Biological Agents: An Overview

Training Seminar on Laboratory Biosecurity and Biosafety

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And
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18 July 2006

www.biosecurity.sandia.gov

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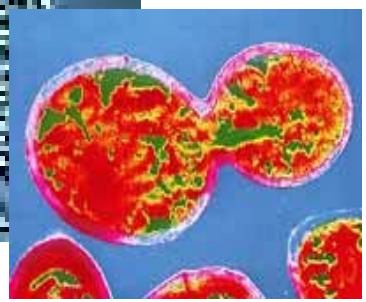
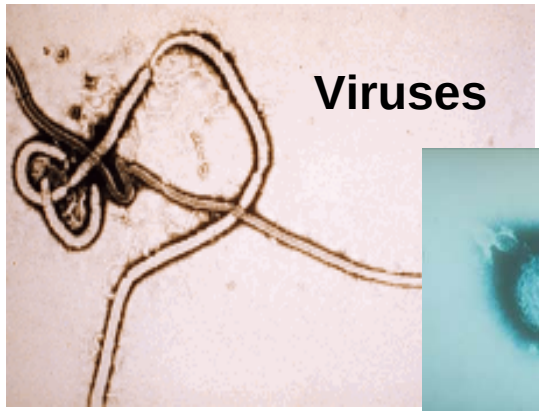
Types of Biological Agents

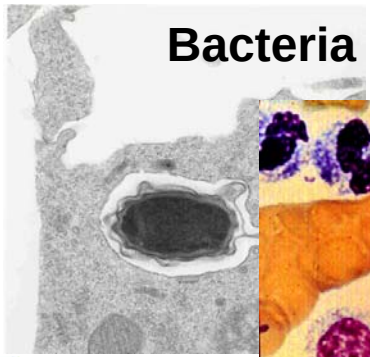
Fungi



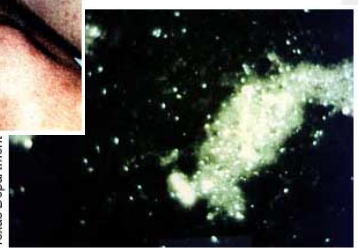


Viruses

Bacteria

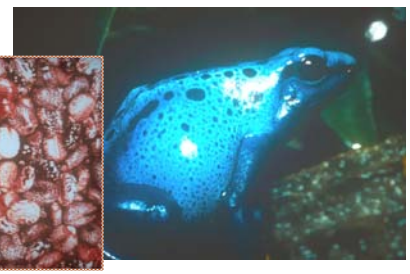


Texas Department of Health



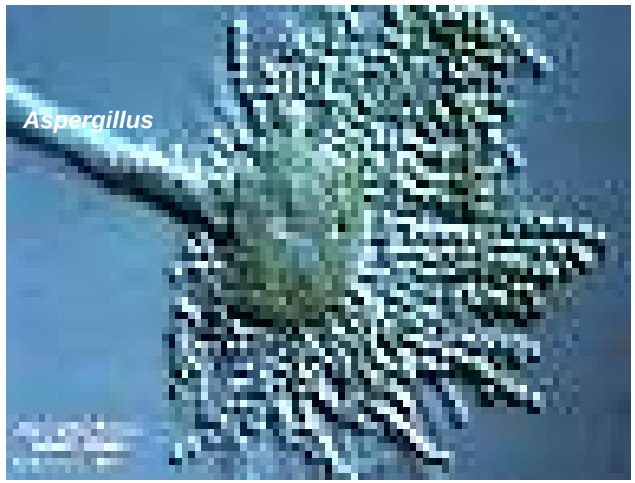
Texas Department

Obligate intracellular parasites:
Rickettsiae and Chlamydia



Proteins:
Toxins and Prions

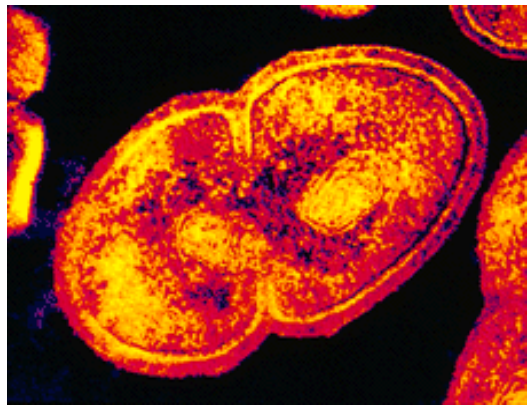
Fungi - Mycelial

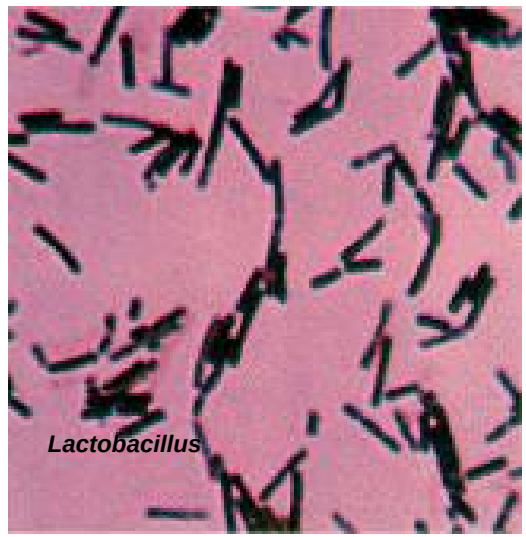


- size: **highly variable**
- complexity: **moderate**
- chemical: **DNA/RNA, complex metabolic, structural & enzymatic chemistry**
- toxins: **often important - wide range of mycotoxins**
- risk: **mainly RG2; C*occidioides, Histoplasma* are RG3**
- pathol: **inflammation, vesic-ulation, granuloma formation, necrosis, hypersensitivity**

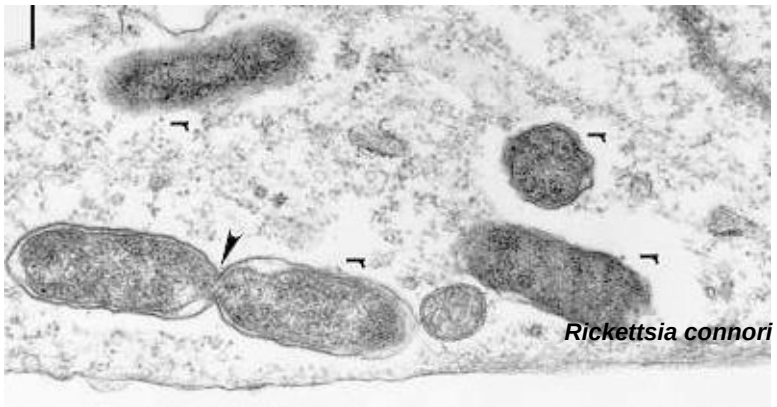
Bacteria

- size: **0.2 μm - 500 μm**
- complexity: **moderate**
- chemical: **DNA/RNA, simple structural & metabolic compo-nents, limited enzyme systems**
- toxins: **many important**
  - exo: **tetanospasmin, diphtheria, botulinum, TSST-I, cholera**
  - endo: **lipopolysaccharide (LPS) of many pathogenic G- bacteria**
- risk: **RG2, few RG3 (e.g., anthrax, brucellosis, tularemia)**
- pathol: **many factors influence transmissibility, invasiveness, pathogenicity, virulence**





Rickettsiae and Chlamydia

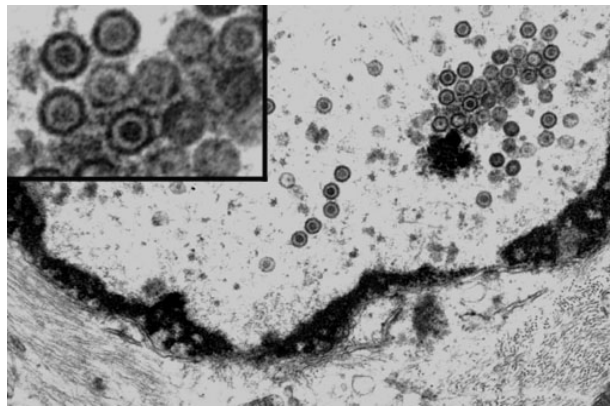


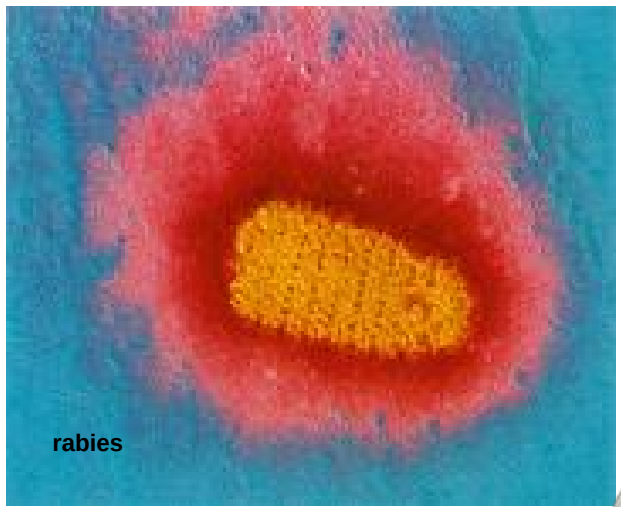
- size:
  - **0.3 μm – 0.6 μm (Rickettsia)**
  - **0.3 μm – 1.0 μm (Chlamydia)**
- complexity: **similar to Gram-negative bacteria**
- chemical: **DNA/RNA, similar to Gram negative bacteria but can't metabolize energy**
- toxins: **one (a Chlaymdia) but not important in pathogenesis**
- risk: **RG3 (Rickettsia) and RG2 (Chlamydia)**
- pathol: **obligate intracellular parasites ➔ vasculitis, cell death, inflammation, etc.**

Viruses

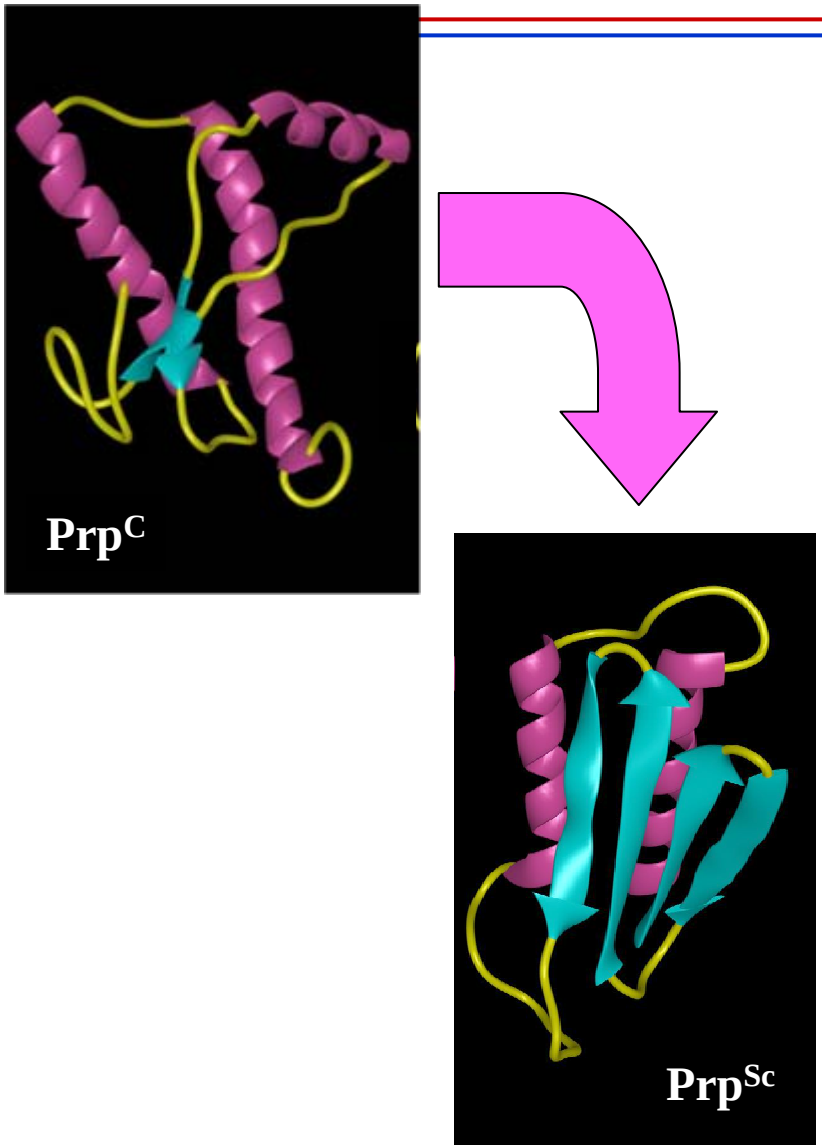
- size: **20 nm - 400 nm**
- complexity: **simple**
- chemical: **DNA or RNA; protein capsid; lipids, viral carbohydrates in membrane envelope; few other chemicals**
- toxins: **no, but genes may code for toxic products**
- risk: **most RG2, several RG3, a few RG4**
- pathol: **obligate intracellular parasites ➔ cell death or hyperplasia (cancer); disease relates to target sites**

Herpes simplex





Prions



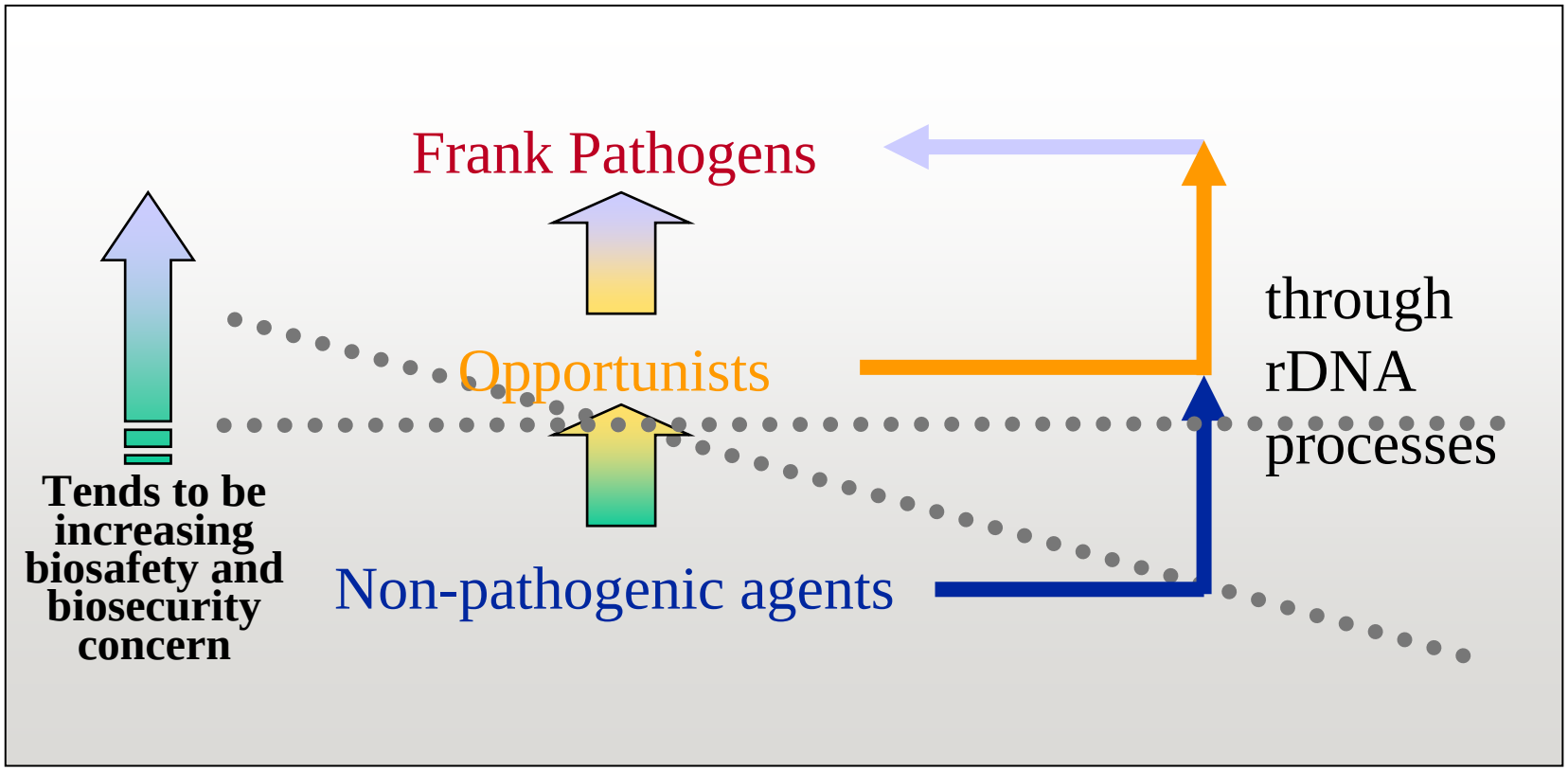
- "proteinaceous infectious particles"
- abnormal isoform of a normal cellular protein
- PRP^{C} ---(increased β sheet)---> PRP^{Sc}
- no prion-specific nucleic acids or virus-like particles
- risk: RG2 (animal)
  RG3 (human)
- causes transmissible spongiform en cephalopathy (TSE)

Koch's Postulates

- **Robert Koch applied these four precepts in 1884 to establish the etiology of tuberculosis.**
- **The only way to conclusively demonstrate microbial etiology of a disease:**
  - **The organism must be found in all animals suffering from the disease, but not in healthy animals;**
  - **The organism must be isolated from a diseased animal and grown in pure culture;**
  - **The cultured organism should cause disease when introduced into a healthy animal;**
  - **The organism must be re-isolated from the experimentally infected animal.**

The Dividing Line

- **Based on pathogenicity for humans**

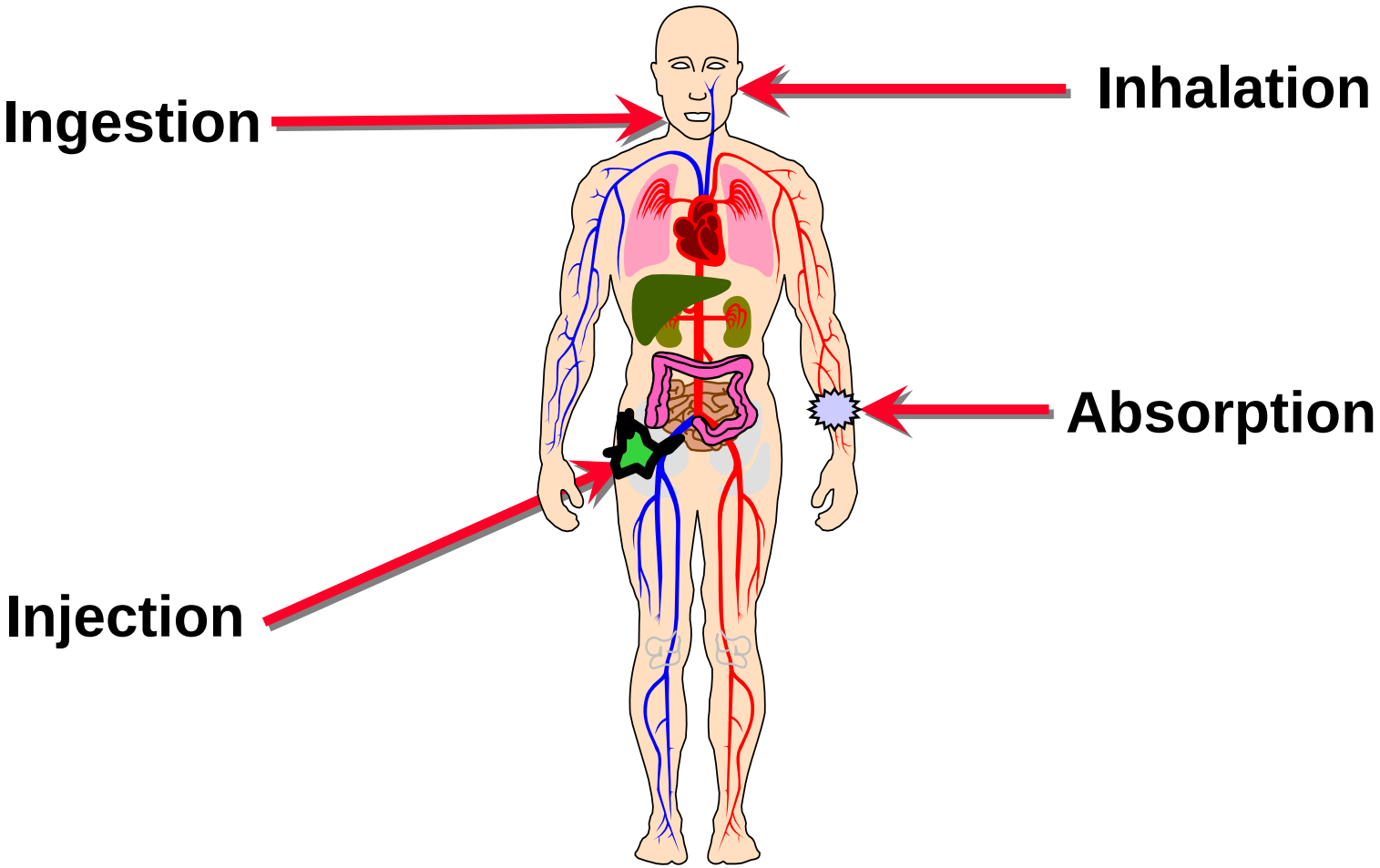


Sources of Pathogens and Toxins

- Natural environment
  - Endemic
  - Outbreaks
- Legitimate facilities
  - Culture collections
    - More than 400
    - 67 countries
  - Laboratories
  - Pharmaceutical companies
  - Biotechnology companies
  - Clinical and diagnostic laboratories
- Synthetic biology
  - De-novo synthesis
    - Polio virus
    - Ebola virus
  - Modifying less virulent pathogens

ATCC

Routes of Entry

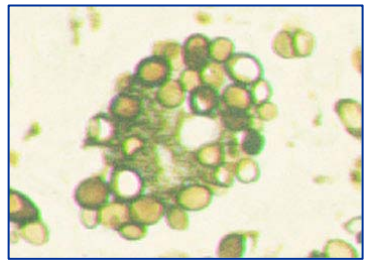


Overview of Selected Agents

- **Fungi**
  - ***Coccidioides immitis***
- **Bacteria**
  - ***Bacillus anthracis***
  - ***Yersinia pestis***
  - ***Francisella tularensis***
  - ***Brucella spp.***
- **Rickettsiae and Chlamydia**
  - ***Rickettsia rickettsii***
- **Viruses**
  - **Hemorrhagic Fever viruses**
  - **Variola major virus**
  - **Avian influenza virus, H5N1**
  - **Foot-and-mouth Disease virus**
  - **Rinderpest virus**
- **Proteins**
  - **Botulinum toxin**
  - **Bovine Spongiform Encephalopathy**

Fungi: *Coccidioides immitis*

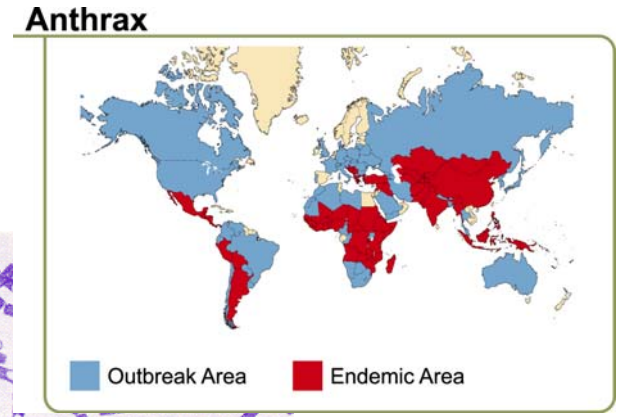
- Coccidioidomycosis ("Valley fever" or "desert fever")
- Zoonotic
- Endemic to arid and semi-arid regions of the Western Hemisphere
- Highly stable – easy to produce spores
- Usually asymptomatic, 30-40% of infected become ill
- Not contagious
- 5-10 out of every 1000 infected develop life-threatening infection
- 10th most common laboratory-acquired infection
- In US: BSL3 recommended

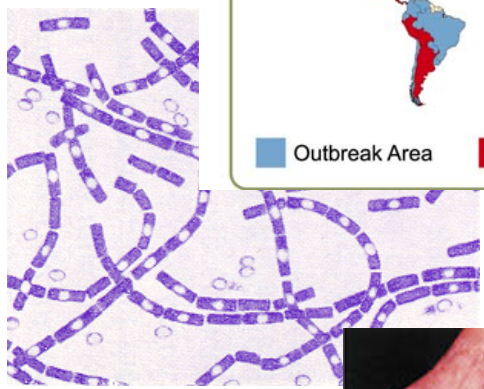


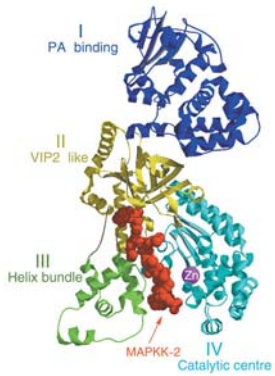
Coccidioides immitis

Bacteria: *Bacillus anthracis*

- Anthrax
  - Cutaneous
  - Gastrointestinal
  - Pulmonary
- Zoonotic
- Global distribution
  - Especially Middle East, Africa, Asia, US
  - Many less virulent strains
- Very stable – spore former
- ID_{50}: 8000-50,000 spores
- Mortality rate: 90 – 100% (pulmonary)
- Vaccine available
- Antibiotics effective if administered shortly after exposure
- In US: often used in BSL2 laboratories

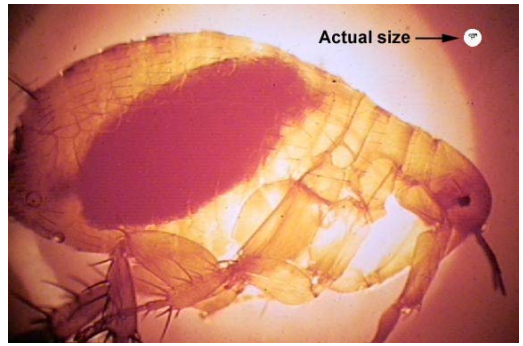


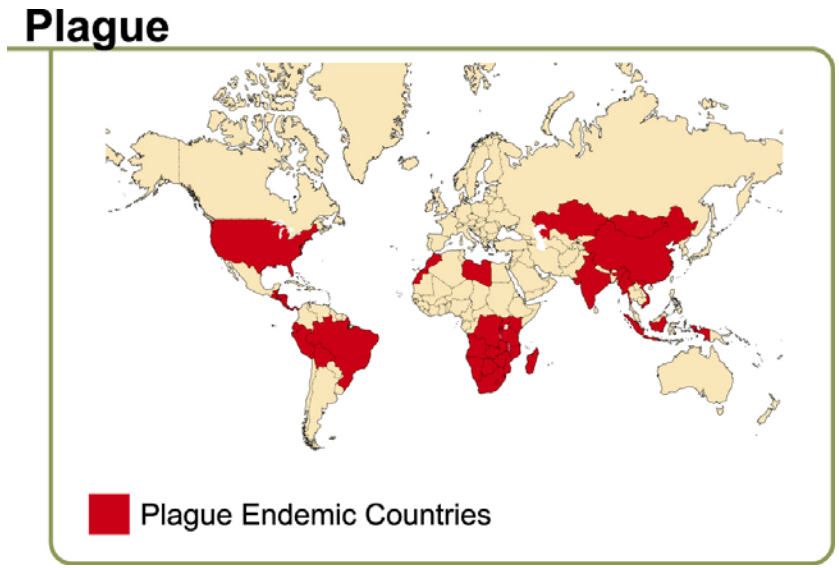




Bacteria: *Yersinia pestis*

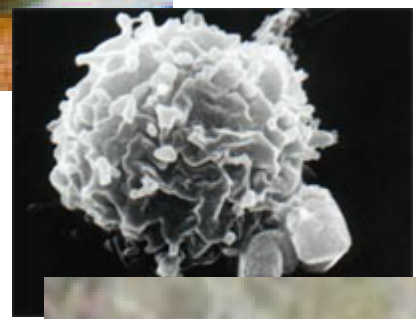
- Plague
  - Bubonic
  - Septicemic
  - Pneumonic
- Zoonotic
- Global distribution
  - Except Australia and Antarctica
  - Virulence highly variable
- Less stable – easily degraded by drying and sunlight
- ID_{50}: 100 – 20,000 organisms
- Mortality rate: ~100% for pneumonic if treatment not started within 24 hours of exposure
- No licensed vaccine in US; vaccine available in FSU and Mongolia
- In US: BSL2 for samples; BSL3 for large amounts

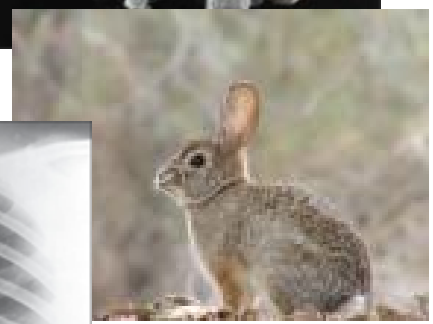




Bacteria: *Francisella tularensis*

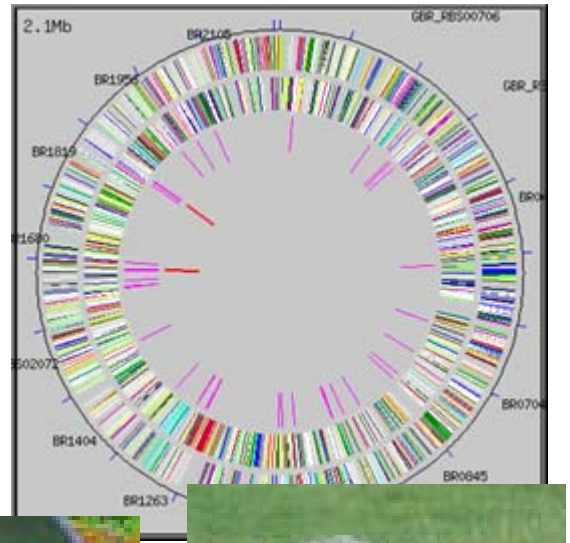
- Tularemia ("rabbit fever")
  - Glandular
  - Gastrointestinal
  - Pulmonary
- Zoonotic
- Distribution
  - North America, Europe, Middle East, Russia, and Japan
  - Rare in UK, Africa, Central and South America
- Persists in water but sensitive to UV radiation and oxidation
- ID_{50}: 10 – 25 organisms by respiratory routes
- Mortality rate: most forms rarely fatal but untreated pulmonary is 30 – 60% fatal
- Antibiotics
- In US: BSL3 most common

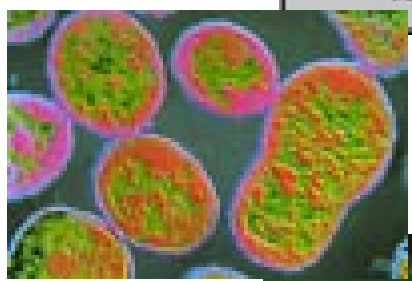


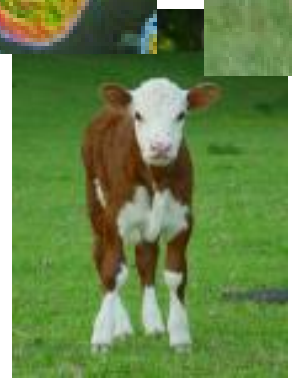


Bacteria: *Brucella spp.*

- Brucellosis
- Zoonotic
- Wide distribution
  - South America, Central America, Eastern Europe, Asia, Africa, Middle East
- Stable
- 6 species; 4 cause disease in humans
- ID_{50}: 10 – 100 organisms
- Low mortality
- Treatment with antibiotics
- In US: BSL 3 most common

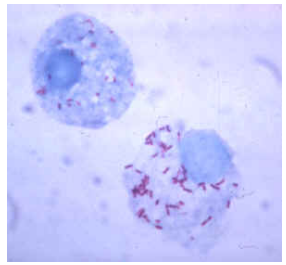






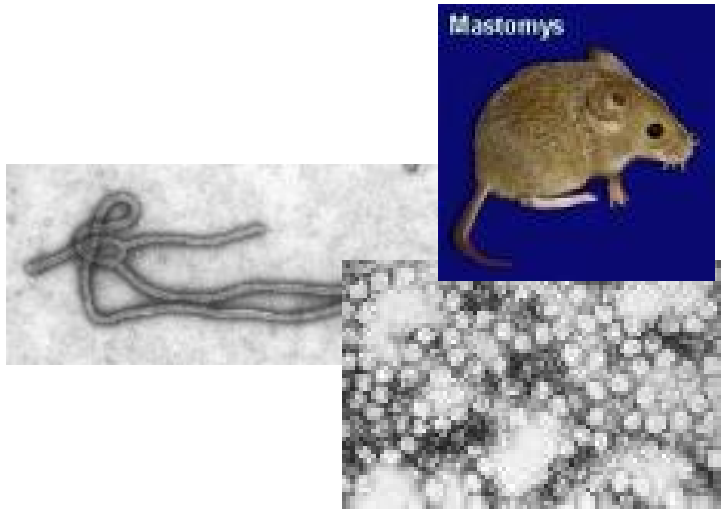
Rickettsiae: *Rickettsia rickettsii*

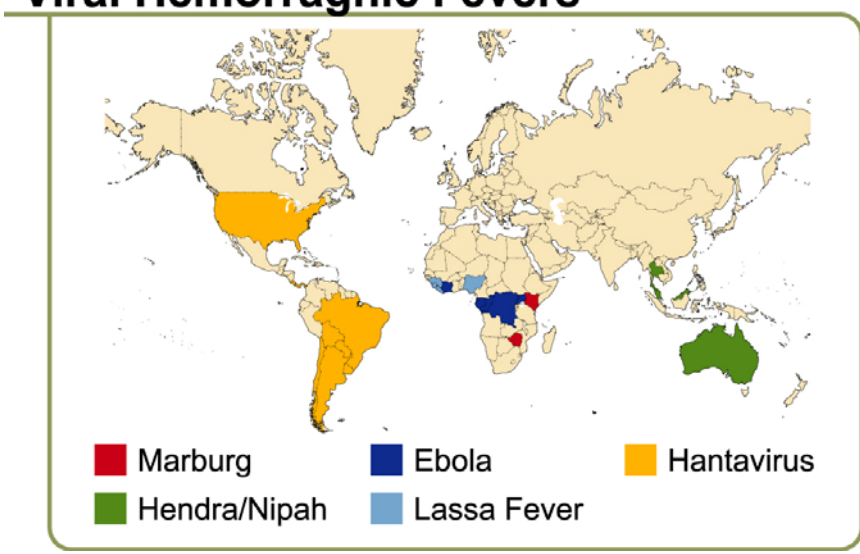
- Rocky Mountain Spotted Fever
- Zoonotic
- Distribution
  - US, Mexico, Central and South America
- Stable in tick blood at ambient T; 1 year survival
- ID_{50}: 1-10 organisms
- Mortality 15-20% if untreated
- Antibiotics: doxycycline; delayed diagnosis contributes to increase in fatalities
- In US: BSL3



Viruses: Hemorrhagic Fever viruses

- Viral Hemorrhagic Fevers
  - Filoviruses: Ebola and Marburg
  - Arenaviruses: Lassa, Junin, Machupo, Guanarito, Sabia
  - Hantaviruses
  - Dengue
  - Yellow fever
- Zoonotic
- Distribution varies by species
- Relatively unstable (enveloped viruses)
- ID_{50}: 1 – 10 virions
- Mortality varies
  - Ebola is highest: 50 – 90%
  - Lassa: 15 – 20%
- Generally only supportive treatment
  - Ribavirin somewhat effective for arenaviruses
  - Yellow fever vaccine
- In US: Most are BSL4





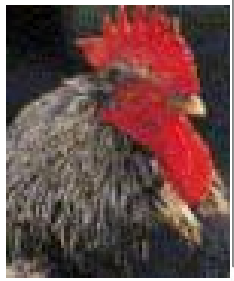
Viruses: Variola major virus

- Smallpox
- Human only
- Eradicated; officially available in only 2 laboratories
  - CDC (USA)
  - Vector (Russia)
- Very stable
- ID_{50}: 10 – 100 virions
- Mortality rate: ~30% (unvaccinated)
- Vaccine available
- Other treatments limited
  - Post-exposure vaccination (within 4 d
  - Supportive care
  - Cidofovir has shown promise
- BSL4




Viruses: Avian Influenza H5N1 virus

- Highly Pathogenic Avian Influenza (HPAI)
- Zoonotic
- Distribution
  - Spreading rapidly in environment
- Relatively unstable
  - But stable in water
- Highly infectious in poultry; apparently limited infectivity currently in humans
- Vaccine for animals available; human vaccine under development
- Treatment for humans:
  - Oseltamivir
  - Zanamavir
- In US: BSL3



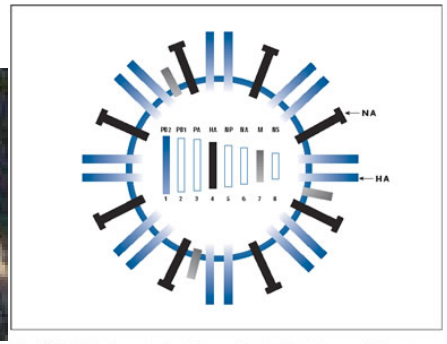
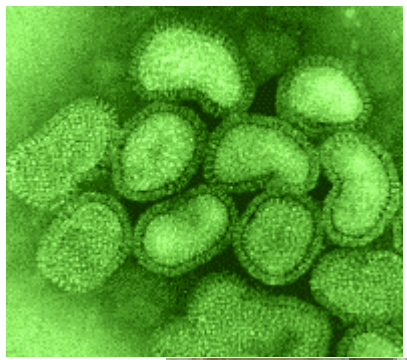
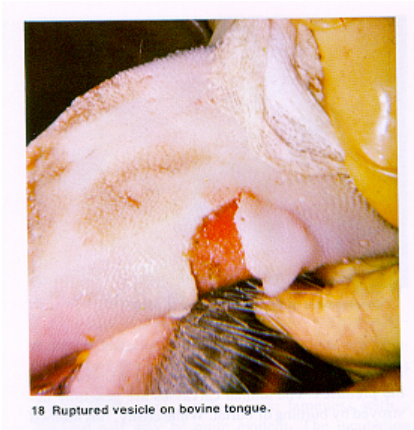


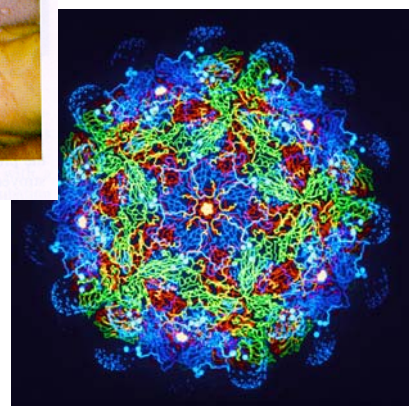
Figure 3. Model of the influenza virus showing the segmented nature of the viral genome and the two major surface glycoproteins, hemagglutinin (HA) and neuraminidase (NA).

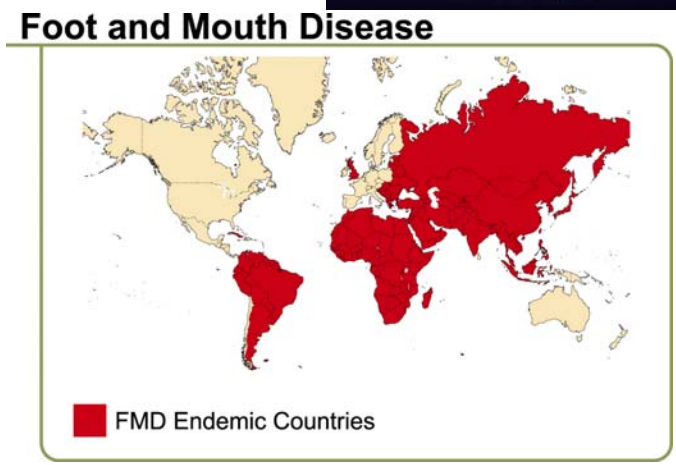


Viruses: Foot-and-Mouth Disease virus

- Foot-and-mouth disease
- Animals only
- Wide distribution
  - South America, Europe, Asia, and Africa
- Very stable
- Highly infectious for cattle
  - ID_{50} < 10 virions
- High morbidity; low mortality for adult animals (< 5%)
- Vaccine
- In US: BSL3-Ag

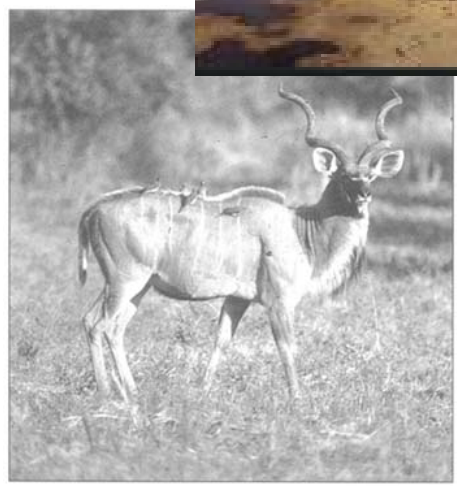

18 Ruptured vesicle on bovine tongue.





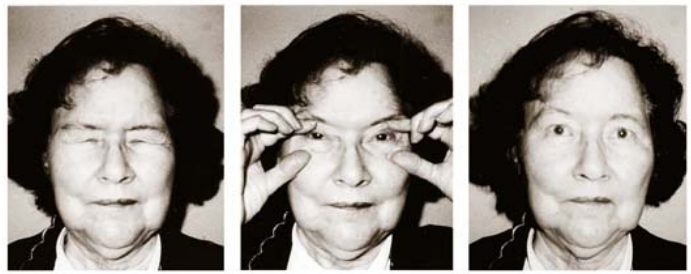
Viruses: Rinderpest virus

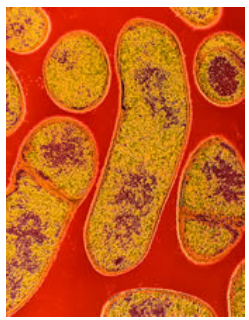
- Rinderpest disease
- Animals only
- Distribution:
  - Eastern Africa, Middle East, South Asia
- Susceptible to pH, heat and sunlight
- Mortality can reach 100%
- Distinguished from FMD by diarrhea



Proteins: Botulinum toxin

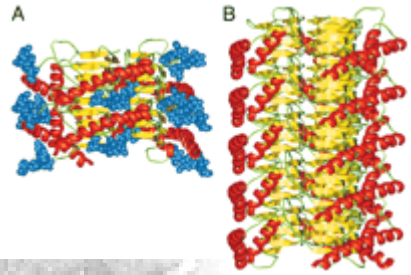
- Botulism
- Produced by *Clostridium botulinu*, *C. baratii*, and *C. butyricum*
  - Multiple types of toxin: A, B, C, D, E, F, G
  - Only A, B, E, and F produce human disease
- Zoonotic
- Degraded by heat and humidity – relatively stable for a protein
- LD_{50}: 0.001µg/kg
- Treatment
  - Antitoxin (limited supplies)
  - Supportive care

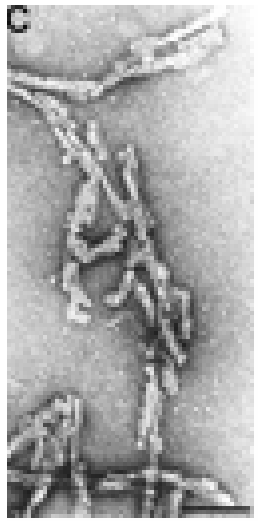


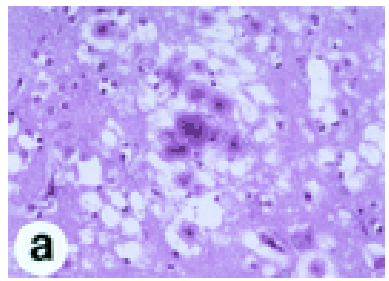


Proteins: Bovine Spongiform Encephalopathy Prion

- Mad cow disease
- Causative agent of BSE causes variant Creutzfeldt Jakob disease (vCJD)
- Diagnosed in cattle in:
  - Europe, Canada, US, Japan
- Long incubation period
- Extremely stable – not inactivated by conventional fumigants, very heat resistant
- Laboratory recommendations:
  - In US: BSL2 or BSL3
  - In UK: modified BSL3 (room need not be sealable, HEPA filters not required)
  - OIE: BSL3

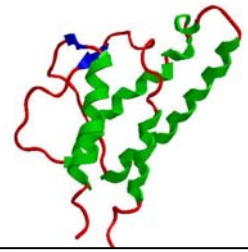


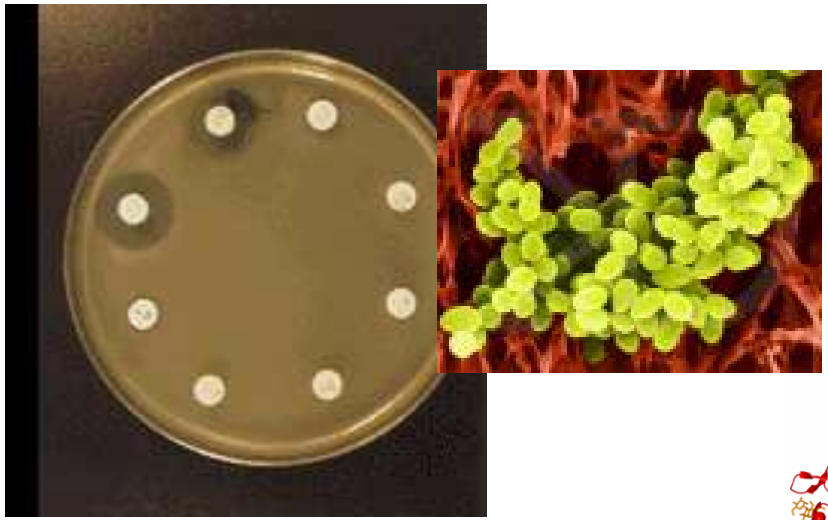


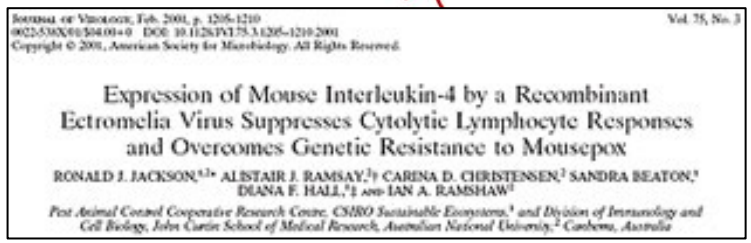


Biological Threats are Evolving

- Drug resistant agents
- Genetically-engineered agents







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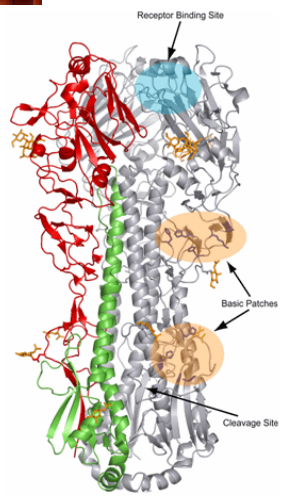
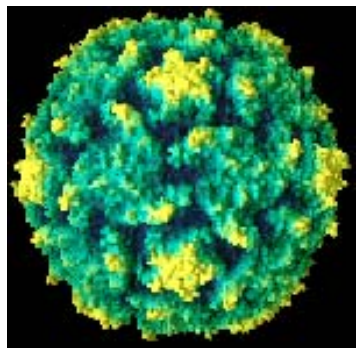
Expression of Mouse Interleukin-4 by a Recombinant Ectromelia Virus Suppresses Cytolytic Lymphocyte Responses and Overcomes Genetic Resistance to Mousepox

RONALD J. JACKSON,[1,2]* ALISTAIR J. RAMSAY,[2]† CARINA D. CHRISTENSEN,[2] SANDRA BEATON,[2] DIANA F. HALL,[2]‡ AND IAN A. RAMSHAW[1]

Pest Animal Control Cooperative Research Centre, CSIRO Sustainable Ecosystems,[1] and Division of Immunology and Cell Biology, John Curtin School of Medical Research, Australian National University,[2] Canberra, Australia





Characterization of the Reconstructed 1918 Spanish Influenza Pandemic Virus

Terrence M. Tumpey,[1]* Christopher F. Basler,[2] Patricia V. Aguilar,[2] Hui Zeng,[1] Alicia Solórzano,[2] David E. Swayne,[4] Nancy J. Cox,[1] Jacqueline M. Katz,[1] Jeffery K. Taubenberger,[3] Peter Palese,[2] Adolfo García-Sast

SCIENCE VOL 310 7 OCTOBER 2005

Summary

- Types of agents
  - Fungi
  - Bacteria (including mycoplasma, rickettsae, chlamydia)
  - Viruses
  - Proteins
    - Prions
    - Toxins
      - Produced by many sources
- Almost all biological agents available in nature
- Many factors to consider when evaluating biological hazards
- Delayed onset of symptoms – many cause flu-like illness