



# Ecological Systems and Learning Progressions: applications of basic principles across multiple scales of organization

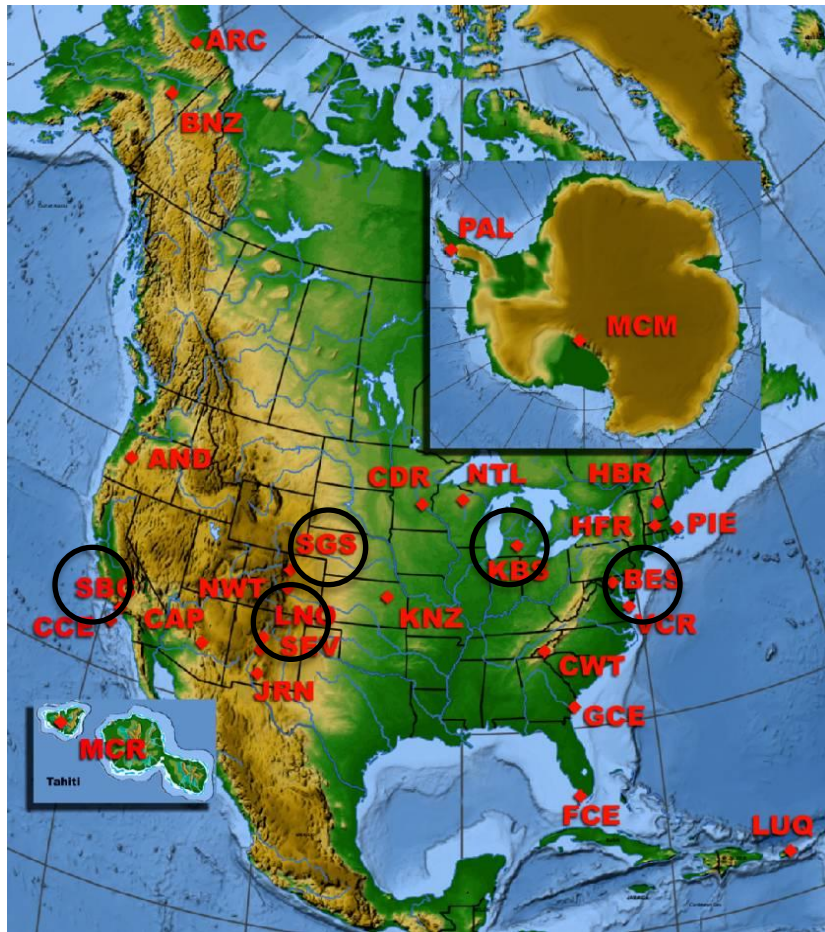


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# MSP – Pathways to Environmental Literacy



Colorado State University

Cary Institute

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Michigan State University

Towson University

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University of Northern Colorado

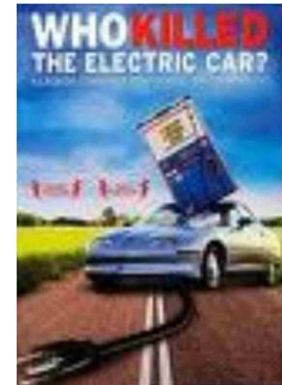
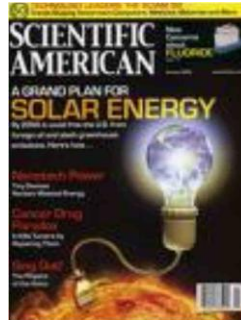
University of Wyoming

Montana State University

Arizona State University

# Environmental Science Literacy

*The capacity to understand and participate in evidence-based decision-making about socio-ecological systems.*



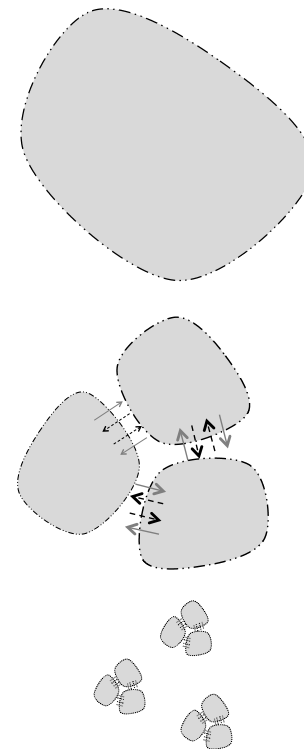
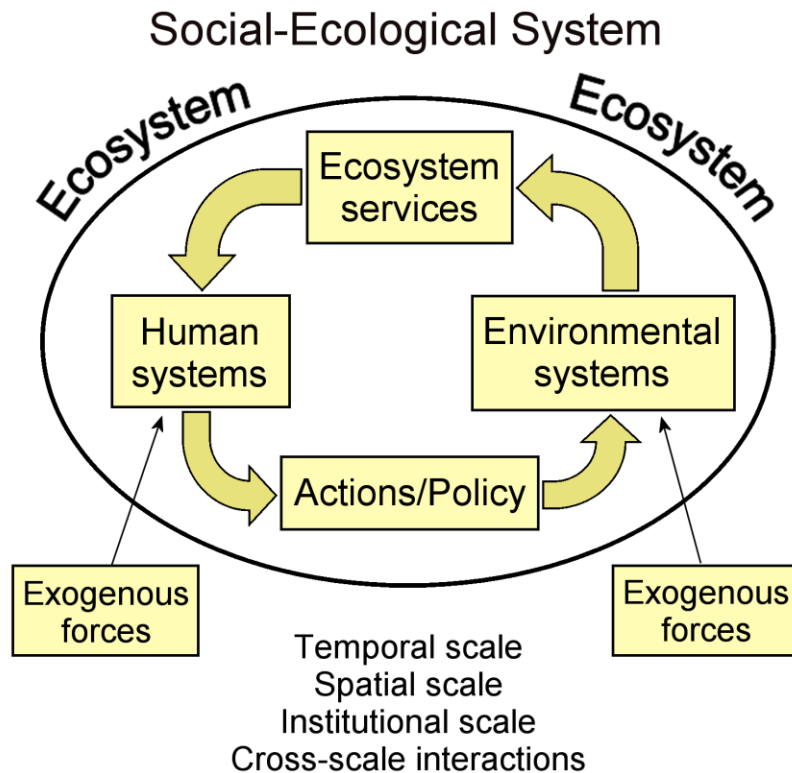
Colorado State University

Department of Ecosystem  
Science and Sustainability



# System Thinking

**System Thinking** is the process of understanding how components of a system interact and respond to disturbance, yet influence one another to act a whole.



Significance/Emergent Properties?

Scale of Observation?

Mechanisms?

# Research Learning Progressions

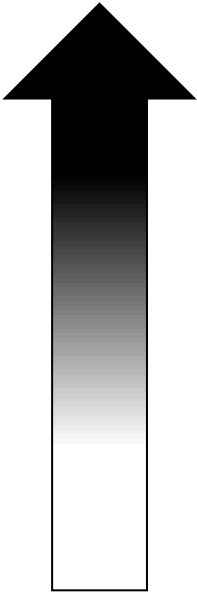
Learning progressions are **descriptions** of increasingly sophisticated ways of thinking about a subject

Anchored at the lower end by what we know about how younger students reason

Anchored at upper end by what experts in the field believe students should understand when they graduate

Level of achievement	Type of account (explanations & predictions)	Elements of accounts	
		Structure & systems	Scientific principles
Level 4: Model-based accounts	Scientific, model-based accounts of how and why events happen	Multiple, detailed connected systems	Driving forces & constraining factors
Level 3: School science accounts	Primarily descriptions of what happens	Connected systems, including visible and some hidden components	Puts events in order, names processes, uses “school rules”
Levels 1 & 2: Force-dynamic accounts	Force-dynamic perspectives of events	Visible, familiar components of systems	Force-dynamic reasoning

**Scientific Reasoning**  
What high school students should know and be able to do

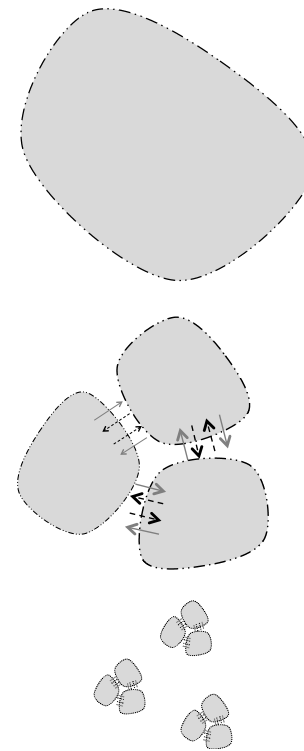
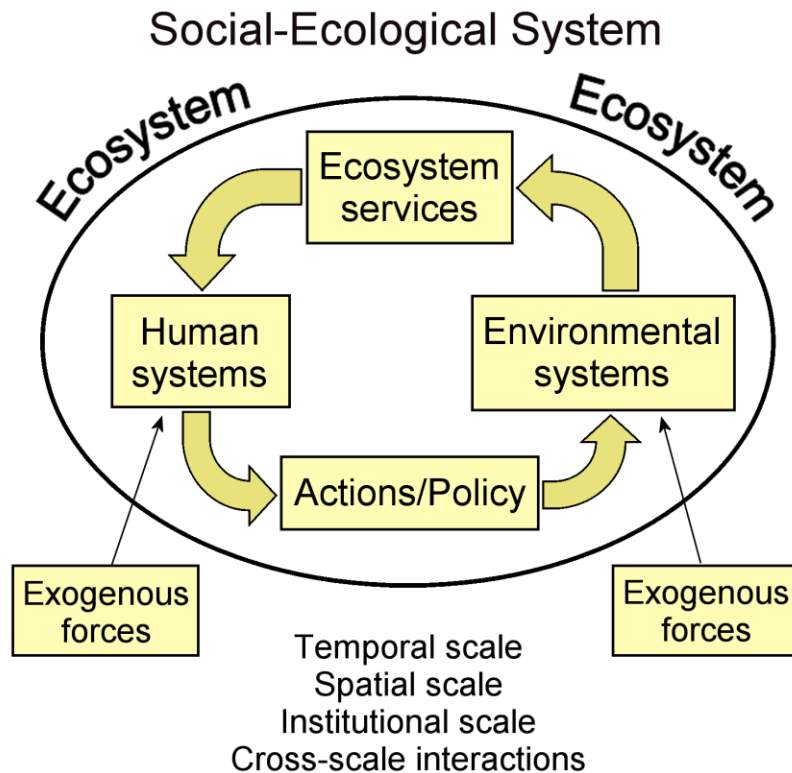


**Informal Ideas**  
How children think about and make sense of the world

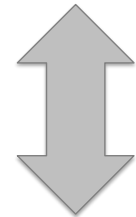


# System Thinking

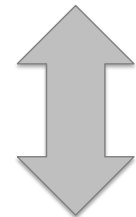
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Significance/Emergent Properties?



Scale of Observation?



Mechanisms?

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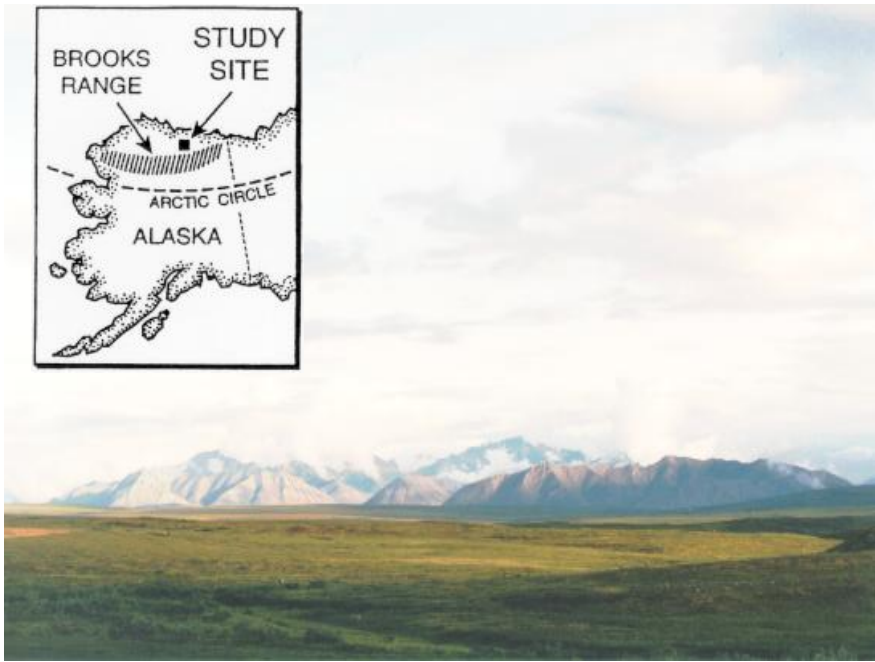
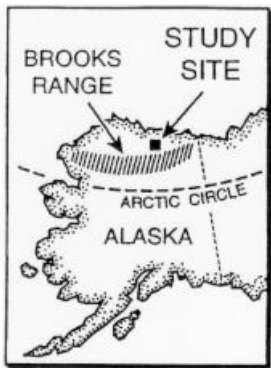
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*The topics may include multiple principles operating simultaneously.*

*The relationships among the principles in terms of their relative importance to the topic change as one moves up and down the hierarchy.*

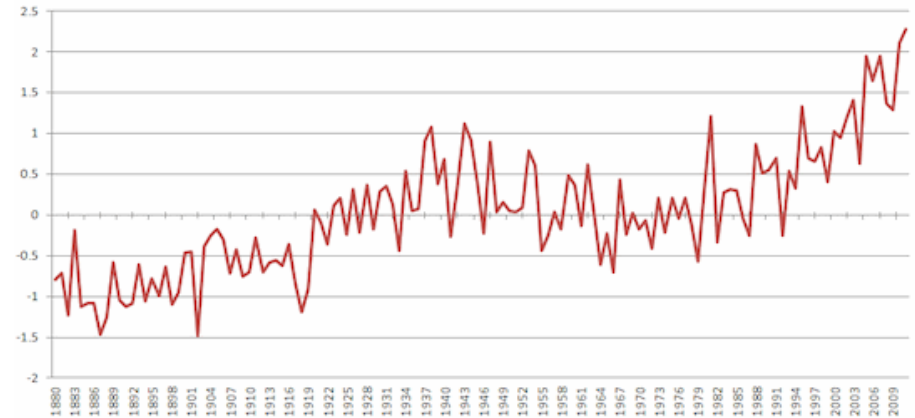
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## Climate Change in the Arctic

Surface Temperature Anomaly, 64°N - 90°N, 1880-2011 (°C)  
(base period 1951-1980) (source: NASA GISS)

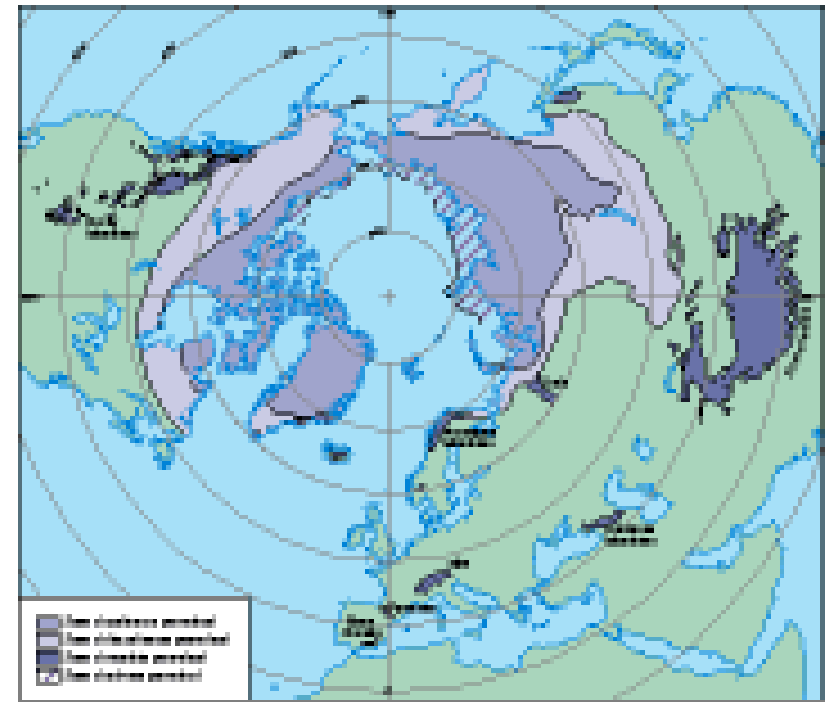


**Control**



**Fertilized**





## Permafrost

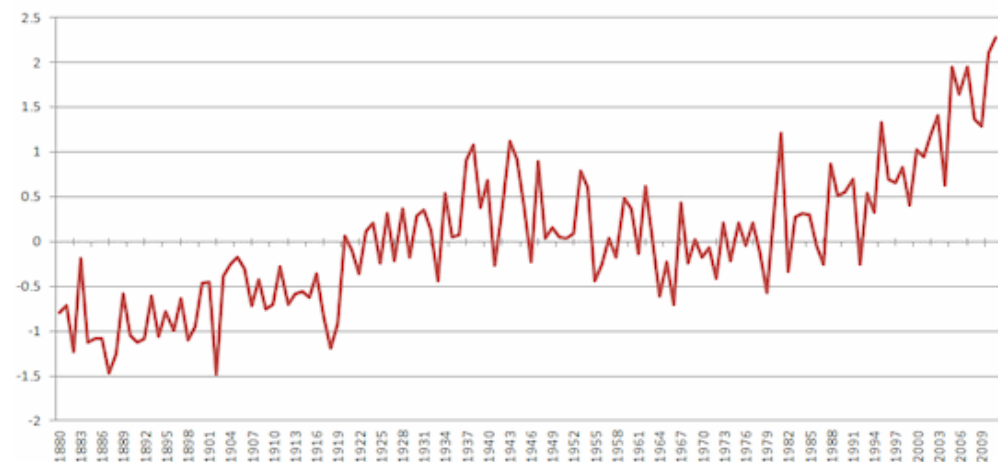
Increase in the active layer

Increase in available N

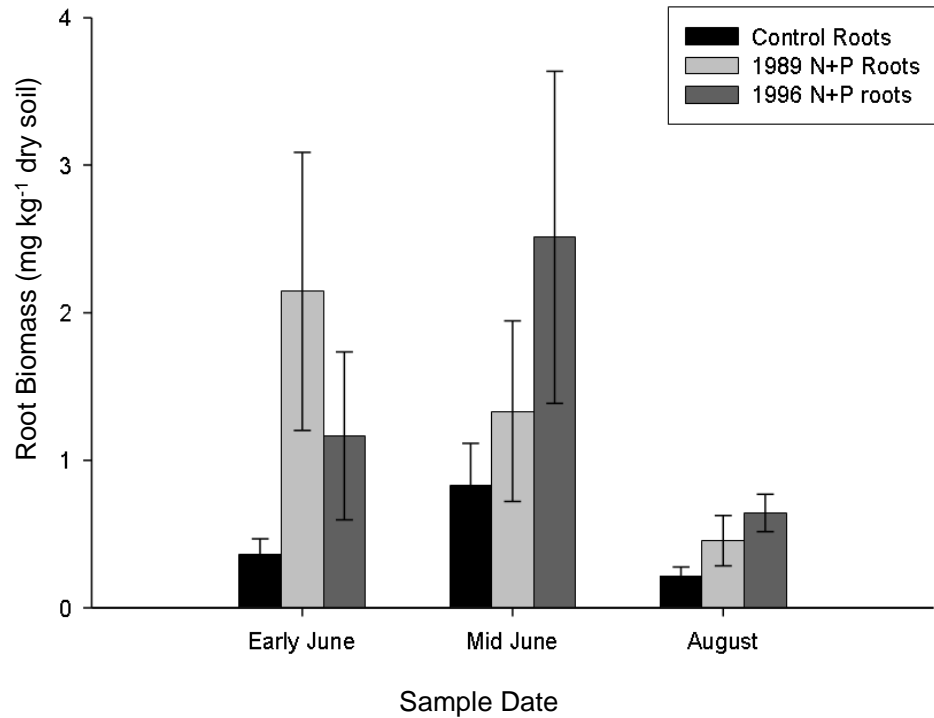
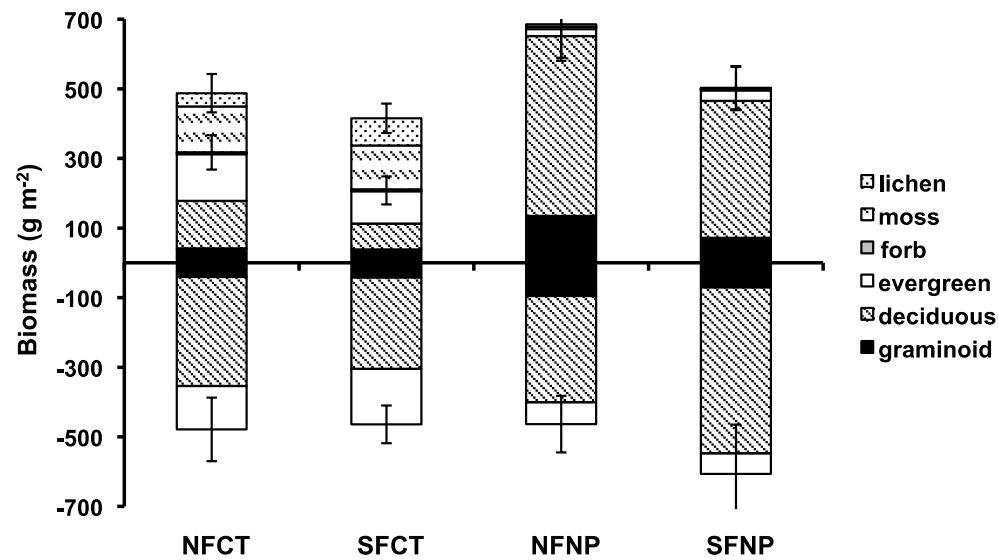
Alterations in the plant community

Increase in decomposition rates (?)

Surface Temperature Anomaly, 64°N - 90°N, 1880-2011 (°C)  
(base period 1951-1980) (source: NASA GISS)







## Aboveground

- Increase in shrub
- Decrease in mosses and lichens

## Belowground

- Increase in roots

Initial Phase  
(control plots)

Transition Phase  
(1996 + 1988 Fertilization Plots)

New Stable State

Soil Horizon

Upper Organic

Lower Organic

Mineral

Permafrost

↓ moss  
↑ shrubs

↑ shrubs  
↑ root depth  
↑ litter layer

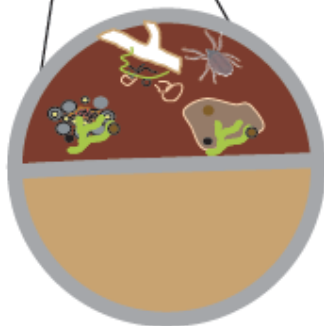
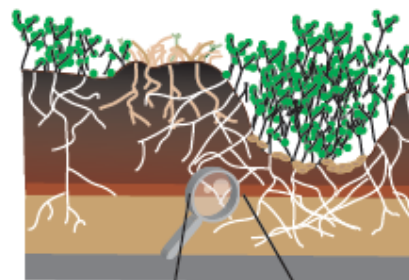
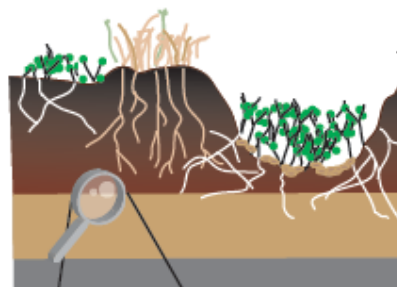
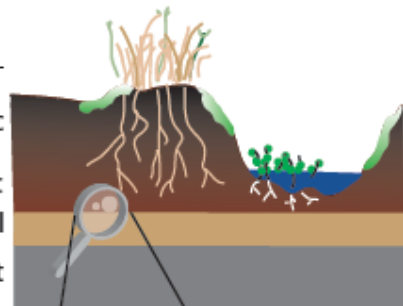
↑ faunal activity  
↑ microbial activity

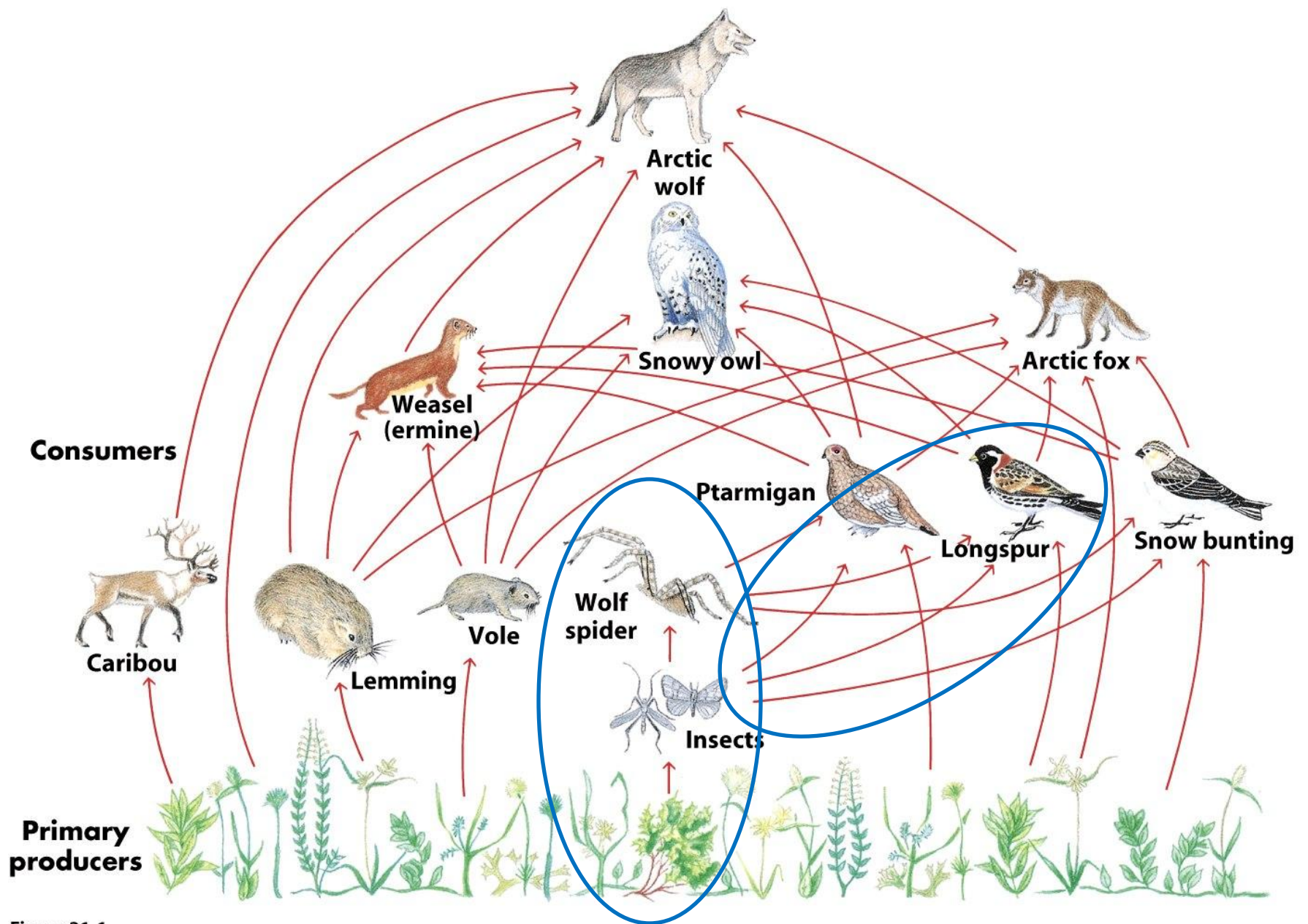
↑ mycorrhizae  
↑ root depth and biomass  
↑ faunal and microbial biomass and activity  
↑ enzyme activity  
↑ complexity of soil food web  
-Shifting microbial communities

↓ total organic C  
↓ mean diameter weight of soil aggregates

-Increasing detritus heterogeneity  
-Increasing mean diameter weight of soil aggregates

Climate Warming/Increasing N Availability





**Figure 31-1**  
*Biology of Plants, Seventh Edition*  
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*The topics may include multiple principles operating simultaneously.*

*The relationships among the principles in terms of their relative importance to the topic change as one moves up and down the hierarchy.*

*The questions we ask when developing learning progression define a pivotal node, level, or scale within the hierarchy that serves as an entry point for the student.*

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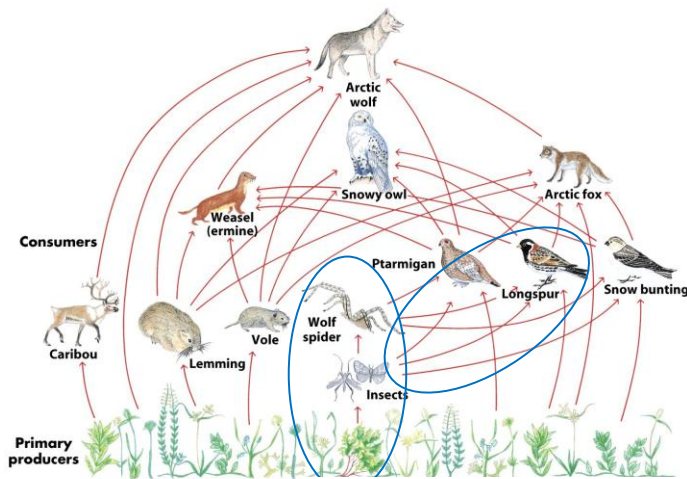
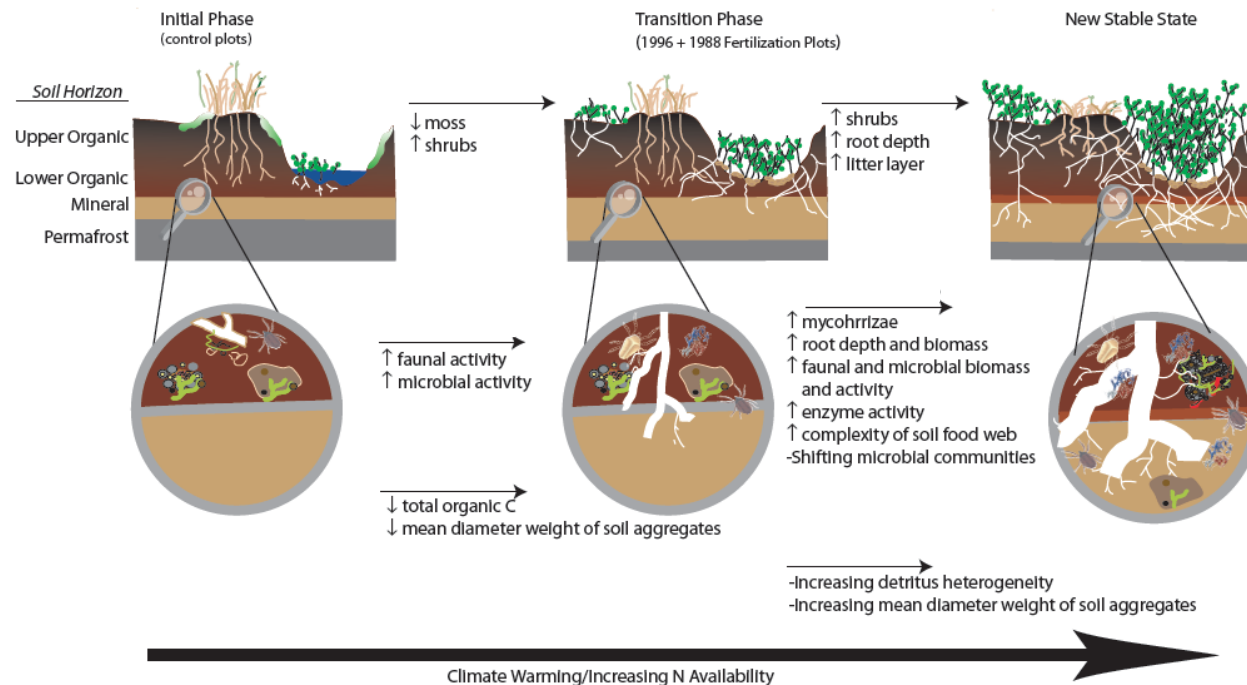


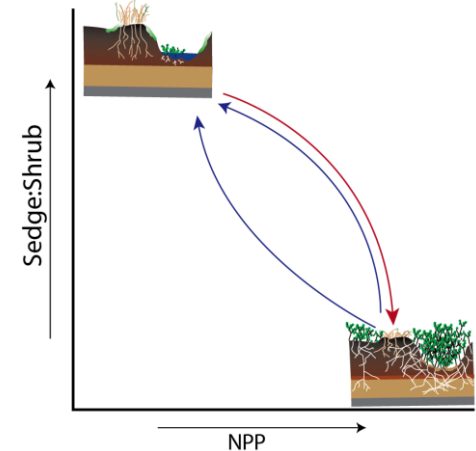
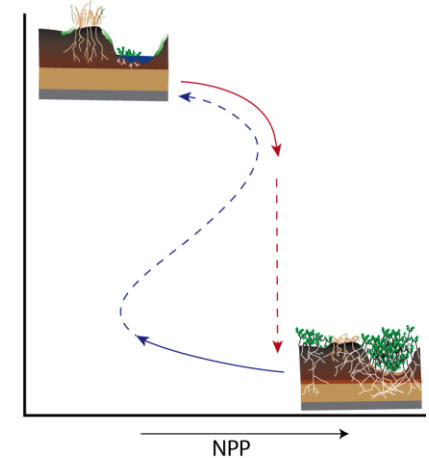
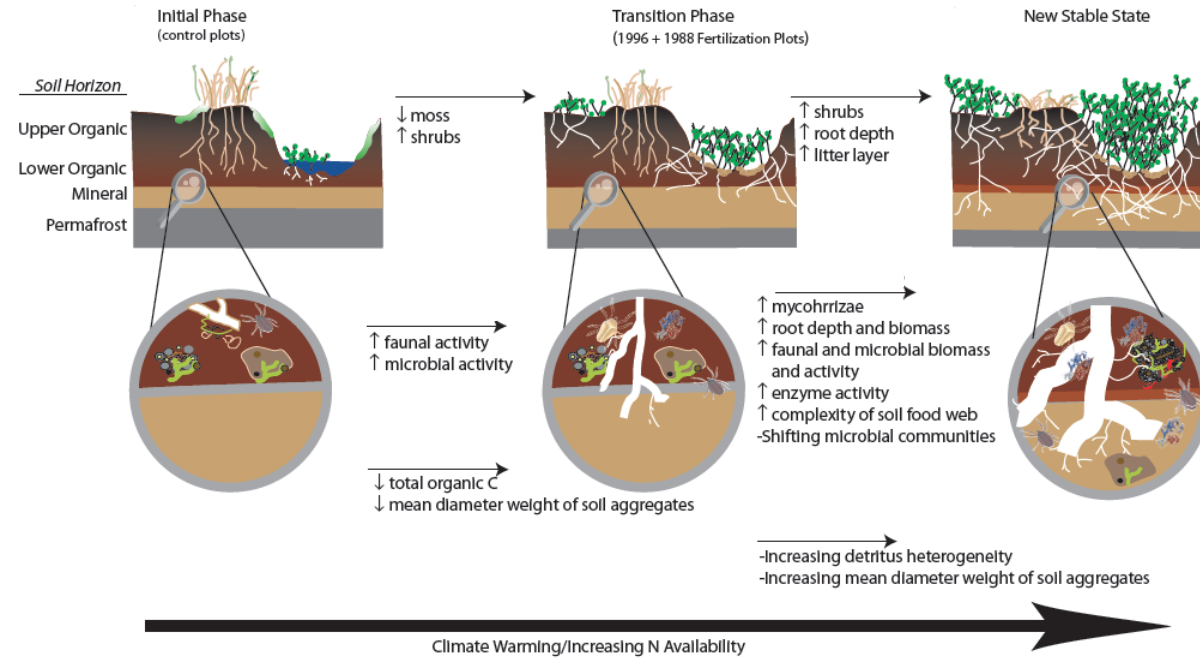
Figure 31-1  
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<i>Level</i>	<i>Dominant Principle(s)</i>
Molecular/Cellular	Genetics and Evolution
Individual/Species	Genetics and Evolution/Thermodynamics
Population/Species	Genetics and Evolution/Thermodynamics
Community/Multiple Species	Thermodynamics/Systems Theory
Ecosystem	Thermodynamics/Systems Theory



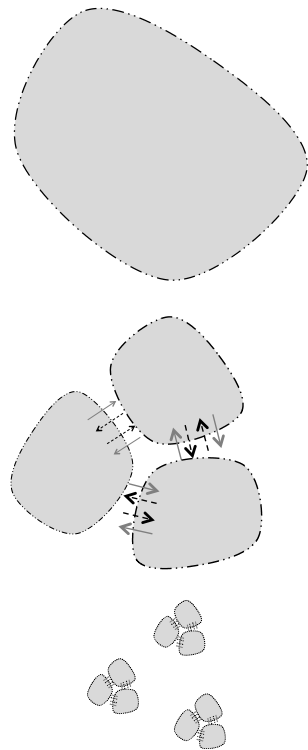
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Significance/Emergent Properties



Scale of Observation



Mechanisms

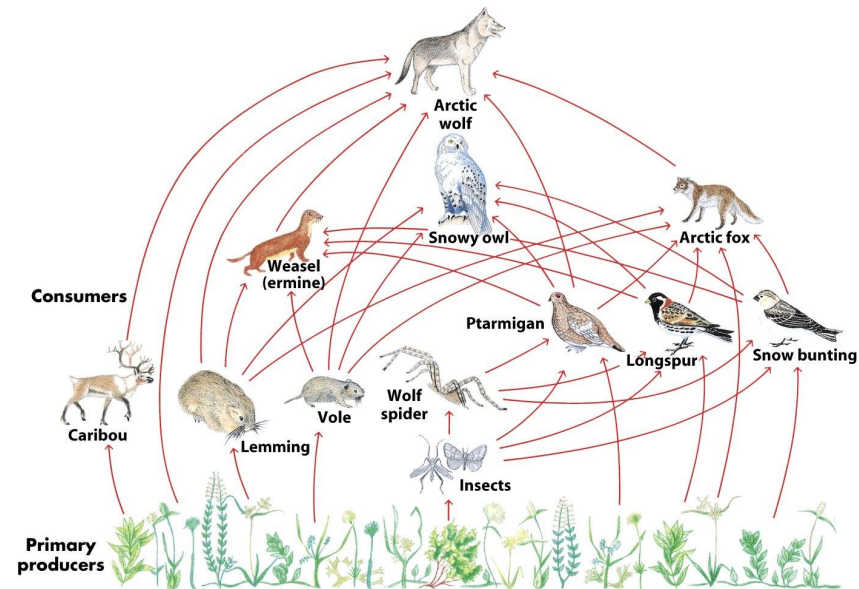


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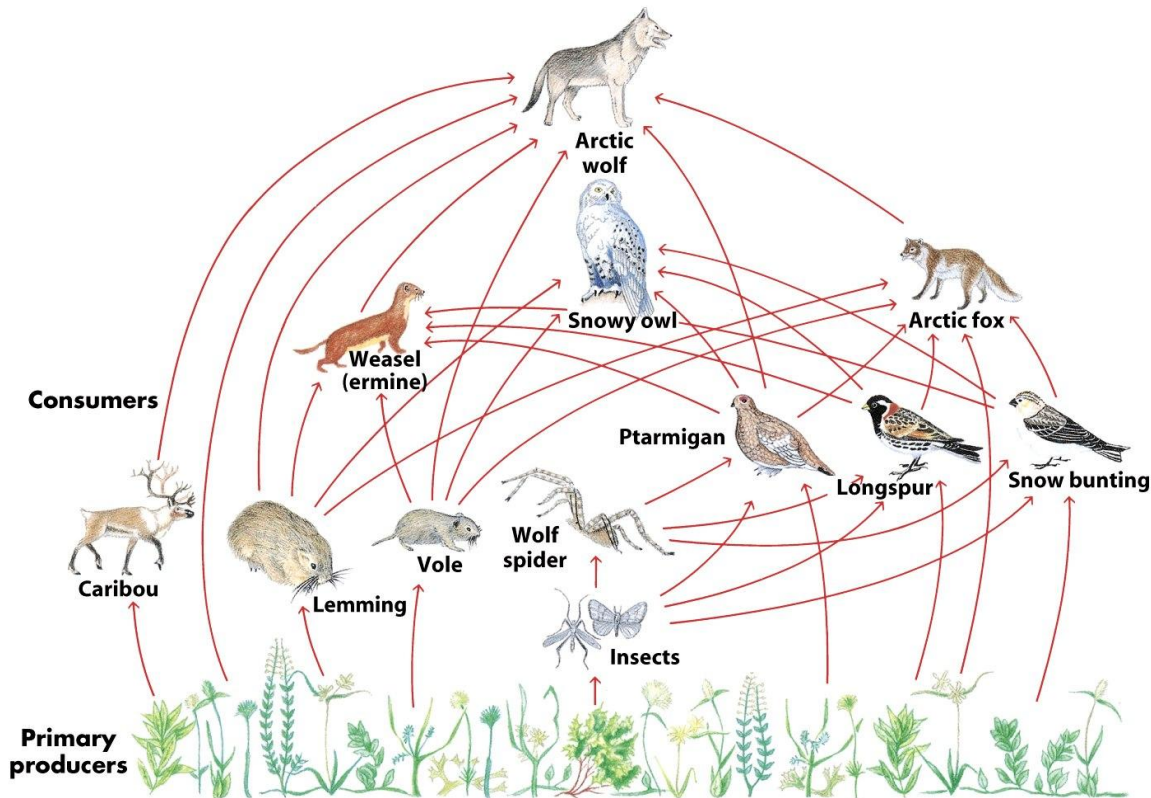
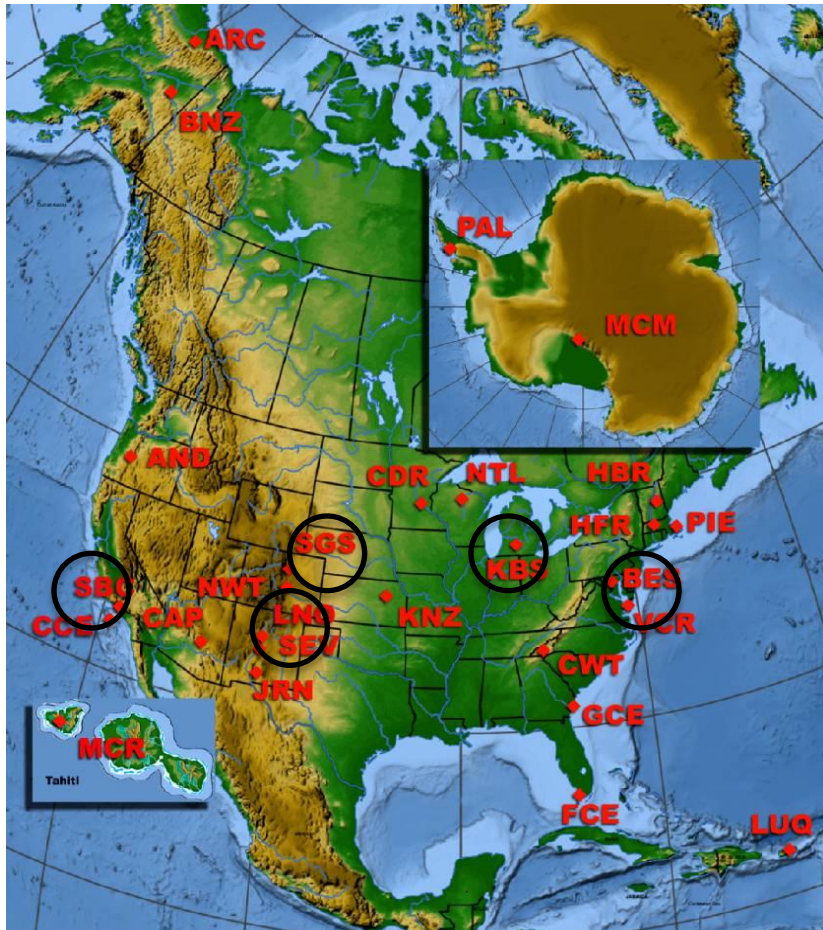


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*Hartley et al. – Disturbance and communities*

*Doherty et al. – Disturbance and Evolution*

*Wyner and Doherty – Pivotal nodes and entry points*

# Energetic Food Webs

*An Analysis of Real and Model Ecosystems*

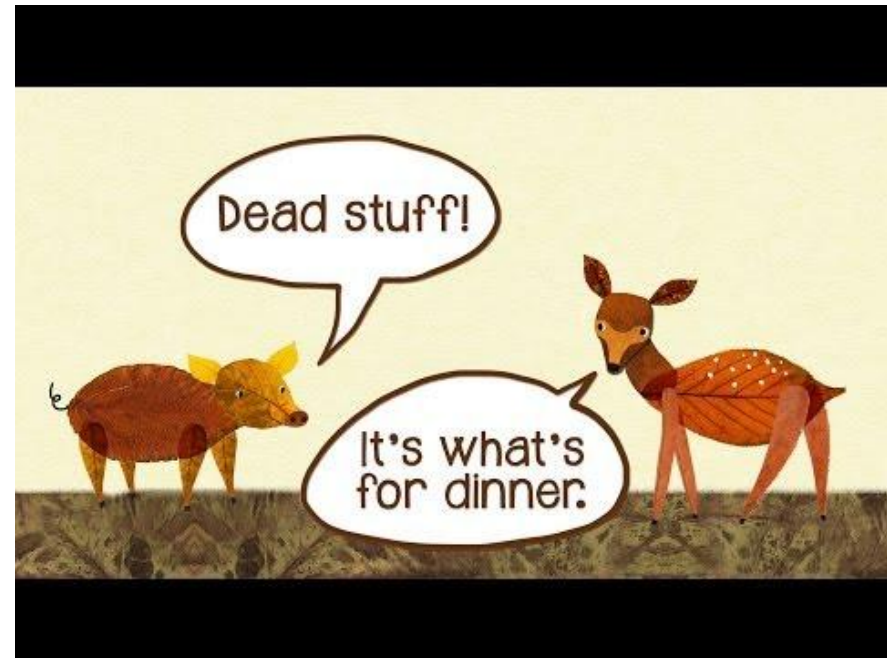
John C. Moore

Peter C. de Ruiter



Oxford Series in Ecology and Evolution

**TED**  
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<http://ed.ted.com/lessons/dead-stuff-the-secret-ingredient-in-our-food-chain-john-c-moore>