Charles Babbage (1791-1871)

Thomas J. Bergin

American University

Technology and Man's Limitations

- Seven Wonders of the World
- vessels, navigation, maps
- cities: water and sewage systems
- farm machinery
- clocks, watches, music boxes
- automata, toys, etc.

The Context

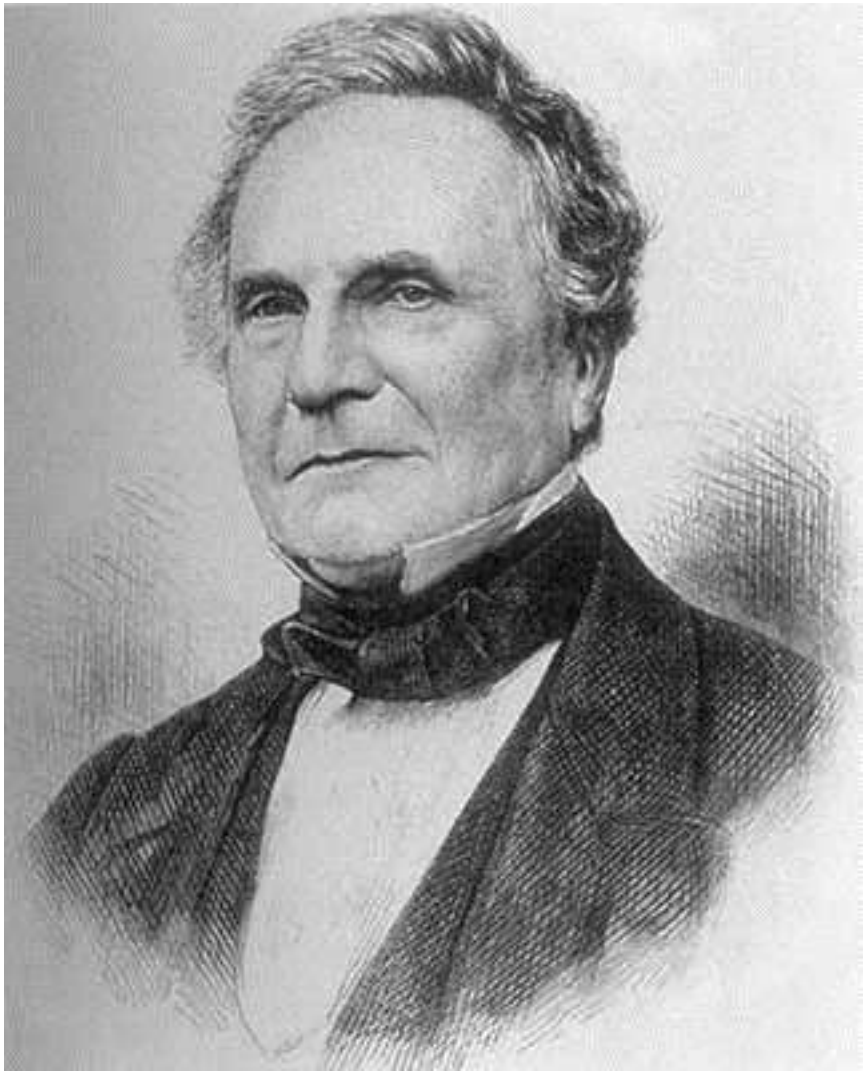
- Industrial Revolution 1733
- American Revolution 1775
- French Revolution 1789

Industrial Revolution (1733-1878)

- John Kay's *flying shuttle loom*: 1733
- Richard Arkwright's *water frame* and the need for a *factory* 1769
- Thomas Newcomen's *steam engine* 1765
- James Watt's *steam engine* 1765
- Steam Powered Cotton Mill 1785

- Bridgewater (Worsley) Canal 1761
- Coal gas for *lighting* 1800s
- Major European Cities with lighting 1820s
- Rise of the Engineer: *Cyrus McCormick*, *Josiah Wedgwood*, *Joseph-Marie Jacquard*, *Marc Isambard Brunel*, *Robert Fulton*, *Joseph Paxton*, *Eli Whitney*
- Mechanization of farming: *tractor*
- Practical *electric lamps:*Thomas Edison 1879

Charles Babbage (1791-1871)



Charles Babbage (1791-1871)

- Born: December 26, 1791
- son of Benjamin Babbage a London banker

  (part of the emerging *middle class: property, education, wealth, and status*)
- Trinity College, Cambridge [MA, 1817]

  with John Herschel and George Peacock, produced a translation of LaCroix's calculus text.

polymath (*polymathes*, much learning)

- Royal Astronomical Society
- Royal Statistical Society (founder)
- Analytical Society (founded with Herschel)
- Papers: *optics, atmospheric observations, electricity and magnetism, life insurance actuarial calculations, cryptology, geology, metal working, taxation systems, lighthouse operations, and diving bells*
- Inventor: *skeleton key, opthalmascope, cow catcher, and speedometer*

Selected Publications

- "Observations on the Application of Machinery to the Computation of Mathematical Tables," *Memoirs of the Astronomical Society*, 1825.
- *On the Economy of Machinery and Manfactures*, 1832 (an origin of operations research)
- "On the Mathematical Powers of the Calculating Engine," unpublished manuscript, 1837
- *Passages from the Life of a Philosopher*, 1864

The Tables Crisis

- Multiplication and Division
- Logarithms
- Trigonometric Functions
- Values of X^2, X^3, etc.
- Polynomials such as $X^3 + X^2 + X + 11$
- Nautical tables such as: *Nautical Ephemeris for Finding Latitude and Longitude at Sea*

Difference Engine

- July 1822, wrote to the president of the Royal Society describing a plan for *calculating* and *printing* mathematical tables
  - *(Note: Babbage had over 300 books of tables in his library)*
- June 1823, granted 1,500 pounds
- December 1829, additional grant of 3,000 pounds

Method of differences

- Tables of Polynomials:
- F(X) = 2 X + 3

X	1	2	3	4	5	6	7
F(X)	5	7	9	11	13	?	?
Diff. ▲	?						

Method of differences

- $F(X) = X^2 + 2X + 3$

X	1	2	3	4	5	6	7
F(X)	6	11	18	27	38	51	66
D_1		5	7	9	11	?	?
D_2			?	?			

- **X^n would use the n^{th} difference to achieve a constant value**

Method of differences: $F(X) = X^2 + X^3$

N	N^2	N^3	Sum	D_1	D_2	D_3
0	0	0	0			
1	1	1	2	*2*		
2	*4*	8	12	*10*	*8*	
3	9	*27*	36	*24*	*14*	*6*
4	16	64	80	*44*	*20*	*6*
5	25	125	150	70	26	6
6	**?**	**?**	**?**			
7	**?**	**?**	**?**			

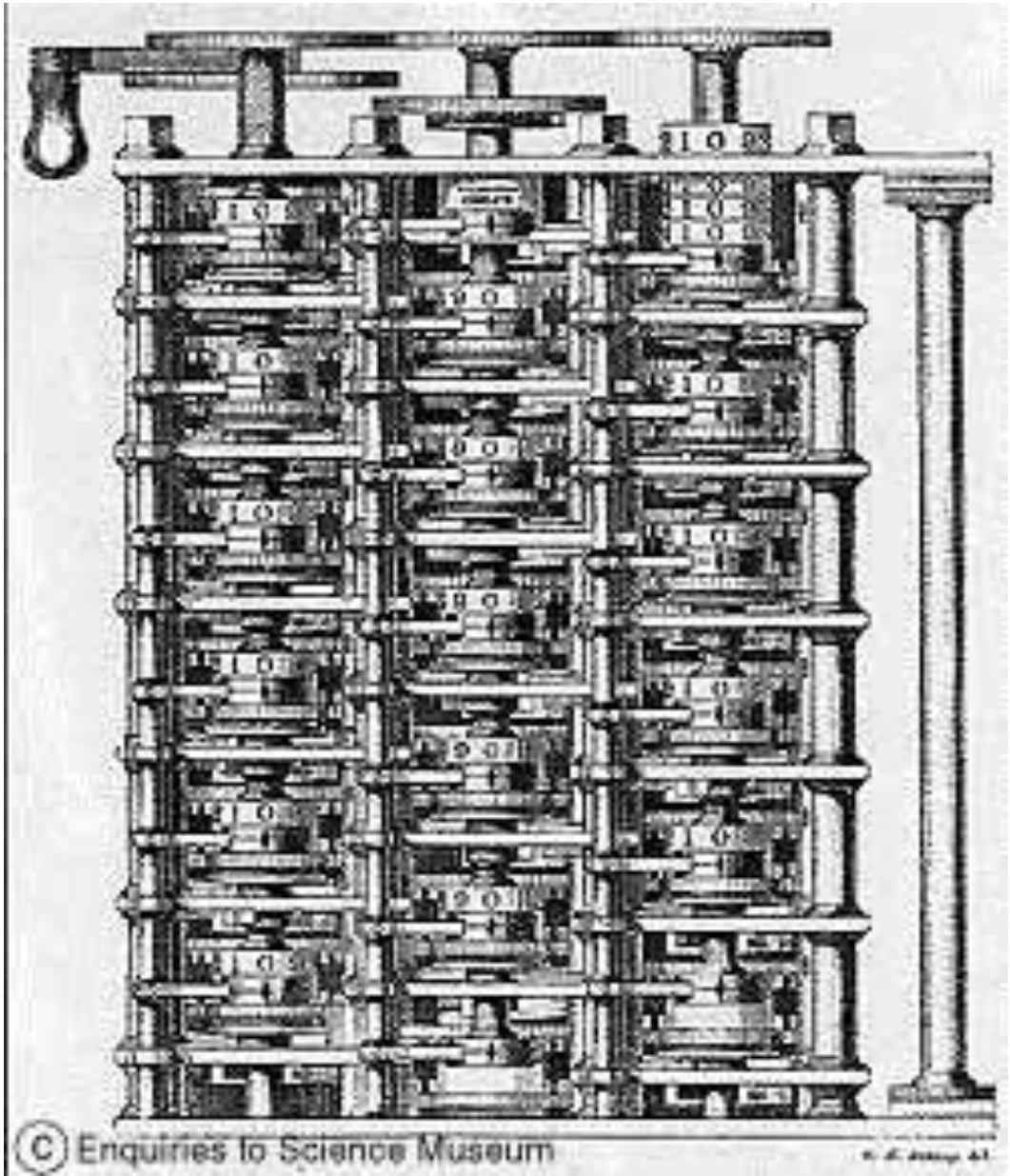
A vision of calculating by steam!

My friend Herschel, calling upon me, brought with him the calculations of the computers, and we commenced the tedious process of verification. After a time many discrepancies occurred, and at one point these discordances were so numerous that I exclaimed, "I wish to God these calculations had been executed by steam."

1821

Difference Engine

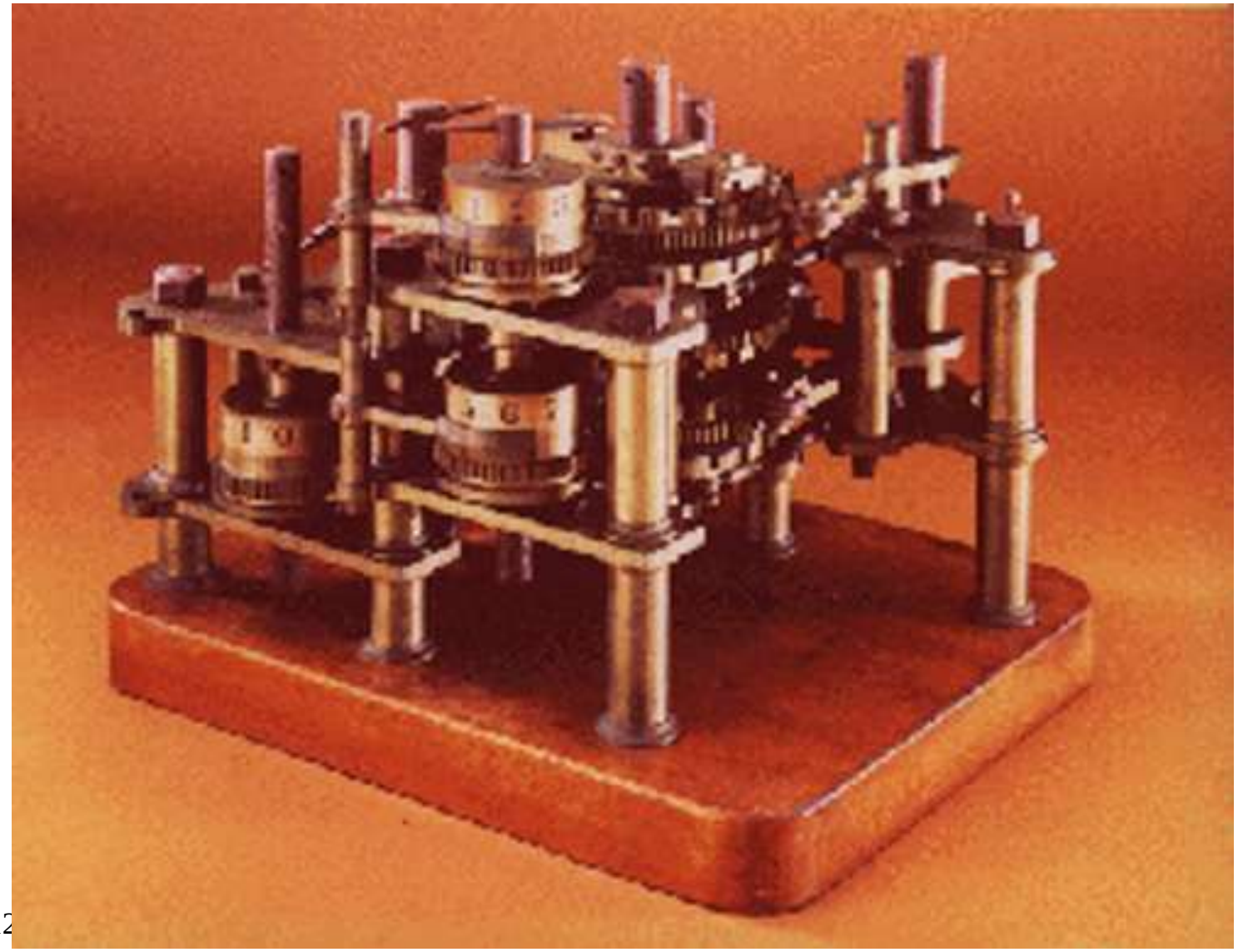
- 1822 original design called for 6 decimal places with second-order difference
- 1830 redesigned difference engine with 20 decimal places and a sixth-order difference



Never to be completed

- December 1830, a dispute with his chief engineer, Joseph Clement, over control of the project, ends work on the difference engine
- Clement is allowed to keep all tools and drawings by English law

Trial piece to test ideas



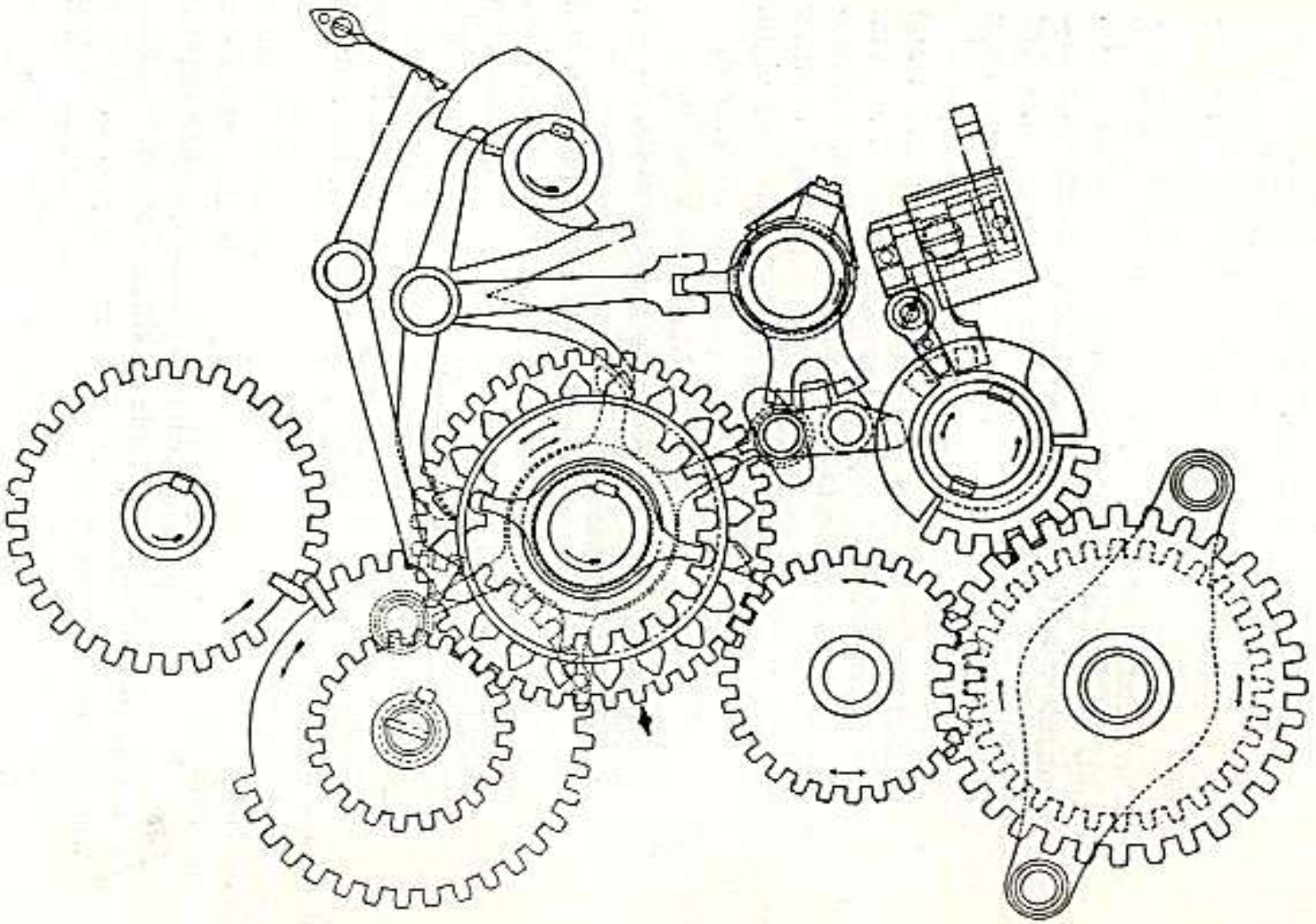
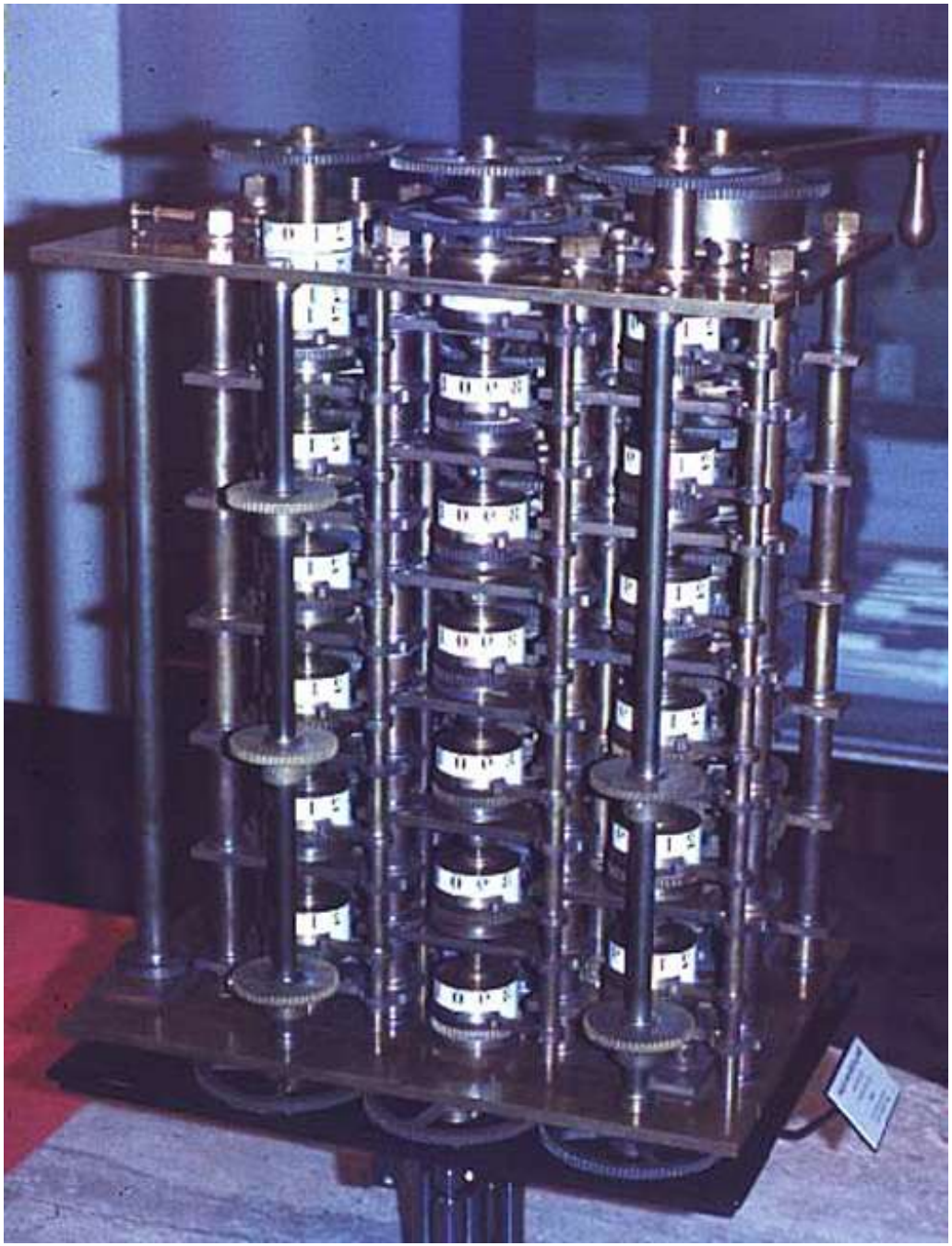
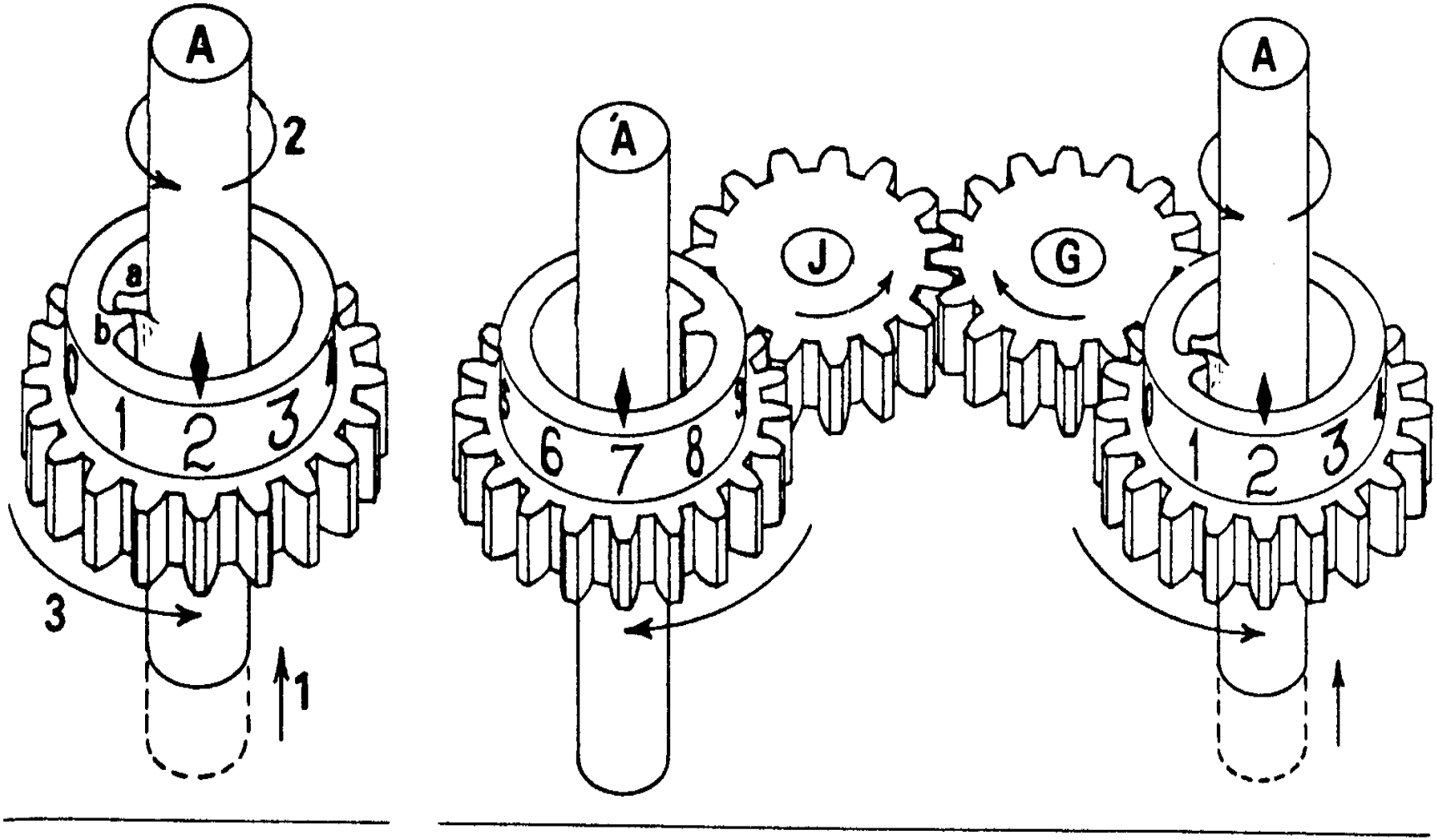


FIG. 1/1. One of Babbage's drawings of part of his engine




A
2
a
b
1 2 3
3
1
Á
J
G
A
6 7 8
1 2 3

Stereotypes

- **Ster-e-o-type, n., v., -typed, -typing, --n.**

1. a process of making metal plates to use in printing by taking a mold composed type or the like in papier-mache or other material and then taking from this mold a cast (plate) in type metal. 2. a plate made by this process. 3. a set form; convention. 4. to make a stereotype.

Furthermore….

- Problem of errors in calculations
- Problem of errors in transcription, i.e., in the process of printing the tables
- Babbage conceived of and designed a mechanism to make stereotype plates which could be used to print the tables
- Presently being built to Babbage's design by the Science Museum, London

But, to no avail....

- 1834-1842 Babbage applied for additional grants
- 17,000 pounds of the public's money and an equal amount of his own had been spent on the project
- Prime Minister Robert Peel: *"I would like a little previous consideration before I move in a thin house of country gentlemen a large vote for the creation of a wooden man to calculate tables from the formula* $x^2 + x + 41$."

Critique

- Limited industrial and “engineering” capabilities
- Had to plan for, design, and make the *tools* and *machines* to make all the parts for the engine
- No industrial *standards* at this time such as for machine screws; everything was *one of a kind*
- No “engineering” schools, only *Guilds* and the *apprentice* system
- Used *steam engines* as a base for his thinking, i.e., steam locomotives with their huge scale for parts

Importance of the Difference Engine

- 1. First attempt to *devise* a computing machine that was *automatic in action* and well adapted, by its printing mechanism, to *a mathematical task of considerable importance*.
- 2. An example of *government subsidization* of innovation and technology development
- 3. Spin offs to the *machine-tool "industry*"

Benefits....

I wrote to one of the most eminent mechanical engineers to enquire whether I should be safe in stating to the Government that the expense of the Calculating Engine had been more than repaid by the improvements in mechanism directly referable to it; he replied, -- "unquestionably."

William Parsons, Earl of Rosse, 1854

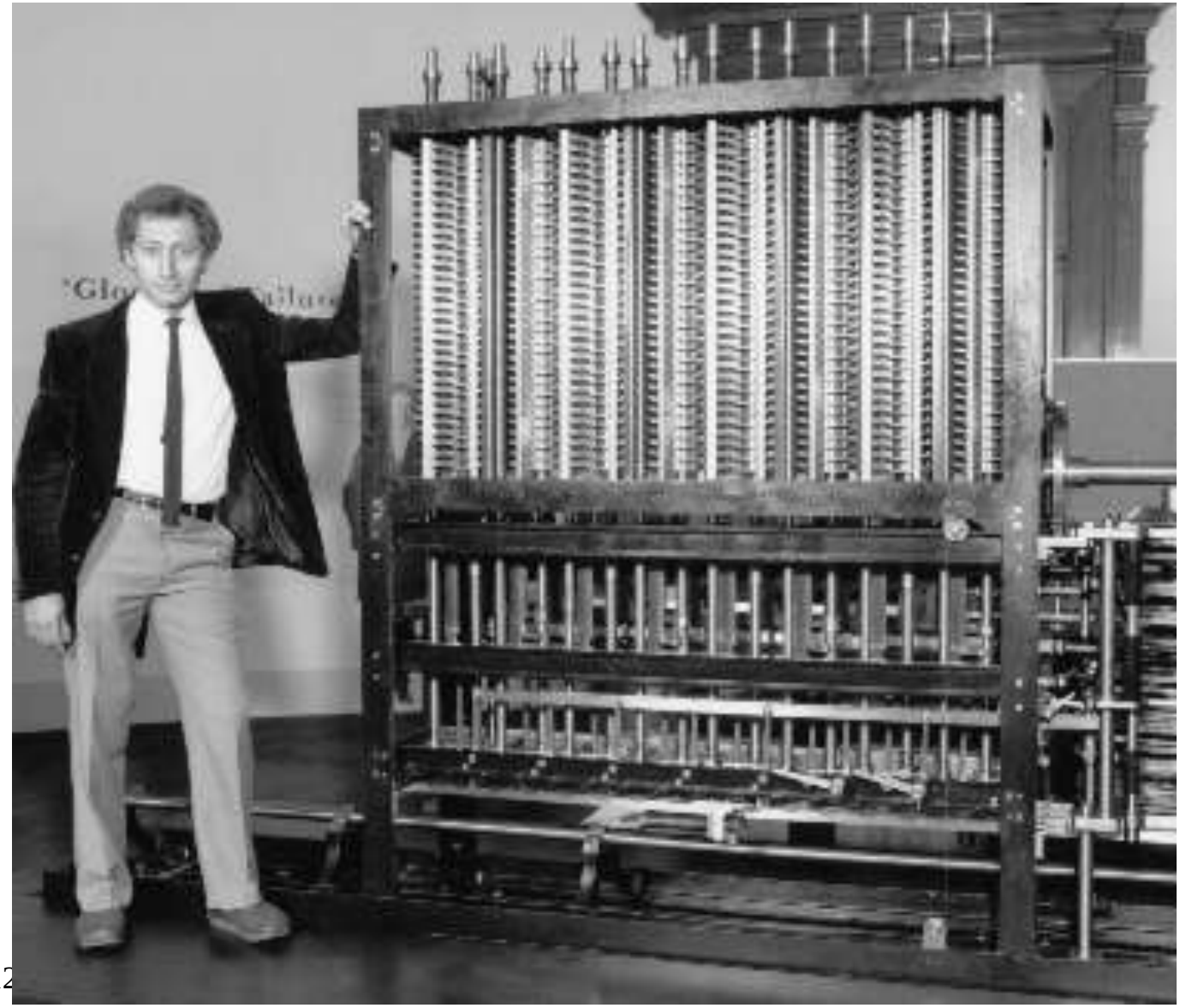
"Babbage's Calculating Engines," *Edinburgh Review,* Dionysius Lardner, 1834

...it has nevertheless been demonstrated, to the satisfaction of many scientific men of the first eminence, that the design in all its details, reduced as it is, to a system of mechanical drawings is complete; and requires only to be constructed in conformity with those plans, to realize all that its inventor has promised.

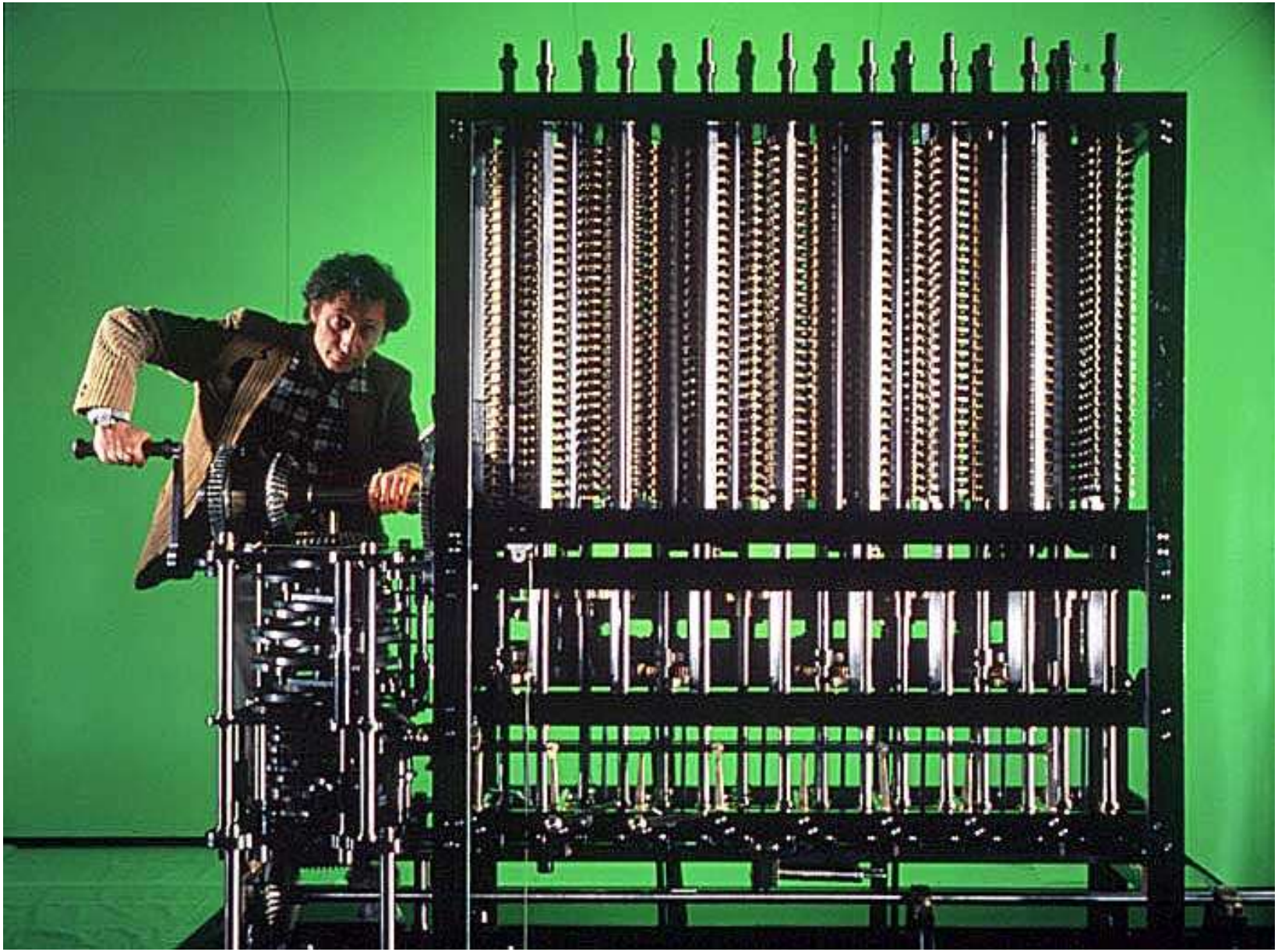
Science Museum's Reconstruction

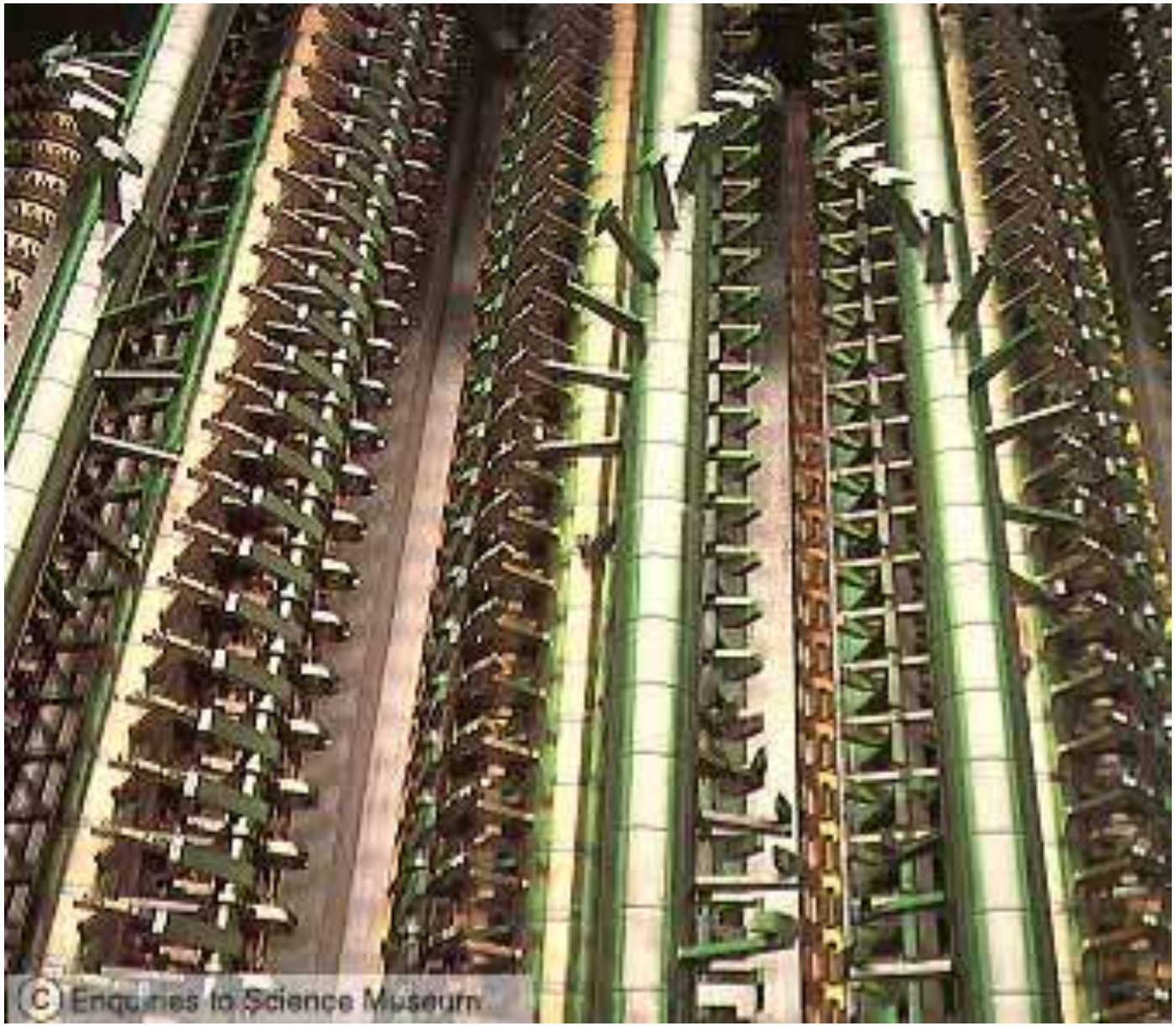
- *Difference Engine Number 2* (1847 to 1849) constructed according to Babbage's original drawings (*minor modifications*)
- 1991 Bicentenary Celebration
- 4,000 parts
- 7 feet high, 11 feet long, 18 inches deep
- 500,000 British Pounds

Science Museum Recreation 1991



Trial Piece




© Enquiries to Science Museum

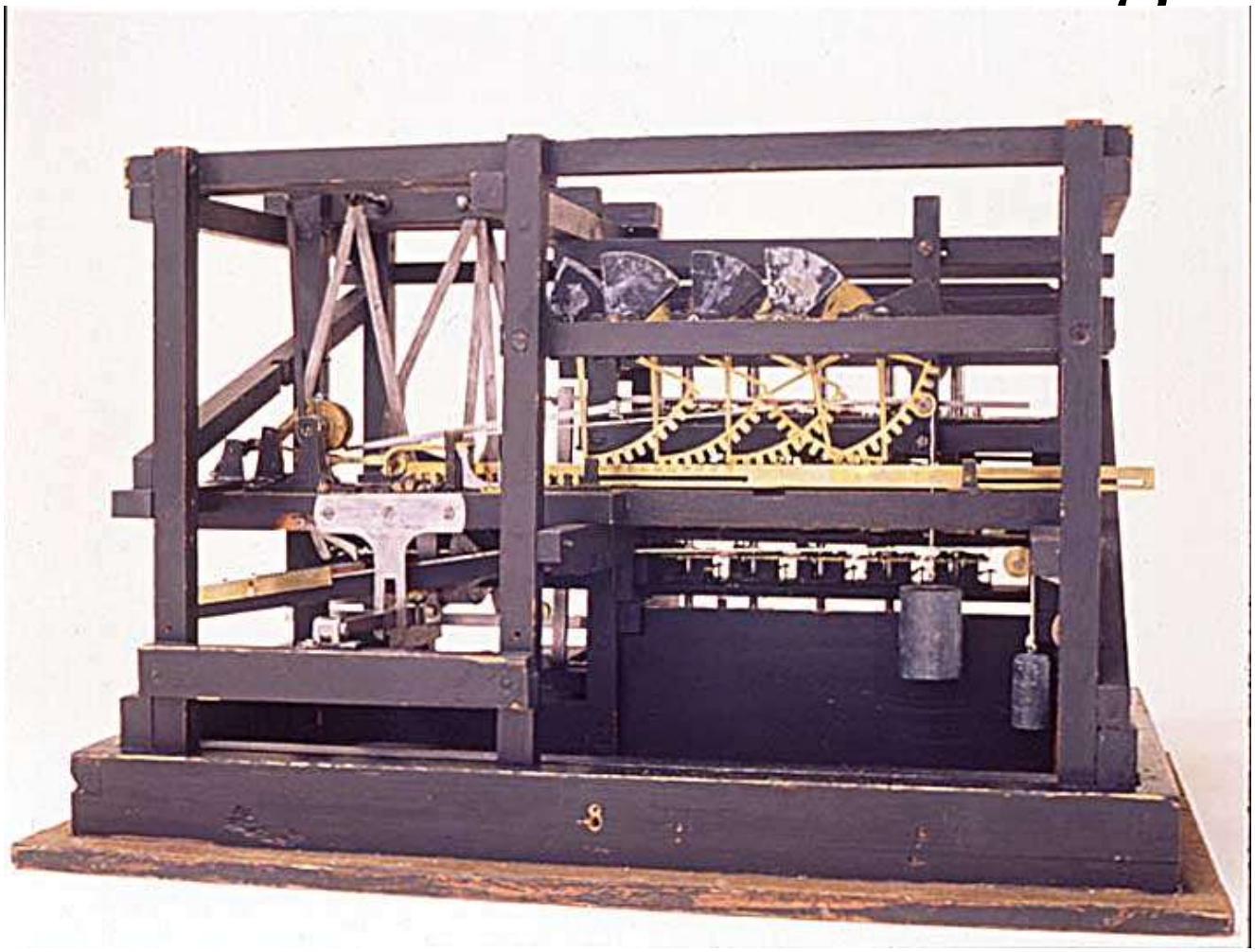
It's all a matter of perspective....

- Johann Meuller, ***Universal Calculator*** 1784
- Georg and Edvard Scheutz (after Lardner)
  - **Difference Engine #1** a prototype which 1843

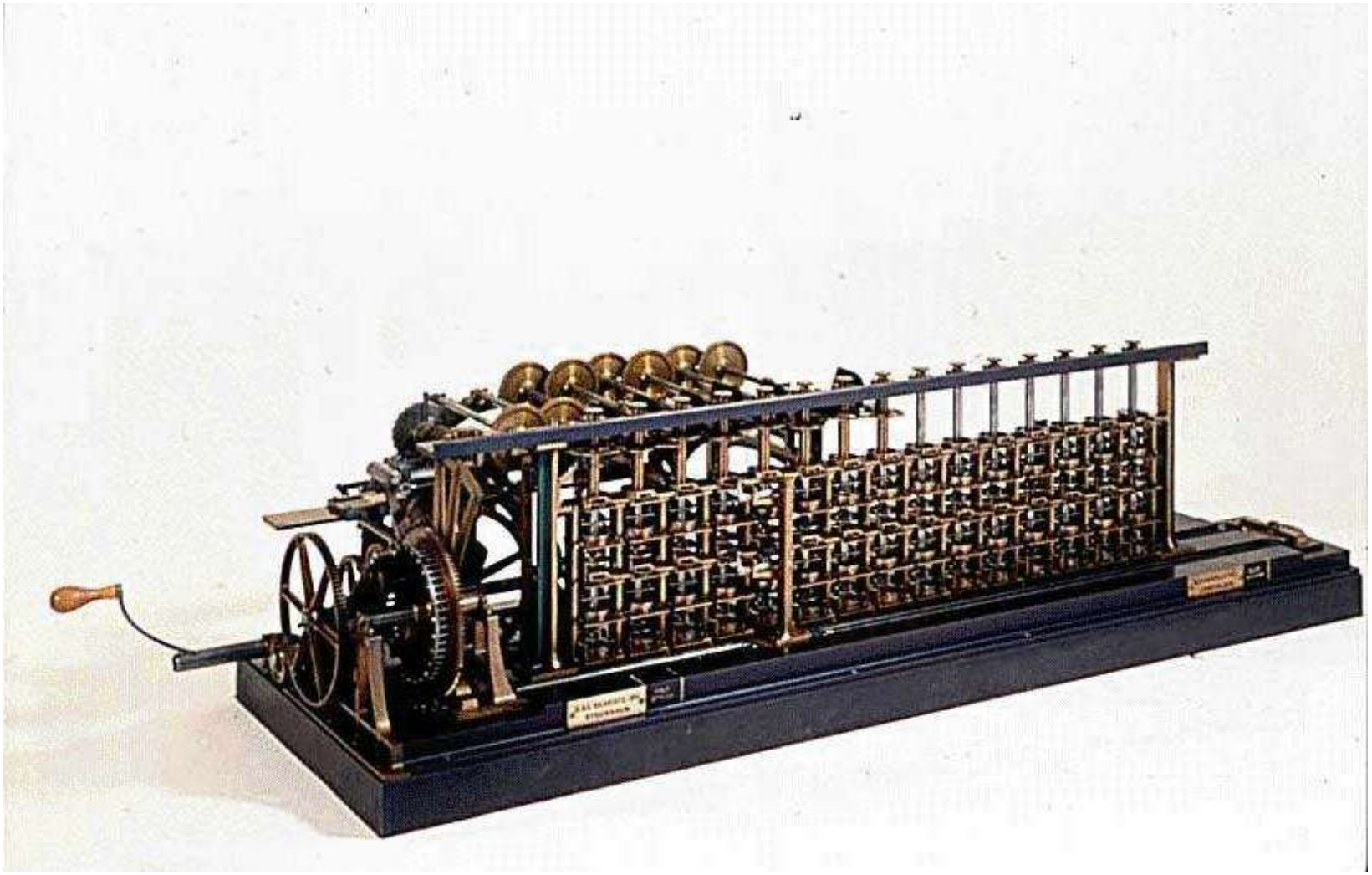
    produced the first tables *calculated and printed by machinery*
  - **Difference Engine #2** sold to Dudley Observatory, Albany, NY (*in Smithsonian's Info. Age*) 1853
  - **Difference Engine #3** was a copy of #2, 1859

    sold to General Register Office in London; used to produce the *English Life Table*, 1864

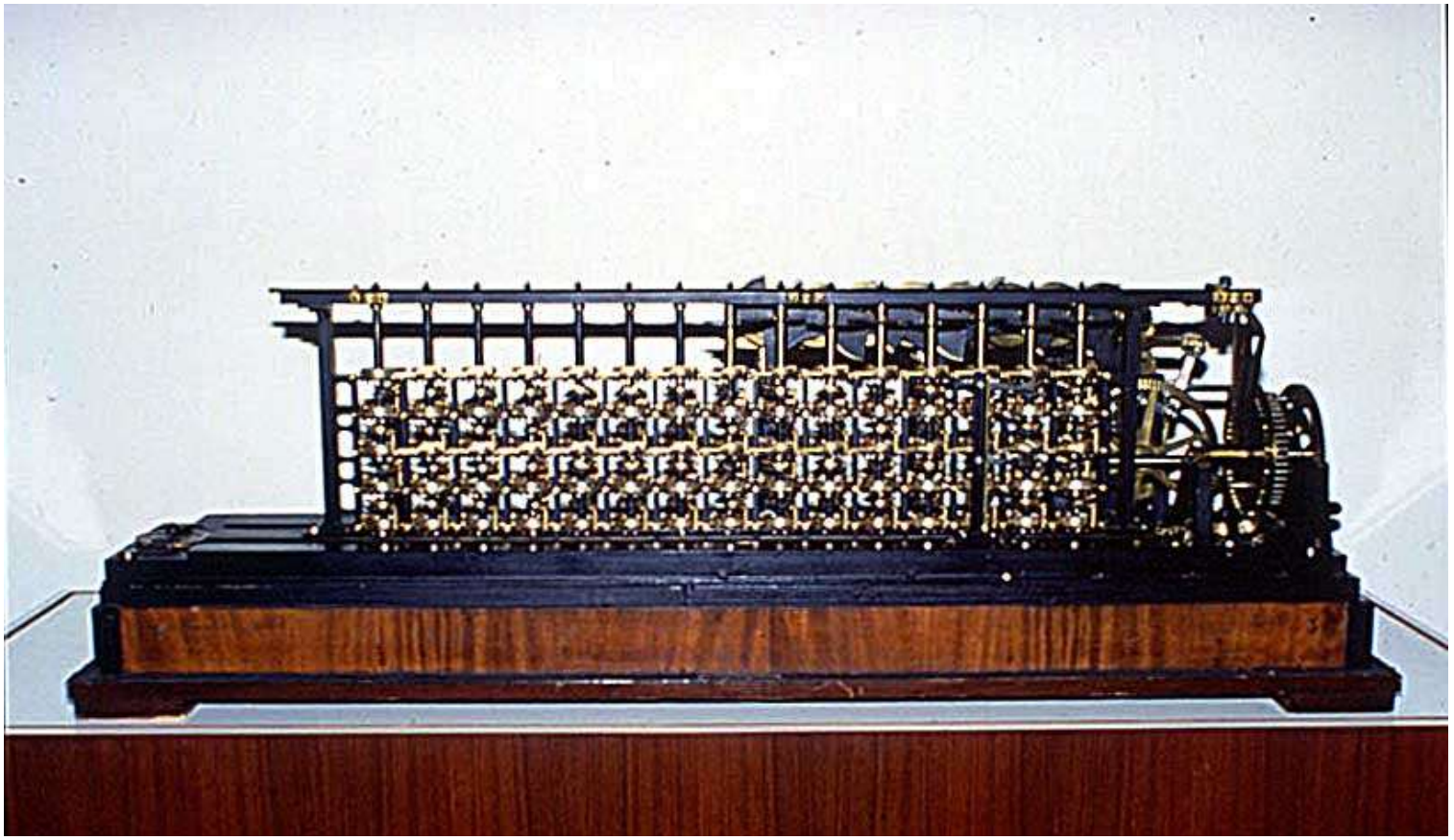
Scheutz: first difference engine



Scheutz: second difference engine



Scheutz: third difference engine



Scheutz Difference Engine

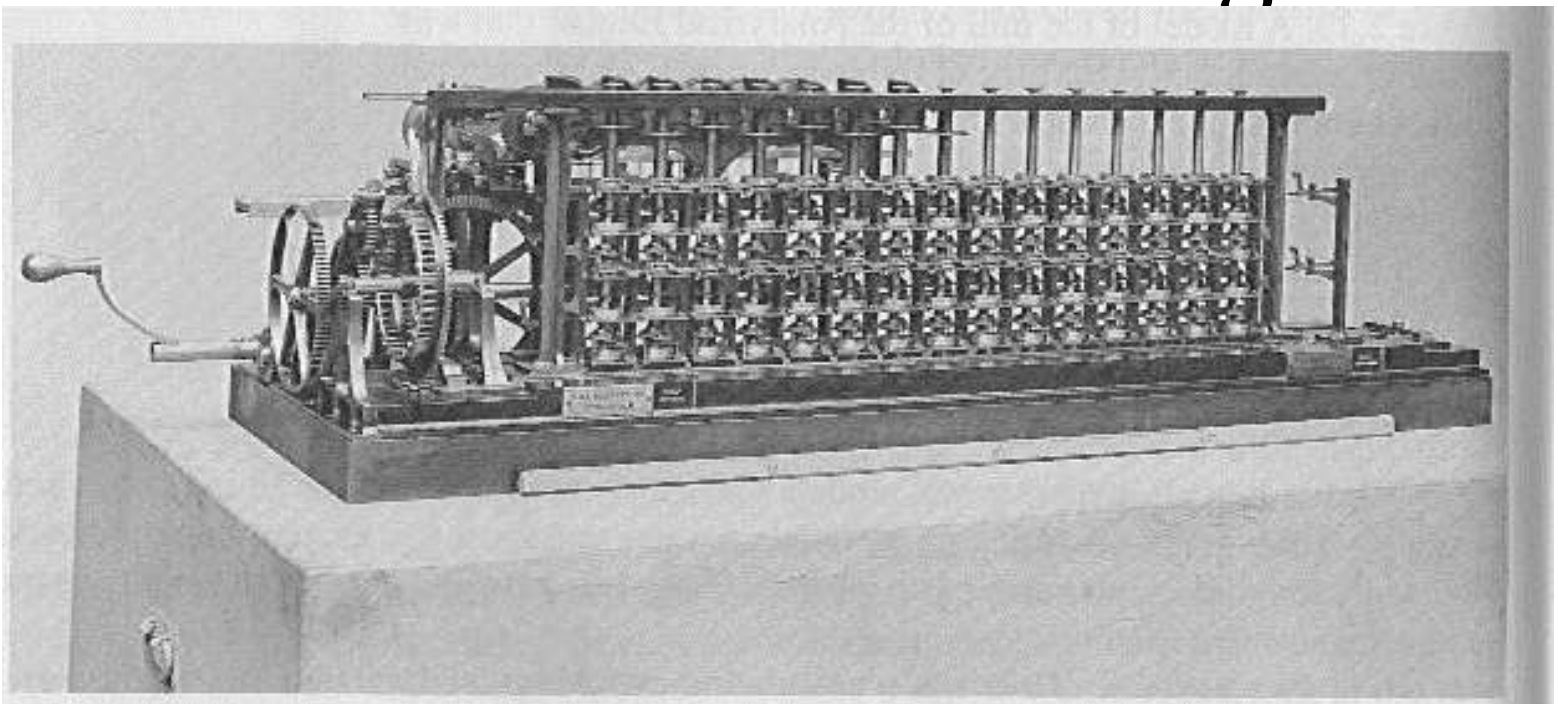
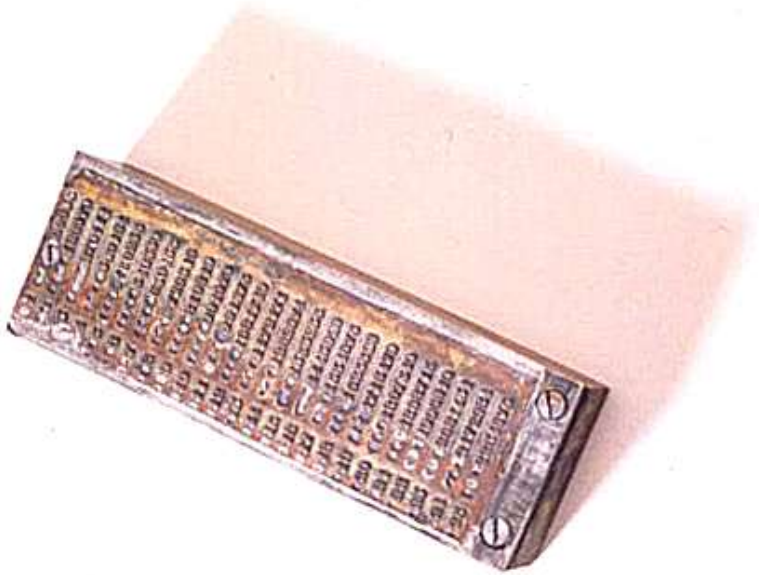


Figure 2.14. The copy of the Scheutz Difference Engine built for the General Register Office, London. The pillar at the right moves across the front of the figure wheels to effect the carriage propagation. The printing mechanism is behind the calculating wheels at the left. Courtesy Science Museum, London.

Scheutz stereotype plate (1849)



The Long and the Short of it!

- Wilberg's Difference Engine c1860
  - same capacity as Scheutz's (four orders of difference and fifteen digits) but about 1/10th the size; used metal disks on a horizontal azis; size: 23 x 42 x 21.5 cm.
- G.B. Grant, Philadelphia Centennial 1876 Exhibition, 5feet high, 8 feet long, weighed 2,000 pounds and contained 15,000 parts.

Sir John Herschel, 1842

- *An undetected error in a logarithmic table is like a sunken rock at sea yet undiscovered, upon which it is impossible to say what wrecks may have taken place.*

Analytical Engine

- 1834 basic plans formulated for an improved device, capable of calculating *any mathematical function!*

- Basic problem: *how to feed the digits of the result wheels back into the calculation.*

- 1834 to 1848 30 sets of plans; seems to have given up on construction due to the problems with the difference engine.

- *...for six months been engaged in making the drawings of a new calculating engine of far greater power than the first. I am myself astonished at the power I have been enabled to give to this machine; a year ago I should not have believed this result possible.*
- Letter to Quetelet, April 27, 1835

Analytical Engine

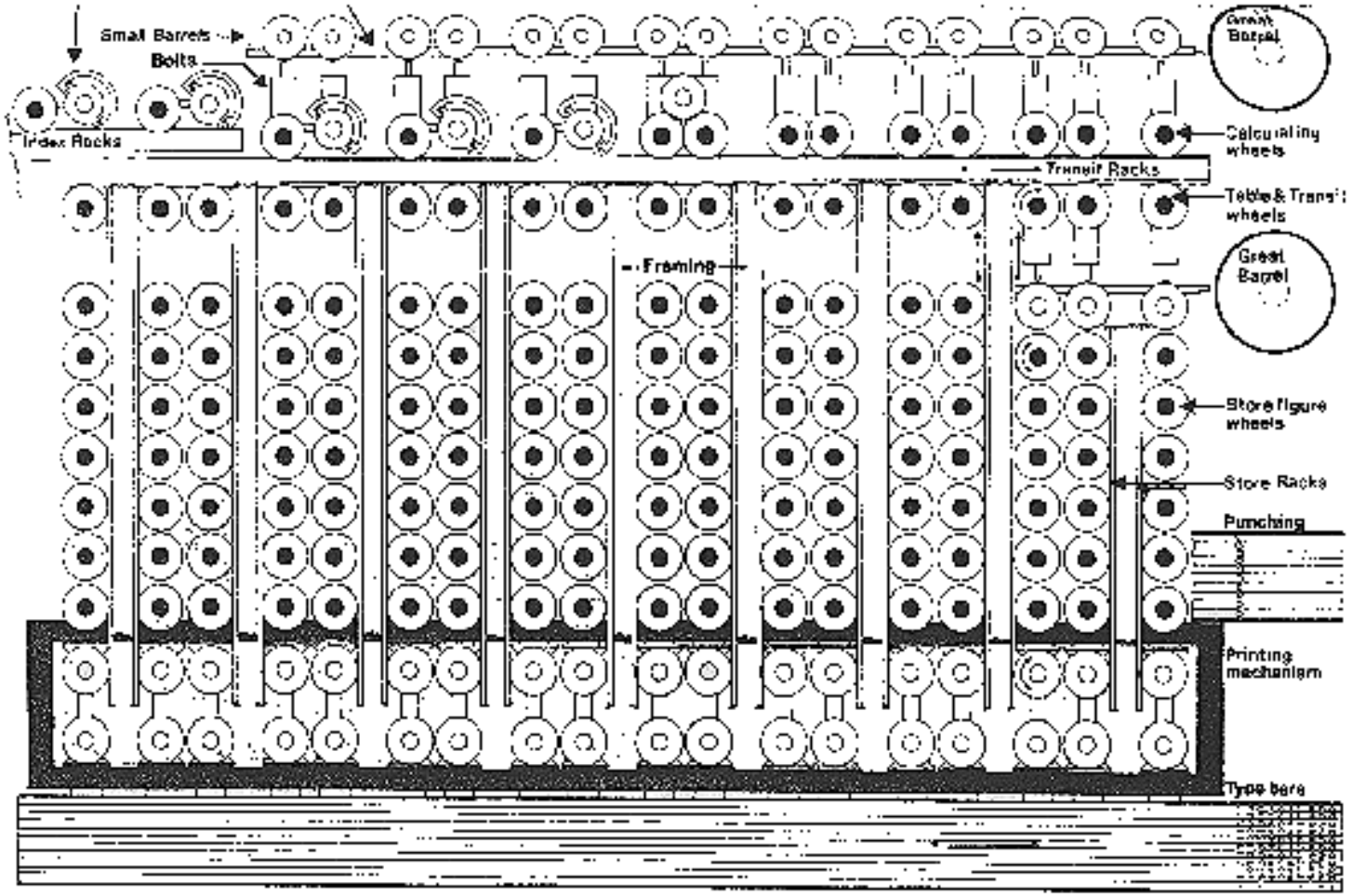


Fig. 2. Plan of Analytical Engine with grid layout, 1858 Redrawn

Architecture

- Separation of storage and calculation:

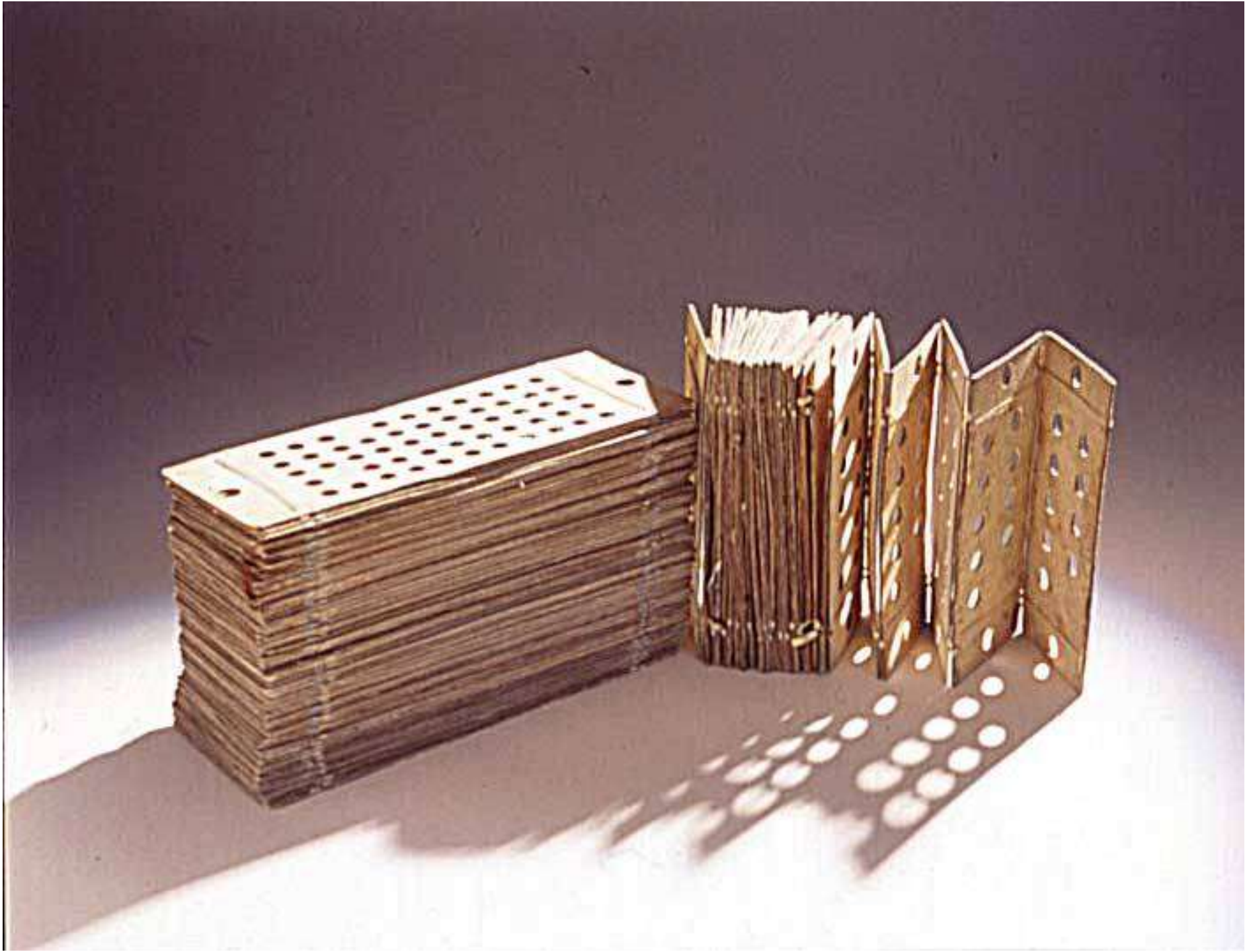
  (V) *store*

  mill: (A) are accumulators

- Control of operations by microprogram:

  (B) *control barrels*

- user program control using punched cards
  - *operations* **cards**
  - *variable* **cards**
  - *number* **cards**



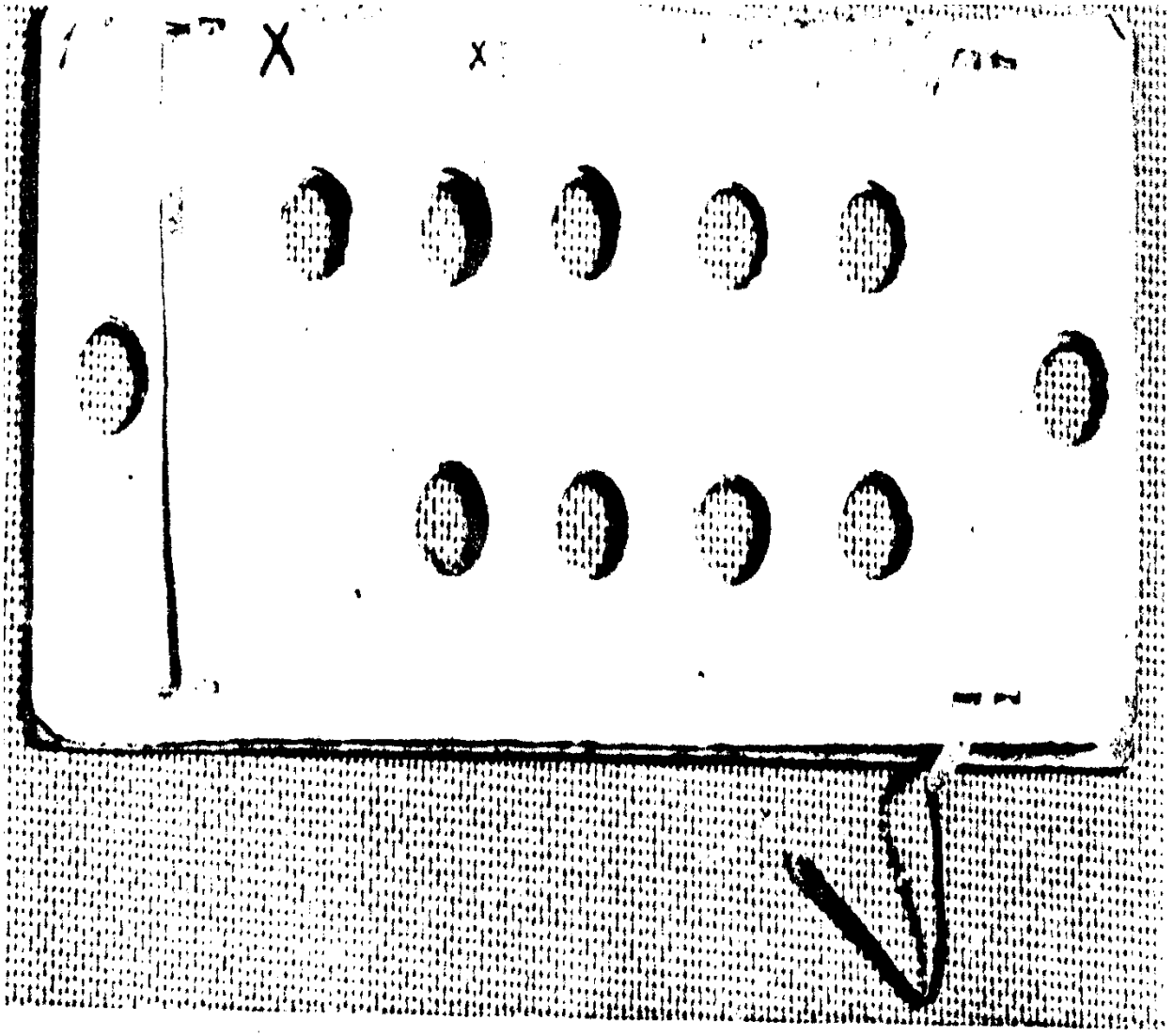


Figure 4–10. One of Babbage's sample punched cards containing the instruction to multiply the contents of the storage location V6 by the contents of storage location V2. (Photograph courtesy of the Science Museum, London.)

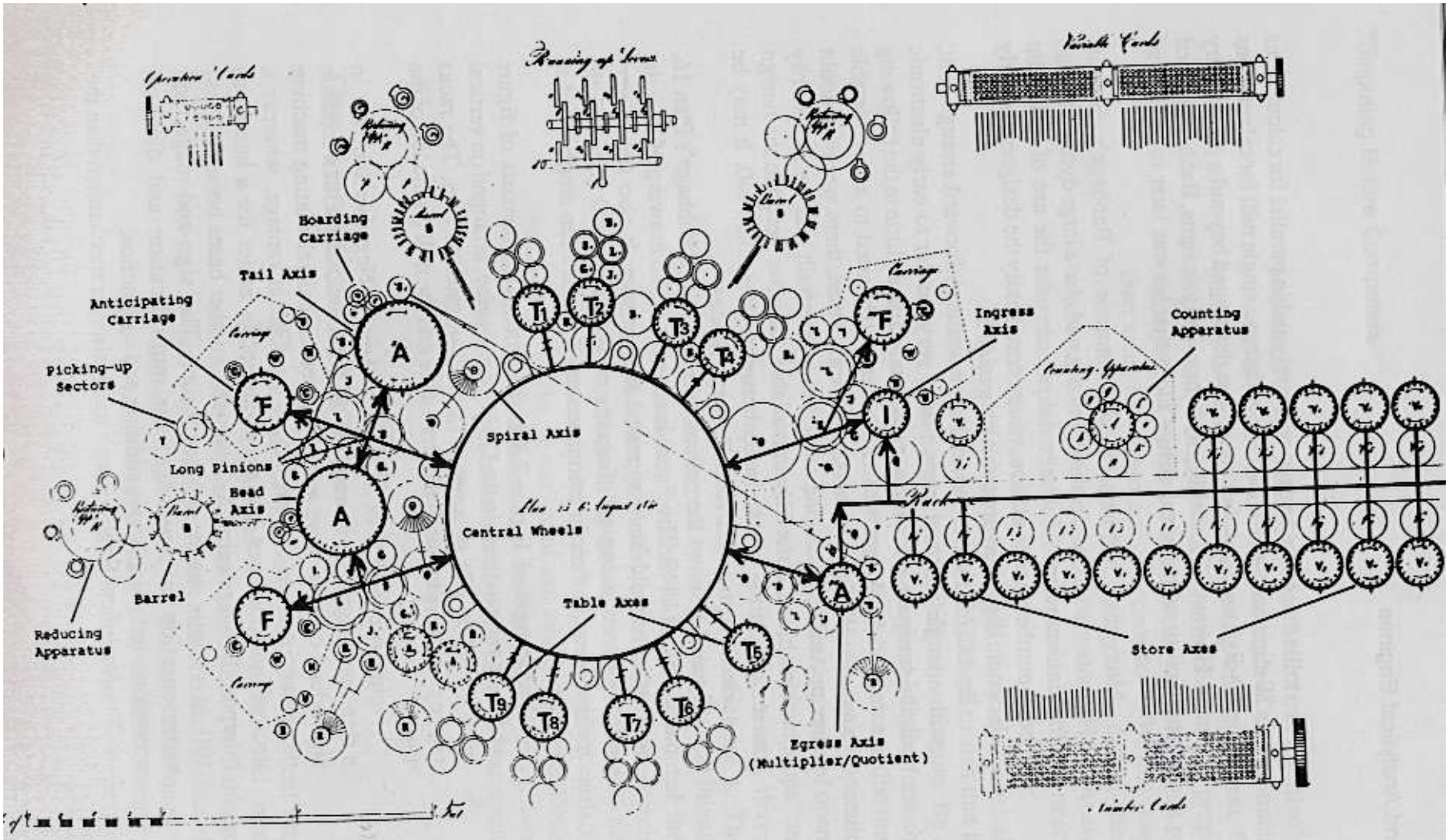


Figure 2.8. Babbage's Plan 16 for the Analytical Engine in August 1840. The original plan drawing of the mechanism has been annotated to show the functional relationships of the principal

- 200+ columns of gear trains and number wheels
- 16 column *register* (store 2 numbers)
- some designs had 50 register columns, with 40 decimal digits of precision
- *counting apparatus* to keep track of repetitions
- cycle time: 2.5 seconds to transfer a number from the store to a *register* in the *mill*
- addition: 3 seconds
- *anticipatory carriage*

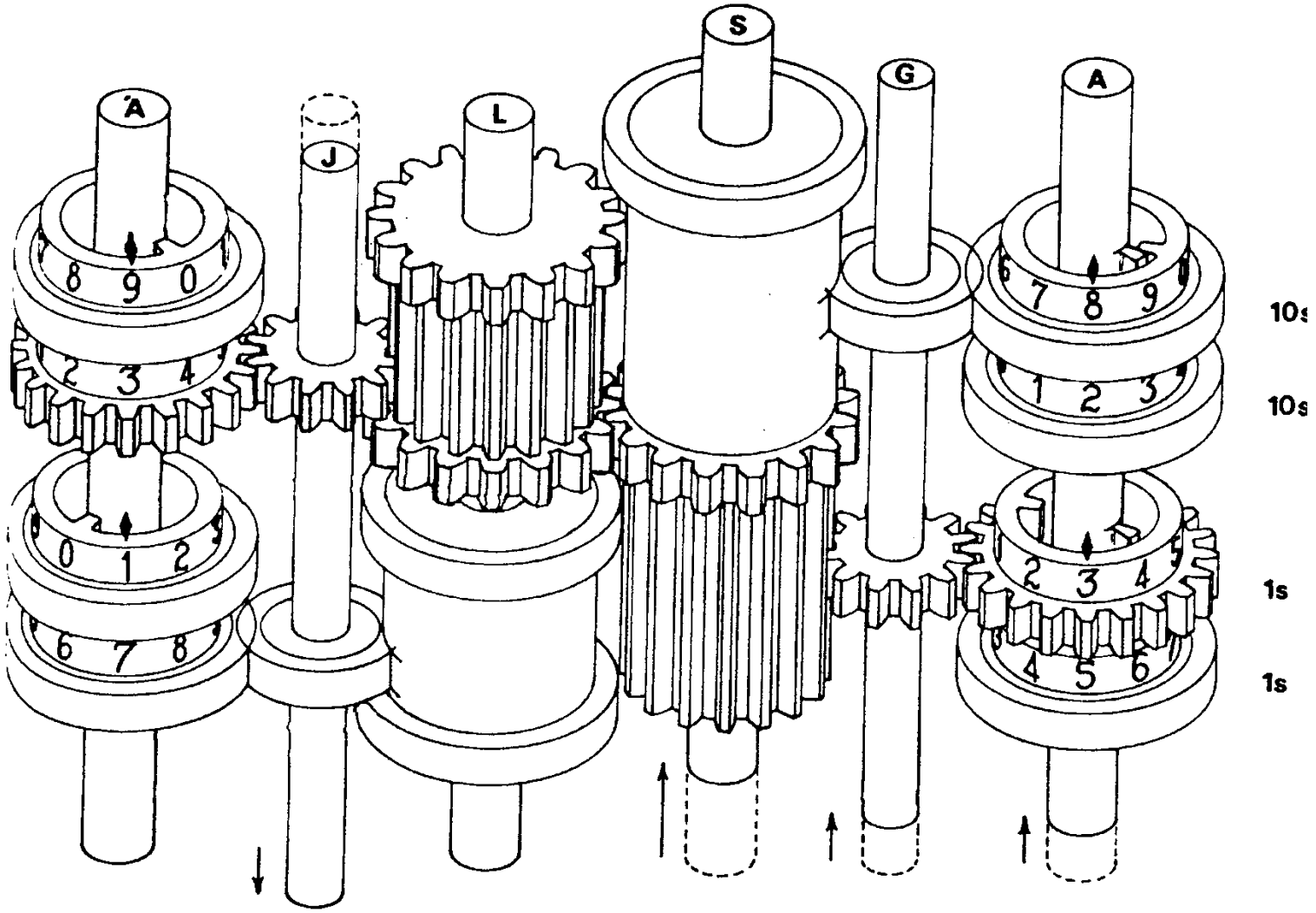


Figure 4. *Process of stepping, or multiplication, and division by 10.* The "*long pinions*" S are raised with their axis to engage the long pinions L in the cage above. A number given off will therefore be stepped up a cage, or multiplied by 10. A transfer in the reverse direction will divide by 10.

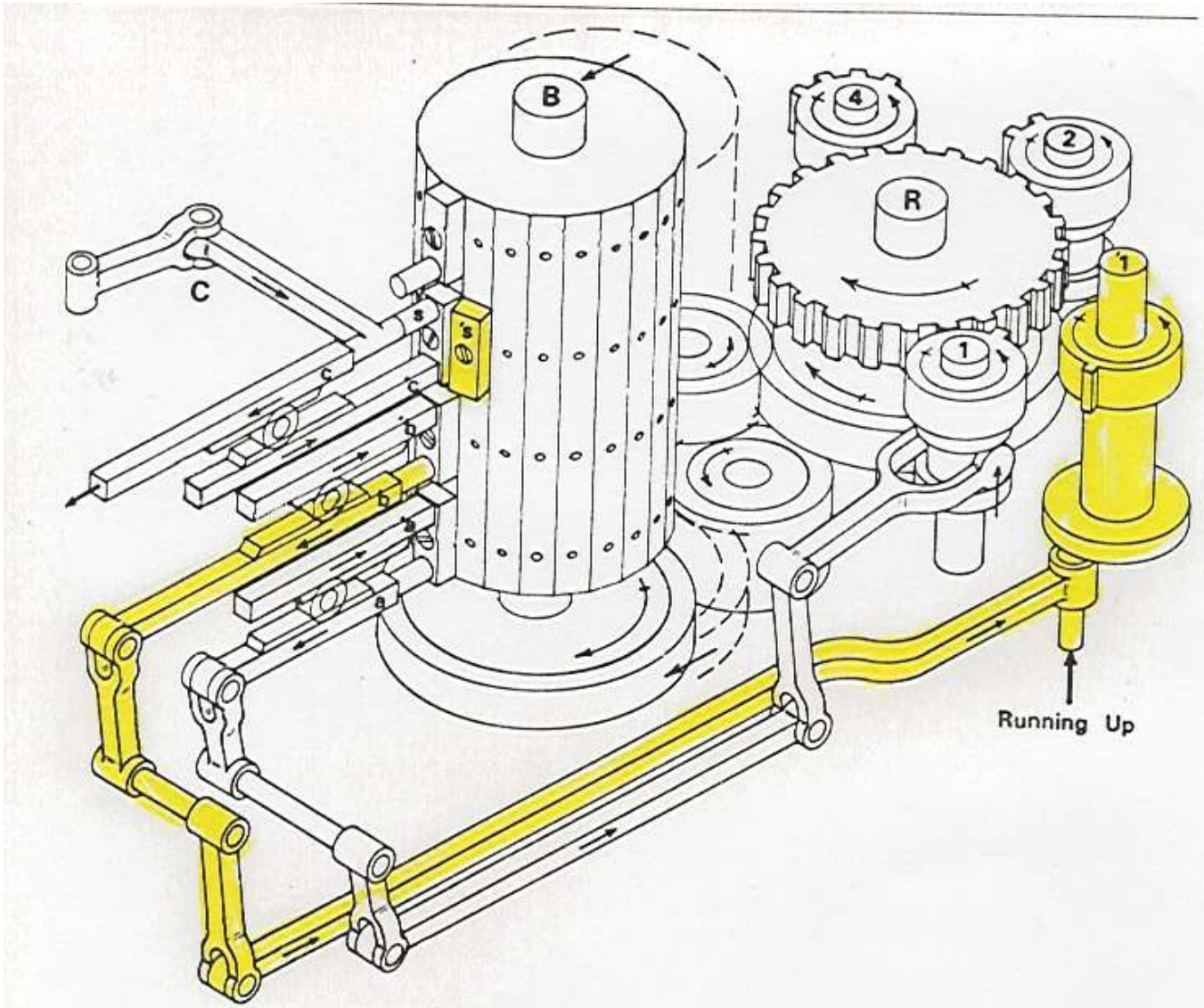
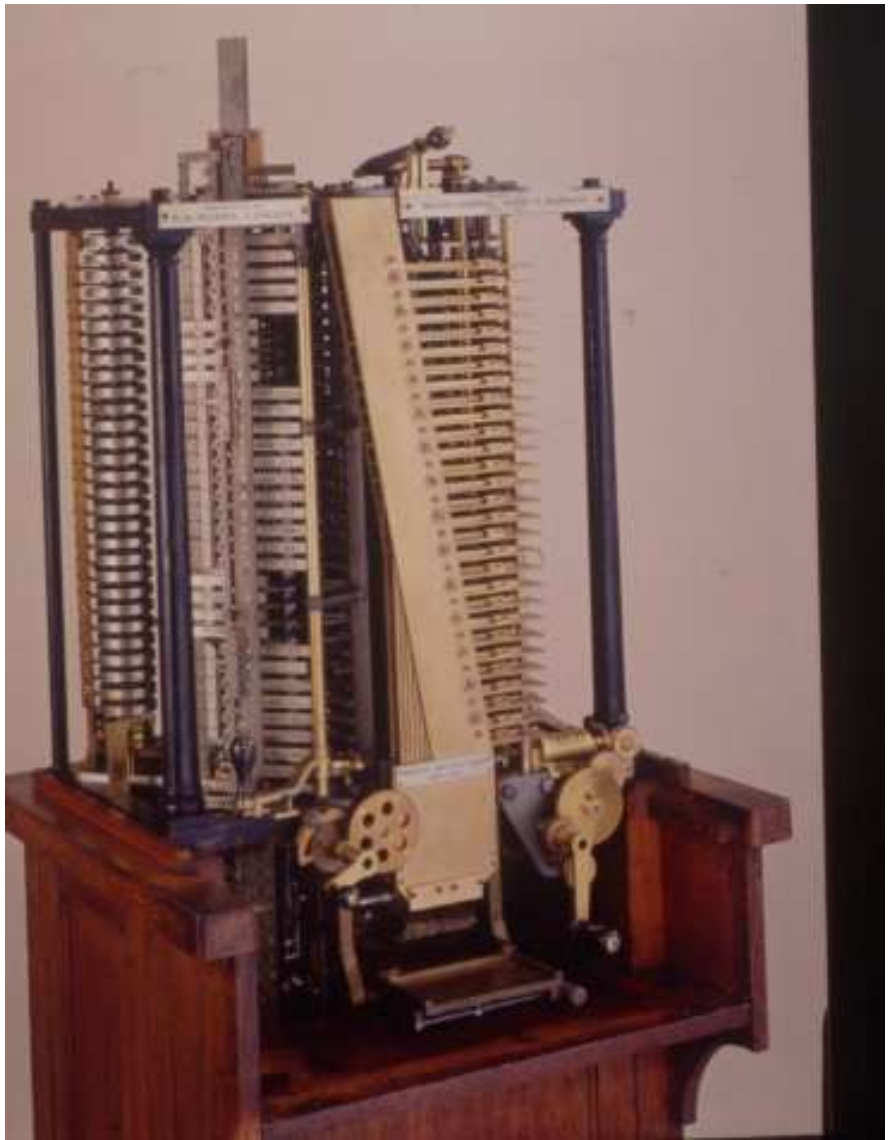


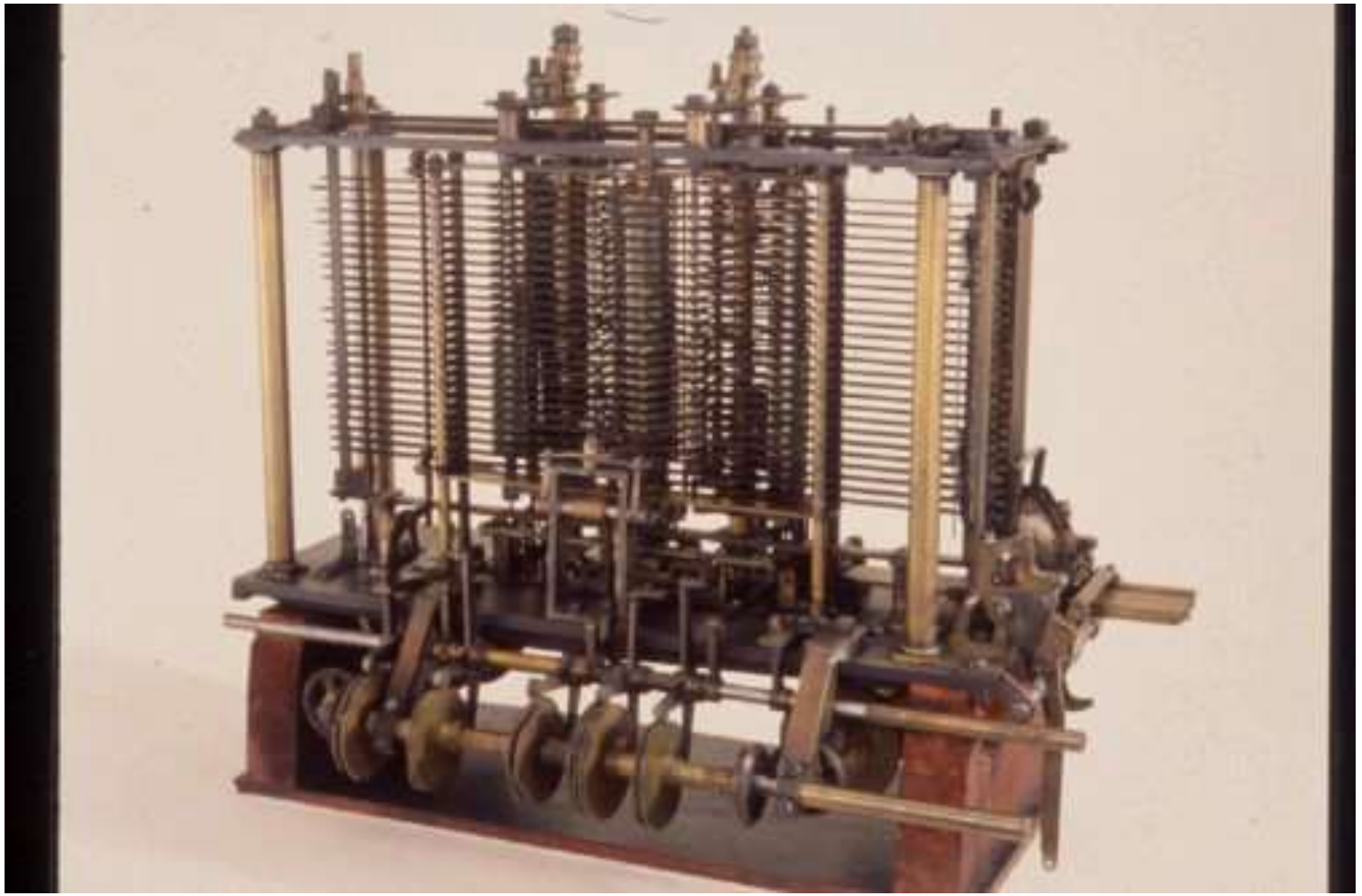
Figure 8. *"Barrel" and its "reducing apparatus."* A microprogram word is represented by a vertical row of studs screwed to the barrel. These act on the ends of the control levers when the barrel moves sideways. The "*reducing sectors*" of one, two, and four teeth advance the barrel over the corresponding number of verticals, and several may act in combination at one time. In the figure, reducing sector 1 is put into gear directly by order of the barrel via control lever a. Reducing sector '1 is put into gear by a "*running up*" from the carry apparatus if enabled to do so by the barrel and lever b. The effect is a conditional transfer. A "*conditional arm*" is sensed by control lever c to provide an action conditional on a previous event.

Portion of the Mill

By Henry Prevost Babbage, 1910



Portion of the Mill with Printing Mechanism
(under construction at Babbage's death)



Babbage's Analytical Engine

- Portion of mill completed 1847
- Portion of printing mechanism
- Returned to work on design 1858
- Substantial trial model being developed: 1871

2 accumulators of 25 digits each; an anticipating carry mechanism; a system of rods for transfer of numbers to the printing mechanism

What in the world...?

- L. F. Menebrea, an (Italian) Office of Military Engineers writes “Sketch of the Analytical Engine invented by Charles Babbage, Esq.,” in *Taylor’s Scientific Memoirs*, Vol.III.
- *...the much-admired machine of Pascal is now simply an object of curiosity, which whilst it displays the powerful intellect of its inventor, is yet of little utility itself.”*

Ada Augusta Byron, 1815-1852

- born on 10 December 1815.
- named after Augusta, Byron's half sister, who had been his mistress.
- After Byron had left for the Continent with a parting shot - 'When shall we three meet again?' - Ada was brought up by her mother.

From *Childe Harold*

by Lord Byron

Is thy face like thy mother's, my fair child!
Ada! sole daughter of my house and of my heart?
When last I saw thy young blue eyes they smiled
And then we parted, not as now we part,
but with a hope.

Ladv Lovelace

Ada Augusta Byron, Countess of Lovelace

- Translated Menebrea's paper into English
- Taylor's: "*The editorial notes are by the translator, the Countess of Lovelace.*"
- Footnotes enhance the text and provide examples of how the Analytical Engine could be used, i.e., how it would be programmed to solve problems!
- Myth: "world's first programmer"

Babbage's Honors

- Lucasian Professor of Mathematics at Cambridge (Newton, Hawking)
- 15 European Scientific Societies
- Order of St. Maurice and St. Lazarus (Italy)

Percy Ludgate (1883-1922)

- Irish accountant who designed an analytical engine around 1908

- *I have myself designed an analytical machine, on different lines from Babbage's, to work with 192 variables of 20 figures each. Complete descriptive drawings of the machine exist, as well as a description in manuscript, but I have note been able to take any steps to have the machine constructed*.

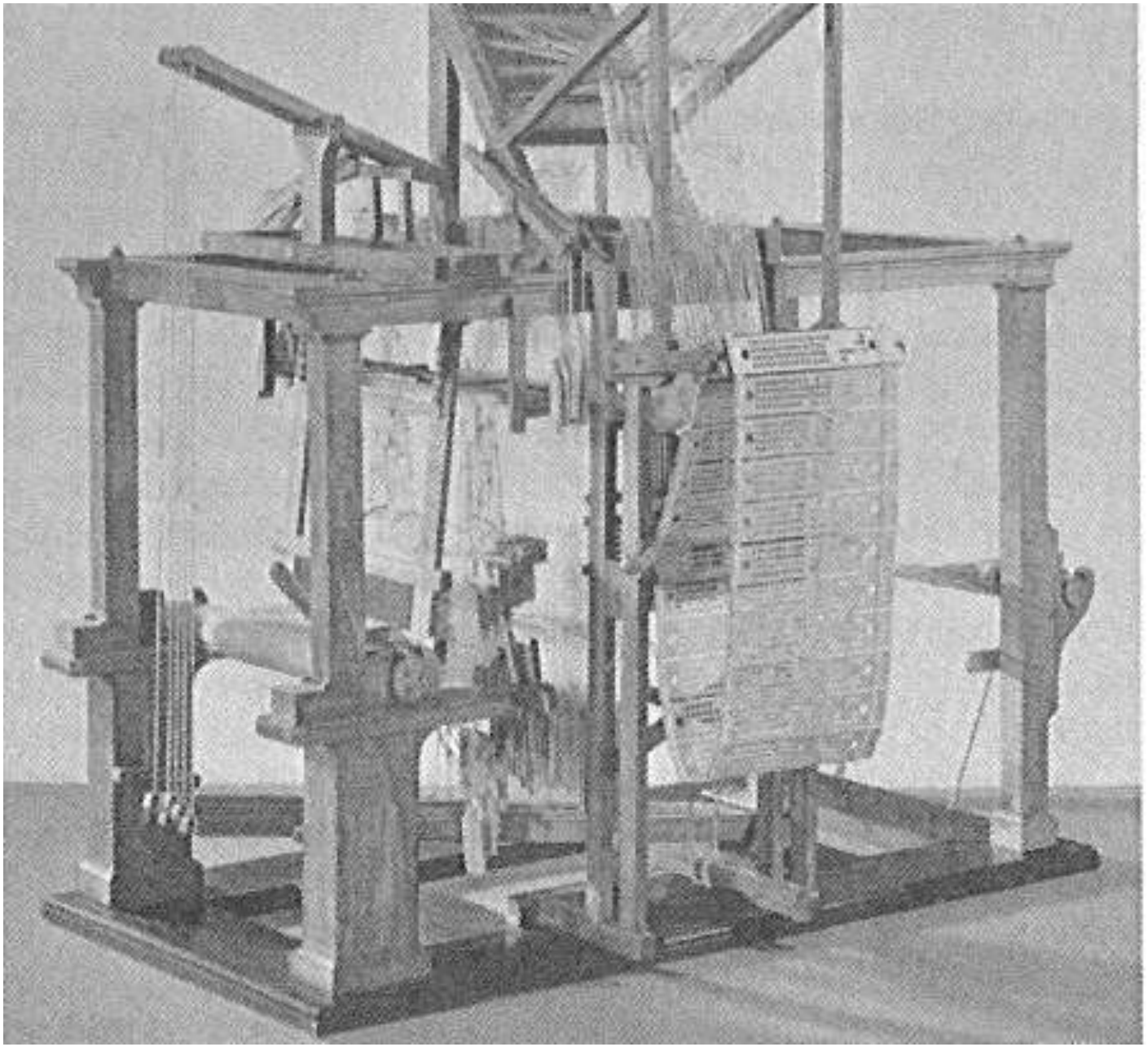
Joseph Marie Jacquard (1752-1834)

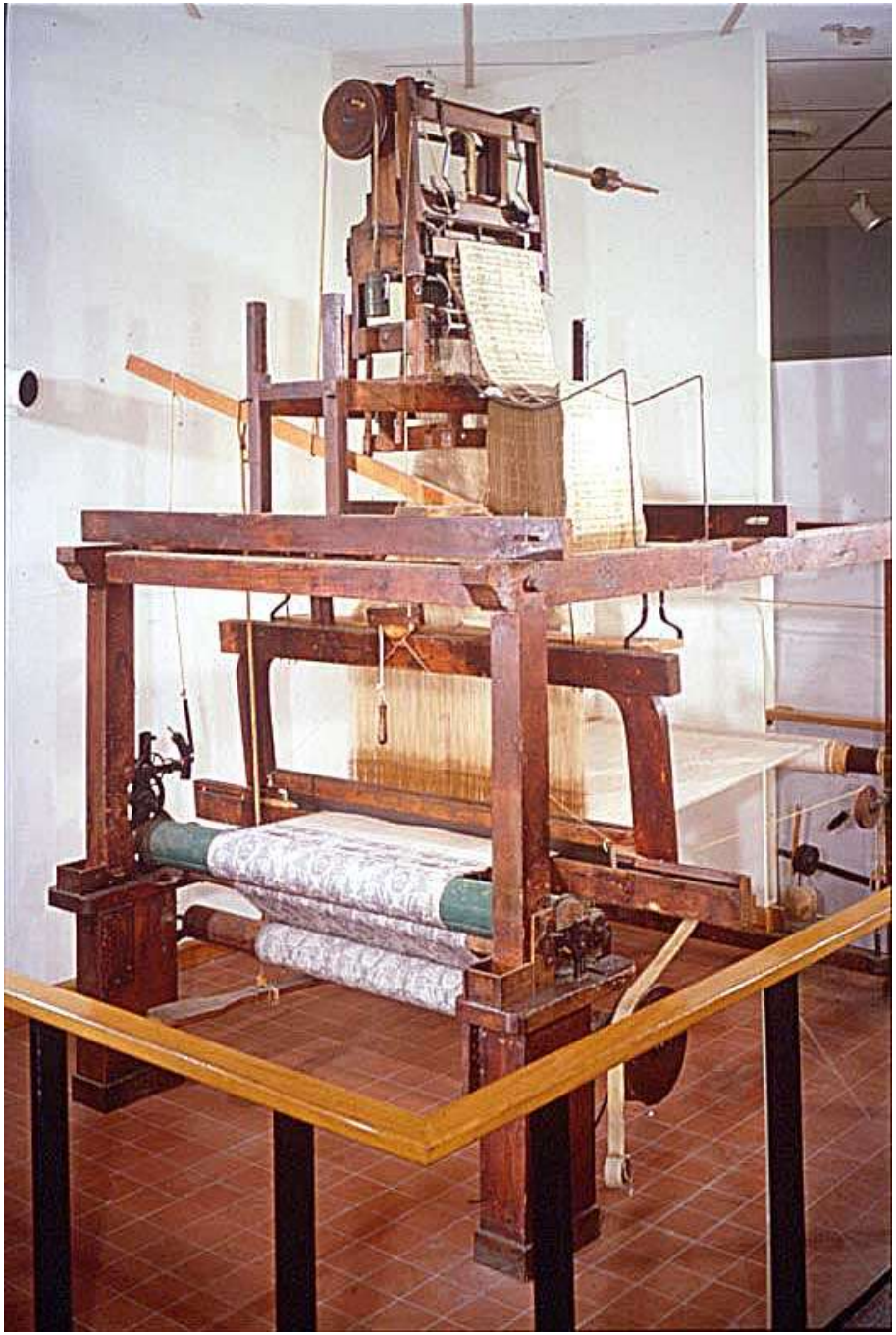
- Born in Lyons, France
- Son of silk weavers
- Father died and he inherited a small house and a hand loom, which he started improving. 1772
- Existing technology:
  - M. Bouchon (1725) pierced paper
  - M. Falcon (1728) chain of cards
  - Jacques deVancason (1754) automaton

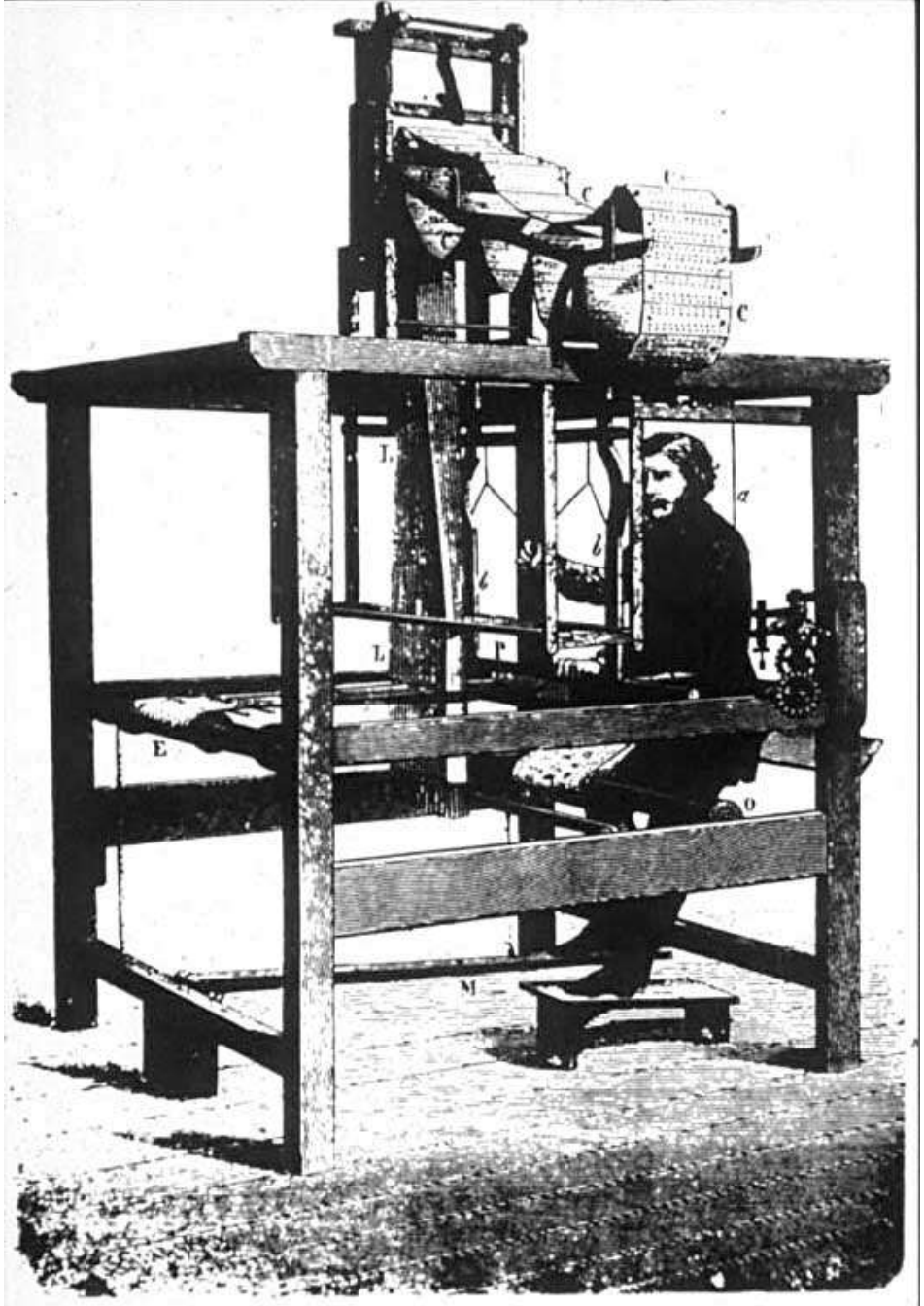
Another revolution....

- Finished his “machine” 1804
- *Invention?* First person to obtain a *practical arrangement* which could be generally adapted to a wide range of problems
- Consiel de Prudhomes broke up his machines 1810
- sabotage: 1. malicious injury to work, tools, machinery, etc. *(sabot, Fr. wooden shoe)*
- died, August 7, 1834 in Quillons at age 82
- 30,000 machines in use in Lyons alone!


A LA MÉMOIRE DE J. M. JACQUARD.
DIDIER PETIT ET Cie LYON M DCCC XXXII

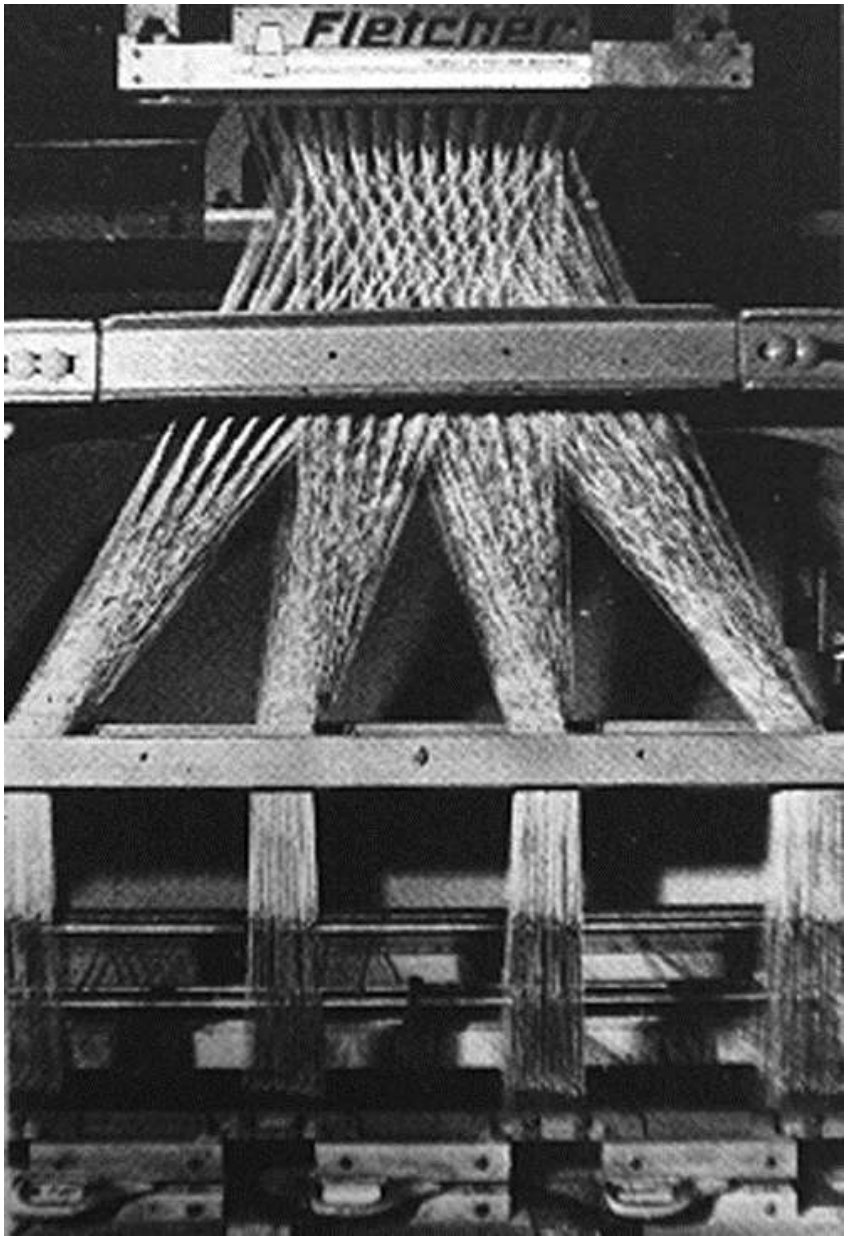






JACQUARD LOOM CARDS

Modern Jacquard Loom



[Jacquard-card Making.]

Sources

- Overhead slides from Alan Bromley's papers:
  - "Charles Babbage's Analytical Engine, 1838," *Annals*, Vol.4, No.3 (1982)
  - "The Evolution of Babbage's Calculating Machines," *Annals*, Vol.9,No.2 (1987)
  - "Babbage's Analytical Engine Plans 28 and 29a--The Programmer's Interface," *Annals*, Vol.22,No.4 (2000) (part of a special issue dedicated to Allan Bromley, which also contains a Eulogy to Babbage from the Smithsonian's Report of 1873)
- 35mm slides courtesy of Science Museum, London

References

- Doron Swade, *Charles Babbage and his Calculating Engines*, Science Museum, London, 1991
- Doron Swade, *The Cogwheel Brain, Charles Babbage and the Quest to build the First Computer*, Little, Brown and Company, 2000
- J.A.N.Lee, *Computer Pioneers*, IEEE Press, 1995
- Brian Randell, ed., *The Origins of Digital Computers*, Selected Papers, Springer, 1973
- Bunch & Hellemans, *The Timetables of Technology*, Simon and Schuster, 1993

- Michael Lindgren, *Glory and Failure, The Difference Engines of Johann Mueller, Charles Babbage, and Georg and Edvard Scheutz*, MIT Press, 1990
- William Aspray, ed., *Computing Before Computers*, Iowa State University Press, 1990
- Aspray and Campbell-Kelly, *Computer: A History of the Information Machine*, BasicBooks, 1996
- Video: The Machine That Changed the World, first 10 minutes

Biographies

- Anthony Hyman, *Charles Babbage: pioneer of the computer*, Princeton U Press, 1982
- Maboth Mosley, *Irascible genius: a life of Charles Babbage, inventor*, London, Hutchinson, 1964
- Dorothy Stein, *Ada: a life and legacy*, MIT Press, 1985
- Doris Langley Moore, *Ada, Countess of Lovelace: Byron's legitimate daughter*, London, John Murray, 1977

Show and Tell

- Jacquard loom and cards
- Skeleton Key
- Books of Tables
- Stereotype
- *Difference Engine figure wheel and carry mechanism*
- Music boxes: barrel "*memory*"
- Babbage Eulogy from *Smithsonian Annual Report for 1871*