

# The History of Logic

Aristotle (384–322 BC) invented logic.

- Predecessors: Fred Flintstone, geometry, sophists, pre-Socratic philosophers, Socrates & Plato.
- Syllogistic logic, laws of non-contradiction and excluded middle, modal logic.
- Some logic in a “wider sense”: definitions, fallacies, inductive reasoning, etc.
- Parallels in “Buddhist logic.”
- The basis for the “traditional logic” that dominated until the early 20th century.

## The Stoics developed a rival logic.

- A propositional logic, focusing on “and,” “or,” and “if-then” (controversies).
- Much about modal logic and determinism.
- Philosophy had three parts: physics, ethics, and logic.
- Eventually merged with the “traditional logic” based on Aristotle.

# The Medievals developed logic further.

- Boethius: modal logic and translations of Aristotle.
- Arab logic and rediscovery of Aristotle's writings.
- Refined the details: Barbara-Celarent, rules for valid syllogisms, university textbooks.
- Modal logic, problem of universals, etc.
- Much use of logic in philosophy (e.g. Thomas Aquinas); we still use many Latin terms in logic (like "modus ponens" and "a priori").

# Renaissance to 19th century logic

- The Enlightenment (e.g. Kant) brought little progress in logic.
- Leibniz proposed a symbolic logic that would reduce reasoning to a kind of calculation.
- Hegel and Marx proposed a *dialectical logic*.
- Others (like De Morgan) proposed new ways to symbolize logical operations.

# George Boole (1815–64) invented “mathematical logic.”

- Letters stand for sets. So “H” might stand for the set of humans” – and “HM” might stand for the set of entities that are both humans and mortals. Then “all humans are mortals” is “ $H = HM$ .”
- We can symbolize a syllogism as a series of equations and validate it algebraically:

|                                     |                     |
|-------------------------------------|---------------------|
| All humans are mortal.              | $H = HM$            |
| All Greeks are humans.              | $G = GH$            |
| $\therefore$ All Greeks are mortal. | $\therefore G = GM$ |

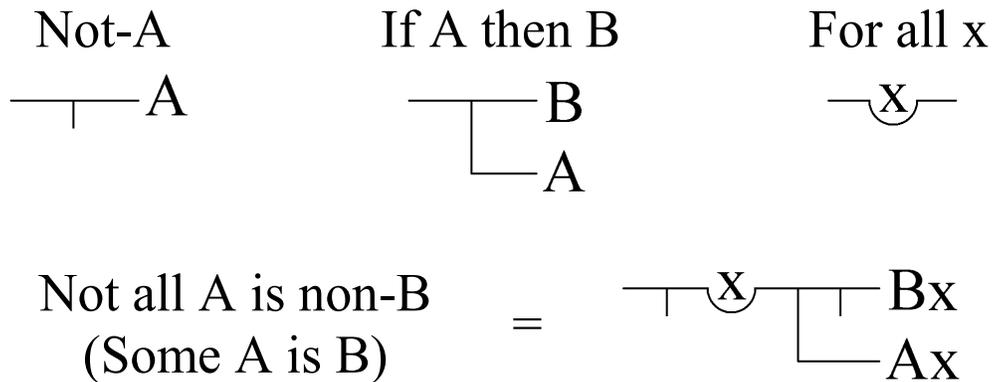
- “Boolean algebra” can be interpreted to be about sets or about statements. For example:

|            |                                  |         |
|------------|----------------------------------|---------|
| $\neg A$   | The set of non-As                | Not-A   |
| $A \cap B$ | The intersection of sets A and B | A and B |
| $A \cup B$ | The union of sets A and B        | A or B  |

- Similar laws cover both interpretations, like “ $A \cap B = B \cap A$ ” and “ $\neg(A \cap B) = (\neg A \cup \neg B)$ .”
- Boole wanted mathematicians to take over logic. But logic today is studied in philosophy, mathematics, and computer science departments.

# Gottlob Frege (1848–1925) invented “classical symbolic logic.”

- This overcame the gap between Aristotelian and Stoic logic in a higher synthesis.
- Frege used lines for “not,” “if-then,” and “all”:



- Frege tried to show that arithmetic was reducible to logic: every arithmetic truth can be formulated using just notions of logic and proved using just axioms and inference rules of logic.
- One of Frege's axioms said that every condition on  $x$  (like “ $x$  is a cat”) picks out a set. But then “ $x$  is not a member of itself” ( $x \notin x$ ) picks out a set  $R$  containing just those things that are not members of themselves. Then:

For all  $x$ ,  $x \in R$  if and only if  $x \notin x$ .  
Therefore,  $R \in R$  if and only if  $R \notin R$ .

Bertrand Russell (1872–1970) tried to put classical logic on a firmer basis.

- *Principia Mathematica* (1910–1913, co-authored with Alfred North Whitehead) used a better notation and tried to avoid “Russell’s Paradox.”
- This became the standard formulation of *classical symbolic logic* – which gradually replaced *traditional logic* to become the new orthodoxy.

# After Principia

- Wittgenstein created truth tables, which gave a *semantic* test of validity.
- Principia's systematization of propositional and quantificational logic was later shown to be sound and complete.
- Kurt Gödel in 1931 showed, against Frege and Russell, that arithmetic was not reducible to any sound and complete axiomatic system.
- Classical logic played a big role in the birth of modern computers.

## Non-classical logics arose.

- *Supplementary non-classical logics* include modal, deontic, belief, and temporal logics.
- *Deviant non-classical logics* include multi-valued and paraconsistent logic.

# Logic “in a broad sense” is much pursued.

- *Informal logic* covers various non-formal skills that we need to appraise reasoning.
- *Inductive logic* is about forms of reasoning in which we extrapolate from observed patterns to conclude that a given conclusion is probably true.
- *Metalogic* is the study of formal systems.
- *Philosophy of logic* deals with wider philosophical issues raised by logic (like “What is truth?” and “Are there abstract entities?”).