Introduction to Big Data

Lesson 1.2 Computer science survival kit

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Wednesday, March 30, 2022

Computer science survival kit

A computer can be abstracted by four key components:

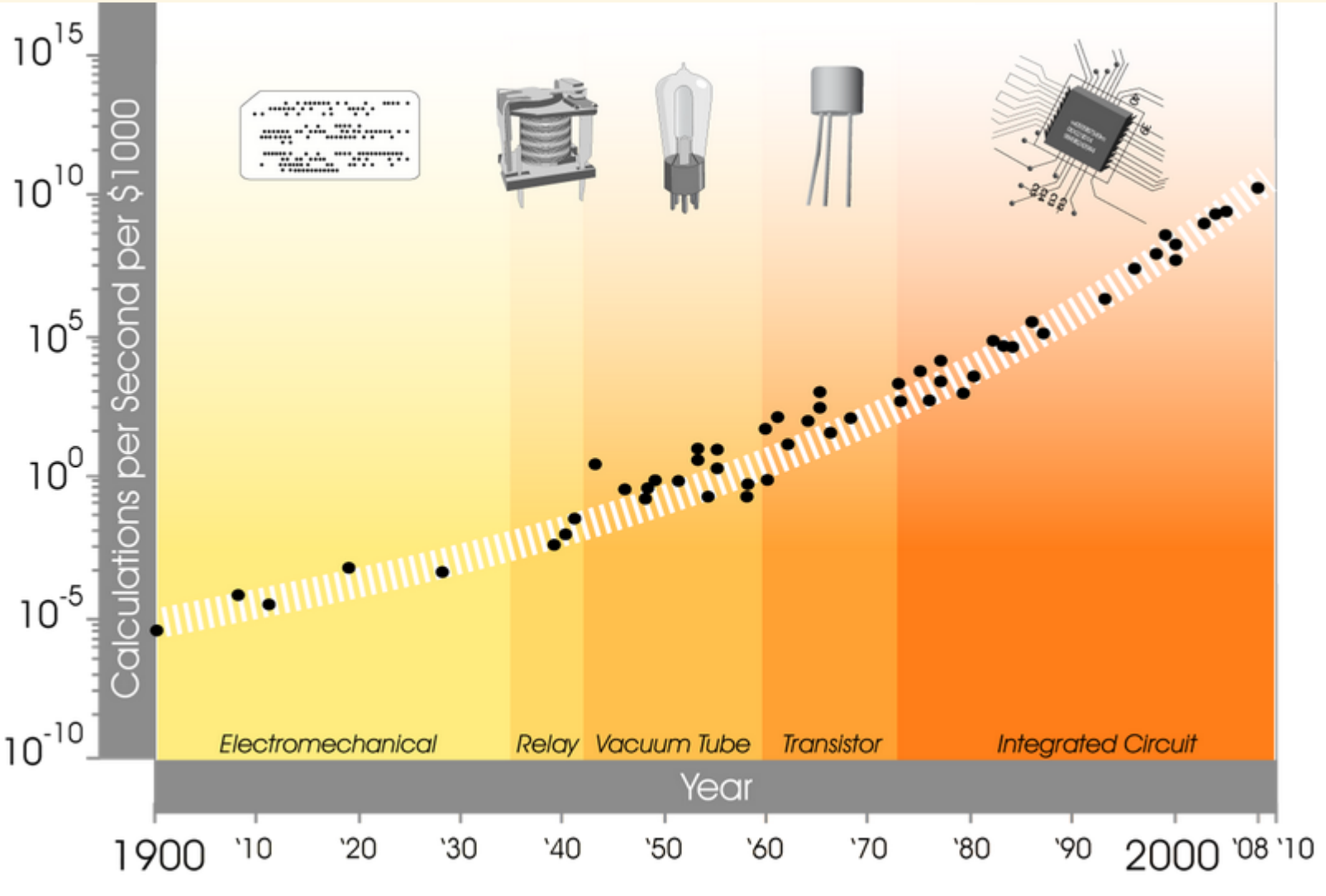
- processing (FR: processeurs)
- memory (FR: mémoire vive)
- storage (FR: stockage)
- wiring / network (FR: connexions / réseau)

Processors

Processors

What is important for us to know?

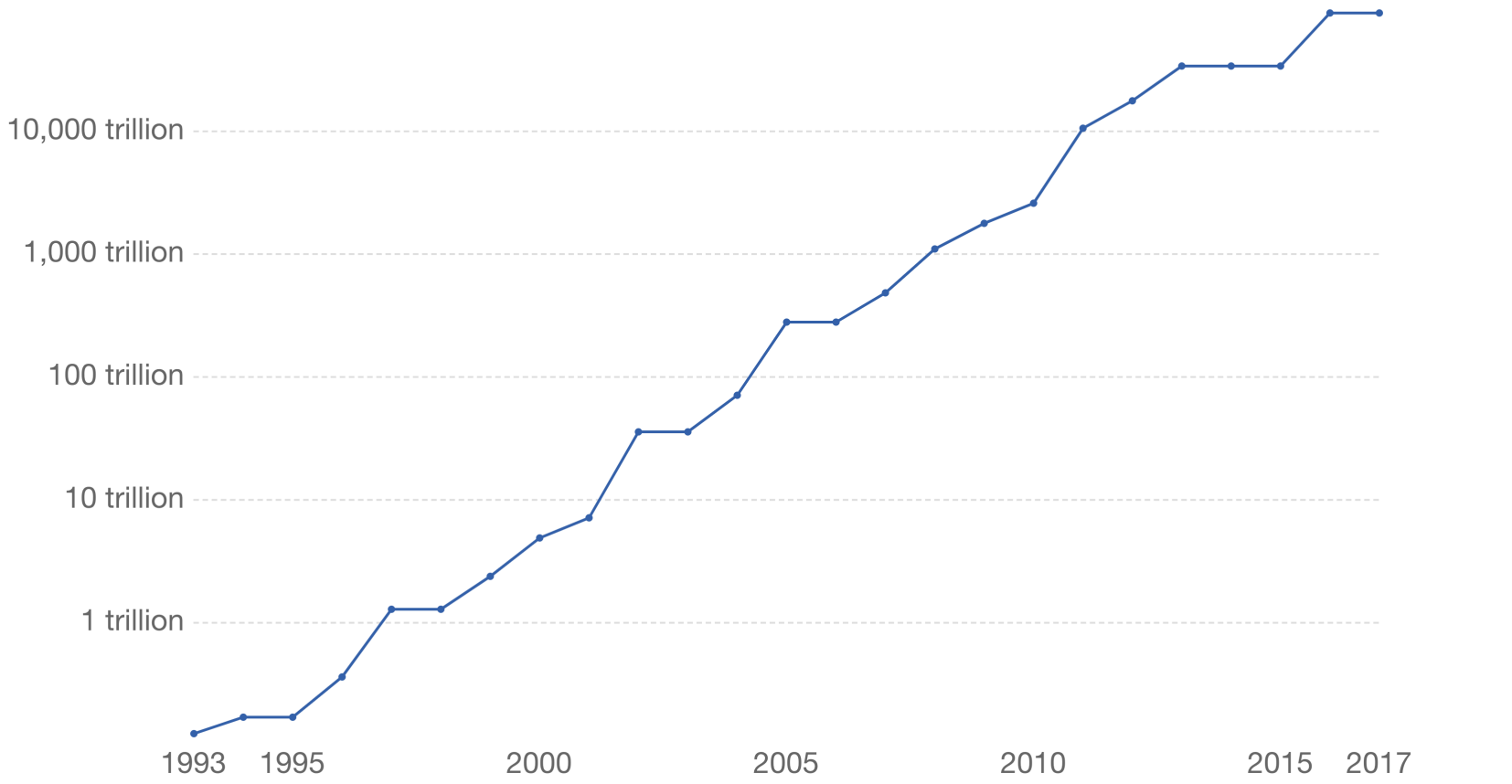
- computation happens ***physically*** in **transistors**
- **programs must be converted to machine-code**, i.e. to a list of formatted instructions that the processor can execute
- **instructions are stored sequentially** in one or several stacks / threads / queues
- Mono vs multi threaded application.
- **processors can be specialized** (e.g. GPU)
- performance is measured in number **operations** or **instructions per second** (FLOPS, IPS)



Source: Kurzweil (link) via Our World in Data (link)

Supercomputer Power (FLOPS)

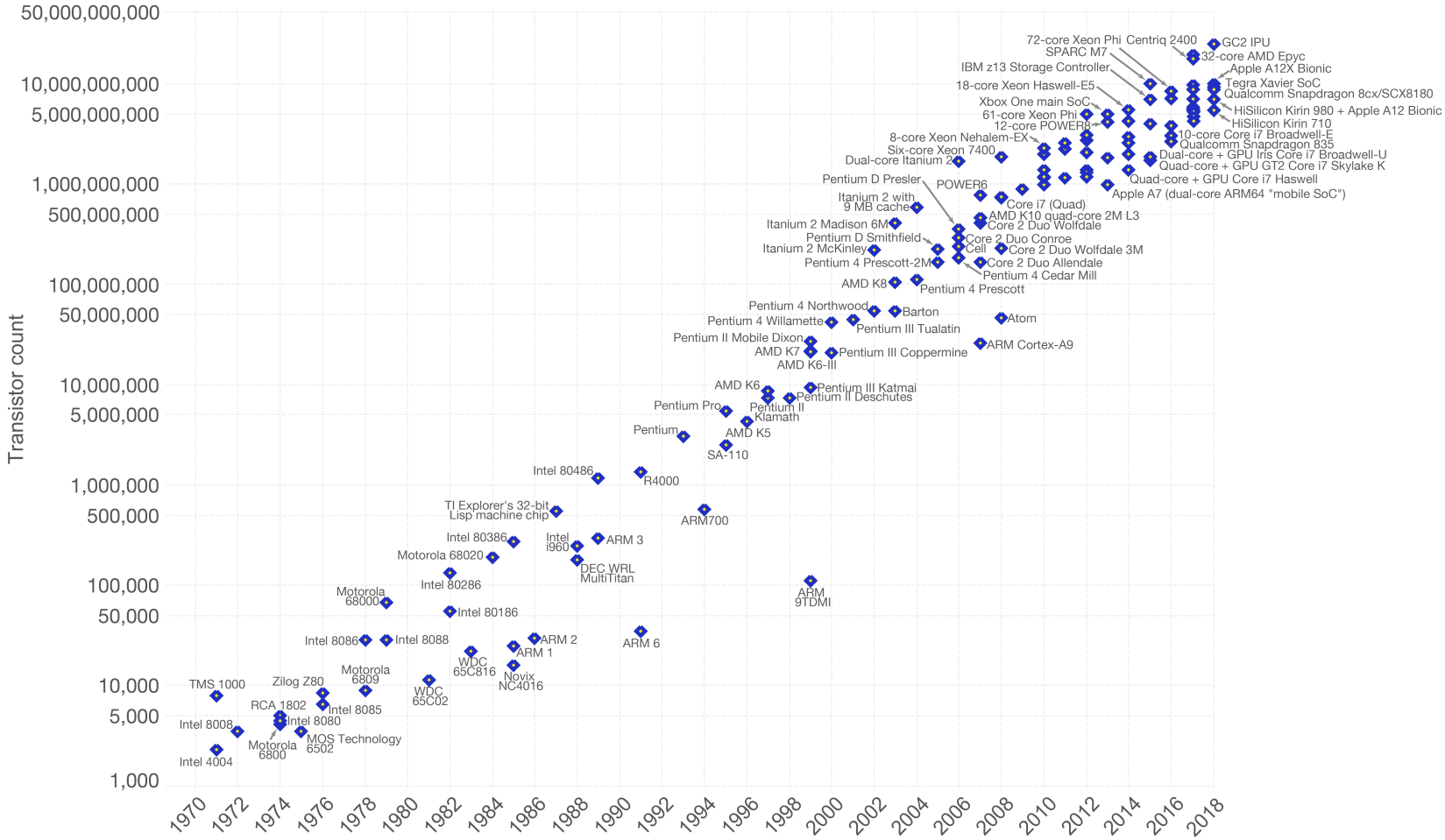
The growth of supercomputer power, measured as the number of floating-point operations carried out per second (FLOPS) by the largest supercomputer in any given year. (FLOPS) is a measure of calculations per second for floating-point operations. Floating-point operations are needed for very large or very small real numbers, or computations that require a large dynamic range. It is therefore a more accurate measured than simply instructions per second.



Source: TOP500 Supercomputer Database

Moore’s Law – The number of transistors on integrated circuit chips (1971-2018)

Moore's law describes the empirical regularity that the number of transistors on integrated circuits doubles approximately every two years. This advancement is important as other aspects of technological progress – such as processing speed or the price of electronic products – are linked to Moore's law.



Data source: Wikipedia (https://en.wikipedia.org/wiki/Transistor_count)
The data visualization is available at OurWorldinData.org. There you find more visualizations and research on this topic.

Processors

Processing is a limitting factor.

- processors are **the most expensive part** of the hardware
- energy consumption of the processors are the **main cost of computation**
- one core can **only** perform **so many operations** per second
- it is **non-trivial** problem to **coordinate multiple processors** on the same complex task

Memory

Memory

What is important for us to know ?

- moving data around takes time
- memory is **fast** (ns)
- memory is **volatile** (lost in case of power interruption)
- memory-processor units are **heavily** optimized
- processors always access the the hard disk through **memory caching**

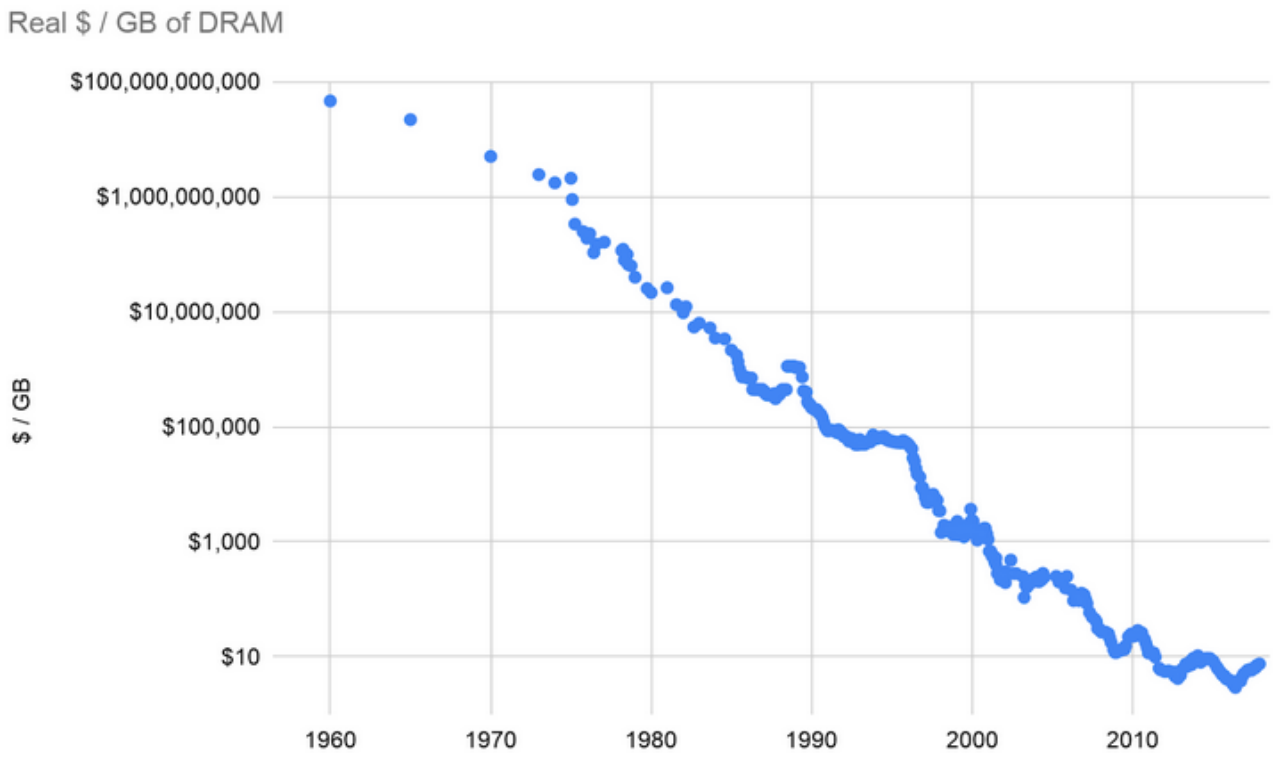


Figure 1: Price per gigabyte of DRAM from 1957 to 2018 from John McCallum's dataset, which we converted to 2020 dollars using the Consumer Price Index.[7]

Source : https://aiimpacts.org/trends-in-dram-price-per-gigabyte/

Memory

Memory is a limitting factor.

- it is non trivial to work with data that **can't fit into memory**
- memory is **the second-most expensive part** of a computer
- memory is **shared** with other programs on the computer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Storage

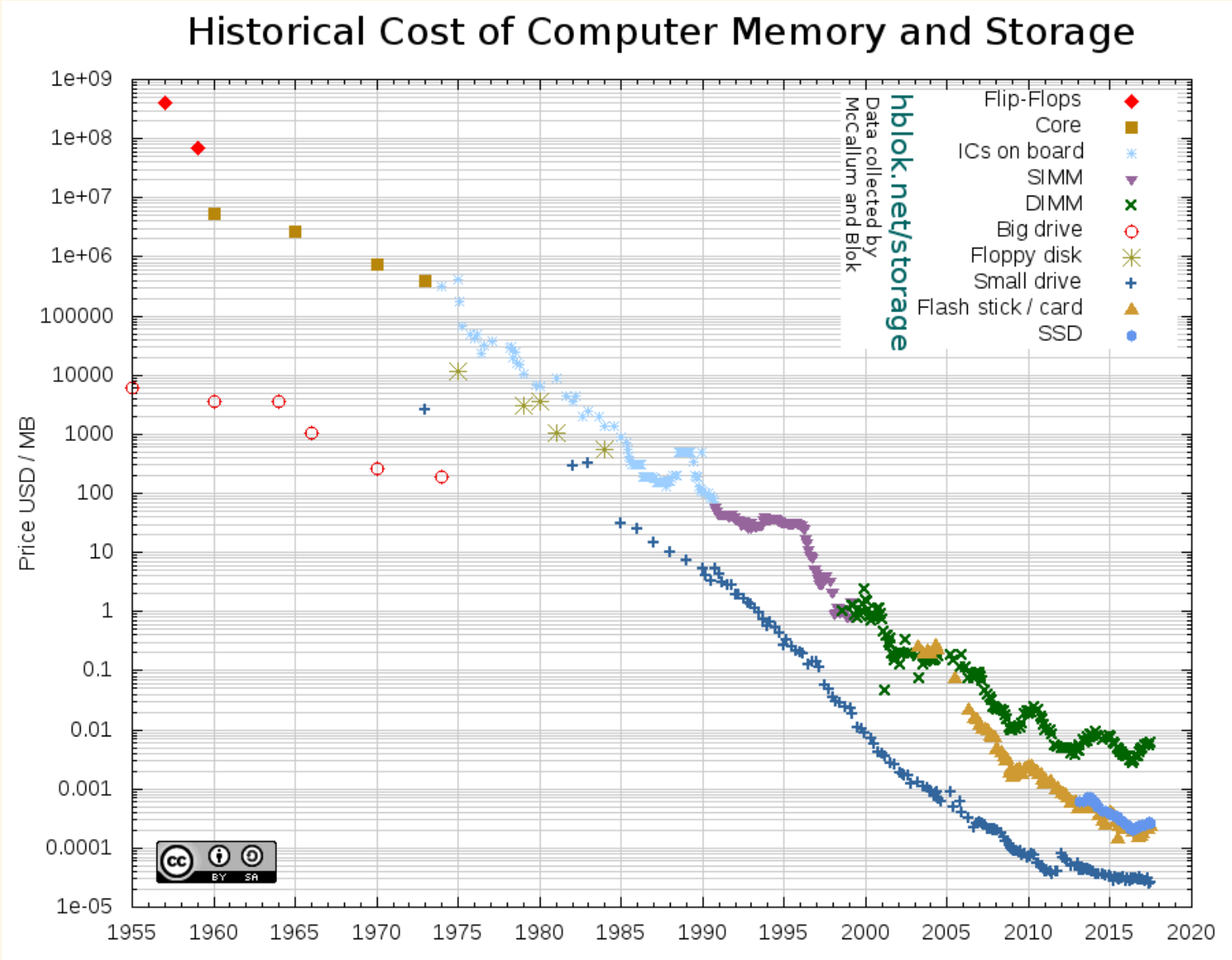
- for long-term storage of information
- can have **multiple forms**: electronic disk (SSD), magnetic disk (hard disk, floppy disk), physical engraving (vinyls, CDs, DVDs), magnetic tape, paper (books, punch cards, bar codes, QR codes), biological (DNA), etc.
- commonly referred to as "(disk / storage) space" or "(hard) disk"
- **non-volatile**, contrary to memory
- valuable properties:
  - **size**
  - **integrity**, resistance to degradation
  - **speed**, in read and write

Storage

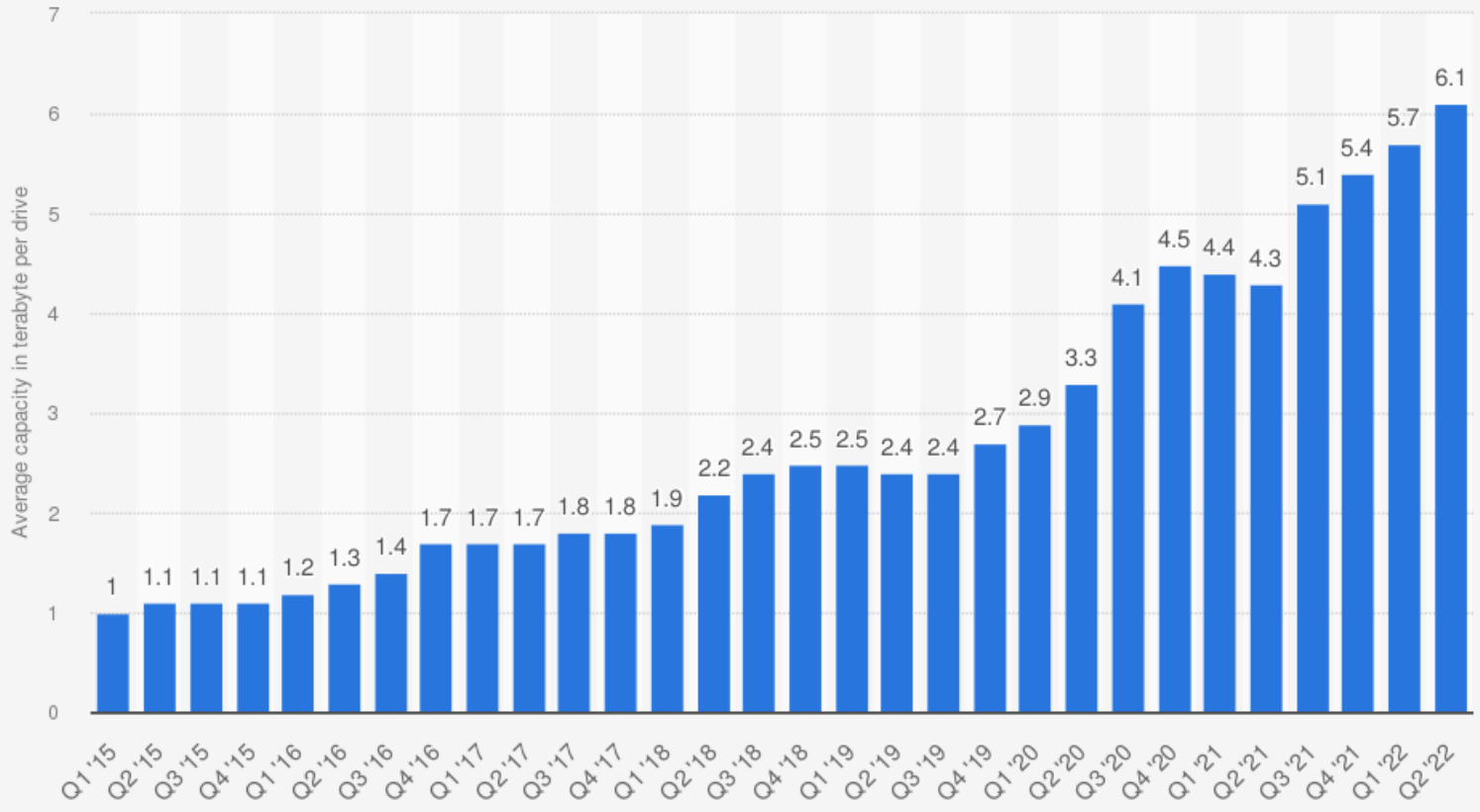
Storage is evaluated in **bytes** (B) or **octets** (o) and their mutiples:

Number of bytes	Symbol	Full name	Order of magnitude
	ko	kilobyte	a vectorial icon
	Mo	megabyte	a high resolution image, a book
	Go	gigabyte	a high-resolution video
	To	terabyte	the whole Friends series in high-resolution
	Po	petabyte	Spotify database
	Eo	exabyte	monthly Internet traffic

Since and since storage is essentially binary, you often find the convention . The official symbols , ... never really caught on.


Historical Cost of Computer Memory and Storage
Price USD / MB
1e+09
1e+08
1e+07
1e+06
100000
10000
1000
100
10
1
0.1
0.01
0.001
0.0001
1e-05
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Flip-Flops
Core
ICs on board
SIMM
DIMM
Big drive
Floppy disk
Small drive
Flash stick / card
SSD
hblok.net/storage
Data collected by McCallum and Blok
BY SA

Seagate's average capacity of hard disk drives (HDDs) worldwide from FY2015 to FY2022, by quarter (in terabyte per drive)



Source
Seagate

Additional Information:
Worldwide; Seagate; 2015 to 2021

Storage

What is important for us to know ?

- storage is **faillible**
- writing and reading is **slow** (ms)
- **data is always cached** (copied / charged into memory) for computation

Storage

Storage is a limiting factor.

- on a given computer, **you can only store so much**
- dealing with **files distributed over multiple computers** is non-trivial

Cost and speed are usually not an issue.

Network

- information transfer is **time-consuming**
- usually not an issue on a personal computer:
  - processors and memory are **closely integrated** in the same circuits
  - physical connection between memory and disk is **short** and **fast**
- becomes an issue with **remote** (or **distributed**) storage (or computing)

Network

For transferring volumes above 1 Po (1000 To) to their servers, Amazon actually sends a truck, which is faster than a fast Internet connection.

IN THE NEXT SECTION

Each of the basic components of a computer can cause issues.

- disk space is a limiting factor -> consider **distributed storage**
- even when data is relatively small, computation can be a challenge
- memory size and number of processors are a limiting factor -> consider **distributed computing**

But distribution is **non-trivial** (future lesson) and often not needed. Always consider first:

- consider simple **good practices** (next section)
- consider commercial **remote**, **cloud-based services** (future lesson)