The Adaptive Cycle / Panarchy

Unsuccessful natural resource policies / management programs fail because do not understand:

- Ecological systems are complex, do not deal with uncertainties
- Problems in economic-ecological systems time-dependent
- Role of feedbacks
- Transformations in interacting human/natural systems
- Cross-scale problems

Problems occur when policies/ management programs lead to loss of system resilience

Development of Resilience Theory -

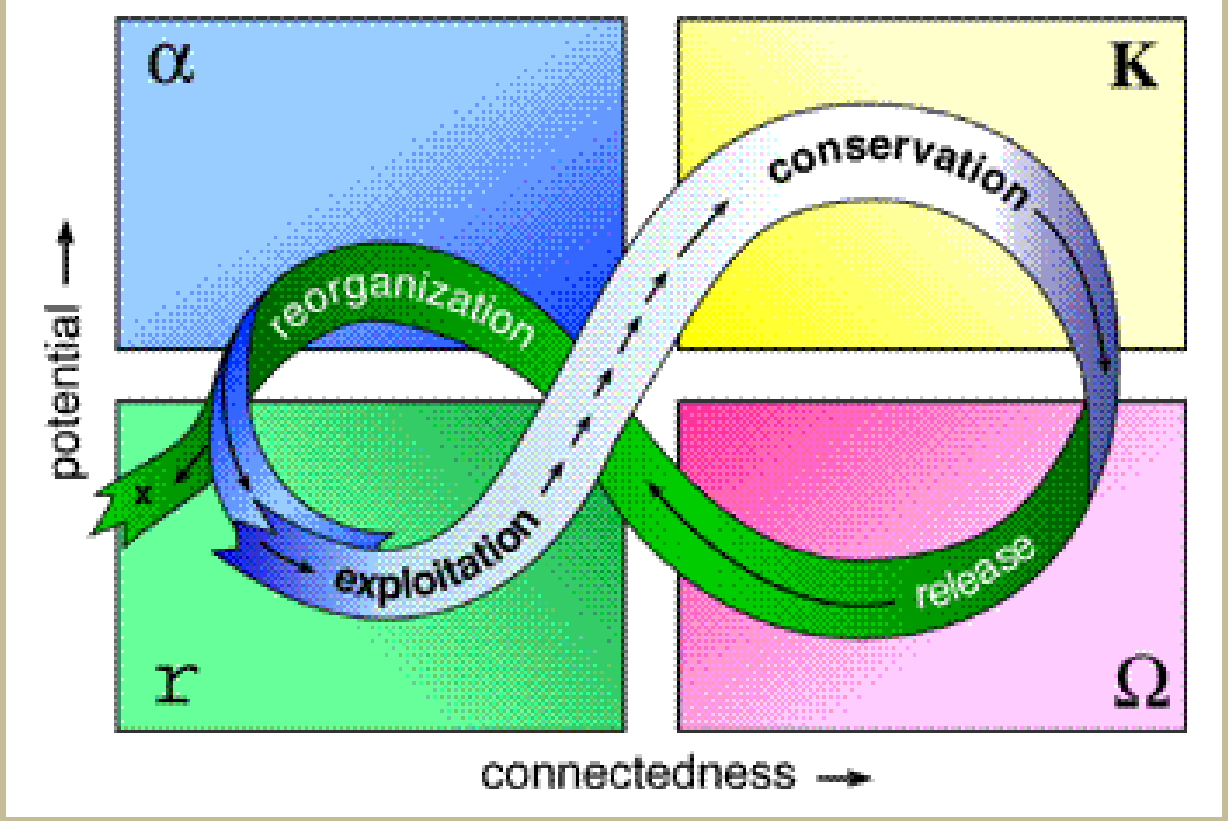
Attempt to understand nature of changes and interactions between human and natural systems

Epistemiological Approach

Patterns of change explained by several heuristic (= teaching, learning) devices:

- **Adaptive cycle**
- **Panarchy**
- **Resilience**
- **Adaptability**
- **Transformability**

The Adaptive Cycle



Four phases:

r = early successional system

k = late successional system

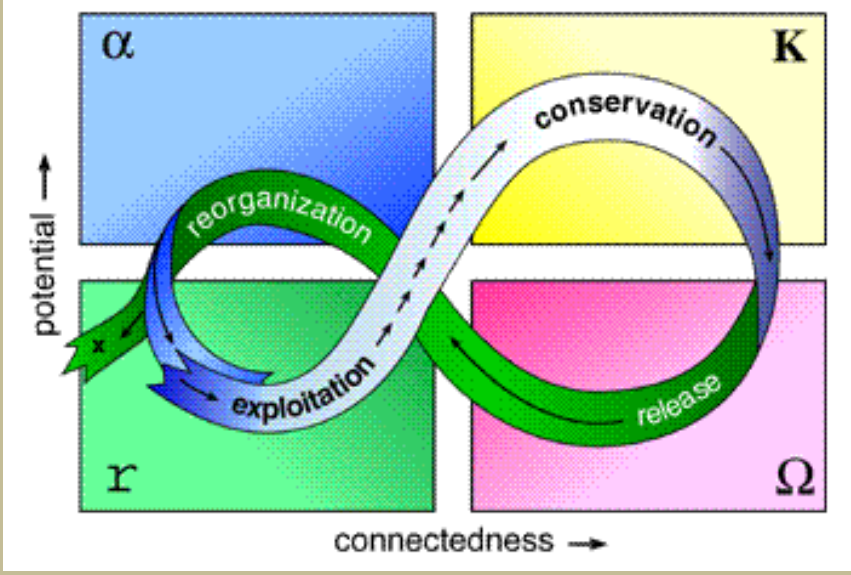
Ω = system during a large, intense disturbance

α = system after disturbance but before becomes stable

Adaptive Cycle

- **Heuristic model to understand change in complex systems**

- **Used to identify:**
  - **- structure**
  - **- patterns**
  - **- causality**



Gunderson and Holling, 2002

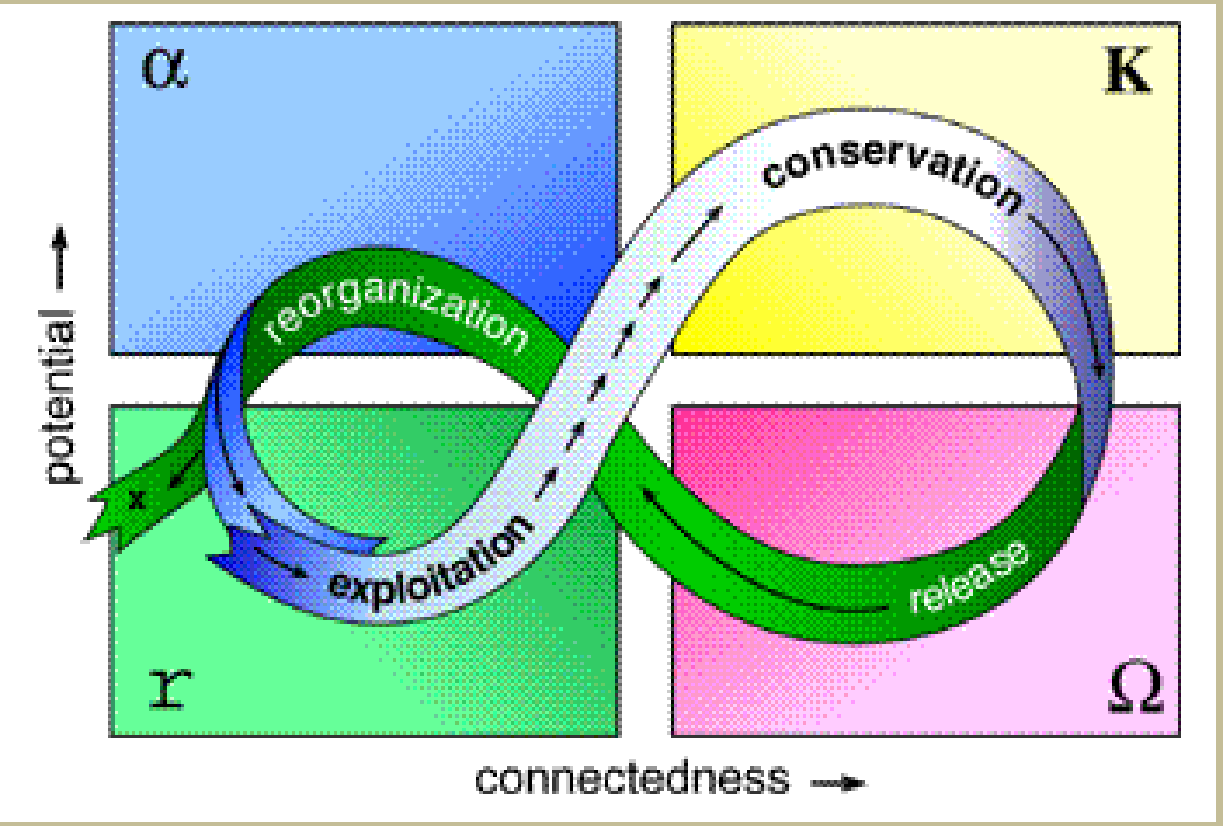
in the complex adaptive system studied

Adaptive Cycle

In ecosystem management cases – appear to be 3 properties that influence future responses of ecosystems, agencies and people:

1. Amount of potential for change – determines range of possible future options
2. Degree of connectedness between variables and processes:
   - how sensitive to external factors
   - how much does system control own destiny
3. Resilience – how vulnerable is system to disturbances

Four Phases of Adaptive Cycle



k – conservation:

- slow accumulation
- slower growth
- higher competitive ability
- bureaucratic

r – exploitation:

- rapid colonization
- rapid growth
- high dispersal ability
- entreprenurial market

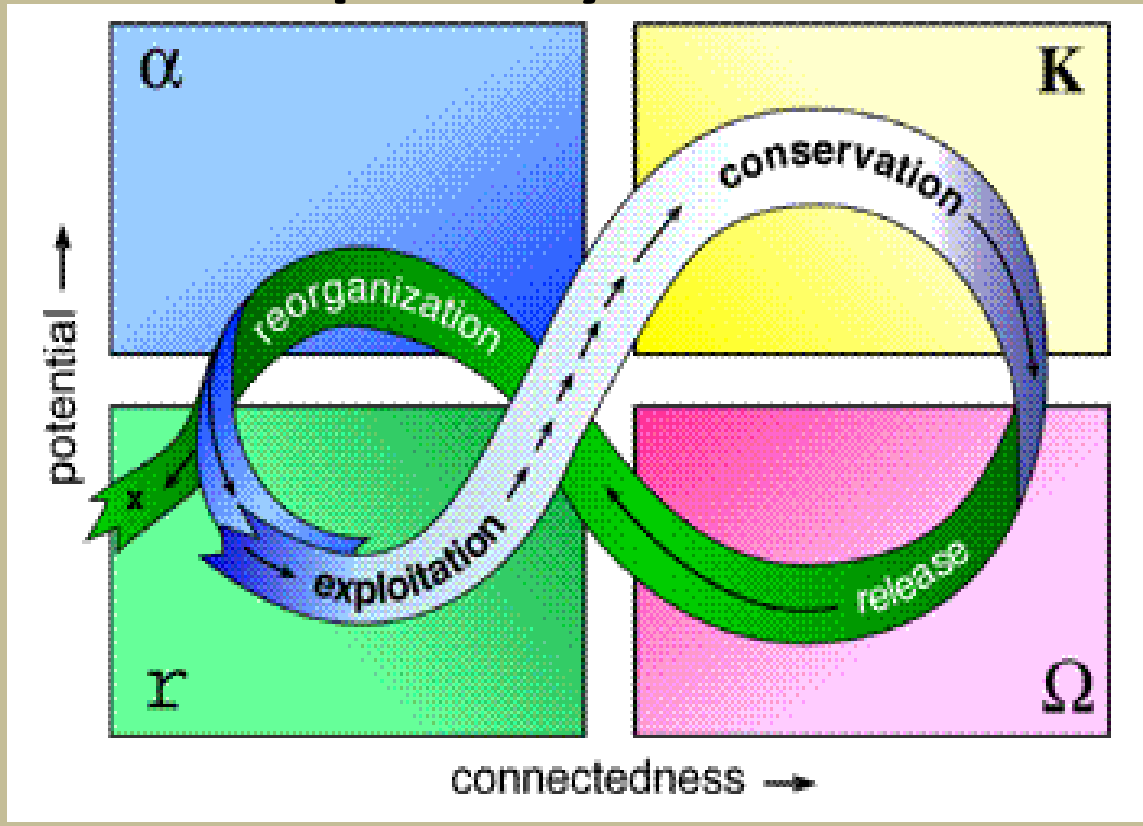
r to k phases called the fore loop

Represents succession in ecosystems; development mode in organizations

Four Phases of Adaptive Cycle

α – reorganization:

- reduced resource loss
- more available for use
- pioneer species colonize
- ecosystem reorganizes
- innovation / restructuring
  - in industry

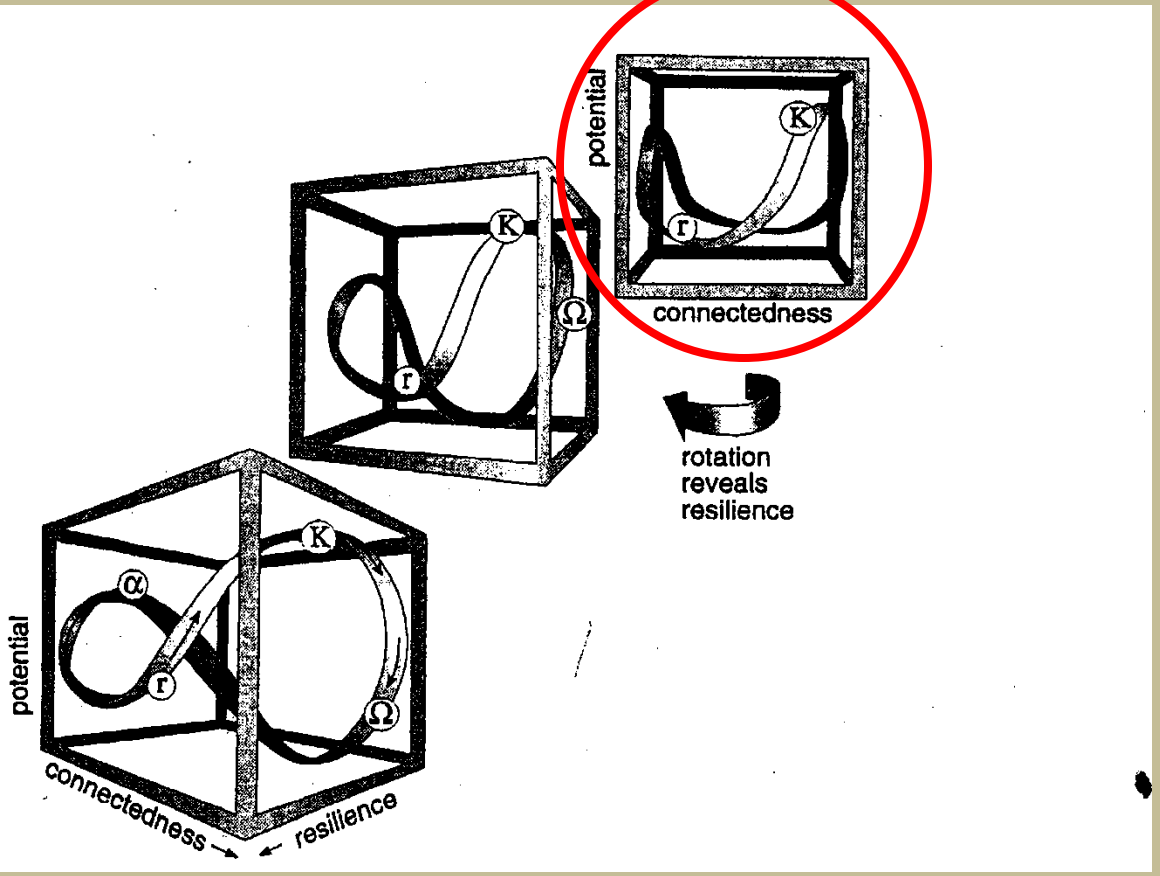


Ω – creative destruction / release:

- have over connected system
- sudden release of material due
  - to disturbance
- released material becomes available
- increased loss of resources

Ω to α phases called the back loop

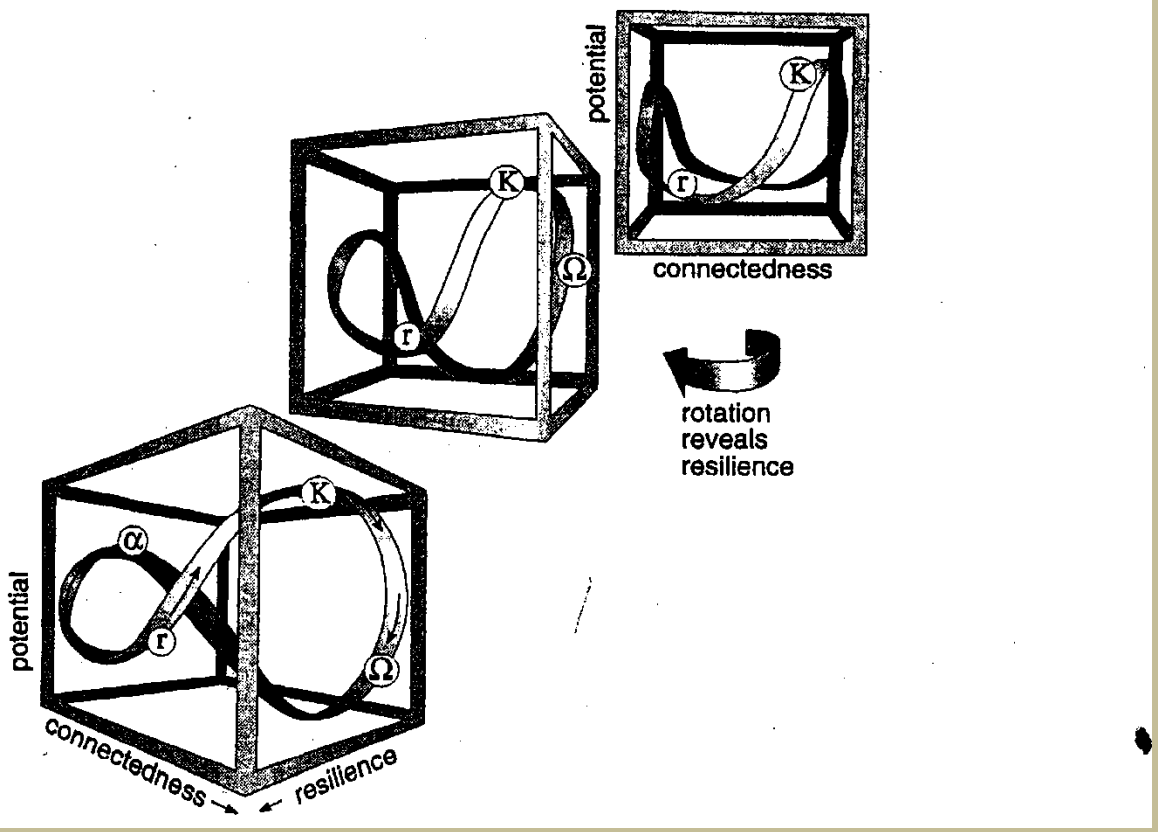
Potential and Connectedness Dimensions



Start of cycle – r ⟶ k:

- increased resource accumulation / sequestration
- increased connectivity and stability
- decreasing diversity (dominated by highly competitive species)

As near k end, resources tightly bound – not available but represent increased potential



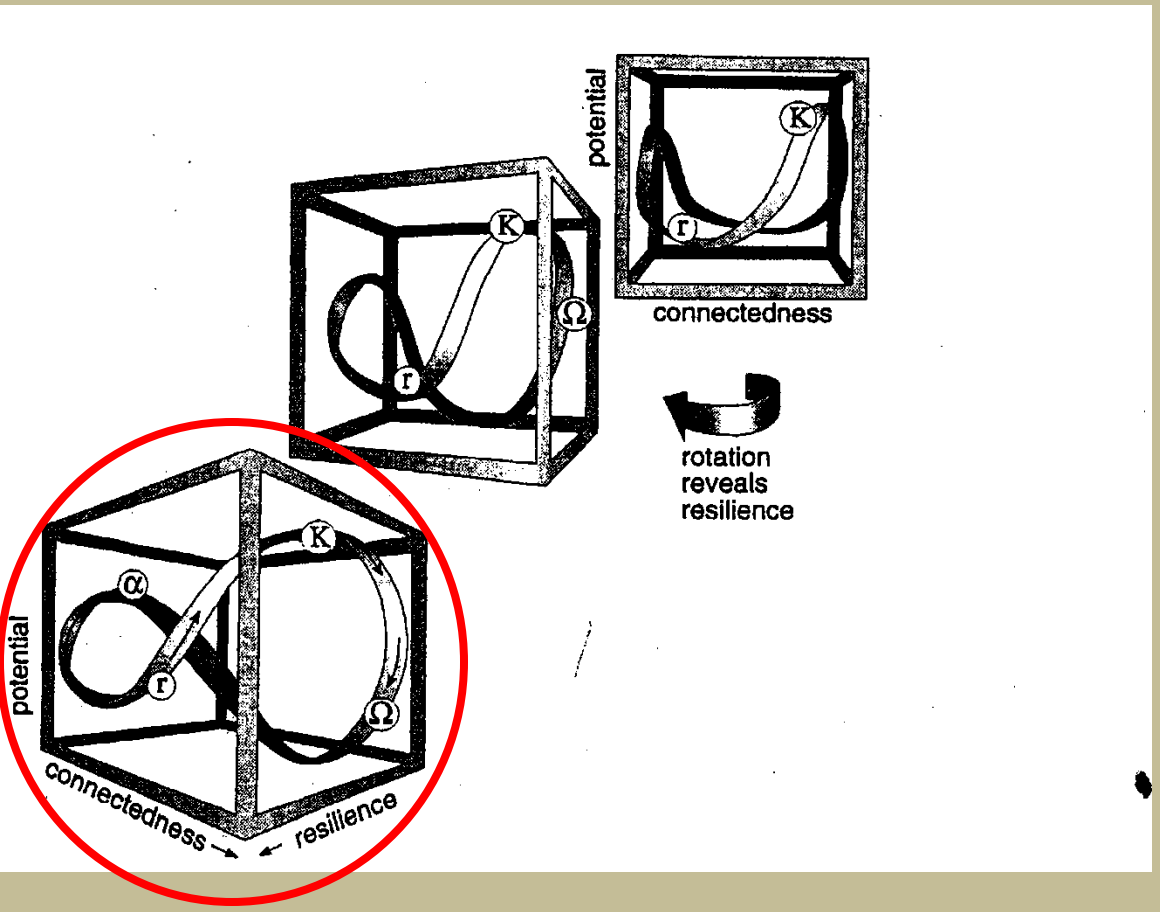
k ⟶ Ω

Disturbance - rapid release of resources
- lose tight, connected organization
- large loss of resources (loss of potential)

Ω ⟶ α - period of rapid reorganization – can have new combinations (alternate systems) – increased potential but low connectivity

α ⟶ r - lower potential – loss of resources / pioneer species colonize and sequester resources
- who gets there first (initial conditions) determines how system develops

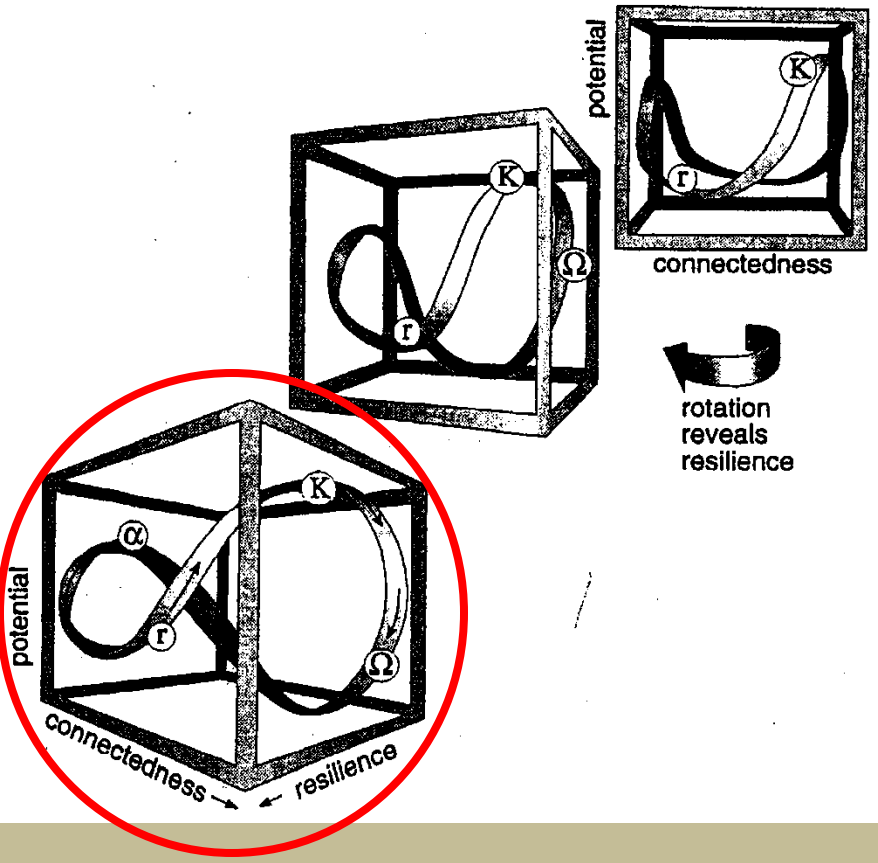
Third Dimension - Resilience



Increases and decreases
- is dynamic factor
- context-dependent

r phase:
- high resilience
- species with high adaptability

r → k: potential and connectedness increase but resilience decreases
- system more stable, efficient and predictable
- but more specialized entities more vulnerable to disturbance

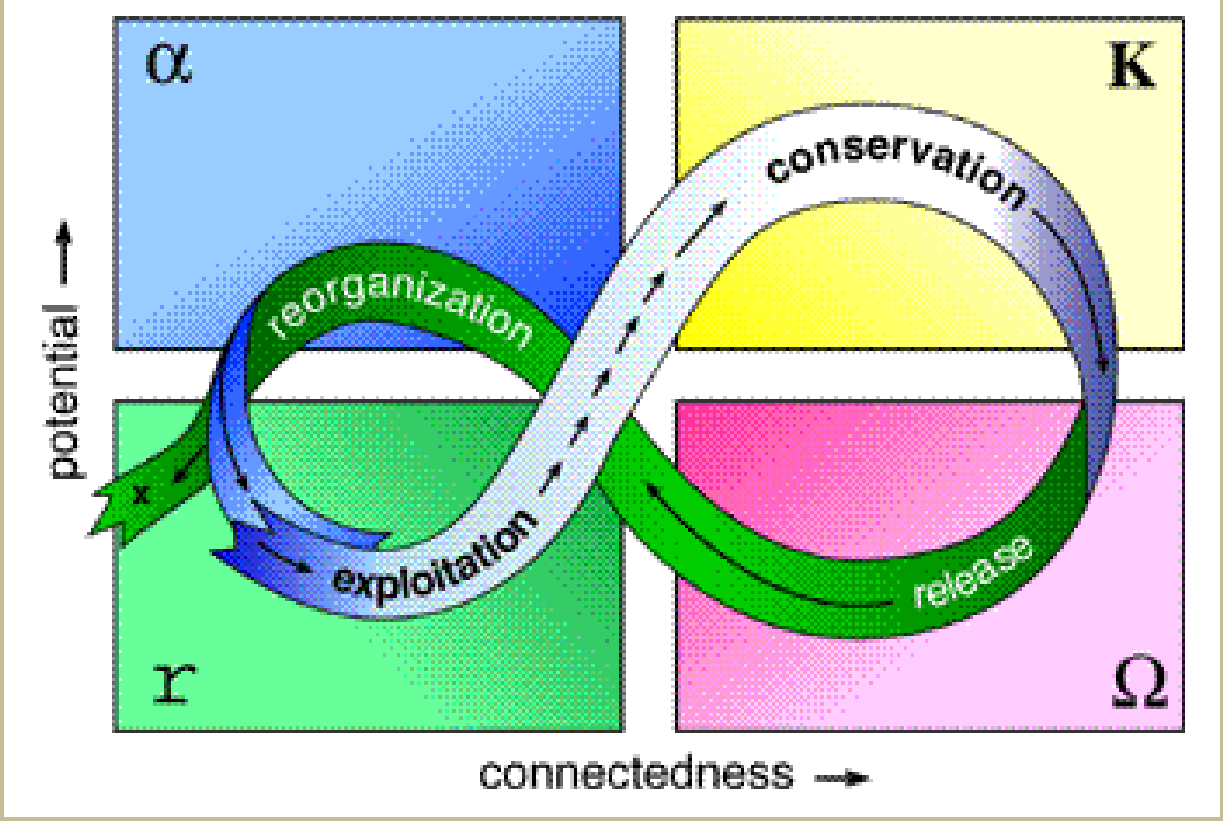


k ⟶ Ω:

- rigid systems collapse
- strong destabilizing positive feedback
- as resources released, more structure destroyed….
- end with low potential and low resilience

α phase: have low connectivity, high potential and higher resilience

- low connectivity allows for experimentation of different structures – has low cost to system
- have potential remaining from past cycle – legacy
- legacy + new entrants (pioneer species) can form new structures – alternative state



Cycle has 2 objectives:

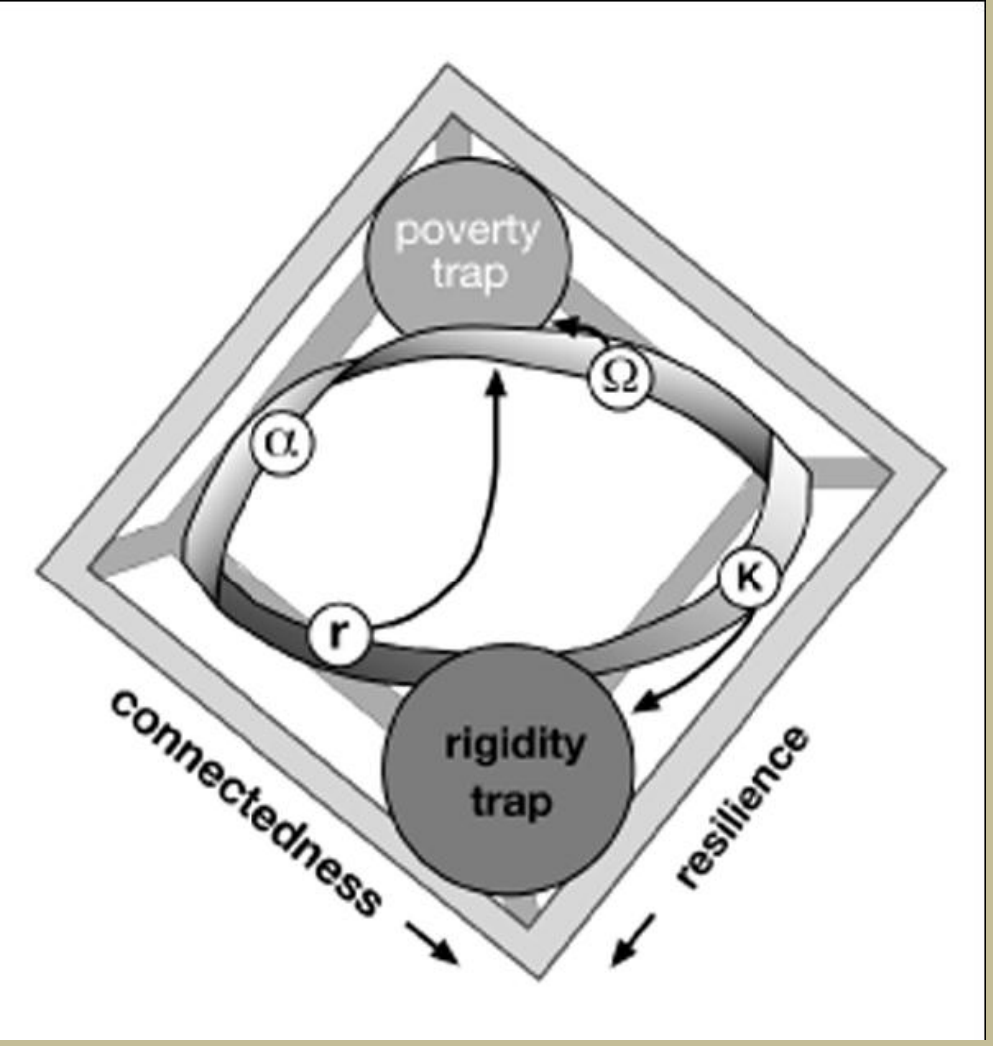
1. **maximize growth and stability (r, k)**
2. **maximize change and variety (Ω, α)**

Objectives cannot be maximized at same time – occur sequentially
- success of one leads to the other

The level of each of the three variables that characterize the four phases of the adaptive cycle

Phase	Potential	Connectedness	Resilience
α Reorganization	**high**	**low**	**high**
K Conservation	**high**	**high**	**low**
r Exploitation	**low**	**low**	**high**
Ω Release	**low**	**high**	**low**

Are 8 possible combinations of 3 properties – only 4 shown



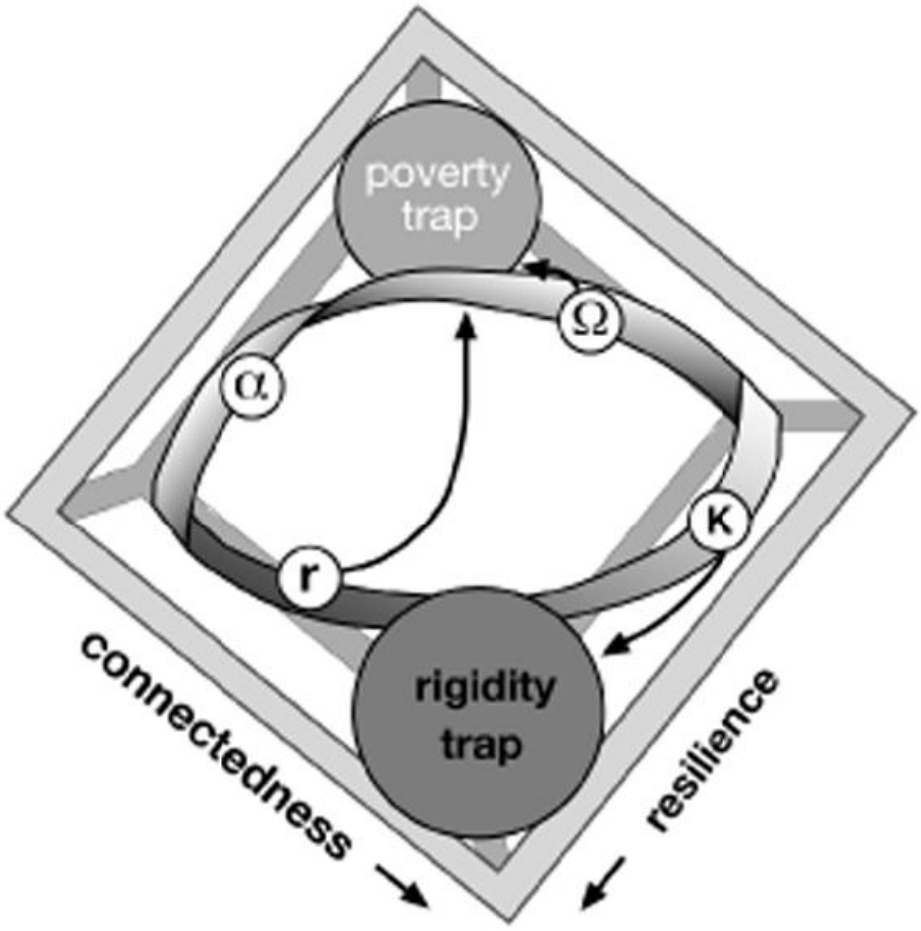
Two other, implied combinations:

Poverty Trap
Rigidity Trap

Poverty Trap:
- **all 3 properties have low values**
- **have impoverished system**

Numerous examples:
- **systems commonly in state of crisis**
- **disintegration of societies**

Examples: **overfishing of Peruvian anchovies**
increased irrigation in semi-arid / arid habitats (Sumer)



Rigidity Trap:

- people and their institutions highly connected, rigid and inflexible

- common in bureaucratic systems

- high connectedness and resiliency; low potential

Example: resource management for commodities
aim to reduce natural variation for economic reasons
Hindu caste system

Panarchy

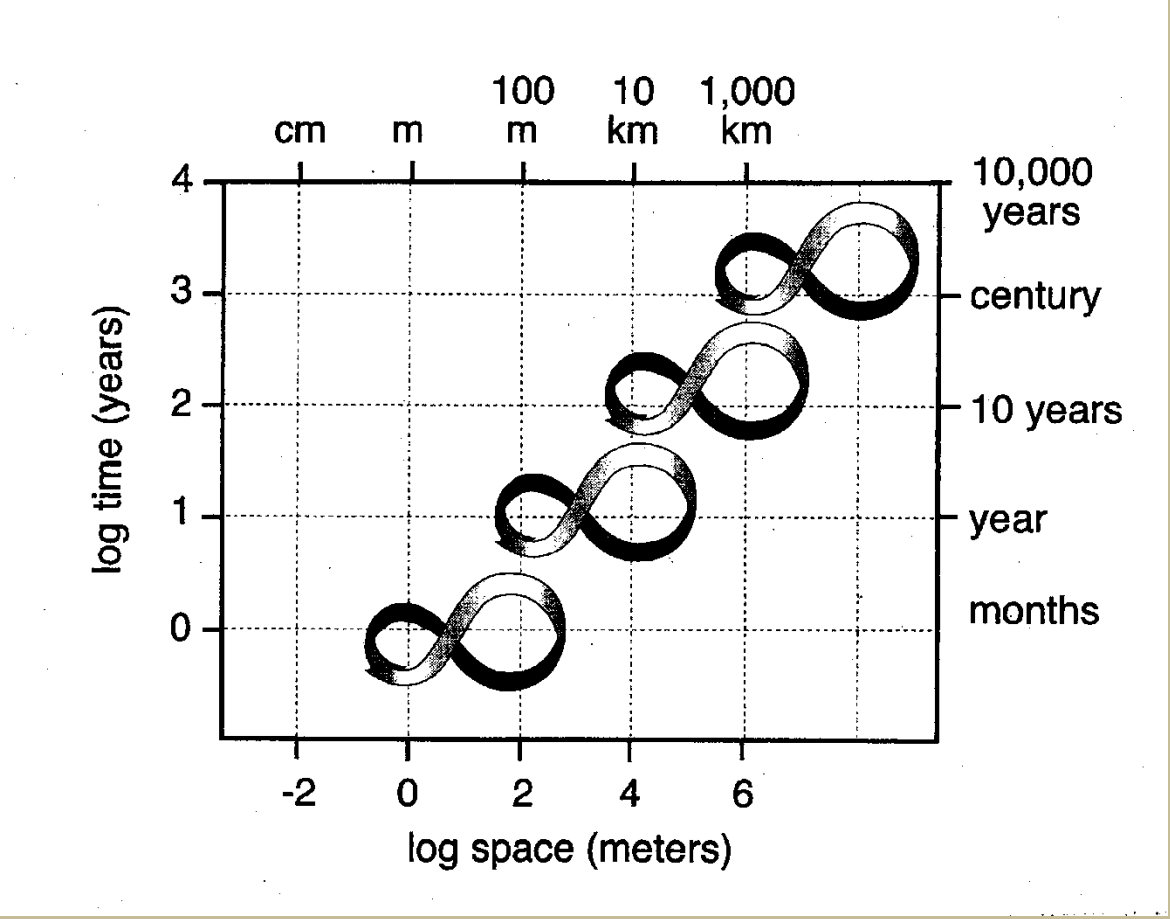
- **Definition: a hierarchical structure in which natural and human systems interact in never ending cycles of growth, accumulation, restructuring and renewal**

- **Cycles occur as nested sets across scales**

- **Combines hierarchy theory with concept of adaptive cycles**

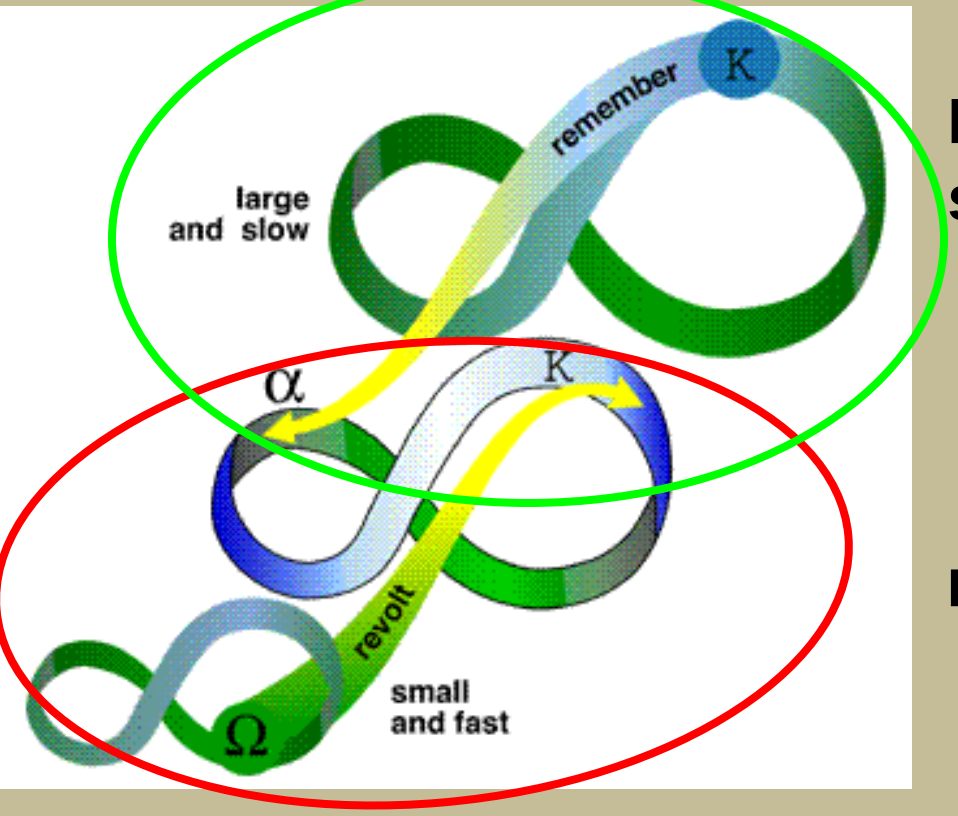
Panarchy – mix of hierarchy and adaptive cycle

Have adaptive cycles at each level of a hierarchy



Transforms hierarchies to dynamic, adaptive entities

Levels sensitive to disturbances during α and Ω phases



Events in upper levels affect smaller, faster levels

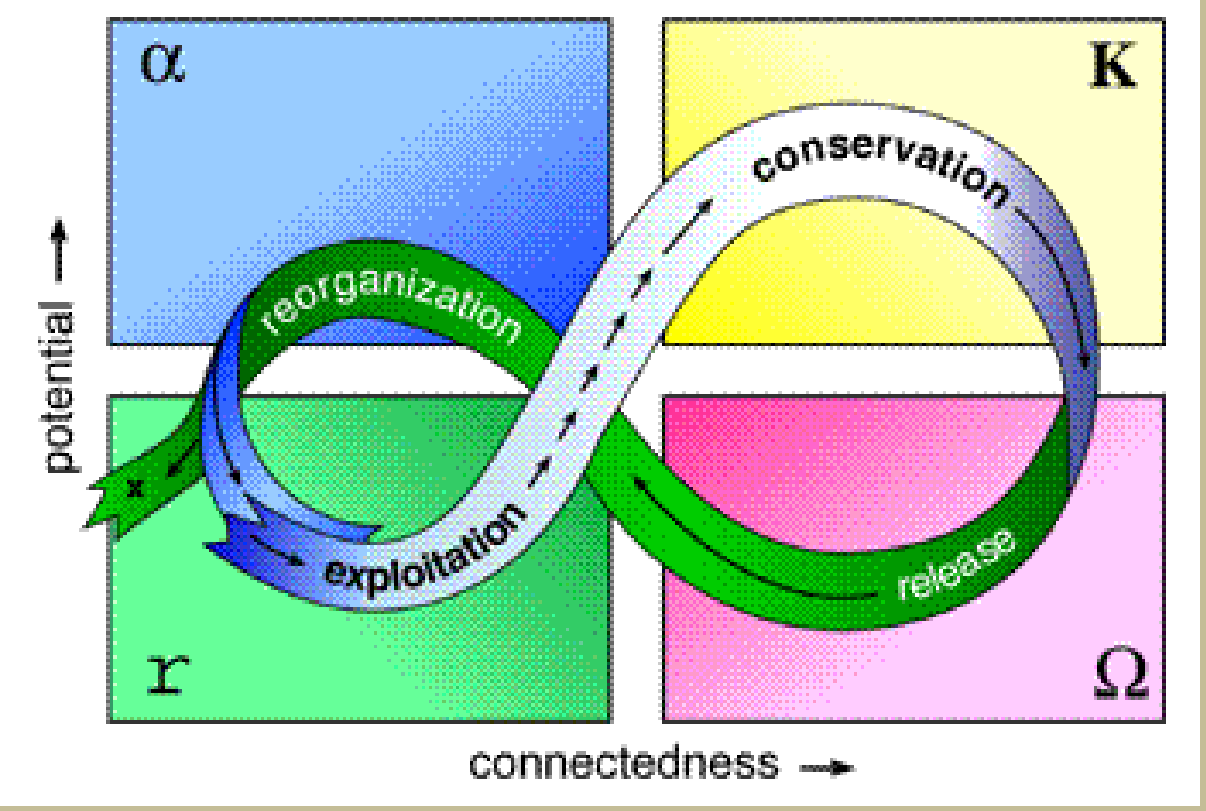
- lower level in α phase
- renewal opportunity greatly organized by k phase of upper level

EXAMPLE: re-vegetation following fire

Lower level cycle enters Ω phase:

- collapse may cascade up to next level – causes crisis
- more likely if higher level in k phase (low resilience)
- lower level collapse is disturbance on upper level

EXAMPLES: forest fires / spruce bud worm outbreaks



Some human institutions / societies show same sequences

BUT – 3 human factors may lead to increased potential of panarchy:

- **foresight**
- **communication**
- **technology**

Adaptive cycle:

Developed from observations of ecological systems
- many show the properties of the 4 phases

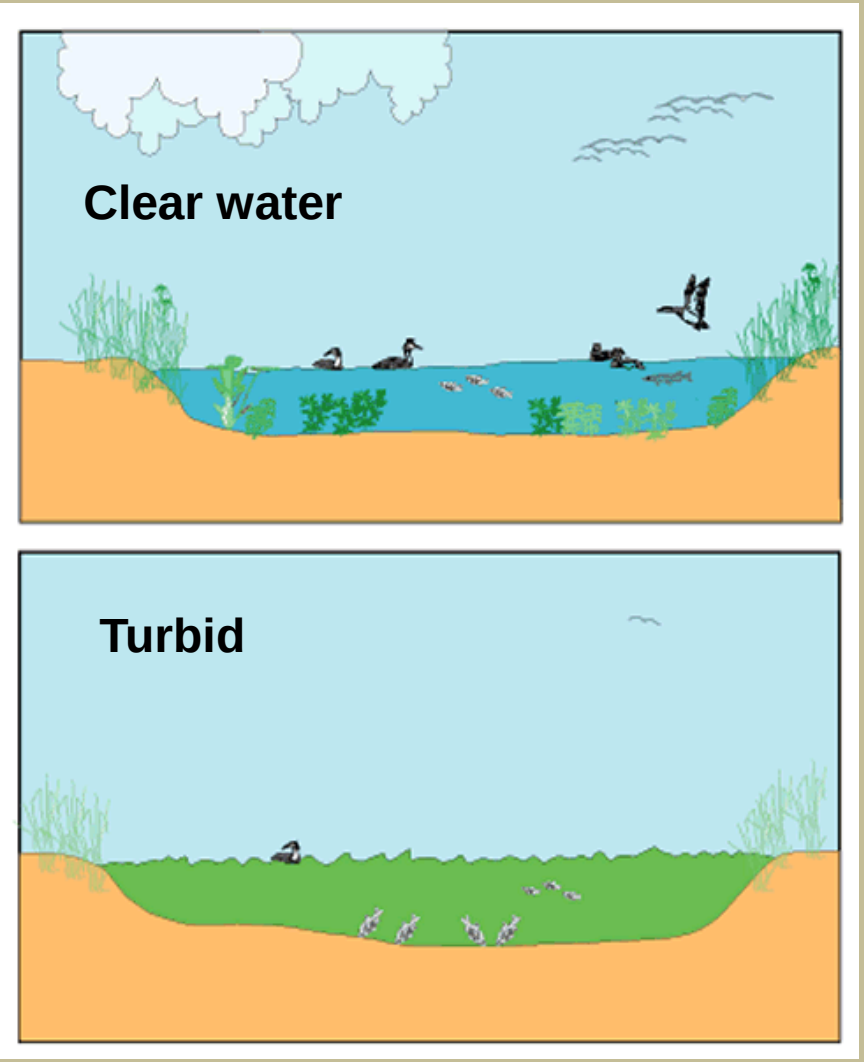
But what of human systems?

Example – Lake Mendota, WI

- **Two alternate states:**

  1. **Clear water phase**
  2. **Turbid phase**

- **Management aim – maintain resilience of clear water phase but decrease resilience of turbid phase**

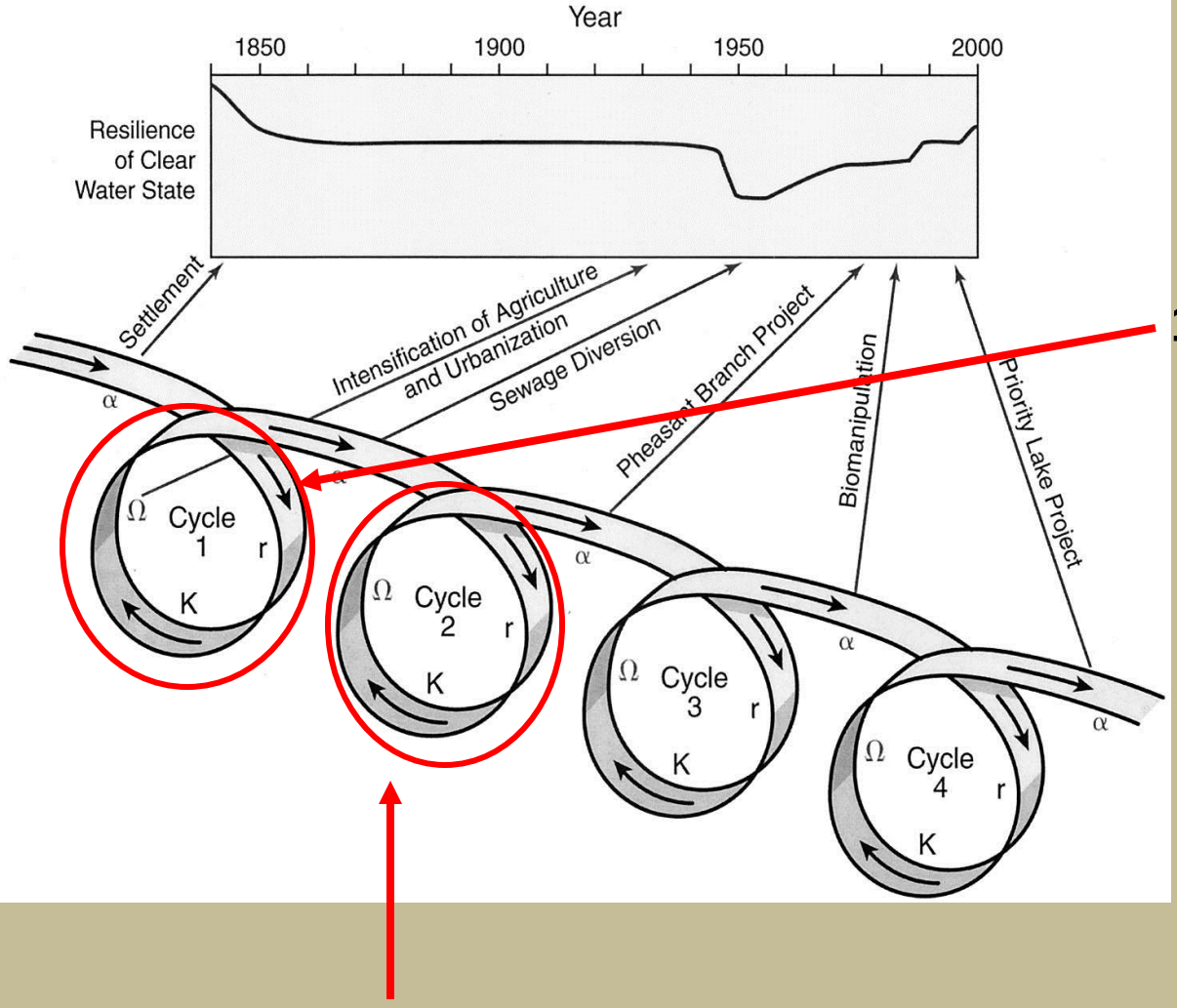


- **Found P most important nutrient in lake eutrophication:**

P added as fertilizer to farm fields

Excess P accumulates in soil and / or leaks to streams and lakes

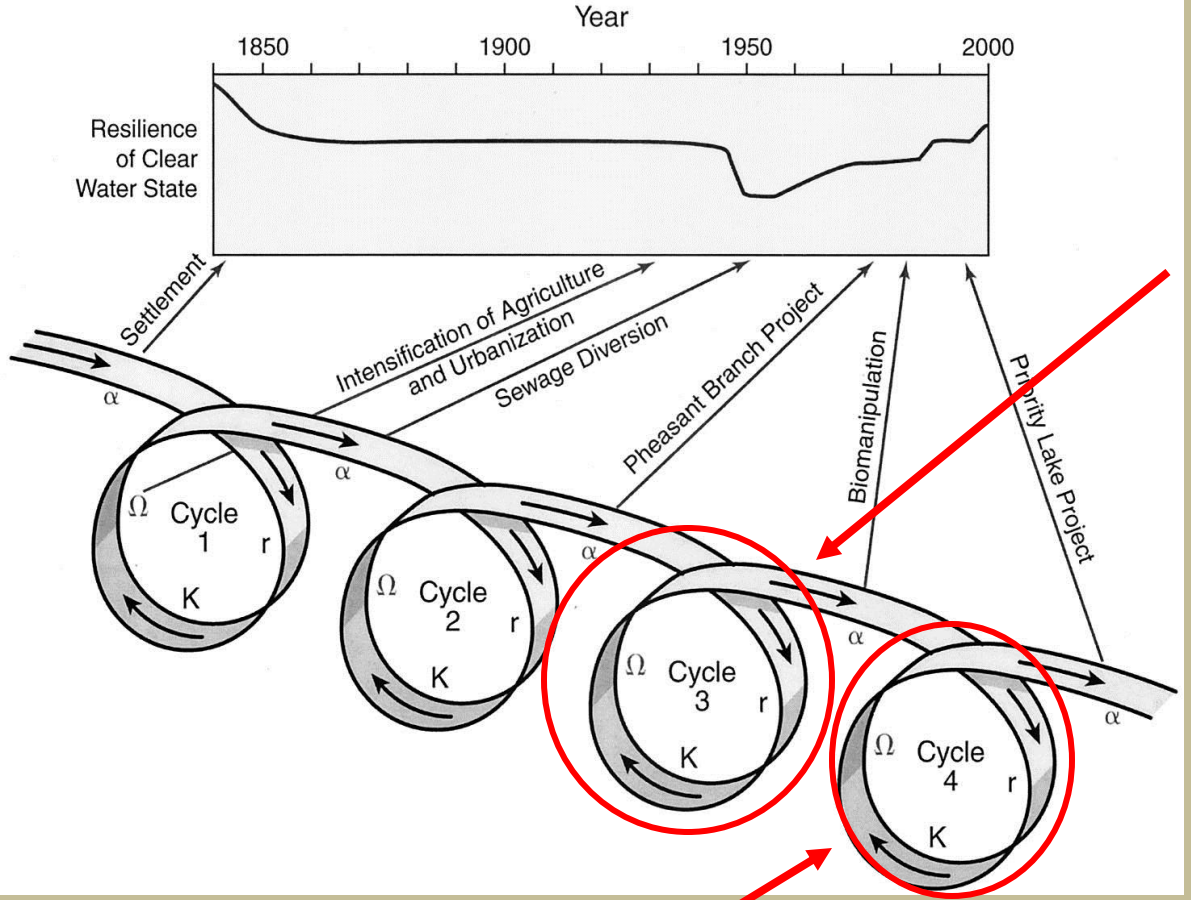
Soil P – important variable – because is slow changing variable



Management History

1. **Area settled – 1840**
   Agriculture disrupts soil
   1940s – intensive agriculture
   Increased nutrient additions – collapse of water quality

2. **New sewage system – stop sewage flowing into lake**
   Little change – sewage P replaced by increased fertilizer use
   Increased farm P runoff – increased soil P around lake
   Invasion of non-native fish and plants – lower water quality



3. Plan to stop farm P runoff
Farmers uncooperative
- no financial incentive

4. Biomanipulation of lake food web
Add piscivorous fish – eat invasive planktivorous fish
Worked until increased fishing pressure decreased piscivorous fish
Heavy rains – high erosion – large inputs of P from surrounding lands

What Use the Adaptive Cycle?

- **Useful as heuristic tool**
  - **Teach non-experts how nature works**
  - **Show how different policies / actions may affect natural systems**
- **Good for describing past changes**
- **BUT – how useful for making predictions (is it like economics?)**