The field of ecology has expanded dramatically over the last few decades, with an ever greater focus on the effects of humans on the **biosphere** (e.g. habitat destruction, introduced species and climate change). We will spend most of our time on the topics of Behavioral Ecology, Population Ecology, Community Ecology and Ecosystems, while referring to human effects as they fit into these other topics.

**Chapter 52: Introduction to Ecology**

This field began in 1869 when Ernest Haeckel coined the term **Ecology**, the study of an organism’s home life (Oikos: Greek for ‘home’). Modern ecology focuses on interactions. Be able to define Ecology:

> The scientific study of the interactions between organisms and their environment that determine the distribution and abundance of organisms (after CJ Krebs, 1972).

This modern definition (above) focuses on the **processes** of ecology, whereas earlier ecologists were primarily concerned with describing **patterns** of distribution and abundance. Throughout this section we will see how ecologists attempt to explain the patterns observed by various processes. Ecologists address their subject via: **observations**, **experiments** (e.g. removals and additions) and **models**.

Ecology can be studied at many levels; at each new level of complexity emerge new properties. Be able to define each type of ecology (and related terms) with examples of the patterns and processes related to each:

<table>
<thead>
<tr>
<th>organismal</th>
<th>behavioral</th>
<th>population</th>
<th>community</th>
</tr>
</thead>
<tbody>
<tr>
<td>ecosystem</td>
<td>landscape</td>
<td>biome</td>
<td>global (biosphere)</td>
</tr>
</tbody>
</table>

Initially, ecologists studied the basic distribution and abundance of individual organisms or species. Two important concepts are **habitat** (an organism’s ‘address’) which may vary in scope from a biome (e.g. desert) to a specific microhabitat (e.g. within cavities of Saguaro cactus), and **niche** an organism’s role or ‘job’ (e.g. photoautotroph).

Where an organism is found (and thrives) depends on a variety of **Environmental Factors**, both **abiotic** (non-living) and **biotic** (living). Be able to provide several examples of each. How does variation in these factors affect the distribution of organisms? Many of the most important **abiotic factors** can be summarized as **climate**. Be familiar with the causes and consequences of **global climate patterns**. At what latitudes are the major deserts found? Are eastern or western coastal waters typically colder or warmer? What terms are used to define the sun’s extreme positions relative to the earth?

What is **disturbance**? How does **disturbance** effect organisms’ distributions?

In addition to current climate, the distribution of organisms depends on their evolutionary history and **biogeography**. A species distribution may be limited by its ability to disperse, habitat choice (behavior), and the effects of other species (interspecific interactions), as well as abiotic factors (e.g. climate factors). Read the sections on the world’s major biomes. Be able to describe three features of desert biomes, and of at least two other biomes of your choice (at least one aquatic biome).

The study of ecology has also lead to concerns by **environmentalists**. Scientific studies can suggest possible problems of human activities, such as pollution, habitat change, climate change and the introduction of ‘exotic’ species. Be able to compare and contrast ecology and environmentalism and examples of the above problems.
Chapter 51: Behavioral Ecology (Animal Behavior)

The study of Animal Behavior has been conducted by several ‘schools’. In the first half of the 20th century, much behavioral work was divided between Ethology and Behaviorism. Be familiar with these approaches and the more recent Behavioral Ecology and Sociobiology. We will draw on a subset of the material in Chapter 51 (particularly pages 1134, 1138-1141, 1143-1154) and additional material.

Ethologists accepted that Natural Selection has shaped animal behavior. They studied innate behavior (instinct, genetically programmed behavior) and typically described Fixed Action Patterns (FAP’s). They developed the ‘four questions’ of behavior, two proximate and two ultimate questions. Proximate (how) questions include studies of behavioral development and the mechanism(s) (or stimulus) that triggers a behavior pattern. Ultimate (why) questions focus on the fitness benefits of behavior or the evolution of a particular behavior pattern.

Behaviorists, from Pavlov (Classical Conditioning) to Skinner (Operant Conditioning), studied learned behavior. Skinner held that any behavior could be elicited by the proper conditioning. However, several studies, particularly the work of Garcia with rats and conditioning, demonstrated natural biases in learning. Similarly, even innate, fixed action patterns show some affect of experience. Thus, the nature vs. nurture debate was resolved (tie?): both genes and the environment affect behavior.

Modern studies of behavior assume that natural selection (via environmental factors) shaped behavior in the past and continues to affect behavior today. This framework suggests that organisms will behave in ways that maximize their fitness. Additionally, behavioral biologists follow the rules of parsimony – simple explanations are likely to be best. Be familiar with these ideas and the terms and concepts in bold in this section.

Behavioral Ecology and Sociobiology became the dominant schools of behavioral biology in the latter part of the 20th century. They tend to focus on ultimate questions, particularly the current fitness benefits of behavior. They often assume an Optimality Model of behavior (e.g. optimal foraging theory). These models of behavior, similar to other models in ecology, provide a test of assumptions and stimulate experiments that may provide novel findings that generate new hypotheses. Game Theory extends these models to include the effects of the variable behavioral patterns of other individuals.

Behavioral ecologists may subdivide behavior into four general types or ‘goals’ (the “Four F’s” of Behavior): Feeding (Foraging), Fleeing, Fighting, and Reproduction. Be familiar with some of the questions and results from each of these fields.

What is a territory? What does it mean to be economically defensible?

What is the importance of courtship behavior? How does anisogamy theory affect predictions of mating behavior? Mating systems? Be able to describe the different types of mating systems.

What is altruism? How does Kin Selection explain apparent examples of altruism?
What is Reciprocal Altruism? What are the four requirements for Reciprocal Altruism to be maintained?

Be able to describe the problem of anthropomorphism in studies of animal behavior.

Can human behavior be explained as animal behavior? Should we be concerned about anthropomorphism?

How might a Behavioral Ecologist apply studies of altruism toward problems such as Climate Change?
Chapter 53: Population Ecology

How do ecologists define a population? How does this differ from evolutionary biologists?

Two important characteristics of any population are its density (number per unit area) and dispersion.

- Be able to describe two methods for estimating population density. When taking samples to estimate population size, it is important to follow the three R’s: Random, Replicates and Repeatable. Samples should be made randomly (without bias); there should be multiple samples (replicates) and the count for each sample should be repeatable (same number measured on repeated counts of the same sample).
- Name the three patterns of dispersion (clumped, uniform and random). Provide an example of each that illustrates the relationship between each pattern of dispersion to the dispersion of environmental factors.

What is the effect of a population’s dispersion pattern on the mating system? Is a uniform dispersion correlated with polygamy or monogamy? How do resources affect this dispersion?

Demography is the study of a populations ‘vital statistics’. Populations increase in size (gain) via _____ and __________ and decrease in size via __________ and ________.

What is a life table? Be able to read a life table and draw **Type I, Type II & Type III survivorship curves** (graph with appropriate units). Which curve is typical of humans? of birds & squirrels? of oysters?

What is a **reproductive table**? Be able to define and describe the effects of variation in each of the factors below:

- age structure
- birth rate (fecundity)
- death rate
- generation time
- sex ratio
- cohort

Be able to describe the terms and use these equations of population growth:

**Exponential growth model** and **Logistic growth model**

\[
\frac{dN}{dt} = r_{\text{max}}N \\
\frac{dN}{dt} = r_{\text{inst}}N (K - N)
\]

- \( r_{\text{max}} \): intrinsic rate of increase
- \( r_{\text{inst}} \): instantaneous rate of growth

What are the assumptions of these models? How do their shapes (graphs) compare? How well do these models fit changes in real populations? Note the Daphnia example and skills exercise (pp 1193-1194).

Be able to define or describe the following terms and how the models above have provided new ways of looking at organismal characteristics.

- zero population growth
- carrying capacity (K)
- limiting resource

What are **Life History Traits**? Be able to describe three life history traits and discuss variation in these traits in terms of ‘trade-offs’ (or ‘Principle of Allocation’): frequency of reproduction, clutch size and parental investment. Note that current investment in reproduction may affect future survival and reproduction, etc. How can ecologists test hypotheses about life history strategies experimentally? How does variation in these strategies reflect trade-offs?
Be able to define semelparity and iteroparity and describe the fitness advantages of both.

Be able to describe the relationship between clutch size and age at first reproduction relative to other life history characters.

Be able to describe ‘alternative life history strategies’ as found in fishes.

Population density can be affected by both density-dependent factors and density-independent factors. Be able to describe multiple examples of each of these types of factors. Note the emphasis on density-dependent factors in the text (pages 1198-99). Why this emphasis? Which factors are most important in shaping populations?

What is the relationship between snowshoe hare and lynx populations in North America? What other factors may affect these populations?

What can be learned by studying metapopulations? (review immigration and emigration).

The human population has experienced exponential growth over the last 400 years. Despite predictions of disaster (going back to Malthus) humans continue to live longer, healthier lives (although that trend has slowed). How can ecologists explain this?

Will human growth ever be checked by density-dependent factors? What is the global carrying capacity for the human population?

Be prepared to write an essay that addresses this question (20-points, take home portion of final exam). What environmental factor would you hypothesize will limit humans? (if any)

**Chapter 54. Community Ecology**

What is a community? What new questions emerge at this level of ecology? Be able to define and use: species richness and relative abundance. Which of these better describes biodiversity (aka species diversity)? (Answer: neither, best combined). The text provides the Shannon Diversity Index formula. We used a modified formula in our study of desert ecology that limits the values between 0 and 1.0.

It has long been assumed that greater diversity leads to more stable communities. What evidence supports this hypothesis?

Community Ecologists study interspecific interactions. Be able to describe these interspecific interactions and provide examples:

- interspecific competition
- predation / parasitism
- commensalism
- mutualism

For each type of interaction, who benefits and who loses? Which of these are symbioses? Which of these is most difficult to diagnose in nature?

Models of competition led to the competitive exclusion principle. Explain the foundation for this idea. Be able to describe the competition experiments of Gause with Paramecium. What is the difficulty in testing this hypothesis? What is ‘the ghost of competition past’?
Describe the difference between a fundamental niche and a realized niche. What factor(s) accounts for this difference? Be able to describe Connell’s field study of barnacles (Balanus and Chthamalus).

What is resource partitioning and character displacement? Be able to compare and contrast these hypotheses and illustrate with an example of each.

Be able to compare and contrast: predator, parasite, parasitoid & herbivore.

What is the evolutionary arms race between predators and their prey?

Be able to describe several forms of prey responses to predators.

What is mimicry? Compare and contrast: Batesian, Mullerian & Aggressive mimicry.

What is symbiosis? What is the difference between commensalism and mutualism? Which of these appears to be less common both empirically and theoretically? Be able to give examples of both.

Trophic structure is studied as part of Communities and Ecosystems. The following topics will be referenced in both Ch. 54 & 55. Be able to define and describe:

- trophic structure
- trophic level
- food chain
- food web

Be familiar with the simplified food chains and food web described in your text and lecture. How does energy affect the length of food chains? How well is energy converted between trophic levels? How does this affect the length of food chains?

What is a dominant species? What is a keystone species? ecosystem engineers? Be able to describe examples of each, such as the interactions in a tide pool community that demonstrates the effect of multiple interspecific interactions: competition and predation.

Are communities determined by bottom-up or top-down processes?

Read the section on disturbance & nonequilibrium. Be able to describe primary and secondary succession, and the dynamic equilibrium and intermediate disturbance hypotheses. Is there a balance to nature? How do natural and human disturbances provide material for community ecologists?

Describe how two large-scale factors (latitude and water) correlate with community diversity. Relate this to studies of Island Biogeography.

Read section 54.5 and consider these effects on the future of the human population.

Chapter 55. Ecosystems

Ecosystems consist of communities and their abiotic factors, with particular focus on two processes:

1. The Flow of Energy through the Ecosystem, and
2. The Cycling of Nutrients through the Ecosystem

The trophic structure described for communities (above) identifies many of the critical links in an ecosystem. In addition, decomposers and detritivores play a critical role in both energy and nutrients.
Be able to describe measures of primary productivity and associated factors, and an ecological pyramid (Fig. 55.11 & 55.12). What is biomass standing crop? What is unusual about some aquatic pyramids?

Read and be familiar with the generalized model of nutrient cycling, and the specific cycles for: water, carbon and nitrogen. Which of these is often a limiting nutrient?

What is biological magnification?

**Chapter 56. Conservation Biology and Global Change**

Humans are the current cause of mass extinctions. Indeed, the current rate of extinctions is so high that scientists are debating whether to give a new name to this period of geological time, the Anthropocene (the age of humans). We will discuss the issues of human impacts as time permits, but you will only be responsible for material (and films) discussed in class. In the 1990’s five major factors threatening our world were summed as HIPPO:

- Habitat Destruction
- Invasive Species
- Population growth (human overpopulation)
- Pollution
- Over Exploitation of resources (overfishing, cutting down rainforest)

Your text has modified this list with a new emphasis on Climate Change: the most profound threat to our Biosphere (see pages 1258-1260).

This chapter discusses in detail additional problems: both the source and effect on ecosystems, and some sustainable solutions.

This chapter may provide useful examples of what might limit the human population and how we might mitigate these problems before they overwhelm us.