NUTRIENT CYCLING and RETENTION

Exchange of nutrients between organisms and their environment is one of the essential aspects of ecosystem function.

Energy makes a one-way passage through ecosystems, whereas essential nutrients, such as phosphorus (P), may be recycled.

Nutrient Cycles

Nutrient cycles involve the storage of chemical elements in nutrient pools, or compartments, and the flux, or transfer, of nutrients between pools.

A nutrient pool is the amount of a particular nutrient stored in a portion, or compartment, of an ecosystem. In addition, all nutrient cycles are, as the name implies, dynamic, with **nutrient flux** moving nutrients between the pools of an ecosystem.

Ecosystems are not closed and nutrients may be lost from the ecosystem to a nutrient sink.

A nutrient sink is a part of the biosphere where a particular nutrient is absorbed faster than it is released.

A **nutrient source** is a portion of the biosphere where a particular nutrient is released faster than it is absorbed.

For example, burning of fossil fuels acts as a source of carbon dioxide to the global ecosystem.

The Phosphorus Cycle

Phosphorus is essential to the energetics, genetics, and structure of living systems. ATP, DNA & RNA and phospholipid molecules.

In contrast to carbon and nitrogen, the global phosphorus cycle does not include a substantial atmospheric pool.

The largest quantities of phosphorus occur in mineral deposits and marine sediments.

The Nitrogen Cycle

Nitrogen is important to the structure and functioning of organisms.

It forms part of key biomolecules such as amino acids, nucleic acids, and the porphyrin rings of chlorophyll and hemoglobin.

Nitrogen supplies may limit rates of primary production in marine and terrestrial environments. Because of its importance and relative scarcity, nitrogen has drawn a great deal of attention from ecosystem ecologists.

The nitrogen cycle includes a major atmospheric pool in the form of molecular nitrogen, N2.

However, few organisms can use this atmospheric supply of molecular nitrogen directly.

Nitrogen fixers,

(1) the cyanobacteria, or blue-green algae, of freshwater, marine, and soil environments;

(2) certain free-living soil bacteria;

(3) bacteria associated with the roots of leguminous plants; and

(4) actinomycetes bacteria, associated with the roots of alders, and several other species of woody plants.

Nitrogen fixation is an energy-demanding process.

During nitrogen fixation, N2 is reduced to ammonia, NH3.

Nitrogen fixation takes place under anaerobic conditions in terrestrial and aquatic environments, where nitrogen- fixing species oxidize sugars to obtain the required energy.

Nitrogen fixation also occurs as a physical process associated with the high pressures and energy generated by lightning.

The Haber Process combines nitrogen from the air with hydrogen derived mainly from natural gas (methane) into ammonia. The reaction is reversible and the production of ammonia is exothermic.

Once nitrogen is fixed by nitrogen-fixing organisms, it becomes available to other organisms within an ecosystem.

Upon the death of an organism, the nitrogen in its tissues can be released by fungi and bacteria involved in the decomposition process. These fungi and bacteria release nitrogen as ammonium, NH_4^+, a process called **ammonification**.

Ammonium can be converted to nitrate, NO_3^-, by other bacteria in a process called **nitrification**. Ammonium and nitrate can be used directly by bacteria, fungi, or plants.

The nitrogen in dead organic matter can also be used directly by mycorrhizal fungi, which can be passed on to plants.

The nitrogen in bacterial, fungal, and plant biomass may pass on to populations of animal consumers or back to the pool of dead organic matter, where it will be recycled again.

Nitrogen may exit the organic matter pool of an ecosystem through denitrification. **Denitrification** is an energy-yielding process that occurs under anaerobic conditions and converts nitrate to molecular nitrogen, N2. The molecular nitrogen produced by denitrifying bacteria moves into the atmosphere and can reenter the organic matter pool only through nitrogen fixation.

The Carbon Cycle

Carbon is an essential part of all organic molecules, and, carbon compounds such as carbon dioxide, CO_2, and methane, CH_4, as constituents of the atmosphere, substantially influence global climate.

Carbon moves between organisms and the atmosphere through:

photosynthesis and **respiration**.

Photosynthesis removes CO_2 from the atmosphere, whereas respiration by primary producers and consumers, including decomposers, returns carbon to the atmosphere in the form of CO_2.

While some carbon cycles rapidly between organisms and the atmosphere, some remains sequestered in relatively unavailable forms for long periods of time. Carbon in soils, peat, fossil fuels, and carbonate rock would generally take a long time to return to the atmosphere.

Peatlands are a type of wetlands that occur in almost every country on Earth, currently covering 3% of the global land surface. The term 'peatland' refers to the peat soil and the wetland habitat growing on its surface.

https://www.iucn.org/resources/issues-briefs/peatlands-and-climate-change

Peatlands and climate change

- **Peatlands are a type of wetlands which are among the most valuable ecosystems on Earth:** they are critical for preserving global biodiversity, provide safe drinking water, minimise flood risk and help address climate change.
- **Peatlands are the largest natural terrestrial carbon store**; the area covered by near natural peatland worldwide (>3 million km^2) sequesters 0.37 gigatonnes of carbon dioxide (CO_2) a year – storing more carbon than all other vegetation types in the world combined.
- **Damaged peatlands are a major source of greenhouse gas emissions**, annually releasing almost 6% of global anthropogenic CO_2 emissions. Peatland restoration can therefore bring significant emissions reductions.
- **Countries are encouraged to include peatland restoration in their commitments to global international agreements**, including the Paris Agreement on climate change.

Rates of Decomposition

Decomposition rate is influenced by temperature, moisture, and chemical composition of litter and the environment.

Conversion of nutrient supplies from organic to inorganic form is called **mineralization**. Mineralization takes place principally during **decomposition**, which is the breakdown of organic matter accompanied by the release of carbon dioxide. Consequently, ecosystem ecologists consider decomposition as a key ecosystem process.

Detailed shot of a soil horizon studied to examine litter decay.
https://phys.org/news/2017-11-foliage-decomposition-carbon.html

- Decomposition of organic matter involves chemical and physical processes such as **leaching** and **fragmentation of litter**, and biological processes dominated by fungi and bacteria.
- The fine hyphae of fungi can penetrate litter and release external digestive enzymes that speed decomposition.
- Fragmentation and ingestion of litter by invertebrates also plays a key role during decomposition processes.
- The rate of decomposition in ecosystems is significantly influenced by temperature, moisture, and the chemical composition of both plant litter and the environment.
- The chemical characteristics of plant litter that influence decomposition rates include nitrogen concentration, phosphorus concentration, carbon:nitrogen ratio, and lignin content.

Organisms and Nutrients

Plants and animals can modify the distribution and cycling of nutrients in ecosystems.

Plants and the Nutrient Dynamics of Ecosystems

Plants are not simply the passive recipients of influences from the physical environment or from animals and microbes.

Plant species can influence ecosystem nutrient dynamics by a variety of mechanisms. Differences in plant species traits, such as nutrient uptake, allocation, and loss, affect nutrient cycling.

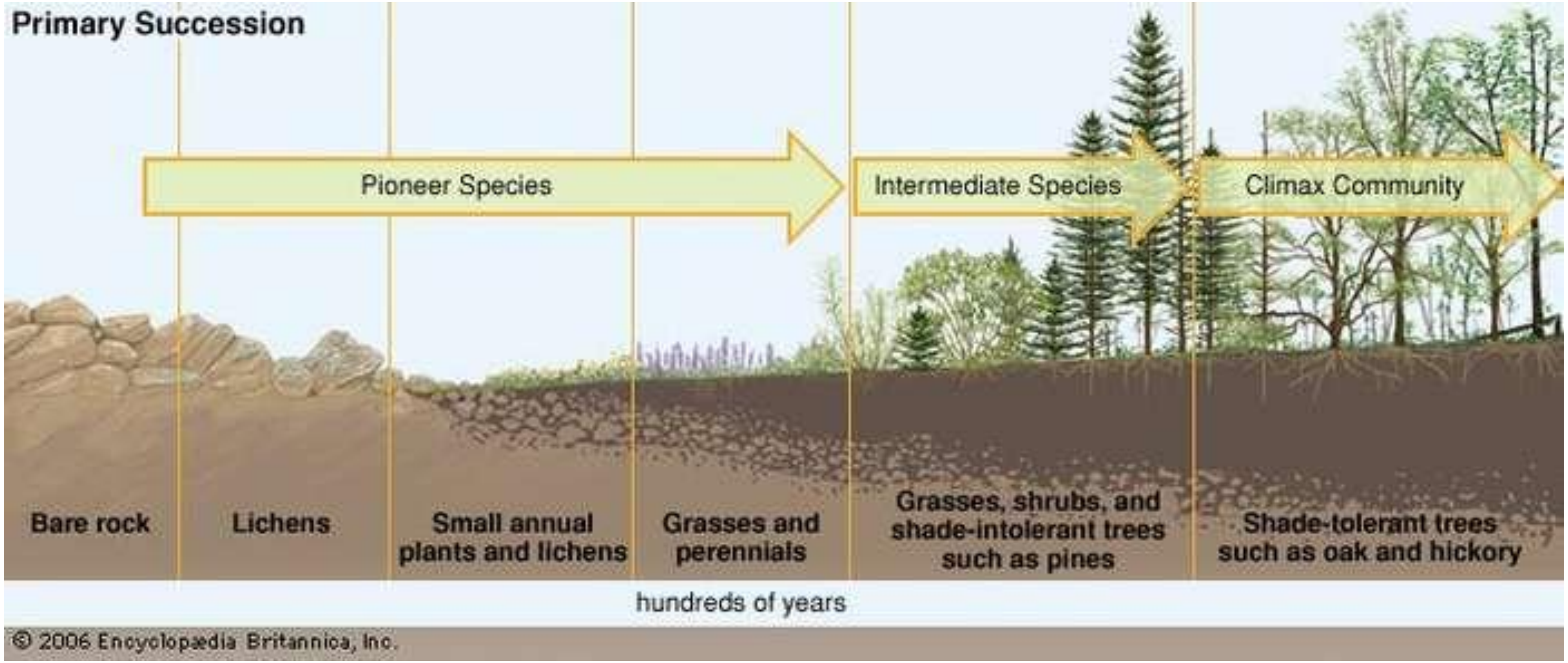
Introduced plant species and their influences on new habitats…

Example from Hawai –*Myrica faya* (Vitousek & Walker)

Disturbance and Nutrients

Disturbance generally increases nutrient loss from ecosystems.

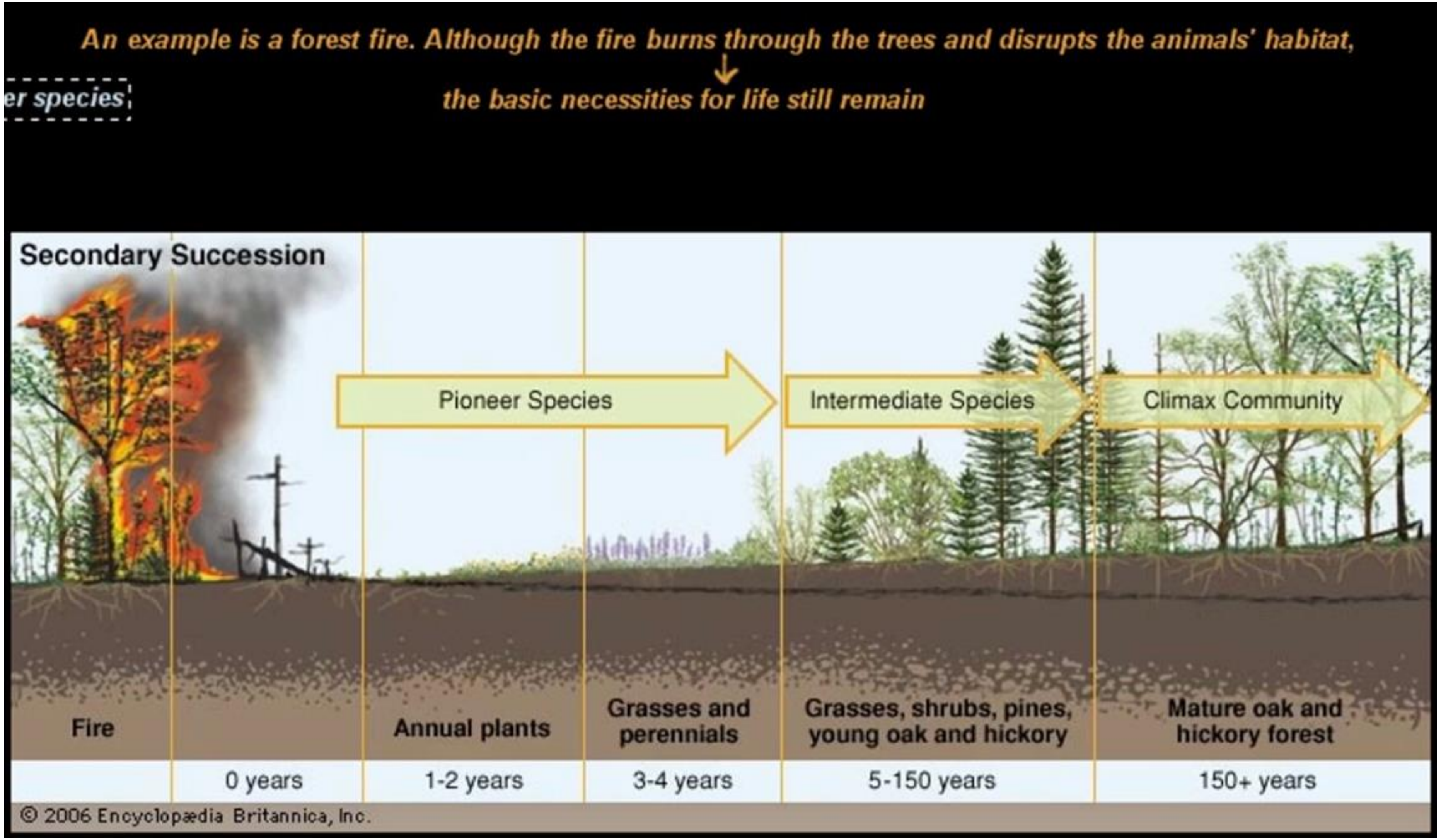
SUCCESSION and STABILITY



Ecological succession, the change in plant, animal, and microbial communities in an area following disturbance or the creation of new substrate.

Succession on newly exposed geological substrates, not significantly modified by organisms, is called as **primary succession** by ecologists**.**

For example on newly formed volcanic surfaces such as lava flows.



In areas where disturbance destroys a terrestrial community without destroying the soil, the subsequent succession is called **secondary succession**. For instance, secondary succession occurs after agricultural lands are abandoned or after a forest fire.

The first organisms to colonize in a successional sequence following a disturbance or the formation of a new geologic surface, form a **pioneer community**.

The late successional community that can persist until disrupted by disturbance is called the **climax community**. The nature of the climax community depends upon environmental circumstances.

Community Changes During Succession

Community changes during succession include increases in species diversity and changes in species composition.

Ecosystem Changes During Succession

Ecosystem changes during succession include increases in biomass, primary production, respiration, and nutrient retention. As succession changes the diversity and composition of communities, ecosystem properties change as well. For instance, many properties of soils, such as the nutrient and organic matter content, change during the course of succession.

Mechanisms of Succession

Mechanisms that drive ecological succession include facilitation, tolerance, and inhibition. An early model for successional change proposed by Frederic E. Clements (1916) emphasized the role of **facilitation** as a driver of ecological succession. Later, Joseph Connell and Ralph Slayter (1977) proposed three alternative models of succession: (1) **facilitation**, (2) **tolerance**, and (3) **inhibition**. This classic paper stimulated ecologists to think beyond facilitation and to also consider tolerance and inhibition as mechanisms underlying successional change (fig. 20.19).

Community and Ecosystem Stability

Community stability may be due to lack of disturbance or community resistance or resilience in the face of disturbance. **The simplest definition of stability is the absence of change.** A community or ecosystem may be stable for a variety of reasons;

1.may be there has been no disturbance. For instance, the benthic communities of the deep sea may remain stable over long periods of time because of constant physical conditions. Consequently, ecologists generally define stability as the persistence of a community or ecosystem in the face of disturbance.

2. Stability may result from two very different characteristics. **Resistance** is the ability of a community or ecosystem to maintain structure and/or function in the face of potential disturbance. However, stability may also result from the ability of a community to return to its original structure after a disturbance. The ability to bounce back after disturbance is called **resilience**. A resilient community or ecosystem may be completely disrupted by disturbance but quickly return to its former state.

Ecological Succession Informing Ecological Restoration

The massive impacts of human activity on earth’s ecosystems present us with pressing challenges. 1. to conserve the surviving biodiversity of the planet. 2. to restore damaged ecosystems to acceptable levels of biodiversity, physical structure, and ecosystem functioning, a process called **ecological restoration.**

A specialized area within the science of ecology, restoration ecology, focuses on exploring ways to improve the effectiveness of ecological restoration by providing a conceptual framework to guide such work. The concepts derived from studies of ecological succession have much to contribute to ecological restoration (Walker, Walker, and Hobbs 2007). **Some ecologists have even gone so far as to define ecological restoration as “essentially the manipulation of succession in order to achieve some predetermined goal” (Walker, Velazquez, and Shiels 2009).**