Integrative Biology 335:
Systematics of Plants

Biodiversity

Announcements:

Today's lecture on biodiversity will be given by Dr. Ken Robertson of the Illinois Natural History Survey.

Lecture Assignment 5 will be due, in lecture, on Monday, May 3rd. Late assignments (after class on due date) will incur a 50% penalty; assignments more than 24 hours late will not be accepted.

The final lab exam is on Tuesday, May 4th (stations in lab) and Wednesday, May 5th (slides in lecture). The exam will be comprehensive, but with emphasis on the last half of the course. This exam is worth 15% of your final grade. There is a sample final exam in the back of your Class Notes (pp. 269-284) and the exam will be similar in style to what you saw in Lecture Exam 2. For the final, be sure to review all readings, quizzes and assignments. You should also review your past two lecture exams (by coming by Prof. Downie's office and looking at your graded exams).

If there is interest, there will be a final lecture exam review (most likely on Reading Day; time and place TBA). Currently, there will NOT be a lecture review, as only two students have indicated an interest.

Lastly, since this is our last formal lecture, any further announcements I need to make will be presented on the General Course Announcements webpage.

Web Resources:

Some of the information presented below parallels that used in 100/101. This information was prepared by Prof. Downie many years ago when he was teaching in that course.

- Scientific Definitions of Biodiversity, California Biodiversity Council
- Millennium Ecosystem Assessment, assessing the consequences of ecosystem change for human well-being
- World Conservation Monitoring Centre, an overview of biodiversity
- World Resources Institute, the diversity of life
- Biodiversity and Conservation, a hypertext book
- Biodiversity and Conservation: The Web of Life, Field Museum of Natural History, Chicago
- Illinois Natural History Survey, Institute of Natural Resource Sustainability

Objectives:

1. Define the term biodiversity and explain how the three levels of biodiversity (genetic, species, and ecosystem) are related and dependent on one another.
2. Define what a species is and discuss why this definition is important in knowing how many species there are.
3. Have an idea how many species of flowering plant species have been described, how many may actually exist, and where in the world species richness is the greatest.
4. Know approximately how many species of flowering plants occur natively in Illinois today, as well as how many species are endemic to Illinois.
5. Explain how biodiversity is lost, how rapidly it is currently being lost, and some of the reasons why we might be concerned about this loss.
6. Explain the role of systematics in studying biodiversity.

After studying this material you should be able to:

"How Systematics Works"

- Field botanists explore the world's ecosystems and collect herbarium specimens
- These specimens are examined and identified to known species (if indeed possible)
- New species are formally described, named, and published
- These names are eventually incorporated into identification manuals (or floras)
- Herbarium specimens that have been identified are then placed in herbaria
- Scientists study herbarium material and, when possible, living plants to understand how species, genera, and families are circumscribed and related to each other
- Molecular studies often use herbarium specimens by extracting DNA from them; phylogenies derived from molecular data can be used to answer all sorts of systematic and evolutionary questions.

For several hundred years now, botanists have explored the far regions of the world, as different parts became accessible, and collected herbarium specimens, which were sent back to herbaria; sometimes seeds were also collected and set back to botanical gardens. Botanical explorers were, and are, interested in collecting:

- native plants growing wild
- new agricultural crops
- new horticultural plants
- medicinal plants

The scientific discipline of "taxonomy" or "systematics" grew out of the need to formally describe, name, and classify all the newly discovered species. The original goal of taxonomy was to catalog life on earth.

Taxonomy progresses with the gain of accumulated knowledge and advances in technology. Consequently, in the past 250 years, the science of taxonomy and systematics has grown and diversified. Today, it can be said, perhaps a bit simplistically, that there are two major branches in systematics:

- cataloging, that is the basic process of exploring,
collecting herbarium specimens, and describing and naming new species and other taxa.

- studies that concentrate on inferring evolutionary histories within and among taxa across all hierarchical levels.

While also simplistic, most current research in the cataloging takes place at major botanical gardens, arboreta, and natural history museums, while most evolutionary work is concentrated at universities.

In this lecture, the emphasis is on the cataloging aspect of taxonomy and on the more general topic of BIODIVERSITY.

**BIODIVERSITY = Biological Diversity**

The world’s living species and populations of organisms along with their associated habitats and ecological systems.

Biodiversity is defined at three levels:

- Genetic diversity
- Species diversity
- Ecosystem diversity

Simply put, biodiversity increases when new genetic variation is produced, a new species arises, or a novel ecosystem (or habitat) is formed.

Biodiversity decreases when genetic variation within a species decreases, a species becomes extinct, or an ecosystem (or habitat) is lost.

Biodiversity is a dynamic process, and what we see today is the product of hundreds of millions of years of evolutionary history.

**Genetic Diversity:**

Individuals belonging to the same species are usually not identical genetically.

- Differences in the amount and distribution of genetic variation within a single species can be attributed to the enormous variety and complexity of habitats, and the different ways organisms have adapted to these habitats.

- Genetic diversity can be measured using a variety of DNA and protein-based techniques to determine genotypic differences. It can also in part be catalogued based on differences in expressed, phenotypic traits.

**Species Diversity:**

- The variety of living species.

- The question "What is a species?" is very important, for it has implications on how many species there actually are. Many different definitions of species have been proposed:
  - Morphological species concept: Plants that look alike are treated as the same species
  - Biological species concept: Plants that are reproductively isolated from each other are treated as different species
  - Genetic species concept: Species are defined by the amount of genetic distance between them
  - Phylogenetic species concept: A group of common ancestry that is diagnosably distinct from other such groups. (This means that geographic forms of the same species should be treated as distinct species—they have evolved separately, have unique evolutionary histories, and are diagnosably distinct. As such, the PSC can inflate species numbers.)

Some examples from: Systematics Agenda 2000: Charting the Biosphere

<table>
<thead>
<tr>
<th>Group</th>
<th>Number Described</th>
<th>Estimated Total Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viruses</td>
<td>5,000</td>
<td>10,000–50,000</td>
</tr>
<tr>
<td>Bacteria</td>
<td>4,000</td>
<td>400,000–5 million</td>
</tr>
<tr>
<td>Fungi</td>
<td>70,000</td>
<td>1–1.5 million</td>
</tr>
<tr>
<td>Protists</td>
<td>40,000</td>
<td>100,000–200,000</td>
</tr>
<tr>
<td>Algae</td>
<td>40,000</td>
<td>200,000–10 million</td>
</tr>
</tbody>
</table>

"Scientists have a better understanding of how many stars there are in the galaxy than how many species there are on Earth."

An estimated 1.4 million species have been described to date, and estimates for the total number of species vary from 2 to 100 million.

For additional information:

- How many species of flowering plants are there? from the World Resources Institute.
- Relative numbers of described species in major taxa also from the WRI.
How many species of flowering plants are there?

There are over 280,000 species of angiosperms described from throughout the world, with the total number of extant species probably reaching 400,000 by some counts.

The number of angiosperm families is well over 400.

A recent estimate of the number of flowering plant species arrived at a figure of 422,000. [No ref. citation, but numerous webpages cite this number]

Approx. half of the world's angiosperm species are found in three tropical countries: Brazil, Zaire and Indonesia. For comparisons, 18,000 species are found in the US (includes Hawaii and Puerto Rico) and 2,000 occur in Illinois.

Species diversity is not evenly distributed across the globe. In general, species richness is concentrated in equatorial regions (i.e., tropical rainforests) and decreases as one moves to the poles (or increases in altitude). Forty to fifty percent of all species are found in wet tropical rainforests, a region that comprises only 2% of the Earth's land surface.

<table>
<thead>
<tr>
<th>Location and Area</th>
<th>Number of Tree Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Borneo, 10 x 2.5 acre plots</td>
<td>100</td>
</tr>
<tr>
<td>Southeastern Asia, 2.5 acre plots</td>
<td>120 - 200</td>
</tr>
<tr>
<td>Peru, 2.5 acres</td>
<td>900</td>
</tr>
<tr>
<td>United States (3,400,000 miles²)*</td>
<td>600</td>
</tr>
<tr>
<td>Illinois (56,400 miles²)</td>
<td>137</td>
</tr>
</tbody>
</table>

* Includes Alaska, Hawaii, and Puerto Rico

How many species of plants occur in Illinois?

Approximately 2,000 species of flowering plants occur natively in Illinois today.

Only two species of flowering plants are endemic to Illinois; one of these is now extinct.

* *Thismia americana*, Burmanniaceae, collected between 1912-1916 from a single site near Chicago (Calumet)

* *Iliamna remota*, Malvaceae, Kankakee Mallow, restricted to Langham Island in the Kankakee River

Ecosystem (Habitat) Diversity:

- The variety of habitats, biological communities, and ecological processes occurring within and between each type of ecosystem.

- Ecological processes, such as water and nutrient cycling, energy flow, succession, predation, competition, mutualism, parasitism, primary production, decomposition of organic matter, soil rehabilitation, pest and disease regulation, water quality, and pollination/dispersal mechanisms are maintained by a wide range of biologically diverse populations in natural ecosystems.

- An ecosystem is a community of organisms and their physical environment interacting together. An ecosystem can cover a large area, such as a whole forest, or a small area, such as a pond.

- Ecosystem diversity is a precondition for genetic and species diversity.

*The natural community classification system used in Illinois*

- **Reduction of Biological Diversity**
  - **Species Loss (Extinction):**
    - In the geologic record, five mass extinctions have reset the level of biodiversity on earth

- Currently, we are in a biodiversity crisis, the sixth and fastest mass extinction in Earth's history.

- The rate of species extinction is 1,000–10,000 times higher now than at any time before humans evolved.

- In Illinois, 329 species of flowering plants are threatened or endangered.

  - **Endangered Species Program**, US Fish and Wildlife Service
  - **Endangered and Threatened Species in Illinois**
  - **The Sixth Extinction**, by Niles Eldredge

- **Population Loss (Loss of genetic variation):**
  - The decline in numbers and sizes of populations

  - Lack of variety in mate selection and potential for inbreeding
National Invasive Species Information Center
Their pictures and stories.
Loss of genetic diversity in Illinois populations of the Greater Prairie Chicken

Habitat Loss:
- Deforestation. About 60% of all the tropical rainforests which existed 100 years ago are now gone. Now, 1–2% of the remaining tropical forests are removed each year. This is equivalent to losing an area the size of Florida each year! This translates to about 2.4 acres (1 hectare) per second, equivalent to two football fields (or 149 acres per minute or an area larger than NYC every day). If deforestation continues at current rates, it is estimated that all tropical rainforests will be destroyed by the year 2030.
- Also pollution and development causes

Habitat Loss:
- Fragmentation of once continuous habitats into small remnants. Illinois once had 22 million acres of prairie (60% of Illinois). Now, only 2200 acres of high quality prairie exists (less than 1/100 of 1%).

Rainforest Action Network
The Tallgrass Prairie in Illinois, an endangered ecosystem in the state

Efforts to Preserve Biodiversity
There are many efforts to help preserve

Biodiversity "Hotspots"
"The most remarkable places on Earth are also the most threatened, and many of them have been reduced to less than 10 percent of their original vegetation. These are the Hotspots: the 25 richest and most threatened reservoirs of plant and animal life on Earth. Hotspots are one of CI's main areas of focus for biodiversity conservation."

- Conservation Hotspots from Conservation International
- I.U.C.N, Biodiversity Hotspots & CEB Research Sites
- I.U.C.N., The World Conservation Union

Efforts in Illinois
- Chicago Wilderness Ecosystem Partnership
- The Critical Trends Assessment Program
- The Illinois Headwaters: An Inventory of the Region's Resources (Area around Champaign County)

What are the benefits of preserving biodiversity?

1. Pharmaceuticals
- 80% of people in less-developed countries rely heavily or entirely on drugs derived from natural sources
- More than 20,000 species have been used for medicinal purposes
- 41% of our prescription drugs have their active ingredients derived from living organisms
- 70% of promising anti-cancer drugs come from rain forest plants
- Relatively few flowering plants have been examined for their medicinal properties

2. Food
- 30,000 plant species have edible parts; 7,000 species are grown and used as food; 20 species feed 90% of the world; just 3 species are major world-wide staples (rice, wheat and corn)
- Many underutilized food crops have the potential to become important in the future

3. Wood and other biological products
- Biofuels, ethanol, new hybrids and varieties of ornamental plants, fibers, adhesives, natural rubber, etc.

4. Genetic resources
- Land races (vs. modern, cultivated races) are diverse genetically and are important to augment the narrow genetic base of established food crops

5. Ecosystem level benefits
- Protection of water resources, soil
formation and protection, pollution breakdown and absorption, recovery from disturbances, etc.

6. Ethical, Cultural, Historical
   - Who are we to decide on the value of a species or an ecosystem?

For numerous other examples (and references), access the [IB 100/101 Biodiversity lecture webpage](#).

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**The importance of systematics in studying biodiversity**

Much of our knowledge of biodiversity comes from the basic activities of systematic biologists, namely:

- the inventorying of known species from the world's ecosystems
- the discovery, description and naming of new species
- the determination of their characteristics and evolutionary relationships to other species
- the understanding of how species arise

- the organization of this knowledge into classification systems

Phylogenetic classification systems are powerful predictive tools that help us understand, maintain, and effectively utilize this great biological wealth.

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**And finally...**

"When you take a flower in your hand and really look at it, it's your world for the moment. I want to give that world to someone else. Most people in the city rush around so, they have no time to look at a flower. I want them to see it whether they want to or not."

Georgia O'Keeffe, New York Post, May 16, 1946.

This is our last formal lecture! We hope that you've enjoyed the course, and we would like to think that next time you travel, eat, or simply observe flowers in passing, you'll have a whole new appreciation of the plant life around you.