Classification of Microorganisms
(Chapter 10)
Lecture Materials
for
Amy Warenda Czura, Ph.D.
Suffolk County Community College
Eastern Campus

Primary Source for figures and content:

Taxonomy = science of classification
1.7 million organisms identified so far estimated 10-100 million total on earth
All cellular organisms evolved from common ancestor:
- similar plasma membrane
- use ATP for energy
- use DNA for genetic storage
Observed differences due to random mutation and natural selection (Theory of Natural Selection: Darwin 1859)
All organisms organized into taxonomic categories by relatedness
Systematics / Phylogeny = study of evolutionary history and relatedness of organisms
- originally classification based on appearance: arbitrary, many taxonomic schemes introduced
- modern taxonomy based on genetic sequence information (molecular biology)

rRNA sequences show three distinct groups:
1. eukaryotes (animals, plants, fungi, protists)
2. bacteria
3. archaea (prior to sequencing, Bacteria and Archaea had been grouped together in the kingdom Monera)
rRNA sequencing (1978) led to addition of Domain category to scientific nomenclature
Gene sequencing now allows for more accurate and precise placement of organisms into the taxonomic hierarchy of relatedness
(track progression of genetic change: ancestry)

Scientific Nomenclature (binomial nomenclature)
- every organism has unique binomial that indicates the individual and its taxonomic placement among other organisms:
  Genus: noun, capitalized
  species / specific epithet: adjective
  - whole name in italics, latinized
    e.g. Homo sapien (= “man” “wise”)
  - when new organisms discovered, name must follow nomenclature rules and classify organism correctly in the taxonomic hierarchy:
    Genus = group of species that differ from each other in certain ways but are related by descent
    e.g. Canis lupus (wolf)
    Canis latrans (coyote)
    Canis aurea (jackal)
    Canis familiaris (common dog)
Taxonomic / Phylogenetic Hierarchy:
- groups based on similarities
- begins very general, becomes more restricted
- DNA hybridization and rRNA sequencing
  used to determine evolutionary relationships and thus classification of each organism

Domain
Kingdom
Phylum
Class
Order
Family
Genus
Species

E.g. You (modern humans)
Dom. Eukarya (all eukaryotes)
Kingdom Animalia (that are animals)
Phylum Chordata (with a backbone)
Class Mammalia (have hair, produce milk)
Order Primate (apes & monkeys)
Family Hominidae (great apes & human)
Genus Homo sapien (all human ancestors)
Species sapien (modern man)

- organisms are grouped together based on relatedness: very general relatedness at the top, followed by more and more specific and restricted subgroups
  genus = all related species
  species = single unique organism group

Eukaryotic Classification
-all eukaryotes = domain eukarya
-four kingdoms:
  1. Kingdom Protista ( unicellular eukaryotes)
     - algae and protozoa
     - simple eukaryotes, don’t fit elsewhere
     - nutritionally diverse: autotrophs, heterotrophs, intracellular parasite, etc.
  2. Kingdom Fungi
     - yeasts, molds, mushrooms
     - absorb organic material through plasma membrane
  3. Kingdom Animalia
     - multicellular animals
     - ingest organic food through a mouth
     - have cells organized into tissues
  4. Kingdom Plantae
     - multicellular plants
     - undergo photosynthesis to convert CO₂ + H₂O into organic molecules
     - have cells organized into tissues

Eukaryotic species = defined as a group of closely related organisms that can breed among themselves and produce fertile offspring

E.g.
- horse, donkey, and zebra are all in the genus Equus: each is different enough to be a separate species:
  - Equus caballus (horse)
  - Equus somalicus (donkey/ass)
  - Equus grevyi (zebra)
- separate species usually cannot interbreed at all, if they can offspring are sterile:
  - horse X donkey = mule (sterile)

Therefore, (repeated from above)
- a eukaryotic species is defined as a group of closely related organisms that can breed among themselves and produce fertile offspring
**Prokaryotic Classification**

-prokaryotes = two domains:

1. Bacteria
   - all pathogenic prokaryotes
   - many non pathogenic prokaryotes
   - all photoautotrophic prokaryotes
2. Archaea
   - all prokaryotes with walls that are not peptidoglycan
   - often carry out unusual metabolism and live in extreme environments
   - no kingdoms, but all other taxonomic groups
   - groupings based entirely on gene sequencing since most look similar

**Prokaryotic species** = defined as a population of cells with similar characteristics (no sexual reproduction)

Pure culture = clones, population derived from a single cell, genetically identical

Strains = cells of the same species that are not genetically identical in all ways
   - each culture or group that is slightly different is called a strain
   - each strain is indicated by a number or letter designation following the Genus species name

E.g. *Escherichia coli* - normal intestinal flora
*Escherichia coli 0157:H7* - produces a toxin all other stains do not, deadly pathogen of humans

**Viral Classification**

-viruses do not fit domain system as they are acellular
-usually only classified by Family and Genus
-usually only referred to by common name
E.g. HIV (human immuno-deficiency virus)
   - Genus = Lentivirus
   - Family = Retroviridae

Viral species = defined as a population of viruses with similar characteristics (including morphology, genes and enzymes) that occupy a particular ecological niche

-viruses are obligate intracellular parasites: they evolved to infect cells
-they usually only infect one type of cell: the one that best supports the viral replication
-thus viruses tend to be very specific about their niche:
E.g. HIV: infects only human T helper cells

**Identification of Microorganisms**

-classification into taxonomic hierarchy based on morphological characteristics, DNA hybridization, and rRNA sequencing

-identification of an unknown (but previously discovered and classified) microbe requires more specific and often combined methods

1. Morphological characteristics
   - size, shape, cellular characteristics (capsule, flagella, endospores, etc.)
2. Differential staining
   - e.g. Gram stain, Acid fast stain
3. Biochemical tests
   - probe for specific enzyme activities:
     - carbohydrate fermentation
     - nitrogen fixation
     - sulfur oxidation
     - gas production
     - acid production
     - nitrate reduction
     - etc.
4. Serology

serology = science of serum and immune responses that are evident in serum (blood plasma w/o fibrinogen)

-involves use of antibodies to detect specific microbe antigens (foreign proteins)

-used to detect proteins in samples

antibody = special protein, produced by animals, to bind to a specific target (its antigen/epitope, usually a protein)

-the immune response of an animal can produce antibodies to any molecule (antigen) that is foreign to that animal

-diagnostic antibodies can be produced to detect particular microbes:

1. inject animal with microbe
2. allow immune response (1-2 weeks)
3. harvest blood
4. purify out antibodies

antiserum = a solution that contains purified antibodies against a particular antigen (or microbe)

Antiserum to known antigens can be used to identify the antigen in an unknown sample:

A. Agglutination tests

specific antibody + its antigen = clumps (clumping = agglutination: antibody bound to antigen) e.g. blood typing
B. ELISA
(enzyme linked immunosorbent assay)
- antibody + antigen = color change
- 96 reactions at a time in microtiter dishes
- can be automated
- rapid, but risk false positives
  e.g. rapid HIV, pregnancy

False positives in serology:
- Antibodies bind only a small part of a protein; typically a shape/structure made up of only 5-8 of the total 300-3000 amino acids.
- Two unrelated proteins could, by random chance, have the same epitope (the same sequence of 5 to 8 amino acids that is recognized by the antibody).
- It is highly unlikely though that two unrelated proteins that happen to have the same epitope would also be exactly the same overall size.

C. Western Blot
- antibody + antigen = color change on blot
- more precise and accurate than ELISA;
  confirms size of antigen to rule out false positives
- more time consuming than ELISA, no automation
  e.g. HIV conformation, Lyme disease

5. Phage typing / Plaque assay
- Phage = bacterial virus
- each phage is very specific: infects only one species or even strain of bacteria
- when phage infects, it causes lysis of the bacteria
- apply known phages to a lawn of the unknown bacteria and look for bacterial cell death: clear zone = plaque
6. DNA Sequence Methods
- identify based on unique nucleotide base sequence in the chromosomal DNA

A. DNA fingerprinting/RFLP Analysis
- use restriction enzymes to cut the chromosomal DNA at specific known sequences (each enzyme specific for one sequence e.g. EcoRI cuts GAATTC)
- resulting fragments of DNA are separated by size via gel electrophoresis
- since genomic sequences vary with each species and strain, each produces a unique pattern of fragment sizes

B. PCR (Polymerase Chain Reaction)
- “DNA photocopying”
- allows tiny amounts of DNA to be replicated specifically out of a sample
- identify species or strain by DNA sequence of a particular gene, or presence of some unique gene or DNA segment

7. Nucleic Acid Hybridization
- heat DNA to separate the strands (break H-bonds between complementary bases)
- when cooled double helix will reform by complementary base pairing
- actual direct sequencing can be time consuming, not practical for large DNA
- hybridization can more rapidly determine the similarity of two sequences (for relatedness of two species)

A. Southern Blot
- probe suspect samples with single stranded, dye-labeled known DNA
- complete hybridization (exact sequence match) results in visible color
- can be performed on bacterial colonies

- heat DNA of organisms to be analyzed
- mix, cool, allow to anneal (complementary base pair)
- assess degree of hybridization
- the more hybridization, the more similar the DNA sequence, the greater the degree of relatedness
B. DNA Chips
- chip contains single stranded DNA probes (e.g. library of all viruses, library of all *E. coli* strains, etc.)
- add patient sample to chip
- binding of matching sequences causes color change
- colors detected by computer and scored for intensity
- read out indicates identity of probe that bound best (identifies matching species)

C. FISH (Fluorescent In Situ Hybridization)
- fluorescent dye labeled DNA probes are added to mixed sample (e.g. biopsy, environment sample, etc.)
- hybridization “tags” cells with that DNA sequence
- cells are observed using UV light