Changes in Academic Food Safety Microbiology Teaching Laboratories: Are We Throwing the Baby Out with the Bath Water?

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SUMMARY

Reports of outbreaks of human disease associated with college microbiology teaching laboratories have provided impetus for changed thinking regarding students' exposure to pathogenic microbes, including those studied in food microbiology laboratory courses. Although U.S. federal regulations stipulate that biological agents must be handled by use of a series of procedures to prevent loss of containment and potential human exposure, these regulations are frequently more rigorously applied to research laboratories than to teaching laboratories. Regulation of biosafety by university administrators can become unnecessarily restrictive, potentially dampening student learning. This paper arose from a roundtable discussion by food microbiology teaching faculty, university biosafety compliance administrators and committee members, and food safety officers in industry regarding the implementation of biosafety practices in undergraduate food microbiology teaching laboratories. Issues addressed include the use of surrogate organisms for pathogens and criteria for their selection; the appropriateness of using uninoculated versus inoculated "spiked" samples for microbiological analysis by students; and proper administration of laboratory biosafety regulations with respect to the immuno-compromised student. The panel recommends that course instructors and university compliance officers strive to communicate concerns with one another to reach agreement on mutually acceptable practices for teaching laboratory safety preservation, toward the shared goal of successful training of young professionals entering food science and food safety-related positions.

OVERVIEW

The development of competency in the handling, manipulation, and analysis of foodborne microorganisms, pathogenic or not, is of critical importance to the development of young food science professionals. Nevertheless, the need for skills development in the analysis of foodborne microorganisms must be met within the confines of institutional laboratory biosafety requirements. Not only have food microbiology courses traditionally included a laboratory component, the Institute of Food Technologists (IFT; Chicago, IL), in its revised curricular standards for a Bachelor of Science degree in the food sciences, mandates the inclusion of a laboratory component in undergraduate food microbiology coursework *(1, 2, 4)*. The American Society for Microbiology (ASM; Washington, D.C.) Task Force for Curriculum Guidelines published a series of guidelines on the development of standardized undergraduate microbiology curricula, incorporating recommendations that students be required to complete significant laboratory-based coursework to introduce them to critical microbiological analysis skills *(3)*. These documents directed undergraduate microbiology teaching faculty to engage their students in the safe manipulation of microbial organisms of relevance to human and/or pet foods, including native food and environmental microflora, fermentation organisms, and pathogens.

Since 1984, the U.S. Centers for Disease Control and Prevention (CDC; Atlanta, GA) and the National Institutes of Health (NIH; Bethesda, MD) have elaborated procedures for handling microorganisms used in laboratories requiring containment from biosafety levels (BSL) 1 through 4 *(9)*. These guidelines deal with many different biosafety-related procedures, including but not limited to: (1) facility and

equipment design; (2) aseptic technique; (3) containment; (4) personal protective equipment; (5) signage; and (6) procedures for disinfection and sanitation. The rigor of the guidelines is proportional to the biosafety classification of the laboratory. University food microbiology teaching labs have historically been taught at the combined BSL1/2 level. This is largely a result of many microbial foodborne microorganisms (including human pathogens) having been identified as requiring either BSL1 or BSL2 containment, as well as the general inexperience of undergraduate students enrolled in food microbiology courses.

In recent years, increased scrutiny of teaching laboratories has emerged, largely in response to published incidents of cases and/or outbreaks of disease. For example, in a letter to the Editor of the journal *Applied Biosafety*, Bavoil *(5)* reported on a single severe *Escherichia coli* O157:H7 infection in a well-trained microbiologist that was likely acquired by accidental exposure in a federal research laboratory. Subsequent CDC investigation of the incident resulted in a report that was highly disputed. The author posited that laboratory-acquired infections are under-reported because of lack of investigation and reporting, as well as the absence of written guidelines for prior review and approval of proposed experiments or exercises.

While this case could be considered anecdotal, the CDC reported two multi-state outbreaks of human salmonellosis in the past 5 years that may have been laboratory acquired. In an outbreak occurring in 2010–2011, 109 cases of human disease by a strain of *Salmonella* Typhimurium were identified in 35 states *(7, 11)*. While no hospitalizations were reported, there was one fatality. There was a significant connection between illness and exposure to a microbiology laboratory, either clinical or teaching, in a subset of the patients. In some cases, children of those who had participated in microbiology laboratory work were infected. Factors that might have contributed to the outbreak included improper hand-washing procedures or cross-contamination due to the use of non lab-dedicated writing implements or personal electronic devices (e.g., music players, smart phones, etc.) while working in the laboratory *(7)*. From November 2013 through May 2014, another 41 cases of human salmonellosis were associated with teaching or clinical laboratory exposure in 13 states *(8)*. This outbreak was also caused by a *S.* Typhimurium isolate, which was indistinguishable by pulsed field gel electrophoresis (PFGE) from a *S.* Typhimurium strain used for laboratory quality control purposes. Behaviors that might have contributed to that outbreak included failure to wash hands properly, use gloves, or use only dedicated writing instruments *(8)*. In both outbreaks, some patients suggested a failure of teaching faculty or laboratory directors to provide fundamental biosafety training.

Illness and outbreak reports such as these underscore the need for responsible application of biosafety procedures in teaching laboratories. In response, the ASM commissioned a task force to provide biosafety-focused guidance for teaching faculty supervising undergraduate microbiology laboratory courses *(10)*. The ASM Task Committee on Laboratory Biosafety recommended that responsible faculty should first complete a thorough risk assessment to evaluate likely exposure risks to students, both immuno-competent and immuno-compromised, in cooperation with university biosafety officer(s). A series of recommended practices adhering to federally mandated procedures for handling of agents within BSL2 containment were provided in a written document, summarized in *Table 1 (10)*. Additionally, recommendations were made regarding the use of personal protective equipment, laboratory physical construction and layout, standard laboratory safety practices usage, student and instructor/graduate teaching assistant training, record keeping, and documentation procedures *(Table 1)*. The Committee concluded that application of these practices did not constitute an overly cumbersome task for faculty.

Nevertheless, an *ad hoc* survey of various food microbiology laboratory instructors in the U.S. revealed that implementation of these recommendations in some institutions has been burdensome and expensive and may come at the price of effective student training. During the 2013 Annual Meeting of the International Association for Food Protection, the authors conducted a roundtable panel session discussing the needs of identified stakeholders (teaching faculty, students, university administrators charged with biosafety oversight, and food industry professionals as employers of food science graduates) to cooperatively find solutions to the problem of maintaining laboratory safety in food microbiology teaching laboratories while not diluting the quality and depth of knowledge transfer. The objective of this article is to relay the opinions and conclusions of the panel members and provide recommendations for instructors charged with the teaching of food microbiology laboratory course(s) so that they can incorporate adequate biosafety instruction into their teaching laboratories while also allowing for a rich learning experience for students.

BIOSAFETY IN THE FOOD MICROBIOLOGY TEACHING LABORATORY: THE TEACHING FACULTY PERSPECTIVE

Author Taylor began the session by describing his experience with changes following installation of multiple new biosafety policies and systems within his institution. He described these changes in policy and recommendations to be practically unattainable for some investigators, in large part because of the cost of new equipment sufficient for the numbers of students in courses with large student enrollments. Dr. Taylor described an instance in which university biosafety officers recommended the installation of biological safety cabinets for all students in a laboratory used to teach undergraduate food microbiology students. This was

Table 1. Recommended practices for safe handling of microbial agents in the food microbiology teaching laboratory under biosafety level (BSL) 2 containment[a]

Category	Recommended Practice
Personal Protection and Personal Protective Equipment (PPE) Usage	Wear safety goggles or safety glasses for laboratory procedures involving liquid cultures not anticipated to produce splash risk (e.g., proper pipetting, spreading of agar plates, etc.). Use safety goggles or face shield for procedures anticipated to produce a splash hazard. Work completed in a biological safety cabinet (BSC) does not require use of safety goggles or face shield.
	Wear closed-toe shoes covering the top of the foot.
	Wear gloves when handling microorganisms or hazardous chemicals.
	Wear laboratory coats. Coats should be launderable or be disposable to assist in prevention of disease agent exposure during completion of laboratory procedures.
Laboratory Physical Space Requirements	Include in all laboratory space: (1) nonporous bench tops, chairs, and stools; (2) sink for hand washing, and; (3) eyewash station (checked regularly for proper water flow).
	Follow proper pest control plans/procedures.
	Keep the storage area for personal belongings separate from working area.
	Keep a working, validated autoclave in the building or arrange for licensed waste removal according to local, state, federal regulations.
	Post biohazard signage: wherever cultures are used and stored; on the door to the laboratory, and on all containers used to transport cultures.
	Recommended: Maintain working BSC (required for use with large volumes of culture or when the procedure is expected to create aerosol).
Standard Laboratory Practices	Wash hands after entering and before exiting laboratory.
	Tie back long hair out of face and off shoulders.
	Do not wear loose/dangling jewelry.
	Disinfect bench top before and after laboratory session with disinfectant known to inactivate organisms handled.
	Use disinfectant according to manufacturer instructions.
	Do not bring food, gum, drinks, or water bottles into laboratory.
	Do not touch face, apply cosmetics, adjust contact lenses, or bite nails.
	Do not handle personal items (e.g., cosmetics, cell phones, calculators, writing instruments, etc.) while in the laboratory.
	Do not mouth pipette.
	Label all containers clearly.
	Keep door closed while laboratory is in session. Laboratory director or instructor approves all personnel entering the laboratory.
	Minimize use of sharps. Use needles and scalpels according to manufacturer instructions.
	Use proper transport vessels for moving cultures in the laboratory and store vessels containing cultures in leak-proof container when work is complete.
	Use leak-proof containers for storage and transport of infectious materials.
	Use micro-incinerators or disposable loops rather than platinum loops requiring Bunsen burners.
	Arrange for proper (safe) decontamination and disposal of contaminated material (in properly maintained and validated autoclave) or arrange for licensed waste removal according to local, state, and federal regulations.
	Do not handle broken glass with fingers; use a dustpan and broom.

(Continued)

Table 1. Recommended practices for safe handling of microbial agents in the food microbiology teaching laboratory under biosafety level (BSL) 2 containment[a] (cont.)

Category	Recommended Practice
Standard Laboratory Practices	Notify instructor of all spills or injuries.
	Document all injuries according to university or college policy.
	Keep note taking and discussion practices separate from work with hazardous or infectious material.
	Use only institution-provided marking pens and writing instruments.
	Teach, practice, and enforce the proper wearing and use of gloves.
	Advise immunocompromised students (including those who are pregnant or may become pregnant) and students living with or caring for an immunocompromised individual to consult physician to determine the appropriate level of participation in the laboratory.
Training Practices	Be aware that student assistants may be employees of the institution and subject to OSHA, state, and/or institutional regulations.
	Conduct extensive initial training for instructors and student assistants to cover the safety hazards of each laboratory. The institution's biosafety officer (BSO) or microbiologist in charge of the laboratories should conduct the training.
	Conduct training for instructors whenever a new procedure or procedural change is implemented.
	Conduct training for student assistants annually.
	Require students and instructors to handle microorganisms safely and responsibly.
	Require students to demonstrate a competency at BSL1 before working in a BSL2 laboratory.
	Inform students of safety precautions relevant to each exercise before beginning exercise.
	Emphasize to students the importance of reporting accidental spills and exposures.
Document Practices	Require students to sign safety agreements explaining that they have been informed about safety precautions and the hazardous nature of the organisms they will handle throughout the course.
	Maintain student-signed safety agreements at the institution.
	Prepare, maintain, and post proper signage.
	Document all injuries and spills; follow institutional policy if available.
	Make Material Safety Data Sheets (MSDS) available at all times; follow institutional documentation guidelines regarding number of copies, availability via print or electronic form, etc.
	Post emergency procedures and updated contact information in the laboratory.
	Maintain and make available (in syllabus, laboratory manual, online) to all students a list of all cultures (and their sources) in the course.
	Keep a biosafety manual specific to the laboratory and/or course in the laboratory.
	Keep a copy of the current version of *Biosafety in Microbiological and Biomedical Laboratories* (BMBL), in the laboratory.

[a]Adapted from Emmert et al. *(10)*

debated with regards to the added safety versus cost to the university, since such equipment is usually not easily acquired through use of competitive extramural grant funds. He noted that while non-pathogenic surrogates exist for some pathogens, they do not always produce the same phenotypic characteristics on microbiological media, are not always readily available by clearinghouses such as the American Type Culture Collection (ATCC), and in some instances require BSL2 containment according to university policy or CDC recommendations. Finally, Dr. Taylor discussed the concern/question about how to solve the need to give students an effective "hands-on" experience while protecting their safety such that they are appropriately trained to enter the professional workforce. Dr. Lee-Ann Jaykus also expressed concerns that changes to academic teaching guidelines can be quite burdensome to instructors, as they may necessitate full overhaul of facilities and equipment, laboratory exercises, and in some cases, curricula. In addition, she reiterated that the purpose of teaching laboratories is to teach and train students, and universities must carefully

balance their mandate to provide student training with the need to ensure a safe learning environment. Montville *(15)* also made this point, stating that inexperience increases the need for proper teaching by the experienced microbiologist, and extensive restrictions to laboratory instruction removes the opportunity for skills development and knowledge transmission to students.

Dr. Ruth Gyure discussed her role on the ASM Task Committee and the challenges of developing biosafety-focused recommendations in light of sometimes contradictory CDC recommendations *(9)*. She identified the lack of a set of unified recommendations for biosafety procedures in teaching laboratories, indicating great disparity between policies used across universities and colleges. She elaborated further on the work the ASM Task Committee members completed in risk assessments of BSL1 and BSL2 practices, their applicability to teaching laboratories, and the identification of practical recommendations that would produce significant risk reduction *(10)*. Finally, she identified common failures in good laboratory practices that assisted in the development of recommended biosafety guidance, particularly that of failure to effectively use personal protective equipment, wash hands routinely, and properly use and disinfect biological safety cabinets.

IMPLEMENTING BIOSAFETY IN THE TEACHING LABORATORY: THE UNIVERSITY BIOSAFETY OVERSIGHT PERSPECTIVE

Panel member Robert Nobles explained that various factors have increased the need for more rigorous biosafety-focused regulatory procedures in the university teaching environment. One of the prime factors was the general movement of universities into an enhanced regulatory enforcement-focused mindset, as a result of an increasingly higher level of scrutiny by federal and state regulatory bodies. This, he stated, was at least partially the consequence of recognized laboratory-acquired infections for which poor biosafety training and/or oversight were cited as contributing factors. The consequences of such infractions are often large fines, loss of federal funding, and/or even criminal charges. Such penalties have produced a desire among university administrators to engage with investigators to attain greater recognition of, and adherence to, regulatory policies.

Dr. Nobles stated, on the basis of his experience, that a university Institutional Biosafety Committee (IBC) should always have representation by both teaching and research microbiologists to aid other committee members in understanding project descriptions submitted by university investigators for approval. He also emphasized that investigators, teaching and/or research, should engage with their relevant health and safety administrators, discussing and debating the legitimacy of university-identified laboratory safety practices or regulatory policies. Dr. Jaykus pointed out a perceived "us vs. them" atmosphere on university campuses between faculty and biosafety officials, which complicates this process. Dr. Nobles responded that biosafety professionals need to clearly communicate the reasons for new policies but noted that failure to comply with evolving biosafety policies will likely lead to significant action on the part of administrators to move teaching and/or research faculty to a state of enhanced compliance. Communication is key to preventing such actions.

Dr. Francisco Diez-Gonzalez discussed his role as an investigator and member of his institution's IBC. In line with remarks made by Dr. Nobles, Dr. Diez-Gonzalez indicated that past failures in biosafety oversight at his institution have resulted in increased attention to compliance and greater proactive efforts at preserving laboratory biosafety across the campus. Dr. Diez-Gonzalez discussed examples of failure to provide appropriate containment for human cell culture lines in laboratories and the use of outdated methods for the handling and manipulation of microorganisms, as cause for concern and increased stringency in biosafety procedures enforcement. He noted that, until recently, there was a heavy focus on research laboratories, with little attention being paid to teaching laboratories.

BIOSAFETY AND THE PREPARATION OF FOOD SCIENCE STUDENTS FOR ENTRY INTO THE FOOD INDUSTRY

Dr. Kelly Stevens presented commentary on the food industry's perspective. Using a former undergraduate intern employment experience as an example, she described an instance in which a microbiology project had not been performed correctly, in large part because the student intern had not completed a laboratory-intensive microbiology course and was over-confident of microbiological analysis skills. She stated that poor laboratory safety knowledge and skills of recent college graduates is a concern to the food industry. This is especially true at present when food safety is a high profile public health issue and microbiological analysis is such an important component of food safety and quality programs. As an example, the need for skilled microbiologists to support efforts in implementation and execution of the Food Safety Modernization Act was identified. In short, Dr. Stevens concluded that first-hand experience with proper laboratory techniques, including work with pathogens, is critical to the food industry as they seek to hire well-qualified young professionals. In fact, she made the point that students leaving the university without strong laboratory skills may be less competitive in the marketplace. Dr. Stevens also argued that student capabilities are best discussed at the interview stage, and there should not be an expectation that basic microbiological skills will be acquired on the job rather than in the classroom or teaching laboratory.

I. Hazardous agent identification and risk assessment.	• Define hazard characteristics of agent(s) (e.g., infectivity, host susceptibility, disease severity, prevention, therapeutic measures). • Assemble information on known transmission routes for laboratory-acquired infection (LAI), host range, infectious dose, environmental stability, and availability of attenuated strains. • Assess preliminary biosafety level (BSL) appropriate for agents within laboratory.
II. Identify laboratory procedure hazards.	• Identify routine procedures presenting biosafety risks (e.g., aerosol generating methods, sharps use and wounding). • Determine procedure complexity and opportunities to simplify laboratory procedures to reduce or eliminate potential risk for agent unintentional exposure or release.
III. Determine BSL and select any additional needed precautionary practices.	• Identify whether intended agent use requires higher BSL containment than that recommended in agent Summary Statement *(9)*. • Consult with institutional research compliance and/or occupational health official to determine specialized needs for immunocompromised students for course completion.
IV. Determine instructor biosafety proficiency and equipment integrity.	• Identify course instructor/graduate assistant understanding of proper biosafety-related agent handling procedures. • Provide and document training in areas of identified instructor deficiency. • Confirm proper working condition of laboratory equipment, proper formulation and potency of laboratory work-space sanitizing solutions.
V. Review risk assessment with research compliance officer or Institutional Biosafety Committee (IBC).	• Submit laboratory risk assessment for biosafety review and approval. • Implement recommended changes.

Figure 1. Recommended process for food microbiology teaching laboratory risk assessment execution (adapted from Chosewood and Wilson (9))

PANELIST AND AUDIENCE INTERACTIVE DISCUSSION OF BIOSAFETY IN TEACHING LABORATORIES

Following the description of the core stakeholder perspectives, audience members were invited to submit questions to panelists for discussion. Questions were varied, and a full delineation of them is not possible here. However, a synopsis of some of the more meaningful discussions is provided below.

Is the use of pathogen surrogates a suitable alternative to the handling of foodborne pathogens in food microbiology teaching laboratories?

Dr. Diez-Gonzalez indicated that most food microbiology teaching laboratory modules at his institution have abandoned the use of BSL 2 containment-requiring foodborne pathogens completely, moving to the use of non-pathogenic microbes to function as pathogen surrogates. Hence, at his institution, hands-on work with foodborne pathogens has been more or less replaced by demonstration or display of typical biochemical reactions. Dr. Jaykus raised the question of how to systematically evaluate candidate microorganisms as pathogen surrogates for use in teaching laboratory practices. Further, she suggested there is a need for development and publication of listings of useful pathogen surrogates appropriate for teaching laboratory purposes, the pathogen(s) or reaction(s) the surrogate organism may be used for, and any changes to media formulation required to achieve proper phenotypic results. She closed her comments with a concern that the absence of one virulence factor did not necessarily mean that an organism was not pathogenic, and the fact that microorganisms can acquire mobile elements (e.g., plasmids, phages) may render them pathogenic. Dr. Taylor echoed Dr. Jaykus's concerns over the lack of clear guidance on pathogen surrogate selection and acknowledged that pathogen surrogates in research often are selected only for a small number of shared traits (e.g., thermal resistance), which does not guarantee their utility as surrogates in other applications of microbiological analysis that might be the subject of teaching laboratory exercises *(6, 12, 14)*. Finally, Dr. Jaykus noted that proper instruction, including hands-on experience manipulating pathogens, instills a healthy respect for these agents that the use of surrogates cannot replace.

Should food microbiology teaching laboratories preferentially train students through the analysis of uninoculated food samples versus "spiked" food samples?

Dr. Gyure addressed the question of allowing students to analyze retail food samples not previously inoculated with a relevant microbial pathogen, versus pre-inoculated "spiked" food samples. She acknowledged that, while trained graduate assistants would usually complete sample inoculation procedures, there is an elevated risk of exposure of students to pathogens following their intentional inoculation into the food sample(s). The major issue here is that, without spiking, students will largely be analyzing a "negative" sample, and consequently will lack the opportunity to observe, identify and characterize the pathogen or surrogate on relevant microbiological media following handling and manipulation of the experimental sample. Likewise, laboratory exercises focusing on food preservation and processing technologies, requiring evaluation of microbial inhibition or inactivation following exposure to the processing technology (e.g., thermal processing, high hydrostatic pressure), would be compromised. Dr. Taylor commented that, under circumstances such as these, student learning could be by the application of biosafety procedures so stringent as to make it impossible to teach key concepts or principles. Excessively stringent requirements might ultimately lead instructors or institutions to discontinue teaching with BSL2 containment-requiring agents as containment requirements become too expensive and/or added record-keeping and compliance demands too burdensome. Dr. Jaykus pointed out failure to provide students with hands-on experience with BSL2-requiring agents would mean that they must obtain that training and experience outside of the classroom. This means that universities will no longer provide the training historically expected of them, and young professionals will start their careers having to obtain that training elsewhere or jump into jobs without the appropriate training.

What procedures/needs exist to maintain biosafety in the food microbiology teaching laboratory with respect to the immuno-compromised student?

Perhaps one of the most challenging aspects of universal implementation of biosafety procedures in the food microbiology teaching laboratory is that of properly managing the risk incurred to the immuno-compromised (IC) student. Dr. Nobles pointed out the IC student may choose to not divulge his/her health status to teaching faculty, given the privacy protection afforded by the Health Information Portability and Accountability Act of 1996 (HIPAA). Additionally, the Americans with Disabilities Act of 1990 (ADA) stipulates that reasonable effort must be made to accommodate the needs of a student with a defined disability or other condition that might otherwise limit his/her ability to complete the college degree. Clearly, a tension exists between these pieces of federal legislation, as well as the need for a mechanism to identify the IC student so that appropriate risk management procedures can be implemented.

Dr. Nobles provided some examples of how to address this issue based on his professional experience. For instance, special language can be inserted into course documentation (e.g., course syllabus) to direct students to notify the university occupational health officer if they believe they fall into the IC category. This officer is then responsible for follow-up to assess the student's concerns and identify needed procedures to assure the student can safely complete course requirements. Although these procedures may be viewed as difficult

to implement, they remove the responsibility of faculty to investigate and identify IC students, placing it on the shoulders of the enrolled student working in concert with the responsible university official(s). Nonetheless, the willingness of IC students to self-identify remains a hurdle.

Another issue that was discussed was how to protect students' household members who might belong to at-risk groups (e.g., children, the elderly, pregnant women, IC individuals). This was considered particularly tricky, as their recognition and identification is more complicated. It was also commented that even commensal microorganisms could cause disease in IC individuals, prompting discussion about what constitutes a pathogen if even BSL1 containment-requiring organisms can cause disease under certain circumstances. Clearly an argument without a resolution, this illustrates the fact that zero risk is impossible and brings us back to the risk-benefit argument initially mentioned by Dr. Gyure.

An audience member commented that teaching faculty should focus on building an atmosphere of safety in the teaching laboratory for students, regardless of the types of foods or microbes handled during differing laboratory exercises. Panel members agreed with this assessment, restating that indeed some organisms designated as pathogen surrogates may present an infection risk for the IC student and/or his/her family members or roommates. In view of this, the use of pathogens when surrogates are not readily available or particularly useful was considered feasible as long as it was justified and student exposure was limited. Dr. Taylor commented that university biosafety personnel can be quite helpful in these sorts of discussions.

OVERARCHING THEMES:

While the purpose of this panel discussion was not to come up with recommendations per se, there were some common themes, detailed as follows.

1. Faculty should communicate concerns with university biosafety administrative personnel, including the university biosafety officer (BSO), in a timely fashion to allow discussion and dialogue on the best approach for policy development and implementation.
2. Teaching faculty should share and utilize resources available from within their institution or from other institutions whenever such resources are available. The sharing of training resources between institutions could be beneficial, although this is not currently done in any formal manner.
3. When appropriate, avirulent or attenuated pathogen surrogates should be used; however, keeping in mind that surrogates do not always behave identically to the real pathogen, there are instances in which it is appropriate to use pathogens.
4. "Risk assessments" are supposed to be completed for all microbiology laboratories and all agents and exercises in order to determine likely pathogenic agent exposure risks, likelihood of disease and consequence of disease onset, and means of exposure prevention/reduction *(9)*. However, few if any institutions provide guidance on *how* to do these risk assessments. Biosafety personnel must provide guidance to teaching faculty in this regard, e.g., what organism attributes must be considered, likely exposure routes (e.g., contact with cross-contaminated sharps/needles, aerosol inhalation/ingestion), relevant containment methods, etc. The term risk assessment is frequently misused and might be replaced with a more appropriate term, such as hazard assessment *(13)*. The ways in which risk management is approached also differ when comparing teaching laboratories to research laboratories. An example of a risk assessment/management plan as applied to these two distinct university laboratory types is provided in *Table 2*, prepared by authors Nobles and Taylor. The common theme is the assumption of greater risk to participants in teaching labs relative to research labs and the adjustment of risk management accordingly.
5. Working with university biosafety administration, instructors should develop written language for syllabus insertion and a legal and effective means by which to promote student self-identification of IC status.
6. Students should be taught from the perspective of building knowledge and skills in aseptic technique, sample preparation, quantitative and qualitative analysis of both BSL1 and 2 containment-requiring microorganisms. With proper engagement, students can become allies of faculty and university officials in identifying exposure risks and managing those risks appropriately. Indeed this process could serve as an excellent learning exercise in and of itself.

CONCLUSIONS

The need remains for B.S. degree-holding young professionals trained to perform comprehensive microbiological analysis of foods. As has been the case historically, it is the responsibility of university food microbiologists to oversee the effective training of students in these techniques. Training must be completed in a safe environment, but achieving this is complicated by the mere fact that working with microbial pathogens implies some degree of health risk. Actively incorporating appropriate biosafety procedures and practices in the teaching laboratory can help manage disease agent exposure risks, and knowledge of such practices is critical to student training. However, in an increasingly risk-averse, regulatory enforcement-focused society, it can be difficult to balance the need to give students useful experiences with the microbial agents they will encounter during their careers with the need to provide an "appropriate level of protection" of their health.

Everyone in the audience recognized the conundrum discussed in this roundtable session. This was not a consensus exercise, so all participants spoke from his/her own unique perspective. Perhaps the central recommended outcome was the need for frequent and thoughtful communication between university biosafety officers and teaching faculty/

Table 2. Hypothetical comparative hazard and risk assessments for completion of procedures anticipated to cause agent aerosol risk in research versus teaching laboratory settings

	Research Laboratory	Teaching Laboratory
	Virulent *Salmonella* Typhimurium streaking on selective/differential agar medium.	*Salmonella* Typhimurium LT2 streaking on selective/differential agar medium.
1.0: Hazard Assessment		
1.1: Recognized to cause human disease in healthy, immuno-competent adult?	Yes	No
1.2: Risk Group Classification:	2	1
1.3: Potential exposure routes?	A. Aerosol inhalation or ingestion.	Same
	B. Direct contact with skin, eye, mucous membrane.	
	C. Accidental ingestion following cross-contamination of fomite.	
1.4: Immuno-competence status of researcher/student(s) known? (1: Yes; 2: Likely; 3: Possibly; 4: Unlikely; 5: Unknown).	1, 2	1, 2, 3
2.0: Risk Assessment		
2.1: Required agent biosafety level (BSL) containment.	2	2
2.2: Institutional procedures to limit exposure risk.	Use of gloves, lab coat to reduce skin exposure risk. Task completion in BSC to limit aerosol contact/inhalation/ingestion risks.	Use of gloves, lab coat to limit skin exposure risk. Use of eyeglasses to limit inhalation, ingestion risk. Added biosafety measure: use of BSC to limit contact risk.
2.3: Staff/student competency and experience.	Expected: strong competency/skill. Potential low competency/no skill.	Expected: low competency, no training/skill.
2.4: Risk mitigation for low competency/skill scenarios.	Use of trainer/trainee system for teaching good aseptic technique from highly trained researcher to untrained/low competency researcher.	Use of graduate assistant with strong competency and good aseptic technique to train students, install biosafety-focused mindset, and continuously observe to reinforce aseptic technique and biosafety.
2.5: Trainer:trainee ratio.	Expected low (1:1, not expected to exceed 1:5)	Expected high (1:12 – 1: 24)
2.6: Equipment/resource availability.	Required PPE, BSC, entry/exit signage, wash stations, hand soap and one-use towels, bench sanitizers, spill clean up kit, MSDS forms, biosafety manual.	PPE (gloves, disposable lab coats, eyeglasses/face-shield), eyewash and hand washing stations, hand soap, spill clean-up kits, lab MSDS forms and biosafety manual.

instructors. It is clear that both parties put protection of health as the highest priority. Thereafter, perspectives differ, with the former focusing more on issues of institutional liability and regulatory compliance adherence and the latter on student education and job preparation, with some concern about overly burdensome compliance requirements. All of these are important. There is a middle ground, although it probably has not yet been identified, and currently there are incredible institutional differences that range from complete bans on use in teaching laboratories of

agents requiring BSL2 containment to "business as usual." However, dialogue across disciplines and universities, and sharing of experiences and resources, can go a long way in solving differences. After all, the ultimate goal is the same: to provide a safe environment that fosters the relevant training of young professionals so as to promote students' futures and support the agri-food industries to supply the world's population with wholesome, safe food for consumption.

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