Knowledge of clinical microbiology is an integral component in the management of patients with infectious diseases. Clinical microbiologists validate, implement and ensure quality control of all the tests and cultures performed in the clinical microbiology laboratory servicing hospitals and outpatient clinics. Typically, microbiology is taught to medical students by basic science microbiologists or infectious diseases physicians with minimal input from clinical laboratory specialists. Emory University School of Medicine implemented a course in the final month of the senior year of medical school to ensure that students are ready for postgraduate residency. As part of this course and emphasizing the Systems-Based Practice core competency of the Accreditation Council for Graduate Medical Education (Gregory et al., 2009), one full day was allotted to the Department of Pathology and Laboratory Medicine. During this 'Laboratory Medicine Experience', students toured different hospital clinical laboratories and solved cases designed to stimulate discussions that emphasized laboratory medicine fundamentals as delineated by the Academy of Clinical Laboratory Physicians and Scientists (Smith et al., 2010; Molinaro et al., 2012). Using case-based learning (Srinivasan et al., 2007), an additional 4 h elective in clinical microbiology was offered 1 day after the 'Laboratory Medicine Experience'.

The leadership of the Emory microbiology laboratory has prepared 70 vignettes that are used daily for microbiology rounds. Each vignette presents a case with pertinent images, and has a series of questions that facilitate and guide discussions that highlight microbiology skills that are applicable in the clinical setting. Attendees to microbiology rounds include medical students, internal medicine and pathology residents, infectious disease fellows, pathologists, microbiologists and infectious disease clinicians. The breadth of the questions and answers is designed to accommodate the various levels of the trainees present as well as to take advantage of the multidisciplinary learning environment. A printout of the vignette is given to everyone attending rounds so that participants can take notes and retain a copy for future reference. Eight of the 70 vignettes were selected for the senior year elective as these are illustrative regarding specimen requirements, microbiological techniques and interpretations that are important for clinicians to establish a diagnosis. Topics included Gram-positive and Gram-negative organisms, antimicrobial susceptibility testing, mycobacterial, parasitic and fungal infections, and serology for a viral infection.

The elective began with a 14-question multiple-choice knowledge quiz to assess awareness of clinical microbiology by fourth-year medical students. After the quiz, the medical students were divided into four groups of six to eight students each. A multidisciplinary team composed of a clinician and microbiologist/pathologist was assigned to lead the discussion of two of the vignettes to each of the student groups which rotated from one group of faculty facilitators to the next. Each vignette presentation and discussion took approximately 20 to 25 min. After the students had gone over all the vignettes they were given the same 14 question multiple-choice quiz. In order to compare the initial and final quiz results but maintain anonymity, students were assigned a code that was used as identifier for both quizzes. The final quiz also contained an elective student satisfaction survey.

Approximately one quarter of the graduating medical student class enrolled in the clinical microbiology elective (30 of 114). Thirteen (43 %) of the 30 enrolled students will be training in internal medicine, while the remaining students will be training in other specialties including surgery, paediatrics and obstetrics/gynaecology. Twenty-four (80 %) students taking the elective completed both quizzes. The mean score before the discussion of the vignettes was 53 % correct answers (range 36–71 %) as compared with 85 % (64–100 %) at the completion of the session (P=0.0001; 95 % confidence interval 3.86, 5.55). The mean improvement was 4.75 (mode 4) correct questions, with a minimum of 3 and a maximum improvement of 7. Fig. 1 demonstrates there were many more incorrect answers (grey cells) in the initial quiz compared with the number of incorrect answers in the final quiz. There was improvement in all questions except for one question related to the frequency of positive Gram stains in patients with meningitis (Fig. 2).

The satisfaction survey showed that 25 % of the students had previous exposure to clinical microbiology vignettes since they had done clinical rotations in infectious diseases and had attended microbiology rounds. Overall, 90 % of students agreed or strongly agreed with the format that included two faculty members leading the case-based discussions, they thought the elective would be useful for their daily work as residents, and that the elective helped prepare them for exams such as the National Board of Medical Examiners. The students were asked to indicate which vignette they liked the most and 13 of them picked the one regarding diagnosis of fungal infections, citing that this topic is not taught in medical school. When choosing qualifiers for the elective, 21 (87 %) students thought it was very useful and practical, 14 (58 %) found it interesting and informative, 13 (54 %) thought it was stimulating, while 11 (45 %)
found the activity challenging and 4 (16%) found it difficult and demanding.

Our results show that medical students taking a 4 h clinical microbiology elective improved their knowledge as demonstrated by a knowledge quiz given before and after the activity took place. The quiz could only measure a small amount of recently acquired knowledge which may not adequately estimate what was learned and does not assess whether or not the students will retain these concepts once in practice. Although the quizzes did not count towards passing or failing the elective most students that participated completed both quizzes.

We believe the combination of the ‘Laboratory Medicine Experience’ and microbiology elective gave medical students a better understanding of how the clinical laboratory functions and how it is critical in clinical decision making. In this era when laboratory test results are available electronically and medical students and house staff are not trained to be competent to perform basic tests such as Gram stains, there is little reason for them to visit the clinical laboratory or learn how laboratories function. The elective allowed us to showcase some of the specimen requirements for microbiology and pathology tests and the procedures used to make a microbiological diagnosis, and also to encourage consultation of clinicians with clinical microbiologists.

Finding the time to teach clinical microbiology in an already robust medical school curriculum has proved to be challenging. Case-based learning allows for open-ended exploration of topics with a structure and well-defined goals so that there is more efficient use of time (Srinivasan et al., 2007). It also has the

Fig. 1. Visual representation of the students’ answers to the initial and final elective knowledge quiz. Incorrect answers are in grey, students are numbered, and questions are lettered. The final column represents the absolute number of questions that were gained between the pre- and post-elective quiz.

Fig. 2. Percentage of students having correct answers for each question before and after the activity.
advantage of allowing application of facts in a sequence that mimics the actual processes from patient presentation with various signs and symptoms to having culture results. A previous study which compared the traditional lecture approach to a combined lecture and case-based format showed significantly better scores in median and final exams by those students who were enrolled in the combined lecture case-based format (Chamberlain et al., 2012). The authors commented that microbiology concepts required memorization of random facts that only had clinical relevance when they were placed in the context of a clinical case. The Infectious Disease Society of America also proposes using an interdisciplinary group of facilitators to guide small group discussions of cases as an approach to improve teaching of medical microbiology and infectious disease concepts (Southwick et al., 2010). From our survey, it is clear that the interdisciplinary case-based approach is liked by students.

The faculty has identified some limitations and areas for improvement. Suggestions included increasing the time spent in some vignettes but reducing the time spent in others and reviewing the other vignettes available for microbiology rounds to determine if there are ones better suited to teaching the foundations presented by the Academy of Clinical Laboratory Physicians and Scientists. Although it may be desirable that activities such as the one presented here occur earlier in the medical school curriculum and include the entire medical student class, one advantage of offering the activity at the end of the medical school curriculum is that it selects those students interested in the topic. A disadvantage of having this activity so late in the medical school curriculum is the decreased opportunity for students to practice an integrated clinico-microbiological diagnosis with effective feedback. To provide opportunities for students to practice clinico-microbiological diagnosis we encouraged students to use the online vignettes (http://www.path.emory.edu/Vignettes/ username: MicroV; password: MicroV) we have created which include the vignettes presented during the activity. The online vignettes have 10 to 18 multiple-choice questions each followed by immediate feedback and are similar to interactive electronic learning tools with questions and real-time feedback that have been used to teach medical students infection control modules (Conn et al., 2012; O'Neill et al., 2011).

The case-based elective format could easily be adopted by other institutions and could be applied earlier in the medical school curriculum. The elective would ideally include a tour of the clinical laboratory either preceding or following the case discussions. Further objective studies are required to assess the presented structure as well as other approaches to teaching clinical microbiology to medical students. It will also be important to determine, in future years, how knowledge gained in electives such as this may contribute to the medical students’ residency experience and which of these approaches has proved most useful to their success as practising physicians providing quality patient care.

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