Chapter-wide learning goals:

1. Defend the assertion that the first law of thermodynamics (conservation of energy and matter) governs the flow of energy through and the cycling of matter within ecosystems.
2. Describe how energy flows through ecosystems, including sources of energy, the paths energy takes moving through and being stored in an ecosystem, and how energy is lost from an ecosystem.
3. Defend the assertion that the second law of thermodynamics (inefficient energy transfer and transformations) explains why ecosystems and their component organisms are reliant on a continuous input of energy to maintain order.
4. Describe how secondary production relates to primary production across a broad range of ecosystems.

Section 1: Energy Powers Ecosystems

1. Diagram the flow of energy from the Sun through a plant, accounting for absorption, reflection, heat loss, respiration, gross primary production, and net primary production.
2. Explain how NPP and GPP are related.
3. Compare the sustainability of different individuals, communities, countries, and the entire human population using the ecological footprint concept.
4. Compare the sustainability of different individuals, communities, countries, and the entire human population using the ecological footprint concept.
5. Describe sustainable resource use in terms of consumption and production.

Section 2: Primary Production and Respiration

1. Explain how to calculate primary production and/or respiration by measuring changes in the main products/reactants (O_2, CO_2, biomass) of the photosynthetic equation.
2. Defend the method you would use when estimating production in a given ecosystem (e.g., forest versus lake).
3. Estimate net primary production from changes in biomass.
4. Deduce whether a given procedure for measuring productivity gives estimates of NEP or NPP.
5. Explain spatial patterns in primary production and respiration within a forest over the course of a day.
6. Demonstrate how changes in CO_2 can be used to estimate GPP, NEP, and Re.
7. Demonstrate how changes in O_2 can be used to estimate GPP, NEP, and Re.
8. Explain the stoichiometric equation that relates photosynthesis and respiration, including when energy is stored and when it is released.
9. Describe the photosynthesis and respiration reactions in terms of energy flow and storage.
10. Predict, based on environmental factors, how primary production varies across time and space at different scales in both terrestrial and aquatic systems.
11. Compare how light intensity and nutrient availability affect rates of photosynthesis in terrestrial and aquatic ecosystems.
12. Explain seasonal fluctuations in global atmospheric CO_2 concentrations and why the magnitude of these swings tends to vary with latitude.
13. Interpret plots of GPP, NEP, and Re versus depth from oceans and lakes.

Section 3: Secondary Production

1. Use Sankey diagrams to depict energy flow through individuals and ecosystems.
2. Compare and explain the flow of energy through different food chains, including how differences in trophic efficiency and average biomass can affect ecosystem structure.
3. Use data on field metabolic rates to contrast differences in production efficiencies of endotherms vs. ectotherms.

4. Compare and contrast different consumer taxa on their production efficiencies based on their trophic levels, endothermy, and size.
5. Describe the flow of energy through the grazer food chain from primary producers to secondary carnivores.
6. Explain why growth efficiency of many herbivores tends to decline as the C:N and/or C:P ratio of their food increases.
7. Diagram the flow of energy from plants through a grazer and to detritus, including the energy not consumed by the grazer as well as energy that is ingested, egested, assimilated, respired, and stored as secondary production.
8. Calculate consumption efficiency, assimilation efficiency, production efficiency, and trophic efficiency from data on NPP, ingestion, egestion, and production.

Section 4: Ecosystem Energetics

1. Calculate Residence time from a pool (e.g., standing stock of biomass) and a flux (e.g., net primary production).
2. Use Sankey diagrams to depict energy flow through individuals and ecosystems.
3. Classify ecosystems in terms of energy flow and biomass storage.
4. Evaluate the two hypotheses for why consumption efficiency tends to vary from one ecosystem to another.
5. Contrast energy pyramids with pyramids of numbers for grassland, forest, and open ocean ecosystems.
6. Determine whether an ecosystem is heterotrophic or autotrophic using a plot of ecosystem respiration versus primary production.

Section 5: Ecosystem Services

1. Distinguish several types of ecosystem services and how each relates (where appropriate) to NPP and ecological footprint.
2. Discuss reasons for why ecosystem services are often ignored in politics, and what implications this might have for human communities.
3. Recognize that the monetary value of ecosystem services can be estimated.
4. Illustrate how a given ecosystem's ability to furnish a particular ecosystem service may be threatened by the tragedy of the commons.
5. Recognize that there are potential solutions to the tragedy of the commons.