TOPIC 2.5 AND 2.7
NATURAL DISRUPTIONS TO ECOSYSTEMS AND ECOLOGICAL SUCCESSION

Enduring Understanding: Ecosystems have structure and diversity that change over time.

Learning Objective: Explain how natural disruptions, both short and long term, impact an ecosystem and describe ecological succession and its effect on ecosystems.

Related Readings: pg 84 – 93, "Environment, The Science Behind the Stories" 4th edition, Withgott, Jay and Laposata, Matthew.

ESSENTIAL KNOWLEDGE
(AS IDENTIFIED BY COLLEGE BOARD)

ESSENTIAL KNOWLEDGE

ERT-2.G.1
Natural disruptions to ecosystems have environmental consequences that may, for a given occurrence, be as great as, or greater than, many human-made disruptions.

ERT-2.G.2
Earth system processes operate on a range of scales in terms of time. Processes can be periodic, episodic, or random.

ERT-2.G.3
Earth's climate has changed over geological time for many reasons.

ERT-2.G.4
Sea level has varied significantly as a result of changes in the amount of glacial ice on Earth over geological time.

ERT-2.G.5
Major environmental change or upheaval commonly results in large swathes of habitat changes.

ERT-2.G.6
Wildlife engages in both short- and long-term migration for a variety of reasons, including natural disruptions.

ESSENTIAL KNOWLEDGE

ERT-2.I.1
There are two main types of ecological succession: primary and secondary succession.

ERT-2.I.2
A keystone species in an ecosystem is a species whose activities have a particularly significant role in determining community structure.

ERT-2.I.3
An indicator species is a plant or animal that, by its presence, abundance, scarcity, or chemical composition, demonstrates that some distinctive aspect of the character or quality of an ecosystem is present.

ERT-2.J.1
Pioneer members of an early successional species commonly move into unoccupied habitat and over time adapt to its particular conditions, which may result in the origin of new species.

ERT-2.J.2
Succession in a disturbed ecosystem will affect the total biomass, species richness, and net productivity over time.

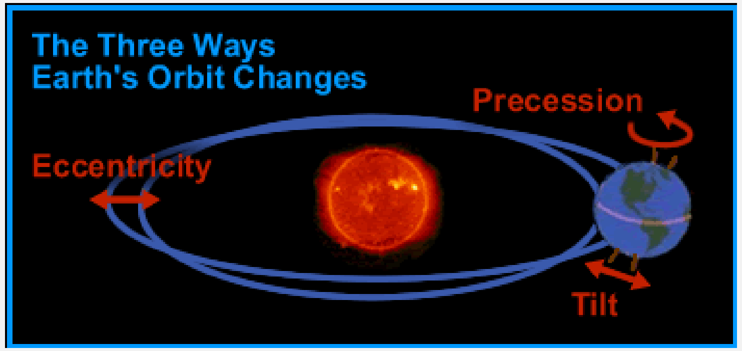
NATURAL DISRUPTIONS TO ECOSYSTEMS

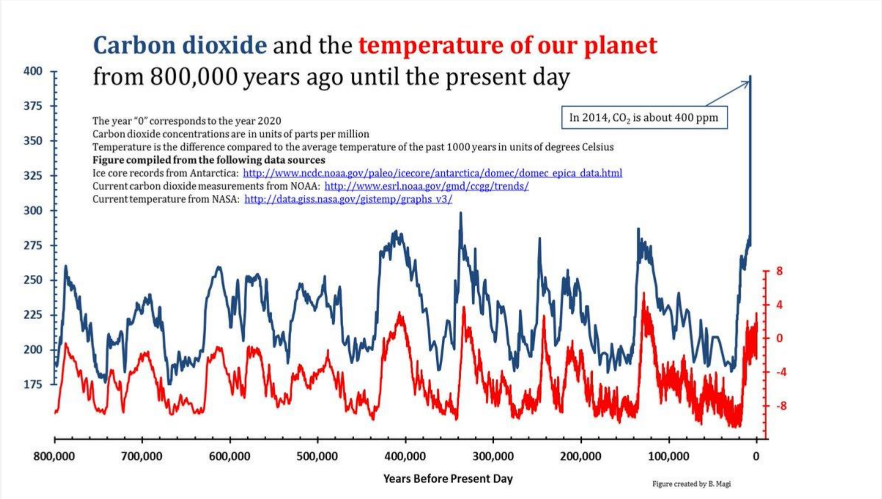
- Naturally occurring disruptions are common in ecosystems and result in cycles and steady states, as well as directional change in the environment.
- Disruptions and environmental change occurs at various magnitudes
  - a tree falling in the forest (small scale), Fires and tropical storms, introduction of invasive species / removal of a keystone species (moderate scale), meteor impacts and global climate change (large scale)
  - Some have greater impacts than human caused disruptions
- Disruptions and environmental change occur on several different possible time scales:
  - ***Periodic changes***: Occur with regular frequency such as seasons and tides, are predictable and allow organisms to adapt
  - ***Episodic changes***: Occasional events with irregular frequency and are somewhat predictable; hurricanes, droughts, fires.
  - ***Random changes:*** no regular frequency. We know why they happen but are not able to predict them based on the timing of past events; volcanic eruptions, earthquakes, meteor strikes

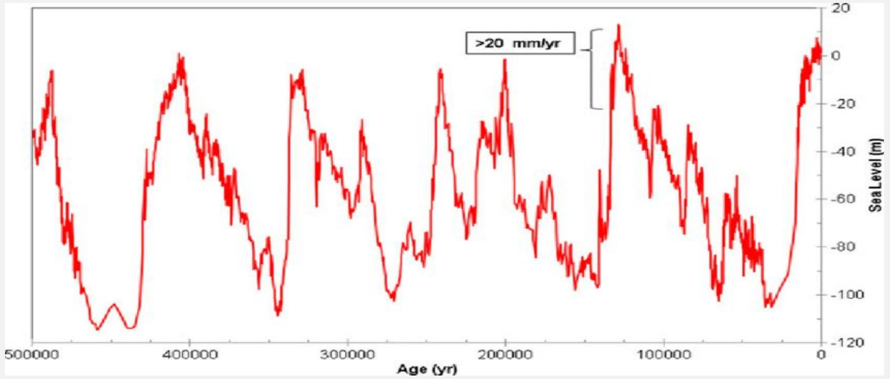


LONGER TERM ECOSYSTEM CHANGE: GLACIAL AND INTERGLACIAL PERIODS OF THE CURRENT ICE AGE

- Periodic changes in Earths orbit and tilt alter climate, sea levels and CO_2 concentrations
  - We are currently in an interglacial period (most recent 20,000+ years) of the fifth major ice age (lasting the last 2.6 million years) in the history of Earth.
  - We are due for another period of glacial advance based on the periodicity of glacial and interglacial cycles within the current ice age.
  - The magnitude of change on earth is sizeable between glacial and interglacial periods.
    - Temperature changes of 10-14 °C
    - result in changes of up to 130m in sea levels (thermal expansion and melting ice caps)
    - CO_2 levels rise and fall as a result of temperature change (Ocean absorption of CO_2, Permafrost sequestration of C), but CO_2 levels can also cause temperature change (greenhouse effect)
    - Current CO_2 levels are much greater than historic levels



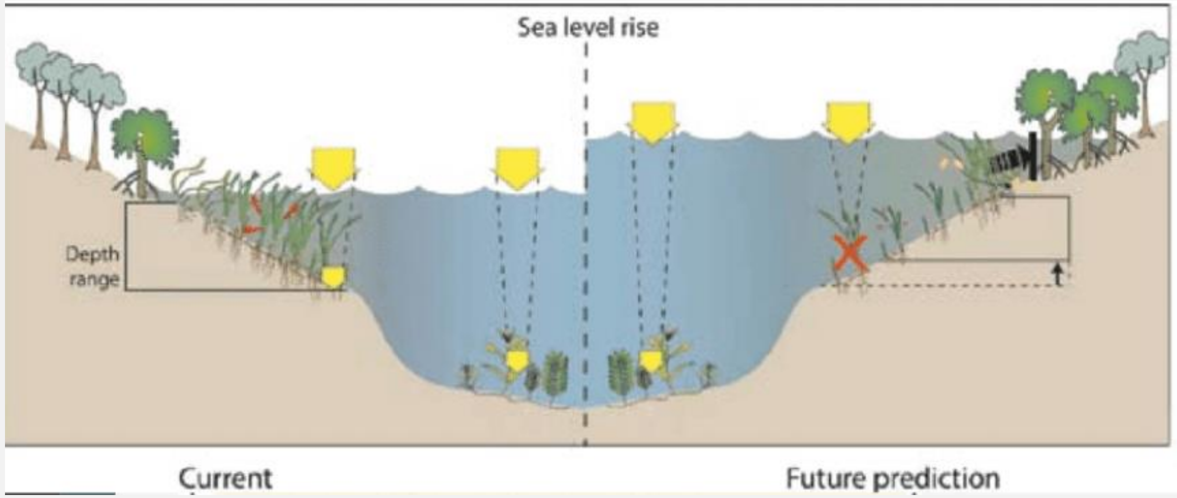


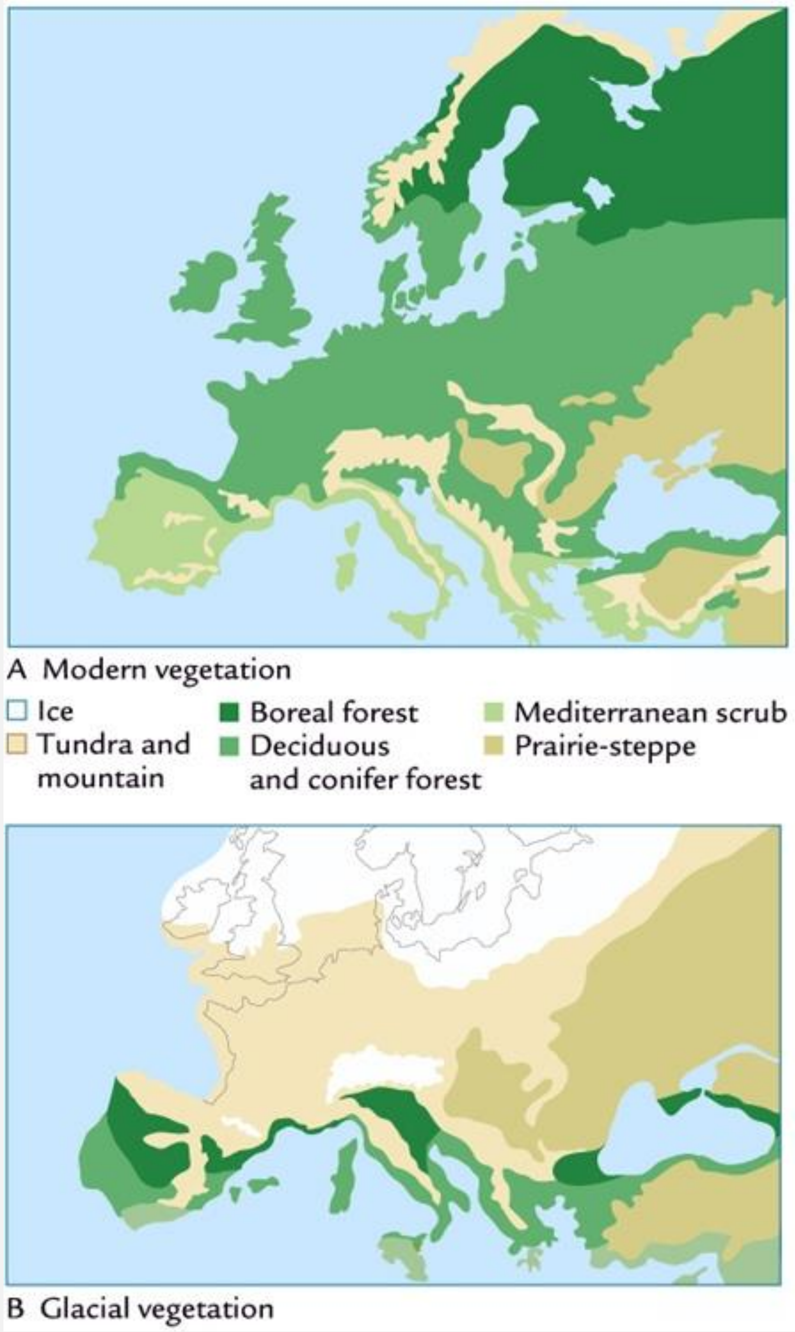


Change in Sea Level (500,000 years)

LONGER TERM ECOSYSTEM CHANGE: GLACIAL AND INTERGLACIAL PERIODS OF THE CURRENT ICE AGE

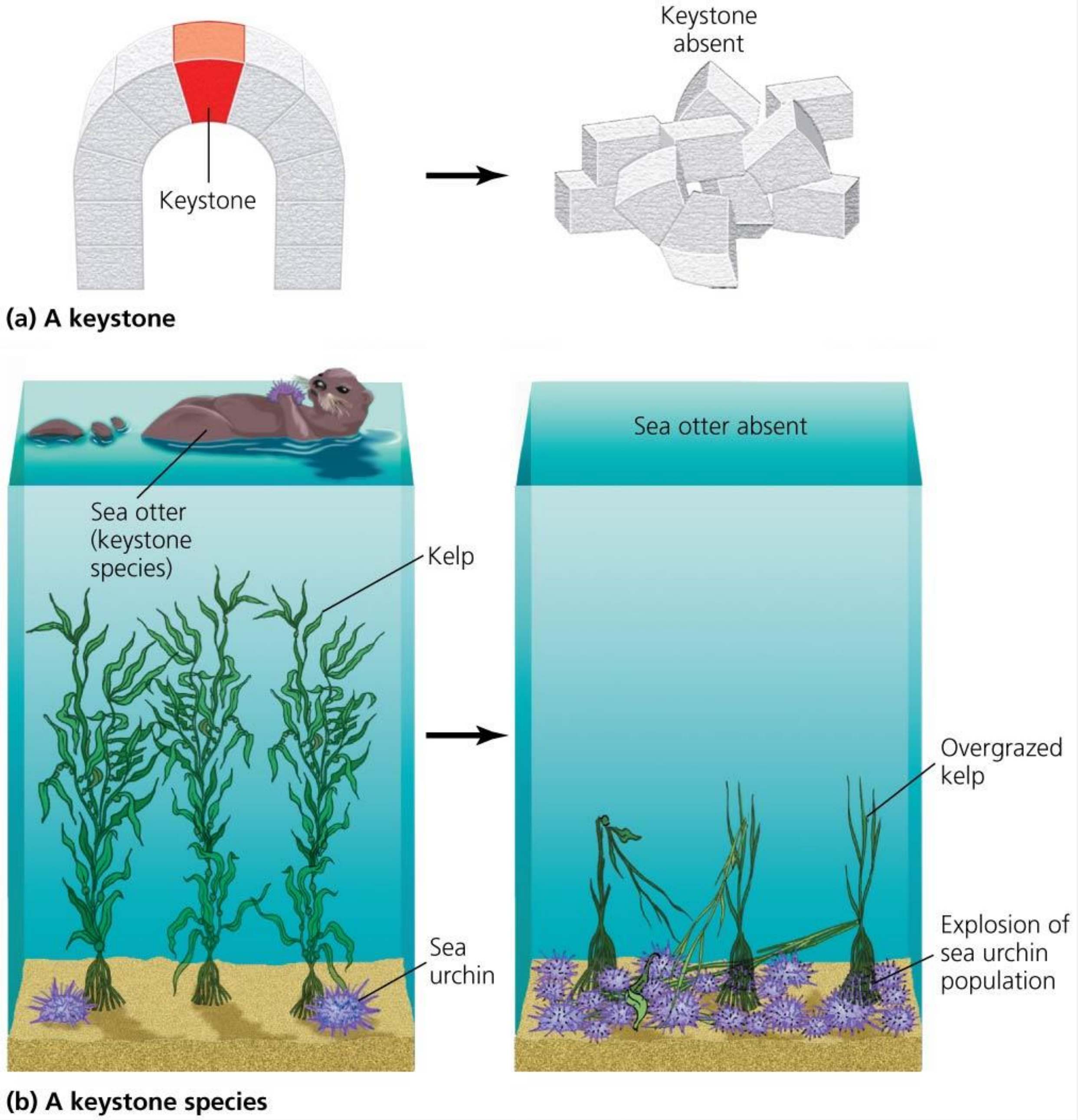
- Changes in climate throughout Earth's history have resulted in changing ecosystems
  - Sea level drops during glacial periods increasing the size of exposed land masses and creating land bridges
  - Aquatic and terrestrial biome distribution changes globally in response to glacial and interglacial periods.





SOME ORGANISMS PLAY OUTSIZED ROLES IN COMMUNITIES

- ***Keystone species*** have a strong or wide-reaching impact far out of proportion to their abundance.
  - Many, but not all, are apex predators (top of the food chain).
- Removal of a keystone species has substantial ripple effects on other members of the biological community.
  - Removal of otters significantly alters the entire food web of kelp forest ecosystems.



(a) A keystone
(b) A keystone species

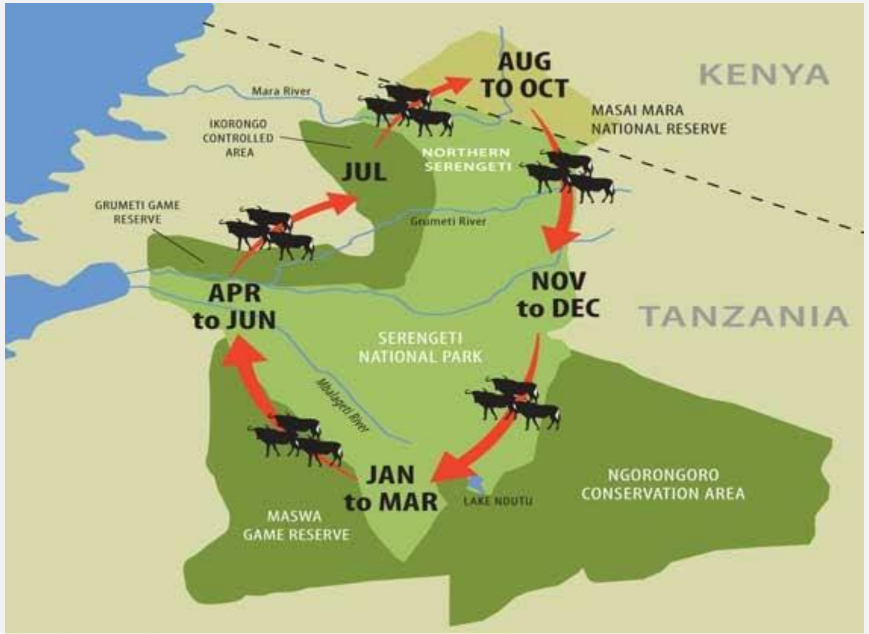
SOME ORGANISMS PLAY OUTSIZED ROLES IN COMMUNITIES

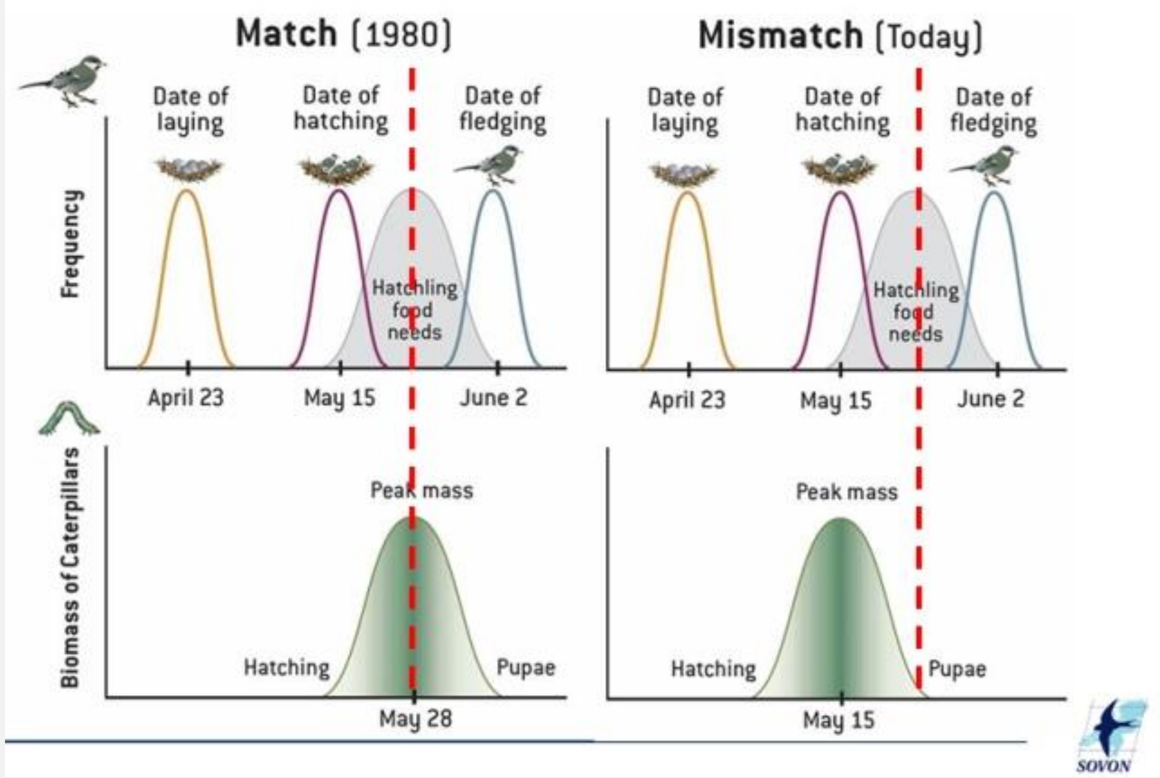
- **Keystone species may cause a *trophic cascade***
  - a phenomenon in which predators at high trophic levels indirectly affect populations at lower trophic levels
  - Predators keep species at intermediate trophic levels in check, allowing growth of species at a lower level
  - Extermination of wolves led to increased deer and elk populations, which overgrazed vegetation and changed forest structure

- **Other keystone Species are "Ecosystem Engineers"**
  - They physically modify the environment
  - Beaver dams, prairie dogs, ants, zebra mussels

RESPONSE TO DISTURBANCES

- Organisms respond to environmental changes caused by disturbances by:
  - ***Migrating*** (e.g. shifting biome distributions)
  - ***Adapting*** (many examples of evolutionary changes)
  - Or simply dying out (***extinction / extirpation***) when changes are too drastic and/or sudden
- Examples:
  - Grazers and browsers of the Serengeti migrate with the rains
  - Caterpillars have adapted to a warming climate
  - Will songbirds adapt too, or go extinct?



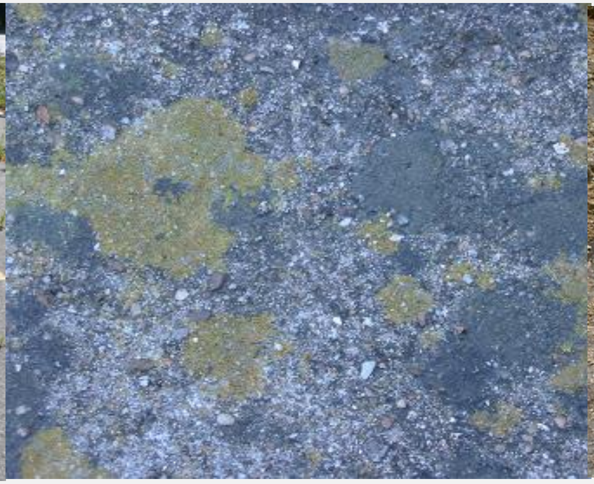


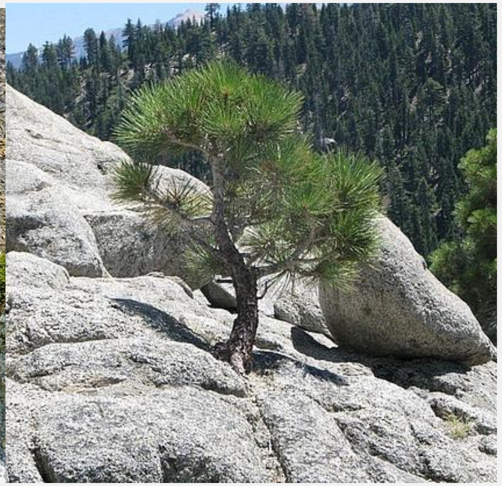
COMMUNITIES RESPOND TO DISTURBANCE THROUGH THE PROCESS OF SUCCESSION

- Disturbances change conditions in ecosystems and alter the biological community of the ecosystem
  - Populations can respond to disturbance by migrating, adapting or perishing.
- Many communities experience regularly occurring patterns of disturbances.
  - The pattern of disturbances in a community is referred to as a communities ***disturbance regime.***
  - *Disturbance regimes will vary in* scale, frequency, and intensity
- ***Succession*** is the predictable series of changes in a community following a disturbance
  - ***Primary Succession***
  - ***Secondary Succession***

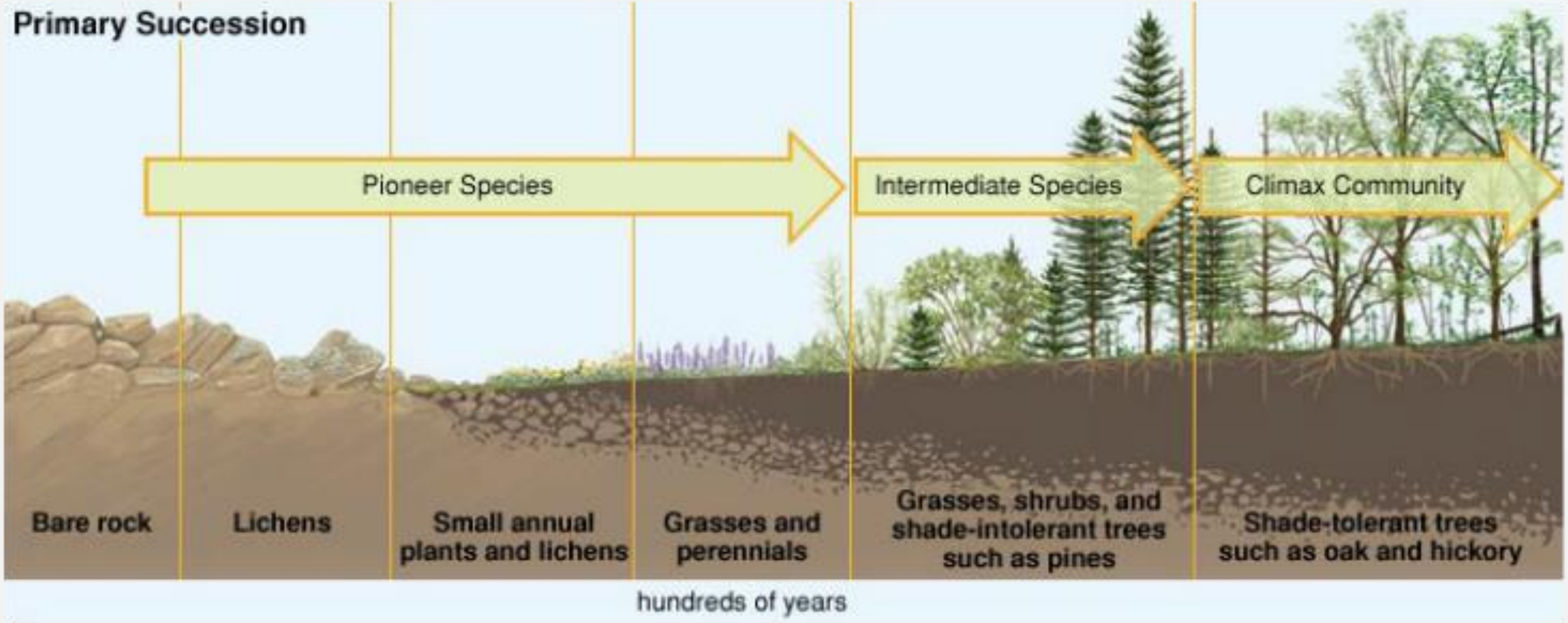
PRIMARY SUCCESSION FOLLOWS SEVERE DISTURBANCE

- ***Primary succession*** occurs after disturbance removes all vegetation and soil; starts from bare rock
  - Follows extreme disturbances that damage or remove existing soils such as glaciation, volcanic eruptions, abandonment of paved areas.
  - Physical and chemical weathering of rocks and wind and water erosion increase mineral content of newly forming soils.
  - Biological communities play important roles in rebuilding soils
    - Chemical (secretions of lichens) and physical processes of rock erosion (growth of plant roots) to form mineral sediments in soil.
    - Decomposition of dead organisms and organic wastes add organic material and nutrients to mineral sediments created by erosion to form new soils.



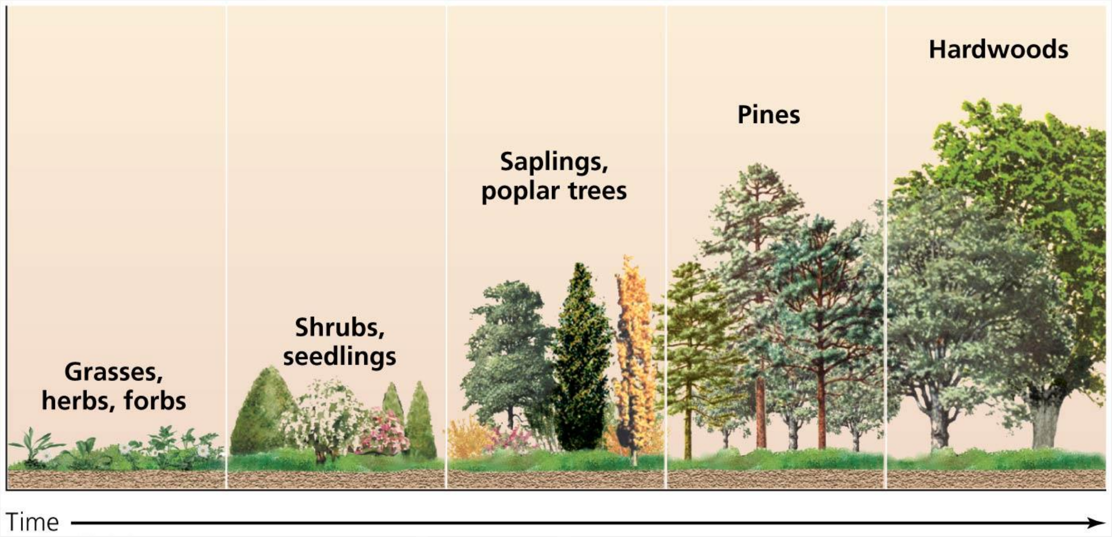
SEQUENCE OF BIOLOGICAL COMMUNITIES DURING PRIMARY SUCCESSION



- Succession following the eruption of Mount Saint Helens (link)

SECONDARY SUCCESSION

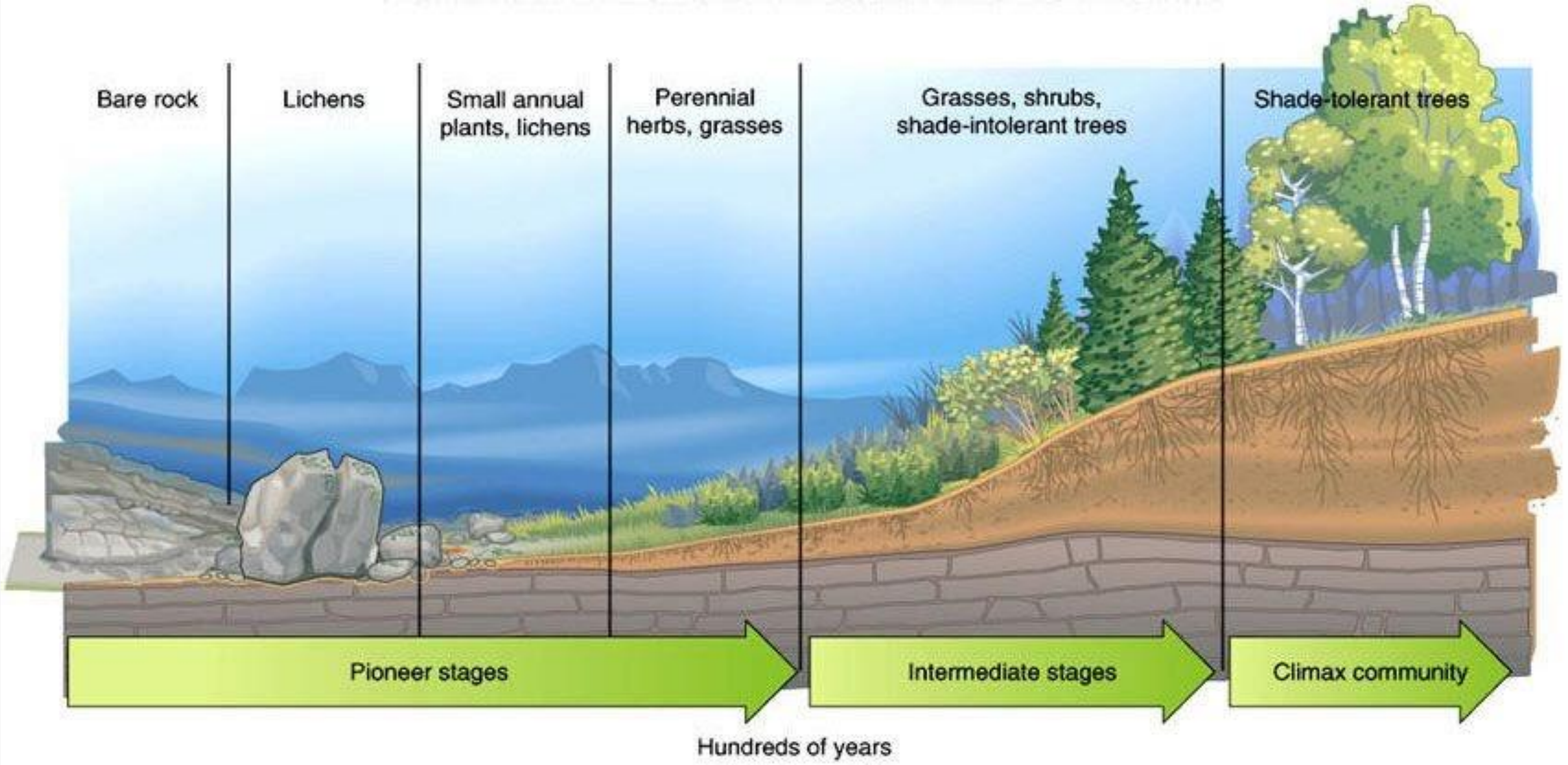
- ***Secondary succession*** is the process of recovery from a disturbance that dramatically alters the biological community, but does not destroy the soil or seed banks in the soil.
- The soil and seed banks, as well as root stocks form "building blocks" that help jump start the process of secondary succession
- Secondary succession usually occurs more rapidly than primary succession.
  - it does not require the slow, geologic processes that build soil.
  - Seed banks and roots stocks may remain intact in the soil, allowing producers to immediately repopulate, without waiting for others to spread to the disturbed area from nearby source populations.
- Fires, hurricanes, farming, logging can lead to secondary succession.



SPECIES ARE ADAPTED TO CERTAIN STAGES OF SUCCESSION

***Pioneer species* are the first species to arrive after a disturbance**

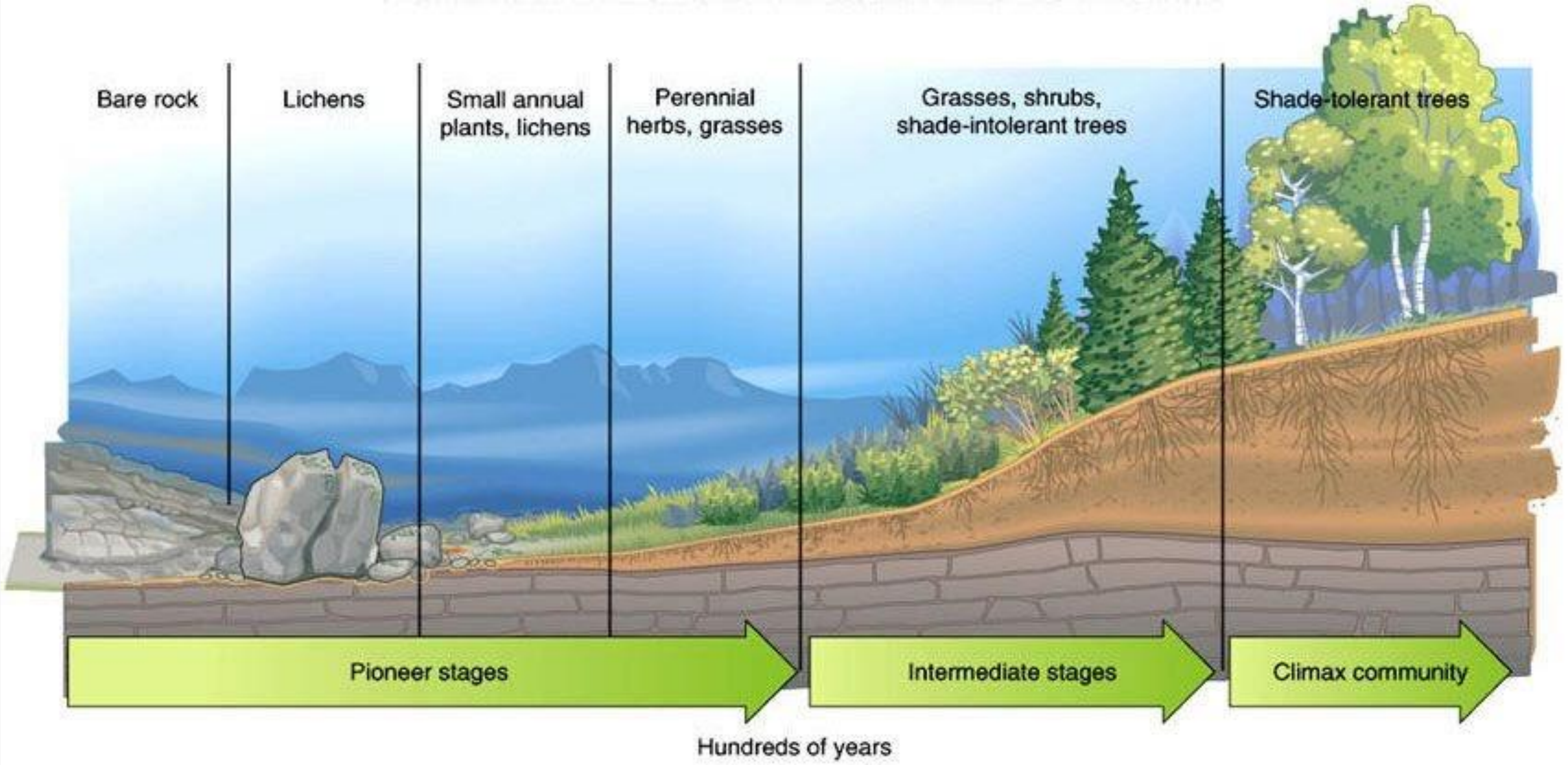
- Often wind dispersed seeds, fast growing, fast reproducing, annuals, tolerant of shallow soils, bright sunlight
- Primary succession: lichens, mosses, liverworts
- Secondary succession: grasses, sedge, wildflowers, raspberries, "weeds"



SPECIES ARE ADAPTED TO CERTAIN STAGES OF SUCCESSION

Mid-successional Species

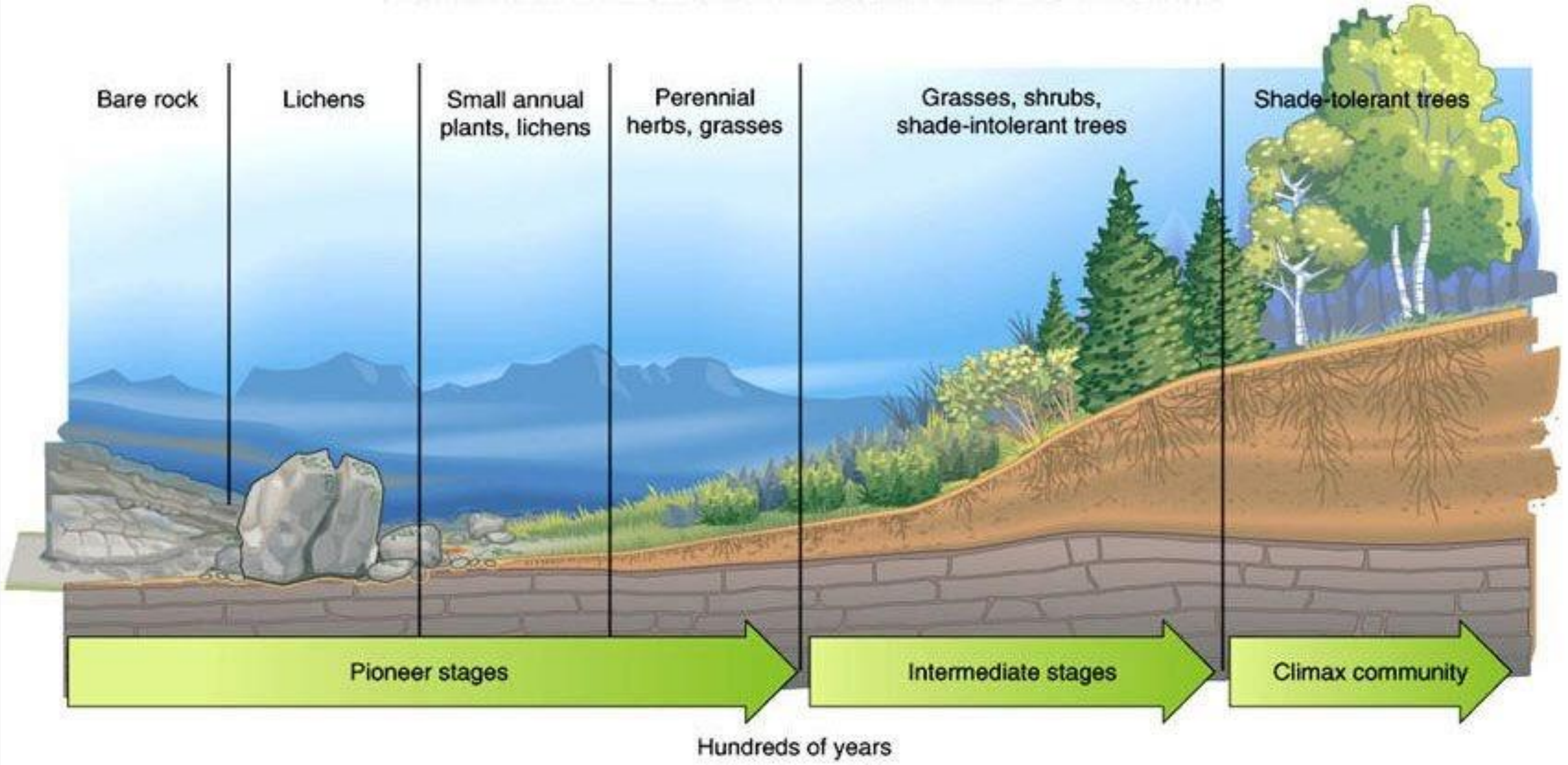
- Help develop deeper soils through cycles of their death and decomposition
- Broad range of tolerance and broad niches, generalists
- Individuals with moderate growth rates and reproductive rates, perennials, sun tolerant, require deeper, more nutrient rich soils than pioneers
- Shrubs and small trees



SPECIES ARE ADAPTED TO CERTAIN STAGES OF SUCCESSION

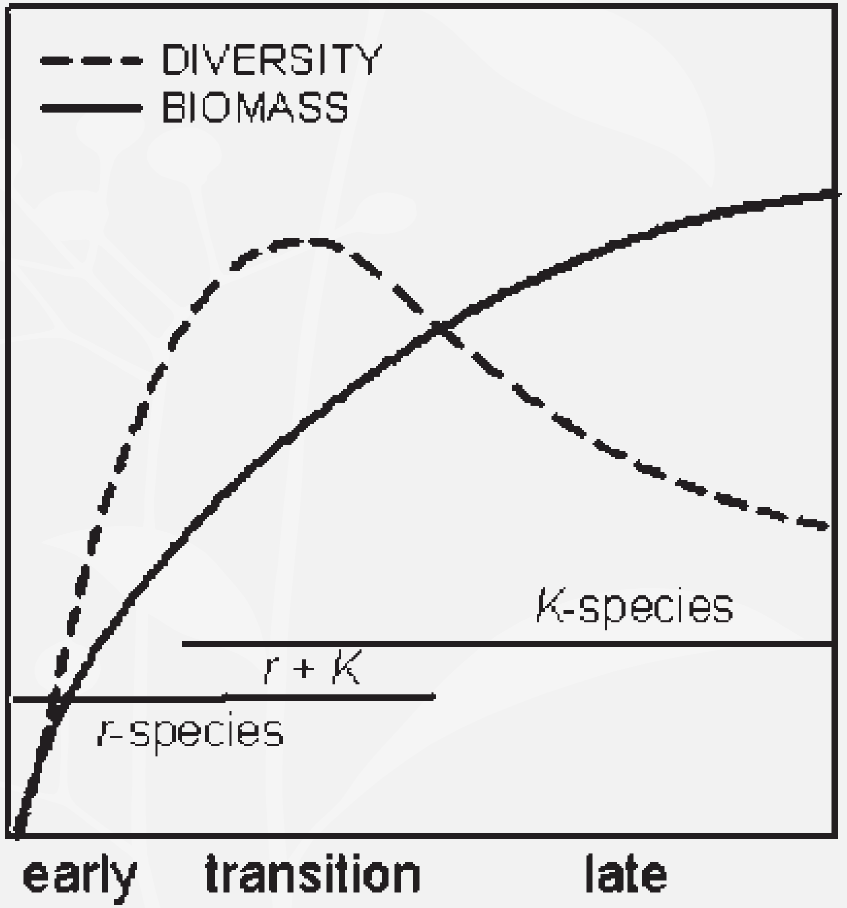
Late Successional Species* of the *Climax community

- Community that would develop and remain in place with few changes if no new disturbances were to restart the process of succession (species composition varies depending on biome)
- Narrower ranges of tolerance, narrower niches, specialists
- Larger, slow growing trees, more shade tolerant seedlings, require deep soils for extensive root networks
- Maples and oaks for example



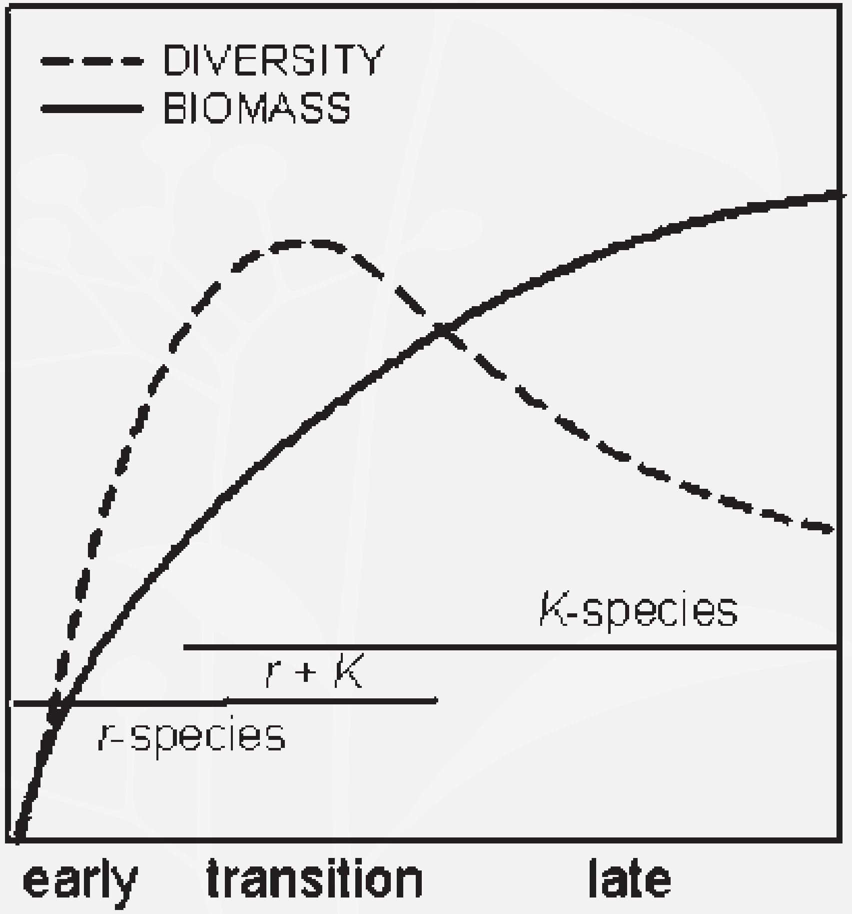
CHARACTERISTICS OF COMMUNITIES CHANGE DURING SUCCESSION – SPECIES DIVERSITY

- **Diversity increases during early stages of succession but declines during later stages.**
  - Initially, few species have adaptations that allow them to tolerate conditions following the disturbance so diversity is low.
  - As pioneer and early successional species return, diversity goes up.
  - As the community reestablishes itself, additional species can tolerate conditions in the formerly disturbed area and diversity increases further.
  - As abiotic conditions stabilize, and populations in the once disturbed area have grown, competition intensifies and weaker competitors must migrate to other areas or face extirpation. Species diversity declines in late-middle stages before leveling off.



CHARACTERISTICS OF COMMUNITIES CHANGE DURING SUCCESSION – BIOMASS AND PRODUCTIVITY

- **Biomass increases throughout succession, but the rate that biomass increases (productivity) declines throughout succession.**
  - Initially there are few individuals and biomass is low.
  - Producers colonize the area with seeds that dispersed into the disturbed area and begin to grow. Biomass increases.
  - Individuals are young and grow rapidly so biomass continues to increase and does so at a rapid rate.
  - As the community establishes itself, there are more mature individuals who have reached full size so biomass is high, but biomass is increasing slowly or not at all.
    - Biomass is high, but NPP is relatively low in climax communities



COMMUNITIES EVOLVE IN RESPONSE TO DISTURBANCE

- Communities have adapted different ways of responding to disturbance scale, intensity and frequency.
  - ***Resistance***
    - Communities with large amounts of energy and matter stored in biomass are well suited to resisting many potential disturbances. Most forests types are resistant (e.g. taiga and temperate deciduous).
  - ***Resilience***
    - Communities that experience frequent, low intensity disturbance are often not very resistant, but the they recover quickly and are highly resilient. Grasslands and scrublands (chaparral) are resilient biomes.
  - A community that is highly resistant to disturbance is usually not very resilient; a highly resilient community is generally not very resistant.
- A disturbed community may never return to its original state.
  - Disturbance may lead to crossing a physical threshold.
  - e.g. Allowing invasive species to gain a foothold, extirpation of keystone species, recent megafires, combined with long-term drought.
  - Such communities are said to undergo a ***phase shift*** or ***regime shift***

VIDEO RESOURCES

- Succession Interactive
  - https://biomanbio.com/HTML5GamesandLabs/EcoGames/succession_interactive.html?fbclid=IwAR1eGvk8it7DZDZWNVhZoZGEBLxhhL28mCOYh8AQEdBLCg9IpUbWHzqE2CM