Future of Occupational Health Project: Final Report and Recommendations

November 9, 2015

Report Authors:
Noah Seixas, Trevor Peckham, Marissa Baker

Steering Committee:
Marissa Baker[1], Janice Camp[1], Dave Eaton[1,2], Howie Frumkin[1,3], Dan Jacoby[4], Dave Kalman[1], Joel Kaufman[1], Trevor Peckham[1], Peter Rabinowitz[1], Noah Seixas[1] and Mike Yost[1]

[1]Department of Environmental and Occupational Health Sciences, University of Washington

[2]Dean and Vice Provost, Graduate School, University of Washington

[3]Dean, School of Public Health, University of Washington

[4]Interdisciplinary Arts and Sciences Program, University of Washington-Bothell

INTRODUCTION

The occupational health and safety field is in the midst of a significant transformation. Many of the established researchers and practitioners in the field entered it during the 1970s, an era in which the OSHA law was enacted, the labor movement was strong and environmental and women's rights movements were on the rise. Since this time, industrial globalization, technological innovation, economic transformation and a waning labor movement have fundamentally altered the landscape for occupational health.

Traditional manufacturing is being replaced with automated and contained processes, many labor-intensive industries are being exported to developing economies and there has been a profound increase in the use of part time, temporary and contingent workers. Evidence suggests that in developed economies the use of a number of highly toxic or carcinogenic industrial materials has been curtailed, workplace exposures have diminished and injury rates have gone steadily down [1, 2]. The practice of occupational medicine today has also substantially changed from that of 25 years ago, with worksites less likely to employ physicians directly, and more of the occupational care of workers performed by contract clinics where providers may be less familiar with worksite exposures. The content of the services has also changed to include more health promotion and primary care services in many locations.

Yet the number of workplace injuries, illnesses and deaths remains unacceptably high and imposes an enormous burden on society. Every year an estimated 2.3 million workers are killed on the job worldwide, while over 300 million are injured and 160 million get sick from work-related hazards [3]. In the U.S., there are about 4,500 deaths and three million injuries and illnesses recorded annually on legally mandated logs [4, 5]. The economic costs of these occupational injuries are immense, an estimated $190 – 250 million in the U.S. alone [6, 7], with most of these costs borne by injured workers,

their families and taxpayer-supported programs [8]. However, it is well understood that these estimates of occupational injuries and illnesses are likely only a fraction of the true number [9-12]. While estimating the burden of work-related injuries and disease is complicated due to latency, underreporting, etc., we understand even less the impact of work-related psychosocial factors that can influence health (positively or negatively), or the contribution of work in facilitating social disparities in health within and across generations [13].

Despite recognition of these realities, researchers and practitioners entering the field are largely being trained to assess and control exposures using approaches developed under old models of work which may not adequately address health hazards in the workplace of the present and future. We find ourselves wondering if the traditional professional approaches to understanding and controlling risks in the workplace, and the methods being taught to trainees, are out of date, or even obsolete.

These concerns prompted a project to examine the future of occupational health. In particular, what is the role of the occupational health professional as a practitioner, and what skills are needed to be effective? What are the key research questions that will need to be tackled in the future, and what means of investigation will help inform them? What social policies will help support effective occupational illness and injury prevention strategies in our altered world of work, including approaches in government, industry and non-governmental organizations?

THE OCCUPATIONAL HEALTH FIELD MUST ACT

It is incumbent upon occupational health researchers, practitioners and policymakers to identify new and creative approaches to workplace health and safety as a component of the changing workplace, economic, environmental and public health priorities. Around the country, programs in industrial hygiene, occupational medicine and occupational health nursing have experienced a decline or threats in program funding and a decreasing number of supporting faculty [14]. These programs require updating of curriculum and research portfolios to stay current and responsive to the interests of students and needs of the workplace. The restriction of available funding underscores the importance of keeping these programs on the leading edge of work health and safety and effective in competing for available funds. Additionally, current regulatory approaches to control workplace hazards are antiquated and their effectiveness has declined, suggesting that alternative strategies need to be proposed, investigated and evaluated. These observations, and others described herein, make the need for a revision of our occupational health activities compelling.

SPEAKER SERIES AND SYMPOSIUM

To aid the exploration of how these changes may affect occupational health, a series of speakers from different disciplines was invited to discuss their perspectives on current challenges and future directions for occupational health and to stimulate discussion among faculty, staff and students at the University of Washington. A diverse group of individuals was selected to discuss important trends affecting occupational safety and health, each with a solid understanding of the field, but also strongly connected to other spheres of research and public health practice. The speaker series culminated in a two-day

symposium exploring the future of occupational health practice, research and policy, with content informed by our speaker series, keynote talks from some of the top minds in the field and input from a diverse group of symposium participants that included researchers, physicians, policymakers, students and others. Keynote speakers generally addressed the themes of occupational health practice, research and policy, with a historian putting the future in the context of past development of occupational health. About 125 participants attended and contributed to small and large group discussions following each of the keynote presentations. A list of the individuals contributing to the speaker series and keynote presenters is provided in Table 1.

Table 1. List of Invited Speakers and Discussion Themes for Speakers Series and Symposium

Speaker	Affiliation	Assigned Theme
Speaker Series		
Hans Kromhout	Institute for Risk Assessment Sciences, Utrecht University	Measuring the burden of occupational exposure, injury, illness
Hester Lipscomb	Community and Family Medicine, Duke University	
Paul Schulte	Director, Education and Information Division, NIOSH	Worker well-being (work and non-work factors)
Gregory Wagner	Special Assistant to the Director of NIOSH	Policy, regulatory and voluntary approaches to control
Emily Spieler	Former Dean, Northeastern Law School	
Roel Vermeulen	Institute for Risk Assessment Sciences, Utrecht University	Emerging investigative technologies
Matthew Sparke	International Studies, Global Health and Geography, University of Washington	Globalization
Arne Kalleberg	Sociology, University of North Carolina at Chapel Hill	Work organization
Glen Kenny	Health Sciences, University of Ottawa	Climate change
Marc Schenker	Occupational Medicine, University of California at Davis	Workplace health disparities (vulnerable populations)
Xochitl Castaneda	Public Health, University of California at Berkeley	
Symposium Keynote Speakers		
Linda Rae Murray	Former Chief Medical Officer, Cook County Department of Health	The future of occupational health practice
John Volckens	Environmental & Radiological Sciences, Colorado State University	The future of occupational health research
David Michaels	Assistant Secretary of Labor for the Occupational Safety and Health Administration	The future of occupational health policy
Gerald Markowitz	John Jay College of Criminal Justice	History of occupational health

SUMMARY OF OUTCOMES AND EMERGING CROSS-CUTTING THEMES

It is abundantly clear from the speaker series, symposium and resulting discussions that the nature of work and the understanding of worker health is changing as new economic, social, technical and political drivers emerge. Despite the relatively diverse group of presenters and topics addressed in this speaker series and symposium, some important cross-cutting themes emerged from these discussions (see Table 2). Notably, pressures due to changing work organization and demographics in the workplace, an increase in globalization, and the blurring of lines between work and non-work were themes that were discussed by many speakers, in many different contexts. Below we attempt to describe these and

other trends we feel are most important based on outcomes of this project, to assess the state of the field, develop a vision of the future and, ultimately, to develop strategies that maximize the positive contributions of occupational health to the working and living situations of people in the U.S. and around the world.

It is important to note that many topics other than those covered here were broached in discussions throughout this project, especially in small groups at the symposium. These ranged from philosophical discussions about potential alternative funding sources or the role of researchers as advocates, to specific proposals such as promoting healthier diets at workplaces or offering primary care onsite for agricultural workers—and much in between. While many of these ideas help focus the discussions and provide potential action items, only the broad cross cutting themes and trends are discussed here. Abstracts of presentations at the symposium can be accessed at the University of Washington Department of Environmental and Occupational Health Sciences website (deohs.washington.edu/future/summary-abstracts).

We also note that this project, and most of the speakers and discussions, was on domestic issues facing workers and OH researchers and practitioners in the U.S. However, ideas emerging from this project suggest several of the most important trends and pressures affecting U.S. working conditions are directly influenced by economic globalization and are relevant internationally.

Finally, while acknowledging that there are many ways to conceptualize ongoing trends affecting occupational health, as well as priorities and solutions to improve the status quo, this summary report presents only one possible view of these developments and is intended to further discussion, planning and innovation in research, training, practice and policy initiatives related to the health of workers.

Work Organization

The organization of work, especially the decreasing prevalence of stable long-term employer-employee relationships and growing use of contract, contingent, part time and generally precarious employment, emerges as among the most profound changes affecting occupational health [15]. The relationship between so-called 'standard' employment and the various flexible but insecure types of employment is illustrated in Figure 1. Although precarious employment is not a new phenomenon—it has always represented a significant portion of overall employment historically—these large-scale shifts in workplace dynamics alter the landscape for the practice of occupational health professions in myriad ways.

The various forms of contract and contingent labor make identification of the employer responsible for working conditions less clear and open to dispute. It means that workers likely have many different jobs and worksites (and employers and co-workers) over short periods of time and are thus less familiar with hazards in a particular site, as well as less accustomed to safe work practices and equipment. Likewise, evidence suggests temporary workers are more vulnerable to injury [16, 17], and new workers are many times more likely to get injured in their first months on a job [18-20]. Employers may feel they have less

investment in particular employees and therefore spend less on training, mentorship, protective systems and supportive supervision. Combined with the dynamics of workforce competition, deunionization, immigration both legal and undocumented, deregulation and precarity in general, workers are much more reluctant to exercise their rights by either advocating for their own working conditions or refusing particularly hazardous work [21].

These same forces are likely to reduce the investment in occupational safety and health systems within a company, including a reduction in in-house expertise and increased use of outside consultants for any required health and safety activities. In addition to the challenges that private sector professionals have with these dynamics, regulatory agencies are also confronted with workers reluctant to speak out and employers shifting hazards to suppliers and sub-contractors, often out of reach for inspection and enforcement.

Contingent work also shifts our ability to conduct traditional employer-, or place-based occupational studies, with workers frequently changing location, employer or occupation. Thus, epidemiology based on cohorts of workers in specific companies or industries are less feasible, and are inadequate to address risks in industries using such employment strategies.

Changes in work organization have been discussed in detail as the 'fissuring of the workplace,' with sub-contracting, global supply chains and franchise business models becoming the predominant system for lead brand companies [22]. Precarious employment arrangements have been associated with a variety of adverse physical health outcomes, including increased risk of occupational injuries, increased presenteeism, reduced job satisfaction, worse self-reported health and a number of mental health illnesses and disorders [23]. The need for additional research on health and safety impacts of shifts in work organization have been noted by the National Institute of Occupational Health and Safety (NIOSH) [24] and Occupational Safety and Health Administration (OSHA) [8].

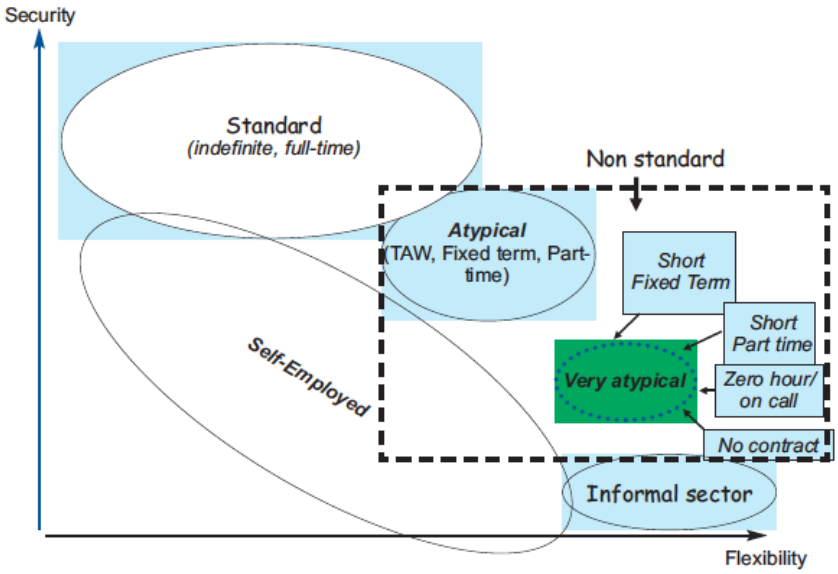

Figure 1. Security and Flexibility in various forms of employment relations [25]

Table 2. Identified Emerging Trends and Challenges in Occupational Health

Cross-cutting Themes in Occupational Health	Resulting Challenges
Changes in work organization	
• Transition from Standard Employer Relationships (i.e., stable, long-term) to contract, contingent, part-time and generally precarious employment	• Employers may perceive less of an investment in a worker, spending less resources on training, mentorship, protective systems and supportive supervision • Difficult to identify employer liability and responsibility for working conditions • Workers may frequently change jobs and worksites, reducing familiarity with relevant hazards, work practices and equipment and limiting ability to perform employer- or place-based occupational epidemiology • Increased reluctance by workers to exercise rights • Reduced investment in occupational safety and health systems and in-house expertise
Changing demographics	
• Aging workforce	• Restriction of physical and mental abilities and increased presence of chronic disease
• More women in the workplace	• Potential for alteration of psychosocial dynamics of workplace, and increased importance of reproductive hazards and work/life balance
• Increasing diversity of workforce in terms of race, ethnicity and Nativity	• Potential for discrimination, increased vulnerability, weakened collective identity and/or bargaining power and related stress, and increased health disparities
• Increasing presence of chronic disease in labor force	• Poor health is associated with reduction in hours of work, lower wage rates, early retirement and disability transfer programs
Globalization	
• Development of corporate supply chains in which providers of goods and services outsource production to vendors on a global scale • Increase in labor migration and immigrant workers	• Demand for greater 'flexibility' of workforce, leading to increased precarity of US employment and pressure against labor organization • Emergence of post-industrial economies, shifting away from manufacturing toward service and transportation industries • 'Race to the bottom' for regulation and policies, including wages, benefits, environmental and labor rights
Interaction of work and non-work factors	
• Acknowledgment that many factors contribute to health and safety of workers in addition to working conditions, including economic, social and environmental conditions facing various worker populations	• Employment conditions are less 'place-based', more dynamic, with higher frequency of job change • Assessing relevant factors impacting worker health, including community-based conditions. • Understanding the role of work in supporting or compounding these other determinants of health.

Changing Demographics and Vulnerable Populations

The changing demographics of the workforce in age, gender, race and ethnicity, and particularly nativity (immigrant status) are identified as another large-scale shift occurring in recent decades. The increase in number of women [26] and aging [27] of the workforce have been widely discussed previously, and shifts in race, ethnicity and nativity are potentially related to globalization, discussed below. Immigrants are a growing part of the U.S. labor force, making up over 16% of the total (>23 million workers) [28, 29]. Many of these foreign-born workers earn less money than native workers [29], and they're more likely to work in industries with high risks of occupational injury such as agriculture and construction, partly due to lower English-language ability and educational attainment [30]. Likewise these workers are more vulnerable to injury and death on the job [31, 32]. Further, workers who are members of racial or ethnic minorities, and/or are immigrant to the US, may have less safety and health training, experience greater real or perceived barriers to occupational health services, have less awareness and utilization of workers' compensation (WC) insurance programs and access and use occupational health services differently [33]. Workers migrating from places with civil strife and/or who have risked their lives (and potentially those of their family) during migration may also have different expectations of safe working conditions [34]. These demographic shifts have important implications for the nature of workplace risks and prevention strategies. As the American workforce becomes more diverse, occupational health professionals must be able to navigate potential communication and cultural barriers.

Another profound shift in the labor force demographics is emergence of chronic disease, and in particular, the epidemic of obesity and diabetes, among US working population. The cost, in terms of both direct medical expenses and lost productivity, due to chronic disease in the working population is very high and growing rapidly [35-38]. These costs affect individuals, as well as their employers and the community at large, and compel us toward a holistic approach to health in the workforce and the difference that a healthy workplace can make in preventing, or mitigating these effects.

Globalization

Another important change in work and health is related to globalization, of both capital investment in productive work, and in labor force dynamics [39, 40]. Globalized competition generally supports labor flexibility, or limiting labor rights. This can occur through development of corporate supply chains in which providers of goods and services outsource production to vendor businesses on a global scale, and the resulting competition among vendors further reinforces a 'race to the bottom' in terms of wages, workers' rights and safety. Further, hyper-competition and exploitation affects the ability of workers to advocate for improved work conditions. Globalization also reinforces pressures toward deregulation. For instance, international trade agreements are often affected by harmonization, which involves the direct reworking of national laws—often those related to laws protecting health, for example, reducing limits on the usage of dangerous pesticides or labeling requirements—to encourage trade. These pressures may affect the ability of governments to regulate the workplace (for example, by causing frequent shifting of worksites and/or reduced transparency and accountability along the chain) while also diminishing the significance of national agencies and rules.

One strategy for addressing these effects of global production systems is the use of global supply chain regulation schemes. Such strategies are voluntary, and can take the form of individual corporate social responsibility programs, or independent monitoring organizations such as the Fair labor Association (fairlabor.org). Pressure for participation in such efforts, and transparency of the results are substantially influenced by organized efforts of consumers such as the Students Against Sweatshops on many college campuses, or publicity about working conditions and industrial disasters of the garment industry [41]. While such voluntary efforts have potential, there are many barriers to their success and have not been shown to be highly effective without significant governmental regulatory involvement [42].

Although our main focus here is working conditions in domestic and developed world workplaces, the devastating conditions and health and safety threats found in many developing economies, are compelling for occupational health professionals. Use of child labor, forced labor, informal sector work, lack of corporate or governmental infrastructure or regulation, combined with shifting of hazardous operations to these unregulated markets, gives rise to a large toll of occupational health and injury burden [40]. While documentation of such conditions calls attention to many of these problems, models for effective intervention in such conditions are badly needed.

Globalization also includes the demographic shifts mentioned above, in particular the large increase in immigrants in the workforce. In addition to language and cultural barriers, the vulnerability of immigrants to exploitation through the threat of deportation is a major challenge for workplace-based health and safety prevention activities.

Blurring of Lines between Work and Non-work Exposures

These new realities of the workplace coincide with another theme addressed by several of our presenters. The traditional occupational health paradigms of specific exposures leading to specific outcomes among specific work groups, and the near complete separation of work-related risks from non-work related risks, is less and less pertinent. In particular, a shift from “occupational health” to a more public health-based model of “worker health” that acknowledges the many factors contributing to health and safety of various communities is indicated [43]. Such an approach allows for the integration of the many economic, social and environmental impacts, including the impact of working conditions on the health of specific groups in society.

A very similar vision was presented that described how workplace dynamics contribute, but do not solely determine groups of people’s sense of well-being at individual, enterprise and societal levels [44, 45]. While part of well-being is having the physical safety and health of workers well-protected in the workplace, it also involves social support, autonomy and self-determination, etc. A model of how the workplace, can contribute to health and well-being in both a prevention and promotion mode was presented, and is shown in Figure 2.

NIOSH's concept of Total Worker Health (TWH) [46] significantly overlaps with this model, in that both workplace and non-work-related factors contribute to the overall health of the individual and community. However, while TWH focuses primarily on using the workplace to intervene on individual lifestyle derived risks (i.e., behavior-focused health promotion at the workplace), the concepts discussed here identify the workplace itself, with its technical, structural and social organizational characteristics, as a significant contributor to health and well-being of the workforce.

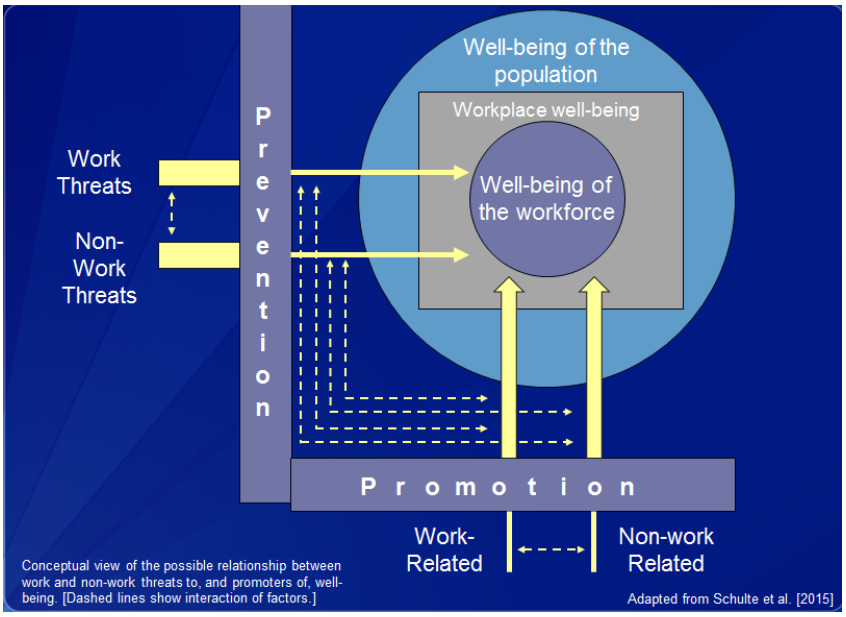

Figure 2. Model of workplace contributions to both prevention and promotion for work and non-work related risk factors [45]

Other Ongoing Trends Affecting Occupational Health

While the cross-cutting trends identified above were themes discussed by multiple presenters, a number of additional key trends affecting the health and working conditions of workers were noted in these discussions.

Global Climate Change – The changing climate, including rising temperatures, extreme heat events and extreme weather events, will affect workers and workplaces in myriad ways [47]. In addition to creating increased risks to many workers, especially those working outdoors, climate change is also likely to increase the number of catastrophic storms, fires, floods, etc., requiring an increasing number of first responders and clean-up/remediation efforts, all of which may engender high-risk tasks. Climate change also is expected to increase exposure to vector-born disease risks. But global climate change is also forcing large-scale socio-technical and economic changes that are fundamentally altering the global economy, producing new industries and workplaces (e.g., renewable energy production and sustainable agriculture) and profoundly changing cultures in existing workplaces (e.g., altered hours for jobs that require working outdoors).

Decline in Organized Labor – The reduction in the number and percent of the workforce organized by labor unions in the U.S. [48, 49] has significant implications for occupational health practice and policy. Labor unions have been an important force for health and safety regulations, represented workers in advocating with employers for improving conditions, and provided the security workers need to advocate on their own behalf. The decline of labor representation, especially in the manufacturing sector, is an important impediment to affect public health action in the workplace. A strong sentiment heard from the speakers and symposium participants was that although labor continues to play an important role in occupational health, other social movements and forms of worker organization are increasingly important forums for workplace health and safety.

Dysfunction of Federal Government – The profound dysfunction we are experiencing within the U.S. government limits the ability to form a cohesive national strategy to address workplace health issues. In addition, the current (and likely, future) political landscape has restricted funding for education, regulatory action and research funding for occupational health and safety. Similarly, public confidence in the federal government is very low with no signs of recovery. The limitations of the OSHA law for effectively controlling workplace risks, even in traditional Standard Employment Relationship-type manufacturing contexts are well known, and the reach of OSHA into the new forms of work organization and to address health in the context of well-being are even more limited. Thus, while OSHA plays a critical role in defining a minimum set of criteria for a safe workplace, and the potential for a complete overhaul of the OSHA law seems remote, there was strong support for the idea that local and state governments provide a great opportunity for leading development of policy and shifting standards to address emerging challenges facing workers and their health. A recent example is New York's efforts to curb both wage violations and exposures to hazardous chemicals in the nail salon industry. Both the State and City developed aggressive policies and programs to end the abuses, and educate the shop owners and workforce about their rights and responsibilities [50]. Another example is the recent establishment of Office of Labor Standards for the City of Seattle, which will work directly with employers to establish new policies, as well as through community-based organizations that represent many of these low income communities (seattle.gov/laborstandards).

Emerging Technologies and Data Capabilities – Technological developments have opened opportunities to address health among working populations, improving our ability to collect and analyze exposure and health data at multiple scales without necessarily making a clear distinction between risks at work and outside work. The concept of the exposome [51], which aims to integrate the sum of lifetime exposures from all sources, is another direction promising a framework for environmental, including occupational risks. Techniques such as metabolomics and proteomics permit collection of data on biological indicators of exposure and/or health conditions that can be compared among populations at risk. Likewise, low-cost sensors and distributed electronic sensing and communication technologies (e.g., cell-phone based applications) have the potential to identify risks and effects among large populations, both at work and at home. The exposome concept has also been proposed as a framework to characterize health disparities [52].

Additionally, new and improved methods and tools are becoming available to analyze exposure data (e.g., Geographical Information Systems, multi-scale exposure modeling, predictive modeling), and

advances in information management capabilities are making it easier to collect and generate large data sets from multiple linked sources. These advances provide opportunity for improved baseline surveillance of workplace injuries and illnesses—still a major issue plaguing the field—but also make feasible studying the health of populations for the impact of multiple environmental stressors, in non-standard employment relationships, rather than restricting studies to within specific occupational groups and facilities.

Contribution of Work to Health Disparities

Changes in work organization, workforce demographics, globalization and blurring of work/non-work exposures, and perhaps the interaction of these factors, can also be seen as a part of a larger shift in our economy and health. The enormous increase in income and wealth disparities among the US population has been widely discussed [53]. At the same time, the wide gulf in health, morbidity and mortality between those in the top tier, and those struggling to survive is continuing to increase. The link between socioeconomic status and health disparities is at least partially mediated by work conditions [54, 55]. Thus the future of occupational health, or worker health, requires that we engage in the larger framework of health disparities and the structure of employment. This expanded vision of occupational health provides the opportunity, or necessity, of linking our work with others on health disparities, and in the wider academic community of interest in population well-being. It further suggests expanding the context of our work to include local governmental agencies, public health departments and community-based organizations working on behalf of workers in many types of employment contexts. Thus, a number of directions are suggested for developing a new vision of occupational health.

CREATING OCCUPATIONAL HEALTH FOR THE FUTURE

Ideas emerging from the Future of Occupational Health project form the basis for a continuing discovery of what the key challenges are in occupational health, and what directions the field needs to move in order to make the work relevant and effective in preventing the continuing burden of work-related injury and illness. We propose the following general directions for moving traditional occupational health training, professional practice and research toward a more holistic, public health oriented model for addressing the health and safety needs of workers. The ideas are summarized in Table 3 and discussed below.

Engaging Others in Work-related Health Issues

To ensure that future occupational health research, educational and service activities are able to address emerging trends discussed herein, it is critical to engage a network of leaders interested in the intersection of work and health. Thus, rather than seeing occupational health as a narrow technical field, we need to redraw the lines of interest across academic disciplines, business, labor and community interests, and from key governmental agencies. This engagement allows the field to better connect relevant communities of interest to practitioners in occupational health, identify and pursue new areas for collaboration, develop new models of workplace and community intervention and reach high-risk worker populations.

Developing Interdisciplinary Networks across Academic Disciplines – To effectively address the emerging issues discussed above, it is critical that universities with occupational health programs seek opportunities to develop academic interactions for interdisciplinary teaching and research on work-related determinants of health, health disparities and the social conditions underlying these relations. This will require engagement and building relationships with faculty that have expertise in social sciences, economics, policy and political science, employment and human relations law, occupational health psychology and health disparities and health promotion fields, among others. These connections enable sharing of ideas and methods, as well as opportunities for novel research collaborations and funding sources.

Engaging State and Local Government – There was strong support among speakers and symposium participants that state and local government has the power to influence policy and standards affecting worker health and safety. Universities and research institutions should therefore seek opportunities to engage with practitioners involved in compliance, enforcement and policy at agencies within state and local government. Due to gridlock at the federal-level these agencies may offer the most opportunity for policy experimentation to improve working conditions, and researchers and practitioners should seek ways to support development and evaluation of such initiatives. Effectiveness of such actions will vary by local governmental structures and administrations, as well as public opinions/political preferences.

Engaging Community-based and Labor Organizations – Occupational health practitioners will continue to have direct involvement within workplaces in assessing and controlling the traditional physical and chemical risks, providing protective systems, conducting health surveillance, etc. But as more of the population moves toward small employers and participate as contract or contingent workers, new models of health and safety intervention are needed. Several speakers and discussions noted the increasing importance of community-based organizations as a locus to supply occupational health resources. Researchers, practitioners and policymakers should seek opportunities to engage groups such as community centers, health clinics, faith-based organizations, national consulates, organizations that serve specific communities or industries, and other groups that have the potential to take on such roles. Practitioners will increasingly be working through such community-based organizations to reach into the worksite and influence conditions of work. A number of speakers also noted the value of situating researchers and practitioners with labor and worker organizations during their training, and development of these networks could help foster internships and other training opportunities for students and collaborative research projects.

Engaging Industry in New Models of Occupational Health – Traditional occupational health researchers and practitioners have always been directly involved in evaluating and improving working conditions; however the focus of such work has largely been technical, and specifically addressed work-related exposures. Engaging employers in developing a more holistic approach to supporting the health and well-being of workers will require development, demonstration and communication of models of the costs and benefits to the enterprise of alternative workplace policies. Such programs would include both traditional occupational health programs, and supportive safety climate approaches, but may also

extend to health supportive programs, pay and benefits, family leave policies and other aspects of employment that affect health and well-being. Models for such approaches need to be developed for different sectors, alternative work organizational models, and include both economic and health outcomes.

Aligning with Current Social Movements – Several speakers noted the absence within the public consciousness of the enormous burden workplace injuries, illnesses and deaths pose to society. One key challenge to the field is to change the national conversation about workers and their health. To this end, the field should pursue opportunities to integrate efforts to improve working conditions and move health and safety into public consciousness by aligning and engaging other social movements. These may include movements related to technological innovation, environmentalism and sustainability, feminism, and those related to human rights, immigrant rights and economic disparities and health disparities.

Broadening Academic Research and Training Portfolios

Academic programs will continue to evolve through faculty and staff hiring and retirement, and through responses to perceived needs and funding opportunities. However, research institutions have the potential to make a much bigger impact on the future scientific basis and practice of occupational health, and to develop training programs that will support new directions and initiatives.

Moving from 'Occupational Health' to 'Worker Health' – While continuing to work with employers and unions on the incorporation of physical exposure control, the field needs to expand the notion of occupational health to include a health-supportive work environment including concepts of well-being. Because this idea is so far beyond our current industrial, regulatory and health paradigm, we will need research on all aspects of what makes for a health-supportive workplace. The broad themes emerging from the Future Project provide an opportunity to redefine occupational health with a population-based model that moves from a focus on the workplace toward a focus on working populations – thus, 'worker health' instead of 'occupational health.' In this more public health-oriented approach, the health of specific populations of workers (and their families and communities) can be addressed in a more holistic way, integrating physical and psychosocial health parameters and exposures that occur at work with non-work conditions which may arise at least partially from employment conditions. The concept of well-being for the worker, enterprise, community and society, may be a useful construct for this new approach.

One component of this focus on worker health requires integrating a broader concept of work-related exposures and risks. Whereas occupational health researchers and practitioners often focus on assessing physical risks in the workplace (for example, work at height and work with uncontrolled or unknown chemical hazards), most are ill-equipped to evaluate psychosocial conditions of work that may contribute to health and or disease (for example, job-related stress or harassment). These psychosocial exposures may be especially important for workers engaged in precarious employment where stress and economic impacts on health are potentially significant. Similarly, at-risk populations including

immigrants, women and racial or ethnic minorities may also be at risk for injury or illness due to general social conditions often ignored in biomedical and individually-oriented theories of disease causation [56]. Thus, research models should allow for more inclusive definitions of health and well-being when examining the role of work on health, including integrating multiple dimensions of exposure and embracing social determinist frameworks.

Estimating the Effects (Burden) of Work on Health and Well-being – Traditional estimates of the 'burden of occupational disease' rely on the prevalence of specific occupational exposures (e.g., noise, asbestos, etc.) and models of population exposures and risks associated with those exposures. If we are to move toward a more inclusive measure of health impacts of work-related factors, new multi-factorial metrics which incorporate stress, social support (at and outside of work), ergonomics, physical activity, organizational factors (e.g., shift work and reorganization), etc., will be needed. Multivariate approaches to occupational health studies may allow for identification of groups with similar working conditions, examine associations between working and living conditions and health, and provide a basis for preventative actions [57, 58]. Such models will have to include both the supportive and detrimental aspects of employment and work on health and well-being.

Leveraging New Investigative Technologies – Some of the more technologically driven ideas shared during the Future Project fit well into a 'worker health' model. The use of distributed sensors technologies for both health and exposure assessment support the idea that exposure and effects come both at work and outside work, and can affect whole communities. Additionally, limitations of coverage and cost faced by occupational health researchers and practitioners in assessing exposure supports the need to move to low-cost, high-throughput samplers that integrate exposures over long time periods—even if this means decreased accuracy and sensitivity. The potential for 'big data' to demonstrate patterns of exposure, including the varied exposures that occur at work, and their relation to health may produce meaningful associations. And the various 'omics' technologies which use biological indicators of exposure and effects will cut across specific occupations to understanding the totality of environmental exposure as experienced by individuals and their communities in work and non-work settings. Thus all of the burgeoning technologies associated with distributed or population-based exposure and health effects have the potential to further our understanding of work factors and health.

Developing Global Health Perspectives – Several components of globalization provide ample opportunity for effective research in occupational health. Incorporating a focus on work and occupational conditions into global health initiatives provides the opportunity for a significant impact in less developed economies. Developing such a focus provides the opportunity to link traditional global health initiatives with economic development projects, seeking to develop or improve local economies through health-supportive enterprises.

In addition, the potential for work on effective monitoring and enforcement of labor and health standards throughout global supply chains is a potentially rich area for development within occupational health and public health programs. Although a number of important investigations have demonstrated both the potential and limitations of voluntary supply chain regulation for improving working conditions

[42], opportunities for building upon this work abound. Supply chain regulation is an important area for business strategies, and the field's involvement in such efforts could be fruitful. In addition to both descriptive and intervention effectiveness research projects, there may be a rich opportunity for training supply chain regulators in the recognition of occupational health and safety violations.

Incorporating global health perspectives into occupational health can also drive domestically-oriented research projects, including focusing on the special challenges facing high-risk immigrant and refugee worker populations within the U.S. Many community organizations serving such communities and helping workers find employment see health and safety as a component of their work.

Developing and Improving Curriculum

The jobs that graduates of occupational health programs are being prepared for may not reflect the jobs available in the future. Thus, revision of our current research and training portfolios are warranted to better align them with the current realities of work and health, and to prepare graduate students leaving their training programs for the changing array of occupational health challenges they will likely encounter.

Strengthening Competencies of Graduates – It is important to consider what skills are needed in the future to effectively address the issues above. There is no doubt that these include the traditional occupational hygiene, medicine, nursing, epidemiology, toxicology and engineering skills. But as we broaden our perspective, our research and professional communities will also need to understand more of social sciences, management, business economics and policy processes—particularly to address psychosocial factors and population health determinants of workers' health. Leadership and the ability to effectively communicate to varied audiences, which are commonly identified by employers as a place where occupational health curriculum needs improvement [14], will become even more valuable in the future. Related, cultural competencies will become increasingly important to working with vulnerable and immigrant populations, as well as community-based organizations and international occupational health work. Clearly, we can't expect any one training program to be able to do all of this, but we need to define the array of skills needed and how best to form specialties, all with an ability to address work and health.

Incorporating Broader Social, Political and Legal Contexts – Issues emerging from the Future Project suggest occupational health practitioners would benefit from an improved understanding of larger social, political and legal contexts affecting workers' health. Academic and research institutions should pursue opportunities to develop curriculum elements that enhance teaching and learning for students engaged in occupational safety and health, general public health and social science disciplines with interests in worker health including public affairs, social work, labor studies, etc. Programs should consider making current and emerging regulatory policy and structures a significant component of new curriculum. Faculty should also strive to incorporate teachings related to the social context of work, work organization, impact of health on business sustainability, labor and political movements and their

impact on work conditions, and the relationship between work and health disparities into classes, coursework and seminars.

Identifying and Addressing Health, Safety and Well-being for Future Workplace Technologies – Occupational health training programs should periodically assess the needs of the developing businesses to assure that our training addresses current and future risks. For instance, as the global economy transitions to low-carbon forms of energy production, resilient development and sustainable agriculture, new work technologies will emerge, and physical and cultural aspects of traditional workplaces will evolve. There is opportunity to identify and address specific hazards related to these workplaces. Additionally, there is evidence that certain disciplines related to occupational health are facing a shortfall in sufficiently trained professionals, for instance in health physics and radiation protection [59].

CONCLUSION

Economic, social, technical and political drivers are fundamentally changing the nature of work and work environments, with profound implications for the priorities in occupational health. Over the past several decades significant improvements have been made to workplace conditions in the United States and many other societies around the world. Yet the overall burden of occupational injuries and illnesses remains unacceptably high.

Changes in work organization due to fissuring of organizations and the resulting insecurity and precarious employment arrangements change the nature of risk to a large fraction of the workforce. The workforce continues to become increasingly diverse in gender, age, race and nativity, and economic disparities among working groups are rapidly growing. Globalization exacerbates the 'race to the bottom' for cheap labor, poor regulatory oversight, and limited labor rights. These effects of globalization work both between countries, and within the US between localities competing for business investments.

Largely as a result of these phenomena, the historical distinction between work and non-work exposures have become largely artificial and less useful in understanding risks, and developing effective public health intervention models. Additional changes related to climate change, governmental and regulatory limitations, and inadequate surveillance systems challenge and frustrate occupational health progress, while new biomedical and information technologies expand the opportunities for understanding and intervening to improve worker health.

The ideas and evidence discussed during the Future of Occupational Health Project suggest a reconceptualization of "occupational health" toward a more comprehensive and public health-oriented model addressing the multifaceted relationships between work and health. Through the lens of work and health, we can integrate specific conditions found at the workplace, including traditional physical, chemical and biological hazards, and psychosocial stressors, with the economic and social conditions created for individuals and communities through work. This integrated approach more directly addresses the role of work and work conditions in public health, including those giving rise to stark

health disparities throughout society, and offers the field tremendous opportunity to increase its positive contribution in promoting health and well-being of communities locally, nationally and globally.

Table 3. Summary of Directions for Creating Occupational Health for the Future

Engage Others in Work-related Health Issues	
	Develop Interdisciplinary Networks across Academia
	Engage State and Local Government
	Engage Community-based and Labor Organizations
	Engaging Industry with New Models
	Align with Current Social Movements
Broaden our Research and Training Portfolios	
	Move from an 'Occupational' to a 'Work and Health' Paradigm, integrating psychosocial conditions impacts with traditional exposures and effects.
	Develop Metrics to Estimate the Effects (Burden) of Work on Health and Well-being
	Leverage New Technologies for Understanding Exposures and Health Risks
	Develop Global Health Perspectives
	Pursue Interdisciplinary Research Collaborations
Develop and Improve Curriculum	
	Strengthen Competencies of Graduates
	Incorporate Broader Social, Political and Legal Contexts into Training
	Identify and Address Health, Safety and Well-being for Future Workplace Technologies

Acknowledgments:
The authors appreciate the financial support from the Department of Environmental and Occupational Health Sciences to develop and complete this project. We thank the series and keynote speakers, those that submitted and presented abstracts at the Symposium, and others involved in the many discussions throughout the project for their input and energy. Important contributions were also made by Symposium facilitators Jenna Armstrong, Louis Lim, Laurel Kincl, Kevin Riley and Ken Scott. In addition, we acknowledge the thoughtful insights provided on early drafts from Howie Frumkin, Mike Yost, Peter Rabinowitz, Dan Jacoby, Dave Kalman, Janice Camp and Ken Scott.

References

1. Bureau of Labor Statistics. *Employer-Reported Workplace Injuries and Illnesses--2013*. 2014; Available from: http://www.bls.gov/news.release/pdf/osh.pdf.
2. Creely, K.S., et al., *Trends in Inhalation Exposure—A Review of the Data in the Published Scientific Literature.* Annals of occupational hygiene, 2007. **51**(8): p. 665-678.
3. ILO, *The Prevention of Occupational Diseases*. 2013, International Labour Organization.
4. Bureau of Labor Statistics. *Census of Fatal Occupational Injuries Summary, 2013*. 2014 [10/7/2015]; Available from: http://www.bls.gov/news.release/cfoi.nr0.htm.
5. Bureau of Labor Statistics. *Employer-Reported Workplace Injury and Illness Summary, 2013*. 2014 [10/7/2015]; Available from: http://www.bls.gov/news.release/osh.nr0.htm.
6. Leigh, J.P., *Economic Burden of Occupational Injury and Illness in the United States.* The Milbank Quarterly, 2011. **89**(4): p. 728-772.
7. National Safety Council, *Injury Facts*. 2014 edition: Itasca, IL.
8. OSHA, *Adding Inequality to Injury: The Costs of Failing to Protect Workers on the Job*. 2015, Occupational Health and Safety Administration.
9. Azaroff, L.S., C. Levenstein, and D.H. Wegman, *Occupational Injury and Illness Surveillance: Conceptual Filters Explain Underreporting.* American Journal of Public Health, 2002. **92**(9): p. 1421-1429.
10. Rosenman, K.D., et al., *How Much Work-Related Injury and Illness is Missed By the Current National Surveillance System?* Journal of Occupational & Environmental Medicine, 2006. **48**(4): p. 357-365.
11. Spieler, E.A. and G.R. Wagner, *Counting matters: Implications of undercounting in the BLS survey of occupational injuries and illnesses.* American Journal of Industrial Medicine, 2014. **57**(10): p. 1077-1084.
12. Wiatrowski, W.J. *Examining the completeness of occupational injuries and illnesses: an update on current research*. Monthly Labor Review 2014 [10/7/2015]; Available from: http://www.bls.gov/opub/mlr/2014/article/examining-the-completeness-of-occupational-injury-and-illness-data-an-update-on-current-research-1.htm.
13. Burgard, S.A. and K.Y. Lin, *Bad Jobs, Bad Health? How Work and Working Conditions Contribute to Health Disparities.* The American behavioral scientist, 2013. **57**(8): p. 10.1177/0002764213487347.
14. McAdams, M.T., et al., *National Assessment of the Occupational Safety and Health Workforce*. 2011.
15. Kalleberg, A.L., *Good jobs, bad jobs*. 2011, New York, NY: Russell Sage Foundation.
16. Smith, C.K., et al., *Temporary workers in Washington State.* American Journal of Industrial Medicine, 2010. **53**(2): p. 135-145.
17. Grabell, M., O. Pierce, and J. Larson, *Temporary Work, Lasting Harm*, in *Propublica*. 2013.
18. Breslin, F.C. and P. Smith, *Trial by fire: a multivariate examination of the relation between job tenure and work injuries.* Occupational and environmental medicine, 2006. **63**(1): p. 27-32.
19. Morassaei, S., et al., *Examining job tenure and lost-time claim rates in Ontario, Canada, over a 10-year period, 1999-2008.* Occupational and environmental medicine, 2013. **70**(3): p. 171-178.
20. Health and Safety Executive. *Analysis of the impact of job tenure on workplace injury rates*. [9/29/15]; Available from: http://www.hse.gov.uk/statistics/adhoc-analysis/workplace-injury-rates.htm.
21. Aronsson, G., *Contingent Workers and Health and Safety.* Work, Employment & Society, 1999. **13**(3): p. 439-459.
22. Weil, D., *The Fissured Workplace*. 2014: Harvard University Press.

23. Benach, J., et al., *Precarious Employment: Understanding an Emerging Social Determinant of Health.* Annual Review of Public Health, 2014. **35**(1): p. 229-253.
24. Howard, J. *The Changing Employment Relationship and Its Impact on Worker Well-Being*. NIOSH eNews 2015 [9/29/15]; Available from: http://www.cdc.gov/niosh/enews/enewsv12n12.html.
25. Kalleberg, A.L., *Changing Organization of Work and the Future of Occupational Health*, in *Presentation to Department of Environmental and Occupational Health Sciences, University of Washington*. 3/11/2015.
26. Wagener, D.K., et al., *Women: work and health.* Vital Health Stat 3, 1997. **31**: p. 1-91.
27. Hedge, J.W., W.C. Borman, and S.E. Lammlein, *The aging workforce: Realities, myths, and implications for organizations*. 2006, Washington, DC, US: American Psychological Association. v, 203.
28. Singer, A., *Immigrant Workers in the U.S. Labor Force*. 2012, Brookings Institution.
29. Mosisa, A.T., *Foreign-born Workers In The U.S. Labor Force*, in *Spotlight on Statistics*. 2013, U.S. Bureau of Labor Statistics.
30. Orrenius, P.M. and M. Zavodny, *Do Immigrants Work In Riskier Jobs?* Demography, 2009. **46**(3): p. 535-551.
31. Loh, K. and S. Richardson, *Foreign-born workers: trends in fatal occupational injuries, 1996-2001*, in *Monthly Labor Review*. 2004, U.S. Bureau of Labor Statistics.
32. Byler, C.G., *Hispanic/Latino fatal occupational injury rates*, in *Monthly Labor Review*. 2013, U.S. Bureau of Labor Statistics.
33. Washington State Department of Labor & Industries. *Occupational Health Disparities*. [9/29/2015]; Available from: http://www.lni.wa.gov/Safety/Research/OccHealth/Reports/Disparities/.
34. Whittaker, W., *Labor Practices in the Meat Packing and Poultry Processing Industry: An Overview*. July 20, 2005, Congressional Research Service.
35. Hertz, R.P., et al., *The impact of obesity on work limitations and cardiovascular risk factors in the U.S. workforce.* journal of Occupational and Environmental Medicine, 2004. **46**(12): p. 1196-203.
36. DeVol, R., et al., *An unhealthy America: The economic burden of chronic disease.* 2007.
37. Hammond, R.A. and R. Levine, *The economic impact of obesity in the United States.* Diabetes, metabolic syndrome and obesity : targets and therapy, 2010. **3**: p. 285-295.
38. Breton, M.-C., et al., *Burden of Diabetes on the Ability to Work: A systematic review.* Diabetes Care, 2013. **36**(3): p. 740-749.
39. Sparke, M., *Introducing globalization: Ties, tensions, and uneven integration*. 2012: John Wiley & Sons.
40. Benach, J., et al., *Employment, work, and health inequalities: A Global perspective.* Geneva: WHO, 2007.
41. Harrison, A. and J. Scorse, *Multinationals and Anti-Sweatshop Activism.* American Economic Review, 2010. **100**(1): p. 247-273.
42. Locke, R., *The Promise and Limits of Private Power: Promoting Labor Standards in a Global Economy*. 2013, Cambridge/New York, NY: Cambridge University Press.
43. WHO, *Healthy workplaces: a model for action for employers, workers, policymakers, and practitioners.* 2010, World Health Organization.
44. Schulte, P. and H. Vainio, *Well-being at work--overview and perspective.* Scandinavian Journal of Work, Environment and Health, 2010. **36**(5): p. 422-429.
45. Schulte, P.A., et al., *Considerations for Incorporating "Well-Being" in Public Policy for Workers and Workplaces.* American Journal of Public Health, 2015. **105**(8): p. e31-e44.
46. NIOSH. *Total Worker Health*. [9/29/2015]; Available from: http://www.cdc.gov/niosh/twh/.

47. Kiefer, M., et al. *Climate Change and Occupational Safety and Health*. NIOSH Science Blog 2014 9/29/2015]; Available from: http://blogs.cdc.gov/niosh-science-blog/2014/09/22/climate-change/.
48. Hirsch, B. and D. Macpherson, *Union Membership and Coverage Database from the Current Population Survey: Note.* Industrial and Labor Relations Review, 2003. **56**(2): p. 349-54.
49. Hirsch, B. and D. Macpherson. *Union Membership and Coverage Database from the CPS*. 2014 [cited [10/7/2015; Available from: http://unionstats.com/.
50. Grynbaum, M.M. *New York Nail Salons Now Required to Post Workers' Bill of Rights*. 2015; Available from: http://www.nytimes.com/2015/05/30/nyregion/new-york-nail-salons-workers-bill-of-rights.html.
51. NIOSH. *Exposome and Exposomics*. [9/29/2015]; Available from: http://www.cdc.gov/niosh/topics/exposome/.
52. Juarez, P.D., et al., *The Public Health Exposome: A Population-Based, Exposure Science Approach to Health Disparities Research.* International Journal of Environmental Research and Public Health, 2014. **11**(12): p. 12866-12895.
53. Saez, E., *Striking it Richer: The Evolution of Top Incomes in the United States (updated with 2012 preliminary estimates)*. 2013, University of California, Berkeley, Department of Economics.
54. Brand, J.E., et al., *Do job characteristics mediate the relationship between SES and health? Evidence from sibling models.* Social Science Research, 2007. **36**(1): p. 222-253.
55. Goh, J., J. Pfeffer, and S. Zenios, *Exposure To Harmful Workplace Practices Could Account For Inequality In Life Spans Across Different Demographic Groups.* Health Affairs, 2015. **34**(10): p. 1761-1768.
56. Krieger, N., *Epidemiology and the web of causation: Has anyone seen the spider?* Social Science & Medicine, 1994. **39**(7): p. 887-903.
57. Härenstam, A., et al., *Patterns of working and living conditions: a holistic, multivariate approach to occupational health studies.* Work and Stress, 2003. **17**(1): p. 73-92.
58. Schulte, P.A., et al., *Interaction of Occupational and Personal Risk Factors in Workforce Health and Safety.* American Journal of Public Health, 2012. **102**(3): p. 434-448.
59. National Council on Radiation Protection and Measurements, *National Crisis: Where are the Radiation Professionals?* 2013.