Epidemiology

• Science that evaluates occurrence, determinants, distribution, and control of health and disease in a defined human population
Epidemiology

- Monitor public health
  - Morbidity rates
  - Determine causes of outbreaks
- Respond to disease outbreaks, epidemics and pandemics
  - Mortality rates
  - Institute control measures
- Investigate emerging and reemerging diseases
  - Determine risk factors
  - Recommend control measures
Centers for Disease Control and Prevention (CDC)

- Located in Atlanta, GA
- Functions as national focus for
  - developing and applying disease prevention and control
  - environmental health
  - health promotion and health education activities designed to improve the health of the people
- Worldwide counterpart is the World Health Organization (WHO) located in Geneva, Switzerland
Epidemiology

• Determine:
  – causative agent
  – source and/or reservoir of disease agent
  – mechanism of transmission
  – host and environmental factors that facilitate development of disease within a defined population
  – best control measures
Epidemiology Terminology

• Sporadic disease
  – occurs occasionally and at irregular intervals

• Endemic disease
  – maintains a relatively steady low-level frequency at a moderately regular interval

• Hyperendemic diseases
  – gradually increase in occurrence frequency above endemic level but not to epidemic level
More Terms

• Outbreak
  – sudden, unexpected occurrence of disease
  – usually focal or in a limited segment of population

• Epidemic
  – sudden increase in frequency above expected number
  – index case – first case in an epidemic

• Pandemic
  – increase in disease occurrence within large population over wide region (usually worldwide)
Epidemiological Methods

- Public health surveillance
  - protecting populations/improving the health of communities via education, promotion of healthy lifestyles, and prevention of disease and injury
  - methodical approach to identify issues
    - review of death certificates
    - field investigation of epidemics
    - investigation of actual cases
Measuring Infectious Frequency

• To determine if an outbreak, epidemic or pandemic is occurring, epidemiologists measure disease frequency at single time points and over time

• Statistics
  – mathematics dealing with collection, organization, and interpretation of numerical data

• Three important statistical measures of disease frequency
  – morbidity rate (number of illnesses)
  – prevalence rate (number of individuals infected)
  – mortality rate (number of deaths per number of cases of the disease)
Patterns of Infectious Disease in a Population

• Infectious disease
  – disease resulting from an infection by microbial agents such as viruses, bacteria, fungi, protozoa, and helminths

• Communicable disease
  – can be transmitted from one host to another
Patterns of Infectious Disease in a Population

• Two types of epidemics
  – common source epidemic
    • single common contaminated source (food)
  – propagated epidemic
    • one infected individual into a susceptible group, infection propagated to others
Patterns of Infectious Disease in a Population

• To recognize and measure an infectious disease in a population various surveillance methods used
  – gathering information on development and occurrence of a disease
  – collating and analyzing the data
  – summarizing the findings
  – selecting control methods
Herd Immunity

- Resistance of a population to infection and to spread of an infectious organism because of the immunity of a large percentage of the population
- Level can be altered by introduction of new susceptible individuals into population
Herd Immunity

- Level can be altered by changes in pathogen
  - antigenic shift – major change in antigenic character of pathogen
  - antigenic drift – smaller antigenic changes
  - this means that the population would not have the same antibodies against the pathogen
Emerging Infections

- Infectious disease mortality has increased since 1982 in U.S.
  - incidence of infectious disease due to emerging microbial populations
  - some are novel or reemerging infectious diseases
  - some reemergence in U.S. due to decline in current population vaccinating

- Hot spots of emerging infectious diseases
  - northeast U.S., west Europe, Japan, and southeast Australia
Reasons for Increases in Emerging and Reemerging Infectious Diseases Include:

- World population growth
- Increased international travel
- Habitat disruption
- Microbial evolution and development of resistance
- Inadequate public infrastructures
More Reasons

• Changes in ecology and climate
• Social unrest, wars, and bioterrorism
• Changes in food processing and agricultural practices
• Changes in human behavior, technology, and industry
• Medical practices that lead to immunosuppression
Nosocomial Infections

• Hospital-acquired infections
  – from pathogens within a hospital or other clinical care facility, acquired by patients in the facility
  – ~10% of all hospital patients acquire a nosocomial infection

• Often caused by bacteria that are members of normal microbiota

• Many hospital strains are antibiotic-resistant
**Ventilator-Associated Pneumonia**
- *Acinetobacter* spp.
- *Burkholderia cepacia*
- *Enterobacter* spp.
- *Klebsiella pneumoniae*
- *Pseudomonas aeruginosa*
- *Serratia marcescens*
- *Staphylococcus aureus*
- *Stenotrophomonas maltophilia*

**Bloodstream**
- *Candida* spp.
- Coagulase-negative staphylococci
- *Enterobacter* spp.
- *Enterococcus* spp.
- *Escherichia coli*
- *P. aeruginosa*
- *S. aureus*

**Intestinal Tract and Liver**
- *Clostridium difficile*
- Hepatitis viruses

**Urinary Tract**
- *Candida* spp.
- *Enterobacter* spp.
- *Enterococcus* spp.
- *E. coli*
- *P. aeruginosa*

**Surgical Sites**
- *Acinetobacter* spp.
- Coagulase-negative staphylococci
- *Corynebacterium jeikeium*
- *Enterobacter* spp.
- *Enterococcus* spp.
- *E. coli*
- *P. aeruginosa*
- *Rhodococcus equi*
- *S. aureus*
Sources of Nosocomial

- Endogenous pathogen
  - brought into hospital by patient or acquired when patient is colonized after admission

- Exogenous pathogen
  - microbiota other than the patient’s

- Autogenous infection
  - caused by an agent derived from microbiota of patient despite whether it became part of patient’s microbiota following admission
Control, Prevention, and Surveillance

- Nosocomial infections
  - prolong hospital stays by 4–13 days
  - result in over $4.5 billion costs
  - result in 20,000–60,000 deaths annually
- Proper training of personnel in basic infection control measures
  - e.g., handling of surgical wounds and hand washing
- Monitoring of patient for signs and symptoms of nosocomial infection
Prevention and Control of Epidemics

• Three types of control measures
  – reduce or eliminate source or reservoir of infection
  – break connection between source and susceptible individual
  – reduce number of susceptible individuals
Reduce or Eliminate Source or Reservoir

- Quarantine and isolation of cases and carriers
- Destruction of animal reservoir
- Treatment of sewage
- Therapy that reduces or eliminates infectivity of cases
Break Connection Between Source and Susceptible Individuals

- Chlorination of water supplies
- Pasteurization of milk
- Supervision and inspection of food and food handlers
- Destruction of insect vectors with pesticides
Reduce Number of Susceptible Individuals

- Raises herd immunity
- Passive immunity following exposure
- Active immunity for protection
Vaccines and Immunization

• Vaccine (see Table 37.3 for examples)
  – preparation of microbial antigens used to induce protective immunity
  – may consist of killed, living, weakened (attenuated) microbes or inactivated bacterial toxins (toxoids), purified cell material, recombinant vectors, or DNA
<table>
<thead>
<tr>
<th>Disease</th>
<th>Vaccine</th>
<th>Booster</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Viral Diseases</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chickenpox</td>
<td>Attenuated Oka strain</td>
<td>None</td>
<td>Children 12–18 months: older children who have not had chickenpox</td>
</tr>
<tr>
<td>Hepatitis A</td>
<td>Inactivated virus</td>
<td>6–12 months</td>
<td>International travelers</td>
</tr>
<tr>
<td>Hepatitis B</td>
<td>Viral antigen</td>
<td>1–4 months</td>
<td>High-risk medical personnel: children, birth to 18 months and 11–12 years of age</td>
</tr>
<tr>
<td>Human papillomavirus infections</td>
<td>Recombinant protein subunits</td>
<td>6–18 months</td>
<td>Girls and boys 11–12 years of age</td>
</tr>
<tr>
<td>Influenza A/B</td>
<td>Inactivated virus or live attenuated</td>
<td>Yearly</td>
<td>All persons</td>
</tr>
<tr>
<td>Measles, Mumps, Rubella</td>
<td>Attenuated viruses (combination MMR vaccine)</td>
<td>None</td>
<td>First dose 12–15 months, 2nd dose 4–6 years</td>
</tr>
<tr>
<td>Poliomyelitis</td>
<td>Attenuated (oral polio vaccine) or inactivated virus (inactivated polio vaccine)</td>
<td>Adults as needed</td>
<td>First dose at 2 months, 2nd at 4 months, 3rd at 16–18 months, 4th at 4–6 years</td>
</tr>
<tr>
<td>Rabies</td>
<td>Inactivated virus</td>
<td>None</td>
<td>For individuals in contact with wildlife, animal control personnel, veterinarians</td>
</tr>
<tr>
<td>Respiratory disease</td>
<td>Live attenuated adenovirus</td>
<td>None</td>
<td>Military personnel</td>
</tr>
<tr>
<td>Smallpox</td>
<td>Live attenuated vaccinia virus</td>
<td>None</td>
<td>Laboratory, health-care, and military personnel</td>
</tr>
<tr>
<td>Yellow fever</td>
<td>Attenuated virus</td>
<td>10 years</td>
<td>Military personnel and individuals traveling to endemic areas</td>
</tr>
<tr>
<td><strong>Bacterial Diseases</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anthrax</td>
<td>Extracellular components of unencapsulated Bacillus anthracis</td>
<td>None</td>
<td>Agricultural workers, veterinary, and military personnel</td>
</tr>
<tr>
<td>Cholera</td>
<td>Fraction of Vibrio cholera</td>
<td>6 months</td>
<td>Individuals in endemic areas, travelers</td>
</tr>
<tr>
<td>Diphtheria, Pertussis, Tetanus</td>
<td>Diphtheria and tetanus toxoids, and acellular Bordetella pertussis vaccine (DTaP) or tetanus toxoid, reduced diphtheria toxoid, and acellular pertussis vaccine (Tdap)</td>
<td>10 years</td>
<td>Children from 2–3 months old to 12 years, and adults; children 10–18 years, at least 5 years after DPT series, should receive Tdap</td>
</tr>
<tr>
<td>Haemophilus influenzae type b</td>
<td>Polysaccharide-protein conjugate (HbCV) or bacterial polysaccharide (HbPVI)</td>
<td>None</td>
<td>First dose at 2 months, 2nd at 4 months, 3rd at 6 months, 4th at 12–15 months</td>
</tr>
<tr>
<td>Meningococcal infections</td>
<td>Neisseria meningitidis polysaccharides of serotypes A/C/Y/W-135</td>
<td>None</td>
<td>Military; high-risk individuals; college students living in dormitories; elderly in nursing homes</td>
</tr>
<tr>
<td>Plague</td>
<td>Fraction of Yersinia pestis</td>
<td>Yearly</td>
<td>Individuals in contact with rodents in endemic areas</td>
</tr>
<tr>
<td>Pneumococcal pneumonia</td>
<td>Purified S. pneumoniae polysaccharide of 23 pneumococcal types or pneumococcal conjugate of 13 strains</td>
<td>None</td>
<td>Adults over 50 with chronic disease</td>
</tr>
<tr>
<td>Q fever</td>
<td>Killed Coxiella burnetii</td>
<td>None</td>
<td>Workers in slaughterhouses and meat-processing plants</td>
</tr>
<tr>
<td>Tuberculosis</td>
<td>Attenuated Mycobacterium bovis (BCG vaccine)</td>
<td>3–4 years</td>
<td>Individuals exposed to TB for prolonged periods of time; used in some countries, not licensed in the U.S.</td>
</tr>
<tr>
<td>Typhoid fever</td>
<td>Salmonella enterica Typhi Ty21a (live attenuated or polysaccharide)</td>
<td>None</td>
<td>Residents of and travelers to areas of endemic disease</td>
</tr>
<tr>
<td>Typhus fever</td>
<td>Killed Rickettsia prowazekii</td>
<td>Yearly</td>
<td>Scientists and medical personnel in areas where typhus is endemic</td>
</tr>
</tbody>
</table>
Vaccines and Immunization

- Immunization
  - result obtained when vaccine stimulates immunity
- Vaccines attempt to induce antibodies and activated T cells to protect host from future infection
- Vaccinomics is the application of genomics and bioinformatics to vaccine development
Immunized Hosts

- Vaccination of children should begin at ~2 months
- Further vaccination depends on relative risk
  - living in close communities
  - reduced immunity
  - international travelers
  - health-care workers

Table 37.4

<table>
<thead>
<tr>
<th>VACCINE</th>
<th>AGE</th>
<th>1 month</th>
<th>2 months</th>
<th>4 months</th>
<th>6 months</th>
<th>9 months</th>
<th>12 months</th>
<th>15 months</th>
<th>18 months</th>
<th>19-23 months</th>
<th>2-3 years</th>
<th>4-6 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hepatitis B</td>
<td>Birth</td>
<td>HepB</td>
<td>HepB</td>
<td></td>
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</tr>
<tr>
<td>Rotavirus</td>
<td>RV</td>
<td>RV</td>
<td>RV</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Diphtheria, tetanus, pertussis</td>
<td>DTaP</td>
<td>DTaP</td>
<td>DTaP</td>
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<td></td>
</tr>
<tr>
<td>Haemophilus influenzae type b</td>
<td>Hib</td>
<td>Hib</td>
<td>Hib</td>
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<td></td>
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<tr>
<td>Pneumococcal</td>
<td>PCV</td>
<td>PCV</td>
<td>PCV</td>
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</tr>
<tr>
<td>Inactivated poliovirus</td>
<td>IPV</td>
<td>IPV</td>
<td>IPV</td>
<td></td>
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</tr>
<tr>
<td>Influenza</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Influenza (Yearly)</td>
</tr>
<tr>
<td>Measles, mumps, rubella</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>MMR</td>
<td></td>
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</tr>
<tr>
<td>Varicella</td>
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<td></td>
<td></td>
<td></td>
<td>VAR</td>
<td></td>
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</tr>
<tr>
<td>Hepatitis A</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Dose 1—HepA series</td>
</tr>
<tr>
<td>Meningococcal</td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>MCV4—See source website</td>
</tr>
</tbody>
</table>

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1 Source: http://www.cdc.gov
Global Health Considerations

- ~500,000 infectious disease deaths in developed countries
- ~18 million infectious disease deaths in less-developed countries
- Precautions needed for
  - global travel
  - clean water, sanitation
  - health care infrastructure
  - vaccination

Table 37.5 Vaccine Recommendations for Travelers

<table>
<thead>
<tr>
<th>Category</th>
<th>Vaccine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Routine recommended vaccination</td>
<td>Diphtheria/Tetanus/Pertussis (Td or Tdap)</td>
</tr>
<tr>
<td></td>
<td>Hepatitis B (HBV)</td>
</tr>
<tr>
<td></td>
<td>Hepatitis A (HAV)</td>
</tr>
<tr>
<td></td>
<td>Human papillomavirus</td>
</tr>
<tr>
<td></td>
<td>Influenza</td>
</tr>
<tr>
<td></td>
<td>Measles (MMR)</td>
</tr>
<tr>
<td></td>
<td>Poliomyelitis (IPV)</td>
</tr>
<tr>
<td></td>
<td>Varicella</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Selective vaccination based on exposure risk</th>
<th>Cholera</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Japanese encephalitis</td>
</tr>
<tr>
<td></td>
<td>Meningococcal (polysaccharide)</td>
</tr>
<tr>
<td></td>
<td>Pneumococcal (polysaccharide)</td>
</tr>
<tr>
<td></td>
<td>Rabies</td>
</tr>
<tr>
<td></td>
<td>Tick-borne encephalitis</td>
</tr>
<tr>
<td></td>
<td>Typhoid fever</td>
</tr>
<tr>
<td></td>
<td>Yellow fever</td>
</tr>
</tbody>
</table>

1 Based on CDC and WHO 2012 recommendations.
2 Vaccination recommendations replace mandatory immunization; in general, U.S. citizens do not need to provide proof of yellow fever immunization; see WHO and CDC travel advice for latest requirements.
The Role of the Public Health System: Epidemiological Guardian

- Network of health professionals involved in surveillance, diagnosis, and control of epidemics
- Form county, regional, state, national, and international public health organizations
Bioterrorism Preparedness

• Bioterrorism
  – “intentional or threatened use of viruses, bacteria, fungi, or toxins from living organisms to produce death or disease in humans, animals, and plants”
<table>
<thead>
<tr>
<th>Category</th>
<th>Definition</th>
<th>Disease (Agent)</th>
</tr>
</thead>
</table>
| A        | Easily disseminated or transmitted from person to person; high mortality rates; potential for major public health impact; cause public panic and social disruption; require special action for public health preparedness | Anthrax (*Bacillus anthracis*)  
Botulism (*Clostridium botulinum* toxin)  
Plague (*Yersinia pestis*)  
Smallpox (variola major virus)  
Tularemia (*Francisella tularensis*)  
Viral hemorrhagic fever (filoviruses and arenaviruses) |
| B        | Moderately easy to disseminate; moderate morbidity and mortality rates; require specific enhancements of CDC’s diagnostic capacity and enhanced disease surveillance | Brucellosis (*Brucella* spp.)  
Glanders (*Burkholderia mallei*)  
Melioidosis (*Burkholderia pseudomallei*)  
Psittacosis (*Chlamydia psittaci*)  
Q fever (*Coxiella burnetii*)  
Typhus fever (*Rickettsia prowazekii*)  
Viral encephalitis (alphaviruses)  
Toxemia  
Ricin from castor beans  
Staphylococcal enterotoxin B  
Epsilon toxin *Clostridium perfringens*  
**Other**  
Water safety threats (e.g., *Vibrio cholerae, Cryptosporidium parvum*)  
Food safety threats (e.g., *Salmonella* spp., *E. coli* O157:H7, *Shigella* spp.) |
| C        | Emerging pathogens that could be engineered for mass dissemination; potential for high morbidity and mortality rates; major health impact potential | Nipah virus  
Hantaviruses  
Tick-borne hemorrhagic fever viruses  
Tick-borne encephalitis viruses  
Yellow fever virus  
Multidrug-resistant and extremely drug-resistant *Mycobacterium tuberculosis* |
Examples of Intentional Uses of Biological Agents

• 1984 in Dalles, OR
  – *Salmonella typhimurium* in 10 restaurant salad bars

• 1996 in Texas
  – intentional release of *Shigella dysentariae* in a hospital lab break room

• 2001 in seven eastern U.S. states
  – use of weaponized *Bacillus anthracis* spores delivered through U.S. postal systems

• All of the above caused hospitalizations, while the anthrax episode resulted in five deaths
Choosing Biological Agents as Weapons

• Biocrime when chosen as a means for a localized attack vs. bioterrorism when chosen for mass casualties

• Characteristics that favor their use
  – invisible, odorless, and tasteless
  – difficult to detect
  – take hours or days before awareness that they have been used
  – fear and panic associated with the anticipation that they were used
U.S. Biological Weapons Defense Initiative

- Procurement of specialized vaccines and medicines for a national civilian protection stockpile
- Invigoration of biodefense research including genome sequencing, vaccine, and therapeutic research
- Development of improved detection and diagnostic systems
- Preparation of health care professionals to be members of the “first responder” team
Additional Government Responses

- 2002 – the Public Health Security and Bioterrorism Preparedness and Response Act
  - identified “select” agents whose use is tightly regulated
  - 2005 – final rules issued

- 2003 – the Department of Homeland Security established to coordinate the defense of the U.S. against terrorist attacks
  - responsible for developing/maintaining a National Incident Management System to monitor large-scale hazards
Partnerships to Protect the U.S. Population

• CDC partnering with academic institutions to educate health care providers

• Establishment of Centers for Public Health Preparedness

• The Laboratory Response Network (LRN)
  – ensuring effective laboratory response to terrorism by improving U.S. public health lab infrastructure
    – a CDC-managed program
  – partners with FBI and Association of Public Health Laboratories (APHL)

• A CDC managed program
Key Indicators of a Bioterrorism Event

• Sudden increased numbers of sick people, especially with unusual diseases for that place and/or time of year

• Sudden increased numbers of zoonoses, diseased animals, or vehicle-borne illnesses