Propositional Logic

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If you take my medication, you will get better
But you are not taking my medication.

So, you will not get better. $\therefore$

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- . . . with this valid argument:

(2.6)

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So, you have not taken my medication. $\therefore$

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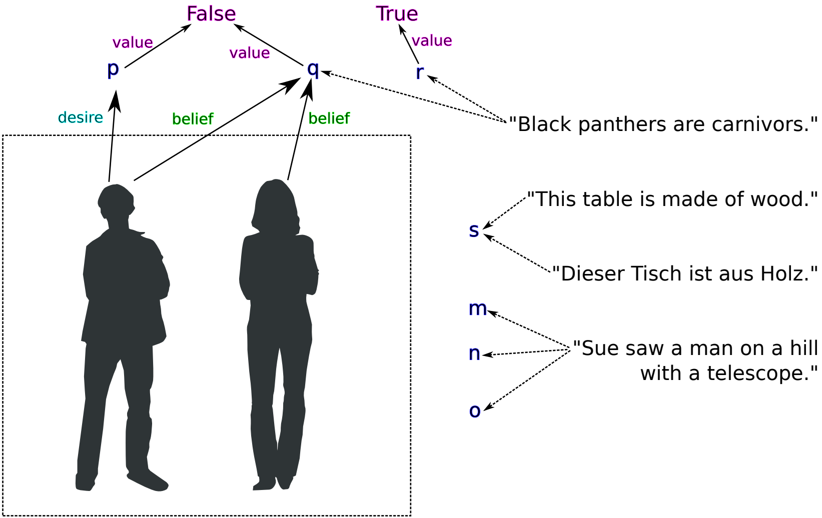
- The same rules that govern valid argumentation also enable information systems to answer interesting questions.
- But it takes an entire semester course in logic before you start to get good at logical inference.
- This semester we'll focus mainly on logic as a means to describe a *domain* (some part of the world we're interested in).

Propositions, statements, and sentences



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- States of affairs are the parts of reality responsible for making propositions true or false.

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- A set of proposition letters generates a set of states of affairs: ways the world might be.
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- $\{pqr, pq\overline{r}, p\overline{q}r, p\overline{qr}, \overline{p}qr, \overline{p}q\overline{r}, \overline{pq}r, \overline{pqr}\}$

Logical Operators

Table 1: 2.15 from van Benthem, et al.

Symbol	In natural language	Technical name
$\neg$	not	negation
$\wedge$	and	conjunction
$\vee$	or	disjunction
$\rightarrow$	if ... then	implication
$\leftrightarrow$	if and only if	equivalence

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- The sentence is mapped to a truth value via the following tables

Semantics of the operators

φ	$\neg\varphi$
0	1
1	0

Table 3: 2.18 from van Benthem, et al.

φ	ψ	$\varphi \wedge \psi$	$\varphi \vee \psi$	$\varphi \rightarrow \psi$	$\varphi \leftrightarrow \psi$
0	0	0	0	1	1
0	1	0	1	1	0
1	0	0	1	0	0
1	1	1	1	1	1

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- $(j \land m)$
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- $(((e \lor l) \land \neg a) \to s)$
- $e =$ "A foreign national has legal employment."
- $l =$ "He has had legal employment less than three years ago."
- $a =$ "He is currently employed abroad."
- $s =$ "He is entitled to social security."

Drawing truth tables for expressions

p	q	r	(($\sim$	p	$\vee$	q)	$\rightarrow$	r)
1	1	1	0	1	1	1	1	1
1	1	0	0	1	1	1	0	0
1	0	1	0	1	0	0	1	1
1	0	0	0	1	0	0	1	0
0	1	1	1	0	1	1	1	1
0	1	0	1	0	1	1	0	0
0	0	1	1	0	1	0	1	1
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1	0	1		0	1	0	0		1	1	
1	0	0		0	1	0	0		1	0	
0	1	1		1	0	1	1		1	1	
0	1	0		1	0	1	1		0	0	
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0	1	0	1	0	1	1	0	0
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0	0	0	1	0	1	0	0	0

Exercise 2.11

p	q	((p	→	q)	∨	(q	→	p))
1	1	1	1	1	1	1	1	1
1	0	1	0	0	1	0	1	1
0	1	0	1	1	1	1	0	0
0	0	0	1	0	1	0	1	0

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p	q	r	(((p	∨	∼	q)	&	r)	↔	(∼	(p	&	r)	∨	q))
1	1	1	1	1	0	1	1	1	1	0	1	1	1	1	1
1	1	0	1	1	0	1	0	0	0	1	1	0	0	1	1
1	0	1	1	1	1	0	1	1	0	0	1	1	1	0	0
1	0	0	1	1	1	0	0	0	0	1	1	0	0	1	0
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0	0	0	0	1	1	0	0	0	0	1	0	0	0	1	0

Grammar of propositional logic

Let P be a set of proposition letters and let $p \in P$.
The following expression defines the recursive grammar for a logical expression φ in Backus–Naur Form:
$\varphi ::= p|\neg\varphi|(\varphi \wedge \varphi)|(\varphi \vee \varphi)|(\varphi \rightarrow \varphi)|(\varphi \leftrightarrow \varphi)$

Syntactically conforming expressions

Let $P = \{o, q, r, s\}$
Examples of grammatically conforming expressions include:

- r

Grammatically *incorrect* expressions would include:

How many correct expressions are consistent with the last one?

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- $\vee)p\neg$

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- $\neg p \vee q \rightarrow r$

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Syntactic ambiguity

These conforming expressions are all consistent with $\neg p \vee q \to r$

- $((\neg p \vee q) \to r)$

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- $\neg((p \vee q) \rightarrow r)$
- $(\neg p \vee (q \rightarrow r))$

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- $((\neg p \vee q) \rightarrow r)$
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- $\neg((p \vee q) \rightarrow r)$
- $(\neg p \vee (q \rightarrow r))$
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Which of the following are formulas in propositional logic?

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- $\neg\neg \land q \lor p$
- $p\neg q$

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- For "$V(\varphi) = 1$" we also write "$V \models \varphi$" read as "V is a model of φ" or "V satisfies φ."
- If V doesn't satisfy φ we write "$V \not\models \varphi$". In other words $V(\varphi) = 0$.

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- A set of propositional logic statements is inconsistent if no state of affairs satisfies every statement in the set.

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- A conclusion is *valid* with respect to a set of premises if the conclusion is true in every sitation where the premises are true (van Benthem, et al, page 2-4).
- One can validly infer a conclusion φ from a set of premises P if the negation of φ is inconsistent with the set of statements P.

Computation and expressive power

(From van Benthem, et al., chapter 2)

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1. Computing a truth value for a formula takes linear time.
2. Computing a truth table for validity takes exponential time.
3. The problem of testing for validity in propositional logic is decidable: there exists a mechanical method that computes the answer, at least in principle.