Session Objectives: Students will be able to...

- define taxonomy, the binomial nomenclature system, and how are plants ordered
- accurately define evolution, including how evolution occurs, and the causal agents
- describe cladistics, and construct a simple phylogenetic tree from a character chart
- define convergent evolution and give examples from the plant world
- describe the three domains of life and provide examples of each

What is Evolution?

- Evolution is not just change over time. *e.g.* you have changed over time, but you haven’t evolved
  - Biological evolution is change in the properties of populations that transcend the lifetime of a single individual.
- Individual organisms do not evolve.
- Evolutionary changes are inheritable from one generation to the next.

Modern Evolutionary Synthesis

- Population Genetics merged Darwinian evolution and Mendelian principles
  - Evolution needed an explanation for inheritance of information
- **Population**: localized group of individuals belonging to the same species
- **Species**: a group of populations that could interbreed
- **Allele**: one of many forms of a gene
- **Genotype**: all genes in an organism
- **Gene pool**: sum total of all alleles of all the genes of all individuals in a population.
- **Phenotype**: the physical appearance of an organism

Evolution is the change in the frequency of alleles in a population over time

What creates evolutionary change? These are the Agents of Evolution:

- **Mutations**: 
  - Most are detrimental; raw material for evolution
- **Gene Flow**:
  - New alleles will change proportions or frequencies in population
- **Genetic Drift**:
  - Laws of probability will greatly affect small populations; **founder effect** and **bottleneck effect**
- **Nonrandom mating**:
  - **Inbreeding**: mating of closely-related individuals (e.g. self-pollination)
- **Natural selection**:
  - **Artificial selection**: a similar process that is controlled by humans to breed favorable plants and animals

Speciation: the origin of new species

- **Allopatric speciation**: a geographic barrier separates populations which evolve “away” from each other.
  - *e.g.* islands, mountains, waterfalls

J. Boyer, Ph.D.
May lead to an adaptive radiation of species (e.g. Galapagos Islands)

- **Sympatric speciation**: genetic changes create a reproductive barrier which allow a new species to arise even though it is within breeding distance. *e.g.* polyploidy - having more than two sets of chromosomes
  - **Autopolyploidy**: doubling of chromosomes within an individual
    - non-disjunction during meiosis
  - **Allopolyploidy**: cross between two close species
    - Offspring usually sterile, but still can spread asexually
    - If autopolyploidy occurs in this “sterile” offspring then it becomes fertile and can produce gametes

**Evolution and Deep time**
- What is **microevolution**? Evolution on a small scale; within a single population of a species.
- What is **macroevolution**? Evolution *above the species level*, assessing the diversity of an entire clade and its position on the tree

**Convergent Evolution**
- Unrelated species evolve a similar form or function
- *Example*: plant form in arid environments (cacti and spurges look alike but evolved from different ancestors)

**The Pace of Evolution**
- **Phyletic Gradualism**: evolution occurs at a slow but constant rate
  - Species continue to adapt to new challenges over the course of their history, gradually becoming new species.
  - There is no clear line of demarcation between the old species and the new species
- **Punctuated Equilibrium**: abrupt changes in form followed by long periods of stasis
  - Most sexually reproducing species will show little change for most of their geological history
  - When phenotypic evolution occurs, it is localized in rare events
  - Branching speciation occurs relatively quickly compared to the species’ full and stable duration on earth

**Binomial System of Nomenclature**
Carolus Linnaeus: (1707-1778)
- *Species Plantarum* (1753): The 1st official reference of scientific names for botanical descriptions
  - Each name has 2 parts (bi-nominal system)
    - Generic epithet (“genus name”) both epithets create a “species name”
    - Specific epithet
  - Binomial System of Nomenclature
    - All organisms are named with this system, and placed in a taxonomic classification
**Taxonomy:** A classification system used to sort organisms based upon similarities
- Domain (e.g. Eukaryota: membrane bound organelles)
- Kingdom (e.g. **Viridiplantae:** green algae and land plants)
- Phylum (e.g. **Streptophyta:** group including algal ancestors and land plants)
- Class (e.g. **Spermatopsida:** seed plants)
- Order (e.g. Rosales: specific group of flowering plants)
- Family (e.g. Rosaceae: rose family)
- Genus (e.g. *Rosa*): always capitalized; always underlined or italicized
- Species* (e.g. *Rosa multiflora*): always underlined or italicized

**CLADISTIC METHODOLOGY**
Method to determine evolutionary relationships of organisms based upon features or genetic information of taxa; relationships are visually represented as phylogenetic trees
- Features or characteristics of the organism are “coded” for each organism in the study...
  ...Is a feature present (1), absent (0) or unknown (?) for this taxa (=some taxonomic unit: e.g. species)
- Researchers need to determine which characters are “ancestral” and which are “derived”
- An ancestral feature, called a **pleisomorphy**, is less informative (e.g. a nucleus is not informative for resolving flowering plant evolution)
- A derived feature is called an **apomorphy**, and is most important; uniquely evolved feature to a group and its descendant
  - Computer algorithm (program) calculates the possible evolutionary relationships of taxa in study, based on coded features provided by the researchers
  - The result is a **phylogenetic tree** or cladogram, which the hypothesized evolution of the taxa based on the data
  - Researchers use **parsimony** (i.e. simplest assumption is best) to determine between several cladograms
- Cladistics is concerned with natural, evolutionary groupings, not an artificial collection of taxa
  - **Monophyletic** group includes an ancestor and all derived taxa; natural evolutionary group
    → A-F, D-F, or B-C (below) all form monophyletic groups (e.g. angiosperms)
  - **Paraphyletic** group is a grade of taxa that include an ancestor, but **not all derived taxa**
    → B-D (below) would form a paraphyletic group (e.g. “pteridophytes”)
  - **Polyphyletic** group is a selection of non-contingent taxa
    → A, C, D & F (below) would form a polyphyletic group (e.g. “algae”)

- Taxa A would be the most ancestral taxon in this group
- A, B, C, D, E, & F form a monophyletic group all possessing feature “X”; This feature is a apomorphy for the A-F clade
- A synapomorphy for taxa E and F is feature “Y”. These two taxa (E-F) form a monophyletic group
Pattern and Process
- Cladistics defines the pattern of how organisms are related, but evolution is the mechanism/process that creates this pattern

DIVERSITY OF LIFE

PROKARYOTES, are paraphyletic group of organisms, that lack a nucleus or organelles
- The oldest living organisms on earth (at least 3.55 billion years ago; maybe 4.2 bya)
  - These organisms have ancestral features, but not primitive
  - Dominant forms of life on earth, found everywhere and inside almost everything
- There are two groups of prokaryotes
  1. Bacteria
  2. Archaea

BACTERIA, in the domain Bacteria, are the most abundant organisms on Earth
- Cellular features
  - Cell wall: complex suite of molecules
  - Nucleoid: circular DNA (chromosome)
  - Flagella: allows motility
  - Pilus: connects organisms; allows conjugation
- Forms: spherical-, rod-, and spiral-shaped
  - Heterotrophs and autotrophs (photo- & chemo-synthetic)
  - Aerobic (O₂-rich) and anaerobic (O₂-free) environments
- Ecological Importance
  - Major impact on global carbon balance
  - Able to “fix” free nitrogen into usable form (nitrate)
  - Decompose toxic substances, natural & artificial
- Diseases:
  - Plant: most blights, soft rots, and wilts are bacterial
- Cyanobacteria: photosynthetic (chlorophyll a)
  - Some fix nitrogen through heterocyst (in the Fabaceae, some Cycads, Azolla)
- Stromatolites: large, ancient bacterial communities
- Purple & Green Bacteria: chemosynthetic
  - Use bacteriochlorophyll along with sulfur (not oxygen)
• endosymbiont group for eukaryotes (mitochondria)
• **Prochlorophytes**: photosynthetic
  • Possess **chlorophylls a and b**, same as plant chloroplasts
• **Millicutes**: lack cell walls; **very small** (0.1 – 0.3 μm)
  • Spiroplasmas, mycoplasmas, phytoplasmas
  • *e.g.* Citrus stubborn disease, Peach X-disease, Pear decline, Aster-yellows (carrots),
    Lethal yellowing of coconuts
  • Infect the phloem sieve elements of plants

**ARCHAEA**, in the domain **Archaea**, were once called Archaebacteria
• They are microscopic, prokaryotic organisms living in **extreme environments**
• Archaea are a major component of ocean picoplankton (less than <1μm or <0.001 millimeter in size), as well as soil dwelling
• These organisms possess genes that are more closely related to those of eukaryotes, such as the enzymes involved in **transcription** and **translation**
• Archaea have cell walls with a double layer, unlike bacteria or eukaryotes
• **Types**:
  • **Halophiles**: extreme salt-loving
  • **Methanogens**: methane-producing prokaryotes: sewage-treatment, bogs, ocean depths
  • **Thermophiles**: extreme heat-loving: hot springs, geysers, deep-sea vents

**LABORATORY DRAWING**
• Cyanobacteria (*Nostoc* or *Anabaena*): DRAW vegetative cells and heterocysts

**QUESTIONS FOR THOUGHT**:
• What is evolution?
• How does evolution occur? What are the agents?
• What is taxonomy and how are plants ordered?
• What is cladistics?
• Could you make a cladogram from a character chart?
• What is a prokaryote?
• What are Bacteria?
• What unique role do bacteria play in the environment?
• How are they important for horticulturists?
• How are they different from the other domains?
• What are Archaea?
• Where could I find Archaea?
• What important role do they play in the environment?