SD ∪ OBS ∪ {mode$_i$(C_i) | C_i ∈ COMPS} ... ?

Processes are not faulty:
They are present/active or not, we have to look at the preconditions.
➔ **No mode asumptions**

We don't blame an **existing** (behavior) constituent:
There are **additional** entities or unusual exogeneous conditions.
➔ **No components (COMPS)**
A different strategy for model revision is needed

There are no "failures of nature":
The phenomena are always in accordance with the laws of physics.
The conflict is with our intentions / goals!
➔ **Explicit specification of GOALS needed**

Towards a New Theory of Model-based Diagnosis

More general

- Cover process-oriented models
- Account for unexpected interactions and objects
- Distinguish between different tasks (more flexible)

➔ **Beyond components**

More specific

- Specify vocabulary for ontology, structure and behavior
- Formalization in logic

➔ **What's in SD?**

Include the standard component-oriented approach as a special case

Distinguish Different Tasks

What's going on? **(situation assessment)**

$SD_0 \cup OBS \vdash \perp \longrightarrow SD_1 \cup OBS \nvdash \perp$

What's going wrong? **(diagnosis)**

$SD_1 \cup GOALS \vdash \perp \longrightarrow SD_2 \cup GOALS \nvdash \perp$

What can be done? **(therapy planning)**

$SD_1 \cup GOALS \vdash \perp \longrightarrow SD_1 \cup ACTIONS \cup GOALS \nvdash \perp$

What's in SD? - Survey

SD

- **DOMAIN THEORY**
  - **ONTOLOGY**
    - **STRUCTURE** (object types and object relation types)
    - **BEHAVIOR**
      (quantity associations,
      behavior constituent types with instantiation/activity rules)
  - **BASIC LAWS**
- **SYSTEM STRUCTURE**
  (objects, object relations)
- **QUANTITY SPECIFICATIONS**
  (variable and parameter values)

$$SD = SD_{rev} \cup SD_{fix}$$

Behavior Constituent Descriptions

Behavior constituent types:
- Process descriptions / component behavior models

Instantiation rules:
- (Structural) instantiation conditions: $\mathbf{IC_i}$

$\mathbf{IC_i \Rightarrow \exists Obj_i \wedge beh\text{-}const_i}$

Activity rules:
- (State dependent) activity conditions: $\mathbf{AC_i}$

$\mathbf{beh\text{-}const_i \wedge AC_i \Rightarrow active_i = T}$

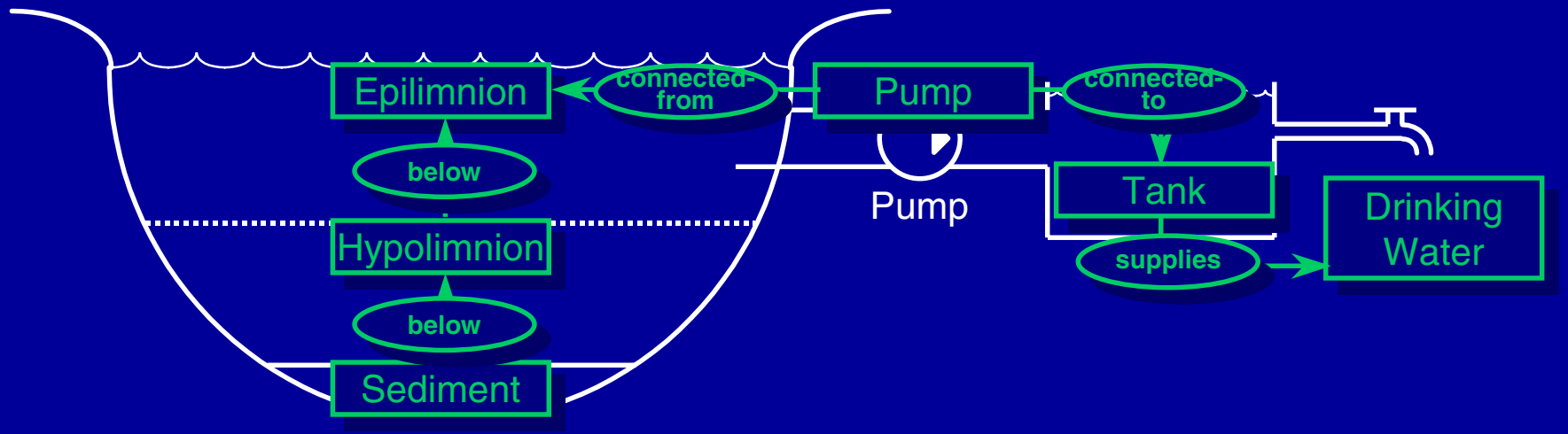
Behavior description:
- Constraints and influences

$\mathbf{active_i = T \Rightarrow beh\text{-}constraints_i \wedge influences_i}$

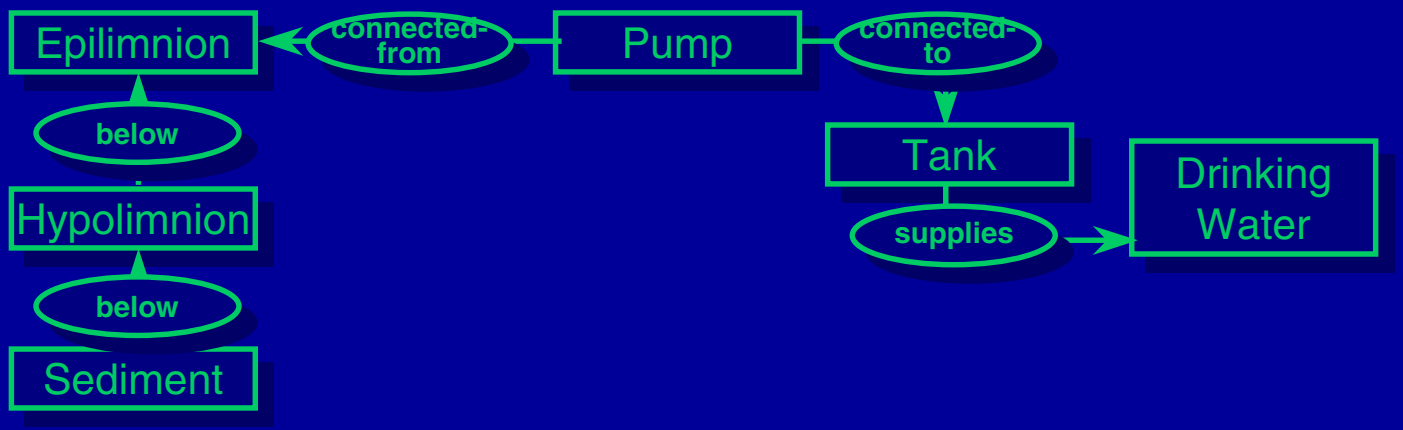
An Example from the Water Treatment Domain - Modelling

Modeling the scenario

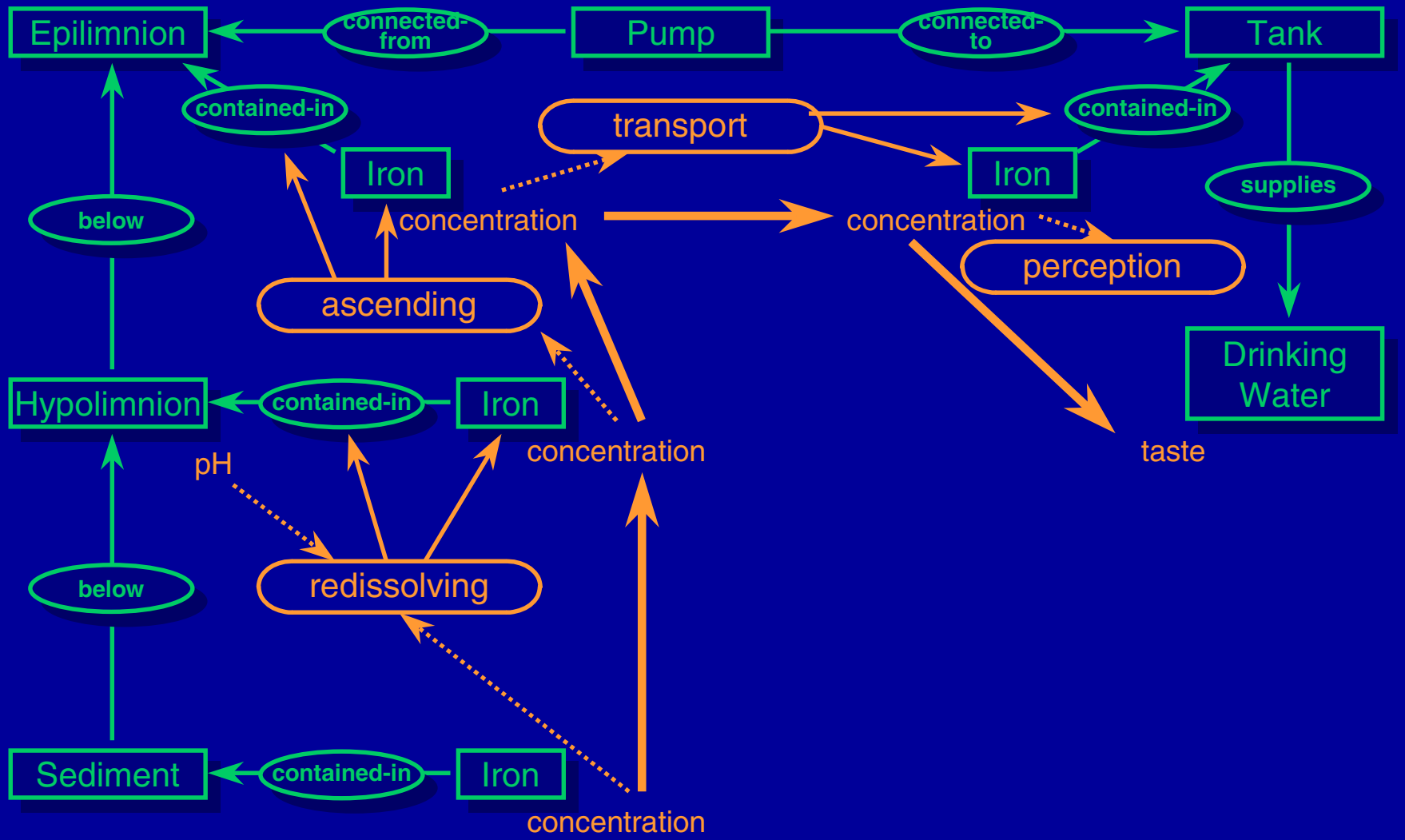
- Objects for spatial locators, components, substances, ...
- A set of relations complement the object structure



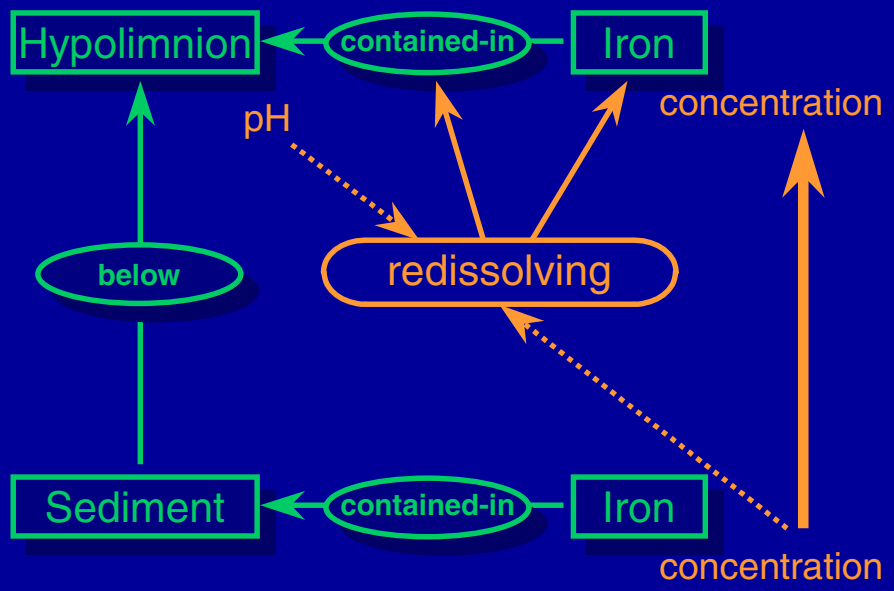
An Example from the Water Treatment Domain - Modelling



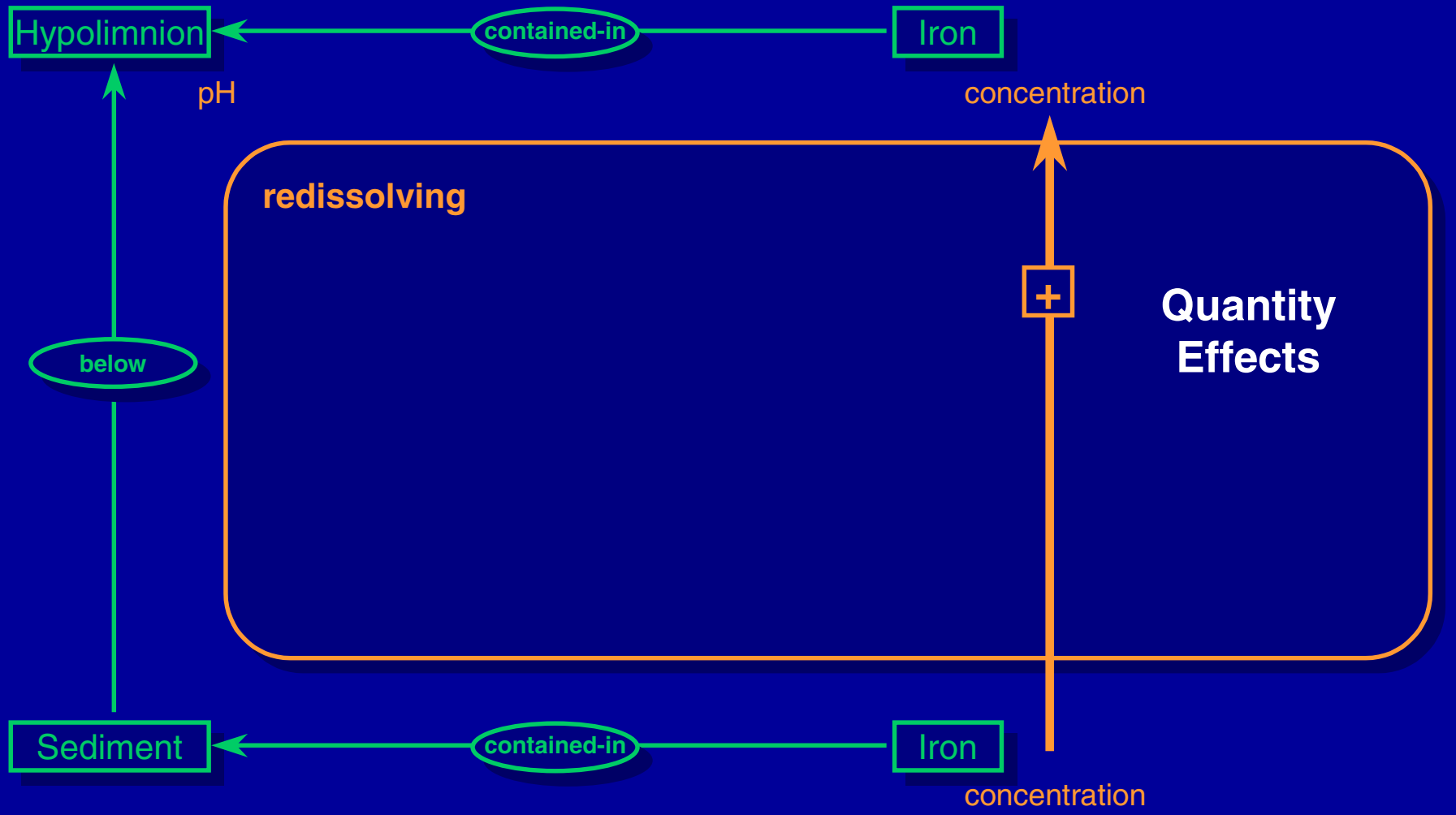
Example - Processes: Conditions and Effects



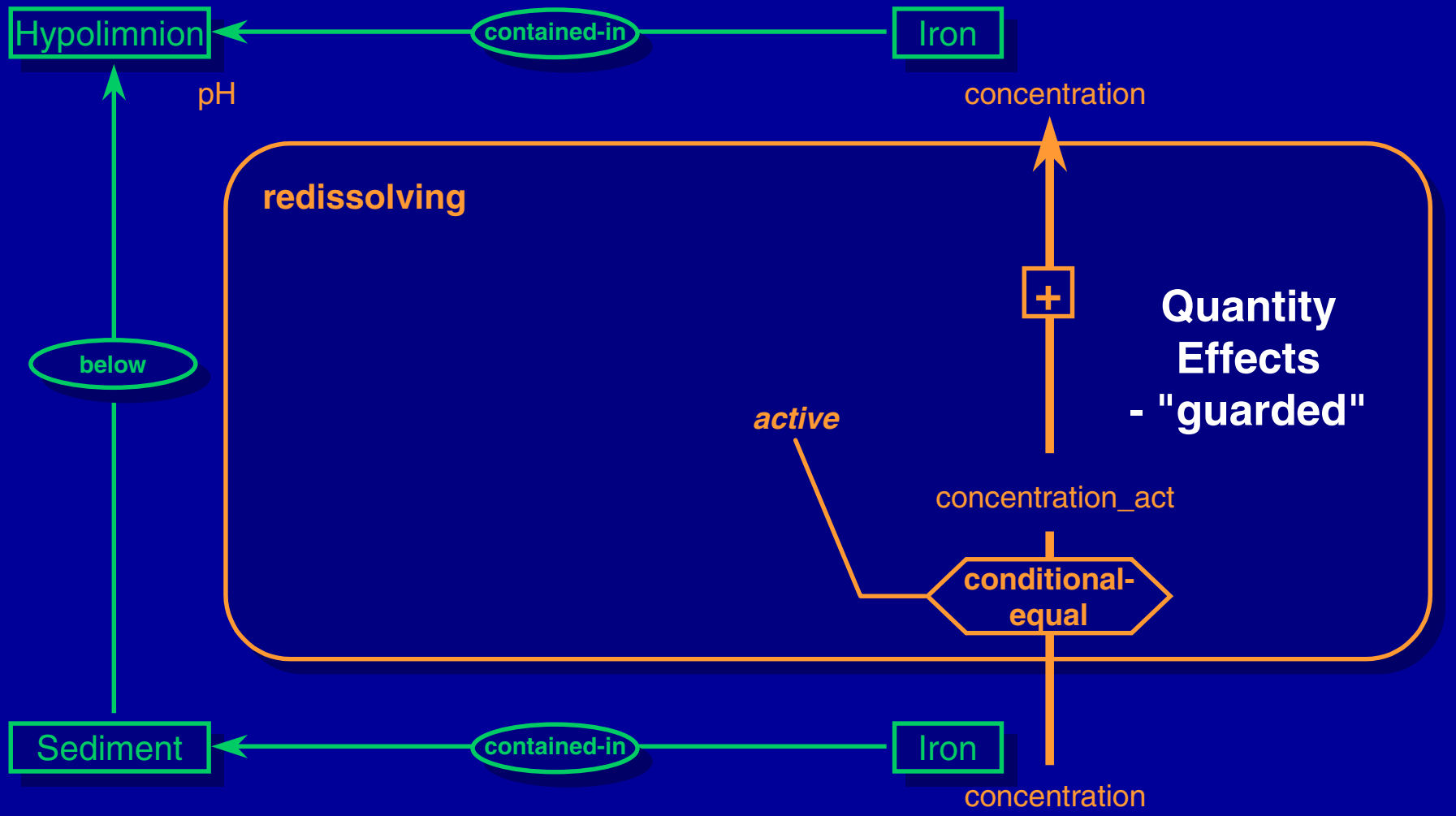
Example - Details of Conditions and Effects



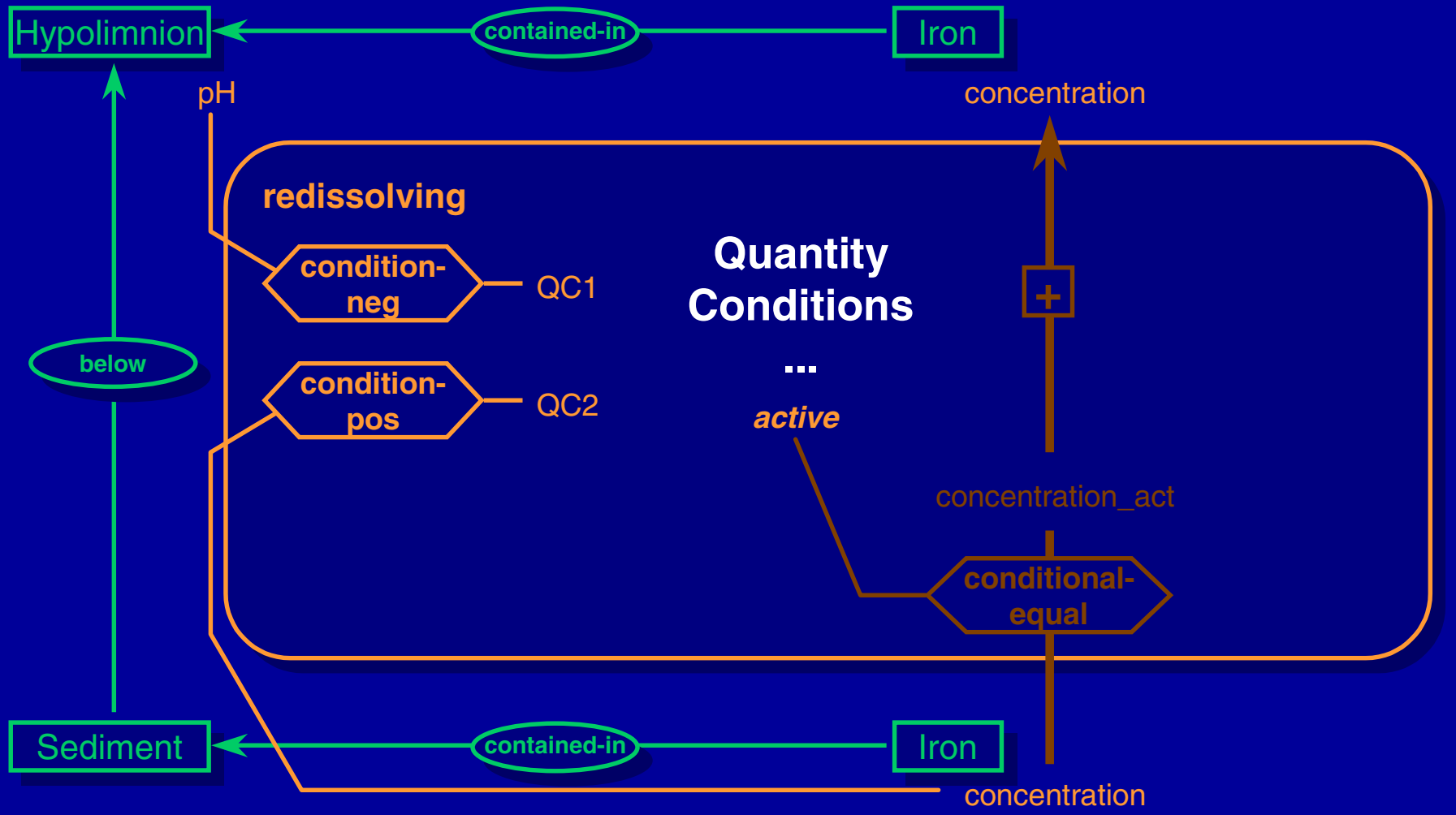
Example - Details of Conditions and Effects



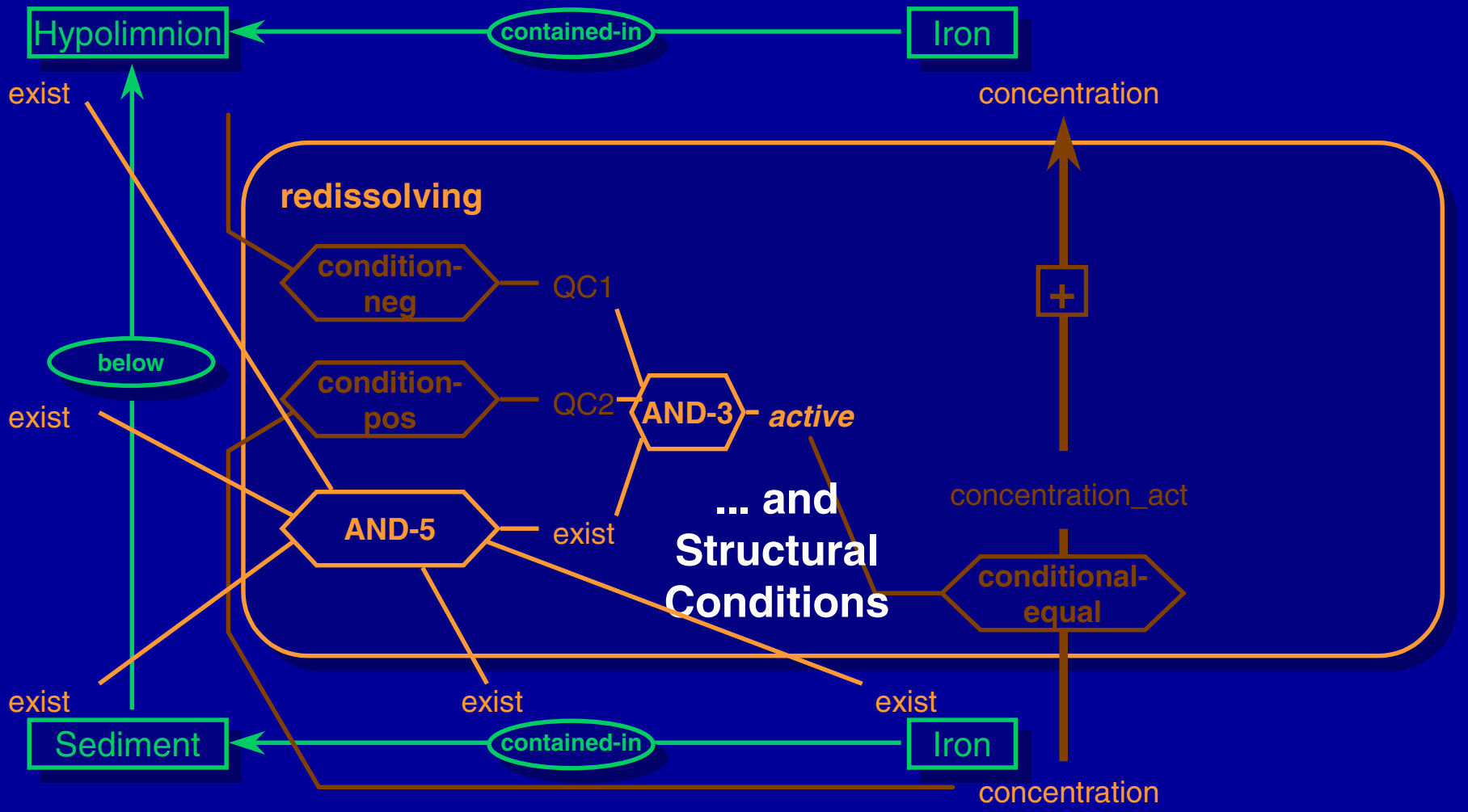
Example - Details of Conditions and Effects



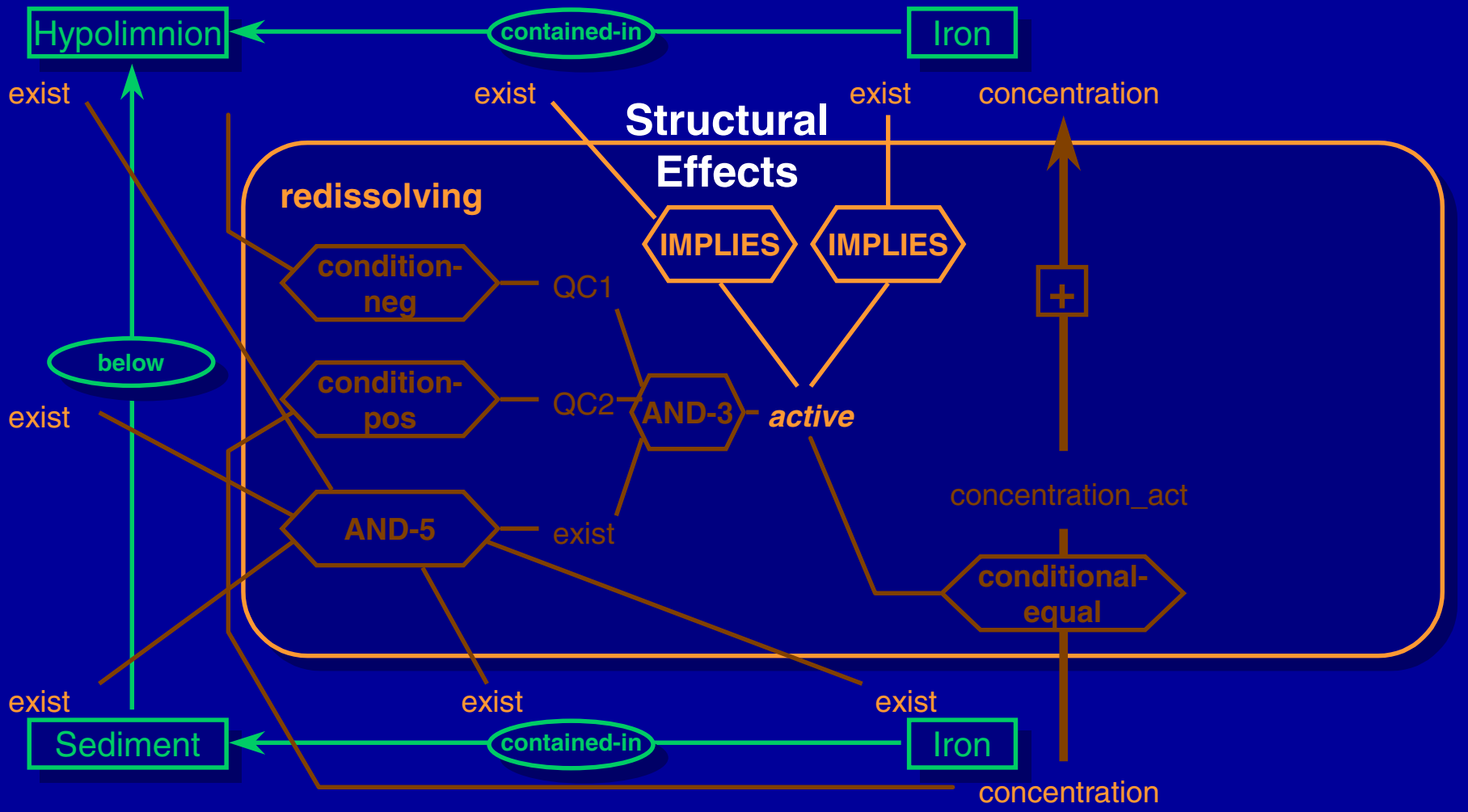
Example - Details of Conditions and Effects



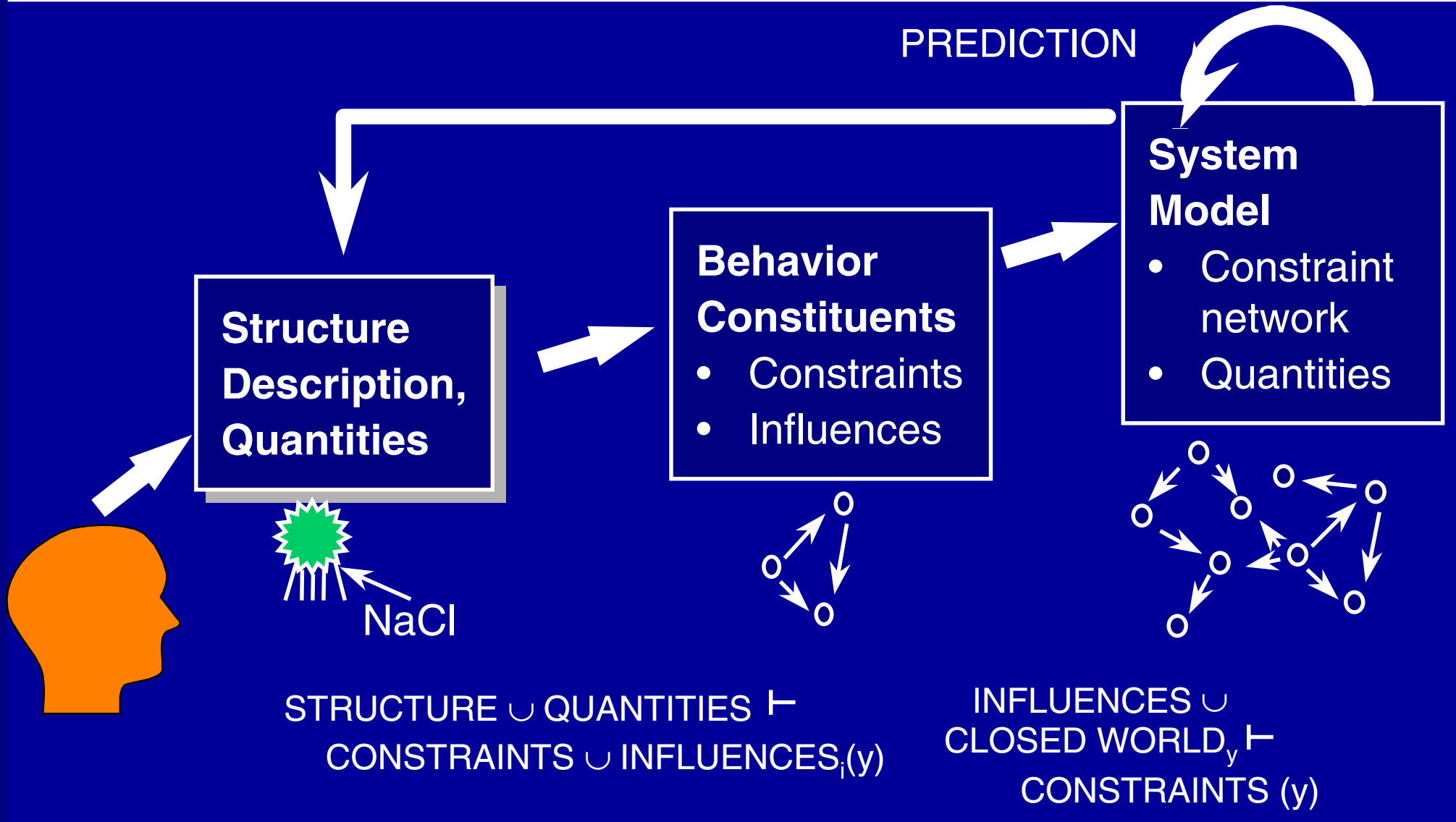
Example - Details of Conditions and Effects



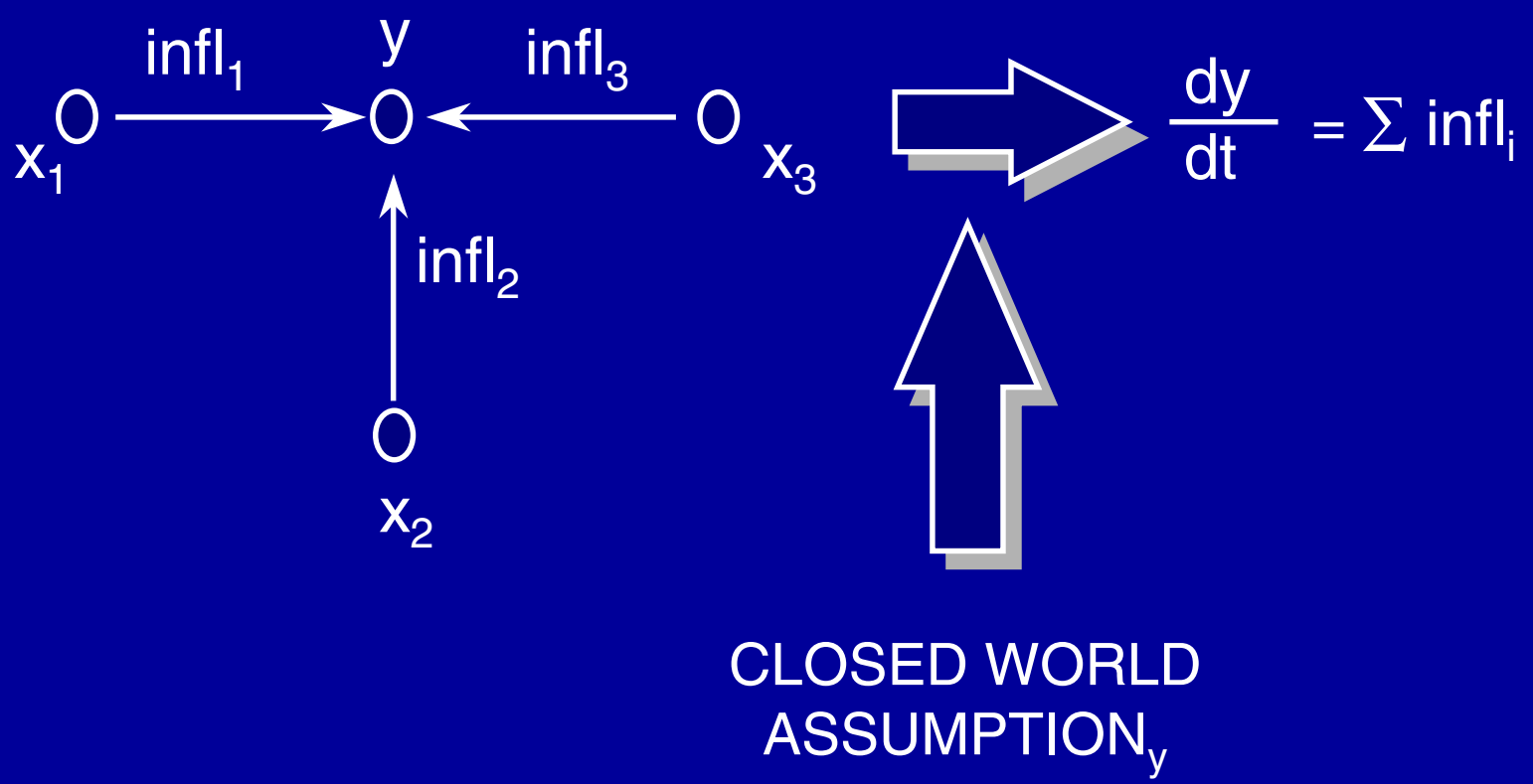
Example - Details of Conditions and Effects



Model Generation



Resolving Influences



Tasks: Situation Assessment

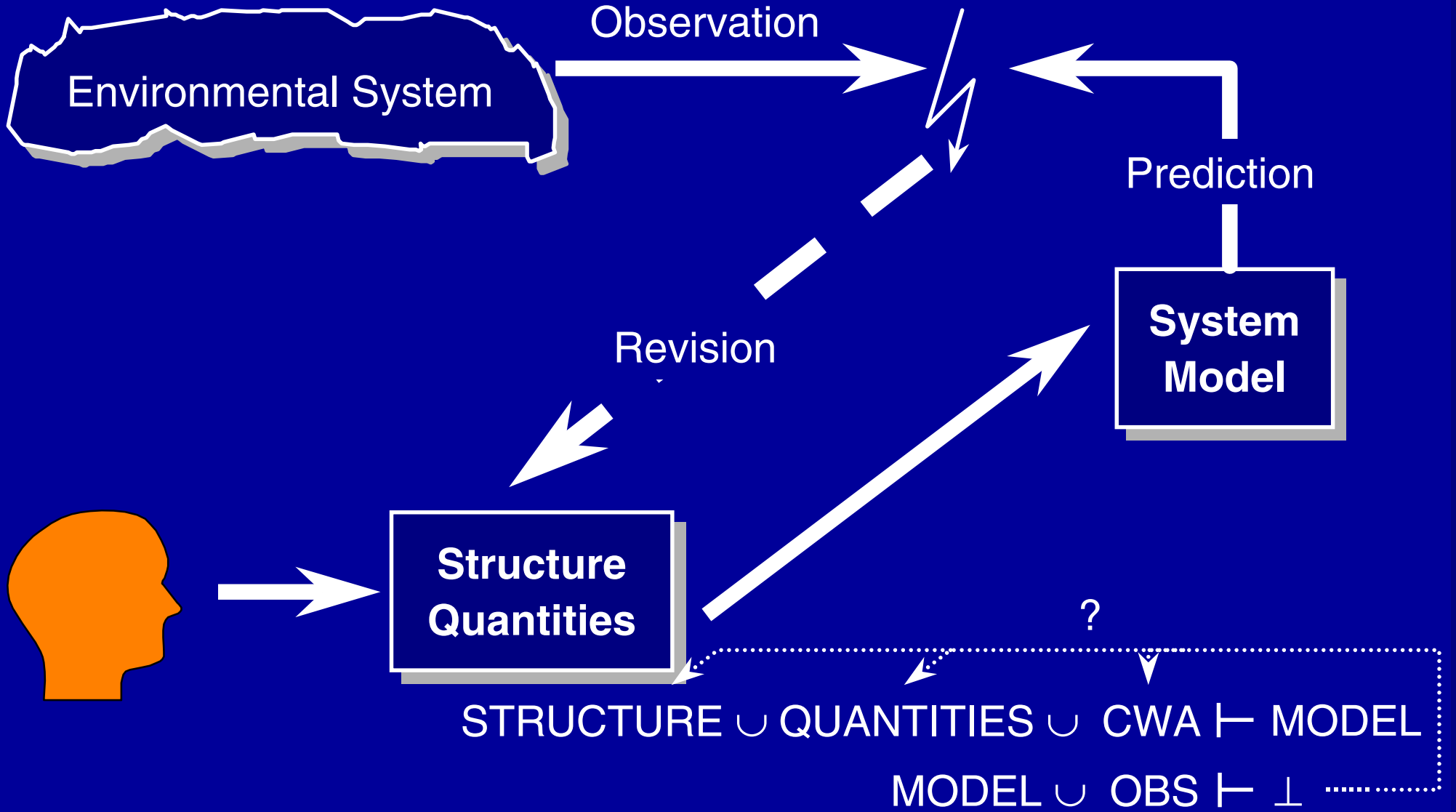
In area *x*, trees of specifier *y* shed their leaves at an unusual rate - what's going on?

OBS → SYSTEM SITUATION

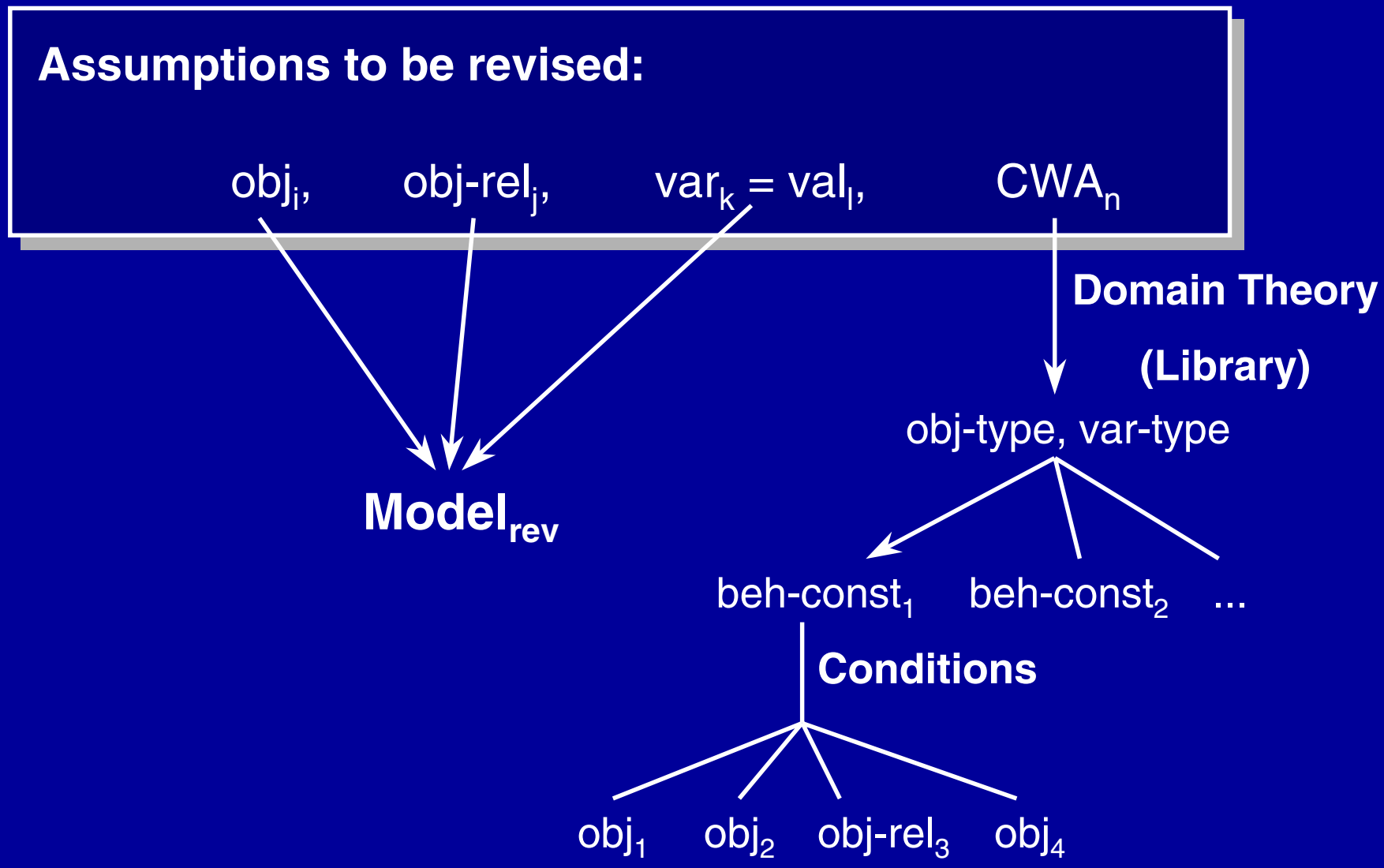
Determine

- relevant constituents and their relationships and parameters
- their current state: values of variables
- that collectively account for the observation

We May Be Wrong - Model Revision



Searching for Revisions



Specification of Revisables

$SD = SD_{rev} \cup SD_{fix}$

- We **know** (based on observations) something about the domain, the system, the state
- We **assume** some things about the system (objects and relations), the state

E. g. for situation assessment:

$OBS \subset QUANT_{fix} \subset SD_{fix}$

$SD_{rev} = STRUCT_{rev} \cup QUANT_{rev}$

Situation Assessment: Formalization

What Does not Fit the Observations?

- $MODEL_0 \cup OBS \vdash \perp$

  $\rightarrow$
- $MODEL_1 \cup OBS \nvdash \perp$

  or $\rightarrow$
- $MODEL_1 \vdash OBS$

System Identification

- $MODEL_{rev} = STRUCTURE_{rev} \cup PAR\text{-}SPEC_{rev} \cup CWA$

State Identification

- $MODEL_{rev} = VAR\text{-}SPEC_{rev}$

Diagnosis: Formalization

What Causes Violation of Goals?

- $MODEL_1 \cup GOALS \vdash \perp$
  $\rightarrow$
- $MODEL_2 \cup GOALS \nvdash \perp$
  or $\rightarrow$
- $MODEL_2 \vdash GOALS$

Revisable: What Can Be Influenced?

- $MODEL_{rev} = STRUCTURE_{rev} \cup VAR\text{-}SPEC_{rev} \cup CWA$

Tasks: Therapy Generation

Hearing identified possible causes of the mangrove degradation - what can be done?

GOALS →REMEDIATE ACTIONS

Determine

- responsible factors that can be influenced
- actions that create appropriate influences

Therapy Generation: Formalization

What Can Reach the Goals?

- $MODEL_1 \cup GOALS \vdash \perp$
  $\rightarrow$
- $MODEL_1 \cup ACTIONS \cup GOALS' \nvdash \perp$
  or $\rightarrow$
- $MODEL_1 \cup ACTIONS \vdash GOALS'$

- Actions as unconditioned processes
- Intermediate goals may be different from ultimate ones
- Goals may be revised

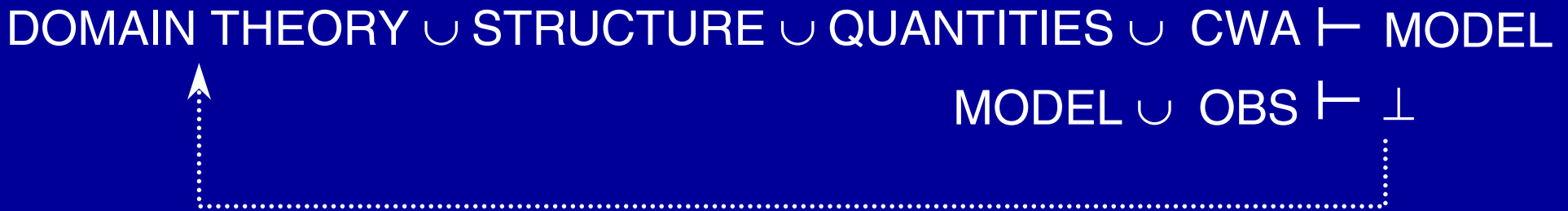
Reconstructing the Standard (Component-based) Approach

- **Object types:** Component types, terminal types
- **Object relation types:** connected (terminal, terminal)
  part-of (terminal, component)
- **Quantity associations:** Variables for terminal types,
  modes for components
- **Behavior constituents:** ok and fault models
  (and terminal identification)
  (IC: component-type, AC: mode)
- **Structure:** connection and part-of structure
- **State:** (terminal) variable values

GOAL $\Leftrightarrow$ {ok(C_i)}

Even More Ambitious: Model-guided Discovery

- Revise the domain theory (model fragment library)



Process-oriented Diagosis and Therapy Proposal: Discussion

Benefits

- More **general** theory
- Natural and **technical** processes
- Covers **component**-oriented diagnosis
- Systematic approach to **structural faults**
- **Integration** of processes and components

Open Issues

- Dynamics
- Search heuristics
- Minimality - of ultimate causes
- Termination
- Negation vs. irrelevance

Application Area: Ecology

Needs

- support understanding/research/ model building
- data overload: interpretation!
- partial information, knowledge
- robust computer systems
- support decision making (of non-experts)
- bridge between concepts and mathematical models

Relevant Features

- systematic modeling
- compositional modeling
- symbolic, conceptual modeling
- abstraction, low granularity
- reasoning with incomplete information, imprecision
- explicit representation
- problem solving

Applications in Ecology - Current State

- It's basic research!
- Appropriate ontologies?
- Mathematical formalisms?
- e.g. partial differential equ's
- Spatial reasoning
- Abstraction:
  individuals --> population
- Tiny model libraries
- Limited awareness of ecologists