Science 1000: Lecture #6 (Wareham):

How We Think:
Analogy-based Cognitive Processing

Difficult to
analogize.
Need to, though

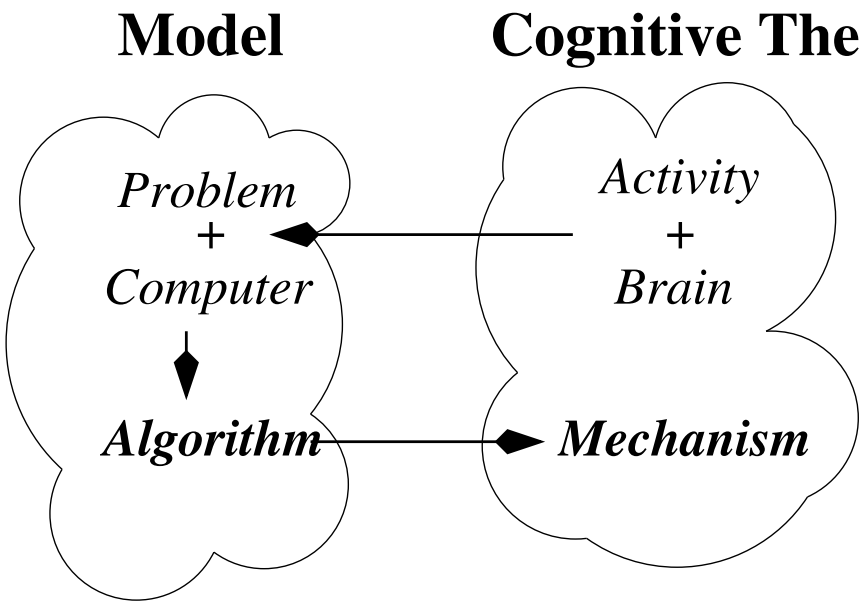
Complexity Analysis of Important Problems

The Tractable Computation Thesis:
WHERE POSSIBLE, IMPORTANT PROBLEMS SHOULD BE SOLVED QUICKLY.

- Two conceptions of "quickly":
  - quick in general (poly-time solvability)
  - quick under restrictions (fp-tractability relative to P)
- If a problem is intractable, look for restrictions to make it tractable.
- One way to do this is to look for parameters whose values are small in practice and then see if these restrictions yield fp-tractability.

Computational Models of Cognition

- Goal is to develop theories of cognitive activities stated in terms of models, problems, and algorithms.



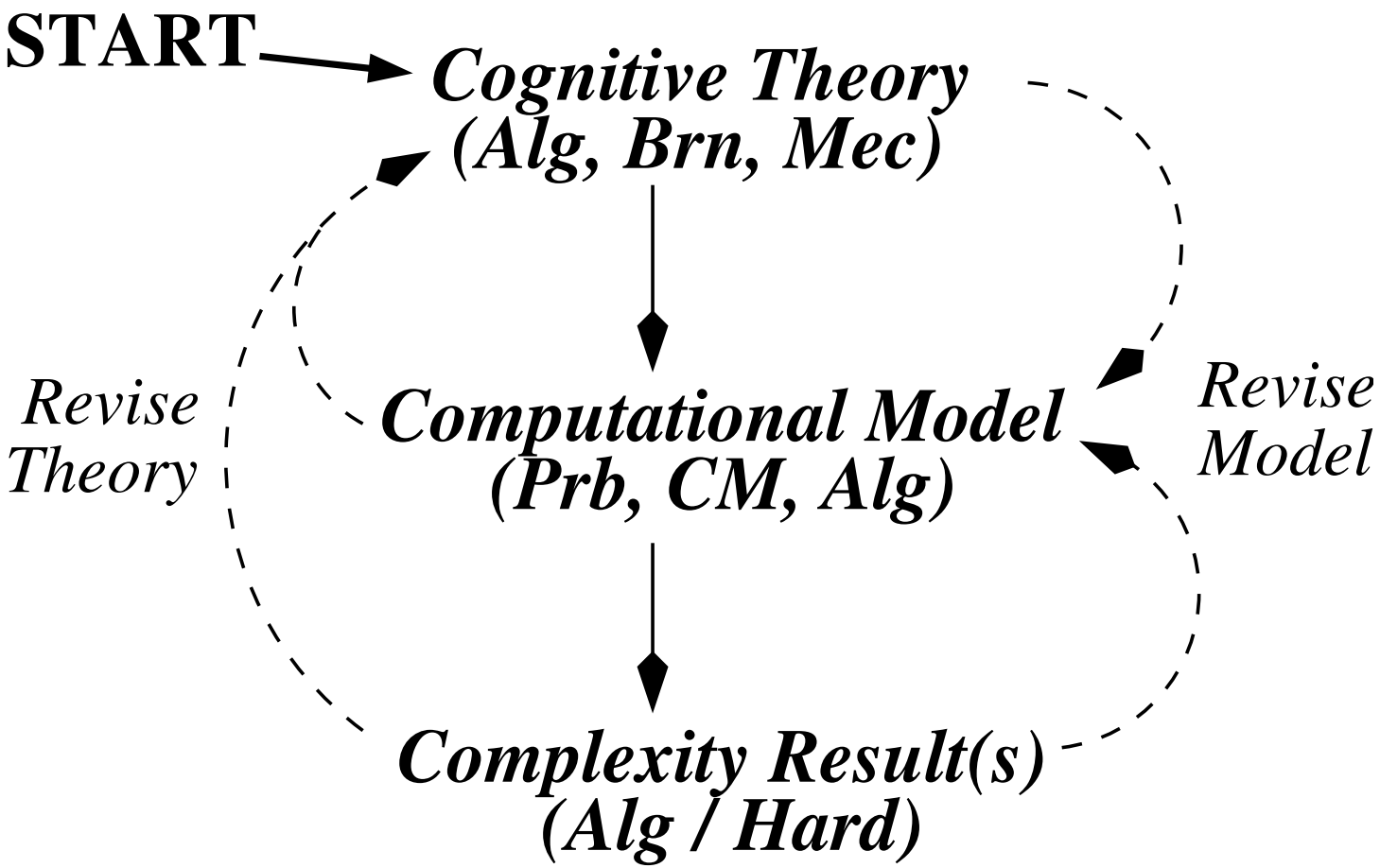
- Each cognitive theory has an associated model whose computations can be stated as a problem.

Complexity Analysis of Cognitive Theories

The Tractable Cognition Thesis:
AS COGNITION IS FAST, COGNITIVE MODELS SHOULD HAVE PROBLEMS THAT CAN BE SOLVED QUICKLY.

- Two conceptions of "quickly":
  - quick in general (poly-time solvability)
  - quick under restrictions (fp-tractability relative to P)
- If the problem associated with a model is intractable, revise mechanisms in model to make it tractable.
- One way to do this is to look for restrictions that yield fp-tractability, and then see if these restrictions hold in actual cognition.

The Cognition Complexity Game

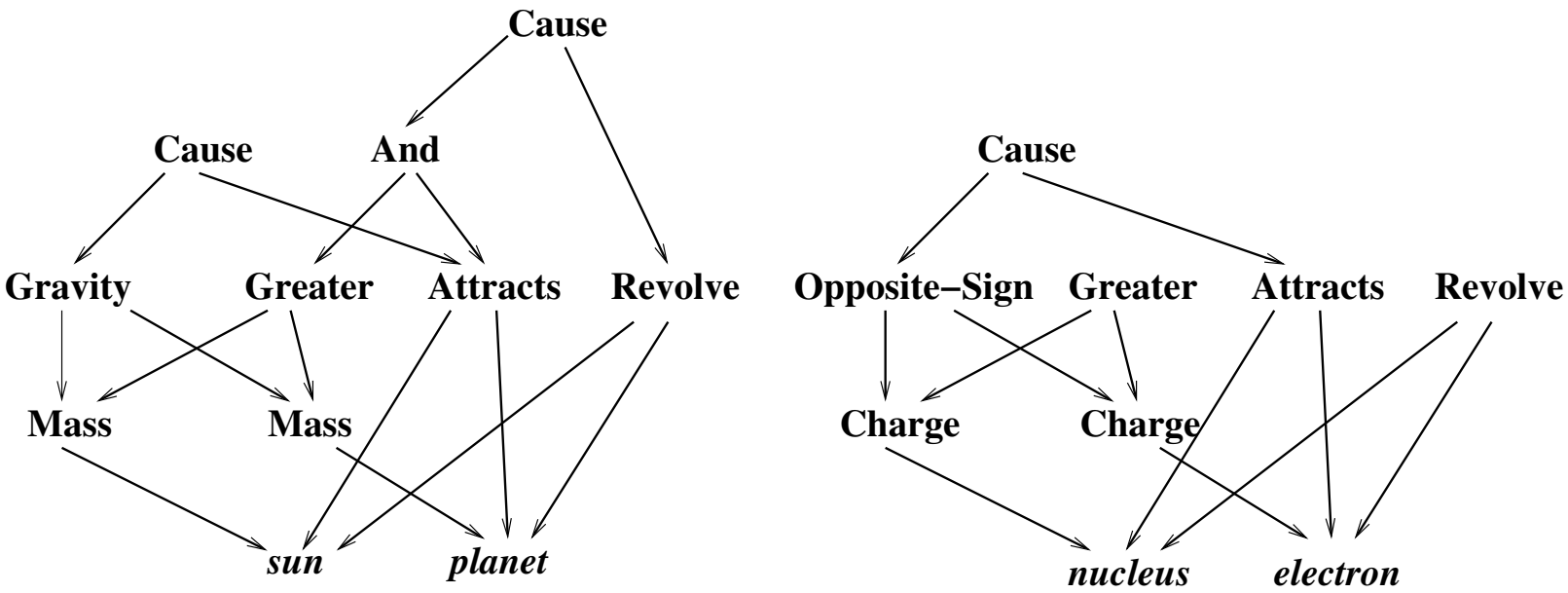


Analogy Derivation

- Given two concepts, an analogy is essentially a mapping between common parts of both concepts.
- Analogies can be good, *e.g.*, “Genghis Khan is like Adolf Hitler”, or bad, *e.g.*, “An orange is like Adolf Hitler”.
- Analogy derivation underlies many cognitive processes, *e.g.*, memory retrieval, problem solving, learning.
- Sometimes, deriving analogies is easy; sometimes, it is hard. What characterizes these situations?
- There are many cognitive theories of analogy derivation; focus here on Structure Mapping Theory (Gentner, 1983).

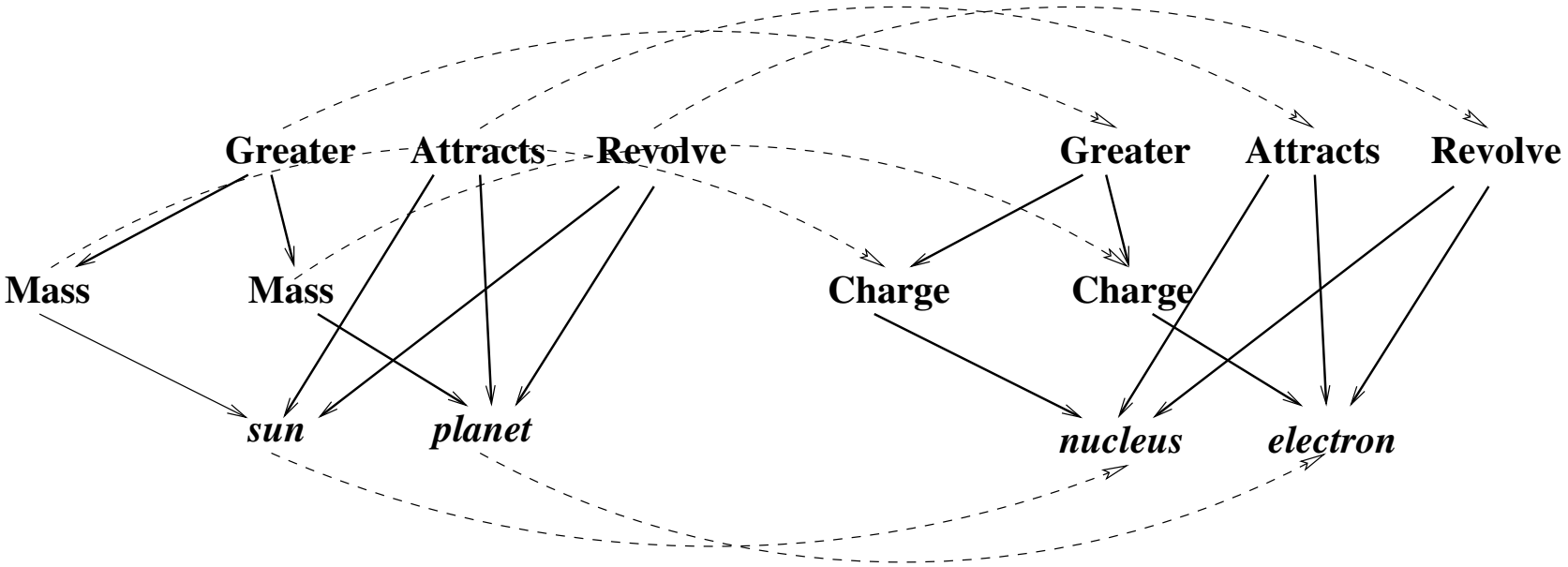
Analogy Derivation as Structure Mapping

- Represent concepts as predicate-structures, *e.g.*,



Analogy Derivation as Structure Mapping (Cont'd)

- Represent analogies as largest common sub-structures of given predicate-structures, *e.g.*,



Analogy Derivation as Structure Mapping (Cont'd)

ANALOGY MAPPING
Input:Two predicate-structures B and T.
Output: The best analogy mapping between B and T.

- Is NP-Complete in general. Various conjectures have been made about what restrictions do and do not make this problem easy, *e.g.*, fp-tractable.
- **All** published conjectures have been proven wrong (van Rooij et al, 2008)!
- Lots of work remains to be done . . .

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Computing
enlightenment is
yours. Enjoy!