MICR2209 Introduction to Infectious Diseases and Immunology

Lecture 1: Unit outline and Introduction to Host-Parasite Interactions

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Welcome

The purpose of **Introduction to Infectious Diseases and Immunology** is to provide students with a sound knowledge of the diversity and sources of disease-causing microbes and major infections they are responsible for, the mechanisms of body defences against infection, and factors determining the spread and extent of infectious diseases.

Four Modules		Module Co-ordinators
Module 1	**Introduction to immunology and the immune system**	**Allison Imrie**
Module 2	**Introduction to bacteria and bacterial diseases**	**Barbara Chang**
Module 3	**Introduction to fungal and protist diseases**	**Chris Peacock**
Module 4	**Introduction to viruses and viral diseases**	**Allison Imrie**

Unit structure

- Theory

  - two lectures per week

- 'Practical' content:

  - delivered as workshops and lab demonstrations

	Dry Labs (compulsory)	Workshops (compulsory)
Module 1: Immunology	-	✓
Module 2: Bacteriology	✓	-
Module 3: Fungi & Protists	✓	-
Module 4: Virology	-	✓

- Textbook

  - Prescott's Microbiology, 9th or 10th edition: highly recommended

Unit assessment

Item	Marks	Duration	Covers	Week
Final exam	56%	2 h	All lectures	End of semester exam period
Lecture MCQ	20%	1 h	Lectures 1 - 16	Week 9
Practical/Workshop on-line quizzes	24% (6% per module)	~20min each	Practical and Workshop material	Weeks 4-13

INTRODUCTION

Lecture outcomes: at the end of this lecture you should know:

- the terms used in describing host-parasite relationships
- the four phases of an infectious disease
- details of the six links of the infection chain
- details of the key microbial virulence factors

Reference:

- Chapter 35, Prescott's Microbiology. 9th/10th ed. 2014/2017.

What is Infectious Disease?

http://nothinginbiology.org/tag/host-parasite/

- a battle over resources
  - the host provides protection, nutrients and energy
- pathogen must:
  - access and exploit the host
  - access new hosts
- the host must resist infection

Images from Prescott's Microbiology unless noted

Host-Parasite Relationships

- parasitism is one type of symbiotic interaction (symbiosis = "living together")

- parasites:
  - live on or within a host organism
  - use the host to achieve metabolism ('dependence')
  - typically cause disease in the host
  - but some parasitic interactions can be mutually beneficial

Many parents are incorrect in thinking they know the meaning of the term parasitism

http://www.mypoweranimals.org/kola_the_polar_bear.html

- the host is usually a larger organism that supports the survival and growth of a smaller organism (the parasite)
  - ➢ the term “parasite” as used here includes bacteria, viruses, fungi, protists

Host-Parasite Relationships…

- infection (a process)
  - the parasite grows and multiplies in or on its host
- infectious disease (an outcome)
  - where infection detrimentally affects host function
- pathogen
  - a parasite causing infectious disease
- pathogens
  a) Primary pathogens
     - cause infectious disease in healthy hosts

  b) Opportunistic pathogens
     - cause infectious disease in 'compromised' hosts, e.g. immunocompromised or wounded hosts
     - may be part of the normal microbiota (normal flora)

Chicken pox

- pathogenicity
  - the ability to cause disease
  - varies among pathogens
- virulence
  - the degree of pathogenicity e.g. indicated by fatality rate or ability to damage host tissues

Host-Parasite Relationships…

Infectious diseases can be:

- chronic (persistent or otherwise long-lasting) e.g. AIDS/HIV
- acute (rapid onset and/or short in duration) e.g. Ebola

http://science.nationalgeographic.com/science/photos/aids/#/thailland-aids_1246_600x450.jpg

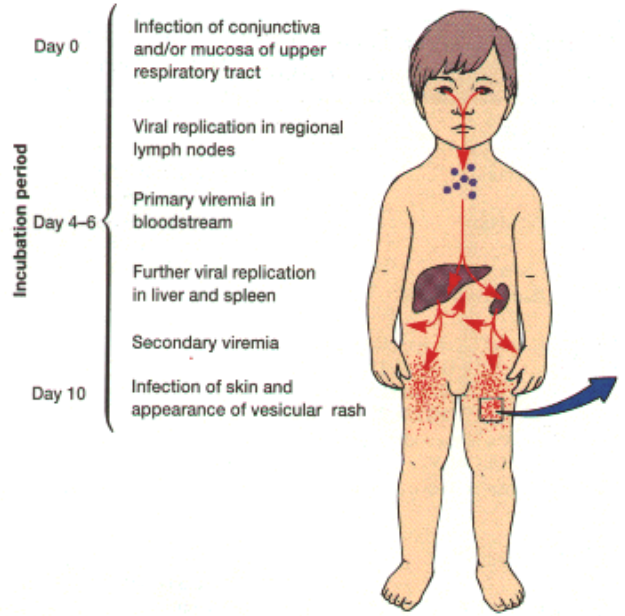
Ebola: http://seamusmurphy.com

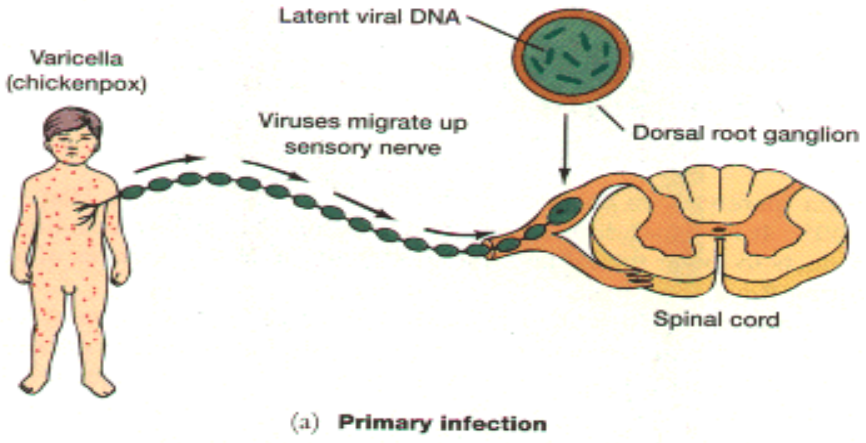
Host-Parasite Relationships…

Some pathogens can enter a *latent state:*

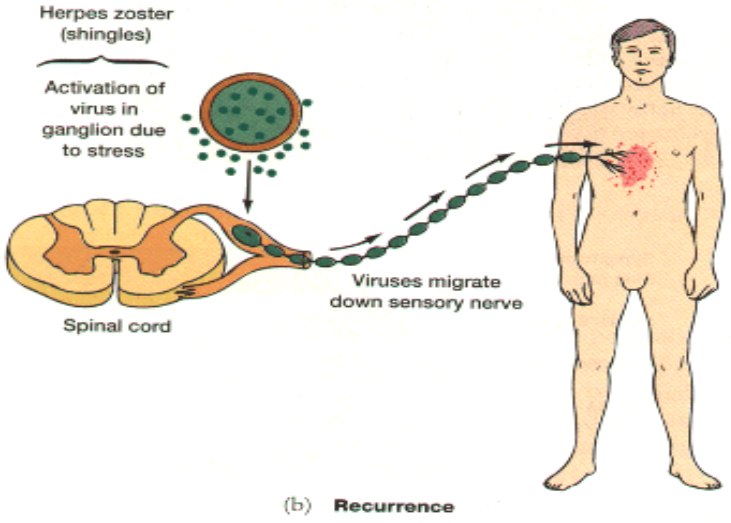
- the parasite is present but no symptoms are evident
- e.g. herpesvirus infection, tuberculosis, leprosy, chicken pox/varicella

Chickenpox course of infection





Chickenpox primary infection, virus becomes latent



Virus reactivated to cause Shingles

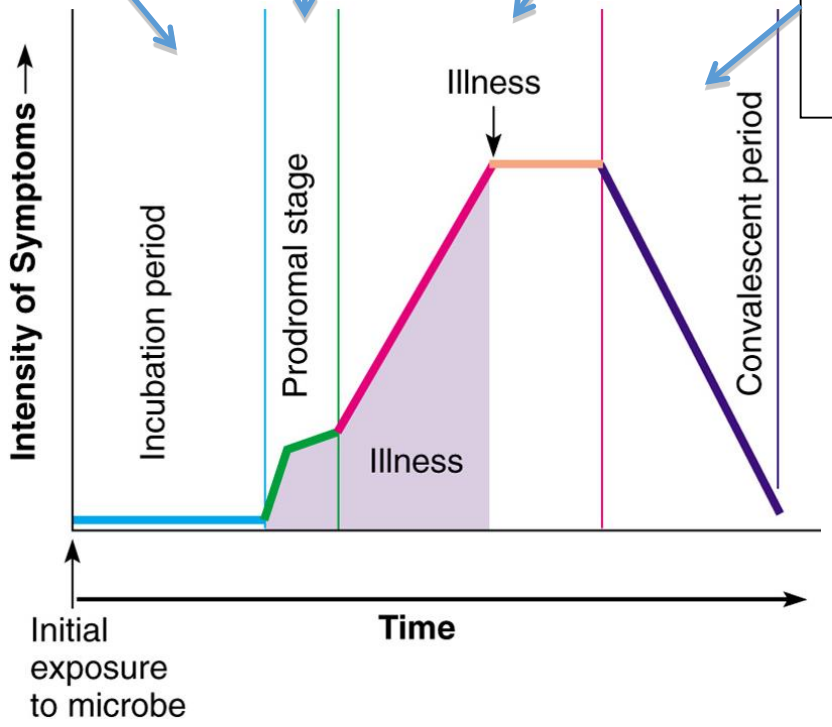
The Infectious Disease Process

- from pathogen entry to development of signs and symptoms
- pathogen development but no clinical manifestations

- clinical manifestations insufficient for diagnosis

- disease most severe
- characteristic signs and symptoms of the illness
- immune response triggered

- recovery
- signs and symptoms decline



- Several phases typically characterise infectious disease
  1. **Incubation period**
  2. **Prodromal stage**
  3. **Illness**
  4. **Convalescent period**

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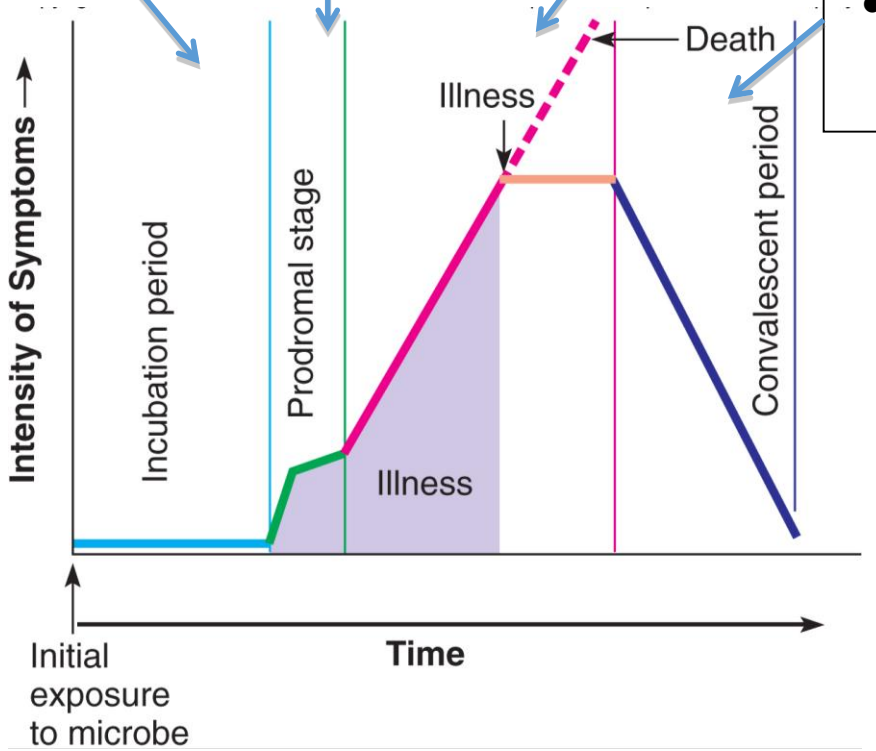

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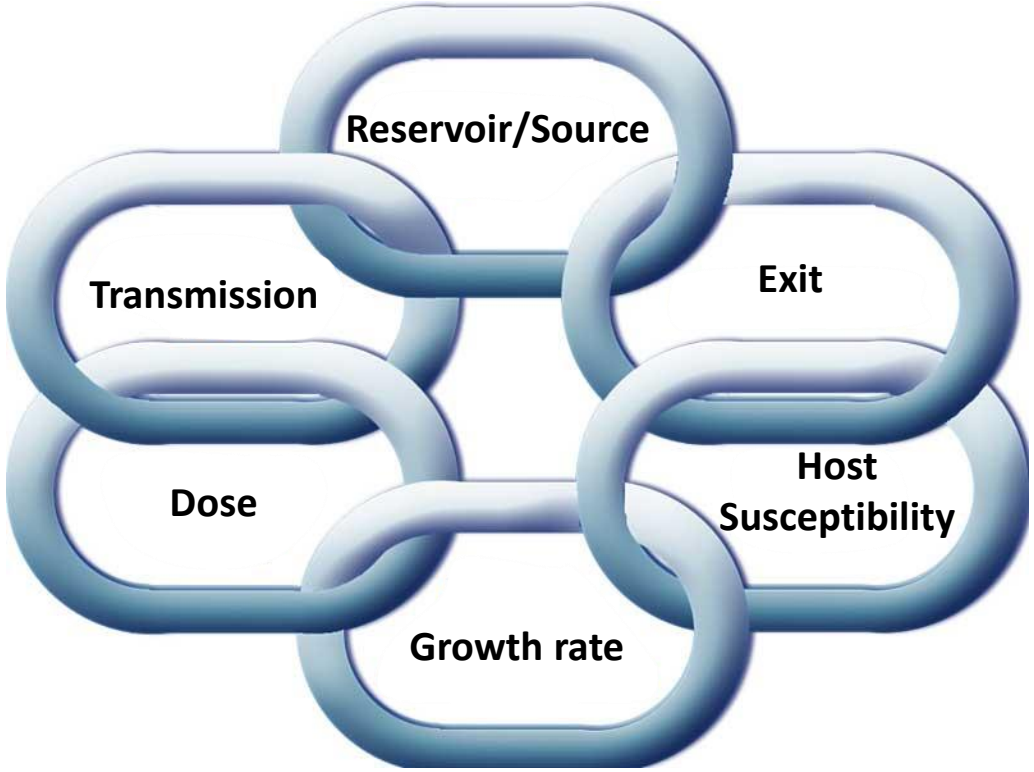
  1. **Incubation period**
  2. **Prodromal stage**
  3. **Illness**
  4. **Convalescent period (or death)**

The Infection Chain

- The infectious disease cycle involves a sequential combination of processes/events referred to as 'the infection chain'

- The main links of the infection chain are:
  1. **pathogen source/reservoir**
  2. **transmission**
  3. **infectious dose**
  4. **growth rate**
  5. **host susceptibility**
  6. **exiting the host**



1. The Source or Reservoir

Source - the location from which pathogen is transmitted to host

- **animate** (humans, plants, animals)
  - infected humans e.g. common cold
  - zoonoses (**zoonosis: disease of animals that can be transmitted to humans** e.g. rabies/dogs, monkeys; SARS/bats
- **inanimate** (soil, water, food)
  - soil-borne fungal infections e.g. aspergillosis
  - water-borne e.g. amoebic dysentery
  - food-borne e.g. hepatitis A

Reservoir - environmental location where the pathogen is normally found

- sometimes also the source of the pathogen
  - e.g. healthy human disease carriers of TB
- sometimes reservoir and source are different
  - e.g. Hendra virus
    - reservoir = bats
    - source of human infection = horses

http://theconversation.com

2. Pathogen Transmission

- Ignaz Semmelweis was the first to demonstrate the occurrence of human-human disease transmission (~1848)
  —hospital vs midwife delivery; childbirth fever; $CaCl_2$/hypochlorite handwashing

- initial transmission of pathogen to host is a critical step in the infection chain

- four main modes of transmission
  A. **airborne**
  B. **contact**
  C. **vehicle**
  D. **vector borne**

www.zmescience.co

2. Pathogen Transmission

A. Airborne transmission

a) via water droplets

- typically infections with respiratory involvement e.g. colds, influenza
  - small particles (1–4 μm diameter)
  - can remain airborne for long time
  - can travel long distances
  - propelled from respiratory tract by sneezing, coughing, or vocalization
- also from reservoirs
  - e.g. Legionnaires disease (air-conditioning cooling towers)

bcrf.ucsd.edu/images/sneeze.jpg

b) via dust

- many systemic fungal infections
- can be source of hospital-acquired (nosocomial) infections

2. Pathogen Transmission

http://funnycoolstuff.com/2007/04/

B. Contact transmission

- pathogen source and host come into contact
  - a) person-to-person
    - touching, kissing, sex (e.g. AIDS)
    - oral or wound secretions (e.g. oral herpes)
    - nursing mothers (staphylococcal infections)
  - b) animal-to-person
    - animal handlers e.g. Lissavirus (wildlife bat handlers)

2. Pathogen Transmission

C. Vehicle transmission

- An inanimate 'vehicle' is a source that has become contaminated
- Common vehicles are termed “fomites”
  - surgical instruments, drink containers, bedding, door handles, taps
  - food and water
  - cosmetics
  - drugs, needles

http://artgib.hubpages.com/hub/How-to-Prevent-Food-Cross-Contamination-in-Your-Own-Home

2. Pathogen Transmission

D. Vector transmission

- Vectors are living agents of pathogen transmission
- Most are arthropods
  - insects such as mosquito e.g. malaria; dengue fever, Zika virus
  - ticks e.g. Lyme disease
  - fleas e.g. plague

http://www.abc.net.au/news/stories/2010/04/12/2870182.htm?site=kimberley

2. Pathogen Transmission

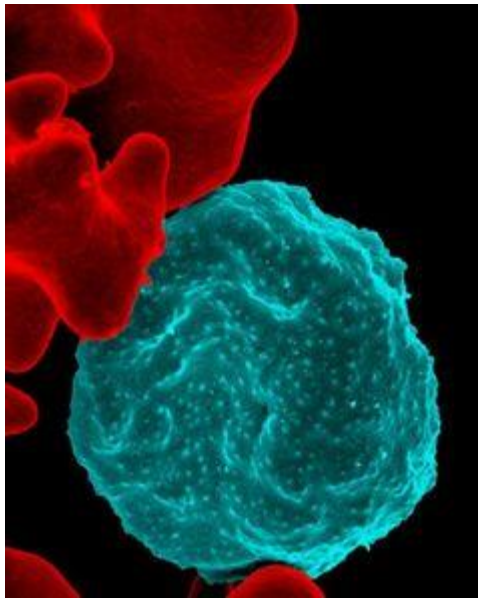
D. Vector transmission

a) external transmission

- passive carriage of pathogen on body of vector
- no growth of pathogen during transmission
- e.g. *Shigella dysenteriae* (shigellosis): flies carry the bacterium on their feet from faecal sources to food

b) internal transmission

- pathogen carried within vector
- e.g. the plague bacterium *Yersinia pestis* in rat fleas during transmission from rat to human
- e.g. malarial parasite undergoes developmental changes in the mosquito vector



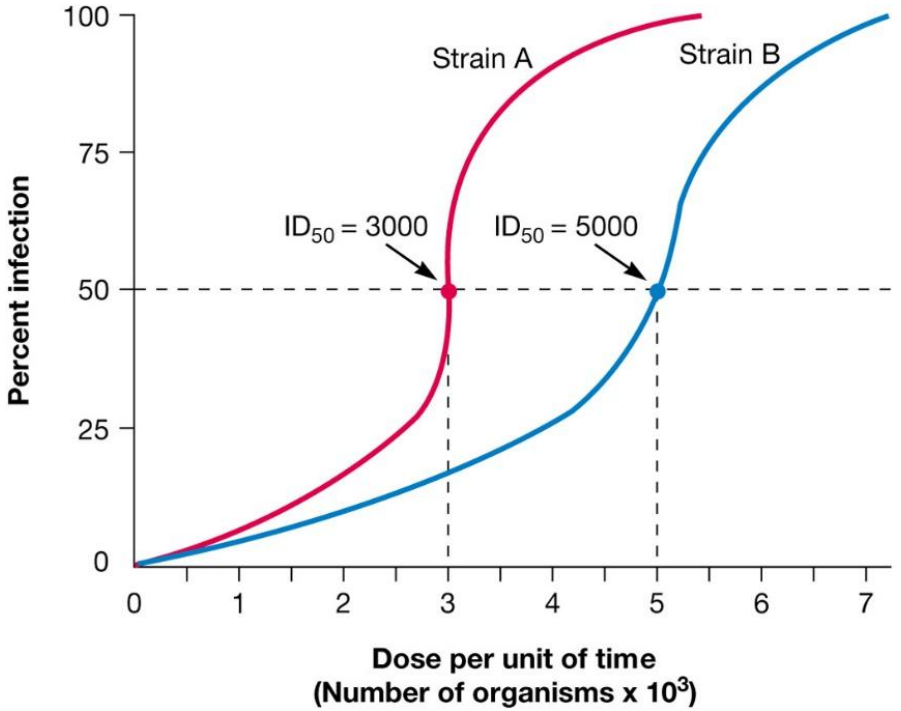
Malaria parasite (blue) infecting red blood cell

au.pinterest.com

3. Infectious Dose

Infectious dose 50 (ID_{50}) = number of pathogens necessary to infect 50% of an experimental group of hosts in a specified time

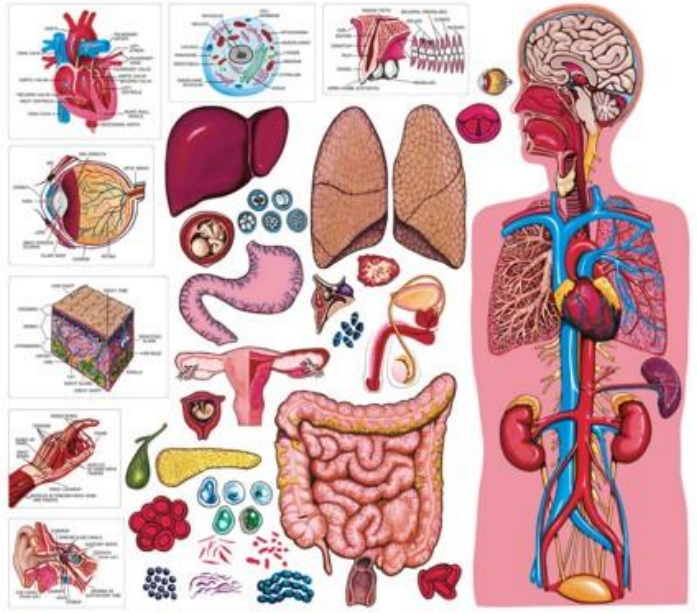
- varies with pathogen
  - ID_{50} for *Salmonella* spp. ingested in contaminated food has been calculated to be 1×10^5 cells
  - *Entamoeba histolytica* (amoebiasis) – probably 1 cyst
- highlights the importance of handwashing/hygiene in reducing the number of pathogens that can be transmitted



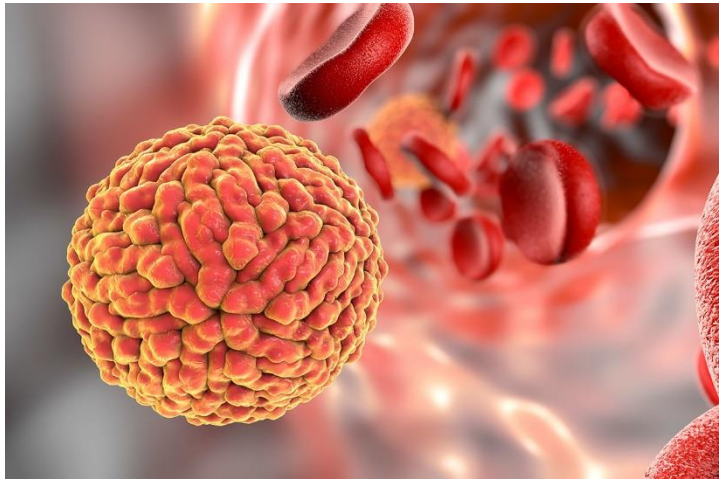
http://www.yourhealth.net.au/Practice.aspx?id=118&Article=169

4. Growth Rate

- transmission alone not enough for infection to occur
- pathogen must make contact with appropriate host tissues
  - specific cell surface receptors for pathogen must be present
  - pathogen must find appropriate nutrients, pH, temperature etc. to grow
- pathogens vary in the systems they affect in hosts
  - respiratory
  - urogenital
  - gastrointestinal
  - circulatory
- some affect multiple systems



http://poster.4teachers.org/worksheet/view.php?id=140793



Zika virus in blood.
www.newscientist.com

4. Growth Rate

- pathogens vary in their location in hosts
  - extracellular pathogens grow outside cells in blood, tissue fluids
  - intracellular pathogens grow and multiply within cells
    - ➢ **Facultative intracellular pathogens** = grow within or outside cells
    - ➢ **Obligate intracellular pathogens** = only grow when inside cells

jb.asm.org

Coxiella sp., an obligate intracellular bacterium infecting a Vero cell

5. Host Susceptibility

- defence mechanisms of host include two components (covered in immunology module)
  - innate host resistance factors
  - adaptive immune mechanisms
- the pathogenicity of the microbe plays a role
  - pathogen has genetically determined 'virulence factors'
  - host may be susceptible to some strains, resistant to others
- host nutrition, genetic predisposition, and stress also play a role in host susceptibility to infection

biochemreview.weebly.com

Bacteria (yellow) being phagocytosed by host immune cell

6. Exiting the Host

- must occur if the microbe is to be perpetuated
- active escape
  - movement of pathogen to portal of exit from host
  - relatively uncommon (some helminths burrow out through the skin)
- passive escape
  - the usual method
  - excretion in faeces, urine, droplets, blood, saliva, or in host cells shed from the body

Hookworms (helminths) attached to the intestinal mucosa
Wikipedia

Virulence

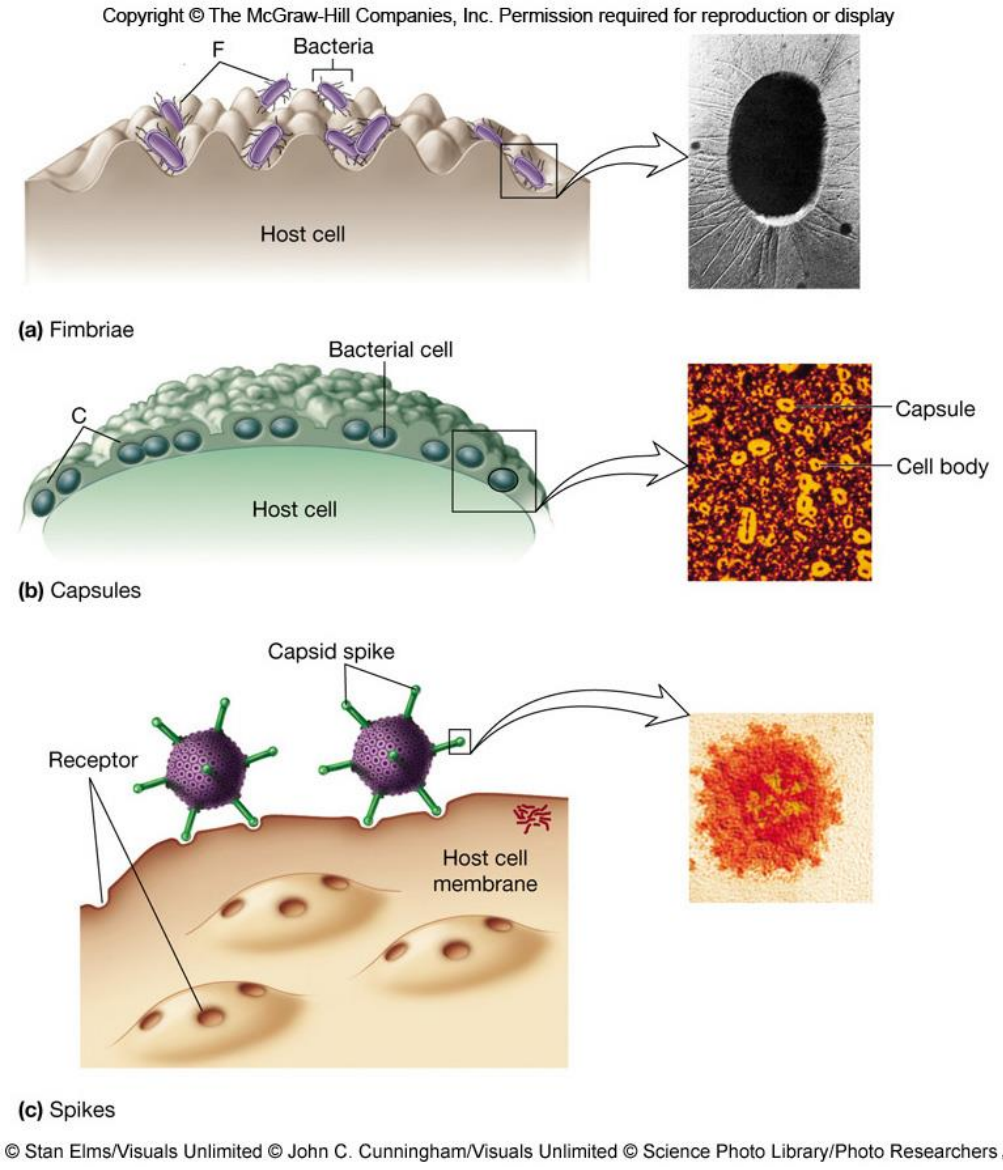
- *the magnitude of harm caused by a microbe*
- determined by pathogen's 'virulence factors'
  - can involve physical and chemical characteristics

    e.g. structures for adherence to host cells

    e.g. chemicals that bypass host defenses
  - determine the degree to which the pathogen causes damage, invasion, infectivity
- key elements of virulence involve factors related to:
  - **adherence and colonization**
  - **invasion**
  - **avoiding/resisting host defenses**
  - **toxin formation**

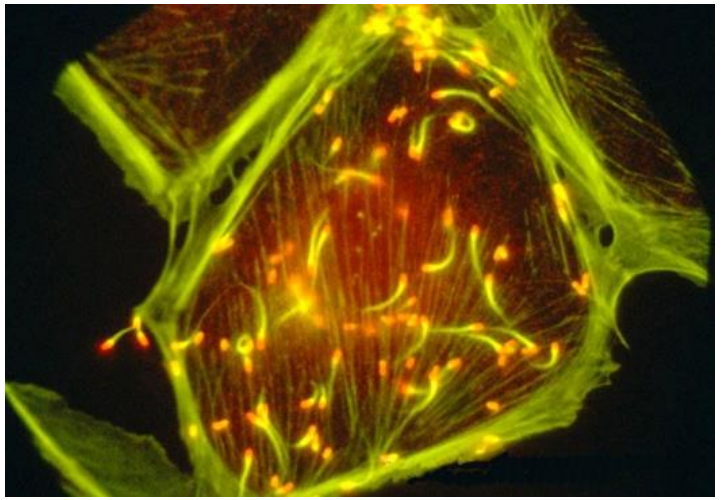
Virulence – adherence and colonization

- adherence factors = **adhesins**
- help microbes to attach to host tissue
  - fimbriae/pili (hair-like structures) of bacteria
  - capsules (sticky polysaccharide materials) of bacteria
  - capsid spikes of viruses
- once attached, if reproduction follows the host is said to have been '*colonized*'



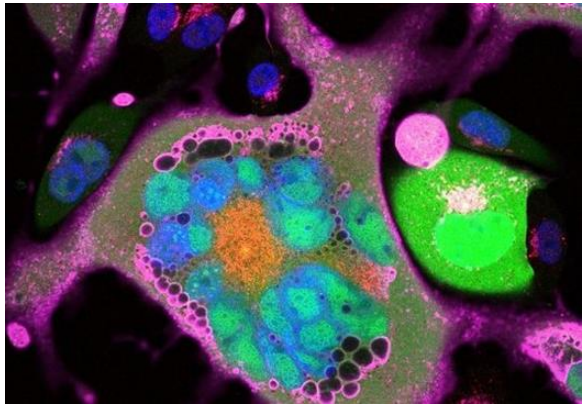
Virulence – invasion

- many pathogens spread from the initial site of infection
- pathogens can spread by producing chemicals that disrupt the host cell surface, or that induce uptake by the host cell
- invasiveness and invasion mechanisms vary among pathogens



Listeria moving within a white blood cell.
Credit: Whitehead Institute for Biomedical Research

Staphylococcal invasion of epithelial cell



Cytomegalovirus invasion of human endothelial cells
Credit: Princeton University/Joerg Schroeer

Virulence – resisting host defenses

- most microbes are eliminated by the immune system (no disease)
- pathogens can evade the immune system
- there are numerous mechanisms, e.g.
  - HIV causes fusion of host cells, enabling viral movement without exposure to extracellular host antimicrobial chemicals
  - *Haemophilus influenzae* produces a mucoid capsule that prevents capture by immune cells
  - Hepatitis B virus causes infected cells to produce 'decoy' proteins that confuse the immune system

A neutrophil (immune cell) engulfing bacterial cells (MRSA)

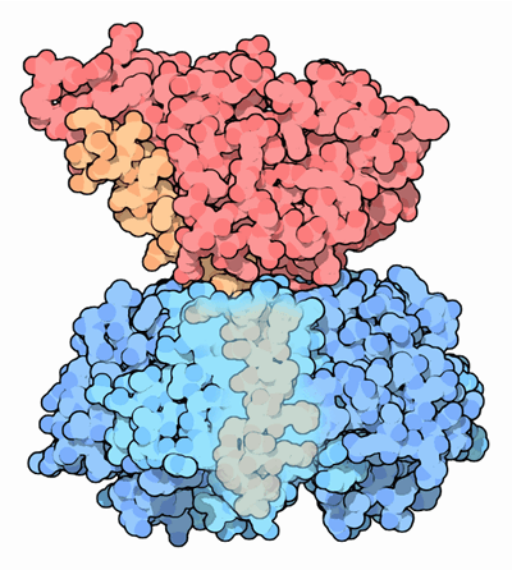
Virulence – toxins

- a toxin is a microbial product or component that injures another cell or organism
- bacterial exotoxins are secreted proteins

  e.g. tetanus toxin, cholera toxin
- fungal mycotoxins are secondary metabolites

  e.g. deliberate ingestion of toxic mushrooms

  e.g. inadvertent consumption of fungus-contaminated foods



Model of cholera toxin

Amanita muscaria

Fungi growing on coffee beans

Summary

- Infectious disease reflects a battle over resources
- Parasitism is a symbiotic interaction in which the host is typically detrimentally affected
- Infectious disease can be chronic or acute, and /or involve latency
- There are six links in the infection chain of infectious disease
- Transmission of infectious agents typically involves one of four modes
- Pathogen virulence is determined by virulence factors
- Virulence factors are predominantly associated with adherence and colonisation, invasion, avoidance of host responses and toxin formation
- The immune system has two major components: innate resistance and adaptive immune response