CLINICAL MICROBIOLOGY

GOALS AND OBJECTIVES

Bacteriology-Antimicrobial Susceptibility Testing (3 months) and Mycobacteriology-Mycology (2 months)
Rotation Director: Humphries

These areas are considered together since bacterial, mycobacterial, and fungal studies procedurally overlap at numerous points in the pre- and post-analytical phases and are performed in contiguous space in the microbiology laboratory. Fellows receive focused, intensive training in each area by laboratory technologists with the expectation that the fellow will be able to independently perform and interpret each test or testing sequence upon conclusion of the rotation.

Enrichment of training in antimicrobial susceptibility testing (AST) is urged by the increasing importance and technologic developments in this area, in turn driven by the growing problem of globally spreading resistance in the community and healthcare settings. (*Essentials* section 2.2.3.3)

Fellows currently receive substantial training and experience through formal rotations and patient-case management (e.g., daily microbiology rounds and MDMT conference) in the performance and interpretation of antimicrobial susceptibility testing using a variety of methods: broth microdilution (automated [BD Phoenix]), disk diffusion (Kirby-Bauer), and agar diffusion (E-test [bacteria and *Candida spp.*]). Education in AST is done on a broad front that ensures technical competence and intensive exposure to the wider dimensions of AST principles, clinical applications, and stewardship. The fellow will review annual AST guideline (CLSI) updates and collaborate with the laboratory director, supervisors, and staff; LIS personnel; and vendor field-applications specialists in the implementation of any required modifications to procedures or interpretive rules. Additionally, the fellow will serve as primary liaison to the Vanderbilt Antimicrobial Stewardship Program and Infection Prevention service for bidirectional communication between the laboratory and these groups, who interact closely with the laboratory to establish policies and procedures for antimicrobial susceptibility testing, interpretation, and reporting. The fellow also will actively participate in pilot assessments, assay validations, and implementation planning for new antibiotics, testing methodologies (e.g., direct susceptibility testing from blood cultures, chromogenic assays for carbapenemase production, and molecular detection of resistance genes) and related R&D activities. Contributions by the fellow will include review of relevant guidelines and medico-scientific literature, involvement in each aspect of method quality control, and development of associated documents—e.g., verification summaries, test procedures, and if appropriate, scholarly products such as a meeting abstract or publication. The content and depth of training in AST will be customized to each fellow's previous education and experience.

Fellows will learn the clinicopathologic correlations, principles, and performance characteristics associated with each test through discussions at daily teaching rounds, conferences, and independent study. The detailed checklist below serves as a guide for concepts and techniques to

master during the rotation. Completion of training in each area is documented by the trainer technologist recording their initials and the date and name of each section.

CHECKLIST

Area	Topic or Procedure	Trainer Signature	Date of Completion
Specimen handling	Proper specimen collection, transportation, and storage		
	Rejection of specimens		
	Specimen processing for culture		
	Sterile technique		
	Biosafety cabinet use and principles		
Bacteriologic media	Basic, differential, and selective		
	Base composition		
	Supplements		
	Applications		
Isolate preservation	Slants, cryo beads, liquid suspensions		
Bacterial cultures: major organism groups (processing, distinguishing morphologic features, important biochemical reactions)	*Enterococcus* (including vancomycin-resistant)		
	Staphylococcus		
	Streptococcus		
	Gram-negative cocci, aerobic and anaerobic		
	Gram-negative rods, aerobic and anaerobic		
	Gram-positive cocci, anaerobic		
	Gram-positive rods, aerobic and anaerobic		
Bacterial cultures: special	Cystic fibrosis respiratory cultures		
	Potential bacterial agents of bio terrorism		
	Shiga-toxin producing organisms		

Bacterial cultures: specimen sites, expected organisms, morphologies	Abscess and wound cultures		
	Blood cultures		
	CSF cultures		
	Genital cultures		
	Respiratory cultures (including quantitative)		
	Stool cultures		
	Tissue and bone cultures		
	Urine cultures (quantitative)		
Biochemical tests and kit-based bacterial identification systems	API 20C		
	API 20E		
	Automated identification systems and databases (Becton-Dickinson Phoenix, other platforms)		
	Catalase		
	Coagulase		
	LEMB		
	NF Plus, NH, and Anaids		
	PYR		
	Spot indole		
	Spot oxidase		
	Strep. and *Stash.* particle agglutination		
	Tube biochemicals (TSI, LIA, MIO, urea)		
Antimicrobial susceptibility testing	Automated (BD Phoenix)		
	Kirbyy-Bauer disc diffusion		
	MIC, E-test		
	MIC, broth microdilution methods		
	Screening methods for acquired resistance: AmpC, carbapenemase, extended spectrum β-lactamase, high-level gentamicin, inducible clindamycin resistance (D-test), MRSA, vancomycin		

	CLSI AST interpretive criteria/breakpoints		
Purity subculture			
Smears/stains	Gram stain		
	KOH		
	India ink		
	Acridine orange		
	Kinyoun		
	Rhodamine-auramine		
	Wright's stain		
Antigen and nucleic acid tests	*C. difficile* testing *methods, algorithms*		
	Cryptococcus		
	Group A *Strep*.		
Fungal cultures	Media and incubation		
	Identification of yeasts		
	Identification of molds		
Mycobacterial cultures	Stains		
	Media		
	Processing (including digestion and decontamination)		
	Incubation (solid media, automated systems)		
	Identification		
Administration	Quality control (QC)		
	Laboratory quality assurance (QA)		
	Policy and procedure manuals		
	Critical values and other communication issues		
	Regulatory compliance and accreditation		
	Human resources issues, performance evaluation		
	Proficiency testing		

Recommended Learning Resources*

Amsterdam, D. Antibiotics in Laboratory Medicine, 6th edition. Wolters Klucer, Indianapolis,

IA, 2014

Bennett, J.E., *et al.* Principles and Practice of Infectious Diseases, 9th edition. Elsevier, Atlanta, GA, 2019

Biosafety in Microbiological and Biomedical Laboratories, 6th edition, HHS Publication No. (CDC) 21-1112 Revised November 17, 2020 (Available at https://www.cdc.gov/labs/BMBL.html).

Clinical Infectious Diseases (periodical)

Engleberg, N.C., *et al.* Schaechter's Mechanisms of Microbial Disease, 5th edition. Lippincott, Williams, and Wilkins, Philadelphia, 2012

Carroll, K.C. *et al*. Manual of Clinical Microbiology, 12th edition. American Society for Microbiology, Washington, D.C., 2019

Journal of Clinical Microbiology (periodical)

Journal of Infectious Diseases (periodical)

Leber, A.L., et al. Clinical Microbiology Procedures Handbook, 4th edition. American Society for Microbiology, Washington, D.C., 2017

Miller, M.J. A Guide to Specimen Management in Clinical Microbiology, 3nd edition. American Society for Microbiology, Washington, D.C., 2017

Morbidity and Mortality Weekly Report (periodical)

Procop, G.W., *et al*. Koneman's Color Atlas and Textbook of Diagnostic Microbiology, 7th edition. Wolters Kluwer, Indianapolis, IA, 2016

Procop, G.W. Medically Important Fungi: A Guide to Identification, 5rd edition. American Society for Microbiology, Washington, D.C., 2014

Rinaldi, M.G., *et al.* Guide to Clinically Significant Fungi. Williams & Wilkins Co., Baltimore, 1998

Love, GL, *et al*. Color Atlas of Mycology. College of American Pathology, Northfield, Illinois, 2018

**Most resources available in the laboratory or through Eskind Biomedical Digital Library*

Virology (2 months)

Rotation Director: Gaston

This is a guideline for fellowship training in the clinical diagnostic virology laboratory. Fellows will work alongside a technologist as he/she rotates through each of the testing areas and receives individual instruction in test performance and interpretation. Learning goals for the rotation are to develop an advanced level of expertise in the core principles and methods of laboratory diagnostic virology, including:

- Bench QC
- Confirmatory testing of viral agents using immunofluorescence
- Implementation and validation of virologic tests
- Interpretation and reporting of results
- Isolation of virus in cell culture
- Laboratory administration
- Laboratory QA plan
- Post-analytical specimen handling
- Pre-analytical specimen handling (*i.e.*, specimen acquisition, transport, processing)
- Rapid viral diagnostic tests
- Recognition and handling of unusual, unsuspected, or potential biothreat agents
- Serologic diagnosis of viral infections (manual and automated)
    - Screening, confirmatory, and algorithmic serologic assays
- Results requiring caregiver notice
- Antigen detection
- Virus containment and laboratory safety

The detailed checklist below will serve as a guide for concepts and techniques to learn during the rotation. Completion of training in each area is documented by recording the date and name of the trainer technologist.

CHECKLIST

Area	Topic or Procedure	Trainer Signature	Date of Completion
Organization of virology lab	Orientation by lab supervisor		
Facilitation	Proper specimen collection, transport, and storage		
	Troubleshooting and rejection of specimens		
	Specimen accessioning and processing for serology, culture, and antigen detection		
	Receiving tissue culture cells		
	Reagent and specimen labeling		
	Rapid testing: RSV antigen, Flu A and B antigen, HIV antibody/antigen		
	Direct fluorescent antigen: HSV, VZV, respiratory viruses		
	Miscellaneous testing and special requests		

Virus isolation	Hybrid cell cultures (shell vials) and range of viruses isolated: R-Mix Too, H&V Mix, Super E-Mix		
	Endogenous viruses of cultured cells		
	Communicating results to caregivers		
Serology	<u>Automated EIA or CIA</u>: CMV IgM and IgG Coronavirus IgG EBV capsid IgG EBV capsid IgM EBNA IgG HAV IgM (core lab) HAV total ab (core lab) HBV core IgM HBV surface ag HBV surface ag neutralization HBV surface ab HBV total core ab HBV e ag HBV e ag HCV IgG HIV-1/2 ag/ab combo HSV 1 and 2 IgG HSV IgM VZV IgG Measles IgG Mumps IgG Parvovirus B19 IgM and IgG Rubella IgG		
	<u>Indirect immunofluorescence</u>: VZV (confirmation of negative or equivocal EIA) EBV capsid IgM (resolution of conflicting or ambiguous EIA) EBV capsid IgG (resolution of conflicting or ambiguous EIA) EBNA (resolution of conflicting or ambiguous EIA)		
	<u>Reflexive testing</u>: HIV (differentiation assay) HBV (core IgM, e ag, and e ab) HCV (PCR)		

All areas	Results reporting: Preset codes Free-text comments		
	Unusual results		
	Error correction		
	Test results requiring caregiver notice		
Administration	QA/QC		
	Proficiency testing		
	Procedure manuals		
	Regulatory compliance and accreditation		
	Performance evaluation		

Recommended Learning Resources*

Bennett, J.E., *et al.* Principles and Practice of Infectious Diseases, 9th edition. Elsevier, Atlanta, GA, 2019

Biosafety in Microbiological and Biomedical Laboratories, 6th edition, HHS Publication No. (CDC) 21-1112 Revised November 17, 2020 (Available at https://www.cdc.gov/labs/BMBL.html).

Clinical Infectious Diseases (periodical)

D.M. Knipe and P.M. Howley. Fields Virology, 6th edition. Wolters Kluwer, Indianapolis, IA, 2013

P.M. Howley and D.M. Knipe. Fields Virology: Emerging Viruses, 7th edition. Wolters Kluwer, Indianapolis, IA, 2020

Engleberg, N.C., *et al.* Schaechter's Mechanisms of Microbial Disease, 5th edition. Lippincott, Williams, and Wilkins, Philadelphia, 2012

Hodinka, R.L. et al. Clinical Virology Manual, 5th edition. American Society for Microbiology, Washington, D.C., 2016

Carroll, K.C. *et al*. Manual of Clinical Microbiology, 12th edition. American Society for Microbiology, Washington, D.C., 2019

Journal of Clinical Virology (periodical)

Journal of Infectious Diseases (periodical)

Morbidity and Mortality Weekly Report (periodical)

Reviews in Medical Virology (periodical)

Rhodes, K.H. Essentials of Diagnostic Virology. Mayo Clinic Proceedings, Rochester, Minnosota, 2000

**Most resources available in the laboratory or through Eskind Biomedical Digital Library*

Molecular Diagnostics (1.5 months)
Rotation Director: Gaston

The overarching training goals for fellows conducting rotations in MIDL are as follows:

- Demonstrate competency in laboratory procedures commensurate with the independent practice of diagnostic molecular microbiology
- Explain the scientific basis of diagnostic molecular microbiology and demonstrate ability to utilize the medical literature and modern techniques to provide accurate laboratory diagnoses of infectious diseases
- Communicate effectively in verbal and written form with clinical, administrative, technical, and clerical personnel
- Establish skills required to develop, validate, and implement state-of-the-art molecular techniques for infectious disease diagnosis and monitoring

Test Platforms

Currently, 11 systems are used in MIDL to diagnose and monitor infectious diseases. The fellow should acquire a thorough understanding of principles, techniques, performance characteristics, capabilities, and limitations associated with each. The fellow should also develop awareness and working knowledge of available alternatives.

- Abbott *m*2000 automated specimen processing and real-time PCR
- Abbott ViroSeq HIV-1 genotype analysis/ABI 3130 xl capillary electrophoresis
- Cepheid GeneXpert
- Digene Hybrid Capture
- GenMark eSensor XT-8
- Luminex xMAP
- Qualitative and quantitative TaqMan PCR (ABI 7900)
- Roche Cobas Ampliprep/Cobas TaqMan quantitative real-time PCR
- Roche Cobas 4800 automated specimen processing and real-time PCR
- Siemens Trugene PCR product sequence analysis
- User-developed qualitative PCR-EIA

Techniques

Core techniques performed in MIDL include specimen decontamination, nucleic acid extraction, RNA/DNA hybrid capture followed by signal amplification, endpoint PCR, amplicon capture and detection using microtiter plate EIA, qualitative and quantitative real-time PCR, sequence analysis, liquid-suspension array, and solid-phase microarray.

Testing Categories

Tests performed in MIDL fall within three major categories.

Organism detection

- Adenovirus
- BK virus
- *Bordetella pertussis*
- *Chlamydia pneumoniae*
- *Chlamydia trachomatis*
- Coronavirus
- Cytomegalovirus
- *Ehrlichia* species, covering *E. chaffeensis, E. ewingii,* and *Anaplasma phagocytophilum*
- Enteroviruses, covering polio, Coxsackie, ECHO, and new enterovirus serotypes
- Epstein-Barr virus
- Hepatitis B virus
- Hepatitis C virus
- Herpes simplex virus types 1 and 2 detection and differentiation
- HIV-1
- Human herpesvirus 6
- Human herpesvirus 7
- Human herpesvirus 8
- Human papillomavirus
- *Mycobacterium tuberculosis*
- *Neisseria gonorrhoeae*
- Parvovirus B19
- Respiratory viruses (RSV A, RSV B, Flu A, Flu B, PIV-1, PIV-2, PIV-3, PIV4, hMPV A/B, rhinovirus/enterovirus, adenovirus B/E, coronavirus 229E/OC43/ NL63/HKU1, bocavirus)
- Varicella-zoster virus
- West Nile virus

Organism quantification

- BK virus
- Cytomegalovirus
- Epstein-Barr virus
- Hepatitis B virus
- Hepatitis C virus
- HIV-1

Organism sequence analysis

- Hepatitis C virus genotyping
- HIV-1 drug-resistance genotype analysis

The following checklist should be used to ensure that technical training in all laboratory sections has been accomplished. Pathogens detected/quantified in each area should be the emphasis of fellow learning (including detection/identification strategies, pathogenesis, clinical syndromes, treatment, prevention, and epidemiology) while there.

CHECKLIST

Laboratory Section	Trainer Signature	Date of Completion
Nucleic acid extraction		
A.QIAGEN DNA Mini Kit		
B. QIAGEN MinElute Virus Vacuum Kit		
C. QIAGEN MinElute Virus Spin Kit		
D. RNAeasy Mini Kit		
E. AmpliPrep		
1. HIV		
2. TNAI		
F. easyMAG		
PCR and RT-PCR		
A. Principles		
1. Denaturation		
2. Primer annealing		
3. Extension		
B. AmpliTaq, AmpliTaqGold, Tth, GoTaq		
C. Master mix		
D. Thermal cycling		

ELISA detection		
A. Plate set up		
B. Incubation		
C. Washing		
D. Reading		
Quality control		
A. Positive, negative, and blank controls		
B. Cleaning schedule and swabs		
C. New reagent lot # vs. prior lot #		
D. Thermal cycler diagnostics		
E. Calibrator verification		
F. Clinical Laboratory Standards Institute		

G. College of American Pathologists		
H. Virology Quality Assurance		
Amplicon production control		
A. Physical		
1 Separate benches		
2. Dedicated pipettes and dead-air chambers		
3. Controlled traffic		
B. Chemical		
1. dUTP/UNG		
2. Bleach		
3.UV		
Cobas AmpliPrep/Cobas TaqMan		
A. Specimen processing		
B. Workload handling		
C. Extraction procedures		
1. HBV		
2. HCV		
3. HIV		
D. Loading instrument		
E. Reporting results		
Luminex xMAP		
A. Principle		
B. Multiplex PCR		
C. Extension and hybridization		
D. Data acquisition		
E. Data analysis		
F. Instrument maintenance and calibration		
ViroSeq/3130		
A. Principle		
B. RT-PCR and product quantification		
C. Cycle sequencing		
D. Capillary electrophoretic separation of sequencing products		
E. Data analysis and base-calling		
F. Reports		
G. Attendance of antiretroviral therapy conference at Vanderbilt Comprehensive Care Clinic		
m*2000*sp* and *m*2000 *rt		
A. Principle		
B. Acceptable specimen types and storage media		
C. *m2000sp* operation		

D. *m2000rt* operation		
E. LDA's		
F. Instrument maintenance and troubleshooting		
eSensor XT-8		
A. Principle		
B. Multiplex PCR		
C. Detection		
D. Reports		
Cobas 4800		
A. Principle		
B. Acceptable specimen types and storage media		
C. Instrument operation		
D. Real-time analysis		
E. Instrument maintenance and troubleshooting		
Trugene sequence analysis system		
A. Principle		
B. RT-PCR product generation		
C. CLIP sequencing		
D. Gel preparation and loading		
E. Data analysis and base calling		
F. Reports		
Specimen processing		
A. Proper specimen collection, transport, and storage		
B. Troubleshooting and rejection of specimens		
C. Review of test menu		
D. Reprint of labels		
E.. Specimen aliquoting		
F. Patient database entry		
Tissue/respiratory processing		
A. Paraffin tissue processing		
B. Formalin-fixed tissue processing		
C. Fresh tissue processing		
D. Cell-rich fluid (BAL) processing		
ABI 7900		
A. Master mix preparation		
1. CMQ		
2. EBQ		
3. WND		
B. Diluting the standard		

C. Loading the plate/tube strip		
D. ABI 7900 software		
1. Start of a run		
2. Analyzing data		
3. Troubleshooting		
4. Maintenance		
F. Reporting results		
GeneXpert		
A. Cartridge setup		
B. Starting a run		
C. Reporting results		
D. Maintenance		
Digene HPV		
A. PreservCyt specimen processing		
B. Denaturation		
C. Hybridization microplate		
D. Capture microplate		
E. DMS software		
1. Plate setup		
2. Reading plate		
F. Maintenance		

Recommended Learning Resources*

Diagnostic Microbiology and Infectious Diseases (periodical)

Dieffenbach C.W., and G.S. Dveksler. PCR Primer: A Laboratory Manual, 2nd edition, Cold Spring Harbor Laboratory Press, Cold Spring Harbor, 2003

Journal of Clinical Microbiology (periodical)

Journal of Molecular Diagnostics (periodical)

Persing D.H., *et al.* Molecular Microbiology: Diagnostic Principles and Practice, 3nd ed. American Society for Microbiology Press, Washington, D.C., 2016

Procedure manuals (in-depth disease descriptions, rationale for testing, procedures, and expected results)

**Most resources available in the laboratory or through Eskind Biomedical Digital Library*

Parasitology (1 month)

Rotation Directors: Levinson and Humphries

A limited number and range of diagnostic parasitology procedures are conducted in the Vanderbilt hospital laboratories. Currently, stool analysis for *Cryptosporidium*, *Cyclospora,* and *Isospora* is performed as a routine microbiology test. The hematopathology service consults with the microbiology laboratory in the interpretation of presumptively positive malaria smears, and the surgical pathology and cytopathology services seek microbiology consultation when entertaining a parasitic etiology. As the volume and diversity of parasitology studies performed at Vanderbilt are limited, fellows receive supplemental parasitology training during their rotations at the TDH central laboratory (see **PUBLIC HEALTH MICROBIOLOGY** section). Further, fellows are exposed to a local curriculum—including annotated electronic images, a variety of web-based image galleries linked to clinical histories and tutorials, a comprehensive collection of parasitology texts and atlases, and teaching responsibilities in parasitology; these experiences are designed to build trainee competence in the clinical, ecologic, geographic, and diagnostic aspects of important parasitic diseases. Fellows perform functions and utilize the resources summarized below as training tools in clinical parasitology. These activities are intended to maximize informational diversity and depth in the field and facilitate mastery of essential concepts that underpin diagnostic laboratory parasitology.

Consultation

- Serve as primary contact for consultative questions regarding parasitology, including malaria blood smears, biopsy specimens, and cytopathology specimens
- Review slides and clinical histories associated with specimens submitted to the microbiology lab for stool parasitology studies; discuss findings, implications, and any indicated additional testing with laboratory staff and microbiology directors

Slide review

- Review positive malaria blood smears from the hematopathology service
- Review VA microbiology laboratory parasitology kodachrome slide collection
- Review CAP parasitohematology proficiency challenges

Presentations and teaching

- Present at least one case of parasitic disease weekly at teaching rounds (based on current or past Vanderbilt cases or, alternatively, drawn from contemporary medical literature)
- Participate in parasitology didactic lectures to medical technology students

Electronic resources for self-study

- Kansas State University parasitology tutorial (https://www.k-state.edu/parasitology/546tutorials/titlepage.html)
- University of Delaware parasitology tutorial (http://www1.udel.edu/mls/dlehman/medt372/)
- Chiang Mai University (Thailand) parasite image database (https://w1.med.cmu.ac.th/parasite/หน้าแรก-image/)
- Oklahoma State University veterinary entomology and parasitology page (https://vetmed.okstate.edu/veterinary-pathobiology/index.html)
- Malaria link (https://www.cdc.gov/parasites/malaria/index.html)
- CDC Division of Parasitic Diseases' DPDx comprehensive medical parasitology information resource (https://www.cdc.gov/dpdx/az.html) and monthly parasitology quiz (https://www.cdc.gov/dpdx/monthlycasestudies/2020/index.html)
- Public Health Training Center (https://www.jhsph.edu/research/centers-and-institutes/mid-atlantic-public-health-training-center/training_events/online_training.html)
- Gorgas Courses in Tropical Medicine (http://gorgas.dom.uab.edu/index.html)
- Purdue University Program in Vector Biology and Vector-Borne Diseases (http://extension.entm.purdue.edu/publichealth/index.html)

Parasitology text and electronic resources in the microbiology laboratory available for unrestricted use by trainees

CDC Division of Parasitic Diseases' DPDx CD: Laboratory Identification of Parasites of Public Health Concern

CDC Division of Parasitic Diseases' DPDx CD: The Primate Malarias

CDC Division of Parasitic Diseases' DPDx CD: Arthropods, Reptiles, Birds, and Mammals of Public Health Significance

Farrar, J. et al. Manson's Tropical Diseases, 23th edition. Elsevier, Atlanta, GA, 2013

Garcia, L.S., Diagnostic Medical Parasitology, 6th edition. ASM Press, Washington, D.C., 2016

Halstead, S.B., and K.S. Warren. Diseases of Travelers and Immigrants. Upjohn, Kalamazoo, MI, 1990

Heelan, J.S. Cases in Human Parasitology. American Society for Microbiology, Washington, D.C., 2004

Magill, A.J., et al. Hunter's Tropical Medicine, 9th edition. Elsevier, Atlanta, GA, 2012

Markell, E.K., and M. Voge. Diagnostic Medical Parasitology. Saunders, Philadelphia, 1958

Orihel, T.C., and L.R. Ash. Parasites in Human Tissues. American Society of Clinical Pathologists, Chicago, 1995

Peters, W., and H.M. Gilles. Color Atlas of Tropical Medicine and Parasitology. Year Book Medical Publishers, Chicago, 1977

Petersen, E., and Chen, L.H. Infectious Diseases: A Geographical Guide, 2nd edition. Wiley Blackwell, Hoboken, N.J., 2017

The checklist below is a general guide to major topics in clinical laboratory parasitology that may be used for self-directed learning. (Table entries and their organization are reproduced, with some modifications, from Murray, P., et al. Manual of Clinical Microbiology, 9th edition. American Society for Microbiology, Washington, D.C., 2007). Special emphasis should be accorded to the following:

- Clinical syndromes
- Parasite life cycles
- Hosts: incidental, obligate, and definitive
- Vectors
- Geographic distribution, including regional incidence of resistance to therapy
- Diagnostic microscopic (and macroscopic, if applicable) features
- Optimal specimen sources and approaches for diagnosis
- Optimal specimen preparation and staining techniques, including unique features of leading methodologies that determine their appropriateness or inappropriateness for various parasites and specimen types
- Arthropod identification to species levels where relevant to a particular disease or transmitted agent

CHECKLIST

Area	Topic or Procedure	Trainer Signature	Date of Completion
Specimen handling	Specimen collection, transport, and processing		

	Specimen acceptability criteria		
Algorithms for parasite detection	Reagents, stains, and media		
	Concentration		
	Filtration		
	Fixation		
	Wet mounts		
	Identification of trophic and cystic stages		
	Immunoassays		
	Fluorescence assays		
	Thick and thin blood smears		
Predisposing factors	Travel		
	Immune status of host		
Parasites	*Plasmodium* and *Babesia*		
	Leishmania and *Trypanosoma*		
	Toxoplasma		
	Pathogenic and opportunistic free-living amebae		
	Intestinal and urogenital amebae, flagellates, and ciliates		
	Isospora, *Cyclospora*, and *Sarcocystis*		
	Cryptosporidium		
	Microsporidia		
	Nematodes		
	Filarial nematodes		
	Cestodes		
	Trematodes		
	Less common nematodes and cestodes		
Antiparasitic agents	Spectrum of activity, mechanisms of action, and pharmacology		
	Mechanisms of resistance		
	Susceptibility test methods		
Arthropods of medical importance	Crustaceans (decapods and copepods)		
	Fleas		

	Flies		
	Lice		
	Mites		
	Mosquitos		
	Ticks		
	Triatomids		

Clinical Infectious Diseases (1.5 months)
Rotation Directors: Banerjee and Fiske

Fellows spend two weeks each on the adult general, pediatric general, and adult transplant infectious diseases (ID) hospital services developing an appreciation for the nature of clinical practice in these disciplines, including the interdependence of patient care and the microbiology laboratory, role of the clinical microbiologist in patient care, unique challenges to disease diagnosis and case management that are associated with ID, and clinical problem solving. Activities of the microbiology fellow are mainly linked to routines of the ID fellow and team rounds. The microbiology fellow is expected to actively engage intellectually as a member of the patient-care team and bring thoughtful input to rounds and team meetings. This role presumes a substantial degree of daily self-directed study focused on clinical syndromes; disease pathophysiology; and concepts of disease epidemiology, prevention, and diagnosis exemplified by the constantly changing case mix. Functions and activities of clinical microbiology fellows rotating on the ID services are summarized below.

- Accompany ID fellow (or other designated team member) in the evaluation of new consults and on daily inpatient rounds.
- Observe patient care and decision-making processes surrounding ID diagnosis, treatment, and prevention
- Participate in case analysis and management discussions during work rounds, team meetings, and attending rounds
- Serve as liaison to the microbiology lab (and public health lab, if necessary) for information about status of incomplete or unreported testing
- Perform literature searches for information relevant to current cases (case reports, antimicrobial therapy, clinical features, epidemiology, etc.) and present findings to the team
- Attend weekly adult and pediatric ID conferences, journal clubs, and didactic lectures

Microbiology fellows are not expected to directly participate in patient care activities otherwise the responsibility of residents or ID fellows, such as physical examinations, note-writing, case presentations to attending physicians or other team members, chart reviews/summaries, or coordination of patient care with nurses or other hospital services. However, fellows should carefully observe the synthesis of these activities in the management plan for each patient and

ensure their understanding of elemental concepts and practices in clinical infectious diseases, summarized in the checklist below, which impact the microbiology laboratory and require comprehension by laboratory directors. Particular focus should be placed on an understanding of clinical, laboratory, pharmacologic, and social factors underpinning antimicrobial management of different disease states, pathogens, and individual patients. Within this framework, fellows are admonished to broaden and integrate their knowledge of antimicrobial activity spectra, mechanisms of action and resistance, pharmacodynamic and pharmacokinetic properties, and principles and technique of susceptibility testing.

CHECKLIST

Area	Topic of Procedure	Trainer Signature	Date of Training Completion
Design of antimicrobial therapy	Microorganism		
	Site of infection		
	Activity spectrum		
	Community-acquired vs. healthcare-associated infections		
	Pharmacokinetics, pharmacodynamics, and routes of administration		
	Interactions between antimicrobials (*e.g.*, synergism and antagonism)		
	Interactions of antimicrobials with other drugs		
	Anticipated patterns of pathogen susceptibility and resistance		
	Cell and tissue penetration		
	Microbistatic vs. microbicidal drugs		
	Formulary		
	Selection of resistance		
	Adverse effects		
	Duration		
	Empiric coverage		
	Tailored therapy		
	Therapeutic drug monitoring (TDM)		
	Approved vs. off-label use		

	Role of pharmacy consultation service		
	Clinical and laboratory evaluation of therapeutic responses		
	Antimicrobial stewardship		
Adverse events of antimicrobial therapy	Hypersensitivity		
	Toxicity		
	Predictable vs. idiosyncratic		
	Screening for genetically-determined susceptibility to adverse events		
Specimen procurement	Site-specific methods		
	Post-procurement handling and delivery to lab		
Utilization of microbiology laboratory data	Pathogens vs. normal flora		
	Significance ascribed to results based on testing methodology		
	Disease monitoring and tests of cure		
	Conflicting or ambiguous results		
	Impact of turnaround times		
	Impact of laboratory errors		
Communication with the microbiology laboratory	Methods (phone, visits, electronic)		
	Frequency		
	Temporality		
	Impediments		

Recommended Learning Resources*

Amsterdam, D. Antibiotics in Laboratory Medicine, 6th edition. Wolters Klucer, Indianapolis, IA, 2014

Bennett, J.E., *et al.* Principles and Practice of Infectious Diseases, 8th edition. Elsevier, Atlanta, GA, 2014
Long, S.S., *et al.*, Principles and Practice of Pediatric Infectious Diseases, 5rd edition. Elsevier, Atlanta, GA, 2018

**Most resources available in the laboratory or through Eskind Biomedical Digital Library*

Immunology (1 month)*
Rotation Director: Gaston

Fellows receive training in immunology and immunopathology through a one-month rotation experience in the immunology laboratory, which supports testing for the diagnosis and management of immunologic, hematopoietic, and a limited range of infectious diseases. Primary goals for this rotation are to educate fellows in the following areas:

- Quantitative measurements of inflammatory responses to infection
- Immunopathologic basis of disease
- Laboratory approaches to the diagnosis of autoimmune disorders

Rapid advancements in the fields of immunology, diagnostic biomarkers of inflammatory and infectious diseases, and immunotherapy require continuous efforts to update and improve training in immunology/ID serology.

Training in immunology and infectious diseases serology includes a one-month rotation in the immunology laboratory (mixture of testing for infectious, autoimmune, and hematologic disorders) as well as a rotation in the virology laboratory (viral serology), which includes exposure to immunology testing done in the chemistry laboratory (viral hepatitis serology and various assays of immune function and inflammatory states). These immunology tests represent a combination of manual and automated testing methodologies. Furthermore, daily microbiology teaching and bench rounds and daily MDMT rounds provide frequent opportunities for instructive discussions about the use and interpretation of serologic testing as it pertains to clinical cases under review. These forums will be further exploited to visit precepts underlying the immunobiology of health and disease and the serologic evaluation of infectious and noninfectious diseases. The fellow's exposure to key concepts in immunodeficiency diseases and the burgeoning area immunotherapy will be augmented through provision of contemporary literature (e.g., textbooks, journal articles, and online instructional materials) exploring these topics. In addition, the rotation in immunopathology for pathology residents has been revised under Dr. Aaron Shaver, the medical director of the immunology laboratory. The fellow also will benefit from the revision of the immunopathology rotation and will participate according to the extent that curriculum content addresses his/her training needs as a clinical microbiologist.

Immunology topics addressed as part of bench rotations include basic immunology of lymphocyte differentiation; flow cytometry of immunodeficiency, leukemia, and lymphoma; diagnostic electrophoretic abnormalities of serum, urine, CSF, and hemoglobin; antibody and complement in health and disease; autoantibodies of diagnostic significance, and serologic detection of bacterial and parasitic infections. Fellows review clinical cases that have immunology laboratory testing and discuss interpretation of the results with the laboratory director and/or the attending pathologist. Fellows are expected to familiarize themselves with literature relevant to the specific cases and broader immunologic concepts which they daily encounter. A checklist is provided as a guide to principles and techniques that fellows should learn during their rotation through the immunopathology laboratory.

CHECKLIST

Area	Topic or Procedure	Trainer Signature	Date of Training Completion
Specimen handling	Proper specimen collection, transport, and storage		
	Troubleshooting and rejection of specimens		
	Specimen accessioning and processing		
Immunofluorescent antibody tests	Antinuclear antibody		
	Antimitochondrial antibody		
	Antineutrophil cytoplasmic antibody		
	Toxoplasma IgG		
Electrophoresis	Isoelectric focusing for CSF oligoclonal bands		
	Serum and protein electrophoresis, immunofixation		
	Hemoglobin electrophoresis		
	Cryoglobulins		
Serology: infectious diseases	*Helicobacter pylori* IgG		
	Toxoplasma IgM		
	Antistreptolysin O (screen and quantitative)		
	Syphilis RPR (qualitative and quantitative), treponemal and		

	nontreponemal tests and algorithms		
	EBV heterophile antibodies		
	CSF IgG		
Serology: allergy, autoimmunity, and immunodeficiency	Antimyeloperoxidase (quantitative)		
	Antiproteinase 3 (quantitative)		
	C3 (quantitative)		
	C4 (quantitative)		
	Quantitative IgM, IgG, IgA, IgE		
	Rheumatoid factor		
	Functional complement quantification (CH_{50} using sheep RBC's)		
Serology: acute phase reactants	C-reactive protein		
	Haptoglobin		
	Ceruloplasmin		
	Transferrin		
	Prealbumin		
	α1-antitrypsin		
Flow cytometry	T and B cell counts		
	Leukocyte differentiation markers; clonal populations		
	CD4 and CD8 T cell quantification		
	NK cell counts		
	Stem cell counts		

*Serologic testing for infectious diseases at VUMC is performed in the immunology, virology, and chemistry laboratories. Fellows assimilate principles, techniques, and clinical correlates of viral serology during the virology rotation. Serologic diagnosis and management of major bacterial, fungal, and parasitic diseases are addressed in daily microbiology teaching rounds, the rotation in public health microbiology (state reference laboratory), daily MDMT rounds, and the clinical pathology didactic lecture series.

Recommended Learning Resources**

Abbas, A.K., et al. Cellular and Molecular Immunology, 9th Edition. Elsevier, Atlanta, GA. 2017

Firestein, G.S., et al. Kelley's Textbook of Rheumatology, 10th ed. W.B. Saunders, Philadelphia, 2016

McPherson, R.A., and M.R. Pincus. Henry's Clinical Diagnosis and Management by Laboratory Methods, 23nd edition. Saunders, Philadelphia, 2016

Murphy, K.M., *et al.*, Janeway's Immunobiology, 9th ed., Taylor and Francis, Philadelphia, 2016

***Most resources available in the laboratory or through Eskind Biomedical Digital Library*

Public Health Microbiology (1 month)
Rotation Director: Levinson

The Tennessee Department of Health (TDH) Division of Laboratory Services is supported by a central laboratory located in Nashville, TN, in addition to two regional laboratories located in Jackson, TN, and Knoxville, TN. A wide range of microbiological testing is performed in the areas of bacteriology, molecular biology, environmental microbiology, mycobacteriology, parasitology, mycology, immunoserology, virology, and newborn screening. Thirty technical staff and a total of 10 managers and supervisors are responsible for performance of over 1,000,000 microbiology tests annually. Laboratory Services also is the State Emergency Preparedness Laboratory for biological agents. Special secured facilities at the Nashville laboratory are equipped to identify potential agents of bioterrorism using microbiologic, molecular, chemical, and spectrometric techniques. The TDH laboratory forms a hub of state public health operations for the identification of emerging infections, STD testing, and detection of other agents required by law, state health officer, or state epidemiologist. Clinical microbiology fellows spend a minimum one month at the TDH Nashville laboratory gaining exposure to all aspects of public health microbiology, including (but not limited to) enteric microbiology, identification and susceptibility testing of *Mycobacterium tuberculosis* and atypical mycobacteria, identification of new or unusual organisms by sequence analysis, pulsed-field gel electrophoresis for molecular epidemiologic studies, HIV-1 and HIV-2 western blot interpretations, food microbiology, diagnosis of sexually transmitted infections (e.g., syphilis, *N. gonorrhoeae, C. trachomatis*), viral serology, and enteric parasitology. Trainees participate in outbreak investigations potentially involving field work with TDH epidemiologists and attend weekly epidemiology conferences where regional and national trends in infectious diseases are discussed. Trainees also gain familiarity with STARLIMS, a web-based laboratory information management system linking the TDH laboratory to more than 20 other public health labs; the National Electronic Disease Surveillance System (NEDSS), which is a CDC-developed web-based infrastructure for public health surveillance and data exchange among local, state, federal (including CDC), and commercial entities; and electronic surveillance systems for food-borne pathogens (PulseNet, CaliciNet, and FoodNet). Fellows receive a full day of training in the state Tuberculosis Elimination Program conducted at the State of Tennessee Department of Health and Metro Public Health Department of Nashville/Davidson County. Packaging & shipping training along with how to perform a Biosafety Risk Analysis is also integrated into the fellow's training while at the TN State Public Health Laboratory.

An additional month at the TDH laboratory can be arranged to permit a deeper learning experience in areas of special interest to the trainee or participation in a project that would lead to a publication, e.g., a case report describing the identification of a new organism (which occurs on average once monthly).

Fellows should ensure that each item in the checklist below has been addressed upon completion of the rotation.

CHECKLIST

Area	Topic or Procedure	Trainer Signature	Date of Training Completion
Microorganism identification	All major agents of public health importance		
Outbreaks	Principles and logistics of investigations		
	Risk communication		
	Incident command		
	Resource management		
	GIS systems		
Consultation	Provision of educational and professional assistance to other clinical microbiologists and general public		
Laboratory methods	Potable and waste water testing		
	Food and dairy microbiology		
	Sexually transmitted diseases testing		
	Tuberculosis testing		
	Microbial typing		
	Identification of unusual isolates		
	Rabies virus detection		
	Newborn/developmental screening		
	Botulism testing		
	Environmental microbiology testing		
	Stool O&P examination		
Bioterrorism (BT)	Identification characteristics of biothreat agents		

	Laboratory safety procedures, *e.g.*, safe handling of BT agents in clinical microbiology laboratories		
	Role of local clinical microbiology laboratories in the Laboratory Response Network (LRN); role of other local, state, and federal government agencies		
	Role of the microbiology laboratory in the institutional BT preparedness plan (specifically, the internal lines of communication and documentation depending on who first becomes aware of a BT threat/event [police, lab, ER, MD])		
	Local, state, and federal sources of information and emergency assistance regarding the response of clinical microbiology laboratories during a BT event		
	Clinical syndromes produced by the respective organisms including those listed in the MMWR, April 21, 2000		
	The Laboratory Response Network		
	Packaging & shipping training along with how to perform a Biosafety Risk Analysis		
State department of health notifiable diseases and events (categorized reporting requirements)	Categories 1A, 1B, 2, 3, 4, and 5		
Laboratory information and disease surveillance systems	STARLIMS		
	NEDSS		
	PulseNet		
	FoodNet		
	CaliciNet		

Tuberculosis elimination program	Planning and policy, identification and management of persons with TB, laboratory and diagnostic services, data collection and analysis, and training and education		

Recommended Learning Resources

Clinical and Vaccine Immunology (periodical)

Doyle and Beuchart, Food Microbiology: Fundamentals and Frontiers, 3rd edition. ASM Press, Washington, DC, 2007

Emerging Infectious Diseases (periodical)

Hurst et al., Manual of Environmental Microbiology, 3rd edition. ASM Press, Washington, DC, 2007

Jorgensen, J.H., et al., Manual of Clinical Microbiology, 11th edition, ASM Press, Washington, DC, 2015

Morbidity and Mortality Weekly Report (periodical)

Reddy et al., Methods for General and Molecular Microbiology, 3rd edition, ASM Press, Washington, DC, 2007

Rose et al., Manual of Clinical Laboratory Immunology, 6th edition, ASM Press, Washington, DC, 2002

Infection Prevention/Healthcare Epidemiology (1 month)
Rotation Director: Talbot

Microbiology fellows receive training in healthcare epidemiology and infection control and prevention (IC&P) through interactions with the Department of Infection Prevention at Vanderbilt. The Department is led by VUMC Chief Hospital Epidemiologist Thomas R. Talbot, M.D., M.P.H., two associate epidemiologists, Vanderbilt Children's Hospital (VCH) epidemiologist Gregory J. Wilson, M.D., a Director, and a staff of eight preventionists. The Department of Infection Prevention is primarily responsible for conducting surveillance of hospital-acquired infections and investigating and controlling outbreaks or infection clusters among patients and health care personnel. IP personnel also evaluate new and existing products, examine the latest innovations in personal protective equipment and safe needle devices, and conduct detailed special projects that investigate infection control issues at VUMC and VCH. The IP practitioners develop infection surveillance policies and procedures and educational programs to assure quality of patient care.

The Department calculates rates of hospital-acquired infections, collates antibiotic susceptibility data, performs analysis of aggregated infection data, and provides comparative data to national benchmarks over time. These data are provided to various boards and committees on a routine basis. Working with various physicians and departments, the Department of Infection Prevention also provides data for research and publications. Department staff works closely with the Occupational Health Clinic and Vanderbilt Environmental Health and Safety Risk Management, as well as state and local health departments.

The multifaceted, dynamic practice of hospital epidemiology and IP makes the time-delimited rotation model impractical for educating clinical microbiology fellows in these areas. Therefore, to take full advantage of training opportunities provided by the hospital epidemiology and IP services, microbiology fellows interact frequently and regularly with this group throughout the fellowship period in other ways as described below. In aggregate, fellows receive the equivalent of one month of training in hospital epidemiology and IP through clinical experience and formal didactic instruction. Opportunities may also exist for involvement in focused research projects in IP. Key elements of IC&P training for clinical microbiology fellows are summarized below.

-Attendance at ID fellows' orientation

- Operational IP discussion/didactic training
- Additional training on basics of antibiotic use, stewardship, and antimicrobial resistance
- Forge initial linkage between microbiology fellows and ID fellows

-Attendance at weekly IP working group meetings

- This forum of wide-ranging discussions addressing current issues in operational IP is attended by fellows throughout their training, leading to a substantial amount of accrued knowledge about IP topics and protocols, unique roles and responsibilities of IP practitioners, and reciprocal functions of IP and the microbiology laboratory in the prevention, surveillance, and containment of healthcare-associated infections.

-Attendance of monthly IP Committee meetings focused on systematic review of epidemiologic trends, institutional policy approval, prevention strategies, immunization rates, and educational campaigns throughout the medical center.

-Attendance of Topics in IP didactic lectures (five to six per year) presented as part of the wider ID curriculum by Drs. Tom Talbot, Bill Schaffner, Greg Wilson, and invited national experts in the field.

-Attendance at Antibiotic Subcommittee meetings of the VUMC Pharmacy and Therapeutics Committee (approximately eight meetings annually). Topics discussed on a regular basis include:

- Antibiotic use and stewardship
- Antibiotic resistance

- Antibiotic formulary
- Antibiotic safety and efficacy

-Attendance at any non-recurring special seminars or conferences themed by discussions of IP or healthcare epidemiology

-Function as microbiology lab principal point of contact for IP and carry responsibility for initiating and coordinating laboratory activities in support of IP activities

-Participate with IP practitioners in outbreak investigations

- Collection and analysis of microbiologic data
- Accompany practitioners to gain understanding of investigation strategies and processes
- Coordination of microbiology lab support of investigations

Competency in each of the following areas should be ensured by the microbiology fellow upon completion of training.

CHECKLIST

Area	Topic or Procedure	Trainer Signature	Date of Training Completion
The diagnostic laboratory in infection control	Role of clinical microbiology in hospital infection control		
Functions of the infection control committee	Implementation of an infection control program		
	Surveillance, recognition, and control of healthcare-associated infections		
Principles of isolation in healthcare infection control			
Infection control precautions and required level for each of the major pathogens	Standard		
	Contact		
	Airborne		
	Droplet		
Immunization of health care			

workers			
Hand hygiene programs			
Principles of disinfection and antisepsis			
Public health responsibility to the community			
VUH and VCH antimicrobial stewardship programs			
Aggregation and analysis of microbiology data for infection control	Vanderbilt Infection Prevention Electronic Resource (VIPER)		
IDSA/SHEA infection control fellows course (http://www.iccourse.org/)	Pre-test		
	14 lectures (approximately 12.5 hours)		
	Post-test		
	Certificate of completion		

Recommended Learning Resources

Association for Professionals in Infection Control and Prevention (www.apic.org)

CDC information resource, Infection Control in Healthcare Settings (http://www.cdc.gov/ncidod/dhqp/)

Lautenbach et al, Practical Handbook Healthcare Epidemiology, 4nd edition. Cambridge University Press, New York, NY, 2018

Society for Healthcare Epidemiology of America (www.shea-online.org)

VUMC Department of Biostatistics (http://biostat.mc.vanderbilt.edu/wiki/Main/WebHome) (an excellent knowledge resource of theory and application pertaining to statistical methods in basic and clinical biomedical research)

**Most resources available in the laboratory or through Eskind Biomedical Digital Library*

Management & Informatics (1 month)
Rotation Director: Sefers

Fellows receive the equivalent of one-month aggregate training in clinical laboratory management, information systems, and automation spanning the two-year fellowship period; this exposure and experience occurs concomitant with other rotations and is acquired through a variety of learning formats.

Fellows meet regularly with Dr. Romney Humphries (Director of the clinical microbiology laboratory) and/or Susan Sefers (Manager of the microbiology, virology, and molecular infectious diseases laboratories) for ongoing instruction across the continuum of laboratory management activities.

Management

Fellows are deliberately and consistently included in discussions and decision-making activities among supervisors, managers, and directors pertaining to laboratory operations and development and, thus, receive continuing practical experience in the management of a diversified, high-volume infectious diseases testing facility. Additionally, emerging issues in clinical laboratory management at VUMC are discussed in daily MDMT rounds. These discussions serve as frameworks for assimilation of core management principles and highlight current medical, economic, regulatory, and workforce trends shaping the operational profiles of medical and public health microbiology laboratories. Fellows acquire knowledge and understanding of laboratory quality assurance, control, indicators, and management through participation in regular meetings of each infectious diseases laboratory section, attendance of monthly clinical laboratory-wide quality-indicator and directors' meetings, involvement in daily supervisors/managers problem-solving meetings as dictated by laboratory events, and investigation of laboratory errors. Fellows gain skill and expertise in regulatory compliance and laboratory accreditation through completion of the CAP inspector training curriculum and participation in external and internal ("mock") CAP inspections.

Fellows attend the management lecture series, *Fundamentals of Laboratory, Business, and Human Resource Management*, developed by the Department of Pathology, Immunology, and Microbiology to equip clinical trainees with foundational knowledge in clinical laboratory-management concepts. This series consists of 26 lectures (Appendix VIII) provided by departmental faculty and staff as well as invited extradepartmental speakers, including nationally recognized experts from the Vanderbilt Owen School of Business Management and Vanderbilt Department of Health Policy. Topics include the US healthcare system, consulting, innovation, workforce management, operational analytics, point-of-care testing, pre-analytical variation, budget management, coding/billing/compliance, problem solving, inventory management and instrument selection/purchasing, performance and competency, leadership and team dynamics, healthcare workflow/operations, LEAN strategies and workflow optimization, negotiation and conflict management, quality management, identification and investigation of laboratory errors, laboratory regulation (e.g., CLIA, CAP, FDA), and career planning.

Fellows participate in the investigation of laboratory errors (i.e., root-cause analysis) and the development and implementation of corrective actions, which may include crafting new policies or procedures. Fellows attend Morbidity, Mortality, and Improvement (MM&I) Conferences that involve laboratory errors that they have investigated. In addition, fellows are trained in disclosure, early reporting, and the MM&I process. They also assume integral roles in the laboratory response to outbreak investigations and other infection-control concerns.

Fellows learn applied principles of laboratory quality assurance, quality control, quality indicators, and quality management through participation in meetings of each infectious diseases laboratory section. They also attend laboratory-wide quality-improvement meetings and supervisors/managers problem-solving meetings, where quality issues are explored at analytical, clinical, and programmatic levels. Skill and expertise in regulatory compliance and laboratory accreditation are acquired through completion of the CAP inspector training curriculum, participation in internal ("mock") CAP inspections, and active involvement in preparations for external CAP inspections. In order to develop a more solid working knowledge of these issues as well as to hone practical skills in clinical laboratory management, fellows also participate in the following activities that focus specifically on laboratory quality assurance/control as well as to general principles of laboratory management.

-Involvement in a quality project under the supervision of a program director or another member of the clinical laboratory faculty. The project will address a specific quality problem or enhancement opportunity relevant to infectious diseases testing and include the following elements: identification of a quality issue, development of an approach for systematic investigation of contributing factors and data collection, data analysis, design and implementation of an improvement plan (likely in pilot format) that includes specific quality indicators, impact assessment, iterative modifications to the plan as required, final plan implementation, and documentation of quality improvement.

-Systematic exposure to individual laboratory PT programs while performing rotations in each infectious disease section and during six months of official responsibilities as laboratory "subdirector"; documented review and analysis of PT results, accompanied by participation in the investigation and corrective action of unacceptable performance.

-Documented review of staff competency evaluations in the Microbiology, Virology, and Molecular Infectious Diseases Laboratories and participation in the development of new or revised competency requirements (e.g., following changes to test systems or procedures); familiarization with content and assessment tools of competency programs implemented in each laboratory section: the fellow is assigned to participate in the development or revision of staff training plans, as well as corresponding competency assessments plans within the laboratory for at least one procedure.

-Participation in the development of and updates to individualized quality control plans in the Microbiology, Virology, and Molecular Infectious Diseases Laboratories: the fellow is assigned to write or participate in the writing of an IQCP for at least one test system during his/her fellowship.

-Familiarization with relevant CLSI documents, professional-society (e.g., IDSA) guidelines, and

state/federal regulatory mandates; leading regular guideline-review sessions during microbiology rounds or microbiology diagnostic management team rounds.

-Documented regular attendance of infectious diseases section (Microbiology, Virology, Molecular Infectious Diseases Laboratories) meetings while performing rotations in these laboratories and during six months of official responsibilities as laboratory "subdirector".

-Attendance of monthly clinical pathology quality-improvement meetings when quality projects or indicators specifically related to the infectious diseases testing areas are presented and discussed.

-Fellows are provided with two contemporary authoritative management texts in clinical laboratory management in order to facilitate systematic self-directed learning. The first is *Laboratory Administration for Pathologists* (CAP Press, 2011), which is an effective, contemporary resource for structured self-directed learning in this area. The second is the laboratory management text by Lynn Garcia (*Clinical Laboratory Management, 2nd Edition*. ASM Press, Washington, D.C., 2013).

The checklist below contains key concepts and information in laboratory medicine that fellows should master prior to completion of training.

Area	Topic or Procedure	Trainer Signature	Date of Training Completion
Budgeting	Capital equipment process		
	Labor		
	Flat vs. seasonal		
	Fixed and variable costs		
	Projections		
	Variance reports		
Billing	CPT codes		
	Compliance		
Cost accounting			
Staffing and personnel	Workload assessment		
	Preparation of job descriptions		
	Interviewing		
	Performance appraisals		
	Disciplinary actions		
	Competency assessment		
Project management	Techniques of policy change and implementation		

	Instrument selection and implementation		
	Strategic planning		
Workflow			
Specimen management	Labeling, transport, tracking, sharing, storage, and documentation		
Pre-analytic variables			
Space planning and laboratory design			
Test performance specifications	Analytical and clinical sensitivity, analytical and clinical specificity, PPV, NPV, ROC curve analysis, likelihood ratios, and pre- and post-test probabilities		
Test verification and validation	Participation in all phases of verification/validation of at least one test, to include project design, statistical analysis of the data, authorship of verification/validation summary, and generation of the report format and language		
	Key elements: method comparison, repeatability, reproducibility, LOD, calibration, AMR/linearity, interferences, specimen matrices		
	FDA-approved/cleared vs. laboratory-developed tests		

Development and maintenance of test menu			
Values requiring caregiver notice	Critical vs. courtesy		
	Governing institutional and extramural (e.g., Joint Commission) policies		
	Challenges to communication		
QC and proficiency testing	Lab-wide and area-specific QM programs		
	CAP proficiency testing program		
	Participation in data submission and presentation at lab-wide QI meetings		
	Statistical analysis of QC		
	Pseudo-outbreaks and laboratory contamination issues		
Antibiograms	Purpose		
	Data sources and extraction tools (EpiCenter, electronic data warehouse, Sentri7)		
	Data adequacy		
	Institution and area-specific		
	Formatting		
	Distribution policies		
Clinical and Laboratory Standards Institute (CLSI) documents			
Accreditation and laboratory inspection	CAP (including laboratory general, microbiology, virology, molecular ID, and		

	immunology checklists)		
	Joint Commission		
	State Department of Health		
	Participation in external and internal (mock) CAP inspections		
	CLIA licenses		
Point-of-care testing			
Use of reference laboratories	Factors impacting decision to outsource or insource		
Vendor management and relationships	Purchasing process		
	Preferred vendor arrangements		
	Pricing research		
	Medical Economic and Outcomes Committee		
Laboratory outreach	Billing and compliance		
	Medicare fraud and abuse initiatives		
	Office of Inspector General		
Benchmarking and metrics			
Roles of the laboratory director	Clinical		
	Administrative		
	Scientific and academic		
	Educational		
	Professional and volunteer		
	Advocacy		
Laboratory safety	Composition and use of a laboratory safety manual		
	Standard precautions		
	OSHA requirements		

	Biosafety hazards		
	Waste management, including disposal of biohazardous materials and sharps		
	Safe handling of radioactive materials		
	Physical and chemical hazards, including carcinogens		
	Methods of disinfection and sterilization		
	Baseline medical testing (immune status, protection, immunization)		
	Laboratory design as it applies to safety		
	Biological safety cabinets: maintenance and certification, safe use		
	Policy for managing laboratory accidents, including managing a safety emergency		
	Rules and regulations related to packaging, shipping, and disposal of biohazardous materials		
	Select agents		
Medicolegal issues	Medical errors and patient safety		
	Documentation practices		
	Relationship with risk management office		
	Completion of disclosure training		
Donor screening	Living and deceased solid organ donors		
	Hematopoietic cell donations		
	Blood-product donation		
	Transfusion-transmitted infections		

	Regulation by FDA and OPTN/UNOS		

Informatics and Computer Training

Fellows receive instruction in use of the main laboratory information system (LIS) during orientation. The seminar series on Laboratory Management includes one lecture on the basics of LIS/informatics. There are online resources available for acquainting fellows with LIS basics (including interfaces with instruments and other clinical systems) as well architecture, capabilities, and management of hospital electronic ordering and medical records systems. The best of these online courses is offered by the University of Pittsburg Medical Center < https://epssecure.upmc.com/VRPI/index.cfm >. The fellow should possess proficiency in the monitoring and analysis of antimicrobial susceptibility testing (AST) data, which includes active participation in the development of annual antibiograms. Therefore, rigorous training in the retrieval, evaluation, and formatting of information from the relevant data repositories will be provided by expert users in the Microbiology Laboratory in regards to the antibiogram. In addition, the fellow will take a lead role in the creation of the annual antibiogram. Training in LIS capabilities, functionality, data management, reports, instrument interface, electronic medical record interface, database interrogation, and trouble-shooting are provided through a series of individual sessions with the supervisors of the microbiology, virology, and MID laboratories. The checklist below summarizes essential concepts and skills in information management that fellows should learn during the course of their training.

CHECKLIST

Area	Topic or Procedure	Trainer Signature	Date of Training Completion
Storage, retrieval, and analysis of bacterial identification and antimicrobial susceptibility testing data	BD EpiCenter		
Applications supporting statistical analysis of QC and test verification and validations	EP Evaluator		
Microbiology-specific aspects of the LIS	Specimen receipt and accessioning		
	Preliminary and final reporting		
	Test menu		
	Test ordering		
	Entering results		

	Recalling epidemiologic data		
	Generation of reports		
	Communication with electronic order entry and medical record systems		
Abnormal laboratory values	Alerts Monitor system		
Informatics	Digital imaging		
	Copyrights		
	Principles of communication in the digital age		
	BIOVU DNA databank and electronic medical record Synthetic Derivative		

Recommended Learning Resources*

Byham, W.C. Targeted Selection Interviewer Program. Development Dimensions International, Bridgeville, Pennsylvania, 1998

Compendium of Costs Savings Projects: Laboratory. University Hospital Consortium Services Corporation, Oak Brook, IL, 1995

Cowan, D.F. Informatics for the Clinical Laboratory: A Practical Guide for the Pathologist. Springer, 2005

Garcia L.S., *et al.* Clinical Laboratory Management, 2nd Edition. ASM Press, Washington, D.C., 2015

Howantiz , P. J. Quality Assurance in Physician Office, Bedside, and Home Testing. College of American Pathologists, Washington, D.C., 1986

Joregensen, J.H., *et al*., Manual of Clinical Microbiology, 11th edition, ASM Press, Washington, DC, 2015

McPherson, R.A., and M.R. Pincus. Henry's Clinical Diagnosis and Management by Laboratory Methods, 23nd edition. Saunders, Philadelphia, 2016.

UPMC On-Line Informatics Course < https://epssecure.upmc.com/VRPI/index.cfm>

Varnadoe, L.A. Medical laboratory Management and Supervision. F.A. Davis, Philadelphia, 1996

Wagar, E. *et al*., Laboratory Administration for Pathologists, CAP Press, Washington, DC, 2011

**Most resources available in the laboratory or through Eskind Biomedical Digital Library*

Microbiology Diagnostic Management Team (MDMT)
Rotation Directors: Humphries, Gaston and Schmitz

The MDMT consists of laboratorians actively supporting clinicians in their patient care activities by maximally leveraging all information, technology, and expertise uniquely contained within the diagnostic laboratory to aid clinical decision-making. The MDMT functions as a partner with and resource for hospital services focused on the clinical management, therapeutic assurance, control, and prevention of infectious diseases. Team members include the clinical microbiology faculty, microbiology fellow, and pathology residents on the microbiology rotation. The MDMT meets daily, M-F, from 1:30 pm – 3:00 pm to review significant (or "sentinel") microbiology results and support clinical care by ensuring that important results are recognized and addressed, assisting with proper utilization and interpretation of microbiology tests, serving as an internal informational and diagnostic resource to other laboratory services, resolving testing problems and concerns experienced by the clinical staff, and providing clinician education in the laboratory diagnosis of infectious diseases. MDMT actions in response to sentinel results include verbal and/or electronic contact with decision-making members of the primary clinical team, coordinating consultation by the infectious diseases services when appropriate, and entering microbiology interpretations in the medical record.

Microbiology fellows occupy several key, cementing roles in the MDMT, which include sentinel result monitoring; case analysis, presentation, and follow-through; creation of continuity during resident transitions; and orientation of new residents to the MDMT service. Fellows remain on the MDMT service throughout the course of their training and attend case rounds daily, excluding rotations that remove them from the laboratory (e.g., public health microbiology and infectious diseases service). A primary goal for extensive involvement of fellows on the MDMT is to integrate their knowledge of medical microbiology, clinical infectious diseases, systems-based clinical practice, and laboratory management preparatory to a career that overlaps each of these knowledge domains.

In addition to routine daily case review and management, the MDMT serves as the primary portal for microbiology consultation sought by anatomic pathology services, including cytopathology, surgical pathology, hematopathology, and autopsy. These frequent consultations expose the microbiology fellow to an array of concepts, techniques (including special stains, immunohistochemistry, *in situ* hybridization, and other methods) and clinical questions associated with histopathologic diagnosis of infectious diseases. Additionally, this experience creates the context for review and understanding of host responses to infection. The microbiology fellow serves as first point of contact for MDMT consults requested by anatomic pathologists, mediates communication of MDMT impressions to the requesting teams, and facilitates additional

microbiology studies that may be indicated.

Research (6 months)
Rotation Directors: Schmitz, Humphries, and Gaston

Fellows spend six or more calendar months of aggregate time engaged in clinical, translational, or basic research. Clinical or translational projects might focus on the design, development, validation (analytical or clinical), or implementation of diagnostic systems in the infectious diseases testing laboratories. Alternatively, the research might emphasize infectious diseases epidemiology, prevention, or treatment. Basic science relevant to clinical microbiology training and practice could take numerous directions depending on active programs within the department, funding availability, and trainee goals. All research will be performed in compliance with current regulatory expectations (please see Laboratory Ethics below). Key objectives for microbiology fellows engaged in research are to:

- Acquire mentored research experience that can form the basis of future independent scholarship
- Contribute to the literature of clinical microbiology or infectious diseases with information that substantively impacts the field
- Prepare for a future career as a clinical microbiologist capable of maintaining pace with the rapid dynamics of medicine and science

Teaching
Rotation Directors: Humphries, and Gaston

The VUMC microbiology fellowship program seeks, as a core goal, to nurture skilled educators who can effectively disseminate knowledge in the field to learners of all backgrounds and train future generations of clinical microbiologists. Fellows gain continuous teaching experience in both structured and casual settings throughout the course of training. Teaching activities include:

- Regular case presentations at daily microbiology teaching rounds
- Small-group (“bench-side”) instruction of pathology residents and ID fellows in principles and techniques of microbe identification
- Continuing education for the technologist staff
- Education of students in medical, graduate, and medical technology training

Laboratory Ethics
Rotation Director: Humphries, Gaston and Schmitz

Microbiology fellows receive training in the ethics of clinical laboratory practice through formal and informal mechanisms. Daily microbiology teaching rounds not only address central concepts of infectious disease prevention, diagnosis, and treatment, but also intentionally explore the role of laboratory medicine within the broader sphere of healthcare, which includes ethics topics related, for example, to patient care, resource utilization, billing, consultation, and protection of health information. Additionally, ethical questions attached to specific situations in the VUMC diagnostic or other laboratories are often discussed *ad hoc* as opportunities to consider defined ethical standards of laboratory medicine and as well as areas demanding individual judgment for lack of clear consensus. Similar questions and themes are addressed more formally in the Department of Pathology, Microbiology, and Immunology Laboratory Medicine Rounds, in which four morbidity-and-mortality conferences per academic year (led by Dr. Hoffman) pertaining to VUMC cases are presented as frameworks for discussions of ethical issues surrounding the practice of laboratory medicine. Additional standardized training in biomedical laboratory ethics is obtained through attendance of a day-long course in the responsible conduct of research (RCR) presented by the Vanderbilt Biomedical Research, Education, and Training Program. RCR topics include institutional and NIH polices regarding grants, research, animal use, and human subjects; data management and record keeping; conflict of interest; authorship and publication; and self-deception and the goal of objectivity. Topics are accompanied by illustrative case studies.

Fellows are required to complete the web-based Collaborative Institutional and Training Initiative (CITI) course in research ethics education (Group I, biomedical), accessible through the following portal: http://www.mc.vanderbilt.edu/irb/training/citi_instructions.php. Documentation of successful course completion should be provided to the fellowship program coordinator, who will maintain the certificate with the fellow's training records. CITI training must be completed prior to commencement of research activities.

As a house staff member under the aegis of the Vanderbilt Office of Graduate Medical Education, the microbiology fellow receives training in patient safety, medical/legal liability, and risk management during orientation. This instruction incorporates discussions of event reporting as well as case analyses. Additionally, annual completion of a HIPAA basic training course offered through the VUMC on-line Learning Exchange is required of all Vanderbilt house staff.