Strategies in Ecological Systems
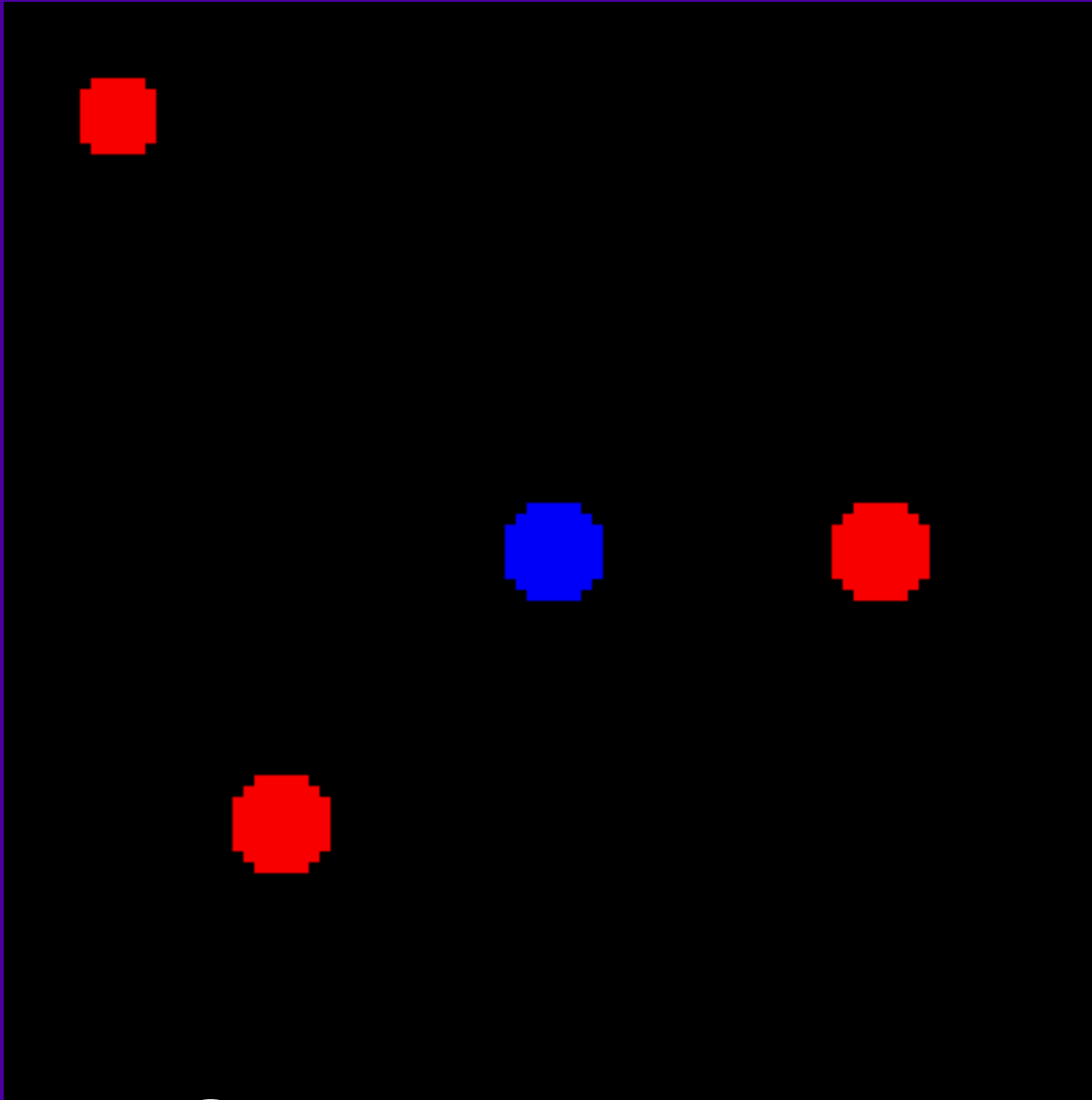
Norman L. Johnson
Norman@SantaFe.edu
http://CollectiveScience.com

Jen Watkins
jhw@LANL.GOV
http://public.lanl.gov/jhw

Ant Consumer Model

Collective information
Pheromones with
evaporation & diffusion
Ant/Agent internal state
Current direction
Have food?
Three rules of action
Carry food to nest
Drop food and turn
Search for food

■ **Productive collective**
■ **"Salaried men"**
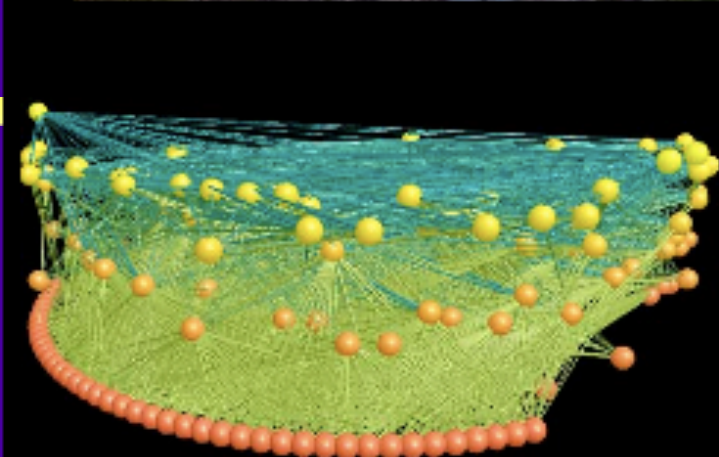■ **Individual/Innovator**
■ **Collective structure**

● **Nest**   ● **Food supply**

Competitive Strategies in Changing Environments

Lake

Grassland

Desert

Dunne, SFI
foodwebs.org

Lauren Buckley
Santa Fe Institute
August 2007
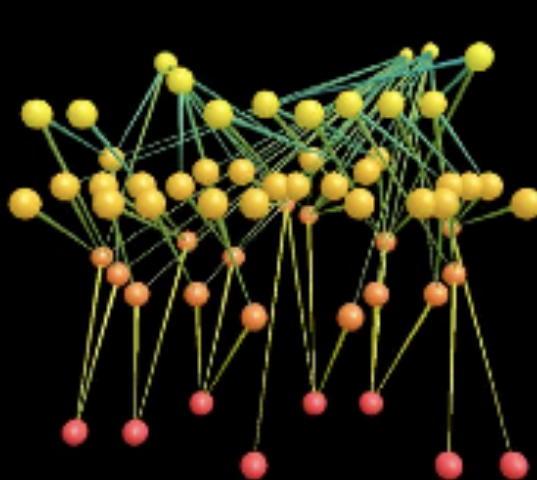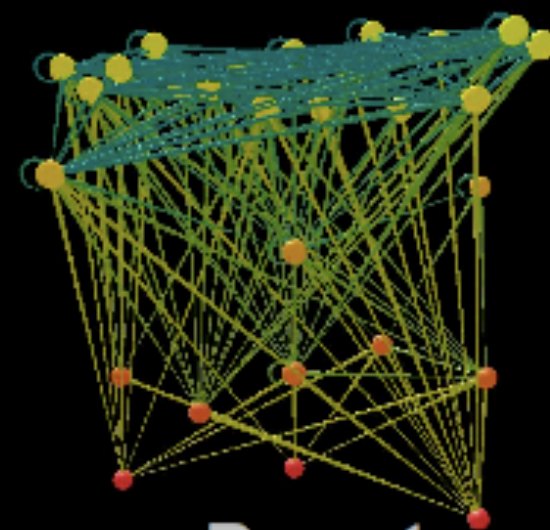
- **Mass communication**
  - Greater and tighter coupling between different "ecosystems"
- Speeding up of processes
  - Change happens faster and faster

Buckley: Competitive Strategies in ecosystems

Finding a competitive strategy

Paradox of the plankton

(Hutchinson 1961)

Buckley: Competitive Strategies in ecosystems

Context matters

medium ground finch

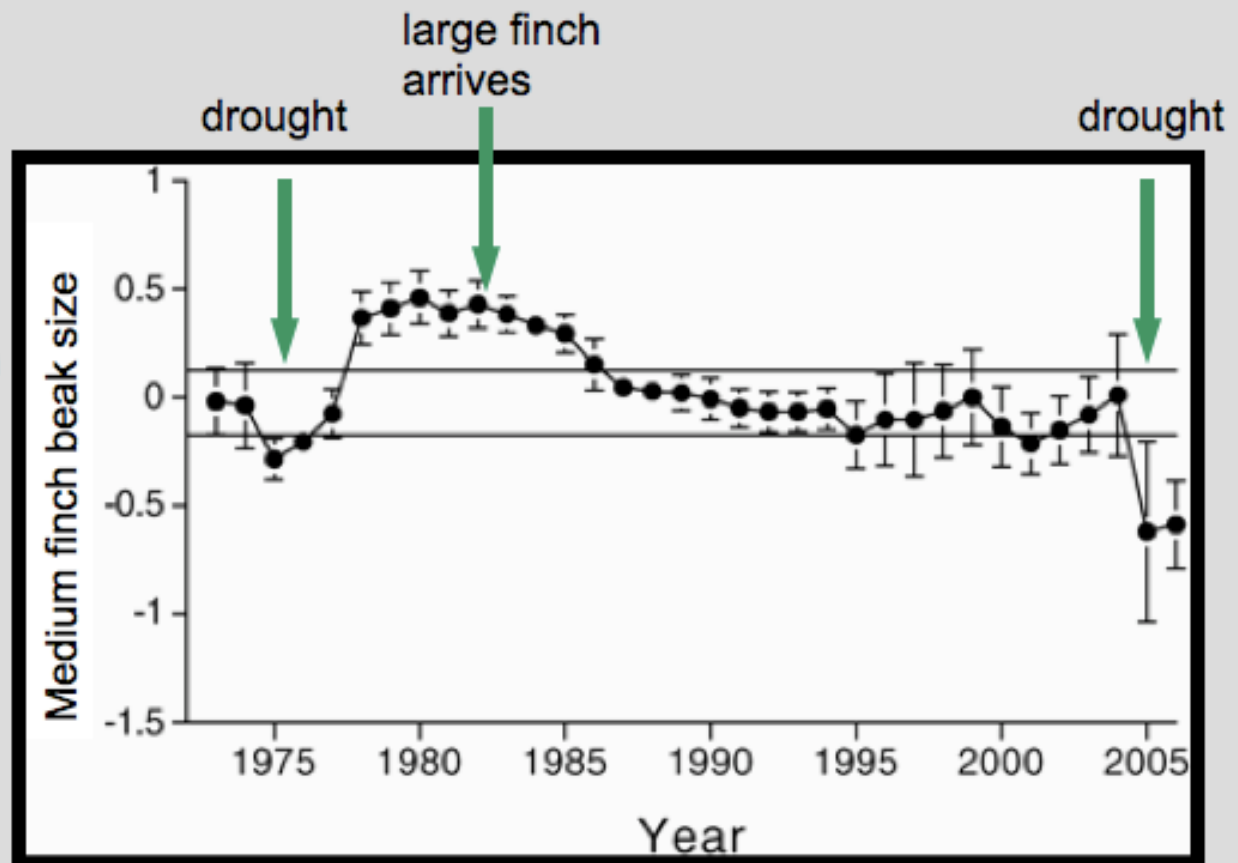large ground finch

Galapagos finches
(Grant & Grant 2006)

Buckley: Competitive Strategies in ecosystems

Adapting strategies through time

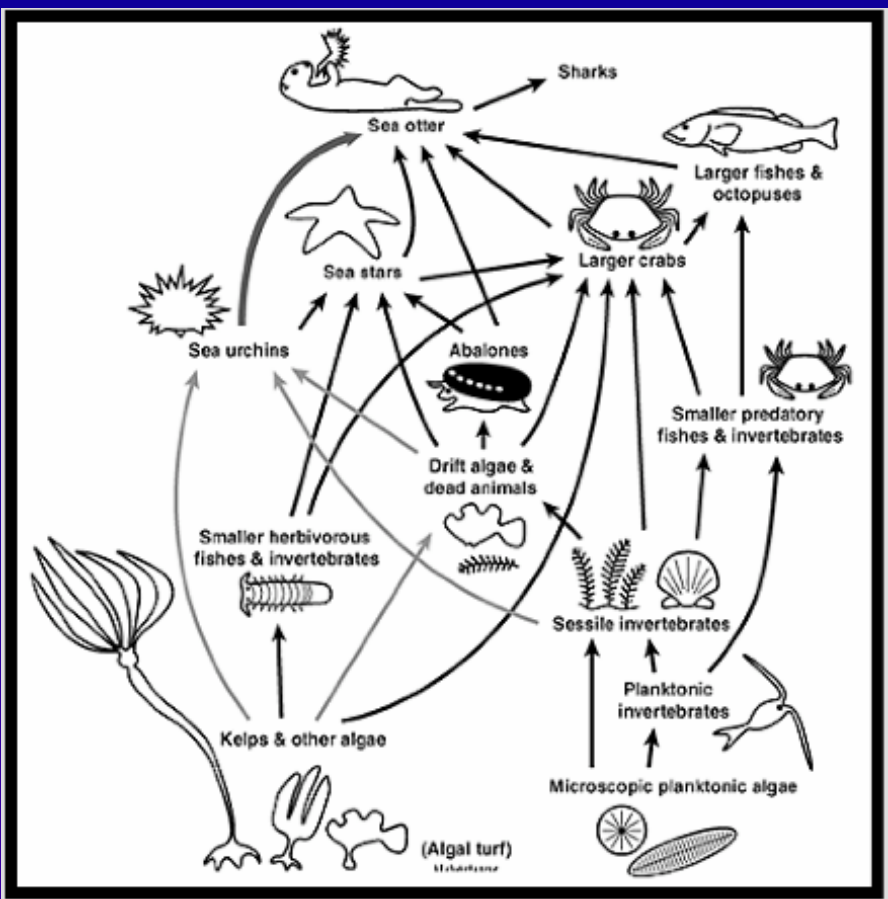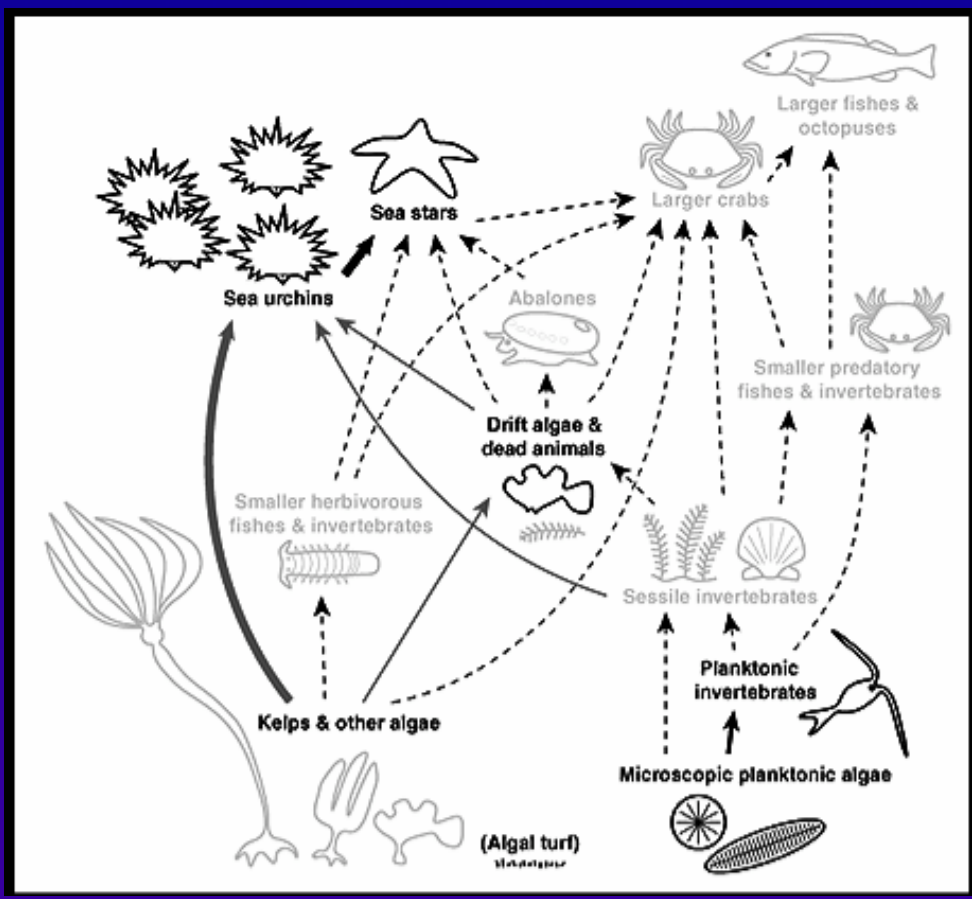Competition - colonization tradeoff

colonize ——————————→ compete

Buckley: Competitive Strategies in ecosystems

Before

After no otters

Buckley: Competitive Strategies in ecosystems

Intermediate disturbance principle

(Connell 1978)
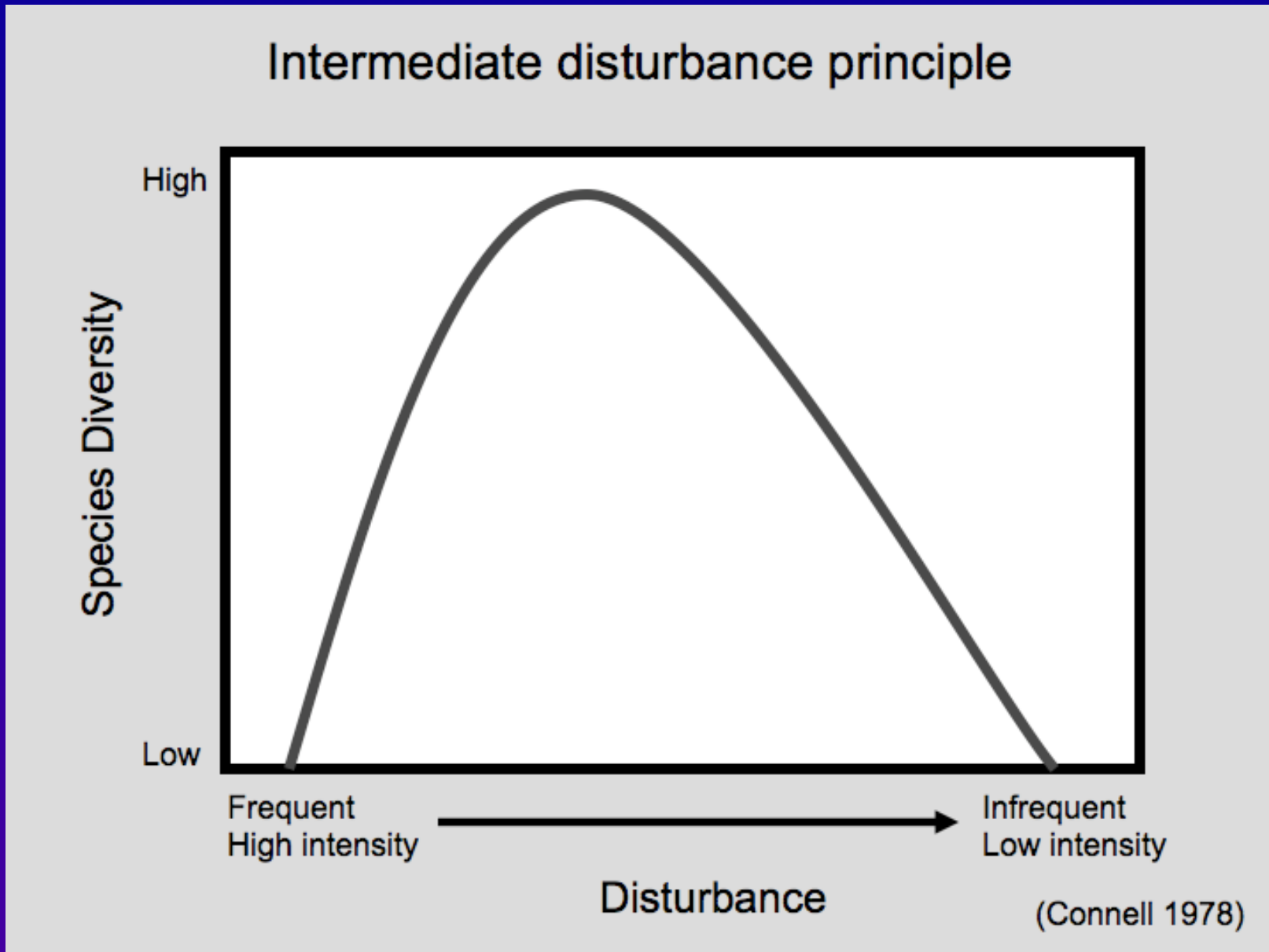
Buckley: Competitive Strategies in ecosystems

Competitive strategies in changing environments

Diverse strategies provide

resistance
resilience

Buckley: Competitive Strategies in ecosystems

Ecosystems are complex and difficult to anticipate

Optimal competitive strategy depends on context

- Early in "development", important to out reproduce (not about fitness alone)

- Later in development, few offspring of high fitness best

Diversity (including strategies) contributes to resilience

Intermediate divergence principle

- Diversity peaks at moderate disturbances

- Diversity also increased in long established species

- Australian aboriginals have the greatest diversity

Buckley: Questions and Observations

What about diseases within ecosystems? (host-pathogen)

What is the right amount of disturbance?

Do you use agent-based models?

What's the means for creating disturbances?

What are the different strategies?

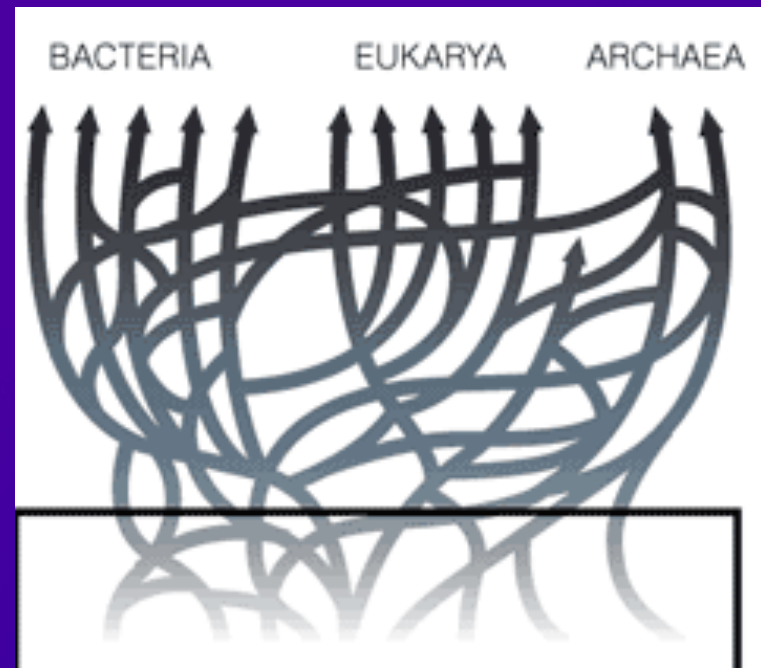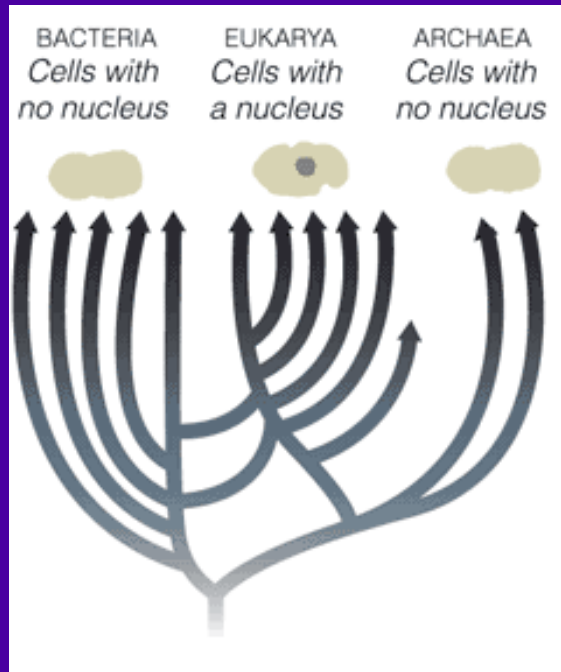- Ultimately: create more strategies for resilience

How can we know we have sufficient diversity?

- Follow up from Michael's diversity talk

Do you use scenarios in your research?

Observe: Professionalism is systematic way to reduce diversity and survivability

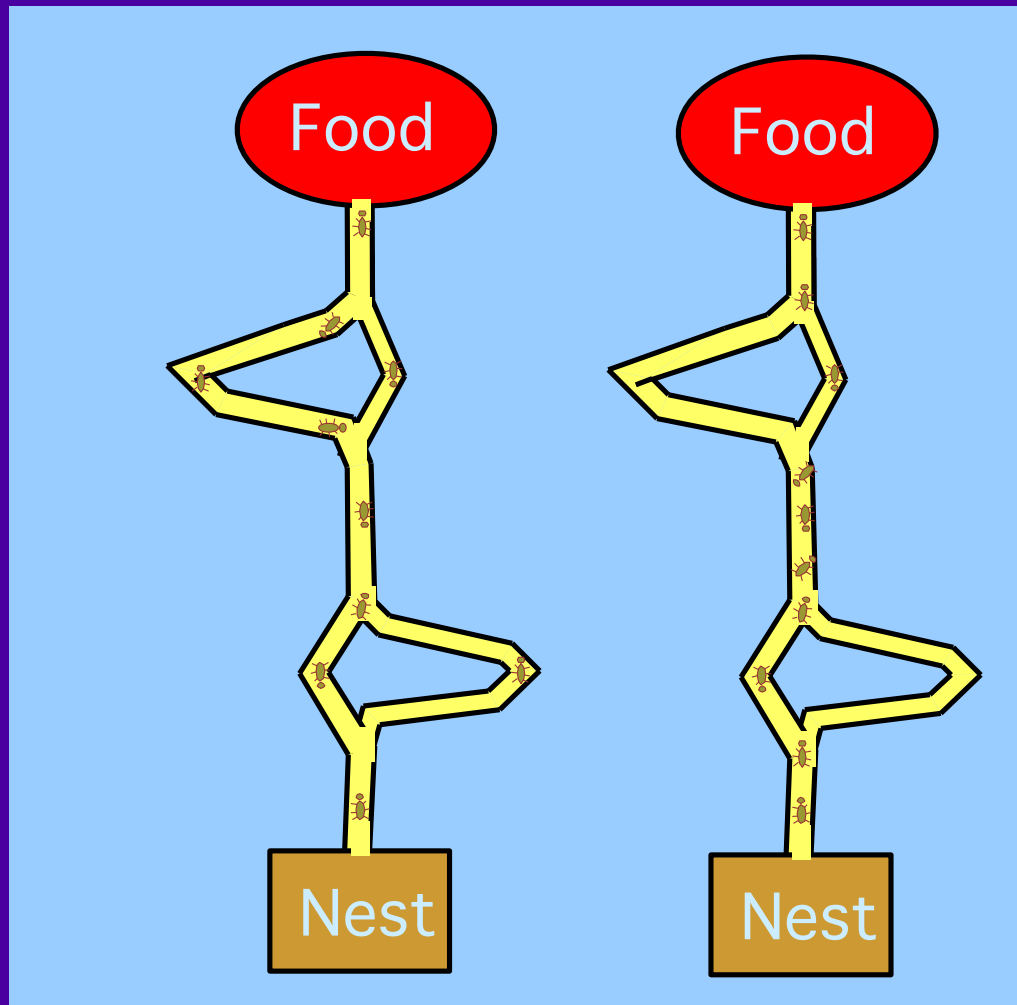# What are the "experts" saying?

A crisis being caused by timings of evolution based on DNA

❓*Lamarckian Evolution (experience is heritable)*

Ants Solving "HARD" problems

Most ants foraging for food find the shortest path.

- Individuals are "dumb," chaotic, no global perspective

- No leaders or central coordination

- Only works for groups of **diverse** ants

(Goss, et al. 1989)

"Normal" Technology Development Phases
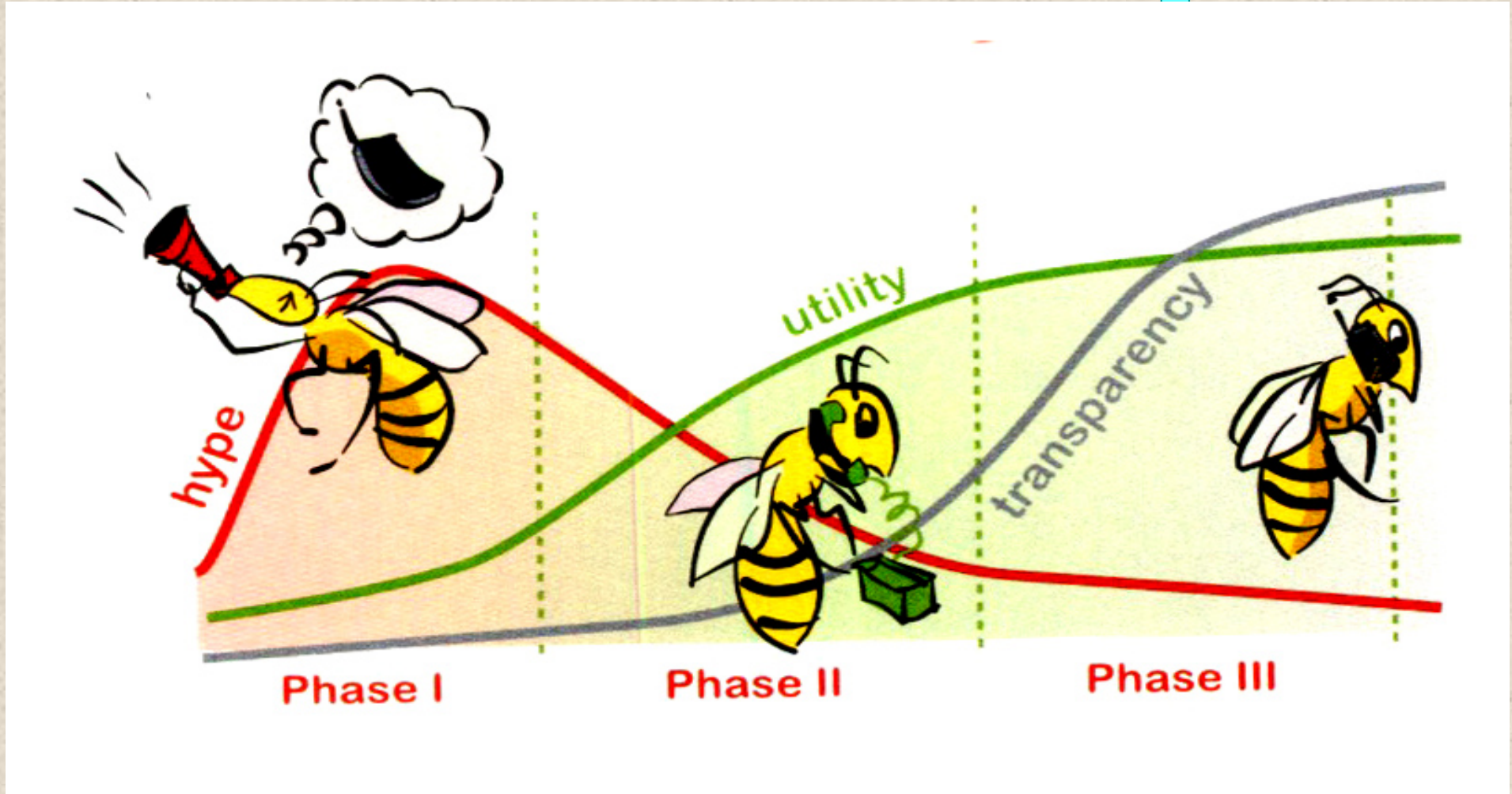
How to organize a movement, that changes/coordinates 100s of organizations and impacts 700,000 physicians?

How do you then build processes that support new "utility"?

How do new structures then become "transparent" and the building blocks of new options and structures?

A single stationary source of infinite supply
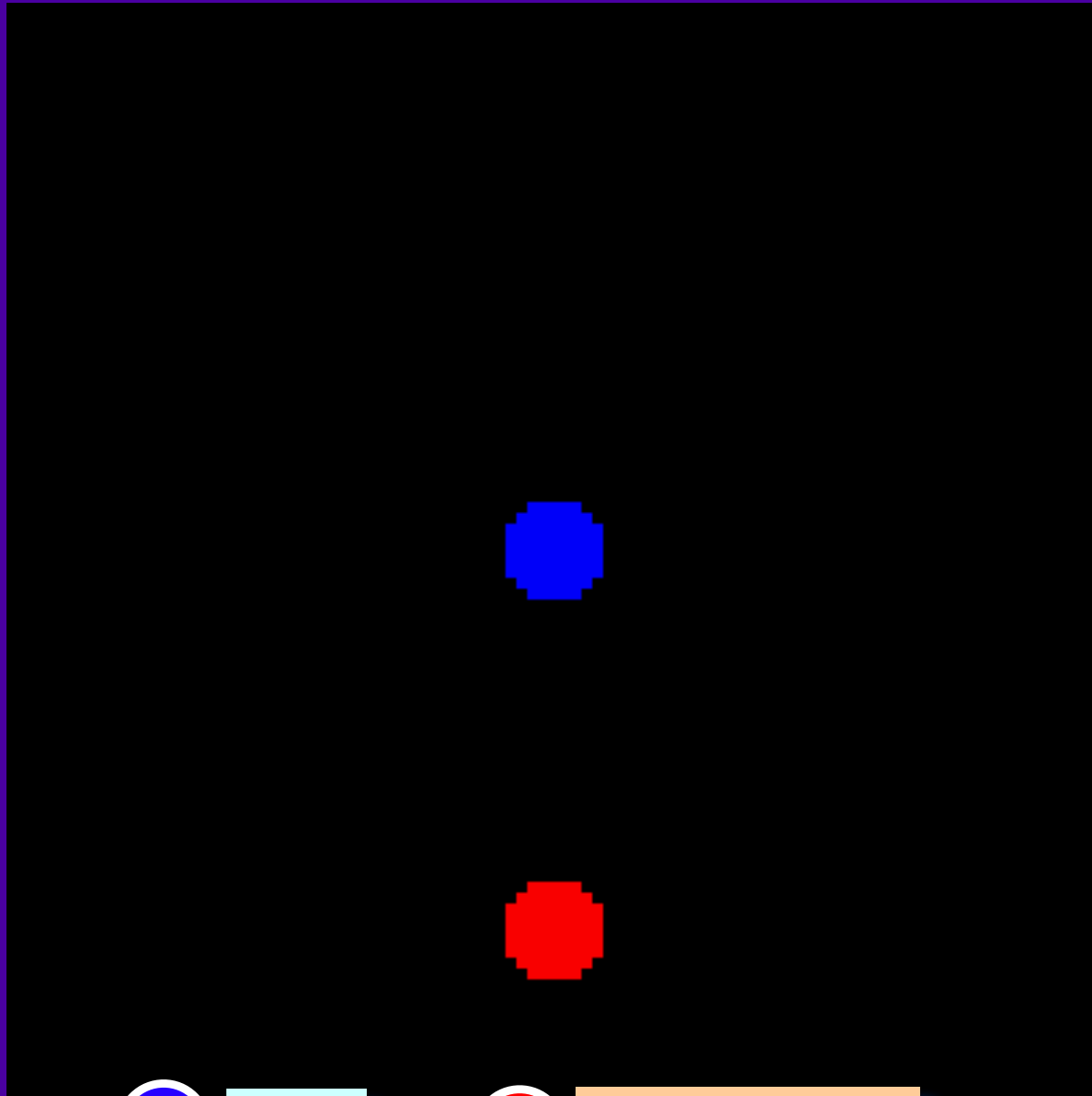
Collective information
Pheromones with
evaporation & diffusion
Ant/Agent internal state
Current direction
Have food?
Three rules of action
Carry food to nest
Drop food and turn
Search for food

■ **Productive collective**
■ **"Salaried men"**
■ **Individual/Innovator**
■ **Collective structure**

● **Nest**   ● **Food supply**

Define three "production" stages

Time

Three Performance Stages
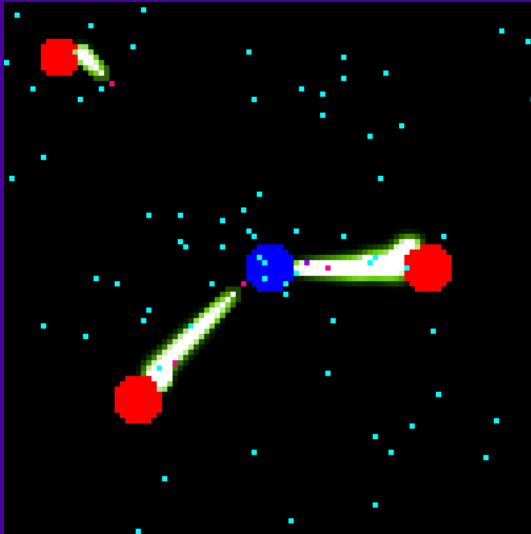
Formative
Forming structure

Synergistic
Synergy of Individuals
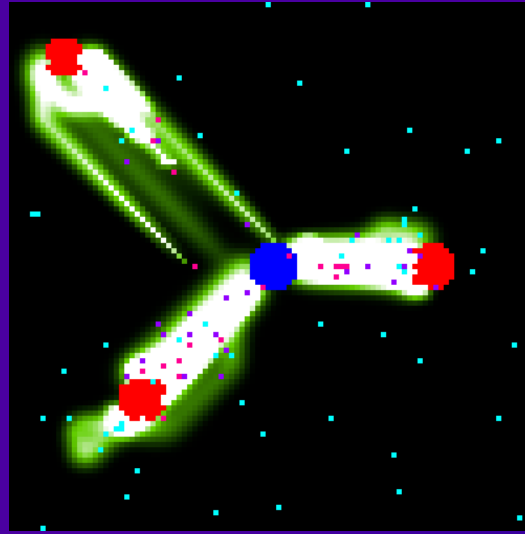
Optimized
System optimization
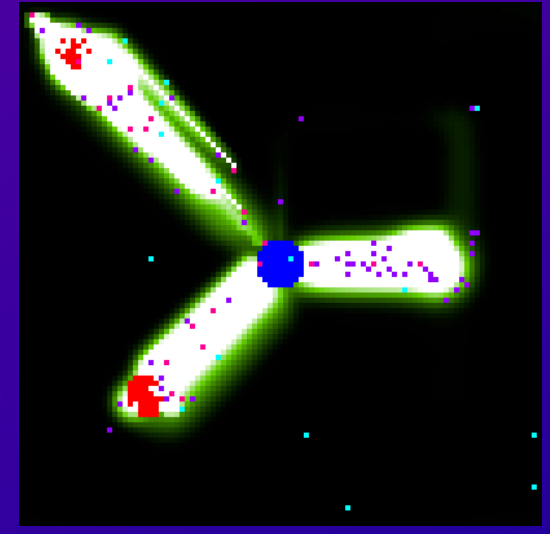
Formative	Synergistic	Optimized
• Locally chaotic (agent's path)	• Locally chaotic	• Locally predictable
• Globally chaotic (productivity)	• Globally predictable	• Globally predictable
• Low and evolving "structure" – no collective network	• Adaptive "structure" – robust collective network	• Unchanging "structure" – dominant collective network
• Performance due to uncorrelated diverse contributions	• Performance from combination of diverse contributions	• Performance due to optimized population
• Production by "innovative" agents	• Production by both classes	• Production by collective
• Growing diversity	• High diversity of options	• Low diversity of options

MV Sept 2002

Connecting the stages by structure
for decentralized, self-organizing collectives

Structure

(the rules required to "run" the system)

Structure declines because the number of new rules are limited by past rules.

Structure increases rapidly as components build structure together

Structure increases first by components developing structure

time →
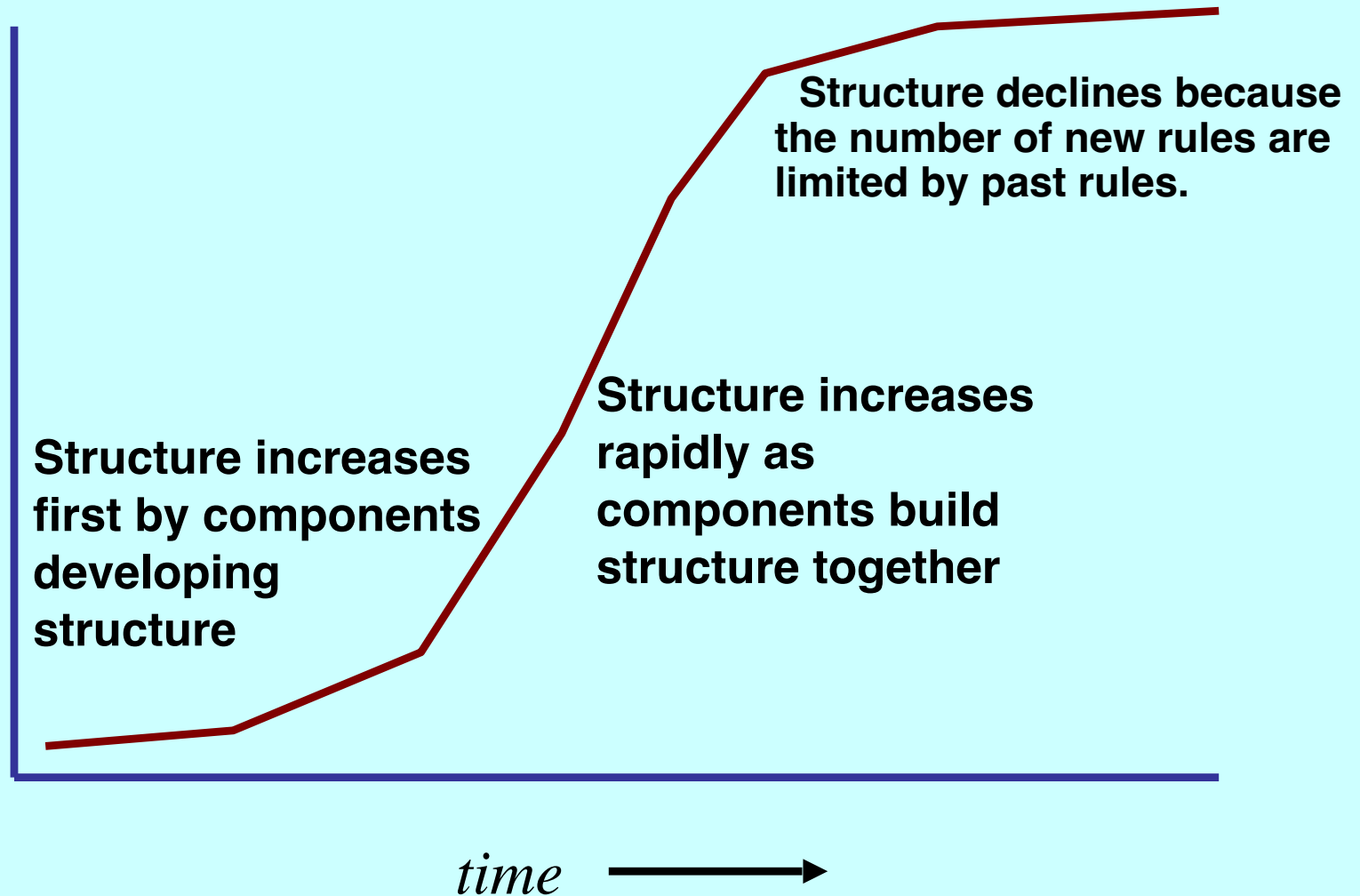
Options around Structure also change

Options are the free choices both created and limited by the structure (example: the rules of chess create an "environment" where many options are possible- while also limiting what choices are available)

Options

Structure

(the rules required to "run" the system)

Options

Options are reduced as more and more structure restricts all options

Options are greatest when structure connects the components

Because there is little initial structure, there are few options ("tall giraffes need tall trees")
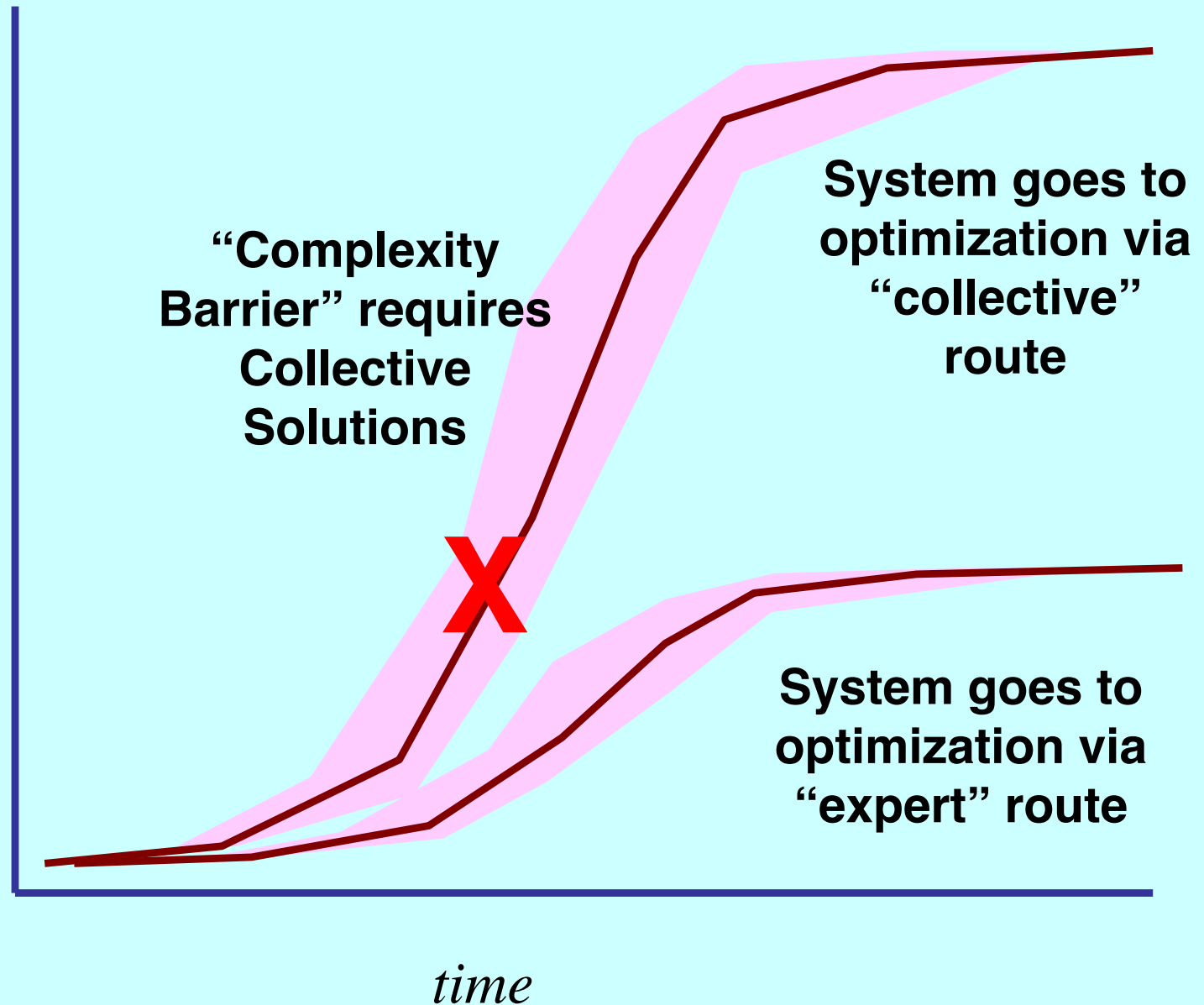
time
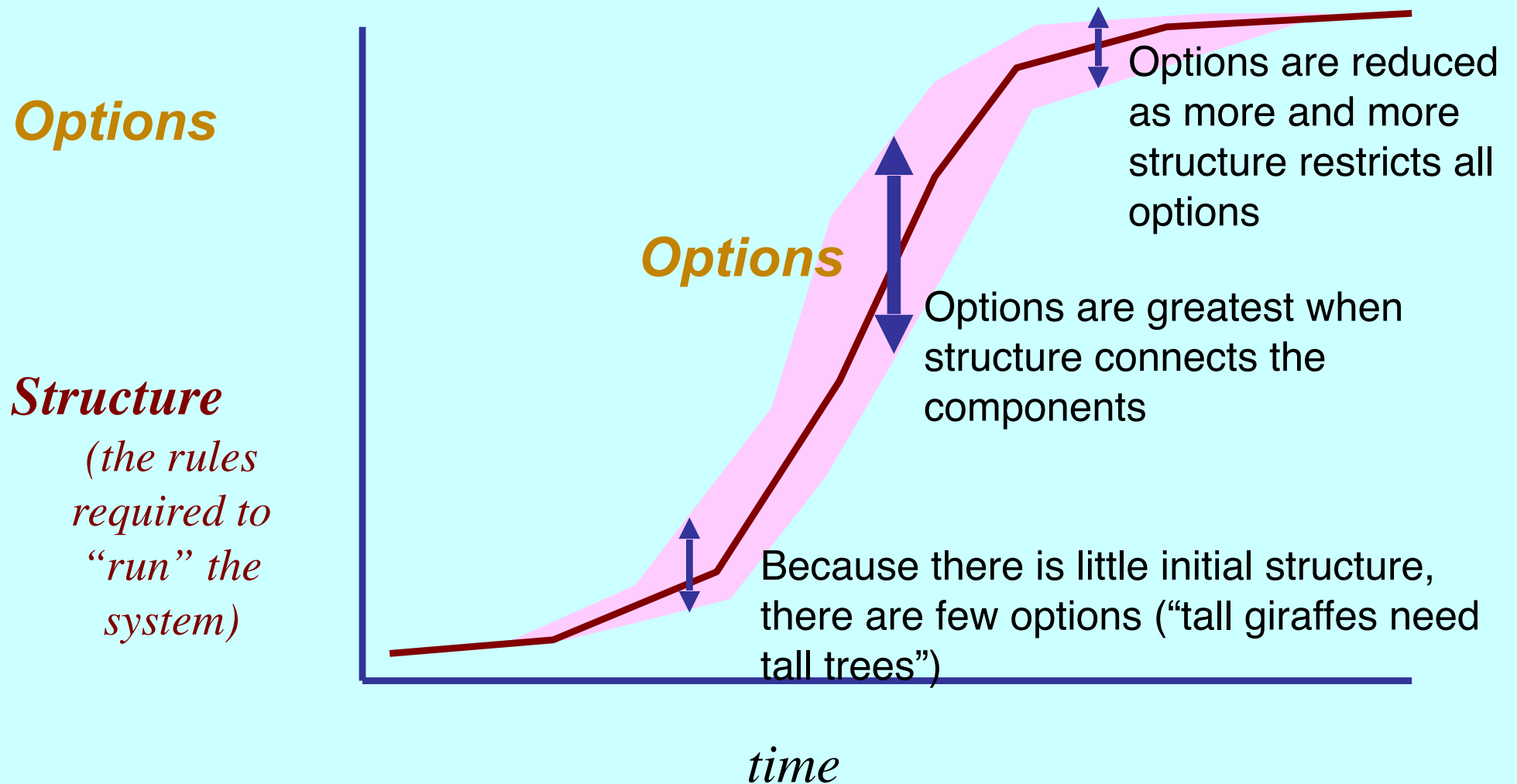
These ideas are captured by researchers

Effect of Complexity in Stable Systems

Options

Structure
(the rules required to "run" the system)
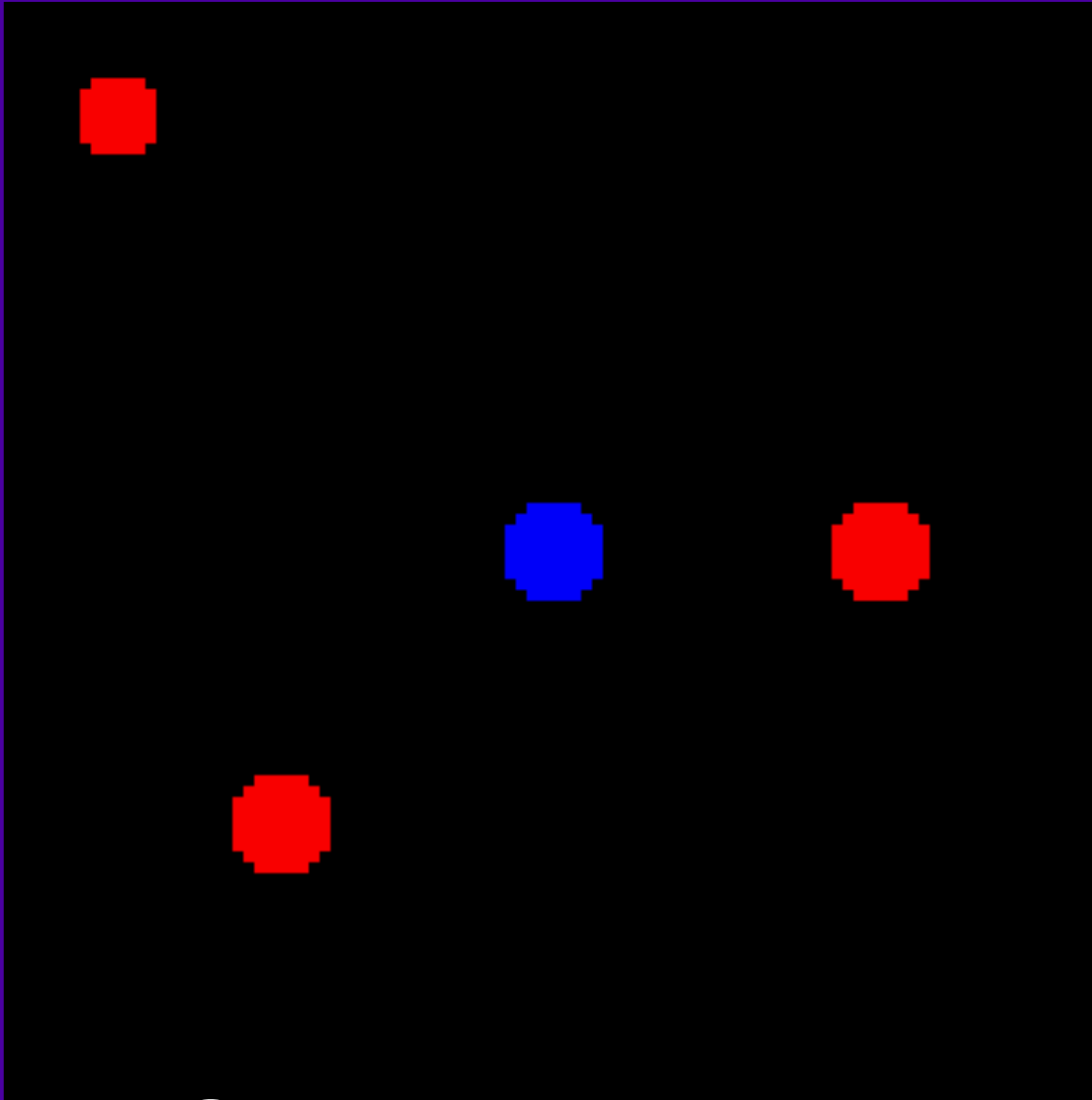
"Complexity Barrier" requires Collective Solutions

System goes to optimization via "collective" route

System goes to optimization via "expert" route

time

Ant Consumer Model

Collective information
  Pheromones with
    evaporation & diffusion
Ant/Agent internal state
  Current direction
  Have food?
Three rules of action
  Carry food to nest
  Drop food and turn
  Search for food

■ **Productive collective**
■ **"Salaried men"**
■ **Individual/Innovator**
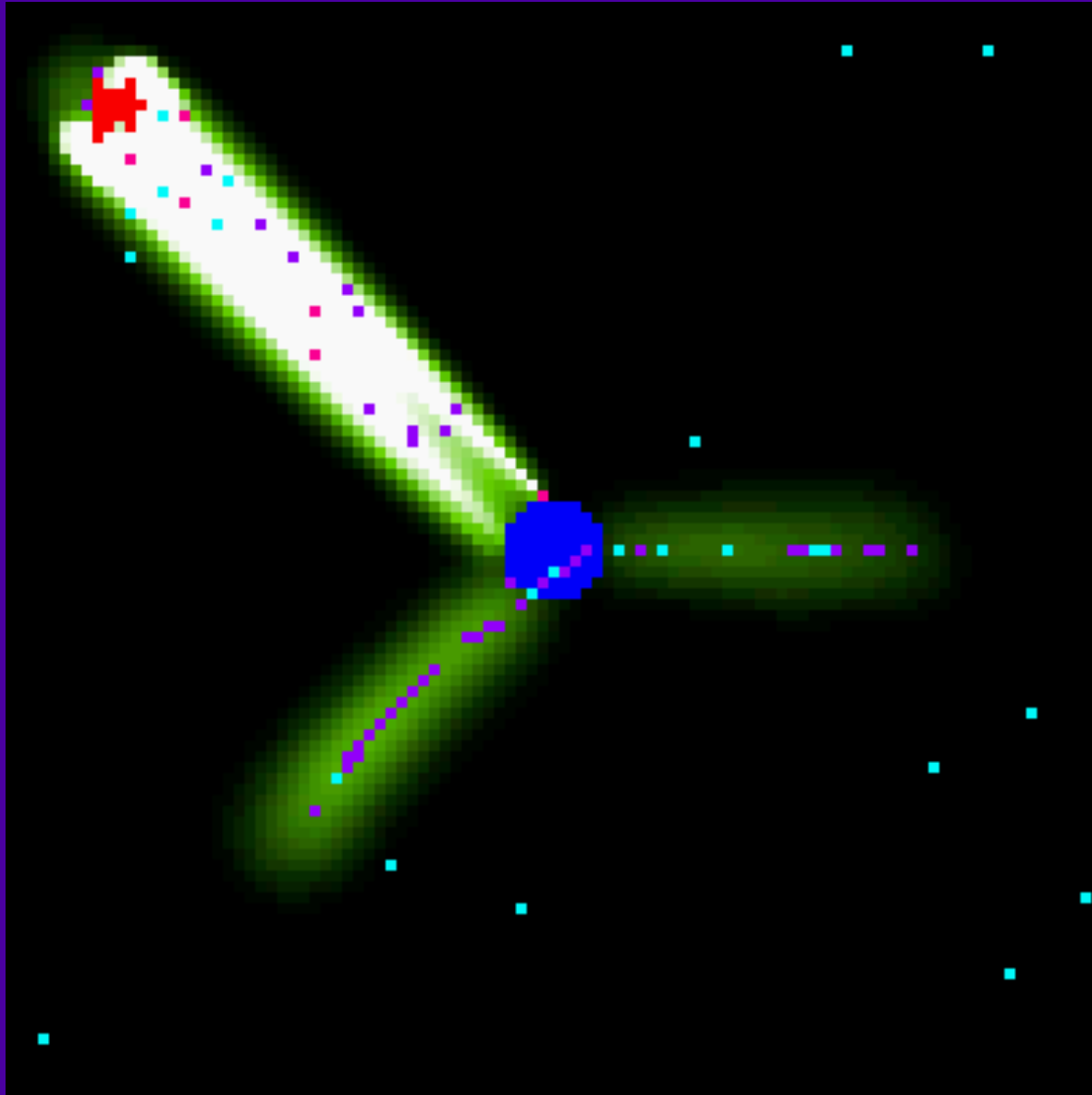■ **Collective structure**

● **Nest**　　● **Food supply**

The "Herd" Effect and Rapid Change

Add some food to an existing solution

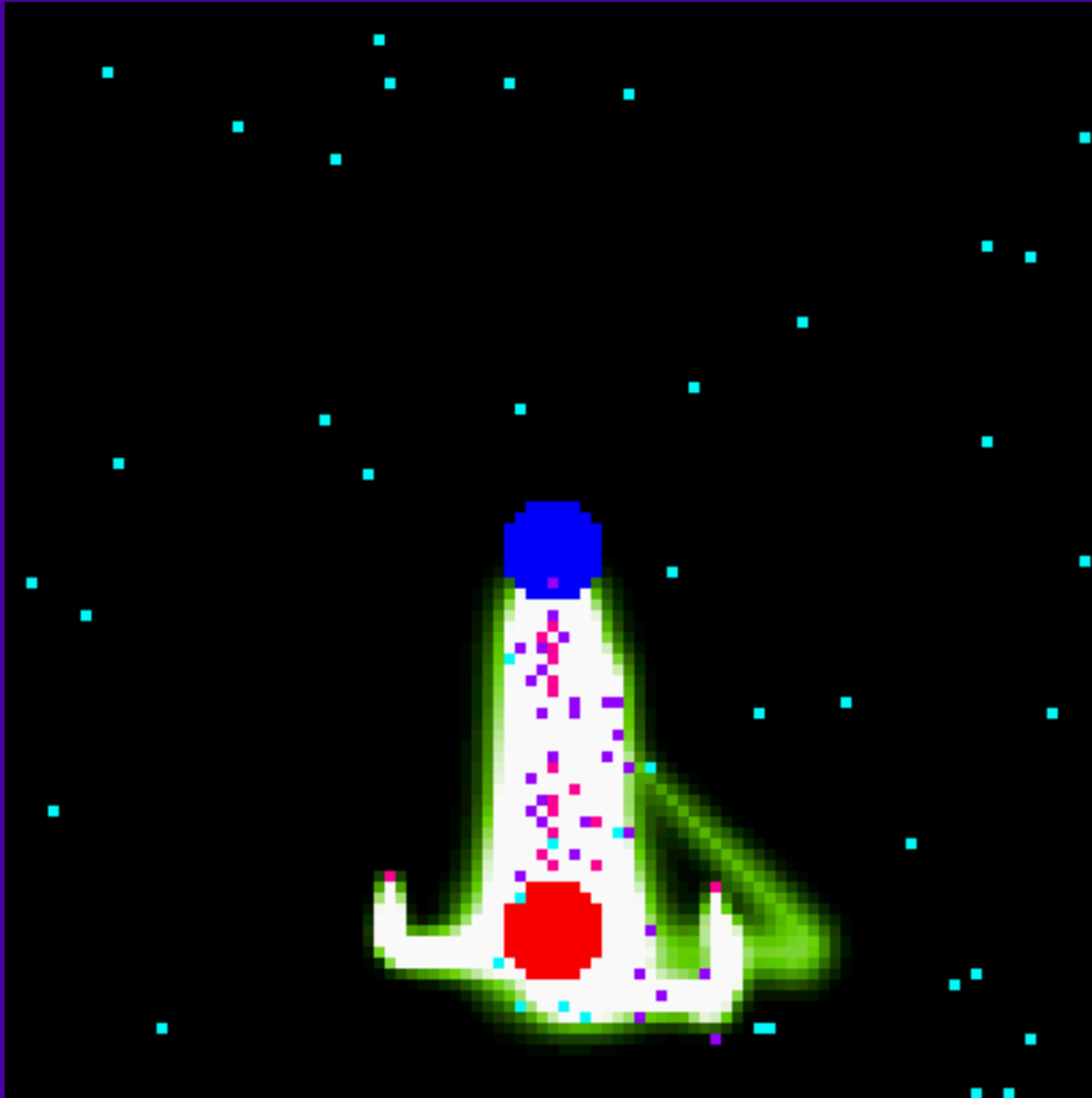**The prior "optimized" solution prevents the system from further optimization**

Worse for systems with that internalize optimal solutions.

MV Sept 2002

Quantified Environmental Change

Moves at a fixed radius and constant angular velocity
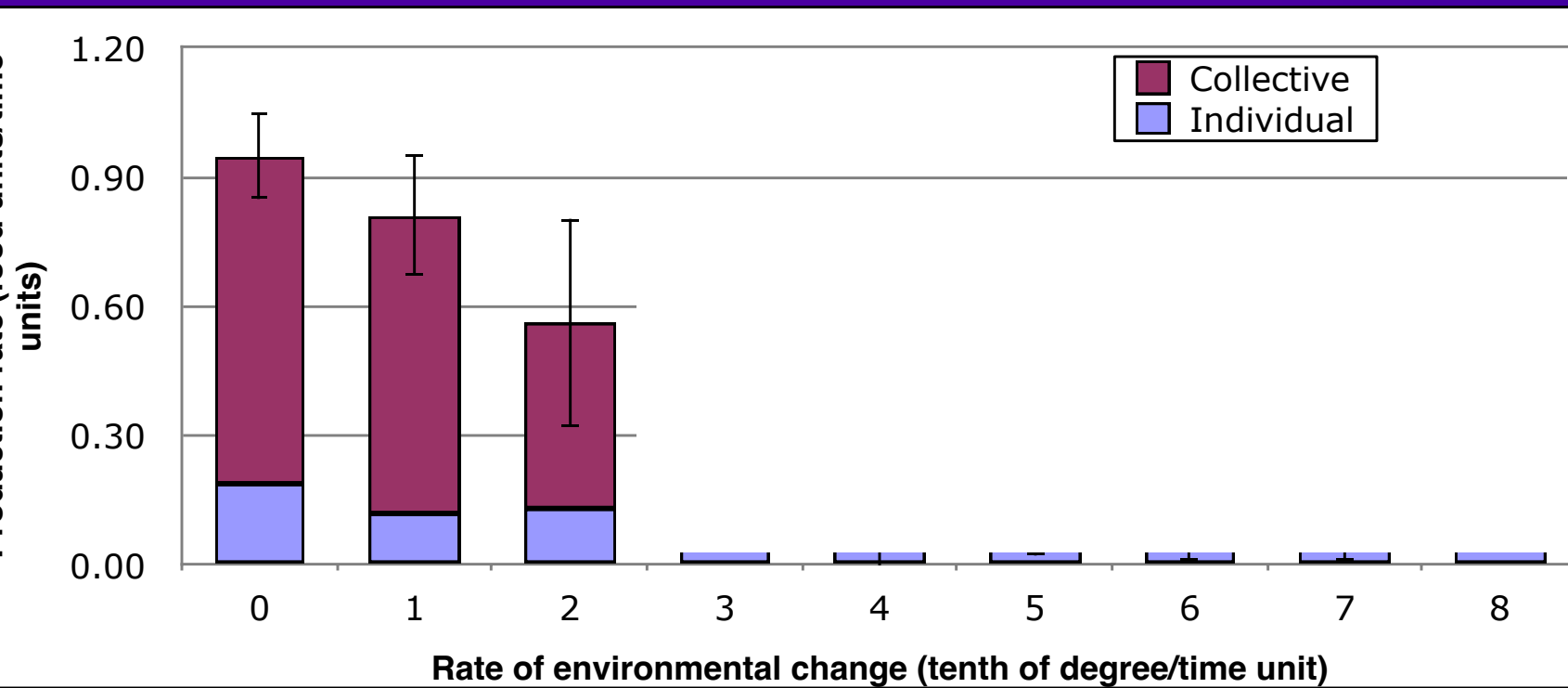
Slowly changing environment

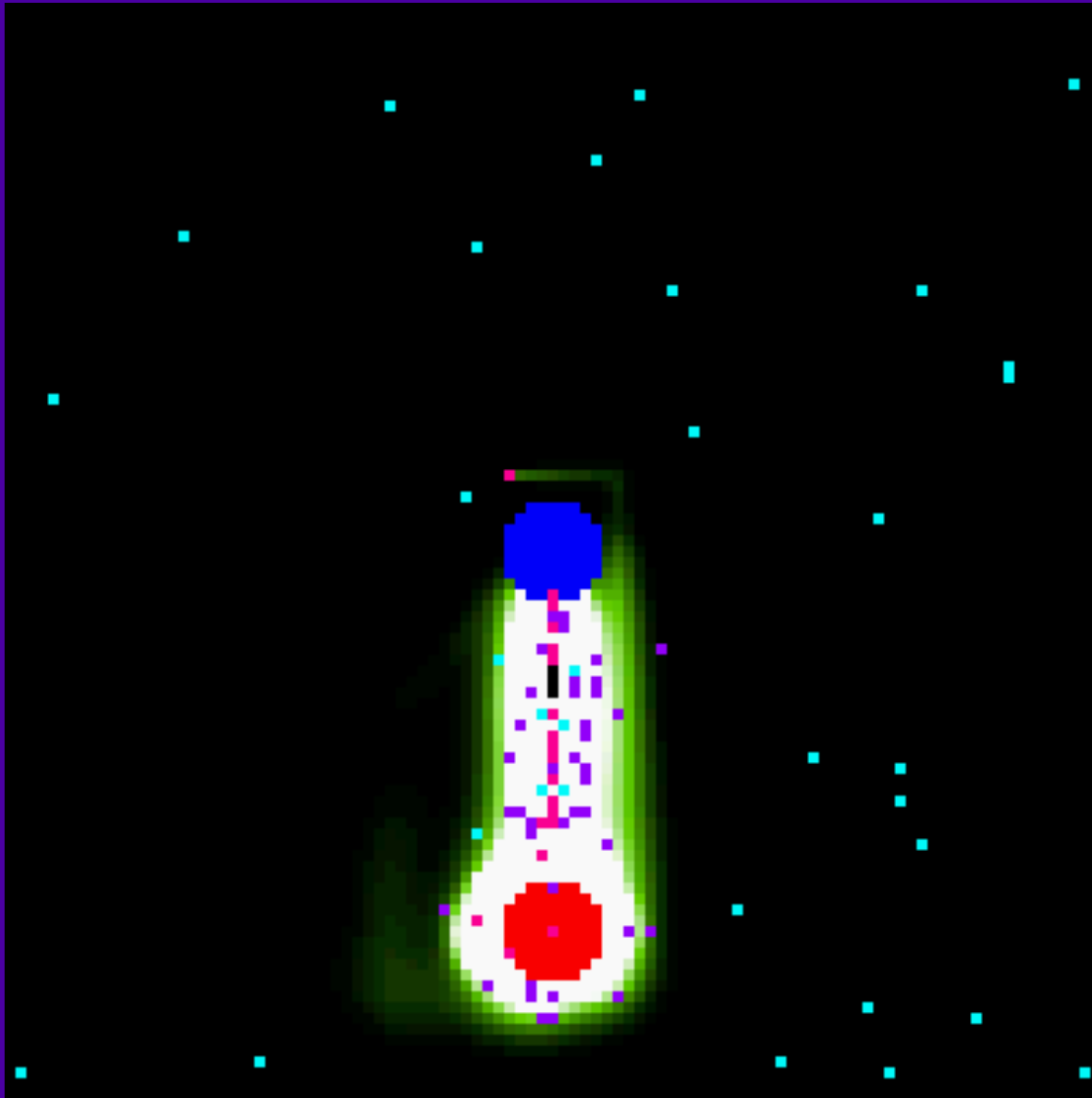**Productivity is only slightly less than an unchanging source**

Herd effect allows for quick utilization of new resource location

Innovators become important (again) by sustaining optimal performance of the collective

MV Sept 2002

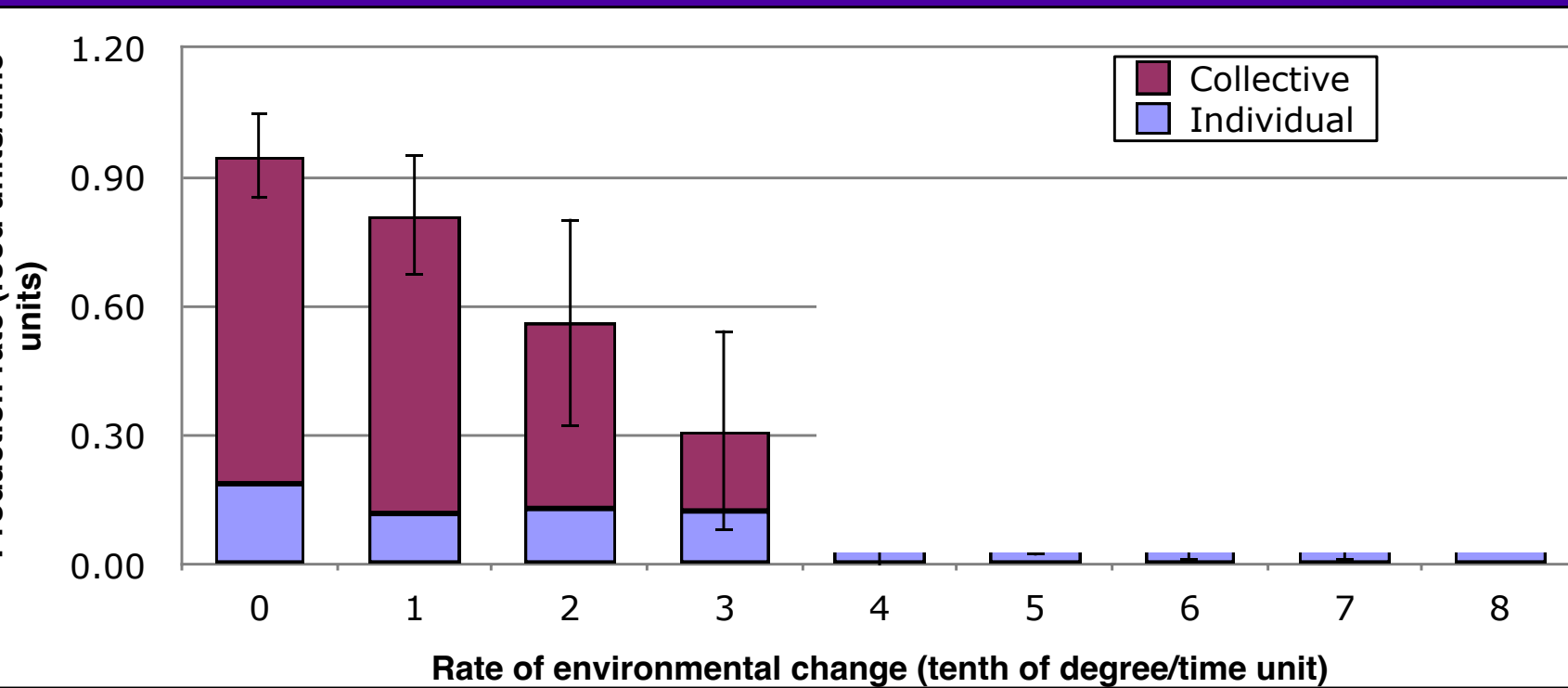# Total Food Production

Faster by 1/2

Boom and bust cycle

Instabilities lead to reversion to prior developmental stages.
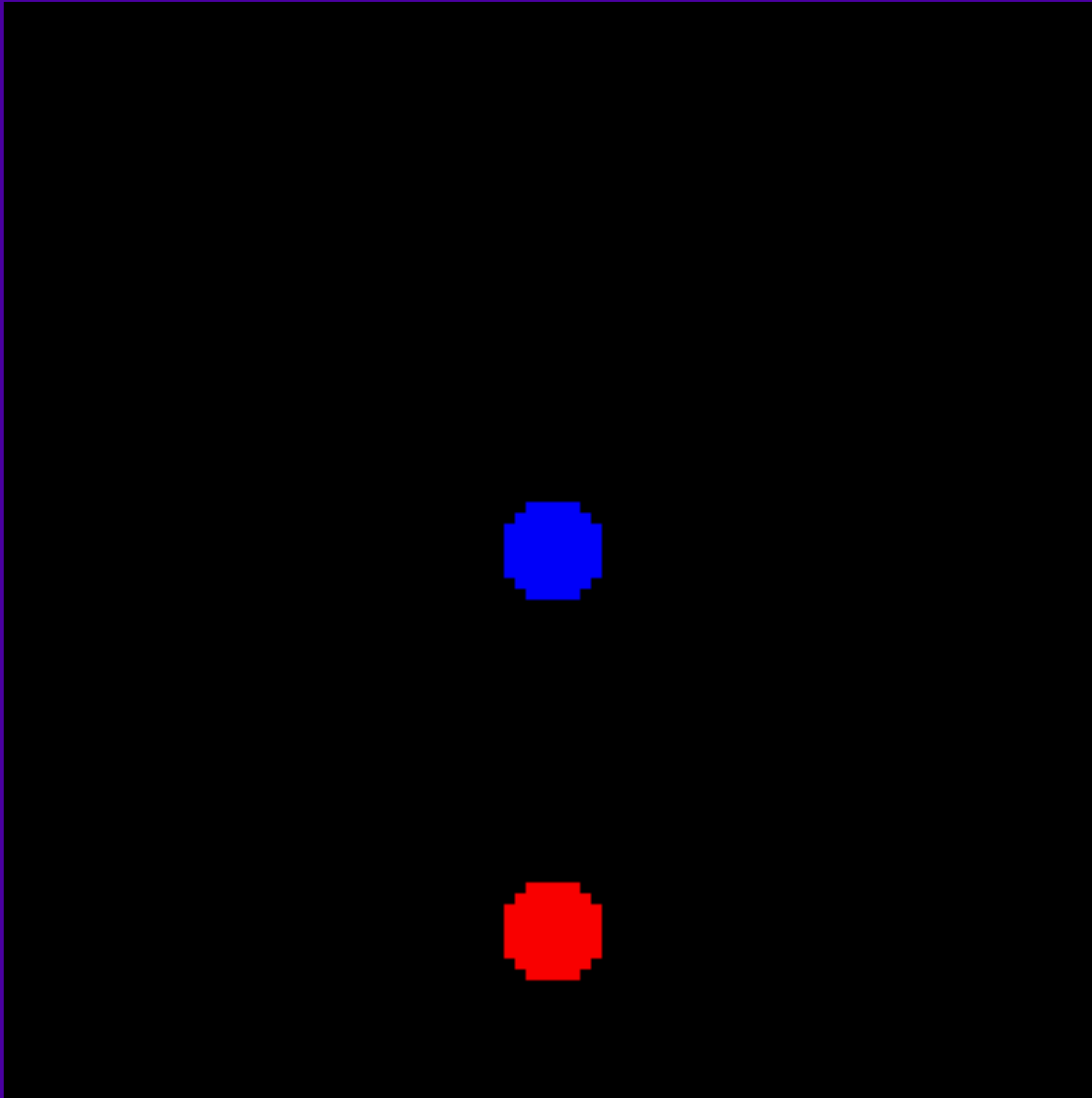
Equal importance of herd effect and innovators

Total Food Production

Production can be increased 40% by doubling the evaporation rate

Rapidly changing in environment

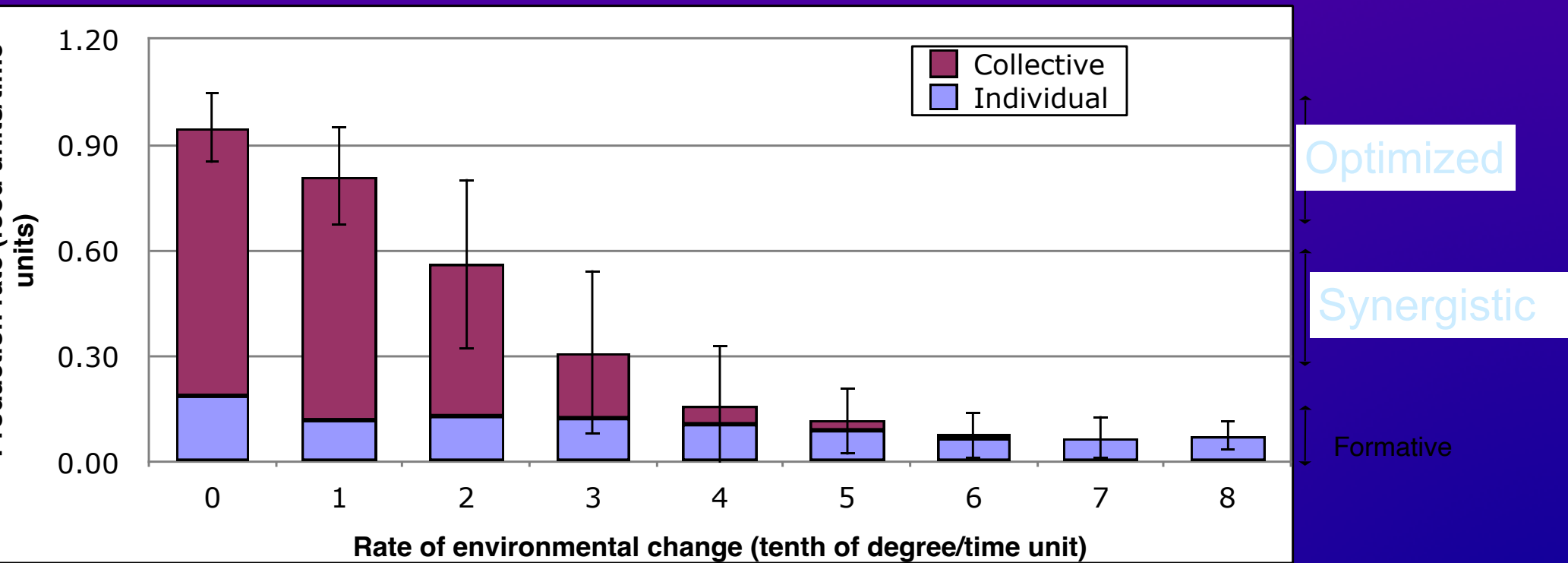**Almost all productivity is from innovators**

The highly productive Condensed stage is never realized

The herd effect can actually degrade the performance by tying up resources

Total Food Production

Y-axis: Production rate (food units)

X-axis: **Rate of environmental change (tenth of degree/time unit)**

Legend:
- Collective
- Individual
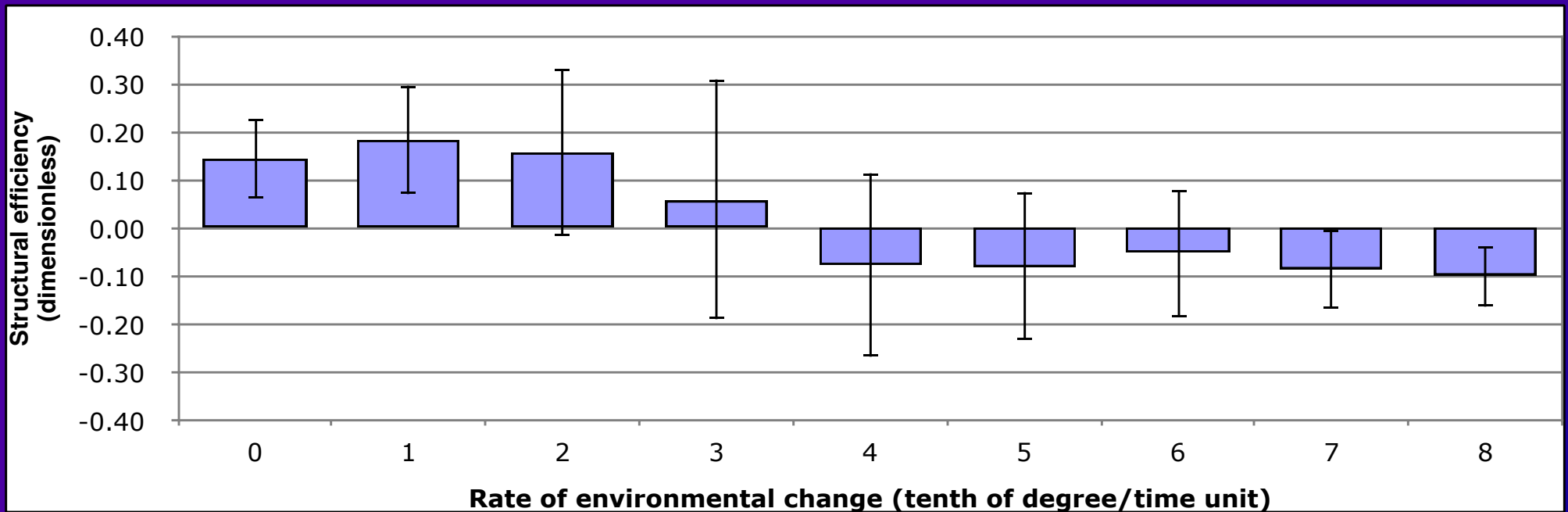
Right-side labels: Optimized, Synergistic, Formative

Structural Efficiency - Boom and Bust

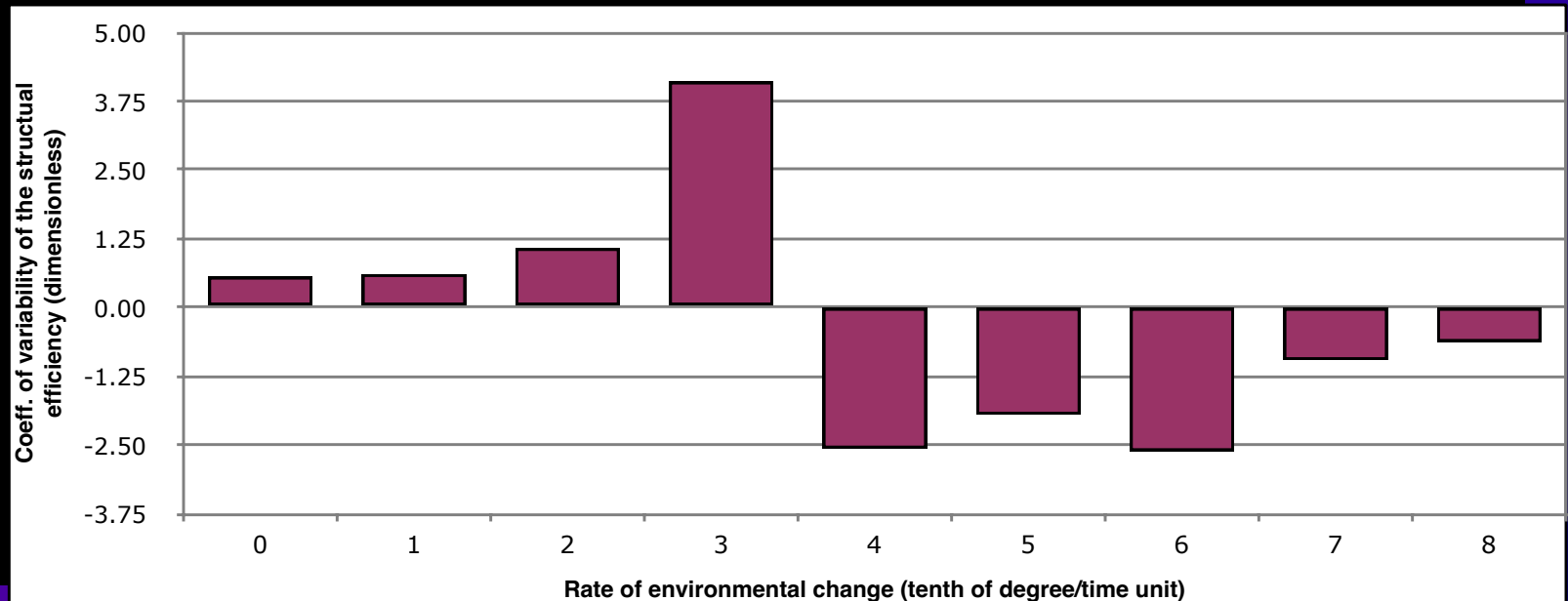**Lower average production -> crash avoidance**

Greater minimums and maximum when compared to extreme rates!

Bust is proceeded by increased production

Collective efficacy (structural efficiency)

Coefficient of Variability (mean / s.d.)
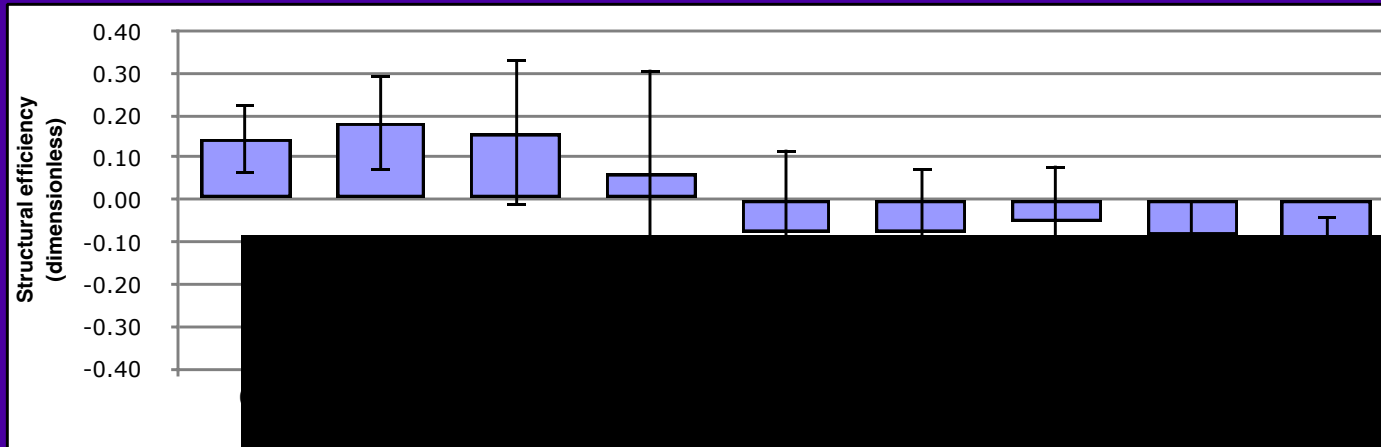
Collective Response to Environmental Change

Stages in Development

Unimpeded development

Optimized
(optimization of collective)

Synergistic
(synergism from individuals)

Formative
(creation of individual features)

Featureless

Stable
"no change"

Rate of Environmental Change

MV Sept 2002
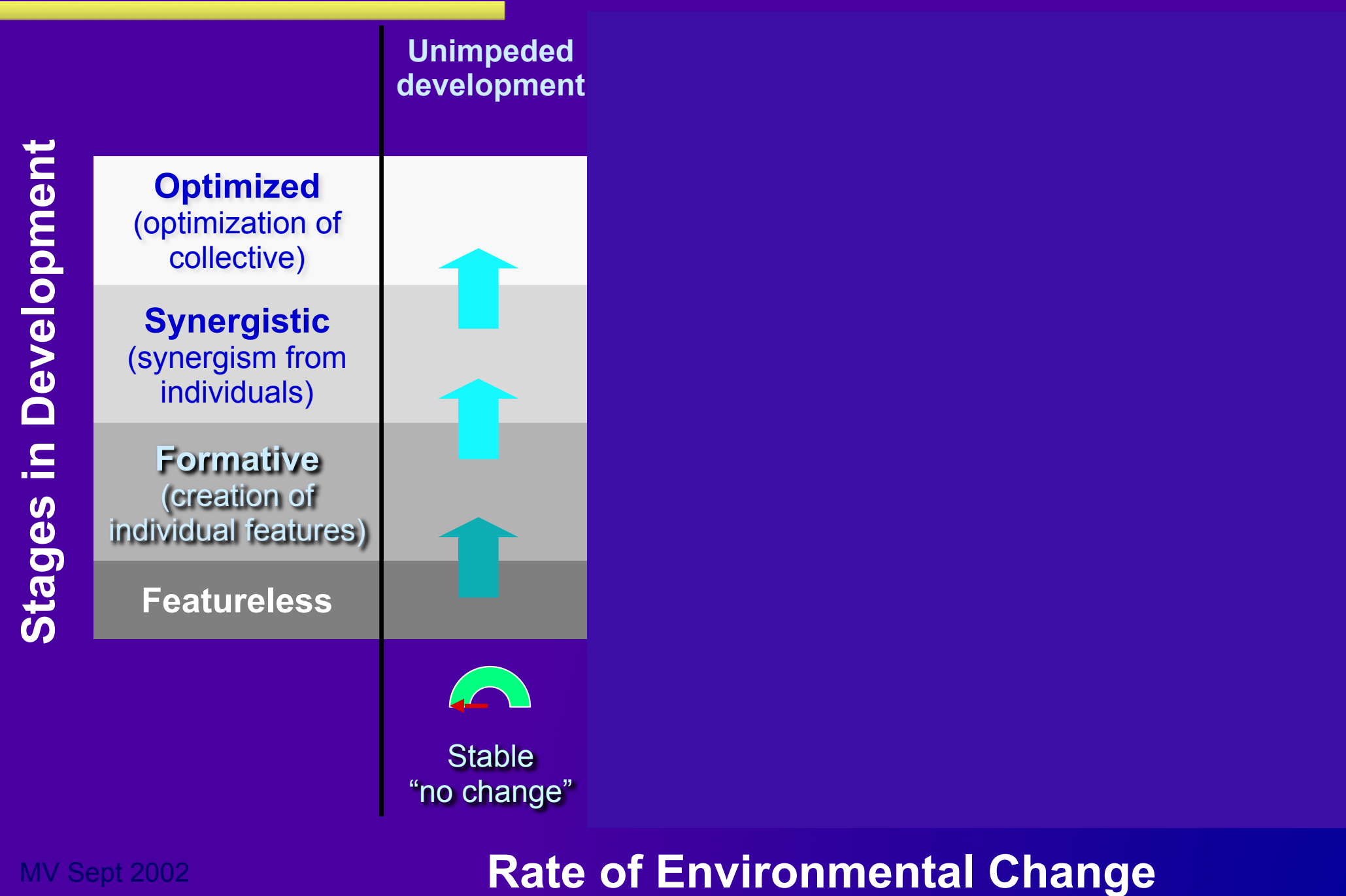
The Structure of **Structures**

Structures direct the evolution of the system by creating and limiting potential options

Combination of Sustained Structure and Change

How does the retention of structure change the collective response?
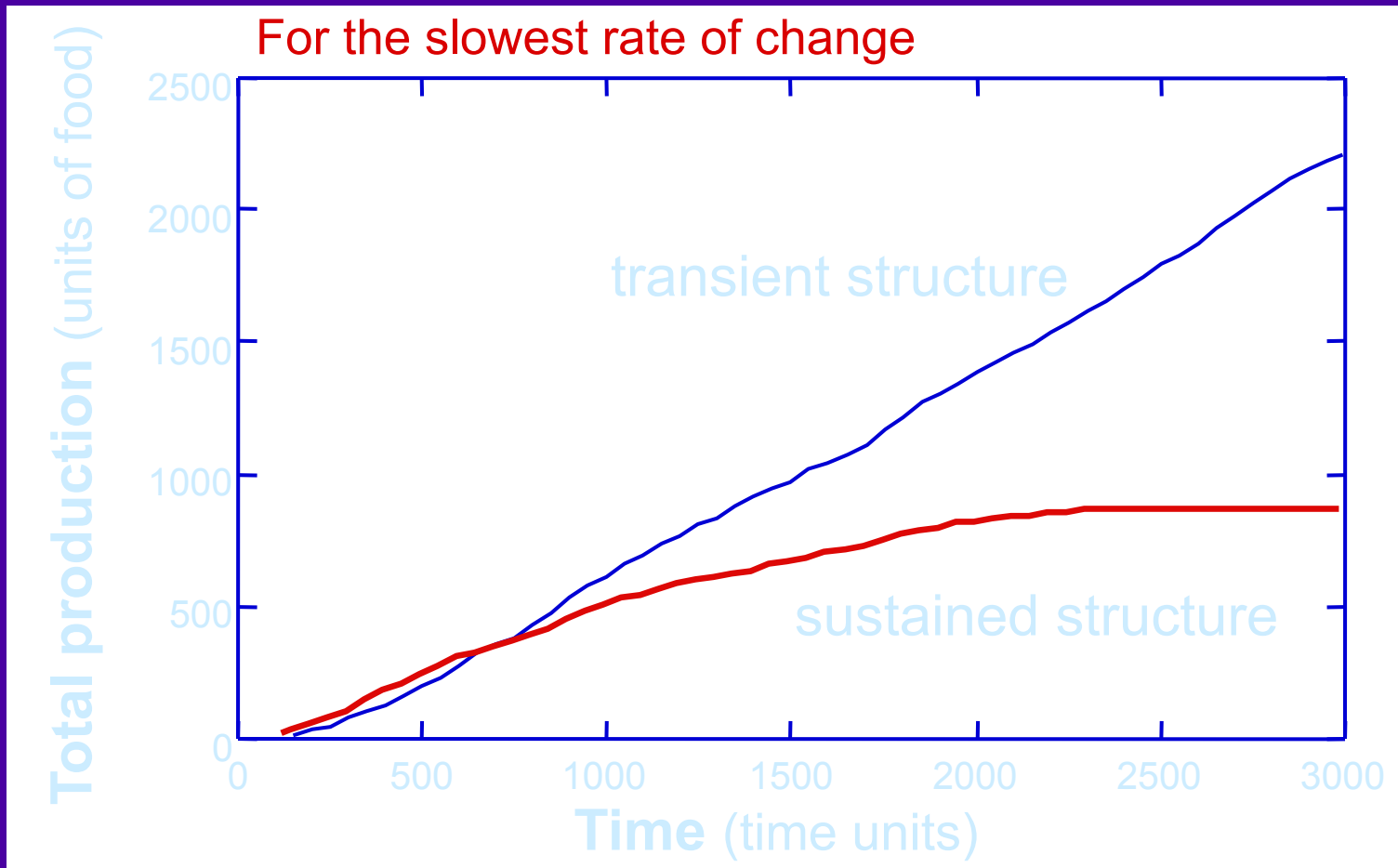
Suggests that fixed evolutionary adaptations lead to inefficiencies in the presence of even small rates of change
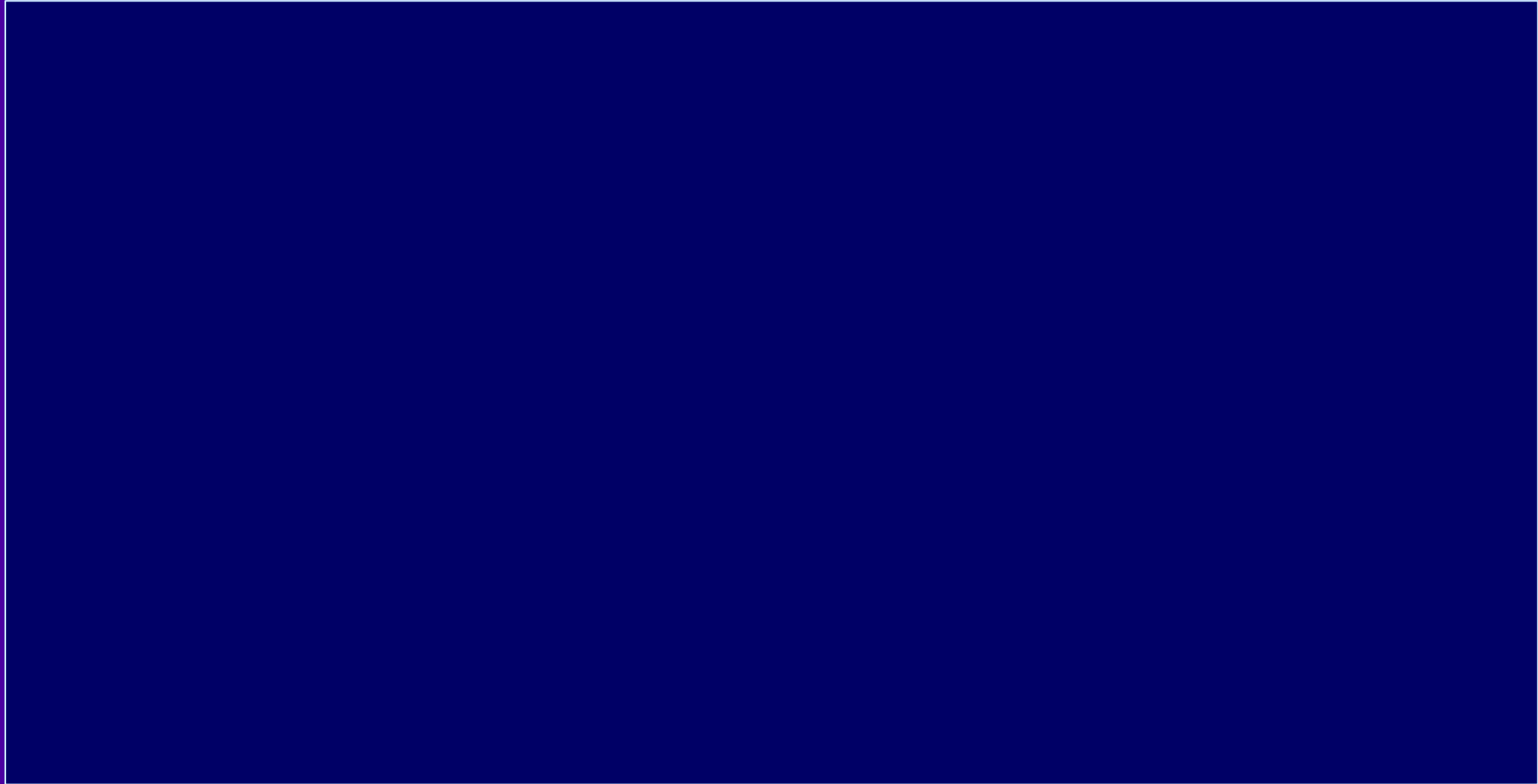
What would be the effect of a faster ant?

What would be the effect of mass communication?

See "Creative Destruction" by Foster

MV Sept 2002

Prediction: Speed up by 10 times & change distance
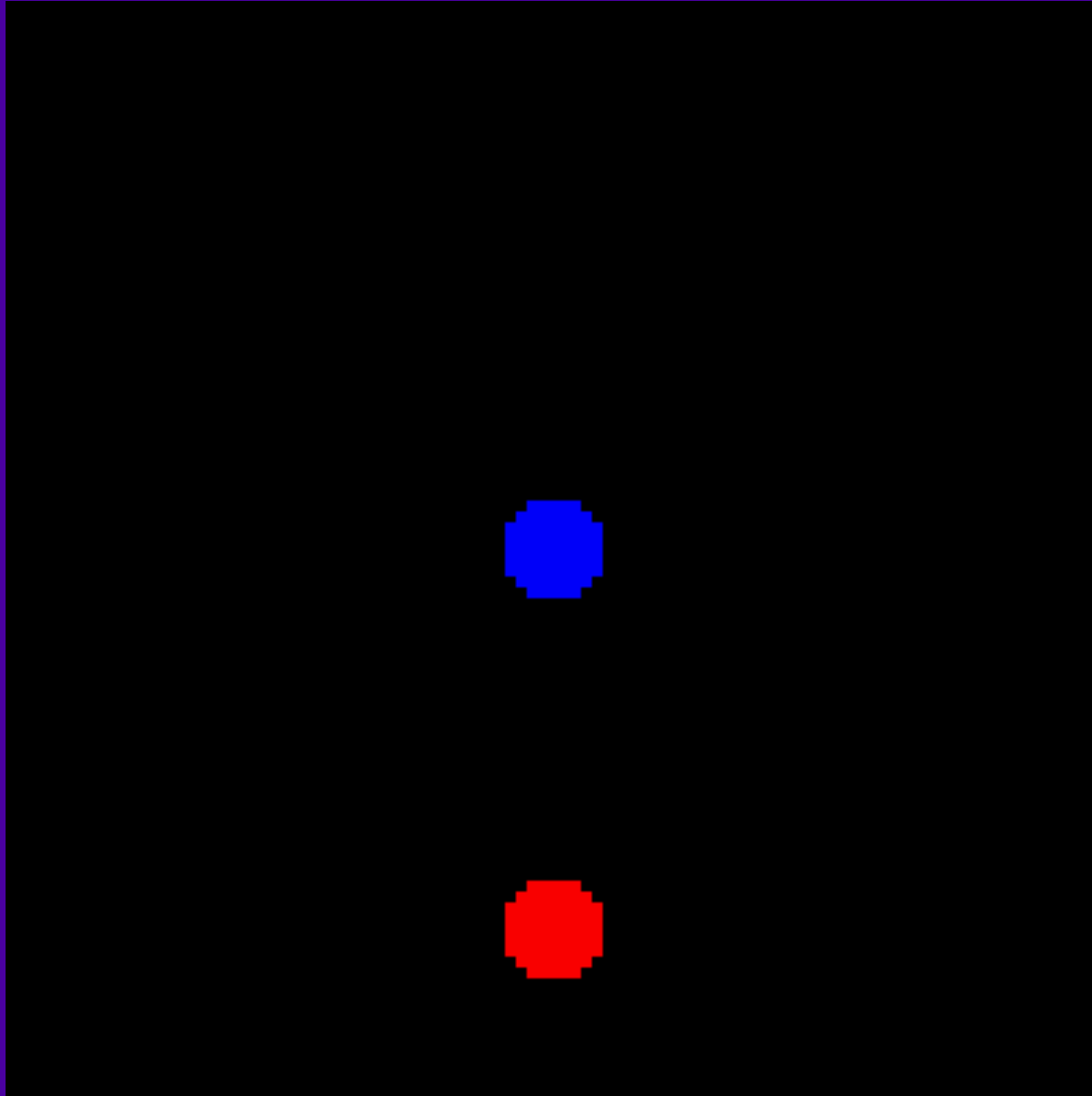
Almost as productive at stationary source!

At a later time…

Exploits natural resonance of collective

Optimality of a Dynamical Environment

Production rates

Extreme rates
Production rates a
high as a stable state

Individual production
rates highest

Structural Efficiency

Structural efficiency
also high

Conclusions about Collectives and Change

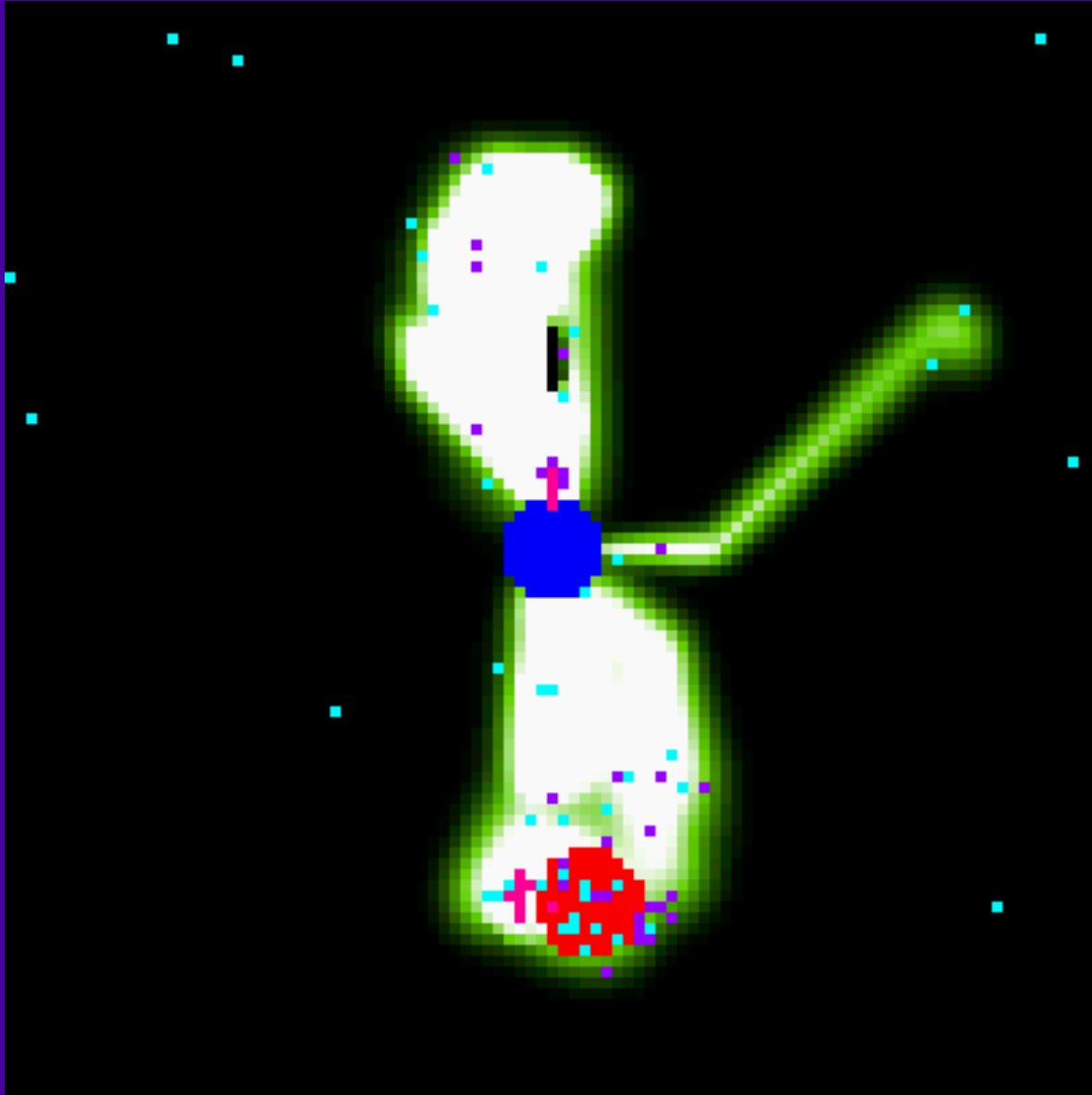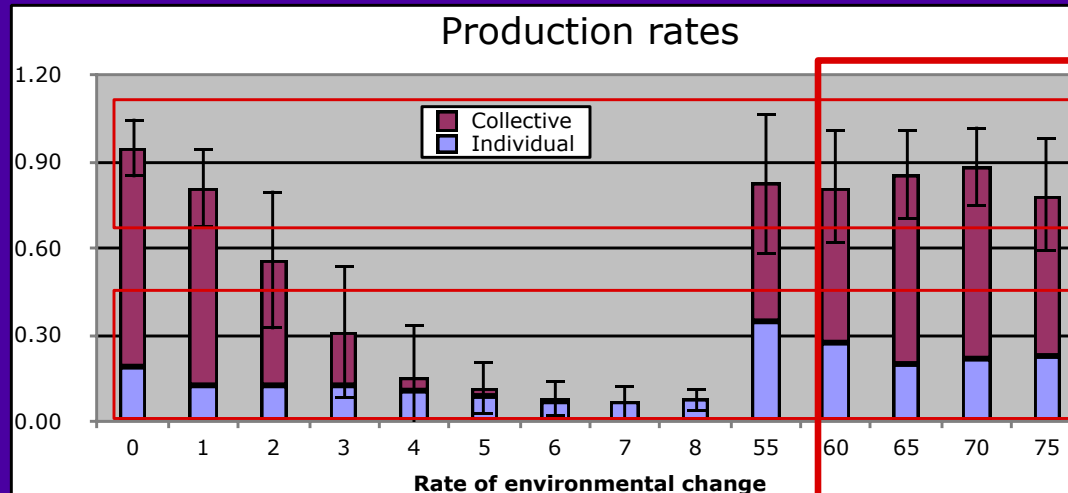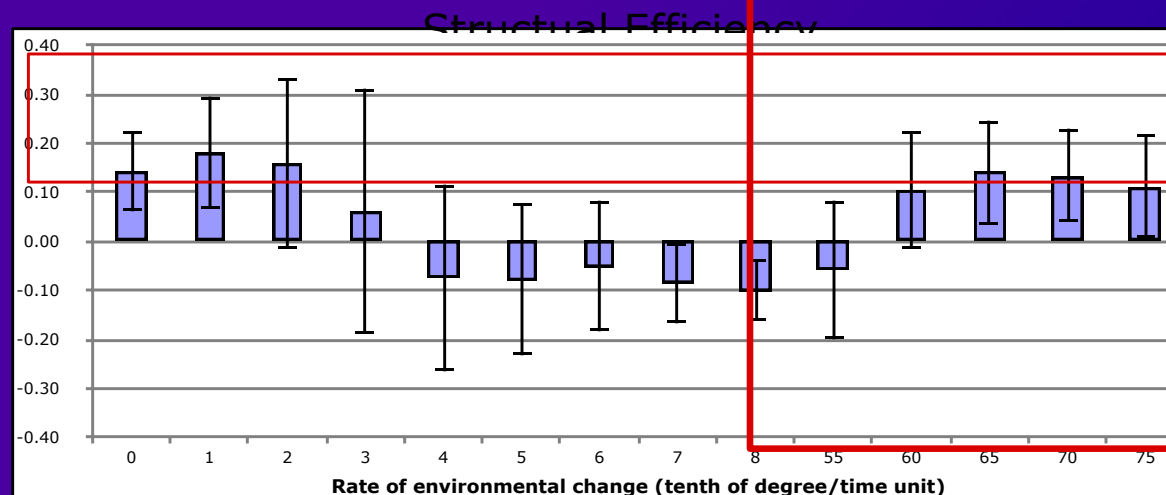☒ **Consider both competitive and synergistic strategies**

☒ **"Busts" are worse than lower average performance**

☒ **Different types of structures have different reproducibility**

☒ **How to evolve an overly-constrained system?**
- – Either "creatively destroy" structure or build on structure
- – Seek diverse strategies
- – Focus on process, instead of product (KISS)
- – Emergent solutions can't be planned but can be enabled by diversity

☒ **Optimize structure (rules) and options based on:**
- – Required performance and robustness
- – Stage of development
- – Rate of change (internally or externally)

☒ **Use stages of development as guideposts**
- – Formative: lots of building of structure, fragile
- – Synergistic: sweet spot for resilience and change
- – Optimized: only for slowly changing or stable environments

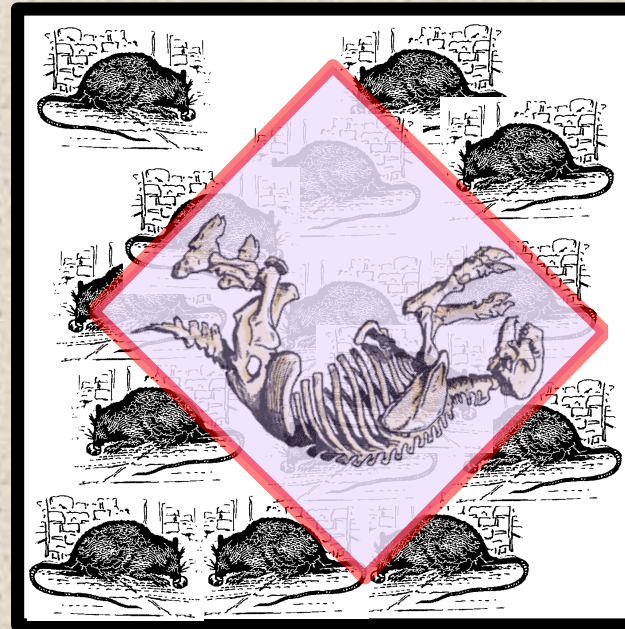http://CollectiveScience.com

Rat Studies of Maximum Carrying Capacity

Cooperative social structure

Control - no imposed social structure

NIMH psychologist John B. Calhoun, 1971

Both systems loaded to 2 1/2 times the optimal capacity.

Social order system can carry 8 times the optimal capacity.

Environment

(culture, economy, demography, technology, nature)

Individual types
- Peers
- Bosses
- Clients, …

Individual
- Sensory
- Memory
- Motivation
- …

Social-organizational -information network
- Diversity
- Connections
- Strengths
- Asymmetry
- Change

Groups
- Media
- Organization
- …

Regulations
- Feds
- Agencies
- …

Dynamics on the network

performance - stability - resilience - transients
- Change of states
- Creation/destruction of structure & options
- Dynamics under stable conditions
- Dynamics in response to change

Levels of Social complexity

slime molds	"low" social insects	"high" social insects	social mammals	"low" apes	"high" apes	humans

←———→

Social: diverse, decentralized, collective survival and problem solving
Collectively adaptable, self-organizing, emergent properties

←———————————————————————————————————→

Collective memory, Intelligence, Deception

From a workshop on "The Evolution of Social Behavior" which covered a wide range of social organisms

←———————————————————————————→

Individual intelligence & emotions

←———————————————→

Individual Self-awareness & Consciousness

MV Sept 2002

Cook County Hospital

- **First blood bank**

- **Cobalt beam therapy**

- **First attachment of 4 severed fingers**

- **Inspired ER TV series**

- **Diagnosis of chest pain in ED (Goldman) - funded by Navy => Heart attack decision tree**

  - How to catch the 10% actually having a heart attack?
  - Algorithm: 70% better at recognizing who's not having an attack
  - Doctors: 75-89% correct on most serious patients
  - Algorithm: 95% correct on most serious patients
    - Algorithm gives no consideration of diabetes, race, gender, age, prior heart attack, diet, lifestyle. "this is nonsense"
  - What if a change happens?