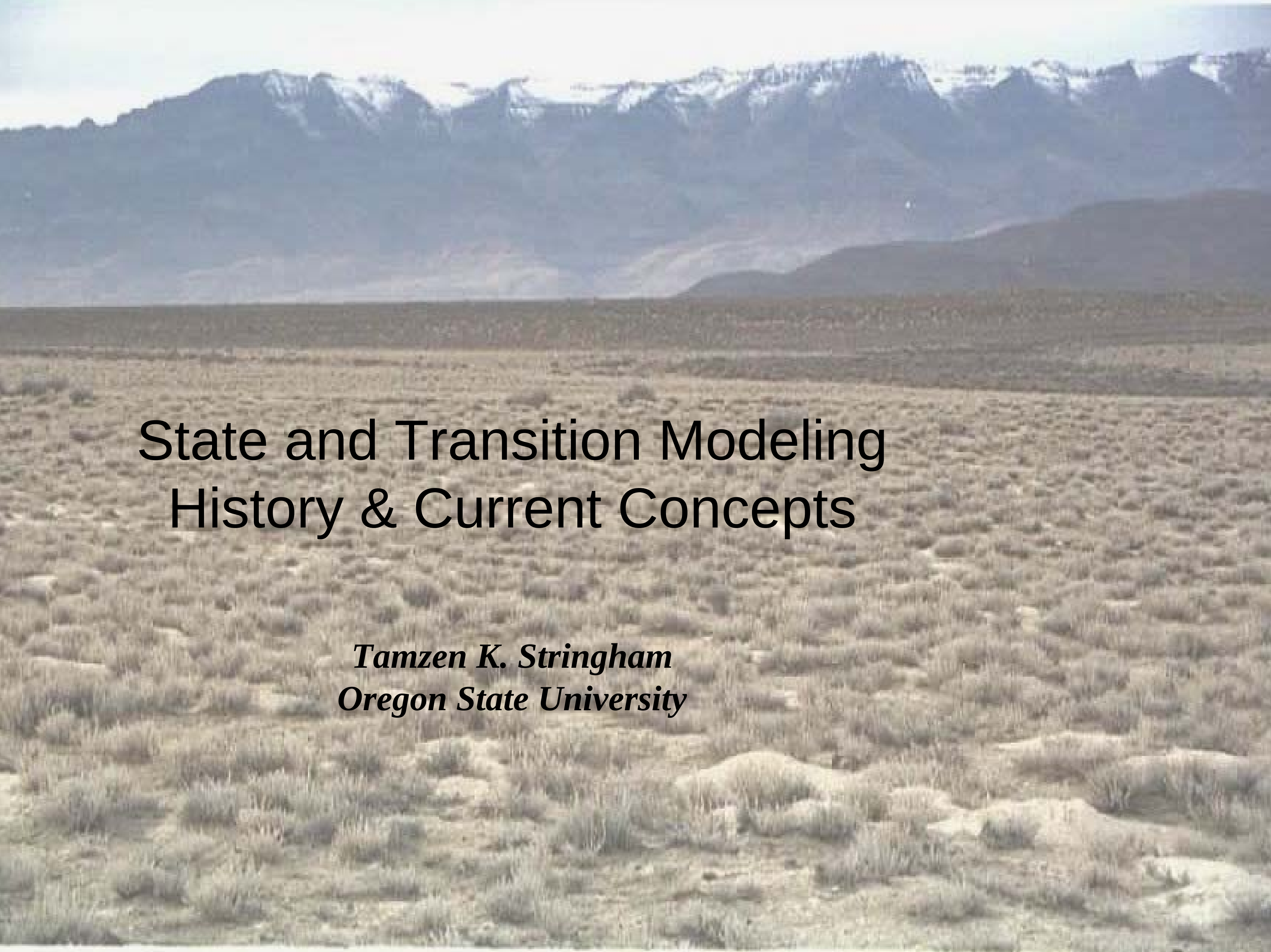

State and Transition Modeling
History & Current Concepts

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Models: Old & not as old!
(SRM 2000)

- **Range Succession Model**
  - Linear models (single or multiple)
  - Hysteresis ?
  - Works well in many applications
    - Great Plains
    - Mountain Grasslands
    - Some dynamics in arid and semi-arid systems
  - Many instances where this model does not adequately describe vegetation change

Models: Old & not as old!

- Non-equilibrium Models (States, Transitions and Thresholds)
  - Encompass Range Succession Model where it fits
  - Accounts for thresholds, hysteresis and multiple steady states
  - Allows for more detail in triggers and pathways of vegetation change

Non-equilibrium Ecology:
Theory in its infancy

- Opportunities
  - Clear, accepted definitions needed for
    - States
    - Transitions
    - Thresholds
  - Clarification and incorporation of ‘Stability’ and ‘Resilience’
  - Experiments to test hypotheses and further develop the theory

Definitions: State (Westoby et al. 1989)

- …relatively stable, recognizable assemblages of species occupying a site
- Two types: transient and persisting
- "…necessarily an abstraction encompassing a certain amount of variation…"

Definitions: State (Iglesias & Kothmann 1997)

- physiognomically characterized ecological entities
- usually described by botanical composition of dominant vegetation
- one of only <u>two</u> types of objects in a state and transition model (thresholds not considered)

Application: States

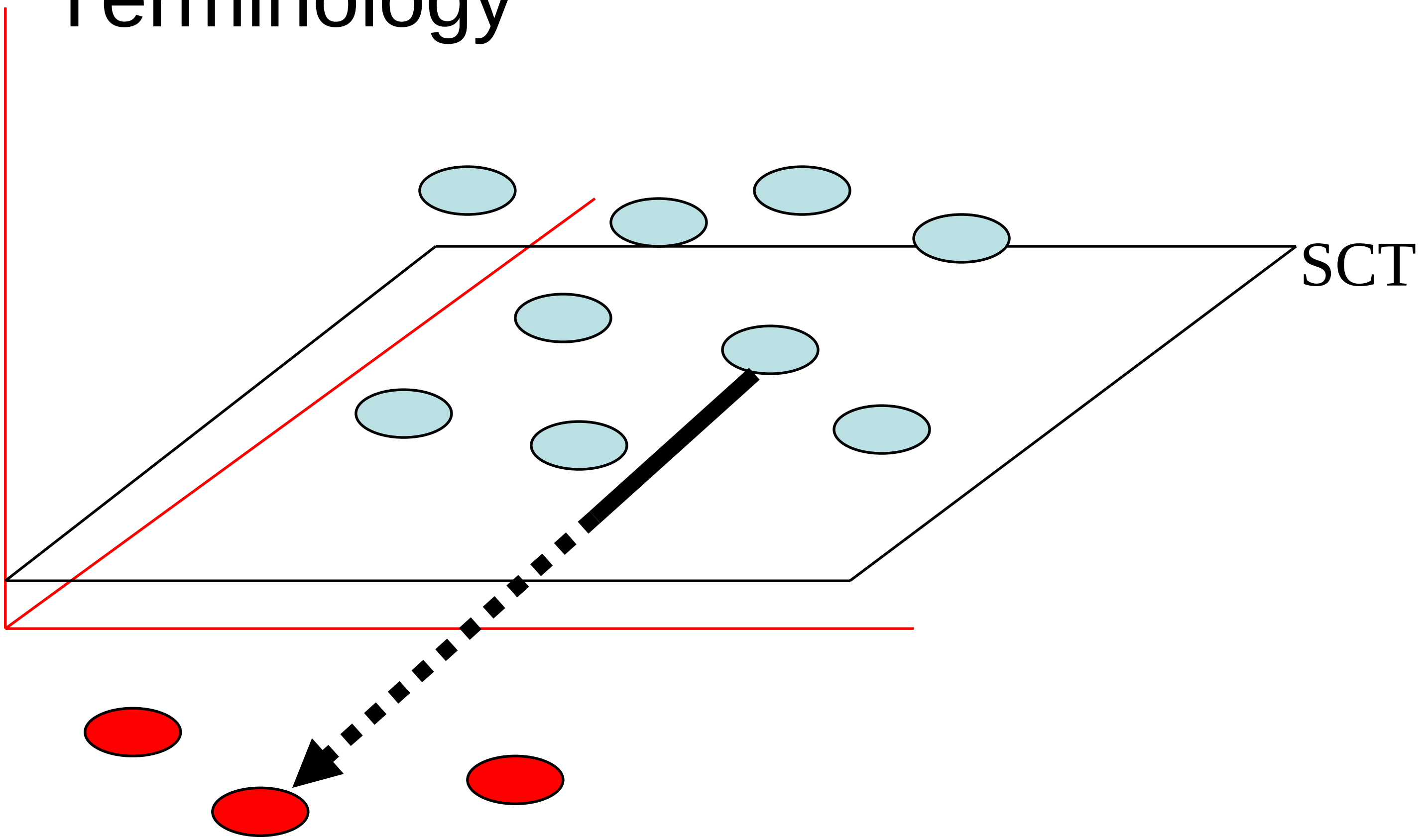
- The Westoby team's "certain amount of variation" VARIES!
  - – ***broad*** classifications
  - – more ***specific*** classifications that sometimes approximate seral stages

States: Broad application

- Westoby et al. (1989)
  - grass driven succession vs. shrub driven succession
- Archer (1989)
  - assemblages within grassland domain & shrubland domain
- Davenport et al. (1998)
  - low erosion state vs. high erosion state
- Friedel (1991)
  - grass dominance vs. woody dominance

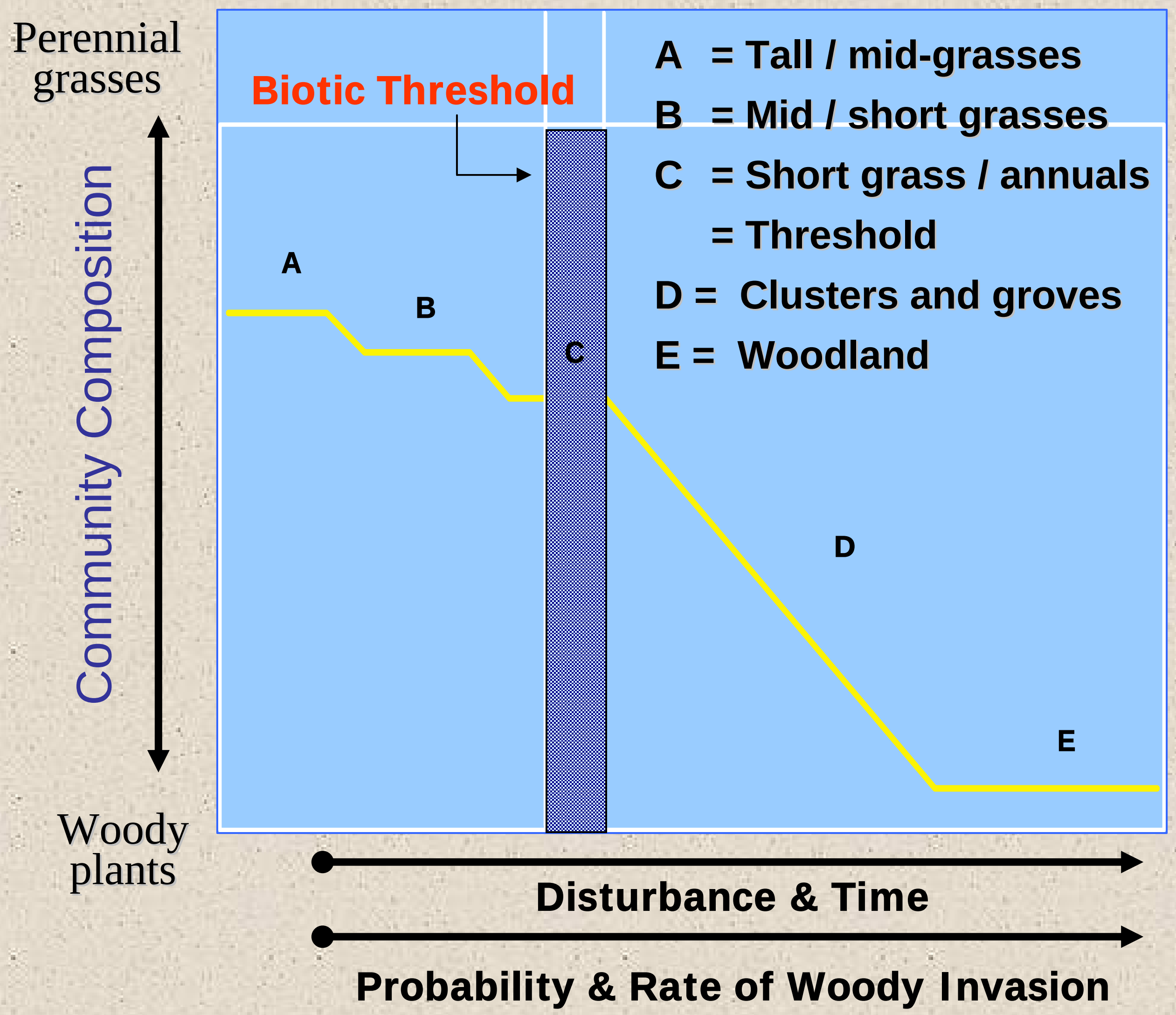
States: Broad application

- SRM Task Group, Unity in Concepts and Terminology



NONEQUILIBRIUM SYSTEM DYNAMICS

(Modified from Archer, 1989)

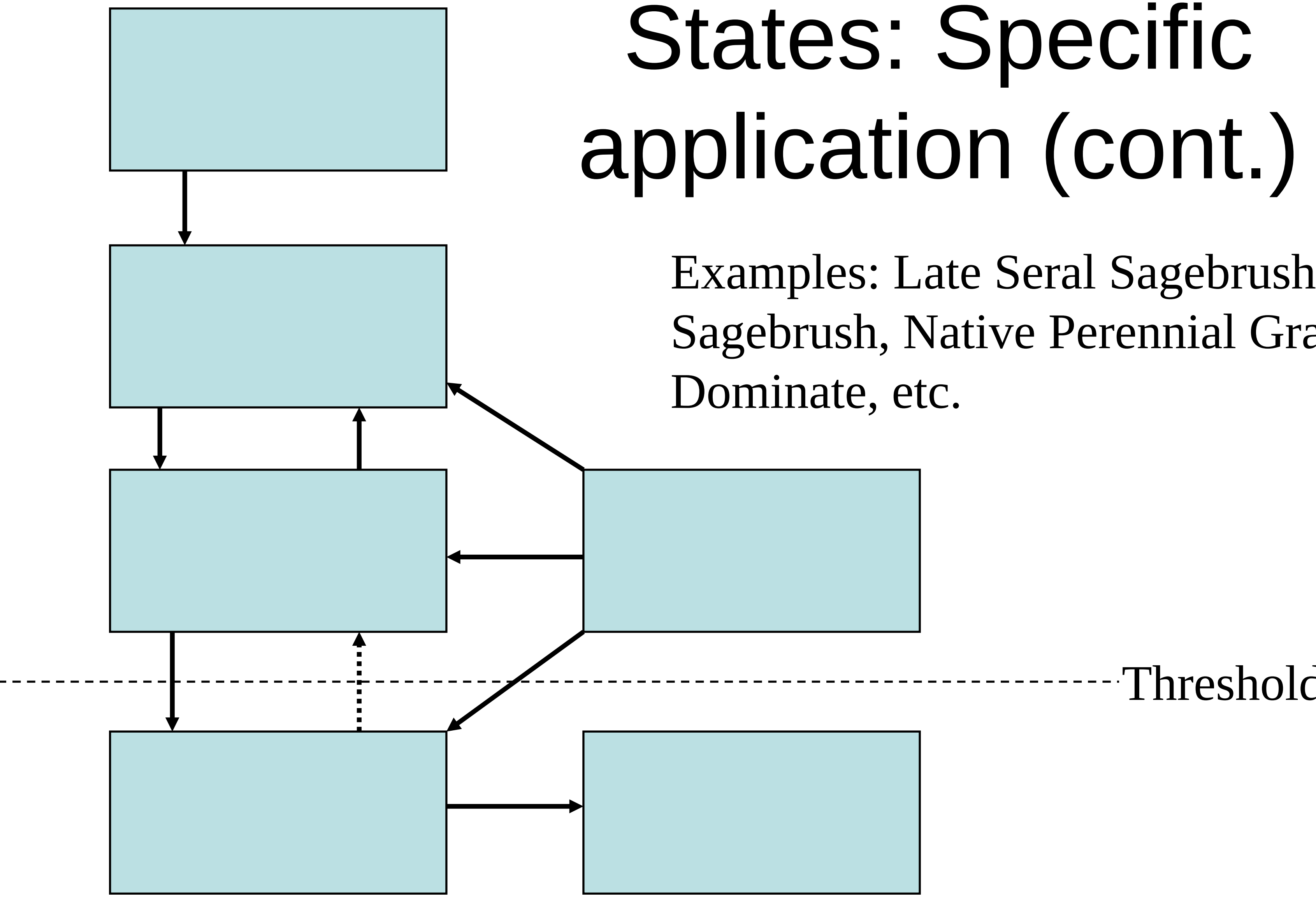


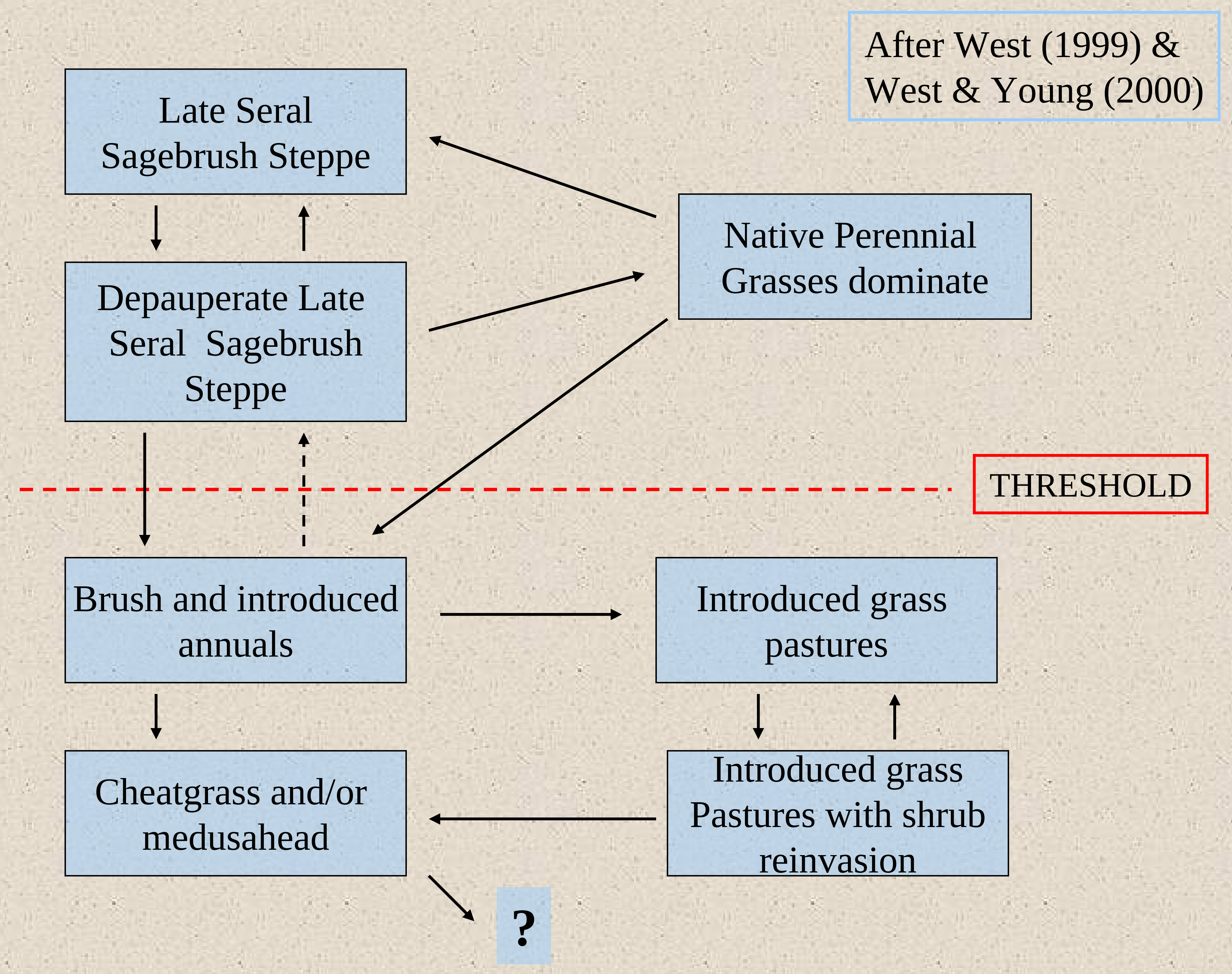
States: Specific application

- West (1999) - Successional change in sagebrush steppe
- Laycock (1991) - S & T for sagebrush-grass vegetation
- Olivia et al. (1998) – Patagonia
- Many others

States: Specific application (cont.)

Examples: Late Seral Sagebrush, Dense Sagebrush, Native Perennial Grasses Dominate, etc.




After West (1999) &
West & Young (2000)
Late Seral
Sagebrush Steppe
Native Perennial
Grasses dominate
Depauperate Late
Seral Sagebrush
Steppe
THRESHOLD
Brush and introduced
annuals
Introduced grass
pastures
Cheatgrass and/or
medusahead
Introduced grass
Pastures with shrub
reinvasion
?

Definitions: Transitions

- **“Transitions not always clearly defined”** (Iglesias & Kothmann 1997)
- **Characteristics** (Westoby et al. 1989)
  - triggered by natural events, management or both
  - may occur quickly or over a long period of time
  - once initiated, system does not come to rest 1/2 way through

Application: Transitions

- Applied fairly universally
  - trajectory or pathway of change
  - among / between states
  - among / between assemblages within states

Definitions: Threshold

- **Westoby et al. (1989) didn't define thresholds**
  - transitions that do not occur
  - transitions that require management input

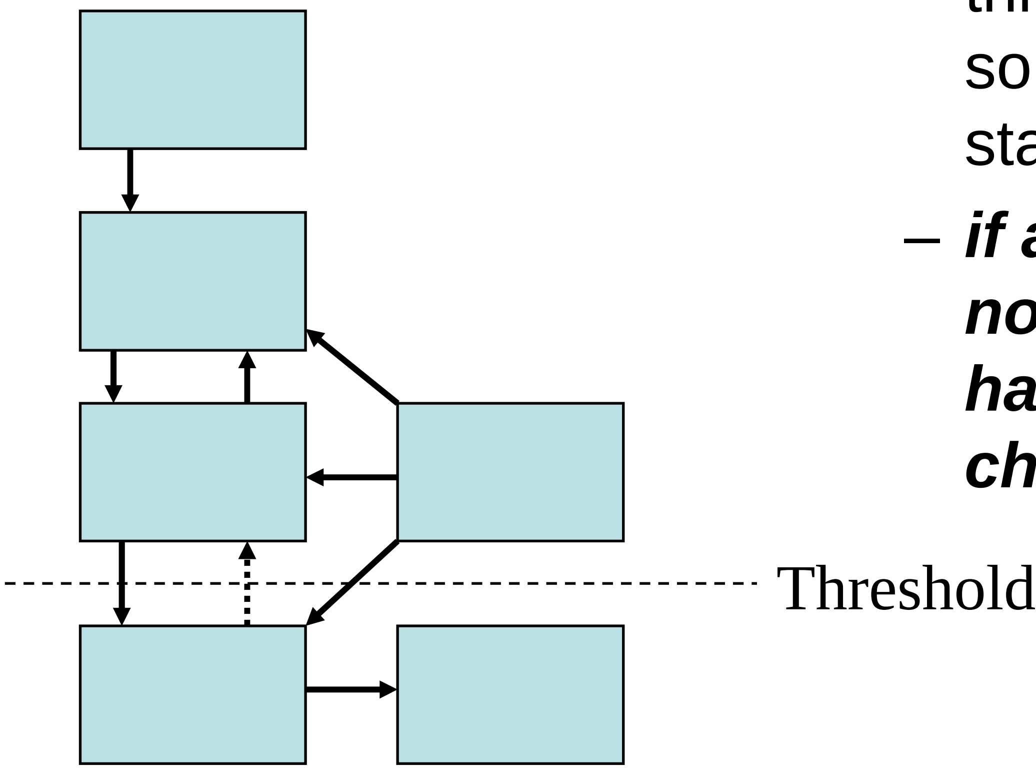
- **Friedel(1991) concentrated on thresholds**
  - "…compatible with state and transition theory focusing on those transitions that are one-way."

- **Archer (1989) identified a "transitional threshold"**

Definitions: Thresholds (Friedel 1991)

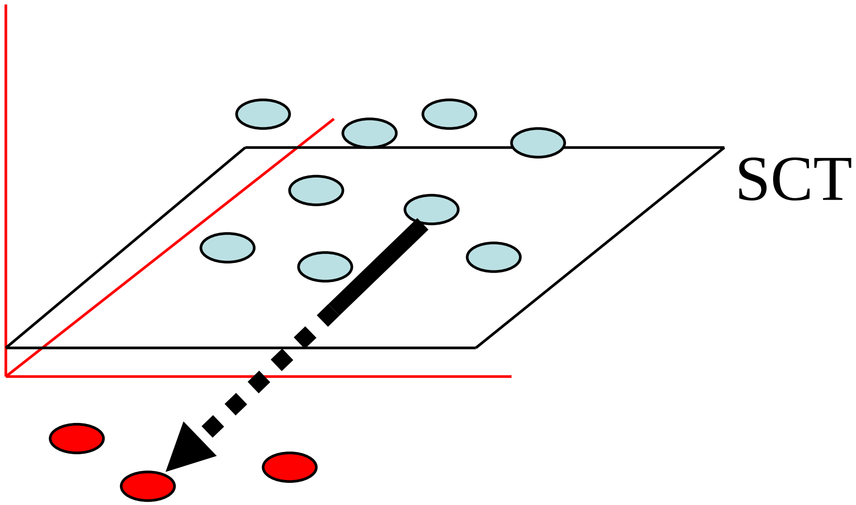
- **Thresholds exist between alternative states & have 2 characteristics:**
  - boundary in space and time between states
  - initial shift across the boundary is not reversible on a practical time scale without input of energy (management)

Applications: Thresholds



- Most Common
  - thresholds between some, but not all states
  - ***if a threshold has not been crossed, has the state truly changed?***

Applications: Thresholds



- An alternative
  - thresholds “define” the bounds of states
  - must cross a threshold to change states

MODEL REFINEMENT (2003)

1989 - present

States, Transitions and Thresholds

- Encompass Range Succession Model where it fits
- Account for thresholds, inertia and multiple steady states
- Allow for more detail in triggers and pathways of vegetation change (***process AND competition***)
- Spatial scale: Ecological Site
- Temporal framework: Current climate

ECOLOGICAL SYSTEM DYNAMICS

competing paradigms

Linear Change

CLEMENTS (1916)

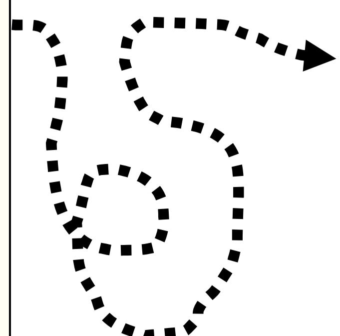
DYKSTERHUIS (1949, 1958)

climatic climax endpoint

deterministic

disturbance unimportant

competition important



Non-linear Change

VON BERTALANFFY 1968

HOLLING 1973

MAY 1977

WESTOBY et al 1989

multiple steady states

disturbance important

competition-less important

thresholds

(from Brown and Tugel 2001)

COMPETITION v. PROCESS

Competition: plant to plant interactions

- **facilitation**
- **tolerance**
- **inhibition**

Connell & Slatyer 1977
Noble & Slatyer 1980
Egler 1954

Process: functional capacity

- **hydrology**
- **energy capture**
- **nutrient cycling**

Whisenant 1999
Ludwig et al. 1997
Pellant et al. 2000

Rangeland Ecological Processes

- Hydrology: capture, storage and on-site use of precipitation
- Energy Capture: conversion of sunlight to plant and animal matter
- Nutrient Cycling: the cycling of nutrients through the physical and biotic components of the environment

Interpreting Indicators of Rangeland Health
Technical Ref. 1734-6 2000

- Ecological processes functioning within a normal range will support a suite of specific plant communities

- Maintenance of a functional site or repair of a damaged site requires management focused on:

❖ soil stability
❖ nutrient cycling
❖ capture, storage and safe release of moisture

- Vegetation should be used as a tool for repair or maintenance

- Vegetation *or soil* change may be an indicator of a change in the functional capacity of the ecological processes

STATE

A recognizable, resistant and resilient complex of two ecosystem components, the soil base and the vegetation structure

Vegetation Structure

- above ground communities of plant species assemblages
- competitively capture and utilize the available resources

Soil Base

- developed through time from specific parent material, climate, landscape position and interaction with biota
- determines the site's capability

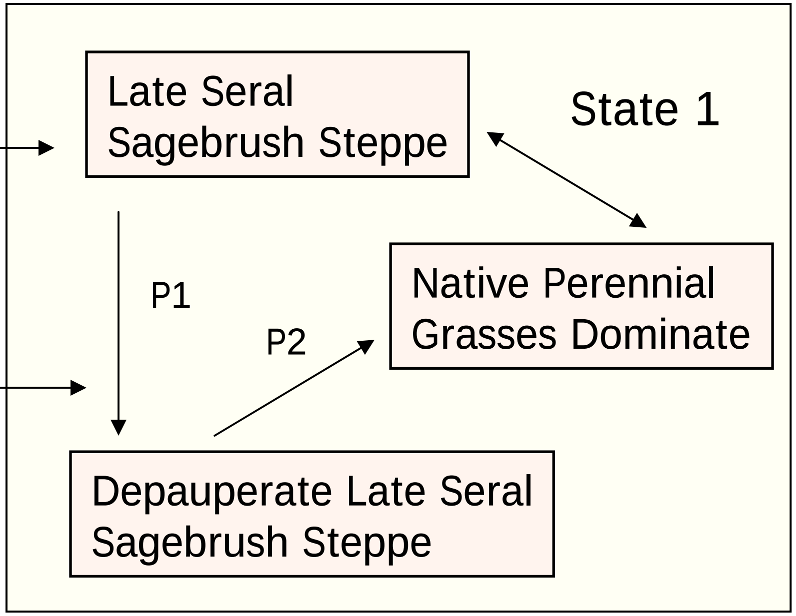
❖ interaction between **soil** and vegetation determines the functional status of the site and inherent resistance to change

STATE

The soil and vegetative components combined produce a sustained equilibrium that is expressed by a specific plant community in its various seral stages

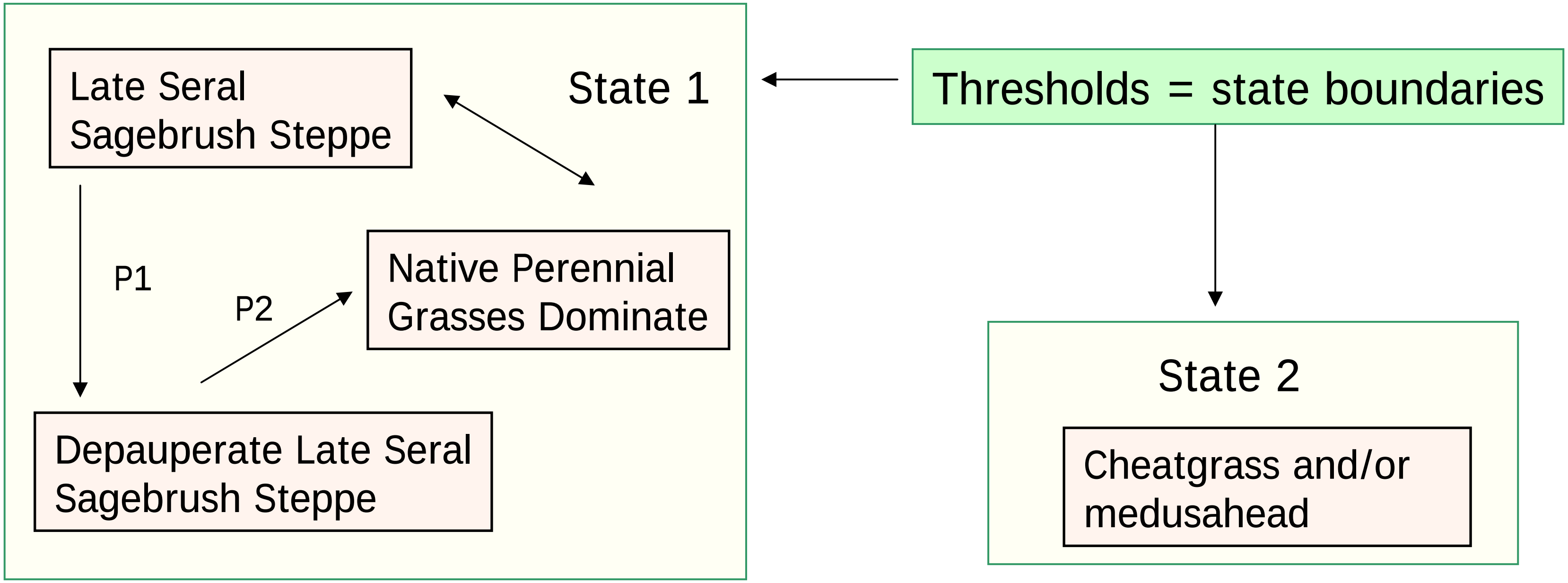
Plant Community Phases = Seral Stages

Plant Community Pathways = dynamics



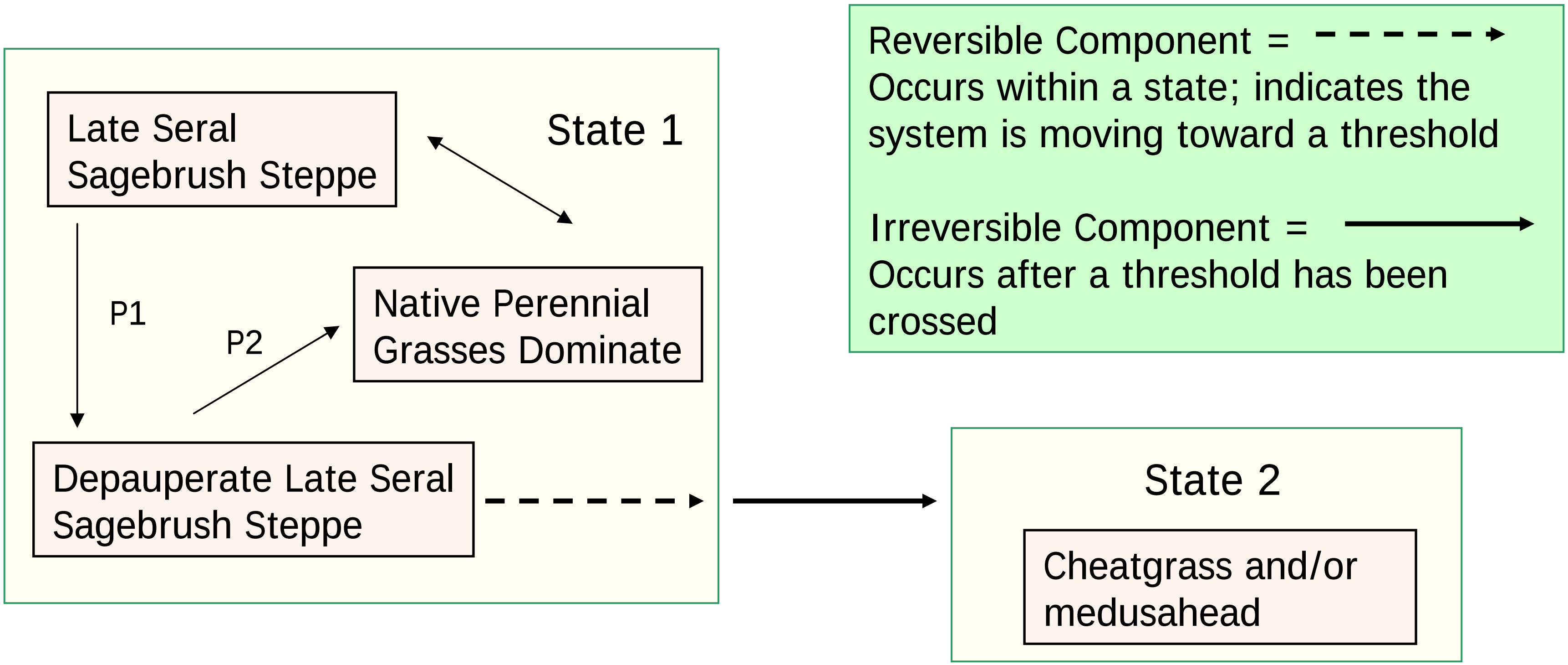
Threshold

Point is space and time between any and all states such that one or more of the primary ecological processes has been irreversibly changed precluding return to the prior state

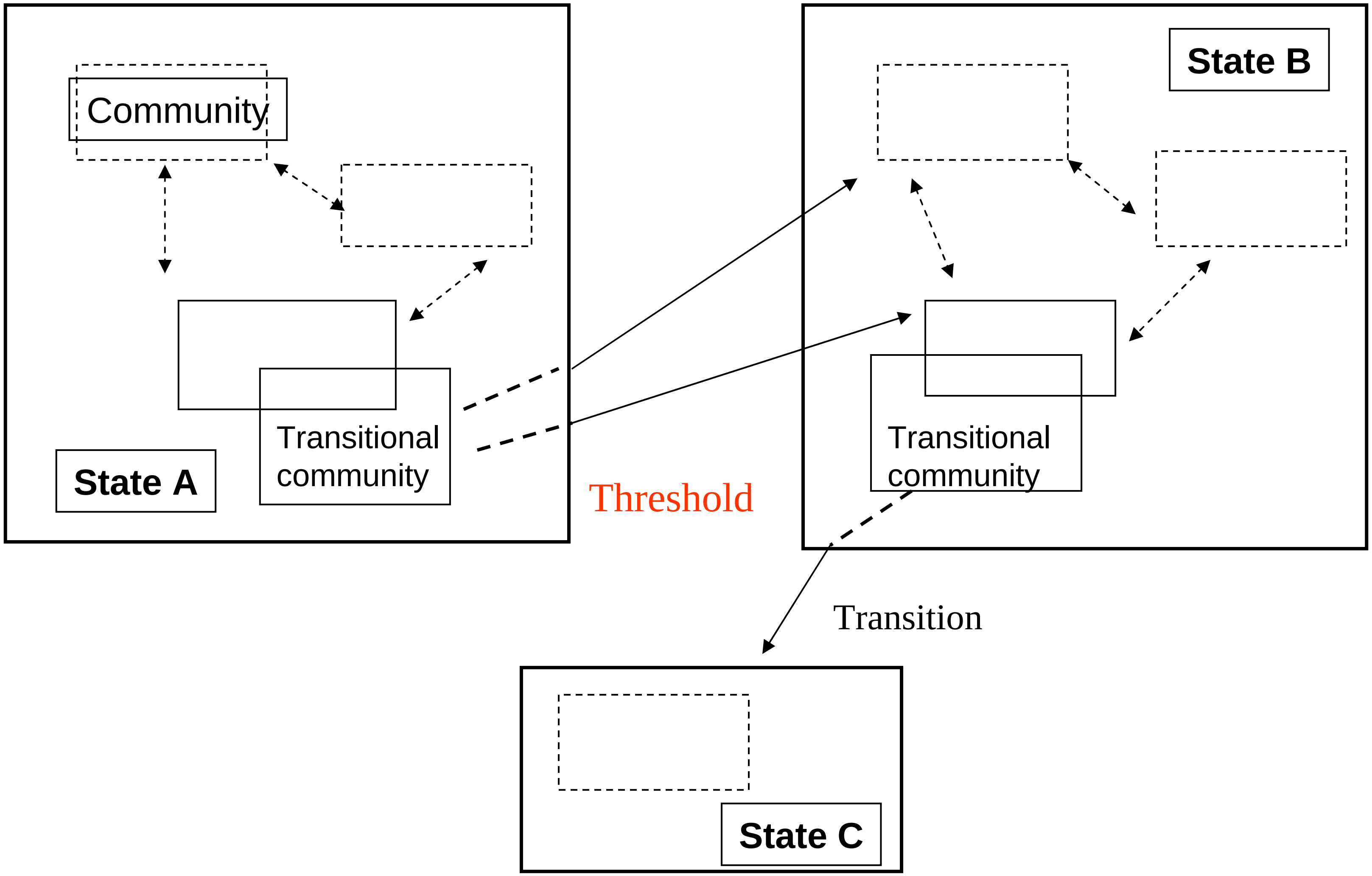


Transitions

A trajectory of system change away from the current stable state that is triggered by natural events, management actions, or both



General state-and transition model format



Revisions - *Proposed*

- *Boundary in space and time between any and all states, or along irreversible transitions, such that one or more of the primary ecological processes has been irreversibly changed and must be actively restored before return to a previous state is possible. Stringham et al. 2003*

- *Thresholds are boundaries in space and time where ecosystem resilience has been exceeded to the point that ecological structure and function are altered beyond the capacity for autogenic repair, resulting in alternative states.*
- *Ecological structure and function must be actively restored before ecosystem resilience of the previous state is recovered or alternative state(s) will persist.*

Revisions - *Proposed*

- A state is a recognizable, resistant and resilient complex of 2 components, the soil base and the vegetation structure that interact to produce a specific suite of plant communities. The vegetation and soil components are connected thru integrated ecological processes that interact to define the range of variability that is expressed by a specific suite of plant community phases.

- *A state is a suite of plant community phases occurring on similar soils that interact with the environment to produce persistent functional and structural attributes associated with a characteristic range of variability maintained thru autogenic repair mechanisms.*

Revisions - *Proposed*

- Resilience focuses on how far a system can be displaced from equilibrium before return to equilibrium is precluded. The emphasis is placed on the persistence of relationships as they affect the systems ability to adapt to change.

- *Ecological resilience is defined as the magnitude of disturbance and/or stress that can be absorbed before the system redefines its structure by changing the variables and processes that control function (Gunderson 2000).*

- ***At-risk community phase is the plant community most vulnerable to exceeding the resilience limits of the state.***