

# Concepts for the prevention and control of microbial threats – 1

Center for Infectious Disease Preparedness  
UC Berkeley School of Public Health  
URL: <http://www.idready.org>

Updated June 2006

Created using freely available, open source software:  
<http://www.openoffice.org>

Center for Infectious Disease Preparedness  
UC Berkeley School of Public Health  
[www.idready.org](http://www.idready.org)



1

[INSTRUCTIONS ARE IN CAPITAL LETTERS. Talking points are in normal type.]

This lecture covers the core epidemiologic concepts necessary for the investigation, prevention, and control of infectious diseases, including microbial threats.

The purpose of this talk is to provide you with the underlying principles on how to prevent and control infectious diseases. As communicable disease investigators and controllers, this lecture reviews why you do what you do.

**BASED ON THEIR EXPERIENCE, ASK ATTENDEES TO IDENTIFY INTERVENTIONS TO CONTROL INFECTIOUS. MAKE LIST, THEN GO TO NEXT SLIDE...**

## Learning objectives: Participants will be able to ...

- Describe how and why microbial agents are transmitted from an infectious source to a susceptible human host;
- Describe the natural history of infection and infectiousness;
- Describe how humans and microbes interact with each other and their environment to produce infectious disease epidemics.



## Understanding interventions to control infectious diseases

- Alter risk factors (e.g., behavior)
- Post-exposure prophylaxis
- Diagnosis, treatment
- Vaccination, immune globulin
- Infection control practices
- Case finding and isolation
- Contact tracing and quarantine
- Environmental disinfection
- Identify and control infectious sources

3

Center for Infectious Disease Preparedness  
UC Berkeley School of Public Health  
[www.idready.org](http://www.idready.org)

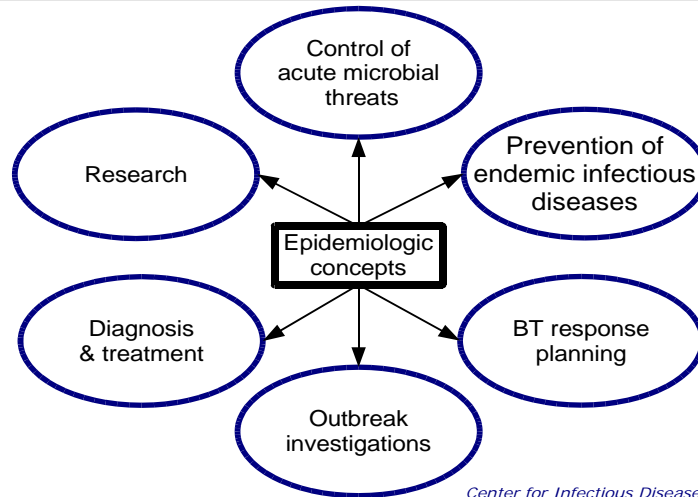


Great! These are the types of interventions you just identified. These are the core public health and medical measures to prevent and control infectious disease threats.

In this talk, we will be covering the epidemiologic concepts that provide the rationale for these measures.

By the end of this lecture we should be able to understand the core epidemiologic concepts supporting these control measures, and how these control measures relate to each other.

## Use of epidemiologic concepts



Center for Infectious Disease Preparedness  
UC Berkeley School of Public Health  
[www.idready.org](http://www.idready.org)

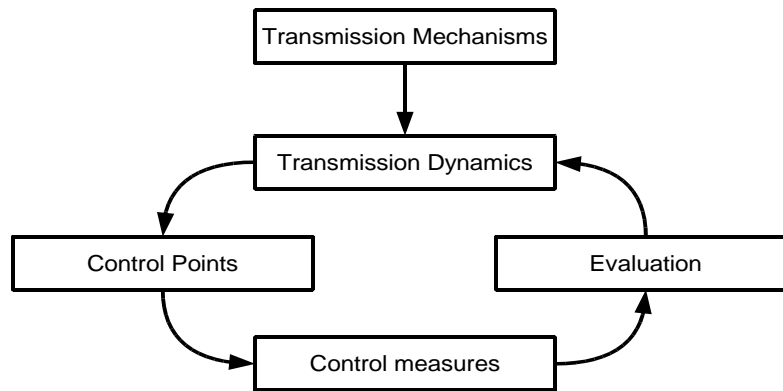


4

These epidemiologic concepts are fundamental and are used for planning, implementing, and evaluating

- Control of acute microbial threats (SARS, pandemic influenza)
- Prevention of endemic infectious diseases (HIV infection, tuberculosis)
- Bioterrorism preparedness and response planning (smallpox)
- Outbreak investigations
- Diagnosis and treatment (understanding the contribution clinical diagnosis and treatment make to the control of infectious diseases)
- Research

## Epidemiologic concepts for the control of microbial threats



5

Center for Infectious Disease Preparedness  
UC Berkeley School of Public Health  
[www.idready.org](http://www.idready.org)



We will take a systematic, comprehensive, and integrated approach:

First, we will cover infectious disease transmission mechanisms: How are infections transmitted and why?

Second, we will cover infectious disease transmission dynamics: How does the occurrence of infectious disease cases appear at the population level and how does this help us control transmission?

Third, from transmission dynamics we will identify critical control points for understanding, preventing, and controlling infectious diseases.

Fourth, we will use these critical control points to systematically develop comprehensive disease control measures (strategies plus interventions).

Finally, this process helps us to evaluate our control plan.

## Infectious disease epidemiology concepts – Overview

- Mechanisms (Part 1)
  - Chain model of infectious diseases
  - Natural history of infection/infectiousness
  - Convergence model for human-microbe interaction
- Dynamics (Part 2)
  - Reproductive number (R)
  - Conditional infection rate (I)
  - Generation time (T)
- Control points and Control measures

6

Center for Infectious Disease Preparedness  
UC Berkeley School of Public Health  
[www.idready.org](http://www.idready.org)



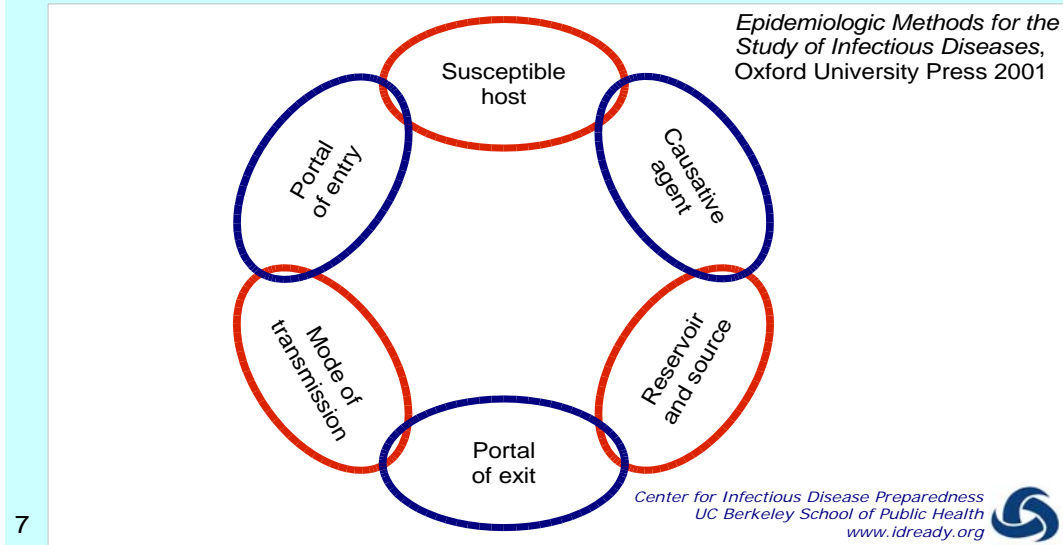
First, we will review the Chain model of infectious diseases. All links in the chain must exist in order for infection to occur. We will cover important terms such as reservoir, source, portals of exit and entry, and modes of transmission.

Second, we will review the Natural history of infection and infectiousness. We will cover the incubation period, the latent period, the infectious period, and how they relate to each other.

Finally, we will review the Convergence model for human-microbe interaction (from the Institute of Medicine). Think of this model as an updated version of the epidemiologic triad: agent—host—environment.

In part 2, we will cover transmission dynamics, critical control points, and how to develop an appropriate transmission containment strategy.

## Chain model of infectious diseases



For infection to occur, all the links in the chain must connect. First, there must be a susceptible host. Next, there must be a causative agent. In its natural settings, the agent resides and replicates in a reservoir (for example, cattle are the reservoir for E coli O157:H7—a cause of bloody diarrhea and kidney failure in humans). The source is where the agent is prior to infecting the host (for example, ground beef contaminated with E coli O157:H7). Sometimes the source is the reservoir (humans getting E coli O157:H7 by visiting a cattle ranch). The portal of exit, when it exists, is how the agent exits the source/reservoir (cattle fecally excrete E coli O157:H7). The mode of transmission is the mechanism by which the agent is transmitted from the source/reservoir to the host (contact, droplet, airborne, etc.). The portal of entry is how the agent enters the host (respiratory, gastrointestinal, mucous membranes, etc.).

## Chain model of ID: Causative agent

- Transmissible microbe, microbe-like, or microbial toxin
  - Bacteria
  - Viruses
  - Fungi
  - Parasites (protozoa, multicellular)
  - Prions

8

Center for Infectious Disease Preparedness  
UC Berkeley School of Public Health  
[www.idready.org](http://www.idready.org)



We will focus on transmissible agents that are microbes, microbe-like, or their toxins. By microbes we think of complex, reproducing microorganisms such as viruses, bacteria, parasites, and fungi.

Prions are transmissible, self-propagating proteins that can cause disease (usually neurodegenerative diseases called spongiform encephalopathies). For our purposes, I will just refer to microbes, microbial agents, or a specific agent.

Although we are focusing on the transmission of microbial agents, communicable diseases can be caused by transmission of non-microbial agents; for example, chemical toxicants.

## Chain model of ID: Agent transmission and infection

- Transmissibility =  $P(\text{transmission}|\text{exposure}^a)$
- Infectivity =  $P(\text{Infection}|\text{transmission}^b)$
- Pathogenicity =  $P(\text{Disease}|\text{Infection})$
- Virulence =  $P(\text{Complication}|\text{Disease})$

a. Exposure to external source; could be within species (e.g., human influenza to humans) or between species (e.g., avian influenza to humans)

b. Or colonization; could be endogenous

9

Center for Infectious Disease Preparedness  
UC Berkeley School of Public Health  
[www.idready.org](http://www.idready.org)



Transmission could occur within species (intra-species) or between species (inter-species).

Transmissibility describes the probability of transmission given exposure to an exogenous source. By transmission we mean sufficient transfer of the microbe to cause at least “temporary” colonization. The agent must sufficiently survive the journey in order to invade. In some cases, colonization can last for weeks or longer (methicillin-resistant staphylococcus aureus).

Infectivity describes the probability of infection given transmission or colonization (this includes endogenous flora such as *Neisseria meningitidis*)\*.

Pathogenicity describes the probability of clinical disease given infection.

Virulence describes the probability of severe disease or complication given disease.

\*In our second lecture we will use the operational term “transmission probability” which will be defined as the probability of infection (or disease) given exposure.

## Chain model of infectious diseases: Reservoir

- Human
  - Symptomatic illness
  - Carriers
    - Asymptomatic (no illness during infection)
    - Incubatory (pre-illness)
    - Convalescent (post-illness recovery)
    - Chronic (persistent infection)
- Animal (zoonoses)
- Environmental

10

Center for Infectious Disease Preparedness  
UC Berkeley School of Public Health  
[www.idready.org](http://www.idready.org)



For controlling the transmission of microbial agents, we must know the primary reservoir. Reservoirs for microbes are either human, animal, or environmental.

Examples of diseases where humans are the reservoir for the microbial agent include: polio, hepatitis A, B, & C, measles, mumps, rubella, varicella, and smallpox (before eradication), malaria, etc

Examples of diseases where animals are the reservoir for the microbial agent include: West Nile virus disease (migratory birds), Lyme disease (rodents), E coli O157:H7 (cattle), cryptosporidiosis (cattle), avian influenza (wild and domestic waterfowl)

Examples of diseases where the environment is the reservoir for the microbial agent include: legionellosis (water), leptospirosis (water), mycobacterium avium complex (soil, water), coccidioidomycosis (soil dust).

## Modes of transmission for an exogenous agent

- Contact
  - Direct contact (touch, kissing, sex)
  - Indirect contact (intermediate objects, fomites)
  - Vertical transmission (before, during, and after birth)
- Respiratory droplets/secretions (cough, sneeze)
- Airborne (droplet nuclei, dust)
- Vehicle-borne (ingestion, instrumentation, injection, infusion)
- Vector-borne (mechanical, biologic)

11

Center for Infectious Disease Preparedness  
UC Berkeley School of Public Health  
www.idready.org 

To prevent and control infectious disease we must know the mode of transmission. To the extent the mode of transmission is unknown, it becomes a primary focus of an investigation and research.

Direct contact: e.g., sexually transmitted diseases

Indirect contact: e.g., contaminated surfaces and fomites (respiratory viral infections such as influenza)

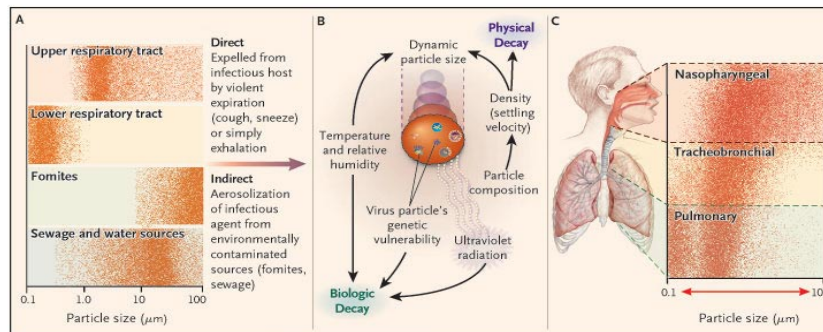
Respiratory droplets\*\* : SARS, smallpox, pneumonic plague; [Droplet precaution emphasizes barrier protection (face mask, goggles), hand and respiratory hygiene, and cough etiquette.])

Airborne\*\* : TB, measles, varicella [Airborne precaution emphasizes breathing filtered air (respirators; e.g., N-95) and dilution (increasing air exchange by ventilation and negative pressure rooms).]

Vehicle-borne: Ingested food or water; intravenous infusions, urinary catheters, injection drug use

Vector-borne: mosquitos transmitting West Nile virus, malaria

## Aerobiologic transmission of a respiratory microbial agent



12 PMID: 15102996

Center for Infectious Disease Preparedness  
UC Berkeley School of Public Health  
[www.idready.org](http://www.idready.org)

The Aerobiologic Pathway for the Transmission of Communicable Respiratory Disease.

**Panel A:** Whether it is an infected human or a contaminated environmental matrix, each source generates particles with a characteristic range of sizes.

**Panel B:** The length of time a particle resides in the air (physical decay) depends on its initial size, its composition, and environmental factors. Similarly, the length of time an airborne organism remains infectious (biologic decay) is affected by the infectious agent's initial metabolic state, genetic characteristics, and environment.

**Panel C:** The portion of the respiratory tract of a susceptible host in which inhaled particles are deposited is a function of the particles' aerodynamic size; in the middle of the range, particles may be deposited in both the upper and the lower airways.

## Good infection control starts with common sense



American Society for Microbiology

*Cover the source!*

Center for Infectious Disease Preparedness  
UC Berkeley School of Public Health  
[www.idready.org](http://www.idready.org)



13

In this slide, we see an example of how respiratory droplets can infect close contacts and contaminate environmental surfaces.

This has obvious infection control implications: Cover the source!!!

In general, when you are thinking about interrupting transmission, attack the problem from the perspective of an infectious person (cover the source: cough etiquette and respiratory hygiene) AND the perspective of a susceptible host (mask, goggles, hand hygiene, etc.).

Something that seems so obvious can be overlooked by even the most highly trained professionals: NEXT SLIDE

## Disease scare at San Jose airport 5 on flight from Asia examined -- none found with SARS, SF Chronicle April 2, 2003

In a false alarm heard 'round the world, the Santa Clara County health system jumped into high alert Tuesday morning when an American Airlines flight from Tokyo radioed that it might have five cases of the mysterious flulike illness known as SARS on board.

[Joan] Krizman said she had no hard feelings about being treated as a potential health threat. The couple had just completed an exhausting, monthlong journey that included stops in Vietnam, Thailand and Hong Kong -- three Southeast Asian hot spots for SARS.

"There were four fire trucks and eight police cars and four or five ambulances," she recalled. "I couldn't believe it. I thought, 'Wow! What's going on here?' Little did I know that we were to be the 'victims.' "

The couple were asked twice to go to Valley Medical Center, and twice they politely declined. "And then," Krizman said, "they soon opened up the ambulance doors and said, sorry, we're taking you to the hospital."

At the hospital, according to Krizman, "we were the only ones there not wearing masks." When word got out just who they were, she said, "People started running like crazy, like we were the bubonic plague. They put us in a room full of people with plastic boots and face shields and masks."

*Center for Infectious Disease Preparedness  
UC Berkeley School of Public Health  
[www.idready.org](http://www.idready.org)*



14

READ THIS SLIDE TO THE AUDIENCE. (OR SUMMARIZE THIS SLIDE IF YOU ARE FAMILIAR WITH THE STORY)

THE LAST PARAGRAPH IS THE "PUNCH LINE."

This newspaper story is a reminder that even the most highly trained personnel will forget to implement common sense, effective infection control measures.

Remember, if we think of transmission from the perspective of an infectious case AND the susceptible host, we will not make this same mistake!

## Nurse wearing N-95 respirator outside of intensive care unit



Associated Press: In a ward at Sunnybrook and Womens Hospital in Toronto, a nurse waits outside the door of a patient diagnosed with the illness [SARS].

Center for Infectious Disease Preparedness  
UC Berkeley School of Public Health  
www.idready.org



15

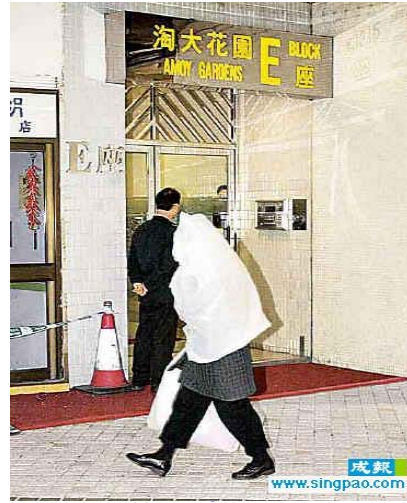
Here is a nurse wearing a N-95 respirator while standing outside of an intensive care unit (ICU) in Toronto, Canada during the outbreak of severe acute respiratory syndrome (SARS) in February, 2003.

Early in the SARS outbreak the mode of transmission was not known; therefore, hospitals implemented airborne precautions. As the uncertainty cleared, it appeared that the SARS-associated coronavirus was spread primarily by respiratory secretions and large droplets.

## Public devised infection control during SARS outbreak, 2003



16



Public health professionals must understand the underlying concepts in infectious disease spread because the public itself will draw their own conclusions and implement their own control strategies—which may be ineffective or even harmful.

Here are two individuals in Hong Kong during the SARS outbreak. While their behavior may seem to be an over-reaction; in fact, it is not irrational based on infection control principles. Their barrier methods would protect them against infections spread by respiratory droplets—as SARS was spread.

The gentleman on the right is walking past the Amoy Gardens, a highrise apartment building where about 350 SARS cases occurred in a short time period.

## Inappropriate infection control during SARS outbreak, 2003



Reuters: An Indian woman diagnosed with SARS sits on her bed at the Doctor Naidu Infectious Diseases Hospital in the western city of Pune. Doctors reported India's first case of the disease in a marine engineer from the western coastal state of Goa on Friday, April 18, 2003

Center for Infectious Disease Preparedness  
UC Berkeley School of Public Health  
[www.idready.org](http://www.idready.org)



17

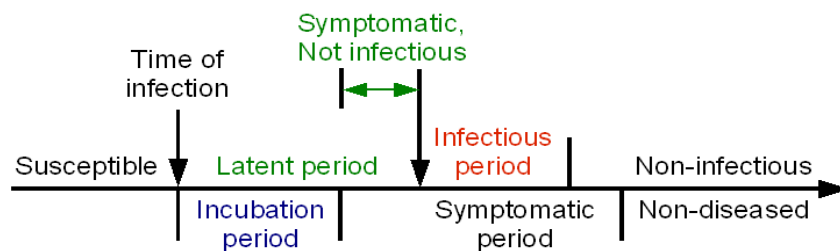
Here is a patient with SARS in India in 2003.

ASK ATTENDEES: What is wrong with this picture?

Unfortunately, the physicians that cared for this patient had limited knowledge of (1) how infections are transmitted and (2) common sense infection control measures.

At most, this patient only needs a surgical mask, especially if she is coughing.

## Natural history of infection: Latent period > Incubation period



When the latent period is *longer* than the incubation period, an infected person becomes infectious after symptom onset.



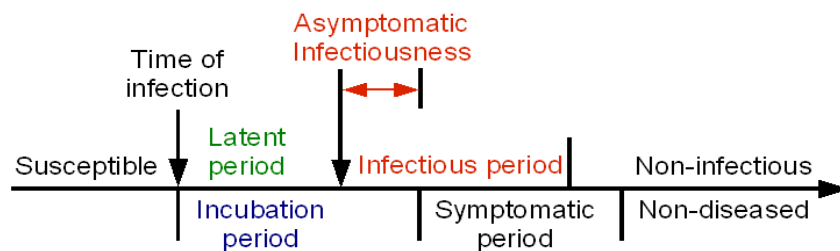
Our second major concept is the natural history of infection and infectiousness.

Most clinical providers are familiar with the incubation period. The incubation period is the time from infection until the development of symptoms.

In contrast, in public health, we are primarily interested in infectiousness and transmission. Therefore, we are also the latent period—the time from infection until the onset of infectiousness.

Whether the latent period is shorter or longer than the incubation period is very important. When the latent period is *longer than* the incubation period, patients develop symptoms *before* they become infectious. Disease where this was the case included smallpox and SARS. In smallpox, patients were generally not infectious until they develop the rash. In SARS, patients became increasingly infectious as their symptoms progressed.

## Natural history of infection: Latent period < Incubation period



When the latent period is *shorter* than the incubation period, an infected person becomes infectious before symptom onset.

Center for Infectious Disease Preparedness  
UC Berkeley School of Public Health  
[www.idready.org](http://www.idready.org)



19

In contrast, when the latent period is *shorter than* the incubation period, a patient becomes infectious *before* developing symptoms.

What current, large impact pandemic is driven primarily by this process?

ANSWER: HIV/AIDS pandemic: Patients are asymptomatic and infectious for years before developing symptoms of AIDS.

What other bloodborne pathogen is also driven by this process?

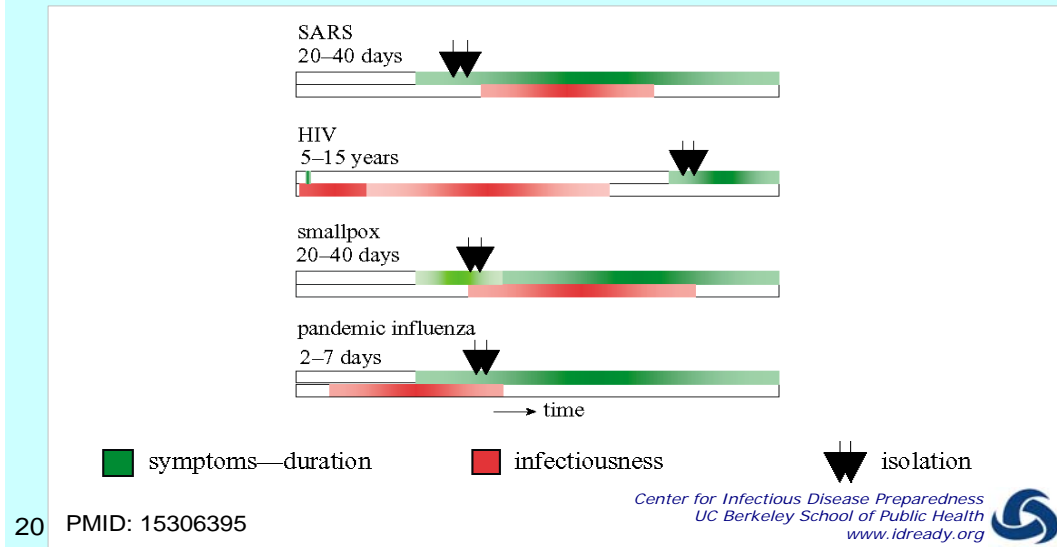
ANSWER: hepatitis C

Other infections that are transmitted by asymptomatic infectious persons include hepatitis A (~1 week), influenza (~1 – 2 days), measles, mumps, and varicella

Therefore, this transmission mechanism is an important driver in several important infections.

**HOMEWORK: WHAT IS THE PERIOD OF ASYMPTOMATIC INFECTIOUS IN MEASLE, MUMPS, AND CHICKEN POX.**

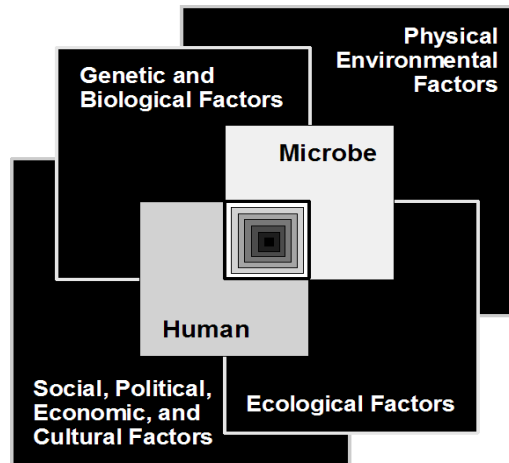
## Distribution of infectiousness of selected infectious diseases



Here are a few examples to consider.

1. For SARS, the latent period was longer than the incubation period, therefore patients developed symptoms **BEFORE** becoming infectious. This made detection and isolation of cases an effective disease control strategy.
2. For HIV, the latent period is about 10 years shorter than the incubation period. Hence, an HIV-infected person is potentially infecting many people (by sex or injection drug use) for years before knowing they are infected.
3. For smallpox (when it existed), the latent period was longer than the incubation period, therefore patients developed symptoms **BEFORE** becoming infectious. In fact, patients with smallpox were most infectious during the appearance of the rash. This made detection and isolation of cases, and contact tracing and vaccination an effective disease control strategy.
4. For influenza, the latent period is 1 to 2 days shorter than the incubation period; hence patients are infectious before symptom onset.

## Convergence model for human-microbe interaction



21

Adapted from Institute of Medicine. *Microbial threats to health: Emergence, Detection, and Response*. National Academy Press 2003

Center for Infectious Disease Preparedness  
UC Berkeley School of Public Health  
[www.idready.org](http://www.idready.org)



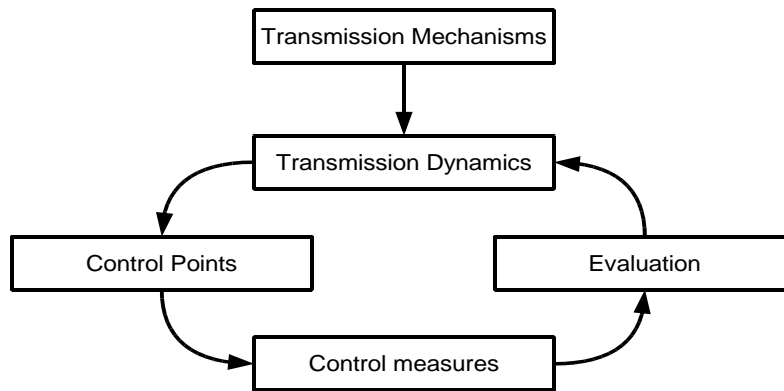
Our third (and final) transmission mechanism conceptual model is the “Convergence model of human-microbe interaction” published by the Institute of Medicine in March 2003. Think of this model as the updated version of the agent-host-environment model of infectious disease causation (also referred to as the “epidemiologic triad”).

The model reminds us that the emergence of microbial threats to humans is the result of the interaction of the microbial agent, the human host, and the physical-ecological-social-political-economic environment.

The emergence of West Nile virus infection in the United States is a great example of the interaction of all these components. This broad approach helps us to understand the interrelated causes, and to understand how the success or failure of prevention and control interventions depend on all these interacting factors.

**OPTIONAL: ASK PARTICIPANTS TO DISCUSS HOW THESE DIFFERENT FACTORS INTERACT IN (1) THE CONTROL WEST NILE VIRUS DISEASE; AND (2) AVIAN INFLUENZA AND THE POTENTIAL FOR HUMAN PANDEMIC INFLUENZA.**

## Epidemiologic concepts for the control of microbial threats



22



In this lecture we covered conceptual models necessary to understand infectious disease transmission mechanisms.

NEXT SLIDE

## Infectious disease epidemiology concepts – Summary

- Mechanisms (Part 1)
  - Chain model of infectious diseases
  - Natural history of infection/infectiousness
  - Convergence model for human-microbe interaction
- Dynamics (Part 2)
  - Reproductive number (R)
  - Conditional infection rate (I)
  - Generation time (T)
- Control points and Control measures

23

Center for Infectious Disease Preparedness  
UC Berkeley School of Public Health  
[www.idready.org](http://www.idready.org)



By now, it should be obvious that infectious diseases differ in important ways from non-infectious and non-communicable diseases because of transmission mechanisms and dynamics.

In this presentation, we covered the mechanisms of infectious disease spread by looking at the conceptual models for transmission mechanisms that are listed on this slide.

We will explore transmission dynamics in Core Concepts 2.