Reasoning and Formal Modelling for Forensic Science

Prof. Dr. Benedikt Löwe

2nd Semester 2010/11

Course description according to studiegids.

There are many things that can go wrong in reasoning: we can have flawed formal arguments, informal arguments that refer to false facts, fallacious arguments. In order to avoid the pitfalls of reasoning, it is important to learn what can go wrong and how it can go wrong. In this course, students should learn the basics of argumentation theory, gain some expertise in the use of formal languages for reasoning, and finally obtain some skills in the use of formal models of procedures and processes.

We distinguish between formal reasoning and informal reasoning. After dealing with the most basic forms of formal reasoning (syllogistics and propositional logic), we cover the basics of argumentation theory and the theory of fallacies. In the second half of the course, we will discuss formal models for understanding interactive processes in some simple examples.

Three main goals of the course.

- Basics of formal logic.
- Basics of "informal logic": *Argumentation Theory*
- Proper formalization and techniques to describe complex situations

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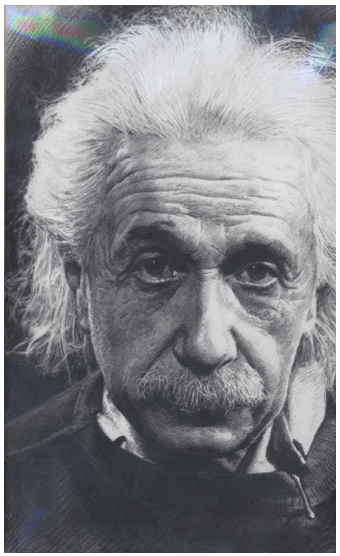

Insofern sich die Sätze der Mathematik auf die Wirklichkeit beziehen, sind sie nicht sicher, und insofern sie sicher sind, beziehen sie sich nicht auf die Wirklichkeit.

If the theorems of mathematics talk about the real world, they are uncertain; and if they are certain, they do not talk about the real world.

Origins of Logic (1).

Aristotle

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Aristotle

Logica vetus. Aristotle, Categories. Aristotle, *De Interpretatione*. Porphyry, Isagoge. *Liber sex principiorum*. Boëthius, *De topicis differentiis*. Boëthius, *De divisione*. Boëthius, *De syllogismis categoricis*. Boëthius, *De syllogismis hypotheticis*.

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Logica nova. Aristotle, *Analytica priora*. Aristotle, *Analytica Posteriora*. Aristotle, *Topica*. Aristotle, *De sophisticis elenchis*.

Origins of Logic (2).

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Roughly, these two parts of logic correspond to "formal logic" and "informal logic" (= Argumentation Theory) in our course.

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Jens Høyrup, Lengths, widths, surfaces. A portrait of old Babylonian algebra and its kin. New York 2002

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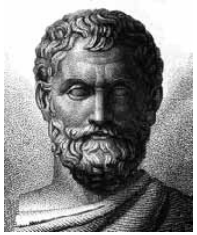
- Thales of Miletus (c.625-c.546 BC): the first proof



Dmitri **Panchenko**, Thales and the Origin of Theoretical Reasoning, **Configurations** 1 (1993), p. 387–414

Greek mathematics (2).

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Theoretical Greek mathematics built on proof and the axiomatic method:

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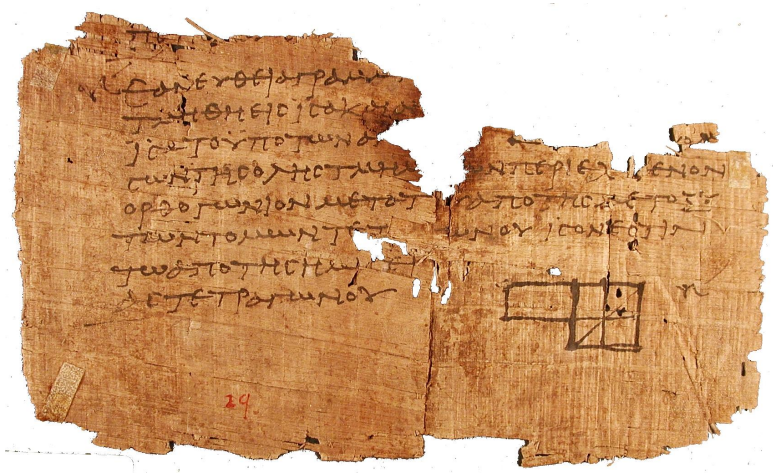
Theoretical Greek mathematics built on proof and the axiomatic method:

- Basic statements which are obviously true: *axioms*.
- Accepted arguments on the basis of axioms and earlier conclusions.

Euclid (c.325-c.265 BC); compilation of mathematical knowledge: the Elements



Informal logic.

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Rhetoric.

> *Of the modes of persuasion some belong strictly to the art of rhetoric and some do not. The rhetorician finds the latter kind (viz. witnesses, contracts, and the like) ready to his hand. The former kind he must provide himself; and it has three divisions – (1) the speaker's power of evincing a personal character which will make his speech credible (ethos); (2) his power of stirring the emotions of his hearers (pathos); (3) his power of proving a truth, or an apparent truth, by means of persuasive arguments (logos). (Aristotle, Rhetorica).*

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The Sophists.

Jacqueline de Romilly. The Great Sophists in Periclean Athens. Clarendon 1992:

> *They knew certain methods and could teach them. They were masters of thinking, masters of talking. ... The sophists introduced an intellectual education that would enable anybody with the means to pay for it to play a distinguished part in city life. ... Practical success was thus the aim of this teaching. With its claim that anybody could learn and profit from it, it opened up to all citizens' careers in public speaking.*

Two approaches to logic.

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The quest for truth.

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Axiomatic method. *Normative* character of logic.

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A description of reasoning and argument.

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The quest for truth.

Axiomatic method. *Normative* character of logic.

A description of reasoning and argument.

Descriptive character of logic. Dependency on how you express things, in what contexts you say things.

An example from the US Supreme Court (1)

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The US Constitution (Article III) gives the congress the power to assign cases in which the parties are from different states to federal courts (rather than state courts): diversity jurisdiction.

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Lewis A. Kornhauser, Lawrence G. Sager, The One and the Many: Adjudication in Collegial Courts, **California Law Review** 81 (1993), pp. 1–59

p: Congress has the right to go beyond the literal meaning of Article III

q: The District of Columbia is a state in the sense of Article III

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$p \vee q \leftrightarrow r$.

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Black	Yes	No	Yes
Burton	Yes	No	Yes
Jackson	Yes	No	Yes
Murphy	No	Yes	Yes
Rutledge	No	Yes	Yes
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The Doctrinal Paradox

A fictitious civil case.

Three judges:

- The first one believes that the contract between P_1 and P_2 was valid, and that P_1 satisfied the requirements of the contract.
- The second one believes that the contract between P_1 and P_2 was invalid, but that if it had been valid, P_1 would have been in breach of contract.
- The third one believes that the contract was valid and that P_1 was in breach of contract.

Judge	Contract	Breach	Liable
1	Yes	No	No
2	No	Yes	No
3	Yes	Yes	Yes

A fictitious criminal case.

Three judges:

- The first one believes that S used the axe to kill V and that the fingerprints prove that he did it.
- The second one believes that the fingerprints got on the axe much earlier and have nothing to do with the death of V, but that S used some other means to kill V.
- The third one believes that S is innocent.

Judge	Axe	Other means	Guilty
1	Yes	No	Yes
2	No	Yes	Yes
3	No	No	No

A fictitious social study

In a US state considering the reinstatement of capital punishment, a social scientist studies the opinions of people concerning the death penalty. There is a famous murder case where John Smith is believed to have murdered Jane Miller. The social scientist does a representative study asking the following three questions:

Q1 "Do you agree that people guilty of murder should be executed?"

Q2 "Do you believe that John Smith murdered Jane Miller?"

Q3 "Do you agree that John Smith should be executed?"

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Q2 "Do you believe that John Smith murdered Jane Miller?"

Q3 "Do you agree that John Smith should be executed?"

	Q1	**Q2**	**Q3**
Yes	55%	91%	35%
No	39%	2%	38%
Undecided	16%	7%	27%

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The interpretation of what is happening in real world cases of reasoning depends on the context. Depending on context, there are different phenomena we would like to highlight and study. "Violations of rationality" can be explained or even endorsed after taking into account additional information.

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Social Choice Theory. (At the UvA: "computational social choice")

For us, the question is not "which mechanisms can we use in order to enforce coherence with the doctrine", but rather "what is the correct doctrine" or "where does the doctrine come from"?

Psychology of Reasoning

Marian Counihan, Looking for logic in all the wrong places: an investigation of language, literacy and logic in reasoning. PhD thesis, Universiteit van Amsterdam, 2008. DS-2008-10.

A browse through the psychology shelf at your local bookshop makes clear that bad reasoning is big business. Popular titles include

- *"Inevitable Illusions: How Mistakes of Reason Rule Our Minds" (Piattelli-Palmarini, 1996, a best-seller in Italian),*
- *"Don't Believe Everything You Think: The 6 Basic Mistakes We Make in Thinking" (Kida, 2006, ranked number 38 on Amazon's list of over 5000 cognitive psychology titles1), and*
- *"How We Know What Isn't So: The Fallibility of Human Reason in Everyday Life" (Gilovich, 1991, number 74 in the same ranking).*

Such titles are not very encouraging about the state of human reasoning ability. It seems that at every turn we are tricked by 'cognitive illusions' into drawing compelling but invalid conclusions. We might wonder: are things really that bad? Or is this just populist hype to sell books?
Actually, if some researchers in the psychology of reasoning are to be believed, things really are that bad. Byrne, Espino and Santamaria (1999) go so far as to blame the disaster at the Chernobyl nuclear faculty on the failure to draw the fairly simple [...] inference. (p. 13)

Example 1.

Luria, A. (1976). Cognitive development: its cultural and social foundations. Harvard University Press, Cambridge, Massachusetts.

Khamrak, age forty, miller from remote village, illiterate.

E: In the Far North, where there is snow, all bears are white. Novaya Zemlya is in the Far North and there is always snow there. What color are the bears there?
S: I don't know what color the bears are there, I never saw them.
...
E: But what do you think?
S: Once I saw a bear in a museum, that's all.
E: But on the basis of what I said, what color do you think the bears are there?
S: Either one-colored or two-colored ... [ponders for a long time]. To judge from the place, they should be white. You say that there is a lot of snow there, but we have never been there!

Example 2.

Sylvia Scribner, Mind and Social Practice: selected writings of Sylvia Scribner. Cambridge University Press, Cambridge 1997

'All Kpelle men are rice farmers; Mr Smith is not a rice farmer. Is he a Kpelle man?'

S: I don't know the man in person. I have not laid eyes on the man himself.
E: Just think about the statement.
S: If I know him in person, I can answer that question, but since I do not know him in person I cannot answer that question.

Example 3.

'Cotton can only grow where it is hot and dry. In England it is cold and damp. Can cotton grow there?'

S: I've only been in Kashgar country; I don't know beyond that.
E: But on the basis of what I said to you, can cotton grow there?
S: If the land is good, cotton will grow there, but if it is damp and poor, it won't grow. If it's like the Kashgar country, it will grow there too. If the soil is loose, it can grow there too, of course.

Example 4.

E: Suppose all the women in Nigeria are married. Now there's a woman called Connie and she's not married. Can we say she lives in Nigeria or not?
S: What kind of clothes do they wear in Nigeria?8
E: Just suppose the world is a strange one in which all the women in Nigeria are married.
S: We can say she's a Nigerian but she hasn't got married yet.

Example 5.

E: Another one. Remember that it doesn't matter if it's true or false. Just listen to the words. Suppose all the birds in Cape Town are penguins. (translator has to explain what they are; subject nods). If someone sees a bird in Cape Town, what kind of bird will they see?
S: When she sees it in Cape Town?
E: Yes. Repeats question.
S: It could be a dove, or a raven, or a swallow.
E: But ignore what the real world is like, and just pretend that all the birds are penguins in Cape Town, then if you see a bird, what kind of bird is it?
S: It will be a bird, maybe a dove or any other kind of bird.
. . .
E: Imagine we are talking about the North Pole, and I tell her that all the birds there are penguins. If you see a bird there, what kind of bird will you see?
S: I don't know.
E: And if I tell you all the birds there are penguins?
S: I don't accept that.
E: Why not?
S: I don't know these penguins, I've never seen them.

What is going wrong here? (1)

Generic statements are characterised by their tolerance of putative counterexamples, which turn out to be mere exceptions to the rule. The statement "chairs have four legs" can be accepted along with the existence three-legged barstools which, strictly, falsify the statement. In fact, it is sometimes surprising how tolerant generics are taken to be, as the following example illustrates.

Women long for plastic surgery / One in two young women are so dissatisfied with their appearance they would consider plastic surgery, a new poll has revealed (ITV.com news, Jan 29, 2007)

According to the British ITV's news website, just half of a set is enough to justify a generic claim! (Counihan, p. 57)

What is going wrong here? (2)

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- "all" in the *generic* sense, allowing for counterexamples ("All birds can fly", "All swans are white"...)

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"all Nigerian women are married"

- "all" in the mathematical / formal sense: indicating a real universal quantifier
- "all" in the *generic* sense, allowing for counterexamples ("All birds can fly", "All swans are white"...)

But how do we know which one is meant?

What is going wrong here? (3)

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In normal question-answer situations "there is epistemic asymmetry between questioner and addressee, which motivates the asking of the question in the first place." (Counihan, p. 53)

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> *But imagine that you haven't got the benefit of schooltrained eyes ... Then you would find ... as strange as the train conductor asking you the way to the station, after telling you how to get there. (Counihan, p. 54)*

Course schedule: February.

- Wednesday, 2 Feb, 13-15, **G4.15**: Motivation, History, Overview of the Course, Formal issues.
- Wednesday, 2 Feb, 15-17, **A1.10**: Questions and some discussion.
- Friday, 4 Feb, 11-13, **C1.110**, *hoorcollege*: Wason task, Definitions, Propositional Logic, the distinction Syntax-Semantics-Pragmatics, Truth Tables, Truth Functionality.
- Tuesday, 8 Feb, 11-13, **A1.04**, *werkcollege*.
- Tuesday, 8 Feb, 15-17, **A1.04**, *hoorcollege*: Truth tables for propositional logic, proofs with truth tables.
- Tuesday, 15 Feb, 11-13, **A1.04**, *werkcollege*.
- Tuesday, 15 Feb, 15-17, **A1.04**, *hoorcollege*: Syllogisms, psychological studies of syllogisms, existential import.
- Friday, 18 Feb, 11-13, **F1.02**, *hoorcollege*: Quantifiers, basic model theory.
- Tuesday, 22 Feb, 11-13, **A1.04**, *werkcollege*.
- Tuesday, 22 Feb, 15-17, **A1.04**, *hoorcollege*: Formal languages, abbreviations in formal languages, pitfalls and problems of formalization.
- Wednesday, 23 Feb, 15-17, **A1.04**, *hoorcollege*: Argumentation theory, part I

Course schedule: March.

- Tuesday, 1 Mar, 11-13, **A1.04**, *werkcollege*.
- Tuesday, 1 Mar, 15-17, **A1.04**, *hoorcollege*: Argumentation theory, part II
- Tuesday, 8 Mar, 15-17, **A1.04**, *hoorcollege*: Temporal modelling, part I
- Tuesday, 8 Mar, 17-19, **C0.110**, *werkcollege*.
- Thursday, 10 Mar, 17-19, **A1.04**, *hoorcollege*: Temporal modelling, part II
- Monday, 14 Mar, 15-17, **A1.04**, *hoorcollege*: Modelling of belief and action, part I
- Friday, 18 Mar, 11-13, **A1.10**, *werkcollege*.
- Friday, 18 Mar, 13-15, **A1.04**, *hoorcollege*: Modelling of belief and action, part II
- Thursday, 24 Mar, 13-16, **REC-A AB.44 (Zaal D)**, *Written Exam*.

Literature.

Formal logic.

- Our lecture slides.
- Marian Counihan, Looking for logic in all the wrong places: an investigation of language, literacy and logic in reasoning. PhD thesis, Universiteit van Amsterdam, 2008. DS-2008-10.

Informal logic.

- Our lecture slides.
- Douglas Walton, Chris Reed, Fabrizio Macagno. Argumentation Schemes. Cambridge 2008.

Formal Modelling.

- Our lecture slides.

Assessment and grade (1).

Homework.

- There will be four homework sheets, due on 15 February, 22 February, 8 March, and 18 March. Each of these will be worth 25 points.
- You are allowed to either work alone or in a group of at most two people for the homework. It is not necessary to stay in the same group for every homework set.
- Homework is handed in either in class or by e-mail to `carl@math.uni-bonn.de`.
- Late homework is not accepted. Whether extenuating circumstances constitute a reason for exceptions to this rule is decided by Merlin Carl.
- Each homework set will receive a grade. The grade for the homework component will be the average of the four homework grades.

Assessment and grade (2).

Exam.

The exam will be on 24 March 2011, 13–16, **REC-A AB.44 (Zaal D)**. It will have 100 points and 50 points are needed to get a passing grade (6.0).

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Final grade.

The final grade is the average of the grade of the Homework component and the Exam component calculated according to the OER regulations (Part A, Article 23).