MES: Ecological & Social Sustainability

Scientific Models *(Part II)*

Judy Cushing

Part I (Tuesday)

How do we know if a scientific claim is "good"

(Theory, Hypotheses, Fact, Argument, Explanation)

Why does all this matter?

How does this relate to the *Panarchy* Framework?

Part II (Thursday)

Briefly recap Tuesday

How Science changes: Scientific Paradigms & Paradigm Change

What is a Scientific Model?

One Model:

Spruce Budworm & New Brunswick Coniferous Forests

Scientific Models *(Part II)*
References

- *Panarchy*
- *Thinking in Systems*

- Kuhn, Thomas S. *The Structure of Scientific Revolutions*, 2nd ed. Univ. of Chicago Press, 1962, 1970. 210 pp.
- Lucas-Clark, Joyce. Framing the Discussion: What to Tell Students About Science, *Thought & Action*, Vol 26, Fall 2010, pp 123-125.
- Okasha, Samir. Philosophy of Science: A Very Short Introduction. Oxford. 2002. 144 pp.

- Clark, William C., Dixon D. Jones, C.S. Holling. Lessons for Ecological Policy Design, A case study of ecosystem management. *Ecological Modeling*, 7. pp 1-53. Reprinted in L.H.Gunderson, C.R.Allen and C.S.Holling, *Foundations of Ecological Resilience*, Island Press. pp331- 392.

Reprise of Tuesday

The many scientific disciplines each have their own laws, methods. Scientific laws or claims have no single distinguishing feature but might :

- **Deal with the Natural World**
- **Use scientific methods – fact gathering & experimentation**
- **Use valid inference methods– deduction, induction**
- **be substantiated by evidence, "observables, and give a measure of uncertainty**
- **Be disprovable**
- **Answer an explanation-seeking why question and be a logical argument, perhaps deductive (meeting the *Covering Law*)**
- **Be "the best explanation" and plausible, w/ relevant premises**
- **Be simple**
- **Be objective ….**

But how do we reach consensus?

Scientific Paradigms & Paradigm Change

Kuhn: The Structure of Scientific Revolutions

From the Aristotelian World View
Ptolemy to (1800 years later!)

Copernicus, Kepler, Galileo … 16th-17th centuries….
Descartes' Mechanistic World View
Newtonian Physics

Relativity Theory & Quantum Mechanics (200 years later!)

Biology – Darwin *The Origin of the Species* (1859)
Molecular Biology – Watson & Crick (1953)

Geology – Wegener's continental drift

Scientific Paradigms

- Scientists don't (constantly) do metascience
- They are educated and then work within a *Scientific Paradigm**
- They accept its *modus operandi*, and "fill in" gaps

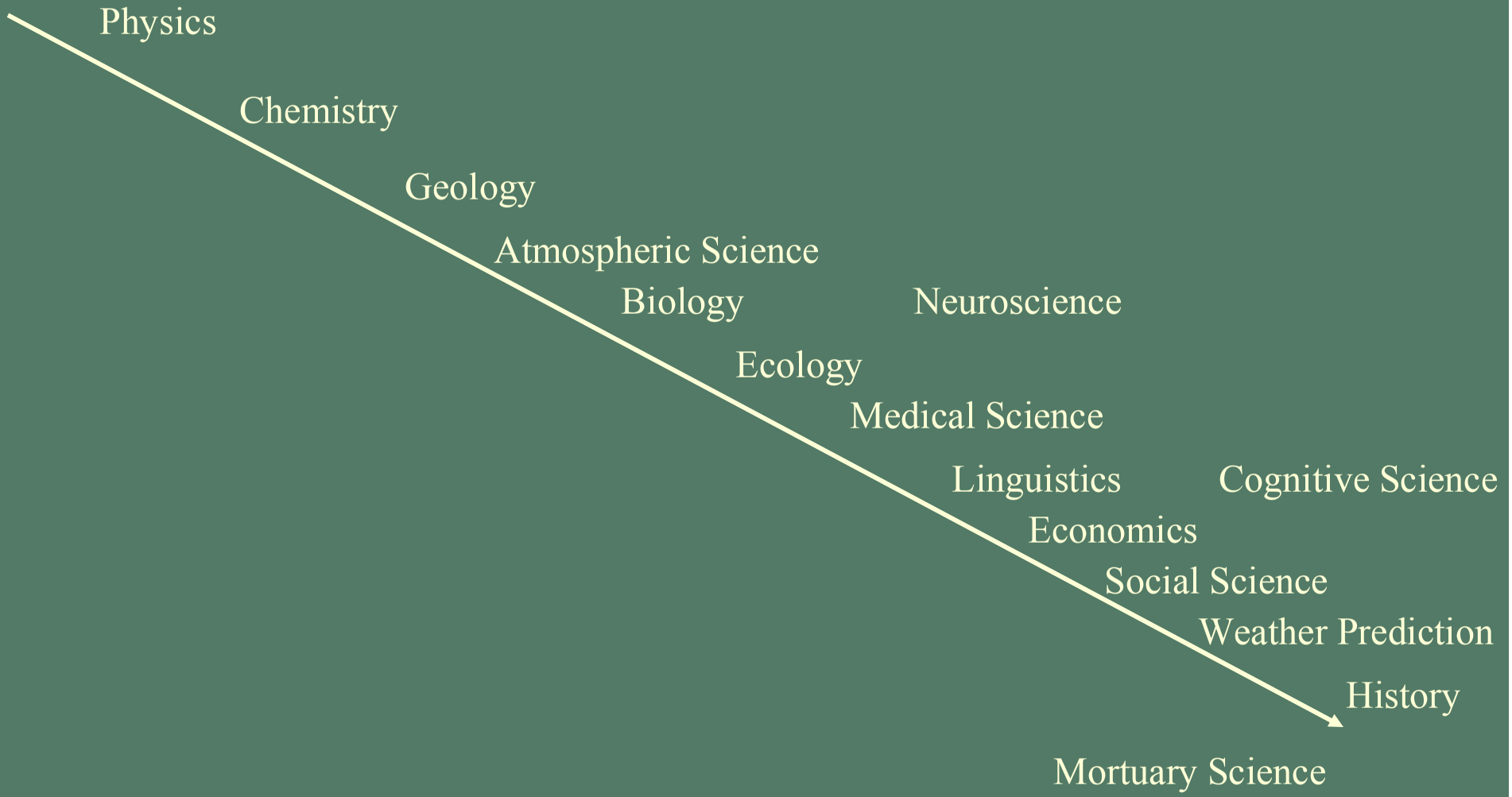
When do paradigms change?

- the current paradigm "fails"
- a "better" alternative is proposed

So, is science "objective"?

*See, e.g., Meadows, p. 162, especially Emerson quote.

Basic Principles : what science is, what it isn't



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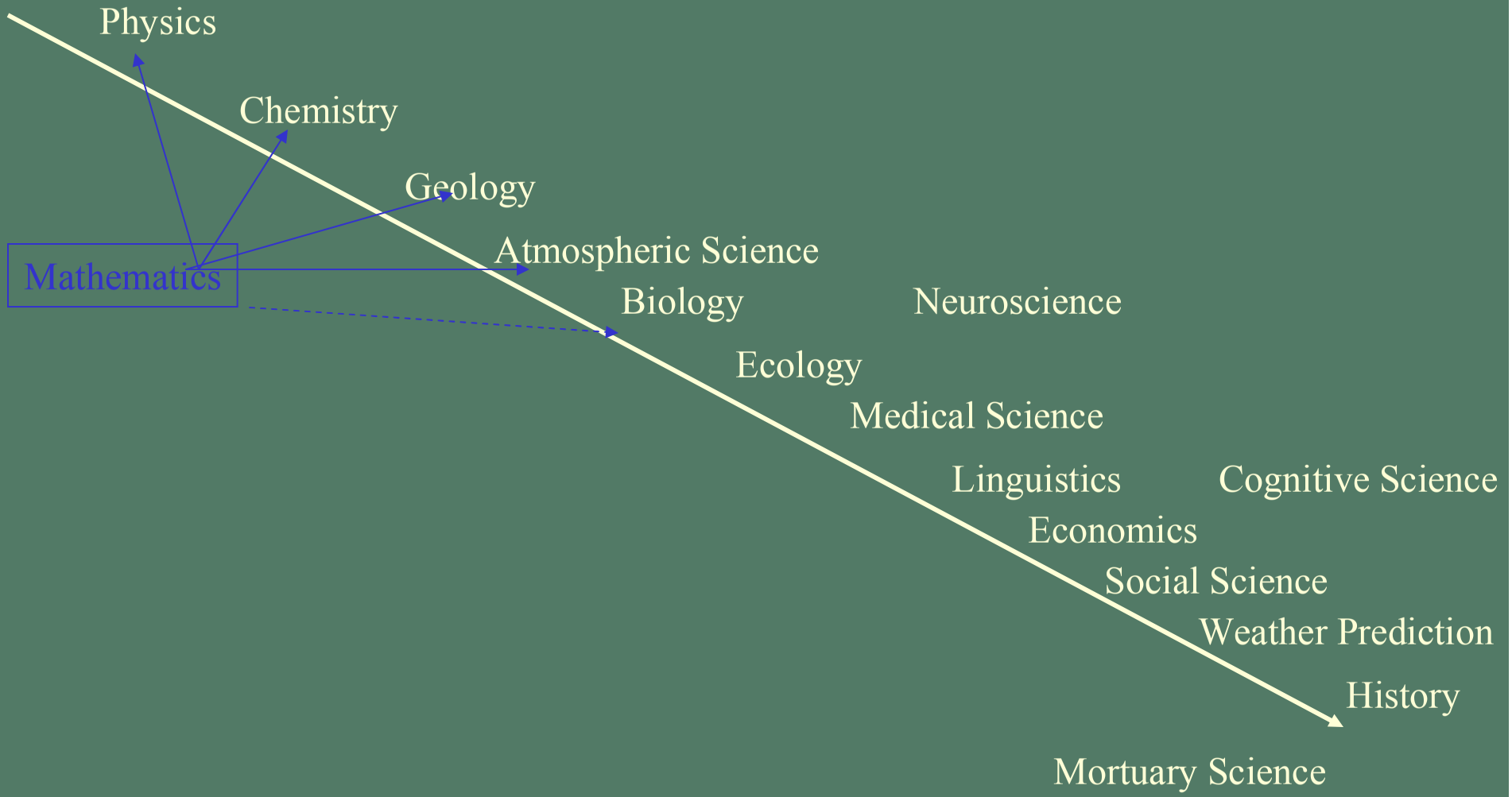

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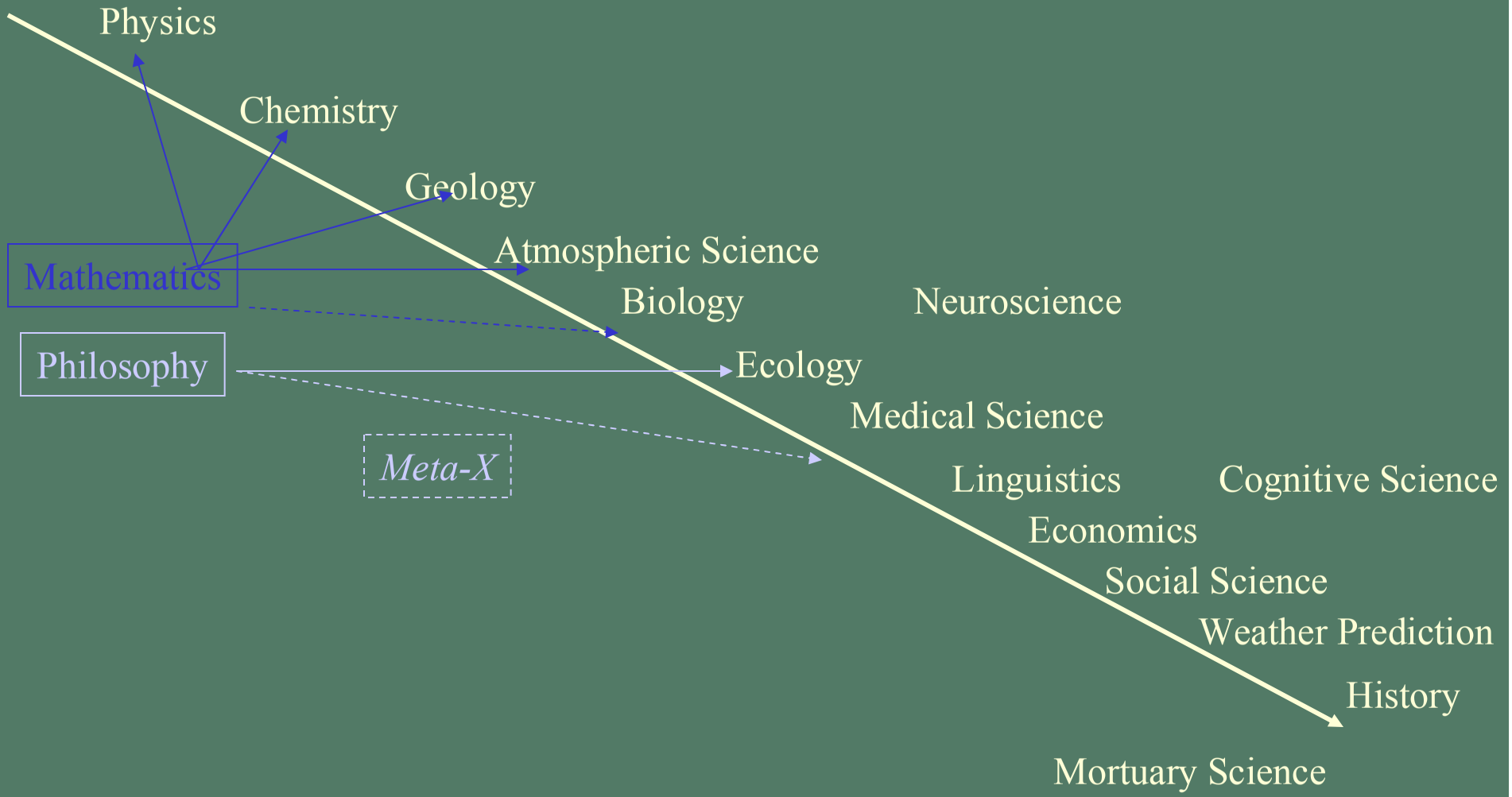
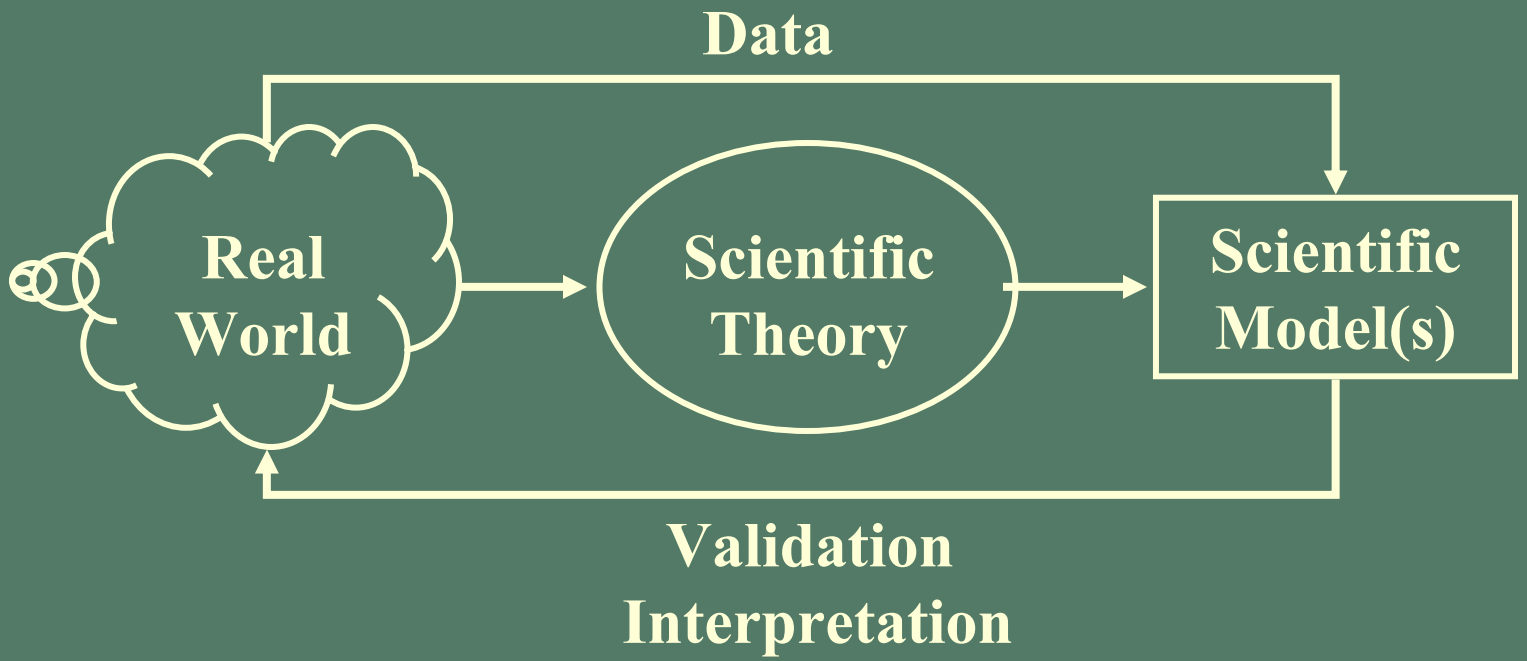


Scientific Paradigms

Scientific Models

how they relate to scientific theory and the world



Science is inductive. Are models inductive, too?

Scientific Models

What constitutes a model?

A formulation (conceptual, mathematical, computational)
Of some phenomenon (natural, built,….)
yielding an answer to a what is, what if, how … question

Some examples?

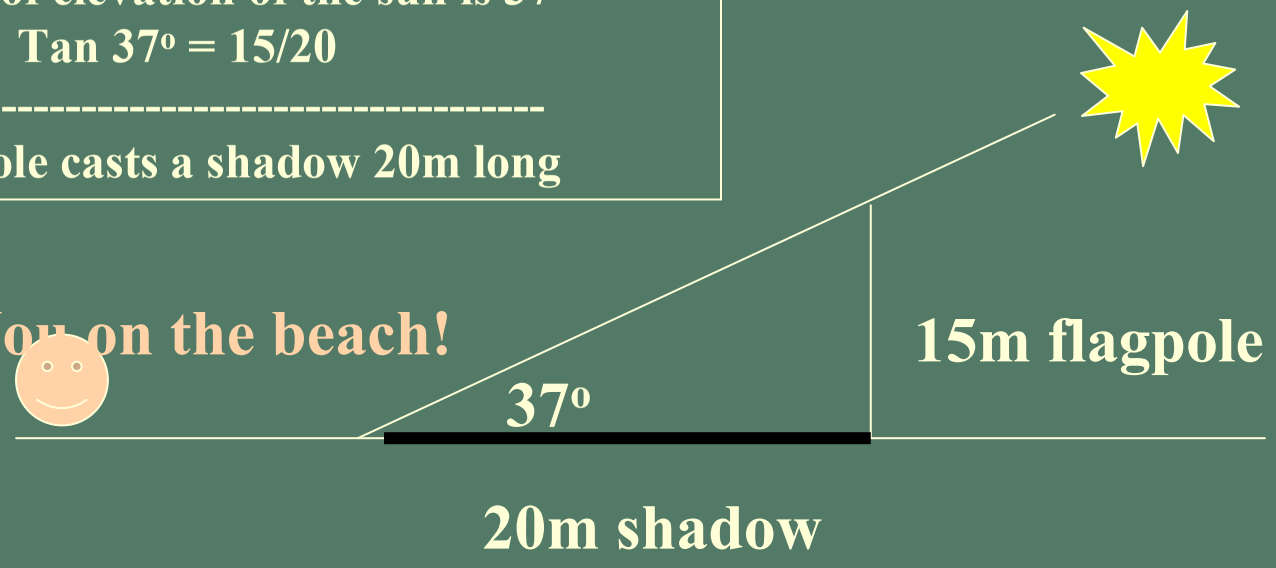
Some Kinds of Scientific Models

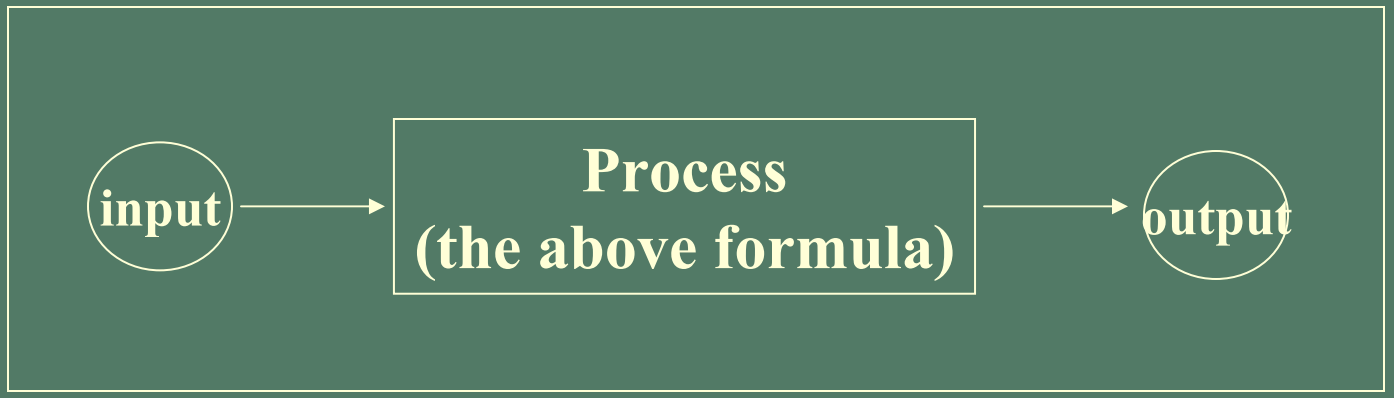
- **Conceptual Model (panarchy)**
- **Mathematical Model**
  - **what is the length of the shawdow (or the flagpole)**
  - **natural system *X ~ some mathematical fcn*, use it to predict x**
- **Statistical Model**
  - **Given my sex, height, weight, age… what is my cholesterol?**
  - **Given size of tumor, trt, age…what is recurrence likelihood?**
- **Theoretical Model**
  - **Ab initio Computational Chemistry. Given the Schroedinger equation, what does is the outer ring of electrons ….**
- **Semi-empirical theoretical models**
  - **my molecule is too big to compute from 1st principles, ….**
- **Models that simulate Real World phenomena (Meadows)**
- **Models of Models….**

Recall….

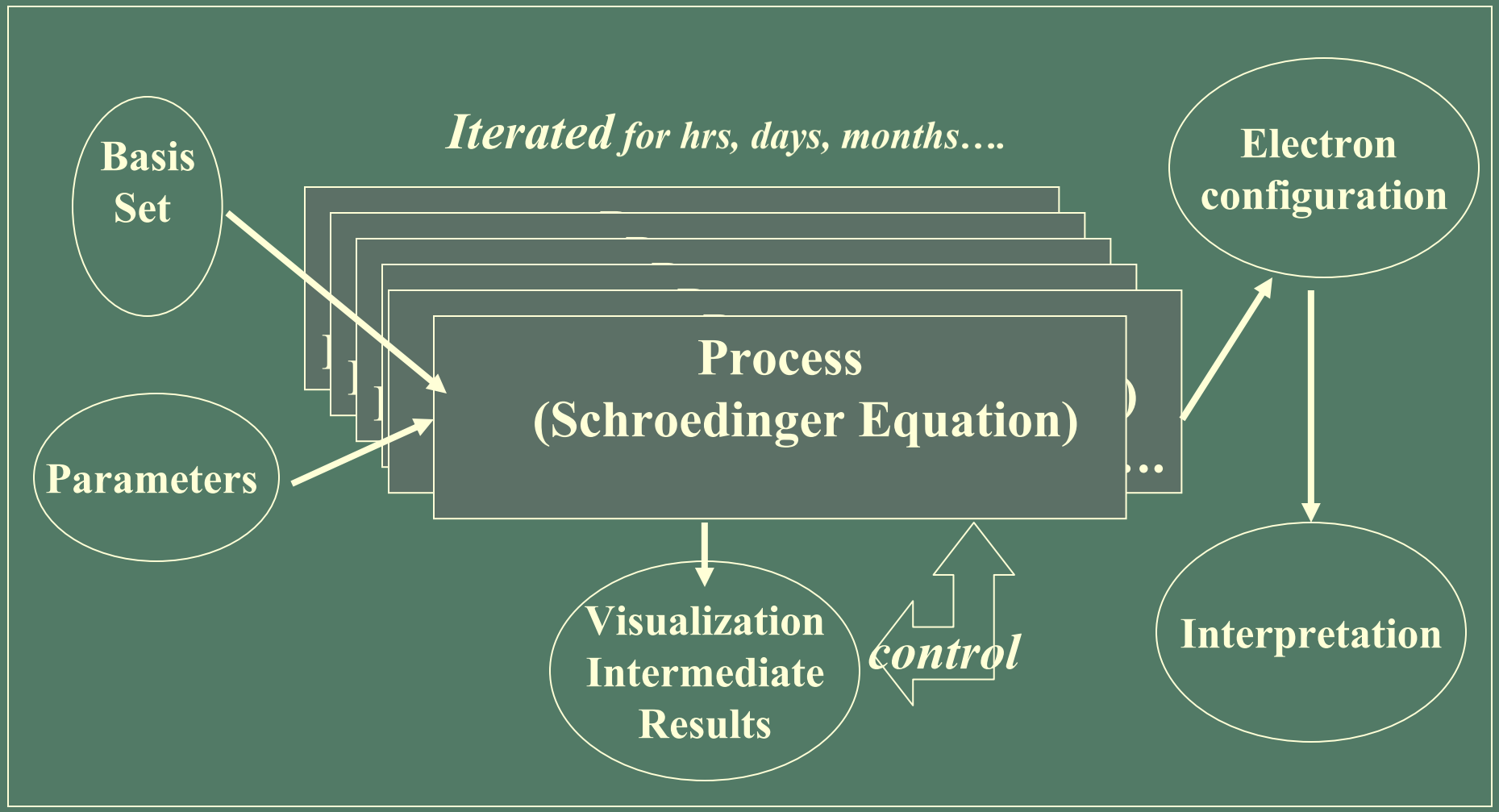
Light travels in straight lines
Trigonometric laws…
Light rays from the sun are hitting the flagpole
The flagpole is 15m high
The angle of elevation of the sun is 37^o
Tan 37^o = 15/20

The flagpole casts a shadow 20m long

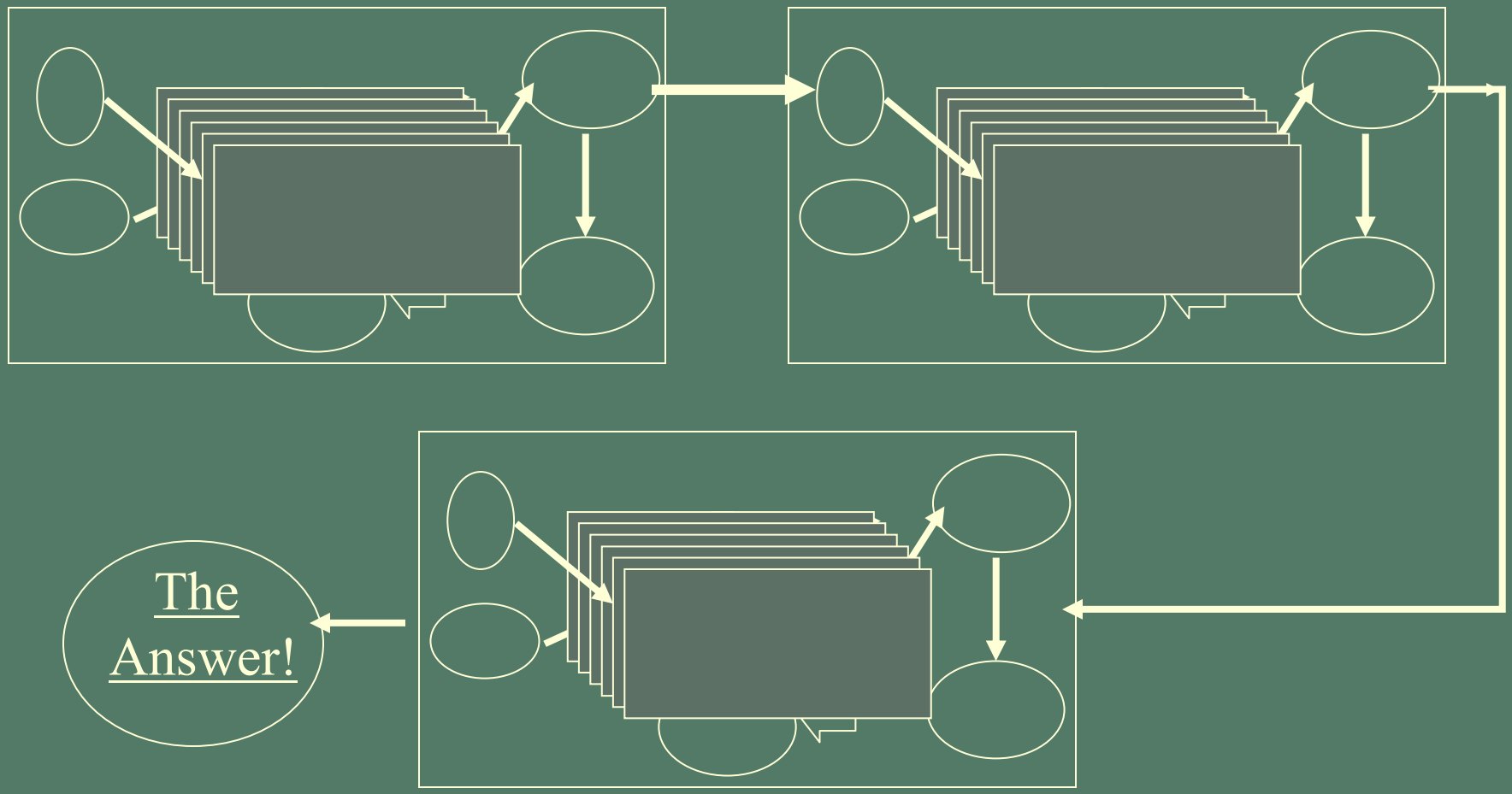




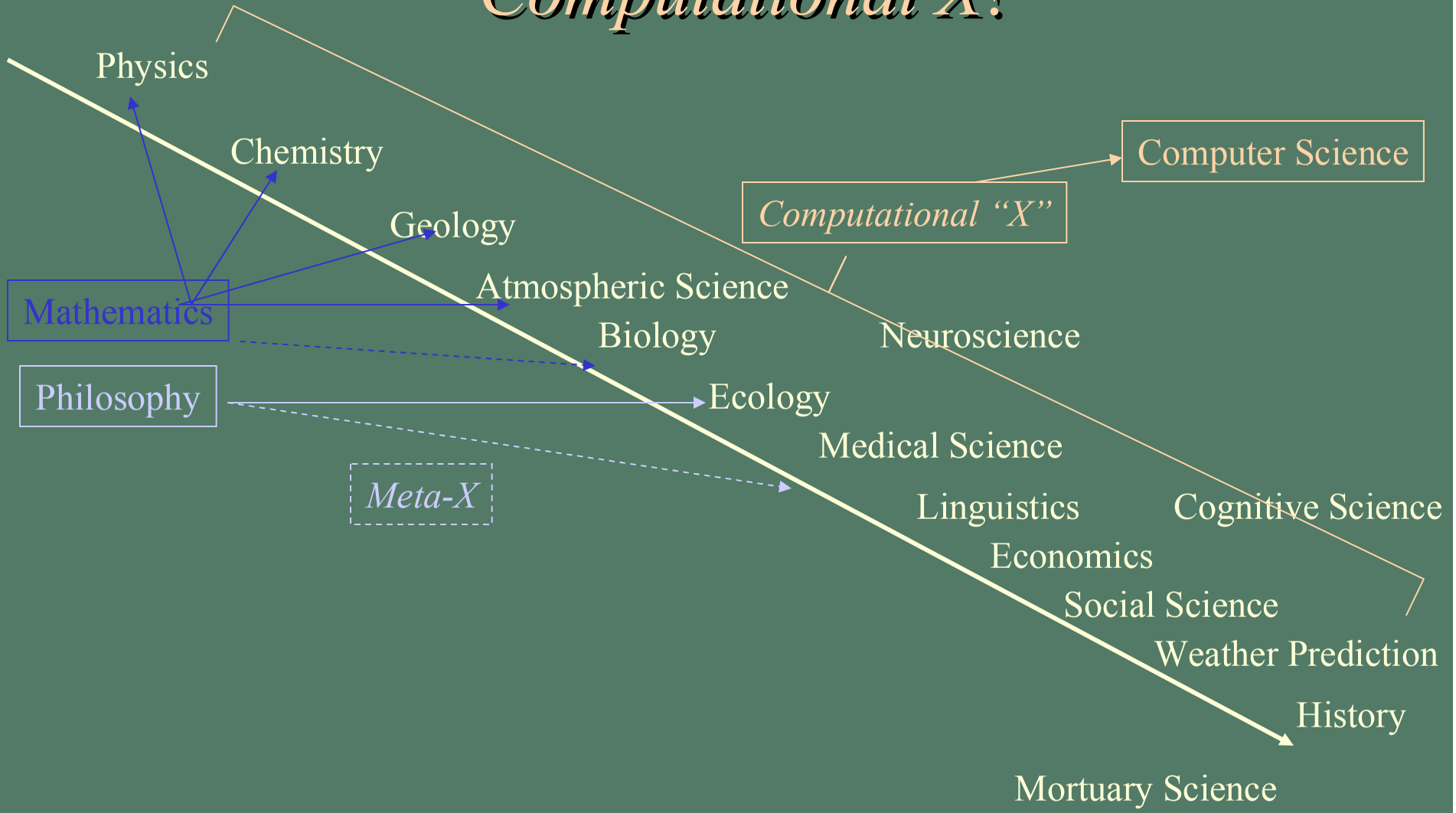
Computational Chemistry….



Model of Models….



"New" Sciences
Computational X!



An Ecological Model

Spruce Budworms, Firs, Pesticides (Holling et al, Meadows, p. 92)

The Problem….

An Ecological Model

Spruce Budworms, Firs, Pesticides (Holling et al, Meadows, p. 92)

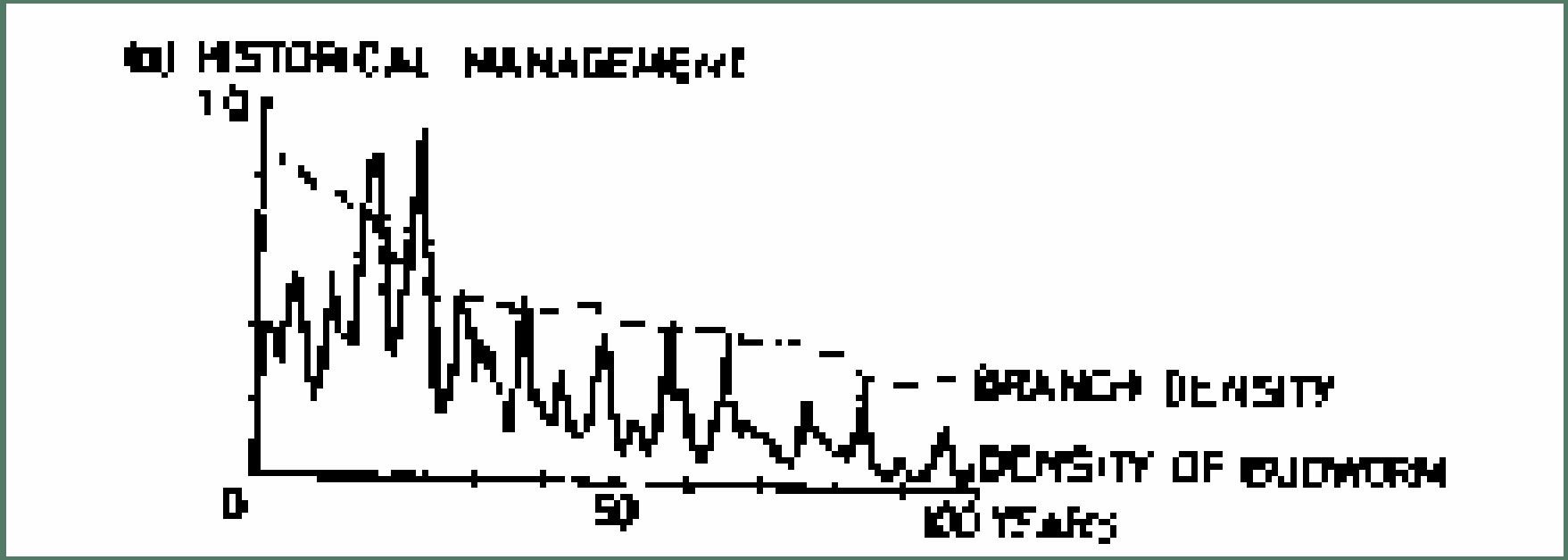
The Problem….

The spruce budworm is the most widely spread destructive forest insect of N. America, And imposes heavy defoliation & mortality on its preferred hosts, balsam fir and white spruce.

How do we "manage" these forests?

An Ecological Model

Spruce Budworms, Firs, Pesticides (Holling et al, Meadows, p. 92)



1st: Understand the Ecology, Build an Ecological Model
(don't start with the decision making environment)

relevant ecological variables?

- **tree species** birch, white/black spruce, balsam fir, hardwoods
- forest density
- Foliage condition
- age class structure

What acts can be applied?

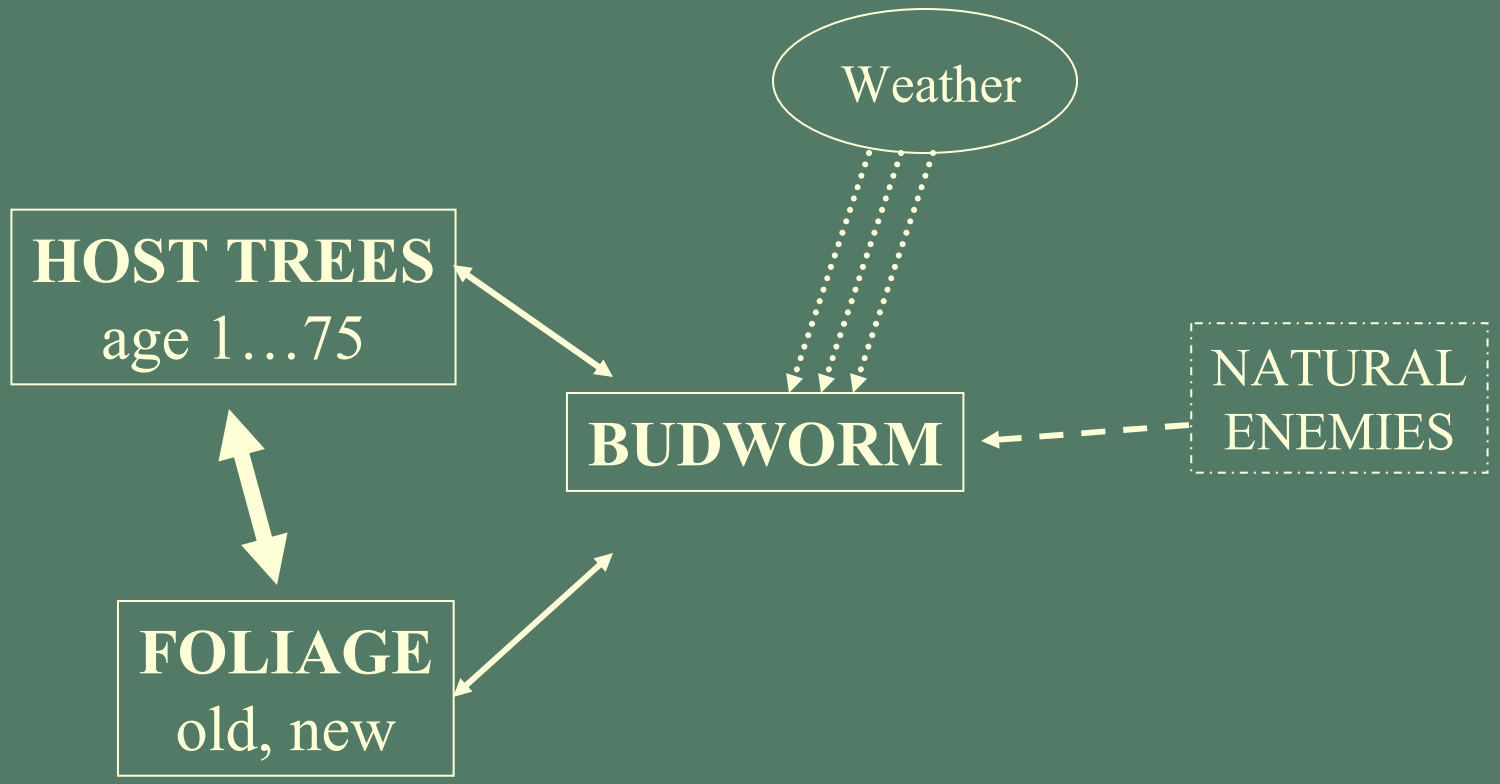
- control insects pop, tree harvest, planting

What indicates policy performance?

- employment, cost of harvest, timber loss, environmental indicators

Time (horizon, resolution) and Space (area, resolution)

An Ecological Model
Key Variables



Decisions on Bounding the Problem

- Key Variables
- Policy domain
- Time horizon – 80-160 years
- Time resolution – 1 yr, w/ implicit seasonal causation
- Space area – 4.5 x 10^6 ha.
- Space resolution – 265 regions of 17,000 ha.

A simple model?

Decisions on Bounding the Problem

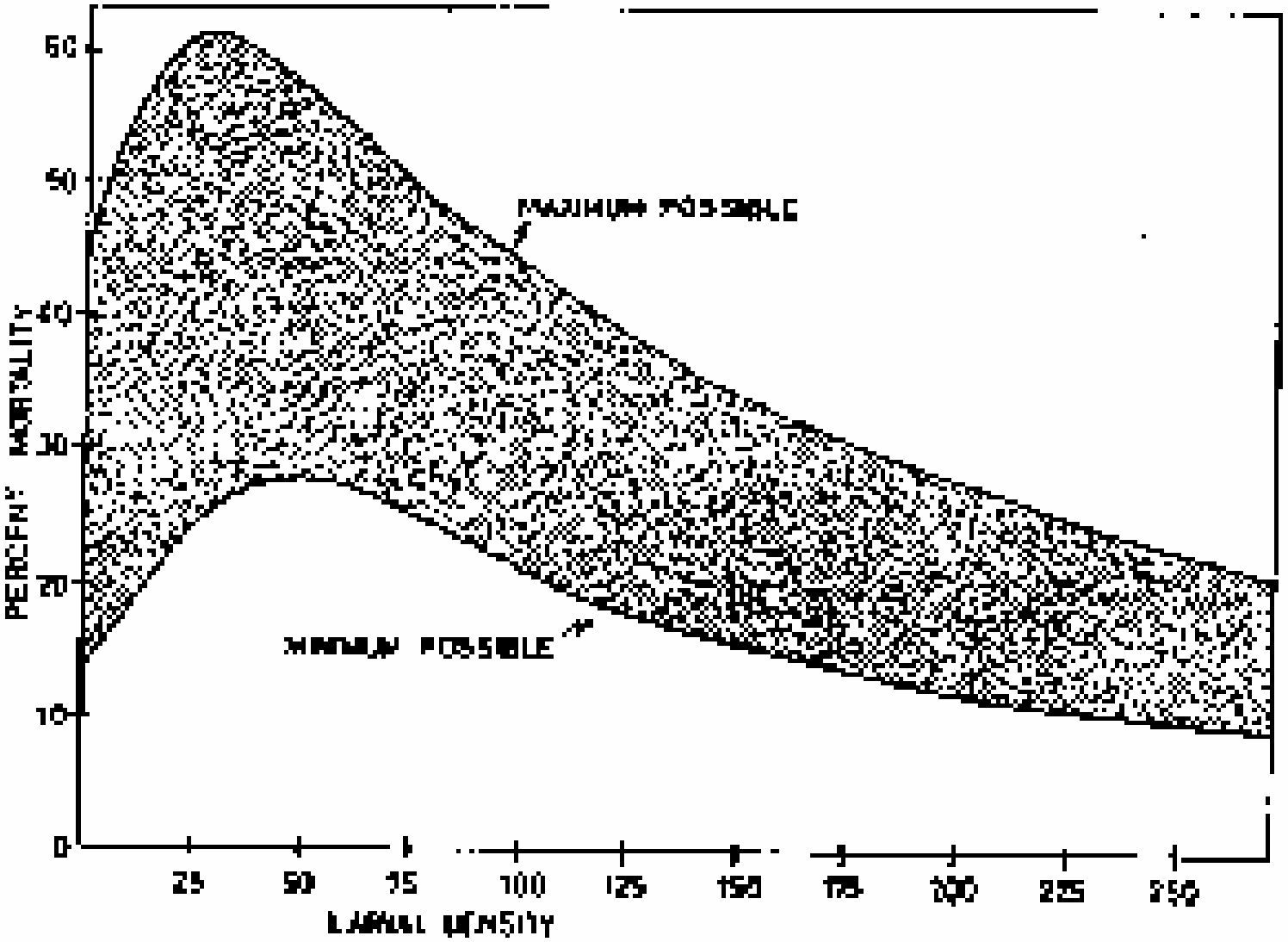
- Key Variables
- Policy domain
- Time horizon – 80-160 years
- Time resolution – 1 yr, w/ implicit seasonal causation
- Space area – 4.5 x 10^6 ha.
- Space resolution – 265 regions of 17,000 ha.

20,935 variables!

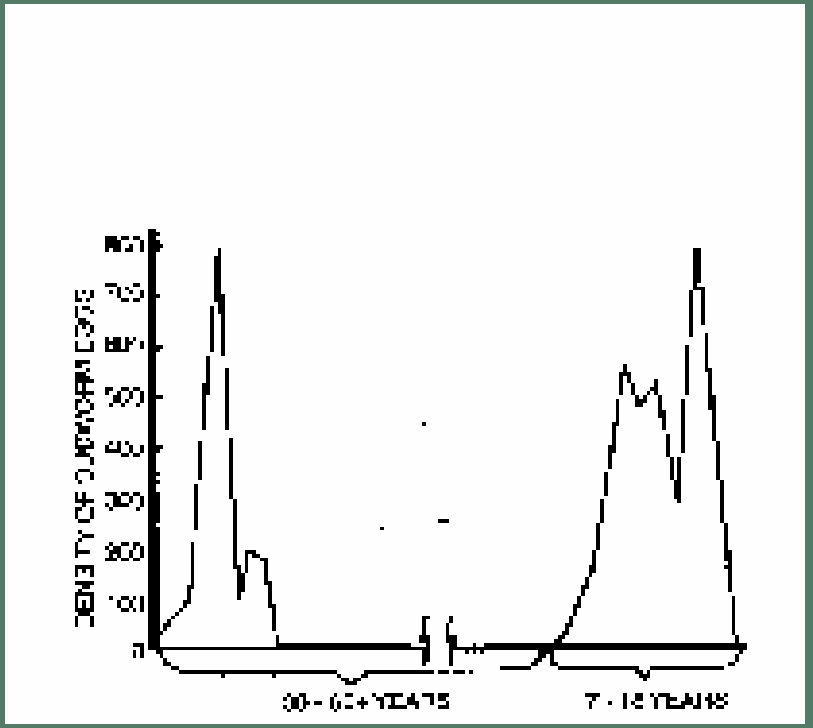
Identify Component Processes
(The Process Cycle of the Natural System)
Causal Resolution!

Fig 4, see handout.

Identify Component Processes (effect of vertebrate predators)



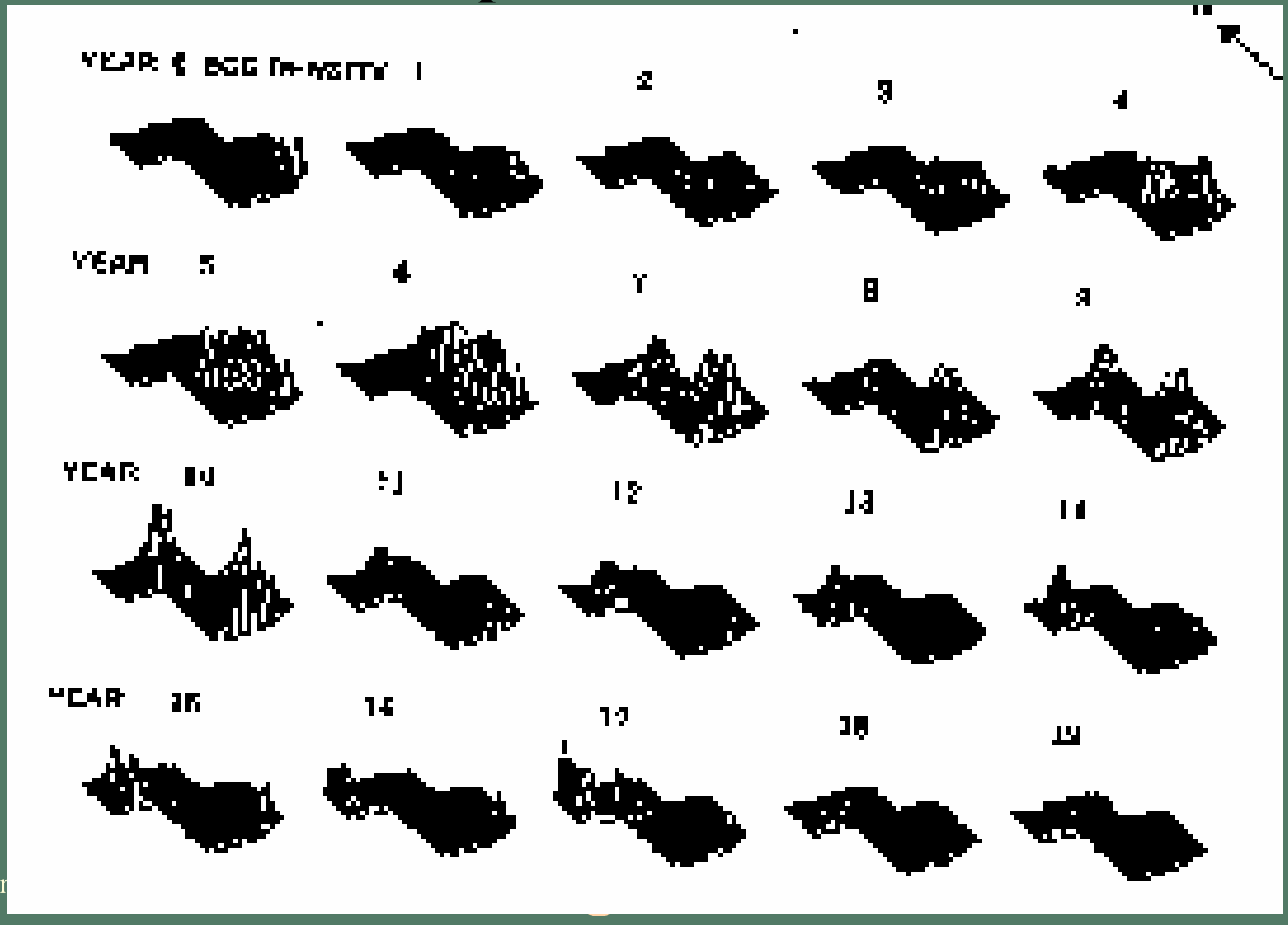
Validate the Model
(Predicted Outbreak Pattern – no mgmt)



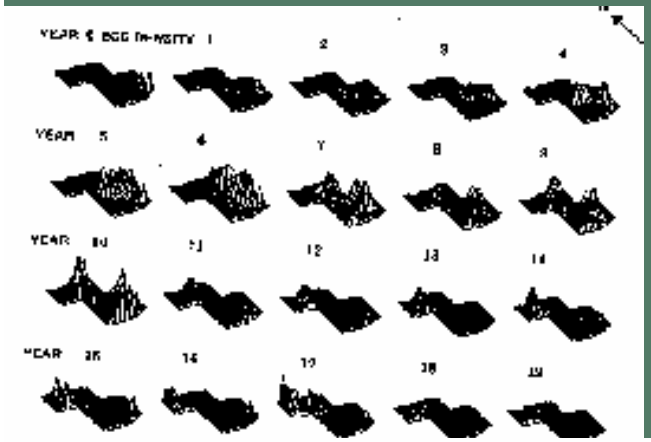
actual outbreak pattern

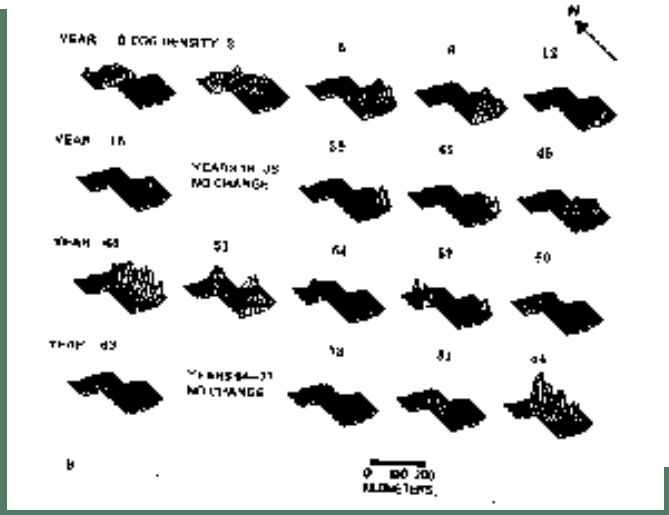
Predicted Outbreak Pattern (fig. 6 handout)

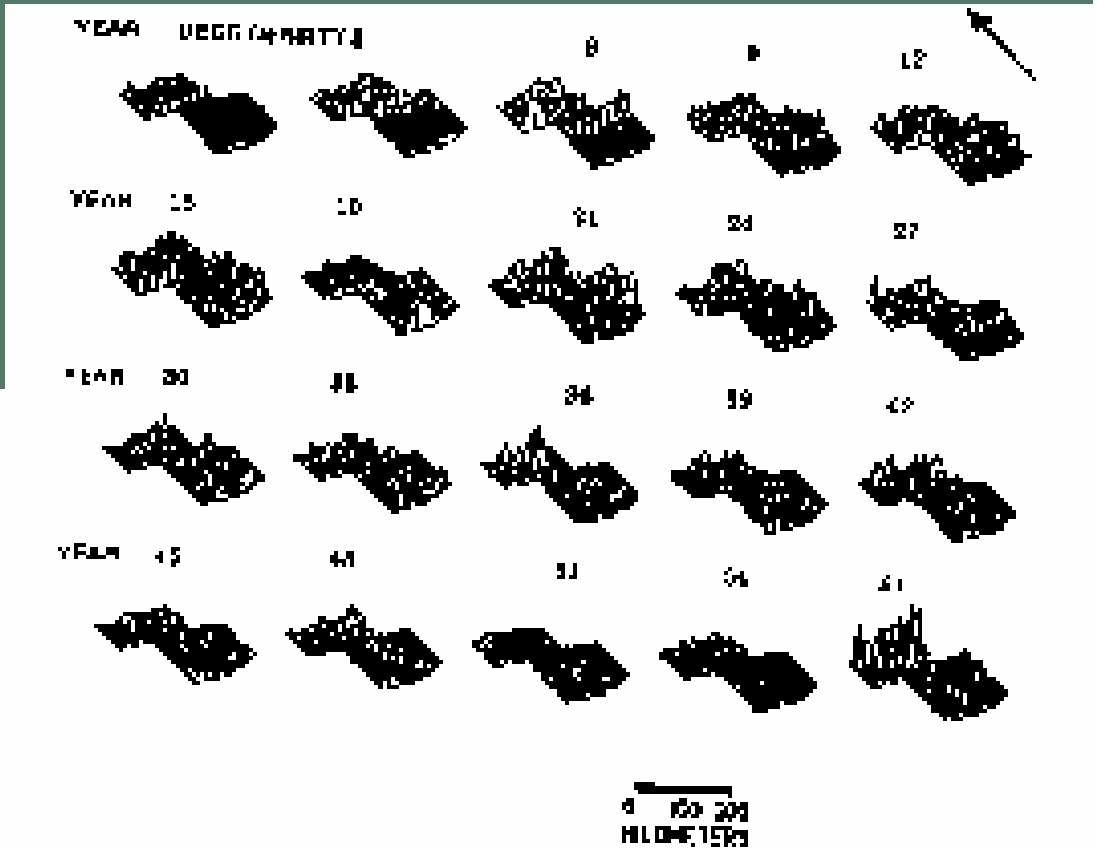
Validate the Model
Examine Spatial Outbreak Patterns



Compare Spatial Outbreak Patterns







No Mgmt, no harvesting

Historical mgmt conditions (insecticide spraying)

Validate the Model
Why?

Are we trying to show that the model is right?

Some conclusions about the Ecological Process

Simplify and Compress Model Results

Why?

Simplify and Compress Model Results

Why?

Confirm initial conclusions
gain explanatory power….

Simplify and Compress Model Results

Why?

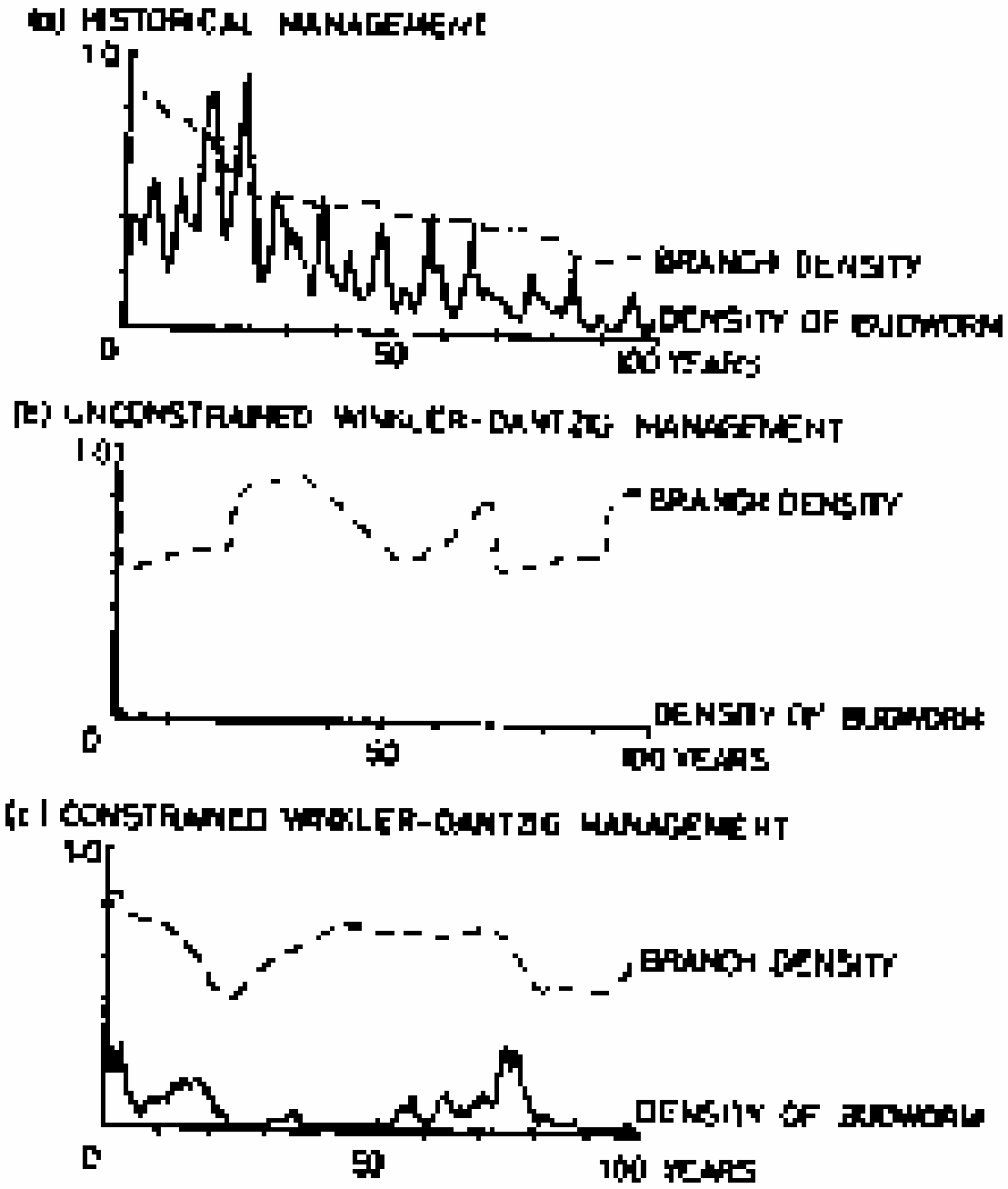
Confirm initial conclusions gain explanatory power….

How?

Simplify and Compress Model Results

Why? Confirm initial conclusions
gain explanatory power….

How? Growth rate curves,
topological models,
Equilibrium manifolds



Develop (and Compare) Policy Alternatives

Develop (and Compare) Policy Alternatives

Is the goal of policy design
the design of optimal policy

Evaluate Policy Performance

Figs 16, 17, 18

Modeling Rules

1. 1st step: analyze decision making environment

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2. The model should be as comprehensive as possible

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5. a complex system requires a complex model

Modeling Rules Myths

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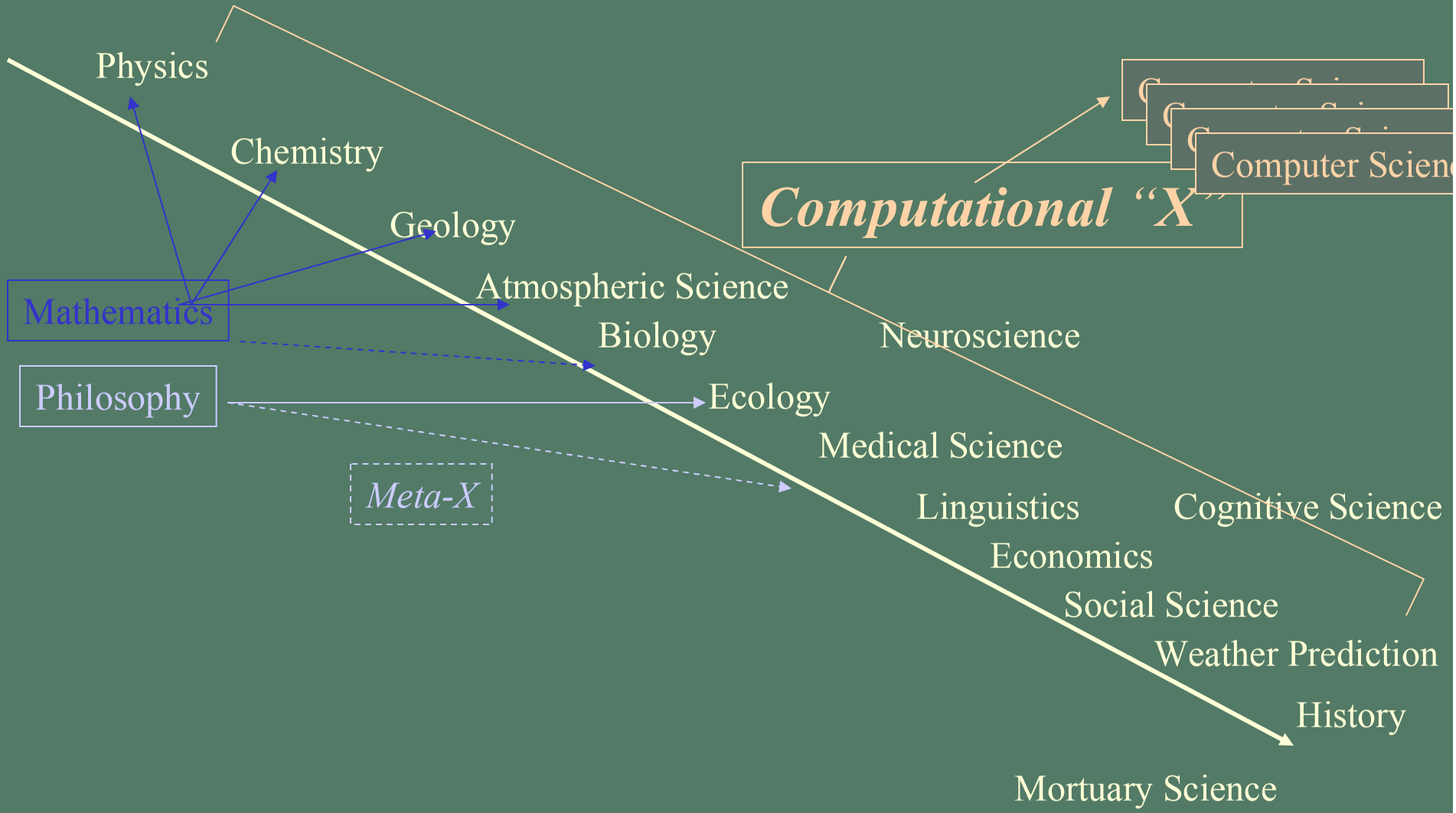
New Emerging Science(s)



Systems Thinking….
Let's do a model