LSM1301
GENERAL BIOLOGY

Biodiversity

Dr. Nalini Puniamoorthy

nalini@nus.edu.sg

Learning objectives

- To define **biodiversity** and list characteristics for the different domains of life
- To describe the various **species concepts** and their limitations
- To describe the **modes of speciation** and isolating mechanisms that restrict gene flow
- To describe how organisms are identified using the **binomial naming system** and are classified using the Linnaean hierarchy
- To interpret **evolutionary relationships** in phylogenetic trees, and distinguish between ancestral and derived traits

Learning activities

- Pre-lecture
  - Watch videos on Tree of Life (5min) and taxonomy crash course (11min)
  - Take down notes and refer to lecture slides.

- Post-lecture
  - Take ungraded quiz to revise lecture material

    (LumiNUS > Quiz > "Biodiversity"

Outline

- Why study biodiversity?
- Species
  - Species concepts
  - Speciation and extinction
- Taxonomy
  - Naming species
  - Linnaean classification
- Phylogenetics
  - Cladistics and cladograms
  - Phylograms
- A quick tour of the Tree of Life

Biodiversity

- Short for “biological diversity”
  - ➢ Refers to the whole range of life on earth
  - ➢ Includes different organizational levels, genes, individuals, populations, ecosystems

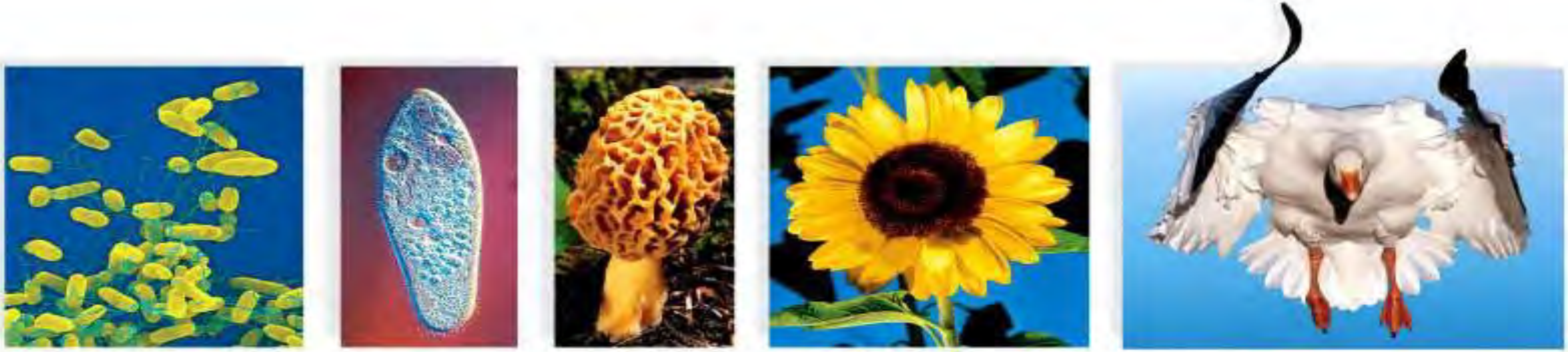


How many species are there?

- ➢ Around 2 million species have been described
- ➢ Estimates given that there are 7-100 million species in total

Biodiversity

- 7,000-10,000 new species are described annually
- Tropical rain forests are believed to be home to two-thirds of the world's existing species, most of which have yet to be named



Bacteria   *Paramecium*   Morel   Sunflower   Snow goose

Biodiversity

To understand biodiversity, we must:

- Define – determine what is a species
- Identify – give each species a unique name
- Classify – put it into a group with similar organisms
- Connect – show the evolutionary relationships

Systematic Biology

- The study of classification
- Two subfields:
  - Taxonomy – science of describing, naming and classifying species
  - Phylogenetics – the science studying evolutionary relationships among species

Why study biodiversity?

1. Economic – food, fuel, leisure, pharmaceutical, tourism
2. Ecological – ecosystem service and climate regulation
3. Scientific – to increase knowledge

Scientists working on material during Expedition Panglao Philippines, photo by Dr Tan Swee Hee

Fishes for sale at seafood market in Thailand

Economic role of biodiversity

Harvesting biodiversity for food, timber and fuel



Economic role of biodiversity

Creating better agricultural yields

- 80% of food sources derived from only 20 plant species (wheat, sugar cane, rice, potatoes, maize)

Monocultures lead to disease susceptibility

- Irish potato famine, US corn leaf blight epidemic

Greater gene pool allows for greater variety

- Wildtypes introduced to cultivars to obtain improved varieties (higher yield, better resistance)

Economic role of biodiversity

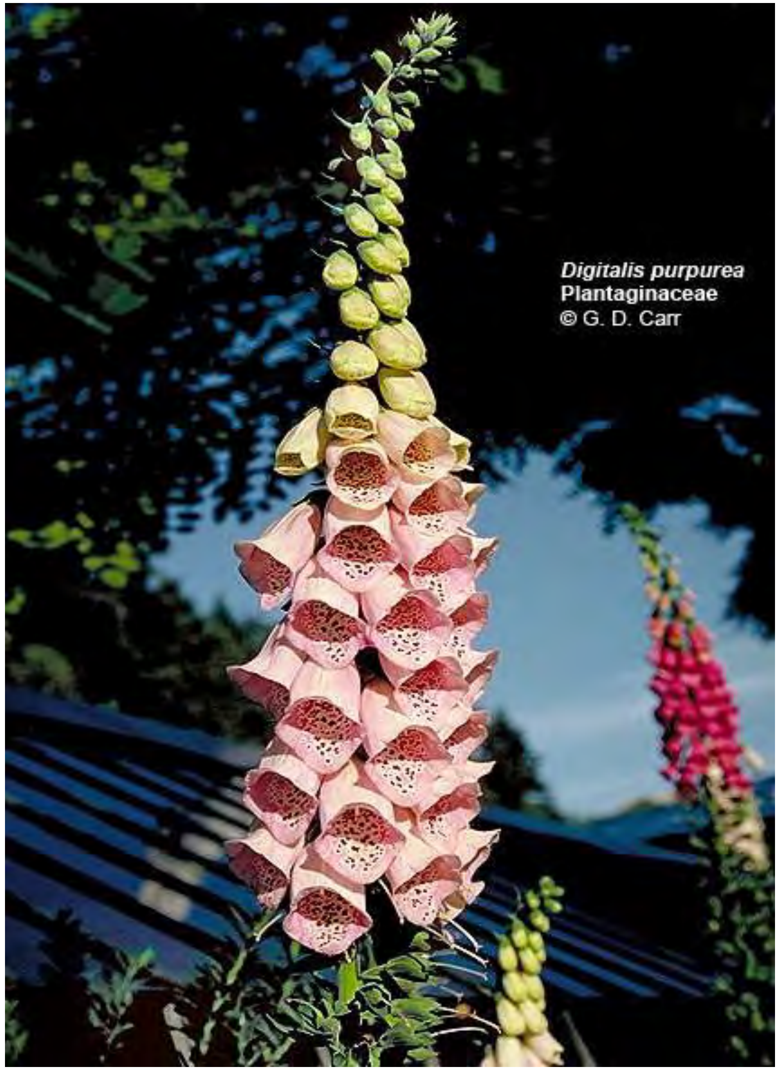
Bio-prospecting

- Extracting active compounds for medication

40% of medicinal compounds from nature

- Tamiflu vaccine - Chinese star anise extracts
- Digitalin (heart conditions) – Foxglove
- Vincristine (childhood leukemia) - Periwinkle

Figure 39-2 Biology: Life on Earth, 8/e



Economic role of biodiversity

Recreation

- Ecotourism is an expanding industry worldwide

Figure 30-4a Biology: Life on Earth, 8/e

Figure 30-4b Biology: Life on Earth, 8/e

Figure 30-4c Biology: Life on Earth, 8/e

Ecological role of biodiversity

Diversity of species and genes affects the functioning of ecosystems which affects ecosystem services

- Removal causes ecosystem collapse – overharvesting of timber and food
- Unchecked internal/external pressures cause ecosystem collapse –widespread bleaching of coral reefs in Indian and Pacific Oceans (2010): coral mortality > 50%.

Figure 30-6a Biology: Life on Earth, 8/e

Ecological role of biodiversity

Diversity of species and genes affects the functioning of ecosystems which affects ecosystem services

- Processes through which natural ecosystems sustain human life
- Air & water purification, replenishment of oxygen, pollination of flowers, dispersal of seeds, provision of wildlife habitats, waste decomposition, erosion and flooding control, pest

Aceh in the wake of the Indian Ocean Tsunami in 2006

New Orleans in the wake of Hurricane Katrina in 2005

Ecological role of biodiversity

Ecological effects of biodiversity in turn affect climate change

- e.g. enhanced greenhouse gases, aerosols and loss of land cover, and biological diversity

Rapid loss of ecosystems causes extinctions of species

Home › News › Feature Series › Ecosperity 2017: Tomorrow Starts Today

Why biodiversity loss is scarier than climate change

Much progress has been made at working out how much climate change will cost humanity. Less is known of the value of biodiversity. This is essential to safeguarding the environment and mankind, argues the head of WWF.

Sumatran tigers on the prowl are scaring residents in Riau province of Indonesia who have fled their homes due to spreading forest fires. Reports show there are only about 400 Sumatran tigers left in Indonesia due to rampant deforestation. Image: Shutterstock

Ecological role of biodiversity

South East Asian biodiversity crisis

Low graphics | Accessibility help

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SE Asia faces 'catastrophic' extinction rate

By Alex Kirby
BBC News Online environment correspondent

The rate of extinction threatening to engulf south-east Asia this century could be a "catastrophic" 20%, scientists say.

They base their warning on the example of Singapore, where key habitats have shrunk by 95% since 1819.

We expect more and more species will go downhill
Caroline Pollock, IUCN

The scientists say it is the unprecedented rate of habitat loss that now threatens so many species.

South-east Asia is one of the Earth's most important biodiversity "hotspots".

The scientists, from Singapore, Japan and Australia, report their findings in the journal Nature.

They found "substantial rates of documented and inferred extinctions, especially for forest species", with butterflies, fish, birds and mammals all affected.

The authors say: "Observed extinctions were generally fewer, but inferred losses often higher, in vascular plants, phasmids (stick and leaf insects), decapods (crustaceans), amphibians and reptiles.

Global impact

"Forest reserves comprising only 0.25% of Singapore's area now harbour over 50% of the residual native biodiversity."

SEE ALSO:
- World 'losing battle against extinctions' 21 May 03 | Science/Nature
- Extinction threat to ancient plant group 04 Jul 03 | Science/Nature
- Wake-up call on extinction wave 19 May 03 | Science/Nature
- Species face tough fight for survival 07 Oct 02 | Science/Nature

RELATED BBCi LINKS:
- The Extinction Files

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Urgent call for Singapore to help safeguard region's biodiversity

The Sunda pangolin, the only species of pangolin native to Singapore, is among critically endangered land and freshwater vertebrates in South-east Asia which are getting emergency conservation attention. PHOTO: WILDLIFE RESERVES SINGAPORE

PUBLISHED MAY 8, 2019, 5:00 AM SGT | UPDATED SEP 3, 2019, 9:14 AM

Longest coral bleaching in Singapore caused by warming seas

by Martha Soezean   Posted 24 Oct, 2016   in Environment   3 MIN READ

TODAY Singapore   MENU

Explainer: Why rapid extinction of plant, animal species matters

By DARYL CHOO

Andrey Armyagov/Shutterstock.com

Hawksbill turtles, a critically endangered species, in the Indian Ocean coral reef, Maldives.

Scientific role of biodiversity

To increase our knowledge and understanding of the natural world





Expedition Panglao Philippines, photo by Dr Tan Swee Hee

Why study biodiversity?

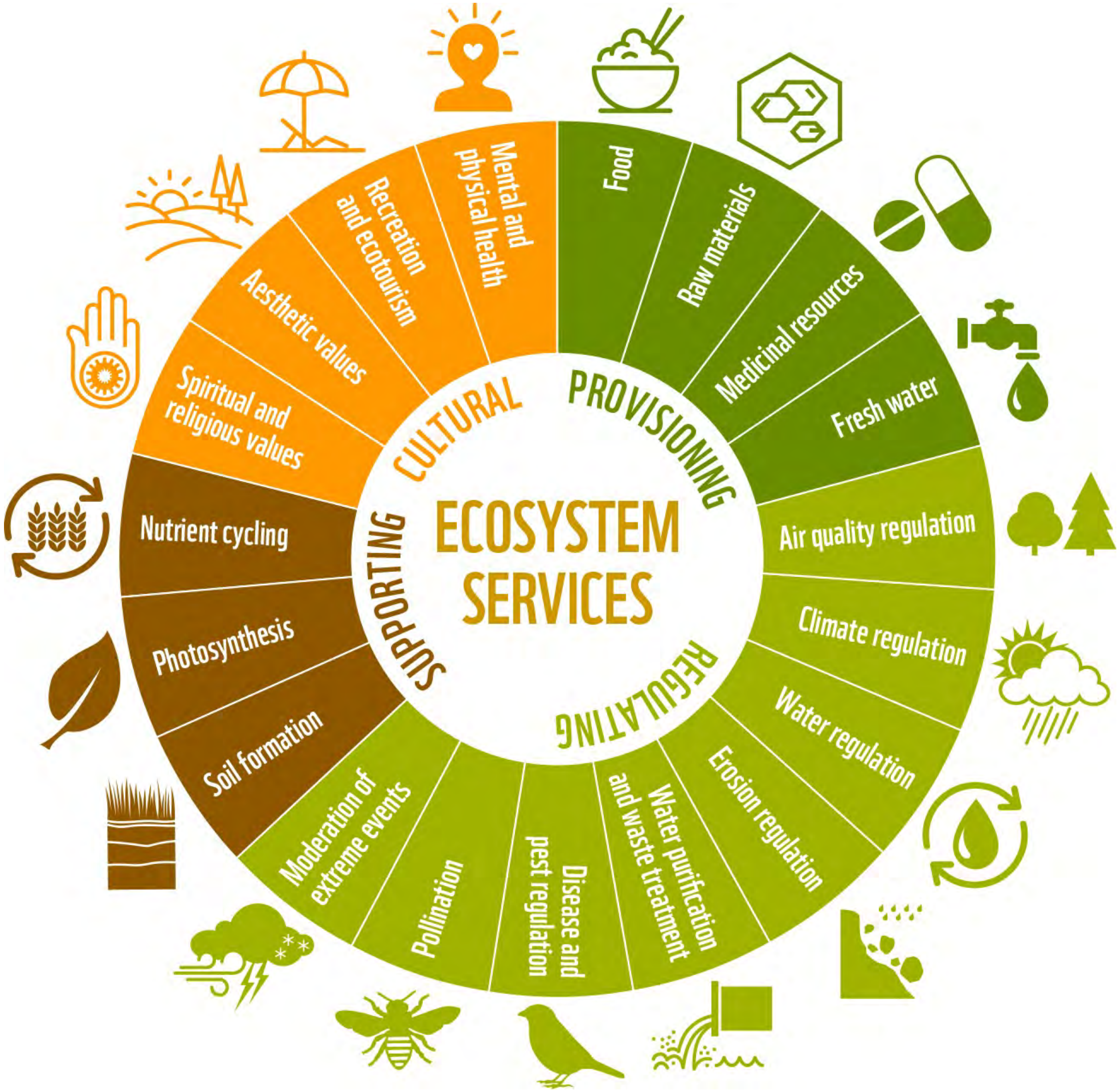
Essential to processes that keep the planet habitable for humans

- e.g. water and carbon cycle, soil formation

Human societies are dependent on properly functioning ecosystems

- Benefit industries such as agriculture, fisheries, pharmaceuticals, veterinary and human medicine
- Increases psychological well-being

Information is needed to be able to monitor and conserve species and environments



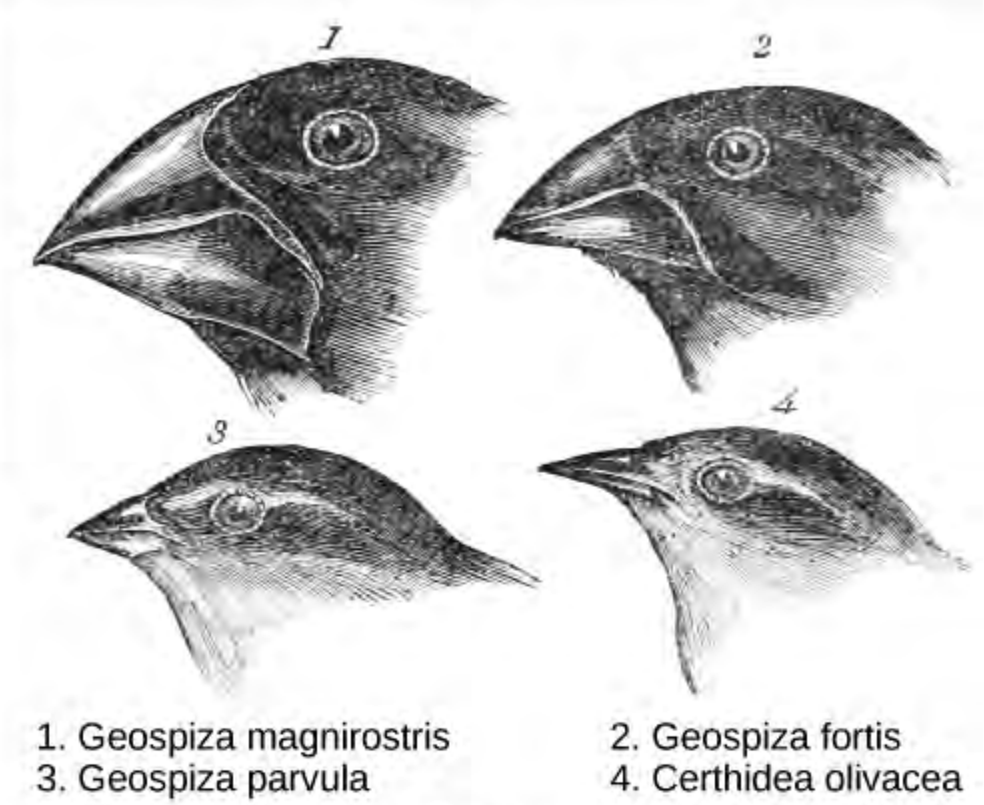
Biodiversity loss threatens ecosystems as well as human development

WWF's Living Planet Report 2018

What are species?

“*No one definition* [of species] *has as yet satisfied all naturalists; yet every naturalist knows vaguely what he* [or she] *means when he* [or she] *speaks of a species*”

- C. Darwin



Finches from Galapagos Archipelago

What are species?

Types or kinds of organisms

- Arise from existing ones through evolution

Species are a **human** concept

- Define species for our purposes
- To be able to identify groups of organisms as being unique
- To have a standard point of reference

Species concepts

Morphological species concept (MSC)

- Earliest definition
- Defines species as organisms sharing distinct anatomical features that distinguish them from others
- Based on a "type specimen"
  - First individual named and described
  - Collected and deposited in a museum
  - Used as a standard for comparison

Species concepts

Problems with MSC

- Wide variation in appearance in the same "species"
- However, type specimens are still used in museums because they are convenient for comparisons

Species concepts

Biological species concept (BSC)

- Defines species as organisms that can breed with each other in the wild and produce fertile offspring
- Reproductive isolation occurs when there is a lack of gene flow and genetic changes accumulate until interbreeding is not possible
- Reproductive barriers classified as pre-zygotic or post-zygotic (before or after a zygote is formed)

Species concepts

Problems with BSC

- Excludes artificial breeding by humans
- Only applies to sexually reproducing organisms
    - Bacteria reproduce asexually

- Mating can occur in closely related organisms – has been observed both in captivity and in nature
    - e.g. mules (donkey+ horse), zorse, liger, *Helianthus anomalus*, ring species

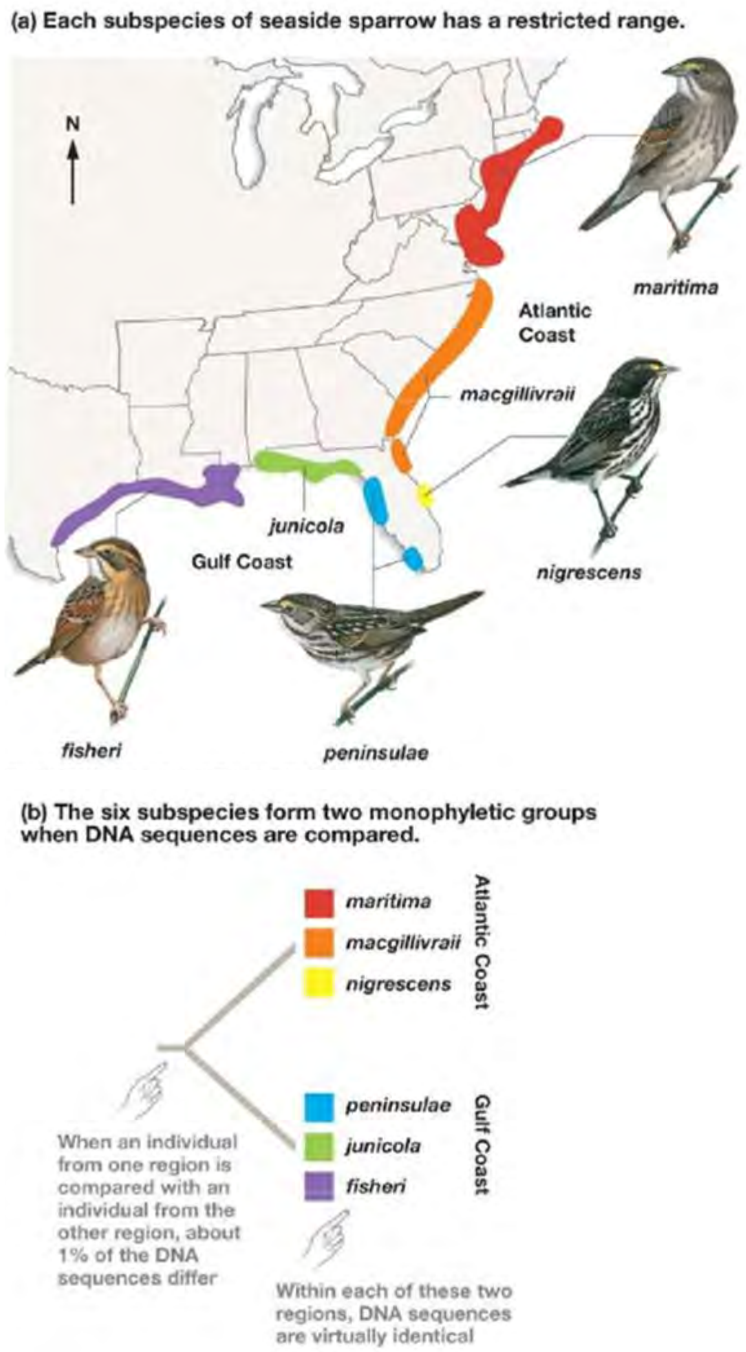
Species concepts

Phylogenetic species concept (PSC)

- A species is the smallest group with a distinct evolutionarily lineage that can be distinguished from others
    - Share a **common ancestor**
- DNA sequence information usually used to distinguish differences between populations

Problems with PSC

- Level of difference to separate species not well defined

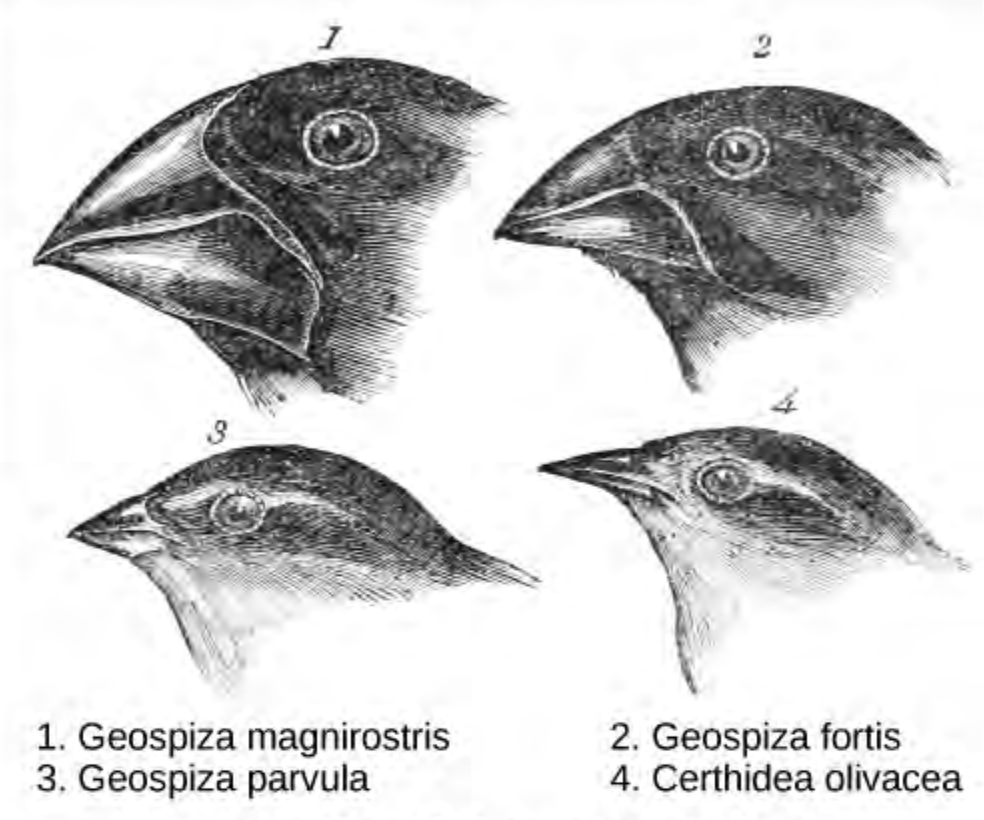


Species concepts

*"I find any discussion about species concepts irrelevant, because these concepts are **human inventions** and only invented because of our anthropogenic desire to put everything into a neatly organized system…*

For birds themselves (or any other organisms) this does not matter."

\- Peter de Knijff



Finches from Galapagos Archipelago

Species concepts

No universal species concept

- **BSC commonly used**
- Species are a moving target since they are evolving
- Many possible levels to which we can distinguish populations
  - Some researchers designate ‘subspecies’
- With modern techniques, DNA sequences can be compared and researchers determine threshold for considering species separate

Useful to consider multiple sources of evidence

Speciation

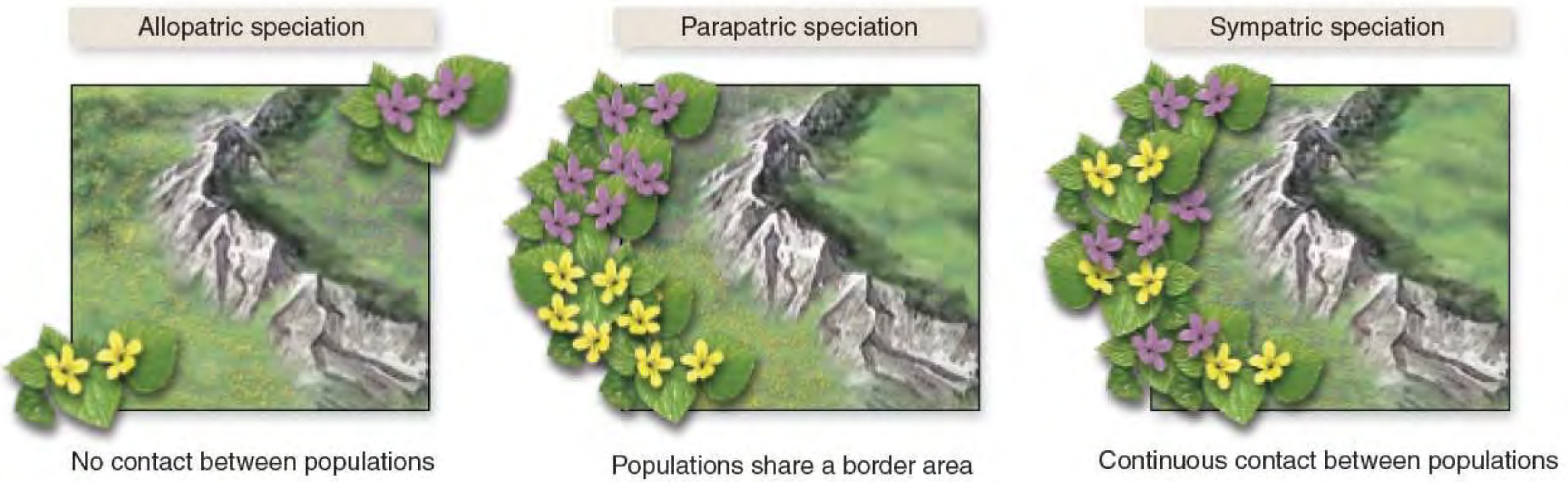
Habitat isolation;
Temporal isolation;
Mechanical isolation;
Behavioural isolation;
Chemical isolation etc.

Formation of new species through **reproductive isolation**

BARRIERS TO GENE FLOW

Three modes of speciation defined by spatial pattern

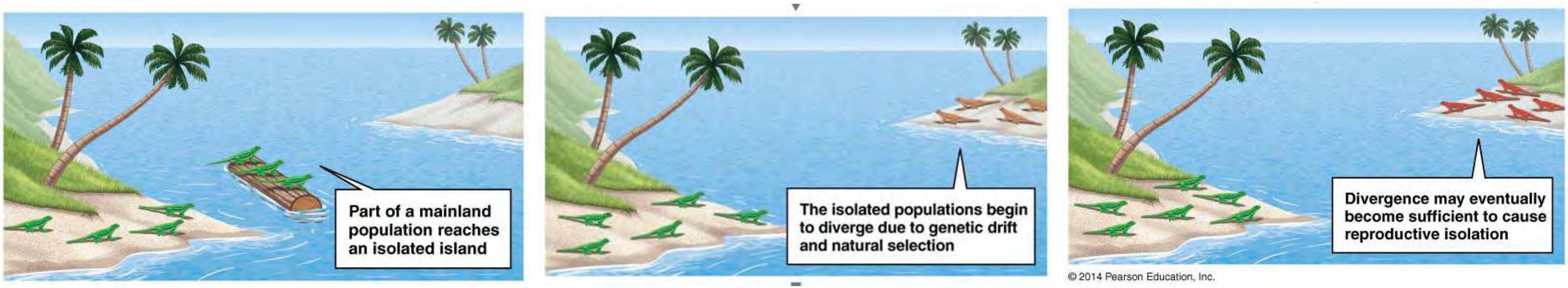
- Allopatric – no contact between populations
- Parapatric – populations share a border area or a cline
- Sympatric – continuous contact between populations



Speciation

Allopatric speciation

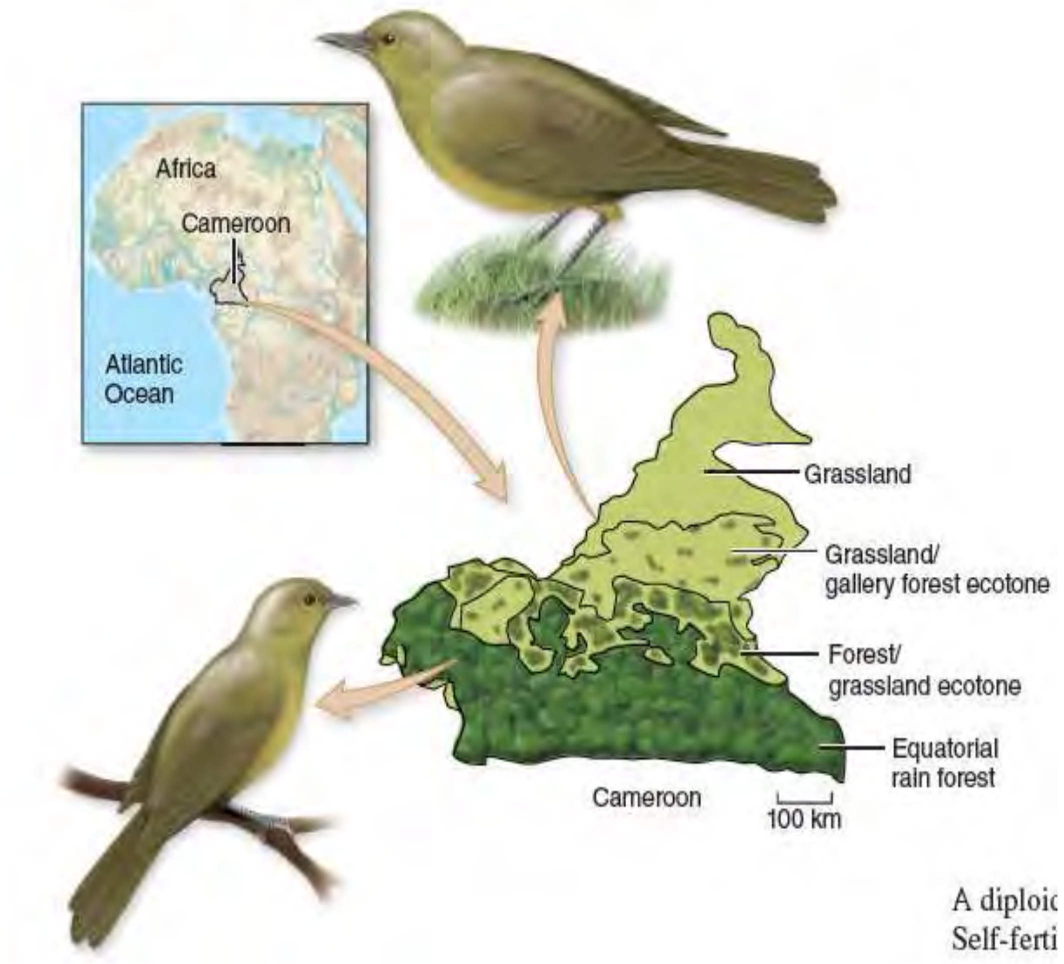
- A barrier physically separates a population into two groups that cannot interbreed
- With no gene transfer between the two populations, each proceeds down its own evolutionary line



Speciation

Parapatric speciation

- Part of a population enters a new habitat bordering the range of the parent species
- Expanding population evolve traits that suit the bordering habitat
- Mating can occur between populations, but most individuals mate within their own population

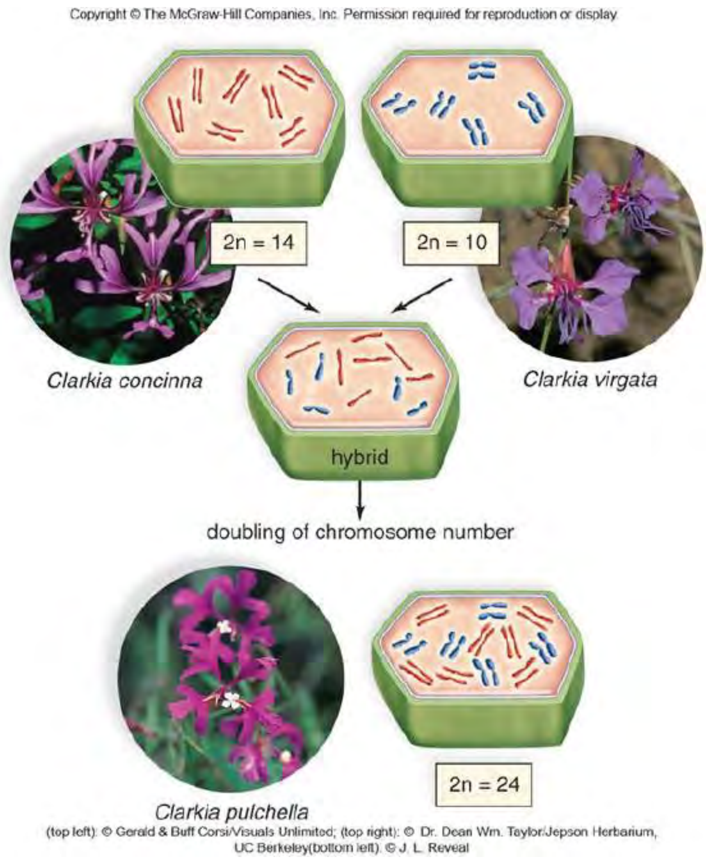


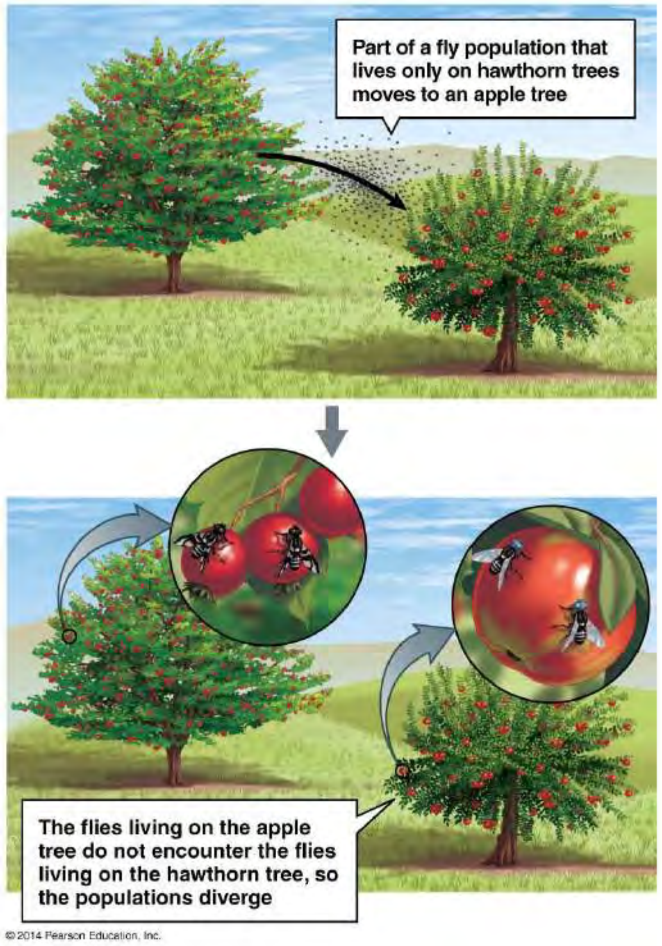
Speciation

Often involves non-random mating

Sympatric speciation

- Populations diverge genetically while sharing a habitat
- Seen to occur in 2 ways:
  - Each species specializes in a unique micro-environment, leading to reproductive isolation
  - Hybridization of 2 species form polyploid offspring with more chromosomes than either parent





Extinction

Extinction is a natural process

- Five mass extinctions in the past
- Fossil record shows that species diversity has been increasing but not steadily
- Periods of high speciation as well as extinction

Species existing today may represent only 2-4% of all species that ever existed

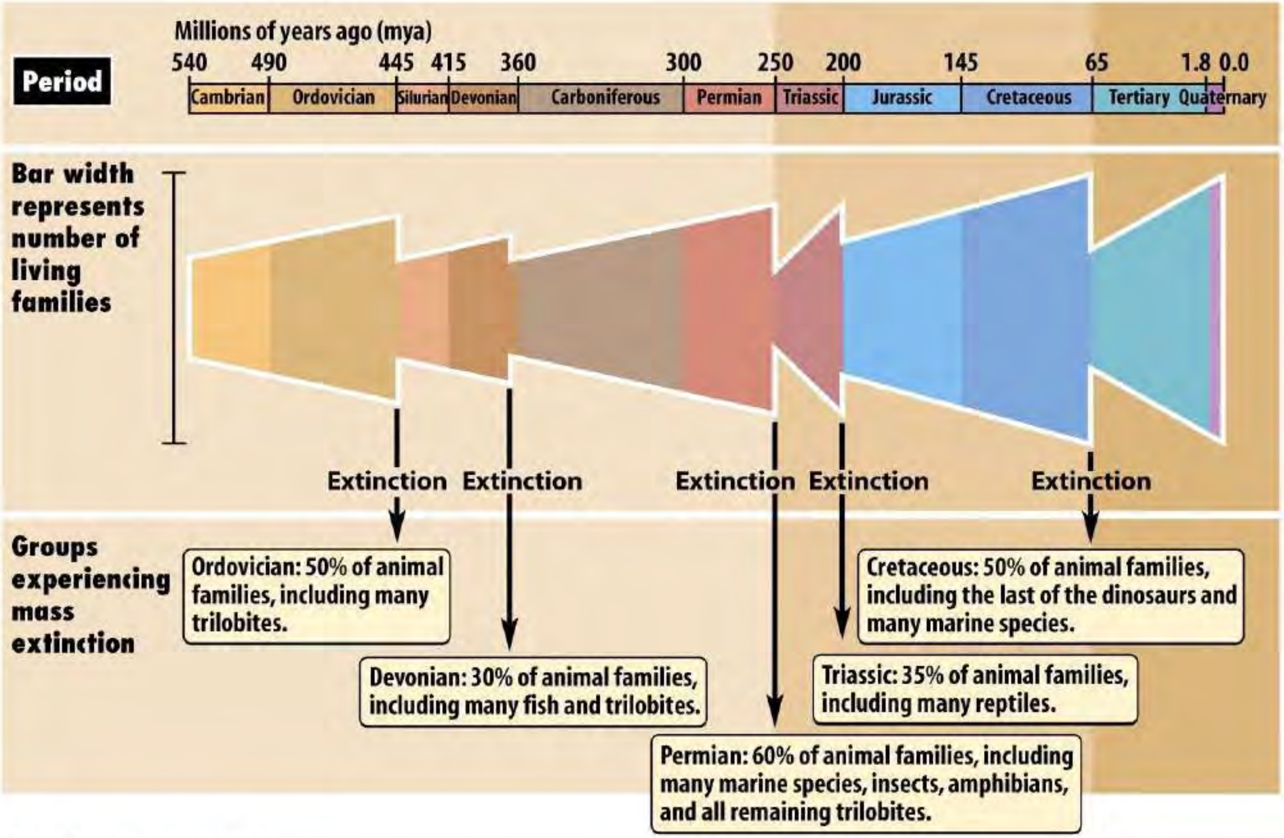


Figure 19-8 Discover Biology 3/e

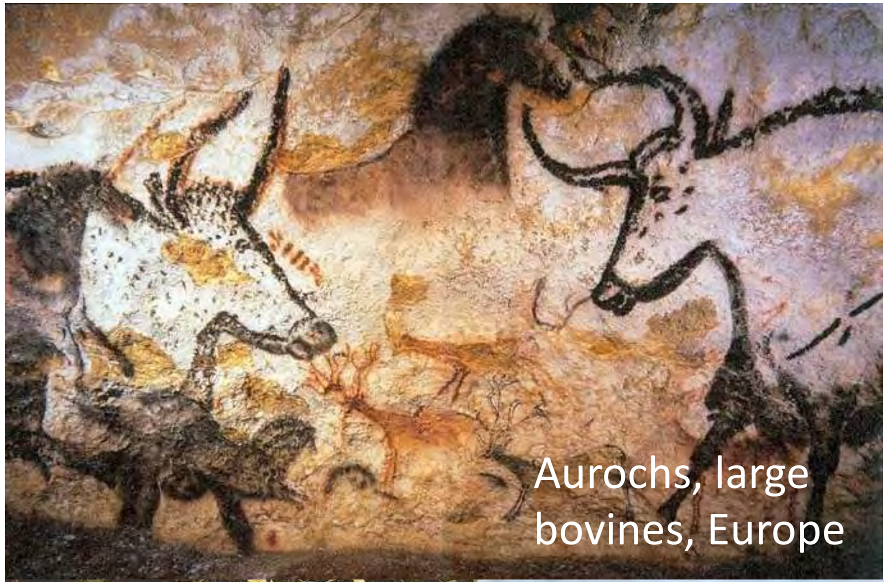
Extinction

Humans have been linked to extinctions in since pre-historic times

- Elimination of megafauna (terrestrial animals >44kg) from different continents roughly corresponds to time of colonization by humans

Possible 6th mass extinction in modern times

- >800 species extinct in the last 500 years
- Estimate >50% of all species will go extinct in the next 500 years



Aurochs, large bovines, Europe

Megalonyx , giant sloth, N America

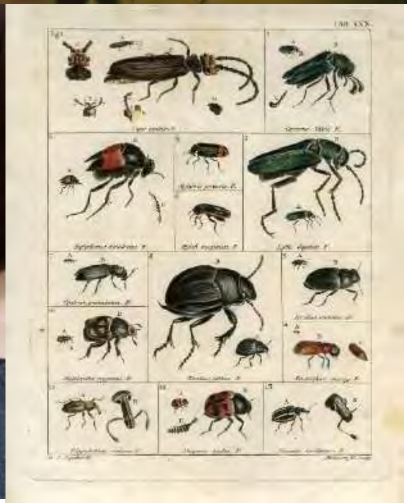
Moa, giant bird, New Zealand

Taxonomy

Taxonomy is the science of

- Identifying, describing and naming species
- Classifying species into hierarchal groups based on similarities to others
- Classical approach used the morphological species concept
- Modern taxonomists also use molecular tools



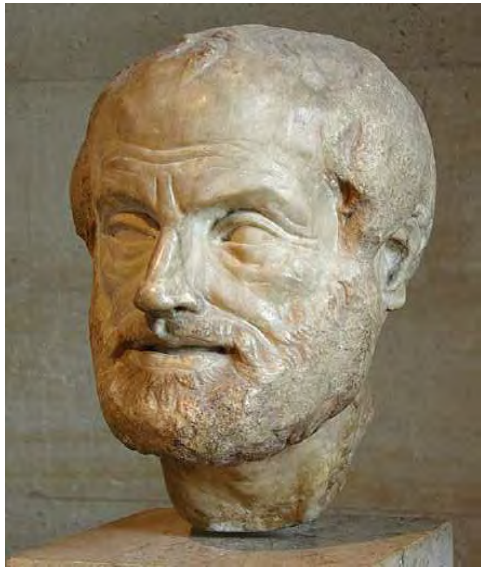



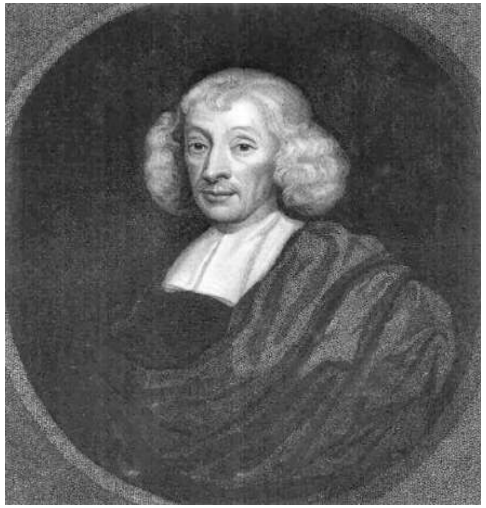
The science of naming organisms

Taxonomy is a branch of biology concerned with classifying, identifying and naming of organisms

Began with the ancient Greeks and Romans

- Aristotle classified organisms into groups such as horses, birds, and oaks
- John Ray, English Naturalist (1627–1705)
  - Believed that each organism should have a set name
  - Otherwise, “men…cannot see and record accurately.”





The science of naming organisms

In the Middle Ages, organisms had long Latin names (complicated/confusing) for example

- E.g. Dog Rose was known as:

  Rosa sylvestris alba cum rubore folio glabro

  (pinkish white woodland rose with hairless leaves)

  Or

  Rosa sylvestris inodora seu canina

  (odorless woodland dog rose)

How does one know if these names refer to the same organism?

Dog Rose

hg p://upload.wikimedia.org/wikipedia/commons/3/32/Divlja_ruza_cvijet_270508.jpg

The science of naming organisms

Many systems were proposed over time

First internationally recognized and adopted system was proposed by :

- Carl Nilsson Linnaeus (1707–1778)
  - Laid the groundwork for modern biological classification
  - Universality, practicality
  - Linnaeus proposed a hierarchical, binomial system where each species has a unique combination of Latin paired names which provides ancestry

Taxonomy

Carolus Linnaeus

- Swedish botanist who developed the scientific naming system still in use today
- Unique binomial name for each species
- Taxonomic hierarchy of classification
- Rules set and standardized by scientific associations

International Commission on Zoological Nomenclature
standards, sense, and stability for animal names

INTERNATIONAL ASSOCIATION FOR PLANT TAXONOMY

iapt

Naming species

What is this organism?

- Common names

Aubergine (French, English)
Eggplant (USA, Canada)
Brinjal (English)
Melanzana (Italian)
Melongena (16th-century Arabic name)
Berenjena (Spanish)
Terung (Bahasa Melayu)
Terong, Encung, Tiung (Bahasa Indonesia)
Kathiri-kai, கத்திரிக்காய் (Tamil)
Makhua-chan, -khao, -yao (Thai)
Talong (Tagalog)
Cà ~m (Vietnamese)
茄子 (Mandarin)
ナス (Japanese)
가지 (Korean)

Naming species

What is this organism?

- Scientific name
  - *Solanum melongena*

Naming species

Common names

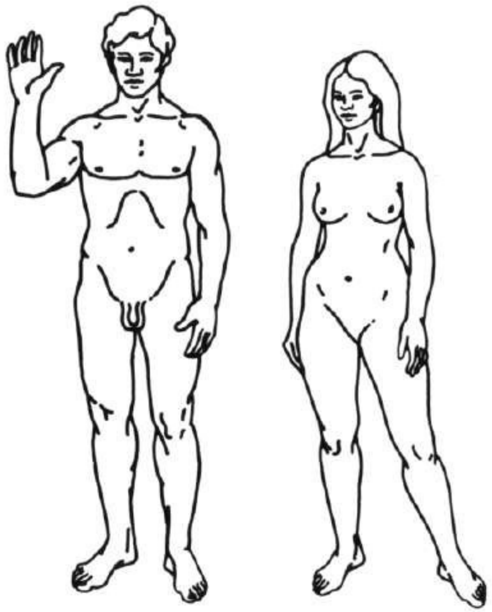
- Imprecise, can lead to confusion
  - One organism can have many names (synonyms)
  - One name can apply to many organisms (homonyms)

Scientific names

- Advantages: Each name is unique, no homonyms or synonyms
- Disadvantages: Difficult to remember and pronounce
  - Usually in Latin, Greek or other ancient language

What's in a (scientific) name?

Year description published



Homo sapiens Linnaeus, 1758

Generic Name or Genus
(*italicised* or underlined; first letter capitalised)

Specific Epithet or Species name
(*italicised* or underlined)

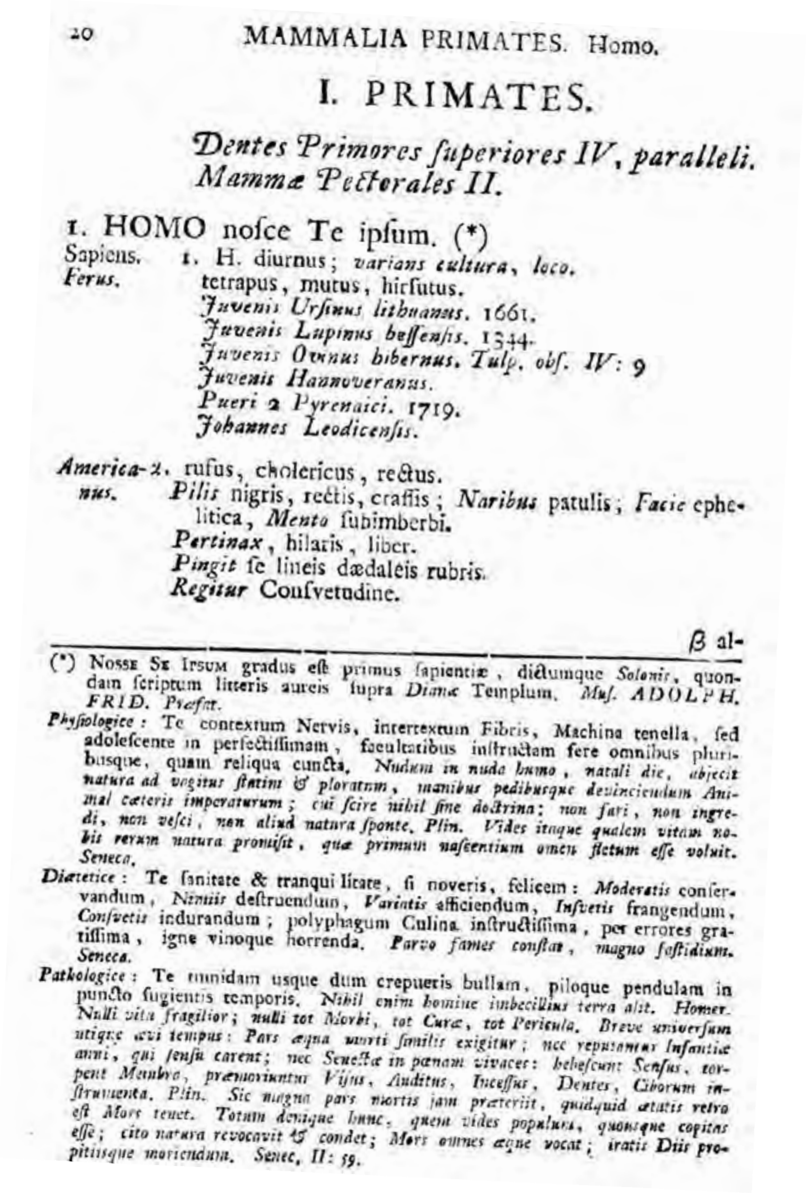
the author of the name (not italicized or underlined)

Etymology: Latin "homo", man + "sapiens", wise

Naming species

All named species have been formally described in a peer- reviewed publication

- Detailed description
- Identify what features make it unique
- Compare with other species that it is closely related to



20 MAMMALIA PRIMATES. Homo.

I. PRIMATES.

Dentes Primores superiores IV, paralleli.
Mammæ Pectorales II.

1. HOMO nosce Te ipsum. (*)

Sapiens. 1. H. diurnus; *varians cultura, loco.*
Ferus. tetrapus, mutus, hirsutus.
Juvenis Ursinus lithuanus. 1661.
Juvenis Lupinus hessensis. 1344.
Juvenis Ovinus hibernus. Tulp. obs. IV: 9
Juvenis Hannoveranus.
Pueri 2 Pyrenaici. 1719.
Johannes Leodicensis.

Americanus. 2. rufus, cholericus, rectus.
Pilis nigris, rectis, crassis; *Naribus* patulis; *Facie* ephelitica, *Mento* subimberbi.
Pertinax, hilaris, liber.
Pingit se lineis dædaleis rubris.
Regitur Consvetudine.

β al-

(*) Nosse Se Ipsum gradus est primus sapientiæ, dictumque *Solonis*, quondam scriptum litteris aureis supra *Dianæ* Templum. *Mus. ADOLPH. FRID. Præfat.*

Physiologice: Te contextum Nervis, intertextum Fibris, Machina tenella, sed adolescente in perfectissimam, facultatibus instructam fere omnibus pluribusque, quam reliqua cuncta. *Nudum in nuda humo, natali die, abjecit natura ad vagitus statim & ploratum, manibus pedibusque devinciendum Animal cæteris imperaturum; cui scire nihil sine doctrina: non fari, non ingredi, non vesci, non aliud natura sponte. Plin. Vides itaque qualem vitam nobis rerum natura promisit, quæ primum nascentium omen fletum esse voluit. Seneca.*

Diætetice: Te sanitate & tranquilitate, si noveris, felicem: *Moderatis* conservandum, *Nimiis* destruendum, *Variatis* efficiendum, *Insvetis* frangendum, *Consvetis* indurandum; polyphagum Culina instructissima, per errores gratissima, igne vinoque horrenda. *Parvo fames constat, magno fastidium. Seneca.*

Pathologice: Te tumidam usque dum crepueris bullam, piloque pendulam in puncto fugientis temporis. *Nihil enim homine imbecillius terra alit. Homer. Nulli vita fragilior; nulli tot Morbi, tot Curæ, tot Pericula. Breve universum utique ævi tempus: Pars æqua morti similis exigitur; nec reputantur Infantiæ anni, qui sensu carent; nec Senectæ in pœnam vivaces: hebescunt Sensus, torpent Membra, præmoriuntur Visus, Auditus, Incessus, Dentes, Ciborum instrumenta. Plin. Sic magna pars mortis jam præteriit, quidquid ætatis retro est Mors tenet. Totum denique hunc, quem vides populum, quonque cogitas esse; cito natura revocavit & condet; Mors omnes æque vocat; iratis* Diis *propitiisque moriendum. Senec, II: 59.*

Cultivated plant varieties

Malus domestica – Apple

Antonovka • Baldwin • Ben Davis • Blenheim Orange • Braeburn • Bramley • Cameo • Cortland • Cornish Gilliflower •Cox's Orange Pippin • Cripps Pink • Egremont Russet • Elstar • Flower of Kent • Fuji • Gala • Ginger Gold • Golden Delicious • Granny Smith • Gravenstein • Haralson • Honeycrisp • Idared • James Grieve • Jazz • Jonagold • Jonathan • Knobbed Russet • Macoun • McIntosh • Northern Spy • Paula Red • Pink Pearl • Pinova • Red Delicious • Rome

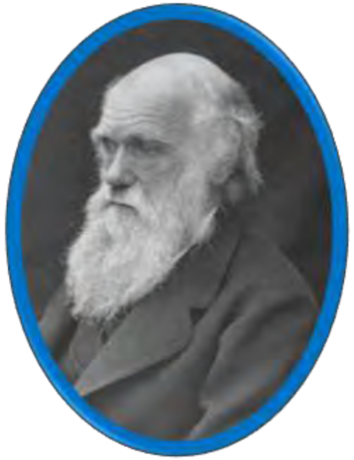
Phylogenetics

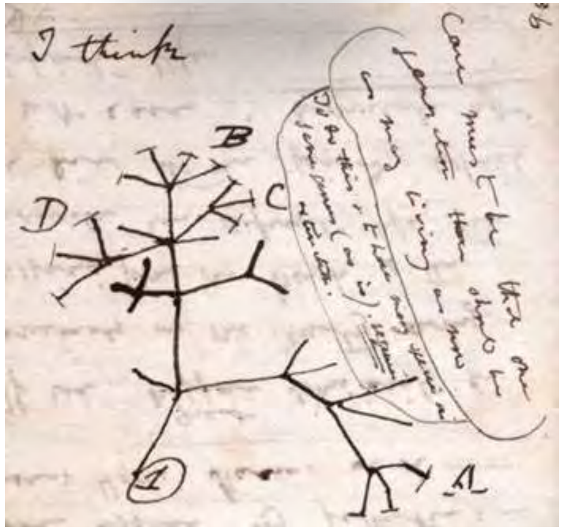
The study of evolutionary relationships among different groups of organisms

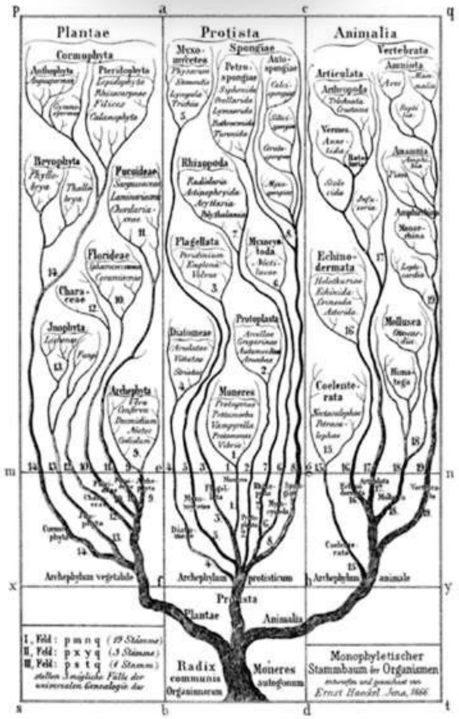
Term coined by Ernst Haeckel

- Phylon = tribe
- Genes = origin, birth

The development of species along different evolutionary paths can be represented as a tree







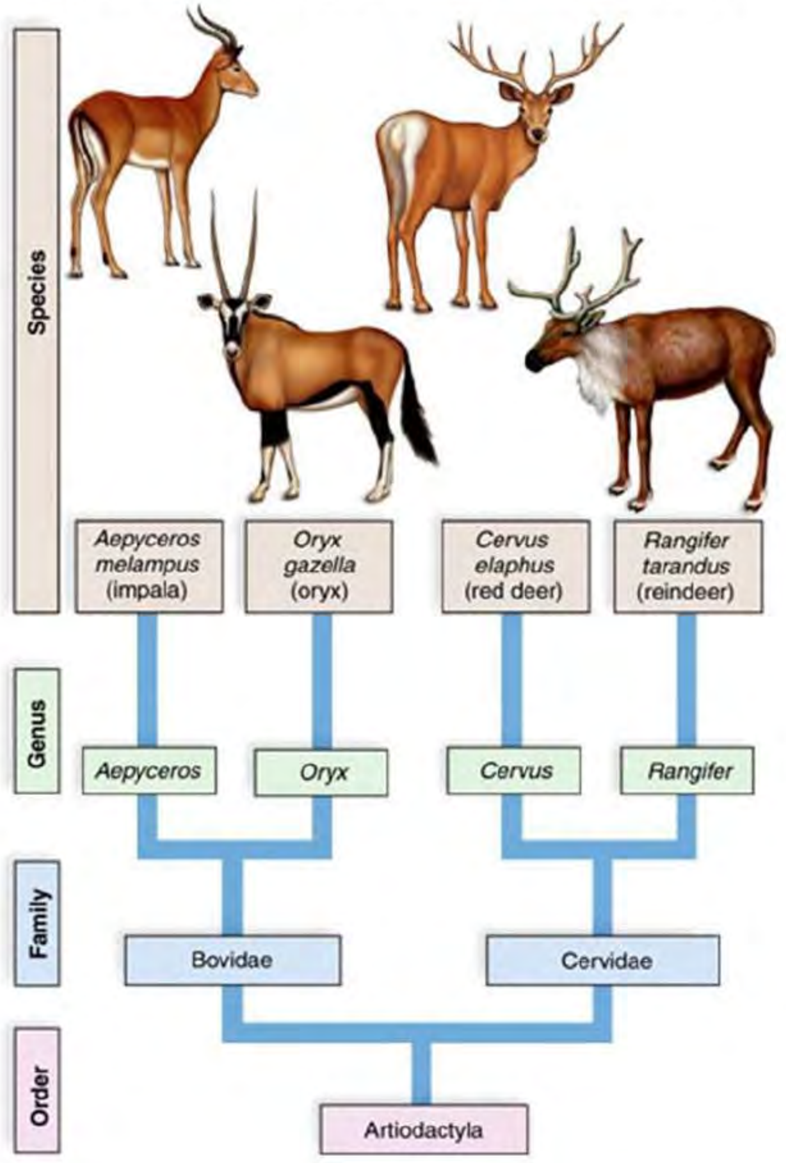
Phylogenetics

Different kinds of trees are possible depending on the data used

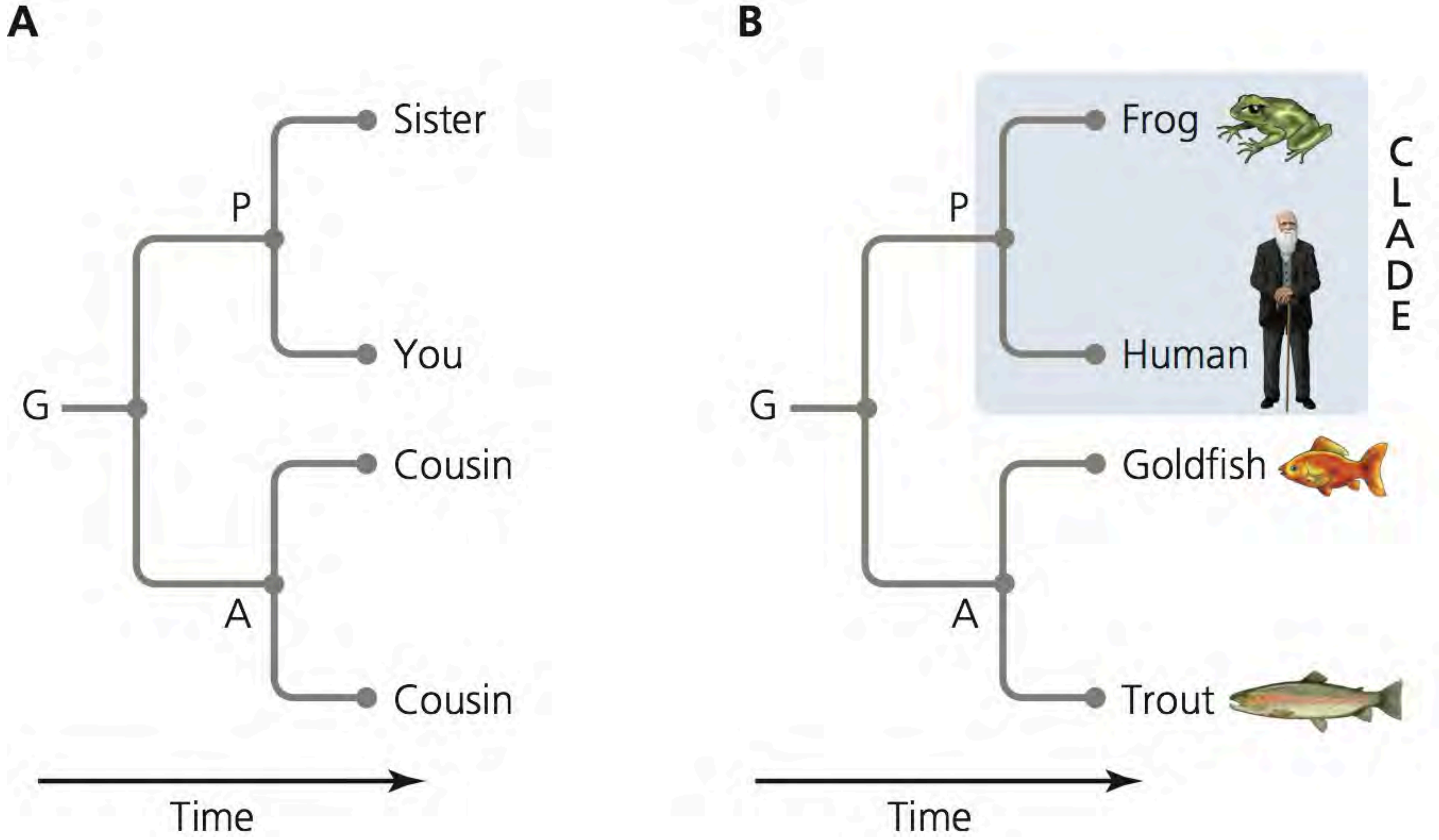
Early trees were based on similarities in morphology

- May be incorrect
- Physical traits may be analogous not homologous

Phylogenetic trees should depict evolutionary relationships based on descent from common ancestors



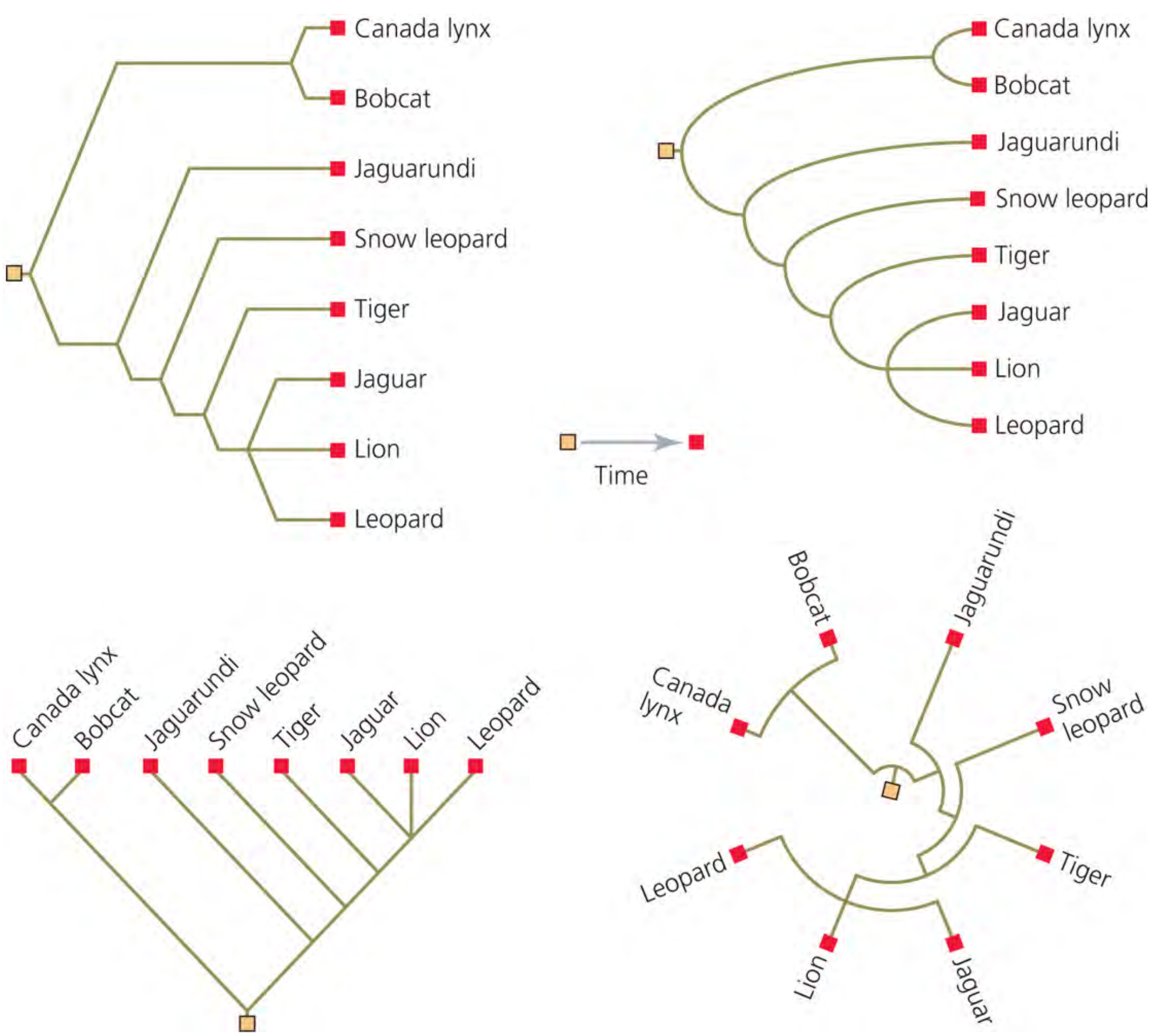
Phylogenetic trees



Characters used to build trees (part A)

Traits used to infer evolutionary events (part B)

Phylogenies may be drawn in different styles

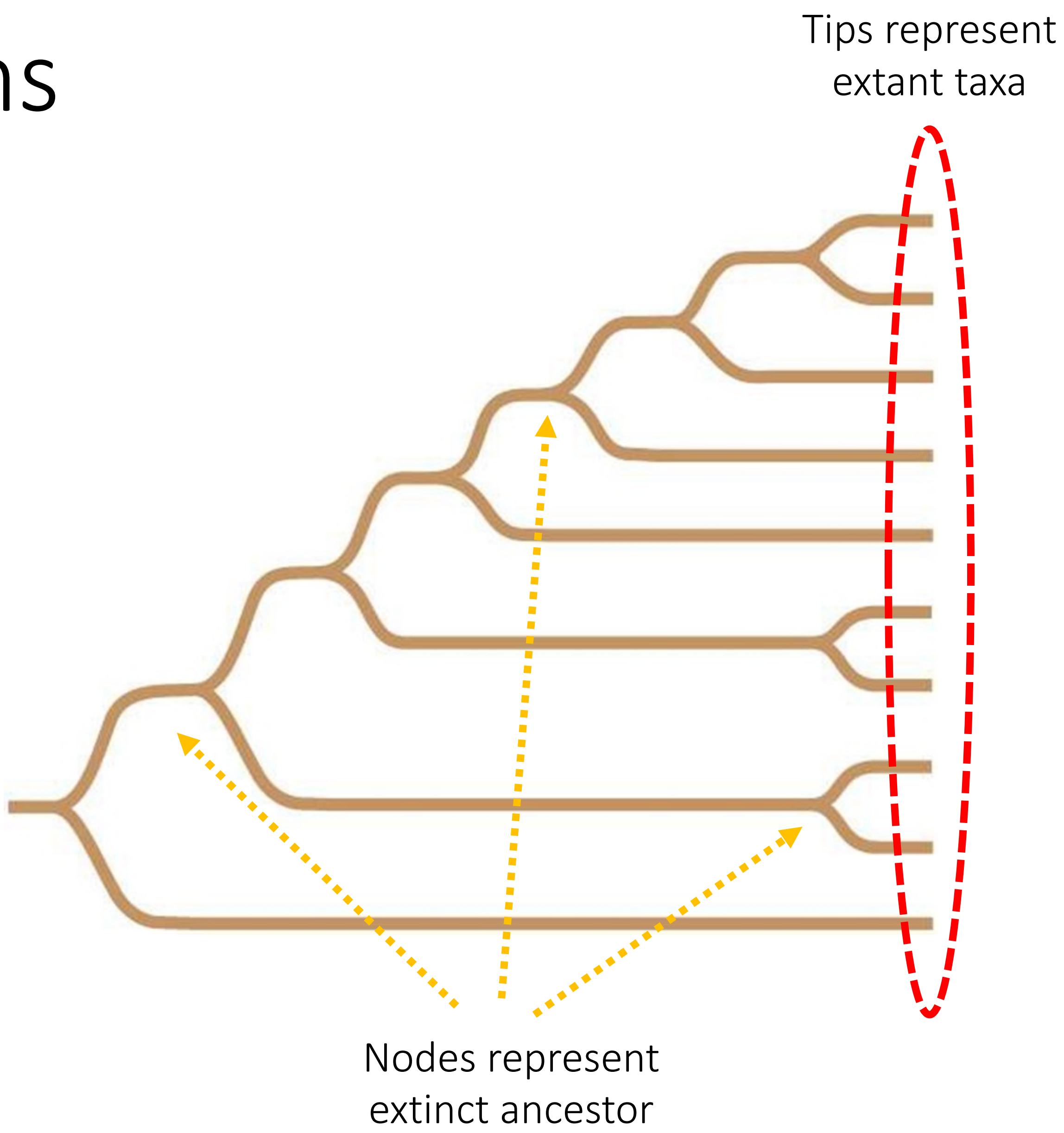


MRCA:
Most Recent
Common Ancestor

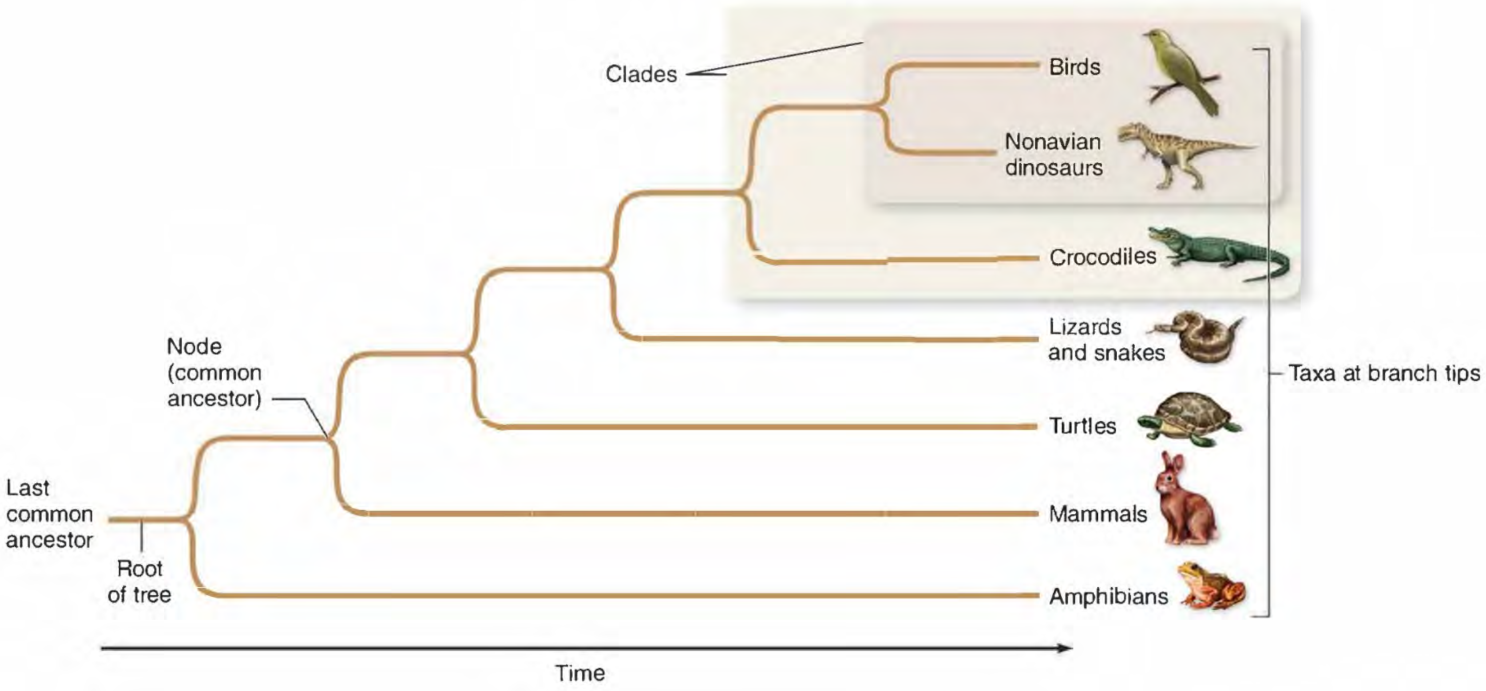
Cladistics and cladograms

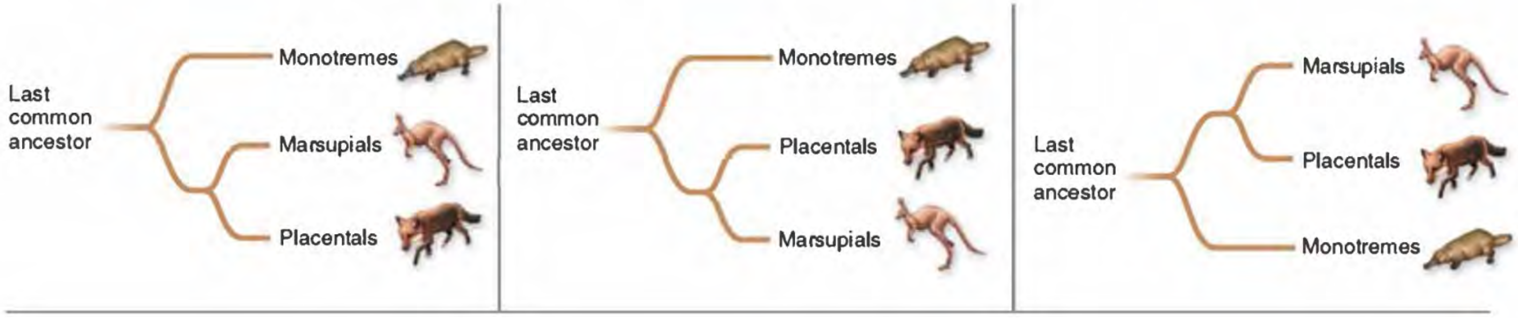
Cladistics is one method of constructing a tree based on common ancestry

- Cladogram represents organisms' evolutionary history
- A clade is a group of organisms that share one or more defining derived traits inherited from a common ancestor



Cladistics and cladograms



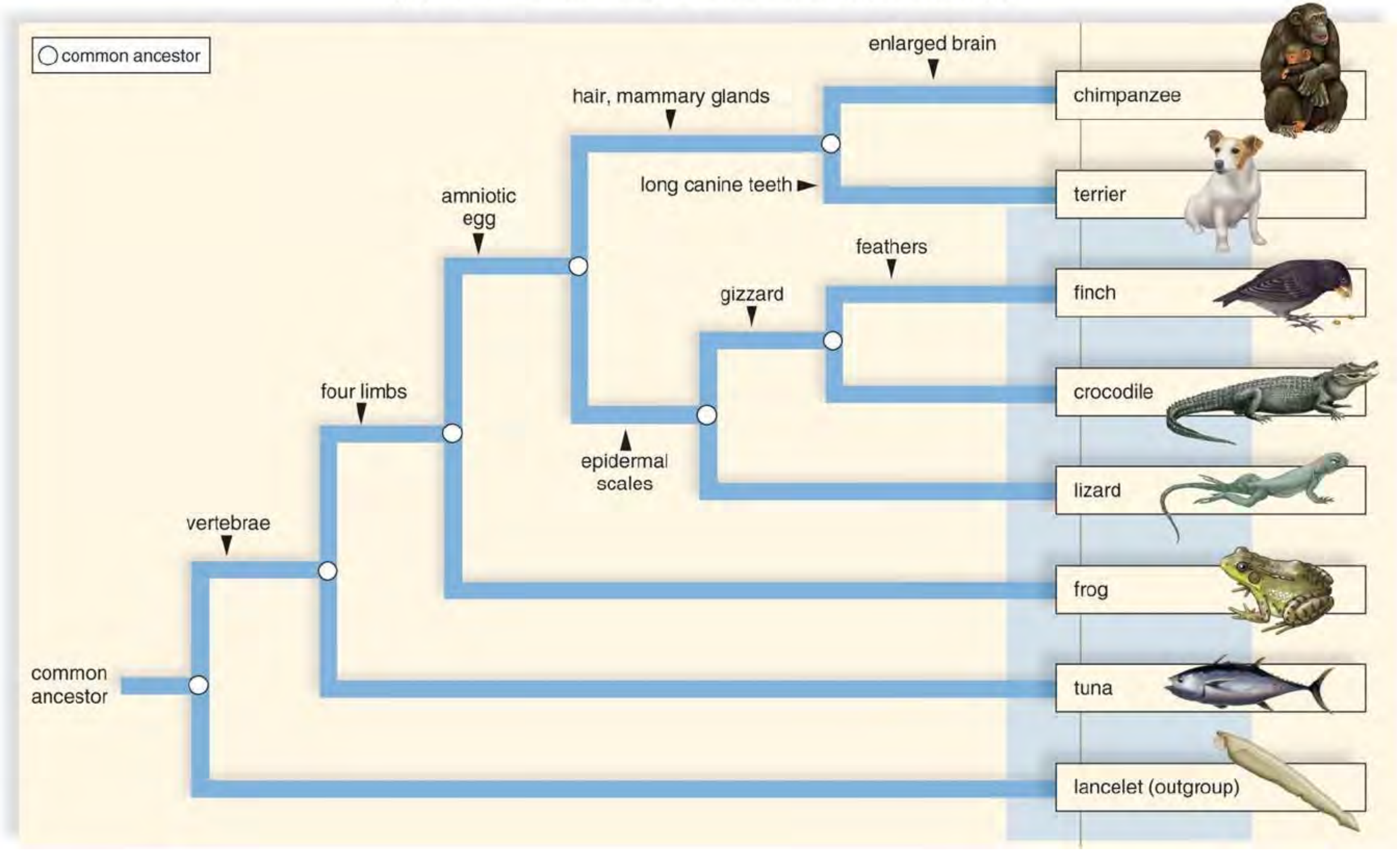


Cladistics and cladograms

Identify the **derived** trait which defines a clade

Identify the **ancestral** trait that two organisms share

Identify which groups are most closely related to each other



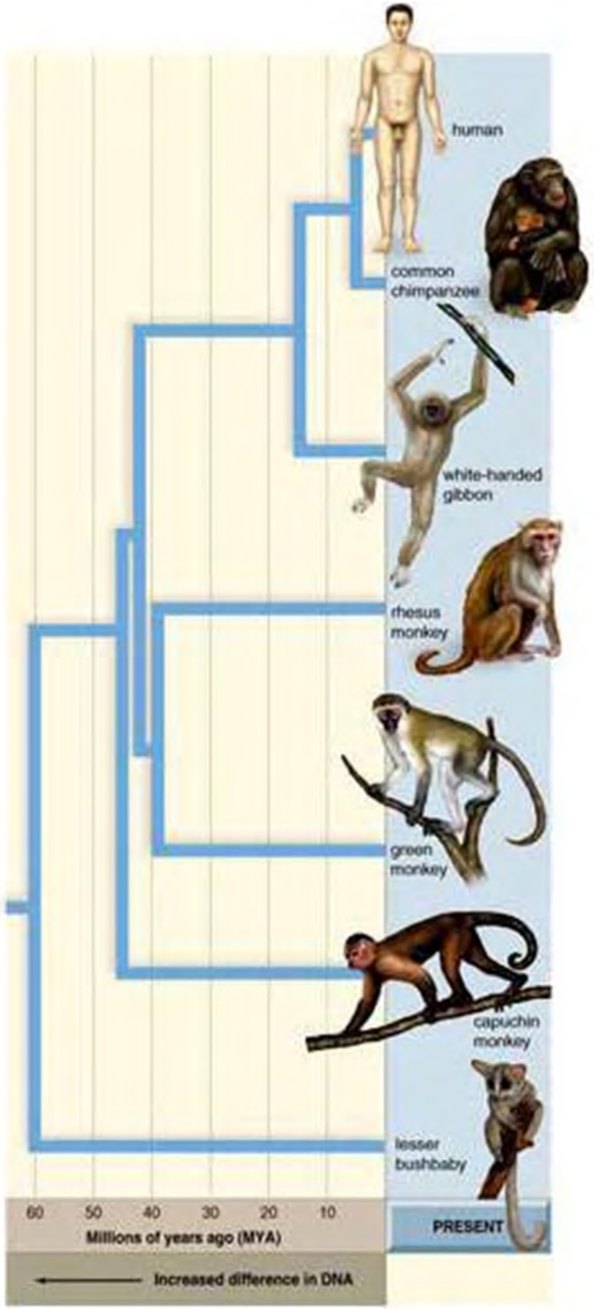
Phylograms

Phylograms are trees where branch lengths correspond to inferred evolutionary change or genetic distance

- DNA sequence data usually used
- "Molecular clock" assumes constant rate of mutation over time
- Estimate when new species emerged

Other trees can be constructed using a combinatior of DNA, morphology, behavior, etc.

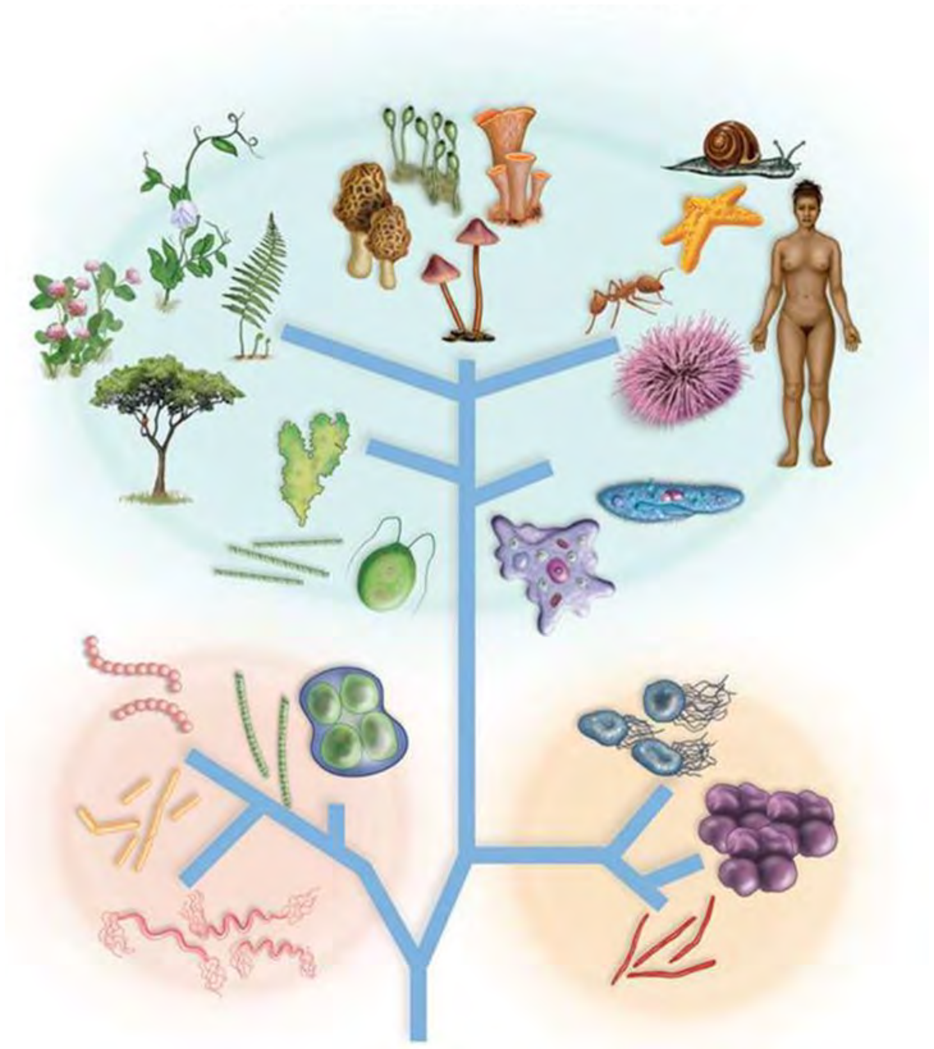
- E.g. most fossils do not have usable DNA



A Quick Tour of the Tree of Life

3 Domains

- Bacteria
- Archaea
- Eukarya
  - 4 Kingdoms
    - Protista
    - Plantae
    - Fungi
    - Animalia

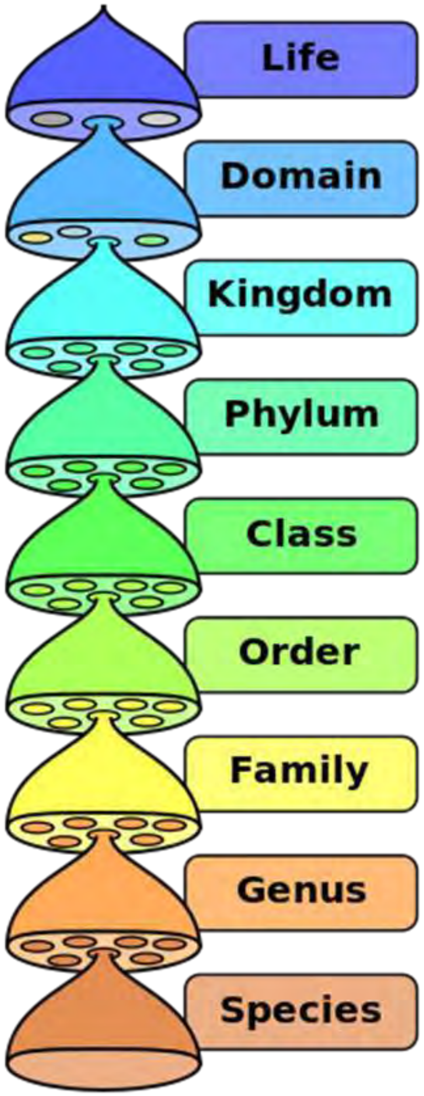


Taxonomic classifications are hypotheses

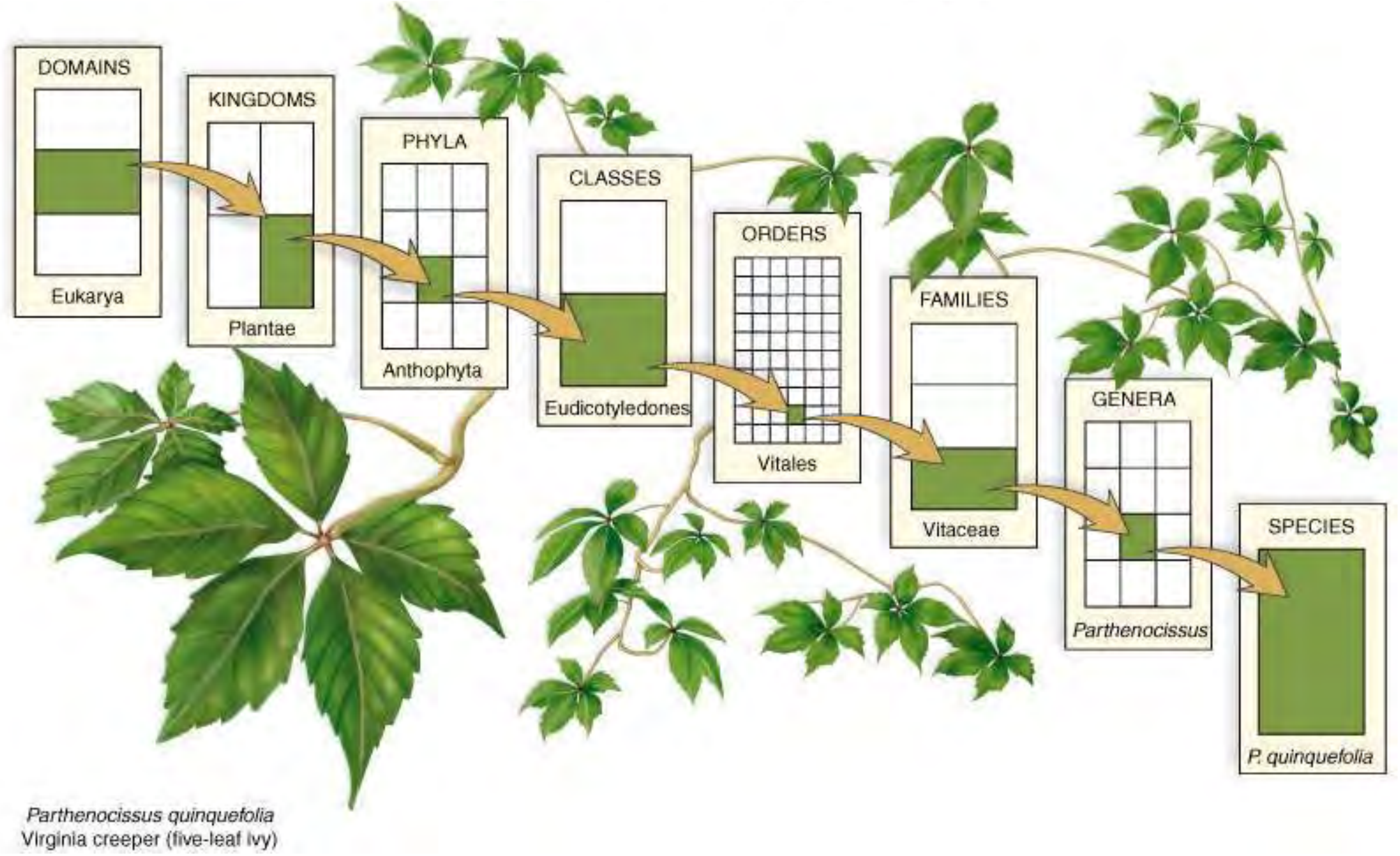
Classification systems can change when better data is available

Linnaean system is still widely used, because there has not been an agreement on how to incorporate phylogenetic methods

Changes to taxonomy are mostly at the species, genus and family level



Complete taxonomic classification for *Parthenocissus quinquefolia*

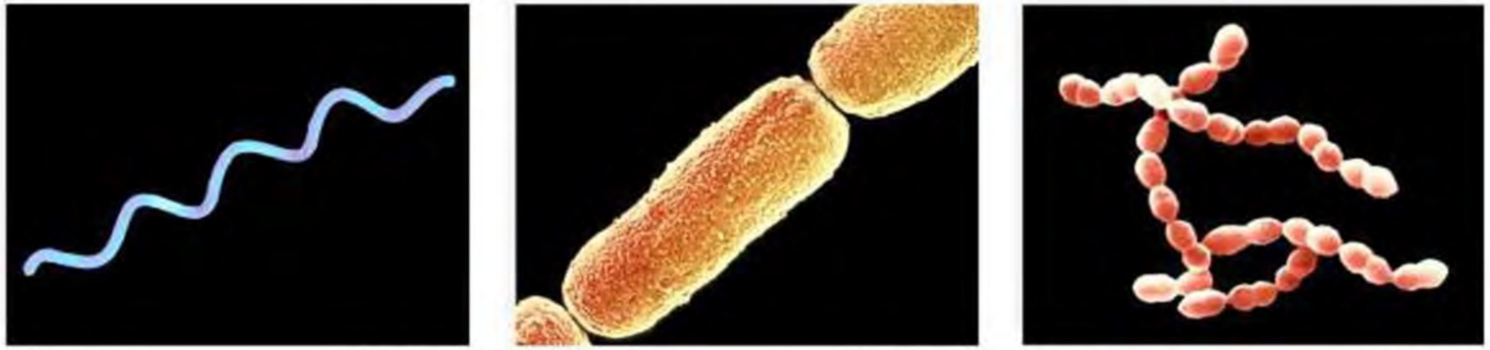


Taxonomic classifications are hypotheses

Domain Bacteria

Very diverse – found everywhere; important in many natural processes

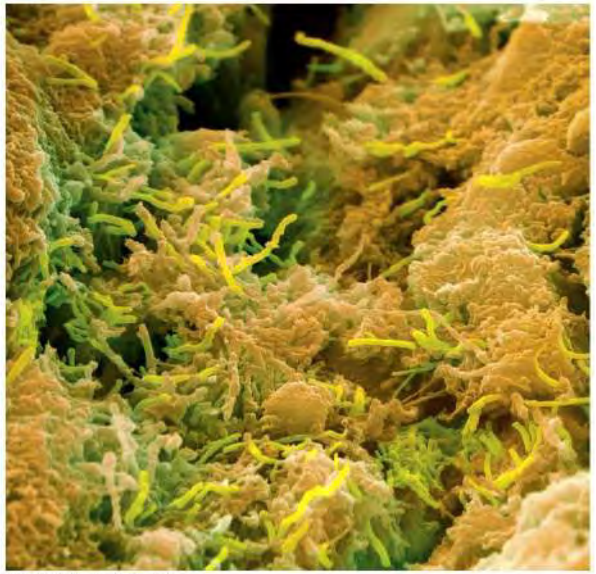
- Prominent in human medicine: some are sources of antibiotics, some cause infections
- Reproduce asexually, have horizontal gene transfer
- Currently has ~23 phyla



a. Spirillum: *Spirillum volutans* SEM 3,520×

b. Bacilli: *Bacillus anthracis* SEM 35,000×

c. Cocci: *Streptococcus thermophilus* SEM 6,250×



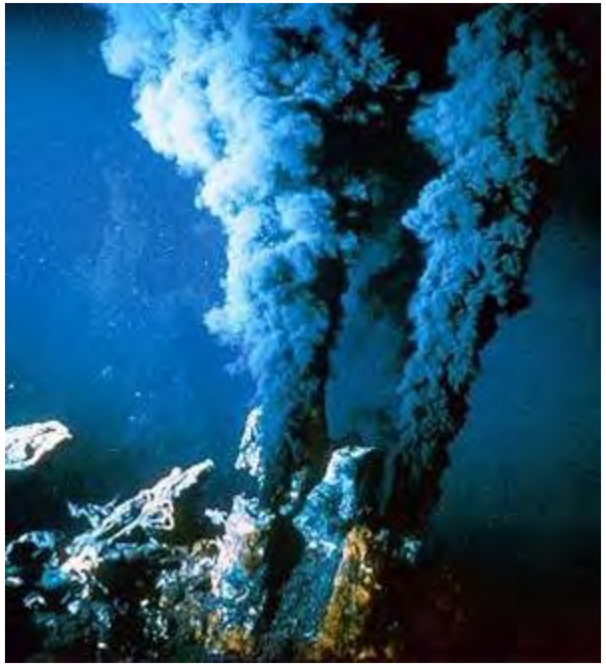
Dental plaque is caused by bacteria

Anthrax – derived from *Bacillus anthracis*

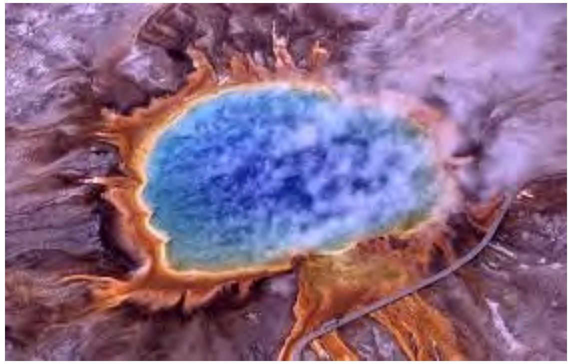
Domain Archaea

Long thought to be part of Domain Bacteria, since they are very similar

- "Extremophiles" – first found in extremely hot, acidic, or salty environments
- Reproduce asexually, have horizontal gene transfer
- 3 phyla



Hydrothermal vents



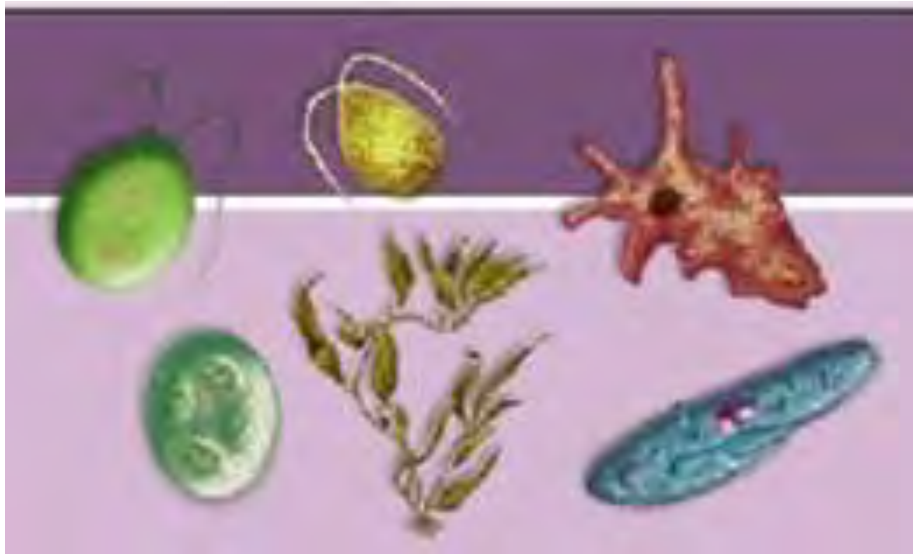
Sulfur-rich volcanic springs

Saline Dead sea

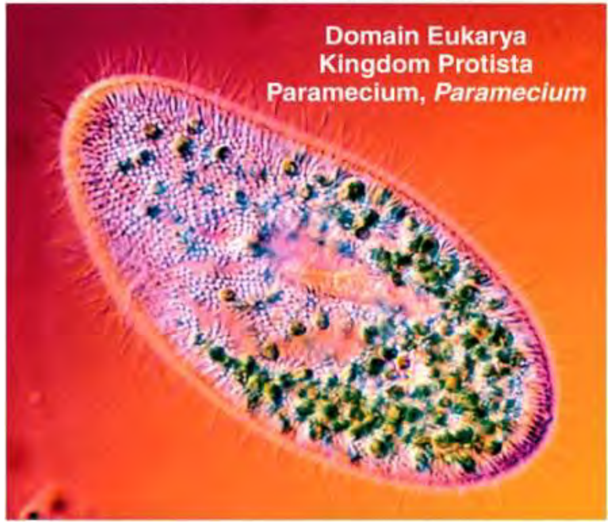
Domain Eukarya

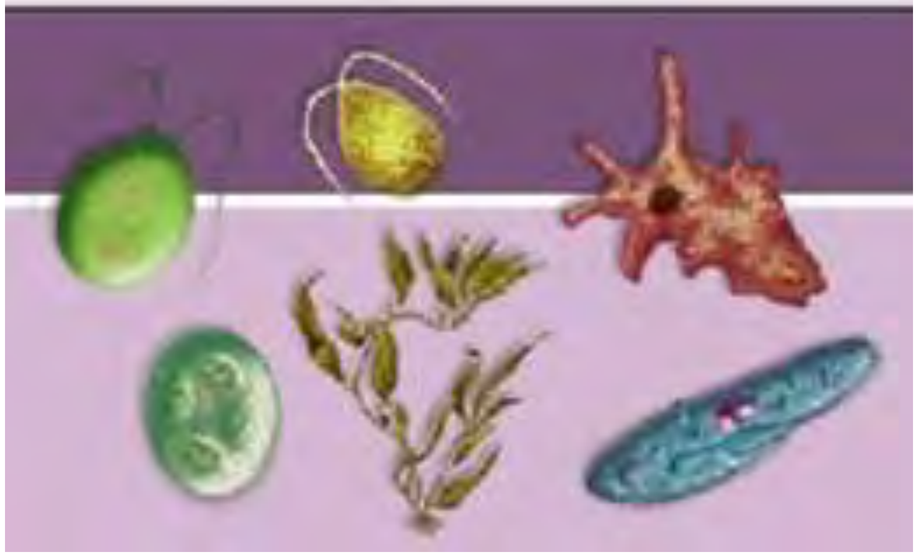
Organisms with membrane-bound organelles

- 4 kingdoms



Domain Eukarya





Kingdom Protista

- Primarily unicellular
- Metabolically diverse
- Structurally complex
- Live mostly in water
- Asexual reproduction usual but also sexual

Well-known groups:

Blue-green Algae	Amoeboids
Diatoms	Ciliates
Dinoflagellates	Slimemolds
Euglenoids	

Domain Eukarya

<u>Kingdom Fungi</u>

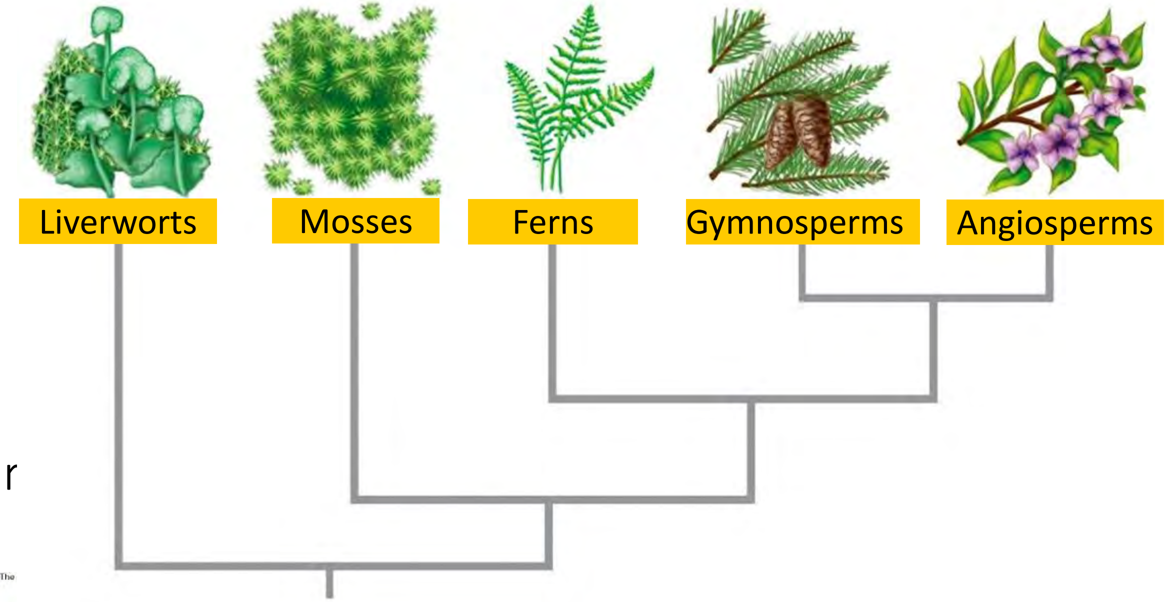
- Cell walls with chitin
- Heterotrophs: obtain food by absorption
- Reproduce asexually and by sexual spores
- Classified by reproductive structures

<u>Well-known groups:</u>
Molds
Yeasts
Mycorrhizae
Mushrooms

Domain Eukarya

Kingdom Plantae

- Cellulose cell walls
- Autotrophic: perform photosynthesis
- Terrestrial plants classified by
  - Tissue structure into non-vascular and vascular
  - Reproductive characteristics



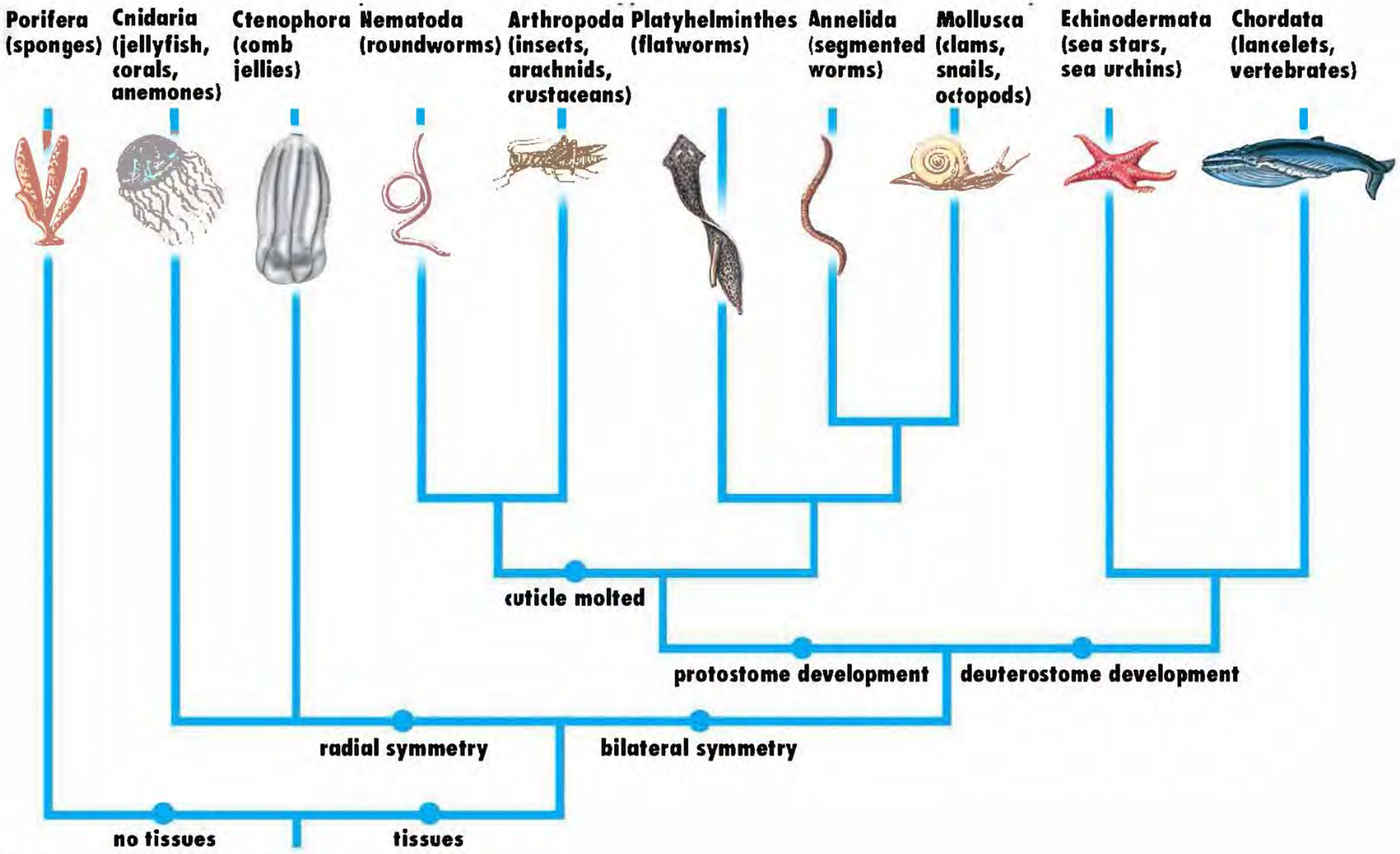
Domain Eukarya

Kingdom Animalia

- No cellulose cell walls
- Heterotrophs: obtain energy from other organisms
- Some have complex organ systems
- Able to move about and respond rapidly to stimuli

Domain Eukarya

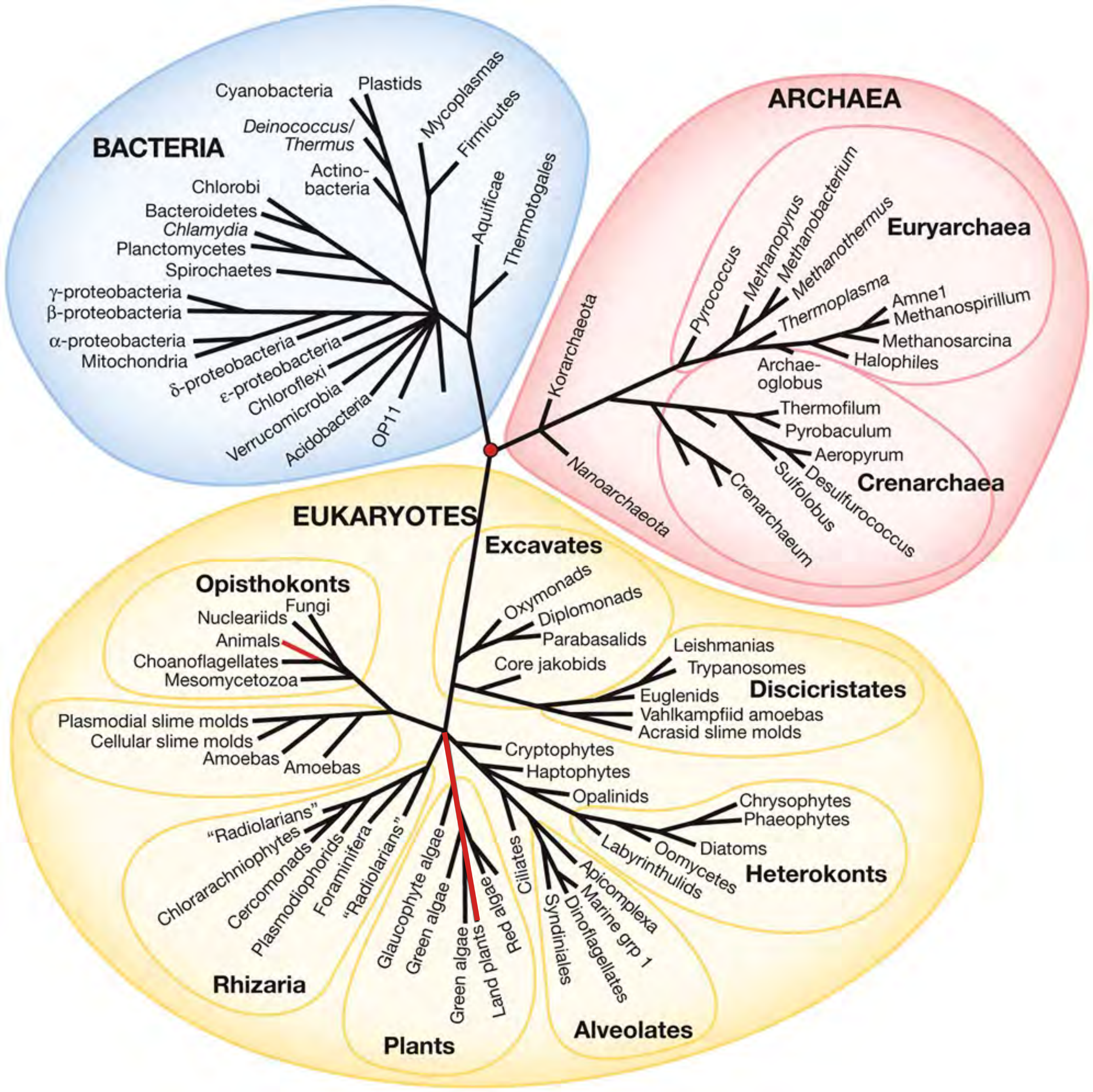
Kingdom Animalia



Future lectures:

CNY holiday - Plant form and function (recorded lecture)

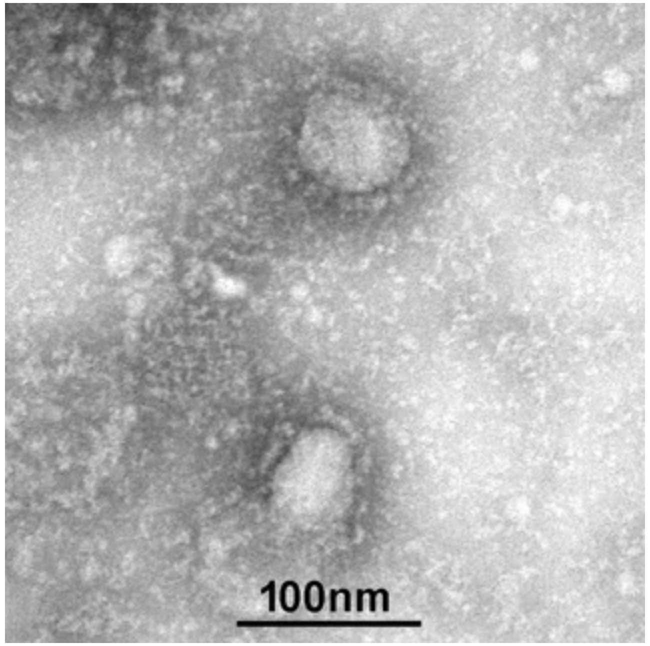
08th Feb - Animal form and function



Viruses

- Replicate inside living cells of other organismal life forms
  - Classification based on morphology, type of nucleic acid, host organisms, type of infections/diseases etc.

2019-nCoV



Coronaviruses
- Respiratory infections (often airborne)
- No known vaccines/antivirals (rapid changes in structure)
  - SARS caused by SARS-CoV
  - MERS caused by MERS-CoV
  - Novel coronavirus pneumonia caused by 2019-nCoV

Summary

Domain: Bacteria

Kingdom: Bacteria

- Unicellular
- Cells lack nuclei and membrane-bounded organelles
- Cell walls different from Archaea and Eukarya
- Some autotrophs
- Some heterotrophs

Escherichia coli

Domain: Archaea

Kingdom: Archaea

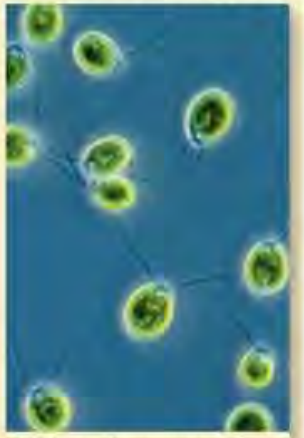
- Unicellular
- Cells lack nuclei and membrane-bounded organelles
- Cell walls and membranes different from Bacteria and Eukarya
- Some autotrophs
- Some heterotrophs

Acidiphilium sp.

Domain: Eukarya

Kingdom: Protista

- Most unicellular
- Cells with nuclei and membrane-bounded organelles
- Some have cell walls
- Some autotrophs
- Some heterotrophs



Chlamydomonas sp.

Kingdom: Plantae

- Multicellular
- Cells with nuclei and membrane-bounded organelles
- Cell walls of cellulose
- Autotrophs
- Complex organ systems

Acer rubrum

Kingdom: Fungi

- Most multicellular
- Cells with nuclei and membrane-bounded organelles
- Cell walls of chitin
- Heterotrophs (by external digestion)
- Tissues

Coprinus quadrifidus

Kingdom: Animalia

- Multicellular
- Cells with nuclei and membrane-bounded organelles
- No cell walls
- Heterotrophs (by ingestion)
- Complex organ systems

Pentatomidae

Summary

- The Linnaean hierarchy is useful in classifying organisms according to different **taxonomic ranks**
- There are several **modes of speciation** that generate different isolating mechanisms to gene flow.
- Phylogenetic trees **reconstruct evolutionary history** and help us differentiate ancestral and derived traits
- Take home questions:
  - Why does the number of species vary so much across different environments?
  - What is the relationship between speciation and extinction?
  - What are the implications for plant and animal form and function?

Thursday: Lab practical on Primate skulls

Prepare for practical by reading instructions **before class**

- Working in small groups
- Individual lab reports

SAFETY REQUIREMENTS

1. You are required to put on **close-toed footwear**. You will **not** be allowed to enter the laboratory if you are wearing sandals, slippers or any other open-toed footwear.
2. You are also required to **wear clothes that cover your legs**. You will also **not** be allowed to enter the laboratory if you are wearing shorts, including bermuda shorts or skirt.
3. You will be given **a lab coat** during the first lab that you have to use for all subsequent labs. You will also **not** be allowed to participate without it.