Problem Solving Paradigms: Causal Reasoning

6.871 – Lecture 14

Outline

- Problem Solving Paradigms
  - What are they and what are they good for
- Causal reasoning as a PSP
  - ABEL
- Causal reasoning + rules + debugging
  - GORDIUS

A Recipe

- Study how experts characterize problems and solution methods, especially their technical vocabulary
- Mimic their *representation,* capture the abstractions
- Mimic their *problem solving mechanism*

This Works Because

- There are generic task types that span many domains
- There are a modest number of problem solving paradigms and their knowledge representations
- Each generic task has a variety of appropriate problem solving paradigms

- *Representations* indicate how to look at the world: capture the important abstractions of the problem domain.
- *Problem solving paradigms* organize representational, inferential and computational processes; indicate when and how to draw conclusions.

Caveats

- A problem solving paradigm suggests control structures and inference mechanisms
  - but is not synonymous with them.
- A knowledge representation suggests certain data-structures and control structures
  - but it is not synonymous with them.
- Problem solving paradigms and knowledge representations are knowledge level constructs, not mechanisms or data structures.

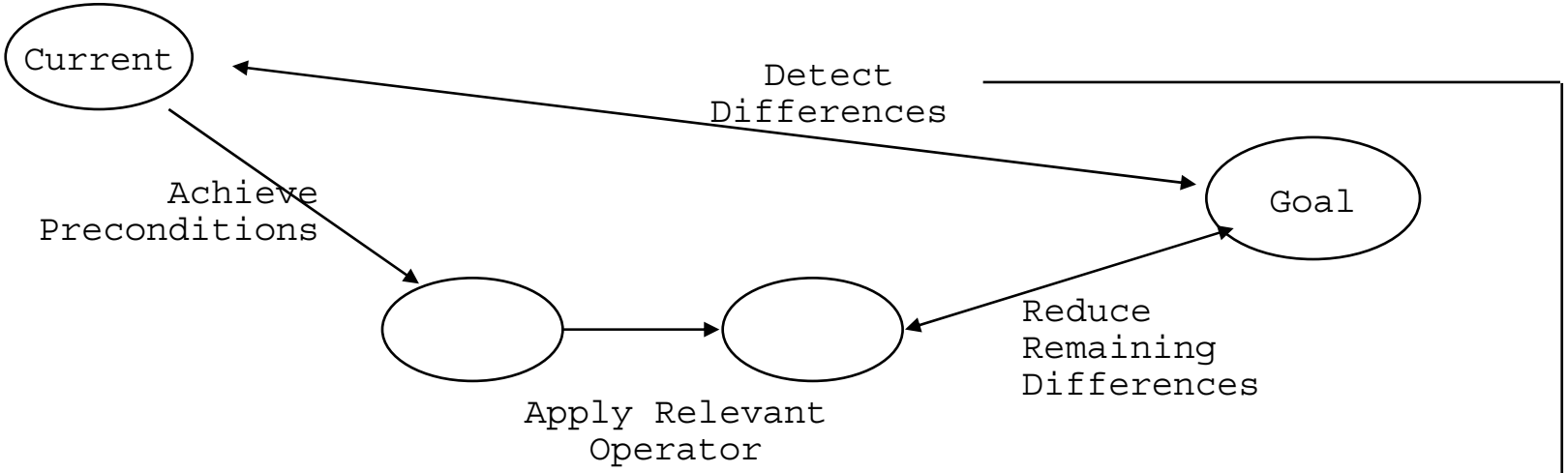
What's In A PSP?

- A representation for factual knowledge.
- Inferential methods
- A control structure dictating when to employ the inferential methods and with what purpose.

Why Concentrate on Paradigms?

- Special purpose programming languages for the paradigm can be created and reused.
- Knowledge acquisition tools specific to the paradigm can be designed and reused.
- Maintainability is improved.
- Need for "programming hacks" reduced.
- Emphasizes the search for the right level of abstraction.

A Basic Paradigm: Means Ends Analysis



Operator Difference Table

	Walk	Bike	Taxi	Bus
<1	x	x		
1-5	x	x	x	
5-50			x	x
50-500				x

Choose Relevant Operator

Diagnosis: A Classic Generic Task

- PSPs
  - Bayesian statistics
    - Naïve Bayes' rule
    - Sequential Bayesian diagnosis
  - Frequency and invoking strength: Internist
  - Empirical associations: Mycin
  - Causal: ABEL

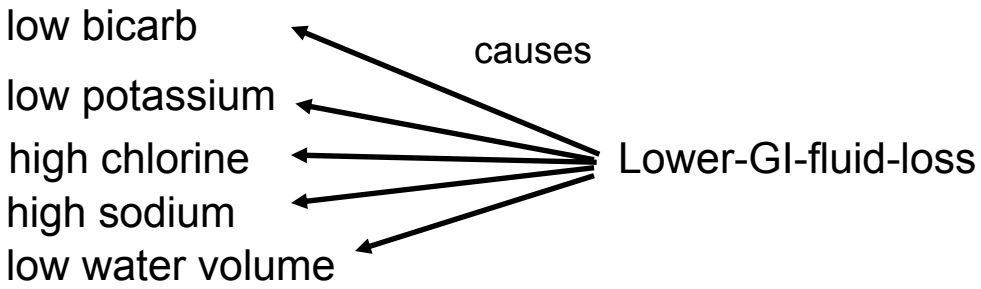
The Intuition

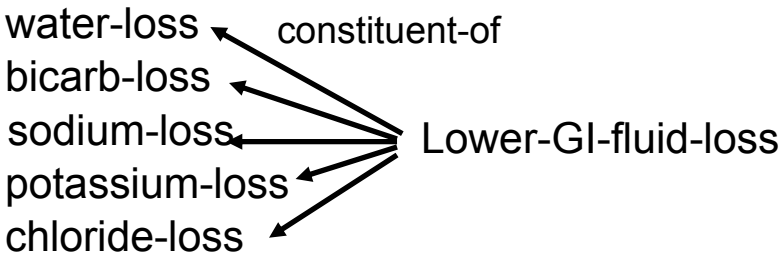
- A flooded basement
- An auto accident

ABEL

- Domain?
- Representation?

ABEL Representations





	Lower GI Fluid	Plasma Fluid
Na	100-110	138-148
K	30-40	4-5
Cl	60-90	100-110
HCO_3	30-60	24-28

Compared to plasma:

Lower GI Fluid is rich in HCO_3 and K; low in NA and Cl

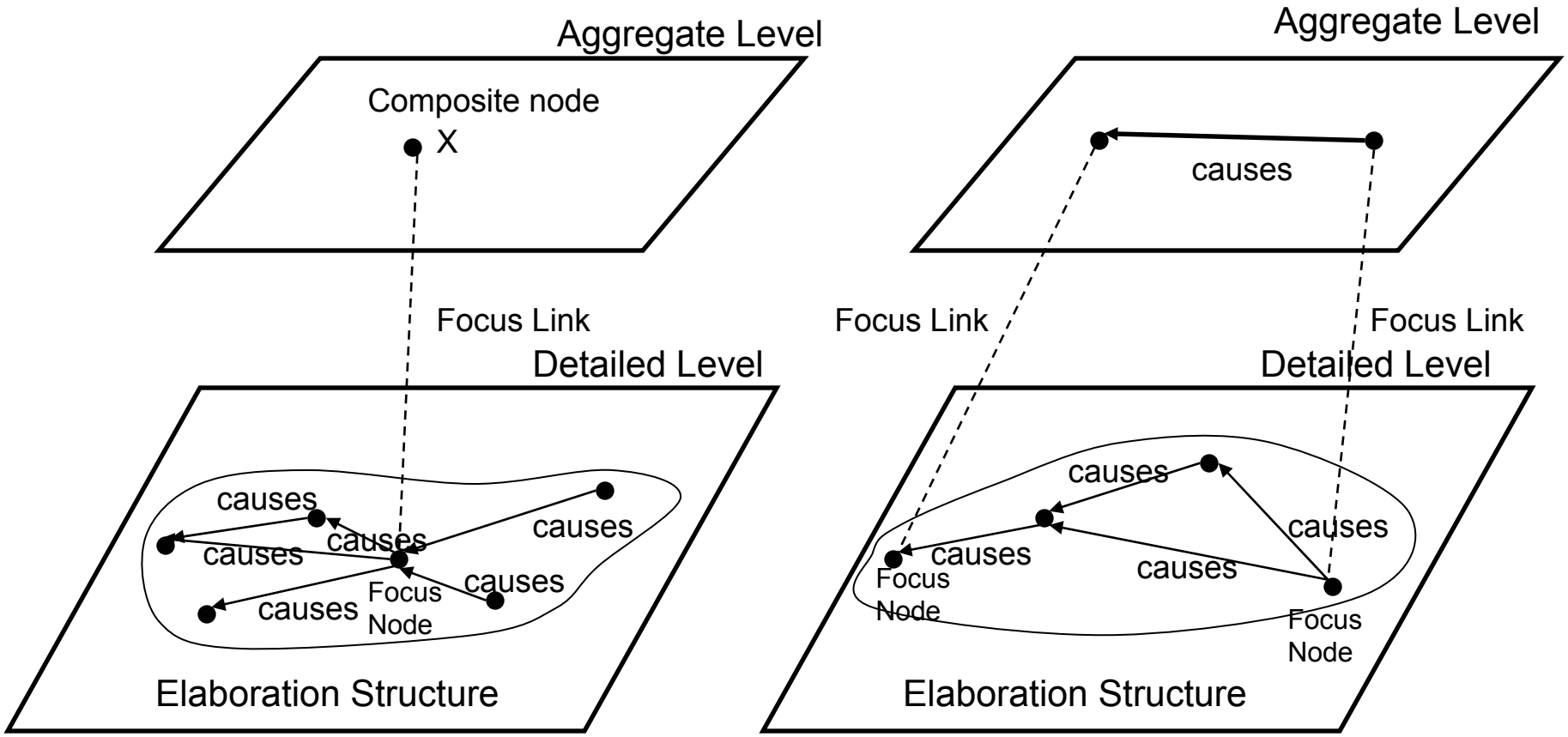
Loss of GI Fluid results in

reduced fluid in (hypovolemia)
reduced K (hypokalemia)
reduced HCO_3 (hypobicarbonatemia)
increased Cl (hyperchloremia)
increased Na (hypernatremia)

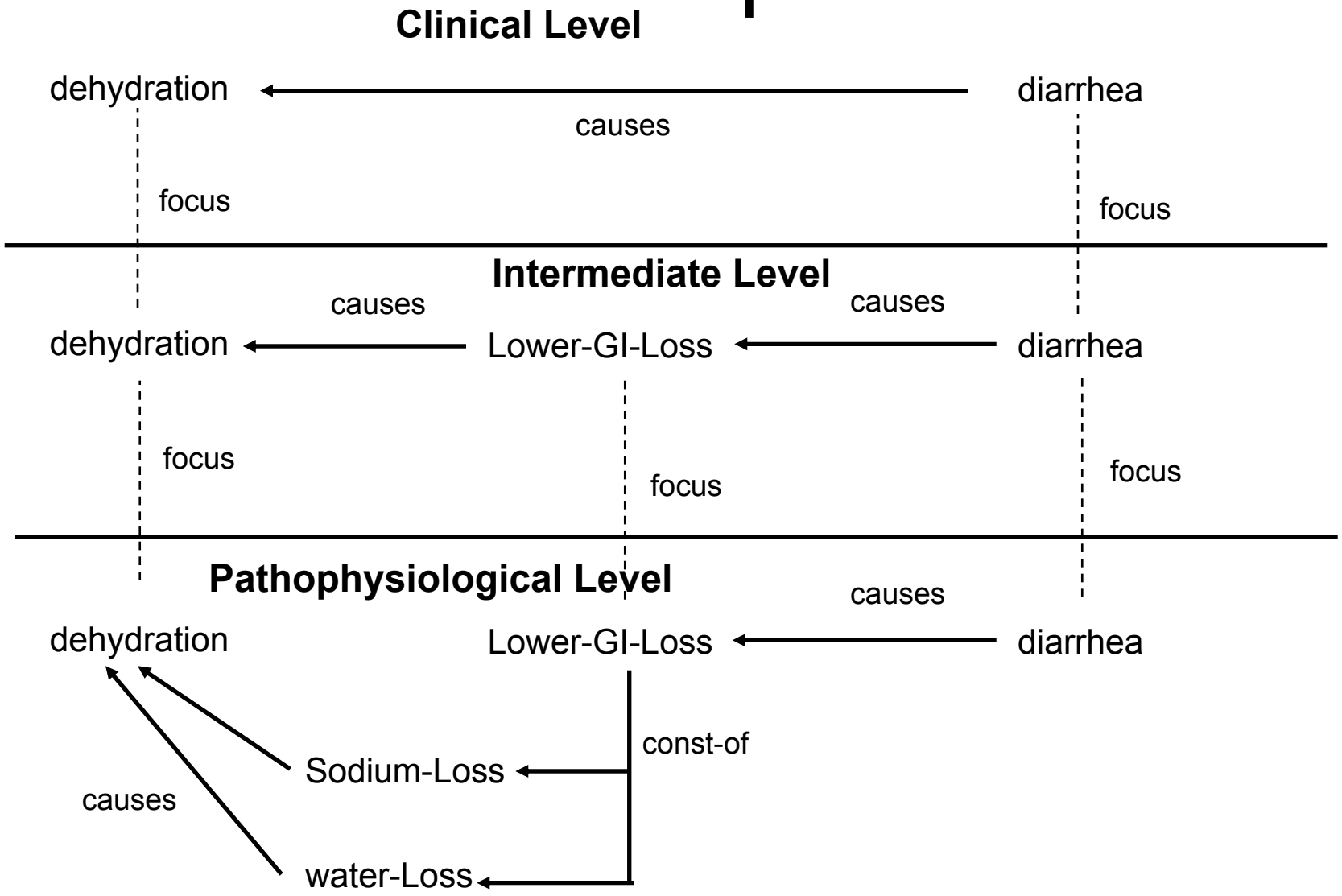
ABEL

- Causal knowledge represented at multiple levels of description
- Each causal relation characterized by constraints among severity, duration, etc. between cause and effect
- Each causal relation described at next more detailed level
- Each disease node described using network of nodes and causal links at next more detailed level
- Goal: assemble a causal explanation of all findings using a network of causal relations at many levels of detail.
- Models interactions between the hypothesized diseases

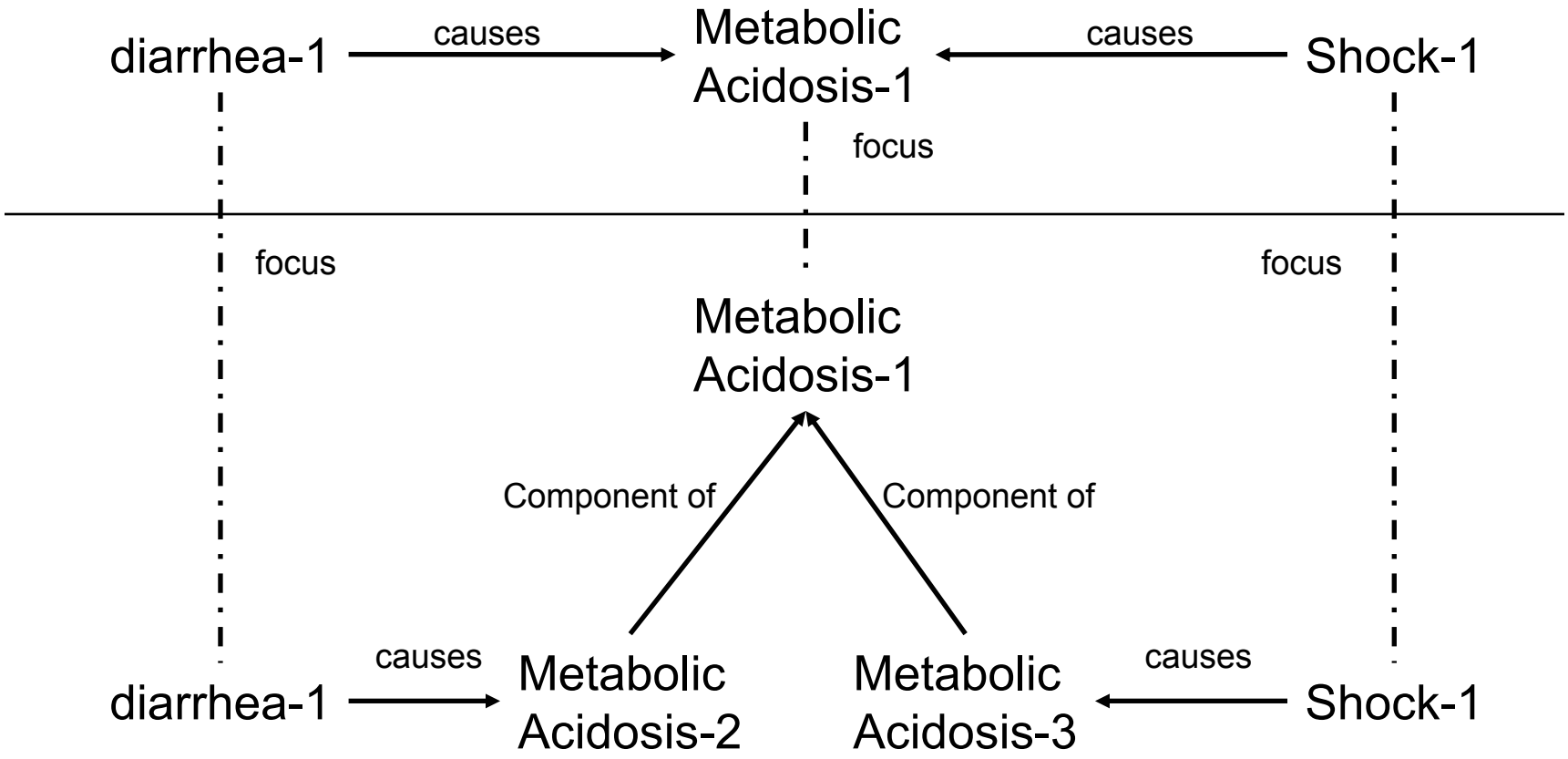
Multiple Levels



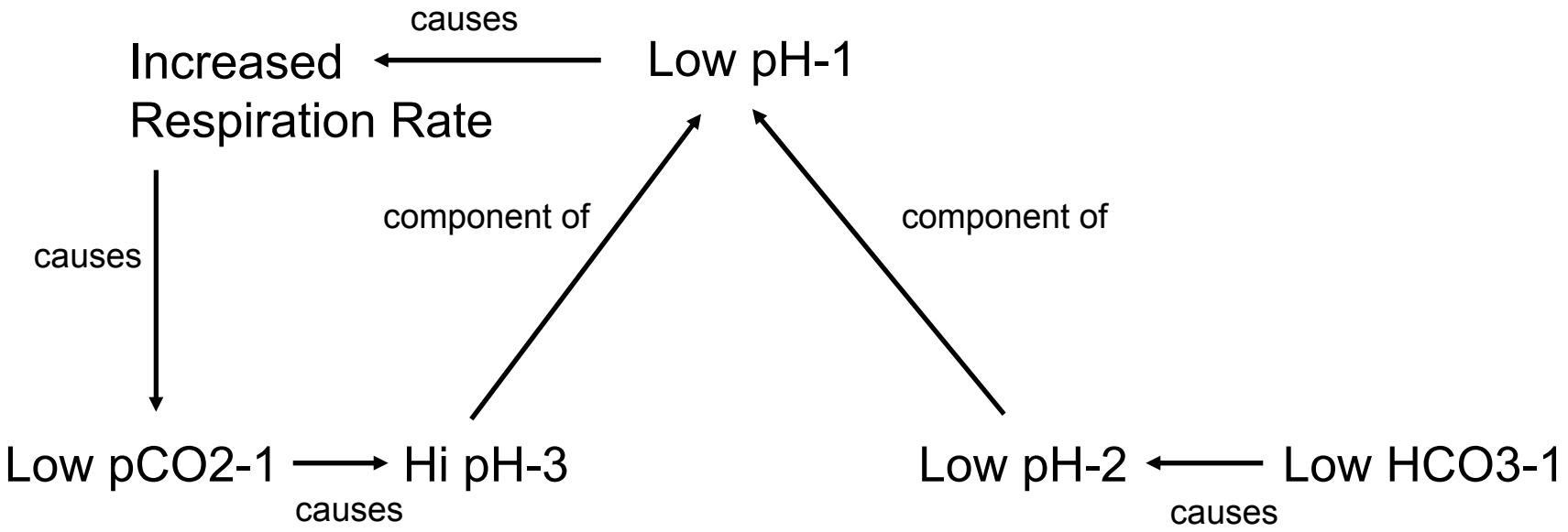
ABEL: Multiple Levels



Accounting For Multiple Causes

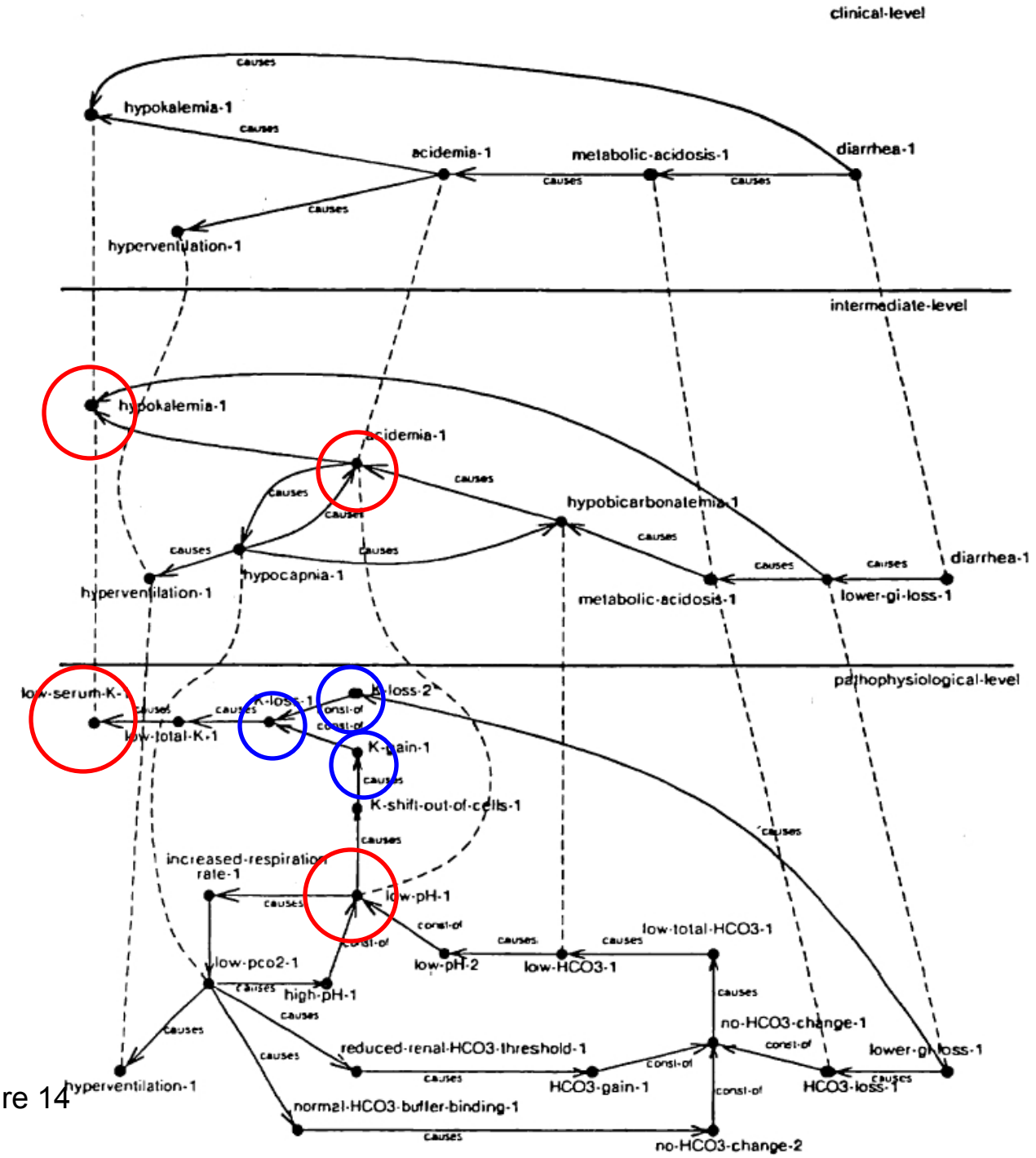


ABEL: Modeling Feedback



ABEL Operations

- Elaboration : Makes connections across levels of detail by filling in the structure below
- Aggregation: Makes connections across levels of detail by filling in the structure above
- Component Decomposition: Relates disorders at the same level of detail by breaking up a node into component parts
- Component Summation: Relates disorders at the same level of detail by summing (arithmetically) contributions of components parts.
- Projection: Forges causal links at the same level of detail in the search for etiologic explanation


clinical-level
causes
hypokalemia-1
acidemia-1
metabolic-acidosis-1
diarrhea-1
hyperventilation-1
intermediate-level
hypokalemia-1
acidemia-1
hypobicarbonatemia-1
hypocapnia-1
hyperventilation-1
metabolic-acidosis-1
lower-gi-loss-1
diarrhea-1
pathophysiological-level
low-serum-K-1
low-total-K-1
K-loss-1
K-loss-2
K-gain-1
K-shift-out-of-cells-1
increased-respiration-rate-1
low-pH-1
low-pH-2
low-HCO3-1
low-total-HCO3-1
low-pco2-1
high-pH-1
hyperventilation-1
reduced-renal-HCO3-threshold-1
HCO3-gain-1
HCO3-loss-1
normal-HCO3-buffer-binding-1
no-HCO3-change-1
no-HCO3-change-2
lower-gi-loss-1

Combining Paradigms

- Gordius:
  - Generate – test – debug
  - Rules + Causal Models

- What's generate and test as a PSP?
  - Dendral as an example
  - What did Dendral's tester tell you?

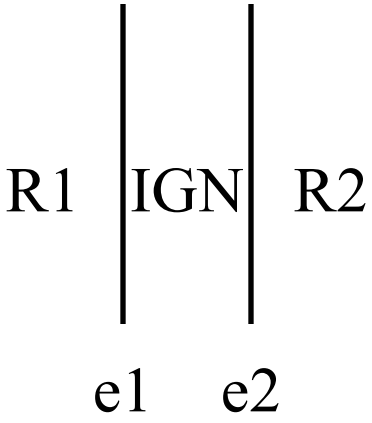
GORDIUS

- Domain/task?

Processes

- Deposition
- Intrusion
- Fault
- Uplift/subsidence
- Tilt

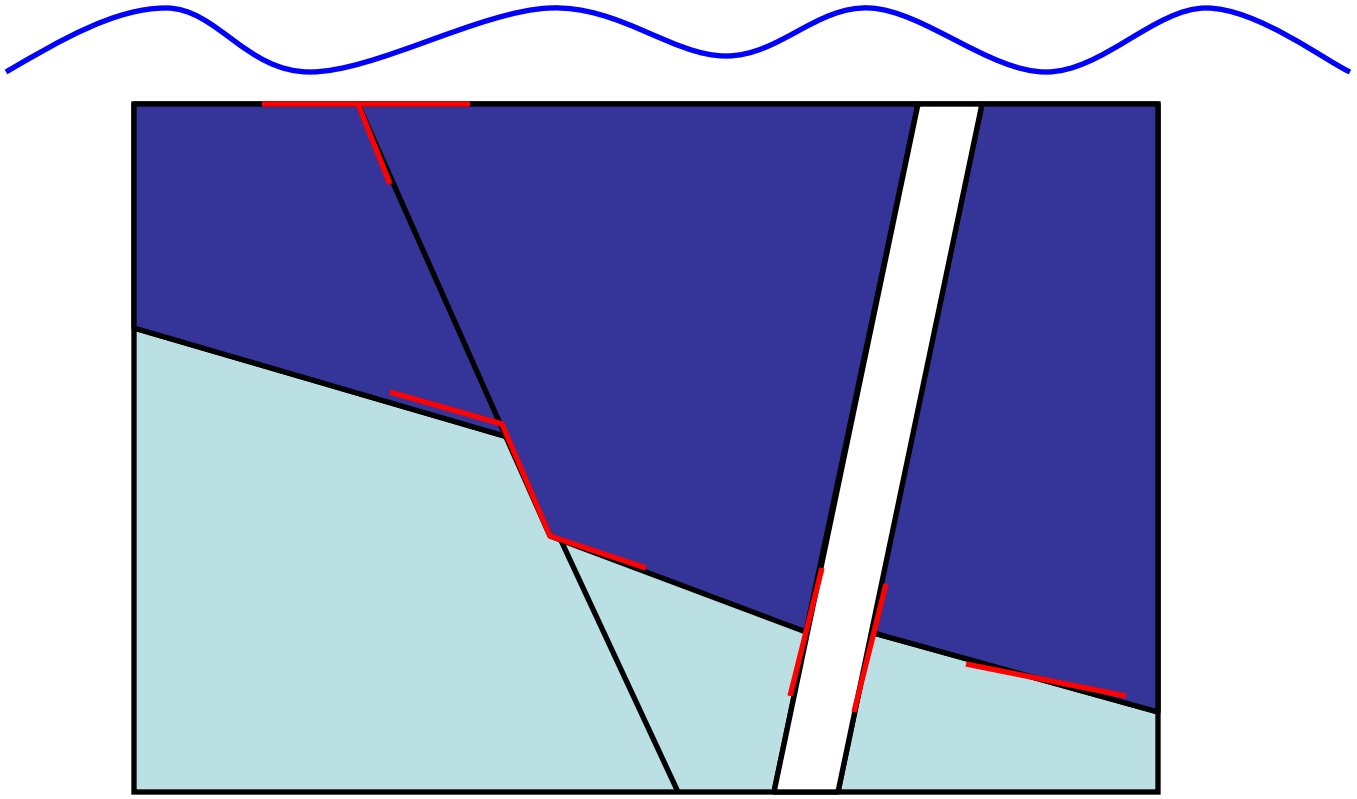
Rules Model Interactions



Pattern constraints
- Igneous(IGN)
- Same-type(R1, R2)
- Parallel(e1,e2)

Events:
- create rock1
- intrude IGN through rock1

Local Matching



Debugging

- Dependency maintenance
  - height affected by:
    - shale is produced underwater
    - shale deposit depth
    - height is unchanged since deposition
    - sea level unchanged since deposition
- Repair strategies
  - “unchanged” assumption
  - parameter value assumption
  - time ordering assumption

Summary

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- Causal reasoning as a PSP
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