

# **JOHN von Neumann: (The COMPUTER and the BRAIN)**

Péter Érdi

Center for Complex Systems Studies

Kalamazoo College, Michigan

and

Dept. Biophysics

KFKI Research Institute for Particle and Nuclear Physics  
of the Hungarian Academy of Sciences, Budapest

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**John von Neumann (Neumann János)**  
**(1903-1957)**



(pictured with his wife Klara and their dog Inverse)

# 1. Short Biography

- 28 December 1903, Budapest, Hungary
- "Lutheran Gymnasium"
- University of Budapest, 1921
- University of Berlin, 1921-23
- Chemical Engineering, ETH, Zurich, 1923-25
- Doctorate, Mathematics (with minors in experimental physics and chemistry, Budapest, 1926
- Institute for Advanced Study at Princeton
- 8 February 1957, Washington DC

## 2. Set Theory

- Russel - Whitehead: the crisis of mathematics
- Hilbert's program: to formalize mathematics (the axiomatization of set theory)
- von Neumann-Bernays-Gödel set theory: (has only finitely many axioms)
- abandoned after Gödel's theorems (1931)  
"no formal system powerful enough to formulate arithmetic could be both complete and consistent"

### 3. Quantum Mechanics

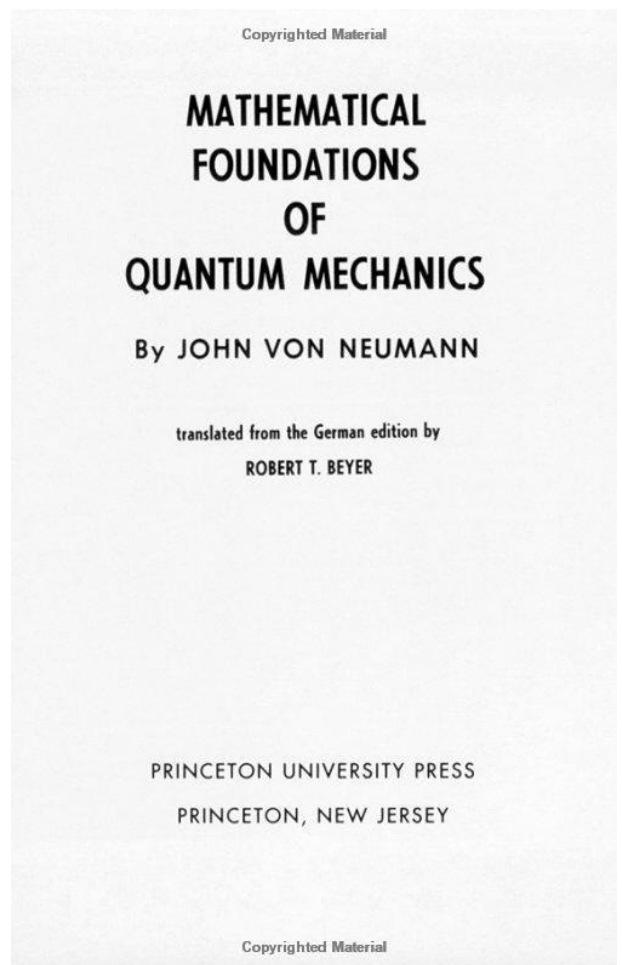
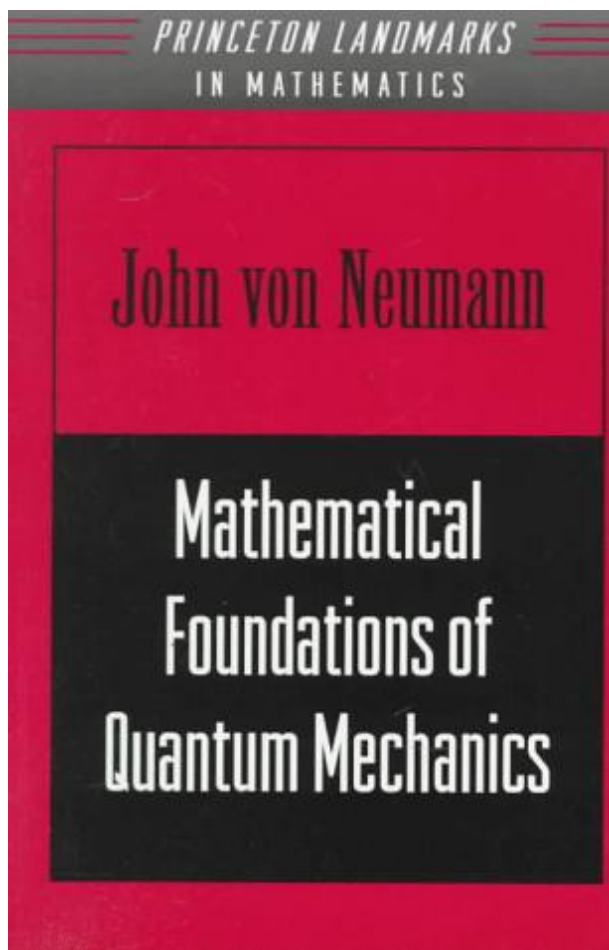
Schrödinger's wave mechanics versus Heisenberg's matrix mechanics

von Neumann's contributions:

- + mathematical equivalence (by using the concept of Hilbert space)

- + the inclusion of "hidden parameters" does not help -> quantum mechanics is inherently indeterministic

- + the measuring apparatus and the quantum system measured as both part of the system

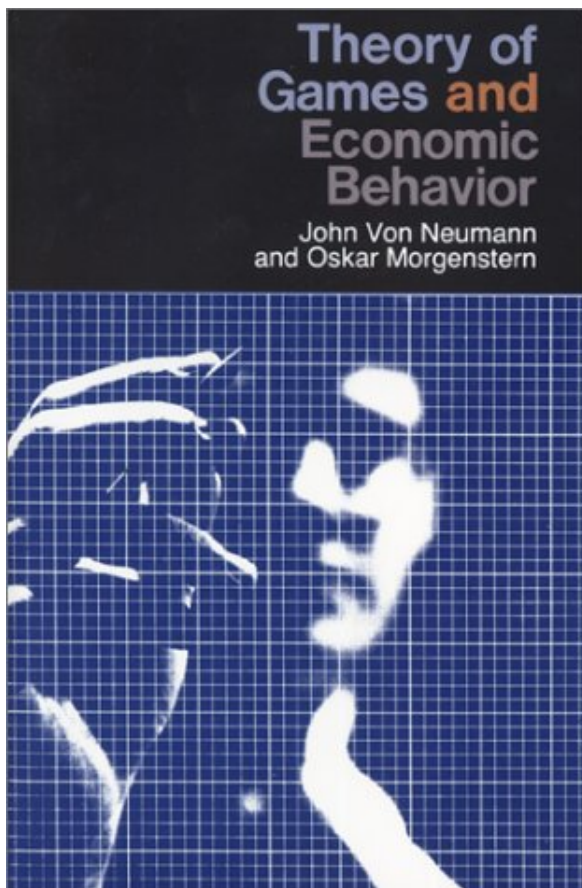


1932 von Neumann put quantum theory on a firm theoretical basis

# Game Theory

von Neumann (1928):

The fundamental theorem of game theory which states that every finite, zero-sum, two-person game has optimal (mixed) strategies.



von Neumann - Morgenstern: Theory of Games and Economic Behavior, 1944  
a landmark of social sciences



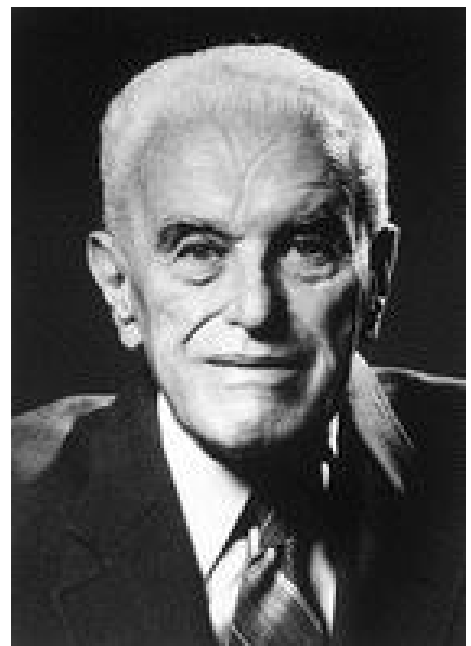
# Game Theory

After Neumann (Nash, Selten and Harsanyi: Nobel prize 1994:

(Harsanyi: Lutheran Gymnasium)

minimax strategy is not a solution for nonconstant sum games

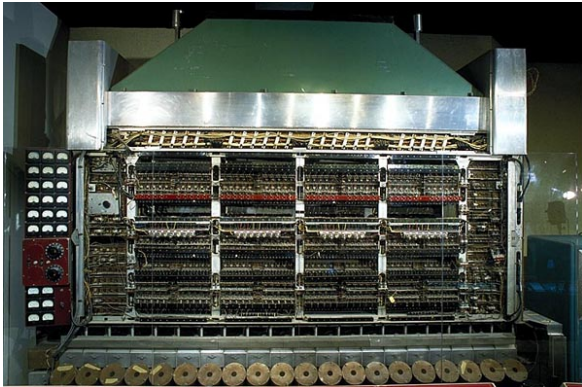
If there is a set of strategies with the property that no player can benefit by changing her strategy while the other players keep their strategies unchanged, then that set of strategies and the corresponding payoffs constitute the Nash Equilibrium.



# Computer Architectures

## Von Neumann architecture

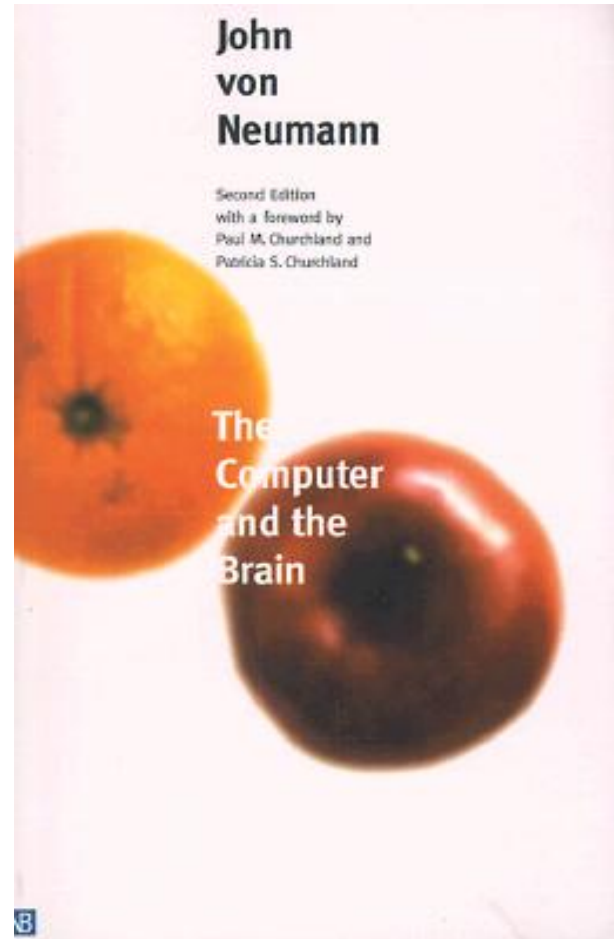
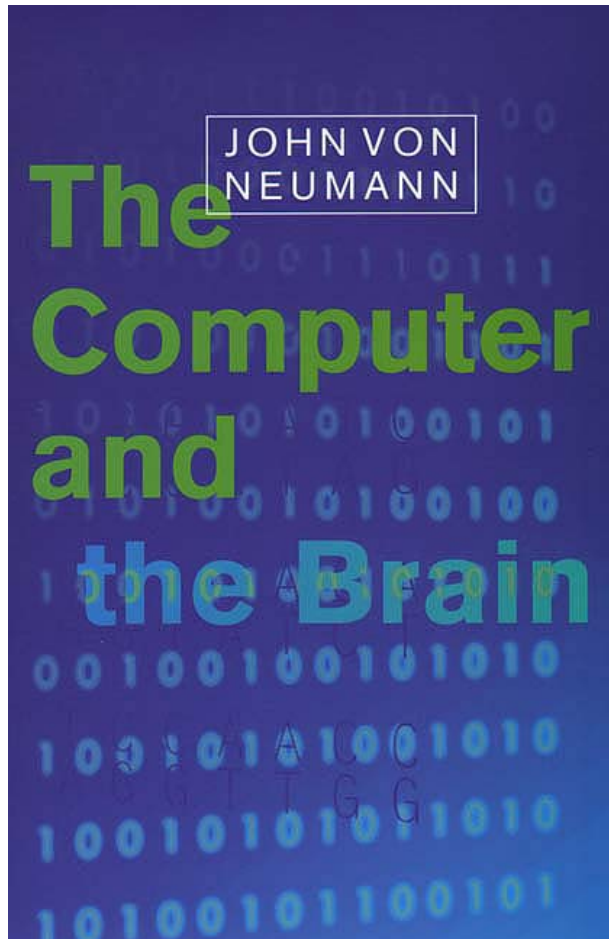
- has three basic hardware subsystems: a CPU, a main-memory system and an I/O system
- is a stored-program computer
- carries out instructions sequentially
- has, or at least appears to have, a single path between the main memory system and the control unit of the CPU; this is often referred to as the von Neumann bottleneck



The IAS Computer was named for the Institute for Advanced Study, Princeton. The machine was built there under the direction of John von Neumann. It cost several hundred thousand dollars. The goal of developing the IAS was to make digital computer designs more practical and efficient. The project to build it began in 1946 and the computer was ready for use in 1952.

Designers of the IAS were required to make their plans available to several other government-funded projects, and several other machines were built along similar lines: JOHNNIAC, MANIAC, ORDVAC, and ILLIAC. -> also IBM 701 (from the website of the Smithsonian Museum)

## 5. The Computer and the Brain



## 5. The Computer and the Brain in broader context

- McCulloch-Pitts and the Cybernetic movement
- Self-replicating automaton: the machine and its description
- Reliable calculation with unreliable elements
- Analog vs. digital machines
- Specialized memory unit
- Language of the brain: "Thus the outward forms of our mathematics are not absolutely relevant from the point of view of evaluating what the mathematical or logical language truly used by the central nervous system is"

## 6. From Cybernetics to AI and back?

August 1955: coincidence:

Neumann was diagnosed with cancer

A proposal for the Dartmouth summer research project on Artificial Intelligence

mechanism vs. function

zeros and ones vs. general symbol manipulation

Newell, A., and H. A. Simon. 1956. The logic theory machine: A complex information processing system. IRE Trans. Inf. Theory IT-2:61-79

## 6. From Cybernetics to AI and back?

While it seemed to be an analogy between Brain and Computer

- + at the elementary hardware level

- + at the level of mathematical (quasi)-equivalence

the Organization Principles are very different

The importance of the actual biological substrate:

Synaptic organization !!

"...Eccles has shown how excitation and inhibition are expressed by changes of membrane potential.."

## Instead of summary

All stable processes we shall predict. All unstable processes we shall control.” –John von Neumann.



Budapest 2003: holo - von Neumann with his daughter, Prof. Marina v.N. Whitman