CIDRAP

Center for Infectious Disease Research & Policy

UNIVERSITY OF MINNESOTA

MCEIRS AVIAN INFLUENZA TRAINING

Individual Study Guide

Version: March 17, 2011

Revised: January 2017

Avian Influenza and Poultry Biosecurity

Minnesota Center of Excellence for Influenza Research and Surveillance

Avian Influenza and Poultry Biosecurity

INTRODUCTION

Avian Influenza and Poultry Biosecurity

Avian influenza (AI) viruses are important pathogens in poultry. Poultry may be exposed to AI viruses through contact with a natural reservoir, such as a wild duck or through exposure to an environment contaminated with wild bird fecal or respiratory secretions. Infected domestic poultry can also serve as reservoirs and movement of people, equipment, or birds can spread the virus. Contact between poultry at live bird markets also poses a significant risk of exposure to AI viruses.

Biosecurity measures can reduce the spread of AI viruses. In this module, industry biosecurity practices and principles and their application to backyard or other outdoor systems are discussed.

LESSON 1: OVERVIEW OF AVIAN INFLUENZA

In this lesson we will cover

- Influenza A Virus
- Avian Influenza Classification
- Clinical Signs of AI in Poultry
- Diagnosis of AI in Poultry
- Reporting of AI
- HPAI H5N1
- H7N9 Avian Influenza
- Interspecies Transmission of Influenza Viruses

INFLUENZA A VIRUS

Influenza viruses belong to the Orthomyxoviridae family of segmented negative-sense RNA viruses. The genus influenza A consists of a single species: influenza A virus, which is the cause of type A influenza. (See Figure 1.) Influenza A viruses cause illness in a variety of mammals and are the most common cause of influenza in humans.

Influenza B is also an important cause of influenza in humans, whereas influenza C is a relatively uncommon cause of human disease. Influenza D has recently been found in swine and cattle, but is not known at this time to cause disease in humans.

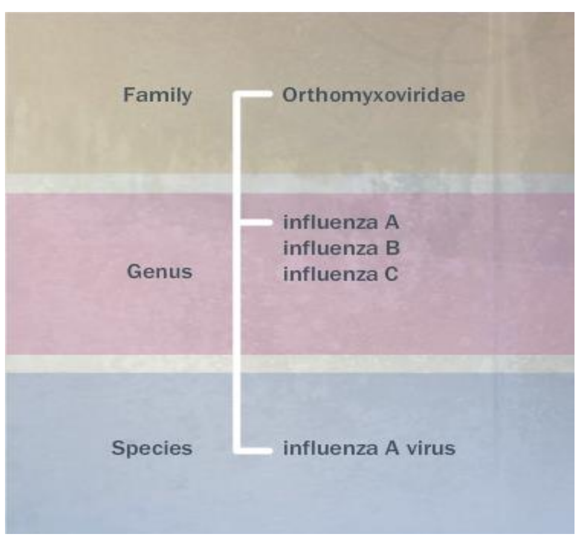

Figure 1

Influenza A virus subtypes are defined by two of the surface proteins, shown in Figure 2, that are part of the structure of the virus:
H: Hemagglutinin
N: Neuraminidase

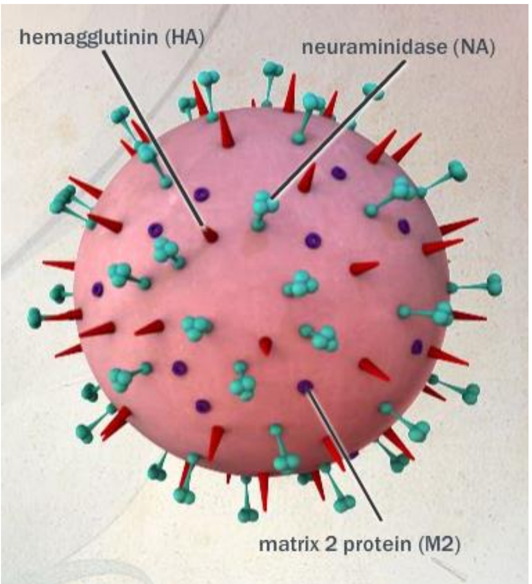

Figure 2: Virus Structure

There are 18 different HA antigens (H1 to H18) and 11 different NA antigens (N1 to N11) for influenza A. These antigens give rise to the subtype designation. Subtypes H1 to H16 and N1 to N9 are found in birds (mostly wild birds) and some of these subtypes have been found in mammals. H17N10 and H18N11 were discovered in bats in Guatemala in 2009 and in Peru in 2013, respectively. The NA genes in these influenza subtypes are highly divergent from other known influenza NAs and researchers propose that the attachment and activation of these viruses occur by a different mechanism than other influenza viruses. As of January 2017, these two subtypes appear to be unique to the bat population, but have been shown to infect and replicate in other mammalian cells (such as canine cell lines).

Because of the segmental nature of the influenza genome, influenza viruses are susceptible to mutation and reassortment events that can result in the evolution of new viral strains.

AVIAN INFLUENZA CLASSIFICATION

Influenza A viruses can infect a variety of domestic and wild bird species. Infection can range from no clinical signs to severe disease, depending on the virulence of the virus, environmental factors, and the susceptibility of the host.

AI viruses are classified according to the disease severity in domestic chickens, with two recognized forms: highly pathogenic avian influenza (HPAI) and low-pathogenic avian influenza (LPAI).

“HPAI” - Highly pathogenic avian influenza (previously known as fowl plague) is rare. It causes severe disease in domestic poultry and can cause mortality rates of up to 100% in affected flocks.

"LPAI" - Low-pathogenicity avian influenza occurs more frequently than HPAI. It can cause mild upper respiratory symptoms in domestic poultry and does not typically cause death in affected poultry.

Only certain subtypes of H5 (such as H5N1) and H7 (such as H7N7) have been associated with HPAI. These subtypes also have been associated with LPAI. H5 and H7 LPAI subtypes may mutate into HPAI viruses.

CLINICAL SIGNS OF AI IN POULTRY

HPAI

- Sudden death
- Coughing, sneezing, nasal discharge, excessive lacrimation
- Fever
- Swelling and/or discoloration of the head, comb, wattles, and legs
- Diarrhea
- Depression, anorexia
- Incoordination or other neurological signs

LPAI

- No visible signs
- Decreased feed consumption
- Decreased egg production
- Ruffled feathers
- Mild respiratory signs

DIAGNOSIS OF AI IN POULTRY

Diagnosis of AI in domestic poultry can be done using serology. The ELISA test screens for the presence of antibodies to the nuclear protein of the influenza A virus, but it is not subtype specific. Further testing such as HA inhibition (HI) tests would need to be done to determine the specific subtype. Laboratories generally require 1 mL of serum to perform the test.

Tracheal/oral-pharyngeal swabs can be tested for the presence of virus using real-time reverse transcriptase polymerase chain reaction (RT-PCR) testing or virus isolation. In the US, diagnosis of AI is conducted by laboratories in the National Animal Health Laboratory Network (NAHLN) or other US Department of Agriculture (USDA)-approved laboratories. Confirmatory testing for HPAI viruses is performed by the National Veterinary Services Laboratory.

REPORTING OF AI

The World Organization for Animal Health (OIE) must be notified when an HPAI virus is identified. An HPAI virus is defined as any influenza A virus with an intravenous pathogenicity index (IVPI) greater than 1.2, or with at least 75% mortality in 4- to 8-week-old chickens, or an influenza A virus that has certain specific amino acids at the HA0 cleavage site. In addition, any H5 or H7 subtype, whether classified as HPAI or LPAI, is reportable to OIE.

In the US, HPAI is considered a foreign animal disease (FAD), and the USDA is the responsible regulatory authority. Individual states are the regulatory authority for LPAI eradication and control.

HPAI H5N1

An HPAI H5N1 virus caused an outbreak of disease in domestic poultry and humans in Hong Kong in 1996. The virus then re-emerged in Southeast Asia in 2003 and has subsequently spread throughout Asia, to Europe and Africa, affecting domestic poultry, humans, wild birds, and other animals.

The virus is now considered endemic in several countries, including Bangladesh, China, Egypt, India, Indonesia, and Vietnam, and outbreaks in those and other countries continue to occur. As of January 2017, the virus has caused outbreaks in domestic poultry in 54 different countries.

The HPAI H5N1 virus is of public health concern and has infected more than 850 humans and caused more than 450 deaths as of January 2017. The major risk factor for HPAI H5N1 in humans is direct contact with sick or dead poultry. The concern remains that the HPAI could develop into a human pandemic virus.

The HPAI H5N1 virus was the precursor to at least 5 additional HPAI H5 subtypes in 2014-15, including an H5N8 subtype that moved into the Pacific flyway of the Western hemisphere. The H5N8 HPAI virus reassorted with North American LPAI viruses resulting in a large outbreak of HPAI H5N2 in poultry in the Midwestern United States. The H5N8 virus returned to Asia, Africa, and Europe in the winter of 2016-17 causing further outbreaks in poultry and wild birds. As of January 2017, no human illnesses or deaths associated with either the H5N2 or H5N8 viruses have been identified.

H7N9 AVIAN INFLUENZA

In the spring of 2013, a novel H7N9 virus emerged in humans in China. The initial wave occurred in the spring of 2013; and one in the winter of 2013-14; a second wave occurred during the winter of 2013-14 and third and fourth waves occurred during the winters of 2014-15 and 2015-16 respectively, demonstrating a seasonal pattern. According to FAO as of January 2017, over 1000 human cases and at least 360 deaths due to H7N9 influenza had been reported. A serological survey of poultry workers in affected areas also detected asymptomatic infections. While the case-fatality rate for this novel strain has been lower than that for the H5N1 virus, H7N9 also can cause a severe pneumonia that may progress to the acute respiratory distress syndrome (ARDS). Similar to the H5N1 virus, human-to-human transmission with H7N9 appears to be limited. As of January 2017, cases of illness have been detected only in China and in persons who had recently visited China, including two travelers from British Columbia, Canada.

China has conducted testing in live-bird markets in the outbreak areas and has reported the detection of an LPAI H7N9 virus in chickens, pigeons, and environmental samples. The virus also has been detected in chickens imported from China into Hong Kong. This LPAI virus is similar to the virus that causes disease in humans.

Since affected birds do not typically show clinical signs of infection with this virus, surveillance for and detection of the virus in poultry is difficult. Because the virus is not readily apparent in poultry, the role of poultry in contributing to human illness remains unclear (although poultry exposure may be an important risk factor for infection).

INTERSPECIES TRANSMISSION OF INFLUENZA VIRUSES

Although most AI viruses infect only birds, the viruses can also infect mammals. Swine are susceptible to avian, swine, and human influenza viruses and have been thought of as mixing vessels for the reassortment of influenza viruses. The HPAI H5N1 virus has been found in a variety of mammals, including wild and domestic cats, civets, dogs, and small mammals such as mink.

There is also evidence that human and swine influenza viruses can infect birds. Decreased egg production, decreased appetite, and respiratory signs have been seen in turkeys infected with swine influenza viruses. The 2009 H1N1 pandemic virus also has been found in several turkey breeder flocks, causing decreased egg production; however, experimentally infected chickens, turkeys, quail, and ducks did not develop clinical signs.

LESSON 2: RESEVOIRS AND TRANSMISSION OF AVIAN INFLUENZA

In this lesson we will cover:

- Wild Birds as a Natural Reservoir for AI Viruses
- Domestic Poultry as a Reservoir for AI Viruses
- Risks in Live-Bird Markets
- Transmission of AI
- Raising Poultry Outdoors

WILD BIRDS AS A NATURAL RESERVOIR FOR AI VIRUSES

HA (1-16) and NA (1-9) subtypes have been isolated from wild birds, and certain groups of wild birds are the primary reservoirs for AI viruses. AI viruses have been isolated from more than 100 wild bird species representing 26 families of birds.

The most important of these are:

- Anseriformes (ducks, geese, and swans)
- Charadriiformes (gulls, terns, and waders)

AI viruses do not generally cause disease in wild birds, but they can be shed into the environment through fecal or respiratory secretions and can be passed from bird to bird. Therefore, wild birds or their environments may be sources of AI for domestic poultry.

Although experts generally agree that wild birds are the major reservoirs of LPAI viruses, their role in the maintenance and spread of HPAI H5N1 or other HPAI viruses is less clear. It is thought that LPAI viruses are introduced into domestic poultry from wild bird reservoirs, where they may then mutate into HPAI viruses.

DOMESTIC POULTRY AS A RESERVOIR FOR AI VIRUSES

Domestic poultry are not natural reservoirs for influenza viruses. However, once infected, domestic poultry can be a source of virus for other birds. The virus can be transmitted from bird to bird, from flock to flock, or from farm to farm.

AI viruses are shed in the feces and in the respiratory secretions of infected birds for up to 4 weeks.

- AI viruses can survive in cool, moist environments for up to several months.
- AI viruses also have been isolated from water sources.
- The viruses generally survive on surfaces and other fomites for up to 6 days.

RISKS IN LIVE-BIRD MARKETS

Live-bird markets are considered to be a reservoir for AI viruses. Live-bird markets mix different species and ages of birds and birds from many sources. The health status of birds going to market may not be known. Live-bird markets pose a high level of risk for disease transmission, have been a source of outbreaks of both HPAI and LPAI, and are thought to be important in maintaining a nidus of AI viruses in some countries.

Live-bird markets can also pose a public health risk, as they bring humans in close contact with live and dead poultry.

TRANSMISSION OF AI

Poultry can be exposed to AI viruses from wild or domestic reservoirs through:

- Direct contact with an infected bird
- Environmental contamination from:
  -Manure
  -Respiratory secretions
  -Carcasses
- Fomites or vectors contaminated with manure or respiratory secretions, including:
  -Footwear or clothing of employees, service persons, or visitors
  -Vehicles
  -Equipment that is shared with or has been on other farms
- Eggs
- Pests (e.g., rodents, wild birds, insects)

Biosecurity measures are the primary means of preventing the introduction of AI viruses into poultry flocks. Strict biosecurity measures are enacted on large commercial farms to prevent and control the transmission of AI.

The USDA has developed a campaign for commercial poultry operations to increase and improve biosecurity called “Defend the Flock” which includes factsheets, training materials, and a self-assessment tool for evaluation of biosecurity practices. (https://www.aphis.usda.gov/aphis/ourfocus/animalhealth/animal-disease-information/avian-influenza-disease/defend-the-flock/defend-the-flock-bio-info-comm-poultry)

RAISING POULTRY OUTDOORS

Smallholder operations and backyard poultry flocks are common production systems in many parts of the world. These operations may face challenges to implementing biosecurity measures, but many of the basic principles and industry practices can be adapted to these systems.

Backyard poultry in the US are kept for a variety of purposes. Birds are kept as a hobby, as a source of eggs and/or meat, for show, for cultural or religious purposes, and for small-scale commercial production. There has also been an increase in organic and free-range farming of poultry, which requires birds to have access to the outdoors.

The USDA has a program titled “Biosecurity for Birds” that is directed toward backyard bird owners in the US. This program emphasizes the practices of looking for signs of disease, reporting any disease or death to local veterinary authorities, and protecting birds through biosecurity practices such as isolation and cleaning.

LESSON 3: BIOSECURITY CONCEPTS

In this lesson we will cover:

- Definition
- Biosecurity Risk Assessment
- Goals of Biosecurity:
- Conceptual, Structural, and Operational Biosecurity
- Compartmentalization and Zoning
- Education
- Surveillance
- Vaccination

DEFINITION

Biosecurity is defined by Merriam-Webster as “security from exposure to harmful biological elements”.

Biosecurity refers to those measures that should be taken to minimize the risk of incursion of HPAI into individual production units (bioexclusion) and the risk of outward transmission (biocontainment) and onward transmission through the production and marketing chain.

Biosecurity is the implementation of measures that reduce the risk of the introduction and spread of disease agents in flocks; it requires the adoption of a set of attitudes and behaviors by people to reduce risk in all activities involving domestic, captive, exotic, and wild birds and their products.

Biosecurity is the prevention of exposure to disease agents through management practices.

Biosecurity measures need to be appropriate to the type of operation, the location of the farm, the risks in the area, and the resources available. Biosecurity practices should be general enough to prevent transmission of any pathogen and specific enough to address particular disease threats.

BIOSECURITY RISK ASSESSMENT

There are many and varied types of poultry production systems, ranging from large-scale commercial operations to smaller-scale operations to backyard or scavenging village poultry. Identification of specific hazards in individual operations and an assessment of the risks will allow producers/owners to prioritize biosecurity practices and customize them to their individualized operations. A risk assessment in small operations would involve determining disease prevalence in the region (i.e., whether AI is endemic, epidemic, or has not occurred) and determining the potential entry points of infection.

Biosecurity risk assessments may be formal or informal, depending on the type of operation, but should be conducted in consultation with a veterinarian or other professional in the field. The risk assessment should lead to the development of an individualized biosecurity plan.

GOALS OF BIOSECURITY - ISOLATION, TRAFFIC CONTROL, AND SANITATION

Biosecurity practices can be thought of in terms of three main goals: isolation, traffic control, and sanitation.

ISOLATION is defined as confinement of animals within a controlled environment; it also refers to the separation of production phases or age-groups.

TRAFFIC CONTROL refers to control of who and what comes onto the farm, traffic patterns within the farm, and who and what leaves the farm.

SANITATION or “cleaning and disinfection” is the physical removal of dirt and debris and the inactivation of potentially pathogenic organisms. Sanitation also refers to personnel hygiene.

CONCEPTUAL, STRUCTURAL, AND OPERATIONAL BIOSECURITY

Biosecurity can also be thought of in terms of conceptual, structural, and operational biosecurity.

An example of conceptual biosecurity would be the separation of facilities for the various phases of poultry production or the location of the farm. Structural biosecurity includes characteristics of the physical facilities and overall management practices. These elements of biosecurity, once established, can be highly effective but difficult to modify.

Operational biosecurity addresses the daily practices and behaviors of people involved in the industry and may be the most difficult to control.

COMPARTMENTALIZATION AND ZONING

On an international level, OIE has developed the concepts of compartmentalization and zoning as applied to international trade.

Biosecurity is managed by veterinarians or farm managers within the compartments or zones, and health status is ensured through standard operating procedures, critical control points, and other measures. These concepts can allow for international trade in countries in which HPAI H5N1 is endemic.

Compartmentalization is defined by OIE as “one or more establishments under a common biosecurity management system containing animals with a distinct health status.”

Commercial poultry compartments are separated from backyard poultry flocks with biosecurity allowing trade to continue from commercial flocks.

Commercial poultry compartments are separated from backyard poultry flocks with biosecurity allowing trade to continue from commercial flocks.

ZONING refers to animals of a certain health status within a distinct geographical area.

If one region of a country is affected, another can be free and thus continue to export.

EDUCATION

Education is an important aspect of prevention and control of AI. Training should be comprehensive, practical, and targeted to the appropriate sector.

Knowledge of the characteristics and behavior of the virus will enable an understanding of how the virus is transmitted and spread. Training and education on biosecurity practices ensure the effectiveness of these measures. Training should also focus on preventing the spread of AI viruses during outbreak control efforts.

Government officials, community leaders, producers, employees, owners, service personnel, paraprofessionals, and veterinarians are groups that should be educated on various aspects of AI and prevention and control practices.

Because of zoonotic and public health concerns, education on safety procedures, including the use of personal protective equipment, is also important.

SURVEILLANCE

Passive surveillance, or the testing of sick or dead birds, is the primary tool for the detection of HPAI. HPAI is considered a foreign animal disease, and suspect cases are investigated by federal or state veterinarians.

However, because birds infected with LPAI may show few if any clinical signs, active surveillance is important for the early detection of LPAI, which may help to stop and control the spread of virus. Active surveillance may be conducted in certain venues such as breeding flocks, slaughter plants, and live-bird markets. In the United States, the USDA requires that all imported birds be quarantined and tested for AI.

Also in the US, the National Poultry Improvement Plan (NPIP) is a cooperative program between the poultry industry, the USDA, and the states to ensure poultry health. Producers can participate in the NPIP by adhering to the provisions of the plan, which include sanitation and record-keeping requirements, inspections, and testing.

VACCINATION

Vaccination can be used as an adjunct to biosecurity measures to prevent and control AI. Inactivated and vectored vaccines are available. AI vaccines are specific to the HA subtype and thus cannot be used as a general preventive measure.

Vaccination will reduce, but not completely prevent, shedding in the event of exposure to the virus. In addition, antibodies to the vaccine may not be able to be differentiated from antibodies to a virus. This is important when evaluating the effectiveness of a vaccination program. The level of risk, the value of the birds, and the cost-benefit ratios of vaccination should be assessed when considering a vaccination program.

The process of genetic drift also has caused changes in the virus and must be considered when selecting vaccine strains. In addition, at least two major lineages of the H3N8 virus (an American strain and a European strain) are currently in circulation, and immunity is not cross-protective.

LESSON 4: BIOSECURITY PRACTICES TO PREVENT INTRODUCTION OF AI FROM LIVE AND DEAD BIRDS

In this lesson we will cover:

- Preventing Contact with Wild Bird Reservoirs
- Preventing Contact with Potentially Infected Poultry
- Carcass Management
- Manure Management

PREVENTING CONTACT WITH WILD BIRD RESERVOIRS

Preventing contact with wild birds, especially waterfowl, is essential in the prevention and control of AI viruses in poultry. Ideally, poultry should be housed indoors. Houses should be bird proof. Pond water should not be used for drinking water for poultry or to clean poultry houses.

Poultry raised outdoors are at higher risk of exposure to AI viruses from wild birds or their feces. If housed outdoors, birds should be confined, provided with shelter, and fed indoors. Feed storage should be in an area that cannot be accessed by wild birds.

Other bird species, especially domestic waterfowl, should not be housed on the same farm as poultry. There should be no ponds or standing water on the farm to attract wild birds. If there is a pond on the property, it should be fenced or have some other means to keep the birds away from the area.

It may be difficult to keep village or scavenging poultry away from wild birds, but fencing off ponds or other water sources may reduce contact.

PREVENTING CONTACT WITH POTENTIALLY INFECTED POULTRY

FARM LOCATION AND SECURITY

The goal of isolation can be met through conceptual and structural biosecurity measures, such as farm location and established management practices.

Ideally, the poultry farm should be in an isolated location, away from other poultry operations, slaughter facilities, or backyard flocks (1 to 2 miles is recommended). Facilities should be set back from the road.

Different age-groups should be housed in separate facilities on the farm. Traffic between facilities should be minimized.

The farm should be fenced and gated to limit access. Signs should be posted at the perimeter to prevent entry or direct visitors to a central office. Houses should be kept locked.

Outdoor birds should be housed separately from other species and the housing area fenced and gated.

MANAGEMENT PRACTICES

An “all in, all out” management system on the farm or within each age-group will reduce AI exposure from other birds. The facility should be cleaned and disinfected once the birds have been removed.

New birds should not be introduced into an established group. If this is not possible, then new additions to the flock should be from a known source and tested for infectious disease prior to arrival, quarantined for 2 to 4 weeks, and housed as far away as possible from the main flock. The birds should be observed and re-tested for any diseases of concern before joining the flock.

On-farm traffic patterns should be established. If it is necessary for workers to move between facilities on the farm, they should move from the youngest to the oldest birds and from the main flock to isolation or quarantine areas.

Birds should be provided with adequate and good-quality food and water. Poultry should receive recommended vaccinations or other veterinary treatments as needed. Good record keeping, including health records and records of bird movement, also will aid in disease control and prevention.

The flock should be monitored for illness and death. Sick birds should be isolated. Sick or dead birds should be submitted to a diagnostic laboratory.

VILLAGE OR COMMUNITY-LEVEL BIOSECURITY

In high-risk situations where poultry are free roaming and scavenge for food, alternative approaches to biosecurity must be considered. In this situation all of the poultry in the village or area would be considered to be the “flock” and biosecurity measures should be implemented at the village or community level.

Although it may be impossible to keep scavenging poultry away from other poultry species within the village, it is important to isolate the village poultry from potentially infected birds outside the village.

New birds entering a village flock should be isolated for at least 2 weeks before joining the flock. Sick birds should be quarantined away from the main flock. Birds brought to market should not be returned to the village. If they do return, they should be isolated from the main flock.

CARCASS MANAGEMENT

Dead birds can be a source of infection. Bird carcasses should be removed from housing areas as soon as possible. Any carcasses that are being sent to the laboratory should be double bagged.

Carcass disposal is best done on site by burial, composting, or incineration. If carcasses must be rendered or sent to a landfill, haulers should not enter the premises for pickup.

In village or backyard systems, carcasses should be picked up immediately and should not be eaten or fed to other animals. Carcasses should not be thrown into water.

MANURE MANAGEMENT

The AI virus can remain active in manure for several months under cold conditions. Manure should be spread and plowed under immediately, composted, or buried. Manure can also be covered and stored away from the housing area. Environmental temperatures of over 90°F for one week will inactivate the virus.

LESSON 5: BIOSECURITY PRACTICES TO PREVENT INTRODUCTION OF AI FROM ENVIRONMENTAL CONTAMINATION

In this lesson we will cover:

- Visitors and Service Personnel
- Vehicles
- Farm personnel
- Equipment
- Eggs
- Pest Management
- Cleaning and Disinfection

Preventing movement of people, equipment, or other fomites between birds, flocks, or farms can help prevent potential exposure to AI viruses. Industry biosecurity practices are outlined in this lesson; these can be adapted to smallholder, backyard, or village systems.

VISITORS AND SERVICE PERSONNEL

The number of visitors to the poultry farm, including service personnel, should be minimized. Visitors should check in at a designated area and should be accompanied at all times by farm personnel. Visitors should not have direct contact with birds unless absolutely necessary.

Visitors should wash their hands before coming onto the farm or entering the yard and should wear clean or designated farm clothing, footwear, and head coverings.
Poultry operations should ensure that visitors have not had recent contact with other poultry (minimum of 24 hours). Visitors and service personnel should not wear clothing or boots that were used for hunting or in a waterfowl environment. Log books can be used to track visitors to the operation and may be of help in tracing the source of an outbreak if a flock becomes infected.
Service personnel who have been on other farms should shower or wash their hands and arms, change footwear or wear foot coverings, and change clothing or coveralls before coming onto the farm.

On a village or backyard level, persons that have been at live-bird markets should change shoes and clothing and wash hands before coming into contact with other poultry. In addition, traders or service personnel who have been in contact with poultry outside the village should wash and change clothing and shoes or boots.

VEHICLES

Visitors and staff should park in designated areas outside the perimeter of the farm if possible. Farm vehicles should stay on the farm.

For vehicles that are coming from another farm, tires and wheel wells should be scrubbed and disinfected before the vehicle is allowed onto the farm. Vehicles that have been used for hunting or fishing should not be driven onto the farm or should be scrubbed and disinfected. The interiors of vehicles should also be kept clean, and contaminated floor mats should be disinfected.

Vehicles such as bicycles or carts should be left at the gate and not allowed into the housing area. Vehicles and crates that have been at live-bird markets should be cleaned of any visible manure, feathers, etc, and disinfected before returning to the village or farm.

Delivery or transport trucks should be decontaminated. The trucks should not be driven in areas where they could become contaminated with manure and, if possible, should remain on the perimeter of the farm. Drivers should stay in their vehicles and not enter the house or yard.

FARM PERSONNEL

Persons working on a poultry farm should not own other poultry, pet, or exotic birds.

Personnel should not visit other poultry farms or live-bird markets. Farm staff should not hunt or fish on the same day they work with poultry and should not wear clothing or boots onto the farm that were worn while hunting or fishing.

Personnel should wear clean farm-specific clothing, boots, and head coverings. Workers should wash hands before coming onto the farm, between groups of birds, between facilities, if hands become otherwise contaminated, and when leaving the farm.

Personnel should follow established traffic patterns on the farm.

Farm staff should be trained in farm-specific biosecurity practices and procedures on a regular basis.

Keepers of backyard poultry should not work in other poultry operations, feed mills, or slaughter houses. Ideally, one person should be responsible for caring for the birds.

Caretakers should wash before and after handling poultry, should wear dedicated clothing when caring for birds, and should wash or change shoes when entering or leaving the housing area. Quarantined birds or birds in isolation should be cared for last, and dedicated clothing and shoes should be worn in the quarantine area.

EQUIPMENT

Equipment should not be shared between farms. Equipment that is moved from farm to farm (such as clean-out equipment) must be cleaned and disinfected between farms.

Other equipment (such as crates, egg flats, etc.) should be disposable or made of a material that is easy to clean and disinfect, such as plastic. Wood is more difficult to clean and disinfect. Any materials that have left the farm, especially materials that have been at a live-bird market, must be cleaned and disinfected before being returned to the farm or entering the yard.

EGGS

The surface of eggs could be contaminated with manure, so the eggs should be washed or fumigated. Eggs should be removed from the farm on dedicated and clean or disposable flats and dedicated and clean pallets or racks. Any egg-handling materials must be cleaned and disinfected before going to another farm.

PEST MANAGEMENT

Rodents, wild birds, and even insects can serve as vectors and spread infected fecal material from one premises to another. Rodent-control systems should be in place, and the outsides of buildings should be maintained free of debris and vegetation.

In outdoor systems, feed should be stored in rodent-proof containers. Spilled feed should be cleaned up as soon as possible.

Wild birds should not be allowed to nest in poultry facilities. Windows or other openings should be screened to keep wild birds out.

Standing water can be a breeding ground for many insects and should be removed from around the facilities and yards.

CLEANING AND DISINFECTION

When cleaning a facility, organic material such as manure must be removed before disinfecting. Many disinfectants are not effective in the presence of organic debris. Use of a high-pressure sprayer to remove debris from floors, walls, and ceilings is recommended.

Outdoor facilities should also be cleaned. Structures, shelters, waterers, and feeders should be cleaned on a regular basis. Yards should be kept free of debris. If footbaths are used, they should be kept clean, and disinfectants should be changed regularly.

Many disinfectants are effective at deactivating AI viruses, including quaternary ammonium compounds, phenols, iodophors, and chlorine. Detergents and drying are also effective. Heating buildings to 90°F will also kill the viruses.

LESSON 6: BIOSECURITY PRACTICES FOR LIVE-BIRD MARKETS

In this lesson we will cover:

- Market Design
- Market Management
- Personnel
- Cleaning and Disinfection
- Alternate Approaches

MARKET DESIGN

Live-bird markets can serve as reservoirs for AI viruses, and biosecurity measures are important in limiting any potential spread of contamination within such environments.

Live-bird markets should be separated from areas of the market where food or other products are sold. Booths should have space between them. Slaughter areas, if present, should be separate from the marketing areas.

If possible, traffic should have a separate entrance and exit and should move from one end of the market to the other. Trucks or other vehicles should unload outside of the market.

MARKET MANAGEMENT

The source and health status of birds coming to market should be known. Sick birds should not be brought into live-bird markets. Different species of birds should be separated in different areas of the market or should be marketed on different days. Birds should be confined and not allowed to roam through the market. Other species of animals (e.g., dogs, cats) should be kept out of the market.

“All in, all sold” should be practiced. Live birds should not be returned to farms or villages.

PERSONNEL

Personnel should wear dedicated clothing and shoes or boots at the market and should wash hands often. Market employees should not own poultry or have contact with other poultry or wild birds outside the market.

Employees should unload delivery trucks if the driver has had poultry contact.

CLEANING AND DISINFECTION

Cages, containers, and other equipment brought to the market should be made of material that is easy to clean and disinfect. Obvious fecal contamination of cages or other materials should be cleaned before coming into the market. Cages, pens, or other material leaving the market should be cleaned and disinfected before returning to the farm.

Transport or other vehicles that must enter the market should be cleaned and disinfected before coming into the market and especially when leaving the market.

Footwear of personnel leaving the market also should be disinfected.

Feed should be stored in closed containers, and pests should be controlled to the extent possible.

The market should be cleaned regularly. Solid-surface flooring, a clean water supply, and drainage systems will help to facilitate cleaning of the market.

Offal, carcasses, and other waste material should be properly disposed of away from the live birds. If rendering trucks are used, they should not drive into the market area for pickup.

ALTERNATE APPROACHES

Some countries have banned live-bird markets and set up systems of slaughter, packaging, and sale of packaged poultry products. This may not be a tenable approach in all areas, and clandestine unregulated market systems may develop. Banning the sale of certain species, such as ducks, has been implemented in some areas as well.

Down days, or days when the market is completely depopulated for cleaning and disinfection, is another approach to disease control. Markets should be closed every 30 to 60 days.

Cheap, disposable transport containers have also been used in areas where HPAI H5N1 is endemic.

Live-bird markets can be a site for distribution of educational materials on biosecurity measures for poultry owners and others. The markets can also be a central area for surveillance for AI viruses.

LESSON 7: BIOSECURITY IN OTHER POULTRY OPERATIONS

In this lesson we will cover:

- Hatcheries
- Game Farms
- Ratites
- Ducks
- Fighting Cocks
- Exotic Birds, Raptors and Zoo Birds
- Hunters

HATCHERIES

Many general biosecurity principles and practices for poultry farms also can be applied to hatcheries. Separation of the facility, limiting visitors, keeping vehicles outside the perimeter of the facility, and personnel hygiene can be accomplished in a similar manner in hatcheries.

Special attention should be paid to cleaning and disinfection of egg trays, pallets, carts, and other equipment that travel from the hatchery to farms and back.

If possible, the entrance and exit to the hatchery should be separated, and traffic flow should be one way. Transport trucks going to or returning from farms should be cleaned and disinfected away from the facility.

GAME FARMS

Game birds often are raised outdoors, so applying biosecurity principles for raising poultry outdoors is important, including keeping the game birds away from wild birds. Tears or holes in flight pens should be repaired quickly to avoid other birds nesting inside the pen. Other poultry should not be kept on the game farm. Infected stock should not be released until they have been demonstrated to be virus-negative.

RATITES

Ratites are often raised on open ranges, so preventing exposures to wild birds may be challenging. Ponds or other water sources should be fenced off, and wild birds should be prevented from nesting on the farm. Feed should be covered and feed spills cleaned up as soon as possible.

DUCKS

Biosecurity for domestic ducks may be problematic, especially if they are raised outdoors. Because ducks may be silent carriers of AI viruses, the risk of spreading such viruses is high. Contact with wild ducks and their feces is impossible to prevent in free-range ducks or ducks that scavenge in rice paddies.

In this situation, the principle of biocontainment rather than bioexclusion applies. Ducks should not be allowed around other poultry, and care should be taken not to spread contamination off of the farm.

FIGHTING COCKS

Cock fighting occurs in many areas of the world, including areas where it is illegal. Birds may be smuggled into countries where the practice is illegal. In such situations, birds may not undergo appropriate screening; therefore, the risk of infected birds entering the system may be increased. Cock-fighting birds are bred for specific physical traits and abilities. They may be moved from place to place and may encounter birds from many different sources, so strict biosecurity procedures in these operations should be followed.

EXOTIC BIRDS, RAPTORS AND ZOO BIRDS

Exotic birds, raptors, and zoo birds may be moved within and between countries and may serve as potential sources of infection. The USDA quarantines all birds entering the US legally, but smuggling of birds occurs, increasing the risk of infected birds entering the country. Some of these birds are of high value, and biosecurity measures will reduce the risk of infection. In some situations, vaccination of these birds is appropriate.

These birds should not be sold in live-bird markets.

HUNTERS

Hunters may also be a source of infection. Hunters should take care when disposing of offal and other parts of the carcasses. The remains should not be fed to other animals. Hunters should keep clothing, shoes, and vehicles used in hunting away from poultry.

LESSON 8: OUTBREAK CONTROL

In this lesson we will cover:

- Outbreak Control for LPAI:
- Outbreak Control for HPAI
- Depopulation
- Carcass Disposal
- Cleaning and Disinfection
- Vaccination

OUTBREAK CONTROL FOR LPAI

Because birds may not demonstrate significant clinical signs, outbreaks of LPAI may not be recognized unless routine surveillance is taking place. In the US, the NPIP monitors poultry for AI and classifies the status of poultry operations. States also may have monitoring plans that take into account the risks of the region and the industry in the area.

Control of LPAI outbreaks is a complex topic that needs to take into consideration local factors. Control strategies, therefore, should be developed by the appropriate regulatory authorities.

ENHANCED BIOSECURITY

Once an outbreak of LPAI has been confirmed, one important consideration is to determine if nearby poultry operations could have been exposed to the outbreak. If personnel, service persons, equipment, vehicles, etc have moved between premises, the risk of farm-to-farm transmission may be increased. Enhancing biosecurity measures and minimizing farm-to-farm traffic can help reduce spread to other operations.

DEPOPULATION

Depopulation is the most common strategy used to control an outbreak of LPAI in a poultry flock.

Depopulation can be accomplished by controlled marketing of healthy, previously infected, non-shedding birds. The flock may be quarantined and strict biosecurity measures enforced until the flock tests negative for the virus. The flock is then marketed in a controlled manner. This approach may allow recovery of grower costs and may be less economically damaging than destruction of infected flocks.

Depopulation can also be accomplished by destruction and disposal of flocks infected with an LPAI virus. It is important not to spread contamination through the depopulation process, so destruction should be delayed until the flock is no longer shedding virus. Carcasses can be disposed of on site if at all possible to prevent further spread of the virus via transport vehicles.

EXTENSIVE CLEANING
Extensive cleaning and disinfection of the premises should occur after depopulation. Control strategies recommend that new birds not enter the facility for at least 2 weeks after the facility has been completely cleaned out.

VACCINATION
Vaccination is also sometimes used as a tool to aid in control of an outbreak of LPAI. The infected flock and poultry determined to be at risk in an established geographical zone around the infected premises can be vaccinated for the circulating strain. It is important that surveillance continue after the use of vaccination. This can be done using sentinel birds or through the use of a neuraminidase heterologous strain, which is also called “differentiating infected from vaccinated animals” or DIVA.

OUTBREAK CONTROL FOR H7N9 IN CHINA
China has conducted serologic and virologic surveillance for H7N9 AI and has found evidence of the virus in poultry and environmental samples from live-bird markets. Control measures have included the culling of birds and temporary closure of affected markets.

Outbreaks of LPAI subtypes H5 or H7 may be handled more aggressively than LPAI outbreaks of other subtypes, since LPAI viruses of these subtypes may mutate to HPAI viruses or infect other species (including humans).

OUTBREAK CONTROL FOR HPAI

Planning for a potential outbreak of HPAI should be done by the appropriate regulatory authorities at the national and state levels. Plans should be tailored to the risks present in the region, the nature of the poultry industry in the region, and the resources available for control efforts.

Passive surveillance, followed by targeted surveillance of daily mortality, will result in early detection, and prompt reporting will allow eradication efforts to begin immediately.

In the event of an outbreak, biocontainment should be exercised on affected farms. No equipment should leave the farm unless it has been cleaned and disinfected.

On unaffected farms, biosecurity measures should be tightened. Traffic onto and off of these farms should be more severely limited, and anything coming onto the farm should be cleaned and disinfected.

“Stamping out” is a process that has been used successfully to control the spread of HPAI. This involves the destruction of all birds on the affected farm as well as birds that may be epidemiologically linked to the infected flock. Compensation to owners for lost animals is important to the success of stamping-out efforts.

Stamping out and strict biosecurity measures may not be practical or effective in all situations. The appropriate approach will depend on the local control plan or recommendations from the local or national government for the involved area. Alternative control measures, such as vaccination and controlled marketing, may be used in some situations.

DEPOPULATION

The methods of mass destruction should be effective, efficient, practical, and safe for the people euthanizing the birds. The process should also be as humane as possible.

For large numbers of birds, carbon dioxide (CO2) is often used for euthanasia. CO2 liquid is converted to gas in a pressurized cylinder, and the gas is then introduced into a closed chamber, where it replaces the air. Once the CO2 is in the birds' bloodstreams, it has an anesthetic effect and eventually causes death. The CO2 also can be introduced into a whole room or house where the ventilation system has been turned off.

For small numbers of birds, an overdose of an injectable anesthetic or a physical method of euthanasia such as cervical dislocation can be used. Electrocution also has been used as a means of euthanasia. With these methods individual birds must be handled, causing more stress for the bird and increased risk of exposure for the handler.

The use of water-based foam recently has been introduced as a method of mass killing. This method works similarly to CO2 in that it causes a lack of oxygen and eventual death of the birds. Research on the most efficient and humane use of this method is ongoing.

CARCASS DISPOSAL

Disposing of large numbers of carcasses from birds that have died or have been destroyed during an HPAI outbreak can be a challenge. On-site methods of disposal are ideal. On-site burial can be used, but care must be taken not to contaminate nearby ground water. Distances of 500 feet from streams, springs, or wells are recommended.

On-site composting is environmentally friendly, relatively simple, and produces fertilizer that can be spread on fields. Carcasses are composted with a carbon source such as shavings, litter, or straw along with adequate moisture and air. Temperatures in the compost can reach 140°F, which will inactivate the AI virus.

When using off-site methods such as landfills, incineration, or rendering, the risk of spreading the virus is increased and should be taken into consideration.

CLEANING AND DISINFECTION

Cleaning and disinfection of premises after an outbreak of HPAI is essential to preventing the spread of disease. Houses should be heated to 90°F to inactivate the virus. Organic material should be removed or composted on site. Dry cleaning and then the use of soaps or detergents should precede disinfection of surfaces. Disinfectants labeled as effective against AI should be used, and label instructions should be followed.

Additional precautions must be taken because of the potential zoonotic nature of the virus. Aerosolization of contaminated particles can occur during the cleaning and disinfection process, so workers should wear protective clothing, respiratory protection, and eye protection.

Restocking of the facility should not occur until regulatory authorities deem it to be safe.

VACCINATION

Vaccination alone is not a satisfactory control measure for AI. Vaccination has been used in conjunction with stamping out programs to aid in controlling the spread of HPAI viruses. Vaccination is also used to aid in controlling disease spread in countries where HPAI is endemic and stamping out or mass depopulation is impractical and ineffective.

Vaccination may be used when restocking a previously infected premise, in village or backyard poultry, in highly valuable animals, or on surrounding farms during an outbreak. Biosecurity measures must be strictly enforced during a vaccination campaign, as crews can spread the virus from farm to farm.

LESSONS LEARNED FROM THE 2015 US HPAI H5N2 OUTBREAK

The 2015 HPAI H5N2 outbreak in the Midwestern states was an unprecedented foreign animal disease event in the US. From December 19 to June 17 2015, over 48 million birds in 15 states died or were destroyed to control spread of the disease. Molecular studies determined that independent introductions or common source introductions were responsible for the spread of the virus.

Ongoing case-control studies by the USDA begun in 2015 have so far demonstrated the following risk factors:

- Being in an established control zone (approximately 10 km radius around an infected premises)
- Rendering dead birds (rendering trucks coming onto the premises)
- Garbage trucks near the barns
- Dead bird disposal near the barns
- High density of corn around the farm

Protective factors included:

- Having visitors change clothes before entering barns
- Having a hard surface entry pad that can be disinfected

In anticipation of a potential outbreak, the USDA is:

- Promoting improved on-farm biosecurity practices
- Improving HPAI surveillance in wild birds to provide early warnings
- Expanding federal, state, and industry response capabilities, including personnel, equipment, and depopulation, disposal, and recovery operations
- Improving the country's capabilities to rapidly detect HPAI in domestic poultry and to depopulate affected flocks within 24 hours
- Streamlining compensation to farmers
- Enhancing communications with producers, consumers, legislators, media, and others
- Making preparations to identify and deploy effective vaccines should they be determined to be warranted and effective

GLOSSARY

Anseriformes - An order of birds that are highly adapted to aquatic environments; anseriformes are characterized by webbed feet. There are approximately 150 species of birds in the order, including ducks, geese, swans, and screamers.

Antigenic Drift - One of two ways that influenza viruses can change (the other is antigenic shift, see below). Antigenic drift refers to small, gradual changes that occur through point mutations in the two genes that contain the genetic material to produce the main surface proteins, hemagglutinin and neuraminidase. These point mutations occur unpredictably and result in minor changes to these surface proteins. Antigenic drift produces new virus strains that may not be recognized by antibodies to earlier influenza strains. This process works as follows: a person infected with a particular influenza virus strain develops antibodies against that strain. As newer virus strains appear, the antibodies against the older strains might not recognize the "newer" virus, and infection with a new strain can occur. This is one of the main reasons why people can become infected with influenza viruses more than one time and why global surveillance is critical in order to monitor the evolution of human influenza virus strains for selection of which strains should be included in the annual production of influenza vaccine. In most years, one or two of the three virus strains in the influenza vaccine are updated to keep up with the changes in the circulating influenza viruses. For this reason, people who want to be immunized against influenza need to be vaccinated every year.

Antigenic Shift - Antigenic shift is one of two ways that influenza viruses can change (the other is antigenic drift, see above). Antigenic shift refers to an abrupt, major change to produce a novel influenza A virus subtype in humans (i.e., one that has not circulated previously among people). Antigenic shift can occur either through direct animal (poultry)-to-human transmission or through mixing of human influenza A and animal influenza A virus genes to create a new human influenza A subtype virus through a process called genetic reassortment. Antigenic shift results in a new human influenza A subtype.

Antigens - A substance that elicits a specific (as opposed to nonspecific) immunological response. Foreign antigens typically stimulate a response from the body's adaptive immune system resulting in the production of antibodies and effector T-cells; antigens that produce an immune response can also be called “immunogens”

Biosecurity - Security from transmission of infectious diseases, parasites and pests. Also refers to the prevention of exposure to disease agents through management practices.

Charadriiformes - A large diverse order of aquatic birds found along sea coasts and inland waters; includes shorebirds and coastal diving birds. This order includes approximately 350 species

Depopulation - Removal of all animals from the particular environment.

Endemic - Present in a predictable, continuous pattern in a population at all times; applies to a condition or disease that is clustered in space but not in time.

Epidemic - A disease occurring suddenly in humans in a community, region or country in numbers clearly in excess of normal.

Epizootic - A disease occurring suddenly in animals in a community, region or country in numbers clearly in excess of normal.

Fomite - Inanimate objects or materials on which disease producing agents may be conveyed.

Genetic Drift - See Antigenic Drift

Genetic Reassortment - The exchange of gene segments between viruses that have a segmented genome.

Hemagglutinin (HA) - An important surface structure protein of the influenza virus that is an essential gene for the spread of the virus throughout the respiratory tract. This protein enables the virus to attach itself to a cell in the respiratory system and penetrate it. It is used to name influenza A subtypes and is referred to as the "H" in the influenza virus subtype (e.g., H5N1).

Host - An organism on or in which a parasite lives.

HPAI (Highly Pathogenic form of Avian Influenza) - Often fatal in chickens and turkeys. HPAI spreads more rapidly than LPAI and has a high mortality rate in domestic birds.

Infection - Invasion of the body or a part of the body with a pathogenic organism, which multiplies in the host. A person or animal with an infection may or may not exhibit symptoms. An infection without symptoms is called asymptomatic

LPAI (Low Pathogenic form of Avian Influenza) - Naturally occurs in wild birds and can spread to domestic birds. In wild birds, LPAI strains generally do not cause signs of infection. In domestic birds, the illness is not severe and mortality rates are low. LPAI H5 and H7 strains have the potential to mutate into HPAI and are therefore closely monitored

Morbidity - Disease; morbidity rate is the incidence or prevalence of disease in a specific population during a specified interval of time or a specific point in time.

Mortality - Death; mortality rate is a measure of the number of deaths in a population during a specified interval of time.

Mutation - Any alteration in a gene from its natural state. Specific mutations and evolution in influenza viruses cannot be predicted, making it difficult if not impossible to know if or when a virus such as H5N1 might acquire the properties needed to spread easily among humans.

Necropsy - Examination of a body after death.

Neuraminidase (NA) - An important surface structure protein of the influenza virus that is an essential enzyme for the spread of the virus throughout the respiratory tract. This protein enables the virus to escape the host cell and infect new cells. It is used to name influenza A subtypes and is referred to as the "N" in the influenza virus subtype (e.g., H5N1).

Outbreak - Presence of disease in numbers in excess of normal in a specific geographic area or population.

Pandemic - A worldwide outbreak of a disease in humans in numbers clearly in excess of normal. A global influenza pandemic may occur if two conditions are met:
- A new subtype of influenza A virus emerges for which there is little or no immunity in the human population.
- The virus can spread easily from person to person in a sustained manner.

Panzootic - A worldwide outbreak of a disease in animals in numbers clearly in excess of normal.

Pathogenic - Causing disease or capable of doing so.

Personal Protective Equipment - Any devices or clothing worn by the worker to protect against hazards in the environment. Examples are respirators, gloves, and goggles.

Polymerase chain reaction (PCR) - The amplification of a specific DNA sequence.

Prevalence - The proportion of individuals (humans or animals) in a population having a disease or specific characteristic (such as a positive antibody test to a particular pathogen).

Reservoir - A person or animal that serves as a host to a pathogenic agent, generally without visible symptoms of the disease or injury.

Risk Assessment - The overall process of identifying all the risks to and from an activity and assessing the potential impact of each risk.

Strain - Influenza virus subtypes are further characterized into strains. New strains of influenza viruses replace older strains through the process of antigenic drift (i.e., small mutations in the genetic material of the virus).

Swine Flu - A respiratory disease in pigs caused by influenza A virus. Outbreaks in swine herds are common; the illness is relatively mild, and most animals recover. Domestic birds can be a source of influenza A in swine, and transmission from humans to swine and from swine to humans has occurred.

Vectored vaccine - The use of viruses as vectors to carry select genes from a pathogen for immunization.

Virulence - A pathogen's ability to invade host tissues and the severity of disease produced.

Virulent - Highly lethal; causing severe illness or death.

Virus - Any of various simple submicroscopic parasites of plants, animals, and bacteria that often cause disease and that consist essentially of a core of RNA or DNA surrounded by a protein coat. Unable to replicate without a host cell, viruses are typically not considered living organisms.

Zoonoses - Diseases that transfer from animals to humans.

RESOURCES

Alexander DJ. Avian influenza - diagnosis. Zoonoses Public Health 2008;55(1):16-23

Beyer RS. Avian influenza prevention in game bird and ratite facilities. Cooperative Extension Service Kansas State University, 1996.
[Web page: http://www.ksre.ksu.edu/bookstore/pubs/mf2114.pdf]

Birnbaum NG, O'Brien B. Methods for inactivation of avian influenza in the environment. In Avian Influenza, DA Swayne ed. 2008 Ames, IA:Blackwell Publishing

Bleich EG, Pagani P, Honhold N. Progress towards practical options for improving biosecurity of small-scale poultry producers. World Poultry Sci 2009;65:211-15

Brglez B, Hahn J. Methods for disposal of poultry carcasses. In Avian Influenza, DA Swayne ed. 2008 Ames, IA:Blackwell Publishing

Cardona C. Farm and regional biosecurity practices. In Avian Influenza, DA Swayne ed. 2008 Ames, IA:Blackwell Publishing

Cardona C. Handout P: sample biosecurity plan. In Avian Flu School Module 4: Prevention and Response. 2007

Cardona C. Module 2: Surveillance. In Avian Flu School. 2007

Choi YK, Lee JH, Erickson G, et al. H3N2 influenza virus transmission from swine to turkeys, United States. Emerg Infect Dis 2004;10(12):2156-60

Fanatico AC, Owens CM, Emmert JL. Organic poultry production in the United States. J Appl Poult Res 2009;18:355-66

FAO. Biosecurity for highly pathogenic avian influenza: issues and options. 2008.
[Web page: Biosecurity for highly pathogenic avian influenza: issues and options. 2008. Accessed January 21, 2011]

FAO. The importance of biosecurity in reducing HPAI risk on farms and in markets. International Ministerial Conference of Avian and Pandemic Influenza, New Delhi, India. 2007.
[Web page: http://www.fao.org/docs/eims/upload/236621/ah691e.pdf]

FAO. Improvement of management and biosecurity practices in smallholder poultry producers. 2007.
[Web page: http://www.fao.org/docs/eims/upload/228410/biosecurity_en.pdf]

FAO. Interventions for improving bio-security of small-scale poultry production in Egypt. 2007.

[Web page: http://www.fao.org/docs/eims/upload//228408/biosecurity_egy_en.pdf]

FAO. Prevention and control of avian flu in small scale poultry: a guide for paraprofessionals in Vietnam. 2005.
[Web page: http://www.fao.org/docs/eims/upload/206313/AImanual_vietnam_en.pdf]

Halvorson DA. Control of low pathogenicity avian influenza. In Avian Influenza, DA Swayne ed. 2008 Ames, IA:Blackwell Publishing

Jeffrey JS. Biosecurity for poultry flocks. 1997.
[Web page: http://animalscience.ucdavis.edu/avian/pfs26.htm]

Kelly TR, Hawkins MG, Sandrock CE, et al. A review of highly pathogenic avian influenza in birds, with an emphasis on Asian H5N1 and recommendations for prevention and control. J Avian Med Surg 2008;22(1):1-16

Krushinskie EA, Smeltzer M, Klein P, et al. Mass depopulation as an effective measure for disease control purposes. In Avian Influenza, DA Swayne ed. 2008 Ames, IA:Blackwell Publishing

Lubroth J, Morzaria S, Theirmann AB. Global strategy for highly pathogenic avian influenza: progressive control and eradication, and post outbreak recovery. In Avian Influenza, DA Swayne ed. 2008 Ames, IA:Blackwell Publishing

Massachusetts Department of Agricultural Resources. Biosecurity for backyard poultry facilities.
[Web page: http://www.mass.gov/eea/docs/agr/animal-health/poultry/biosecurity-for-back-yard-poultry-facilities.pdf]

Massachusetts Department of Agricultural Resources. Biosecurity for commercial poultry facilities.
[Web page: http://www.mass.gov/eea/docs/agr/animal-health/poultry/biosecurity-for-commercial-poultry-facilities.pdf]

Moreira ÉA, Locher S, Kolesnikova L, et al. Synthetically derived bat influenza A-like viruses reveal a cell type- but not species-specific tropism. Proc Natl Acad Sci 2016 Oct 24. pii: 201608821

Msoffe PL, Bunn D, Muhairwa AP, et al. Implementing poultry vaccination and biosecurity at the village level in Tanzania: a social strategy to promote health in free-range poultry populations. Trop Anim Health Prod 2010;42(2):253-63

OIE. Questions and Answers on Influenza A(H7N9).
[Web page: http://www.oie.int/for-the-media/press-releases/detail/article/questions-and-answers-on-influenza-ah7n9/]

Quast M, Sreenivasan C, Sexton G, et al. Serological evidence for the presence of influenza D virus in small ruminants. Vet Microbiol. 2015 Nov 18; 180(0): 281–285

Shapiro D, Stewart-Brown B. Farm biosecurity risk assessments and audits. In Avian Influenza, DA Swayne ed. 2008 Ames, IA:Blackwell Publishing

Spackman E, Suarez DL, Senne DA. Avian influenza diagnostic and surveillance methods. In Avian Influenza, DA Swayne ed. 2008 Ames, IA:Blackwell Publishing

Swayne DA. Avian influenza control strategies. In Avian Influenza, DA Swayne ed. 2008 Ames, IA:Blackwell Publishing

Swayne DA, Pantin-Jackwood M, Kapczynski D, et al. Susceptibility of poultry to pandemic (H1N1) 2009 Virus. Emerg Infect Dis 2009;15(12):2061-3

Tong S, Zhu X, Li Y, Shi M, Zhang J, et al. (2013) New World Bats Harbor Diverse Influenza A Viruses. PLoS Pathog 9(10): e1003657. doi:10.1371/journal.ppat.1003657. Epub October 10, 2013

US Poultry and Egg Association Biosecurity http://www.uspoultry.org/animal_husbandry/biosecurity.cfm

USAID. Stop AI biosecurity practices for smallholder farms, commercial farms, and live bird markets.
[Web page: http://www.stopai.net/STPAIResources/Training%20Manuals%20-%20Final/Nigeria/STOP%20AI%20Nigeria%20Biosecurity%202009%20Handouts.pdf]

USDA, Animal and Plant Health Inspection Service. Avian influenza: diagnostics and testing. 2008.
[Web page: http://www.aphis.usda.gov/publications/animal_health/content/printable_version/fs_AI_diagnostics%26testing.pdf]

USDA. Avian influenza disease.
https://www.aphis.usda.gov/wps/portal/aphis/ourfocus/animalhealth/!ut/p/a1/04_Sj9CPykssy0xPLMnMz0vMAfGjzOK9_D2MDJ0MjDzdgy1dDTz9wtx8LXzMjf09TIAKIoEKnN0dPUzMfQwMDEwsjAw8XZw8XMwtfQ0MPM2I02-AAzgaENIfrh-FpsTd1QmoxM0nwNzby8jA2xSqAJ8TwQrwuKEgNzTCINNTEQDfLcka/?1dmy&urile=wcm%3apath%3a%2Faphis_content_library%2Fsa_our_focus%2Fsa_animal_health%2Fsa_animal_disease_information%2Fsa_avian_health%2Fct_avian_influenza_disease

USDA APHIS Defend the Flock website
https://www.aphis.usda.gov/aphis/ourfocus/animalhealth/animal-disease-information/avian-influenza-disease/defend-the-flock/defend-the-flock-bio-info-comm-poultry

USDA. Epidemiologic and other analyses of HPAI-affected poultry flocks: September 9, 2015 report. https://www.aphis.usda.gov/animal_health/animal_dis_spec/poultry/downloads/Epidemiologic-Analysis-Sept-2015.pdf

USDA, Animal and Plant Health Inspection Service. Biosecurity for birds. [Web page: http://www.aphis.usda.gov/animal_health/birdbiosecurity/]

USDA. 2016 HPAI preparedness and response plan. https://www.aphis.usda.gov/animal_health/downloads/animal_diseases/ai/hpai-preparedness-and-response-plan-2015.pdf

USDA, Animal and Plant Health Inspection Service. Highly pathogenic avian influenza: a threat to US poultry. 2001. Accessed January 21, 2011 [Web page: http://www.aphis.usda.gov/publications/animal_health/content/printable_version/pub_ahhpai.pdf]

USDA, Animal and Plant Health Inspection Service. National poultry improvement plan. 2006. Accessed January 21, 2011 [Web page: http://www.aphis.usda.gov/animal_health/animal_dis_spec/poultry/]

USDA, Animal and Plant Health Inspection Service, Veterinary Services. Reference of health and management of backyard/small production flocks and gamefowl breeder flocks in the United States. 2004. Accessed January 21, 2011 [Web page: http://www.aphis.usda.gov/animal_health/nahms/poultry/downloads/poultry04/Poultry04_dr_PartIV.pdf]

Yee KS, Carpenter TE, Mize S, et al. The live bird market system and low-pathogenic avian influenza prevention in southern California. Avian Dis 2008;52(2):348-52

All glossary definitions are found at one or more of the following sources (or are adapted from those sources):

Cambridge Dictionaries Online. Accessed November 10, 2010 at http://dictionary.cambridge.org/

Centers for Disease Control and Prevention Avian Influenza (Bird Flu). [Web page: http://www.cdc.gov/flu/avianflu/]

The Dictionary of Virology, 4th Edition, 2009

Saunders Comprehensive Veterinary Dictionary, 3rd Edition, 2007

United States Department of Agriculture. Avian Influenza (bird Flu): Avian Influenza Glossary of Terms.
[Web page: http://www.usda.gov/wps/portal/usda/usdahome?contentidonly=true&contentid=influenza_glossary.xml]