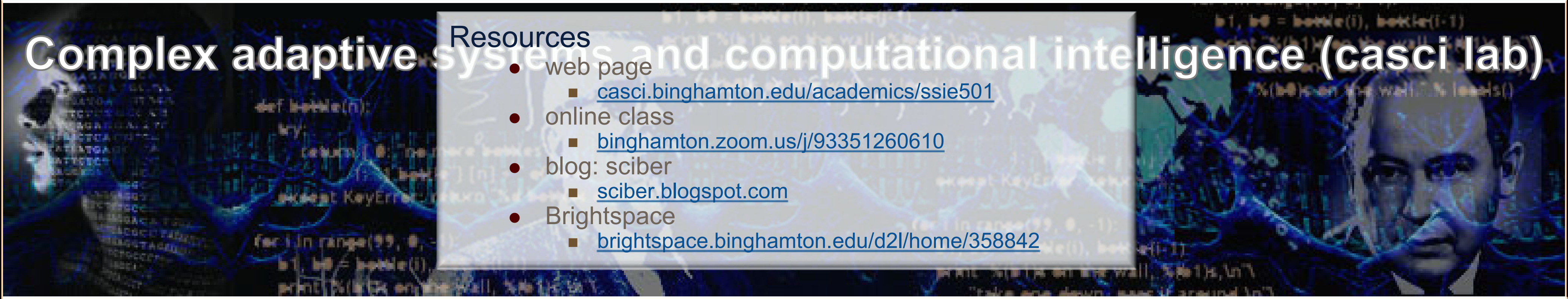
lecture 4

General-purpose computers



Complex adaptive systems and computational intelligence (casci lab)

Resources
- web page
  - casci.binghamton.edu/academics/ssie501
- online class
  - binghamton.zoom.us/j/93351260610
- blog: sciber
  - sciber.blogspot.com
- Brightspace
  - brightspace.binghamton.edu/d2l/home/358842

SSIE-501/ISE-440 - Fall 2024

luis m. rocha

office hours:
Tuesdays 9:00- 11:30am
binghamton.zoom.us/my/luismrocha

Nisreen Al-Bzour

office hours:
Tu & Th: 10:30-13:00
K1,binghamton.zoom.us/j/5124743874

bit.ly/atBIC

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evaluation

- Participation: 20%.
  - class discussion, everybody reads and discusses every paper
  - engagement in class
- Paper Presentation and Discussion: 20%
  - **SSIE501** students are assigned to papers individually or as group lead presenters and discussants
    - all students are supposed to read and participate in discussion of every paper.
  - Presenter prepares short summary of assigned paper (15 minutes)
    - no formal presentations or PowerPoint unless figures are indispensable.
  - Summary should:
    - 1) Identify the key goals of the paper (not go in detail over every section)
    - 2) What discussant liked and did not like
    - 3) What authors achieved and did not
    - 4) Any other relevant connections to other class readings and beyond.
  - **ISE440** students chose one of the presented papers to participate as lead discussant
    - not to present the paper, but to comment on points 2-3) above
  - Class discussion is opened to all
    - lead discussant ensures we important paper contributions and failures are addressed
- Black Box: 60%
  - Group Project (2 parts)
    - Assignment I (25%) and Assignment II (35%)

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key events coming up

- Paper Presentation: 20%
  - Present (501) and lead (501&440) the discussion of an article related to the class materials
    - Enginet students post/send video or join by Zoom synchronously
- Module 1: Cybernetics and the Information Turn
- Next classes
  - Discussion Set 1 (Group 1): September 5th
    - Kline, Ronald R [2015]. *The cybernetics moment, or, why we call our age the information age*. Johns Hopkins University Press. Chapters 1-2.
      - Optional: Heims, S.G. [1991]. *The Cybernetics Group*. MIT Press. Chapters: 1,2, 11, and 12
      - Optional: McCulloch, W. and W. Pitts [1943], "A Logical Calculus of Ideas Immanent in Nervous Activity". *Bulletin of Mathematical Biophysics* **5**:115-133.
    - Gleick, J. [2011]. *The Information: A History, a Theory, a Flood*. Random House. Chapter 8.
      - Optional: Prokopenko, Mikhail, Fabio Boschetti, and Alex J. Ryan. "An information theoretic primer on complexity, self-organization, and emergence." *Complexity* **15**.1 (2009): 11-28.
  - Discussion Set 2 (Group 2) : September 10th and 12th
    - Brenner, Sydney. [2012]. "History of Science. The Revolution in the Life Sciences". *Science* **338** (6113): 1427-8.
    - Brenner, Sydney. [2012]. "Turing centenary: Life's code script. *Nature* **482** (7386) (February 22): 461-461.
    - Cobb, Matthew. [2013]. "1953: When Genes Became 'Information'." *Cell* **153** (3): 503-506.
      - Optional: Searls, David B. [2010]. "The Roots of Bioinformatics". *PLoS Computational Biology* **6**(6): e1000809.
    - Weaver, W. [1948]. "Science and Complexity". *American Scientist*, **36**(4): 536-44. Also available in Klir, G.J. [2001]. *Facets of systems Science*. Springer, pp: 533-540.
  - **Discussion by all**

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more upcoming readings (check brightspace)

- Paper Presentation: 20%
  - Present (501) and lead (501&440) the discussion of an article related to the class materials
    - Enginet students post/send video or join by Zoom synchronously
- Module 2: Systems Science
  - Discussion Set 3:
    - Klir, G.J. [2001]. *Facets of systems Science*. Springer. Chapters 1 and 2.
      - Optional:
      - Rosen, R. [1986]. "Some comments on systems and system theory". *Int. J. of General Systems*, **13**: 1-3. Available in: Klir, G.J. [2001]. *Facets of systems Science*. Springer. pp: 241-243.
      - Wigner, E.P. [1960], "The unreasonable effectiveness of mathematics in the natural sciences". Richard courant lecture in mathematical sciences delivered at New York University, May 11, 1959. *Comm. Pure Appl. Math*, **13**: 1-14.
    - Klir, G.J. [2001]. *Facets of systems Science*. Springer. Chapter 3.
  - Discussion Set 4:
    - Klir, G.J. [2001]. *Facets of systems Science*. Springer. Chapter 8.
      - Optional: Klir, G.J. [2001]. *Facets of systems Science*. Springer. Chapter 11
    - Schuster, P. (2016). The end of Moore's law: Living without an exponential increase in the efficiency of computational facilities. *Complexity*. **21**(S1): 6-9. DOI 10.1002/cplx.21824.
    - Von Foerster, H., P. M. Mora and L. W. Amiot [1960]. "Doomsday: Friday, November 13, AD 2026." Science **132**(3436):1291-5.
- Future Modules
  - See brightspace

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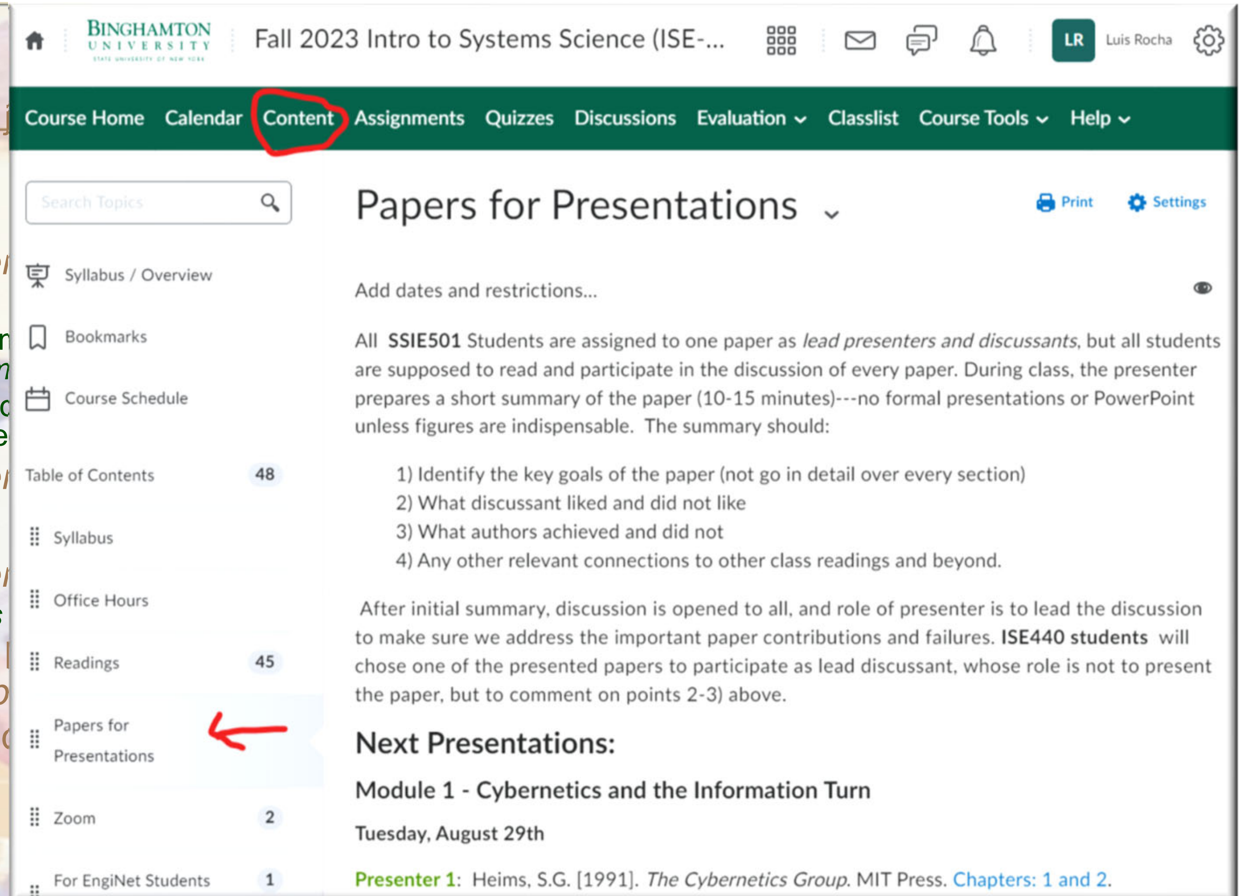
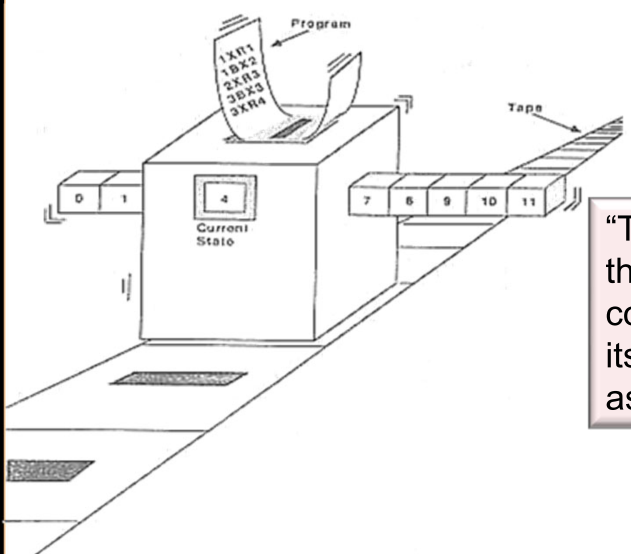
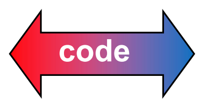


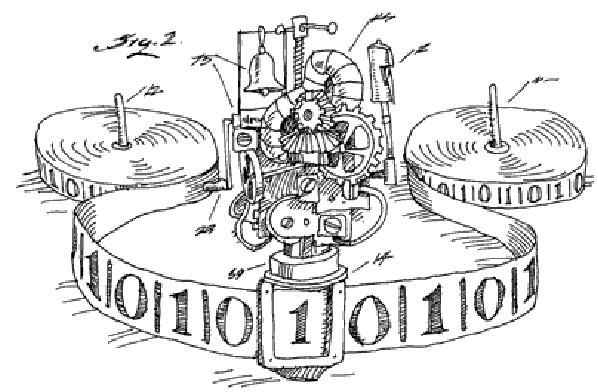
A fundamental principle of computation

- "On computable numbers with an application to the *Entscheidungsproblem*"
  - Turing, A. M. *Proc. Lond. Math. Soc.* **s2–42**, 230–265 (1936–37).
    - **Turing machine**, universal computation, decision problem
  - **Machine**'s *state* is *controlled* by a *program*, while *data* for program is on limitless **external tape**
    - every machine can be described as a **number** that can be stored on the tape (for itself or another machine)
      - Including a Universal machine
    - **distinction** between *numbers that mean things* (data) and *numbers that do things* (program)





"The fundamental, indivisible unit of information is the bit. The fundamental, indivisible unit of digital computation is the transformation of a bit between its two possible forms of existence: as [memory] or as [code]. George Dyson, 2012.



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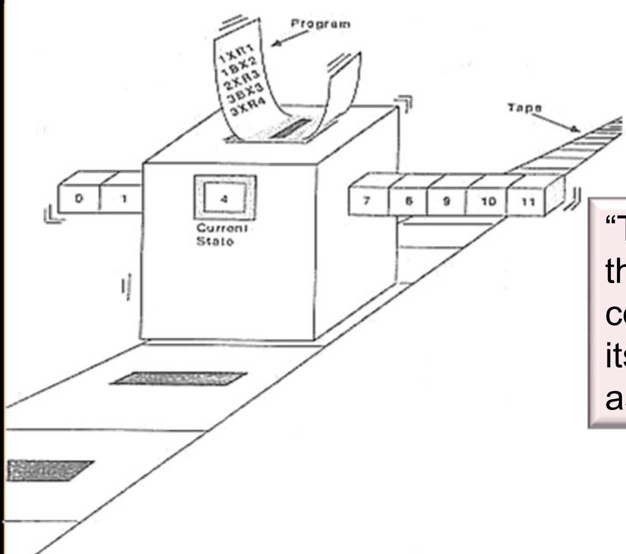

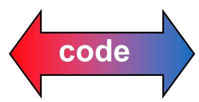

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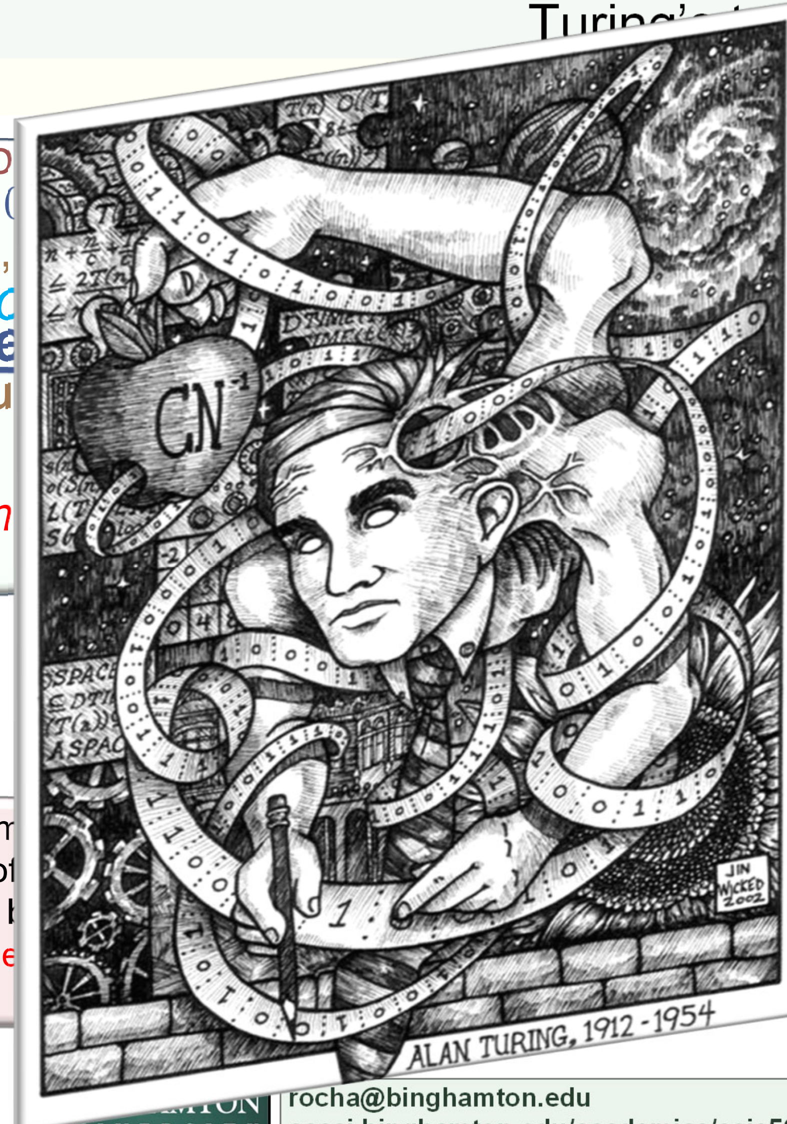

are people (and tables) too!

need to efficiently compute numerical tables, used in math, ballistics, astronomy, etc.


MIRIFICI

Logarithmorum
Canonis descriptio,

Ejusque usus, in utraque *Trigonometria; ut etiam in* omni Logistica Mathematica, *Amplissimi, Facillimi, & expeditissimi explicatio.*

Authore ac Inventore, IOANNE NEPERO, Barone Merchistonii, *&c. Scoto.*

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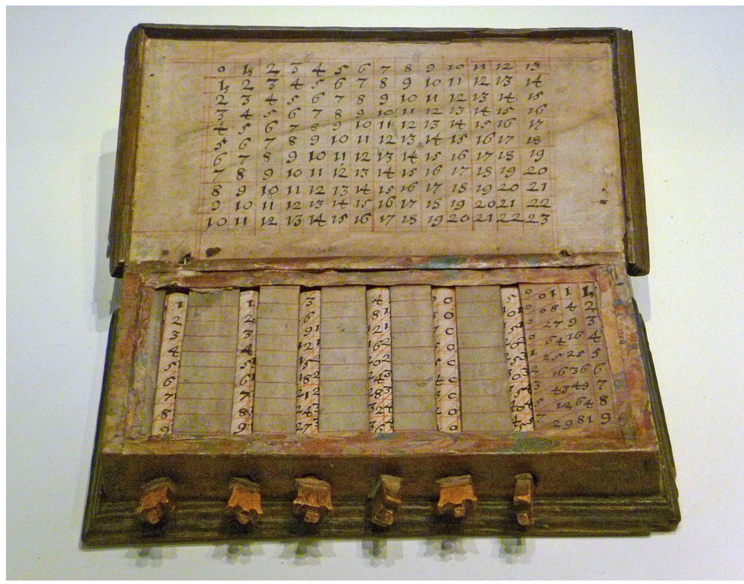
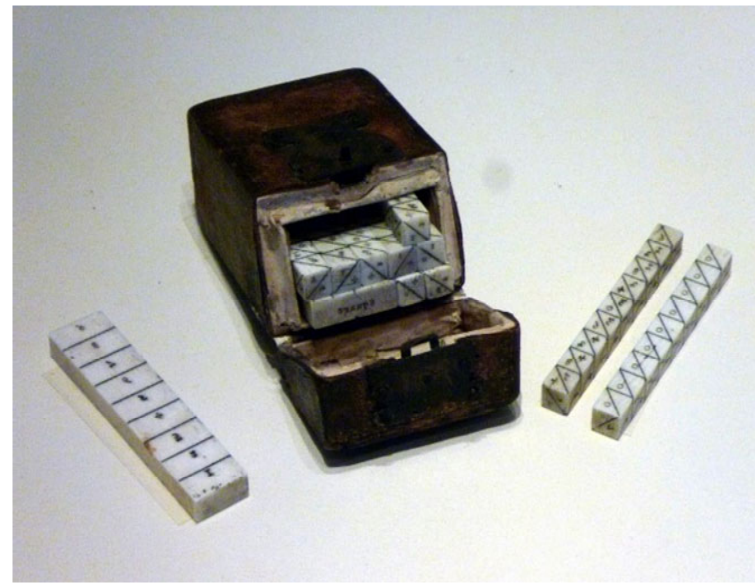
Ex officinâ ANDREÆ HART
Bibliopôle, CIↃ. DC. XIV.





Briggs (1561-1630): decimal algorithm, logs of 30,000 numbers to 14 decimal places and logs/tans of 1/100 of every degree, 14 decimal places

John Napier's (1550-1617)
- 1614: logarithm, "bones" and tables convert multiplication/division to addition/subtraction

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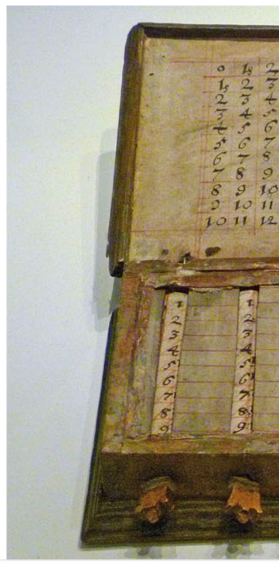

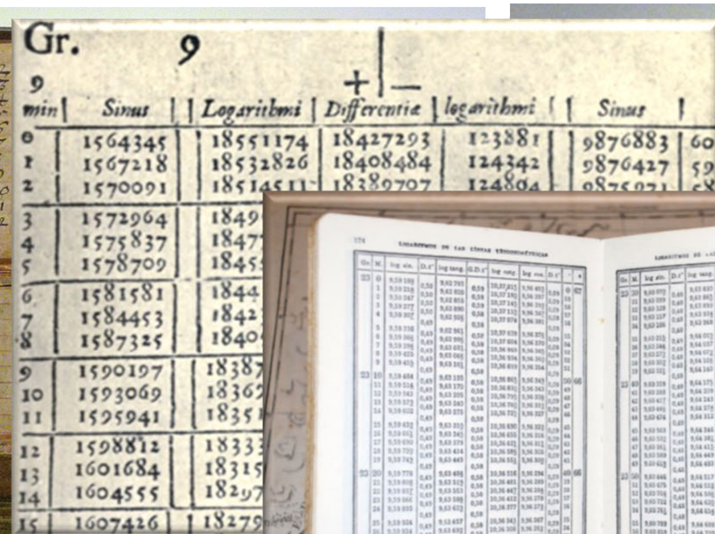

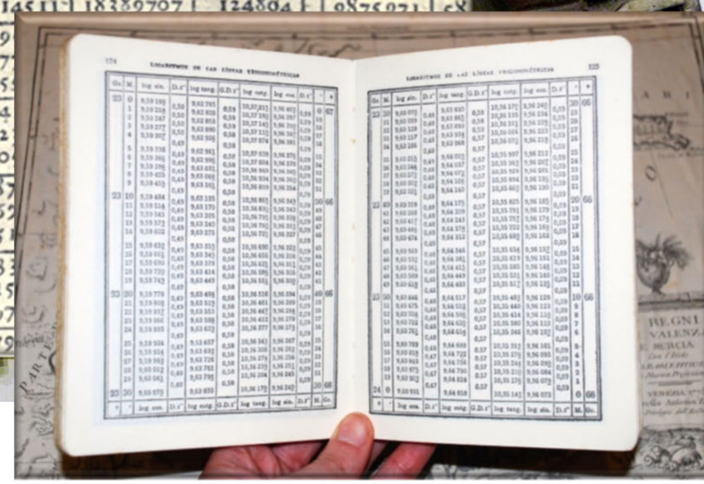

mechanical calculators to replace painstaking and error-prone human calculator work

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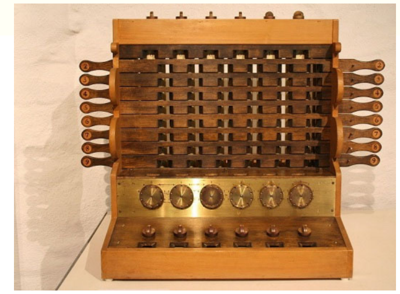
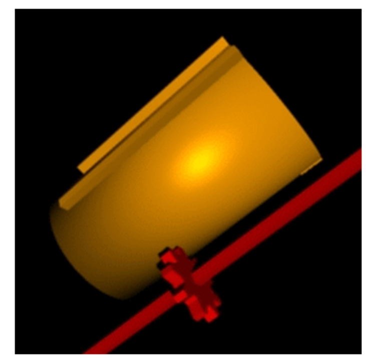
analog machines

- Wilhelm Schickard (1592- 1635)
  - In 1623 built the first mechanical calculator
    - can work with six digits, and carries digits across columns. It works, but never makes it beyond the prototype stage.
- Blaise Pascal (1623-1662)
  - built a mechanical calculator in 1642
    - It has the capacity for eight digits, but has trouble carrying and its gears tend to jam.
    - 10-teeth gears
- Gottfried von Leibniz (1614-1716)
  - built a mechanical calculator in 1670 capable of multiplication and division
    - (shift) registers for binary arithmetic
    - Credited Chinese for Binary arithmetic (I-Ching)
- Closer to abacus
  - Passive register (memory) of states



"The human race will have a new kind of instrument which will increase the power of the mind much more than optical lenses strengthen the eyes… One could carry out the ***description of a machine***, no matter how complicated, in characters which would be merely the letters of the alphabet, and so provide the mind with a method of knowing the machine and all its parts." Leibniz, 1679.



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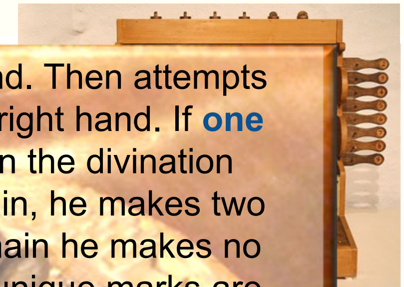
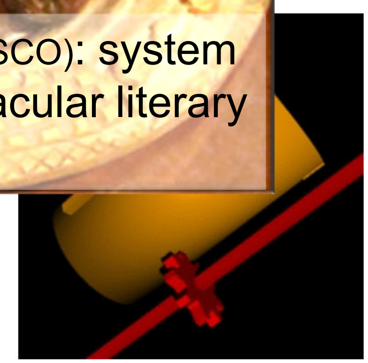


a priest holds six sacred palm nuts in his left hand. Then attempts to grab all of them out at the same time with his right hand. If **one** nut remains in his left hand , he makes a mark on the divination board which represents **a zero**. If **two** nuts remain, he makes two marks which represent **one**. If none or more remain he makes no marks at all. This is continued until four pairs of unique marks are left on the board which generate a 8-bit binary code.

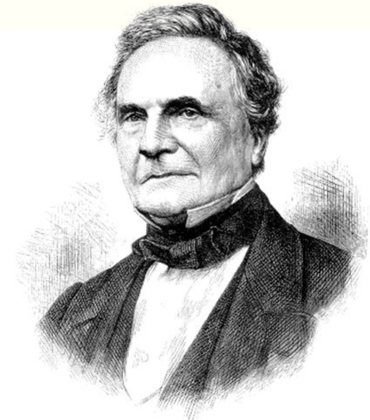
Ifá (intangible cultural heritage of humanity by UNESCO): system of divination is a binary code to access oracular literary body made up of 256 volumes (signs).

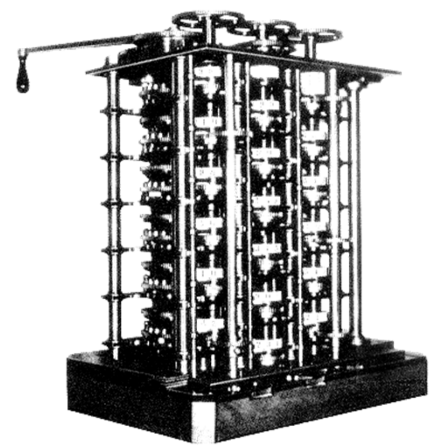
“The human race will have a new kind of ins will increase the power of the mind much mc lenses strengthen the eyes… One could car ***description of a machine***, no matter how complicated, in characters which would be merely the letters of the alphabet, and so provide the mind with a method of knowing the machine and all its parts.” Leibniz, 1679.



difference engine

- Special-purpose digital computing machine for the **automatic** production of mathematical tables.
  - logarithm tables, tide tables, and astronomical tables
  - Steam-driven, consisted entirely of mechanical components - brass gear wheels, rods, ratchets, pinions, etc.
  - Numbers were represented in the decimal system by the positions of 10-toothed metal wheels mounted in columns.
- Never completed the full-scale machine
  - Completed several fragments. The largest is on display in the London Science Museum. In 1990, it was built (London Science Museum)
- The Swedes Georg and Edvard Scheutz (father and son) constructed a modified version of Babbage's Difference Engine.
- For an interesting "what-if" scenario read "The Difference Engine" by Bruce Sterling and William Gibson





Charles Babbage (1791 – 1871)

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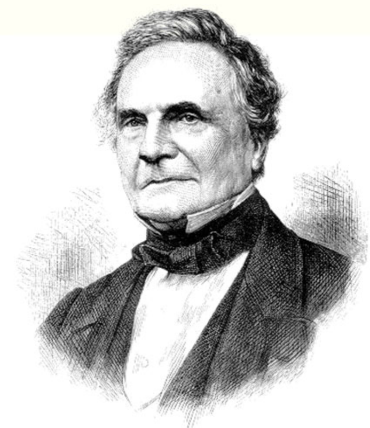

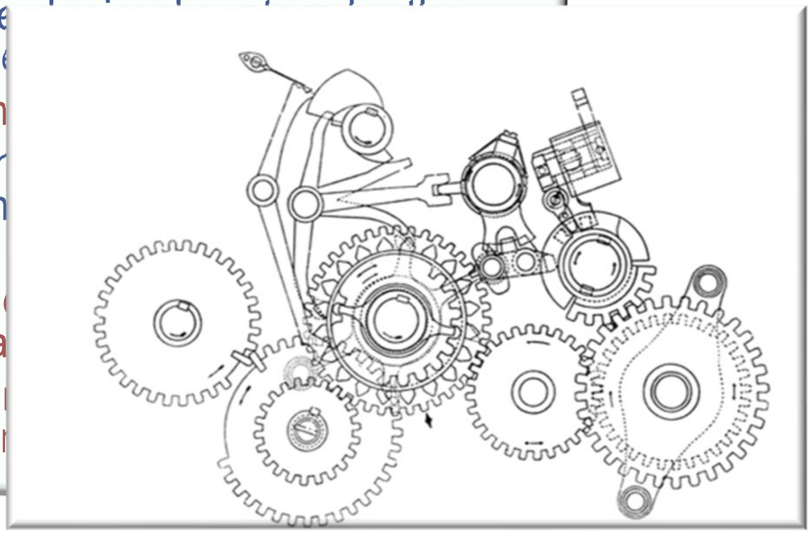

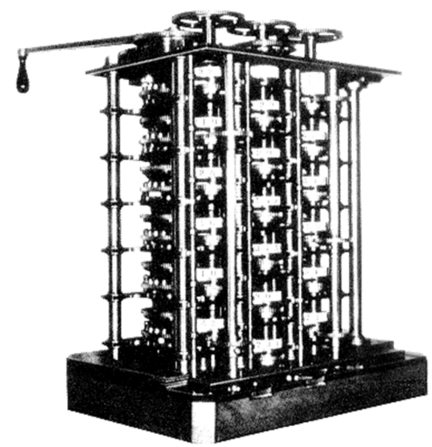

Not a universal Turing machine, but an analog computer

Charles Babbage (1791 – 1871)

difference engine

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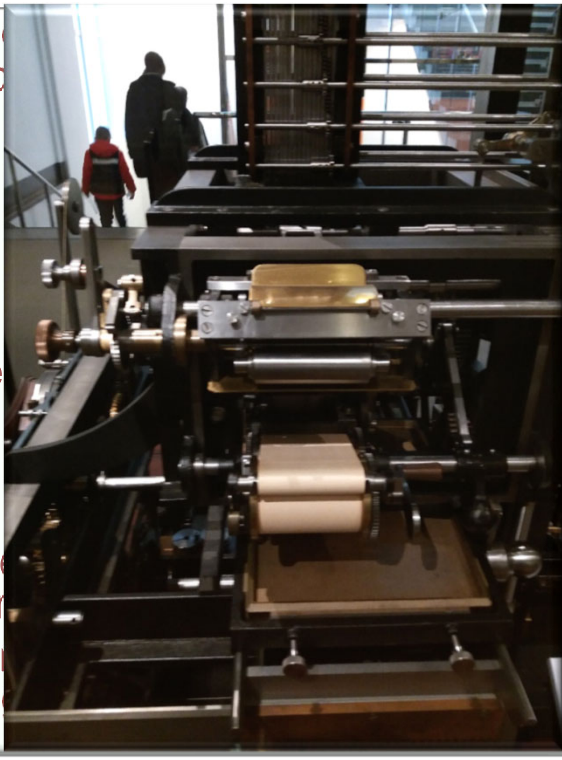

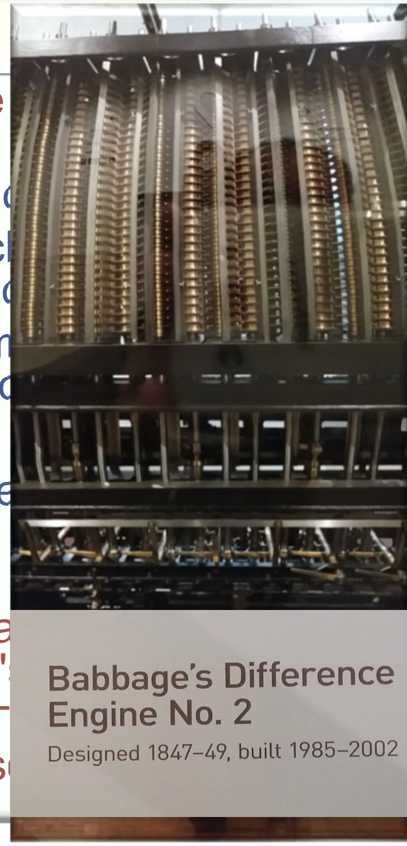

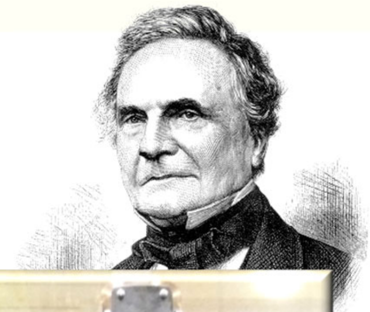

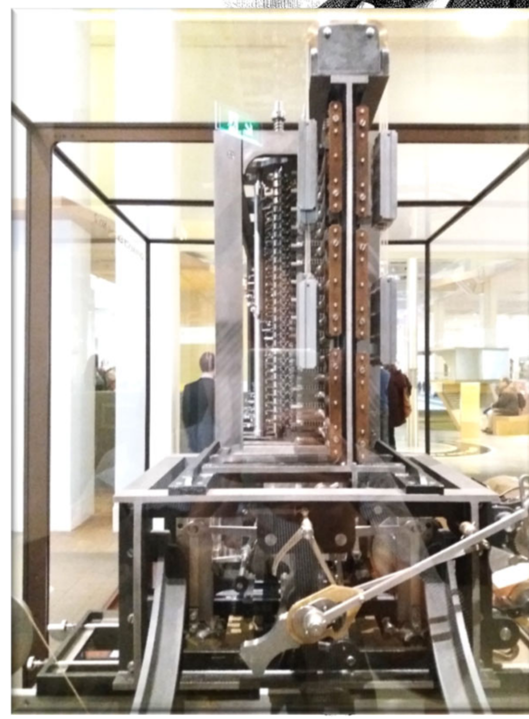

Not a universal Turing machine, but an analog computer

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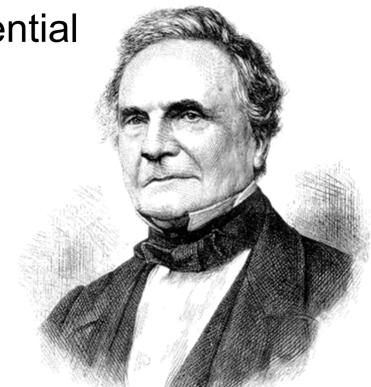
The analytical engine had an "external tape"

Turing on programs (numbers as instructions) : "[Babbage] had all the essential ideas [and] planned such a machine, called the ***Analytical Engine***. […]



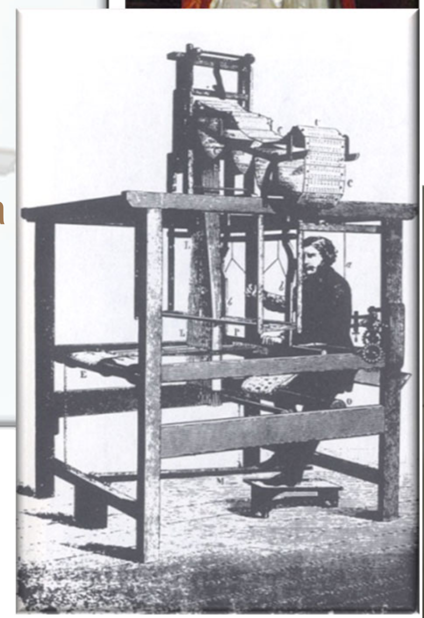
- general-purpose mechanical digital computer.
  - Separated **memory store** from a **central processing unit** (or 'mill')
  - able to select from among **alternative actions** consequent upon the outcome of its previous actions
    - Conditional branching: Choice, information
  - Mechanical cogs not just numbers
    - **Variables** (states/configurations)
- Programmable
  - Data and instructions on distinct **punched cards**

"It is only a question of cards and time, […] and there is no reason why (twenty thousand) cards should not be used if necessary, in an Analytical Engine for the purposes of the mathematician". Henry Babbage (1888)

Charles Babbage (1791 – 1871) and Ada Lovelace (1815-1852)

The external tape as a general design principle (system) of universal computation

- Analytical engine
  - Separated **memory store** from a **central processing unit** (or 'mill')
  - Cogs not just numbers
    - **variables**
- Programmable
  - instructions on **punched cards**
    - Inspired by the Jacquard Loom
  - Ada Lovelace: the science of operations
    - Set of (recursive) rules for producing Bernoulli numbers (a program)
    - **Separation** of variable and operational (data) cards
    - would punch out cards for later use
      - "the Engine eating its own tail." (Babbage)



code

distinction between *numbers that mean things* and *numbers that do things*.

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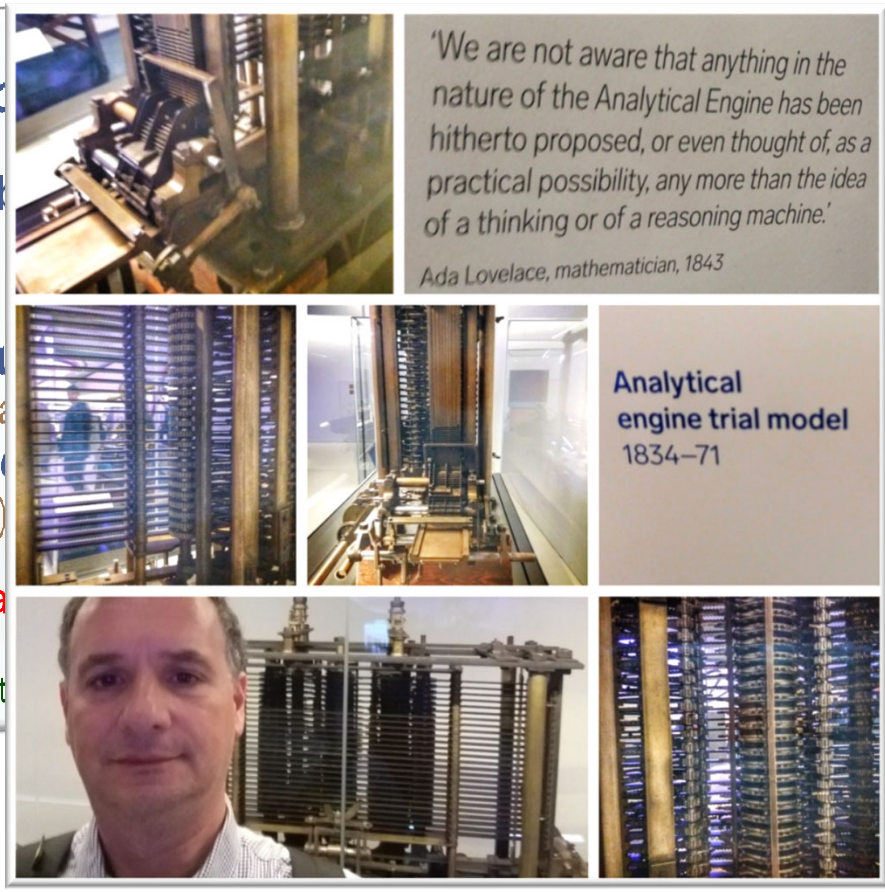
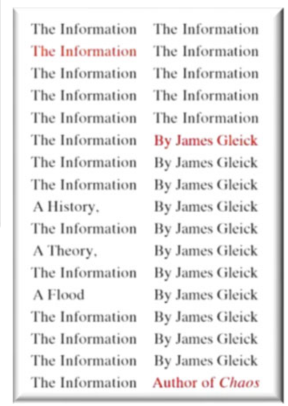
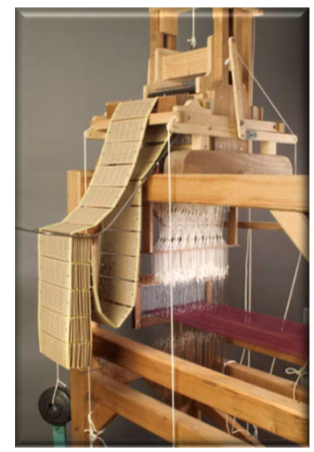




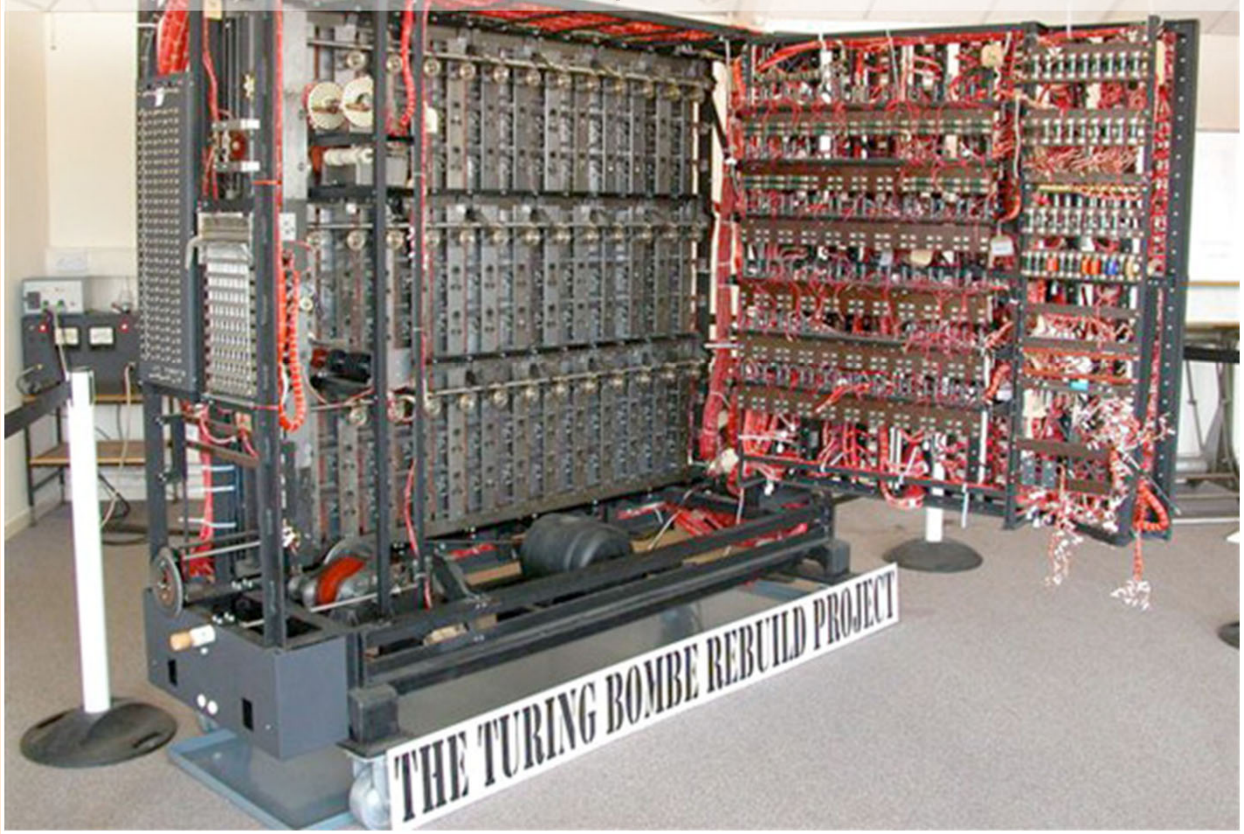


code

distinction between *numbers that mean things* and *numbers that do things*.

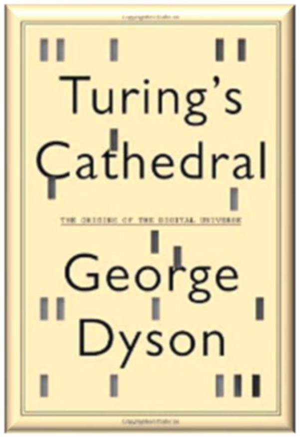
not electronic, not digital, not general-purpose

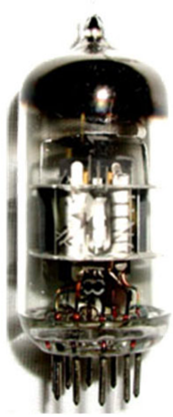
Turing bombe: Enigma Cracker at Bletchley Park (1940-1945)
Electro-mechanical, hundreds produced in UK and US



ENIAC (1945)

Electronic Numerical Integrator And Computer

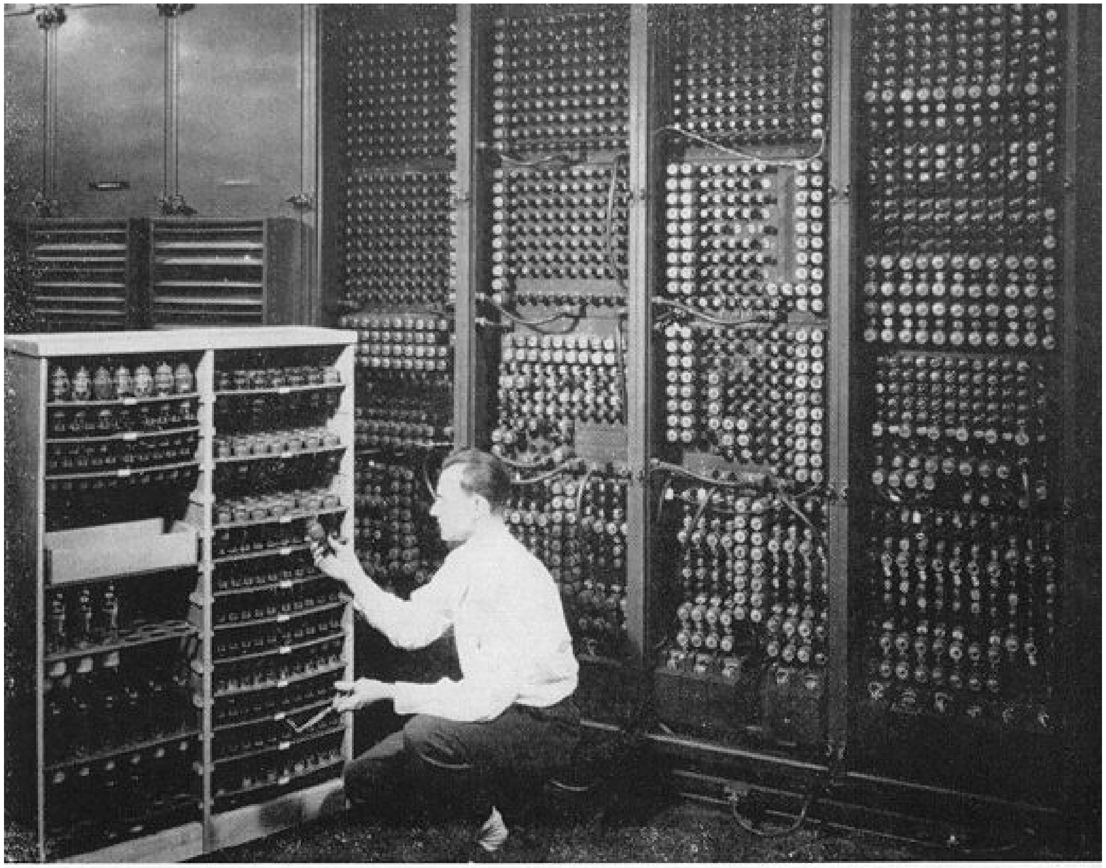




- First fully functioning electronic digital computer to be built in the U.S.
  - Electrical Numerical Integrator and Computer
  - University of Pennsylvania, for the Army Ordnance Department, by J. Presper Eckert and John Mauchly.
    - Far from general-purpose: The primary function was calculation of tables used in aiming artillery.
    - ENIAC was not a stored-program computer, and setting it up for a new job involved reconfiguring the machine by means of plugs and switches.
    - Used decimal digits instead of binary ones
    - Nearly 18,000 ***vacuum tubes for switching.***
      - Storage of all those vacuum tubes and the machinery required to keep the cool took up over 167 square meters (1800 square feet) of floor space.
      - invented by American physicist Lee De Forest in 1906.
      - worked by using large amounts of electricity to heat a filament inside the tube. the presence of current represented a one.
    - punched-card input and output

ENIAC (1945)

Electronic Numerical Integrator And Computer (decimal)



Replacing a bad tube meant checking among ENIAC's 19,000 possibilities.

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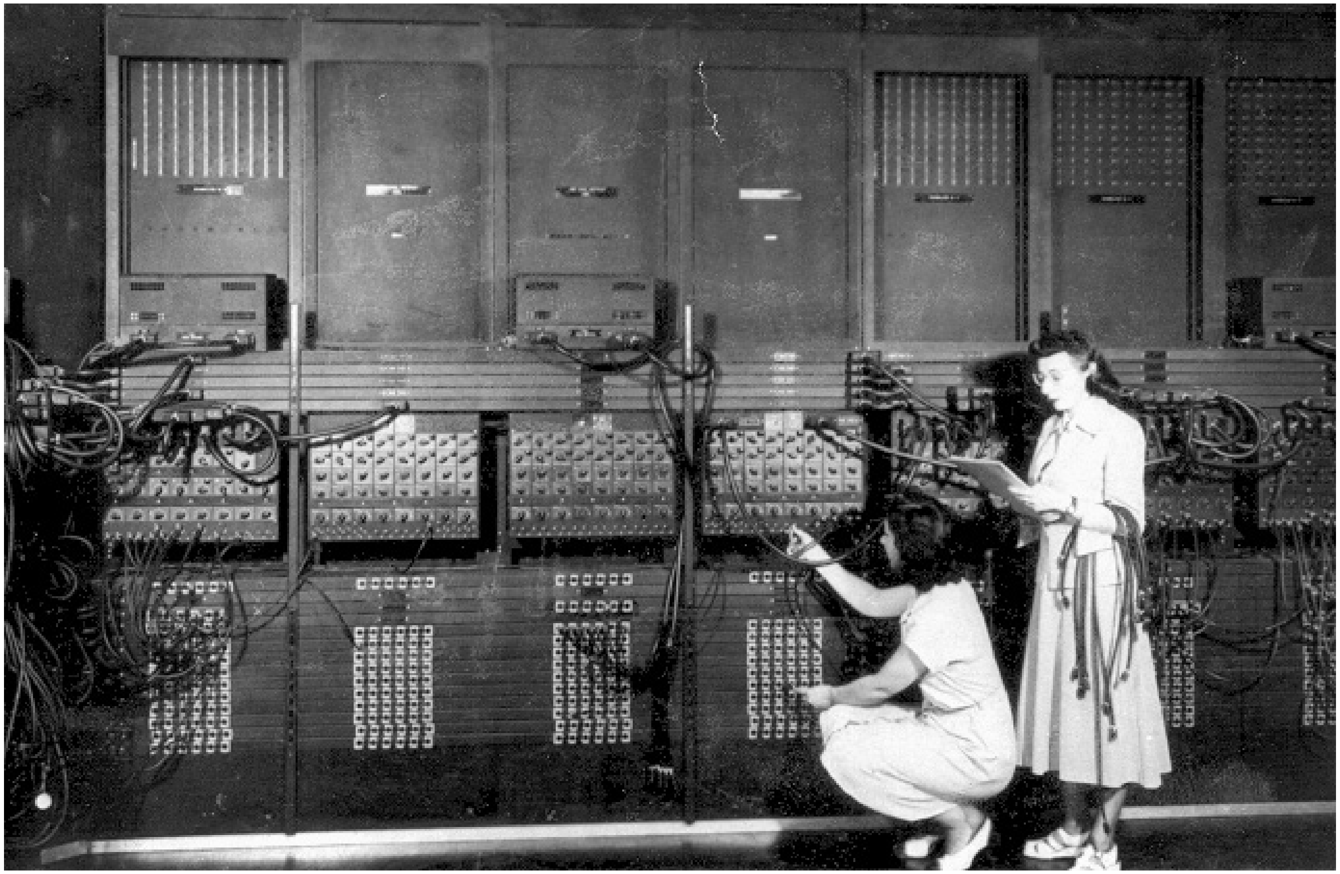
ENIAC (1945)

Electronic Numerical Integrator And Computer



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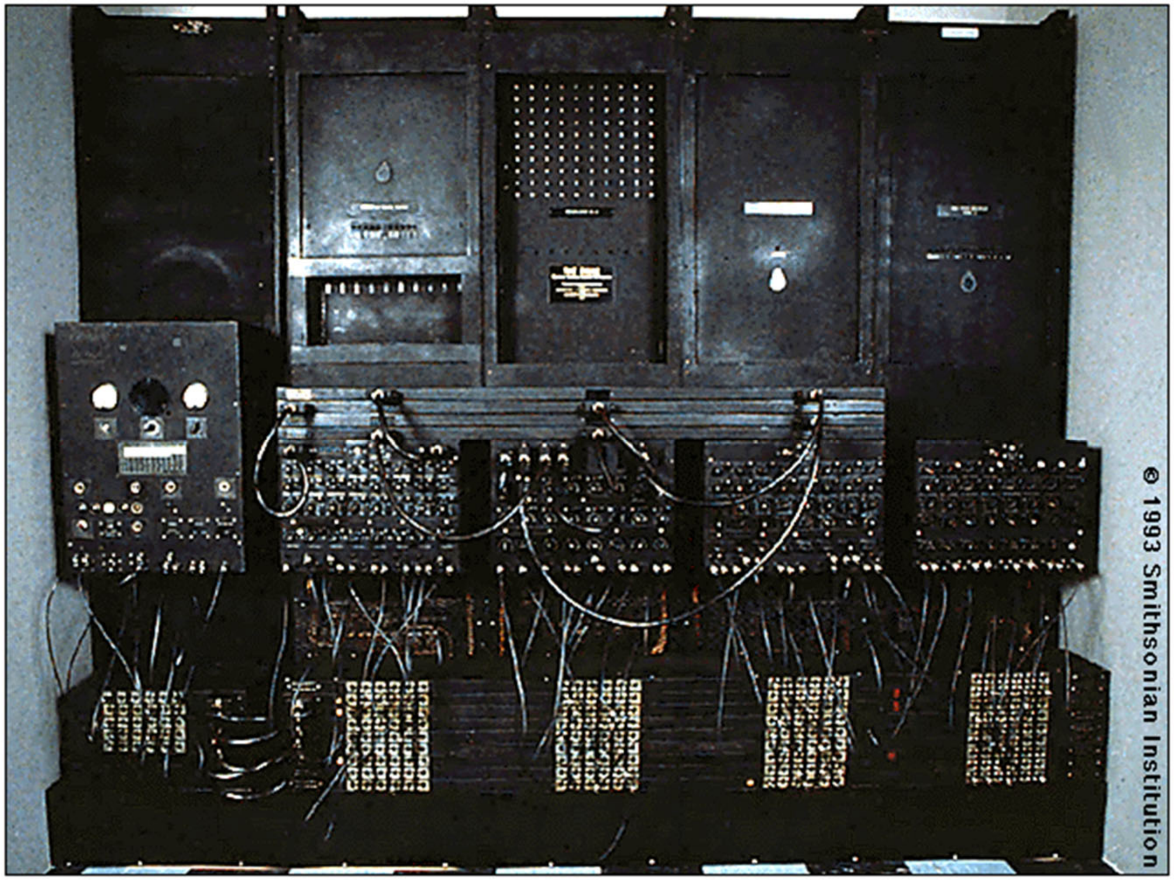
ENIAC (1945)

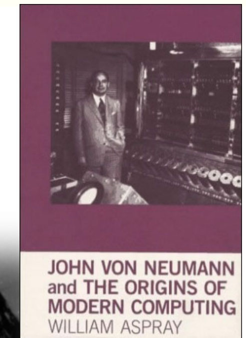
Electronic Numerical Integrator And Computer

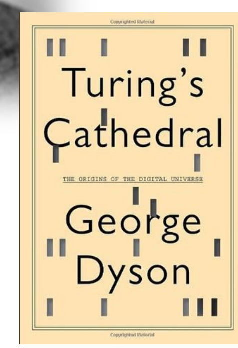


Turing machines beyond the decision problem

" 'Words' coding the orders are handled in the memory just like numbers" --- distinction between *numbers that mean things* and *numbers that do things*.

- realizing the power of Turing's tape
  - physical (electronic) computers
  - emphasized the importance of the ***stored-program computer*** concept (the external tape)
    - EDVAC (1951), IAS Machine (1952) - binary
  - allows machine to modify its own program
    - von Neumann architecture: The functional **separation** of storage from the processing unit.
      - programs can exist as data (two roles)
    - Converts tape to fixed-address memory (random-access memory)
  - Ultimate ***general-purpose*** machines





"Let the whole outside world consist of a long paper tape".
—John von Neumann, 1948

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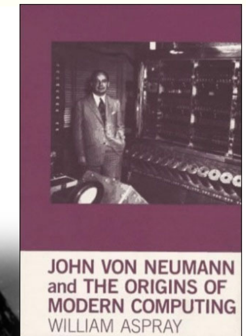
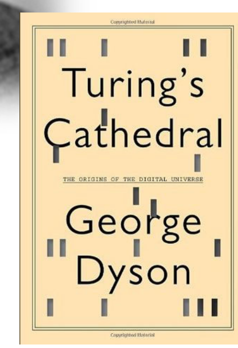
  - Ultimate ***general-purpose*** machines

"Since Babbage's machine was not electrical, and since all digital computers are in a sense equivalent, we see that this use of electricity cannot be of theoretical importance.… The feature of using electricity is thus seen to be only a very superficial similarity." (Alan Turing)





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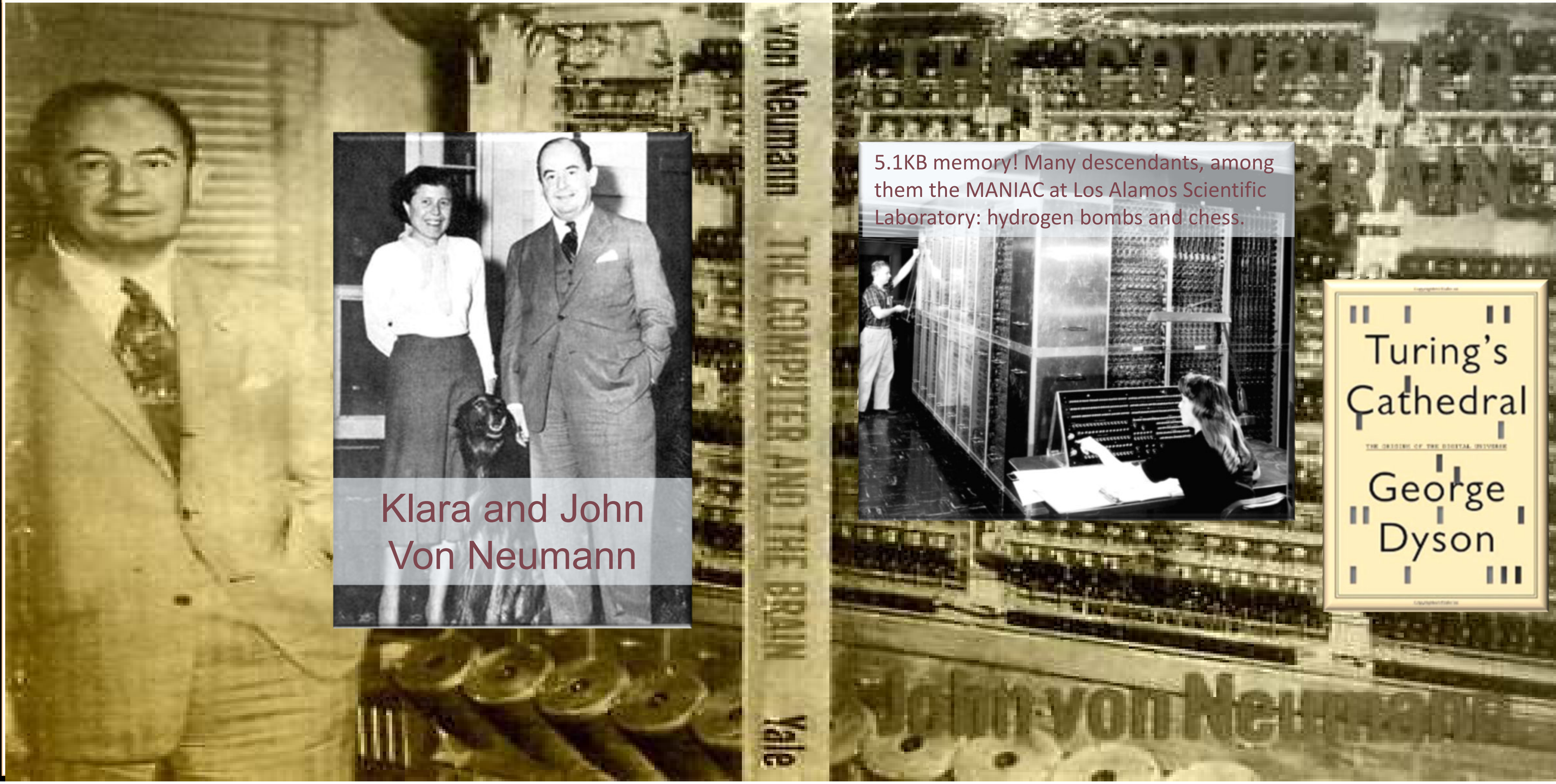
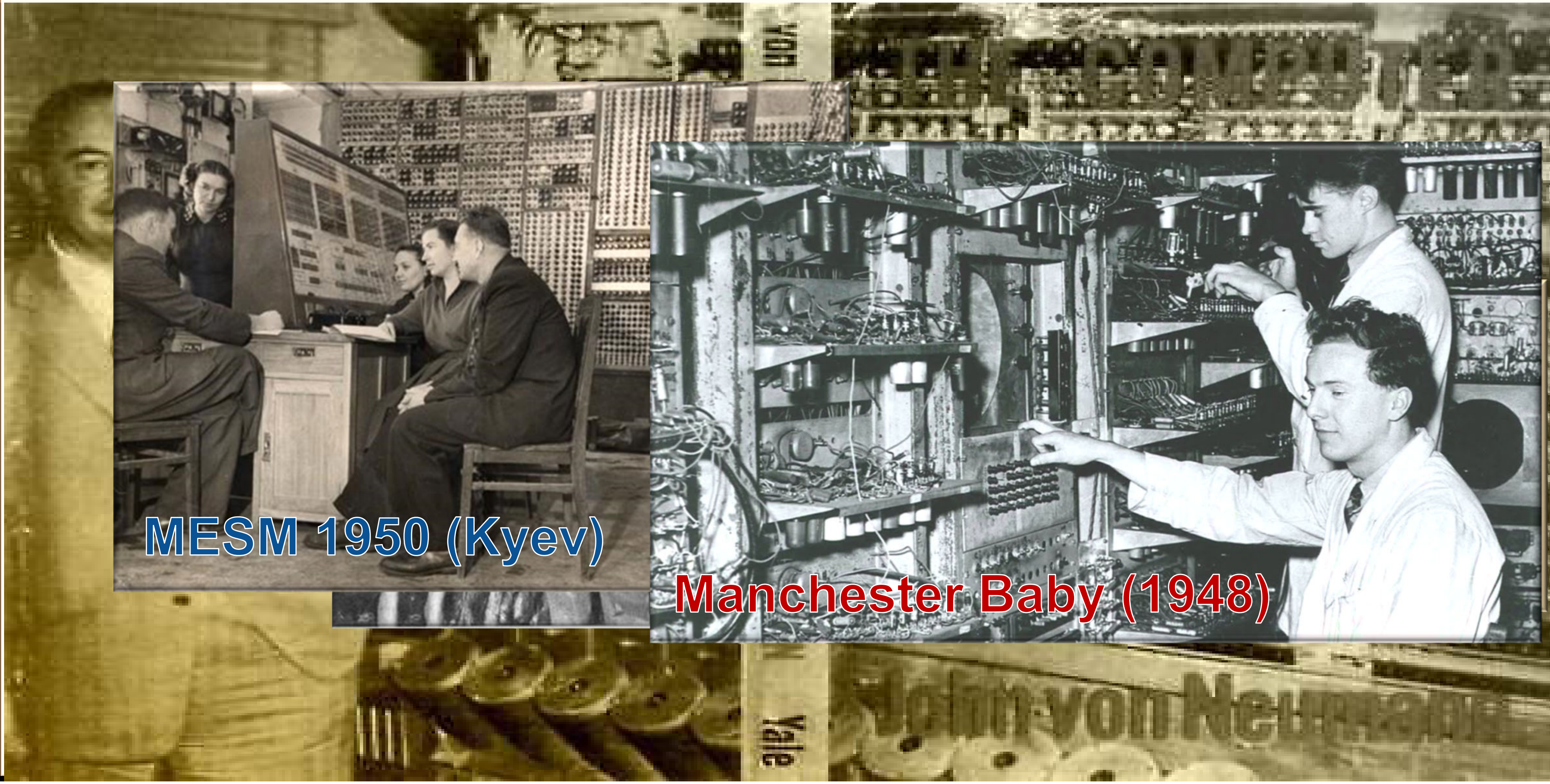
IAS Machine (1952)

electronic digital (stored-program) computer with 40 bit word (IAS, Princeton)



IAS Machine (1952)

electronic digital (stored-program) computer with 40 bit word (IAS, Princeton)

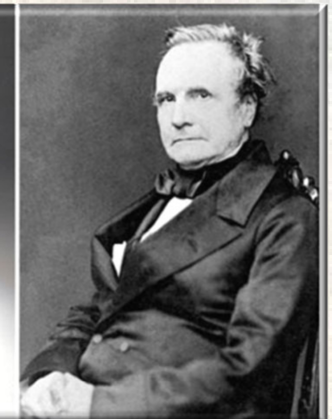


EDSAC (1949)

Electronic Delay Storage Automatic Calculator (Cambridge)

Inspired by Von Neumann's EDCAC design, but built earlier (not earlier than the Manchester Boy)

Babbage/Lovelace first to try to build it (before Turing)



distinction between *numbers that mean things*
and *numbers that (do things) move matter*

readings

- Class Book
  - Klir, G.J. [2001]. *Facets of systems science*. Springer.
- Papers and other materials
  - Discussion Set 1 (Group 1) – September 5th
    - Kline, Ronald R [2015]. *The cybernetics moment, or, why we call our age the information age*. Johns Hopkins University Press. Chapters 1-2.
      - Optional: Heims, S.G. [1991]. *The Cybernetics Group*. MIT Press. Chapters: 1,2, 11, 12.
      - Optional: McCulloch, W. and W. Pitts [1943], "A Logical Calculus of Ideas Immanent in Nervous Activity". *Bulletin of Mathematical Biophysics* **5**:115-133.
    - Gleick, J. [2011]. *The Information: A History, a Theory, a Flood*. Random House. Chapter 8.
      - Optional: Prokopenko, Mikhail, Fabio Boschetti, and Alex J. Ryan. "An information theoretic primer on complexity, self-organization, and emergence." *Complexity* **15**.1 (2009): 11-28.