Computability and Formal Languages (Berechenbarkeit und Formale Sprachen)

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JG|U

Lecturers

Lectures:

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Exercises:

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Laubersheimer, David Anton dlaubers@students.uni-mainz.de

Schmitz, Marcel smarcel@students.uni-mainz.de

Maul, Christian cmaul@students.uni-mainz.de

Program

#	Date:	Topic:
1	**Tue, 14. Apr. 2026**	**Introduction: Computation and languages, Math Tools**
2	**Tue, 21. Apr. 2026**	**Math Tools, Proof Techniques**
3	**Tue, 28. Apr. 2026**	**Boolean Computation, Finite Automata**
4	**Tue, 5. May 2026**	**Finite Automata and Regular Languages**
5	**Tue, 12. May 2026**	**Pumping Lemma and Automata Minimization**
6	**Tue, 19. May 2026**	**Context-Free Languages 1**
7	**Tue, 26. May 2026**	**MIDTERM / Context-Free Languages 2**
8	**Tue, 2. Jun. 2026**	**Push-Down Automata**
9	**Tue, 9. Jun. 2026**	**Turing Machines and the Church-Turing Thesis**
10	**Tue, 16. Jun. 2026**	**Algorithms, Problems, Equivalent Computational Models**
11	**Tue, 23. Jun. 2026**	**The “Entcheidungsproblem”, Rice’s Theorem**
12	**Tue, 30. Jun. 2026**	**Introduction to the Physics of Computation**
13	**Tue, 7. Jul. 2026**	**Introduction to Quantum Computation/ Other topics**

Scheinkriterien

Klausurzulassung:

- 50% der Punkte in den Übungen
- Anmeldung zur Vorlesung: https://jogustine.uni-mainz.de

Übungen:

- Abgabe in 2- oder (max) 3-Gruppen
- Abgabetermin: Freitags, bis 12:00 Uhr, ausschließlich online (LMS)

Midterm Prüfung:

- Nicht pflichtig, aber empfohlen.
- Als Übung gerechnet
- Bis zu 0.3 Punkte in der Endnote (Klausur)

Termine

Veranstaltung:	Lehrenden:	Termin	Raum
Vorlesung	Luca	Di, 10:15-11:45 Uhr	00 212 S1
Übungstermin 1	Nora	Do, 10-12 Uhr	04-512
Übungstermin 2	Jonah	Do, 10-12 Uhr	04-426
Übungstermin 3	Julia	Do, 16-18 Uhr	04-426
Übungstermin 4	David	Fr, 12-14 Uhr	04-512
Übungstermin 5	Marcel	Fr, 10-12 Uhr	04-516
Übungstermin 6	Christian	Fr, 10-12 Uhr	XY-ABC
Klausur		**Fr. 31.07.26, 13-15 Uhr**	

Literature

Notes: Prof. Dr. Luca Doria, **Formal Languages and Calculability:**
https://www.staff.uni-mainz.de/doria/FLC.html
Notes: Univ.-Prof. Dr. Friederike Schmid:
https://www.staff.uni-mainz.de/schmidfr/Lehre/Skripte/fsb.pdf

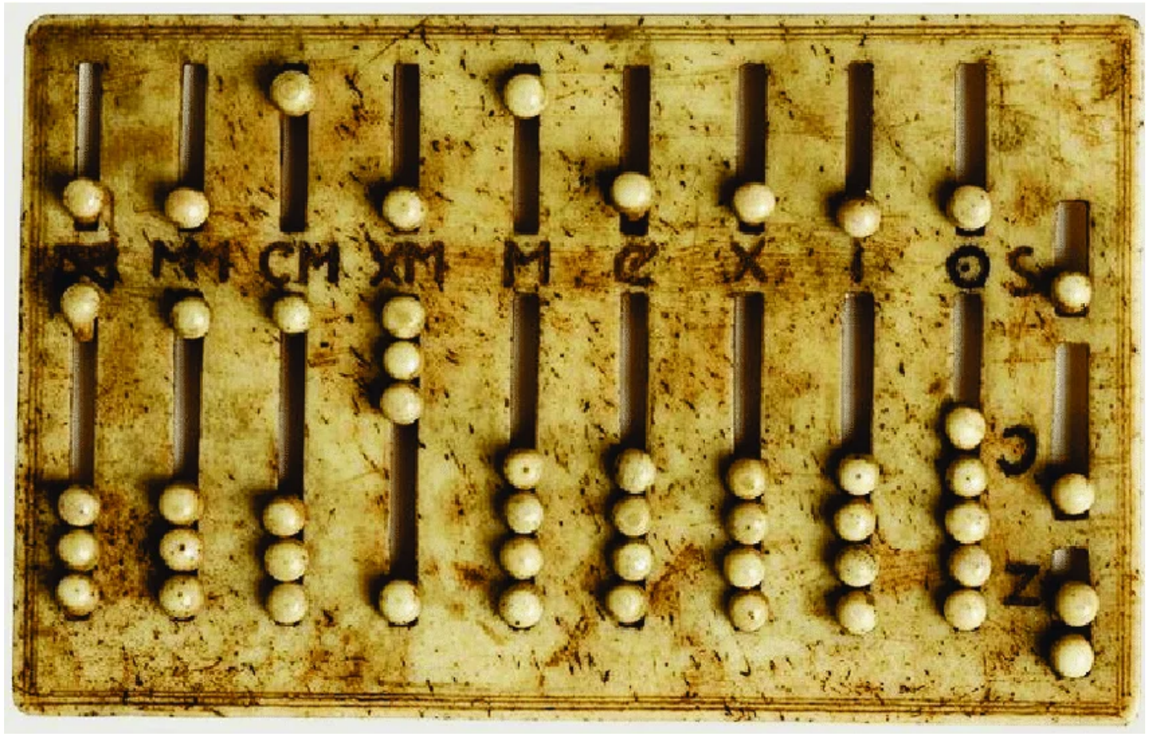
Books:
- J. Hopcroft, R. Motwani, J. Ullman: Introduction to Automata Theory, Languages, And Computation
- M. Sipser: Introduction to the Theory of Computation
- P. Odifreddi: Classical Recursion Theory (Elsevier)

Other Resources:
- Scott Aaronson, Quantum Computing Since Democritus (Cambridge University Press)
- Seth Lloyd, Programming The Universe (Vintage Books)
- Build your Finite Automaton: https://ivanzuzak.info/noam/webapps/fsm_simulator/
- R. Feynmann, Feynman Lectures on Computation (CRC Press)

Calculability
Berechenbarkeit

Calculation Devices

Calculus = Latin for “Little Stone”



Calculation Devices

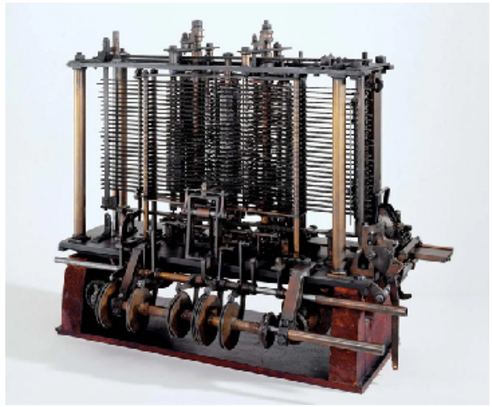
The **Antikythera mechanism:**

Found underwater in 1901
Probably constructed 100-200 BC

37 Bronze Gears (Zahnräder)
Model of the solar system (Earth+Moon+Planets)

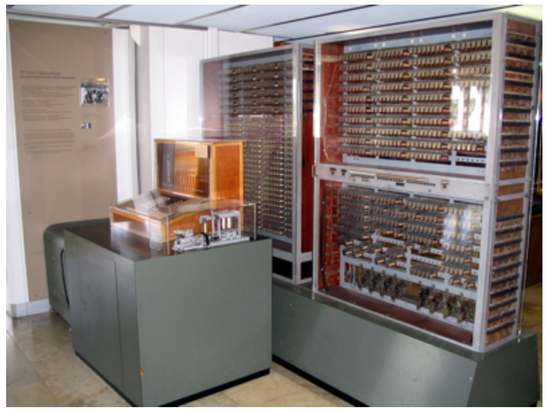
Calculation Devices

Charles Babbage's Difference Engine (1837)



<1Flops

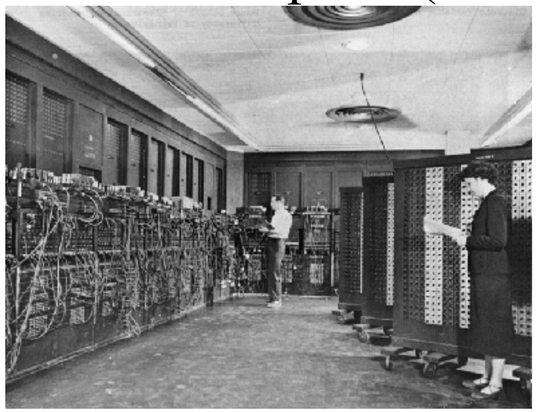
Konrad Zuse's first programmable electro-mechanical computer (1941)



Deutsches Museum reproduction

10Flops

ENIAC: first programmable electronic computer (1945)



(U.S. Army photo, c. 1947–1955)

5kFlops

Today's (2024) supercomputer

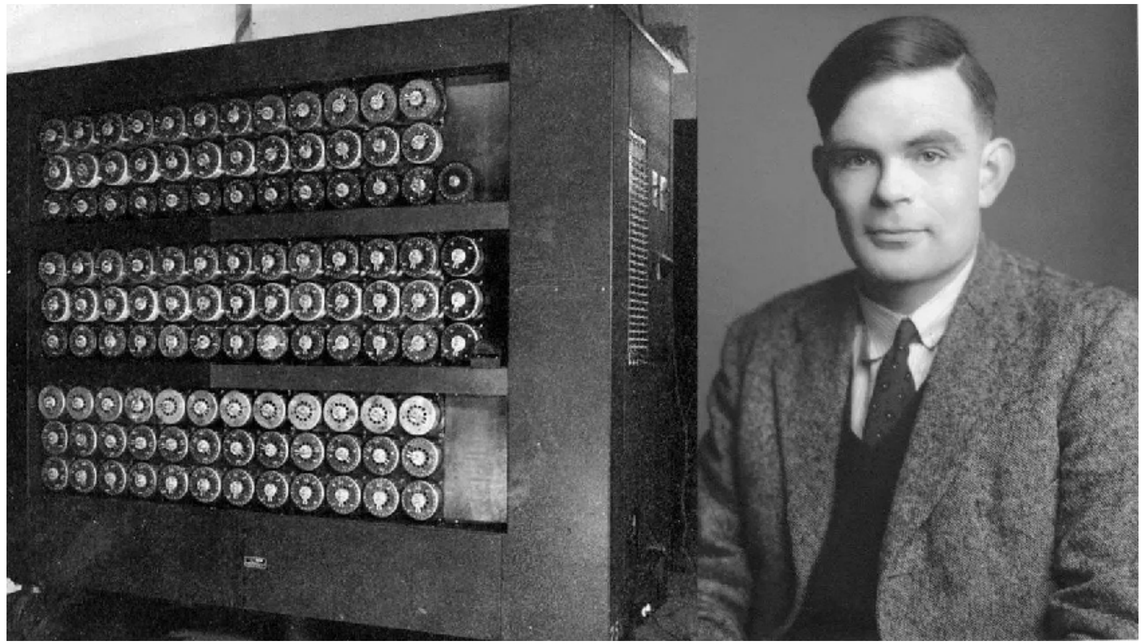
Frontier - HPE Cray EX235a, AMD Optimized 3rd Generation EPYC 64C 2GHz, AMD

8,699,904 cores
1,679.82 PFlops = 1.7 EP!

Theoretical Computer Science

Alan Turing (1912-1954)

- "Father" of Computer Science
- Introduced the "Turing Machine" (among other things)
- Fundamental contributions to Logic/Maths/CS



What does it mean “Calculability”?

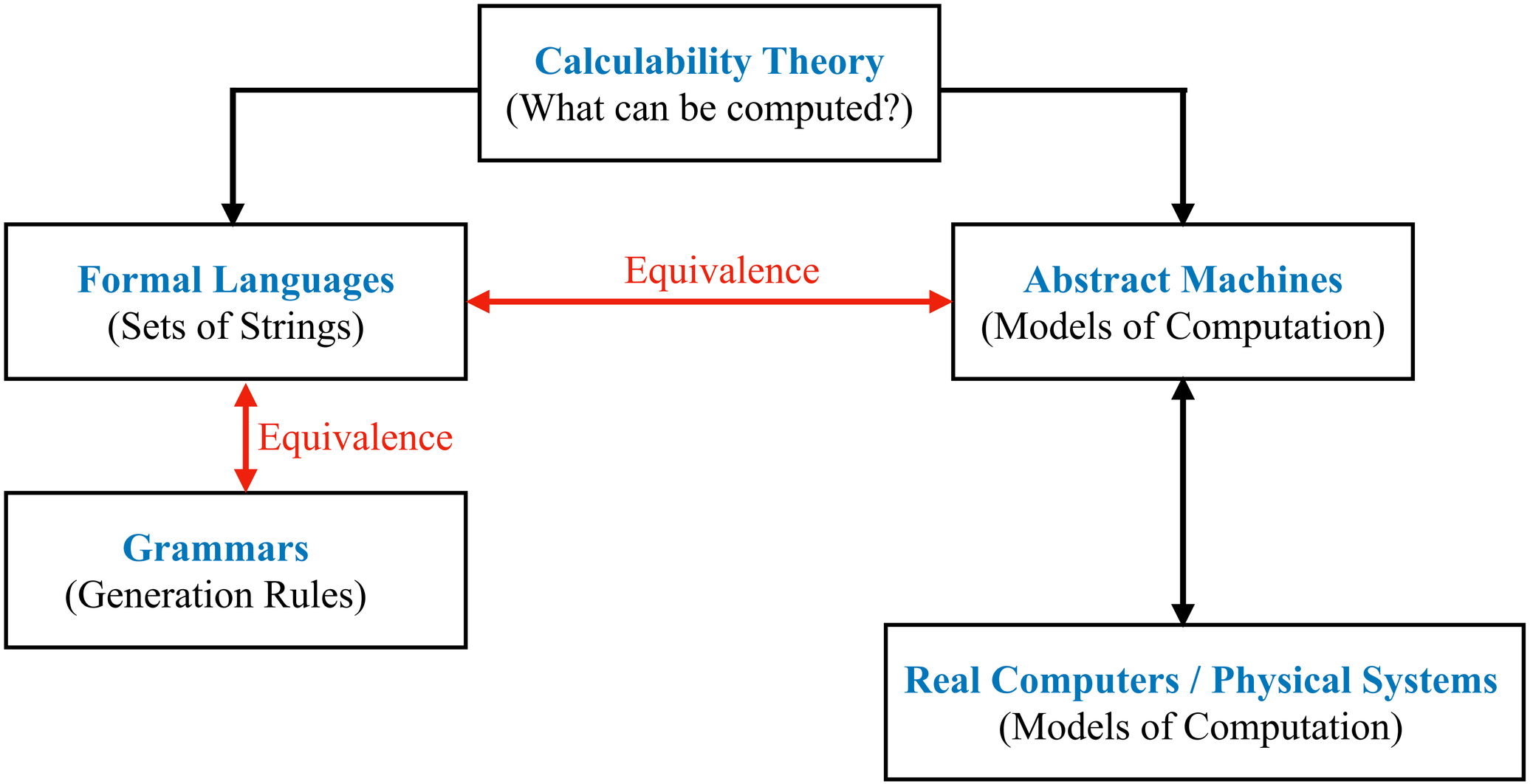
Calculability (or computability) is the property of a question or process whose answer can be obtained by following a definite, mechanical procedure — a sequence of precise steps that requires no insight, creativity, or intuition once the rules are fixed.

Berechenbarkeit ist die Eigenschaft einer Frage oder eines Prozesses, deren bzw. dessen Antwort durch die Anwendung eines festgelegten, mechanischen Verfahrens ermittelt werden kann – einer Abfolge präziser Schritte, die, sobald die Regeln festgelegt sind, weder Einsicht, Kreativität noch Intuition erfordern.

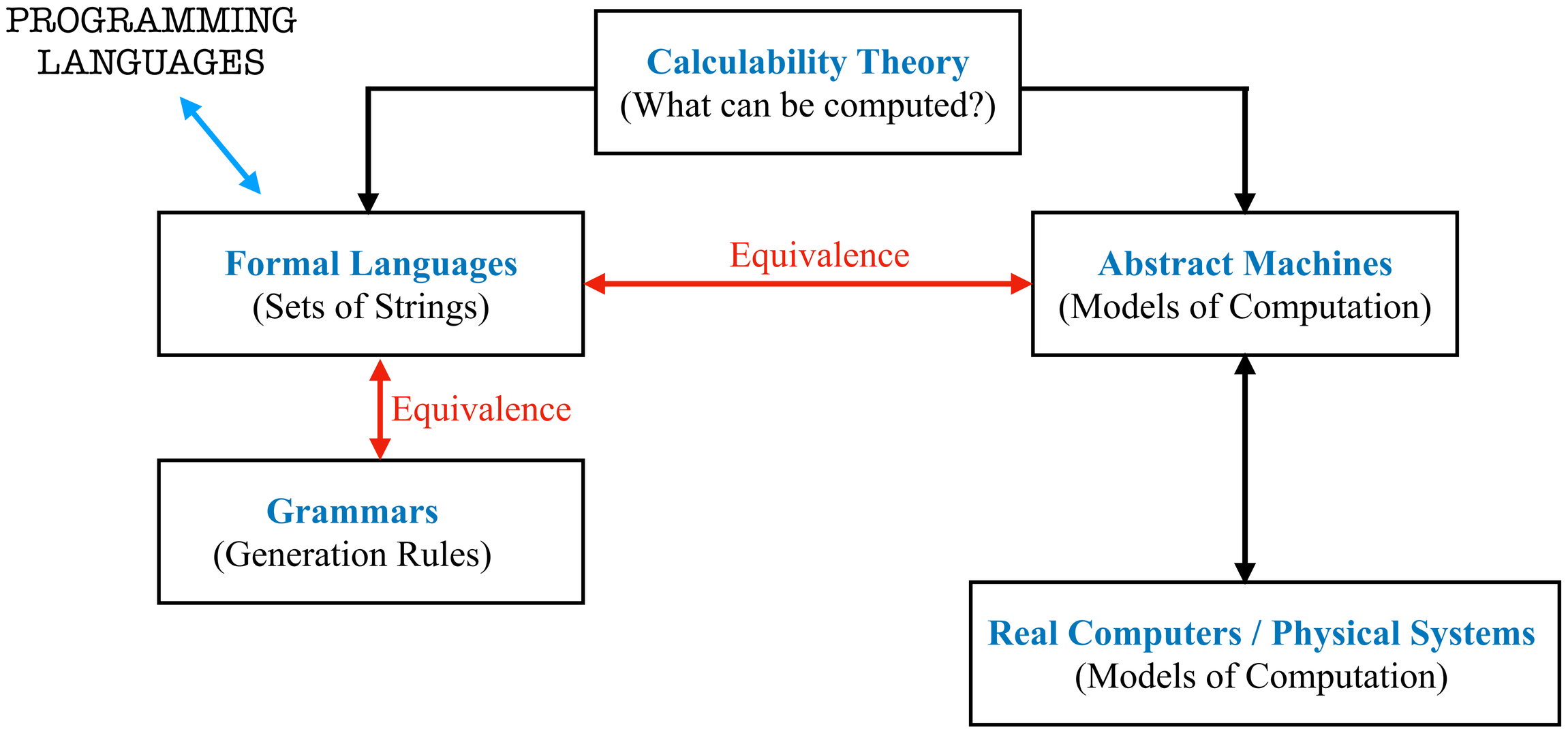
Calculability defines is the boundary between problems solvable by systematic procedure and those that transcend mechanical computation.

Die **Berechenbarkeit** definiert die Grenze zwischen Problemen, die durch systematische Verfahren gelöst werden können, und solchen, die über mechanische Berechnungen hinausgehen.

Calculability and Languages



Calculability and Languages



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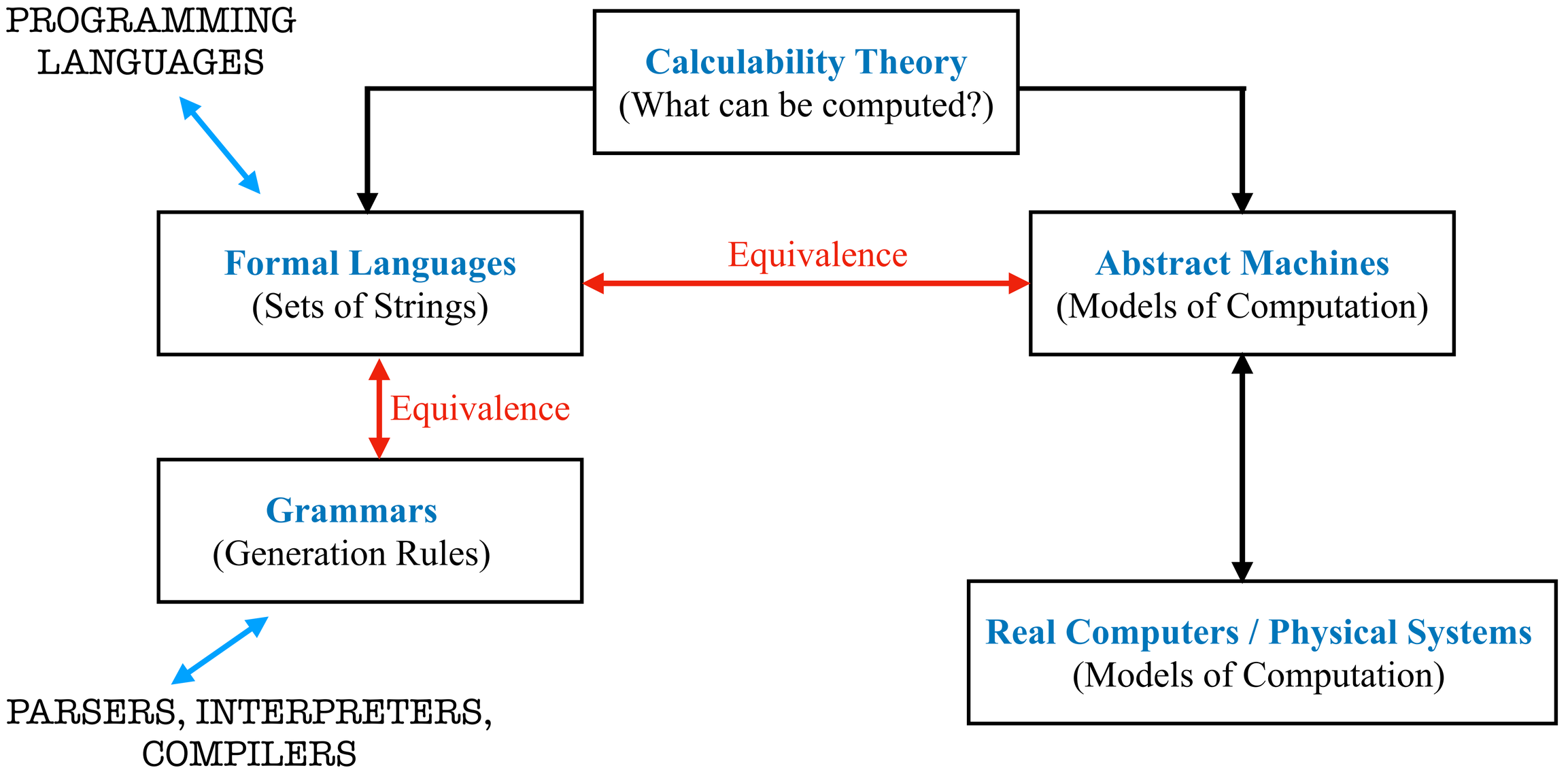
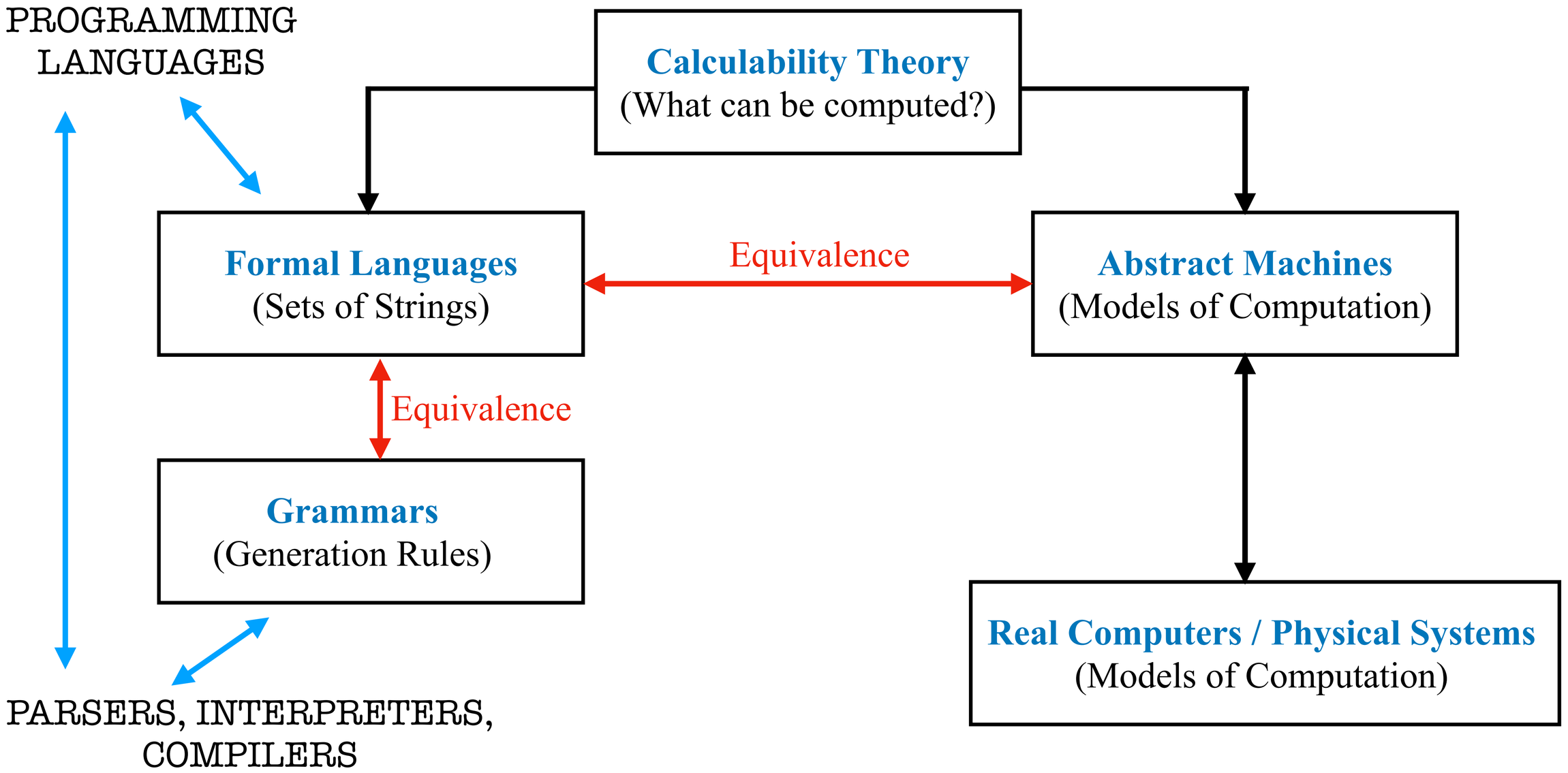


Calculability and Languages



Calculability and Physics

-Computers are physical systems (classical and quantum mechanical).

-Physics laws must ultimately limit computation.

-What are those limits?

-Are they the same for quantum and classical systems?

-What is the role of space, time, energy, and information?

-What are the characteristics of a physical device for reaching “hyper-computation”?

From Calculability to Complexity

NOW: What is calculable (and what not)?
What are the limits of calculability (in theory and in the physical world)?
→ **Theory of Calculability**

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NEXT: How difficult it is to calculate?
Or: how difficult is a certain problem?
→ **Computational Complexity Theory**