Introduction to Microbiology

Anas Abu-Humaidan
M.D. Ph.D.

Overview

Topics that will be discussed this lecture are:

- ***Hospital-Acquired Infections***
- ***Zoonotic Diseases***
- ***Emergence of bacterial pathogens***

Hospital-Acquired Infections- definition

- Hospital-acquired infections, also known as healthcare-associated infections (HAI), are nosocomially acquired infections that are typically **not present or might be incubating at the time of admission**. These infections are usually acquired after hospitalization **and manifest 48 hours after admission** to the hospital.

- HAI infections include **central line-associated bloodstream infections** (CLABSI), **catheter-associated urinary tract infections** (CAUTI), **surgical site infections** (SSI), **Hospital-acquired Pneumonia** (HAP), **Ventilator-associated Pneumonia** (VAP), and **Clostridium difficile infections** (CDI)

Hospital-Acquired Infections- epidemiology

- The risk factors for HAI include **immunosuppression, older age, length of stay in the hospital, multiple underlying comorbidities, frequent visits to healthcare facilities, mechanical ventilatory support, recent invasive procedures, indwelling devices, and stay in an intensive care unit (ICU).**

- Pathogens can be **acquired from other patients, hospital staff, or the hospital facility**. The risk is higher among patients in ICU. In a point prevalence study that included 231,459 patients across 947 hospitals concluded that about **19.5% of patients in ICU had at least one HAI.**

- In 2014, the CDC published a multistate point prevalence survey of healthcare-associated infections involving 11,282 patients from 183 US hospitals. According to this report, about **4% of hospitalized patients** suffered from at least one of the HAI.

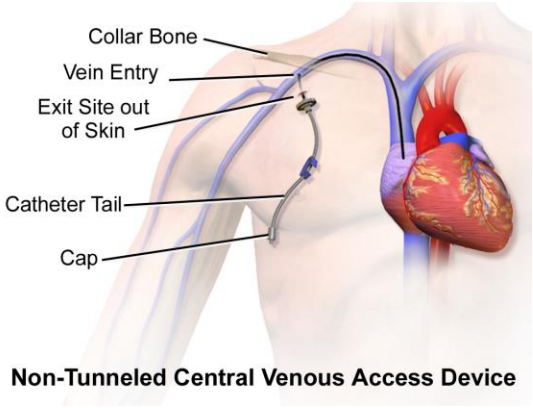
Hospital-Acquired Infections – types species

- The dominant infections (in descending order) include **Pneumonia** (21.8%), **surgical site infections** (21.8%), gastrointestinal infections (17.1%), urinary tract infections or UTIs (12.9%), and primary bloodstream infection (9.9%, and include Catheter-associated bloodstream infections).

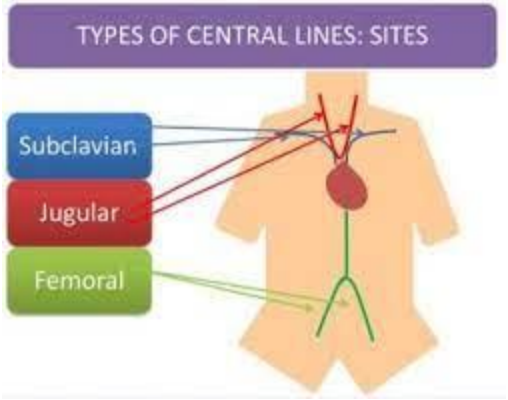
- Among the pathogens causing HAI**, C. difficile** (12.1%) is the leading pathogen and is closely followed by **Staphylococcus aureus** (10.7%), **Klebsiella** (9.9%), and **Escherichia coli** (9.3%). Skin and surgical site infections are usually caused by Staphylococcus aureus and sometimes include Methicillin-resistant staphylococcus aureus (MRSA).

Hospital-Acquired Infections – types species

- **CLABSI:** substantially increase morbidity, mortality, and health care costs, and great attention has been paid to addressing these. As a consequence, in 2009, 25,000 fewer CLABSIs occurred in the ICUs of US hospitals than in 2001, a 58% reduction, with about 6,000 lives saved and estimated financial savings of US$414 million in potential excess health care costs. The most common causative pathogens were **Gram-negative** (39.2%), **Gram-positive** (33.2%), and **Candida spp.** microorganisms (27.6%)



Non-Tunneled Central Venous Access Device

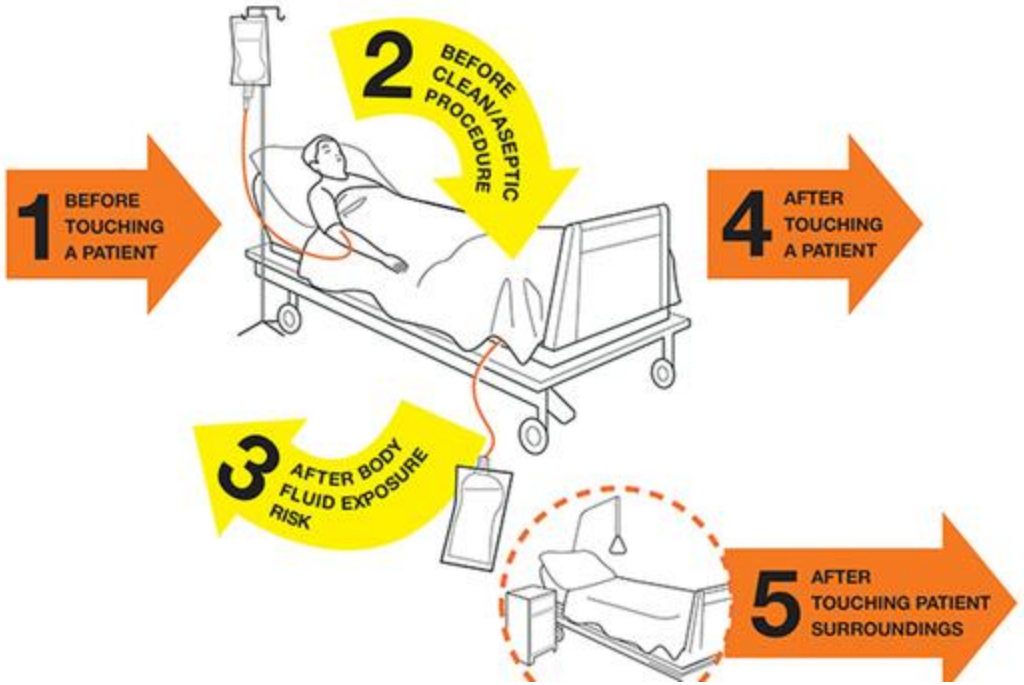


- **SSI:** is the most common complication in postoperative surgical patients, defined as infections arising up to 30–90 days after surgery. One Saudi Arabian study reported an incidence of SSIs in orthopedic patients of 2.55% (79 of 3,096 patients) with the most common pathogens being **Staphylococcus species including MRSA (29.11%); Acinetobacter species (21.5%**; **Pseudomonas species (18.9%),** and **Enterococcus species (17.7%)**

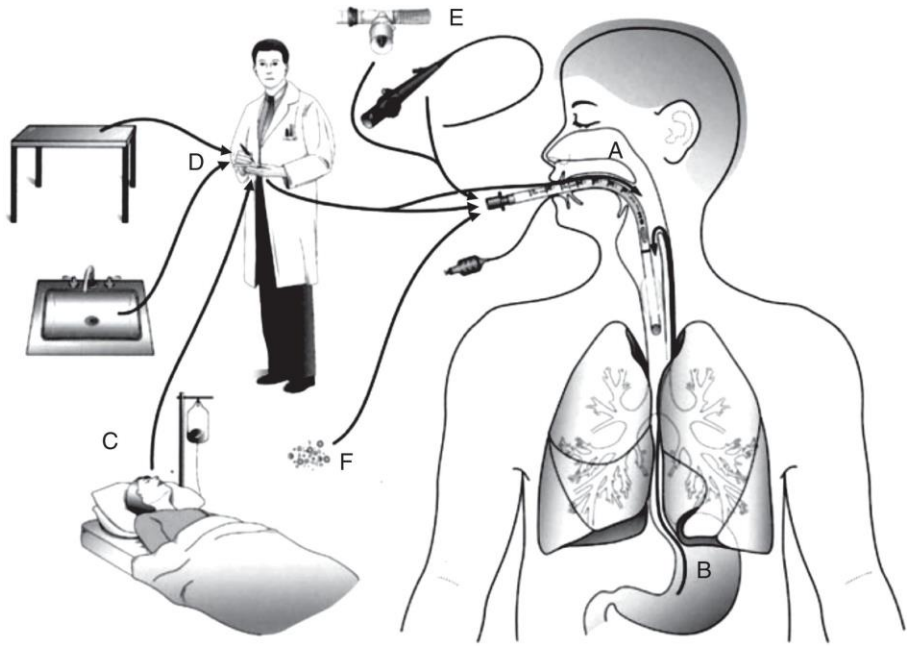
Hospital-Acquired Infections – types species

- **CAUTI:** Internationally, UTIs are the most common HCAIs and one of the top ranking microbial infections, representing around 40% of HCAIs. Although **CAUTIs** are typically benign, some patients have potentially pathogenic virulent bacteria but are asymptomatic, and these patients were associated with a three-times higher mortality than in non-bacteriuric patients.

- **VAP:** Pneumonia is the second commonest HCAI in ICUs, affecting more than one-quarter of patients. Between 9**% and 27% of patients with assisted ventilation** develop this kind of pneumonia, and VAP has been identified internationally as a potential major cause of death. A study at Chonnam National University Hospital in South Korea of the transtracheal aspirates or bronchoalveolar lavage of patients suffering from VAP found **that S. aureus (44%)** was the most frequently detected causative microorganism followed by **A. baumannii (30%), P. aeruginosa** (12%).



https://openwho.org/courses/IPC-CAUTI-EN
Catheter-associated urinary tract infections



VAP Routes of colonization/infection in mechanically ventilated patients A – oral and pharyngeal colonization; B – gastric colonization; C – infected patients; D – handling of respiratory equipment; E – use of respiratory devices; and F – aerosols from contaminated air.

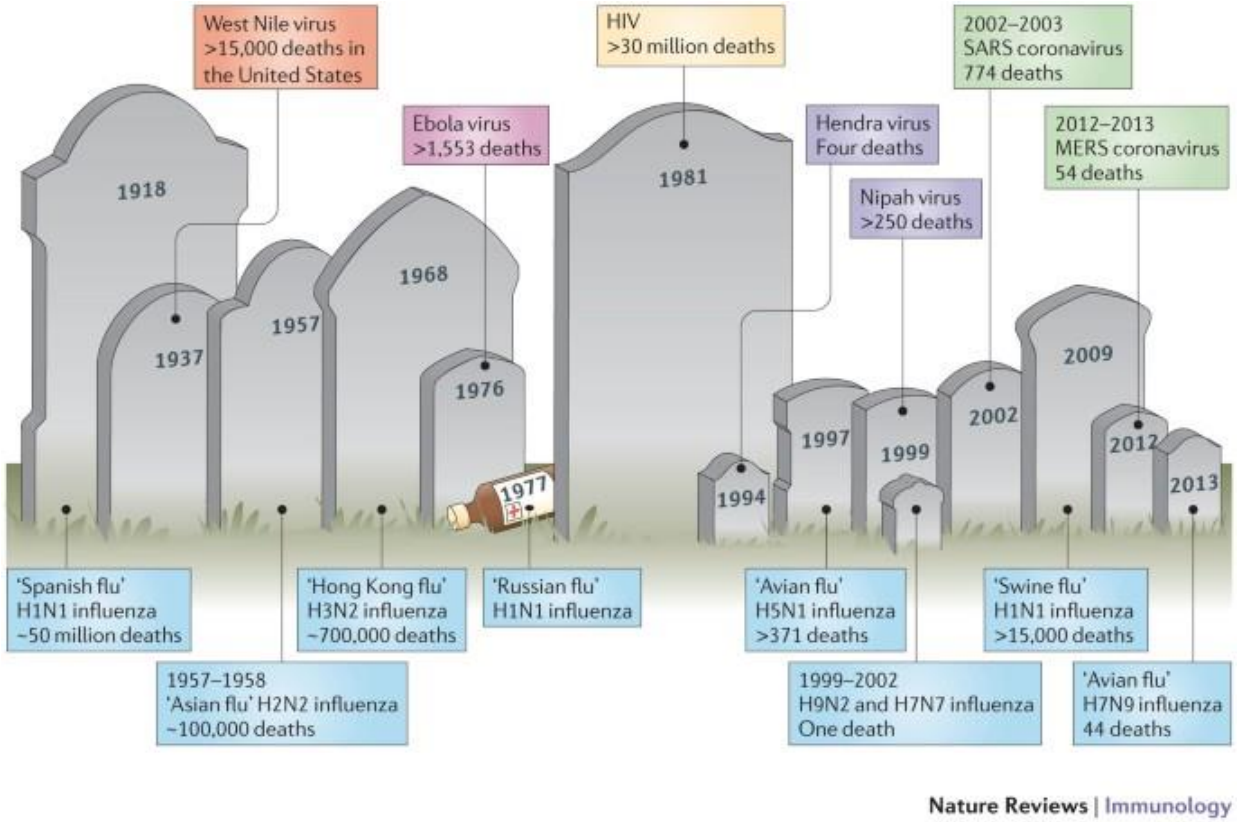
Hospital-Acquired Infections - management

- The selection and timing of initiation of antibiotics are critical. **Empiric antibiotics should be selected based on risk factors for MDR pathogens** and clinical stability of the patient.

- Antibiotics should be started early **within an hour if possible**, and if central line-associated bloodstream infection is suspected, two sets of blood cultures, one from a peripheral venous site and the other from the central venous catheter site, **should be obtained before initiation of antibiotic therapy.**

- **Obtaining samples for cultures before initiation of antibiotics is vital** in early **identification of the pathogen and the antimicrobial susceptibility pattern**. Both the pathogen and the antibiotic susceptibility help narrow down from broad-spectrum antibiotics to specific agents targeted towards the pathogens.

Zoonotic diseases



- Most of the infectious diseases affecting humans are of animal origin. The "Asia Pacific strategy for emerging diseases: 2010" report **estimated that around 60% of the emerging human infections are zoonotic** in nature and among these pathogens more than 70% originated from wildlife species.

- According to the World Health Organization (WHO), any disease or infection that is **naturally transmissible from vertebrate animals to humans** or from humans to animals is classified as a zoonosis

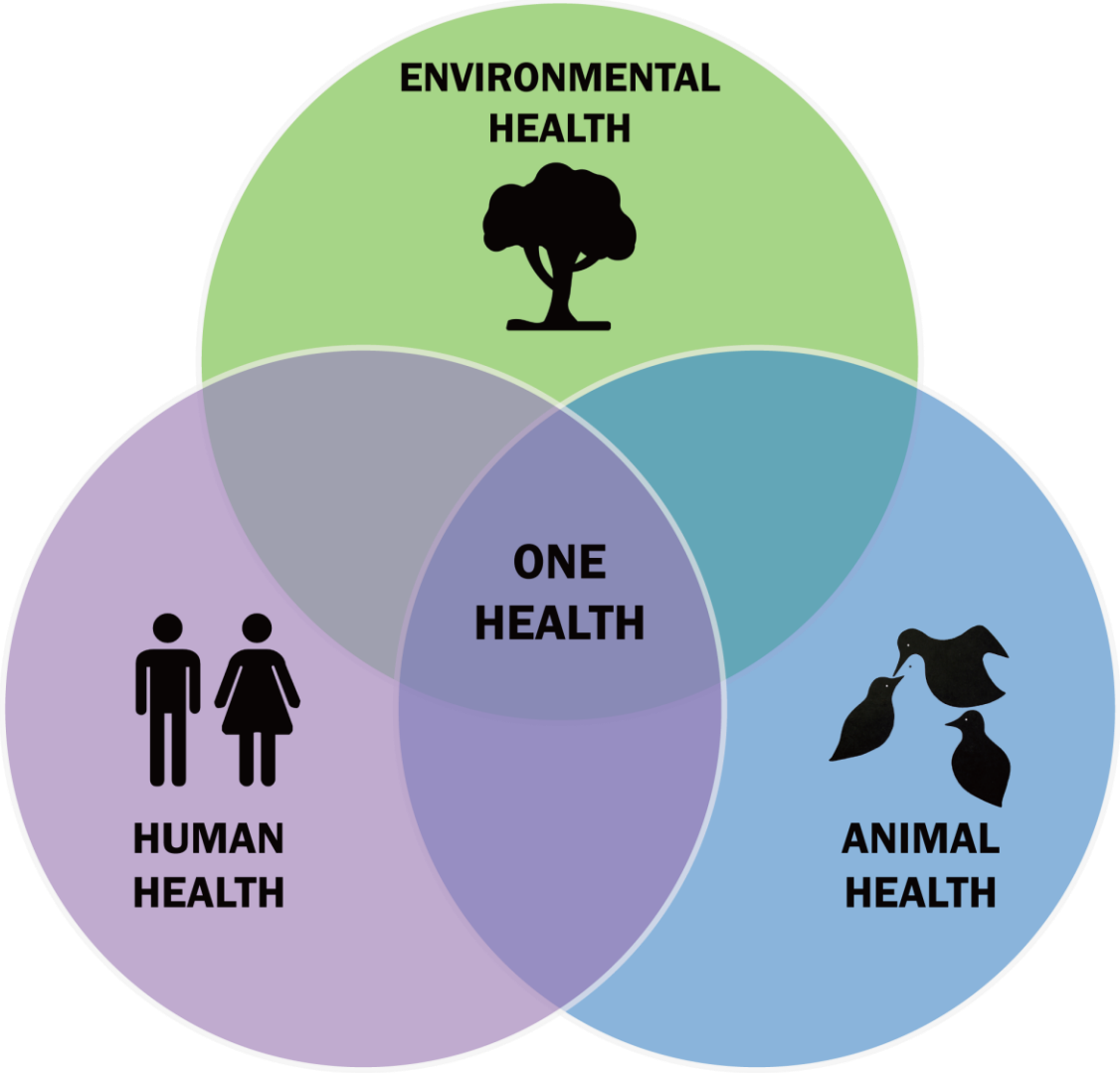
Zoonotic diseases

- Zoonotic diseases are caused by a wide range of pathogens. Based on etiology, zoonoses are classified into:
- bacterial zoonoses (such as anthrax, salmonellosis, tuberculosis, Lyme disease, brucellosis, and plague),
- viral zoonoses (such as rabies, acquired immune deficiency syndrome - AIDS, Ebola, and avian influenza),
- parasitic zoonoses (such as trichinosis, toxoplasmosis, trematodosis, giardiasis, malaria, and echinococcosis),
- fungal zoonoses (such as ring worm),
- rickettsial zoonoses (Q-fever), chlamydial zoonoses (psittacosis), mycoplasma zoonoses (*Mycoplasma pneumoniae* infection), protozoal zoonoses, and diseases caused by acellular non-viral pathogenic agents (such as transmissible spongiform encephalopathies and mad cow disease)

Zoonotic diseases

- Wild animals are intricately connected with humans, domesticated animals, and environmental components, and thereby directly contribute to the transmission and maintenance of different infectious diseases.

- **Globalization, habitat destruction, climatic change, and loss of species and biodiversity are disrupting the ecological relations among the <u>one-health</u> components**, which ultimately triggers the emergence of zoonotic pathogens and causes alterations in their transmission patterns.



Zoonotic diseases

- Based on etiology, **bacteria account for most zoonotic diseases**. It has been estimated that among the zoonotic pathogens originating from bovine origins, about 42% are of bacterial origin, 22% viral, 29% parasitic, 5% fungal, and 2% prion origin.

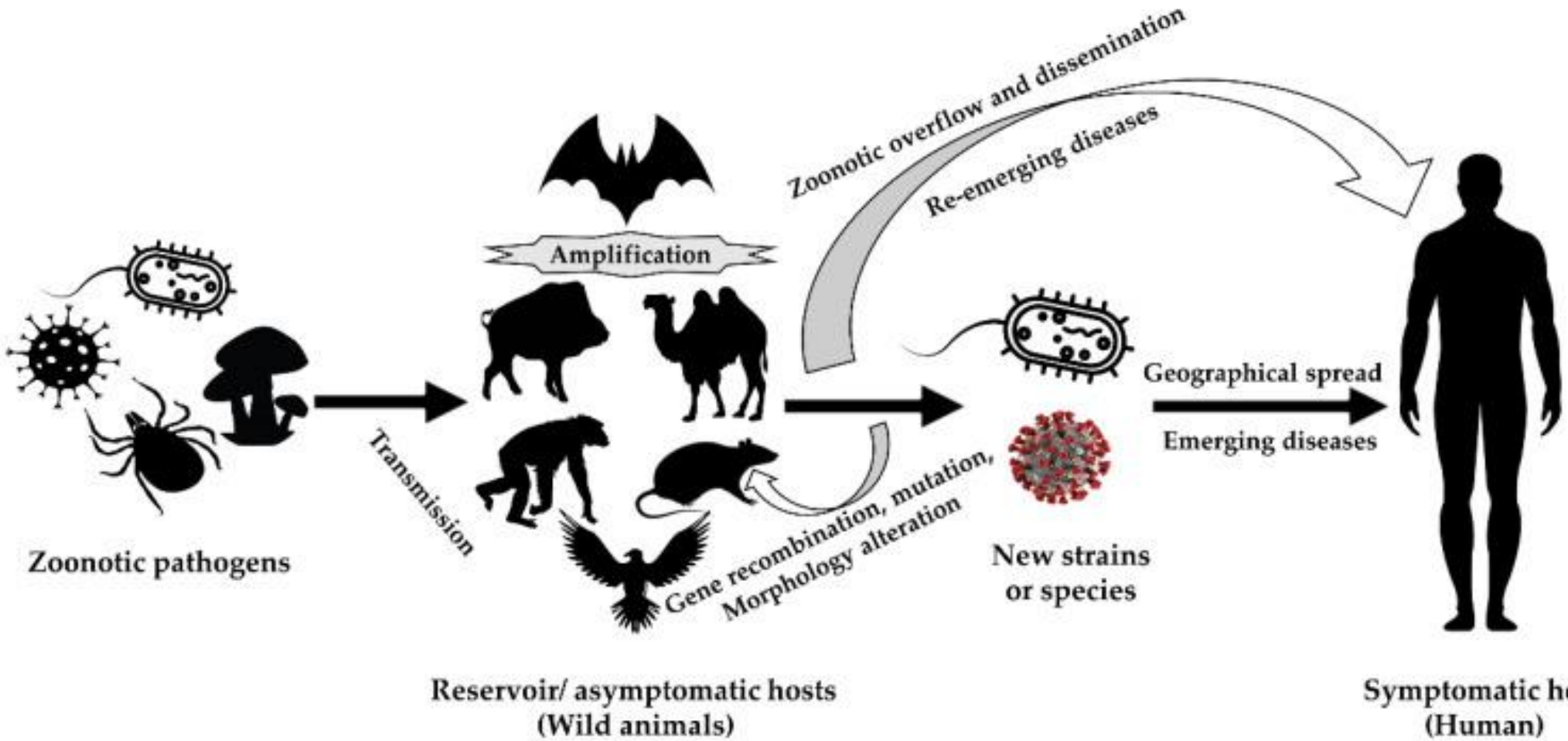
- Most zoonotic diseases are transmitted to humans from animals. Some reports suggested that animals can also get infected from humans. Such diseases are known as **reverse zoonoses**. Examples of such pathogens include **methicillin-resistant Staphylococcus aureus (MRSA),** Campylobacter spp., Salmonella enterica Serovar Typhimurium,

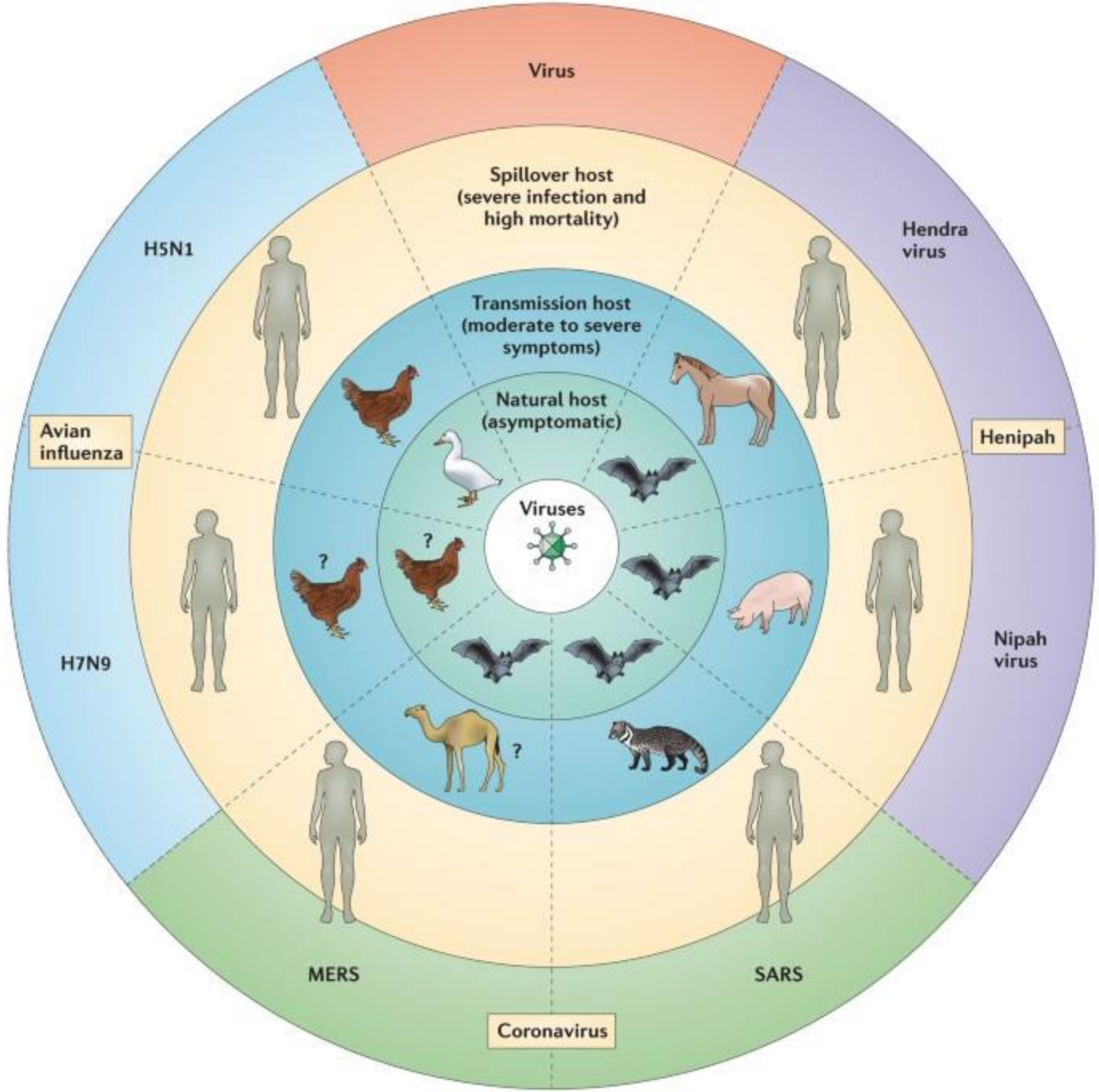
Table 1

Major Zoonotic Diseases, their etiological agents, hosts, and the major symptoms in humans.

Disease	Etiology	Animal Host	Major Symptoms, System or Organs Involved
Bacterial zoonoses			
Anthrax	*Bacillus anthracis*	Cattle, horses, sheep, pigs, dogs, bison, elks, white-tailed deer, goats, and mink	Skin, respiratory organs, or GI tract
Tuberculosis	*Mycobacterium bovis, Mycobacterium caprae, Mycobacterium microti*	Cattle, sheep, swine, deer, wild boars, camels, and bison	Respiratory organs bone marrow
Brucellosis	*Brucella abortus Brucella melitensis, Brucella suis, Brucella canis,*	Cattle, goats, sheep, pigs, and dogs	Fever, usually high in the afternoon, back pain, joint pain, poor appetite, and weight loss
Bubonic plague	*Yersinia pestis*	Rock squirrels, wood rats, ground squirrels, prairie dogs, mice, voles, chipmunks, and rabbits	Fever, chills, abdominal pain, diarrhea, vomiting, and bleeding from natural opening
Glanders	*Burkholderia mallei*	Horses, donkeys, and mules	Fever, sweating, muscle aches, chest pain, muscle tightness, and headache
Leprosy	*Mycobacterium leprae*	Monkeys, rats, mice, and cats	Skin lesions
Leptospirosis	*Leptospira interrogans*	Wild and domestic animals including pet dogs	Fever, abdominal pain, jaundice, and red eye
Tularemia	*Francisella tularensis*	Rabbits, squirrels, muskrats, deer, sheep, bull snakes, wild rodents, beavers, cats	Joint pain, diarrhea, and dry cough
Arcobacter infections	*Arcobacter butzleri, Arcobacter cryaerophilus, Arcobacter skirrowii*	Cattle, sheep, pigs, and chickens	Abdominal pain, fever, and vomiting
Actinomycosis	*Actinomyces bovis*	Cattle, sheep, horses, pigs, dogs, and other mammals	Swelling of lymph nodes, soft tissues, skin, and abscess
Bordetellosis	*Bordetella bronchiseptica*	Cats and dogs	Respiratory problem
Lyme disease	*Borrelia burgdorferi*	Cats, dogs, and horses	Fever, headache, skin rash, and erythema migrans
Campylobacter enteritis	*Campylobacter jejuni, Campylobacter coli*	Cattle, sheep, chickens, turkeys, dogs, cats, mink, ferrets, and pigs	Enteric disorder
Campylobacter fetus infection	*Campylobacter fetus* subsp. *fetus, Campylobacter fetus* subsp. *testudinum*	Cattle, sheep, and goats	Enteric disorder
Clostridioides difficile infection	*Clostridioides difficile*	Cattle, horses, and birds	Pseudomembranous colitis, and diarrhea
Corynebacterium ulcerans and *Corynebacterium pseudotuberculosis* infections	*Corynobacterium ulcerans, Corynobacterium pseudotuberculosis*	Cattle, dogs, and cats	Diphtheria
Enterohemorrhagic *Escherichia coli* infections	*E coli* O157:H7	Cattle, sheep, pigs, deer, dogs, and poultry	Enteritis and Hemolytic–uremic syndrome (HUS)
Helicobacter infection	*Helicobacter pullorum, Helicobacter suis*	Poultry and pigs	Peptic ulcer

Zoonotic diseases / Zoonoses of Fish and Aquatic Environments




Virus
Spillover host
(severe infection and
high mortality)
Transmission host
(moderate to severe
symptoms)
Natural host
(asymptomatic)
Viruses
H5N1
Avian
influenza
H7N9
Hendra
virus
Henipah
Nipah
virus
MERS
SARS
Coronavirus
?
?
?

Zoonotic diseases / Zoonoses of Pets and Companion Animals

- Companion and pet animals have increased over the past several decades, but they are also a comprehensive source of disease-producing agents.

- The zoonotic diseases frequently associated with pets and companion animal include brucellosis, campylobacteriosis, chlamydiosis, catch scratch fever (Bartonella henselae), ehrlichiosis, giardiasis

- It is noteworthy that the most common dog-associated zoonotic disease is rabies is caused by rabies virus that kills tens of thousands of people every year

- One of the important zoonoses associated with pet is cat-scratch disease. The etiological agent of the disease is Bartonella henselae.

Zoonotic diseases / Zoonoses of Fish and Aquatic Environments

- Many microorganisms with zoonotic significance have been isolated from fish.

- Several Vibrio species, at least 12, are often known to be potential for fish-associated zoonoses. Among them **Vibrio cholerae**, V. parahaemolyticus, V. vulnificus

- Fish are susceptible to non-tuberculous mycobacterial infections. The infections are commonly associated with **display aquaria and occasionally with commercial aquaculture systems**. They can also be transmitted to humans during aquaculture practice in farm and handling of ornamental fish in aquarium and equipment

Zoonotic diseases / studies on wild animals

- There are a number of key practical outcomes that research in wild and livestock animal species could achieve. For example, if we better understand influenza virus infection in pigs and birds, will we **be better able to predict where the next pandemic might emerge** or **will we be able to develop vaccines or antivirals** for these animals in order **to prevent the crossover** of the infection to humans? If we understand how the bat and duck immune systems respond to viruses, will this help us to develop new therapeutics and vaccines for **preventing fatal infections** caused by these viruses in humans? Can we **engineer livestock that will be less susceptible to infection** by emerging infectious diseases, such as influenza and Nipah viruses, thereby blocking the transmission cycle?

Emergence of bacterial pathogens

- Why do bacterial pathogens keep emerging?

- Unlike viruses, bacteria possess a more stable genome, and thus bacterial divergence after random mutations is less common. Therefore, are we truly confronted with new pathogenic species and strains, or are we simply confronted with the endless biodiversity of the prokaryote world?

- Retrospectively, it seems that most EIDs are due to bacteria that have long been present in our environment!

Emergence of bacterial pathogens

- With that in mind, three main aspects need to be discussed to understand the dynamics of bacterial diseases emergence:

(1) development of new diagnostic tools,
(2) increase in human exposure to bacterial pathogens and
(3) emergence of more virulent bacterial strains and opportunistic infections.

Emergence of bacterial pathogens

(1) development of new diagnostic tools

Molecular amplification techniques such as PCR for example are extremely powerful to identify unknown bacteria. First, they overcome the culture limitations of fastidious organisms. Second, they are highly sensitive, and are therefore extremely useful to detect bacteria after empirical antibiotic treatments or in cases of latent infections, such as Q fever in cattle.

Matrix-assisted laser desorption/ionization time-of-flight mass spectrometry (MALDI-TOF) was initially used in clinical chemistry and was then adapted to identify bacteria by using an acidic matrix specifically extracting small basic proteins such as ribosomal proteins. Since 2010, this technique has been used in microbiology laboratories to detect bacteria from clinical samples, with excellent results in terms of specificity and speed compared to culture

Emergence of bacterial pathogens

(2) increase in human exposure to bacterial pathogens and

Our environment represents an indefinite reservoir of prokaryote species, some of which play a potential pathogenic role in humans. Most recent emerging bacterial diseases **derive from animals and are therefore considered as zoonoses.**

Currently the **increasing density of the population**, especially in **hospital settings**, and the increasing use of invasive procedures have increased healthcare-associated infections, such as Clostridium difficile infections, which now represent a significant public health challenge

Globalization **increased the speed and rate by which they move across the earth**, enabling rapid spatial dissemination of pathogens.

Emergence of bacterial pathogens

(3) emergence of more virulent bacterial strains and opportunistic infections.

Medical communities have been faced with the apparition of multidrug-resistant species, such as **methicillin-resistant Staphylococcus aureus**, **multidrug-resistant or extensively resistant tuberculosis**, **vancomycin-resistant enterococci**, extended-spectrum β-lactamase E. coli and **carbapenemase-encoding Gram negative bacteria**

Emergence of bacterial pathogens

Future Challenges

It will be difficult, even hopeless, to control the emergence of new bacterial diseases. However, efforts can be made to rapidly identify the epicenters of potential epidemics using new technologies such as social networks and media in order to prevent the uncontrolled spread of emerging diseases.

t should be emphasized that microbes are not only associated with infectious diseases but, as outlined above, also with noninfectious diseases such as asthma or cancer; therefore, research on emerging pathogens should not only focus on emerging infections but also more broadly on new pathologies that may be associated with these newly discovered bacterial agents

Further reading:

- Health care-associated infections – an overview https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6245375/
- Hospital-Acquired Infections https://www.ncbi.nlm.nih.gov/books/NBK441857/
- Studying immunity to zoonotic diseases in the natural host — keeping it real https://www.nature.com/articles/nri3551#Sec11
- Zoonotic Diseases: Etiology, Impact, and Control