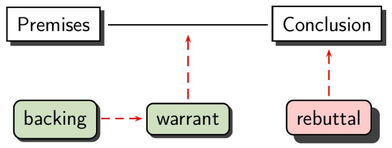
# Non-Monotonic Logics and Formal Argumentation

Institute for Philosophy II

RUB

## Defeasible Reasoning (in short, DR)

Defeasible reasoning (in short, DR) is indispensable when dealing with a world full of uncertainties: we constantly draw conclusions that we may reject later in view of new information. Examples of DR are numerous: induction, abduction, inferences on the basis of expert opinion, etc. We find DR in everyday reasoning, in expert reasoning (e.g. medical diagnosis), and in scientific reasoning. When reasoning defeasibly, people sometimes make mistakes (they fail to reject conclusions when there are good reasons to do so). Given that DR is central for human reasoning, this urges us to study DR with exact formal methods. Only in this way, are we able to explicate and evaluate reasoning processes in a precise way and to assist and correct people in reasoning.




The inference from the available data to our claim is supported by means of a warrant. What is most noteworthy are the elements rebuttal and backing. A rebuttal may indicate exceptional circumstances in which the warrant would have to be set aside. The need of backing indicates that the authority of the warrant may in general be in in need of further support.

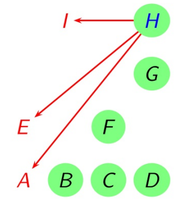
DR forms may not be the fallacies we took them for, nevertheless one could argue that they are too chaotic to be characterized in exact formal ways. Such fears were counterbalanced when in the eighties significant developments in the formal modeling of DR began to take place. The field of non-monotonic logics made important breakthroughs. However, after more than 30 years of research, there still seems to be a vast gulf between the toy examples discussed in formal approaches and real-life examples of DR discussed in informal logic.

What we need is a broader perspective than the one offered by non-monotonic logics. An argumentative approach seems to be ideal for this purpose. Why this is the case becomes clear when contrasting traditional logics (modeling deductive reasoning) and early insights in informal logic. Logics that model deductive reasoning are based on the idea of support: in order to infer some claim we need to find an argument that supports our claim. That is to say, given a set of premises and the rules of our logic (such as Modus Ponens), we need to construct a sequence of rule applications resulting in the derivation of our claim.

This method is insufficient for DR due to the fact that, in view of new information, we may have good reasons to retract a previous inference. While the idea of support still plays an important role, it has to be compensated by a mechanism that takes into account the fallible nature of defeasible inferences. This insight is, for instance, reflected in Toulmin's seminal diagram, pictured on the left.

## Normative Reasoning

Another application context that deserves special attention is normative and ethical reasoning. Normative reasoning constitutes an important part of our everyday reasoning and of expert reasoning in various fields, such as medicine and bio-ethics, where normative considerations are often central and of great social relevance. Moreover, in the sciences we often face normative debates. For instance, when debating about the acceptance or pursuit worthiness of theories, scientists call upon and reason about values and preferences.




$A = m \to O\neg f \Rightarrow m \to O\neg f$
$B = m \Rightarrow m$
$C = a \Rightarrow a$
$D = (m \wedge a) \to Of \Rightarrow (m \wedge a) \to Of$
$E = m, m \to O\neg f \Rightarrow O\neg f$
$F = m, a \Rightarrow m \wedge a$
$G = m, a, (m \wedge a) \to Of \Rightarrow Of$
$H = m, a, (m \wedge a) \to Of \Rightarrow \neg(m \to O\neg f)$
$I = m, a, m \to O\neg f, (m \wedge a) \to Of \Rightarrow O\bot$

- being served a meal you ought not to eat with your fingers
- however, being served asparagus you are obliged to eat with your fingers

$$\Sigma = \{m, a, m \to O\neg f, (m \wedge a) \to Of\}$$

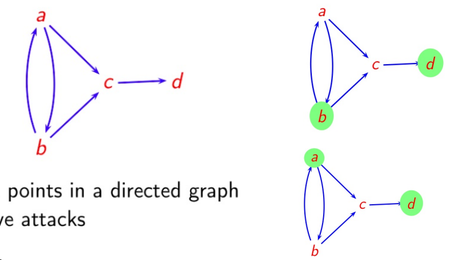
Since we set out to seriously study the rationality of transition phases in the sciences, it is essential to have formally exact tools that enhance our understanding of normative reasoning. The subtleties and technical challenges in the formal research of normative reasoning motivate to study it in-depth and in its own right.

# Formal Models of DR

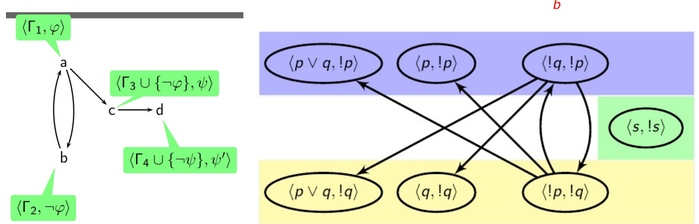
## Formal Argumentation

One of the predominant paradigms in A.I. research are abstract Argumentation Frameworks, that are directed graphs where arguments are abstract entities and arrows represent attacks.

One of the central ideas in formal argumnetation is that an argument is only warranted in case it is defensible from counterarguments.



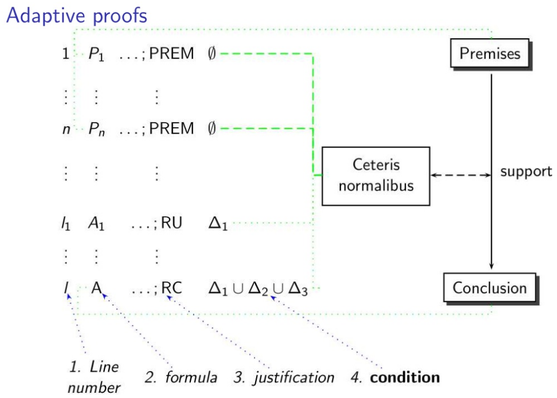

- arguments: abstract, points in a directed graph
- arrows: argumentative attacks




## Adaptive logics

are a type of Non-Monotonic Logics that provide a uniform logical framework for reasoning with defeasible normality assumptions. Its proof theory offers an intuitive formalization of this type of conditional reasoning. The adaptive logic framework has been used to model a wide range of defeasible reasoning forms with various applications in scientific and normative reasoning.

| | | | |
|---|---|---|---|
| 1 | $\diamond p$ | Prem | $\emptyset$ |
| 2 | $\diamond q$ | Prem | $\emptyset$ |
| 3 | $\diamond s$ | Prem | $\emptyset$ |
| 4 | $\neg p \vee \neg q$ | Prem | $\emptyset$ |
| 5 | $s$ | 3; RC | $\{!s\}$ |
| 6 | $p$ | 1; RC | $\{!p\}$ |
| 7 | $q$ | 2; RC | $\{!q\}$ |
| 8 | $p \vee q$ | 6; RC | $\{!p\}$ |
| 9 | $p \vee q$ | 7; RC | $\{!q\}$ |
| 10 | $!q \vee !p$ | RU, 1,2;4 | $\emptyset$ |

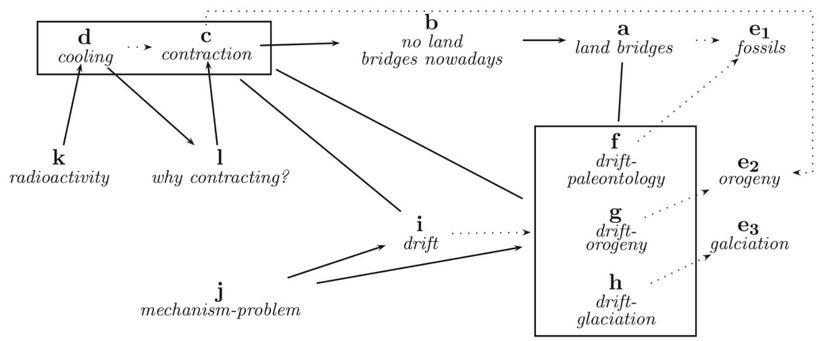



## Non-Monotonic Logic

DR has also been intensively studied within the domain of nonmonotonic logic, leading to a plethora of logics for different types of DR. Defeasible Reasoning, just like deductive reasoning, can follow complex patterns. However, such patterns are beyond reach for classical logic (CL), intuitionistic logic (IL) or other logics that characterize deductive reasoning since they—by their very nature—do not allow for a retraction of inferences.

## Scientific Reasoning

Formal systems become useful when applied to specific domains. Moreover, the modeling of concrete reasoning types provides an excellent test case for a formal framework. While formal argumentation systems have been frequently applied to legal reasoning, scientific reasoning has comparatively been neglected. Nevertheless, scientific rationality is often considered a paradigmatic example of rationality. In this project, we will investigate scientific reasoning with an emphasis on causal, abductive and inductive reasoning and reasoning with and about values and goals. The aim of the workgroup is, on the one hand, to offer a formal framework where the mentioned inference types are explicated and in which they can be combined. On the other hand, we do case studies where we apply our framework to debates in the history of science.

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