Employing One Health Principals in Global Health Research and Training
Outline

• Duke’s One Health (OH) Research & Training network
• Duke One Health Research
  • Themes
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• Duke OH Training
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Duke One Health Research & Training, 2018-2019

One Health Research & Training Sites

- Duke managed
- Collaborators

Duke University, UNITED STATES

National Center for Zoonotic Disease, MONGOLIA

Beijing Institute of Microbiology and Epidemiology, CHINA

Duke Kunshan University, CHINA

PAKISTAN

EGYPT

IRAQ

Yangon, Myanmar

Duke-NUS Medical School, SINGAPORE

Durban, SOUTH AFRICA

Hanoi, VIETNAM

Sibu, MALAYSIA
Opened in 1930
A “top ten” US medical school
2,400 regular rank faculty
Duke Clinical Research Institute - world’s largest academic clinical research organization (130 faculty and 1,200 staff)
~16 percent of Duke medical students are enrolled in the Medical Scientist Training Program (MSTP)
Duke-NUS Medical School, Singapore

- Established in 2005 as Singapore’s first US-style graduate-entry medical school
- Duke University School of Medicine’s curriculum, with an annual enrolment of over 60 medical students
- 11 Academic Clinical Programs: Cardiovascular, Medicine, Neuroscience, OB-GYN, Oncology, Ophthalmology, Oral Health, Pediatrics, Pathology, Radiological Sciences, Surgery
- 5 world-class Signature Research Programs – one of which is Emerging Infectious Diseases
• Liberal arts and sciences undergraduate and graduate degrees
• Founded in 2013 and located just outside of Shanghai, China.
• All courses are taught in English.
• All graduates earn a Duke University degree and a Duke Kunshan University degree.
• Students have the opportunity to study and live on two campuses: Kunshan, China and Durham, US.
• International faculty members are carefully selected by faculty search committees at Duke University.
• Majors are focused to represent the global learning environment of the university, as the inaugural class will be comprised of 225 students from around the world.
How do we apply the One Health approach to research in our Duke network?
Zoonotic Viruses

Close contact

Wild and domestic

Asymptomatic Adaptations Transmission

Human infections originate from animals (60-80%)

From http://www.iisertvm.ac.in/faculties/stalin/research_areas.phpx
Where are large groups of people and animal mixing?
Whether it occurs by a quirk of nature or at the hand of a terrorist, epidemiologists say a fast-moving airborne pathogen could kill more than 30 million people in less than a year.

And they say there is a reasonable probability the world will experience such an outbreak in the next 10-15 years."
Our One Health Laboratory’s Focus - Novel Respiratory Virus Detection & Epidemiological Study

Panspecies (human and animal) diagnostics for:
Influenza A,B,C,D
Adenovirus
Coronaviruses
Enteroviruses
A Mini Review of the Zoonotic Threat Potential of Influenza Viruses, Coronaviruses, Adenoviruses, and Enteroviruses

Emily S. Bailey1,2, Jane K. Fieldhouse3, Jusakto Y. Choi2,4 and Gregory C. Gray4,5,6

1 Duke Global Health Institute, Duke University, Durham, NC, United States; 2Division of Infectious Diseases, Duke University School of Medicine, Durham, NC, United States; 3Global Health Research Center, Duke-Kunshan University, Kunshan, China; 4Emerging Infectious Diseases Program, Duke-NUS Medical School, Singapore

During the last two decades, scientists have grown increasingly aware that viruses are emerging from the human-animal interface. In particular, respiratory infections are problematic; in early 2003, World Health Organization issued a worldwide alert for a previously unrecognized illness that was subsequently found to be caused by a novel coronavirus [severe acute respiratory syndrome (SARS) virus]. In addition to SARS, other respiratory pathogens have also emerged recently, contributing to the high burden of respiratory tract infection related morbidity and mortality. Among the recently emerged respiratory pathogens are influenza viruses, coronaviruses, enteroviruses, and adenoviruses. As the genesis of these emerging viruses is not well understood and their detection normally occurs after they have crossed over and adapted to man, ideally, strategies for such novel virus detection should include intensive surveillance at the human-animal interface, particularly if one believes the paradigm that many novel emerging zoonotic viruses first circulate in animal populations and occasionally infect man before they fully adapt to man; early detection at the human-animal interface will provide earlier warning. Here, we review recent emerging virus treats for these four groups of viruses.

FIGURE 1 | The geographical location of initial detections (with known reservoirs) for recently emerged adenoviruses (AdVs), enteroviruses (EVs), coronaviruses, and influenza viruses. Zoonotic (coronaviruses and influenza viruses) and non-zoonotic viruses (AdVs and EVs) are shown. For zoonotic viruses, the hosts range from cattle, bats, chickens, camels, wild birds, cats, ferrets, goats, and humans (from left to right). The different sizes of the circles represent the number of human cases during the first outbreaks of the emerging respiratory viruses. Human cases of adenoviral infections are shown in blue; human cases of enteroviral infections are shown in yellow; human cases of coronaviral infections are shown in green; and human cases of influenza viral infections are shown in red.
Detecting Novel Respiratory Viruses that Emerge from the Human-Animal Interface

Molecular Detection Algorithms

December 17, 2015
Recent novel pathogen detection workshops

Hanoi, Vietnam

Erbil, Iraq

Tbilisi, Georgia

Singapore

Sibu, Malaysia

Hanoi, Vietnam
An Epidemiological Study of Communities with Intensive Farming for Novel Zoonotic Respiratory Viruses and Antibiotic Resistant Enteric Bacteria

Partners:
Wake Forest University
CommWell Health

Use panspecies (human & animal) assays to detect novel viruses:
- Influenza A,B,C,D
- Adenovirus
- Coronaviruses
- Enteroviruses

Rationale: Animal viruses in these groups have been known to cause disease in man but would likely be missed by the currently used clinical diagnostic assays
Use panspecies diagnostics to detect novel viruses:

- Influenza A,B,C,D
- Adenovirus
- Coronaviruses
- Enteroviruses

Sponsor:
DoD NMRC – Asia
An Epidemiological Study of Communities with Intensive Farming for Novel Zoonotic Respiratory Viruses and Antibiotic Resistant Enteric Bacteria

Use panspecies (human & animal) assays to detect novel viruses:
- Influenza A,B,C,D
- Adenovirus
- Coronaviruses
- Enteroviruses
- Porcine circovirus 2, and porcine rotaviruses

Rationale: This pilot study sought to look for swine pathogens at the human-animal interface in Sarawak
Enrollment questionnaire & sera from 300 exposed and 100 nonexposed workers (6 farms)
Annual serum sampling
Annual risk factor questionnaire
Weekly monitoring for ILI & influenza A
ILI questionnaire
ILI sera and swabs

Monthly rope swab sampling of 50 pigs
Sample various ages (sows, boars, and production pigs)
50 pens x 6 farms per month = 300 rope swabs per month

CAFO questionnaire
Multiple CAFOs in separate provinces
Monthly environmental studies of CAFO environment for influenza A
144 total aerosol, fecal, environmental swab, and water samples/per month
Results

When visiting the farms our research teams noted a frequent lack of biosecurity and sparse use of personal protective equipment, especially in the older and smaller farms. In at least three farms, ducks, geese, chickens, or dogs were housed very near or found comingling with pigs. Often there were no barriers to separate pigs from birds or rodents.
Evidence for Cross-species Influenza A Virus Transmission Within Swine Farms, China: A One Health, Prospective Cohort Study

Mai-Juan Ma, Guo-Lin Wang, Benjamin D. Anderson, Zhen-Gang Li, Bing Li, Xiao-Jun Wang, Chang-Xia Wang, Shao-Hui Chen, Yan-Hua Gong, Shao-Xiao Song, Mike Li, John A. Lumpkin, Tong Zhen, Meng-Hua Wu, Wei Chen Cao, and Gregory D. Gray

Background: Our understanding of influenza A virus transmission between humans and pigs is limited.

Methods: Beginning in 2015, we used a One Health approach and serial sampling to prospectively study 298 swine workers and 100 controls, their 9000 pigs, and 6 pig farm environments in China for influenza A viruses (IAVs) using molecular, culture, and immunological techniques. Study participants were closely monitored for influenza-like illness (ILI) events.

Results: Upon enrollment, swine workers had higher serum neutralizing antibody titers against swine H1N1 and higher nasal wash total immunoglobulin A (IgA) and specific IgA titers against swine H1N1 and H3N2 viruses. Over a period of 12 months, IAVs were detected by quantitative reverse transcription polymerase chain reaction in 46 of 296 (15.6%) environmental swabs, 235 of 296 (79.8%) pig oral secretion, 23 of 296 (7.8%) water, 20 of 296 (6.8%) swab, and 89 of 296 (30.0%) fecal samples. Five of 32 (15.6%) participants with ILI events had nasopharyngeal swab specimens that were positive for IAV, and 17 (53.1%) demonstrated 4-fold increases in neutralization titers against a swine virus. Reassortant Eurasian avian-lineage H1N1, A(H1N1)pdm09-like, and swine-lineage H3N2 viruses were identified in pig farms. The A(H1N1)pdm09-like H1N1 viruses identified in swine were nearly genetically identical to the human H1N1 viruses isolated from the participants with ILI.

Conclusions: There was considerable evidence of A(H1N1)pdm09-like, swine-lineage H1N1, and swine-lineage H3N2 viruses circulating, likely re-assorting, and likely crossing species within the pig farms. These data suggest that stronger surveillance for novel influenza virus emergence within swine farms is imperative.

Keywords: One Health; Influenza A virus; China; emerging pathogens.

Prospective surveillance for influenza A virus in Chinese swine farms

Benjamin D. Anderson, Mai-Juan Ma, Guo-Lin Wang, Zhen-Qiang Bi, Bing Li, Xiao-Jun Wang, Chang-Xia Wang, Shao-Hui Chen, Yan-Hua Gao, Shao-Xiao Song, Min Liu, Ting Zhao, Meng Na Wu, Laura K. Boitnott, Wei-Chun Cao and Gregory D. Gray

Abstract

Pork production in China is rapidly increasing and swine production operations are expanding in size and number. However, the biosecurity measures necessary to prevent swine disease transmission, particularly influenza A viruses (IAV) that can be zoonotic, are often inadequate. Despite this risk, few studies have attempted to comprehensively study IAV ecology in swine production settings. Here, we present environmental and animal sampling data collected in the first year of an ongoing five-year prospective epidemiological study to assess IAV ecology as it relates to swine workers, their pigs, and the farm environment. From March 2015 to February 2016, we collected 396 each of environmental swab, water, broiler, and fecal/swab samples, as well as 3,300 pig oral secretion samples from six farms in China. The specimens were tested with molecular assays for IAV. Of these, 46 (11.0%) environmental swabs, 235 (79.8%) pig oral secretion, 25 (7.8%) water, 20 (6.0%) broiler, and 19 (4.8%) fecal/swab samples were positive for influenza A by qRT-PCR. Risk factors for IAV detection among collected samples were identified using bivariate logistic regression. Overall, these first data suggest that IAV is quite ubiquitous in the swine production environment and demonstrate an association between the different types of environmental sampling used. Given the mounting evidence that some of these viruses freely move between pigs and swine workers, and that mixing of these viruses can yield progeny viruses with pandemic potential, it seems imperative that routine surveillance for novel IAVs be conducted in commercial swine farms.
Bioaerosol Sampling

Partners
North Carolina State University
University of Florida
NIOSH

Airborne Detection and Quantification of Swine Influenza A Virus in Air Samples Collected Inside, Outside and Downwind from Swine Barns
Cesar A. Corzo, Marie Culhane, Scott Dee, Robert B. Morrison, Montserrat Torremorell

Scientists still at a loss to explain spread of avian flu
By Lorna Benson on Apr 20, 2015

Research shows airborne transmission of avian flu a possibility
By Tom Olney on Jun 21, 2015 at 5:30 pm

SKC BioSampler

Midwest Micro Tek air sampling kits

NIOSH 2-stage sampler

SKC personal sampler and filter
Bioaerosol sampling may be a non-invasive and efficient means to conduct surveillance for novel pathogens.

Molecular surveillance of respiratory viruses with bioaerosol sampling in an airport

Emily S. Bailey, Jessica Y. Cho, Juliana Zemke, Myagmarsukh Yondon and Gregory C. Gray

Abstract
Recognizing that crowded, high-traffic airports and airplanes have been implicated in respiratory disease transmission, we partnered with administrators of Raleigh Durham International Airport (RDU) in conducting a pilot study of aerosol surveillance for respiratory viruses at RDU. From January to March 2018 we used NIOSH 2-stage samplers to collect 150 min aerosol samples in crowded areas at RDU. Four (1/7%) of the 24 samples were positive for known respiratory pathogens including influenza A virus and adenovirus. These results suggest the feasibility of employing bioaerosol surveillance techniques in public transportation areas, such as airports, as a noninvasive way to detect and characterize novel respiratory viruses.

Keywords: Respiratory viruses, Bioaerosol, Epidemiology, Air travel

Bioaerosol Sampling for Respiratory Viruses in Singapore’s Mass Rapid Transit Network

Kristen K. Coleman, Tham T. Nguyen, Yvonne Sin, Christophe Hansen Estruch, William G. Lindsley and Gregory C. Gray

As a leading global city with a high population density, Singapore is at risk for the introduction of novel biological threats. This risk becomes even more pronounced in light of the COVID-19 pandemic. In Singapore, MERS-coronavirus, the 2009 pandemic H1N1 influenza A virus, and enterovirus 71. Other major threats to Singapore include MERS-coronavirus and various avian and swine influenza viruses. The ability to quickly identify and robustly track such threats to initiate an early emergency response remains a significant challenge. In an effort to enhance respiratory virus surveillance in Singapore, our team conducted a pilot study employing a modified bioaerosol sampling method to detect respiratory viruses in Singapore’s Mass Rapid Transit (MRT) network. Over a period of 52 weeks, 66 aerosol samples were collected during peak MRT travel hours. Nine (6%) tested positive for adenovirus, four (3%) tested positive for respiratory syncytial virus type A, and one (1%) tested positive for influenza A virus with real-time RT-PCR. To our knowledge, this is the first time molecular evidence for any infectious respiratory agent has been collected from Singapore’s MRT. Our pilot study data support the possibility of employing bioaerosol samples in crowded public spaces to noninvasively monitor for infectious respiratory agents.
Bioaerosol Sampling to Detect Avian Influenza Virus in Hanoi’s Largest Live Poultry Market

Youngh N. Bui,1 Tham T. Nguyen,2,3 Hung Nguyen-Viet,3,4 Aish N. Bui,1 Katie A. McCollum,1 Ho Suk Lee,5 Son T. Tham,6 Kristen K. Coleman,2 and Gregory C. Gray2,3,7

1Virology Department, National Institute of Veterinary Research, Hanoi, Vietnam; 2Program in Emerging Infectious Diseases, Duke-NUS Medical School, Singapore; 3International Livestock Research Institute, Hanoi, Vietnam, and 4Center for Public Health and Economic Research, Hanoi University of Public Health, Vietnam; 5College of Veterinary Medicine, North Carolina State University, Raleigh, North Carolina, and 6Division of Infectious Diseases, Global Health Institute, and Nicholas School of the Environment, Duke University, Durham, North Carolina; and 7Global Health Research Center, Duke-Karazin University, China

Background. Newly emergent and virulent strains of H7N9 avian influenza virus are rapidly spreading in China and threaten to invade Vietnam. We sought to introduce aerosol sampling for avian influenza viruses in Vietnam.

Methods. During October 2017, National Institute for Occupational Safety and Health 2-stage aerosol samplers were assembled on a tripod and run for 4 hours. Concomitantly, up to 20 oropharyngeal (OP) swab samples were collected from chickens and ducks distanced at 0.2–1.5 m from each sampler.

Results. The 3 weeks of sampling yielded 30 aerosol samples that were 90% positive for influenza A, by quantitative reverse-transcription polymerase chain reaction, and 116 OP swab sample pools (5 samples per pool) that were 47% positive. Egg cultures yielded 1 influenza A virus (not H5 or H7) from aerosol and 25 influenza A viruses from OP swab sample pools (5 were H5 positive). The association between positive sample types (over time and position) was strong, with 91.7% of positive OP pooled swab samples confirmed by positive aerosol samples and 81% of influenza A positive aerosol samples confirmed by positive OP swab samples.

Conclusions. We posit that aerosol sampling might be used for early warning screening of poultry markets for novel influenza virus detection, such as H7N9. Markets with positive aerosol samples might be followed up with more focused individual bird or cage swabbing, and back-tracing could be performed later to locate specific farms harboring novel virus. Calling birds in such farms could reduce highly pathogenic avian influenza virus spread among poultry and humans.

Keywords. avian influenza; influenza A virus; Vietnam; poultry; epidemiology.

Our One Health Training
PhD in Public Health

One Health Concentration
The PhD in Public Health with a concentration in One Health is a research-oriented health degree that emphasizes working across public health, veterinary medicine, and environmental health disciplines to tackle difficult health problems. The PhD program focuses on global health, infectious diseases, and environmental health while emphasizing research and elements of grant writing and funding. This is the first known One Health PhD program in the world.

Public Health Core: 15 credits
Quantitative Methods: 12 credits
Concentration: 18-36 credits
Professional Issues: 5-7 credits
Advanced Research: 3 credits
Supervised Teaching: 2 credits
Dissertation: 15 credits
Total: 50 credits

Funding in the form of scholarships and assistantships is available on an individual, competitive basis.

Tuition Rates (2012-2013)
In-state: $4490/credit + fees
Out-of-state: $8500/credit + fees

*Out-of-state tuition rates may be reduced through Graduate Assistantships for PhD students.

Length of Program 2-5 years

Master's of Health Science

One Health Concentration
The MHS program is designed to provide students with advanced analytical skills for applied research careers and a solid knowledge base of public health and health policy. This degree includes advanced applied research and technical skills needed to address emerging and global environmental health threats. The MHS curriculum addresses a diverse range of health issues but has a strong focus upon infectious diseases. Courses are carefully structured to enable students to develop competence in very specific health skills. This is the first such One Health MHS program in the United States.

Public Health Core: 12 credits
Concentration: 24 credits
Professional Issues: 1 credit
Field Experience: 3 credits
Total: 40 credits

Tuition Rates (2012-2013)
In-state: $4490/credit + fees
Out-of-state: $1245/credit + fees

Length of Program 1-2 years

Certificate in One Health

The Certificate in One Health is designed to introduce the graduate student to the principles of One Health. The program is designed to provide One Health training to public health, veterinary health, and environmental health professionals and students who wish to follow such careers. Training includes lectures, tutorials, field experiences, laboratory exercises, public health demonstrations, and written exams.

On-site coursework: 6 credits
One Health Problem Solving in Public Health Lab Techniques
Zoonotic Disease & Food Safety
Environmental Health Concepts in Public Health

Online coursework: 3 credits

Tuition Rates (2012-2013)
In-state: $4490/credit + fees
Out-of-state: $5500/credit + fees

Length of Program 3 months
One Health Intellectual Exchange

Multidisciplinary Approaches to Solve Problems Challenging the Health of People, Animals and the Environment

A monthly discussion series, sponsored by the North Carolina One Health Collaborative (NC OHC) within the NCBC Intellectual Exchange Group (IEG) Program to enhance collaborations between physicians, veterinarians, researchers and other local / global / environmental health professionals by increasing public awareness of the interconnectedness of people, animals and the environment.

Fall 2018 – Tuesday, November 20th
5:00 – 7:00 p.m.
4 graduate courses (May 16 through June 9, 2019)

- An Introduction to One Health Problem Solving (2 credits)
- Public Health Laboratory Techniques (1 credit)
- An Introduction to Entomology Zoonotic Diseases & Food Safety (3 credits)
- Introduction to Environmental Health (3 credits)

The 2018 Duke One Health Training Program class included 31 scholars from eight countries: China, Egypt, Lebanon, Morocco, Pakistan, Sri Lanka, The Philippines, and the USA.
Duke One Health Training Program Alumni Distribution Map 2008-2018

2008-2018 Total Alumni: 338

Note that early training was performed at University of Iowa (2008-9) or University of Florida (10-14) under similar summer short course programs as led by Professor Gray.
One Health Training

- Epidemiology
- ID surveillance
- Analytical epidemiology
- Outbreak response
- Zoonotic diseases
- Entomology
- Food safety
- Viral culture
- Molecular diagnostics

- Ecology
- Serologic assays
- Modern dairy production
- Mosquito & tick collection
- Mosquito & tick control
- Modern meat production
- Aquaculture
- Environmental engineering
One Health Fellowships for Zoonotic Disease Research in Mongolia, NIH D43TW009373

Partners:
Institute of Veterinary Medicine
National Center for Zoonotic Diseases

• 2 Months of One Health Training at Duke University
• 22 Months of mentored research at the National Center for Zoonotic Diseases in Mongolia

Our long term goal is to develop a Global Health Training Program that elicits innovative, multidisciplinary team problem-solving solutions to develop products, alter disease processes, and guide policies in controlling zoonotic diseases in Mongolia.

Team 1 (2014-16):
Tick-borne Diseases

Team 2 (2015-17):
Zoonotic Influenza Surveillance

Team 3 (2016-18):
Zoonotic Parasite Ecology/Epidemiology

Team 4 (2017-18):
Zoonotic Surveillance of Mosquito-borne Arboviruses
Primary Goal:
To conduct a 20-month pilot study of mosquito-borne arboviruses in Mongolia.

In 2017 and 2018, Team 4 collected samples from horses, humans, birds, rodents and mosquitoes in northern, central, and eastern Mongolia. They intend to analyze samples for molecular and serological evidence of West Nile virus, Japanese encephalitis virus, Batai virus, and Getah virus. They will also identify the relevant risk factors for such infections and the potential health and economic burdens they create for nomadic herders in Mongolia.
Are agriculture workers at increased risk for emerging pathogen infections?

Duke One Health helps answer these questions.

http://sites.globalhealth.duke.edu/dukeonehealth/
**Duke One Health Team News**

**Recent Publications**

**Duke One Health Team Searches for Viruses in Air at a Major Airport**

Using NIOSH 2-stage aerosol samplers, air samples were collected from the baggage claim areas of Raleigh-Durham International Airport and screened for common respiratory viruses including influenza A/B/C/D, adenovirus, and coronavirus. In 17% of the 24 samples, known respiratory viruses including adenovirus and influenza D were detected. These findings will be useful for strengthening the surveillance system in high human traffic areas such as airports. [Read more]

**Duke Medical Student Finds Rare Viruses as a Possible Explanation for Respiratory Illnesses Among Singaporean Children**

In a cross-sectional study of 201 pediatric patients with respiratory symptoms in a pediatric hospital in Singapore, Duke University Medical student Christophe Hassan-Franjach joined with collaborators [Read more]

**First Use of Bioaerosol Sampling to Detect Avian Influenza Virus in a Vietnamese Live Poultry Market**

In October 2017, US and Vietnamese collaborators conducted a pilot study of aerosol sampling surveillance in a large wholesale live bird market in Hanoi. Of the air samples collected during a three-week period, 97% were positive for molecular evidence of influenza A. These results were positively associated with molecular results from oropharyngeal swab samples collected from chickens and ducks. Noninvasive bioaerosol samplers may serve as an early warning screening tool for novel influenza virus detection in live bird markets. [Read more]

**2018 Marks the 100th Year Since the 1918 Influenza Pandemic**

In an invited review article, a group of Duke scholars and Duke One Health team members examine the newly described influenza virus types since the 1918 pandemic. [Read more]
Interest in One Health is Spreading

Known academic One Health training, research, and outreach programs in North America

Universities that offer formal One Health, academic credit-earning programs

Universities with non-academic credit-earning One Health programs or research

One Health Research Publications

From PLOS Biology | DOI: 10.1371/journal.pbio.1002448 April 21, 2016. Number of papers captured by our search through time. Blue = veterinary community; gold = ecology community; red = group 3. Numbers are the annual percent growth rate within each community.

"...The number of publications fulfilling our search criteria increased by 14.6% per year, which is faster than growth rates for life sciences as a whole and for most biology subdisciplines."
One Health has now been mentioned as an approach in more than 100 active or archived requests for proposals (RFPs) since 2007 on www.grants.gov. On 9/8/18, we extracted summary data from 96 of these RFP records (HHS, USAID, USDA, DoD, EPA) and found grant funding to total $4,885,519,322
The global health graduate program at Duke Kunshan University has been a one-of-a-kind experience. Enjoying state-of-the-art facilities, rubbing shoulders with profoundly experienced professors, and being in China has allowed me to study the discipline and observe related issues that spur discussion and motivate change.

- Hwee Min Loh, Class of 2016, Singapore
How to Apply to Duke Kunshan University

Email: gh-education@dukekunshan.edu.cn

Apply online: www.dukekunshan.edu.cn

Apply by January 31, 2018 (first wave deadline), last wave deadline May 31st (last deadline)

Requirements:
- GPA (>3.2)
- Statement of Purpose
- Three reference letters
- GRE Test (>308) with writing > 3
- TOEFL (> 90); IELTS (>7)
- CV
One Health is an exciting research and training area.

The Duke One Health Research and Training Network offers numerous One Health opportunities for students and collaborators