plated directly onto the appropriate medium (*e.g.*, blood, chocolate or MacConkey agar) with either 1- μ l or 10- μ l calibrated loops depending on whether the patient is suspected to have an acute urethral syndrome. Consult a clinical laboratory manual for further, specific instructions.

Middle ear fluid

Middle ear fluid is inoculated directly on appropriate medium (*i.e.* depending on the suspected agent). Consult a clinical laboratory manual for further, specific instructions.

Joint fluid

Isolation of an agent from joint fluid can be approached in several different ways (direct plating vs. amplification in a blood culture bottle vs. centrifugation and direct plating of the pellet). Consult a clinical laboratory manual for further, specific instructions.

Nasopharyngeal Swab Specimen Collection and Culture Methodology

Laboratories may receive nasopharyngeal (NP) swabs in the course of prevalence surveys and carriage studies of respiratory organisms. Culture methods for this type of specimen are included below. Once the organism has been isolated, refer to the laboratory manual section specific to that agent for antimicrobial susceptibility testing methodology.

Use swabs taken from the upper respiratory tract (e.g., the nasopharynx) to inoculate the primary culture medium; the nasopharyngeal swab should be rolled over one-fourth of the plate (i.e., one quadrant). Because bacteria other than *S. pneumoniae* and *H. influenzae* are generally present, selective media are used. For *S. pneumoniae*, the selective medium is a tryptone soy agar (TSA) plate containing 5% sheep or horse blood and 5 µg/ml of gentamicin sulfate; for *H. influenzae*, a chocolate agar plate containing 300 µg/ml of bacitracin is used. If one swab is being collected for recovery of both *S. pneumoniae* and *H. influenzae*, the blood agar and gentamicin plate should be inoculated first, followed by the inoculation of the chocolate agar and bacitracin plate (because *S. pneumoniae* is more susceptible to the antibacterial activity of the bacitracin than *H. influenzae* is to the antibacterial activity of gentamicin). After direct plating with the swab, use a bacteriological loop to streak the plate; Appendix 4, “Isolation of Agents from Normally Sterile Sites,” contains figures of properly streaked plates.

In areas where overgrowth of contaminants occurs in <10% of cultures, culture media without antibiotics may be used. However, in this case the primary plates **must** be streaked very carefully to allow separation of individual colonies.

Collection of nasopharyngeal (NP) swabs

NP swab collection is a clinical procedure and should therefore be performed by trained health-care workers. A specifically designed swab with a flexible wire shaft and a small calcium alginate tip should be used; calcium alginate is inert and nontoxic to *Neisseria* and other sensitive bacteria.

Figure 76 depicts the proper method of collecting an NP swab. The patient's head should be tipped slightly backward, as shown, and immobilized. For young infants, a good way to collect NP swabs is for the person taking the specimen to hold

his/her hand behind the neck of the infant while the infant is sitting in the lap of the parent or other adult. For children, the adult should lightly hold the child's head against his/her chest with a hand on the child's forehead; the adult's other arm should be used to restrain the child's arms. Sometimes it is also helpful if the adult's legs are used to stabilize the child's legs; this reduces body movement and kicking during the collection of the NP swab.

When the child's head is immobilized and body is restrained, the NP swab can be collected using the following procedures.

- a) Unwrap the swab.
- b) Insert the swab into a nostril and pass the swab parallel to the ground, back to the posterior nares. Do not use force. The swab should travel smoothly with minimal resistance; rotating the swab during the insertion will help the swab move. If resistance is encountered, remove the swab and try the other nostril.
- c) Once in place, rotate the swab, leave in place approximately five seconds to saturate the tip, and remove slowly.
- d) Use the swab to inoculate the appropriate (selective) medium (sheep blood with gentamicin to isolate *S. pneumoniae*; chocolate agar with bacitracin to isolate *H. influenzae*; blood or chocolate with no antimicrobial for *N. meningitidis*) by direct plating, or place the swab in STGG transport medium for transportation to the laboratory.

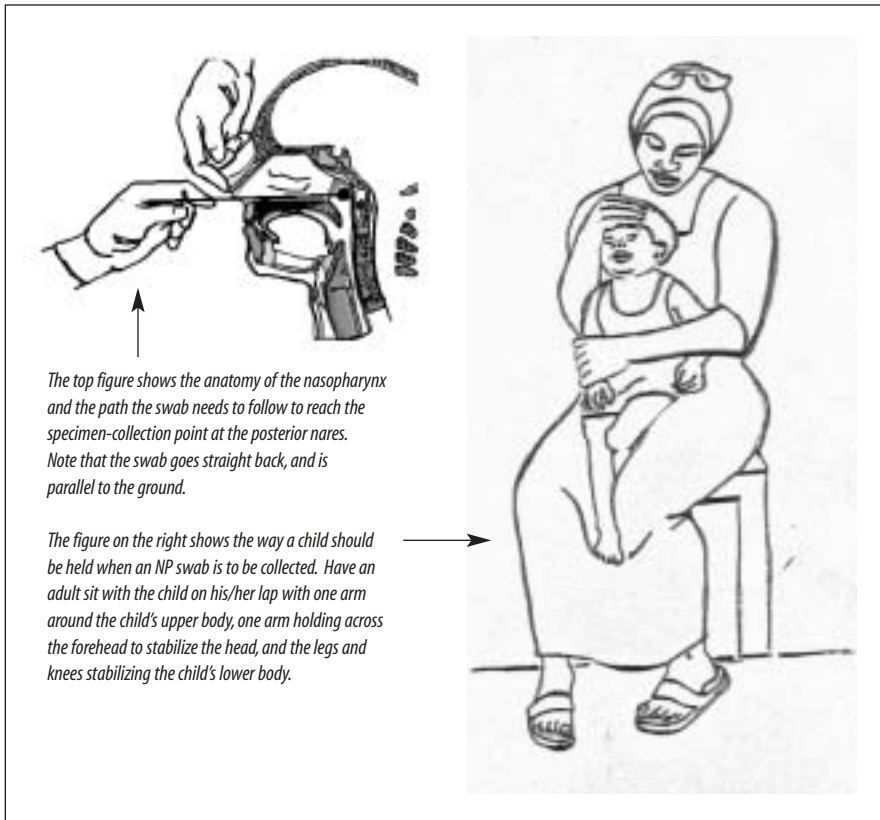
Skim-milk tryptone glucose glycerol (STGG) transport medium for nasopharyngeal secretions

Skim-milk tryptone glucose glycerol (STGG) transport medium is a tryptone broth with skim (nonfat) milk, glucose, and glycerol that can be used to transport NP swabs to the laboratory when the swabs cannot be plated directly from the patient. (The preparation of STGG medium is described in Appendix 2.) Culturing from the STGG as soon as possible is preferred, though STGG can also be used for storage and transport (for a several hours at room temperature; for up to 8 weeks at -20°C; and, for at least 2 years at -70°C).

Inoculation of STGG with an NP swab

- a) Thaw frozen tubes of STGG before use.
- b) Label the tube with appropriate patient and specimen information.
- c) Using a calcium alginate swab, collect an NP swab from the patient.
- d) Insert swab to the bottom of the STGG medium in thawed tube.

FIGURE 76: Collection of a nasopharyngeal (NP) swab



- e) Raise the swab slightly and cut the wire portion (*i.e.*, the shaft) of the swab at the top level of the container. Allow the bottom portion of the swab (*i.e.*, the tip) containing the calcium alginate material to drop into the tube.
- Discard the remaining shaft into disinfectant solution or a sharps container.
- f) Tighten the screw-cap top securely.
- *Optional:* If desired, after tightening the cap, vortex on high speed for 10–20 seconds.
- g) Freeze specimen immediately in upright position at -70°C , if possible.

In some cases, the inoculated STGG medium has been placed on ice for several hours before placing the STGG medium at -70°C without loss of viable *S. pneumoniae*. Extended storage of inoculated STGG stored at -20°C for 8 weeks results in minimal loss of viability of *S. pneumoniae*, and indications are that *H. influenzae* survive as well as *S. pneumoniae* in STGG [CDC unpublished data,

2002]. Data are not available for recovery of *N. meningitidis* from STGG. **Short-term storage of STGG is best at -70°C although a freezer at -20°C may also be used.**

Recovery of bacteria from STGG

- a) Remove the inoculated STGG medium from the freezer.
- b) Allow the tube to thaw at room temperature.
- c) Vortex each tube for a full 10 seconds.
- d) Using a sterile loop, aseptically remove a 50–100 µl sample of inoculated STGG to streak onto a plate for culture. (If attempting isolation of *S. pneumoniae*, a 100-µl inoculum is preferable.)
 - 1) **5% sheep (or horse) blood + 5 µg/ml gentamicin sulfate agar** is the appropriate plated medium for the recovery of *S. pneumoniae* from a nasopharyngeal swab specimen stored in STGG.
 - (If a gentamicin-containing medium is not available, attempt recovery from a standard blood agar plate.)
 - 2) **Chocolate + 300 µg/ml bacitracin agar** is the appropriate plated medium for recovery of *H. influenzae* from a nasopharyngeal swab specimen stored in STGG.
 - (If a bacitracin-containing medium is not available, attempt recovery from a standard supplemented chocolate agar plate.)
 - 3) 5% sheep or chocolate agar is the appropriate plated medium for recovery of *N. meningitidis*.
- e) Re-freeze the specimen (*i.e.*, the STGG) as soon as possible; keep it cool (in an ice water bath if necessary) if the time is extended beyond a few minutes at room temperature.
- f) Avoid multiple freeze-thaw cycles whenever possible. One way to decrease risk of freeze-thaw cycles within the freezer is to make sure the cryotubes are kept in the back of the freezer shelf and not the front or in the door.

Vials of inoculated STGG can be sent to other laboratories, if necessary; regulations for safe and proper packing and shipping of specimens are included in Appendix 12.

Serotyping and Quellung Typing of *Streptococcus pneumoniae*

Typing of the pneumococci isolated from patients with various clinical syndromes (e.g., sporadic cases of meningitis or pneumonia) is not usually necessary. However, in some studies where the study protocols focus on evaluation of vaccine efficacy and transmission of organisms, it will be necessary to serogroup and serotype the pneumococci. The checkerboard typing system will sufficiently identify the serotypes of pneumococci in most cases. Certain studies may require complete testing for all pneumococcal types and the isolates will have to be sent to a reference laboratory for identification of all 90 serotypes. The availability of Omniserum (Statens Seruminstitut, Copenhagen, Denmark), a pooled pneumococcal serum that reacts with all types, provides clinical microbiology laboratories with an invaluable reagent for rapid identification of pneumococci.

The Quellung reaction is traditionally used for the typing of pneumococci and is the method of choice because it is easy, fast, accurate, and economical. A Quellung reaction results when a type-specific antibody is bound to the pneumococcal capsular polysaccharide and causes a change in the refractive index of the capsule so that it appears “swollen” and more visible. The *S. pneumoniae* stains dark blue with methylene blue and is surrounded by a sharply demarcated halo, which represents the outer edge of the capsule; the light transmitted through the capsule appears brighter than either the pneumococcal cell or the background. Single cells, pairs, chains, and even clumps of cells may have Quellung reactions.

In most parts of the world, about 90% of all pneumococcal strains isolated from blood or CSF belong to one of the 23 different types or groups represented in the 23-valent pneumococcal vaccine. Traditionally, a total of seven pooled sera in addition to 21 type- or group sera are needed to type or group these strains by the use of the conventional pneumococcal diagnostic antisera. Most laboratories do not type pneumococcal isolates because of the large number of diagnostic antisera required for typing; a total of 90 different pneumococcal types have been described, and types that exhibit close serological cross-reactivity are grouped together. Of the 90 types, 58 belong to 20 groups containing from two to four types; a total of 46 different pneumococcal types or groups are currently known.³⁹

³⁹ Monovalent factor sera for identification of types within groups are not discussed in this manual. However, the sera are rendered specific by multiple absorptions or by induction of immunological tolerance to cross-reacting types prior to immunization.

The procedure presented in this manual, however, describes a simple checkerboard typing system, based on 12 pooled sera and intended for typing and/or grouping most of the pneumococci isolated from CSF or blood.

Antigen preparation and typing

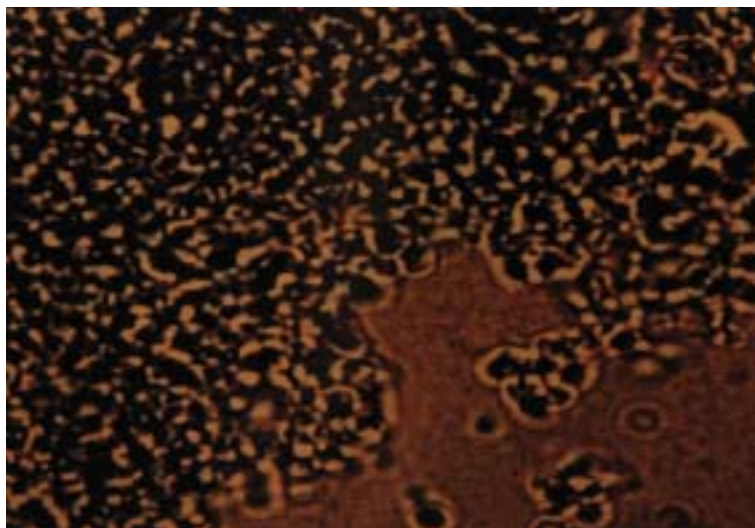
The type and condition of a culture that is received in the laboratory will determine the procedure used to prepare a suitable cell suspension for observation of the Quellung reaction.

- a) Inoculate a freshly prepared blood agar plate with an inoculating loop. Inoculate about one-third of the plate heavily and then streak the remainder of the plate for isolated colonies. Invert the agar plate, place in a candle-jar or a CO₂ incubator and incubate at 35°C for 18–24 hours.
- b) Using a sterile loop, sweep across the surface of the 18–24 hour plate for inoculum. Prepare a light to moderate cell suspension (approximately equal to a 0.5 McFarland density standard) in 0.5 ml of physiological saline. **Optimum Quellung reactions can be observed when there are 25–50 cells visible in a microscopic field.**
- c) With a loop or micropipette, dispense 3–5 µl of pneumococcal pool antiserum and 1–5 µl of the cell suspension on a microscope slide. (Be sure not to contaminate the bottle of antisera with the cell suspension.) Add an amount of 0.3% aqueous methylene blue equivalent to the amount of antiserum, and mix the liquids on the slide.
- d) Cover the mixture with a 22-mm² cover-slip and incubate at room temperature for up to 10 – 15 minutes. **Make sure the fluid on the slide does not dry**, or it will not be possible to read the Quellung reaction.
- e) All positive Quellung reactions appear as shown in Figure 77. The capsule is seen as a clear area surrounding the dark cell (*i.e.*, the clear area between the dark cell and the dark background).

Non-reactive strains

If a Quellung reaction is not observed in one of the pools with the cell suspension from an agar plate, inoculate a tube containing 1.0 ml Todd-Hewitt broth which has been supplemented with 2-3 drops of defibrinated sheep blood. Incubate the tube at 35°C for 1 to 3 hours or until the broth above the blood is turbid. Once turbid, one or two loops of the broth culture should be tested (as described in steps c – e, above). If a Quellung reaction is not observed in any of the pools, the identification of the strain as *S. pneumoniae* should be re-confirmed by re-testing for optochin susceptibility and bile solubility.

FIGURE 77: A Quellung reaction



The capsule is the clear area surrounding the dark cell in a Quellung reaction.

Typing and/or grouping of *S. pneumoniae* using the checkerboard system

The capsular reaction test should be performed using each of the nine traditional pools (A through I) in succession until a positive reaction is observed. Ordinarily, typing then proceeds by testing the strain in question with antisera against those individual types or groups that are included in the serum pool that gave a positive reaction. However, the checkerboard method described here proceeds by testing for a positive reaction with the serum pools (P to T). The type or group is then established from the reaction pattern by the use of a table with the types and groups entered in a rectangular checkerboard arrangement (Table 26, adapted from works by Sørensen (1993) and Lalitha, *et al.* (1999) [Appendix 15]).

TABLE 26: A checkerboard typing system for *Streptococcus pneumoniae*

Existing pool ^{a,b,c}	Type or group with new pool ^{a,b,c}					Non-vaccine-related type or group ^{a,b,c}
	P	Q	R	S	T	
A	1	18*	4	5	2	
B	19*	6*	3	8		
C	7*				20	24*, 31, 40
D			9*		11*	16*, 36, 37
E			12*	10*	33*	21, 39
F				17*	22*	27, 32*, 41*
G^c						29, 34, 35*, 42, 47*
H	14	23*		15*		13, 28*
I^c						25, 38, 43, 44, 45, 46, 48

^a The five pooled sera P to T are composed such that each of the 21 vaccine-related types and/or groups reacts with both one of these sera and with one of the seven pooled sera A to F plus H.

^b All 46 types of groups are shown in the table. (Numbers 26 and 30 are not in use.) Asterisks (*) indicate groups containing the following types: 6, 6A and 6B; 7, 7A, 7B, 7C and 7F; 9, 9A, 9L, 9N and 9V; 10, 10A and 10F; 11, 11A, 11B, 11C and 11F; 12, 12A and 12F; 15, 15A, 15B, 15C and 15F; 16, 16A and 16F; 17, 17A and 17F; 18, 18A, 18B, 18C and 18F; 19, 19A and 19B, 19C, and 19F; 22, 22A and 22F; 23, 23A, 23B and 23F; 24, 24A and 24B; 28, 28A and 28F; 32, 32A and 32F; 33, 33B, 33C and 33F; 35, 35A, 35B and 35C; 41, 41A and 41F; 47 and 47A. Types and/or groups present in the current 23-valent polysaccharide pneumococcal vaccine are indicated by boldface type.

^c Pools G and I do not react with vaccine types and are therefore not included in the checkerboard system.

Checkerboard table is adapted from Sørensen (1993) and LaLitha et al. (1999)

Antimicrobial Susceptibility Testing by Broth Microdilution

Minimal inhibitory concentration (MIC) testing by agar or broth dilution is a complex process that can be expensive and challenging to prepare, but when properly carried out its results are easily interpreted. Different bacteria may be tested in different ways (*i.e.*, using either agar or serial dilutions of the antimicrobial agent in broth). MIC tests for *Neisseria meningitidis* should be performed by broth microdilution if the Etest® is not available. **Careful preparation and quality control are extremely important in order for MIC tests to be performed accurately.**

This laboratory manual recommends the use of the Etest® antimicrobial gradient strip for MIC testing; however, if there are a large number of isolates on which to perform susceptibility testing, it may be more cost-effective to order and use commercially prepared MIC panels. Standard concentrations, or dilutions, of antimicrobial agents used in MIC testing are listed in Table 27.

***N. meningitidis*: Minimal inhibitory concentration (MIC) testing by broth microdilution**

When performing MIC testing by broth microdilution, laboratorians must first confirm the identification of the isolates as *N. meningitidis*, perform a fresh subculture, prepare a suspension equivalent to the 0.5 McFarland turbidity standard, and then use this standardized suspension to inoculate the panel of antimicrobial agents. After incubation, read, record, and interpret the results.

Preliminary examination

Examine the isolates and confirm as *N. meningitidis* prior to MIC testing.

- a) Upon receipt of the isolate(s), examine plates for purity.
- b) With a sterile disposable loop, touch the surface of one colony morphologically similar to *N. meningitidis*. Streak onto a chocolate agar plate, label the plate, and incubate at 35°C in 5% CO₂ for 18–22 hours. Because *N. meningitidis* grows

TABLE 27: Concentrations of antimicrobial agents used in minimal inhibitory concentration (MIC) testing

Standard concentration values *	Comments
0.001 µg/ml	Note: Different organism-antimicrobial combinations require testing with different ranges of concentrations of antimicrobial agents.
0.002 µg/ml	
0.004 µg/ml	
0.008 µg/ml	
0.016 µg/ml	Note: Antimicrobial gradient strips used for minimal inhibitory concentration (MIC) testing often include both the standard concentrations presented here and also concentrations at intervals between the standards.
0.032 µg/ml	
0.064 µg/ml	
0.125 µg/ml	
0.25 µg/ml	Note: When inter-dilutional values are present: measure and record the results according to the intersection of the ellipse of growth with the test strip, as described by the manufacturer. To interpret the results, round the inter-dilutional measurement up to the next highest standard MIC concentration. (For example, an Etest® MIC of 0.096 µg/ml, but interpreted as 0.125 µg/ml for the final report.)
0.5 µg/ml	
1.0 µg/ml	
2.0 µg/ml	
4.0 µg/ml	
8.0 µg/ml	
16.0 µg/ml	
32.0 µg/ml	
64.0 µg/ml	
128.0 µg/ml	
256.0 µg/ml	

* Standard concentrations are also commonly referred to as “dilutions.”

well in a humid atmosphere, laboratorians may choose to add a shallow pan of water to the bottom of the incubator or add a dampened paper towel to the candle-extinction jar.

- c) Examine the chocolate agar plate after incubation for isolated colonies morphologically similar to *N. meningitidis*.
- d) **Perform an oxidase test** on the morphologically suspect colonies using the swab method: gently touch a sterile swab to a suspect colony, being careful not to pick up the entire colony so that enough remains that it can be streaked to subculture if it is oxidase-positive. Using a sterile Pasteur pipette, remove a small amount of Kovac’s oxidase reagent⁴⁰ from the tube and place a drop on

⁴⁰ Some laboratories may use a different reagent, Gordon and MacLeod’s reagent (1% [wt/vol]) dimethyl-p-phenylenediamine dihydrochloride; “dimethyl- reagent”), to perform the oxidase test. The dimethyl- reagent is more stable than the tetramethyl- reagent (Kovac’s reagent), but the reaction with the dimethyl- reagent is slower than that with the tetramethyl- reagent. **If the laboratory is using the dimethyl- reagent**, a positive reaction will be indicated by a color change to blue on the filter paper (not purple, as with the tetramethyl- reagent), and **with the dimethyl- reagent it will take 10–30 minutes for a positive reaction to develop**.

the growth collected on the swab; if it turns purple, the reaction is positive for *N. meningitidis* and those specific colonies should immediately be subcultured with a sterile loop to a chocolate agar plate. Label the plate and incubate at 35°C in 5% CO₂ for 18–22 hours. Use isolated colonies from this plate to set up the antimicrobial susceptibility tests.

Ÿ If the oxidase test is negative, the isolate is not *N. meningitidis*; discard appropriately.

Inoculum preparation

- a) Prepare a suspension of the culture by touching the surface of several morphologically similar isolated colonies with a sterile cotton-tip applicator on the chocolate agar subculture plate, incubated for 18–22 hrs in 5% CO₂ at 35° C.
- b) Immerse the applicator into a tube containing sterile Mueller-Hinton broth. Rub the applicator against the wall of the tube slightly to release a small amount of growth into the liquid. Cap the tube and mix.
- c) Adjust the turbidity of the inoculum to that of a 0.5 McFarland turbidity standard. If the turbidity is greater than the standard, dilute with broth to equal the turbidity of the standard, which will be approximately 1x10⁸ CFU/ml. (Preparation of the 0.5 McFarland turbidity standard is described in Appendix 2.)

Broth microdilution

- a) Remove a sufficient number of MIC frozen plates for testing and allow them to thaw for approximately 30 minutes.
- b) Add 2 ml of the adjusted inoculum to 38 ml of sterile distilled water.
- c) Mix well.
- d) Pour the suspension into the disposable inoculator tray, and inoculate the thawed MIC trays.
- e) Incubate the MIC trays for 18–22 hours in 5% CO₂ at 35°C.

Reading the test results

Use the following *S. pneumoniae* isolate, ATCC 49619, as a quality control strain for *N. meningitidis* antimicrobial susceptibility testing. MIC breakpoints for *S. pneumoniae* ATCC 49619 with antimicrobial agents appropriate for the treatment of infections with *N. meningitidis* are presented in Table 4 of the *N. meningitidis* chapter.

- a) Read and record the quality control results first.
- b) **If all antimicrobial agents are in control**, read the test MICs and note any trailing endpoints.

Record all information in a standard form. A sample worksheet for recording antimicrobial susceptibility results for *N. meningitidis* is included in Figure 13. *N. meningitidis* does not have breakpoints defined by NCCLS (as of 2002); interpretation of the susceptibility of a strain includes accounting for the site of the infection and the dose and pharmacokinetics of the antimicrobial agent (*i.e.*, similar to interpretive criteria laboratorians may use when performing antimicrobial susceptibility testing on other organisms without defined breakpoints), as described in the antimicrobial susceptibility testing portion of the *N. meningitidis* chapter (Chapter V) of this manual.

Specimen Collection and Primary Isolation of *Neisseria gonorrhoeae*

A schematic representation of the isolation and presumptive identification of *N. gonorrhoeae* is presented in Figure 19. For treatment purposes, using a presumptive identification is appropriate; however, for a definition of infection with *N. gonorrhoeae* to be absolutely certain, a series of confirmatory biochemical and enzymatic tests must be conducted.

N. gonorrhoeae is highly susceptible to adverse environmental conditions: strains are susceptible to extreme hot and cold temperatures and to drying. Cultures for *N. gonorrhoeae* should always be incubated at 35°–36.5°C in a CO₂-enriched, humid atmosphere. Conditions affecting the growth of *N. gonorrhoeae* are summarized in Table 28.

Specimen collection and transport

Specimens for the isolation of *N. gonorrhoeae* may be obtained from sites exposed during sexual intercourse (*i.e.*, the genital tract, urethra, rectum, and the oropharynx) or from the conjunctiva of neonates infected during birth. Details on the collection and transport of specimens are presented in Table 29. Specimens may also be obtained from Bartholin's gland, fallopian tubes, endometrium, blood, joint fluid, skin lesions or gastric contents of neonates; methods for isolation of *N. gonorrhoeae* from these less common sites are not included in this document (and laboratorians should refer to a medical microbiology procedures manual for further instruction). **Specimens for culture must not be transported on dry swabs**, but rather inoculated directly on media.

The best method for isolating *N. gonorrhoeae* is to inoculate specimens directly onto a nutritive medium and to incubate the plates immediately after inoculation at 35°–36.5°C in a CO₂-enriched, humid atmosphere for 18–24 hours. Specimens from sites with normal flora (*i.e.*, anogenital or oro-/nasopharyngeal specimens) should be inoculated onto a selective medium such as modified Thayer-Martin (MTM), Martin-Lewis (ML), or GC-Lect® medium. Specimens from other sites may be inoculated onto a nonselective medium, such as GC-chocolate agar (*i.e.*, GC agar base, haemoglobin, and 1% defined growth supplement, as described in Appendix 2).

TABLE 28: Conditions affecting the growth of *Neisseria gonorrhoeae*

Conditions	Comments
Temperature	<i>N. gonorrhoeae</i> is sensitive to extremes of warm and cold temperatures, and requires incubation at 35°–36.5° C.
Atmosphere	<i>N. gonorrhoeae</i> strains require an increased CO ₂ atmosphere (3%–5% CO ₂) for primary isolation. Some strains have an obligate requirement for CO ₂ , whereas other strains lose this requirement on subculture. Use a CO ₂ -incubator or a candle-extinction (candle) jar. Re-light the candle each time the candle-jar is opened to add plates. (Note: Vapor from scented candles can be toxic to the bacteria; therefore, only unscented candles should be used in the candle-jar.)
Humidity	<i>N. gonorrhoeae</i> is extremely sensitive to drying, and must be incubated in a humid atmosphere. To obtain this atmosphere for incubation, place a flat pan of water in the bottom of the incubator or a moistened paper towel in a candle jar. Replace the moistened paper towel daily to prevent the growth of molds, which can contaminate cultures. Periodically, decontaminate the candle jar.
Growth medium	<i>N. gonorrhoeae</i> is a fastidious organism which requires supplements for growth. The growth medium recommended for <i>N. gonorrhoeae</i> is a GC-base medium containing a 1% defined supplement (IsoVitalX or Kellogg's defined supplement).
Time	<i>N. gonorrhoeae</i> will usually survive for 48 hours in culture, but isolates should be subcultured every 18–24 hours for maximum viability. An 18- to 24-hour culture should be used to inoculate any culture-based test.
Storage	For long-term storage, strains of <i>N. gonorrhoeae</i> should be suspended and frozen in a medium such as trypticase soy broth containing 15% glycerol. Freeze the suspensions in liquid nitrogen or in a -70° C freezer. Strains do not survive for more than a short time (a few weeks) at -20° C.
Swab materials	<i>N. gonorrhoeae</i> is sensitive to some materials found in swabs. If gonococcal growth is sparse, consider that the swab material may be toxic. Some untreated cottons can be toxic to <i>N. gonorrhoeae</i>, as can the wooden-stick applicator if it is in contact with the bacteria for an extended period of time. However, laboratorians should not use only swabs made from synthetic materials for two reasons: 1) synthetic swabs often do not absorb liquid easily; and, 2) synthetic swabs have flexible plastic applicators. When these are pressed against the side of a tube or plate to express liquid they can splatter the suspension, which may cause laboratory-acquired infections. For this reason, laboratorians working with flexible-handled swabs should wear safety goggles.

If specimens must be transported from the point of specimen collection to a local laboratory and the inoculated media cannot be incubated during the period before transport, transporting the inoculated plates in a CO₂-enriched atmosphere is more important than incubating them at 35°–36.5°C. Inoculated media may be held at room temperature in a CO₂-enriched atmosphere in candle-extinction jars or an alternative CO₂-generating system for up to 5 hours without appreciable loss of viability; however, if the specimen is going to be transported to a distant

laboratory, it should be incubated for 18–24 hours at 35°–36.5°C in a CO₂-enriched, humid atmosphere **prior to transport**. When specimens must be transported to distant laboratories, they may be inoculated onto transport systems such as Jembec® plates (which contain a CO₂-generating system), Transgrow bottles, or agar slants containing a gonococcal selective or nonselective medium. All inoculated specimens should be delivered to the laboratory within 24–48 hours of collection to maximize recovery of gonococcal isolates.

Nutritive or buffered non-nutritive semisolid transport media (e.g., Stuart's or Amies media) have been used to transport specimens on swabs to laboratories. **Although gonococci may survive in these media for 6–12 hours, viability decreases rapidly thereafter and isolates may not be recovered after 24 hours.** In addition, because the specimen may be diluted in the transport medium, recovering isolates from semisolid transport media may be more difficult than recovery from solid agar media. When commercially available zipper-locked, CO₂-generating systems (such as Jembec®) are available, it is no longer recommended that specimens for the isolation of *N. gonorrhoeae* be transported in semisolid transport media.

Incubation conditions

***N. gonorrhoeae* requires a CO₂-enriched atmosphere for primary isolation.**

Although some strains lose their requirement for a CO₂-enriched atmosphere for growth in subculture, some strains have an obligatory requirement for CO₂ which is not lost on subculture. CO₂ incubators should be used if large numbers of specimens must be processed. If a CO₂ incubator is not available, culture plates may be incubated either with commercial CO₂-generating systems (producing a concentration of 3%–5% CO₂) or in candle-extinction jars. To use a candle-extinction jar:

- a) Place the plates to be incubated into the jar and place a small candle into the jar on the bottom, beside the plates. (The candle can be placed atop the plates, but only if the jar's top is not made of plastic, which can melt and/or produce toxic fumes when exposed to a flame.)
- b) Light the candle, and place the lid on the jar. The flame will soon self-extinguish.

When the candle-flame extinguishes from lack of oxygen, an atmosphere of ~3%–5% CO₂ has been generated. Because the vapor from scented candles may be toxic, it is important to use a non-scented candle in the candle-extinction jar. **Relight the candle each time the jar is opened to add more plates.**

Gonococcal strains also require increased humidity for good growth. Humidity is maintained in incubation chambers by placing a pan of water on the bottom shelf of a CO₂ incubator or by placing moistened but not dripping paper towels on

TABLE 29: Specimen collection procedures for the laboratory diagnosis of *Neisseria gonorrhoeae*

Specimen	Procedure	Special notes
Urethra (male)	1. Insert a urethrogenital swab (rayon or Dacron*) 2–4 cm into the urethral lumen, rotate the swab and leave it in place for at least 2 seconds to absorb the fluid. (* Do not use a cotton swab unless it's been treated by the manufacturer to neutralize toxicity.) 2. Immediately inoculate MTM, ML, or equivalent selective medium for <i>N. gonorrhoeae</i>. Incubate inoculated plates immediately in a CO₂-enriched atmosphere or place in a candle-extinction jar for transport to the laboratory. 3. Prepare a smear for Gram stain.	a. Specimen should be collected no sooner than 1 hour after the patient has urinated. b. A presumptive laboratory diagnosis of gonorrhea may be made immediately by Gram stain (or Loeffler's methylene blue). A high correlation exists between the observation of gram-negative diplococci in Gram stained smear and the isolation of <i>N. gonorrhoeae</i> from the male urethra. c. Clean-catch, midstream urine specimens (5–10 ml) should be centrifuged and the sediment should be inoculated onto a selective medium for the isolation of <i>N. gonorrhoeae</i>.
Cervix	1. Insert a non-lubricated speculum into the vagina so the cervix can be seen. 2. Use a swab to remove mucus and secretions from the cervical os; discard this swab. 3. Use a sterile swab to gently but firmly sample the endocervical canal. 4. Immediately inoculate MTM, ML, or equivalent selective medium for <i>N. gonorrhoeae</i>. Incubate inoculated plates immediately in a CO₂ environment or place in a candle-extinction jar for transport to the laboratory.	a. Ensure that the swab used to collect the endocervical specimen does not touch the vaginal walls during the procedure. b. In pre-pubescent girls, vaginal specimens may be substituted for endocervical specimens.
Vagina (only in prepubescent females)	1. Wipe any excessive secretions or discharge. 2. Rub a Dacron or rayon swab against the mucus membranes of the posterior vaginal wall for 10–15 seconds to absorb secretions. 3. Immediately inoculate MTM, ML, or equivalent selective medium for <i>N. gonorrhoeae</i>. Incubate inoculated plates immediately in a CO₂ environment or place in a candle-extinction jar for transport to the laboratory.	a. Collect the specimen from the vaginal orifice if the hymen is intact.

TABLE 29: Specimen collection procedures for the laboratory diagnosis of *Neisseria gonorrhoeae*, continued

Specimen	Procedure	Special notes
Rectum (if a history of oral-genital or anal-genital exposure exists)	1. Insert a sterile swab approximately 1 inch beyond the anal sphincter. 2. Gently rotate the swab to sample the anal crypts. 3. Immediately inoculate MTM, ML, or equivalent selective medium for <i>N. gonorrhoeae</i>. Incubate inoculated plates immediately in a CO₂ environment or place in a candle-extinction jar for transport to the laboratory.	a. Discard anorectal swabs that are contaminated with fecal material; obtain a second specimen.
Pharynx (if a history of oral-genital or oro-anal exposure exists)	1. Depress tongue with a tongue depressor. 2. Use a sterile swab to sample the posterior pharynx, tonsils, and inflamed areas. 3. Immediately inoculate MTM, ML, or equivalent selective medium for <i>N. gonorrhoeae</i>. Incubate inoculated plates immediately in a CO₂ environment or place in a candle-extinction jar for transport to the laboratory.	—
Conjunctiva	1. Moisten two swabs with sterile saline. 2. Swab each eye with a separate swab by rolling the swab over the conjunctiva. 3. Immediately inoculate each swab onto a non-selective plate (e.g., chocolate agar) and incubate inoculated plates immediately in a CO₂ environment or place in a candle-extinction jar for transport to the lab. 4. Smear each swab onto a separate slide for Gram stain.	a. Sample both conjunctivae if possible, but if prohibitively expensive, culture infected conjunctiva. b. <i>Neisseria</i> spp. other than <i>N. gonorrhoeae</i> (e.g., <i>N. cinerea</i> and <i>M. catarrhalis</i>) may infect the conjunctiva, particularly in newborns. Therefore, confirm the identification of gram-negative diplococci to eliminate non-gonococcal species. c. Gram-negative diplococci may be isolated after prophylactic treatment of newborn conjunctiva to prevent <i>N. gonorrhoeae</i> infection. <i>N. cinerea</i> is less susceptible to erythromycin than <i>N. gonorrhoeae</i>.

the bottom of the candle-extinction jar. Replacing the moistened towels each time that the candle-extinction jar is opened is not necessary; however, the towels should be replaced at least once a week to ensure that they do not become a source of contamination, particularly with molds.

Gonococcal isolates should not be expected to survive for >48 hours in culture, although some isolates may survive for 72–96 hours. Isolates should be subcultured every 18–24 hours to maintain maximum viability. Similarly, isolates that are stored by freezing or lyophilization should also be subcultured at least once after the initial recovery culture before being used to inoculate tests. Diagnostic tests requiring viable organisms and antimicrobial susceptibility tests must be inoculated only with cultures 18–24 hours old.

Consideration for cultures received at the laboratory at the end of the work-week

In some circumstances, a culture is growing but has not been purified by the end of the work-week, or a culture-slant has been received at the end of the work-week and personnel are not available to perform laboratory testing on it for several days. In this scenario, the best procedure for recovery of gonococci is to scrape the growth off the culture medium, avoiding visible contaminants, and prepare it for short-term storage (as described in Appendix 11). Freeze the isolate in glycerol-trypticase soy broth, and then thaw the culture at the beginning of the next work-week, when testing resources are available. (Appendix 11 also includes methods for culturing isolates from frozen cultures.) Although it may seem labor-intensive to prepare and store the isolate in a freezer for only two days, this process is more favorable for the recovery of *N. gonorrhoeae* than just letting it grow on the original medium over the weekend and then trying to recover it from the original slant.

Primary specimen swabs received at the end of the workweek should be plated onto medium appropriate for the specimen collection site (Table 29) and placed into an incubator at 35°–36.5°C in a CO₂-enriched, humid atmosphere. Although the organism might not be viable on the next workday, performing a Gram stain and an oxidase test for presumptive identification of the growth on the culture plate may still be feasible (because neither of these presumptive diagnostic tests requires viable growth).

Culture: Specimen inoculation and isolation

- a) Warm plates of selective or nonselective medium (as appropriate for the anatomic site of specimen collection, see Table 29) to room temperature.
- b) Inoculate specimens onto pre-warmed plates using the ‘Z’ streak inoculation method (Figure 78). Incubate inoculated plates at 35°–36.5°C in a CO₂-enriched, humid atmosphere for 18–24 hours.

- c) Examine the plates after incubation. *N. gonorrhoeae* produces different colony types, which vary in diameter from 0.5 to 1.0 mm. In primary cultures, most colonies will be 0.5 mm in diameter, although a few colonies of 1.0 mm may be present. Typical colonial morphology is described in Table 30 and pictured in Figure 79.

If colonies are observed after incubation for 24 hours, use an inoculating loop to harvest growth of several colonies and streak the growth for isolation on a GC-chocolate agar plate to obtain a pure culture. Incubate the plate at 35°–36.5°C in a CO₂-enriched, humid atmosphere for 18–24 hours.

Note: If only one or two colonies are present on the primary isolation plate, streak a portion on a GC-chocolate agar plate for subculture, but also ‘re-streak’ each colony over a small section of the primary isolation plate. Incubate both plates at 35°–36.5°C in a CO₂-enriched, humid atmosphere for 18 – 24 hours. The primary isolation plate can be discarded if the colony subcultured onto the GC-chocolate agar plate grows successfully.

If no colonies are observed on the primary isolation plate after incubation for 24 hours, re-incubate the plate and examine it after an additional 24 hours (*i.e.*, after a total of 48 hours). If growth is still not observed on the primary isolation plate, this step should be repeated again. If no colonies are present after incubation for a total of 72 hours, the specimen should be reported as having “no growth.”

If colonies exhibit morphology typical of *N. gonorrhoeae* (Figure 79), continue with a Gram stain or simple single stain (*e.g.*, Loeffler’s methylene blue stain) for cellular morphology.

Gram stain (or simple stain with Loeffler’s methylene blue, safranin, or malachite green)

The morphology of the gonococcus can be demonstrated with a Gram stain or, alternatively, with a simple stain using Loeffler’s methylene blue, safranin, or malachite green. Although *N. gonorrhoeae* is a gram-negative diplococcus with a characteristic flattened coffee-bean shape, because of the way cells divide, they may also appear as tetrads or clumps when stained. Images showing results of a typical Gram stain and simple Loeffler’s methylene blue stain of *N. gonorrhoeae* are presented in Figure 80. Performance of the Gram stain is described earlier in this laboratory manual, in Appendix 4 (“Isolation of Agents from Normally Sterile Sites”). Smears for the Gram stain may be prepared from a specimen swab, individual colonies on the primary isolation medium, or from pure culture.

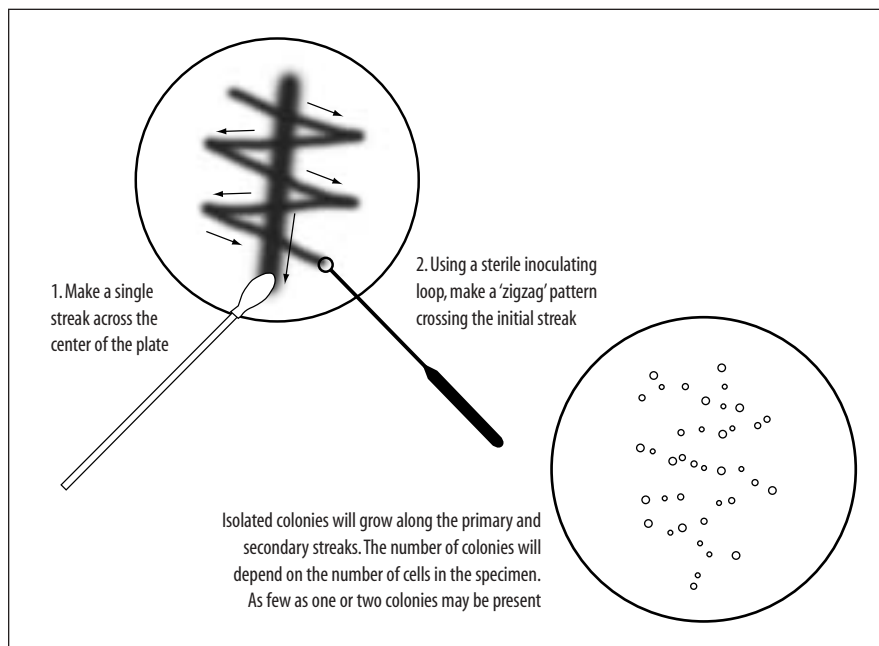
It should be noted that, when Gram staining, clumps of cells might appear a dark color due to the retention of crystal violet in the clump, even after proper decolorization, leading to the misinterpretation of some gram-negative cells as gram-positive. However, attempts to adequately decolorize the clumps may result

TABLE 30: Colonial morphology of *Neisseria gonorrhoeae* and related species on gonococcal selective media

Species	Comments
<i>N. gonorrhoeae</i>	- Colonies are of similar appearance on gonococcal selective and nonselective media: pinkish-brown and translucent, 0.5–1.0 mm in diameter, smooth consistency, and defined margins. 0.5-mm colonies tend to be high-convex in elevation 1.0-mm colonies tend to be low-convex in elevation - Fastidious strains of <i>N. gonorrhoeae</i> produce atypically small, “pinpoint” colonies (~0.25 mm in diameter) compared with other, less fastidious gonococcal strains.
<i>N. meningitidis</i>	- Colonies are of similar appearance on gonococcal selective and nonselective media: pinkish brown and translucent, with smooth consistency and defined margins - Colonies are usually larger and flatter than those of <i>N. gonorrhoeae</i> (1.0– 2.0 mm for <i>N. meningitidis</i> colonies vs. 0.5–1.0 mm for <i>N. gonorrhoeae</i>). - Colonies of encapsulated serogroups A and C strains may be mucoid.
<i>N. lactamica</i> <i>N. cinerea</i> <i>N. polysaccharea</i> <i>K. denitrificans</i>	- Colonies are of similar appearance to <i>N. gonorrhoeae</i> on gonococcal selective and nonselective media: pinkish-brown and translucent, 0.5 – 1.0 mm in diameter, low-convex in elevation, smooth consistency, and defined margins. - Colonies of <i>N. lactamica</i> may have a yellowish pigment. - Colonies of <i>N. cinerea</i> may have a brownish pigment.
<i>N. subflava</i> biovars <i>N. sicca</i> <i>N. mucosa</i>	- Colonies are usually 1.0–3.0 mm in diameter, opaque, and may have yellow pigment (especially <i>N. subflava</i> biovars). - Colonies of <i>N. subflava</i> bv. perflava and <i>N. mucosa</i> are convex and glistening. - Colonies of <i>N. subflava</i> bv. subflava and flava are low-convex to flat with a matte surface and may have a slightly brittle consistency. - Colonies of <i>N. sicca</i> may adhere to the agar surface and become wrinkled with prolonged incubation.
<i>M. catarrhalis</i>	- Colonies are usually 1.0–3.0 mm in diameter, opaque, friable (dry) in consistency, and pinkish-brown. - Colonies may be moved intact over the surface of the medium with an inoculating loop. - Colonies disintegrate in chunks when broken with a loop.

in over-decolorization of the Gram stain, which could render gram-positive organisms to falsely appear gram-negative. Because the division of gonococcal cells may cause them to smear in clumps, as noted above, they can be technically complicated to stain. As a result, when staining is being performed **specifically to detect the gonococcus**, some laboratorians may find it preferable to perform a simple stain with Loeffler’s methylene blue (or another stain such as safranin or malachite green) to reveal information about the characteristic cell morphology and arrangement.

FIGURE 78: Streaking a plate with a specimen swab for primary isolation of *Neisseria gonorrhoeae*: “Z-streak” inoculation method



Methods to perform a simple stain with Loeffler's methylene blue (or safranin or malachite green) are presented below.

- With an inoculating loop or sterile swab, touch a representative colony with morphology typical of gonococcus on the primary isolation plate. The advantage of using a sterile swab for the preparation of this smear is that an oxidase test can be performed directly on the growth remaining on the swab after smear preparation.
- Prepare a thin smear of the suspect colony in a drop of water on a clean microscope slide (as for a Gram stain).
- Heat-fix the smear (as for the Gram stain).
- Cover the smear with methylene blue stain (or safranin or malachite green) for 30–60 seconds.
- Rinse and blot the slide until dry.
- View the stained smear under the oil immersion lens of a light microscope.
- Record results.

FIGURE 79: Colonial morphology typical of *Neisseria gonorrhoeae*

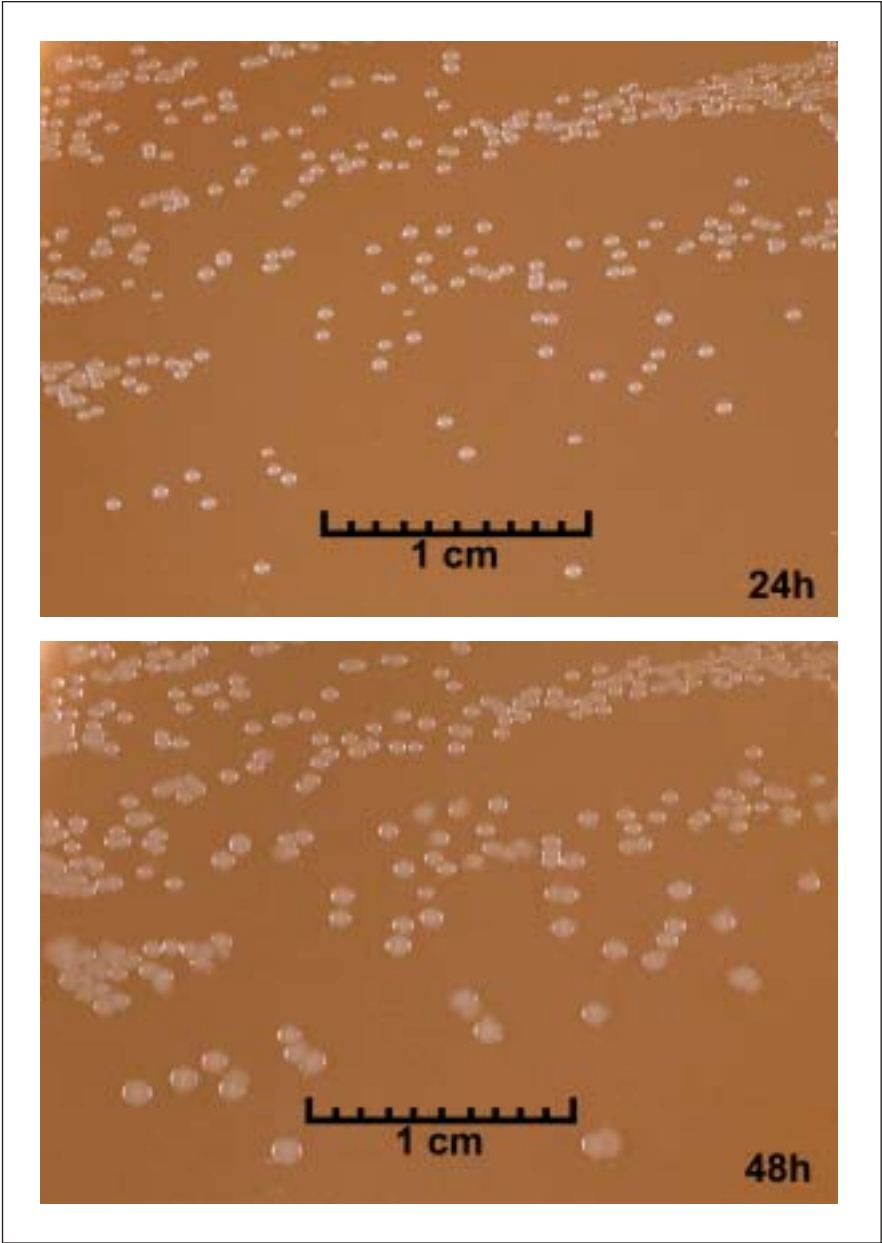
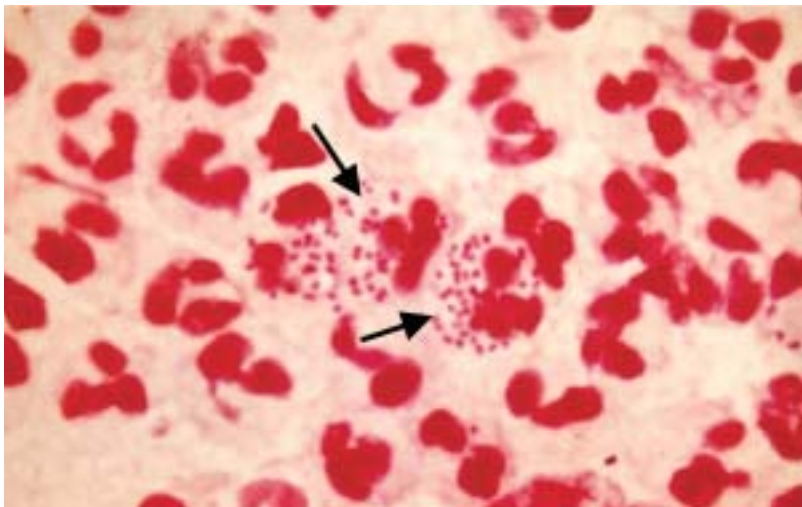
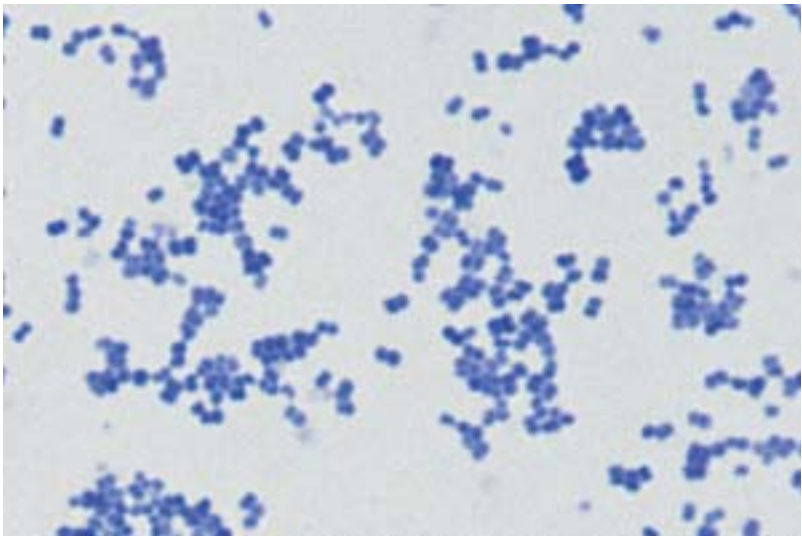


FIGURE 80: Gram stain and simple single Loeffler's methylene blue stain of *Neisseria gonorrhoeae*



A. Gram stain (of clinical specimen)



B. Loeffler's methylene blue stain (of pure culture)

Arrows point to gram-negative diplococci surrounded by polymorphonuclear neutrophils in a typical Gram stained smear of *N. gonorrhoeae* in a clinical specimen (A). The characteristic flattened coffee-bean cellular arrangement is also readily apparent if the culture is stained with a simple single stain only, such as Loeffler's methylene blue or safranin (B, simple stain of pure culture).

If colony and cell morphology are characteristic of *N. gonorrhoeae*, continue testing with the oxidase test. Oxidase testing methods are presented in Chapter V “*Neisseria gonorrhoeae*: Confirmatory Identification and Antimicrobial Susceptibility Testing.”

Confirming pure culture from the primary isolation plate

It is useful to **re-incubate the primary isolation plate and GC-chocolate agar subculture plates for 24 hours after the selection of colonies resembling *N. gonorrhoeae* to determine if colonies of contaminating organisms are present** and were not visible after the first 24 hours. Colonies of staphylococci (gram-positive, oxidase-negative cocci), for example, may be somewhat translucent after incubation for 24 hours, whereas they will form readily distinguishable white, opaque colonies after incubation for 48 hours. Colonies of streptococci (gram-positive, oxidase-negative cocci that often appear as diplococci) may also grow in specimens for gonococci: streptococcal colonies will be very small after incubation for 24 hours but should be clearly visible after incubation for 48 hours and may be surrounded by a zone of α -hemolysis.

Recognition of pure colonies of *N. gonorrhoeae* is often easier after incubation at 35°–36.5°C in a CO₂-enriched, humid atmosphere for 48 hours. Colonies may double in size between 24 and 48 hours, making typical colony characteristics more readily apparent. Repeat the Gram stain (or simple Loeffler’s methylene blue stain) and an oxidase test to confirm that the isolate is an oxidase-positive, gram-negative diplococcus with the typical kidney bean morphology; if the culture is not pure, colonies with morphology typical of gonococcus should be re-streaked over a small section of the primary isolation plate, and incubate the plate at 35°–36.5°C in a CO₂-enriched, humid atmosphere for 24 hours, as described in the primary isolation portion of this chapter. Once the culture is confirmed to be pure *N. gonorrhoeae*, continue with confirmatory identification and antimicrobial susceptibility testing (Chapter VI), and/or preservation and storage of the isolate for future use (Appendix 11). Isolates should always be confirmed as pure prior to storage.

Fecal Specimens: Collection, Transport, and Field Supplies

The information in this appendix is provided to the laboratorian to help ensure appropriate collection of samples and subsequent transport to the laboratory by individuals in the field.

During an outbreak, stool specimens or rectal swabs should be collected from 10–20 persons who meet the following criteria:

- currently have watery diarrhea (cholera) or bloody diarrhea (dysentery)
- had onset of illness <4 days before sampling; and,
- have not received antimicrobial treatment for the diarrheal illness.

Fecal specimens should be collected in the early stages of any enteric illness, when pathogens are usually present in the stool in highest numbers, and before antibiotic therapy has been started (Table 31). An exception to this rule is when stool is collected from persons with febrile illness: in the case of typhoid fever, the etiologic agent *Salmonella* ser. Typhi may be present in highest numbers in stool in the second and third weeks of the disease.

Collection of stool

Stools samples should be collected in clean containers without disinfectant or detergent residue and with tight-fitting, leak-proof lids. Specimens should **not** be collected from bedpans, because the bedpans may contain residual disinfectant or other contaminants. **Unpreserved stool should be refrigerated, if possible, and processed within a maximum of 2 hours after collection. Specimens that cannot be cultured within 2 hours of collection should be placed in transport medium and refrigerated immediately.**

Transport media for fecal specimens

This section provides information regarding media appropriate for the transport of fecal specimens that are suspected to contain *Shigella*, *Vibrio cholerae*, or *Salmonella* (including serotype Typhi) specimens. Once specimens from an outbreak of diarrheal disease have arrived at the laboratory, laboratorians should

TABLE 31: Collection and transport of fecal specimens for laboratory diagnosis

Fecal Specimens for the Laboratory	When to collect	When the patient is having diarrhea, as soon after onset of illness as possible (preferably within 4 days of onset) and before antimicrobial treatment is started.
	How much to collect	Rectal swab or swab of fresh stool in transport medium.
	Transport medium	Cary-Blair or other suitable transport medium (NOT buffered glycerol saline for <i>V. cholerae</i>).
	Storage after collection	Refrigerate at 4 °C if the specimens will be received by the laboratory within 48 hours or freeze at -70 °C. Fecal specimens from patients with suspected cholera can be transported at ambient temperature and held for longer times if necessary; however, refrigeration is preferred.
	Transportation	Seal tubes/containers to prevent leakage; place in waterproof container to protect from wet or dry ice. Ship in insulated box with ice packs, wet ice, or dry ice by overnight delivery.

follow procedures for *Shigella* or *V. cholerae* isolation (Appendix 10) depending on whether reports from the field indicate the outbreak appears to be dysentery or a cholera-like illness. Because persons suspected of having typhoid will commonly present with fever and not diarrhea, laboratories usually do not receive a surge of fecal specimens in an outbreak of typhoid; however, on occasion fecal specimens may be submitted to a laboratory for diagnosis of infection with *S. Typhi* (see Appendix 10 for isolation methods).

Cary-Blair transport medium

Cary-Blair transport medium can be used to transport many bacterial enteric pathogens, including *Shigella*, *Salmonella*, and *Vibrio cholerae* (Figure 81). Cary-Blair’s semisolid consistency provides for ease of transport, and the prepared medium can be stored after preparation at room temperature for up to 1 year. Because of its high pH (8.4), it is the medium of choice for transport and preservation of *V. cholerae*.

Other transport media

Other transport media that are similar to Cary-Blair are Amies’ and Stuart’s transport media. Both of these are acceptable for *Shigella* and *Salmonella* (including ser. *Typhi*), but they are inferior to Cary-Blair for transport of *V. cholerae*.

Alkaline peptone water may be used to transport *V. cholerae*, but this medium is inferior to Cary-Blair and should be used only when the latter medium is not available. **Alkaline peptone water should not be used if subculture will be delayed more than 6 hours from the time of collection**, because other organisms will overgrow vibrios after 6 hours.

Buffered glycerol saline (BGS), a transport medium that is used for *Shigella*, is unsuitable for transport of *V. cholerae*. Additional disadvantages of buffered glycerol saline are that it can be used for only 1 month after it is made and, because it is a liquid medium, it is more likely to leak or spill during transport.

FIGURE 81: Cary-Blair semisolid transport medium



Placing stool in transport medium

If possible, chill the transport medium for 1–2 hours in a refrigerator or cold box prior to use. A small amount of stool can be collected by inserting a sterile cotton- or polyester-tipped swab into the stool and rotating it. If mucus and shreds of intestinal epithelium are present, these should be sampled with the swab. Following sampling of the stool on the swab:

- a) Insert the swab containing fecal material into transport medium immediately.
- b) Push the swab completely to the bottom of the tube of transport medium.
- c) Break off the top portion of the stick touching the fingers and discard it.
- d) Replace the screw cap on the tube of transport medium and tighten firmly.
- e) Place the tube in a refrigerator or cold box.

Collection of rectal swabs

Sometimes rectal swabs are collected instead of stool specimens. Rectal swabs may be collected as follows:

- a) Moisten the swab in sterile transport medium.
- b) Insert the swab through the rectal sphincter 2–3 cm (*i.e.*, 1–1.5 inches) and rotate.
- c) Withdraw the swab from the rectal sphincter and examine to make sure there is some fecal material visible on the swab. (If not, repeat the procedure with the same swab.)

- d) Immediately insert the swab into cold transport medium (as described in the preceding section).
- e) Place the tube in a refrigerator or cold box.

The number of swabs needed will depend on the number of plates to be inoculated. **In general, if specimens will be examined for more than one pathogen, at least two stool swabs or rectal swabs should be collected per patient, and both swabs should be inserted into the same tube of transport medium.** Once the swab is placed in the medium, it should remain in the tube until it is processed in the laboratory.

Storage of specimens in transport medium

If transport medium has been stored at room temperature, it should be chilled in a refrigerator or cold-box, if possible, for 1–2 hours before use. Specimens preserved in transport medium should be refrigerated until processed. If specimens will be kept more than 2–3 days before being cultured, it is preferable to freeze them immediately at -70°C . It may be possible to recover pathogens from refrigerated specimens up to 7 days after collection; however, the yield decreases after the first 1 or 2 days. Prompt plating, refrigeration, or freezing of specimens in Cary-Blair is particularly important for isolation of *Shigella*, which is more fragile than other enteric organisms. Fecal specimens in transport medium collected from patients with cholera need not be refrigerated unless they are likely to be exposed to elevated temperatures (*i.e.*, $>40^{\circ}\text{C}$).

Unpreserved specimens

When transport medium is not available, one option for specimens suspected to contain *V. cholerae* is to soak a piece of filter paper, gauze, or cotton in liquid stool and place it into a plastic bag. The bag must be tightly sealed so that the specimen will remain moist and not dry out. Adding several drops of sterile saline to the bag may help prevent drying of the specimen. Refrigeration during transport is desirable but not necessary. **This method is not suitable for transport of *Shigella* or *Salmonella* specimens and is less effective than transport medium for preserving *V. cholerae* organisms.**

Preparing specimens for shipment

Specimen tubes should be clearly labeled with the specimen number, and if possible, the patient's name and date of collection. Write the numbers on the

frosted portion of the specimen tube using an indelible marker pen. If the tube does not have a frosted area, write the information on a piece of first-aid tape and affix this firmly on the specimen container. Patient information should be recorded on a data sheet; one copy should be sent with the specimens and another kept by the sender. (A sample data sheet is provided in Figure 82).

If a package is to be shipped by air, the International Air Transport Association (IATA) regulations presented in the *Dangerous Goods Regulations* (DGR) publication must be followed; these regulations (current as of 2002) are summarized in Appendix 12, “Packing and Shipping of Diagnostic Specimens and Infectious Substances.” Even if the package will be shipped by other means, these regulations are excellent guidelines for packing all infectious or potentially infectious materials.

Refrigerated specimens

Refrigerated specimens should be transported to the laboratory in an insulated box with frozen refrigerant packs or ice. If wet ice is used, the tubes or containers should be placed in waterproof containers (e.g., plastic bags) that can be tightly sealed to protect the specimens from the water formed by melting ice.

Frozen specimens

Frozen specimens should be transported on dry ice. The following precautions should be observed:

- Place tubes in containers or wrap them in paper to protect them from dry ice. Direct contact with dry ice can crack glass tubes.
- If the specimens are not in leak-proof containers, protect them from exposure to carbon dioxide by sealing the screwcaps with tape or plastic film or by sealing the tubes in a plastic bag. Carbon dioxide will lower the pH of the transport medium and adversely affect the survival of organisms in the specimen.
- Ensure that the cool box is at least one-third full of dry ice. If the specimens are sent by air and more than 2 kg of dry ice is used, special arrangements may be necessary with the airlines. Airlines accept packages with less than 2 kg of dry ice.
- Address the package clearly, including the sender’s name and telephone number as well as the name and telephone number of the receiving laboratory.
- Write in large letters: EMERGENCY MEDICAL SPECIMENS; CALL ADDRESSEE ON ARRIVAL; HOLD REFRIGERATED (or “FROZEN”, if applicable).
- Be sure that all applicable labels and forms, such as those required by IATA, are correctly fixed to the outside of the package (Appendix 12, Table 36).

[illegible]

Laboratory supplies for outbreaks of diarrheal disease

It is important that local laboratories in a region prone to outbreaks of diarrheal disease have supplies available to work with in the event of an epidemic. Laboratories at the regional level have different requirements for supplies than either regional or national reference laboratories.

Tables 32 and 33 present lists of supplies for testing of specimens and identification of isolates from suspected outbreaks of dysentery and cholera, respectively. The supply lists provided permit the collection and transport of 50 specimens by the district laboratory, the processing of 100 specimens by the regional laboratory, and the identification (and antimicrobial susceptibility testing, if appropriate) of 500 isolates by the national or central reference laboratory.

Further information regarding the role of the laboratory in epidemics of dysentery and cholera can be found in the World Health Organization-endorsed Centers for Disease Control manual, *Laboratory Methods for the Diagnosis of Epidemic Dysentery and Cholera*, which was published in 1999; the manual is currently available in English and French. Another useful source of information is the World Health Organization's 1997 publication, *Epidemic Diarrhoeal Disease Preparedness and Response: Training and Practice—Participant's manual*.

TABLE 32: Materials needed to collect, transport, and test specimens from dysentery outbreaks for laboratories at the district level, the regional level, and the national (central) reference level

Supplies	District-level laboratory (based on the collection of 50 specimens from dysentery outbreaks)	Regional-level laboratory (based on the processing of 100 specimens from dysentery outbreaks)	National (or central) reference laboratory (based on the of confirmation 500 isolates of <i>Shigella</i>)
Sterile cotton or polyester swabs	At least 100 swabs	At least 200 swabs	At least 1000 swabs
Cary-Blair (or other transport medium)	50 bottles or tubes	500 grams (100 bottles)	5 x 500 grams
Materials and transportation (to send specimens to higher-level laboratory for additional testing)	(For safe and proper transport to regional laboratory.)	(For safe and proper transport to national laboratory.)	(For safe and proper transport to international reference laboratory.)
Xylose lysine desoxycholate (XLD) medium	~	500 grams	5 x 500 grams
MacConkey medium	~	500 grams	5 x 500 grams
Kligler iron agar	~	500 grams	3 x 500 grams
Motility agar	~	500 grams	3 x 500 grams
Nonselective agar (e.g., tryptone soy agar [TSA] or heart infusion agar [HIA])	~	500 grams	3 x 500 grams
Monovalent <i>S. dysenteriae</i> 1 diagnostic antiserum (Note: not Group A polyvalent)	~	4 x 2-ml bottles	20 x 2-ml
Polyvalent <i>S. flexneri</i> (Group B) diagnostic antiserum	~	2 x 2-ml bottles	10 x 2-ml
Polyvalent <i>S. sonnei</i> (Group D) diagnostic antiserum	~	2-ml bottle	5 x 2-ml
Glass slides for serologic testing	~	At least 300 slides	At least 1500 slides
Disposable Petri plates (9 cm)	~	500 plates	5 x 500 plates
Disposable test tubes (e.g., 13 x 100 mm, or 16 x 125 mm)	~	1000 test tubes	5 x 1000 test tubes
Materials and postage (for the production and dissemination of reports)	~	(Required)	(Required)

TABLE 32: Dysentery supplies, *continued*

Supplies	District-level laboratory (based on the collection of 50 specimens from dysentery outbreaks)	Regional-level laboratory (based on the processing of 100 specimens from dysentery outbreaks)	National (or central) reference laboratory (based on the of confirmation 500 isolates of <i>Shigella</i>)
Antimicrobial susceptibility test supplies for 100 <i>Shigella</i> isolates (for national reference laboratory only)			
• Mueller-Hinton agar	2	2	2 x 500 grams
• Disposable Petri dishes	2	2	200 dishes
• Trimethoprim-sulfamethoxazole [1.25 / 23.75 -µg disks]	2	2	200 disks
• Chloramphenicol [30-µg disks]	2	2	200 disks
• Ampicillin [10-µg disks]			200 disks
• Nalidixic acid [30-µg disks]	2	2	200 disks
• Ciprofloxacin [5-µg disks]	2	2	100 disks
• NCCLS control strain <i>E. coli</i> ATCC 25922	2	2	(Required)
• 0.5 McFarland turbidity standard	2	2	(Required)
• Sterile cotton swabs	2	2	200 swabs
• Sterile saline	2	2	(Required)
• Forceps	2	2	(Required)
• 95% alcohol for flaming	2	2	(Required)
• Calipers (or ruler on a stick)	2	2	(Required)
• Inhibition zone diameter criteria chart <i>[for interpretation per NCCLS]</i>	2	2	(Required)

TABLE 33: Materials needed to collect, transport, and test specimens from cholera outbreaks for laboratories at the district level, the regional level, and the national (central) reference level

Supplies	District-level laboratory (based on the collection of 50 specimens from cholera outbreaks)	Regional-level laboratory (based on the processing of 100 specimens from cholera outbreaks)	National (or central) reference laboratory (based on the of confirmation 500 isolates of <i>Vibrio cholerae</i>)
Sterile cotton or polyester swabs	At least 100 swabs	At least 200 swabs	At least 1000 swabs
Cary-Blair (or other transport medium)	50 bottles or tubes	500 grams (100 bottles)	5 x 500 grams
Materials and transportation (to send specimens to a higher-level laboratory for additional testing)	(For safe and proper transport to regional laboratory.)	(For safe and proper transport to national laboratory.)	(For safe and proper transport to international reference laboratory.)
Thiosulfate citrate bile salts sucrose (TCBS) agar medium	~	500 grams	5 x 500 grams
Sodium desoxycholate (bile salts)	~	25 grams	5 x 25 grams
Glass slides for string test and serologic testing	~	At least 300 slides	At least 1500 slides
Kovac's oxidase reagent	~	5 grams	5 x 5 grams
Filter paper (for oxidase test)	~	(Required)	(Required)
Sterile wooden sticks or platinum inoculating loops for oxidase test	~	(Required)	(Required)
Nonselective agar* (e.g., tryptone soy agar [TSA] or heart infusion agar) (*do not use nutrient agar lacking salt)	~	500 grams	5 x 500 grams
Polyvalent <i>V. cholerae</i> O1 diagnostic antiserum	~	4 x 2-ml bottles	20 x 2-ml bottles
<i>V. cholerae</i> O139 diagnostic antiserum	~	~	5 x 2-ml bottles
<i>V. cholerae</i> O1 serotype Ogawa diagnostic antiserum	~	~	5 x 2-ml bottles
<i>V. cholerae</i> O1 serotype Inaba diagnostic antiserum	~	~	5 x 2-ml bottles
Peptone medium for alkaline peptone water (e.g., Bacto-peptone)	~	500 grams	5 x 500 grams
NaCl (note: if using table salt for NaCl, it must not be iodized)	~	500 grams	5 x 500 grams

TABLE 33. Cholera supplies, *continued*

Supplies	District-level laboratory (based on the collection of 50 specimens from cholera outbreaks)	Regional-level laboratory (based on the processing of 100 specimens from cholera outbreaks)	National (or central) reference laboratory (based on the of confirmation 500 isolates of <i>Vibrio cholerae</i>)
NaOH	2	(Required)	(Required)
pH paper or pH meter	2	(Required)	(Required)
Petri plates (9-cm)	2	500 plates	5 x 500 plates
Test tubes (e.g., 13 x 100-mm or 16 x 125-mm)	2	1 000 tubes	5 x 1 000 tubes
Materials and postage (for the production & dissemination of reports)	2	(Required)	(Required)
Antimicrobial susceptibility test supplies for 100 <i>V. cholerae</i> isolates (for national reference laboratory only)			
• Mueller-Hinton agar	2	2	2 x 500 grams
• Disposable Petri plates	2	2	200 plates
• Trimethoprim-sulfamethoxazole [1.25 / 23.75 -µg disks]	2	2	200 disks
• Tetracycline [30-µg disks]	2	2	200 disks
• Nalidixic acid [30-µg disks]	2	2	200 disks
• Ciprofloxacin [5-µg disks]	2	2	100 disks
• NCCLS control strain <i>E. coli</i> ATCC 25922	2	2	(Required)
• 0.5 McFarland turbidity standard	2	2	(Required)
• Sterile cotton swabs	2	2	200 swabs
• Sterile saline	2	2	(Required)
• Forceps	2	2	(Required)

TABLE 33: Cholera supplies, *continued*

Supplies	District-level laboratory (based on the collection of 50 specimens from cholera outbreaks)	Regional-level laboratory (based on the processing of 100 specimens from cholera outbreaks)	National (or central) reference laboratory (based on the of confirmation 500 isolates of <i>Vibrio cholerae</i>)
• 95% alcohol for flaming	✓	✓	(Required)
• Calipers (or ruler on a stick)	✓	✓	(Required)
• Inhibition zone diameter criteria chart [for interpretation per NCCLS]	✓	✓	(Required)

Laboratory Processing of Fecal Specimens

This laboratory manual includes three pathogens that may be isolated from fecal specimens: *Shigella*, *Vibrio cholerae* O1/O139, and *Salmonella* serotype Typhi. Methods for the laboratory detection of other enteric pathogens can be found in other manuals, such as the American Society for Clinical Microbiology's *Manual of Clinical Microbiology* or the World Health Organization's *Manual for the Laboratory Investigations of Acute Enteric Infections*. The methods presented in this manual are intended to be economical and to offer laboratorians some flexibility in choice of protocol and media. Laboratories that do not have sufficient resources to adopt the methods described in this chapter should consider sending specimens or isolates to other laboratory facilities that routinely perform these procedures.

Enteric pathogens of public health concern cause both diarrheal disease and fever of unknown origin. Only a few pathogens cause epidemic diarrhea, although many cause sporadic diarrhea. *S. dysenteriae* serotype 1 and *V. cholerae* are the two etiologic agents responsible for most epidemic diarrhea in the developing world, contributing substantially to the burden of morbidity and mortality. *S. Typhi*, the etiologic agent of typhoid fever, is responsible for a substantial portion of the burden of fever of unknown origin.

In countries at risk for epidemics of dysentery or cholera, the laboratory's first role is to be prepared for an epidemic; this means having ready access to the supplies necessary to identify *V. cholerae* O1/O139 and *Shigella*. Appendix 9 lists laboratory supplies required for isolation, identification, and antimicrobial susceptibility testing, as appropriate for district-level laboratories, regional laboratories, and national reference laboratories. All countries should have at least one national or central laboratory capable of identifying *Shigella* and *V. cholerae* O1/O139, determining antimicrobial susceptibility, and sending isolates to a regional or international reference laboratory; Appendix 12 includes international shipping regulations and Appendix 14 lists international reference laboratory contact information.

Collection, storage, and transport of stool specimens are addressed in Appendix 9. Methods for isolation of *S. Typhi*, *V. cholerae*, and *Shigella* from stool specimens are detailed in this appendix, whereas each of the pathogen-specific chapters address pathogen identification and antimicrobial susceptibility testing methods, including guidelines for interpretation of results to help shape patient treatment and policy.

Serogrouping and typing methodologies are included and these procedures are encouraged, when resource levels at the laboratory permit. (*S. Typhi* is included in Chapter VII; *Shigella* is included in Chapter VIII; and, *V. cholerae* is included in Chapter IX.)

Determination of antimicrobial susceptibility patterns not only helps shape successful treatment plans for individual patients but also assists with the development of public health policy for populations at risk for exposure. As mentioned in the introduction to this laboratory manual, because antimicrobial susceptibility testing is so resource intensive and requires a consistent investment in laboratory infrastructure and quality control, the World Health Organization (WHO) recommends that antimicrobial susceptibility testing occur at only one or two laboratories in a country with limited resources. Antimicrobial susceptibilities should be determined for the first 30 to 50 isolates identified by the laboratory at the beginning of an epidemic. Peripheral laboratories may perform initial isolation of *Salmonella* (including serotype Typhi), *Vibrio*, and *Shigella* isolates, and then refer isolates to the central or national reference laboratory for final confirmation and determination of antimicrobial susceptibility. Peripheral laboratories may also be the sites of focused studies to determine etiologic agents causing an outbreak. First-level laboratories should be supplied with transport medium and the means of sending the specimens to the next level laboratory or to the central laboratory.

Fecal specimens in the laboratory

Once specimens have arrived at the laboratory, laboratorians should follow procedures to isolate the suspected etiologic agent. In an outbreak situation, usually either dysentery or cholera is suspected on the basis of reports from health personnel in the field, and the laboratory response should reflect this. It should be noted that although some health-care providers believe that diarrheal illnesses can be diagnosed by the appearance of the stool and, for example, diagnose dysentery if the stool is bloody and cholera if the stool is watery, this “bloody” versus “watery” distinction is by no means definitive. Diarrhea caused by *Shigella*, for example, is only bloody approximately 50% of the time, and there are many agents that lead to watery diarrhea. Still, clinical observations may help guide laboratory testing.

Laboratories may also receive fecal (*i.e.*, stool) specimens from patients who are suspected to have typhoid fever. Fecal cultures may be positive during the first week of fever and may be positive 2–3 weeks into the disease. (Because *S. Typhi* is more commonly suspected in cases of febrile illness and isolated from blood, urine, or bone marrow, pertinent isolation techniques are also included in Appendix 4, “Isolation of Agents from Normally Sterile Sites.”)

Recovery of *S. Typhi* from fecal specimens

Maximal recovery of *Salmonella* ser. Typhi from fecal specimens is obtained by using an enrichment broth although isolation from acutely ill persons may be possible by direct plating. Enrichment broths for *Salmonella* are usually highly selective and will inhibit certain serotypes of *Salmonella* (particularly *S. Typhi*). The selective enrichment medium most widely used to isolate *S. Typhi* from fecal specimens is selenite broth (SEL). Selenite broth should be incubated for 14–16 hours at 35°–37°C and then streaked to selective agar (e.g., bismuth sulfite [BS] or desoxycholate citrate agar [DCA]). A nonselective broth (e.g., Gram negative [GN] broth) may also be used for enrichment for *S. Typhi*.

Plating media

Fecal specimens to be examined for *S. Typhi* may be inoculated onto standard enteric plating media (e.g., Hektoen enteric agar [HE], xylose lysine desoxycholate agar [XLD], DCA, MacConkey agar [MAC], or *Salmonella-Shigella* [SS] agar). However, bismuth sulfite agar (BS) is the preferred medium for isolation of *S. Typhi* and should be used if resources permit.

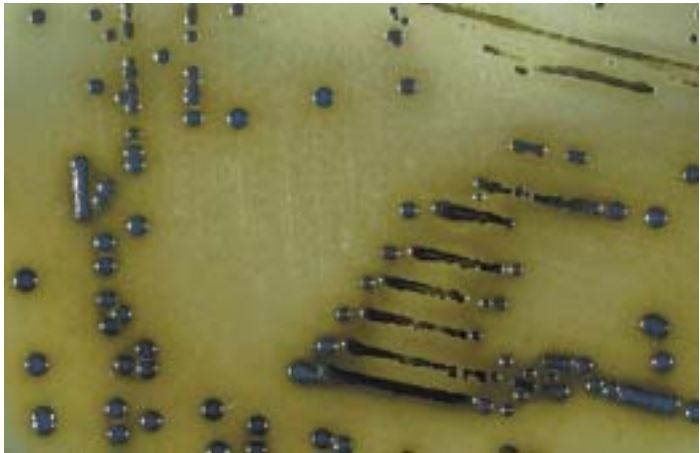
BS plates must be freshly prepared (Appendix 2) and used within 36 hours for isolation of *S. Typhi*. A rectal swab or stool swab may be used to inoculate BS agar by seeding an area approximately 1 inch in diameter on the agar, after which the plate is streaked for isolation. After seeding the plate, the swab may be placed in a tube of selenite broth if enrichment is desired.

If culturing fecal specimens from suspected typhoid carriers, the use of a BS pour plate may enhance isolation. For pour plates, the BS agar must be boiled and cooled to 50°C in a water bath. A 5-ml quantity of fecal suspension is added to a Petri plate, after which approximately 20 ml of cooled BS is immediately poured into the plate. The plate is swirled to mix the fecal suspension and the BS agar and the plate is left to harden.

BS streak and BS pour plates should be incubated for 48 hours at 35°–37°C. On a BS streak plate, well-isolated colonies of *S. Typhi* appear black surrounded by a black or brownish-black zone with a metallic sheen. On a BS pour plate, well-isolated subsurface colonies are black and circular. Table 34 provides descriptions of *S. Typhi* colonies on other types of selective media. When colonies of *S. Typhi* are numerous and crowded, *S. Typhi* frequently does not produce typical blackening of BS; therefore, **plates must be streaked carefully to permit growth of discrete colonies**. When using pour plates, a second plate with a 0.5-ml inoculum may also be prepared to insure that isolated colonies will develop. Figure 83 illustrates the appearance of *S. Typhi* colonies on BS agar medium.

A flowchart for the isolation and identification of *S. Typhi* is included in Figure 29. Isolated colonies from BS or other selective media may be inoculated to Kligler iron agar (KIA) or triple sugar iron agar (TSI) or other screening media.

FIGURE 83: *Salmonella* ser. Typhi colonies on bismuth sulfite (BS) agar



Sub-surface colonies from BS pour plates must be re-streaked for isolation on a medium such as MAC before being inoculated into KIA or TSI.

Colonies of *S. Paratyphi* A, *S. Paratyphi* B, and *S. Paratyphi* C and most other *Salmonella* serotypes have a similar appearance to *S. Typhi* on MAC, BS, HE, DCA, and XLD agar. Methodology for confirmatory identification and antimicrobial susceptibility testing of *S. Typhi* is addressed in Chapter VII.

TABLE 34: Appearance of *Salmonella* ser. Typhi colonies on selective plating media

Selective agar medium*	Color of colonies*	Size of colonies*	Figure number
Bismuth sulfite agar (BS)	Black, surrounded by a black or brownish zone with a metallic sheen	1 – 3 mm	Figure 83
MacConkey agar (MAC)	Transparent or colorless opaque	2 – 3 mm	Figure 59a
Hektoen enteric agar (HE)	Blue-green (with or without black centers) or yellow with black centers	1 – 2 mm	~
Xylose lysine desoxycholate agar (XLD)	Red (with or without black centers) or yellow with black centers	1 – 2 mm	~
<i>Salmonella-Shigella</i> (SS) agar	Colorless	1 – 2 mm	~
Desoxycholate citrate agar (DCA)	Colorless	1 – 2 mm	~

* Most *Salmonella* serotypes appear similar to *S. Typhi* on these media; therefore, confirmatory testing is necessary.

Recovery of *Shigella* from stool: Isolation and preliminary identification

Isolation and identification of *Shigella* can be greatly enhanced when optimal laboratory media and techniques are employed.

An outline of the procedure for isolation and identification of *Shigella* from fecal specimens is presented in Figure 36. Refer to Appendix 9 for a list of supplies necessary for laboratory identification of *Shigella*. (This appendix includes supplies appropriate for district laboratories, regional laboratories and national reference laboratories.) A sample worksheet for organizing laboratory data is presented in Figure 37.

There is no enrichment medium for *Shigella* that consistently provides a greater recovery rate than use of direct plating alone. For optimal isolation of *Shigella*, two different selective media should be used: a general purpose plating medium of low selectivity, such as MAC, and a more selective agar medium, such as XLD. DCA and HE agar are suitable alternatives to XLD agar as media of moderate to high selectivity. **SS agar should not be used** because it frequently inhibits the growth of *S. dysenteriae* serotype 1.

Inoculation of selective agar for recovery of *Shigella* from fecal specimens

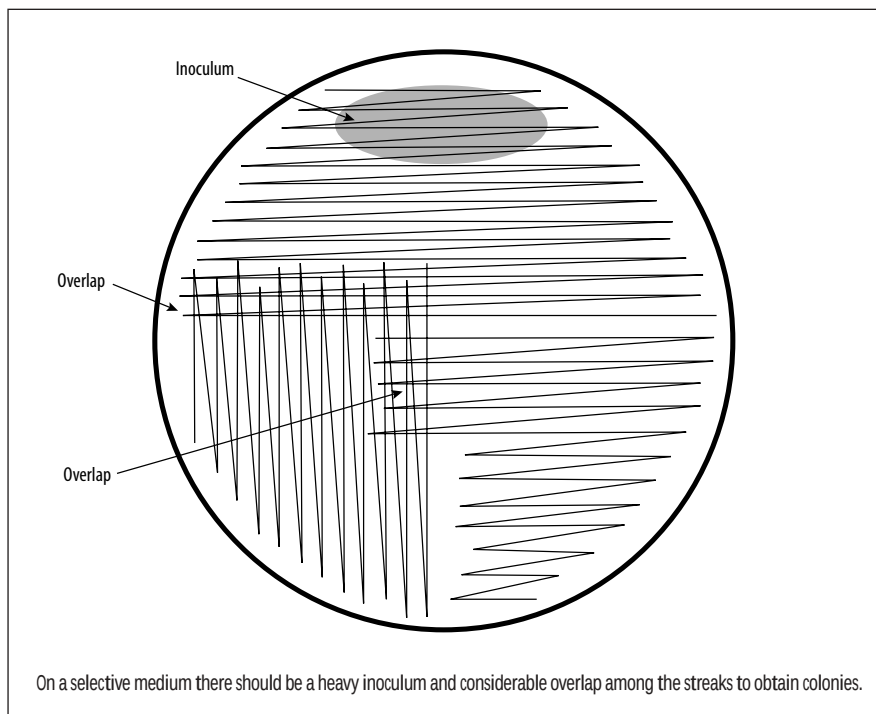
Fecal specimens should be plated as soon as possible after arrival in the laboratory. Selective media may be inoculated with a single drop of liquid stool or fecal suspension. Alternatively, a rectal swab or a fecal swab may be used. If a swab is used to inoculate selective media, an area approximately 2.5 cm (1 inch) in diameter is seeded on the agar plates, and the plates then are streaked for isolation (Figure 84).

When inoculating specimens to a plate for isolation, the entire surface of the agar plate must be used to increase the chances of obtaining well-isolated colonies. Media of high selectivity (e.g., XLD) require more overlapping when streaking than media of low selectivity (e.g., MAC); it is therefore important to pay particular attention to streaking. After streaking, cover the agar plate and place it upside-down (i.e., cover-side down) in the incubator to avoid excessive condensation. Incubate the plates for 18–24 hours at 35°–37°C.

Isolation of suspected *Shigella* from selective media

After incubation, record the amount and type of growth (i.e., lactose-fermenting or -nonfermenting) on each isolation medium for each patient specimen. Colonies of *Shigella* on MAC appear as convex, colorless colonies approximately 2–3 mm in diameter, although *S. dysenteriae* 1 colonies may be smaller (Table 35). *Shigella* colonies on XLD agar are transparent pink or red, smooth colonies, approximately 1–2 mm in diameter, although *S. dysenteriae* 1 colonies on XLD agar are frequently

FIGURE 84. Method of streaking plating medium for isolation of *Shigella* and *Vibrio* species



very tiny. Select suspect colonies from the MAC and XLD plates and inoculate them to appropriate screening media such as Kligler iron agar (KIA) or triple sugar iron agar (TSI). Figures 85, 86, 87, and 88 show the typical appearance of *Shigella* colonies on XLD and MAC.

Following the preliminary identification of suspect *Shigella* colonies on plating media, the laboratorian should conduct biochemical screening tests and serologic testing to confirm the identification of the agent. Methodology for the identification and antimicrobial susceptibility testing of *Shigella* is addressed in Chapter VIII of this manual.

Recovery of *V. cholerae* from stool: Isolation and preliminary identification

Although *V. cholerae* will grow on a variety of commonly used agar media, isolation from fecal specimens is more easily accomplished with specialized media. Alkaline peptone water is recommended as an enrichment broth, and thiosulfate citrate bile salts sucrose agar (TCBS) is the selective agar medium of choice. (Refer to Appendix 2 ("Media, Reagents and Quality Control") before preparing any of these media because incorrect preparation can affect the reactions of organisms in

TABLE 35: Appearance of *Shigella* colonies on selective plating media

Selective agar medium	Color of colonies	Size of colonies	Figure number
MacConkey agar (MAC)	Colorless	2 – 3 mm ^{a,b}	Figure 88
Xylose lysine desoxycholate (XLD)	Red or colorless	1 – 2 mm ^{a,c}	Figures 85, 86, and 87
Desoxycholate citrate agar (DCA)	Colorless	2 – 3 mm ^a	~
Hektoen enteric agar (HE)	Green	2 – 3 mm ^a	~

^a *S. dysenteriae* 1 colonies may be smaller.

^b See Appendix 2 for discussion of different formulations of commercial dehydrated MacConkey agar and how selectivity is affected for isolation of *Shigella*.

^c *S. dysenteriae* 1 colonies on XLD agar are frequently very tiny, unlike other *Shigella* species.

these tests.) Figure 45 provides a schematic representation for the recovery and identification of *V. cholerae* from fecal specimens.

Enrichment of suspected *V. cholerae* in alkaline peptone water

Enrichment in alkaline peptone water (APW) can enhance the isolation of *V. cholerae* when few organisms are present, as in specimens from convalescent

FIGURE 85: *Shigella dysenteriae* 1 colonies on xylose lysine desoxycholate (XLD) agar

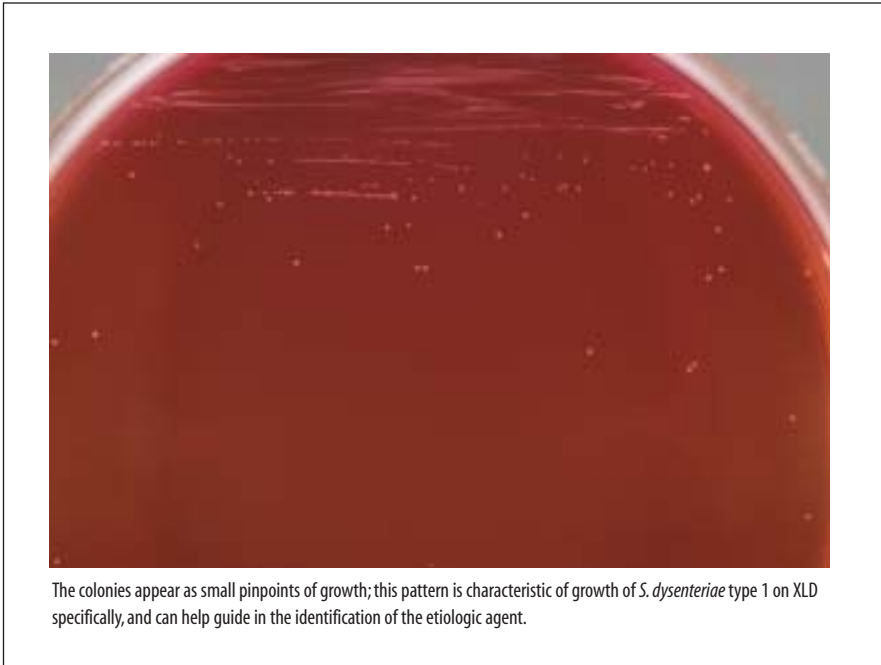
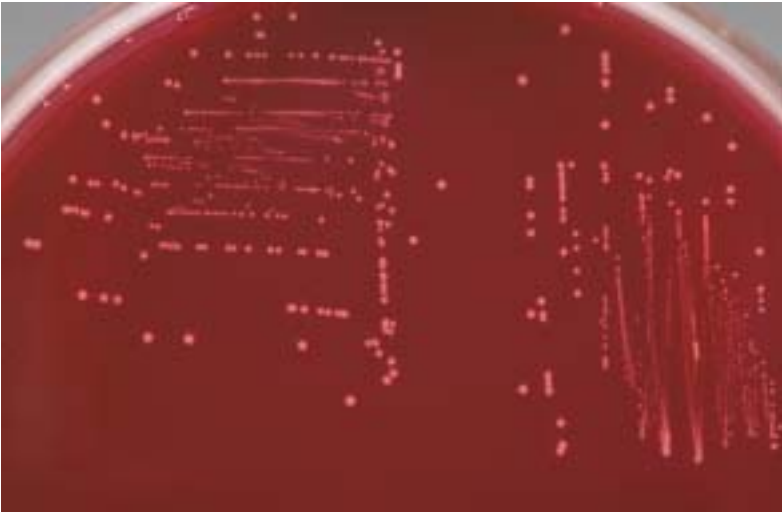


FIGURE 86: *Shigella flexneri* colonies on xylose lysine desoxycholate (XLD) agar



Colonies of *S. flexneri* are larger on XLD than are colonies of *S. dysenteriae* 1.

FIGURE 87: *Shigella flexneri* and *Escherichia coli* colonies on xylose lysine desoxycholate (XLD) agar



S. flexneri colonies are colorless to red, whereas *E. coli* colonies are yellow on XLD.

FIGURE 88: *Shigella flexneri* and *Escherichia coli* colonies on MacConkey (MAC) agar



S. flexneri colonies appear colorless on MAC, whereas *E. coli* colonies are pink to red.

patients and asymptomatic carriers. *Vibrio* spp. grow very rapidly in alkaline peptone water, and at 6–8 hours they will be present in greater numbers than non-*Vibrio* organisms.

Alkaline peptone water can be inoculated with liquid stool, fecal suspension, or a rectal swab. The stool inoculum should not exceed 10% of the volume of the broth. Incubate the tube with the cap loosened at 35°–37°C for 6–8 hours. After incubation, subculture one to two loopfuls of alkaline peptone water to thiosulfate citrate bile salts sucrose (TCBS) medium. (The loopfuls of APW should be obtained from the surface and topmost portion of the broth, because vibrios preferentially grow in this area.) **Do not shake or mix the tube before subculturing.** If the broth cannot be plated after 6–8 hours of incubation, subculture a loopful of the broth at 18 hours to a fresh tube of alkaline peptone water; this second tube of APW should then be subcultured to TCBS agar after 6–8 hours of incubation.

Inoculation and isolation of suspected *V. cholerae* from thiosulfate citrate bile salts sucrose (TCBS) selective agar

TCBS agar is commercially available and easy to prepare, requires no autoclaving, and is highly differential and selective. **Growth from TCBS medium is not suitable for direct testing with *V. cholerae* antisera.**

Inoculate the TCBS plate by streaking (as described in Figure 84). After 18–24 hours' incubation at 35°–37°C, the amount and type of growth (*i.e.*, sucrose-fermenting or sucrose-nonfermenting) on the TCBS plate should be recorded on data sheets (Figure 46). **Colonies suspicious for *V. cholerae* will appear on TCBS agar as yellow, shiny colonies, 2–4 mm in diameter** (Figure 89). The yellow color is caused by the fermentation of sucrose in the medium; in contrast, sucrose-nonfermenting organisms (*e.g.*, *V. parahaemolyticus*) produce green to blue-green colonies.

Isolation of suspected V. cholerae

Carefully select at least one of each type of sucrose-fermenting (yellow) colony from the TCBS plate to inoculate a heart infusion agar (HIA) slant or another nonselective medium; each type of colony selected should be inoculated onto a separate plate. (*V. cholerae* requires 0.5% NaCl [salt] for optimal growth on agar media; some commercially available formulations of nutrient agar do not contain salt, and should not be used for culture of *V. cholerae*.) Using an inoculating needle, lightly touch only the very center of the colony. (Do not take the whole colony or go through the colony and touch the surface of the plate because contaminants may be on the surface of the agar.) If there is doubt that a particular

FIGURE 89: Growth of *Vibrio cholerae* on thiosulfate citrate bile salts sucrose (TCBS) agar



Colonies suspicious for *V. cholerae* will appear on TCBS agar as yellow, shiny colonies, 2–4 mm in diameter. The yellow color is caused by the fermentation of sucrose by the organism; non-sucrose-fermenting organisms (*e.g.*, *V. parahaemolyticus*) produce green to blue-green colonies on this same medium.

colony is sufficiently isolated from surrounding colonies, purify the suspicious colony by streaking on another agar plate, incubating it and then testing colonies from the subculture.

Incubate the heart infusion agar slants at 35°–37°C for up to 24 hours; note that sufficient growth for serologic testing might be obtainable after 6 hours. Slide serology with polyvalent O1 and O139 antisera is sufficient for a presumptive identification of *V. cholerae*, and is described in Chapter IX of this manual.

Following the preliminary identification of suspect colonies as *V. cholerae* on TCBS agar, the laboratorian should conduct other biochemical and serologic identification tests and, if appropriate, antimicrobial susceptibility testing of the isolate. Methodology for the identification and antimicrobial susceptibility testing of *V. cholerae* is addressed in Chapter IX.

Preservation and Storage of Isolates

It is often necessary for isolates to be examined at a time-point following the infection from which the culture was obtained. For example, it is sometimes appropriate to refer back to an isolate for epidemiological purposes; *e.g.*, to learn if a new case-patient is infected with the same strain of a pathogen as an individual who had an earlier case of disease. Another example would be a situation where a laboratory chooses to screen a number of isolates at one time each year to additional antimicrobial agents or, *e.g.*, for beta-lactamase production; this practice would assist in the detection of emerging characteristics in known pathogens. Sometimes isolates need to be sent to reference laboratories for confirmation and/or further testing and must be stored prior to packing and shipping (Appendix 12). Selection of a storage method depends on the length of time the organisms are to be held and the laboratory equipment and facilities available.

Short-term storage may be accomplished with transport media, freezing, or, in some cases (and for some pathogens) at room temperature on simple media plus mineral oil to prevent drying. Methods for short-term storage appropriate to the different bacteria included in this laboratory manual are included later in this appendix.

Long-term storage of bacterial isolates is best accomplished by either lyophilization or freezing. Specific methods appropriate for the bacteria included in this laboratory manual are included later in this appendix. Lyophilization (freeze-drying) is the most convenient method of storage because lyophilized bacteria can be stored for long periods at 4°C or -20°C and can be transported without refrigeration.⁴¹ However, the equipment required is expensive and not all laboratories will have the ability to lyophilize isolates. (Reference laboratories choosing to lyophilize bacteria should always maintain a frozen preparation in addition to larger quantities of lyophilized strains, because some lyophilized preparations may be nonviable upon reconstitution.) Bacterial cultures may be stored frozen or lyophilized in a variety of suspending media formulated for that purpose. There are many formulations of suspending medium, but in general serum-based media, skim milk, or polyvinylpyrrolidone (PVP) medium is used for

⁴¹ Cultures for transport should be packaged according to the IATA shipping regulations presented in Appendix 12. No more than 50-ml of culture should be shipped in one package.

lyophilization, and skim milk, blood, or a rich buffered tryptone soy broth (TSB) with 15%–20% reagent-grade glycerol is used for freezing. **Do not use human blood**, because of safety issues (e.g., HIV and hepatitis transmission), and because of the possible inhibition of growth of isolates resulting from antibodies or residual antibiotics.

Cultures to be prepared for either permanent or short-term storage should be confirmed as pure before proceeding with any of these methodologies. Fresh cultures (i.e., overnight growth) should be used for the preparation of storage strains.

Storage of *Haemophilus influenzae*, *Neisseria meningitidis*, and *Streptococcus pneumoniae* isolates

The three agents of pneumonia and meningitis included in this laboratory manual (*H. influenzae*, *N. meningitidis*, and *S. pneumoniae*) are fragile and care must be taken in their preparation for storage. Maintain sterility at all times during preparation of cultures for storage.

Short-term storage of *H. influenzae*, *N. meningitidis*, and *S. pneumoniae*

If Dorset Egg medium (DE) is available to the laboratory, it is useful for room temperature (i.e., approximately 25°C) storage of *S. pneumoniae*, *H. influenzae*, and *N. meningitidis*. On DE, *H. influenzae* and *N. meningitidis* can each be stored for approximately 3 weeks, whereas *S. pneumoniae* can be stored for approximately 6 weeks on DE. (Instructions for preparation of DE are included in Appendix 2.) Use overnight growth from blood or chocolate agar, as appropriate, to inoculate a 4-ml DE slant in a 7-ml screw-top tube.

If DE is not a medium readily prepared or used by the laboratory, short-term storage of any of these three pathogens can be carried out on supplemented chocolate agar for up to 1 week.

- Viability during the short-term storage (7 days or fewer) is best if *S. pneumoniae* and *H. influenzae* are inoculated onto chocolate agar slants with screw-cap tubes, incubated overnight at 35°C, and then maintained at 4°C. These bacterial species do not survive well in broth and survive only 3 to 4 days on primary agar plates.
- For *N. meningitidis*, solid screw-caps should be loosened during storage but permeable membrane screw caps (which allow for an exchange of gases and are available commercially) should be used when possible. An overlay of TSB may also be helpful and might increase viability to 14 days. ***N. meningitidis* slants should not be refrigerated.**

S. pneumoniae, *H. influenzae*, and *N. meningitidis* can also be stored short-term on swabs stored in silica gel packets; stored in this manner, the isolates will last approximately 2 weeks at room temperature. The packets are inexpensive and easy to use, but are not often available from commercial manufacturers. (One commercial source of silica gel packets is Scientific Device Laboratory, Inc., included in Appendix 13.) Figure 90 shows how to use the packets.

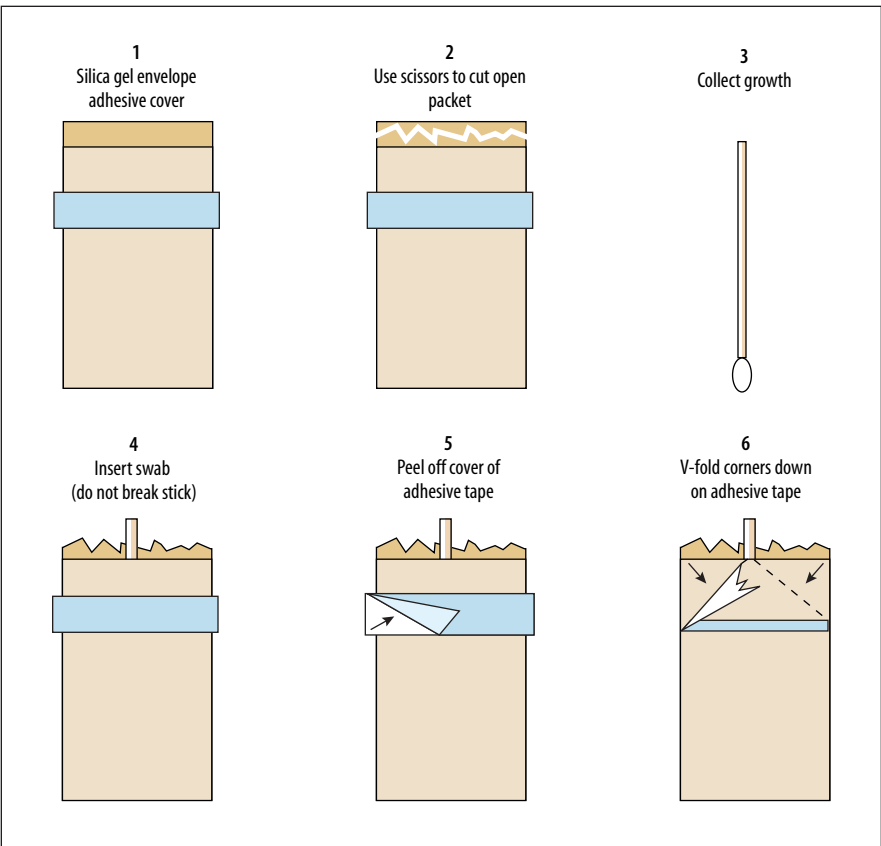
Long-term storage of *H. influenzae*, *N. meningitidis*, and *S. pneumoniae*

Long-term storage can be accomplished by freezing or lyophilization.

- **Frozen storage**

- a) Grow pure culture of *H. influenzae* on chocolate agar and of *S. pneumoniae* and *N. meningitidis* on blood or chocolate agar. Incubate the plates in a CO₂ incubator or candle-jar for 18–24 hours at 35°C. Inspect the plates for purity.

FIGURE 90: Silica gel packets for transport (and short-term storage)



- b) Harvest all of the growth from a plate with a sterile swab.
- c) Dispense the growth in a 2-ml, externally-threaded screw-capped cryogenic vial containing 1 ml of sterile defibrinated blood by twirling the swab to release the organisms. Squeeze the excess blood from the swab by rotating it against the sides of the vial before carefully withdrawing it. Discard the swab in disinfectant.
 - Defibrinated sheep, horse, or rabbit blood can be used for all three of these respiratory organisms. **Human blood should not be used.** Alternatives, such as TSB with 15%–20% reagent-grade glycerol or Greaves solution, can also be used.
 - **Caution:** Do not use glass ampoules (*i.e.*, glass cryovials) for freezing in liquid nitrogen because they can explode upon removal from the freezer.
- d) If possible, rapidly freeze the suspension in a bath of 95% alcohol and dry-ice pellets.
- e) Place the cryovials in a -70° freezer or a nitrogen freezer (-120°C). A -20°C freezer can be used, but some loss of viability can be expected. **Freezers with automatic defrosters should never be used.**

- **Lyophilization**

Some laboratories may have lyophilization (*i.e.*, freeze-drying) facilities.

- a) Grow the *H. influenzae* on supplemented chocolate agar / the *S. pneumoniae* and *N. meningitidis* on blood agar or chocolate agar. Incubate the plates in a CO₂-incubator or candle-jar for 18 – 20 hours at 35°C. Inspect the plate for purity.
- b) Harvest the growth from the plate with 1–2 ml of sterile skim milk and a sterile swab. Place approximately 0.5 ml of suspension into a sterile ampoule or lyophilization vial. Several vials can be prepared from a single plate, if desired. **Maintain sterility at all times during the preparation of the vial.**
- c) The cell suspension should be shell-frozen on the walls of the lyophilization vial. This is accomplished by one of the following two methods:
 - Keep the lyophilization vial at -70°C until just before the cell suspension is added. Add the cell suspension and rapidly rotate the vial to freeze the suspension to the wall. Return the vial to the -70°C freezer until ready to attach to the lyophilizer.

or

- If a -70°C freezer is not available, a mixture of alcohol (95% ethanol) and dry ice can be prepared and used to shell-freeze the cell suspensions. Shell-freezing is accomplished by placing the cell suspension in the lyophilization vial and rotating the vial at a 45° to 60° angle in the alcohol/dry-ice mixture.

- d) Attach the vials to the lyophilizer. **Follow the manufacturer's directions because each instrument uses a different type of apparatus.** The time of lyophilization will depend on the number of vials being lyophilized and the capacity of the instrument. On an average machine, 4–5 hours are required to completely dry 10–20 small vials.
- e) At the end of the run, seal the vials with a torch while they are still attached to the lyophilizer and under vacuum. The vials can be stored at 4°C or at freezer temperatures after being sealed.

- **Recovery of isolates from long-term storage**

Lyophilized specimens of *H. influenzae*, *N. meningitidis*, and *S. pneumoniae* can be recovered by suspending the preparation in 0.25–0.5 ml of broth (e.g., TSB, Mueller-Hinton broth, or PBS). Add one drop of the suspension to a plate of medium (sheep blood agar plate or chocolate agar for *H. influenzae*), and approximately five drops to a liquid (broth) medium containing five drops of blood (sheep, rabbit, goat, or horse blood, but **not human blood**). Incubate the plate and tube for 18–24 hours at 35°C, and observe for growth. If growth on the plate occurs, the tube can be discarded; however, if no growth is observed on the plate, sample the medium in the tube and re-incubate. After another 18–24 hours, the plate should be re-examined for growth. If growth is seen, the tube can be discarded; if no growth is present, examine the tube for turbidity (which would indicate growth). If the tube is turbid, the tube should be re-sampled and re-incubated; if the tube is not turbid, assume the lyophilized sample was dead. (This is why it is strongly suggested that a specimen be prepared for long-term frozen storage in addition to lyophilization.) Organisms grown from lyophilized specimens must be subcultured at least once prior to being used in tests.

Frozen cultures should be thawed at room temperature, and a Pasteur pipette should be used to remove a small amount of inoculum from the cryotube for culture. The inoculum may be taken from the frozen culture before the preparation is completely thawed and should be taken no later than when the frozen culture has completely thawed. (Once completely thawed, the frozen culture will begin to lose viability.) Organisms grown from frozen specimens must be subcultured at least once prior to being used in tests.

Storage of *Neisseria gonorrhoeae* isolates

N. gonorrhoeae is a fragile organism and care must be taken in preparation of the cultures for storage. Maintain sterility at all times during preparation of cultures for storage.

Short-term storage of *N. gonorrhoeae*

Isolates of *N. gonorrhoeae* can be stored for approximately 2 weeks at -20°C. (They **cannot be stored at room temperature or 4°C**; they must be frozen.) Isolates for short-term storage should be stored in TSB containing 20% glycerol at the back of the freezer shelves and not in the door or at the front of the shelves (because when the door to the freezer is opened and the isolates are not at the back of the shelf, they may thaw and not properly refreeze). Repeated freezing/thawing cycles, or failure to re-freeze results in a rapid loss of viability.

Long-term storage of *N. gonorrhoeae*

The best method for storing gonococcal isolates is to freeze them in a -70°C freezer or in liquid nitrogen (at -196°C). Strains may be stored as freeze-dried lyophiles; however, this method is expensive and labor-intensive and lyophiles may lose viability over time.

- **Frozen storage**

To store frozen isolates, use a sterile swab to prepare dense suspensions of 18- to 24-hour pure cultures prepared in TSB containing 20% (vol/vol) glycerin. The best suspensions are prepared by rolling the swab over isolated colonies or the margin of confluent areas of growth. Dispense the suspension into cryovials (*i.e.*, freezing vials specially designed for use at very low temperatures), but **glass ampoules should never be used for freezing in liquid nitrogen** because they can explode upon removal from the freezer.

When frozen suspensions are thawed to inoculate cultures, the suspension should not be refrozen; new suspensions of organisms should be prepared. As many as 99% of the cells in a suspension may be destroyed during the freezing and the thawing of the preparations due to physical destruction (*i.e.*, shearing) of cells by crystals of the suspending medium that form during the freezing processes. One way to minimize the loss of cells during freezing is by “flash-freezing” the specimen in an acetone or alcohol bath containing dry ice. Alternatively, a sample may be taken from the top of the frozen preparation with a sterile bacterial loop if the suspension is not thawed.

If neither a -70°C freezer nor a liquid-nitrogen storage facility is available, gonococcal suspensions may be frozen for **up to 2 weeks at -20°C**; frozen suspensions of *N. gonorrhoeae* will lose viability if stored for periods longer than 2 weeks at this temperature.

- **Lyophilization**

Some laboratories may have lyophilization (*i.e.*, freeze-drying) facilities. To prepare lyophiles, 18- to 24-hour pure cultures of isolates are suspended in special lyophilization media and are distributed in small aliquots (usually

0.25–0.5 ml) in lyophilization ampoules. As with frozen storage, approximately 99% of the organisms are killed during the freezing process.

Gonococcal isolates should not be suspended in skim milk because fatty acids in the milk may be toxic for some organisms and the density of the suspension cannot be determined. The suspensions are frozen at -70°C or in an ethanol/dry-ice bath and are then dried in a vacuum for 18–24 hours until the moisture has evaporated. **The manufacturer's directions must be followed, because each instrument uses a different type of apparatus.** The dried preparation should be powdery in texture; if the preparation has a clear, syrupy appearance, the vial should be discarded. One ampoule of each strain preparation should also be opened and cultured immediately to ascertain that the preparation is viable and pure and to verify the identity of the organism and its characteristics (e.g., antimicrobial susceptibilities). Ampoules are best stored at $4^{\circ}\text{--}10^{\circ}\text{C}$ or at -20°C ; ampoules should not be stored at room temperature. Oxygen may diffuse slowly into the ampoule through the thin seal, particularly with thin-walled ampoules. Thus, one ampoule should be opened every 1–2 years to confirm that the preparation is viable. If the re-suspended lyophilized preparation does not grow after incubation for 48 hours, new ampoules must be prepared.

- **Recovery of isolates from long-term storage**

Lyophilized specimens of *N. gonorrhoeae* can be recovered by suspending the preparation in 0.5–1.0 ml of glycerol TSB, Mueller-Hinton broth, or PBS, and inoculating GC-chocolate agar. An advantage of using glycerol TSB is that the suspension can be re-frozen until purity is assured on the culture plate; after pure culture is confirmed, the suspension can either be appropriately discarded or a new frozen or lyophilized specimen can be prepared. Perform at least one subculture off the initial culture prior to inoculating tests.

Frozen cultures should be thawed at room temperature, and used to inoculate a plate of GC-chocolate agar. The inoculum may be taken from the frozen culture before the preparation is completely thawed, and should be taken no later than when the frozen culture has completely thawed. (Once completely thawed, the frozen culture will begin to lose viability.)

If resources are available and the stored (lyophilized or frozen) isolate is from a different originating laboratory (i.e., a laboratory other than the one recovering it from the stored specimen), it is suggested that selective GC-medium be inoculated at the same time as GC-chocolate. If the culture is contaminated, this selective medium step will purify the culture.

Storage of *Salmonella*, *Shigella*, and *Vibrio* isolates

Salmonella, *Shigella*, and *Vibrio* isolates will usually remain viable for several days on solid medium held at room temperature (22°–25°C) unless the medium dries out or becomes acidic. However, if cultures are to be maintained for longer than a few days, they should be appropriately prepared for storage. As with other bacteria, selection of a storage method depends on the length of time the organisms are to be held and the laboratory equipment and facilities available. Maintain sterility at all times during preparation of cultures for storage.

Short-term storage of *S. Typhi*, *Shigella*, and *V. cholerae*

Blood agar, tryptone soy agar (TSA), and heart infusion agar (HIA) are examples of good storage media for enteric organisms. Carbohydrate-containing media (e.g., Kligler iron agar [KIA] or triple sugar iron agar [TSI]) should not be used because acidic by-products of metabolism quickly reduce viability of the organisms. Blood agar, TSA, and HIA all contain salt (NaCl), which enhances the growth of *V. cholerae*. (Nutrient agar should not be used for growth or storage of *V. cholerae* because it contains no added salt.)

When preparing storage medium, place tubes of medium that are still hot after autoclaving in a slanted position to provide a short slant and deep butt (2–3 cm). To inoculate, stab the inoculating needle to the butt of the medium once or twice, and then streak the slant. Incubate the culture overnight at 35°–37°C. Seal the tube with cork stoppers that have been soaked in hot paraffin or treated in some other way to provide a tight seal. Store cultures at 22°–25°C and in the dark.

Sterile mineral oil may also be used to prevent drying of slants. Add sufficient sterile mineral oil to cover the slants to 1 cm above the top of the agar, and subculture when needed by scraping growth from the slant; there is no need to remove mineral oil to subculture. ***Shigella*, *Vibrio*, and *Salmonella* strains maintained in pure culture in this manner will usually survive for several years.**

Long-term storage of *S. Typhi*, *Shigella*, and *V. cholerae*

Isolates may be stored indefinitely if they are maintained frozen at -70°C or below; these temperatures can be achieved in an “ultralow freezer” (-70°C) or a liquid nitrogen freezer (-196°C). Storage of isolates at -20°C is not recommended, because some organisms will lose viability at that temperature.

- **Frozen storage**

- a) Inoculate a TSA or HIA slant (or other non-inhibitory, salt-containing growth medium) and incubate at 35°–37°C.
- b) Harvest cells from the slant and make a suspension in the freezing medium.

- c) Dispense the suspension into cryovials (freezing vials specially designed for use at very low temperatures).
- **Caution:** Glass ampoules should never be used for freezing in liquid nitrogen because they can explode upon removal from the freezer.
- d) Prepare an alcohol and dry-ice bath by placing dry ice (frozen CO₂) in a leak-proof metal container large enough to hold a metal culture rack, and add enough ethyl alcohol to submerge about half of the cryovial. Rapidly freeze the suspension by placing the sealed vials in the dry-ice bath until frozen. (If no dry ice is available, a container of alcohol may be placed in the freezer overnight and then used to quick-freeze vials.) Transfer the frozen vials to the freezer.

- ***Lyophilization***

Most organisms may be successfully stored after lyophilization, or freeze-drying. Freeze-drying involves the removal of water from frozen bacterial suspensions by sublimation under reduced pressure. **Follow the manufacturer's directions since each instrument uses a different type of apparatus.** Lyophilized cultures are best maintained at 4°C or lower.

- ***Recovery of isolates from long-term storage***

To recover an isolate from frozen storage, remove the frozen cultures from the freezer and place them on dry ice or into an alcohol and dry-ice bath; transfer to a laboratory safety cabinet or a clean area if a cabinet is not available. Using a sterile loop, scrape the top-most portion of the culture and transfer to a growth medium, being careful not to contaminate the top or inside of the vial. Re-close the vial before the contents completely thaw, and return the vial to the freezer; with careful technique, transfers can be successfully made from the same vial several times. Incubate 18–24 hours at 35–37°C; perform at least one subculture before using the isolate to inoculate a test.

To recover lyophilized specimens of *Salmonella*, *Shigella*, or *V. cholerae*, inoculate a tube of nonselective broth (e.g., TSB or heart infusion broth) and incubate the suspension overnight. Subculture the broth to a nonselective growth medium (e.g., TSA or HIA) and incubate 18–24 hours at 35°–37°C.

Packing and Shipping of Diagnostic Specimens and Infectious Substances

Preparation for transport of infectious specimens and cultures

Transport of diagnostic specimens and etiologic agents (*i.e.*, infectious substances) should be done with care not only to minimize the hazard to humans or the environment, but also to protect the viability of suspected pathogens. Transport of infectious items by public or commercial delivery systems may be subject to local, national, and (if crossing national borders) international regulations.

If possible, specimens should be sent so that they will arrive during working hours to ensure proper handling and prompt plating of the specimens. Inform the receiving laboratory as soon as possible that the specimens are coming, preferably before the specimens are sent.

Depending on local conditions, within-country transport may be by ground or by air. If specimens are sent by a messenger, the messenger must know the location of the laboratory and the appropriate person to contact. The sender should identify the fastest and most reliable way of transport in advance (whether it is, *e.g.*, by bicycle, motorcycle, car, ambulance or public transport), and should make sure that adequate funds are available to reimburse costs for fuel or public transport. For longer distances, the fastest transport service may be air-freight or expedited delivery service. Because the ice packs or dry ice will last only 24–48 hours, arrangements should be made for immediate collection at the receiving airport. When the specimens are shipped by air, the following information should be communicated immediately to the receiving laboratory: the air waybill number, the flight number, and the times and dates of departure and arrival of the flight.

Transport and shipment of cultures and specimens

Regulatory organizations

The United Nations Committee of Experts on the Transport of Dangerous Goods is continually developing recommendations for the safe transport of dangerous goods. The International Civil Aviation Organization (ICAO) has used these recommendations as the basis for developing regulations for the safe

transportation of dangerous goods by air. The regulations of the International Air Transport Association (IATA) contain all the requirements of the ICAO Technical Instructions for the Safe Transport of Dangerous Goods. However, IATA has included additional requirements that are more restrictive than those of ICAO. Member airlines of the IATA have adopted the use of the IATA regulations governing dangerous goods, and shippers must comply with these regulations in addition to any applicable regulations of the state of origin, transit, or destination.

The shipment of infectious substances or diagnostic specimens by air must comply with local, national, and international regulations. International air transport regulations may be found in the IATA publication titled *Dangerous Goods Regulations*. This reference is published annually in January and the regulations are often updated each year. A copy of the IATA regulations in English, Spanish, French, or German may be obtained from one of the following regional offices.

Orders for IATA Regulations from the Americas, Europe, Africa, and the Middle East:

Customer Service Representative
International Air Transport Association
800 Place Victoria, P.O. Box 113
Montreal, Quebec
CANADA H4Z 1M1
Telephone: +1 514 390 6726
Fax: +1 514 874 9659
Teletype: YMQTPXB

Orders for IATA Regulations from Asia, Australasia, and the Pacific:

Customer Service Representative
International Air Transport Association
77 Robinson Rd.
No. 05-00 SIA Bldg.
SINGAPORE 068896
Telephone: +65 438 4555
Fax: +65 438 4666
Telex: RS 24200 TMS Ref: TM 2883
Cable: IATAIATA
Teletype: SINPSXB

Internet Information:

<http://www.iata.org>

For Internet Orders, send e-mail to:
sales@iata.org

Shipping regulations for infectious substances and diagnostic specimens

In general, packages that are being shipped by air via commercial and cargo carriers (such as Federal Express, DHL, and passenger aircraft) are affected by IATA regulations. These regulations are outlined in this section of the laboratory manual to provide examples of acceptable packaging procedures for infectious materials. However, because they may not reflect current national or IATA requirements for packaging and labeling for infectious substances, anyone packaging isolates or infectious specimens should consult the appropriate national regulations and the current edition of IATA *Dangerous Goods Regulations* before packing and shipping infectious substances by any means of transport. Tables 36a and 36b include images of labels and packages appropriate for shipping different classifications of packages under IATA regulations (current as of 2002). Note that a completed “Shipper’s Declaration for Dangerous Goods” form is required for shipments of hazardous materials including infectious substances; guidance in the use of this form is provided later in this appendix.

Definition of infectious substances

According to IATA [2003], infectious substances are defined as substances known or reasonably expected to contain pathogens. Pathogens are microorganisms (including bacteria, viruses, rickettsia, parasites, fungi) or recombinant microorganisms (hybrid or mutant) that are known or reasonably expected to cause infectious disease in humans or animals.

Definition of diagnostic specimens

According to IATA [2003], a diagnostic specimen is defined as any human or animal material being transported for diagnostic or investigational purposes. Human or animal material includes (but is not limited to) excreta, secretions, blood and its components, tissue and tissue fluids, and excludes live infected animals.

Diagnostic specimens are to be considered “diagnostic specimens” unless the source patient or animal has or may have a serious human or animal disease which can be readily transmitted from one individual to another, directly or indirectly, and for which effective treatment and preventative measures are not usually available, in which case they must be classified as “infectious substances.”

Guidelines for packaging and labeling infectious substances

Persons who ship infectious agents or diagnostic specimens must comply with all local and international regulations pertaining to the packaging and handling of these materials. They must ensure that specimens arrive at their destination in good condition and that they present no hazard to persons or animals during transport.

TABLE 36a: Summary of labels and markings required for safe and proper shipping of different types of packages

<i>Package Type:</i>								(Figure within table)
Diagnostic Specimens	3		3					Figure A
Diagnostic Specimens on Dry Ice	3		3	3				Figure B
Infectious Substance ...with less than 50 ml ...with 50 ml or more	3 3	3* 3*				3 3	3	Figure C Figure D
Infectious Substance on Dry Ice ...with less than 50 ml ...with 50 ml or more	3 3	3* 3*				3 3	3	Figure E Figure F
Dry Ice	3			3				Figure G

* If overpack used

TABLE 36b: Description of individual labels and markings required for safe and proper shipping of different types of packages

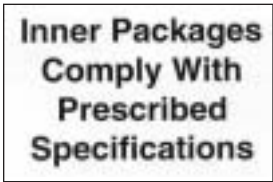
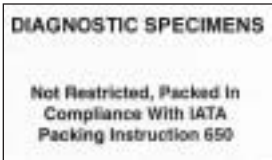
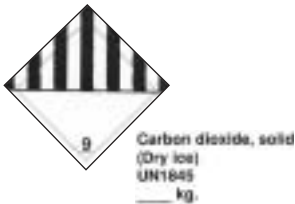
	This orientation label should clearly mark which side is 'Up.' Two labels are required on all boxes, each one on opposite sides of the package.
	This marking must appear on an overpack when the regulations require the use of packagings bearing UN Specification Markings.
	This marking is required when shipping diagnostic specimens.
	These two labels are required when shipping a substance or specimen on dry ice.
	These three labels are required when shipping infectious substances. Please note when shipping infectious substances you <i>must</i> use UN certified 6.2 Infectious Substances Packaging.

TABLE 36b: *continued*

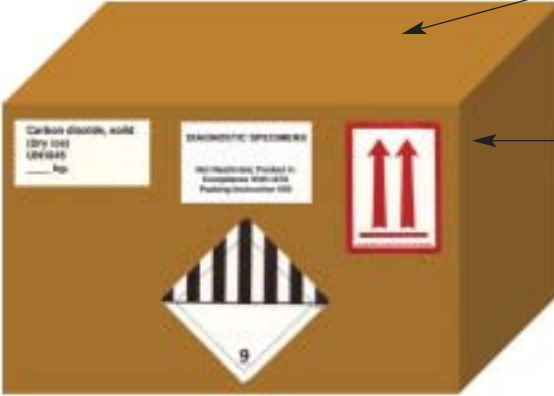
	This label is required when shipping ≥ 50 ml of an infectious substance.
<i>Figure A:</i> Package with diagnostic specimens	 Surface to which air waybill and/or address labels are affixed Must have two “up” arrows on opposite sides
<i>Figure B:</i> Package with diagnostic specimens on dry ice	 Surface to which air waybill and/or address labels are affixed Must have two “up” arrows on opposite sides

Figure C: Overpack with <50 ml of infectious substance

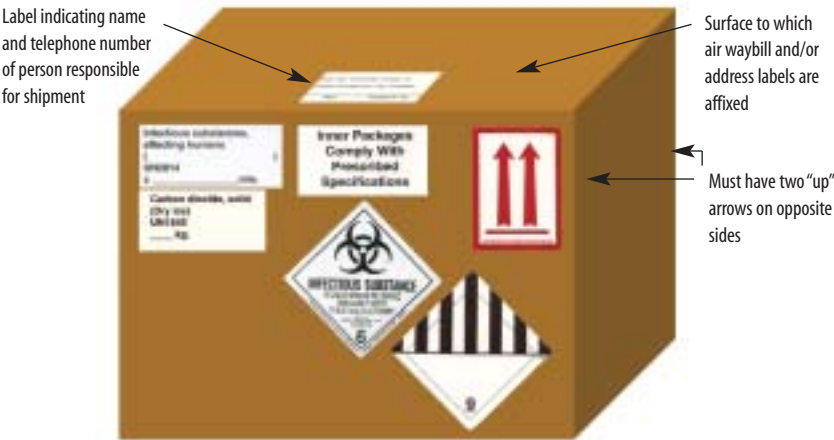


Figure D: Overpack with ≥ 50 ml of infectious substance



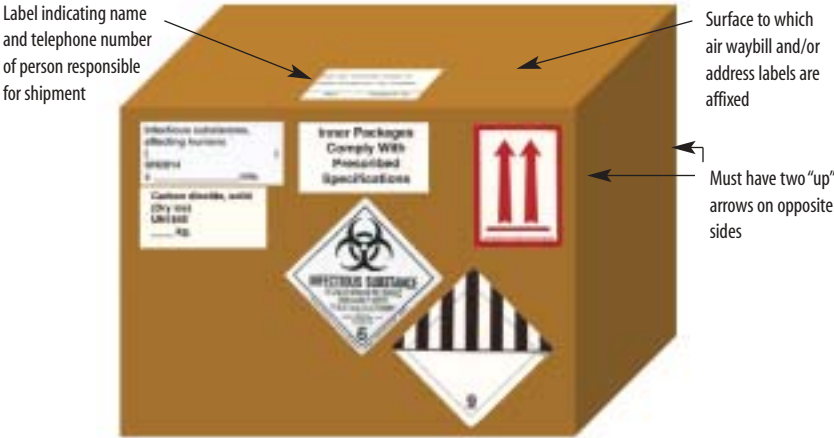
TABLE 36b: *continued*

Figure E: Overpack with <50 ml infectious substance and dry ice

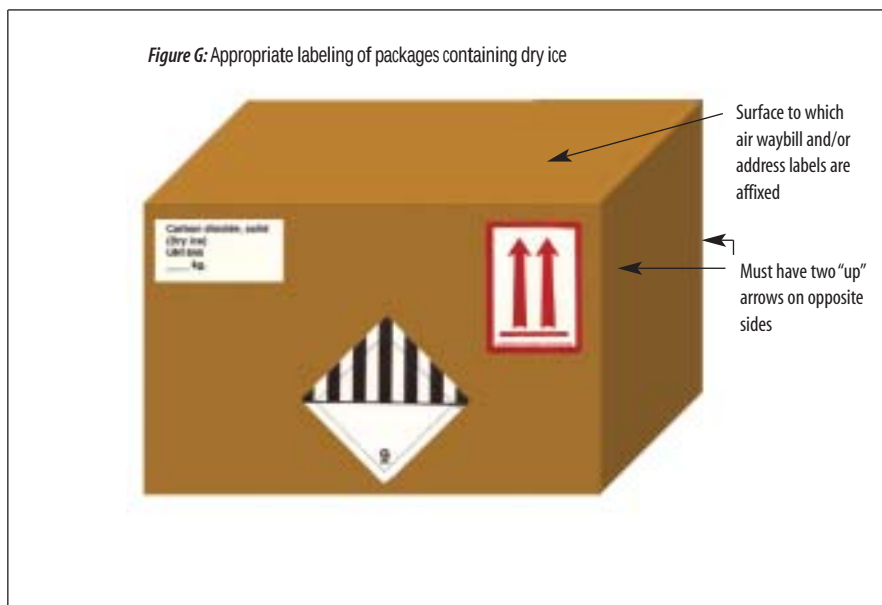


You must use UN certified 6.2 Infectious Substances Packaging.

Figure F: Overpack with ≥50 ml infectious substance and dry ice



You must use UN certified 6.2 Infectious Substances Packaging.



The inner packaging of infectious substance shipments must include the following:

- An inner watertight primary container that is glass, metal, or plastic and has a leak-proof seal.
 - 3 Screw-cap tops should be reinforced with adhesive tape.
 - 3 Petri plates should not be shipped.
- A watertight, impact-resistant secondary container (*i.e.*, United Nations [UN] Specification Packaging that has been rigorously tested and certified for infectious substances)
- Absorbent material between the primary container and the secondary container.
 - 3 If multiple primary containers are placed in a single secondary packaging, they must be wrapped individually to ensure that contact between them is prevented. The absorbing material, such as cotton wool, must be sufficient to absorb the entire contents of all primary containers.
- An itemized list of contents, placed between the secondary packaging and the outer packaging.

Multiple primary receptacles placed in a single secondary packaging must be wrapped individually or, for infectious substances transported in liquid nitrogen, separated and supported to ensure that contact between them is prevented. The absorbing material must be sufficient to absorb the entire contents of all primary receptacles.

The outer packaging of infectious substance shipments must meet the following requirements:

- Be of sufficient strength to adequately protect and contain the contents.
- Be at least 100 mm (4 inches) in its smallest overall external dimension, and of sufficient size to accommodate all labels to be placed on a single surface without overlapping.
- Be durably and legibly marked on the outside with the address and telephone number of the shipper and the consignee (*i.e.*, the intended recipient). The infectious substance label must be affixed to the outside of the outer container, and must bear the inscription, "Infectious substance. In case of damage or leakage immediately notify public health authority." The secondary packaging for infectious substances must be marked with UN Specification Markings denoting that the packaging has been tested and certified for shipping infectious substances.
- Be marked with the infectious substance marking (UN 2814): "Infectious substance, affecting humans (Genus species {or technical name}) x total number of milliliters or grams." The species can be specified, or else indicated as "spp." Note that this marking can be written by hand and does not require a special adhesive label. Genus and species may be written with or without italics or underlining. For example:

 ☐ "Infectious substance, affecting humans (N. meningitidis) x 5.0 ml"

 or

 ☐ "Infectious substance, affecting humans (Streptococcus spp.) x 5.0 ml"

 or

 ☐ "Infectious substance, affecting humans (HIV) x 0.5 ml"
- Be labeled with a set of two up-arrows (⇧⇧) on at least two opposite sides of the outer box to indicate the proper package orientation for the closures to be in the upright position. In addition to the double arrows on the sides, the top of the box may also be labeled with the statement "This End Up" or "This Side Up."
- Be labeled with a "Cargo Aircraft Only" label if the total volume of the infectious substance per outer shipping container is ≥ 50 ml.

- Be marked with the name and telephone number of the person responsible for the shipment.

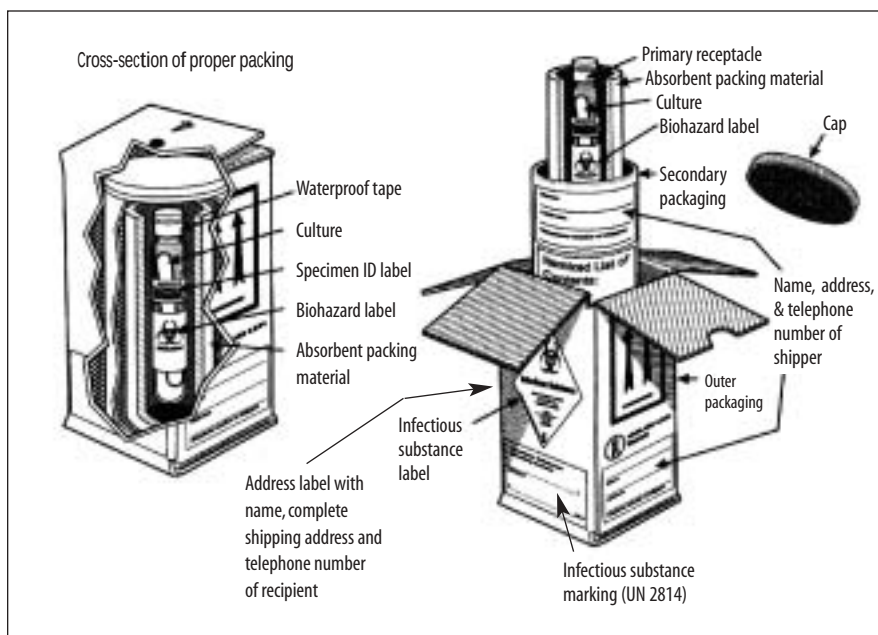
The packaging requirements for transport of infectious substances are illustrated in Figure 91.

Guidelines for packaging and labeling diagnostic specimens

Diagnostic (*i.e.*, clinical) specimens with a low probability of containing an infectious agent must be packaged as follows in packaging that will not leak after a 1.2-meter drop test procedure:

- Be “triple packed” with a watertight primary container, a leak-proof secondary container, and sufficient absorbent material in between the primary and secondary containers.
- 3 The primary receptacle or the secondary packaging must be capable of withstanding, without leakage, an internal pressure differential of not less than 95 kiloPascals when between -40°C and +55°C. (Manufacturers indicate which of their packing and shipping containers meet these criteria.)
 - Infectious substance containers exceed these criteria and are therefore acceptable for use for packing and shipping of diagnostic specimens.
- Contain an itemized list of contents between the secondary packaging and the outer packaging.

FIGURE 91: Proper packing and labeling of the secondary container for shipping of infectious substances



- Be marked with the diagnostic specimens statement on the outside of the outer container: “Diagnostic specimen. UN 3373. Packed in compliance with IATA Packing Instruction 650.” Note that this marking can be written by hand and does not require a special adhesive label.

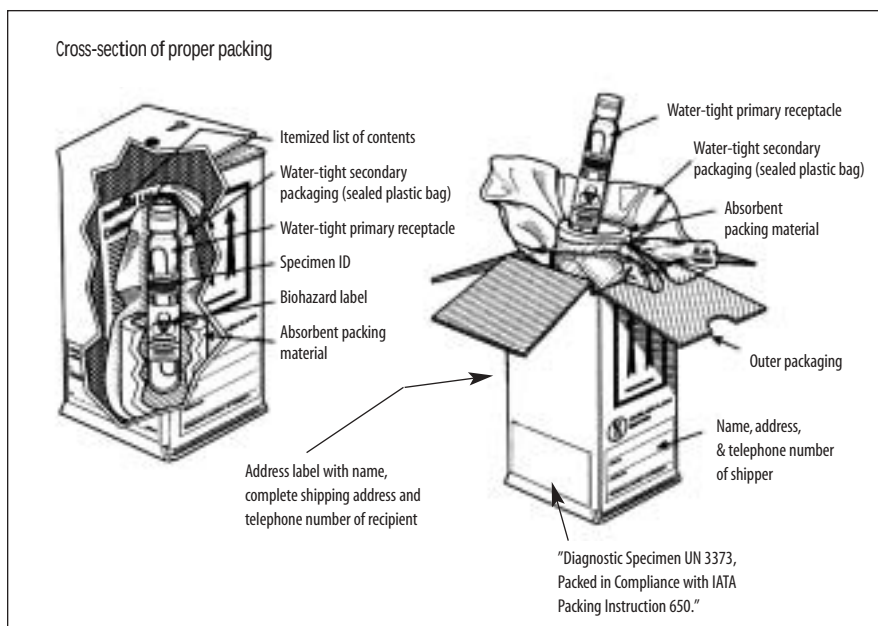
- 3 If being shipped by air, the diagnostic specimens statement (“Diagnostic specimen. UN 3373. Packed in compliance with IATA Packing Instruction 650.”) must be present on the air waybill as well as on the outer container.

The packaging requirements for transport of diagnostic specimens are illustrated in Figure 92.

Guidelines for packaging and labeling of specimens shipped on dry ice (CO₂)

Wet ice or dry ice must be placed outside the secondary packaging in an overpack, and interior supports must be provided to secure the secondary packaging in the original position after the ice has dissipated. If wet ice is used, the packaging must be leak-proof. If dry ice is used, it must be packed according to IATA Packing Instruction 904: the outer packaging must permit the release of carbon dioxide [CO₂] gas. Cardboard and polystyrene (*i.e.*, Styrofoam) are two examples of materials suitable for the packaging of dry ice. In a temperate climate, approximately 6 pounds of dry ice will dissipate in a 24-hour period, and therefore at least that much (and preferably more) dry ice is suitable for a 24-hour shipment/delivery period; this amount should be adjusted accordingly for warmer

FIGURE 92: Proper packing and labeling of the secondary container for shipping of diagnostic specimens



climates and size of the box. The larger the box, the more dry ice required to keep the contents frozen. Note that for air transport, the maximum dry ice allowed in a single outer container is 200 kg (approximately 440 pounds).

Packages containing dry ice **must be properly marked** with the words “Carbon dioxide, solid (dry ice); UN1845; (and net weight of the dry ice in kg),” and a pre-printed Class 9 “Miscellaneous Dangerous Goods” label, as shown in Table 36.

When an overpack is used, the overpack must be marked with the statement “Inner packages comply with prescribed specifications” (because the UN Specification Markings will not be visible on the outer-most packaging).

Guidelines for completion of the “Shipper’s Declaration for Dangerous Goods” form

All shipments of hazardous materials including infectious substances must be accompanied by two original, completed copies of the “Shipper’s Declaration for Dangerous Goods” form, inserted in the pouch along with the other shipping documents. A sample Shipper’s Declaration for Dangerous Goods form with information required for completion is presented in Figure 93. It is important to remember the following in order to reduce the risk of a shipment being refused and returned to the laboratory of origin:

- International regulations require the diagonal hatch marks in the left and right margins to be **printed in red**, and so photocopies of this form may not be used.
- The form **must be completed in English**, although translations may accompany it on the same form.
- Specific terms, spellings, and nomenclature must be used. For example, a cardboard box **must** be referred to as “fibreboard box” (spelled with R before E), and there **must** be a comma after the term “infectious substance” within the statement “infectious substance, affecting humans” (Figure 93).
- The person responsible for the shipment must be listed in one of the address boxes; if the person responsible for the shipment is different than the shipper or recipient, include the responsible person’s telephone number alongside the name.
- Under the “Transport Details” portion of the form, cross out the option that does not apply.
 - If the shipment is **under 50 ml**, cross out “**cargo aircraft only.**”
 - If the shipment is **50 ml or more**, cross out “**passenger and cargo aircraft.**”
- Under the “Nature and Quantity of Dangerous Goods” portion of the form:
 - 3 The proper shipping name for infectious substances is “Infectious substance, affecting humans (technical name).” The technical name of the infectious

substance(s) **must** be included in parentheses after the proper shipping name; however, the specific species is not required, and “spp.” may follow the genus. It is therefore appropriate for the technical name of the infectious substance *Neisseria meningitidis* to be listed as either “(*Neisseria meningitidis*)” or “(*Neisseria* spp.)” Italics are permitted for the genus and species names but are not necessary.

- 3 For “Infectious substances, affecting humans (technical name)”: the proper class is 6.2; the UN number is UN2814; and the packing instruction is 602.
 - 3 For “Carbon dioxide, solid (dry ice)”: the proper class is 9; the UN number is UN1845; the packing group is III; and the packing instruction is 904.
 - 3 For infectious substances, the quantity must be noted in ml under the “Quantity and Type of Packing” portion of the form.
 - 3 For dry ice, the quantity must be noted in kg (measured in whole numbers) under the “Quantity and Type of Packing” portion of the form.
 - 3 If the UN specification marking is not visible on the outer package, the declaration must contain the words “OVERPACK USED” under the “Quantity and Type of Packing” portion of the form.
- Under the “Additional Handling Information” portion of the form, the 24-hour emergency contact telephone number must be answered by a person knowledgeable about emergency response procedures for damaged and leaking boxes.
 - The “Shipper’s Declaration for Dangerous Goods” form is a legal document and must be signed.

Be certain to contact the intended recipient prior to shipment of the box to share all shipping details, and make arrangements for proper handling during shipping and legal importation of the infectious substance without delay in delivery; these guidelines are in keeping with IATA regulation 1.3.3.1.

Reference publication for packing and shipping of dangerous goods

International Air Transport Association *Dangerous Goods Regulations* 44th Edition, Effective January 1, 2003. Montreal - Geneva.

FIGURE 93: Information required for proper completion of the “Shipper’s Declaration for Dangerous Goods” form

SHIPPER'S DECLARATION FOR DANGEROUS GOODS (Provide at least two copies to the airline)

Shipper: Name of Shipper, Company Name, Complete address (no P.O. Boxes), Telephone number (include area code), Person responsible (name and telephone)

Air Waybill No. (use Air Waybill number of package), Page 1 of Pages (REQUIRED), Shipper's Reference Number (optional)

Consignee: Name of Recipient, Company Name, Complete address (Not a P.O. Box), Telephone number (include area code), Person responsible (name and telephone)

Cross-out choice that does NOT apply (infectious substances are usually non-radioactive), red markings are REQUIRED

Two completed and signed copies of this Declaration must be handed to the operator

TRANSPORT DETAILS: This shipment is within the limits prescribed for limited quantities, Airport of Origin: City, State, Country, AIRFREIGHT AND CARGO AIRCRAFT ONLY, CARGO AIRCRAFT ONLY, Airport of Destination: City, State, Country

WARNING: Failure to comply in all respects with the applicable Dangerous Goods Regulations may be in breach of the applicable law, subject to legal penalties. This Declaration must not, in any circumstances, be completed and/or signed by a consolidator, a forwarder or an IATA cargo agent.

NATURE AND QUANTITY OF DANGEROUS GOODS: Dangerous Goods Identification table with columns: Proper Shipping Name, Class or Division, ID or ID No., Packing Group, Substances, Quantity and Type of packing, Packing Inst., Authorization. Entries include: Infectious substance, affecting humans (GENUS SPECIES) and Carbon dioxide, solid (Dry ice).

Cross-out choice that does NOT apply (if quantity >50ml, transport must occur on cargo aircraft), If parcel contains dry ice, include the following:

OVERPACK USED (If UN specification markings are not visible because the overpack covers the secondary packaging, include:)

Additional Handling Information: Prior arrangements as required by the ICAO and IATA Dangerous Goods Regulations 1.3.3.1 have been made (REQUIRED)

I hereby declare that the contents of this consignment are fully and accurately described above by the proper shipping name and are classified, packaged, marked and labelled/placarded, and are in all respects in proper condition for transport according to applicable international and national governmental regulations.

Shipped/Title of Signature: Shipper's name, Title, company name, Place and Date: City, State, Country, Date shipped, Signature: Shipper's signature

Manufacturer, Supplier, and Distributor Contact Information

The following list of the manufacturers, suppliers, and distributors of the commonly used media and reagents does not indicate endorsement of these products and/or manufacturers. Note that contact information may change.

Follow the manufacturer's instructions closely when using commercially available media and reagents, and perform quality control activities regularly as appropriate.

BD (Becton, Dickinson and Co.)

also includes products from:

- **BBL** (*internet catalogue*)
<http://catalog.bd.com/scripts/catalog.exe>
- **Difco** (*internet catalogue*)
<http://www.bd.com/industrial/difco/manual.asp>

BD Microbiology Systems

7 Loveton Circle
Sparks, Maryland 21152 USA

Phone: (+1) 410 316 4000

Fax: (+1) 410 316 4723

BD Worldwide

House of Vanguard
Chiromo Road, Westlands
4th Floor, Wing B, P.O. Box 76813
Nairobi, Kenya

Phone: (+254) 2 44 96 09

Fax: (+254) 2 44 96 19

BD Diagnostics Systems, Asia Limited

5th Floor, Signature Tower South City
Gurgaon – 122016

Haryana, India

Phone: (+91) 124 638 3566

Fax: (+91) 124 638 3224

E-mail: bd_india@bd.com

BD Chile

Carretera General San Martin 16500
Sitio 33, Colina (Casilla 16273 – Correo 9)
Santiago, Chile

Phone: (+56) 2 460 0380

Fax: (+56) 2 460 0306

bioMérieux

bioMérieux Vitek, Inc.
595 Anglum Drive
Hazelwood, MO 63042 USA
Phone: (+1) 314 731 8500
Fax: (+1) 314 731 8700

bioMérieux s.a.
69280 Marcy-l'Etoile, France
Phone: (+33) 4 78 87 20 00
Fax: (+33) 4 78 87 20 90
Telex: 330967

Developing Health Technology
*(low-cost laboratory equipment & supplies
for developing countries, NGOs and aid
agencies)*

Developing Health Technology
Bridge House
Worlington Road
Barton Mills
ENGLAND IP28 7DX.
Phone: (+44) 1603 416058
Fax: (+44) 1603 416066
E-mail: sales@dht-online.co.uk
Internet: <http://www.dht-online.co.uk/>

Fisher Scientific Co.

Fisher Scientific, Puerto Rico
Carreterra #1, Km.56.4
Barrio Montellano
Cayey, Puerto Rico 00737 USA
Phone: (+1) 787 738 4231
Fax: (+1) 787 738 4600

Fisher Scientific International, Inc.
3970 Johns Creek Court
Suite 500
Suwanee, GA 30024 USA
Phone: (+1) 770 871 4500
Fax: (+1) 770 871 4600

Europe/Middle East/Africa Headquarters
Fisher Scientific Overseas Marketing, Inc.
46 Queen Anne Street
London W1M 9LA, United Kingdom
Phone: (+44) 171 935 4440
Fax: (+44) 171 935 5758

Listing of additional locations:
<http://www.fishersci.com.sg/contact.html>

Merck & Co KGaA

*Electronic listing of
global suppliers*

Internet: <http://www.merck.de>

E-mail: service@merck.de

KGaA Darmstadt Germany

Frankfurter Strasse 250

64293 Darmstadt, Germany

Phone: (+49) 6151 720

Fax: (+49) 6151 722000

Merck Laboratory Supplies Division

1 Friesland Drive

Longmeadow Business Estate

Modderfontein, Gauteng, South Africa

Phone: (+27) 11 372 5000

Fax: (+27) 11 372 5254

E-mail: labsupply@merck.co.za

Merck Quimica Argentina

Artilleros 2436

1428 Buenos Aires, Argentina

Phone: (+54) 114 787 8100

Fax: (+54) 114 788 3365

E-mail: wpiersko@merck.com.ar

Merck Limited

Shiv Sagar Estate "A"

Dr. Annie Besant Road

Worli, Mumbai 400018 INDIA

Phone: (+91) 22 4964855 (*through* 862)

Fax: (+91) 22 4950307 *or* 4954590

E-mail: life.science@merck.co.in

Calbiochem

(affiliate of Merck)

Calbiochem

P.O. Box 12087

LaJolla, CA 92039-2087 USA

Phone: (+1) 858 450 9600

Fax: (+1) 858 453 3552

Internet: [http://www.calbiochem.com/
contactUs/sales.asp](http://www.calbiochem.com/contactUs/sales.asp)

E-mail: orders@calbiochem.com

Murex Diagnostics, Inc.

Central Road, Temple Hill

Dartford, Kent DA1 5LR, United Kingdom

Phone: (+44) 132 227 7711

Fax: (+44) 132 227 3288

Customer Services Department

3075 Northwoods Circle

Norcross, GA 30071, USA

Phone: (+1) 404 662 0660

Fax: (+1) 404 447 4989

Murex Diagnostics, Inc.
(continued)

Murex Diagnostics / Embree Diagnostics
Delhi 110006
India
Phone: (+91) 11 326 7172
Fax: (+91) 11 324 1508

Oxoid

Oxoid s.a.
6 route de Paisy, B.P. 13
69572 Dardilly Cedex, France
Phone: (+33) 4 78 35 17 31
Fax: (+33) 4 78 66 03 76

Oxoid Limited
Wade Road, Basingstoke
Hampshire RG24 8PW
England
Phone: (+44) (0) 1256 841 144
Fax: (+44) (0) 1256 463 388
E-mail: oxoid@oxoid.com

Pastorex

Sanofi Diagnostics Pasteur
3, Bld Raymond Poincaré - BP 3
92430 Marnes-la-Coquette, France
Phone: (+33) 1 47 95 60 00
Fax: (+33) 1 47 41 91 33
Telex: 631293F

Quélab Laboratories, Inc.

2331, Dandurand
Montreal (Quebec)
Canada, H2G 3C5
Phone: (+1) 514 277 2558
Fax: (+1) 514 277 4714
Internet: <http://www.quelab.com>
(website in English, French & Spanish)

Remel Laboratories

12076 Santa Fe Drive
P.O. Box 14428
Lenexa, KA 66215, USA
Phone: (+1) 913 888 0939
Fax: (+1) 913 895 4128
E-mail: customersupport@remelinc.com

Scientific Device Laboratory, Inc.

411 E. Jarvis Avenue
Des Plaines, IL 60018
Phone: (+1) 847 803 9545
Fax: (+1) 847 803 8251
E-mail: scidev@aol.com
Internet: <http://www.scientificdevice.com>
(website in English and Spanish)

Sigma-Aldrich Corp.

Sigma-Aldrich
Fancy Road, Poole
Dorset, BH17 7NH, UK
Phone: (+44) 0800 373 731
Fax: (+44) 0800 378 785

Sigma-Aldrich Chimie S.a.r.l.
L'Isle d'Abeau Chesnes
B.P. 701, 38297 St. Quentin
Fallavier Cedex, France
Phone: (+33) 05 21 14 08
Fax: (+33) 05 03 10 52

Sigma-Aldrich
St. Louis, MO USA
Attn: N. Corray
Phone: (+1) 314 286 7690
Fax: (+1) 314 286 7807
E-mail: ncorray@sial.com

TCS Biosciences Ltd.

Botolph Claydon
Buckingham, MK18 2LR
England
Phone: (+44) (0) 1296 714222
Fax: (+44) (0) 1296 714806
E-mail: Sales@TCSgroup.co.uk

Wellcome Diagnostics

GlaxoSmithKline,
Glaxo Wellcome UK Ltd.,
Stockley Park West,
Uxbridge, Middlesex, UB11 1BT
General Enquiries:
Phone: (+44) 20 8990 9000
Fax: (+44) 20 8990 4321

Wellcome Diagnostics*(continued)*

Glaxo SmithKline

Consumo

Av. Presidente Kennedy

5454 Piso 13

Chile

Phone: (+56) 2 370 6600*Fax:* (+56) 2 370 6666

GlaxoSmithKline

South Africa

44 Old Pretoria Road

Halfway House

Midrand Gauteng

South Africa

or

PO Box 3388

Halfway House 1685

Gauteng South Africa

Phone: (+27) 11 3136000*Fax:* (+27) 11 3136111

VWR International

VWR International Ltd.

Merck House

Poole BH15 1TD

England

Phone: (+44) 1 202 669 700*Fax:* (+44) 1 202 665 599

info@uk.vwr.com

VWR International S.A.S.

“Le périgares”–Bâtiment B

201, rue Carnot

F-94126 Fontenay-sous-Bois cedex

Phone: (+33) 1 45 14 85 00info@fr.vwr.com

Quality control strains

Many laboratories purchase QC strains from official culture collections, including the American Type Culture Collection (ATCC) and the National Collection of Type Cultures and Pathogenic Fungi (NCTC). This manual presents the ATCC numbers for quality control strains, but ATCC strains may also be obtained from the NCTC.

American Type Culture Collection (ATCC)

12301 Parklawn Drive, Rockville, MD 20852 USA

Phone (+1) 703-365-2700

Fax (+1) 703-365-2701

E-mail help@atcc.org

Internet <http://www.atcc.org>

National Collection of Type Cultures and Pathogenic Fungi (NCTC)

Public Health Laboratory Service, London NW9, England

E-mail nctc@phls.nhs.uk

Internet <http://www.phls.co.uk/services/nctc/>

Quality control strains also may be purchased from commercial companies such as Lab M. **Lab M** Topley House, 52 Wash Lane, Bury, BL9 6AU, England.

Etest® strips

Etest® strips may be somewhat more difficult to obtain than antimicrobial disks, and so specific information is included here regarding their acquisition. Etest® strips are available from:

AB BIODISK	AB BIODISK North America, Inc	Remel Inc. (Distributor)
Dalvagen 10	200 Centennial Ave	12076 Santa Fe Dr.
S 169 56	Piscataway, NJ. 08854-3910	Lenexa, KS 66215
Solna, Sweden	<i>Phone:</i> (+1) 732 457 0408	<i>Phone:</i> (+1) 913 888 0939
<i>Phone:</i> (+46) 8 730 0760	<i>Fax:</i> (+1) 732 457 8980	<i>Fax:</i> (+1) 913 888 5884
<i>Fax:</i> (+46) 8 83 81 58		

Find AB Biodisk on the Internet at: <http://www.abbiodisk.com>

In some cases discounts on Etest® strips may be available for projects funded by the World Health Organization (WHO), particularly for laboratories in resource-poor regions. To learn more about potential discounts, contact: Anne Bolmstrom, President AB BIODISK, at the company address in Sweden provided here.

International Reference Laboratories

Persons wishing to send isolates to an international reference laboratory for confirmation must **contact the laboratory prior to the packaging and shipping process in order to obtain information about import permits and to ascertain the laboratory is able to accept the shipment.** (*Note:* instructions for the proper packaging of isolates are found in Appendix 12.)

WHO Collaborating Centre for Research, Training, and Control in Diarrhoeal Diseases
International Centre for Diarrhoeal Disease Research, Bangladesh (ICDDR,B)
G.P.O. Box 128
Dhaka 100
BANGLADESH

WHO Collaborating Centre for Diarrhoeal Diseases Research and Training
National Institute of Cholera and Enteric Diseases
P-33, CIT Road Scheme XM
Beliaghata
P.O. Box 177
Calcutta 700 016
INDIA

WHO Collaborating Centre for *Shigella*
National Reference Laboratory for *Escherichia coli* and *Shigella*
Foodborne and Diarrheal Diseases Laboratory Section
Centers for Disease Control and Prevention
1600 Clifton Rd., N.E., MS C03
Atlanta, GA 30333 USA
Phone: (+1) 404 639 3344
Fax: (+1) 404 639 3333
E-mail: nas6@cdc.gov

National Reference Laboratory for *Vibrio cholerae* O1 and O139
Epidemic Investigations and Surveillance Laboratory
Foodborne and Diarrheal Diseases Laboratory Section
Centers for Disease Control and Prevention
1600 Clifton Rd., N.E., MS C-03
Atlanta, GA 30333 USA
Phone: (+1) 404 639 3344
Fax: (+1) 404 639 3333
E-mail: cab4@cdc.gov

WHO Collaborating Centre for Reference and Research on *Salmonella*
Institut Pasteur
28 rue du Docteur Roux
F-75724 Paris Cedex 15
FRANCE
Phone: (+33) 1 45 68 83 46
Fax: (+33) 1 45 68 82 28

WHO Collaborating Centre for Phage-typing and Resistance of Enterobacteria
Division of Enteric Pathogens
Central Public Health Laboratory
Colindale Avenue
London NW9 5HT
United Kingdom
Phone: (+44) 181 200 4400
Fax: (+44) 181 200 7874

WHO Collaborating Centre for Global Monitoring of Antimicrobial Resistant Bacteria
Nosocomial Pathogens Laboratory Branch
Centers for Disease Control and Prevention
1600 Clifton Rd., N.E., MS G-08
Atlanta, GA 30333 USA
Fax: (+1) 404-639-2256
E-mail: zoa6@cdc.gov (e-mail contact is preferred.)

WHO Collaborating Centre for Reference and Research on Meningococci
Attention: Prof. Dominique A. Caugant, Head
Norwegian Institute of Public Health
Geitmyrsveien 75
P.O. Box 4404 Nydalen
N-0403 Oslo
NORWAY
Phone: (+47) 22 04 23 11
Fax: (+47) 22 04 25 18

Unité du méningocoque, Centre Collaborateur OMS
(Meningococcal Unit, WHO Collaborating Centre)
Institut de Médecine tropicale du Service de Santé des Armées
Attention: Dr. Pierre Nicolas
Parc du Pharo, B.P. 46
F-13998 Marseille-Armées
France
Phone: (+33) 4 91 15 01 15
Fax: (+33) 4 91 59 44 77
E-mail: imtssa.meningo@free.fr

WHO Collaborating Centre for STD and HIV
(Gonococcal Antimicrobial Surveillance Programme – Western Pacific Region)
The Prince of Wales Hospital,
Randwick, Sydney
Australia 2031
Phone: (+ 61) 2 9382 9079
Fax: (+ 61) 2 9398 4275
E-mail: j.tapsall@unsw.edu.au or limniosa@sesahs.nsw.gov.au

Gonococcal Antimicrobial Surveillance Program for Latin America and the Caribbean
Centre for Research in Biopharmaceuticals
Room 4170, Guindon Hall
University of Ottawa
451 Smyth Road
Ottawa, Canada K1H 8M5
Phone: (+1) 613 562 5800, ext. 8379
Fax: (+1) 613 562 5699
E-mail: GASPLAC@uottawa.ca

*Quality control strains for supplemental antimicrobial susceptibility testing of
Neisseria gonorrhoeae can be obtained from:*

Neisseria Reference Laboratory
Gonorrhea Research Branch, Building 1 South / Room B260
Centers for Disease Control and Prevention
1600 Clifton Rd NE
Atlanta, GA 30333 USA

Attention:

Dr. David Trees (*Phone:* (+1) 404 639 2134; *Fax:* 404 639 2310;
E-mail: DTrees@cdc.gov)

or

Dr. Joan S. Knapp (*Phone:* (+1) 404 639 3470; *Fax:* 404 639 3976;
E-mail: JKnapp@cdc.gov)

Resources for quality assurance

Laboratorians may also be interested in seeking reference information regarding quality assessment (Q/A). The World Health Organization maintains a website regarding international external Q/A schemes:

http://www.who.int/pht/health_lab_technology/ieqass.html .

As of 2002, the WHO international Q/A assessment scheme organizer for microbiology is:

WHO Collaborating Centre for External Quality Assessment in
Clinical Microbiology

Attention: Dr J. Verhaegen

University Hospital St Raphael
Leuven, Belgium

An additional internet-based resource for information useful to laboratories in resource-limited settings is the “Public Health Care Laboratory” website:

<http://www.phclab.com>.

The organization states a mission, “. . . to serve as a global resource and information exchange forum in support of laboratory services in resource-poor countries and thereby contribute to sustainable quality improvement. . . .”

PHCLab.com can be contacted by e-mail at: mail@phclab.com .

Selected References

Reference manuals

“Laboratory Methods for the Diagnosis of Epidemic Dysentery and Cholera.” Centers for Disease Control and Prevention. Atlanta, Georgia, USA. 1999.

Copies of the above enterics manual can be obtained from:

Foodborne and Diarrheal Diseases Laboratory Section,
Centers for Disease Control and Prevention
1600 Clifton Road, NE MailStop C-03
Atlanta, GA 30333 USA
Fax: 404-639-3333

“Laboratory Methods for the Diagnosis of Meningitis Caused by *Neisseria meningitidis*, *Streptococcus pneumoniae* and *Haemophilus influenzae*.” World Health Organization. 1999.

- *Copies of the above meningitis manual can be obtained from the World Health Organization, Geneva.*

NCCLS. *Performance Standards for Antimicrobial Susceptibility Testing; Twelfth Informational Supplement*. NCCLS document M100-S12 (ISBN 1-56238-454-6). NCCLS, 940 West Valley Road, Suite 1400, Wayne, Pennsylvania 19087-1898, USA 2002. (General NCCLS website: <http://www.nccls.org>)

NCCLS. *Performance Standards for Antimicrobial Disk Susceptibility Tests; Approved Standards – Seventh Edition*. NCCLS document M2-A7 (ISBN 1-56238-393-0). NCCLS, 940 West Valley Road, Suite 1400, Wayne, Pennsylvania 19087-1898 USA 2000. (General NCCLS website: <http://www.nccls.org>)

NCCLS. *Methods for Dilution Antimicrobial Susceptibility Tests for Bacteria that Grow Aerobically; Approved Standard – Fifth Edition*. NCCLS document M7-A5 (ISBN 1-56238-394-9). NCCLS, 940 West Valley Road, Suite 1400, Wayne, Pennsylvania 19087-1898 USA 2000. (General NCCLS website: <http://www.nccls.org>)

Manual of Clinical Microbiology. American Society for Microbiology - Washington, DC USA: 1992

Clinical Microbiology Procedures Handbook. American Society for Microbiology - Washington, DC USA: 1992.

Basic Laboratory Procedures in Clinical Bacteriology. WHO, Geneva: 2001.

Manual of Basic Techniques for a Health Laboratory. WHO, Geneva: 2001.

Reference manuals (pending publication by WHO)

Generic Protocol to Measure the Burden of Pneumonia and Pneumococcal Disease in Children 0 to 23 Months of Age. WHO, Geneva: Pending.

WHO Surveillance Standards for Antimicrobial Resistance : WHO, Geneva: Pending.

Shipping and packing reference

International Air Transport Association *Dangerous Goods Regulations* 44th Edition, Effective January 1, 2003. Montreal - Geneva.

Additional references

Ajello GW, Feeley JC, Hayes PS, Reingold AL, Bolan G, Broome CV, and CJ Phillips (1984) Trans-Isolate medium: a new medium for primary culturing and transport of *Neisseria meningitidis*, *Streptococcus pneumoniae*, and *Haemophilus influenzae*. *J Clin Microbiol* 20: 55-58.

Amies CC (1967) A modified formula for the preparation of Stuart's transport medium. *Can J Public Health* 58: 296-300.

Angyo IA and ES Okpoh (1998) Changing patterns of antibiotic sensitivity and resistance during an outbreak of meningococcal infection in Jos, Nigeria. *J Trop Pediatr* 44 (5): 263-265.

Applebaum PC (1987) World-wide development of antibiotic resistance in pneumococci. *Eur J Clin Microbiol* 6: 367-377.

Atlas RM and JW Snyder (1995) *The Handbook of Media for Clinical Microbiology*. CRC Press: New York.

Austrian R (1976) The Quellung reaction: a neglected microbiological technique. *Mt Sinai J Med* 43: 699-703.

Barker J, Gratten M, Riley I, Lehmann D, Montgomery J, Kajoi M, Gratten H, Smith D, Marshall TF, and MP Alpers (1989) Pneumonia in children in the Eastern Highlands of Papua New Guinea: A bacteriologic study of patients selected by standard clinical criteria. *J Infect Dis* 159: 348-352.

Barry AL, Brown SD, and PC Fuchs (1996) In vitro activity of ceftizoxime, ceftazidime, cefuroxime, ceftriaxone, cefotaxime, and penicillin against *Streptococcus pneumoniae* as determined by three quantitative methods. *Eur J Clin Microbiol Infect Dis* 15: 344-346.

Bopp CA, Brenner FW, Wells JG, and NA Strockbine. "Escherichia, Shigella, and Salmonella." In: Murray PR, Tenover FC, Baron EJ and RH Tenover, eds. (1999) *Manual of Clinical Microbiology*, 7th Edition. ASM Press, Washington, DC: pages 459-474.

Budzinski L, Bronsdon M, Factor S, Schwartz B, Suleymanova F, Chorba T, and R Facklam (1997) Comparison of E-test performed under field conditions and broth microdilution minimal inhibitory concentrations (MIC) performed in a reference laboratory for *Streptococcus pneumoniae* and *Haemophilus influenzae*. Abstract, *Interscience Conference on Antimicrobial Agents and Chemotherapy* p. 89, D36. Toronto, Canada.

Campos JM (1989) Detection of bloodstream infections in children. *Eur J Clin Microbiol Infect Dis* 8: 815-824.

Centers for Disease Control and Prevention (2002) Laboratory-acquired meningococcal disease – United States, 2000. *MMWR Morb Mort Wkly Rep*. 51 (7): 141-144.

Centers for Disease Control and Prevention (2000) *Gonococcal Isolate Surveillance Project Annual Report – 2000*. CDC: Atlanta, Georgia, USA.

Centers for Disease Control and Prevention (1999) Fluoroquinolone-Resistance in *Neisseria gonorrhoeae*, Hawaii, 1999, and Decreased Susceptibility to Azithromycin in *N. gonorrhoeae*, Missouri, 1999; *MMWR Morb Mort Wkly Rep*. 49 (37): 833.

Centers for Disease Control and Prevention (1994) *Laboratory methods for the diagnosis of Vibrio cholerae*. CDC: Atlanta, GA USA.

Centers for Disease Control and Prevention (1990) Recommendations for the collection of laboratory specimens associated with outbreaks of gastroenteritis. *MMWR Morb Mort Wkly Rep.* 39 (No. RR-14).

Centers for Disease Control and Prevention, National Institutes of Health. *Biosafety in microbiological and biomedical laboratories*. Washington, DC: U.S. Government Printing Office; 1999: stock no. 017-040-00547-4.

Cohen ML (1997) Epidemiological factors influencing the emergence of antimicrobial resistance. *Ciba Found Symp* 207: 223-231.

Cohen ML (1992) Epidemiology of drug resistance: Implications for a post-antimicrobial era. *Science* 257 (5073): 1050-1055.

Dershewitz RA, Wigder HN, Wigder CN, and DH Nadelman (1983) A comparative study of the prevalence, outcome, and prediction of bacteremia in children. *J Pediatr* 103: 352-358.

Dillon JR, Carballo M, and M Pauze (1988) Evaluation of eight methods for identification of pathogenic *Neisseria* species: *Neisseria*-Kwik, RIM-N, Gonobio Test, Gonocheck II, GonoGen, Phadebact GC OMNI test, and Syva MicroTrak test. *J Clin Microbiol* 26 (3): 493-497.

Doern GV, Jorgensen JH, Thornsberry C, Preston DA, Tubert T, Redding JS, and Maher LA (1988) National collaborative study of the prevalence of antimicrobial resistance among clinical isolates of *Haemophilus influenzae*. *Antimicrob Agents Chemother* 32: 180-185.

Eandi M and GP Zara (1998) Economic impact of resistance in the community. *Int J Clin Pract Suppl* 95: 27-38.

El-Nageh MM (1996) Coordination for better laboratory services. *World Health Forum* 17 (2): 200-202.

Epidemiological and Statistical Methodology Unit, WHO (1986) *Sample Size Determination: a Users Manual*. WHO: Geneva.

Facklam RR and JA Washington. “*Streptococcus* and Related Catalase-Negative Gram Positive Cocci.” In: Balows, A, Hausler WJ, Herrmann KL, Isenberg HD, & HJ Shadomy, eds. (1991) *Manual of Clinical Microbiology*, 5th ed. American Society for Microbiology, Washington D.C.: pages 238-257.

Fleming DT and JN Wasserheit (1999) From epidemiological synergy to public health policy and practice: the contribution of other sexually transmitted diseases to sexual transmission of HIV infection. *Sex Transm Infect* 75 (1): 3-17.

- Gagneux S, Wirth T, Hodgson A, Ehrhard I, Morelli G, Kriz P, Genton B, Smith T, Binka F, Pluschke G, and M Achtman (2002) Clonal groupings in serogroup X *Neisseria meningitidis*. *Emerg Infect Dis* 8 (5): 462-466.
- Gerbase AC, Rowley JT, Heymann DH, Berkley SE, and P Piot (1998) Global prevalence and incidence estimates of selected curable STDs. *Sex Transm Infect* 74 (Suppl 1): S12 – S16.
- Gibson LF and JT Khoury. 1986. Storage and survival of bacteria by ultra-freeze. *Lett Appl Microbiol* 3: 137-129.
- Global Task Force on Cholera Control (1992) *Guidelines for cholera control*. Publication no. WHO/CDD/SER/80.4 Rev 4. World Health Organization, Geneva.
- Goldmann DA and WC Huskins (1997) Control of nosocomial antimicrobial-resistant bacteria: a strategic priority for hospitals worldwide. *Clin Infect Dis* 24 (Suppl 1): S139 – S145.
- Gratten M, Battistutta D, Torzillo P, Dixon J, and K Manning 1994. Comparison of goat and horse blood as culture medium supplements for isolation and identification of *Haemophilus influenzae* and *Streptococcus pneumoniae* from upper respiratory tract secretions. *J Clin Microbiol* 32: 2871-2872.
- Gratten M, Naraqi S, and D Hansman (1980) High prevalence of penicillin insensitive pneumococci in Port Moresby, Papua New Guinea. *Lancet* ii: 192-195.
- Handsfield HH, Dalu ZA, Martin DH, Douglas JM Jr, McCarty JM, and D Schlossberg (1994) Multicenter trial of single-dose azithromycin vs. ceftriaxone in the treatment of uncomplicated gonorrhea. Azithromycin Gonorrhea Study Group. *Sex Transm Dis* 21 (2): 107-11.
- Hashemi FB, Schutze GE, and EO Mason, Jr. (1996) Discrepancies between results by E-test and standard microbroth dilution testing of *Streptococcus pneumoniae* for susceptibility to vancomycin. *J Clin Microbiol* 34: 1546-1547.
- Heuck C (1998) WHO's laboratory programme. *World Health Forum* 19 (1): 68-70.
- Heuck CC and A Deom (1991) Health care in the developing world: need for appropriate laboratory technology. *Clin Chem* 37 (4): 490-496.
- Holmberg SD, Solomon SL, and PA Blake (1987) Health and economic impacts of antimicrobial resistance. *Rev Infect Dis* 9 (6): 1065-1078.
- Hovig B and EH Aandahl (1969) A selective method for the isolation of *Haemophilus* in material from the respiratory tract. *Acta Pathol Microbiol Scand* 77: 676-684.
- Isenberg HD, ed. (1992) *Clinical Microbiology Procedures Handbook. Volume 1*. American Society for Microbiology, Washington, DC.

Ison CA, Dillon JA, and JW Tapsall (1998) The epidemiology of global antibiotic resistance among *Neisseria gonorrhoeae* and *Haemophilus ducreyi*. *Lancet* 351 (Suppl 3): 8-11.

Jorgensen JH, Turnidge JD, and JA Washington. "Antibacteria susceptibility tests: dilution and disk diffusion methods." In: Murry PR, Pfaller MA, Tenover FC, Baron EJ and RH Tenover, eds (1999) *Manual of Clinical Microbiology*, 7th Edition. ASM Press, Washington, DC: pages 1526 – 1543.

Jorgensen JH, Ferraro MJ, McElmeel ML, Spargo J, Swenson JM, and FC Tenover (1994). Detection of penicillin and extended-spectrum cephalosporin resistance among *Streptococcus pneumoniae* clinical isolates by use of the E test. *J Clin Microbiol* 32: 159-163.

Kay BA, Bopp CA, and JG Wells. "Isolation and identification of *Vibrio cholerae* O1 from fecal specimens." In: Wachsmuth IK, PA Blake and O Olsvik, eds (1994) *Vibrio cholerae and cholera: molecular to global perspectives*. ASM Press, Washington, DC: pages 3 – 26. Worksheet.

Kay HD, Petrie HT, Burge JJ, and LW Klassen (1986) Rapid recovery of non-hemolyzed serum and untraumatized cells by using a new method of blood defibrination in vitro. *J Immunol Methods* 92: 251-260.

Kilian M. "*Haemophilus*." In: Balows A, Hausler WJ, Herrmann KL, Isenberg HD, and Shadomy, HJ, eds. (1991) *Manual of Clinical Microbiology: 5th ed.* American Society for Clinical Microbiology: ASM Press, Washington, DC: Pages 463 – 470.

Kim WJ and SC Park (1998) Bacterial resistance to antimicrobial agents: an overview from Korea. *Yonsei Med J* 39 (6): 488-494.

Klugman KP (1990) Pneumococcal resistance to antibiotics. *Clin Microbiol Rev* 3: 171-196.

Klugman KP and SA Madhi (1999) Emergence of drug resistance: Impact on bacterial meningitis. *Infect Dis Clin North Am* 13 (3): 637-646.

Koneman EW, Allen SD, Janda WM, Schreckenberger PC, and WC Winn, Jr. (1992) *Color Atlas and Textbook of Diagnostic Microbiology*. J.B. Lippincott Company (Lippincott Williams & Wilkins), Philadelphia, PA, USA.

Knapp JS, Fox KK, Trees DL, and WL Whittington (1997) Fluoroquinolone resistance in *Neisseria gonorrhoeae*. *Emerg Infect Dis* 3 (1): 333-339.

Knapp JS, Hale JA, Neal SW, Wintershed K, Rice RJ, and WL Whittington (1995) Proposed criteria for interpretation of susceptibilities of strains of *Neisseria gonorrhoeae* to ciprofloxacin, ofloxacin, enoxacin, lomefloxacin, and norfloxacin. *Antimicrob Agents Chemother* 39 (11): 2442-2445.

- Lalitha MK, Thomas K, Kumar RS, and MC Steinhoff (1999) Serotyping of *Streptococcus pneumoniae* by coagglutination with 12 pooled antisera. *J Clin Microbiol* 37: 263-265.
- Leowski J (1986) Mortality from acute respiratory infection in children less than 5 years of age: Global estimates. *World Health Stat Q* 39: 138-144.
- Lin FY, Ho VA, Khiem HB, Trach DD, Bay PV, Thanh TC, Kossaczka Z, Bryla DA, Shiloach J, Robbins JB, Schneerson R, and SC Szu (2001) The efficacy of a *Salmonella Typhi* Vi conjugate vaccine in two- to five-year old children. *N Engl J Med* 344 (17): 1263-1269.
- Lucas TJ (1979) An evaluation of 12 methods for the demonstration of penicillinase. *J Clin Pathol* 32: 1061-1065.
- Marshall SA, Rhomberg PR, and RN Jones (1997) Comparative evaluation of E-test for susceptibility testing *Neisseria meningitidis* with eight antimicrobial agents. An investigation using U.S. Food and Drug Administration regulatory criteria. *Diagn Microbiol Infect Dis* 27 (3): 93-97.
- Mbori-Ngacha, DA (1997) Rational approach to limiting emergence of antimicrobial drug resistance. *East Afr Med J* 74 (3): 187-189.
- McCarthy PL, Sharpe MR, Spiesel SZ, Dolan TF, Forsyth BW, DeWitt TG, Fink HD, Baron MA, and DV Cicchetti (1982) Observation scales to identify serious illness in febrile children. *Pediatrics* 70: 802-809.
- McLaughlin JC, "Vibrio." In: Murray PR, Baron EJ, Pfaller MA, Tenover FC, and RH Tenover, eds (1995) *Manual of Clinical Microbiology*. ASM Press, Washington, DC: pages 465 – 476.
- Miller MJ (1996) *A guide to specimen management in clinical microbiology*. Microbiology Technical Services, Dunwoody, GA, and Diagnostic Microbiology Section, Hospital Infections Program, Centers for Disease Control and Prevention, Atlanta, GA, USA.
- Morris GK, Merson MH, Huq I, Kibria AKMG, and R Black (1979) Comparison of four plating media for isolating *Vibrio cholerae*. *J Clin Microbiol* 9 (1): 79-83.
- Munson RS, Kabeer MH, Lenoir AA, and DM Granoff (1989) Epidemiology and prospects for prevention of disease due to *Haemophilus influenzae* in developing countries. *Rev Infect Dis* 11 (suppl 3): S5888 – S5897.
- Murray CJL and AD Lopez (1996) *Global Health Statistics: a compendium of incidence, prevalence and mortality estimates for over 200 conditions*. The Harvard School of Public Health on behalf of the World Health Organization and World Bank, Boston, MA, USA: pages 283-309.

O'Brien KL, Bronsdon MA, Dagan R, Yagupsky P, Janco J, Elliott J, Whitney CG, Yang Y-H, Robinson LE, Schwartz B, and GM Carlone (2001) Evaluation of a medium (STGG) for transport and optimal recovery of *Streptococcus pneumoniae* from nasopharyngeal secretions collected during field studies. *J Clin Microbiol* 39 (3): 1021-1024.

Oppenheim BA (1997) Antibiotic resistance in *Neisseria meningitidis*. *Clin Infect Dis* 24 (Suppl 1) : S98 – S101.

ParkCH, Lopen JS, and CB Cook (1978) Acidometric agar plate method for Ampicillin susceptibility testing of *Haemophilus influenzae*. *Antimicrob Agents Chemother* 13: 318-320.

Rice RJ and JS Knapp (1994) Antimicrobial susceptibilities of *Neisseria gonorrhoeae* representing five distinct resistance phenotypes. *Antimicrob Agents Chemother* 38(1): 155-158.

Sahm DF and FC Tenover (1997) Surveillance for the emergence and dissemination of antimicrobial resistance in bacteria. *Infect Dis Clin North Am* 11 (4): 767-783.

Schwartz B and RR Facklam (1994) *Manual for the National Surveillance of Antimicrobial Resistance of S. pneumoniae and H. influenzae: Epidemiological and Microbiological Methods*. WHO: Geneva, Switzerland and Centers for Disease Control and Prevention, Atlanta, GA, USA.

Shann F (1986) Etiology of severe pneumonia in children in developing countries. *Pediatr Infect Dis* 5: 247-252.

Silverman M, Stratton D, Diallo A, and LJ Egler (1977) Diagnosis of acute bacterial pneumonia in Nigerian children. *Arch Dis Child* 52: 925-931.

Sørensen UBS (1993) Typing of pneumococci by using 12 pooled antisera. *J Clin Microbiol* 31: 2097-2100.

Taranta A and MD Moody (1971) Diagnosis of streptococcal pharyngitis and rheumatic fever. *Pediatr Clin North Am* 18 (1): 125-143.

Tenover FC, Baker CN, and JM Swenson (1996) Evaluation of commercial methods for determining antimicrobial susceptibility of *Streptococcus pneumoniae*. *J Clin Microbiol* 34: 10-14.

Tenover FC and JE McGowan Jr. (1996) Reasons for the emergence of antibiotic resistance. *Am J Med Sci* 311 (1): 9-16.

United Nations Children's Fund (1999) *State of the World's Children*. UNICEF: New York, USA.

Van der Ende A, Schuurman IG, Hopman CT, Fijen CA, and J Dankert (1995) Comparison of commercial diagnostic tests for identification of serogroup antigens of *Neisseria meningitidis*. *J Clin Microbiol* 33: 3326-3327.

Wall RA, Corrah PT, Mabey DCW, and BM Greenwood (1986) The etiology of lobar pneumonia in the Gambia. *Bull World Health Organ* 64: 553-558.

Wang S (2002) "Multi-drug resistant *Neisseria gonorrhoeae* with decreased susceptibility to cefixime, Hawaii, 2001." Presentation at the 2001 International Conference on Emerging Infectious Diseases: Atlanta, Georgia, USA. [slide set can be viewed at ftp://ftp.cdc.gov/pub/infectious_diseases/iceid/2002/pdf/wang.pdf]

Weinberg GA, *et al* (1990) Antimicrobial susceptibility patterns in *Haemophilus* isolates from children in eleven developing nations. *Bull World Health Organ* 68: 179-184.

World Health Organization (1998) *Control of Epidemic Meningococcal Disease: WHO Practical Guidelines*, 2nd Edition. WHO: Geneva, Switzerland.

World Health Organization (1997) *Epidemic diarrhoeal disease preparedness and response: training and practice*. Participant's manual. Publication no. WHO/EMC/DIS/97.3. WHO: Geneva.

World Health Organization (1997) *Prevention and control of enterohemorrhagic Escherichia coli (EHEC) infections*. Report of a WHO Consultation. WHO/FSF/FOS/97.6. Geneva, Switzerland, 28 April – 1 May 1997.

World Health Organization (1995) *Guidelines for the control of epidemics due to Shigella dysenteriae 1*. Publication no. WHO/CDR/95.4. World Health Organization, Geneva.

World Health Organization (1993) *Laboratory Biosafety Manual*, 2nd edition. WHO: Geneva, Switzerland.

World Health Organization (1990) *Respiratory infections in children: Case management in small hospitals in developing countries*. Document WHO/ARI/50.5.

World Health Organization (1987) *Manual for the laboratory investigations of acute enteric infections*. Publication no. WHO/CDD/83.3 rev 1. World Health Organization: Geneva, Switzerland.

World Health Organization (1980) *Manual of basic techniques for a health laboratory*. WHO: Geneva, Switzerland.

Wright PE, Thompson J, McKee KT Jr., Vaughan WK, Sell SH and DT Karzon (1981) Patterns of illness in the highly febrile young child: epidemiologic, clinical, and laboratory correlates. *Pediatrics* 67: 694-700.

Yeung KH, Ng LK, and JA Dillon (1993) Evaluation of Etest for testing antimicrobial susceptibilities of *Neisseria gonorrhoeae* isolates with different growth media. *J Clin Microbiol* 31 (11): 3053-3055.

Index

Note: Page numbers followed by *t* or *f* or *n* refer to tables or figures or footnotes, respectively

A

Access to laboratory, 163–164
 Accident response, 167
 Acid production test
 N. gonorrhoeae, 66*f*, 69*f*, 70*f*, 71*t*, 75–77
 N. meningitidis, 70*t*, 71*t*, 77
 See also Carbohydrate utilization test
 Acidometric agar, 175
 Acquisition of media and reagents, 173
 ATCC. **See** American Type Culture Collection
Aeromonas spp., 147
 Aerosols and aerosolization, 164–165
 Agar dilution
 Etest® comparison, 20, 41, 59–60, 61, 99
 H. influenzae, 19, 21
 N. gonorrhoeae, 98*t*
 S. pneumoniae, 53, 59, 61
 Agglutination
 H. influenzae, 6*f*, 7–9, 7*n*
 N. meningitidis, 31*f*, 32–35, 35*f*
 quality control of reagents, 172
 S. pneumoniae, 52–53
 S. Typhi, 110–111, 112*f*
 Shigella, 128–130, 131*f*
 V. cholerae, 149–151
 Alkaline peptone water, 175–176, 293–295
 American Type Culture Collection (ATCC),
 171, 331
 Amies medium, 199
 Amoxicillin
 S. pneumoniae, 62
 S. Typhi, 104
 Shigella, 133

Ampicillin

H. influenzae, 14, 15*f*, 19*t*, 26
S. Typhi, 113*t*, 117*t*, 119*f*
Shigella, 132–133, 133, 136*t*, 138*f*
V. cholerae, 153, 158*t*
 Antimicrobial susceptibility testing, 1, 2,
 86–87
 classification of results, 85
 diarrheal disease outbreak, 288
 H. influenzae, 13–27
 N. gonorrhoeae, 82–101
 N. meningitidis, 38–43
 rationale, 1, 2
 S. pneumoniae, 53–61
 S. Typhi, 111–118
 Shigella, 130–139
 V. cholerae, 142, 151–159
 See also Quality control, antimicrobial
 susceptibility testing; specific test;
 Surveillance
 Autoclaves, 165–166
 Azithromycin, 63, 64, 84, 97*t*, 100*t*

B

Bacitracin-chocolate agar, 179
 Bile solubility test, 48*f*, 50–52
 Bismuth sulfite agar, 176–177
 S. Typhi, 105
 Bleach, 167
 Blood, defibrinated, 173
 Blood agar, 177
 H. influenzae, 6*f*
 N. meningitidis, 31*f*
 S. pneumoniae, 46, 47*f*, 48*f*, 60
 S. Typhi, 105

Blood culture broth, 177–178
 Blood cultures, 227–228
 identifying positive blood culture bottles, 228
 inoculation, 228
 subculturing, 228–229
 Blood specimen collection and transport, 219–223

Bone marrow specimens, 248
 Broth microdilution, 259–262
 Etest® comparison, 20, 59–60
 N. meningitidis, 38
 S. pneumoniae, 53, 59

C

Carbohydrate utilization test
 N. meningitidis, 31*f*, 36, 37*f*
 for *N. gonorrhoeae*, 36*t*
 See also Acid production test
 Cary–Blair medium, 199
 Catalase test, 66*f*, 71*t*, 72, 73*f*
 Cefixime
 N. gonorrhoeae, 64, 89, 97*t*, 98*t*, 100*t*
 typhoid fever, 104

Cefotaxime, 58*t*
 Ceftriaxone
 H. influenzae, 26
 N. gonorrhoeae, 89, 97*t*, 98*t*, 100*t*
 N. meningitidis, 42
 S. pneumoniae, 58*t*, 62

Cephalosporins
 N. gonorrhoeae, 63, 64
 Shigella, 133
 typhoid fever, 104

Cerebrospinal fluid
 collection and transport, 223–226
 culturing, 244–248
 Gram stain procedure, 241–244
 latex agglutination test, 244
 primary laboratory procedures, 240–248

Chloramphenicol
 H. influenzae, 14, 15*f*
 N. meningitidis, 38, 39*f*, 42, 42*t*
 S. pneumoniae, 54*t*, 56, 58*t*
 S. Typhi, 104, 113*t*, 117*t*, 119*f*
 Shigella, 133, 136*t*, 138*f*
 V. cholerae, 142, 153, 158*t*

Chocolate agar, 178, 229
 with bacitracin, 179
 H. influenzae, 5, 6*f*, 7, 9, 17, 19*t*, 20
 N. gonorrhoeae, 64, 66*f*, 74, 81, 93
 N. meningitidis, 31*f*
 quality control, 179
 S. pneumoniae, 46, 48*f*, 56
 S. Typhi, 105

Cholera, 141
 laboratory supplies for diarrheal disease outbreak, 281, 284–286*t*, 287
 See also *Vibrio cholerae*

Ciprofloxacin
 N. gonorrhoeae, 84, 97*t*, 98*t*, 100*t*
 S. pneumoniae, 62
 S. Typhi, 113, 117*t*
 Shigella, 132–133, 136*t*
 V. cholerae, 142, 153, 158*t*

Clindamycin, 62
 Clothing, protective, 168
 Colistin resistance test, 69*f*, 70*f*, 71*t*, 72–74
 Cotrimoxazole. See Trimethoprim-sulfamethoxazole

Culture media abbreviations, 174–175
 Cystine trypticase agar, 179–180
 N. gonorrhoeae, 75–77
 N. meningitidis, 36, 37*f*

D

Defibrinated blood, 173
 Desoxycholate citrate agar, 105, 180–181
 Diarrheal disease outbreak, 288
 antimicrobial susceptibility testing, 288
 causes, 287
 data form, 280*f*
 fecal specimen processing, 288–297
 laboratory supplies for, 281, 282–286*t*, 287

Disinfectants and germicides, 165, 166–167
 Disk diffusion test

H. influenzae, 13–14, 16–18
 N. gonorrhoeae, 83, 91–95, 96*f*
 S. pneumoniae, 53, 56–58
 S. Typhi, 111–112, 113–118
 Shigella, 130–131, 134–139
 V. cholerae, 151, 153, 154–159

Dorset egg medium, 199–200, 300
 Doxycycline, 141–142, 153

Dry ice, 320–321
 Dysentery, 121
 laboratory supplies for diarrheal disease
 outbreak, 281, 282–283*t*, 287
 See also *Shigella* spp., *S. dysenteriae*

E

Enoxacin, 132–133
 Enteric fever, 103
Enterobacteriaceae spp., 146, 147
 Enzyme substrate test, 66*f*, 68–71, 71*t*,
 77–79, 80*f*
 Erythromycin
 S. pneumoniae, 62
 V. cholerae, 142, 153
 Etest® antimicrobial gradient strip, 331,
 22–25*ff*
 accuracy, 20, 53, 59–60
 H. influenzae, 13–14, 19–21
 N. gonorrhoeae, 95–101
 N. meningitidis, 38, 40–41, 42–43
 S. pneumoniae, 53, 58–61
 storage of test strips, 59, 98

F

Fecal specimens
 collection, 275–278
 diarrheal disease outbreak response
 laboratory processing, 287
 laboratory supplies for, 281, 282–286*t*
 documentation, 280*f*
 laboratory processing, 287–288
 S. Typhi recovery, 105, 106*f*, 289–290
 Shigella recovery, 291–292
 V. cholerae recovery, 143*f*, 292–296
 preparation for shipment, 278–279
 transport media, 275–277, 278
 Fever of unknown origin, 219
 Fire prevention, 166
 Flowchart
 H. influenzae, 6*f*
 N. gonorrhoeae, 66*f*, 69*f*
 N. meningitidis, 31*f*
 preparation of McFarland turbidity
 standard, 210*f*
 S. pneumoniae, 48*f*

S. Typhi, 106*f*, 114*t*
Shigella, 123*f*
V. cholerae, 143*f*
 Fluoroquinolone
 H. influenzae, 26
 N. gonorrhoeae, 63, 84
 N. meningitidis, 42
 Shigella sp., 133
 typhoid fever, 104
 Formalin, 33–34
 Frozen storage, 299, 301–302, 304, 306–307.
 See also lyophilization
 Furazolidone, 142, 153
V. cholerae, 153*t*, 157*f*, 158*t*

G

GC. See *Neisseria gonorrhoeae*
 GC-chocolate agar, 64, 181–182
 GC-susceptibility test medium, 91, 182–183
 Gloves, 168
 Gonococcal selective media, 183–184
 Gonococcus–chocolate agar medium.
 See GC-chocolate agar
 Gonococcus–susceptibility test medium.
 See GC-susceptibility test medium
 Gordon and McLeod's reagent, 30*n*, 65*n*,
 208
 Gram-negative broth, 184
 Gram stain test
 cerebrospinal fluid, 241–244
 H. influenzae, 6*f*
 N. gonorrhoeae, 65, 66*f*, 69*f*
 N. meningitidis, 31*f*
 reagents, 202–204
 S. pneumoniae, 48*f*
 S. Typhi, 105, 106*f*, 107*f*
 V. cholerae, 145, 146*t*, 148
 Greaves solution, 200
 Growth factor requirements
 H. influenzae, 5, 6*f*, 9–13, 10*t*, 12*t*
 V. cholerae, 142
 Growth supplement
 H. influenzae, 9
 N. gonorrhoeae, 64
 S. Typhi, 113, 114*f*

H

Haemin. See X Factor

Haemophilus aphrophilus, 10*t*

Haemophilus haemolyticus, 10*t*, 11, 13,
186–187

Haemophilus influenzae, 5–27

antimicrobial susceptibility testing

by antimicrobial gradient strip, 13–14,
19–21, 22–25*ff*

β-lactamase testing, 14, 26–27, 175
control strain, 14–16

by disk diffusion, 13–14, 16–18, 18*f*

documentation and reporting
procedures, 15*f*, 27

media, 14, 16, 175, 184–185, 196

minimal inhibitory concentration
(MIC), 14, 18–21, 23*f*, 24*f*, 25*f*

quality control, 19*t*

quality control, 14–16, 171

surveillance, 18–19, 21–26

suspension characteristics, 16–17, 20

test selection, 13–14

antisera, 7

associated diseases, 5

culturing, 5, 7, 184–185, 186–187,
201–202

from cerebrospinal fluid, 246

growth factor requirements, 10*t*

identification, 5

in cerebrospinal fluid, 240–248

flowchart, 6*f*

growth factor requirements, 5, 7, 9–13,
10*t*

hemolytic reactions, 13

media, 178–179

nasopharyngeal swab specimens,
251–254

presumptive, 232, 233*f*, 233*t*, 234*f*, 237*f*
rapid, 5

serotype testing, 5–9, 7*n*

suspension characteristics, 7–8

Quad ID plates, 7, 11–13, 12*f*

serotypes, 5, 7

storage media and conditions, 199–200

frozen storage, 301–302

lyophilization, 302–303

recovery from storage, 303

short-term, 300–301

subculturing, 228–229

V Factor, 5, 6*f*, 9–13, 10*t*, 11*f*, 12*f*

vaccines, 5

vs. *H. haemolyticus*, 13

X Factor, 5, 6*f*, 9–13, 10*t*, 11*f*, 12*f*

Haemophilus paraphrophilus, 10*t*

Haemophilus parahaemolyticus, 10*t*

Haemophilus parainfluenzae, 10*t*

Haemophilus test medium, 7, 14, 184–185

Hafnia spp., 127

Handwashing, 164

Heart infusion agar, 185

V. cholerae, 142, 145, 148

Heart infusion rabbit blood agar, 185–186

Hektoen enteric agar, 186

Horse blood agar, 186–187

Hucker modification Gram stain reagents,
202–204

Hydrogen peroxide (H₂O₂), in
superoxol/catalase test, 72

I

IATA. See International Air Transport
Association

Identification

cerebrospinal fluid specimens, 240–248

fecal specimens, 287–297

H. influenzae, 5–13, 232, 233*f*, 234*f*, 237*f*

N. gonorrhoeae, 64–82

N. meningitidis, 230*f*, 231*f*, 232, 233*f*, 236,
238*f*

antisera, 30–37

positive blood culture bottles, 228

presumptive, 229–240

S. pneumoniae, 46–53, 230*f*, 232, 233*f*,
234*f*, 237–238, 239*f*

S. Typhi, 104–111, 231*f*, 238, 240*f*

Shigella, 121–130

V. cholerae, 142–151

International Air Transport Association
(IATA), 310–311

International Civil Aviation Organization,
309–310

International Collaboration on Gonococci,
83, 86*n*

J

JEMBEC® plates, 200
Joint fluid, 249

K

Kirby-Bauer test, 14
Kligler iron agar, 187–188
 S. Typhi identification, 105–108, 106*f*
 Shigella identification, 122, 123*f*, 125*t*,
 126*f*
 V. cholerae identification, 145, 146–147,
 148*f*
Klingella denitrificans, 68, 70*f*, 72, 73*f*, 74, 77,
 79
Kovac's oxidase test
 N. gonorrhoeae, 65–67, 66*f*, 67*f*
 N. meningitidis, 30–32, 31*f*, 33*f*
 reagent, 208
 V. cholerae, 142–145

L

Laboratory procedures and practices
 acquisition of media and reagents, 173
 blood collection and transport, 219–223
 cerebrospinal fluid collection and
 transport, 223–226
 fecal specimen processing, 287–297
 preparation of media and reagents,
 173–174
 quality control of materials, 170–173
 response to diarrheal disease outbreak,
 281, 282–286*t*, 287
 See also Antimicrobial susceptibility
 testing; Identification; Safety
 practices
Loeffler's methylene blue stain, 204–205
Lumbar puncture, 224, 225*f*
Lyophilization, 299–300, 302–303, 304–305,
 307
Lysine iron agar, 188
 quality control, 188–189
 S. Typhi identification, 108, 110*t*
 Shigella identification, 123*f*, 125, 125*t*,
 127–128, 129*f*
 V. cholerae identification, 145, 146*t*,
 147–148

M

MacConkey agar, 105, 189
Martin-Lewis agar, 183, 189
McFarland turbidity standards, 209–214
Media
 acidometric agar, 175
 acquisition, 173
 alkaline peptone water, 175–176,
 293–295
 Amies medium, 199
 bismuth sulfite agar, 105, 176–177
 blood agar, 6*f*, 31*f*, 46, 47*f*, 48*f*, 60, 105,
 177
 blood culture broth, 177–178
 Cary-Blair medium, 199
 chocolate agar, 229
 with bacitracin, 179
 with TSA base and growth
 supplement, 178–179
 commonly abbreviated culture media,
 174–175
 cystine trypticase agar, 36, 37*f*, 75–77,
 179–180
 desoxycholate citrate agar, 105, 180–181
 Dorset egg, 199–200
 GC-chocolate agar, 181–182
 GC-susceptibility test medium, 182–183
 gonococcal selective, 183–184
 gram-negative broth, 184
 Greaves solution, 200
 Haemophilus test medium, 7, 14,
 184–185
 heat infusion agar, 142, 145, 148, 185
 heat infusion rabbit blood agar,
 185–186
 Hektoen enteric agar, 186
 horse blood agar, 186–187
 JEMBEC® plates, 200
 Kligler iron agar, 187–188
 lysine iron agar, 187–188
 MacConkey agar, 189
 Martin-Lewis agar medium, 189
 modified Thayer-Martin agar, 183–184
 motility, 190
 Mueller-Hinton agar, 190–191
 plus 5% blood, 191–192
 phosphate-buffered saline, 192
 physiological saline, 193

- polysaccharide, 193–194
- preparation, 173–174
- quality control, 169–171
- selenite broth, 194
- skim-milk tryptone glucose glycerol transport medium, 200–201
- SS agar, 194
- Stuarts medium, 199
- sulfide-indole-motility medium, 194–195
- suppliers/manufacturers, 214, 215–217
- thiosulfate citrate bile salts sucrose agar, 195
- Todd–Hewitt broth, 195–196
- trans-isolate, 201–202
- transgrow, 201
- triple sugar iron agar, 187–188
- tryptone-based soy agar, 196
- tryptone soy broth, 197
- tryptone soy sheep blood agar, 197
- urea, 197–198
- xylose lysine desoxycholate agar, 198–199
- See also index listing for specific medium
- Meningitis
 - antimicrobial resistance, 38
 - collection and transport of blood cultures, 219
 - epidemics, 29
 - H. influenzae*, 5, 7
 - N. meningitidis*, 29, 32
 - S. pneumoniae*, 45
- Meningococcal disease
 - epidemic risk, 29
 - N. meningitidis*, 29
- Methylene blue stain, 204–205
- Metronidazole, 133
- Middle ear fluid specimens, 249
- Minimal inhibitory concentration (MIC) testing
 - H. influenzae*, 14, 18–21, 23f, 24f, 25f
 - N. gonorrhoeae*, 83, 84, 97t, 99, 100t, 101
 - N. meningitidis*, 38, 40–41, 42–43, 42t, 259–262
 - S. pneumoniae*, 53, 58–61
 - See also index listing for specific test
- Modified Thayer–Martin agar, 183–184, 189
- Moraxella catarrhalis*, 68, 74, 77
 - identification, 79
- Motility agar test, 190
 - quality control, 190
 - S. Typhi*, 108–110
 - Shigella*, 125, 125t, 127f
- Mueller–Hinton agar, 60, 91, 113, 115, 134, 154, 182, 190–191
 - H. influenzae*, 14
 - plus 5% blood, 40, 56, 60, 191–192
- N
 - Nalidixic acid
 - S. Typhi*, 113, 113t, 117t, 119f
 - Shigella*, 132–133, 136t, 138f
 - V. cholerae*, 153, 153t, 157f, 158t
 - Nasopharyngeal swab specimens, 251–254
 - National Collection of Type Cultures (NCTC), 171, 331
 - NCCLS, xx, 2, 14, 14n, 41n, 53n, 82n, 85n, 86n, 112n, 131n, 151n
 - H. influenzae* antimicrobial susceptibility testing quality control, 19t
 - N. gonorrhoeae* testing recommendations, 82–83, 84, 85–86, 87, 88, 91–93
 - N. meningitidis* antimicrobial susceptibility testing quality control, 41
 - S. pneumoniae* antimicrobial susceptibility testing quality control, 55, 58t, 59, 61
 - S. Typhi* antimicrobial susceptibility testing quality control, 115–116
 - V. cholerae* antimicrobial susceptibility testing quality control, 153, 156
 - NCTC. See National Collection of Type Cultures
 - Neisseria catarrhalis*, 26t, 70f, 77
 - Neisseria cinerea*, 70f, 74, 77, 78f
 - Neisseria elongata*, 68, 70f
 - Neisseria flavescens*, 70f
 - Neisseria gonorrhoeae*, 26t, 101–102
 - antimicrobial susceptibility testing
 - by antimicrobial gradient strip, 95–101
 - β -lactamase production, 87, 89, 90–91
 - classification of results, 85
 - by disk diffusion, 83, 84, 91–95, 96f
 - documentation and reporting procedures, 64, 92f, 101

- indications for retesting, 101
 - interpretative criteria, 85–86, 97*t*, 98*t*, 99–101
 - media, 91, 182–183
 - methods, 82–84, 89–90
 - minimal inhibitory concentration (MIC), 83, 84, 97*t*, 99, 100*t*, 101
 - nitrocefin test, 90–91
 - penicillin-tetracycline resistance phenotypes, 87–89, 88*t*
 - quality control, 84, 91–93, 95, 99, 171
 - surveillance, 64, 86–87, 89
 - associated diseases, 63
 - clinical characteristics of infection, 63
 - culturing, 64, 181–184, 204, 263, 264*t*, 268–269
 - identification, 67–68, 193, 204, 208, 263, 274
 - acid production test, 70*f*, 71*t*, 75–77, 78*f*
 - biochemical and enzymatic tests, 68–71, 70*t*
 - catalase test, 70*f*, 71*t*, 72, 73*f*
 - colistin resistance test, 72–74
 - differential, 68
 - enzyme substrate test, 71*t*, 77–79, 80*f*
 - Gram stain, 269–274, 273*f*
 - methods, 68
 - nitrate reduction test, 70*f*, 71*t*, 79–82, 83*f*
 - oxidase test, 65–67, 67*f*
 - polysaccharide production test, 70*f*, 71*t*, 74–75, 76*f*
 - presumptive, 64–66, 66*f*
 - procedure, 66*f*, 69*f*
 - quality control, 68–71, 71*t*, 171
 - superoxol test, 70*f*, 72, 73*f*
 - incubation conditions, 265–268
 - morphology, 269, 270*t*, 272*f*
 - neonatal and pediatric infection, 63
 - resistance patterns, 63–64, 84
 - specimen collection and transport, 263, 266–267*t*
 - storage media and conditions, 264–265, 303–305
 - transport media, 201, 264–265
 - subtyping, 89
 - transmission, 63
 - urethral infection, 67–68
- Neisseria lactamica*, 26*t*, 68, 70*f*, 74, 77, 78*f*, 79
- Neisseria meningitidis*, 43
- antimicrobial susceptibility testing, 38
 - by antimicrobial gradient strip, 38, 40–41, 42–43
 - by broth microdilution, 38
 - documentation and reporting procedures, 39*f*, 43
 - media, 42
 - methods, 38
 - minimal inhibitory concentration (MIC), 38, 40–41, 42–43, 42*t*, 259–262
 - quality control, 41–43, 171
 - surveillance, 42
 - suspension characteristics, 40, 42
- associated diseases, 29
- culturing, 30, 179–180, 201–202, 247
- epidemic potential, 29
- identification, 34, 68, 77, 79, 208
- acid production test, 70*f*
 - carbohydrate utilization tests, 31*f*, 36, 37*f*
 - in cerebrospinal fluid, 240–248
 - colistin resistance test, 70*f*, 74
 - commercial kits, 37
 - nasopharyngeal swab specimens, 251–254
 - outer membrane protein subtyping, 30
 - oxidase test, 30–32, 33*f*
 - presumptive, 230*f*, 231*f*, 232, 233*f*, 233*t*, 236, 238*f*
 - procedure, 30, 31*f*
 - rapid sugar utilization tests, 37
 - serogroup, 32–35
 - superoxol/catalase reaction test, 70*f*
 - suspension characteristics, 33–34, 35*f*
- laboratory-acquired infection, 163
- resistance profile, 38
- safe procedures in testing, 30, 227
- serogroups, 29, 32
- storage media and conditions, 199–200
- frozen storage, 301–302
 - lyophilization, 302–303
 - recovery from storage, 303
 - short-term, 300–301
- subculturing, 228–229
- vaccine, 30

Neisseria mucosa, 70f, 78f
Neisseria polysaccharea, 70f
Neisseria sicca, 26t, 70f
Neisseria subflava, 70f, 74, 77
Neisseria weaveri, 68
 Nicotinamide adenine dinucleotide.

See V Factor

Nitrate reduction test
 mechanism, 79–81
N. gonorrhoeae, 66f, 69f, 70f, 71t, 79–82, 83f
 reagents, 205–206
 Nitrocefin test
H. influenzae, 26, 175
N. gonorrhoeae, 90–91
 reagent preparation, 90, 206–207

Nitrofurans, 133

Nomograph, 241, 241n, 242f

Norfloxacin

Shigella, 132–133

V. cholerae, 142

O

Ofloxacin, 97t, 98t, 100t

Optochin susceptibility test, 46–49, 46n, 48f, 49f, 52

Otitis media, *S. pneumoniae*, 45

Oxacillin, 54t, 56, 58t

Oxidase testing

Gordon and McLeod's reagent, 30n, 65n, 208

N. gonorrhoeae, 65–67, 67f

N. meningitidis, 30–32

reagent, 208

V. cholerae, 142–145, 146t

P

Packing and shipping regulations

classification of specimens, 311

coordination with recipient, 309, 322

for diagnostic specimens, 311, 319–320, 320f

goals, 309

for infectious substances, 311, 317–319, 319f

labeling and marking requirements, 312–317t

methods of transport, 309

regulatory organizations, 309–310

scope of, 311

shipper's declaration form, 311, 321–322

use of dry ice, 320–321

Penicillin

N. gonorrhoeae, 63, 87–89, 88t, 97t, 98t

N. meningitidis, 38, 39f, 41, 42, 42t

S. pneumoniae, 56, 58–59, 58t

Phosphate-buffered saline medium, 192

Physiological saline, 193

Pivmecillinam, 132–133

Pleural fluid specimens, 248

Pneumonia, 219

collection and transport of blood
 cultures, 219

H. influenzae, 5

S. pneumoniae, 45

Polysaccharide production test, 66f, 70, 70f, 71t, 74–75, 76f, 193–194

Proteus spp., 127, 128, 148, 188

Providencia spp., 127, 128, 148, 188

Pseudomonas spp., 146

Q

QC. See Quality control

Quad ID plates, 11–13, 12f

Quality control, 169

acidometric agar, 175

alkaline peptone water, 176

antimicrobial susceptibility testing

H. influenzae, 14–16, 15f, 19t

N. gonorrhoeae, 84, 85–86, 91–93, 98t, 99

N. meningitidis, 39f, 41–43, 42t

S. pneumoniae, 55, 58t

S. Typhi, 115–117, 117t

Shigella, 136

V. cholerae, 156–159, 158t

bismuth sulfite agar, 176–177

blood agar, 177

blood culture broth, 177–178

chocolate agar, 179

cystine trypticase agar, 180

desoxycholate citrate agar, 180–181

GC-chocolate agar, 182

GC-susceptibility test medium, 183

gonococcal selective media, 184
 gram-negative broth, 184
Haemophilus test medium, 185
 heart infusion agar, 185
 heart infusion rabbit blood agar, 186
 Hektoen enteric agar, 186
 horse blood agar, 187
 Kligler iron agar, 188
 lysine iron agar, 188–189
 MacConkey agar, 189
 of media, 169–171
 motility medium, 190
 Mueller-Hinton agar, 191
 plus sheep blood, 192
N. gonorrhoeae identification, 71*t*, 77, 81
 polysaccharide medium, 193–194
 preparation of McFarland turbidity
 standard, 210*f*
 of reagents, 172
 in reference laboratories, 3
 selenite broth, 194
 sources of strains for, 171, 331
 SS agar, 193–194
 sulfide-indole-motility medium, 195
 thiosulfate citrate bile salts sucrose agar,
 195
 Todd-Hewitt broth, 196
 triple sugar iron agar, 188
 tryptone-based soy agar, 196
 tryptone soy broth, 197
 tryptone soy sheep blood agar, 197
 urea medium, 198
 xylose lysine desoxycholate agar, 199
 Quellung typing of *S. pneumoniae*, 255–257,
 258*t*
 Quinolone resistance, 104

R

Reagents

acquisition, 173
 Gram stain (Hucker modification),
 202–204
 Loeffler's methylene blue stain, 204–205
 nitrate reduction test, 205–206
 nitrocefin, 206–207
 oxidase, 208
 preparation, 173–174

quality control, 172
 sodium desoxycholate, 209
 suppliers/manufacturers, 214, 215–217*t*
 Reference laboratories
 purpose, 3, 86
 resource and capability requirements, 2,
 3–4, 59
 WHO recommendations, 1, 3, 288
 Refrigeration equipment, 166
 frozen storage of specimens, 299,
 301–302, 304, 306–307
 Regulations, shipping. *See* Packing and
 shipping regulations
 Relative centrifugal force (RCF).
 See Nomograph
 Rifampicin
 N. meningitidis, 38, 39*f*, 41, 42, 42*t*
 S. pneumoniae, 62
 Rifampin. *See* Rifampicin

S

Safety practices

accident response, 167
 aerosolization, 164–165
 autoclave use, 165–166
 blood collection and transport, 220
 cleaning, 166
 decontaminating spills, 167
 disinfectants and germicides, 165,
 166–167
 disposal of contaminated materials, 165
 eating in laboratory areas, 164
 fire prevention, 166
 formalin use, 33–34
 handwashing, 164
 laboratory access, 163–164
 laboratory reference resources, 168
N. meningitidis, 30, 33–34
 pipetting, 164
 protective clothing, 168
 refrigeration equipment maintenance,
 166
 requirements for BSL-2 facilities, 163
 sharps handling and disposal, 164
 shipping of specimens, 309–322
 sources of risk, 163
 staff vaccination, 227
 typhoid fever prevention, 103

- Salmonella* Enteritidis, 103
- Salmonella* Paratyphi, 103, 110*t*, 111
- Salmonella* Typhi, 103, 118–120, 189
 - antigen response, 103, 110–111
 - antimicrobial susceptibility testing
 - antimicrobial agents for, 113*t*
 - by disk diffusion, 113–117
 - documentation and reporting
 - procedures, 105, 107*f*, 119*f*
 - indications for supplemental testing, 113
 - interpretive criteria, 117*t*, 118
 - laboratory resources for, 112
 - medium, 113, 115–116, 176–177
 - methods, 111–112
 - procedure, 114*f*
 - quality control, 115–117, 171
 - in vivo performance and, 112
 - clinical course of infection, 103
 - culturing, 105, 184, 186
 - diagnosis of typhoid fever, 104
 - distribution in infected host, 103
 - identification, 194, 198–199
 - culturing medium, 180–181
 - documentation and reporting
 - procedures, 105, 107*f*
 - in fecal specimens, 287–288, 289–290
 - iron agar tests, 105–108, 109*f*
 - methods, 105, 108
 - motility agar test, 108–110
 - presumptive, 231*f*, 238, 240*f*
 - procedure, 105, 106*f*
 - slide serology, 110–111, 112*f*
 - specimen collection, 104–105
 - urea screening, 110
 - laboratory-acquired infection, 163, 227
 - storage of isolates, 306–307
 - transmission, 103
 - typhoid mortality and morbidity, 103
 - vaccines, 103, 227
- Salmonella-Shigella* agar, 194
- Selenite broth, 194
- Sheep blood agar, 177
 - S. pneumoniae*, 56
 - See also Blood agar
- Shigella* spp., 132, 133, 139
 - antimicrobial susceptibility testing, 130–131
 - antimicrobial agents for use in, 132–133, 133*t*
 - documentation and reporting
 - procedures, 132, 135, 138*f*
 - general guidelines, 131–132
 - inoculum suspension characteristics, 134
 - medium, 134
 - procedure, 134–136
 - quality control, 136, 171
 - sources of error, 136, 137–139
 - surveillance, 132
 - in vivo performance and, 133
- antisera, 128
- boydii*, 121, 122, 128
- clinical characteristics of infection, 121
- culturing, 186
- dysenteriae*
 - clinical characteristics, 121
 - identification, 130*t*, 189, 199
 - in fecal specimens, 291–292
 - serologic, 128–130
- flexneri*, 121, 122, 130*t*, 181, 188, 294*f*, 295*f*
- identification, 189, 198–199
 - agglutination, 130, 131*f*
 - culturing medium, 180–181
 - documentation, 124*f*
 - in fecal specimens, 287–288, 291–292
 - iron agar tests, 122, 126*f*
 - lysine iron agar screen, 125, 127–128, 129*f*
 - methods, 122
 - motility agar test, 125, 127*f*
 - procedure, 121–122, 123*f*
 - serologic, 128–130
 - urea medium screens, 127
- laboratory-acquired infection, 163
- recovery in fecal specimens, 287–288, 291–292
- sonnei*, 121, 130*t*
- storage of isolates, 306–307
- subgroup and serotype classification, 121, 130*t*
- Shipping regulations. See Packing and shipping regulations
- Sickle cell disease, 45
- Silica gel packs, 301

- Skim-milk tryptone glucose glycerol transport medium, 200–210, 252–254, 305
- Slide agglutination. *See* Agglutination
- Sodium desoxycholate reagent, 209
- Sources of prepared media and reagents, 214, 215–217*t*
- Spectinomycin, 63, 97*t*, 98*t*, 100*t*
- Spills, 167
- SS agar, 194
- Storage and handling
 - agar medium, 173–174
 - antimicrobial disks, 117, 135, 139
 - blood specimens, 219–223
 - cerebrospinal fluid, 223–226, 247–248
 - disposal of contaminated materials, 165
 - Etest® antimicrobial gradient strips, 19, 59, 98
 - formalin, 33–34
 - H. influenzae* antisera, 7
 - long-term storage, 299–300, 301–303, 304–305, 306–307
 - N. gonorrhoeae* specimens, 64, 263–268
 - N. meningitidis* antisera, 32
 - N. meningitidis* isolates, 30, 33–34
 - need for storage, 299
 - reagents, 172
 - S. pneumoniae* isolates, 59
 - sharps, 164
 - short-term storage, 299, 300–301, 306
 - transport and storage media, 199–202
 - transport of biohazard materials, 166
 - See also* Packing and shipping regulations
- Streptococci, α -hemolytic viridans, 46–49
- Streptococcus pneumoniae*, 62
 - antimicrobial susceptibility testing
 - by antimicrobial gradient strip, 53, 58–61
 - by disk diffusion, 53, 56–58
 - documentation and reporting procedures, 54*f*, 62
 - media, 55, 56, 60
 - methods, 53
 - minimal inhibitory concentration (MIC), 53, 58–61
 - quality control, 55, 171
 - surveillance, 45, 58–59, 62
 - suspension and inoculum qualities, 55, 56–57, 60
 - associated disease, 45
 - culturing, 46, 47*f*, 195–196, 201–202
 - in cerebrospinal fluid, 246
 - identification, 46
 - bile solubility test, 50–52
 - in cerebrospinal fluid, 240–248
 - commercial kits, 52
 - nasopharyngeal swab specimens, 251–254
 - optochin susceptibility test, 46–49, 49*f*, 52
 - presumptive, 230*f*, 232, 233*f*, 233*t*, 234*f*, 237–238, 239*f*
 - procedure, 48*f*
 - serotyping and Quellung typing, 52–53, 255–257, 258*t*
 - vs.* viridans streptococci, 46–49
 - screening, 45
 - storage media and conditions, 199–200
 - frozen storage, 301–302
 - long-term strategies, 301
 - lyophilization, 302–303
 - recovery from storage, 303
 - short-term, 300–301
 - subculturing, 228–229
 - susceptible populations, 45
 - vaccines, 45
- Streptomycin, 133
- String test
 - reagent, 209
 - V. cholerae* identification, 145, 146, 147*f*
- Stuarts medium, 199
- Subtype characterization, 89
- Sulfide-indole-motility medium, 125*f*, 194–195
- Sulfonamide drugs
 - H. influenzae*, 16
 - N. meningitidis*, 38, 41, 42
 - S. pneumoniae*, 55
 - S. Typhi*, 118
 - Shigella*, 133, 135, 139
 - V. cholerae*, 153
- Superoxol test, 72, 73*f*
 - N. gonorrhoeae*, 66*f*, 69*f*, 70*f*, 71*t*, 72, 73*f*
- Surveillance, 86–87
 - H. influenzae*, 18–19, 21–26

N. gonorrhoeae, 64, 86–87, 89
N. meningitidis, 42
S. pneumoniae, 45, 58–59, 62
Shigella, 132
V. cholerae, 152

T

Tetracycline
N. gonorrhoeae, 63, 87–89, 88*t*, 97*t*, 98*t*
S. pneumoniae, 62
Shigella, 133
V. cholerae, 141–142, 153, 153*t*, 157*f*, 158*t*
 Thiosulfate citrate bile salts sucrose agar, 195
 Todd–Hewitt broth, 195–196
 Trans-isolate medium, 201–202, 247–248, 247*f*
 Transgrow medium, 201
 Transport media, 199–202, 264–265
 for cerebrospinal fluid cultures, 248
 for fecal specimens, 275–277
 for nasopharyngeal swab specimens, 252–254
 Trimethoprim-sulfamethoxazole
H. influenzae, 14, 15*f*, 19*t*
N. meningitidis, 39*f*, 42, 42*t*
S. pneumoniae, 54*t*, 55, 56, 58*t*, 60
S. Typhi, 104, 113*t*, 117*t*, 118, 119*f*
Shigella, 132–133, 133, 135, 136*t*, 137*f*, 138*f*, 139
V. cholerae, 142, 153, 153*t*, 157*f*, 158*t*
 Triple sugar iron agar, 187–188
S. Typhi identification, 105–108, 109*f*
Shigella identification, 122, 123*f*, 125*t*
V. cholerae infection, 146–147, 148*f*
 Tryptone-based soy agar, 177, 178, 196
H. influenzae, 10, 12
 requirements for *V. cholerae*, 142, 145
 quality control, 196
 Tryptone soy broth, 197, 228
 Tryptone soy sheep blood agar with gentamicin, 197
 Turbidity standards, 209–214
 Typhoid fever, 103, 104

U

United Nations Committee of Experts on the Transport of Dangerous Goods, 309

Urea medium, 197–198
 quality control, 198
S. Typhi, 110
Shigella, 125, 125*t*, 127, 127*f*
 Urine specimens, 249

V

V Factor, 5, 6*f*, 9–13, 10*t*, 11*f*, 12*f*
 Vaccine Alliance, 62*n*
 Vaccines
H. influenzae, 5
 for laboratory personnel, 227
N. meningitidis, 30
S. pneumoniae, 45
S. Typhi, 103
 Vancomycin, 62
 Venipuncture, 220–221, 222*f*
Vibrio cholerae, 141–142, 152, 153*t*, 159
 antimicrobial susceptibility testing, 151
 agents for use in, 152, 153*t*
 documentation and reporting
 procedure, 152, 157*f*
 epidemic response, 142, 151–152
 inoculum characteristics, 154–155
 medium, 154, 175–176
 procedure, 154–156
 quality control, 156, 158*t*, 171
 sources of error, 156–159
 special considerations, 152–153
 surveillance, 152
 enrichment in alkaline peptone water, 293–295
 epidemic response, 142, 149, 151–152
 geographic distribution, 141
 identification, 142, 195, 208
 culturing medium, 142
 documentation, 144*f*
 epidemic response, 149
 in fecal specimens, 287–288, 292–296
 Gram stain, 148
 iron agar tests, 146–148, 148*f*
 methods, 142, 145, 146*t*

- microscopy, 149
- oxidase test, 142–145
- presumptive, 149
- procedure, 143*f*
- serologic, 149–151
- string test, 146, 147*f*
- laboratory-acquired infection, 163
- serogroups and biotypes, 141, 149
- storage of isolates, 306–307
- Viridans streptococci, 46–49

W

- Widal test, 104
- World Health Organization
 - recommendations for reference laboratories, 1, 3, 59, 288

X

- X Factor, 5, 6*f*, 9–13, 10*t*, 11*f*, 12*f*
- Xylose lysine desoxycholate agar, 198–199

Z

- Zinc powder, 79–80, 81, 82, 206