Formal Modelling (of social phenomena)

A Specialist Method

MRes, MMUBS

(slides, handout etc. at cfpm.org/mres)

Me – Bruce Edmonds

- *Senior Research Fellow* and *Director* of the Centre for Policy Modelling (CFPM)
- Since 1994 developed the CFPM with Scott Moss as a research centre specialising in agent-based social simulation (http://cfpm.org)
- Now one of the leading such teams in this area in the world, e.g. major UK and EU projects
- One of the few centres in complexity science in the UK for a long time
- Editing a handbook: "*Simulating Social Complexity*" for Springer due out in 2009

What is a model?

Something, A, that is used to understand or answer questions about something else, B

- e.g: A scale model to test in a wind tunnel
- e.g: The official accounts of a business
- e.g: The minutes of a meeting
- e.g: A flow chart of a legal process
- e.g: A memory of a past event
- e.g: A computer simulation of the weather
- e.g: The analogy of fashion as a virus

Models usually abstract certain features and have other features that are irrelevant to what is modelled

What is a *formal* model?

Something that (in theory) can be written down precisely, whose content is specified without ambiguity

- e.g: mathematical/statistical relations, computer programs, sets of written rules

Can make exact copies of it

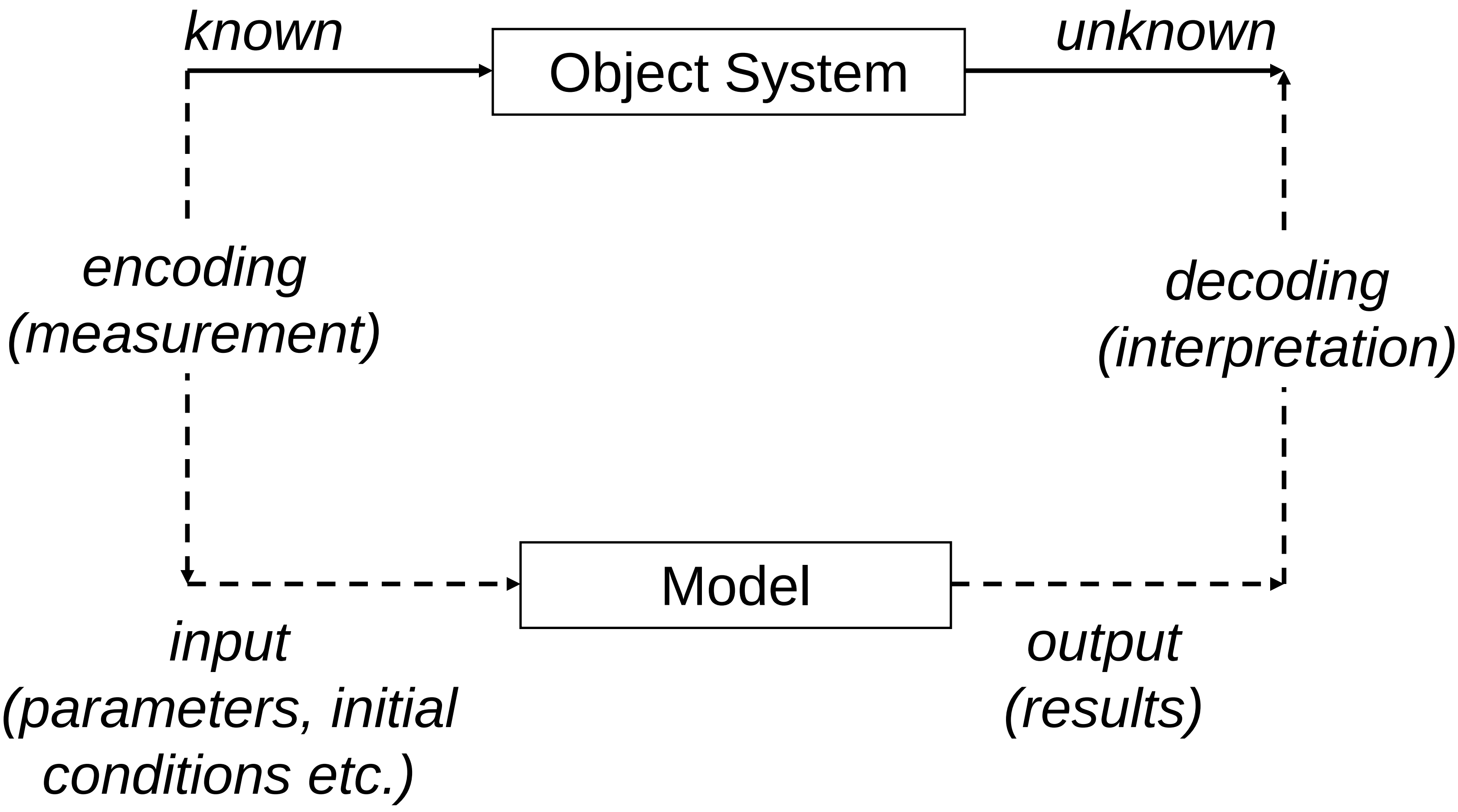
Agreed rules for interpreting/using them

Can make *certain* inferences from them

- *Not*: an analogy, a memory, a physical thing

*There **are grey areas**, degrees of formality*

The Modelling relation



Modelling Purposes

All modelling has a purpose (or several)

Including:

- Description
- Prediction
- Establishing/suggesting explanations
- Illustration/communication
- Exploration
- Analogy

These are frequently conflated!

The Modelling Context

All modelling has a context

- The background or situation in which the modelling occurs and should be interpreted
- Whether explicit or (more normally) implicit
- Usually can be identified reliably but not described precisely and completely
- The context inevitably hides many implicit assumptions, facts and processes

Modelling only works if there is a reliably identifiable context to model *within*

Descriptive **formal models**

Describes in precise terms the state(s) of what is observed

- e.g. the average height of a group of people
- e.g. The words that an individual said
- e.g. the correlation of height with arm span

A sequence of descriptive “snap-shots” can describe aspects of a process

- e.g. A Time series of average wages in UK

Evidence is often recorded as descriptive formal models

All sets of “data” are descriptive models

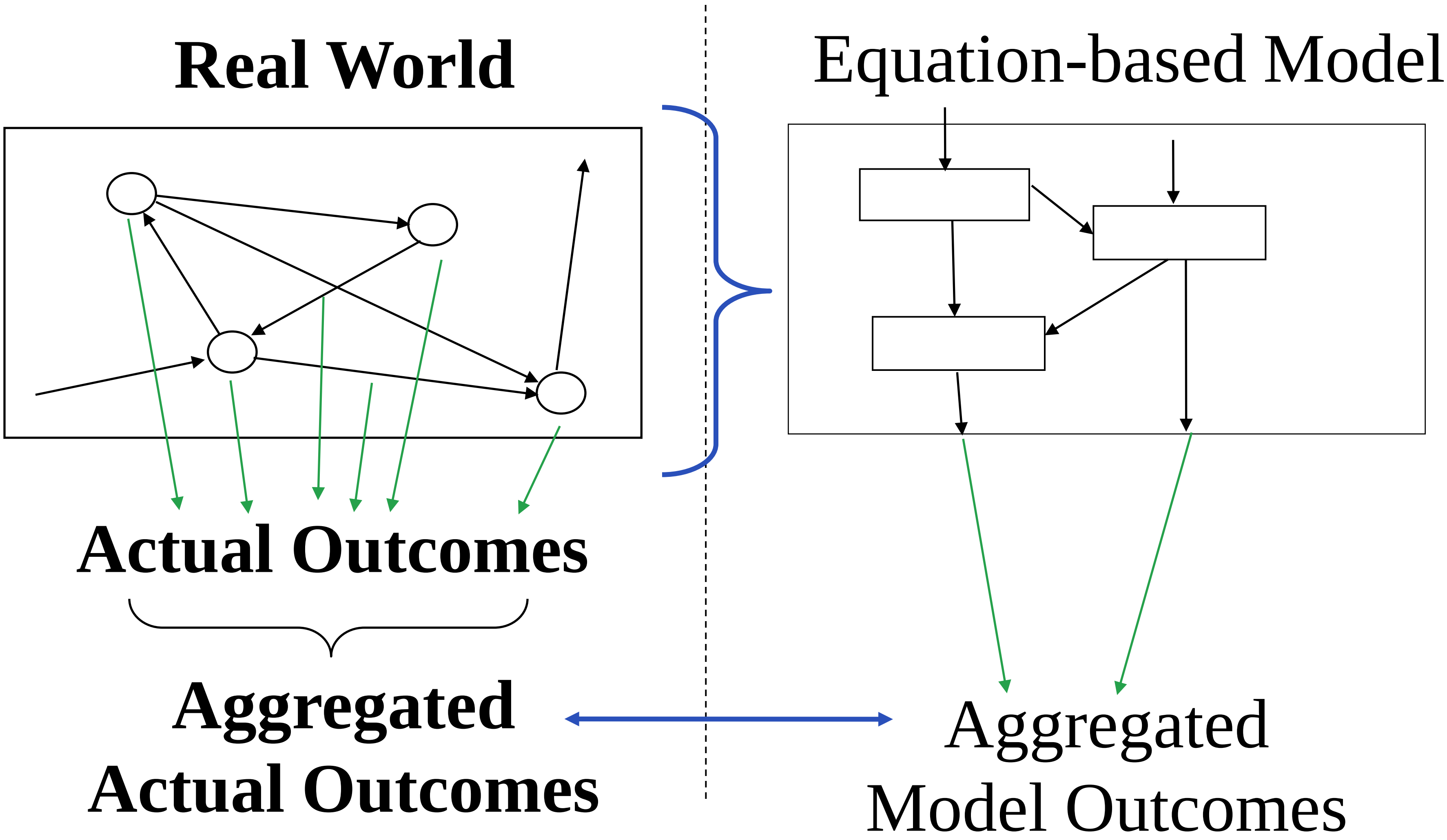
Analytic **formal models**

Where the model is expressed in terms that allow for formal inferences about its general properties to be made

- e.g. Mathematical formulae
- Where you don't have to compute the consequences but can *derive* them logically
- Usually requires numerical representation of what is observed (but not always)

Only fairly "simple" mathematical models can be treated analytically – the rest have to be simulated/calculated

Equation-based or statistical modelling



Statistical **formal models**

Where the collective properties of a group are modelled, eliminating some assumed randomness between individuals

- *Descriptive statistics* just summarise aspects of a group that are assumed to be representative of that group
- *Generative statistics* are a model of some process done using the combination of a target trend plus additional randomness

Statistical models often rely on the "Law of Large Numbers" – that certain aspects are irrelevant and can be treated as random

An analogy: An Ideal Gas

- ***The idea***: although the motion of each particle in the gas is not predictable, *taken together* the gas obeys regular laws and is predictable
- This is an idea that has seeped into the social sciences
- (Asimov 1962, page 7): "*Psycho-history dealt not with man, but with man-masses. It was the science of mobs; mobs in their billions ... The reaction of one man could be forecast by no known mathematics; the reaction of a billion is something else again*"

Problems with this idea…

- This only “works” if there is a signal that is separable from noise and…
  - …the “noise” is essentially random (Law of Large Numbers)…
  - …or can be safely ignored.
- But it is almost impossible to know either of these for sure!
- e.g. in stock markets, what seems to be random noise is rather the result of subtly linked social processes
- In other words, the context of modelling is inadequate and “leaky”

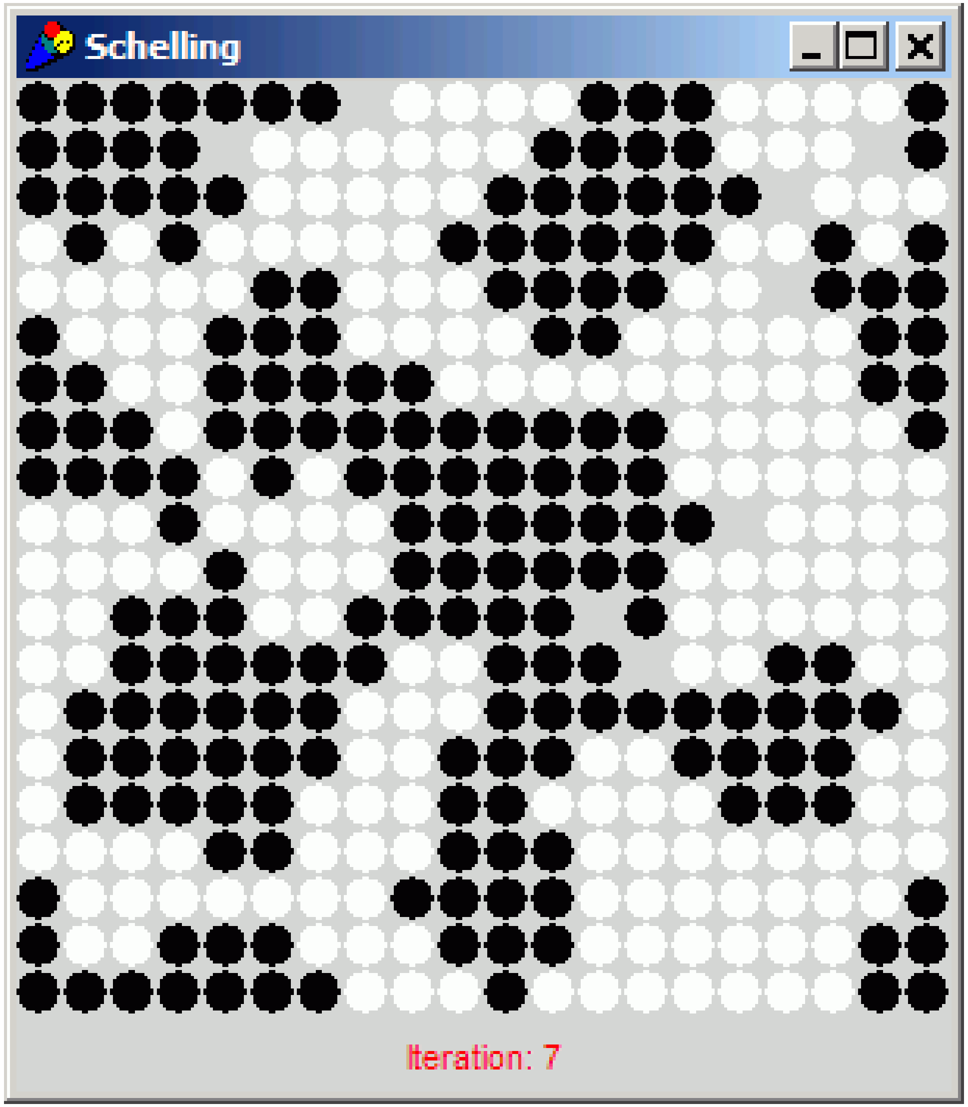
Computational **formal models**

Where a process is modelled in a series of precise instructions (the program) that can be "run" on a computer

- The same program always produces the same results (essentially) but...
- ...may use a "random seed" to randomise certain aspects
- Can be simple or very complex
- Often tries to capture more "qualitative" aspects of social phenomena

Example of Computational Model:
Schelling's Segregation Model

Schelling, Thomas C. 1971. Dynamic Models of Segregation. *Journal of Mathematical Sociology* **1**:143-186.

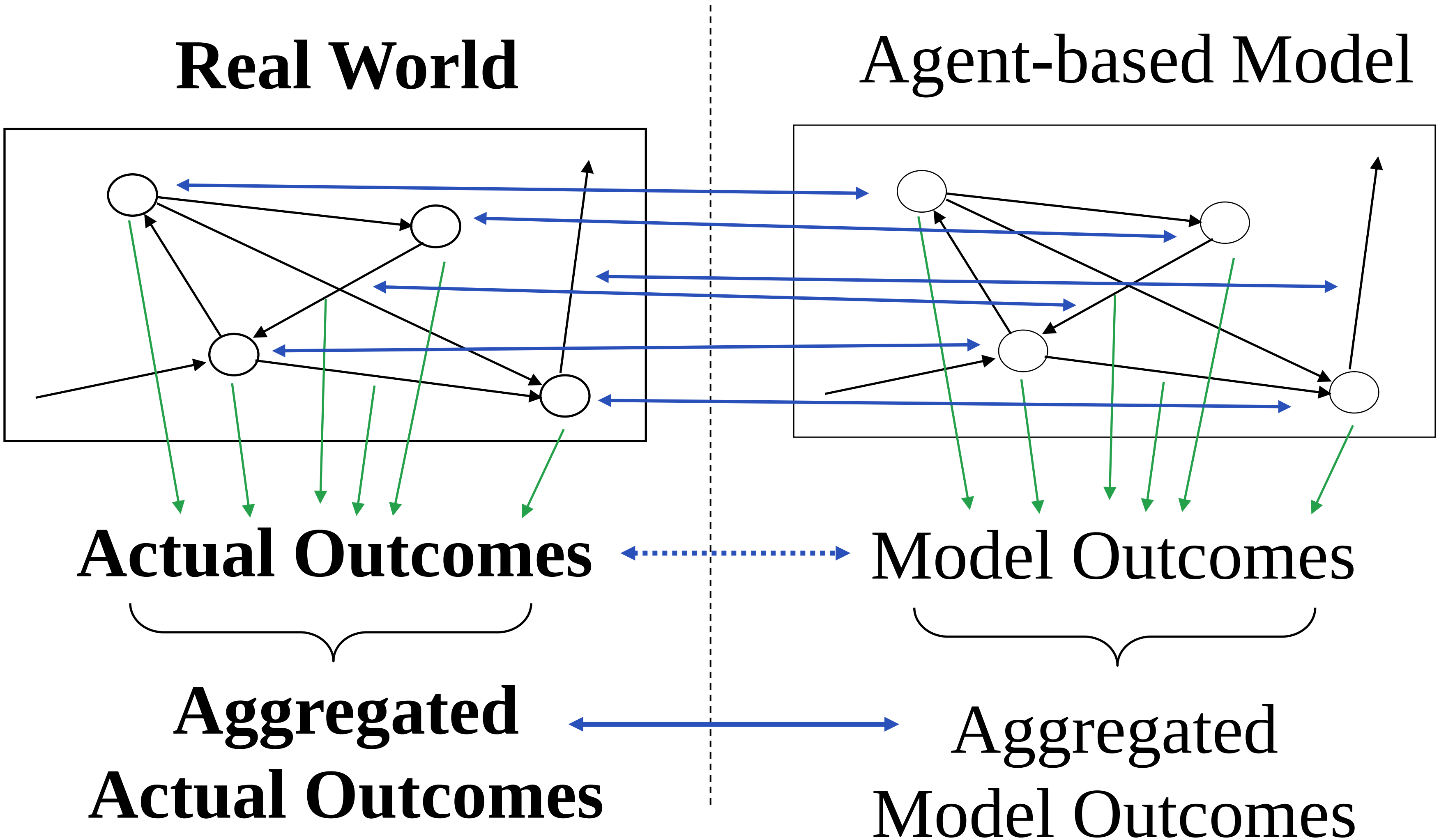


Rule: each iteration, each dot looks at its 8 neighbours and if less than 30% are the same colour as itself, it moves to a random empty square

Segregation can result from wanting only a few neighbours of a like colour

Agent-based simulation

Manchester Metropolitan University



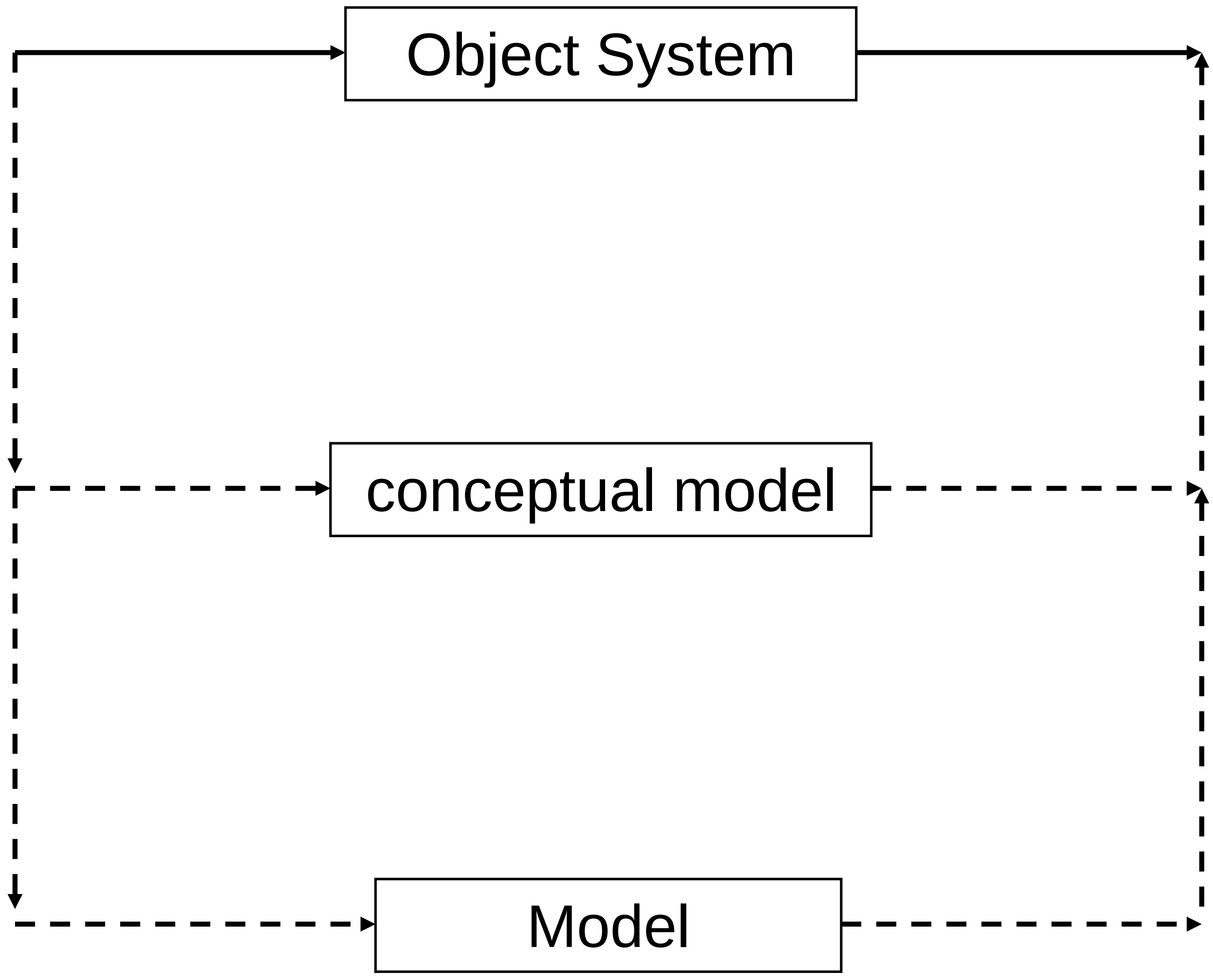
Characteristics of agent-based modelling

- Computational descriptions of processes
- Not analytically tractable
- More context-dependent…
- … but assumptions are much less drastic
- Detail of unfolding prcesses accessible
  – more criticisable (including by non-experts)
- Used to explore inherent possibilities
- Validatable by expert opinion *and* data
- Often very complex themselves

A trouble with such simulations

- Is that they are highly suggestive
- Once you play with them a lot, you start to "see" the world in terms of you model – a strong version of Kuhn's *theoretical spectacles*
- They can help persuade beyond the limit of their reliability
- They may well not be directly related to any observations of social phenomena

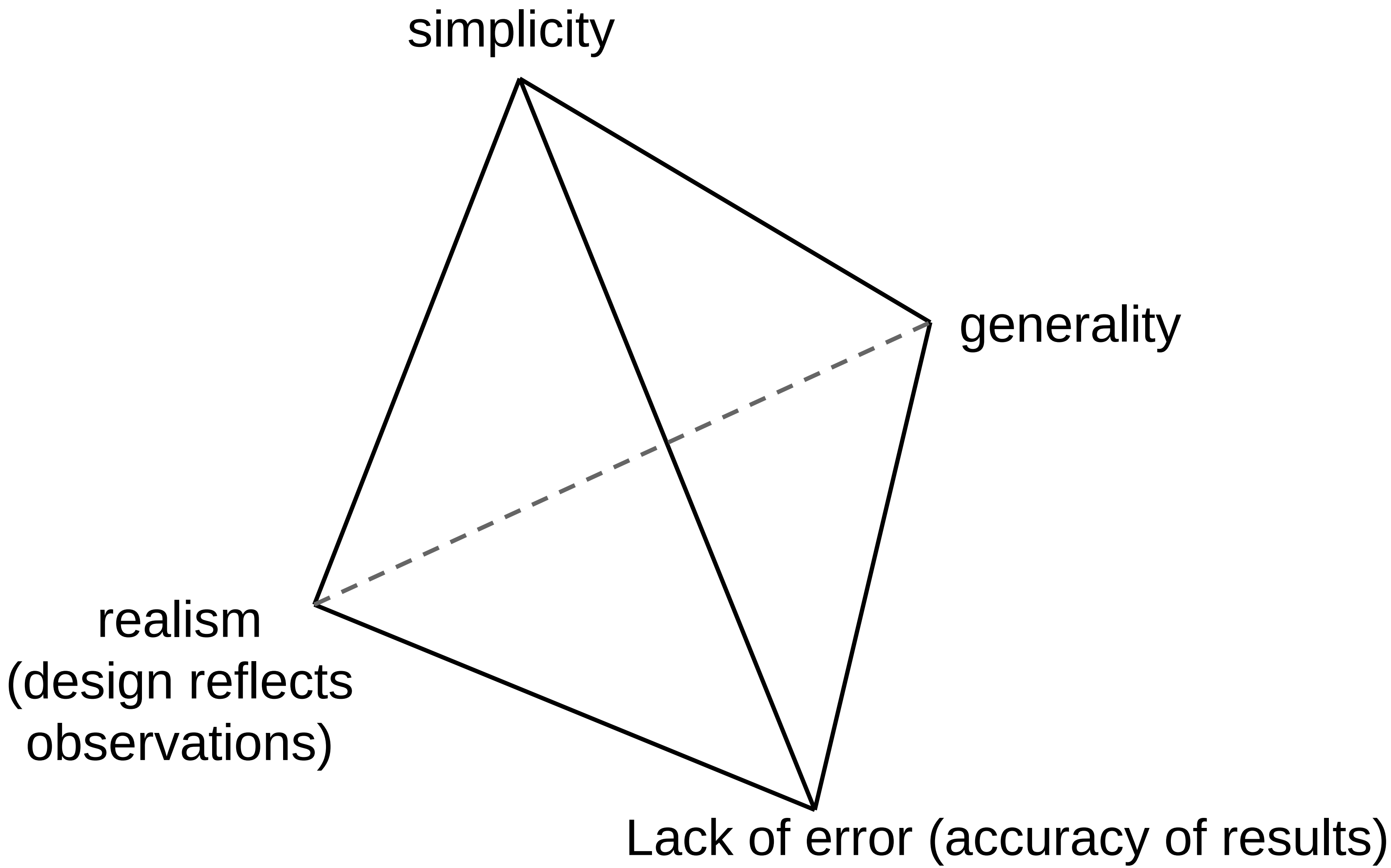
Modelling a concept of something



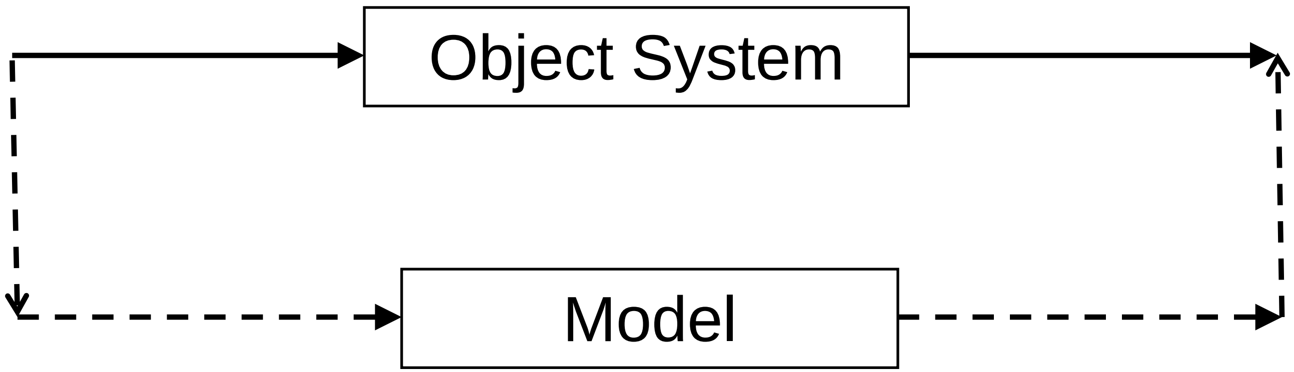
Some Criteria for Judging a Model

- Soundness of design
  - w.r.t. knowledge of how the object works
  - w.r.t. tradition in a field
- Accuracy (lack of error)
- Simplicity (ease in communication, construction, comprehension etc.)
- Generality (when you can safely use it)
- Sensitivity (relates to goals and object)
- Plausibility (of design, process and results)
- Cost (time, effort, etc.)

Some modelling trade-offs

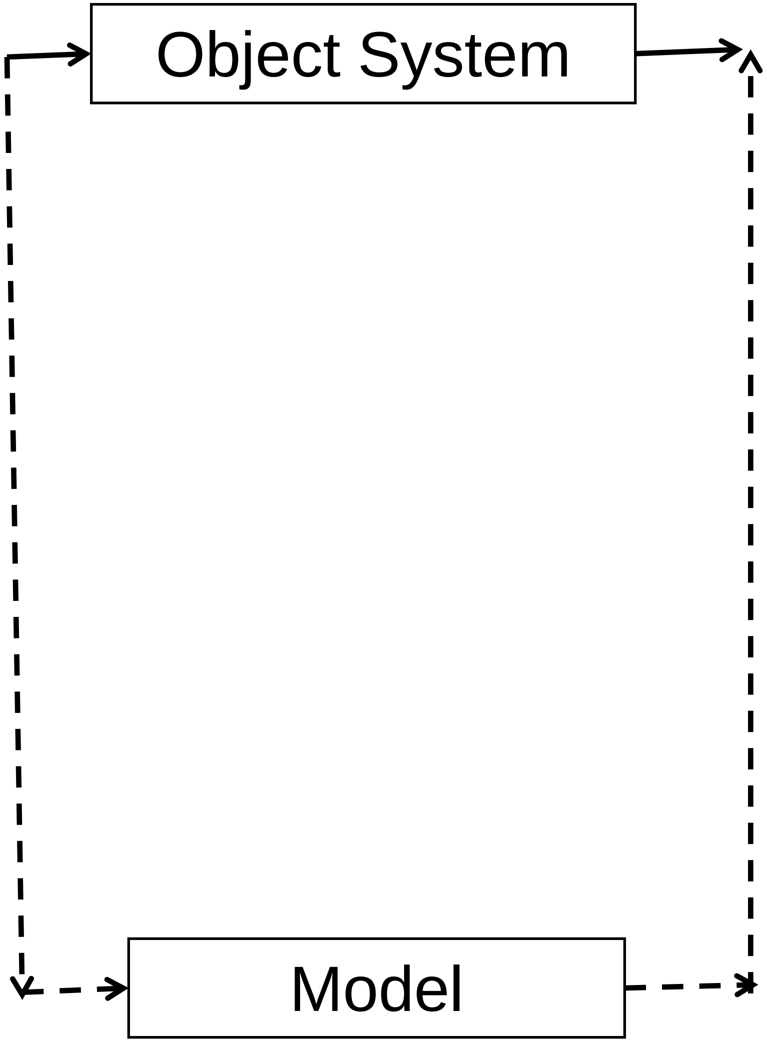


Complex Descriptive Model



Complex but directly relevant model – strong mapping to model, weak inference within model

Abstract Theoretical Model

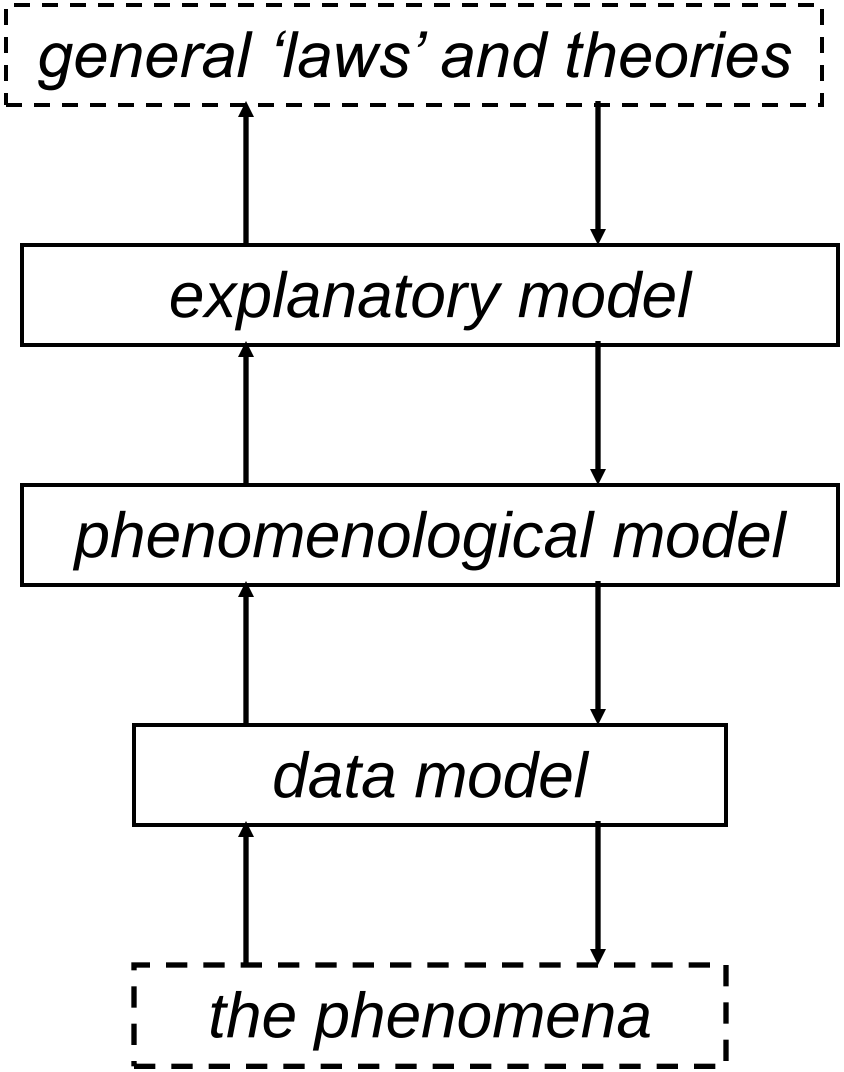


Simple model but abstract – strong inference within model,
but weak mappings to and from the model

Semantic complexity

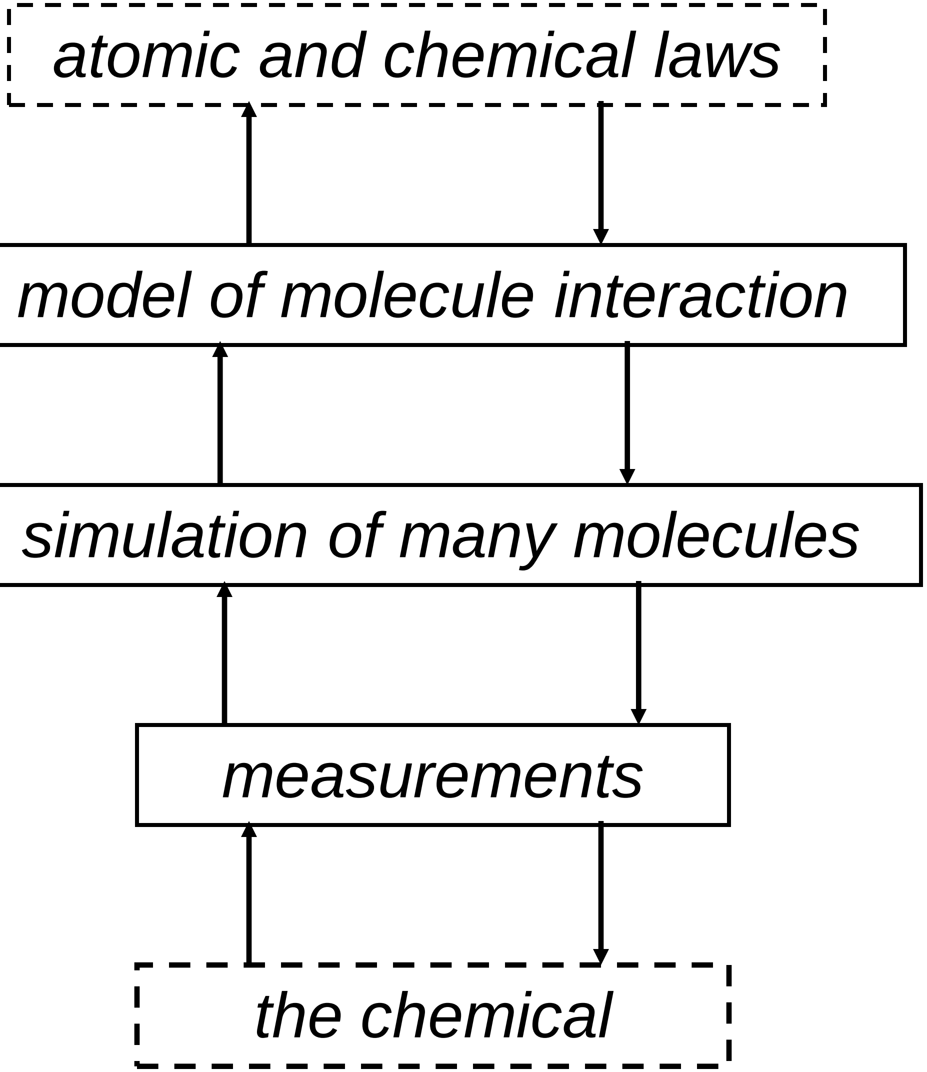
- The difficulty of interpreting a rich meaningful domain and descriptions into an impoverished formal model
- Establishment of symbol meaning by:
  - Importing symbols from natural language
  - Use of symbols in context
  - Cycle of interaction and learning about symbols
  - Imputation by stakeholders and domain experts
- It is *very difficult* to go from models that strongly relate to data and those that give meaningful explanations
- But good science is when you have both

A possible layering of models (by abstraction)



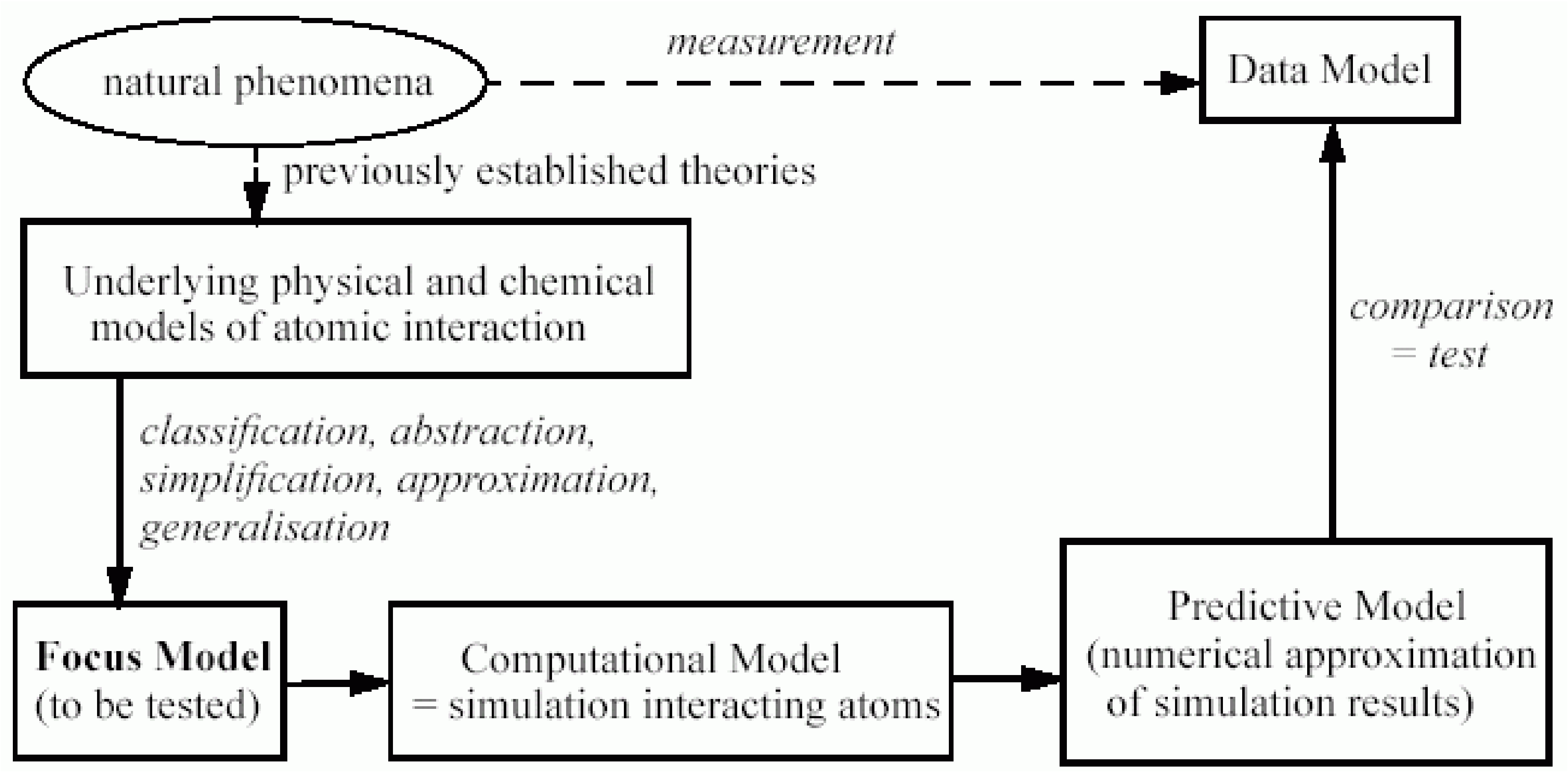
(What really happens)

A possible layering of models (by granularity and abstraction)



(What really happens)

An example from chemistry



Multiple models

- Parallel models
  - e.g. different models gained by different approaches and simplifications, whose results are compared (e.g. Lasers)
- Context-specific models
  - e.g. quantum models in micro-world and relativistic models in macro-world
- Clusters of models
  - e.g. use of analogical models alongside formal models in atomic physics

(What really happens)

An Example

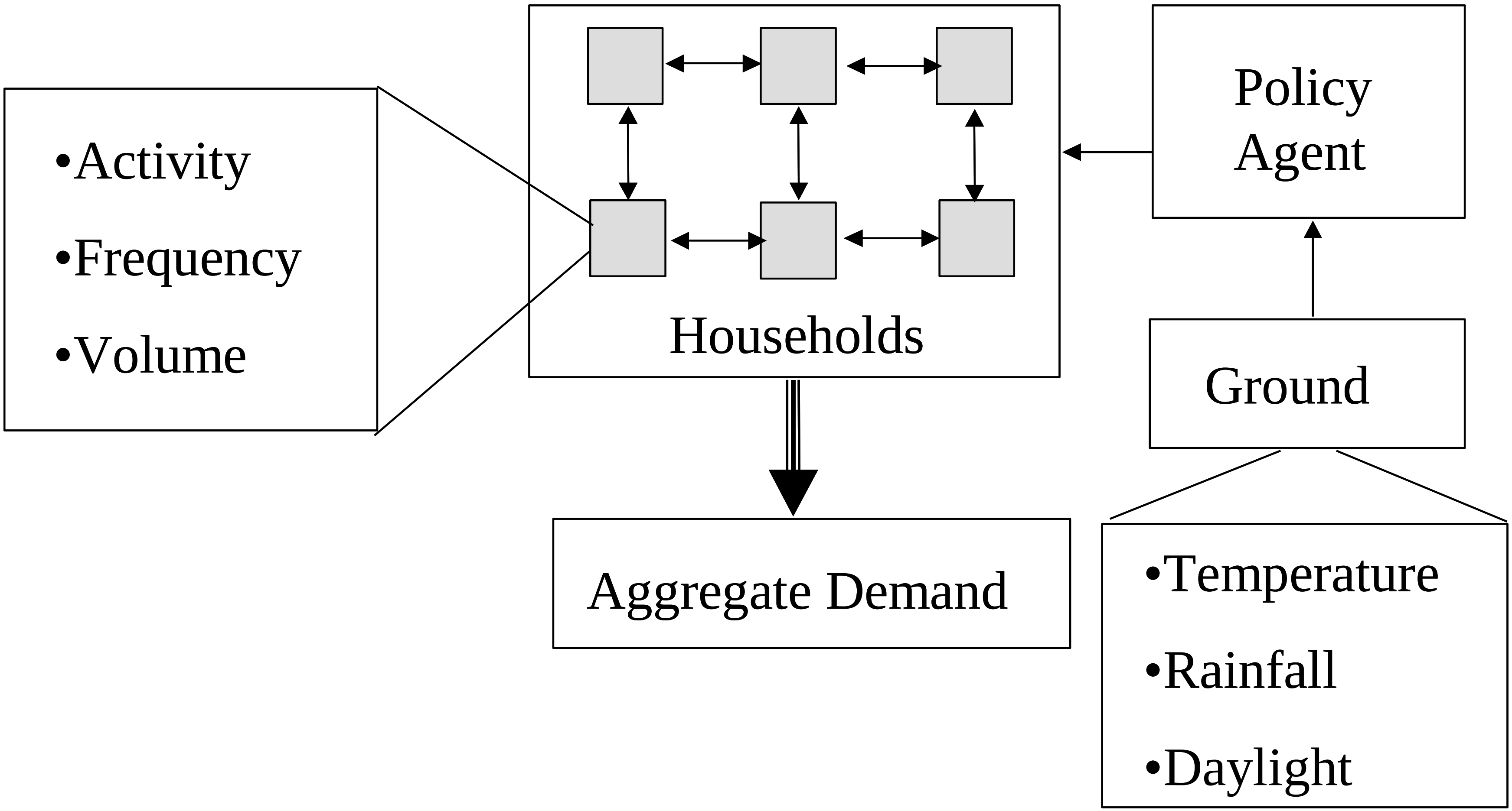
- Type: A complex agent-based descriptive simulation
- Context: statistical and other models of domestic water demand under different climate change scenarios
- Purposes:
  – to critique the assumptions that may be implicit in the other models
  – to demonstrate an alternative

A *model of social influence and water demand*

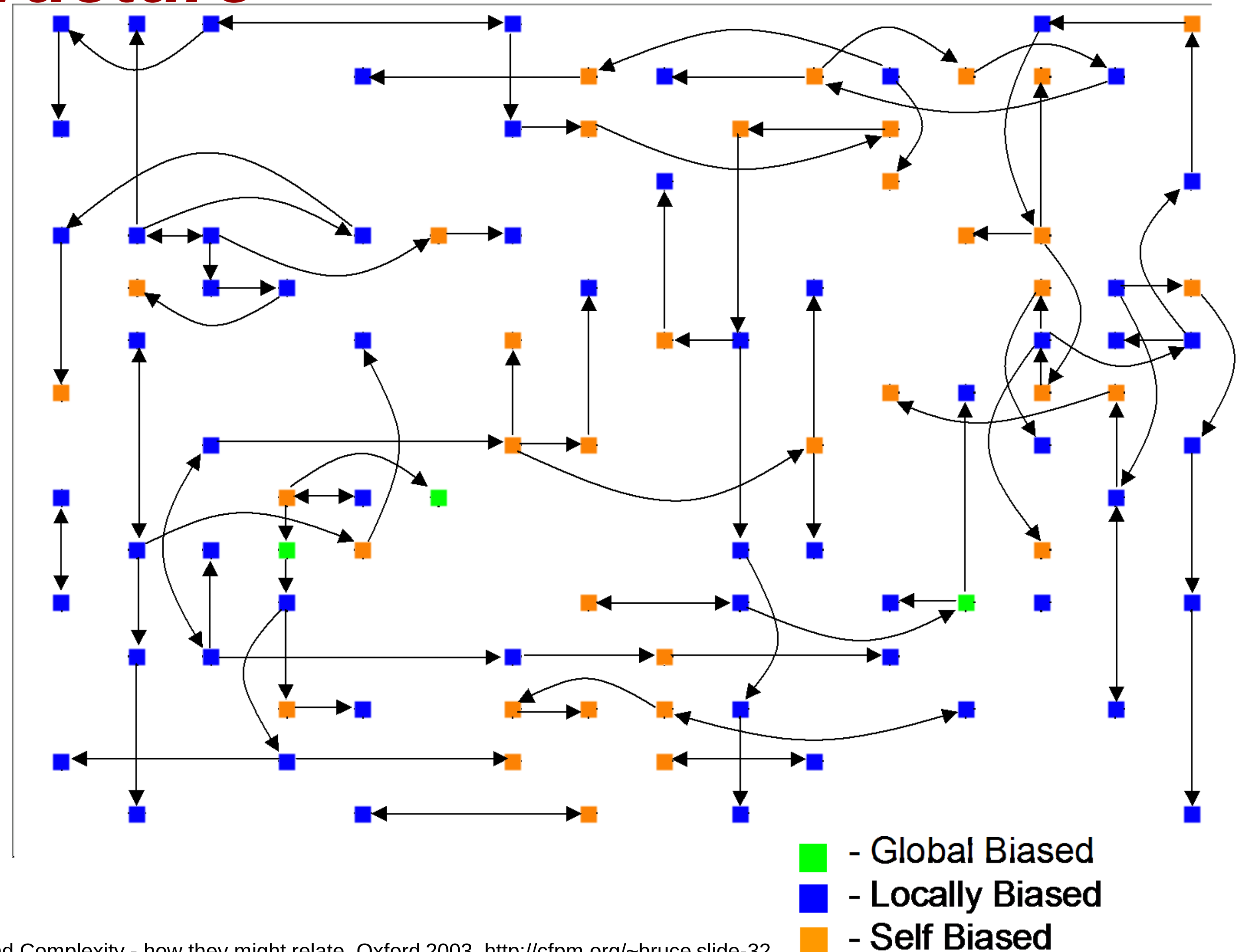
- Investigate the possible impact of social influence between households on patterns of water consumption
- Design and detailed behaviour from simulation validated against expert and stakeholder opinion at each stage
- Some of the inputs are real data
- Characteristics of resulting aggregate time series validated against similar real data

Simulation structure

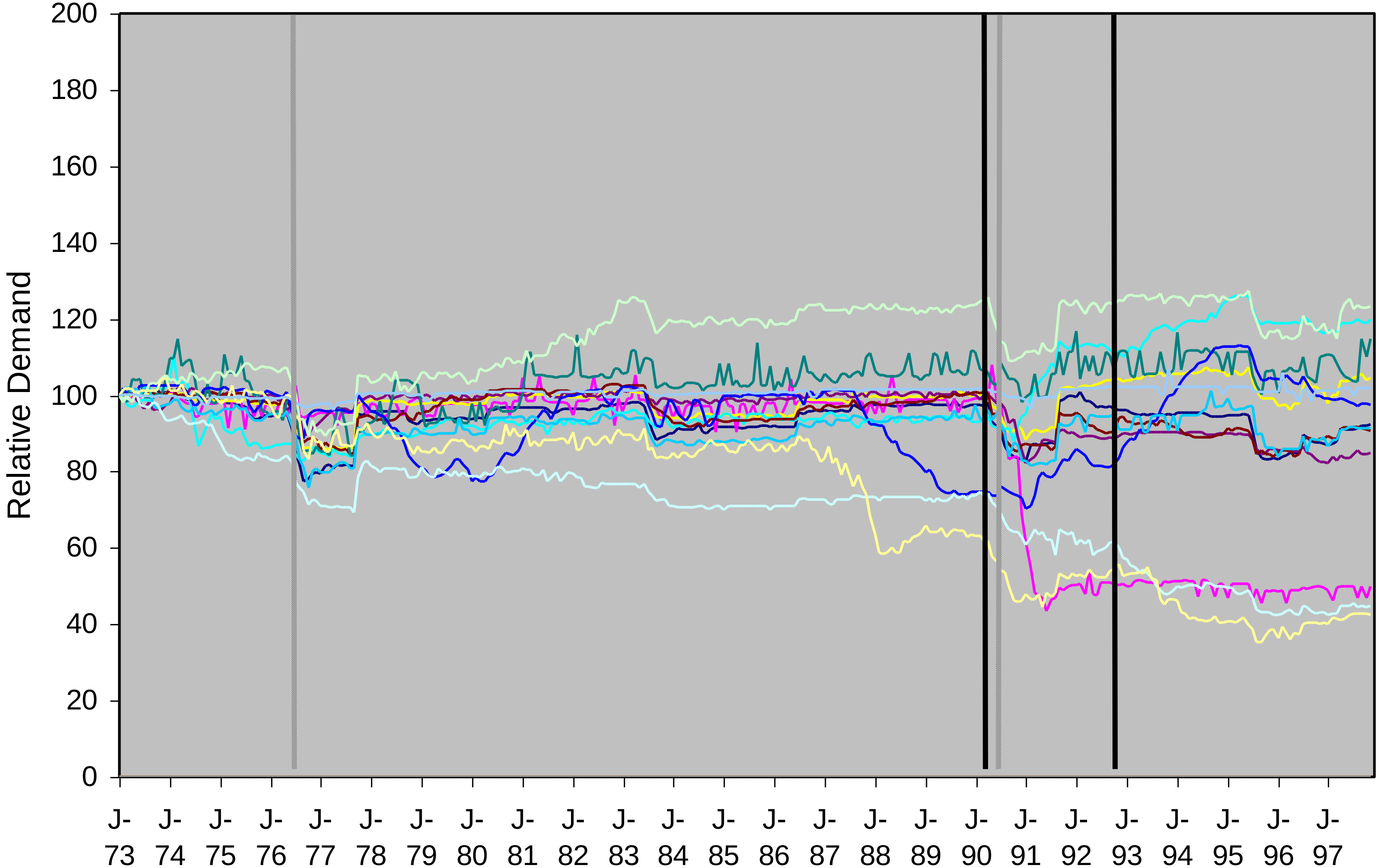
Manchester Metropolitan University



Some of the household influence structure



Example results



Conclusions from Example

- The use of a concrete descriptive simulation model allowed the detailed criticism and, hence, improvement of the model
- The inclusion of social influence resulted in aggregate water demand patterns with many of the characteristics of observed demand patterns
- The model established how it *was possible that* processes of mutual social influence could result in widely differing patterns of consumption that were self-reinforcing

Useful?

- It does show some possible weaknesses and limitations in traditional statistical models
- The model has been imitated by researchers in Spain
- The local authority uses it to assess new residential developments to see some of the possible effects on water demand that could result
- Is this a good idea?

Conclusion – *advantages of formal modelling (for the social sciences)*

- Impressive ☹
- Little confusion about model
- Formal model can be copied and tried by others –a social “evolutionary” process
- Relatively easy to confront with evidence
- Strong inference step
- Helps unearth assumptions
- Suggests new questions to investigate
- Can be shown to be wrong (Popper) or *better* how it is wrong

Conclusion – *dis**advantages of formal modelling***

- Impressive ☹
- Poor in terms of meaning
- Requires expertise
- Easy to fool oneself into thinking the world is like your model
- Tempting to take short-cuts
- Difficult to validate completely
- Difficult to list all assumptions
- Needs **lots** of evidence

The End

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Centre for Policy Modelling

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Slides

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