LECTURE 1 BIOL10003—INTRO INTO CLASSIFICATION

Reason for naming & classification—

- All life originated from a unicellular organism & natural selection and isolation of random variants lead to evolution
- Biodiversity assessment, ecological impact, management etc.
- Understand evolutionary affinities (phylogeny/groupings)
- Extrapolation of important information from closely related species

Taxonomy and systematics—

TAXONOMY (STUDY OF CLASSIFICATION):

- Common names are unreliable
    - some names were simply descriptive
- Agreed upon name for each species

SYSTEMATICS (STUDY OF DIVERSITY):

- Reveals evolutionary relationships
- Classification should reflect those relationships
- Creates a hierarchical system that organises our understanding

Linnaeus—

- Formalised use of the *binomial* (genus & species name)
- Genus name is capitalised but species name is lower case (i.e. *Homo sapiens*)
- Organisms are arranged in a taxonomic hierarchy (showed relation through genus)
    - often intermediate taxa such as subclass, subgenus, subspecies, etc.

Type specimens underlie taxonomy—

- Named species are based on a ***type specimen***
- not necessarily the best example of the species
- Physical samples deposited in places that other people can then access for comparisons:

Taxonomy codes—

- There are distinctly separate rules for the naming of algae, plants and fungi, animals, bacteria, viruses etc.
- Some common rules:

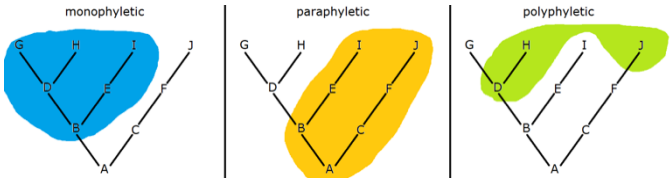
- first validly published name shall be the legitimate name
- Latin ending of the species name must be grammatically-identical to its genus name
- no two plants/fungi or animals can have the same name
- cannot name things after yourself
- have to describe the new species (originally stipulated to be in Latin)
- have to provide a type specimen

- Microscopic eukaryotes have many issues due to their size, limiting clear descriptions to distinguish between species
- Animal names may be **double-barrelled**

Issues with the code—

- Renaming, splitting or joining species is rarely received with unanimous enthusiasm by a research community
- Names have an authority (i.e. the person/people who provided the name and described the species)

Basis for biological classification—



- Closely related organisms are more similar than distantly related organisms
- Groups should be **monophyletic**
    - a single common ancestor for all members in that group
- Established on visible traits (morphology & reproductive parts)
- More recently inferred from molecular evidence (DNA, RNA, proteins and secondary metabolites)

Systematics—

- Cladistics is an approach to classification where organisms are categorised in groups (clades) based on most recent common ancestor
    - infers evolutionary relationships on the basis of ancestral and derived traits
    - identifies branch points in evolution (limited by incomplete fossil record)

Traits—

- ***Homologous*** traits have a common origin (DIVERGENCE)
- ***Analogous*** traits may result from convergence (homoplasy)
- Traits may be lost or reduced and <u>not obvious</u>

Parsimony—

- Concept of producing an outcome with the least number of steps required
    - best hypothesis is one that requires fewest evolutionary changes

Evolution—

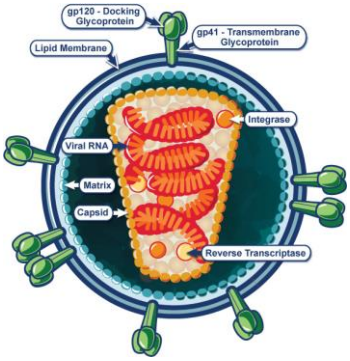
- DNA has a large amount of neutral variation ⇒ provide advantage in comparing organisms
- Character traits are under strong selection
- Neutral changes have no effect on fitness
- Most distantly related organisms have **LESS** similar DNA
    - a method to produce evolutionary relationships is based on %-divergence

Phylogeny—

- Genealogical concordance ⇒ using multiple proteins/genes to show the same relationship

LECTURE 2 BIOL10003—VIRUSES, VIROIDS, PRIONS

What is a virus—



- Non-cellular infectious agent (no organelles)
- No reproduction or energy metabolism on its own (requires a host)
- Comprised of a genome (DNA or RNA), protein capsid, enzymes and sometimes lipid membrane
- **Obligate** parasites (unculturable) ⇒ **REQUIRE host cells**
- **Virion** ⇒ complete infectious viral particle (infectious vector stage)
- **Virus** ⇒ infectious particle either inside a host cell or outside
    - viruses of bacteria are called phages

Giant viruses—

- Isolated from amoeba
- Some have larger genomes than some small bacteria

Tobacco Mosaic Virus (TMV)—

- Infectious agent causing tobacco mosaic disease passes through a bacteriological filter
- First observed under electron microscope (300 nm rods)
- **RNA is the infectious component** (as opposed to DNA)

Viral genomes—

- Can have double- or single-stranded DNA or RNA (i.e. ssDNA, ssRNA, dsDNA, dsRNA)
- RNA/DNA acts as genome encoding >4 proteins
    - Retroviruses package reverse transcriptase (e.g. HIV virus)
        - RNA is reverse transcribed into DNA
        - DNA inserted into host genome
- High mutability ⇒ genome can change rapidly to overcome immune surveillance

Protein capsid—

- Made from protein subunits (capsomeres) & is self-assembling
- Variable appearances depending on virus

Viral replication—

- Taken up by injection, endocytosis or through wounds
- Genome is released
- RNA acts as template for protein synthesis **OR** is reverse transcribed to make DNA
- DNA viruses replicate genome in host nucleus & capsid synthesis via mRNA

LYSOGENIC CYCLE:

- Virus is incorporated into host cell genome BUT does not immediately lyse host cell

LYTIC CYCLE:

- Virus lyses host cell as soon as it replicates (virulent phages)

Virus classification—

- **Baltimore system** ⇒ divided into groups depending on genetic material, replication & mRNA synthesis

Combat against viruses—

- Challenging as viruses use host cellular machinery for replication
- First use of vaccination in 1700s using cowpox virus to vaccinate against smallpox

Influenza (flu) virus—

- Zoonosis ⇒ transmission between species
    - Hemagglutinin (glycoprotein) enables entry into host cell
    - Neuraminidase (enzyme) enables exit from host cell

VIRUS CYCLE:

- **Hemagglutinin (H)** attaches to cell-type carrying sialic acid receptor
- Endocytosis triggering ⇒ virus is internalised by host cell & releases its genome
- Viral proteins are encoded & packaged and virus leaves cell using **Neuraminidase (N)**
    - viruses have specific receptors which can be targeted

NEW STRAINS OF FLU:

- Multiple different versions of **H** & **N** in different strains **(lack of fidelity)**
- Each flu virus contains one gene for **H** and one gene for **N** (on separate pieces of RNA)
- Two different strains of flu infecting one host cell exchange RNA (recombination)
    - immune system cannot recognise new combinations

Chemical treatments—

- Relenza & Tamiflu (neuraminidase inhibitors) **prevent virus exit** from infected host cells
- Emergence and re-emergence of viruses is common

- e.g. HIV, SARS, Ebola, Zika, MERS

Viroids—

- Smallest infectious particle (1/1000 size of virus)
- Single circular strand of naked RNA molecules (do not encode protein) yet replicate autonomously when introduced into host plants
- Require host cell DNA-dependant RNA polymerase to replicate
    - one human example
    - cause stunting of growth, deformation of leaves & fruit, stem necrosis, death in plants

Prions—

- Proteinaceous infectious particles (no nucleic acid)
- Variant protein fibrils (clumps) may infect nervous system
    - unknown pathogenesis
- PrP & PrP^{Sc} are chemically identical **BUT structurally different**

Mode of action—

- PrP^{Sc} when mixed with PrP causes conversion to PrP^{Sc} (chain reaction) in infected animals
- PrP^{Sc} forms insoluble plaques in brain

MAD COW DISEASE:

- Cattle fed bodies of sheep and other cows (some contaminated with PrP^{Sc})
- Conversion of PrP to PrP^{Sc} (spongiform encephalitis)
- People ate brains/CNS of cows (induced CJD)

KURU:

- Brain disease (prion) linked to ritual practice of eating brains of deceased relatives

LECTURE 3 BIOL10003—PROKARYOTES

Three domains of life—

- Conduct glycolysis
- Replicate DNA semi-conservatively
- DNA encodes proteins
- Uses transcription & translation
- Surrounded by a membrane

- **Bacteria & Archaea are prokaryotes**

Lack membrane-bound nucleus, organelles and cytoskeleton (internal structures)

- Different cell walls, ribosomes and rRNA sequences
- May be heterotrophic or autotrophic
- Represent early life forms

Ancient Prokaryotes—

- Chemoautotrophic
- Photosynthetic but anoxygenic
    - environment was hot, saline & high UV (no ozone)
- Oxygenic bacteria (cyanobacteria) appeared ~3.5 bya
    - contain chlorophyll—photosynthetic
    - created O_2 atmosphere
- Prokaryotes changed ancient inorganic environment
    - atmospheric oxygen
    - organic carbon
    - nitrification
    - sulfur metabolism
- Most are saprophytes or symbionts
- **Few bacteria are pathogenic** (no report of Archaea)

Archaea—

- Small genomes
- Unique membranes

- bacterial/eukaryotic phospholipids have ester bonds and use stearic acid
- archaeal phospholipids have ether bonds and use phytanol

- Extremophiles due to composition of cell wall (ether bonds; tolerance)

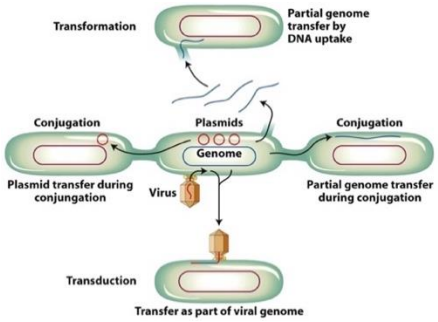
Halobacterium halobium:

- Lives in hypersaline water
- Membrane ruptures below 1.5 M NaCl
- Captures light energy **WITHOUT** any form of chlorophyll
- **Facultative phototroph** (does not photosynthesise by necessity)

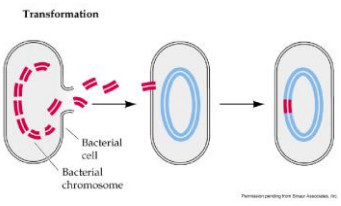
Domain Bacteria—

- Differ from Archaea
  - cell wall structure (peptidoglycan)
  - membrane lipids (ester-linked)
  - sensitivity to toxins and antibiotics
- Gram-positive walls have more peptidoglycan
- Gram-negative have thin peptidoglycan layer and have a capsule

Reproduction—

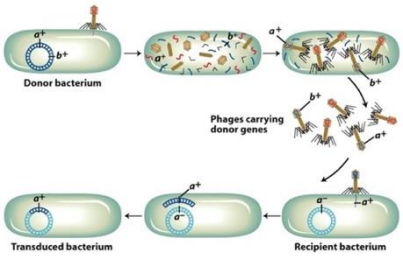


- Binary fission (asexual)
- Spores produced by some species (no meiosis)
- Genetic diversity achieved by;
  - ***mutation***
  - ***conjugation (bacterial sex)***
    - **partial** transfer of metabolic, resistance & fertility genes by mating
    - unidirectional exchange of DNA (F^+ strain transfers information directly to F^- strain)
  - ***transformation (DNA uptake)***
    - partial genome transfer by DNA uptake after bacterial cell dies
    - DNA material degraded into small fragments
    - DNA fragment which recombines into the cell genome (new phenotype)



  - ***transduction by phages***

- accidental packaging of donor DNA into the phage (virus) which infects recipient bacterium
- donor DNA incorporated into bacterium genome (transduced)



Bacterial diversity—

- Coccus (spheres)
- Bacillus (rods)
- Filament

CYANOBACTERIA:

- Single-celled or filaments
- Photosynthetic, may fix nitrogen
    - precursor of plant chloroplasts
- Have specialised cells

SPIROCHETES:

- Cork-screw shaped
- Internal flagellum (axial filaments)
- Cause Lyme diseases and syphilis

MYCOPLASMAS:

- Smallest known cells (200nm) & genomes (600,000 bases)
- Lack cell walls
- Parasites or commensals & cause pneumonia in humans

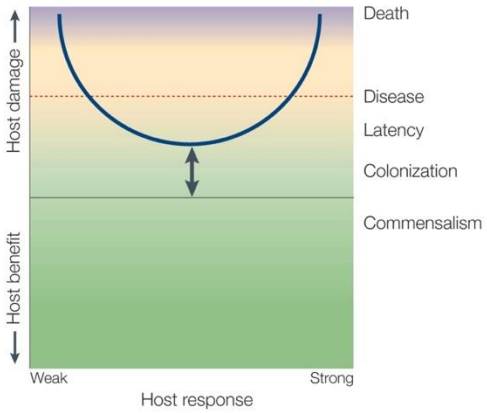
PROTEOBACTERIA:

- Gram-negative rods
- Metabolically diverse (photosynthetic, fix nitrogen)
    - precursors of mitochondria
- Several pathogens (plague, salmonella, cholera) & gut commensals (E.coli)

ACTINOMYCETES:

- Often filamentous and branched
- Soil decomposers & source of many antibiotics
- Some pathogenic (includes TB pathogen)

Bacterial pathogenesis—



- Poor immune system & a microbe strong enough can cause death in patient
- Healthy immune system & a microbe strong enough can form **commensal interaction**
- Strong immune system & microbe provokes such a strong response the host is damaged
    - favourable pathogen
    - susceptible host
    - virulent pathogen

Diphtheria—

- Highly contagious respiratory disease
- Prevented by vaccination
- Infection leads to inflammation & formation of pseudomembrane on pharynx
    - exotoxin is disseminated in blood stream where it can cause damage to the heart, kidneys or NS
    - toxin inhibits protein synthesis
- Bacteria containing the prophage β can produce diphtheria toxin
- AB subunits
    - B domain attaches to heparin-binding epidermal growth factor receptor on host cells
    - cleaved A subunit is active, attaches ADP-ribose to EF-2
    - single molecule of A subunit can inhibit all the EF-2 in a cell, blocking protein synthesis and leading to cell death
    - specifically targets the unique modified histidine, diphthamide, in EF-2

TUBERCULOSIS:

- Some *Mycobacterium* species are free-living saprophytes (others are animal pathogens)
    - *M. bovis* causes tuberculosis in cattle $\Rightarrow$ transmitted to humans
- No toxins, slow growing & slow to progress (may enter a latent state)
- Produces mycolic acids (hydrophobic) that protect against antimicrobials, host defences, pH changes

- Inhibits fusion between phagosome and lysosome

LEPROSY:

- *Mycobacterium leprae*
- Human-specific and unculturable, lepers were isolated from society
- Transmission is air-borne & has long onset before development of symptoms
- Affects nerves, mucous membranes, eyes & testicles

Streptomyces pharmaceuticals—

- Streptomycin was first drug effective against tuberculosis
- 2/3 of all antimicrobial agents used today derive from *Streptomyces* species