Microbial Diversity

A Survey of the Microbial World: All the Organisms that Microbiologists Study Plus a Few More
Typical animal cell, ~10,000 nm

Animal cell nucleus, ~2,800 nm

Bacterial cell, 1,000 nm by 2,000-3,000 nm

- Smallpox, 200 nm
- Rabies, 100-150 nm
- Influenza, 100 nm
- Adenovirus, 70 nm
- Polio, 28 nm
What Is a Microbe?

- 6 major groups studied by microbiologists
  - Prokaryotes
    - Bacteria
  - Archaea
  - Eukaryotes
    - Algae
  - Protists
  - Fungi
  - Viruses
Types of Bacterial Cell Structures and Arrangements
Actinomycetes – Filamentous soil bacteria that produce antibiotics
Alpha Proteobacteria

- Photoheterotrophs
  - *Rhodospirillum*

- Endosymbionts
  - *Rhizobium*, *Agrobacterium* in plants
    - Root nodules, plant tumors
  - *Rickettsias* in animals
    - Obligate intracellular parasites
      - Rocky Mountain spotted fever
Mycoplasmas – bacteria that lack cell walls
Gram-Positive Endospores

- Extremely heat-resistant for millennia
- Toxin-formers
  - *Clostridium*
    - Tetanus, botox, gangrene
  - *Bacillus*
    - Anthrax, Bt
- Spore forms inside mother cell
Gram-Positive Actinobacteria

- Acid-fast cell walls
  - Waxy lipids in cell wall
    - *Mycobacterium tuberculosis, leprae*

- Many form long, multicellular filaments
  - Aerial mycelia carry arthrospores
    - Wind blows spores to new sites
  - *Streptomyces*
    - Very large genome
    - Source of many antibiotics
Epsilon Proteobacteria

- Smallest group of proteobacteria
- *Helicobacter pylori*
  - Cause of stomach ulcers
  - Burrows below protective mucous layer
Spirochetes

- Flexible, narrow spiral shape
  - Flagella at ends
    - Fully enclosed within periplasm
    - Form axial filament
    - Flagellar rotation turns whole cell

*Treponema pallidum*
Chlamydiaceae

- Obligate intracellular parasites
  - Larger reticulate body
    - Grows within cells
    - Does not survive outside host
  - Small elementary bodies
    - Survives outside host cells
    - Transferred to new host
    - Similar in function to a spore
Chlamydia – Elementary bodies inside a host cell
Planctomycetes

- Multiple internal membranes
  - Double membrane surrounds nucleoid
  - Similar to eukaryotic nucleus?

Verrucomicrobia

- Irregular shape
  - Contains tubulin
  - Horizontal gene transfer from eukaryote?
Cyanobacteria

- Oxygenic Phototrophs
- Many fix nitrogen
  - Specialized cell types
- Subcellular structures
  - Thylakoids
    - Site of photosynthesis
    - Similar to chloroplasts
  - Carboxysomes-lipid bodies
  - Gas vesicles
Cyanobacteria

- Can secrete protective mucilage
- Many grow as filaments
  - Multiple cells growing in a line
- Others grow as colonies
- Many form akinetes
  - Specialized spore cells
    - Survive long periods of dessication
    - Germinate when conditions improve
Euryarchaeota: Methanogens

- 5 major orders
  - Thermophiles, mesophiles found in all orders
  - Diverse cell forms
    - Cocci, short bacilli, long bacilli, irregular
Euryarchaeota: Halophiles

- Require > 1.5 M NaCl!
  - Grow best at 4.3 M, pH 7 or basic
- Organic molecules raise internal osmolarity
- High GC content in DNA
  - Prevents denaturation in high salt
- Elongated, round, flattened shapes
Phylogeny of Eukaryotes

- Eukaryotes have greatest diversity of size
  - Cooperation of cells to make organism
- Include many smaller creatures
  - Fungi
  - Algae
  - Protozoa
    - Many groups
Fungi

- Cell walls contain chitin
  - Strong acetylated polysaccharide
    - Exoskeleton of insects
  - Cells cannot extend pseudopods
    - Must absorb food as individual molecules
      - Cannot ingest particulate food

- Secrete growth material at hyphal tips
  - Extend hyphae at tip
    - Branching forms mycelia

Microbiology: An Evolving Science
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Fungi—Yeasts

- Unicellular fungi
  - Reproduce via budding
    - Leave bud scar bud site
    - Mother cell ages, senesces, and dies
  - Reproduce asexually
    - Mitosis
      - Both in $1n$ or $2n$ forms
  - Reproduce sexually
    - Meiosis to make haploid cells
    - Haploid cells fuse
Fungi—Chytrids

- Motile germ cells
  - Flagellated zoospores
    - Haploid or diploid
  - Similar to animals, choanoflagellates
    - Flagellated reproductive form
- Associations with animals
  - Symbionts in rumen
  - Pathogens
Fungi—Zygomycetes

- Nonmotile sporangiospores
  - Spread via air or water currents
- Haploid mycelium
  - 1n sporangiospores
  - 2n zygospores
- Bread mold
- Arbuscular mycorrhizae
  - Essential for plant roots
  - Increase root absorption
Fungi—Ascomycetes

- Unfused nuclei pair before fusion
  - Mycelia form before nuclear fusion
  - Fruiting body forms
  - Meiosis generates gametes
  - Fusion of cytoplasm, not nuclei

- Bread mold
  - *Neurospora*

- Morels
Fungi—Basidiomycetes

- **Mushroom**
  - Gametes fuse, but not nuclei
  - Forms fruiting body
  - Nuclei fuse in basidium
  - Meiosis to form basidiospore, mycelium

- **Mushrooms**
- **Molds** = Ascomycete spores
- **Mycorrhizae** aid plant root absorption
Algae

- Common features
  - All have chloroplasts
  - Many have paired flagella
  - Cell wall made of glycoprotein or cellulose
  - Contractile vacuole removes excess water
  - Pyrenoid concentrates CO₂ for fixation
  - Stores energy as starch
Algae—Chlorophyta

- Green algae
  - Chlorophyll a
- Haploid, diploid reproduction
- Multiple life forms

- Individual cells—Chlamydomonas

- Filaments—Spirogyra

- Sheets—Ulva

- Colonies—Volvox
Algae—Rhodophyta

- Red algae
  - Phycoerythrin
    - Allows growth in deeper waters
  - Sulfated sugar polymers
    - Agar
  - Unicellular, filaments, sheets
Secondary Endosymbionts

- Algae engulfed by a protist
  - Algae still contains chloroplast
    - Plasma membrane of alga surrounds chloroplast
  - Cell retains protist heterotrophy
    - Chlorophyta, rhodophyta autotrophs

- Diatoms
  - Cell secretes SiO\(_2\) (quartz) shell

- Brown algae
  - Energy storage lipid
  - Kelp
Amoebozoa

- Amorphous shape
  - Lobe-shaped pseudopods
    - Actin pushes cytoplasmic streams ahead
    - Cell rolls over membrane
  - Engulf food with pseudopods

- Slime molds
  - Feed, mate as individual cells
  - Aggregate to form fruiting body
    - Aggregation signal is secreted cAMP
    - Spores released from fruiting body
Cercozoa—Shelled Amoebas

- Live in marine habitats

Radiolarians
- Amoebas with filament-shaped pseudopods
- Pseudopods stabilized with microtubules

Foraminiferans
- Shells made of calcium carbonate
Alveolates: Ciliates

- Many cilia for motility
  - Also for feeding
- Multiple copies of nuclear DNA
  - Copies in macronucleus make RNA
  - Original genome in micronucleus
- Used for meiosis, conjugation

- Paramecium
- Stentor
Alveolates: Dinoflagellates

- Two long flagella
  - One wrapped around cell groove
- Secondary endosymbiont
  - Possess a red algal chloroplast
- Extrusome secretes toxins
  - Neurotoxins
- Some are endosymbionts
  - Essential for coral survival
Alveolates: Apicomplexans

- Apical complex invades host cells
- No cilia
- Apicoplast derived from chloroplast
  - Metabolizes fatty acids
- Obligate parasites
  - *Plasmodium*—Malaria
    - Infects blood cells, liver cells in humans
      - Gives rise to gametocytes
    - Infects *Anopheles* midgut, salivary glands
      - Gametes fuse in midgut
Alveolates: Apicomplexans

**Animation:** Malaria: A Cycle of Transmission between Mosquito and Human

Click box to launch animation
Other Eukaryotic Groups

- Includes important parasites
  - Trypanosomes
    - Related to photosynthetic Euglenozoa
    - Also similar to parasitic Leishmania
    - *T. brucei*: African sleeping sickness
    - *T. cruzi*: Chaga’s Disease
  - Excavates
    - Lack mitochondria!
    - Obligate parasites
    - *Giardia*
Nucleic Acid (RNA or DNA)

Capsid

Envelope
1. Attachment

2. Penetration

3. Uncoating

4. Replication of viral nucleic acid and production of viral proteins

5. Assembly of new virus particles

7. Release
Measles viruses being shed from a host cell
Lysogenic Virus Cycle – Herpes virus
Human Immunodeficiency Virus

- Bullet-shaped capsid
  - Encloses 2 identical copies of RNA
  - Plus polymerase proteins
- Surrounded by envelope
  - Envelope proteins embedded
- Binds to receptor
  - CD4 protein
    - Immune system T cells
    - Microglia cells in brain
      - AIDS-related dementia
HIV virus (blue dots) being shed from a host cell
(-) Strand RNA Virus: Influenza

- Pandemic of 1918
  - Greatest one-year loss of life in recorded history
    - Especially deadly among college-aged
    - Get your flu shot!
  - RNA inside shell of matrix proteins
    - Inside lipid envelope
    - 2 major envelope proteins
      - Neuraminidase
      - Hemagglutinin
Bacteriophage T4

- Complicated structure
  - 170 genes
  - 10 different capsid protein types
  - Tail fibers bind host cell
    - Receptor = OmpC porin
      - Outer membrane protein
  - Long tail injects DNA
Viroids
<table>
<thead>
<tr>
<th>DISEASE</th>
<th>CAUSED BY PRIONS?</th>
<th>NATURAL HOST SPECIES</th>
<th>EXPERIMENTAL HOST SPECIES</th>
<th>INCUBATION PERIOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCRAPIE</td>
<td>YES</td>
<td>SHEEP, GOATS</td>
<td>MICE, HAMSTERS, MONKEYS</td>
<td>2 MONTHS TO 2 YEARS OR MORE</td>
</tr>
<tr>
<td>CREUTZFELDT-JAKOB DISEASE</td>
<td>YES</td>
<td>HUMAN BEINGS</td>
<td>APES, MONKEYS, MICE, GOATS, GUINEA PIGS</td>
<td>4 MONTHS TO 20 YEARS OR MORE</td>
</tr>
<tr>
<td>KURU</td>
<td>PROBABLY</td>
<td>HUMAN BEINGS</td>
<td>APES, MONKEYS</td>
<td>18 MONTHS TO 20 YEARS OR MORE</td>
</tr>
<tr>
<td>GERSTMANN-STRAUSSLER SYNDROME</td>
<td>PROBABLY</td>
<td>HUMAN BEINGS</td>
<td>APES, MONKEYS</td>
<td>18 MONTHS OR MORE</td>
</tr>
<tr>
<td>TRANSMISSIBLE MINK ENCEPHALOPATHY</td>
<td>PROBABLY</td>
<td>MINK</td>
<td>MONKEYS, GOATS, HAMSTERS</td>
<td>5 MONTHS TO 7 YEARS OR MORE</td>
</tr>
<tr>
<td>CHRONIC WASTING DISEASE</td>
<td>PROBABLY</td>
<td>MULE DEER, ELK</td>
<td>FERRETS</td>
<td>18 MONTHS OR MORE</td>
</tr>
</tbody>
</table>
PrP<sub>c</sub> and PrP<sub>Sc</sub>

43% α-helix

30% α-helix, 43% β-sheet

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Both normal prion protein (NP) and abnormal prion protein (PP) are present.

Step 1: Abnormal prion protein interacts with the normal prion protein.

Step 2: The normal prion protein is converted to the abnormal prion protein.

Steps 3 and 4: The abnormal prion proteins continue to interact with normal prion proteins until they convert all of the normal prion proteins to abnormal prion proteins.

Abnormal prion proteins
Figure 14.20

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White matter

Grey matter
Incidence of BSE in the UK

- By the end of 2003, a total of 183,803 cases of BSE had been reported in the United Kingdom and 4957 cases elsewhere: