CMPU 101 § 04/05 · Problem-Solving and Abstraction

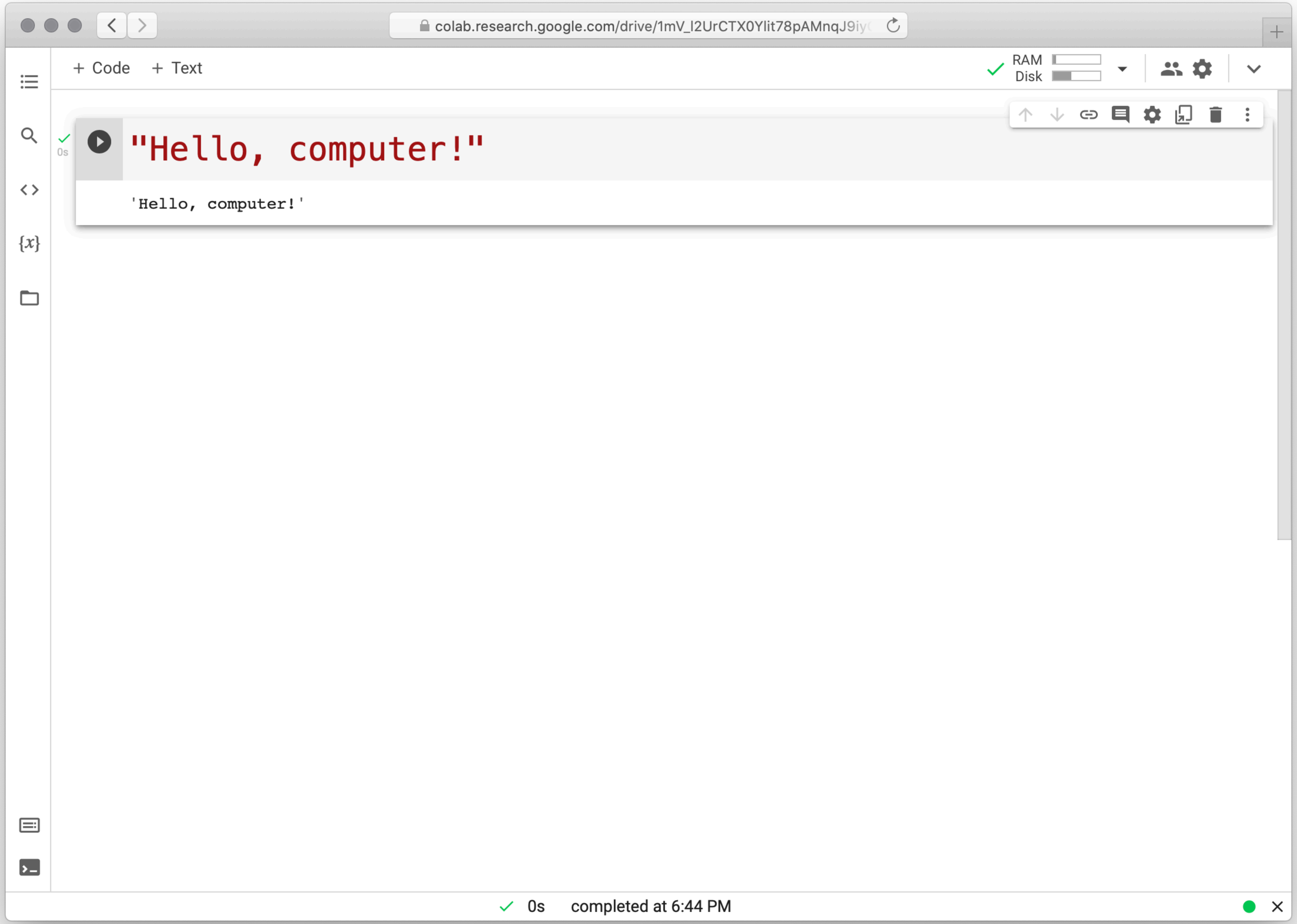
# Computer Science I

6 December 2021

# Computational thinking

# What have we been doing this semester?


code.pyret.org/editor
View
Connect to Google Drive
Run
Stop
1 use context essentials2021
2
3 "Hello, computer!"
"Hello, computer!"
›››
Programming as a guest.


colab.research.google.com/drive/1mV_I2UrCTX0Ylit78pAMnqJ9iy
+ Code
+ Text
RAM
Disk
"Hello, computer!"
'Hello, computer!'
0s
completed at 6:44 PM

We're not *especially* interested in Pyret or Python.

If you're programming 20 years from now, it will be in a different language, using different tools.

What have we been *doing* in these languages?

We've been practicing *computational thinking*.

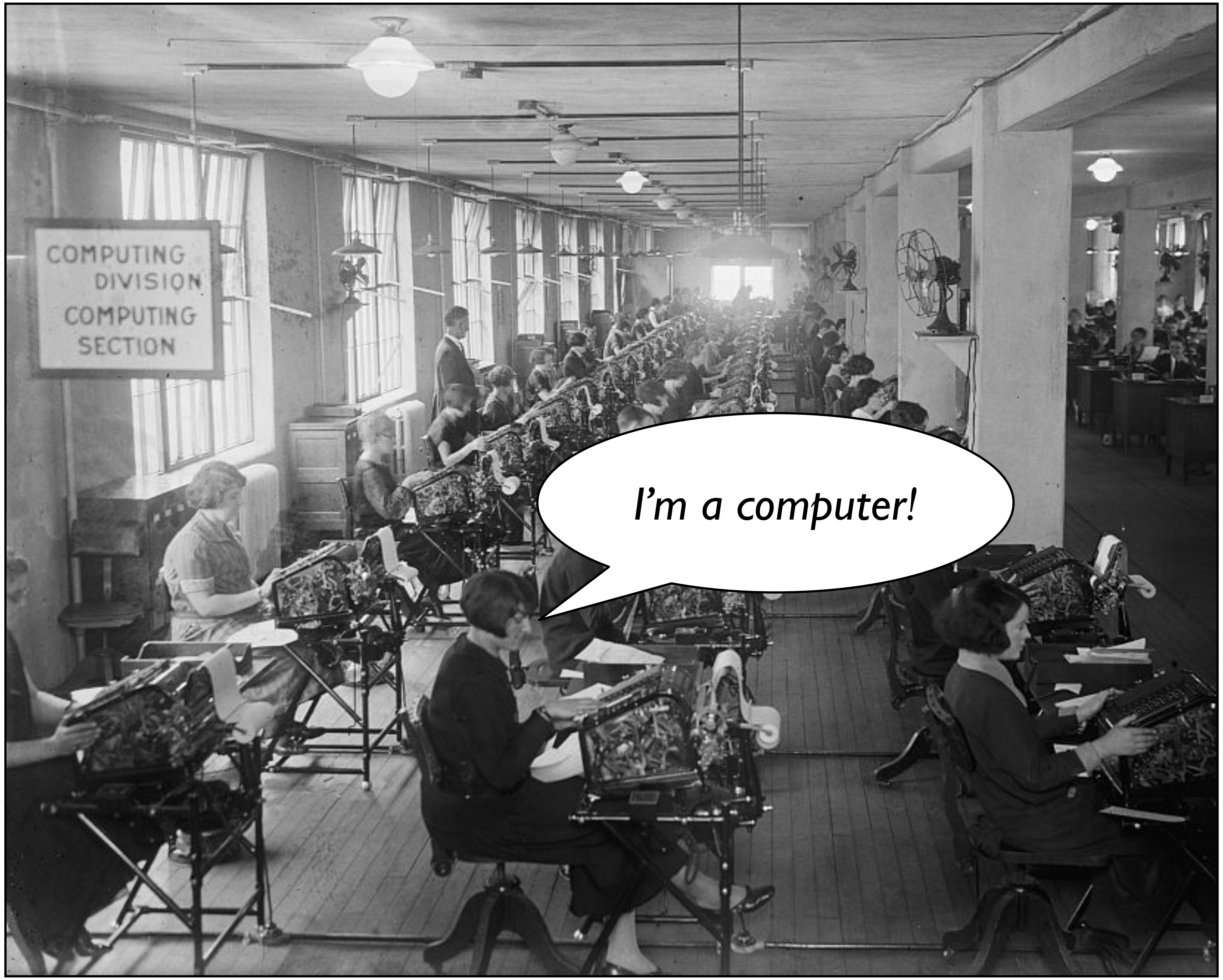
“Modern computer science is the last 1 percent of the historical timeline of computational thinking. Computer scientists inherited and then perfected computational thinking from a long line of mathematicians, natural philosophers, scientists, and engineers all interested in performing large calculations and complex inferences without error.”

Peter J. Denning & Matti Tedre, *Computational Thinking*

# Origins of computational thinking

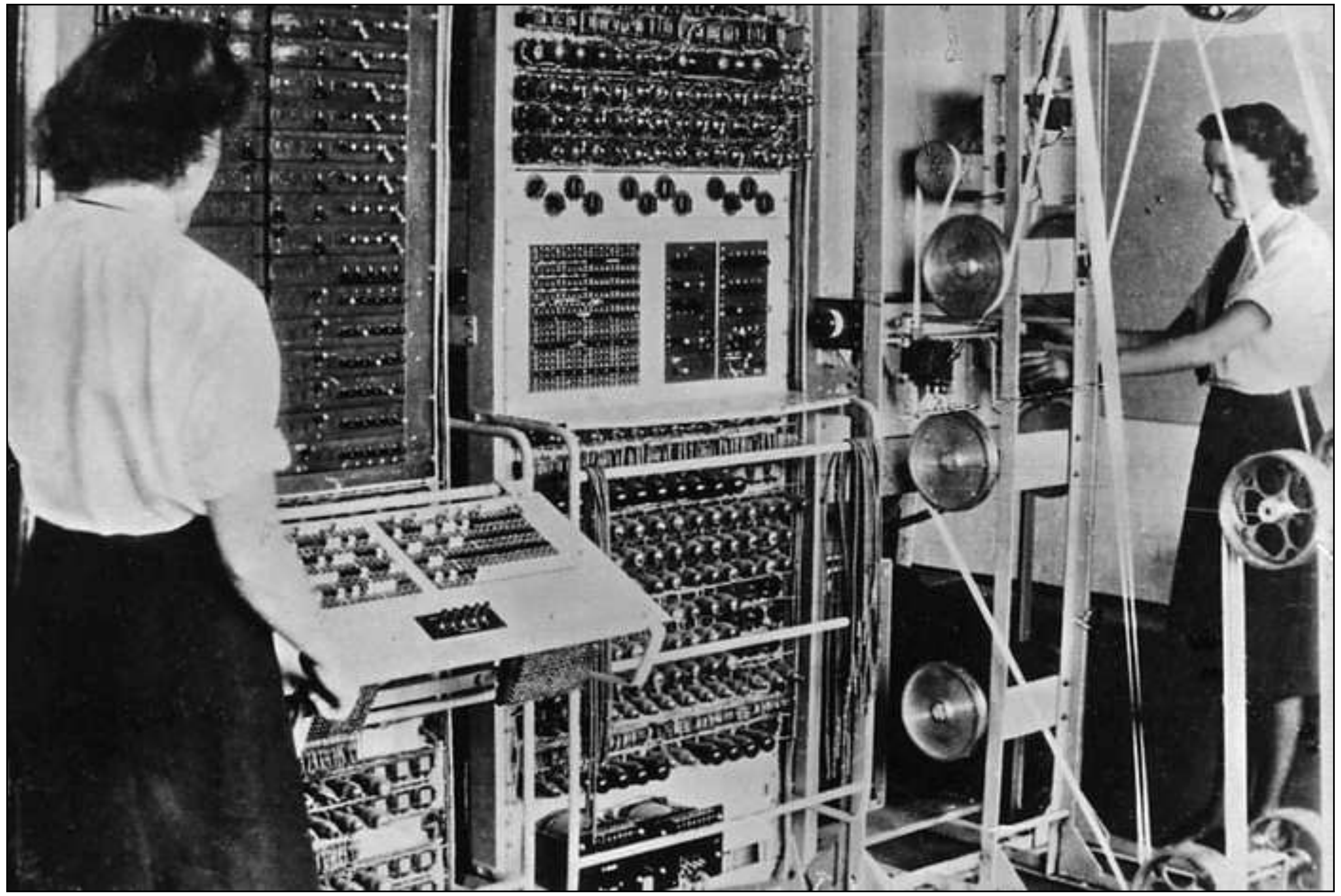
Before the modern computer age, there was a profession of mathematically trained experts who performed complex calculations as teams.

They were called “computers”.




*Bonus Bureau, Computing Division, 1924,* loc.gov/pictures/item/2016838906

The first *electronic* computing machines were called "automatic computers" to distinguish them from the human variety.



*Colossus Mark 2, 1944*

Human computers and the leaders of human computing teams engaged in computational thinking long before the invention of electronic computers.

Early computational thinking can be seen going back to the records of the Babylonians, who wrote down general procedures for solving mathematical procedures around starting around 1800 BCE.

Long before this class, you probably learned these kind of computational methods.

# Euclid’s algorithm

One of the earliest methods, still taught to schoolchildren today, is from the Greek mathematician Euclid, around 300 BCE.

He gave a method to find the ***greatest common divisor*** (GCD) of two numbers, which is the largest integer that divides both numbers.

# Euclid’s algorithm

Euclid noticed that the GCD of two numbers divides their difference.

So, he repeatedly replaced the larger number with their difference until both were the same.

*Sounds a lot like writing a recursive function!*

# Euclid’s algorithm

Euclid noticed that the GCD of two numbers divides their difference.

So, he repeatedly replaced the larger number with their difference until both were the same.

```
  gcd(48, 18)
→ gcd(30, 18)
→ gcd(12, 18)
→ gcd(12,  6)
→ gcd( 6,  6)
→ 6
```

# Sieve of Eratosthenes

This is another famous method dating back to the ancient Greeks, used to find all the prime numbers up to some limit.

# Sieve of Eratosthenes

`2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18`

We begin with a list of all the integers, from 2 to the limit.

# Sieve of Eratosthenes

**2** 3 ~~4~~ 5 ~~6~~ 7 ~~8~~ 9 ~~10~~ 11 ~~12~~ 13 ~~14~~ 15 ~~16~~ 17 ~~18~~

We cross out all the multiples of 2.

# Sieve of Eratosthenes

2 **3** ~~4~~ 5 ~~6~~ 7 ~~8~~ ~~9~~ ~~10~~ 11 ~~12~~ 13 ~~14~~ ~~15~~ ~~16~~ 17 ~~18~~

Then all the multiples of 3.

# Sieve of Eratosthenes

2 3 ~~4~~ **5** ~~6~~ 7 ~~8~~ ~~9~~ ~~10~~ 11 ~~12~~ 13 ~~14~~ ~~15~~ ~~16~~ 17 ~~18~~

Then all the multiples of 5.

# Sieve of Eratosthenes

2 3 ~~4~~ 5 ~~6~~ 7 ~~8~~ ~~9~~ ~~10~~ 11 ~~12~~ 13 ~~14~~ ~~15~~ ~~16~~ 17 ~~18~~

And so on, leaving you with only the primes between 2 and the limit you chose.

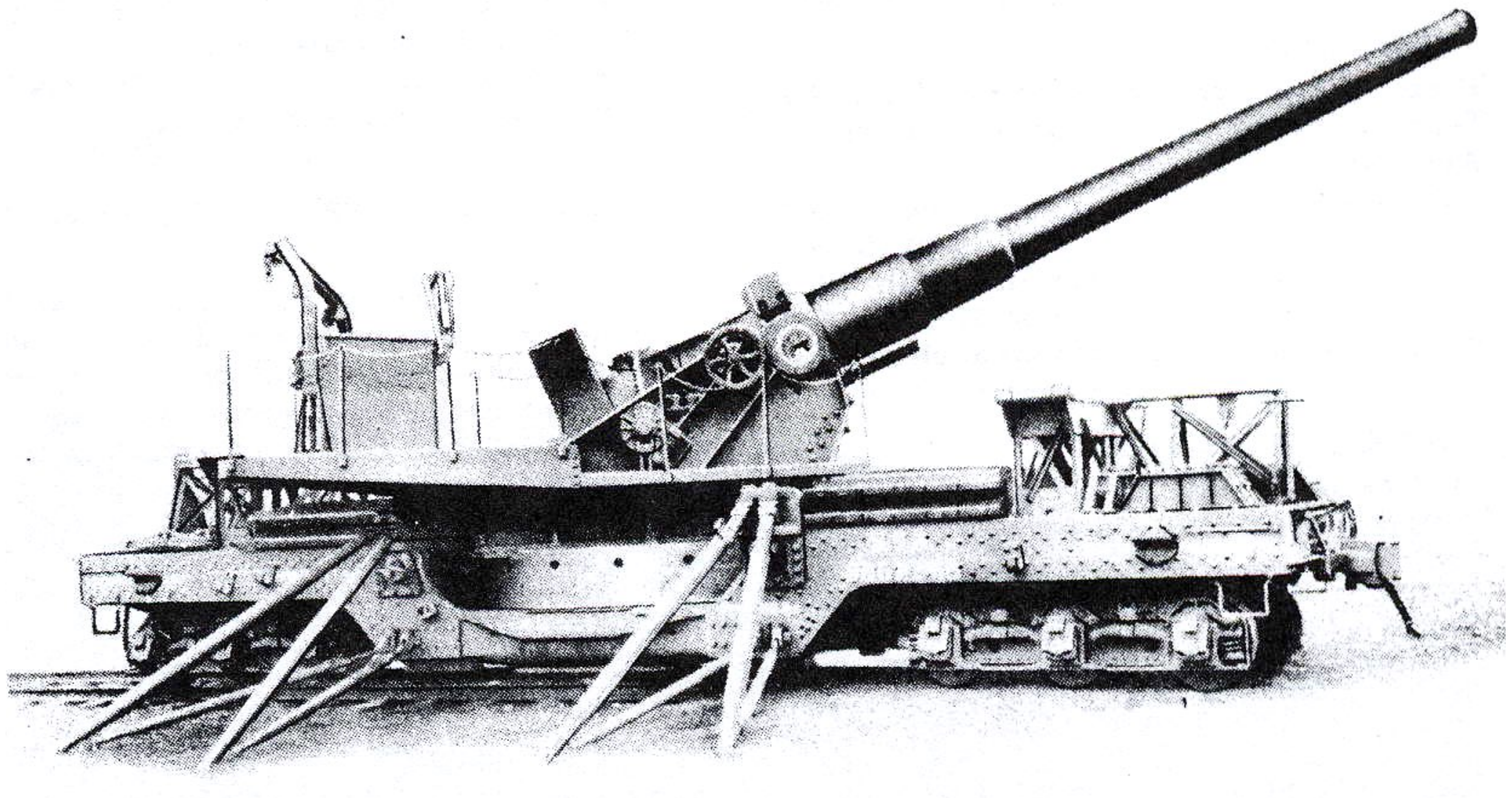
# Sieve of Eratosthenes

After each round of elimination, a new prime will be revealed, and the next round crosses out all its multiples.

These are computational procedures, carried out by hand!

# Decomposing computing tasks

During the time leading up to World War II, the US Army developed ever more sophisticated artillery that could fire shells over several miles.



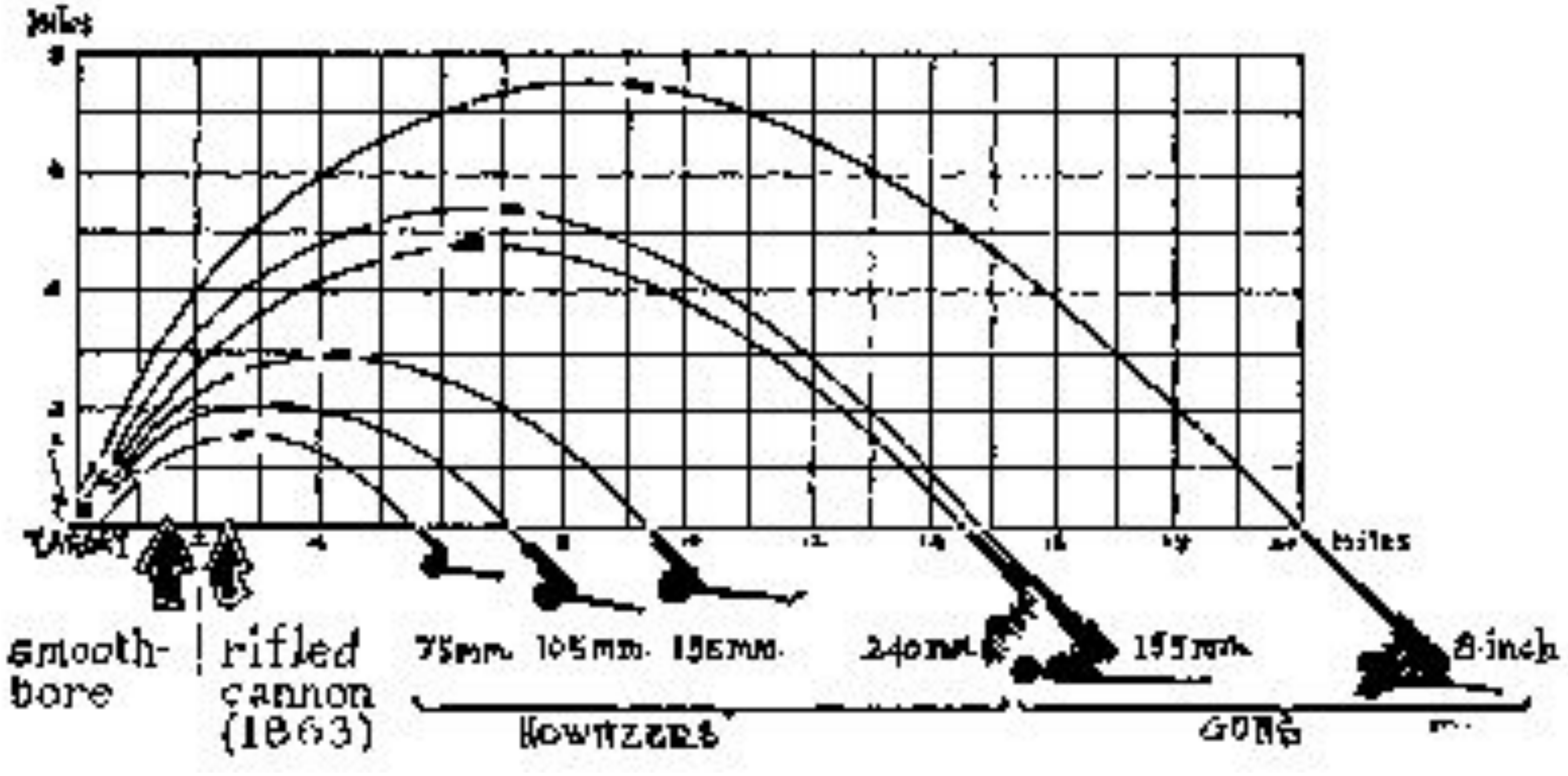
*8-inch Mk. VI railway gun*

Gunners needed to know how to aim their artillery given

the range,

the difference of elevation, and

the winds.



# The Army commissioned teams of human computers to work out firing tables for these guns.

The gunners could then simply look up the proper angle and direction to aim their guns, given their measurement of range, elevation, and winds.

*Range table for 3-inch field gun.* *Range table for 3-inch field gun.*

| Range. | Angle of departure. | Angle of departure. | Angle of elevation. | One minute, in yards of range. | One mil, in yards of range. | △X for ± 10 f. s. M. V. | △X for △C = ± 1/10. | △X for wind 10 miles per hour. | Drift. | Deviation for 10 miles cross wind. | Angle of fall. | Slope of fall. | Time of flight. | Terminal velocity. | Maximum ordinate. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Yds.* | ° ′ | *Mils.* | ° ′ | | | *Yds.* | *Yds.* | *Yds.* | *Yds.* | *Yds.* | ° ′ | *1 on—* | *Secs.* | *F. S.* | *Feet.* |
| 100 | 0 05.9 | 1.7 | 0 00.2 | 16.7 | 56 | 1.08 | 0.2 | 0.01 | 0.4 | 0.04 | 0 05.8 | 592.7 | 0.18 | 1,647.0 | 0.2 |
| 200 | 0 11.9 | 3.5 | 0 06.2 | 15.6 | 52 | 1.9 | 0.8 | 0.06 | 0.7 | 0.08 | 0 12.2 | 281.1 | 0.36 | 1,595.4 | 0.8 |
| 300 | 0 18.3 | 5.4 | 0 13.6 | 15.2 | 50 | 2.8 | 1.7 | 0.12 | 1.0 | 0.12 | 0 19.3 | 178.0 | 0.55 | 1,547.0 | 1.7 |
| 400 | 0 24.9 | 7.4 | 0 19.3 | 14.5 | 48 | 3.7 | 3.0 | 0.26 | 1.2 | 0.16 | 0 27.0 | 127.3 | 0.75 | 1,500.0 | 2.9 |
| **500** | **0 31.9** | **9.5** | **0 26.3** | **13.9** | **46** | **4.6** | **4.6** | **0.43** | **1.5** | **0.21** | **0 35.3** | **99.9** | **0.96** | **1,456.0** | **4.3** |
| 600 | 0 39.0 | 11.6 | 0 33.4 | 13.3 | 44 | 5.5 | 6.9 | 0.65 | 1.7 | 0.27 | 0 44.2 | 87.5 | 1.17 | 1,414.0 | 6.0 |
| 700 | 0 46.5 | 13.8 | 0 41.0 | 12.7 | 42 | 6.4 | 9.4 | 0.89 | 1.9 | 0.32 | 0 53.9 | 75.2 | 1.38 | 1,374.2 | 8.1 |
| 800 | 0 54.4 | 16.1 | 0 48.8 | 12.2 | 41 | 7.3 | 12.1 | 1.20 | 2.1 | 0.38 | 1 04.3 | 63.1 | 1.60 | 1,337.3 | 10.7 |
| 900 | 1 02.6 | 18.5 | 0 57.0 | 11.6 | 40 | 8.1 | 15.0 | 1.50 | 2.4 | 0.44 | 1 15.5 | 51.3 | 1.83 | 1,303.0 | 13.8 |
| **1,000** | **1 11.2** | **21.0** | **1 05.6** | **11.2** | **38** | **8.8** | **18.1** | **1.80** | **2.6** | **0.50** | **1 27.3** | **39.4** | **2.07** | **1,270.2** | **17.3** |
| 1,100 | 1 20.2 | 23.6 | 1 14.5 | 10.8 | 36 | 9.5 | 21.7 | 2.20 | 2.8 | 0.67 | 1 40.8 | 35.8 | 2.31 | 1,242.0 | 21.7 |
| 1,200 | 1 29.4 | 26.4 | 1 23.8 | 10.4 | 35 | 10.2 | 25.3 | 2.60 | 3.1 | 0.85 | 1 54.6 | 32.0 | 2.56 | 1,217.0 | 26.6 |
| 1,300 | 1 39.0 | 29.3 | 1 33.4 | 10.0 | 33 | 10.8 | 29.1 | 3.10 | 3.3 | 1.10 | 2 08.9 | 27.2 | 2.81 | 1,193.0 | 32.1 |
| 1,400 | 1 49.0 | 32.3 | 1 43.8 | 9.6 | 32 | 11.4 | 32.9 | 3.50 | 3.6 | 1.30 | 2 23.6 | 24.5 | 3.07 | 1,168.0 | 38.3 |
| **1,500** | **1 59.4** | **35.4** | **1 53.8** | **9.4** | **31** | **12.1** | **36.9** | **4.00** | **3.9** | **1.50** | **2 38.6** | **21.6** | **3.34** | **1,145.0** | **45.3** |
| 1,600 | 2 10.3 | 38.6 | 2 04.7 | 9.2 | 31 | 12.7 | 41.2 | 4.50 | 4.2 | 1.70 | 2 55.6 | 19.8 | 3.61 | 1,121.0 | 53.1 |
| 1,700 | 2 21.5 | 41.9 | 2 15.9 | 9.0 | 30 | 13.3 | 45.5 | 5.10 | 4.4 | 2.00 | 3 13.0 | 18.1 | 3.89 | 1,099.0 | 61.8 |
| 1,800 | 2 32.9 | 45.3 | 2 27.3 | 8.8 | 29 | 13.9 | 49.8 | 5.60 | 4.7 | 2.30 | 3 30.8 | 16.5 | 4.17 | 1,078.0 | 71.4 |
| 1,900 | 2 44.7 | 48.8 | 2 39.1 | 8.5 | 28 | 14.5 | 54.1 | 6.20 | 4.9 | 2.60 | 3 49.0 | 15.1 | 4.46 | 1,057.0 | 81.8 |
| **2,000** | **2 56.7** | **52.4** | **2 51.1** | **8.3** | **27** | **15.0** | **58.4** | **6.80** | **5.1** | **2.90** | **4 07.6** | **13.9** | **4.75** | **1,038.0** | **93.1** |
| 2,100 | 3 09.3 | 56.1 | 3 03.7 | 8.0 | 27 | 15.5 | 62.9 | 7.40 | 5.3 | 3.20 | 4 26.9 | 12.9 | 5.05 | 1,020.0 | 105.3 |
| 2,200 | 3 22.1 | 59.9 | 3 16.5 | 7.8 | 26 | 16.0 | 67.4 | 8.00 | 5.6 | 3.50 | 4 46.7 | 12.1 | 5.35 | 1,002.0 | 118.4 |
| 2,300 | 3 35.1 | 63.8 | 3 29.5 | 7.7 | 26 | 16.4 | 71.9 | 8.60 | 5.8 | 3.90 | 5 06.9 | 11.3 | 5.65 | 986.0 | 132.5 |
| 2,400 | 3 48.3 | 67.7 | 3 42.7 | 7.6 | 25 | 16.9 | 76.5 | 9.30 | 6.2 | 4.30 | 5 27.6 | 10.5 | 5.95 | 971.0 | 147.5 |
| **2,500** | **4 01.8** | **71.7** | **3 56.2** | **7.4** | **25** | **17.3** | **81.0** | **9.90** | **6.6** | **4.60** | **5 48.8** | **9.8** | **6.26** | **958.0** | **163.5** |
| 2,600 | 4 15.4 | 75.7 | 4 08.7 | 7.3 | 24 | 17.7 | 85.3 | 10.60 | 7.0 | 5.00 | 6 10.4 | 9.3 | 6.57 | 946.0 | 180.0 |
| 2,700 | 4 29.1 | 79.8 | 4 22.7 | 7.1 | 24 | 18.1 | 89.7 | 11.20 | 7.5 | 5.40 | 6 32.5 | 8.8 | 6.88 | 935.0 | 198.0 |
| 2,800 | 4 43.1 | 83.9 | 4 36.7 | 7.0 | 23 | 18.5 | 94.1 | 11.80 | 8.0 | 5.90 | 6 55.0 | 8.3 | 7.19 | 924.0 | 216.0 |
| 2,900 | 4 57.5 | 88.1 | 4 50.9 | 6.9 | 23 | 18.9 | 98.5 | 12.50 | 8.5 | 6.40 | 7 17.9 | 7.8 | 7.51 | 915.0 | 236.0 |
| **3,000** | **5 12.0** | **92.4** | **5 05.4** | **6.8** | **23** | **19.2** | **102.9** | **13.10** | **9.1** | **6.90** | **7 41.2** | **7.4** | **7.83** | **906.0** | **257.0** |

| Range. | Angle of departure. | Angle of departure. | Angle of elevation. | One minute, in yards of range. | One mil, in yards of range. | △X for ± 10 f. s. M. V. | △X for △C = ± 1/10. | △X for wind 10 miles per hour. | Drift. | Deviation for 10 miles cross wind. | Angle of fall. | Slope of fall. | Time of flight. | Terminal velocity. | Maximum ordinate. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Yds.* | ° ′ | *Mils.* | ° ′ | | | *Yds.* | *Yds.* | *Yds.* | *Yds.* | *Yds.* | ° ′ | *1 on—* | *Secs.* | *F. S.* | *Feet.* |
| 3,100 | 5 26.6 | 96.8 | 5 20.0 | 6.7 | 22 | 19.5 | 107.1 | 13.80 | 9.8 | 7.40 | 8 04.2 | 7.1 | 8.15 | 899.0 | 279.0 |
| 3,200 | 5 41.6 | 101.3 | 5 35.0 | 6.6 | 22 | 19.8 | 111.3 | 14.40 | 10.6 | 8.00 | 8 28.0 | 6.7 | 8.47 | 892.0 | 302.0 |
| 3,300 | 5 56.9 | 105.9 | 5 50.3 | 6.5 | 22 | 20.1 | 115.5 | 15.00 | 11.6 | 8.60 | 8 52.5 | 6.4 | 8.80 | 886.0 | 326.0 |
| 3,400 | 6 12.6 | 110.5 | 6 06.0 | 6.3 | 21 | 20.4 | 119.7 | 15.70 | 12.6 | 9.20 | 9 17.7 | 6.1 | 9.13 | 879.0 | 351.0 |
| **3,500** | **6 28.7** | **115.2** | **6 22.1** | **6.1** | **21** | **20.6** | **123.9** | **16.40** | **13.6** | **9.80** | **9 43.7** | **5.8** | **9.47** | **873.0** | **378.0** |
| 3,600 | 6 45.1 | 120.0 | 6 38.5 | 6.0 | 20 | 20.8 | 127.8 | 17.00 | 14.7 | 10.50 | 10 10.4 | 5.6 | 9.82 | 865.0 | 406.0 |
| 3,700 | 7 01.9 | 124.9 | 6 55.2 | 5.9 | 20 | 21.0 | 131.8 | 17.70 | 15.7 | 11.10 | 10 37.6 | 5.2 | 10.17 | 858.0 | 436.0 |
| 3,800 | 7 19.0 | 130.0 | 7 12.4 | 5.7 | 19 | 21.2 | 136.0 | 18.40 | 16.6 | 11.80 | 11 05.4 | 5.0 | 10.53 | 851.0 | 468.0 |
| 3,900 | 7 36.5 | 135.2 | 7 29.8 | 5.6 | 19 | 21.4 | 140.3 | 19.20 | 17.5 | 12.50 | 11 33.9 | 4.8 | 10.89 | 844.0 | 501.0 |
| **4,000** | **7 54.2** | **140.5** | **7 47.5** | **5.5** | **18** | **21.6** | **144.8** | **19.90** | **18.4** | **13.30** | **12 02.9** | **4.7** | **11.25** | **837.0** | **536.0** |
| 4,100 | 8 12.3 | 145.9 | 8 05.9 | 5.4 | 18 | 21.8 | 149.6 | 20.70 | 19.3 | 14.00 | 12 32.6 | 4.5 | 11.62 | 830.0 | 572.0 |
| 4,200 | 8 30.7 | 151.4 | 8 24.0 | 5.3 | 18 | 22.0 | 154.5 | 21.60 | 20.1 | 14.80 | 13 02.9 | 4.3 | 11.99 | 824.0 | 610.0 |
| 4,300 | 8 49.5 | 157.0 | 8 42.9 | 5.2 | 17 | 22.2 | 159.4 | 22.40 | 20.9 | 15.60 | 13 33.8 | 4.1 | 12.37 | 818.0 | 649.0 |
| 4,400 | 9 08.6 | 162.6 | 9 01.9 | 5.2 | 17 | 22.4 | 164.4 | 23.20 | 21.7 | 16.40 | 14 05.2 | 4.0 | 12.75 | 812.0 | 689.0 |
| **4,500** | **9 28.5** | **168.3** | **9 21.8** | **5.1** | **17** | **22.6** | **169.5** | **24.00** | **22.5** | **17.30** | **14 37.3** | **3.8** | **13.13** | **806.0** | **731.0** |
| 4,600 | 9 47.7 | 174.1 | 9 41.9 | 5.0 | 17 | 22.8 | 174.8 | 25.00 | 23.4 | 18.20 | 15 09.9 | 3.7 | 13.52 | 800.0 | 775.0 |
| 4,700 | 10 07.8 | 180.0 | 10 02.0 | 4.9 | 16 | 23.0 | 180.1 | 26.00 | 24.4 | 19.10 | 15 43.1 | 3.6 | 13.92 | 795.0 | 822.0 |
| 4,800 | 10 28.2 | 186.0 | 10 22.4 | 4.8 | 16 | 23.2 | 185.4 | 27.00 | 25.3 | 20.00 | 16 16.8 | 3.4 | 14.32 | 789.0 | 871.0 |
| 4,900 | 10 49.0 | 192.2 | 10 43.2 | 4.7 | 16 | 23.4 | 190.8 | 28.00 | 26.3 | 20.90 | 16 51.1 | 3.3 | 14.72 | 784.0 | 922.0 |
| **5,000** | **11 10.1** | **198.5** | **11 04.8** | **4.7** | **16** | **23.6** | **196.3** | **29.00** | **27.7** | **21.90** | **17 26.0** | **3.2** | **15.12** | **779.0** | **975.0** |
| 5,100 | 11 31.5 | 204.9 | 11 25.7 | 4.6 | 15 | 23.8 | 201.4 | 29.80 | 29.2 | 22.80 | 18 01.9 | 3.1 | 15.52 | 774.0 | 1,029.0 |
| 5,200 | 11 53.3 | 211.4 | 11 47.5 | 4.5 | 15 | 24.0 | 206.5 | 30.70 | 31.1 | 23.80 | 18 38.2 | 3.0 | 15.92 | 770.0 | 1,085.0 |
| 5,300 | 12 15.5 | 218.0 | 12 09.7 | 4.4 | 15 | 24.2 | 211.6 | 31.50 | 33.4 | 24.80 | 19 14.8 | 2.9 | 16.32 | 765.0 | 1,143.0 |
| 5,400 | 12 38.1 | 224.7 | 12 32.3 | 4.3 | 14 | 24.4 | 216.6 | 32.40 | 36.0 | 25.80 | 19 51.7 | 2.8 | 16.73 | 761.0 | 1,202.0 |
| **5,500** | **13 01.1** | **231.5** | **12 55.3** | **4 3** | **14** | **24.6** | **221.7** | **33.40** | **38.8** | **26.90** | **20 29.0** | **2.7** | **17.14** | **757.0** | **1,263.0** |
| 5,600 | 13 24.4 | 238.4 | 13 17.7 | 4.2 | 14 | 24.8 | 226.6 | 34.40 | 41.8 | 28.00 | 21 06.3 | 2.6 | 17.56 | 753.0 | 1,326.0 |
| 5,700 | 13 48.2 | 245.4 | 13 40.5 | 4.1 | 14 | 25.0 | 231.6 | 35.50 | 45.0 | 29.10 | 21 44.1 | 2.5 | 18.00 | 750.0 | 1,391.0 |
| 5,800 | 14 12.3 | 252.5 | 14 04.6 | 4.1 | 14 | 25.2 | 236.5 | 36.60 | 48.8 | 30.30 | 22 22.5 | 2.4 | 18.44 | 747.0 | 1,458.0 |
| 5,900 | 14 36.9 | 259.8 | 14 29.2 | 4.0 | 13 | 25.3 | 241.5 | 37.70 | 51.8 | 31.60 | 23 01.6 | 2.3 | 18.89 | 743.0 | 1,527.0 |
| **6,000** | **15 01.8** | **267.2** | **14 54.1** | **4.0** | **13** | **25.5** | **246.6** | **38.80** | **55.3** | **32.80** | **23 40.9** | **2.3** | **19.36** | **740.0** | **1,598.0** |
| 6,100 | 15 27.1 | 274.7 | 15 19.4 | 3.9 | 13 | 25.7 | 251.6 | 39.90 | 59.0 | 34.20 | 24 20.9 | 2.2 | 19.85 | 737.0 | 1,672.0 |
| 6,200 | 15 52.9 | 282.3 | 15 45.2 | 3.8 | 13 | 25.8 | 256.6 | 41.10 | 62.5 | 35.60 | 25 01.5 | 2.2 | 20.35 | 733.0 | 1,748.0 |
| 6,300 | 16 19.0 | 290.0 | 16 11.3 | 3.8 | 13 | 26.0 | 261.6 | 42.30 | 66.1 | 37.00 | 25 42.7 | 2.1 | 20.86 | 730.0 | 1,827.0 |
| 6,400 | 16 45.6 | 297.8 | 16 37.9 | 3.7 | 12 | 26.1 | 266.6 | 43.60 | 69.5 | 38.80 | 26 24.5 | 2.1 | 21.38 | 727.0 | 1,908.0 |
| **6,500** | **17 12.6** | **305.8** | **17 04.9** | **3.7** | **12** | **26.2** | **271.6** | **44.80** | **73.0** | **39.90** | **27 06.8** | **1.9** | **21.92** | **724.0** | **1,992.0** |

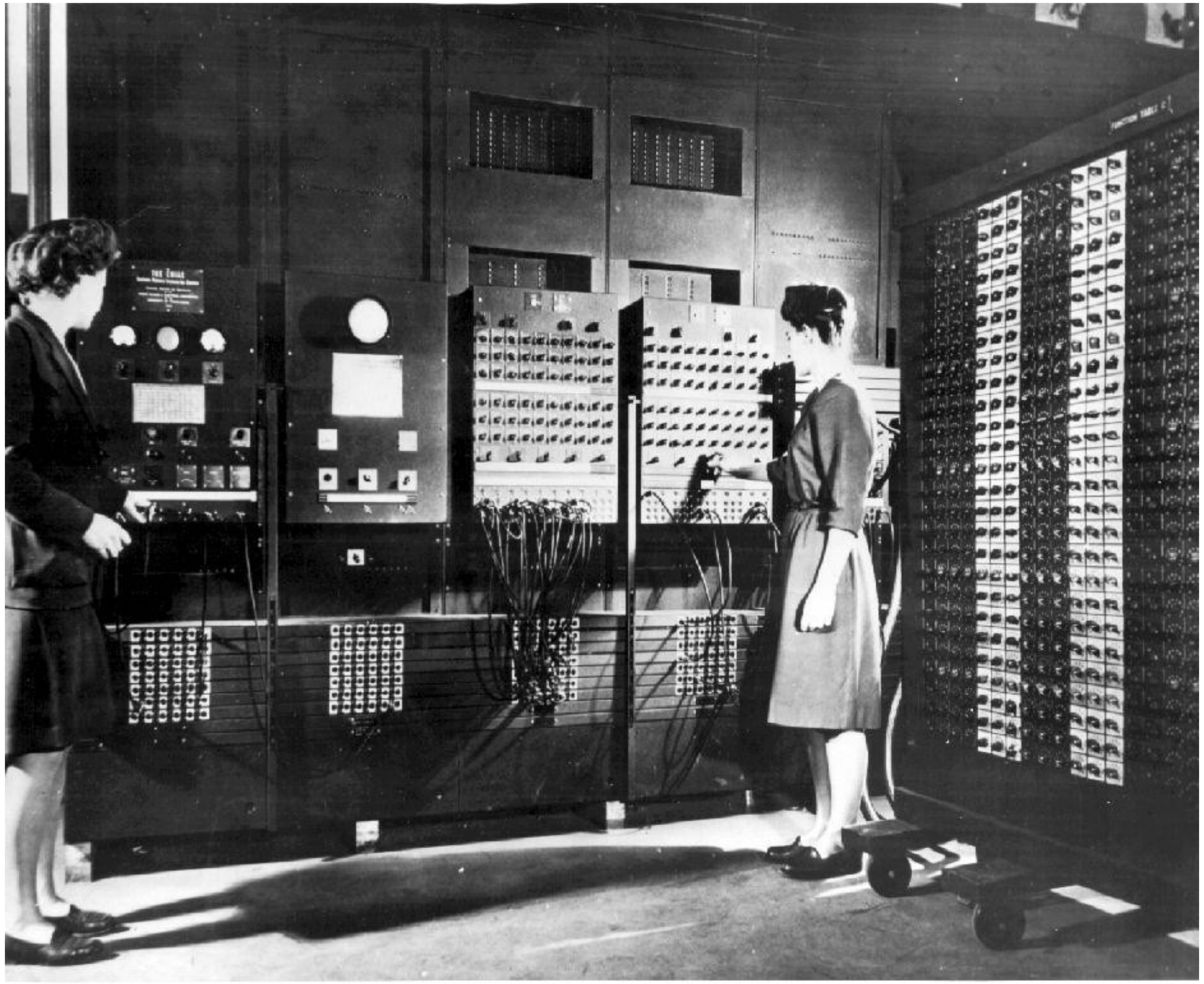
Around 1940, one of these teams comprised women working at Aberdeen Proving Ground in Maryland.

They organized into assembly lines, each doing a different stage of computation, until they compiled the firing tables.

- Each assembly line was working on a different input, like running a function
- Each of the human computers in the assembly line was carrying out a part of the computation, like running a line of code

(breaking down a problem into smaller pieces to carry out the computations much more efficiently)

The Army wanted to perform these computations at much larger scales and faster than humans could, which led to using the ENIAC—Electronic Numerical Integrator and Computer (John Mauchly and J. Presper Eckert, 1945)



But…

The method of decomposing the task into unambiguous steps that passed data between them moved from a *management principle* at Aberdeen to a *design principle* for automatic computers.

# Programmable computers

No matter how simple and unambiguous the steps are made, human computers make mistakes – and lots of them!

So, inventors through the ages have sought to make computing machines to allow people to perform longer computations with fewer errors.

This was a slow process, taking us from…

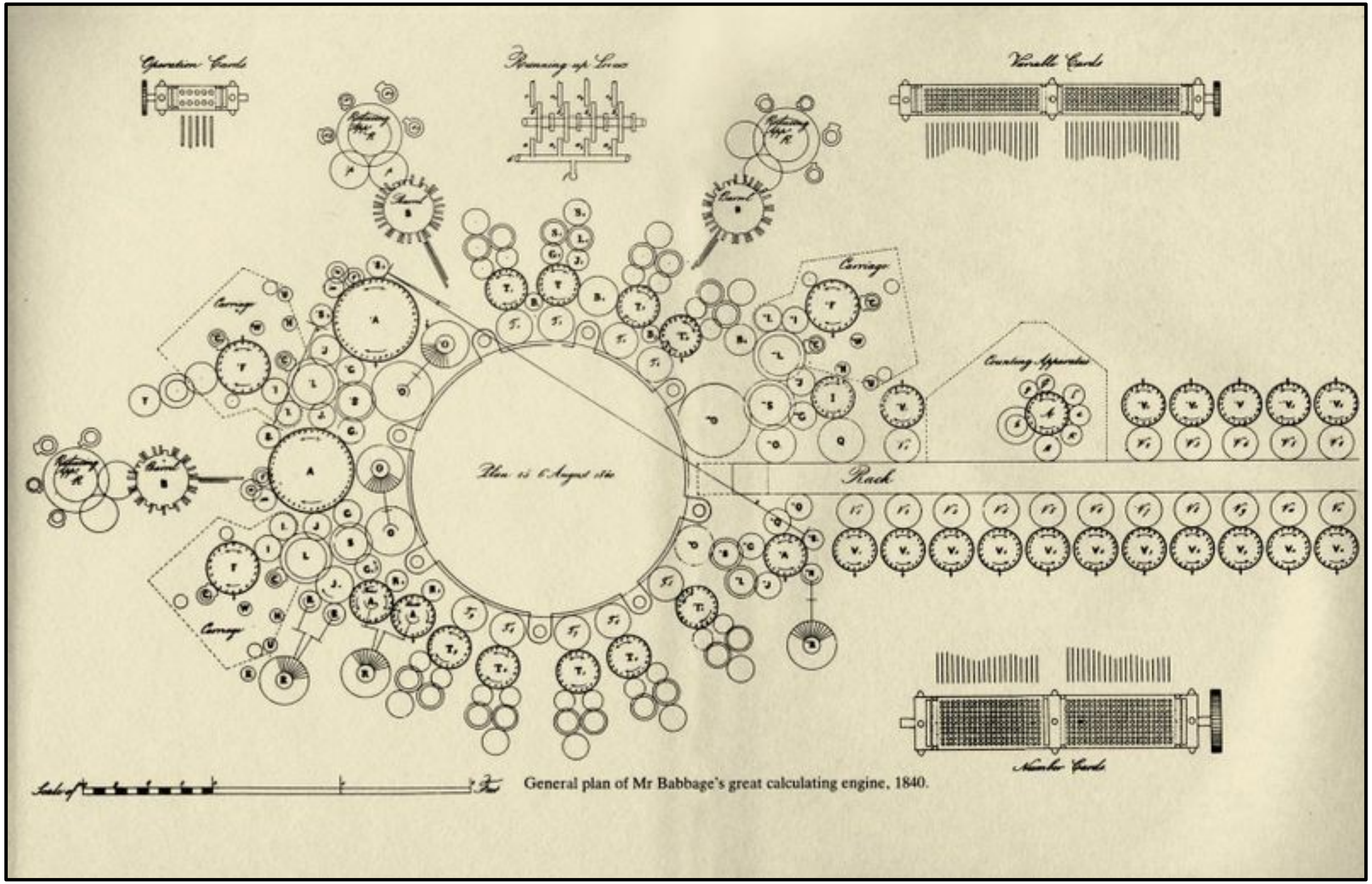
The slide rule
c. 1620


Blaise Pascal's mechanical calculator—Pascaline, or Pascal's wheel
(could add and subtract, but not multiply or divide)
1642

Precursors to the idea of a *programmable* computer originated well before the electronic computing age.

In the early 1700s, French textile weavers experimented with machines that could weave complex patterns using an automatic loom.

One of the more well known is the Jacquard loom, which was controlled by long chains of punched cards.




Plan 25 for Babbage's Analytical Engine
1840

Babbage collaborated with a gifted mathematician, Ada Lovelace, who designed algorithms for the Analytical Engine, even though there was no machine to run them on.

She is considered the first computer programmer.

Lovelace was the daughter of Lord Byron. She assisted Babbage in explaining and promoting his ideas, writing articles describing the operation and use of the analytical engine.

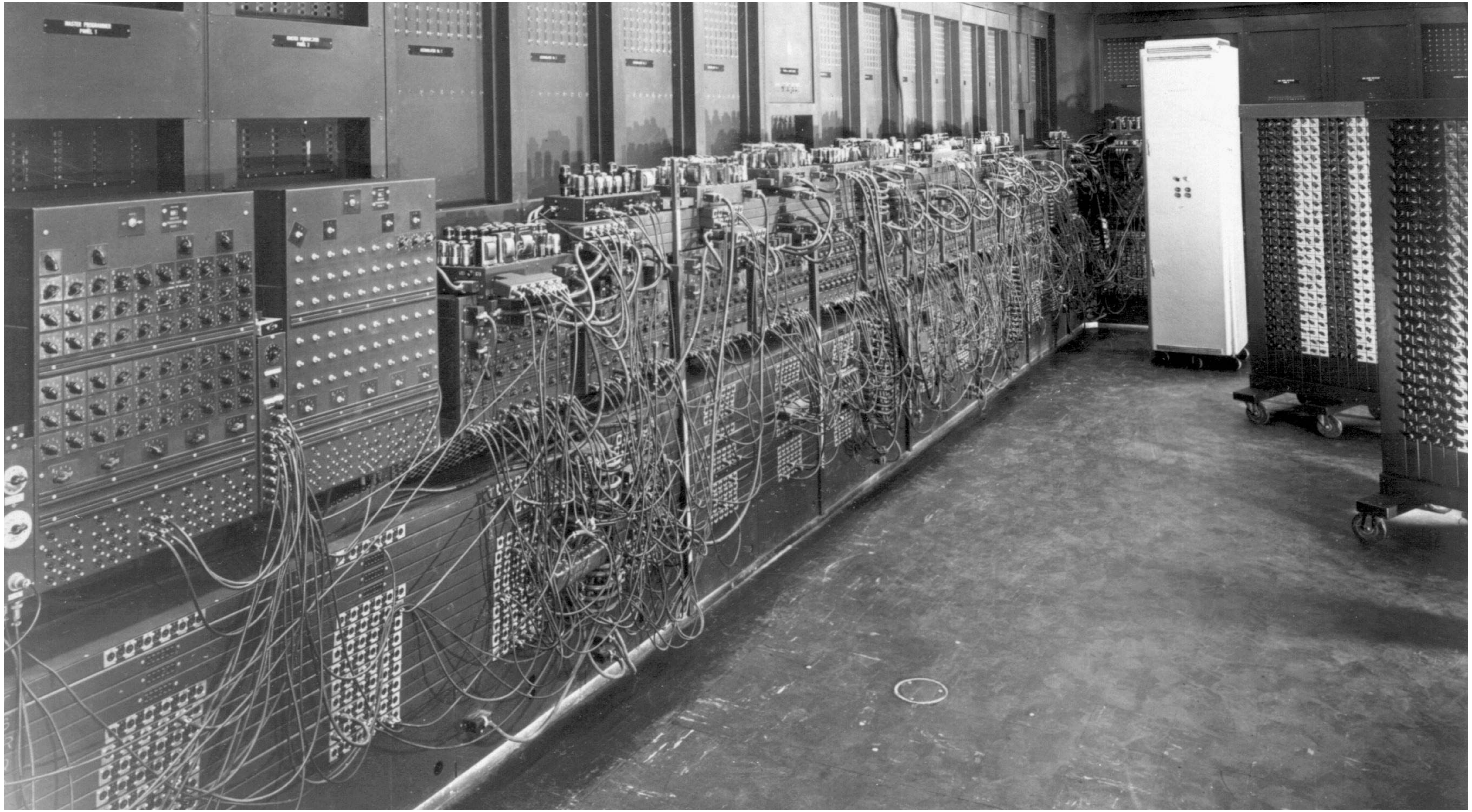
Lovelace saw the Analytical Engine not as a mere calculator but as a processor of *any information that could be encoded in symbols*.

This insight, that computing programs can calculate not only over numbers but over symbols that can stand for anything in the world, anticipated by a hundred years a key tenet of the modern computer age.

Lovelace saw the computer as an *information machine*.

While Babbage's designs for a programmable computer weren't realized at the time, the age of electronics opened new possibilities.

Harvard Mark I
1944



ENIAC
c. 1945

Early computers were very difficult to program, working in languages that were closely tied to the hardware.

Grace Murray Hopper (Vassar '28) popularized the idea of a *Compiler* for machine-independent programming languages and defined FLOW-MATIC, the first English-like data processing language in the early 1950s.

Those ideas were later folded into COBOL (COmmon Business-Oriented Language) (1959).

Since the 1950s, many programming languages have been defined, experienced popularity, and then been supplanted by new designs.

Today, Python is the most common programming language used for work in data science and artificial intelligence.

Programming no longer involves plugging in wires or punching cards, but it’s still hard!

In *The Mythical Man-Month* (1975), Turing Award recipient Fred Brooks writes:

"*The programmer, like the poet, works only slightly removed from pure thought-stuff.* He builds castles in the air, from air, creating by exertion of the imagination…

“Few media of creation are so flexible, so easy to polish and rework, so readily capable of realizing grand conceptual structures. *Yet the program construct, unlike the poet’s words, is real in the sense that it moves and works*, producing visible outputs separate from the construct itself…

"One types the correct incantation on a keyboard, and a display screen *comes to life*, showing things that never were nor could be… It prints results, draws pictures, produces sounds, moves arms. The magic of myth and legend has come true in our time…

"The computer resembles the magic of legend in this respect, too. If one character, one pause, of the incantation is not strictly in proper form, the magic doesn't work. Human beings are not accustomed to being perfect, and few areas of human activity demand it. *Adjusting to the requirement for perfection is, I think, the most difficult part of learning to program.*"

# Data science

We haven’t just been writing programs; we’ve been writing programs to work with data.

# What is data?

“Many people think of data as numbers alone, but data can also consist of words or stories, colors or sounds, or any type of information that is systematically collected, organized, and analyzed…”

D’Ignazio & Klein, “Introduction” in *Data Feminism*, 2020

# Data gathering and privacy

Beyond the relevance and reliability of data, we also need to consider the ethicality of gathering data.

www.theguardian.com/technology/2016/oct/21/how-to-disabl





Google

This article is more than **4 years old**

# Google's ad tracking is as creepy as Facebook's. Here's how to disable it

**Google in June deleted a clause in its privacy settings that said it would not combine cookie information with personal information without consent**

The words and phrases we search for on Google, the times of day we are most active on Facebook, and the number of items we add to our Amazon carts are all tracked and stored as data – data that are then converted into corporate financial gain.

D'Ignazio & Klein, "Introduction" in *Data Feminism*, 2020

Ethics of research using social media data is complex and rapidly evolving, with legitimate disagreements.

# Representing data

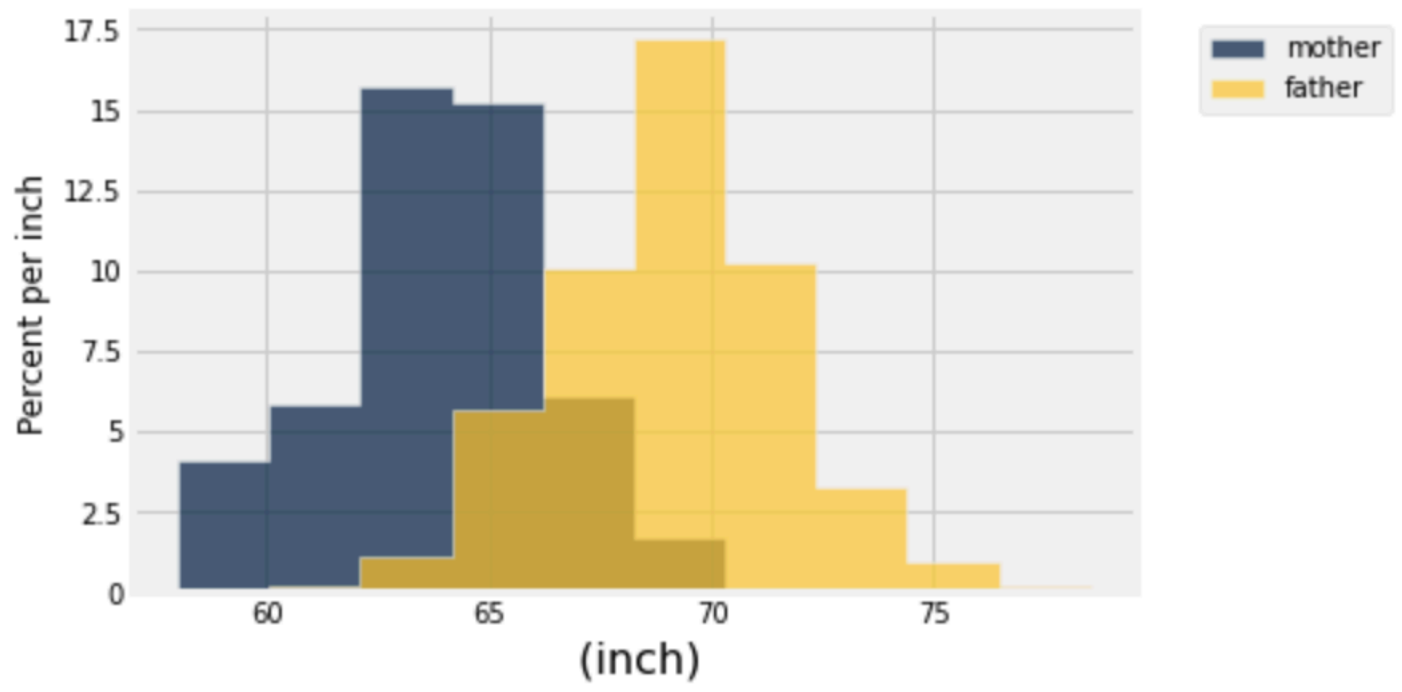
| family | father | mother | children | childNum | gender | childHeight |
|---|---|---|---|---|---|---|
| 1 | 78.5 | 67 | 4 | 1 | male | 73.2 |
| 1 | 78.5 | 67 | 4 | 2 | female | 69.2 |
| 1 | 78.5 | 67 | 4 | 3 | female | 69 |
| 1 | 78.5 | 67 | 4 | 4 | female | 69 |
| 2 | 75.5 | 66.5 | 4 | 1 | male | 73.5 |
| 2 | 75.5 | 66.5 | 4 | 2 | male | 72.5 |

... (928 rows omitted)

We see `father` and `mother`, giving the height of each in inches.

We can see this difference in these distributions by looking at a histogram of mother and father heights together:

```
galton.hist(["mother", "father"], unit="inch")
```



www.pewresearch.org/fact-tank/2019/12/18/gender-options

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DECEMBER 18, 2019

# About four-in-ten U.S. adults say forms should offer more than two gender options

BY NIKKI GRAF

In 2019, at least seven states have started offering a third gender option on driver's licenses for people who don't identify as male or female, and at least four more plan to do so in

**States that offer a third gender option on driver's licenses**



RELATED

REPORT | SEP 5, 2019

About one-in-five U.S. adults know someone who goes by a gender-neutral pronoun

REPORT | JUL 27, 2021

Rising shares of U.S. adults know someone who is transgender or goes by gender-neutral pronouns

REPORT | DEC 28, 2017

10 things we learned about gender issues in the U.S. in 2017

REPORT | DEC 14, 2017

Gender discrimination comes in

pewresearch.org/fact-tank/2019/12/18/
gender-options-on-forms-or-online-profiles/

"…most of the data and data models we have inherited deal with structures of power, like gender and race, with a crudeness that would never pass muster in a peer-reviewed humanities publication."

Miriam Posner, "What's Next: The Radical, Unrealized Potential of Digital Humanities", 2016

"I want us to be more ambitious, to hold ourselves to much higher standards when we are claiming to develop data-based work that depicts people's lives."

Miriam Posner, "What's Next: The Radical, Unrealized Potential of Digital Humanities", 2016

# Data analysis and storytelling

When we’re thinking about data science, we’re trying to tell stories about data. In this class, we only scratched the surface of what that looks like.

# Prediction and machine learning

Lastly, we’ve been talking about prediction — how we use data to make decisions…

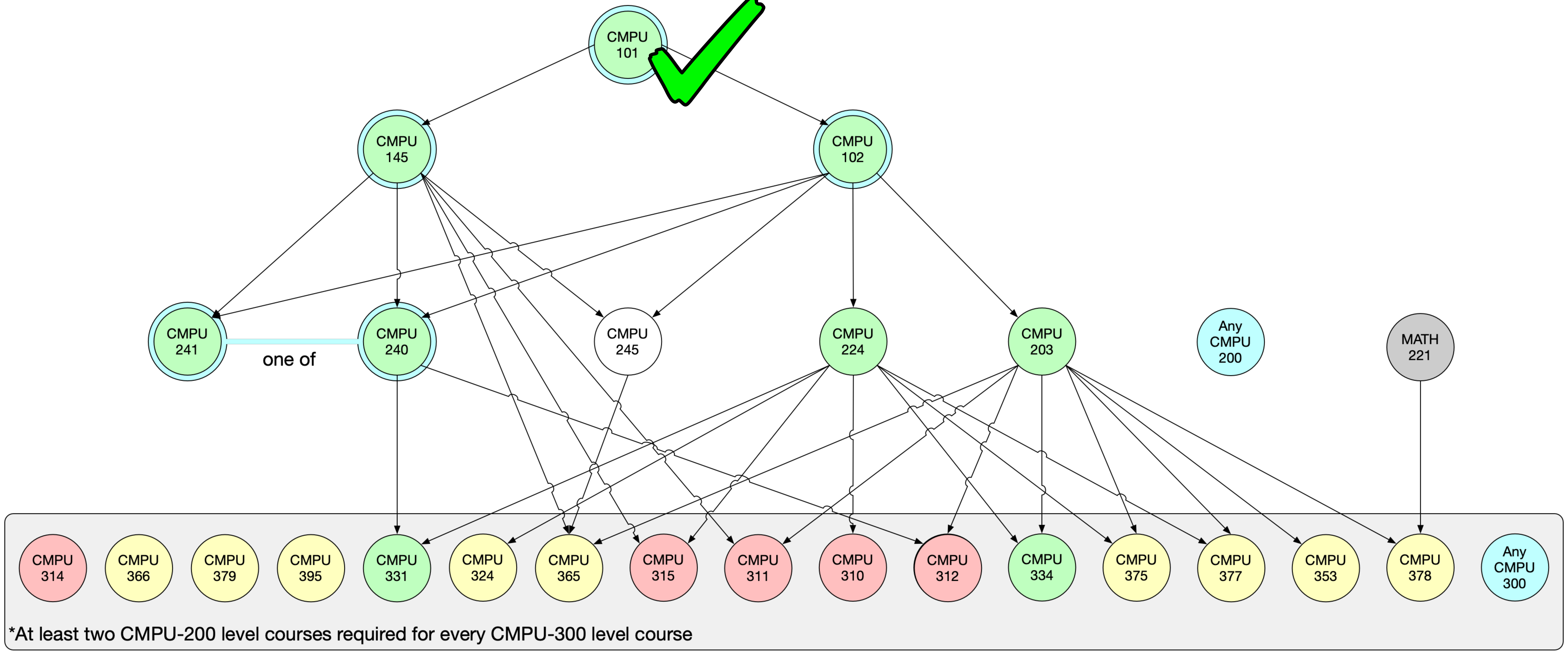
"…mechanical arts are of ambiguous use, serving as well for hurt as for remedy."

Francis Bacon, *The Wisdom of the Ancients*, 1609

# Computer Science I
# —or, where do you go from here?

Congratulations on making it this far!

# CS courses at Vassar




**Major-required courses**

CMPU 101 - Computer Science I: Problem-Solving and Abstraction
CMPU 102 - Computer Science II: Data Structures and Algorithms
CMPU 145 - Foundations of Computer Science
CMPU 203 - Computer Science III: Software Design and Implementation
CMPU 224 - Computer Organization
CMPU 240 - Theory of Computation
CMPU 241 - Analysis of Algorithms
CMPU 331 - Compilers
CMPU 334 - Operating Systems

**300-level electives (at least one for major)**

CMPU 324 - Computer Architecture
CMPU 353 - Bioinformatics
CMPU 365 - Artificial Intelligence
CMPU 366 - Computational Linguistics
CMPU 375 - Computer Networks
CMPU 377 - Parallel Programming
CMPU 378 - Graphics
CMPU 379 - Computer Animation: Art, Science and Criticism
CMPU 395 - Advanced Special Topics

**Intensives (at least one for major)**

CMPU 310 - Topics in Virtualization
CMPU 311 - Database Systems
CMPU 312 - Applications of Artificial Intelligence
CMPU 314 - Projects in Digital Media Production
CMPU 315 - Computer Security

**Correlate-required courses**

CMPU 101 - Computer Science I: Problem-Solving and Abstraction
CMPU 102 - Computer Science II: Data Structures and Algorithms
CMPU 145 - Foundations of Computer Science
CMPU 240 or 241 - Theory of Computation or Analysis of Algorithms
CMPU 2xx - Any other 200-level course
CMPU 3xx - Any 300-level course

**200-level electives (not required for major)**

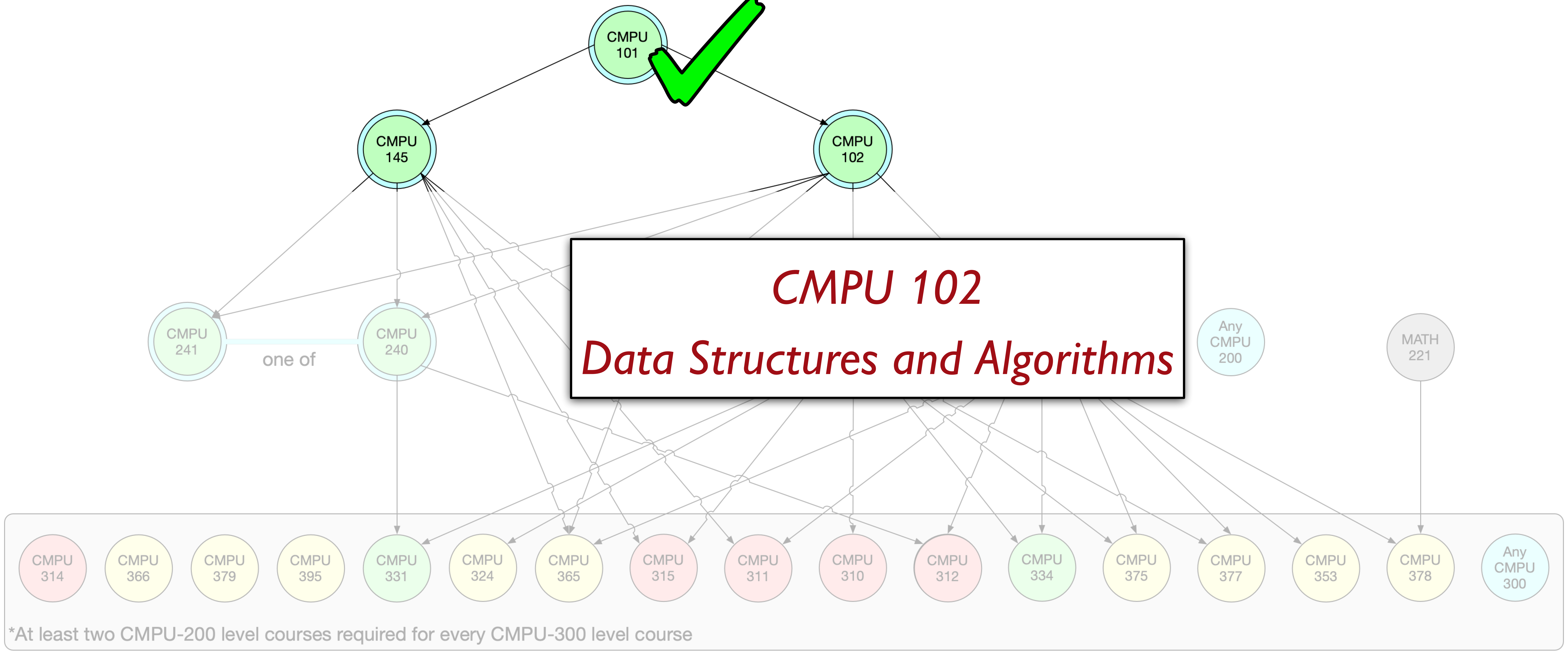
CMPU 245 - Declarative Programming Models

**Extra-departmental**

MATH 221 - Linear Algebra

# *CMPU 102*

## *Data Structures and Algorithms*

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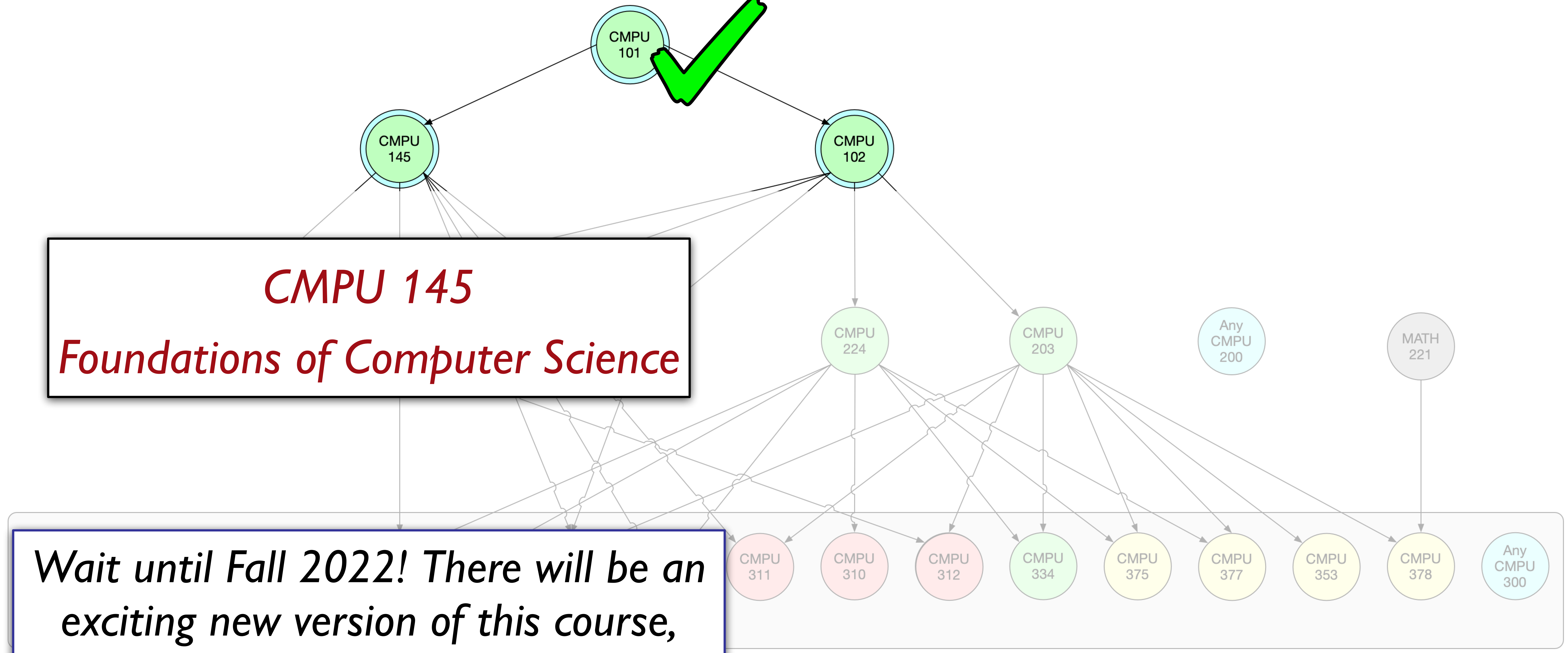


# CMPU 145

# Foundations of Computer Science

*Wait until Fall 2022! There will be an exciting new version of this course, designed to follow the new CMPU 101 you just took!*

CMP
CMPU 102 - Computer Science II: Data Structures and Algorithms
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Try them out!

If you keep going with the CS major sequence, you work your way up to some really exciting courses, including…

CMPU 353 Bioinformatics

CMPU 377 Parallel Programming

*And, you know, probably some cool courses I don't teach as well!*

# That’s it!

Next time, we’ll review for the Exam 3 by working through practice problems and answering your questions.

# go.vassar.edu/course/evals

Numeric sheets are used by the college for deciding things like compensation, contract renewals, promotion, and tenure. This is more important for people's careers than you might imagine, so please fill it out honestly but fairly.

# Acknowledgments

This lecture incorporates material from:

Peter J. Denning & Matti Tedre, *Computational Thinking*

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Jonathan Gordon, Vassar College