Heuristic principles in system dynamics modelling
– through the valley of simplicity

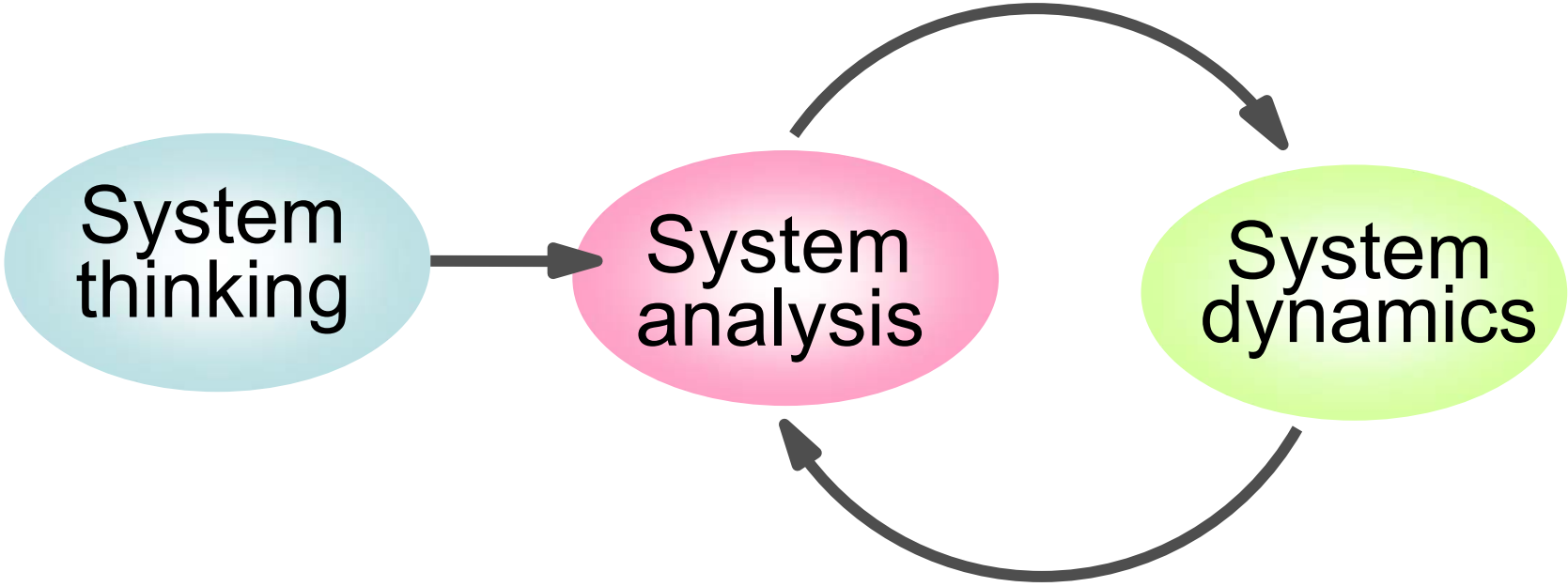
Abstract - When practicing system dynamic modelling, a variety of obstacles needs to be surpassed.
System dynamic modelling consist of three major phases; *Problem formulation*, which includes mental modelling, causal loop diagramming etc; *Model building*; which encompasses the steps from a Causal loop diagram, sometimes over Box and arrow diagrams, to a model, including parameterization; and *Model use*; which includes scenario analysis, back casting etc. Many SD students use their previous learnt rules and habits when doing mental modelling – but without awareness of their limitations and biases. The iterative stages of sorting and structuring needs to be improved, and can be improved with some simple rules of thumb.
Many make the major mistake in directly including too many variables in their first SD model, thus underestimating the difficulties of understanding the output, and overestimating their model understanding. This leads to repetitive failures in the modelling attempts and is one of the most common problems when learning system dynamic modelling. The valley of simplicity is deeper than we think; the path of taking apart and simplifying, before putting together and complexifying is the only route towards true understanding.
Another obstacle is to distinguish what is actually flowing. Many cannot distinguish between different flow types; materia, energy, information, and do not use unit check consistently. Moreover, a repetitive question is also how many components or parameters is optimal to include? It is hard to practice “kill your darlings”, and it is hard to resist encompassing only a limited amount of components.
We report here from 5 years of experiences of teaching and learning SD modelling to a broad variety of students. We suggest some heuristic rules that can improve the SD modelling learning curve.

Heuristic principles in system dynamics modelling – through the valley of simplicity

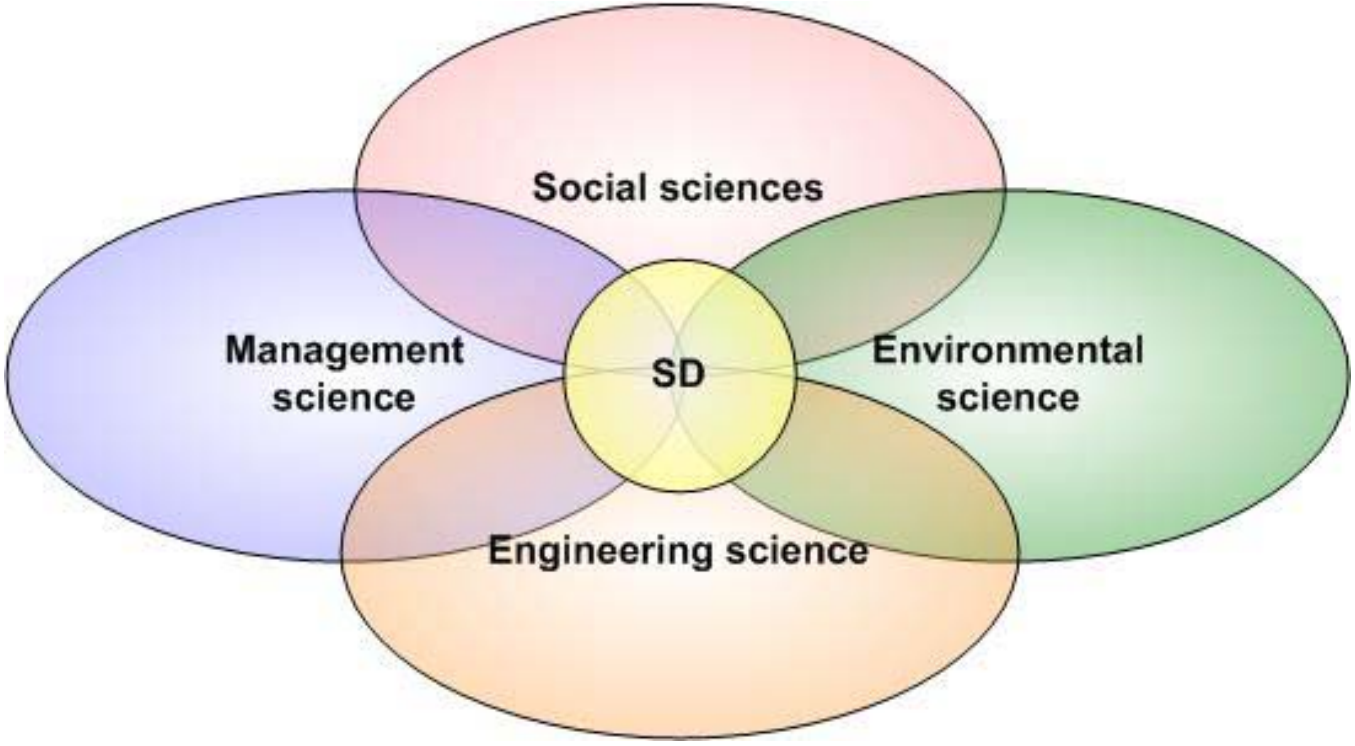
Obstacles in SD modelling

- **Sorting and structuring needs to be improved**
  - Many use their previous learnt rules and habits when doing mental modelling – but without awareness
- **The valley of simplicity is deeper than we think**
  - Many make the major mistake in directly including too much in their first SD model – underestimating difficulties, and overestimating their own model understanding
- **What is actually flowing?**
  - Many cannot distinguish between different flow types; materia, energy, information, and do not use unit check consistently
- **What is optimal?**
  - It is hard to kill your darlings. It is hard to resist to encompass a limited amount of components

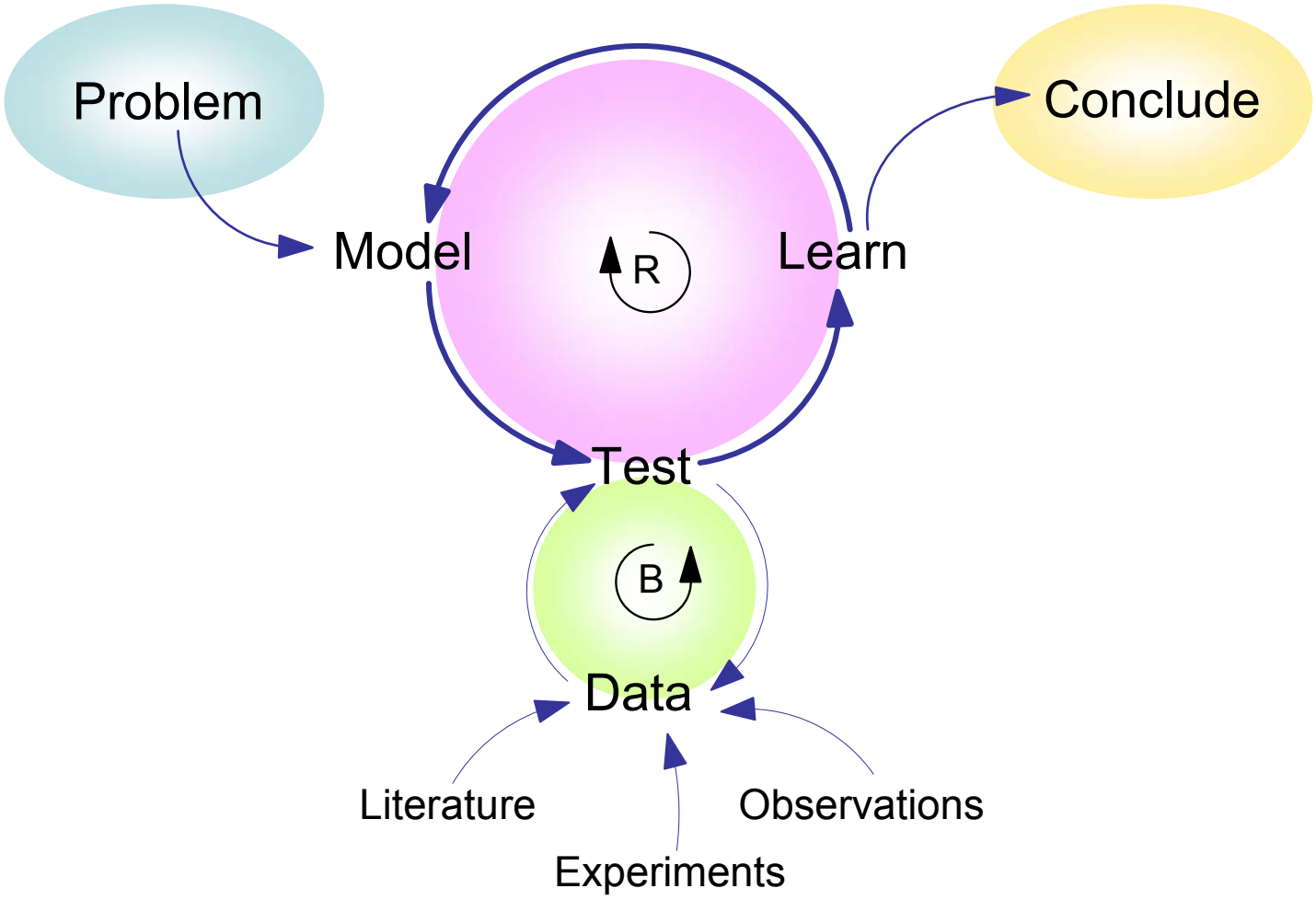
”System Dynamics analysis thinking”



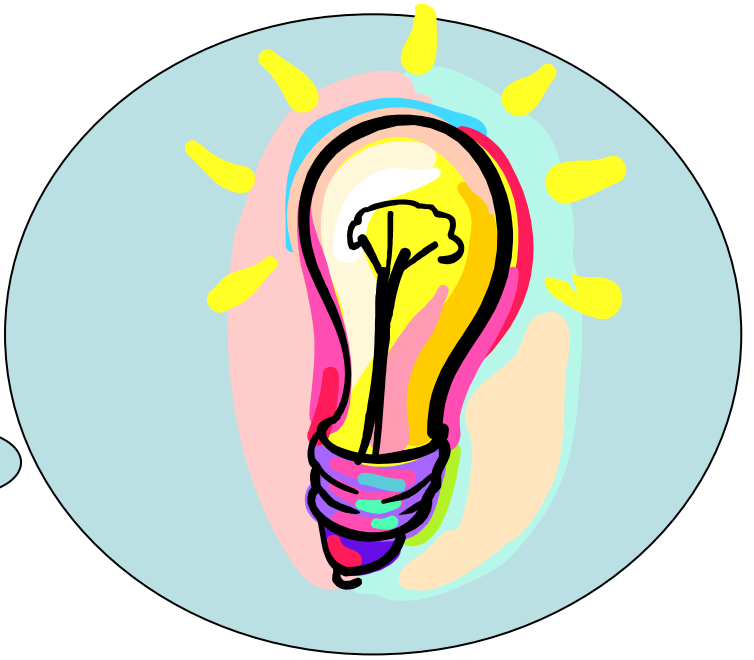
System dynamics fields



The learning loop



Thinking is modelling



Phases in SD modelling

I. **Problem formulation**
   - Mental model construction
   - System boundaries
   - CLD
   - Box&Arrow
   - Reference behaviour

- **Model construction**
   - From CLD/Box&Arrow to Model
   - Parameterization
   - Sensitivity and robustness testing
   - Model validation

- **Model use**
   - Scenario analysis
   - Backcasting

Problems in the mental modelling phase

- What is relevant? Sorting out essentials
- At what level? Micro- or Macro-level
- Static and dynamic factors?
- System boundaries?
- Time horizon
- Qualitative and/or quantitative factors?
- Problems to ”kill your darlings”
- Perception limitations

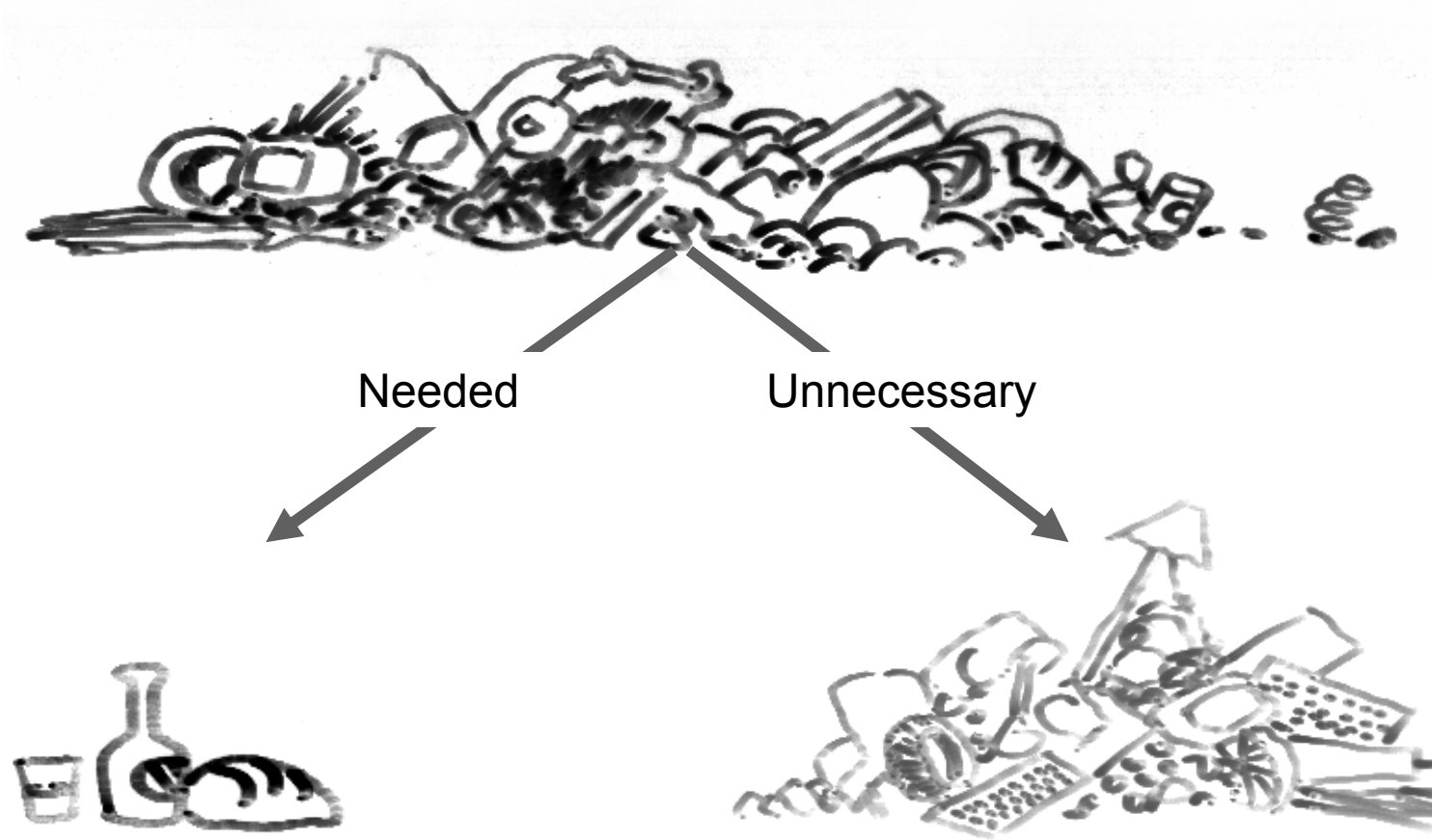
Problem formulation phase

- What is the problem?
- How common is it?
- Who is problem-owner?
- Is the cause and effect separated in space and/or time?
- Many or single-factor problem?
- A ”Commons” problem?

Mental model building factors

- Deletion
  - Select and filter according to preferences, mode, mood, interest, preoccupation and congruency
- Construction
  - See something that is not there, filling in gaps
- Distortion
  - Amplifying some parts and diminishing others, reading different meanings into it
- Generalisation
  - One experience comes to represent a whole class of experiences
- One-sided experiences
  - We tend to only remember one side of experiences

Sorting –
The most difficult step of all !!



Sorting the essentials from the nonessentials!

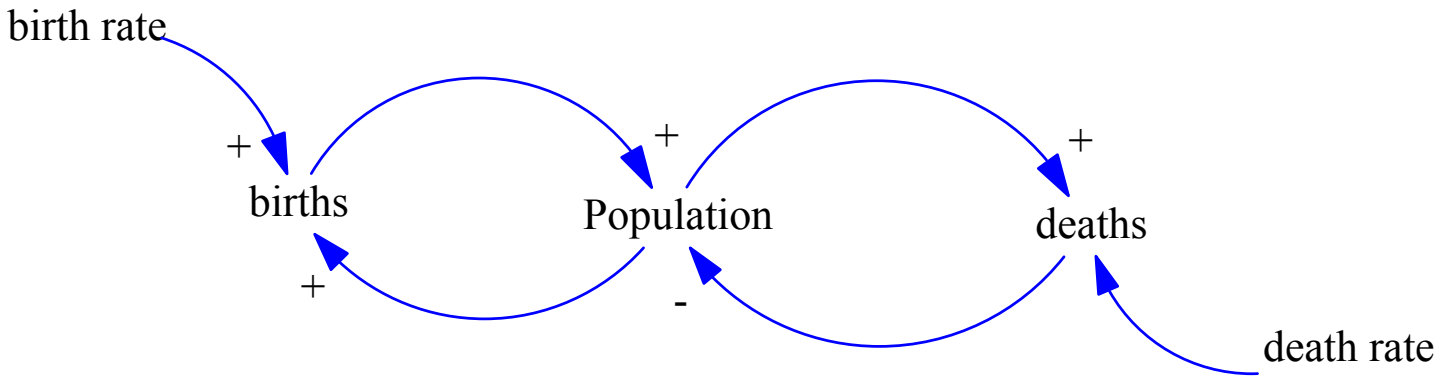
Problems in the CLD to model phase

- Including how many components?
- How to distinguish accumulations from processes?
- Units?
- Scales?
- Introduction of mass and energy balance principles?
- Non-linear relationships
- Qualitative components

Heuristics for distinguishing flows and accumulations

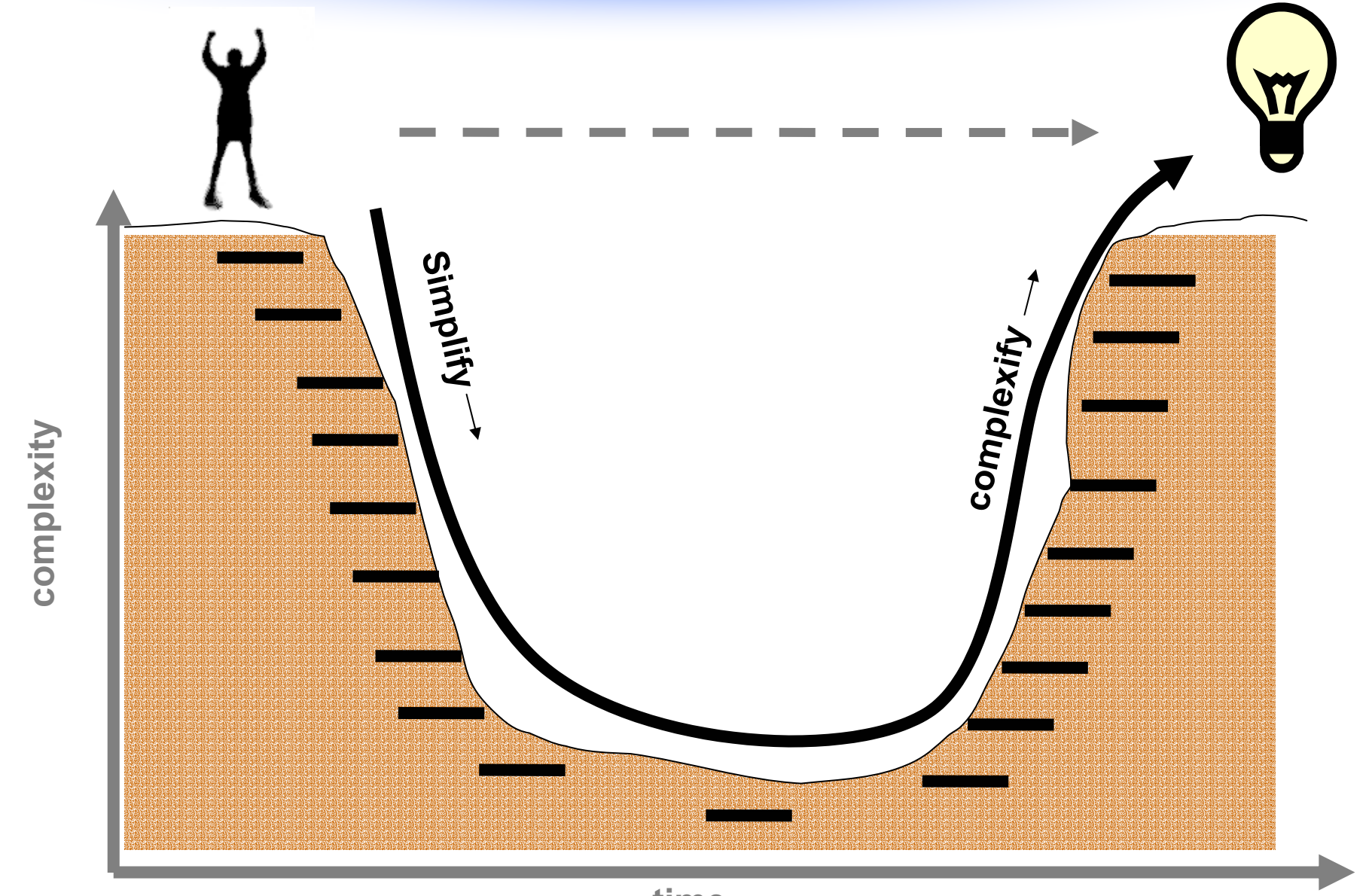
- Go from CLD to Box&Arrow diagram
- Units of measure (Sterman 2000)
- The Snapshot test (Sterman 2000)
- Look at wordings; verbs and nouns
- ”Know ya system”

Take an instant photo of your CLD!



What do you see?

The valley of simplicity



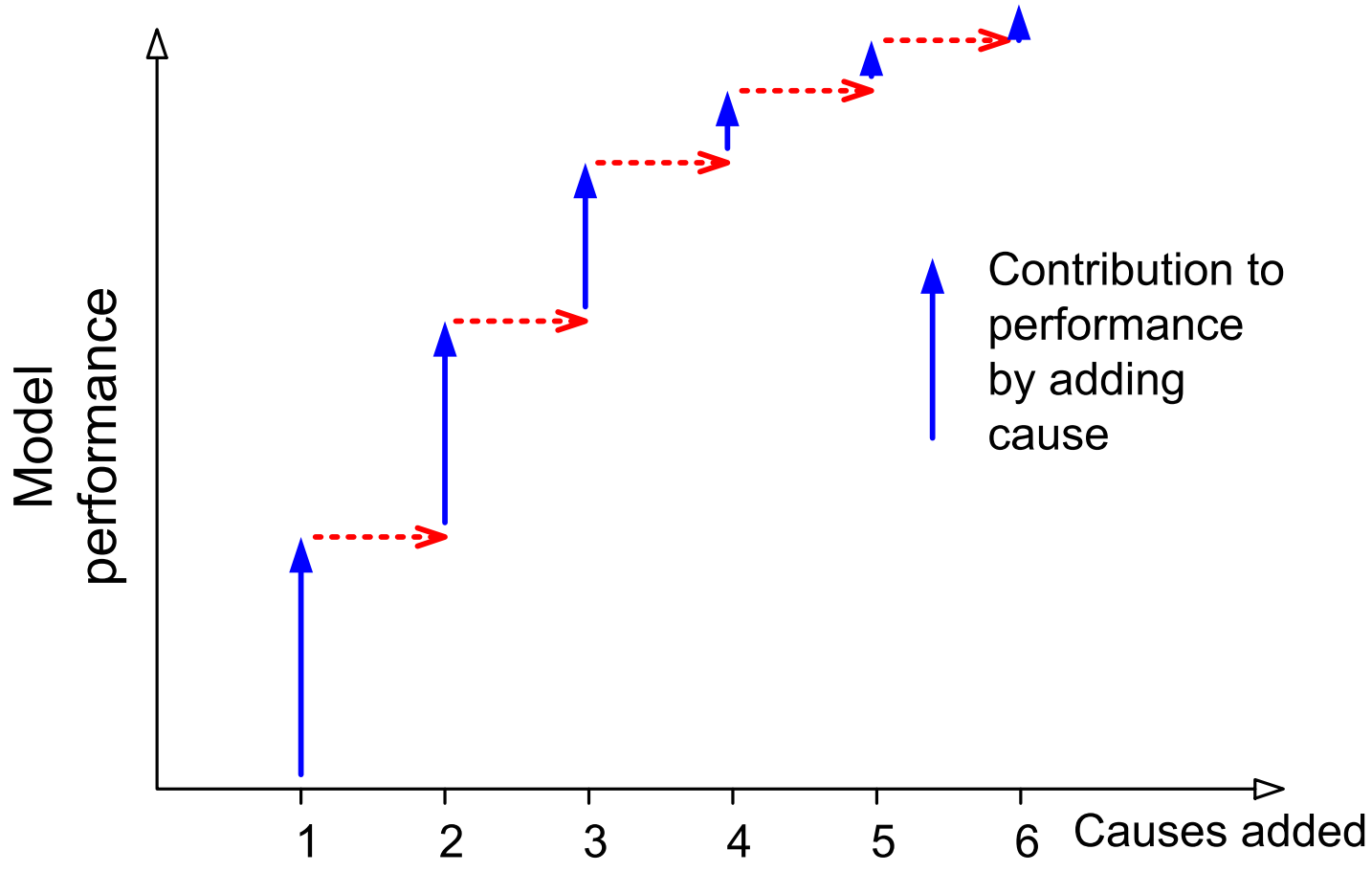
Some rules of thumb

- Start extremely simple! Yes, even stupidly simple!
- Add one component at a time
- Check with yourself the resulting graph BEFORE running the model
- Check units
- Simulate steady-state/stability conditions first
- Reproduce reference behaviour
- Throw away often....

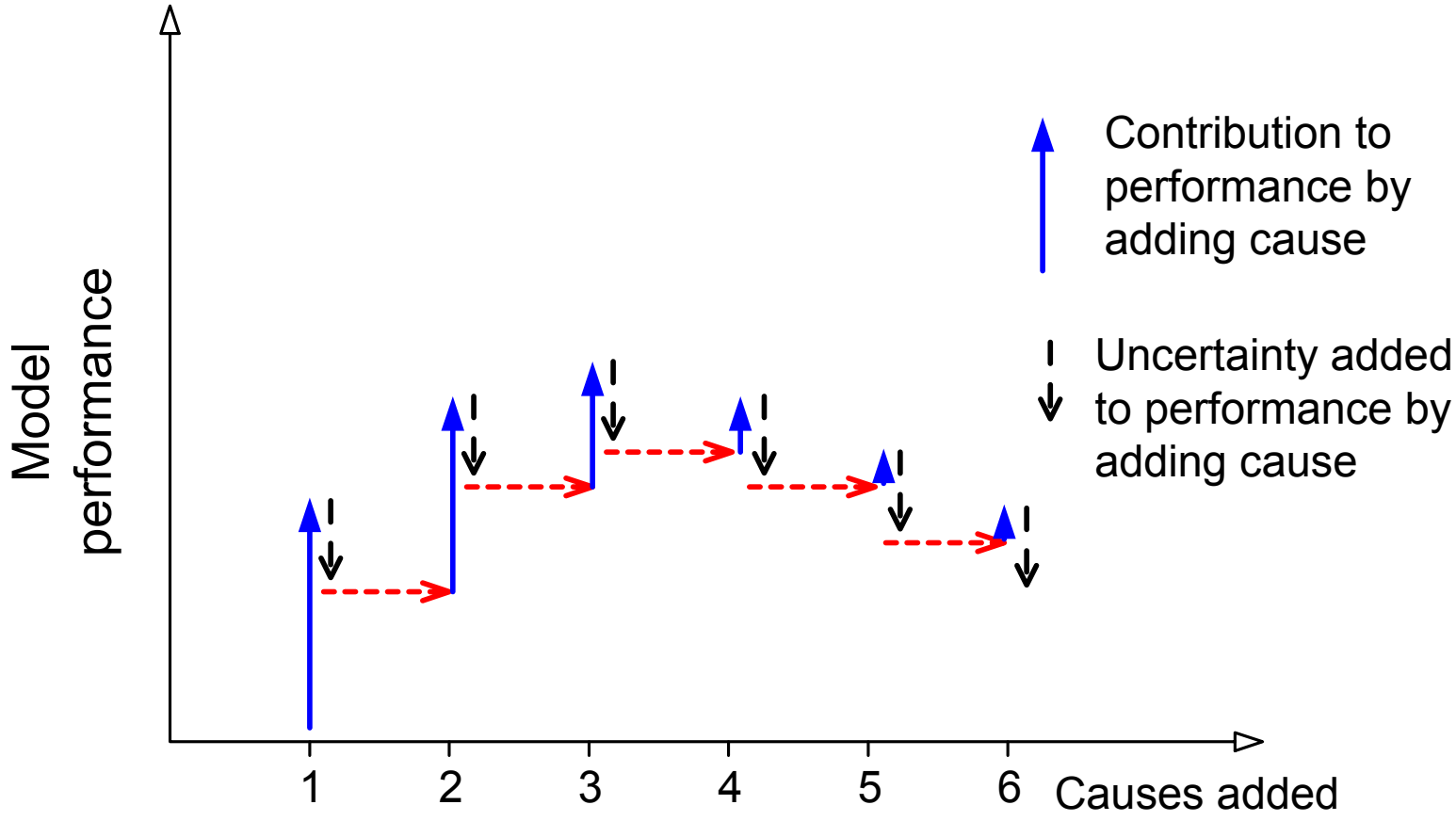
Problems in the model validation phase

- Finding data for validation
- Robustness of model
- Qualitative components
- Appropriate time and space boundaries

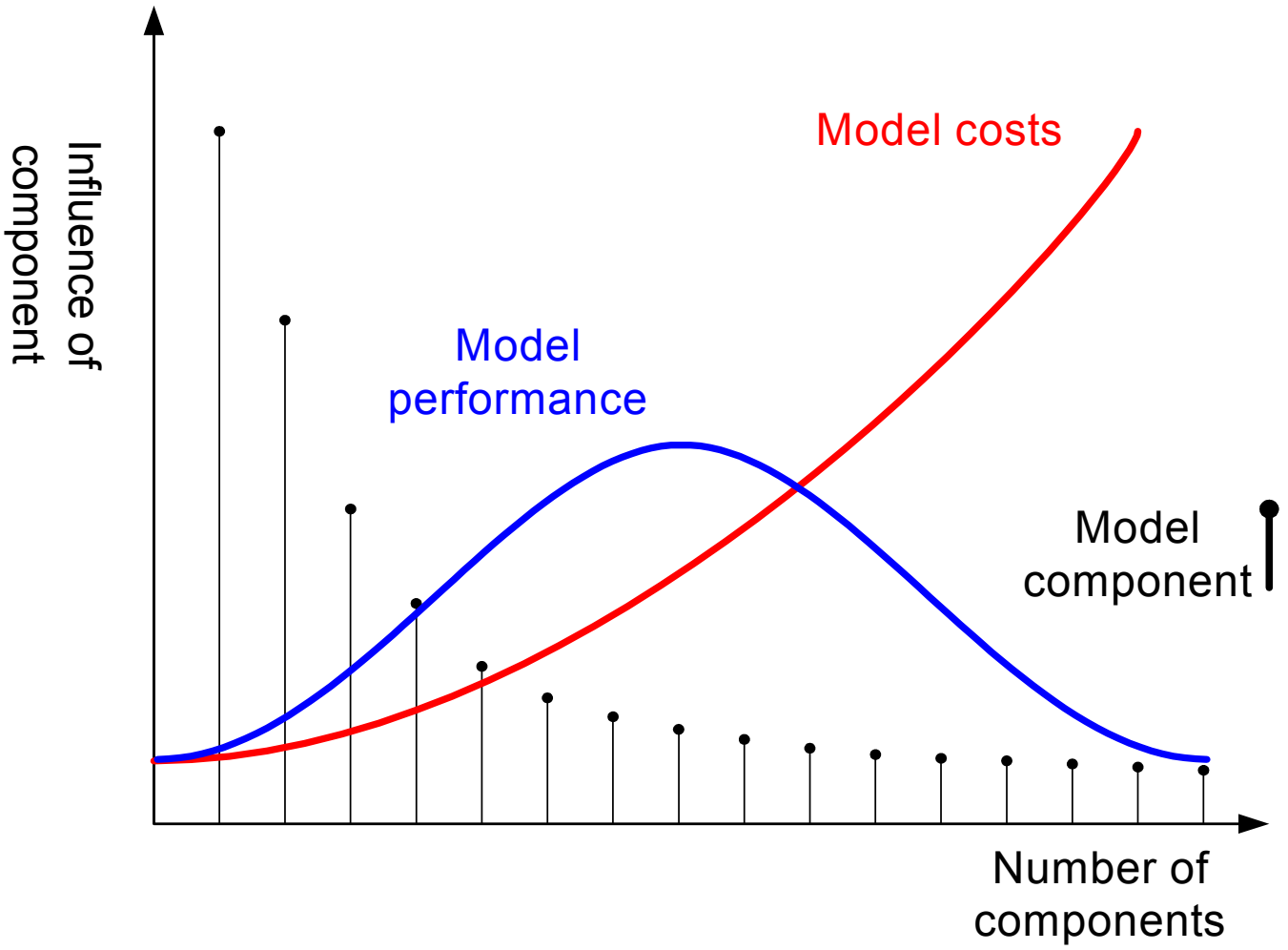
Adding causes to model



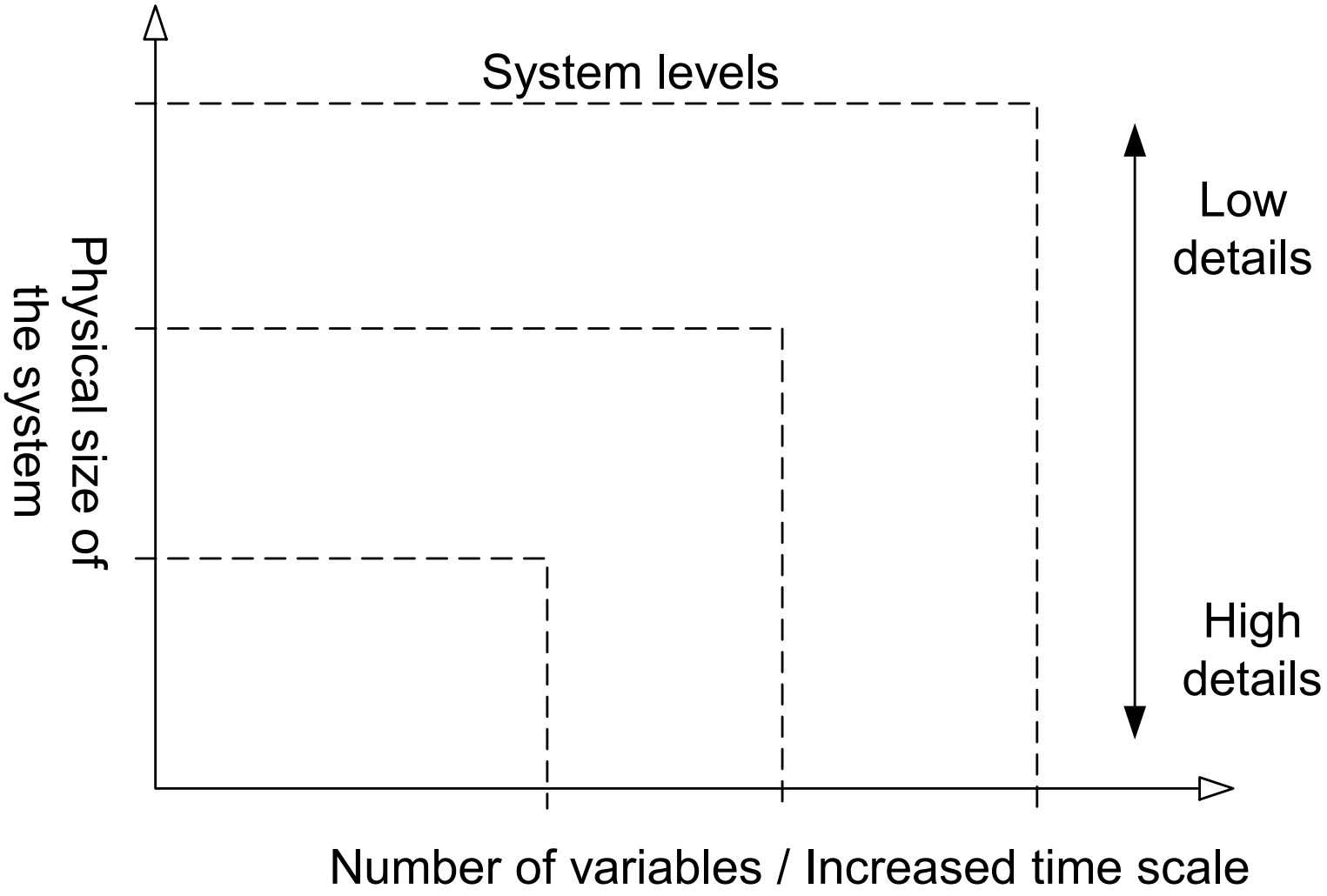
Model performance



Model cost and performance



System Levels



Comparison with other tools for understanding complex problems and decisions

- **Cause & Effect Diagrams** - Identifying the likely causes of problems
- **Causal Loop Diagrams** - Understanding how factors affect one-another
- **Cost/Benefit Analysis** - Evaluating quantitatively whether to follow a course of action
- **Decision Tree Analysis** - Choosing between options by projecting likely outcomes
- **Drill Down** - Breaking problems down into manageable parts
- **Force Field Analysis** - Understanding the pressures for and against change
- **PMI** - Weighing the Pros and Cons of a decision
- **Six Thinking Hats** - Looking at a decision from all points of view (De Bono)
- **SWOT Analysis** - Understanding your strengths, weaknesses, opportunities and threats

Are there any better tools for understanding complexity?

	Qualitative	Quantitative	System behaviour	Predictive
Cause & Effect Diagrams	yes	yes		
Causal loop diagrams	yes	yes	yes	yes
Cost/Benefit analysis	yes	yes		yes
Decision Tree Analysis	yes	yes		yes
Drill down	yes	yes		
Force field analysis	yes	yes		
PMI	yes	yes		
Six thinking hats	yes	yes	(yes)	yes
Swot analysis	yes	(yes)		(yes)

To summarize

- Three major steps in SD modelling; problem formulation, model building and model use
- If problem formulation is not made in an orderly and consistent manner, the modelling will suffer
- Better awareness of the underlying biases and heuristic principles when doing mental modelling improves the results
- By letting SD students make mistakes under controlled circumstances will lead to improved performance later – to do mistakes is good!
- The valley of simplicity is deeper than we think...

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