Biological Diversity [part 1]

IF3211 Domain Specific Computation

School of Electrical Engineering and Informatics ITB

Content

- Phylogeny
- Early Life and the Diversification of Prokaryotes
- The Origin and Diversification of Eukaryotes
- The Colonization of Land
- Tools

Phylogeny

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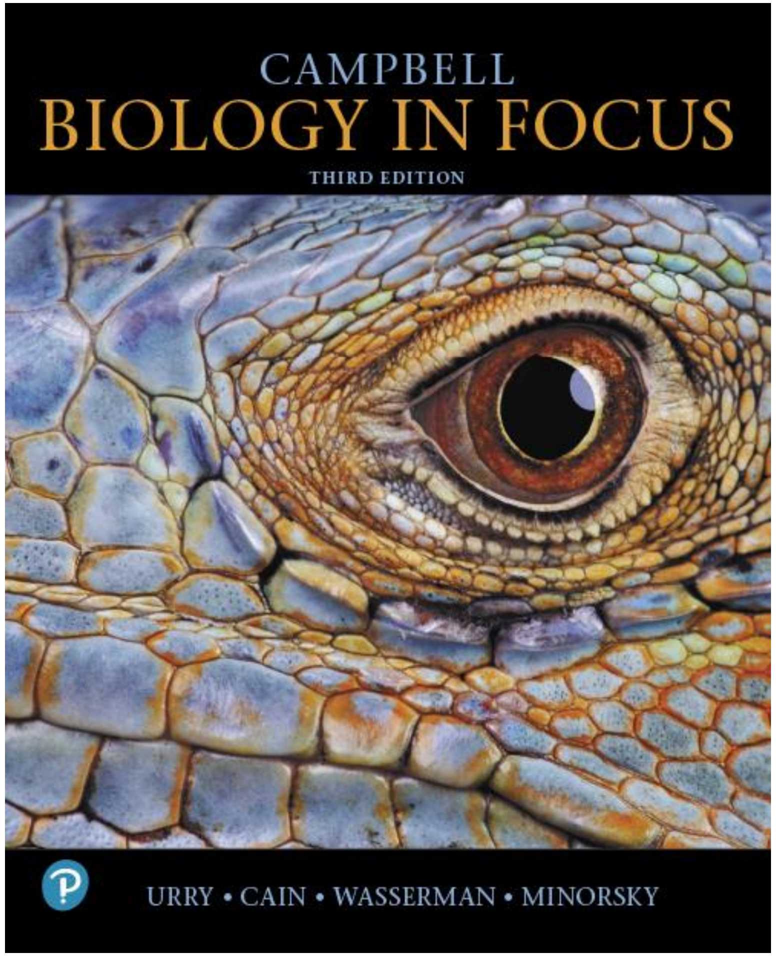


Chapter 20

Phylogeny

Lecture Presentations by
Kathleen Fitzpatrick and Nicole Tunbridge,
Simon Fraser University

Pearson

Overview: Investigating the Evolutionary History of Life (1 of 2)

- Legless lizards and snakes appear similar but evolved from different lineages of lizards with legs
  - For example, the European glass lizard does not share three key traits shared by all snakes
- Legless lizards have evolved independently in several different groups through adaptation to similar environments

Figure 20.1

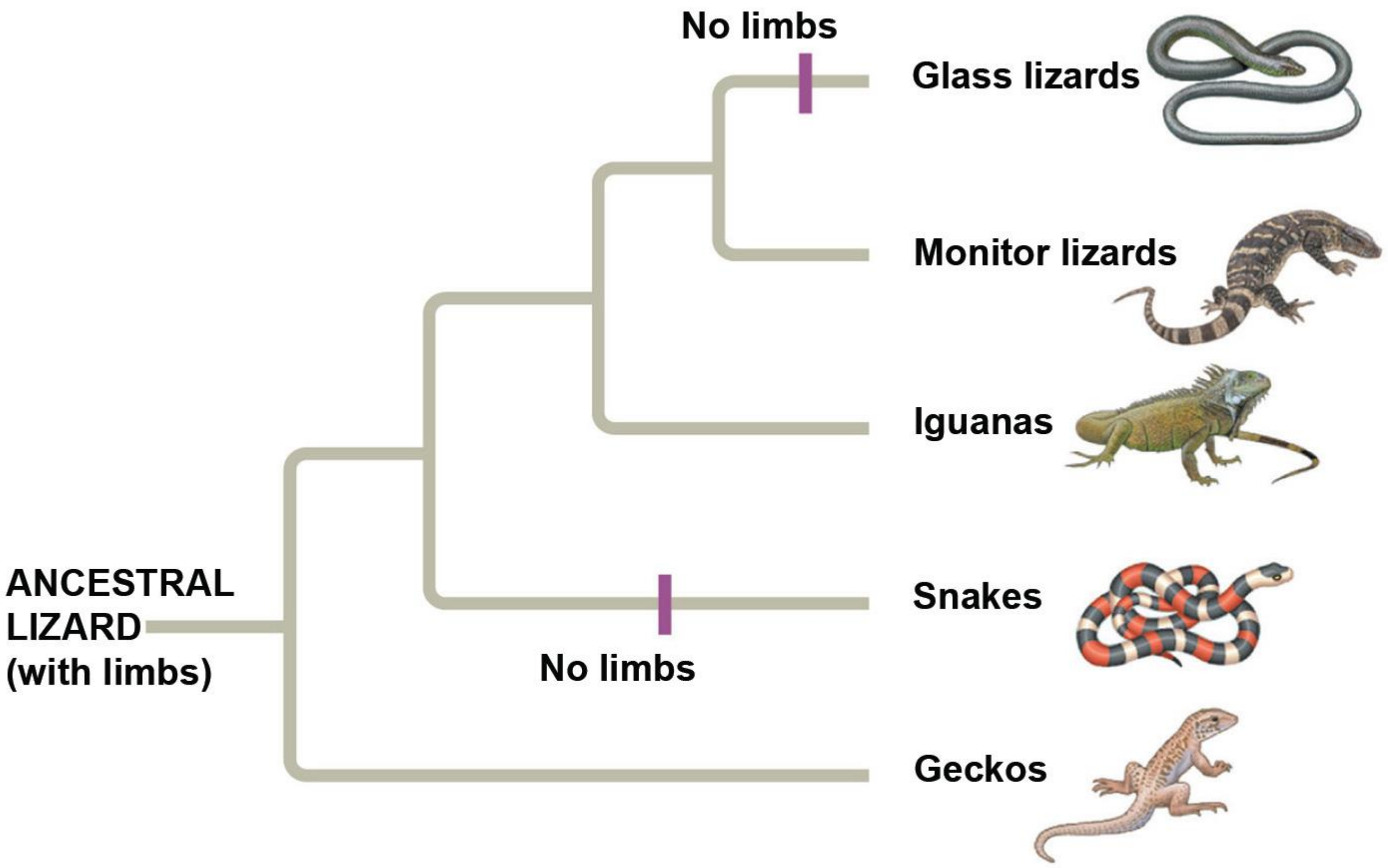
What Kind of Organism Is This?

Overview: Investigating the Evolutionary History of Life (2 of 2)

- **Phylogeny** is the evolutionary history of a species or group of related species
- The discipline of **systematics** classifies organisms and determines their evolutionary relationships

Figure 20.2

Convergent Evolution of Limbless Bodies

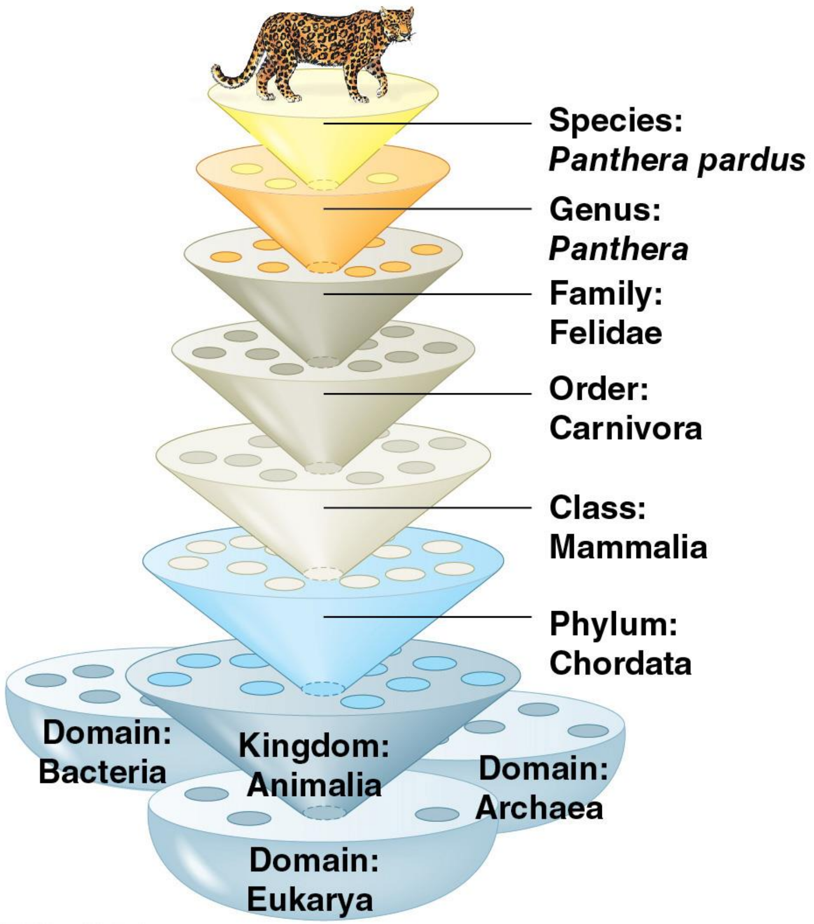


Hierarchical Classification (1 of 2)

- Linnaeus introduced a system for grouping species in increasingly broad categories
- The taxonomic groups from least to most inclusive are species, genus, **family, order, class, phylum** (plural, **phyla), kingdom**, and **domain**
- A named taxonomic unit at any level of the hierarchy is called a **taxon** (plural, **taxa**)

Figure 20.3

Linnaean Classification



Hierarchical Classification (2 of 2)

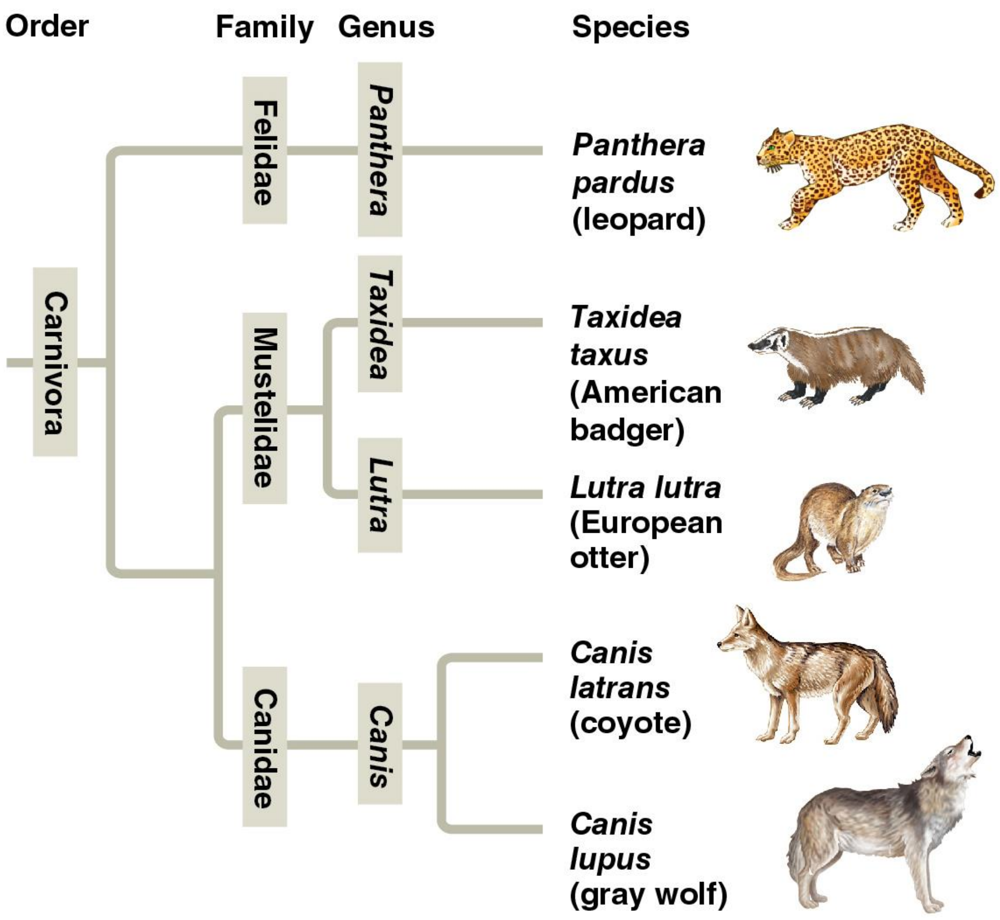
- Characters used to classify one group of organisms are often not appropriate for other organisms
- Larger categories in the hierarchy are usually not comparable between lineages
  - For example, an order of snails does not have the same degree of diversity as an order of mammals

Linking Classification and Phylogeny (1 of 2)

- Evolutionary relationships can be represented in branching diagrams called **phylogenetic trees**
- The branching pattern often matches how taxonomists classify groups of organisms nested within more inclusive groups

Figure 20.4

The Connection Between Classification and Phylogeny

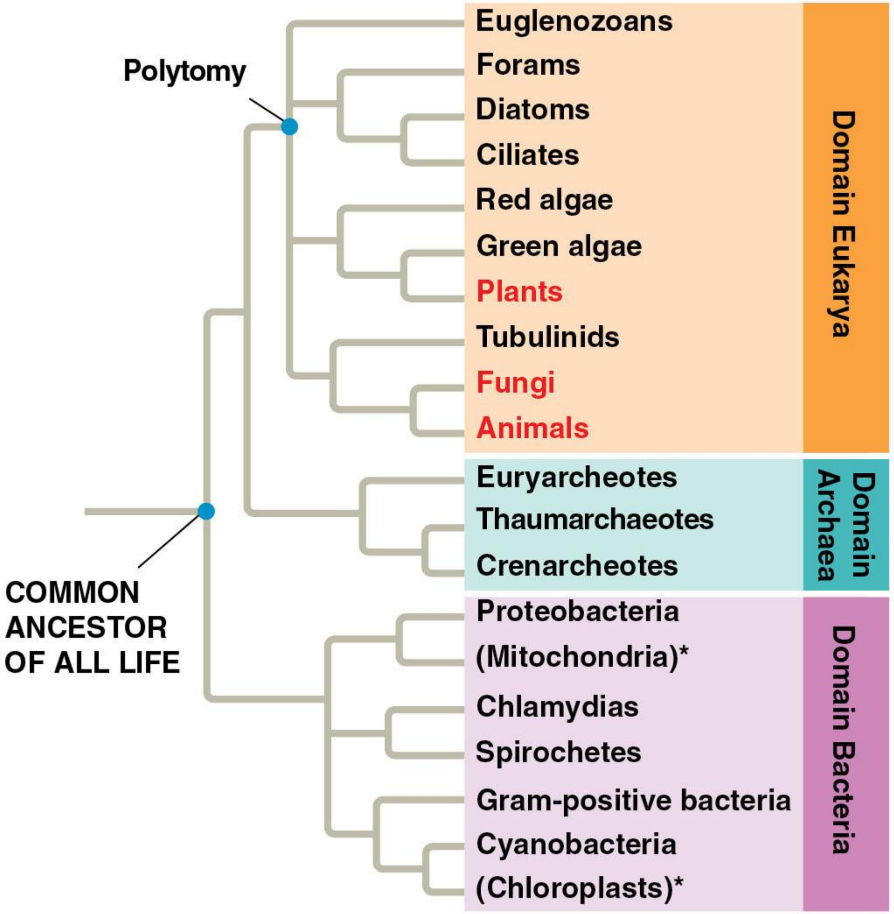


From Two Kingdoms to Three Domains (1 of 4)

- Early taxonomists classified all species as either plants or animals
- Later, five kingdoms were recognized: Monera (prokaryotes), Protista, Plantae, Fungi, and Animalia
- More recently, the three-domain system has been adopted: Bacteria, Archaea, and Eukarya
- The three-domain system is supported by data from many sequenced genomes

Figure 20.21

The Three Domains of Life



Early Life and the Diversification of Prokaryote

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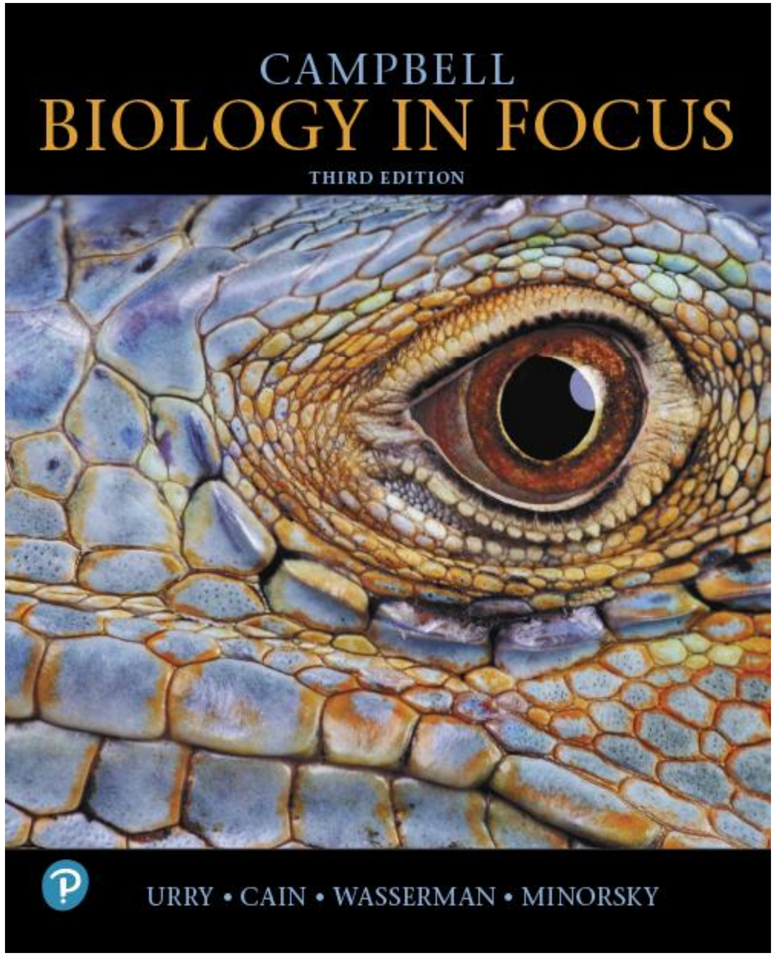


Chapter 24

Early Life and the Diversification of Prokaryotes

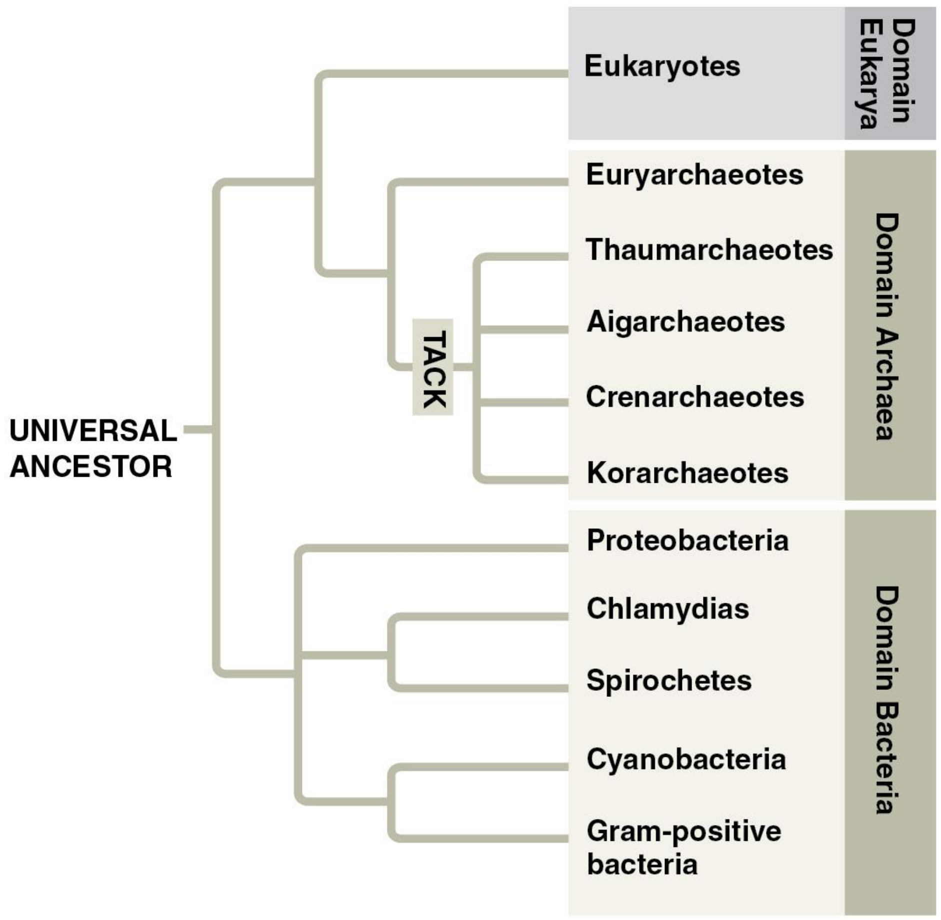
Lecture Presentations by
Kathleen Fitzpatrick and Nicole Tunbridge,
Simon Fraser University

An Overview of Prokaryotic Diversity (1 of 3)

- The application of molecular systematics has led to dramatic revisions of the prokaryote phylogeny
  - For example, the use of molecular systematics led to the splitting of prokaryotes into Bacteria and Archaea

Figure 24.19

A Simplified Phylogeny of Prokaryotes



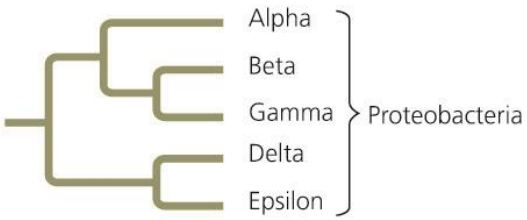
Bacteria (1 of 11)

- Bacteria include the vast majority of prokaryotes familiar to most people
- Every major mode of nutrition and metabolism is represented among bacteria
- A wide diversity of nutritional modes can be found even within small taxonomic groups

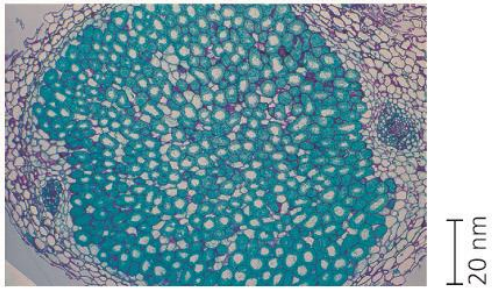
Figure: Three Domains Phylogeny: Bacteria

Figure 24.20 (1 of 2)

Exploring Selected Major Groups of Bacteria



Subgroup: Alpha Proteobacteria

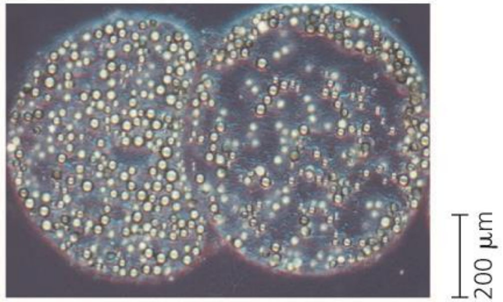


Rhizobium (in teal patches) inside a root nodule of a legume (TEM)

Subgroup: Beta Proteobacteria

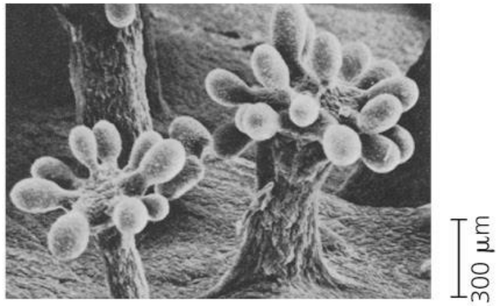
Nitrosomonas (colorized TEM)

Subgroup: Gamma Proteobacteria



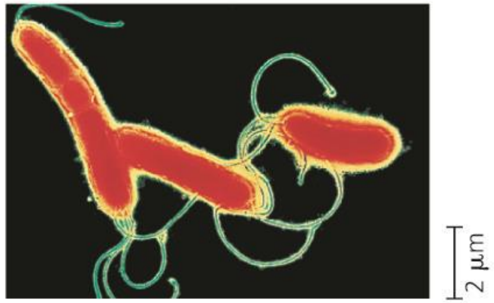
Thiomargarita namibiensis containing sulfur wastes (LM)

Subgroup: Delta Proteobacteria



Fruiting bodies of *Chondromyces crocatus*, a myxobacterium (SEM)

Subgroup: Epsilon Proteobacteria

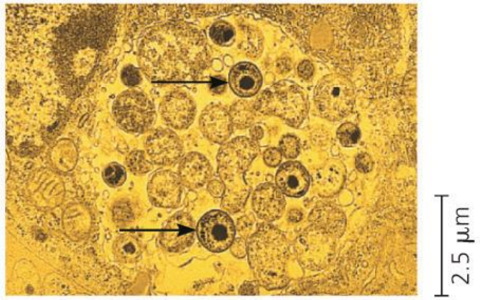


Helicobacter pylori (colorized TEM)

Figure 24.20 (2 of 2)

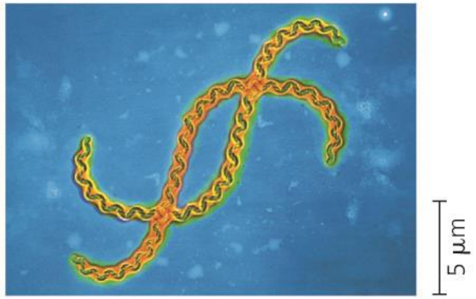
Exploring Selected Major Groups of Bacteria

Chlamydias



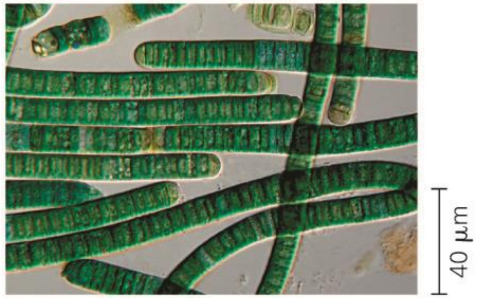
Chlamydia (arrows) inside an animal cell (colorized TEM)

Spirochetes



Leptospira, a spirochete (colorized TEM)

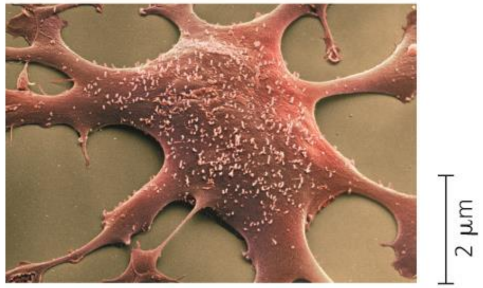
Cyanobacteria



Oscillatoria, a filamentous cyanobacterium

Gram-Positive Bacteria

Streptomyces, the source of many antibiotics (colorized SEM)



Hundreds of mycoplasmas covering a human fibroblast cell (colorized SEM)

Archaea (1 of 5)

- Archaea have many unique traits, but they also share some traits in common with bacteria and others with eukaryotes

Figure: Three Domains Phylogeny: Archaea

Table 24.2

A Comparison of the Three Domains of Life

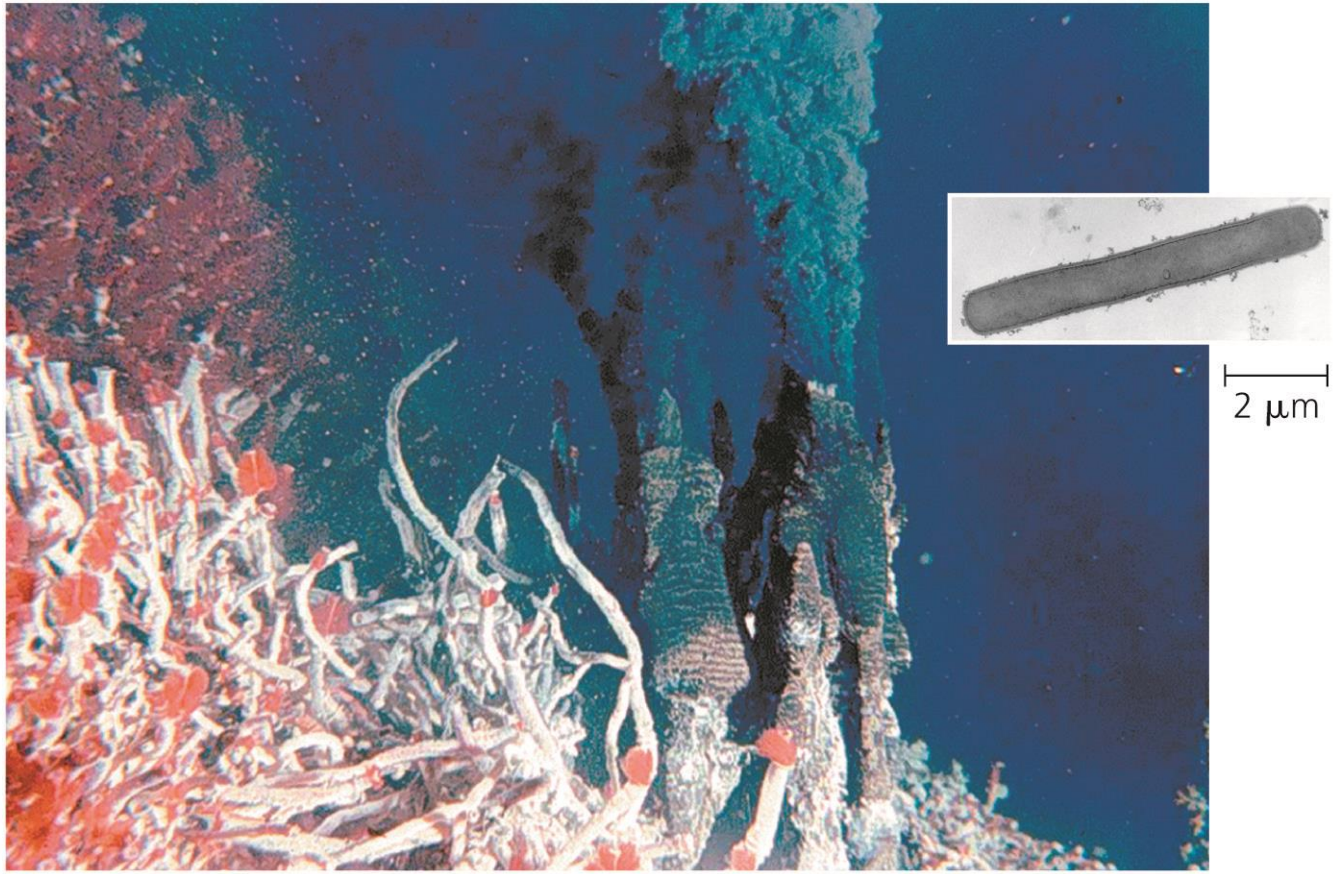
CHARACTERISTIC	DOMAIN		
	Bacteria	Archaea	Eukarya
Nuclear envelope	Absent	Absent	Present
Membrane-enclosed organelles	Absent	Absent	Present
Peptidoglycan in cell wall	Present	Absent	Absent
Membrane lipids	Unbranched hydrocarbons	Some branched hydrocarbons	Unbranched hydrocarbons
RNA polymerase	One kind	Several kinds	Several kinds
Initiator amino acid for protein synthesis	Formyl-methionine	Methionine	Methionine
Introns in genes	Very rare	Present in some genes	Present in many genes
Response to the antibiotics streptomycin and chloramphenicol	Growth usually inhibited	Growth not inhibited	Growth not inhibited
Histones associated with DNA	Absent	Present in some species	Present
Circular chromosome	Present	Present	Absent
Growth at temperatures > 100°C	No	Some species	No

Figure 24.21

Extreme Thermophiles

Figure 24.22

A Highly Thermophilic Methanogen



The Origin and Diversification of Eukaryotes

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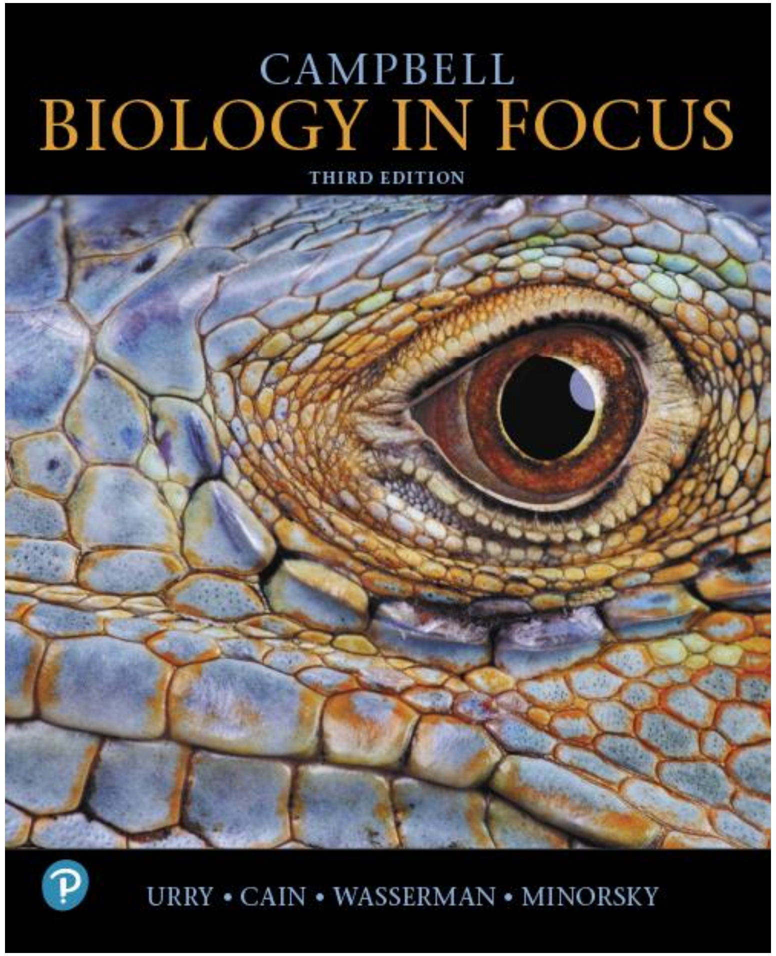


Chapter 25

The Origin and Diversification of Eukaryotes

Lecture Presentations by

Kathleen Fitzpatrick and Nicole Tunbridge,

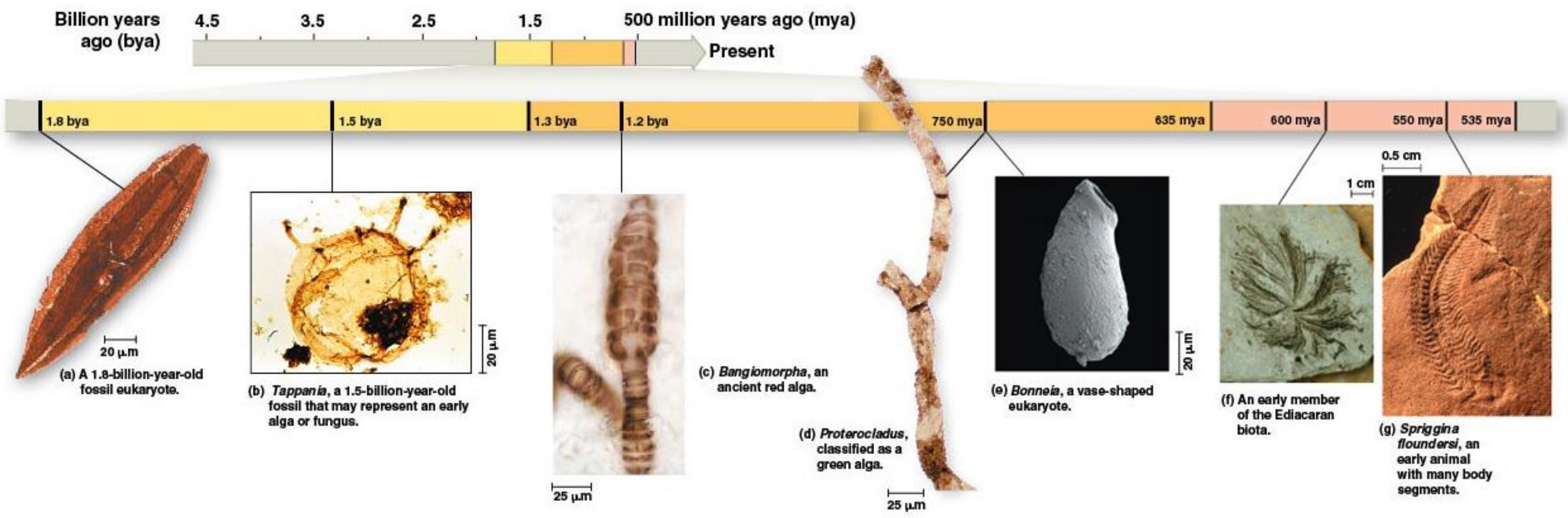
Simon Fraser University

Overview: Shape Changers

- **Protist** is the informal name of the diverse group of mostly unicellular eukaryotes
- Protists are a diverse group of eukaryotic microorganisms that don't fit neatly into other kingdoms like plants, animals, or fungi. They are often referred to as the "odds and ends" kingdom because of their varied characteristics.
- Some protists, like the ciliate **Didinium**, are able to perform dramatic shape changes due to the structural complexity of their cells

Figure 25.2

Exploring the Early Evolution of Eukaryotes



Concept 25.4: Single-Celled Eukaryotes Play Key Roles in Ecological Communities and Affect Human Health

- The majority of the eukaryotic lineages are composed of protists
- Protists exhibit a wide range of structural and functional diversity

Structural and Functional Diversity in Protists (1 of 2)

- Most protists are unicellular
- Single-celled protists can be very complex, as all biological functions must be carried out within an individual cell

Structural and Functional Diversity in Protists (2 of 2)

- Most protists are aquatic, but they are found in diverse environments, including moist terrestrial habitats
- Protists show a wide range of nutritional diversity
- Photoautotrophy, heterotrophy, and mixotrophy have arisen independently in protists many times

Effects on Human Health (1 of 3)

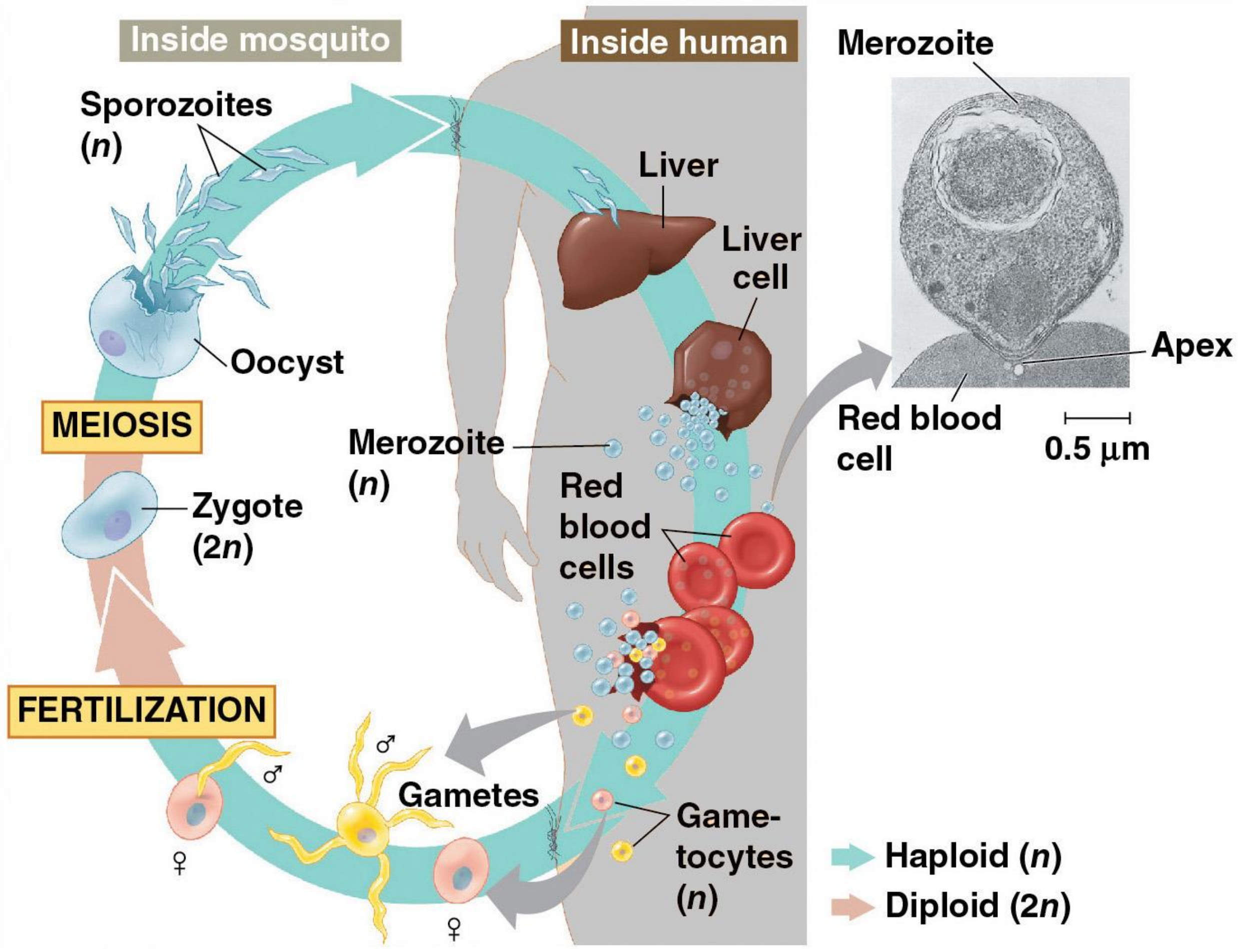
- Some protists cause infectious diseases
  - For example, *Trypanosoma* is an excavate that causes sleeping sickness in humans
  - Trypanosomes evade immune responses by switching cell surface proteins between generations
  - These frequent changes prevent the host from developing immunity

Effects on Human Health (3 of 3)

- The apicomplexan *Plasmodium* is the parasite that causes malaria
- *Plasmodium* requires both mosquitoes and humans to complete its life cycle
- About 200 million people in the tropics are infected, and about 600,000 die each year from malaria
- Efforts are ongoing to develop vaccines that target this pathogen

Figure 25.27

The Two-Host Life Cycle of *Plasmodium*, the Apicomplexan That Causes Malaria



The Colonization of Land

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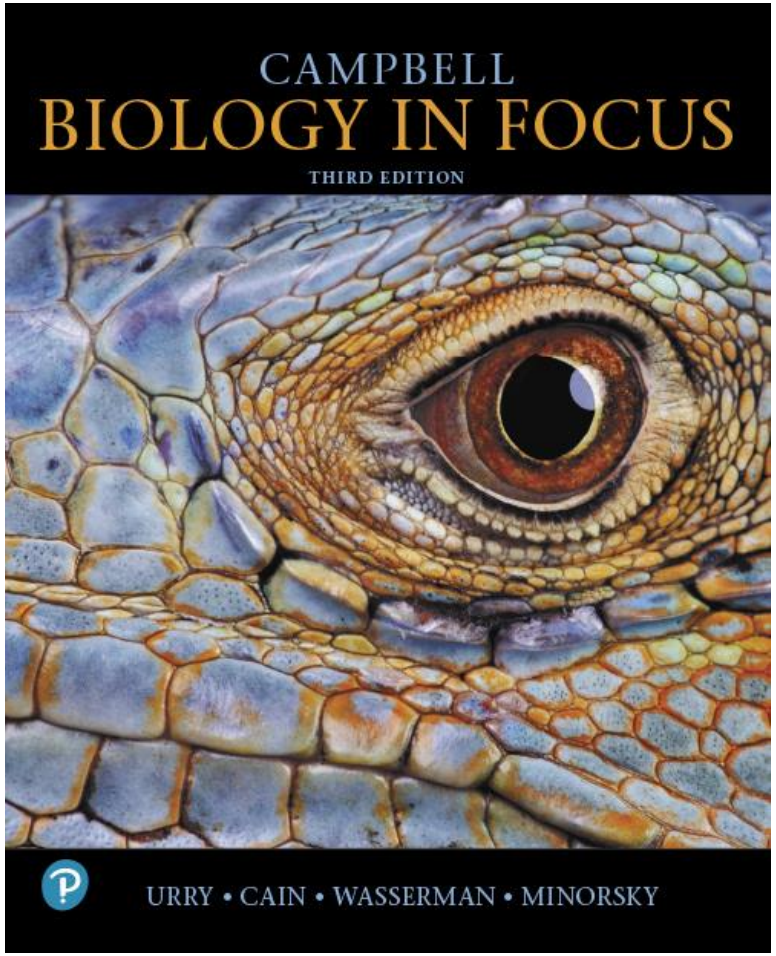


Chapter 26

The Colonization of Land

Lecture Presentations by
Kathleen Fitzpatrick and Nicole Tunbridge,
Simon Fraser University

Concept 26.3: Early Plants Radiated into a Diverse Set of Lineages (1 of 2)

- As early plants adapted to terrestrial environments, they gave rise to a vast diversity of present-day plants

Figure 26.18

Highlights of Plant Evolution

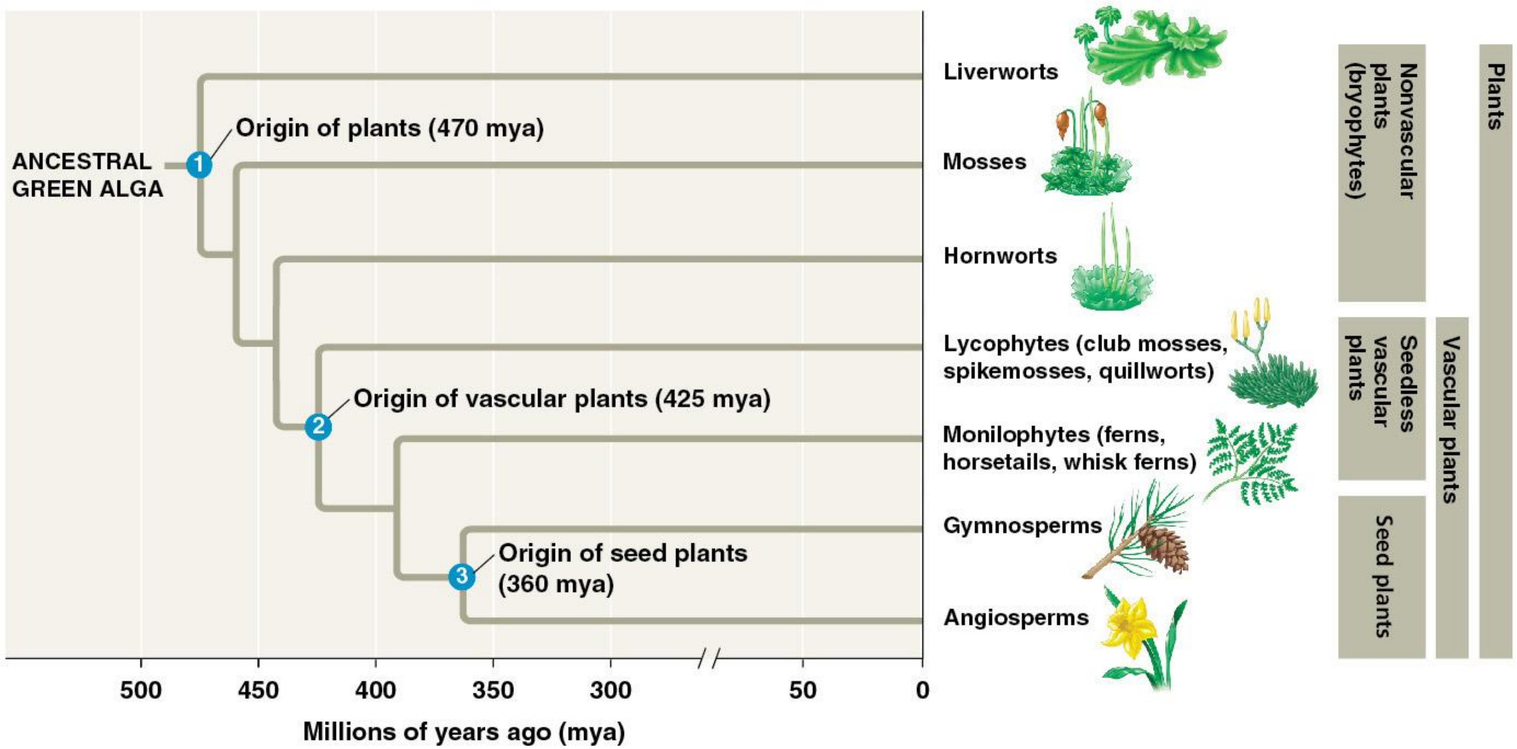


Figure: Plant Phylogeny: Nonvascular Plants (Bryophytes)

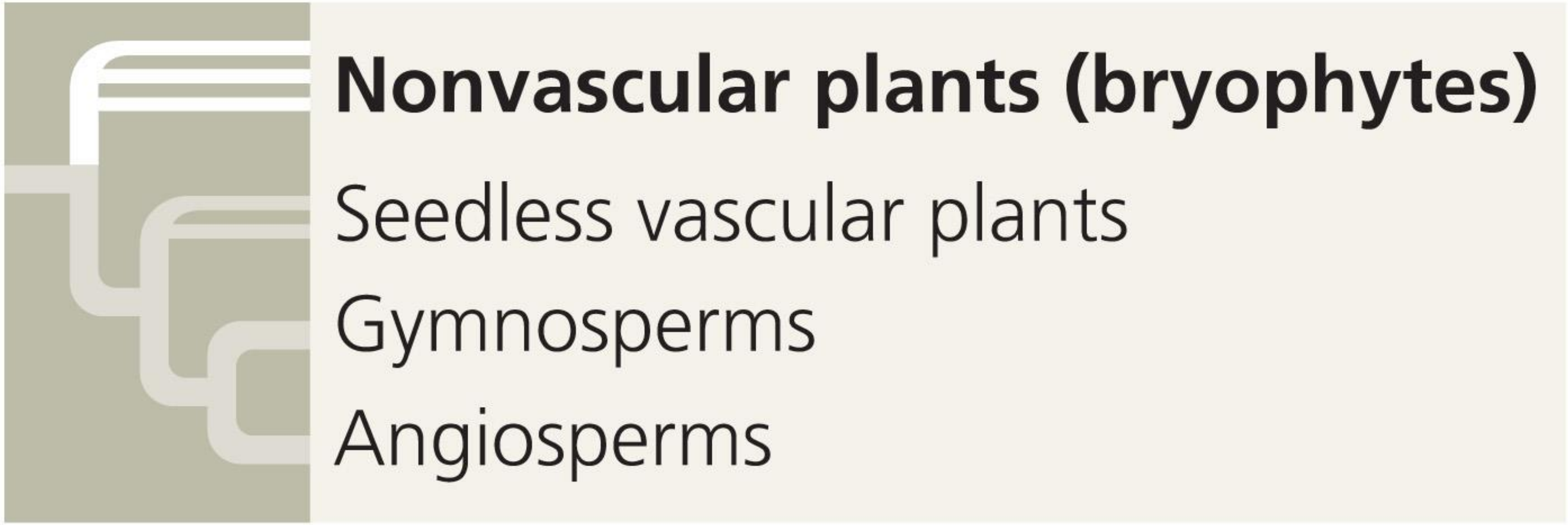
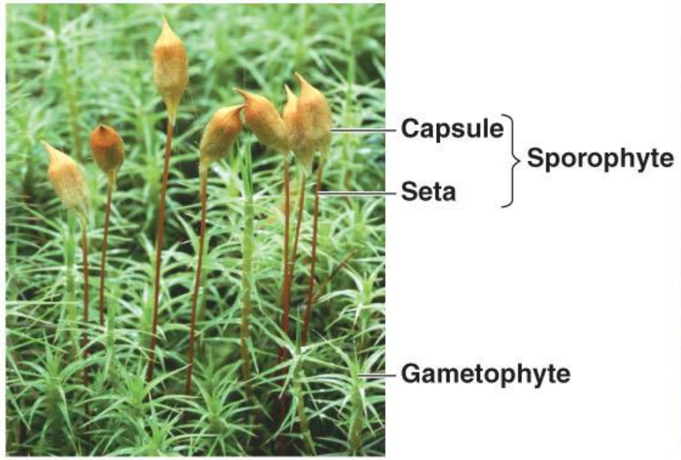


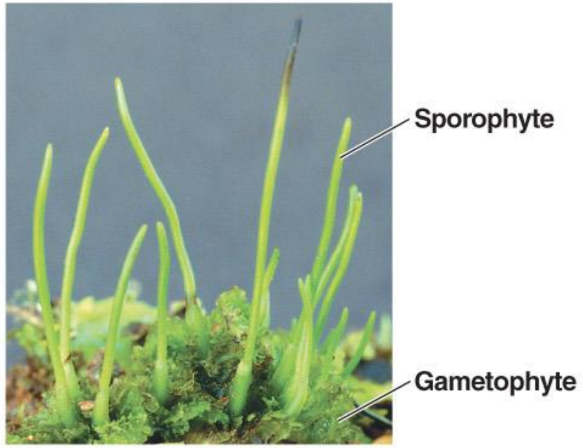
Figure 26.19

Bryophytes (Nonvascular Plants)

(a) *Plagiochila deltoidea*, a liverwort.



(b) *Polytrichum commune*, a moss.



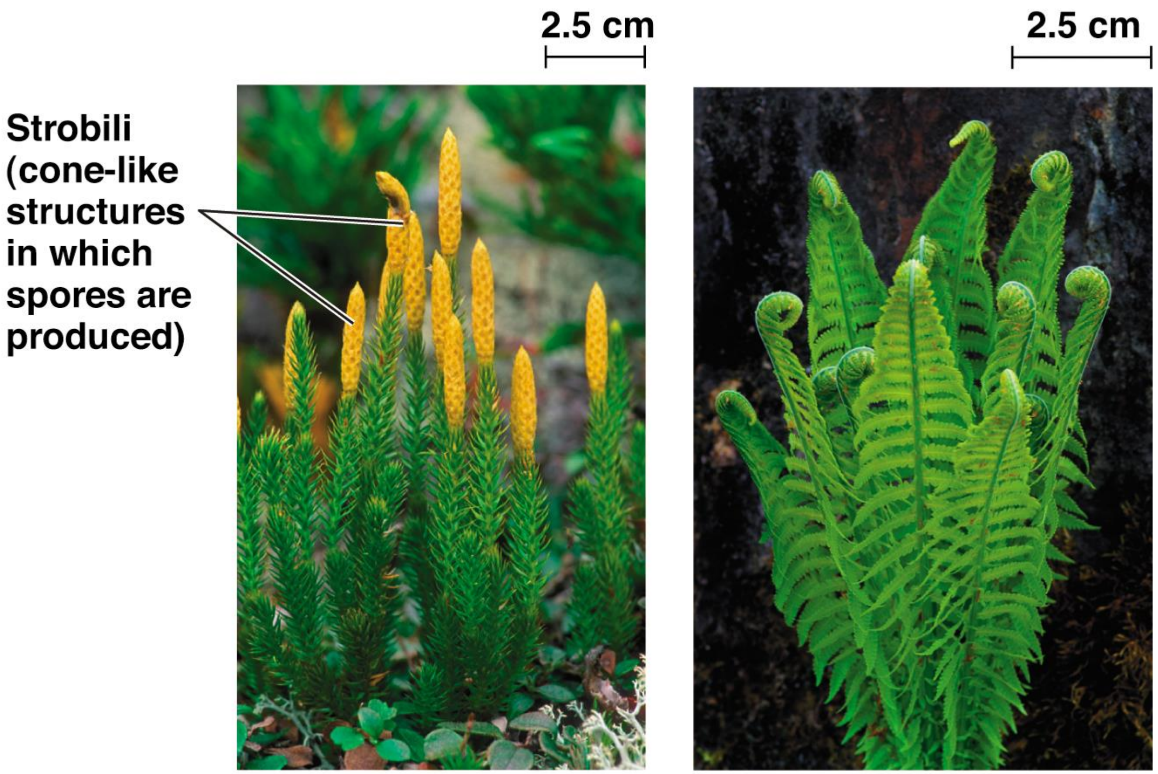
(c) *Anthoceros* sp., a hornwort.

Seedless Vascular Plants: The First Plants to Grow Tall (2 of 2)

- **Seedless vascular plants** can be divided into two clades
  - **Lycophytes** (club mosses and their relatives)
  - **Monilophytes** (ferns and their relatives)

Figure 26.20

Lycophytes and Monilophytes (Seedless Vascular Plants)



(a) *Lycopodium annotinum*, a lycophyte.

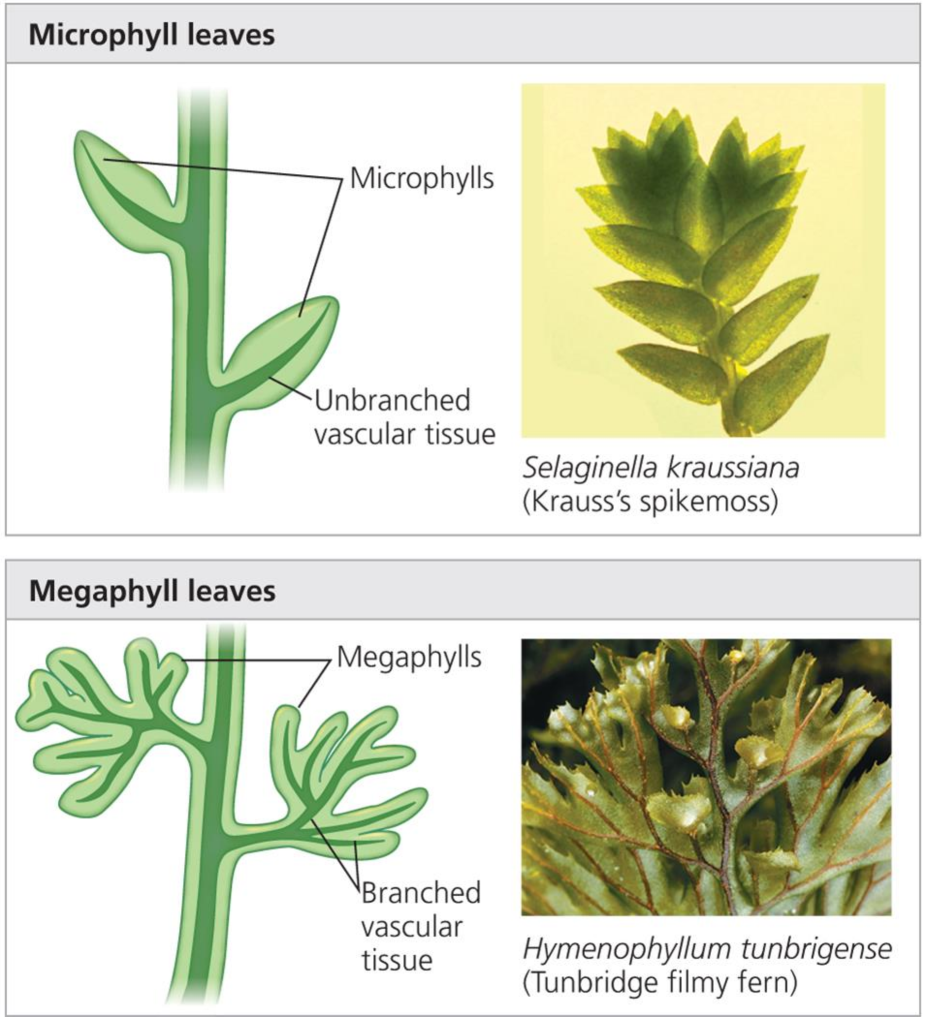
(b) Ostrich fern (*Matteuccia struthiopteris*), a monilophyte.

Evolution of Roots and Leaves (1 of 3)

- **Roots** anchor vascular plants and enable them to absorb water and nutrients from the soil
- **Leaves** are the primary photosynthetic organ of vascular plants

Figure 26.22

Microphyll and Megaphyll Leaves



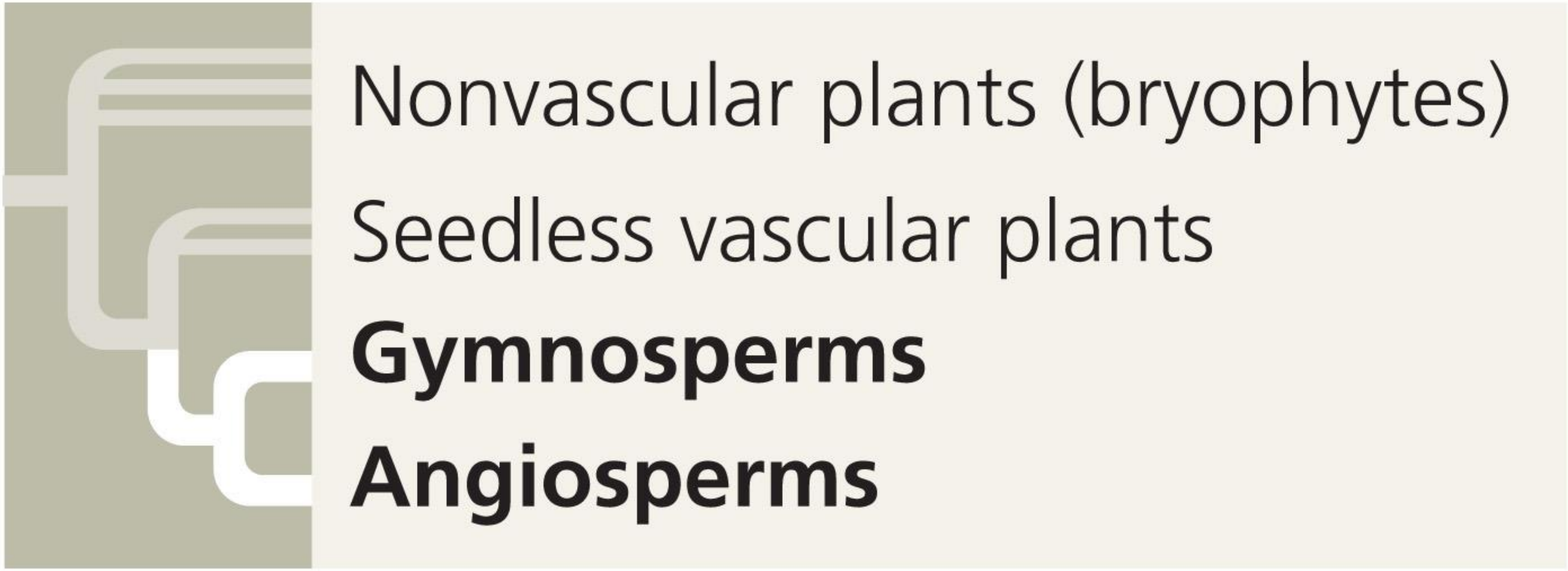
Concept 26.4: Seeds and Pollen Grains Are Key Adaptations for Life on Land (1 of 2)

- Seed plants originated about 360 million years ago
- An adaptation called the seed allowed them to expand into diverse terrestrial habitats
- A **seed** consists of an embryo and its food supply, surrounded by a protective coat
- Mature seeds are dispersed by wind or other means

Concept 26.4: Seeds and Pollen Grains Are Key Adaptations for Life on Land (2 of 2)

- Extant seed plants are divided into two clades
  - **Gymnosperms** have “naked” seeds that are not enclosed in chambers
  - **Angiosperms** have seeds that develop inside chambers called ovaries

Figure: Plant Phylogeny: Gymnosperms and Angiosperms



Terrestrial Adaptations in Seed Plants

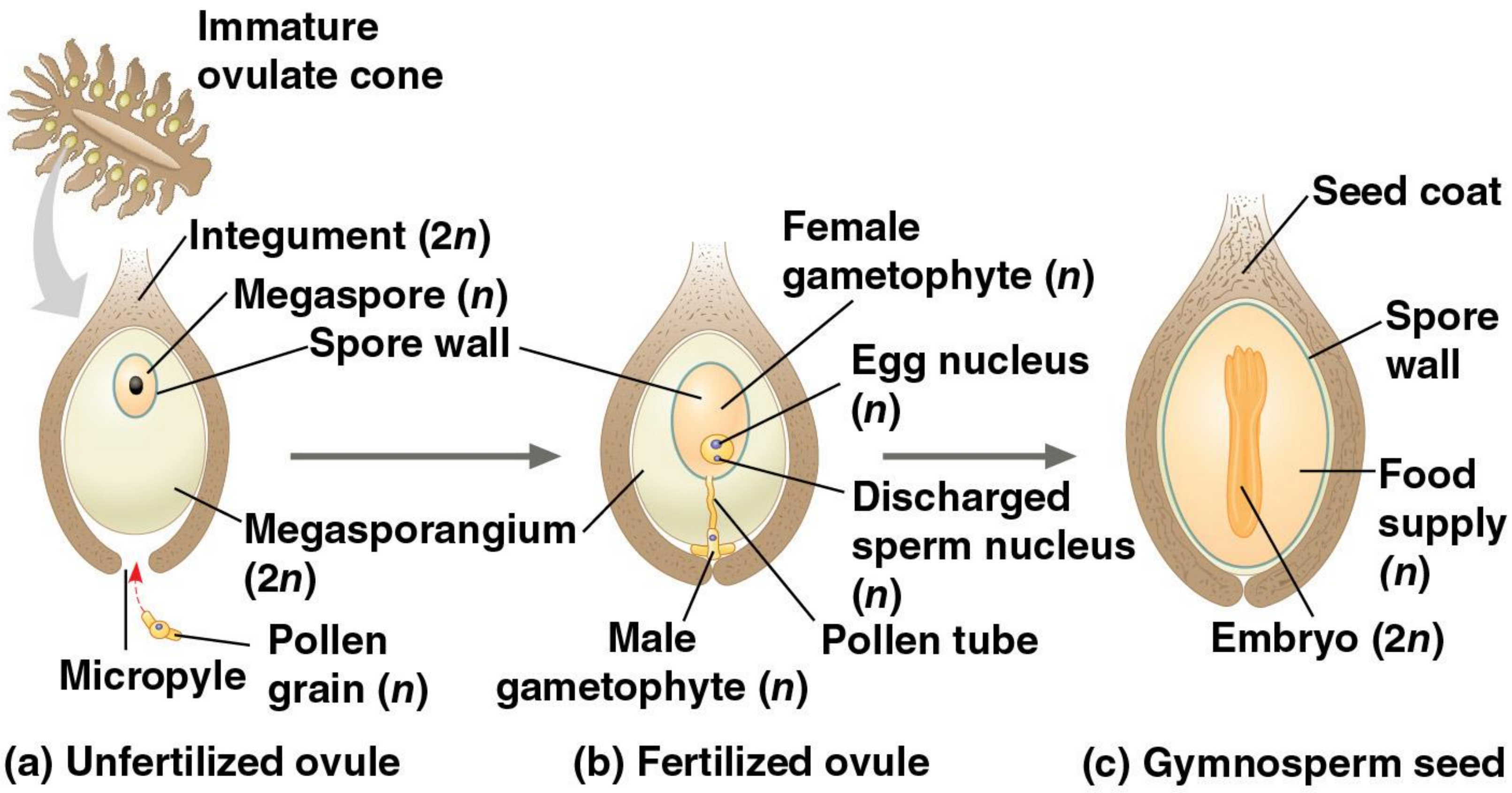
- In addition to seeds, the following are common to all seed plants:
  - Reduced gametophytes
  - **Ovules** consists of an egg-producing female gametophyte surrounded by a protective layer of sporophyte tissue
  - A **pollen grain** develops from a haploid microspore and consists of a male gametophyte surrounded by a protective wall

Ovules and Pollen (2 of 2)

- **Pollination** is the transfer of pollen to the part of a seed plant containing the ovules
- Pollen does not require water for transport; it can be dispersed great distances by wind or animals
- Transfer of sperm without water allowed seed plants to successfully colonize dry habitats

Figure 26.23

From Ovule to Seed in a Gymnosperm



The Evolutionary Advantage of Seeds (2 of 2)

- Seeds provide some evolutionary advantages over spores
  - Seeds are multicellular and have a protective layer of tissue protecting the embryo; spores are usually single-celled
  - They can remain dormant from days to years, until conditions are favorable for germination
  - Seeds have a supply of stored food

Figure 26.25

Examples of Gymnosperms

(a) Sago palm (*Cycas revoluta*)

(b) Douglas fir (*Pseudotsuga menziesii*)

(c) Creeping juniper (*Juniperus horizontalis*)

The Origin and Diversification of Angiosperms

- Angiosperms are seed plants that produce reproductive structures called flowers and fruits
- They are the most widespread and diverse of all plants with over 250,000 species (90% of all plants)

Flowers and Fruits (1 of 6)

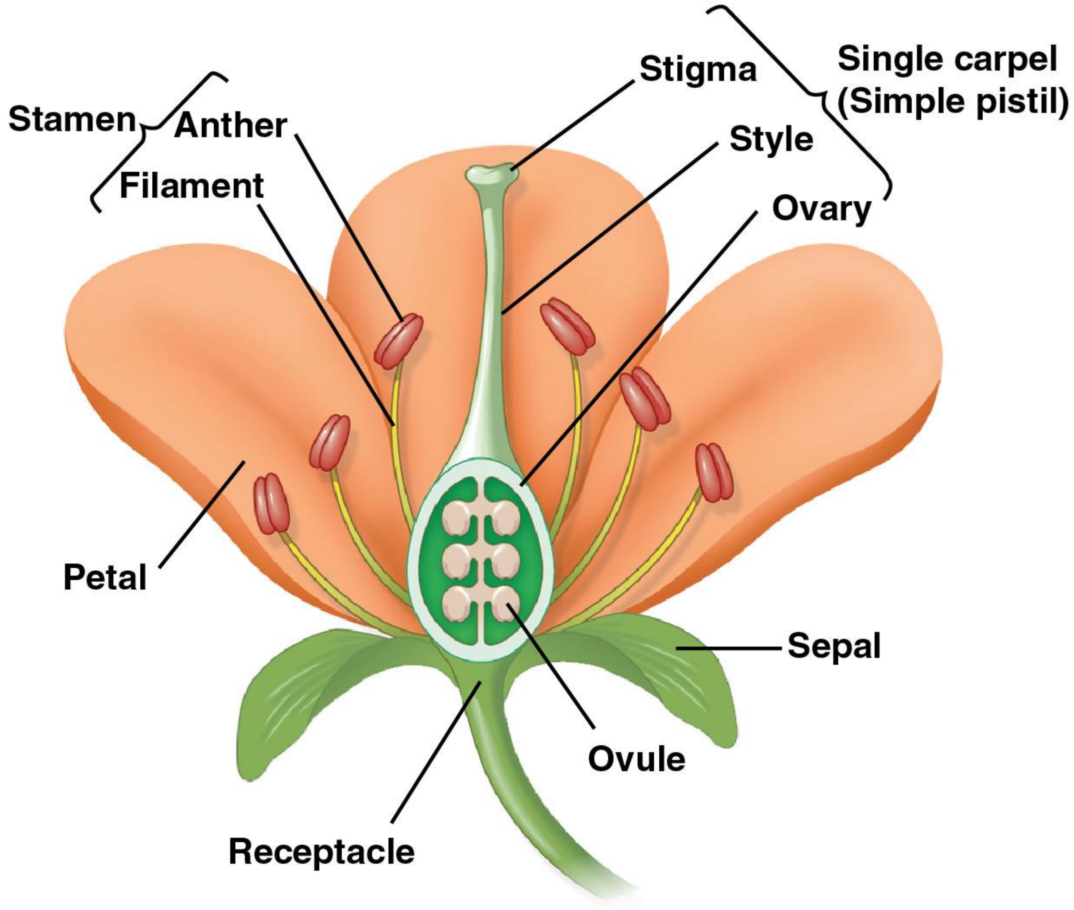
- The **flower** is an angiosperm structure specialized for sexual reproduction
- Many species are pollinated by insects or other animals, while some species are wind-pollinated

Flowers and Fruits (2 of 6)

- A flower is a specialized shoot with up to four types of modified leaves called floral organs
  - **Sepals**, which are usually green and enclose the flower before it opens
  - **Petals**, which are brightly colored and attract pollinators
  - **Stamens**, which produce pollen
  - **Carpels**, which produce ovules

Figure 26.26

The Structure of an Idealized Flower



Flowers and Fruits (5 of 6)

- Seeds develop from ovules after fertilization
- The ovary wall thickens and matures to form a **fruit**
  - For example, a pea pod is a fruit, with seeds (mature ovules, the peas) encased in a ripened ovary (the pod)
- Fruits protect seeds and aid in their dispersal

Flowers and Fruits (6 of 6)

- Various fruit adaptations help disperse seeds by wind, water, or animals
- Fruits can function as
  - Parachutes or propellers for wind dispersal
  - Burrs that cling to animal fur or human clothing
  - Food that is carried in the digestive system of animals with seeds passing unharmed when the animal defecates

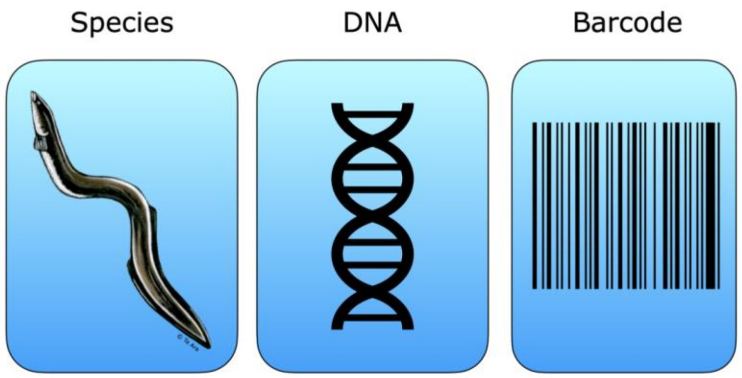
Copyright

Computing Tools

Several Computing Tasks

- Sequence alignment: Aligning DNA or protein sequences to identify similarities and differences between species.
- DNA Barcoding
- Phylogenetic analysis: Using algorithms to build evolutionary trees based on genetic data.
- Data mining and machine learning: Using these techniques to identify patterns and relationships in large datasets.

DNA Barcoding



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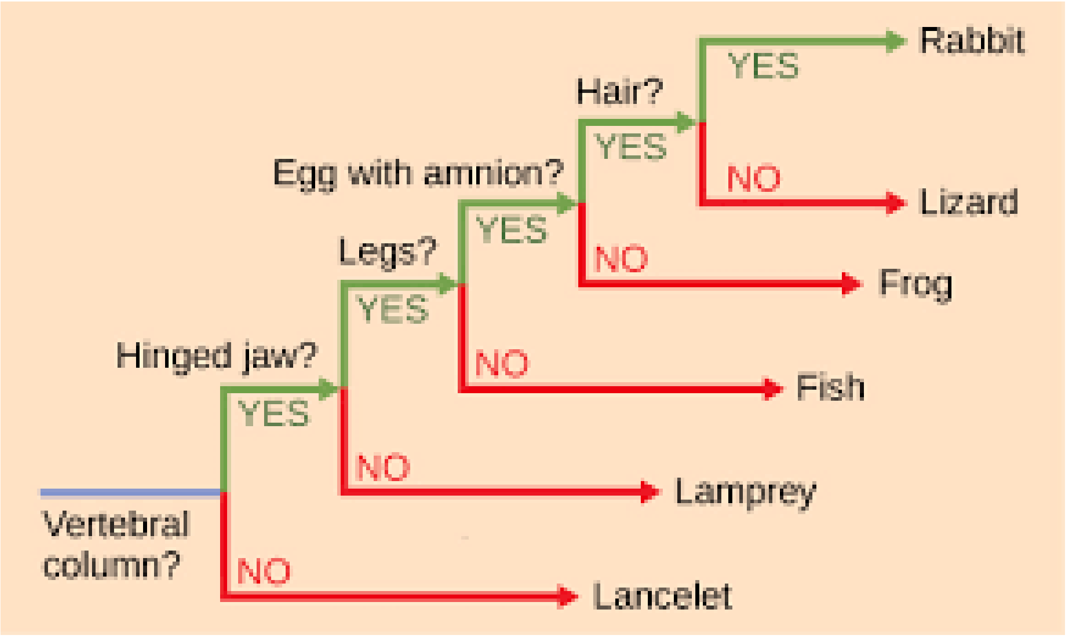
- DNA barcoding is a method of species identification using a short section of DNA from a specific gene or genes.
- By comparison with a reference library of such DNA sections or sequences, an individual sequence can be used to uniquely identify an organism to species.
- Some applications:
  - identifying plant leaves even when flowers or fruits are not available;
  - identifying pollen collected on the bodies of pollinating animals;
  - identifying insect larvae which may have fewer diagnostic characters than adults; or
  - investigating the diet of an animal based on its stomach content, saliva or feces.

Phylogenetic Analysis

- A phylogenetic tree is a visual representation of the relationship between different organisms, showing the path through evolutionary time from a common ancestor to different descendants.
- Similarities and divergence among related biological sequences revealed by sequence alignment often have to be rationalized and visualized in the context of phylogenetic trees. Thus, molecular phylogenetics is a fundamental aspect of bioinformatics.



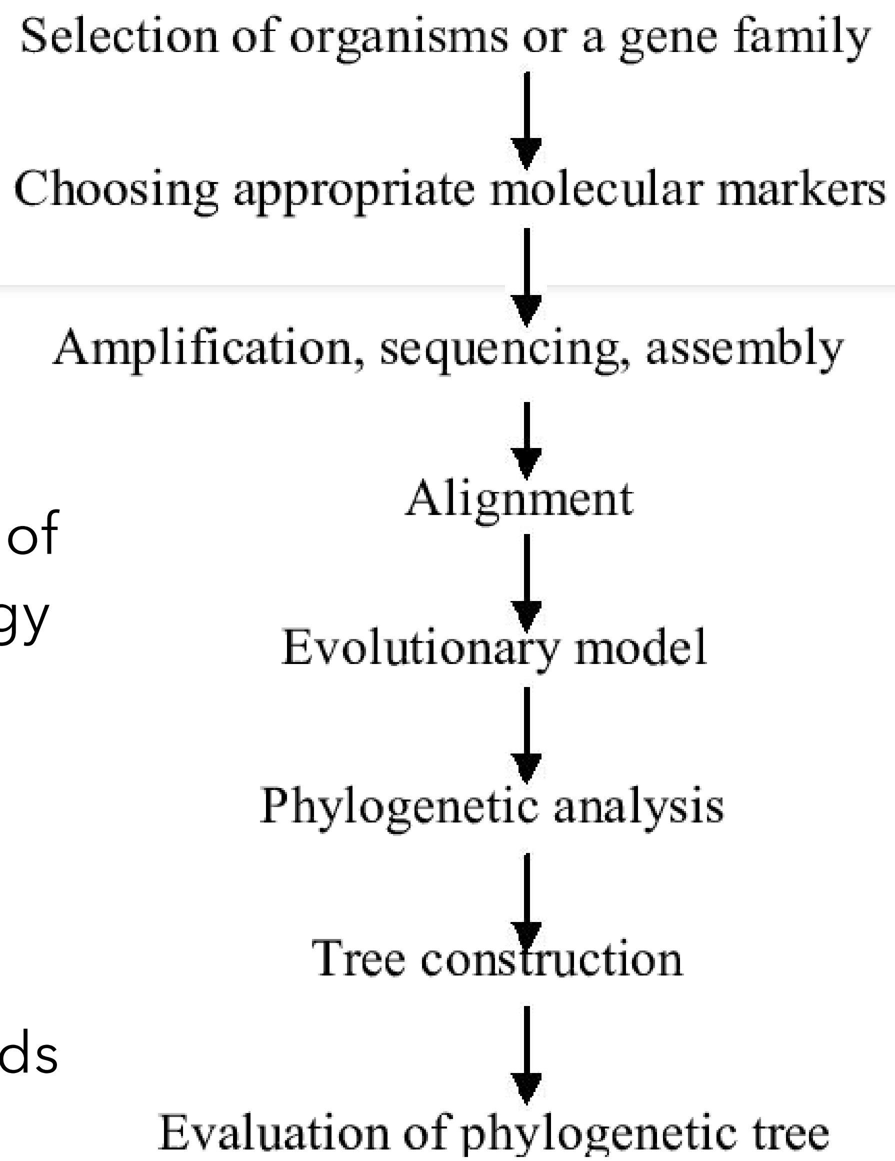
Phylogenetic Analysis

- Basic Steps:

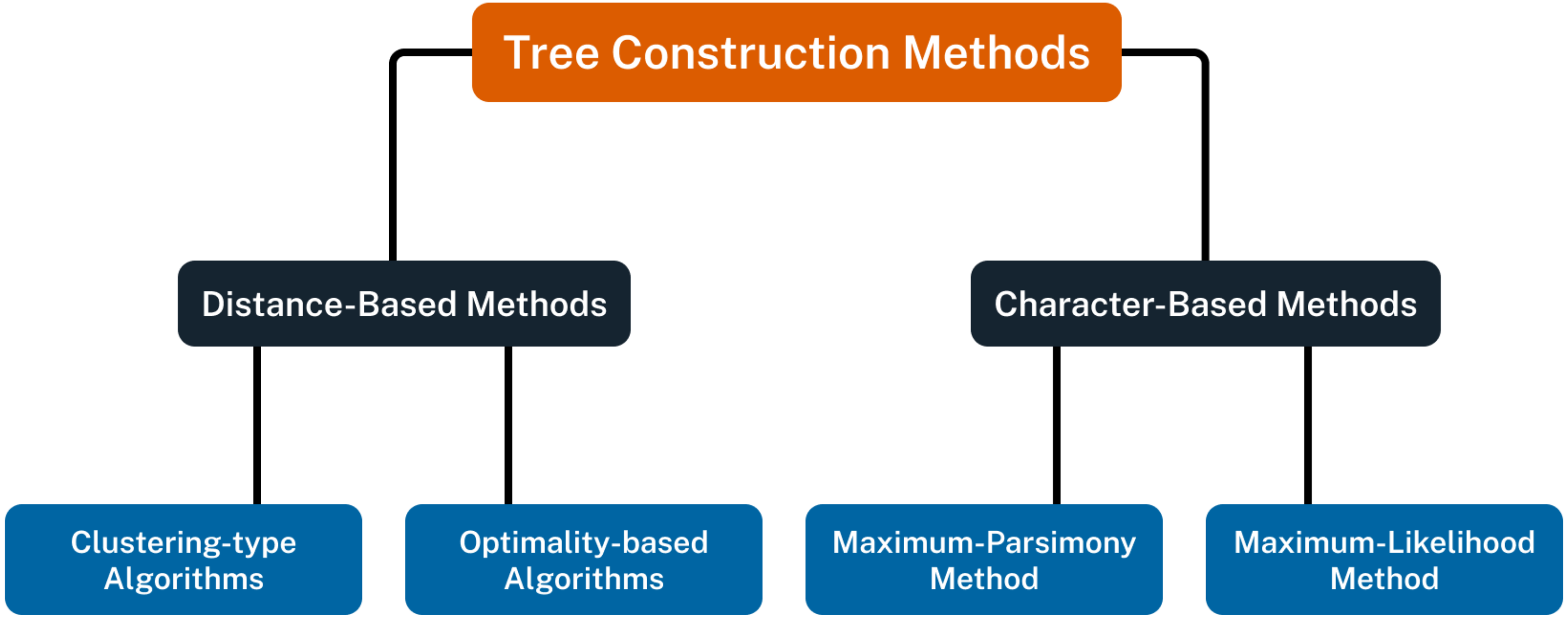
1. **Assemble and align a dataset**: arranging a set of sequences in matrix to identify regions of homology

2. **Build** (estimate) **phylogenetic trees from sequences** using computational methods: maximum parsimony, maximum likelihood.

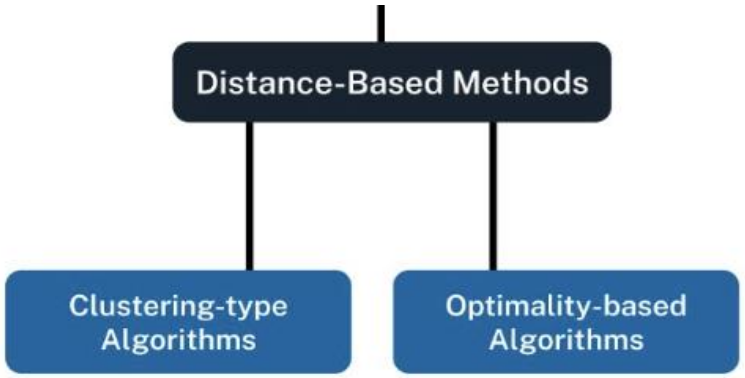
3. **Statistically test and assess the estimated trees**: Bootstrap and Jackknife Resampling methods



Phylogenetic Tree Construction Methods



Distance-Based Methods



- Distance-based: based on the total number of evolutionary changes between pairs of sequences.

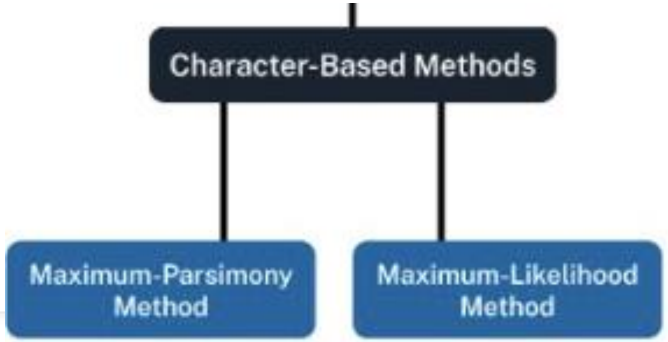
1. Clustering type algorithm

UPGMA: Cluster 2 sequences with the smallest pairwise distance

2. Optimality based algorithm

Neighbor joining: Begin with a star tree where all taxa are joined through a single node. Then, nodes are sequentially added to cluster the two closest related taxa together. Repeats for the rest of the sequences.

Character-Based Methods

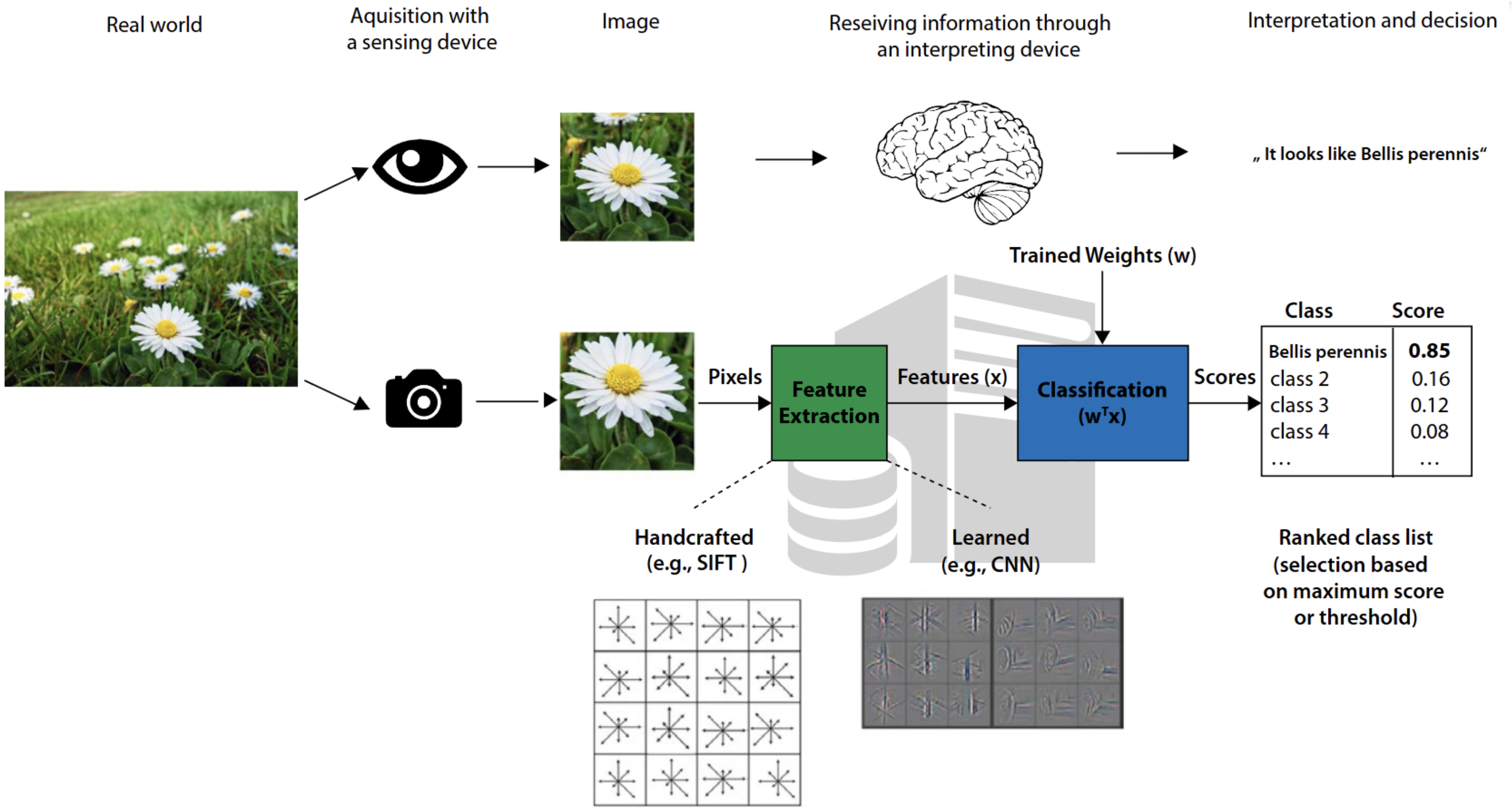


- Character-based methods compare all sequences by considering one "character" (such as the nucleotide or amino acid) in the alignment at a time. More accurate, but more computationally intensive.

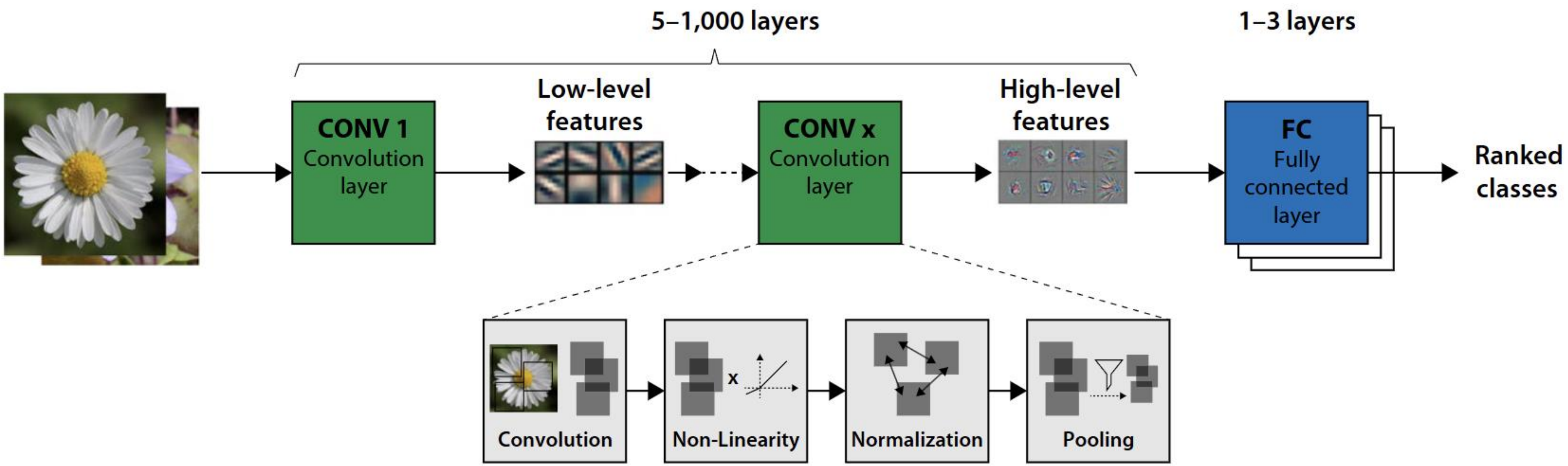
1. Maximum parsimony: building all possible trees and selecting the best tree based on the smallest number of evolutionary changes

2. Maximum likelihood: constructs all possible trees and selects the tree that most likely predicts the relatedness between sequences based on a specific evolutionary model.

Computer Vision



CNN for Image based Species Identification



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