UNIMORE
UNIVERSITÀ DEGLI STUDI DI
MODENA E REGGIO EMILIA

Dipartimento di Scienze Fisiche,
Informatiche e Matematiche

2. I Computer: Astrazioni e Tecnologia

Architettura dei calcolatori [MN1-1143]

Corso di Laurea in INFORMATICA
(D.M.270/04) [16-215]
Anno accademico 2022/2023

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Perché la *computer science*?

- I computer sono **pervasivi**
- La loro continua evoluzione rende possibili applicazioni sempre nuove
  - *Dispositivi personali*
  - *Auto a guida autonoma, droni*
  - *Human brain project*
  - *World Wide Web/Internet, Cloud, IoT*
- Ciò è reso possible dal costante avanzamento della tecnologia
  - *Legge di Moore*

«the number of transistors in an IC doubles every two years»

Moore, G.E., *Cramming more components onto integrated circuits*. Electronics, 38(8), April 1965

Gordon E Moore (1929–)

Classi di Computer

- Personal computers
  - *General purpose, varietà di software*
  - *Trade-off costi/prestazioni*

- Server computers
  - *Network*
  - *Alta capacità (storage), performance, affidabilità*
  - *Da piccolo server privati ad interi edifici*

Classi di Computer

- Supercomputers
  - *Calcoli scientifici e ingegneristici ad alta richiesta di prestazioni*
  - *Prestazioni più alte in assoluto*
    - *Una frazione relativamente piccolo del totale mercato, ma sta crescendo…*

- Embedded computers
  - *Nascosti come component di un sistema*
  - *Vincoli di potenza/performance/costo stringenti*
  - *Requisiti di tipo Real-time e di affidabilità*

L'era Post PC

- Personal Mobile Device (PMD)
  - *Dispositivi a batteria (basso consumo)*
  - *Alta connettività (Internet and more)*
  - *Centinaia di euro (basso costo)*
  - *Smart phones, tablets, electronic glasses*

- Cloud computing
  - *Warehouse Scale Computers (WSC)*
  - *Software as a Service (SaaS)*
  - *Portion of software run on a PMD and a portion run in the Cloud*
  - *Amazon, Microsoft, Google*

Data Center

Microsoft Data Center eastern US - 2017

Getting bigger

Planned expansion: 2km long…

Tipi di Computer

SERVER

LAPTOP
NOTEBOOK
ULTRABOOK

DESKTOP

SMARTPHONE

TABLET

SMARTWATCH
SMARTBAND

Dimensioni maggiori
Alti consumi
Maggiore performance

Dimensioni ridotte
Basso consumo
Minore performance

Tipi di Computer

SERVER

DESKTOP

LAPTOP
NOTEBOOK
ULTRABOOK

INTERNET OF THINGS (IoT)

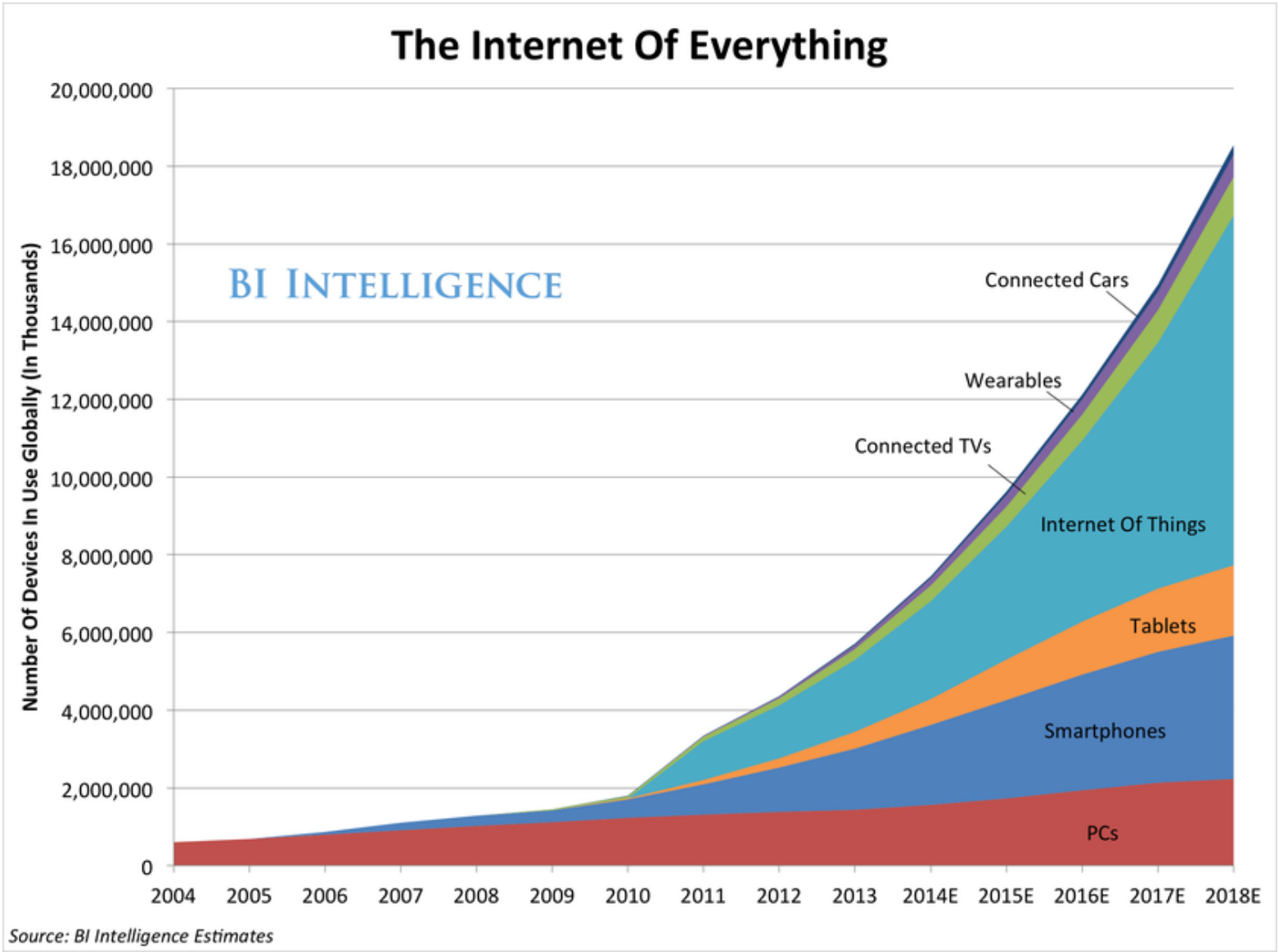
SMARTPHONE

TABLET

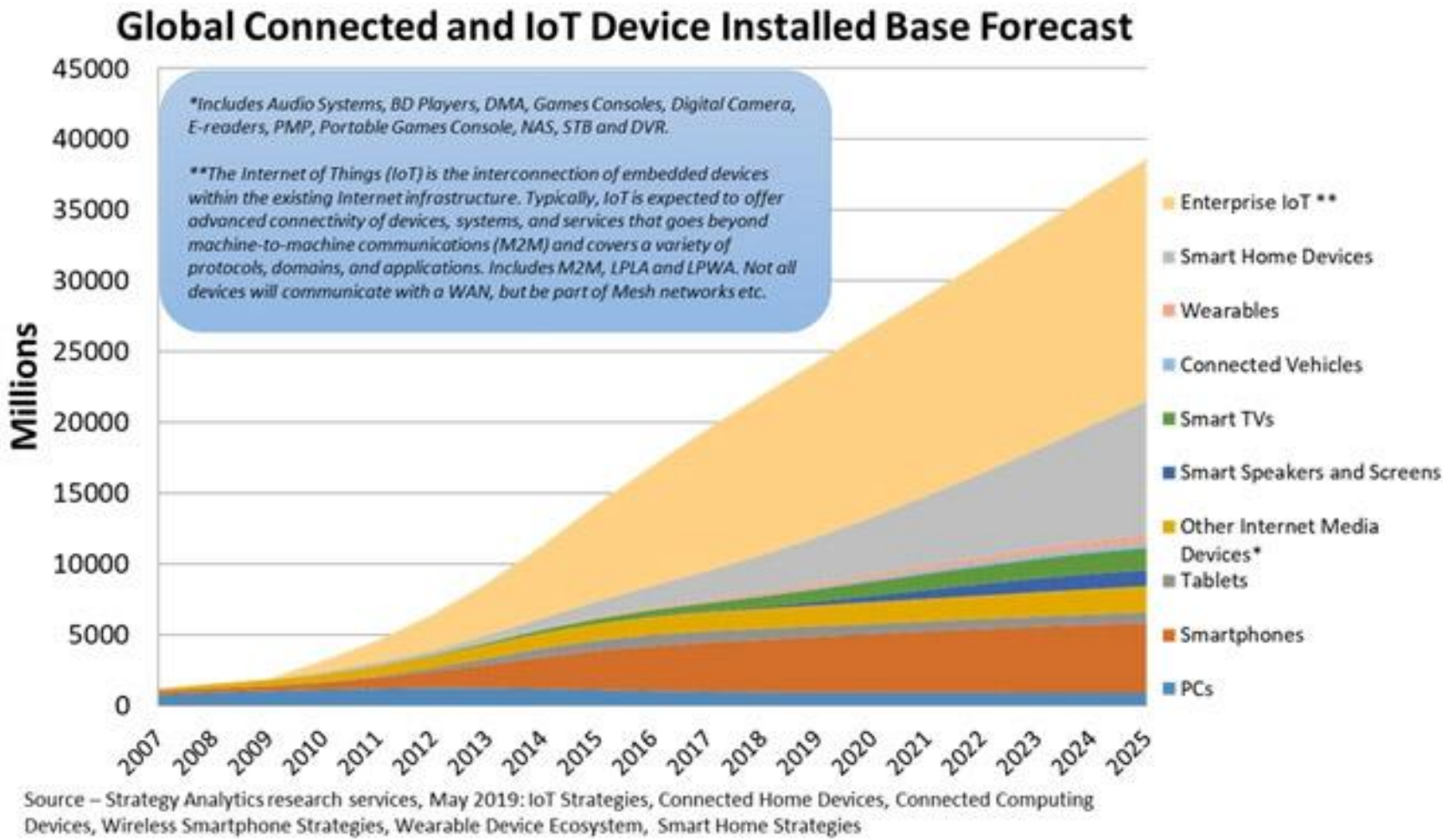
SMARTWATCH
SMARTBAND

CLOUD COMPUTING

L'era Post PC – la visione del 2013



L'era Post PC – la visione odierna



Source – Strategy Analytics research services, May 2019: IoT Strategies, Connected Home Devices, Connected Computing Devices, Wireless Smartphone Strategies, Wearable Device Ecosystem, Smart Home Strategies

Perché la *computer science*?

- In breve…
- I computer sono **pervasivi** e **onnipresenti** in tutti gli aspetti della nostra vita quotidiana
- **Lo studio** di come sono progettati e programmati i computer è **fondamentale** in un mondo (e un mercato) che è dominato da questa tecnologia

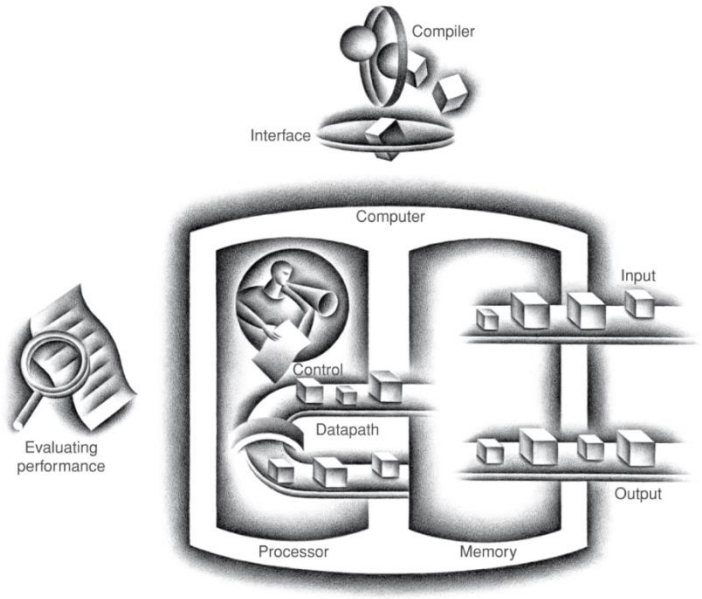
Perché la *computer science*?

- Ma cosa c'è dentro a un computer?
- E i vari tipi di computer sono tanto diversi tra loro?

Perché la *computer science*?

- **Ma cosa c'è dentro a un computer?**
- E i vari tipi di computer sono tanto diversi tra loro?

Cosa c'è dentro a un computer?

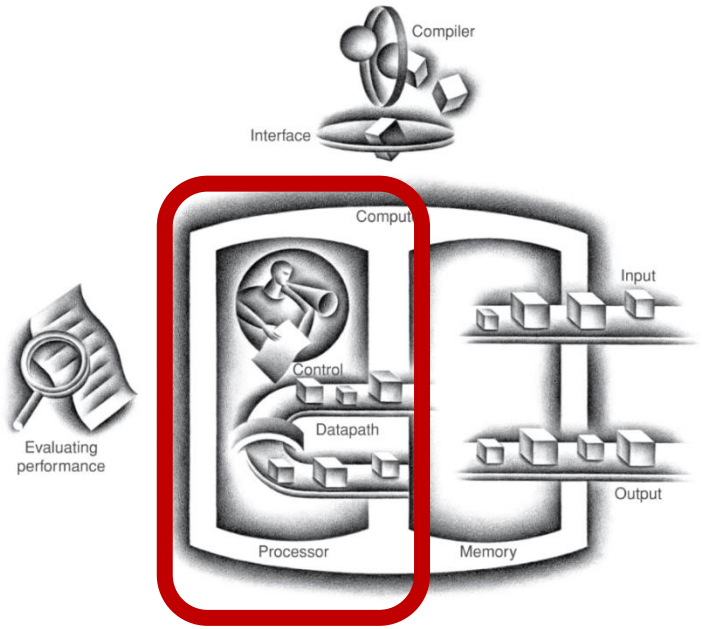


Componenti di un computer

- **[SPOILER]** Gli stessi per tutti i tipi di computer
  - *Desktop, server, embedded*

- **Processore**
- **Memoria**
- **Input/Output (I/O)**

Cosa c'è dentro a un computer?

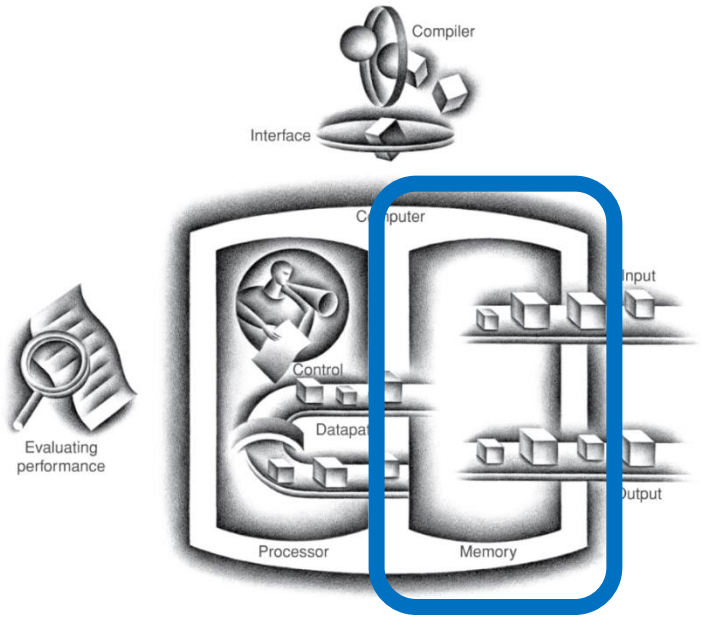


Componenti di un computer

- **[SPOILER]** Gli stessi per tutti i tipi di computer
  - *Desktop, server, embedded*

- **Processore**
  - Central Processing Unit (**CPU**)
  - Il cuore di un computer: processa i dati in *input* per produrre l'*output*
  - **Datapath**: esegue le operazioni sui *dati*
  - **Control**: controlla il funzionamento del datapath, memoria, ...

Cosa c'è dentro a un computer?



Componenti di un computer

- **[SPOILER]** Gli stessi per tutti i tipi di computer
  - *Desktop, server, embedded*

- Memoria
  - Organizzata come una ***gerarchia***
    - Performance/capacity/cost tradeoff
    - La ***DRAM*** è capiente, ma leeenta…
    - I ***registri*** (SRAM[1]) sono veloci quanto la CPU, ma piiiccoli…
  - La **cache** memory sta in mezzo
    - SRAM

1. SRAM is faster but less dense, and hence more expensive, than DRAM

Cosa c'è dentro a un computer?

E se spengo il computer?

- La memoria principale (DRAM) è *volatile*
  - Perde tutta l'informazione quando spengo il PC

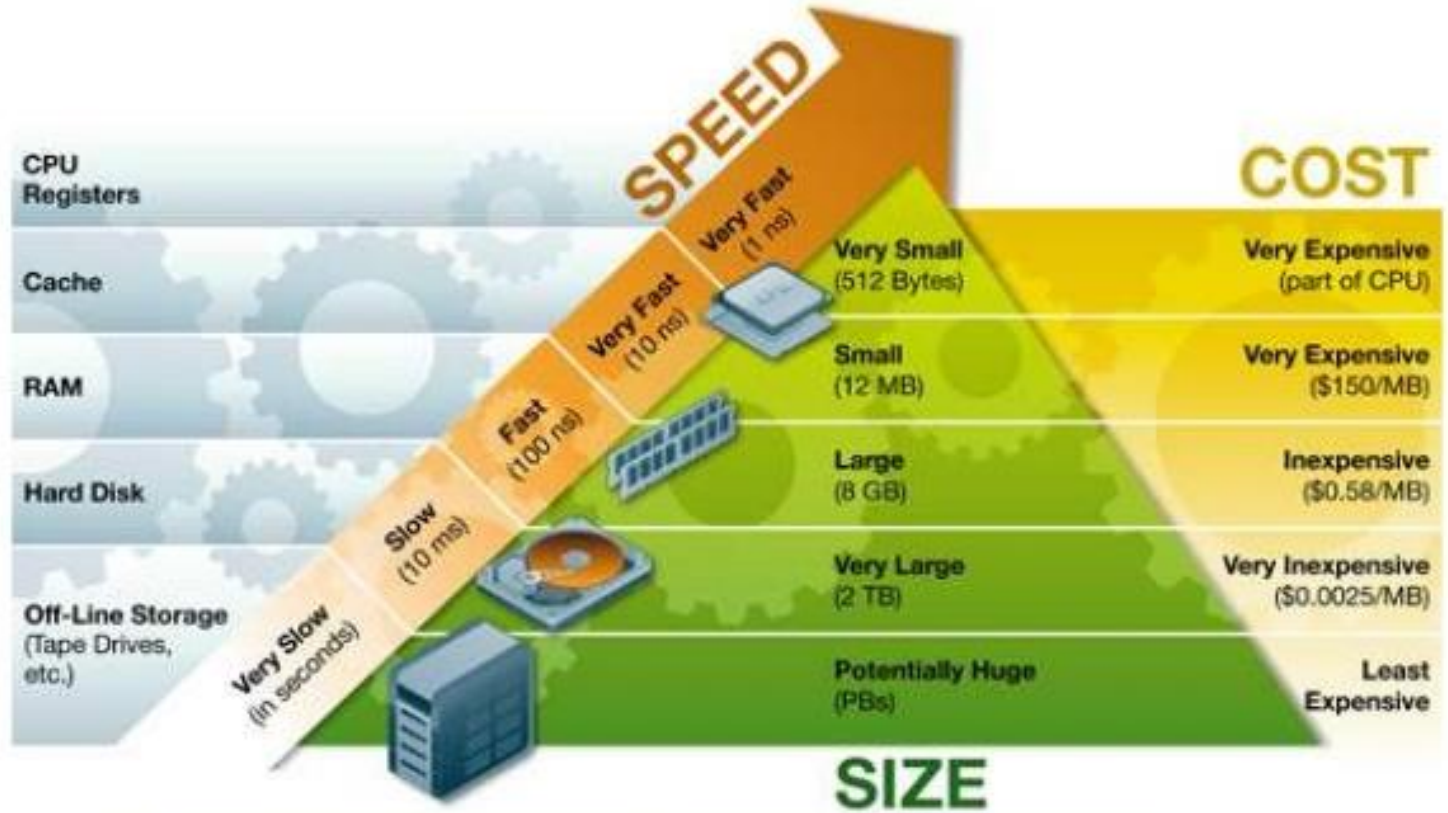
- HARD DISK – Memoria secondaria non-volatile
  - Magnetic disk (HDD)
  - Flash memory (SD, SSD)
  - Optical disk (CDROM, DVD)

HDD

SSD

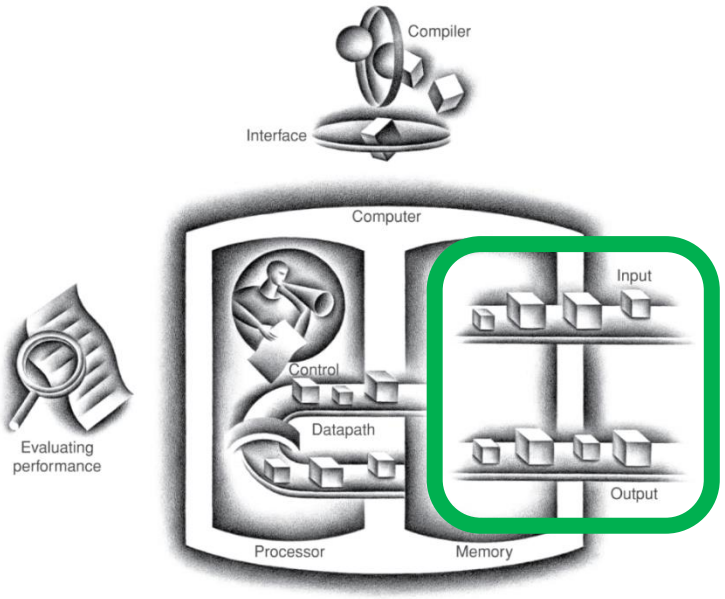
Cosa c'è dentro a un computer?

The memory hierarchy



Source: http://www.ts.avnet.com/uk/products_and_solutions/storage/hierarchy.html

Cosa c'è dentro a un computer?



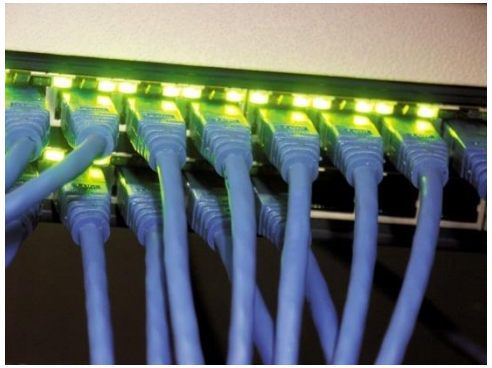
Componenti di un computer

- **[SPOILER]** Gli stessi per tutti i tipi di computer
  - *Desktop, server, embedded*
- Input/output (I/O)
  - ***Storage devices***
    - *Hard disk, CD/DVD, flash*
  - ***User-interface devices***
    - *Display, keyboard, mouse*
  - ***Network adapters***
    - *For communicating with other computers*

Cosa c'è dentro a un computer?

Network adapters

- Communication, resource sharing, nonlocal access
- Local area network (LAN)
  - Ethernet (10/100 Gbit/s)
- Wide area network (WAN): the Internet
- Wireless network (IEEE 802.11)
  - WiFi, Bluetooth → 1-100 Mbit/s

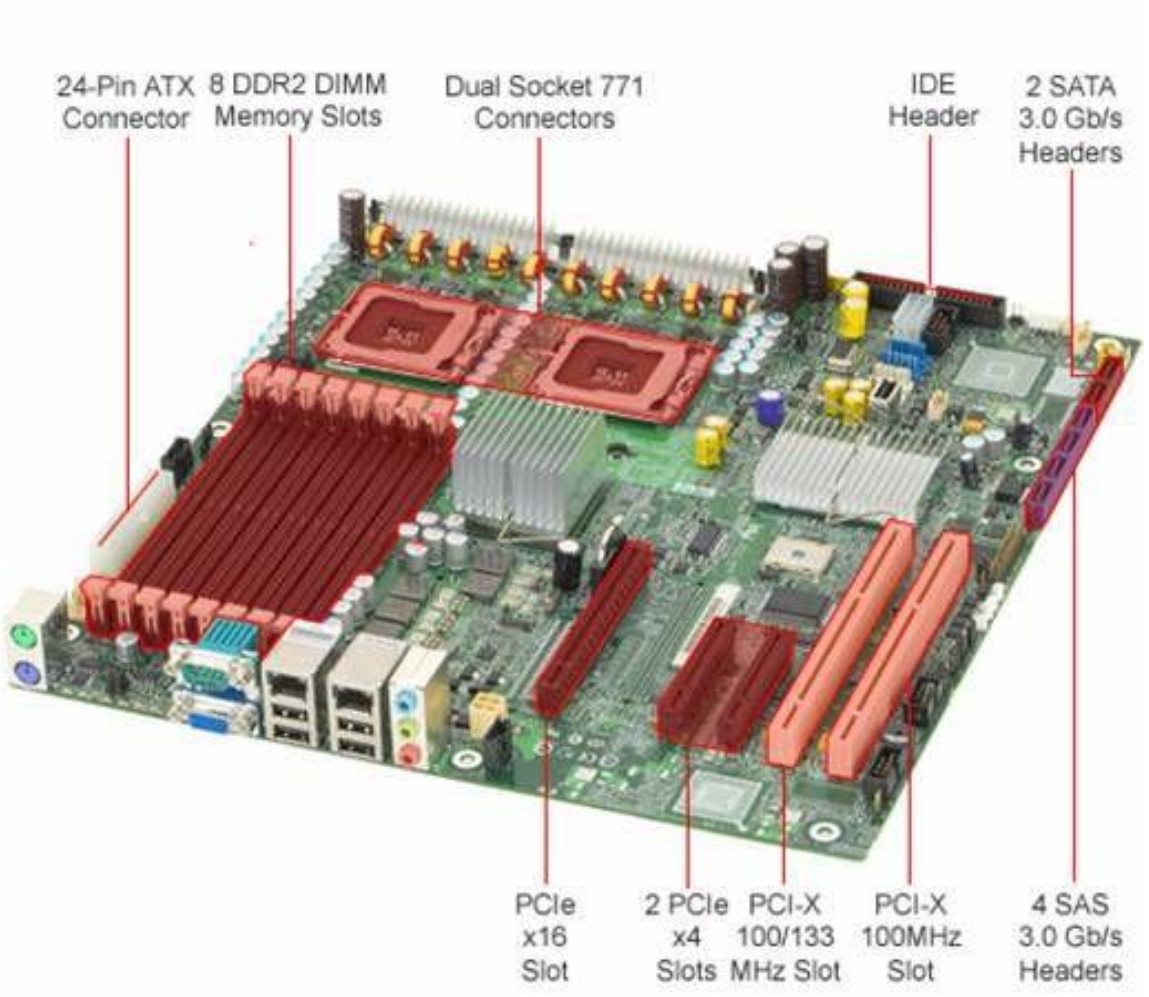


Perché la *computer science*?

- Ma cosa c'è dentro a un computer?
- **E i vari tipi di computer sono tanto diversi tra loro?**

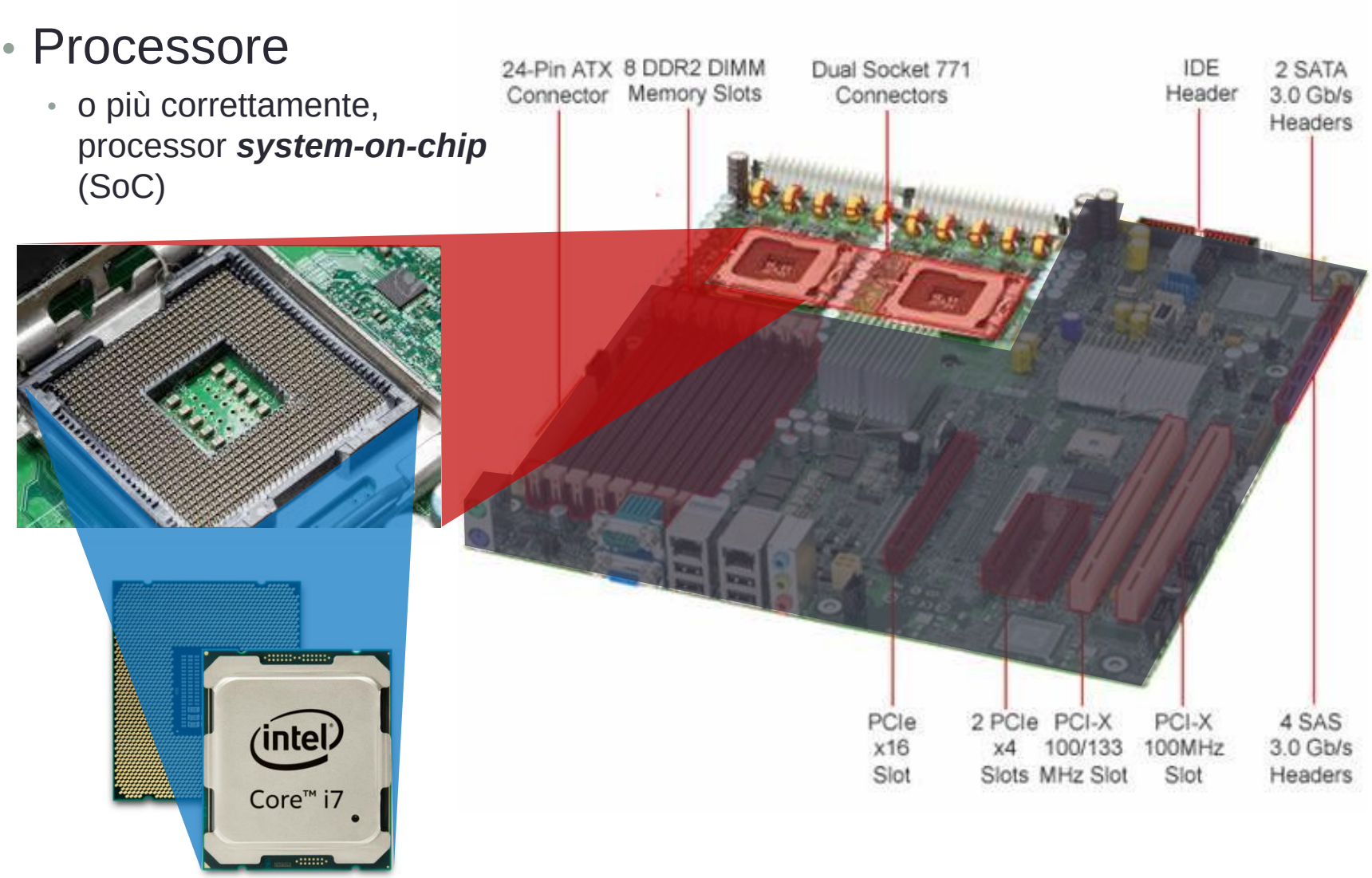
Anatomia di un PC

- Desktop PC
- SCHEDA MADRE

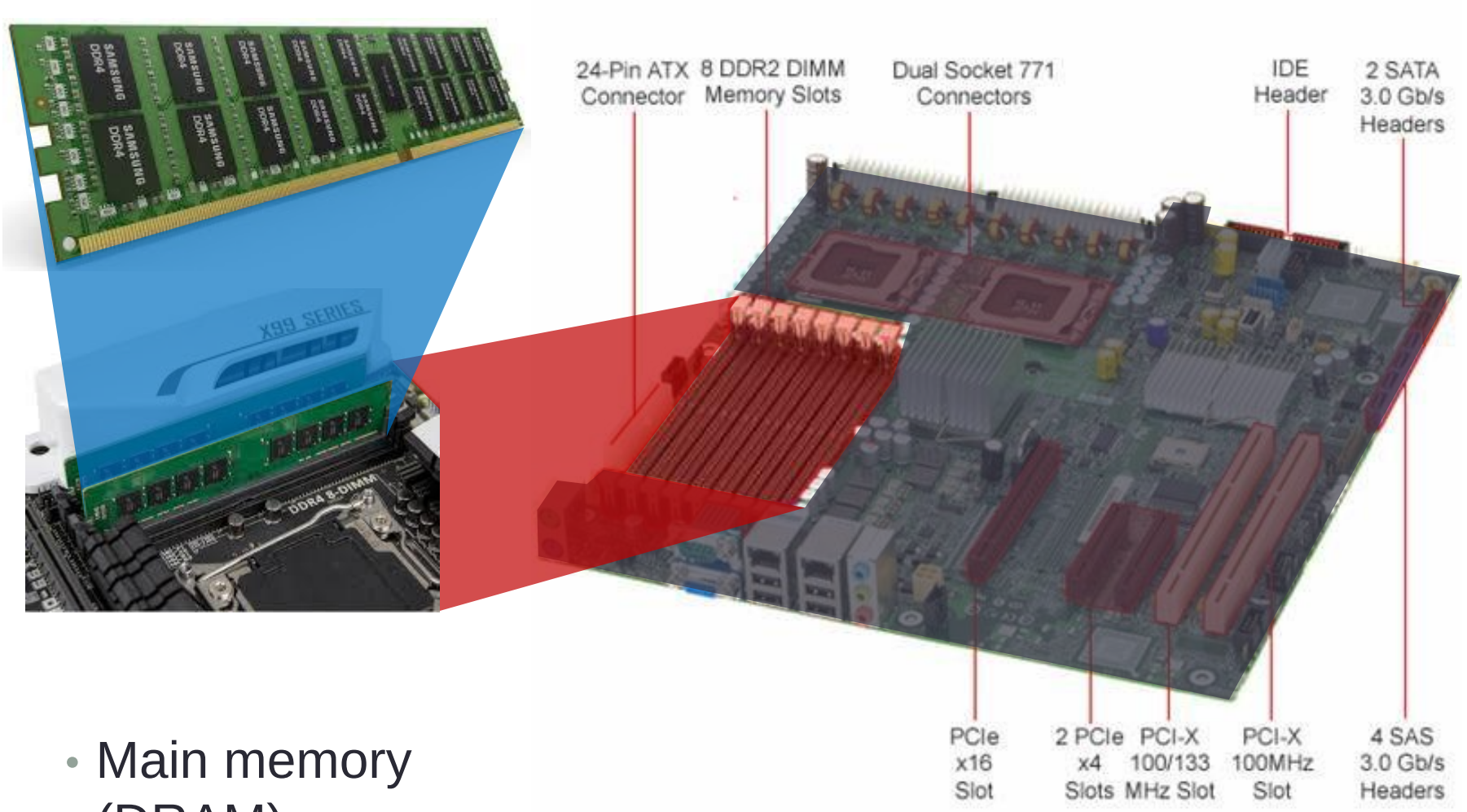


Anatomia di un PC

- Processore
  - o più correttamente, processor ***system-on-chip*** (SoC)



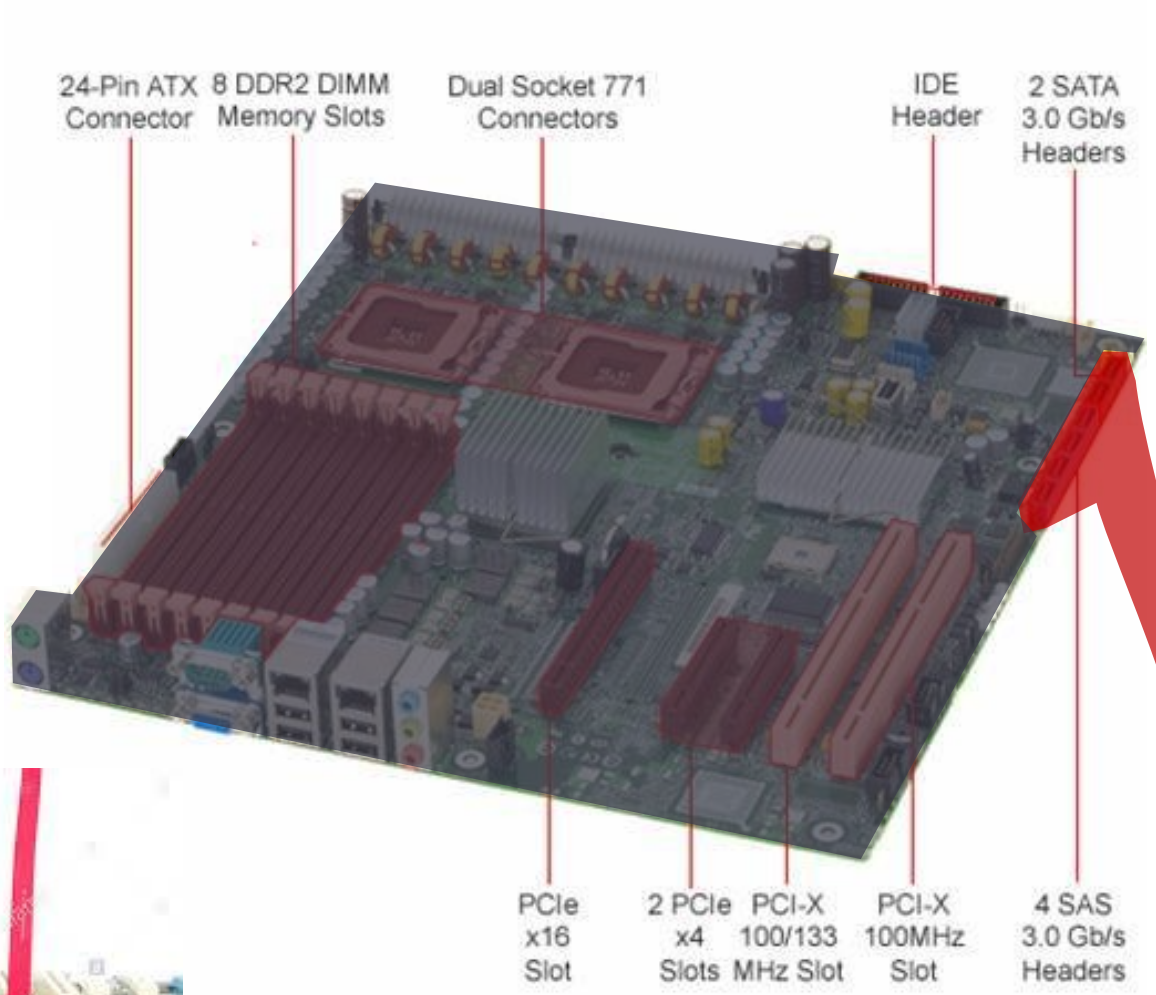
Anatomia di un PC



- Main memory (DRAM)

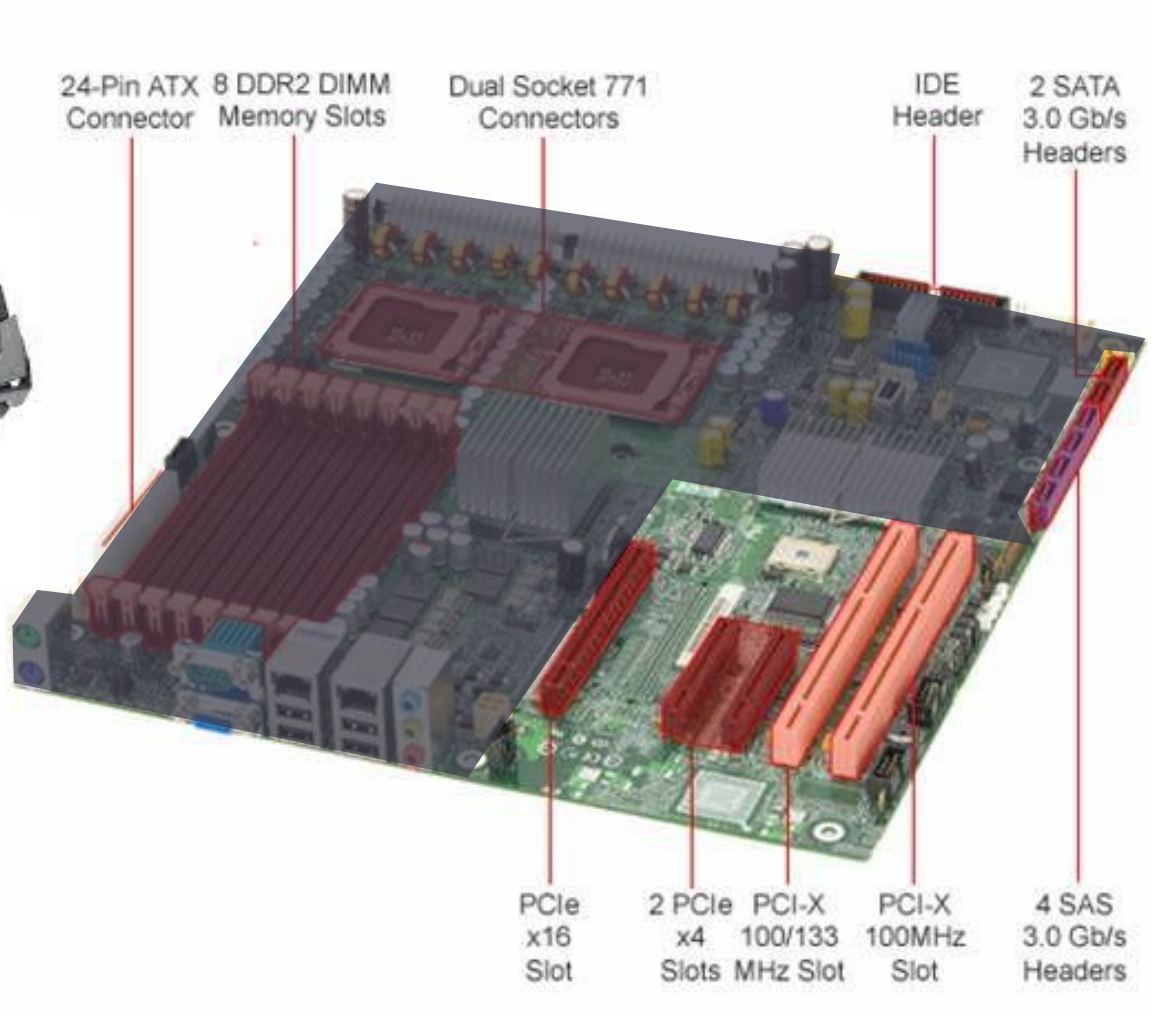
Anatomia di un PC

- HARD DISK (solid state disk)



Anatomia di un PC

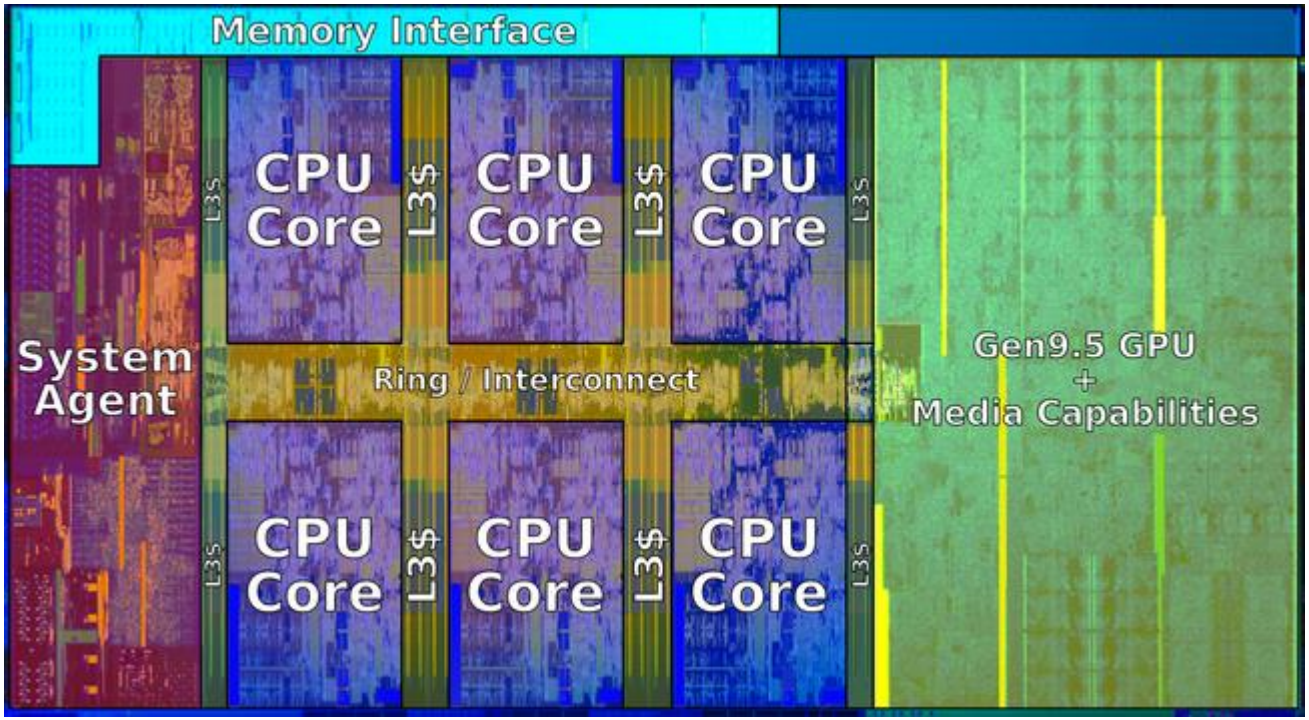
- GPU
  - graphics acceleration



Anatomia di un PC

E cosa c'è dentro al **Processor SoC?**

- Coffee Lake *system-on-chip (2018)*
- **Processo a 14nm**
- **Multi-Core (2 to 8) CPU**
- **GPU**
- **Media**



Anatomia di un Tablet

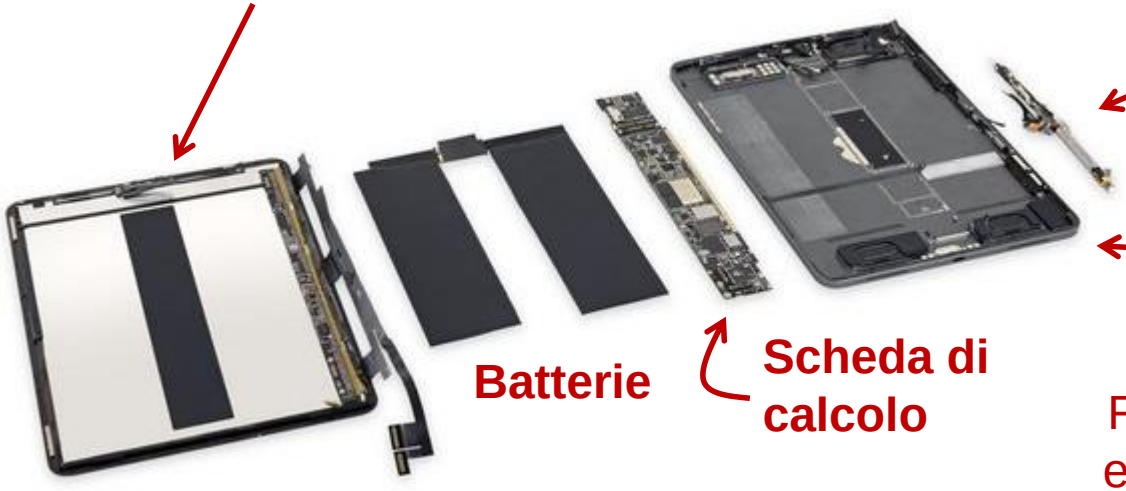
- Un dispositivo dell'era **PostPC**
- Touchscreen
  - rimpiazza keyboard e mouse
  - di tipo Capacitivo
    - consente multipli punti di "tocco" simultaneamente

iPad Pro 11", 2018

Anatomia di un Tablet

Display TFT da 11" Liquid Retina
2388×1668 (264 ppi)

Apple pencil

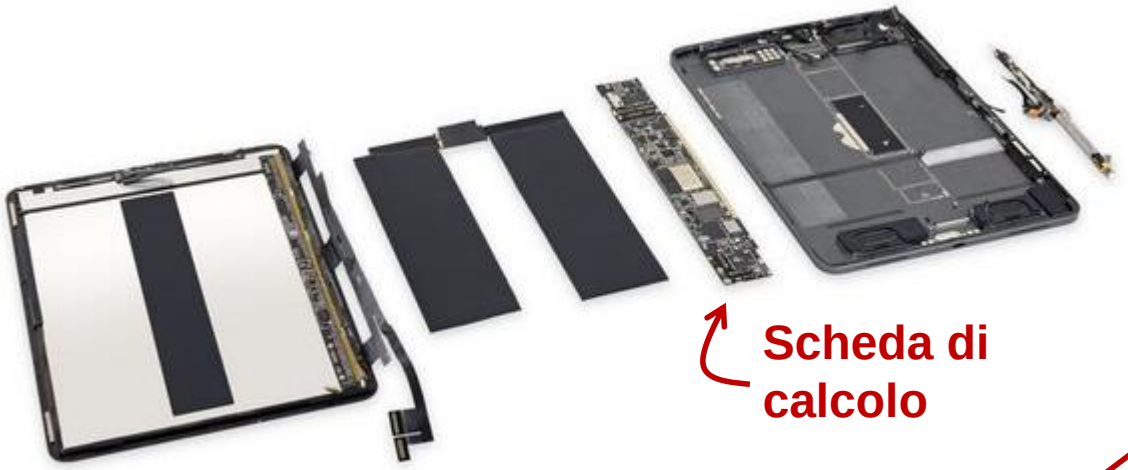


Batterie

Scheda di calcolo

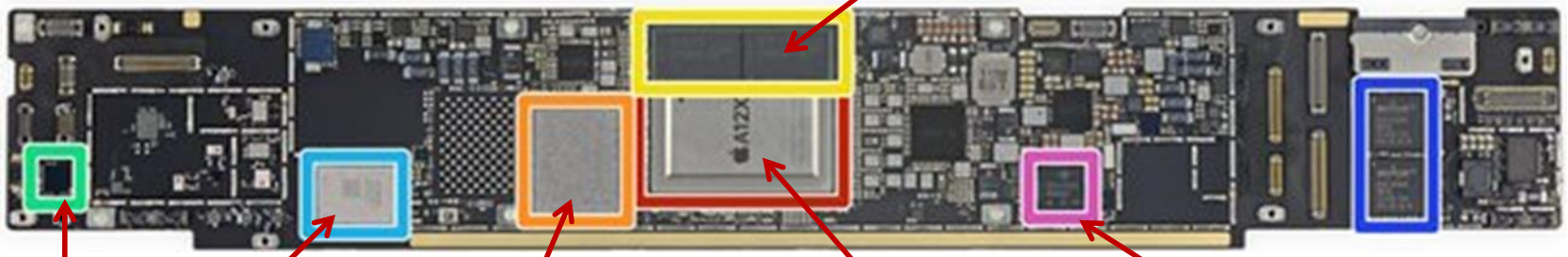
Fotocamera posteriore da 12 MP e fotocamera TrueDepth da 7 MP
quattro altoparlanti, Face ID,
cinque microfoni, sensore luce ambiente, accelerometro,
barometro e giroscopio a tre assi
Wi-Fi + Bluetooth 5.0

Anatomia di un Tablet



Scheda di calcolo

2x RAM (4 GB)



Power, I/O controllers

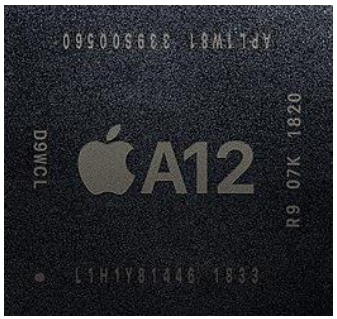
HARD DISK Flash 64 GB

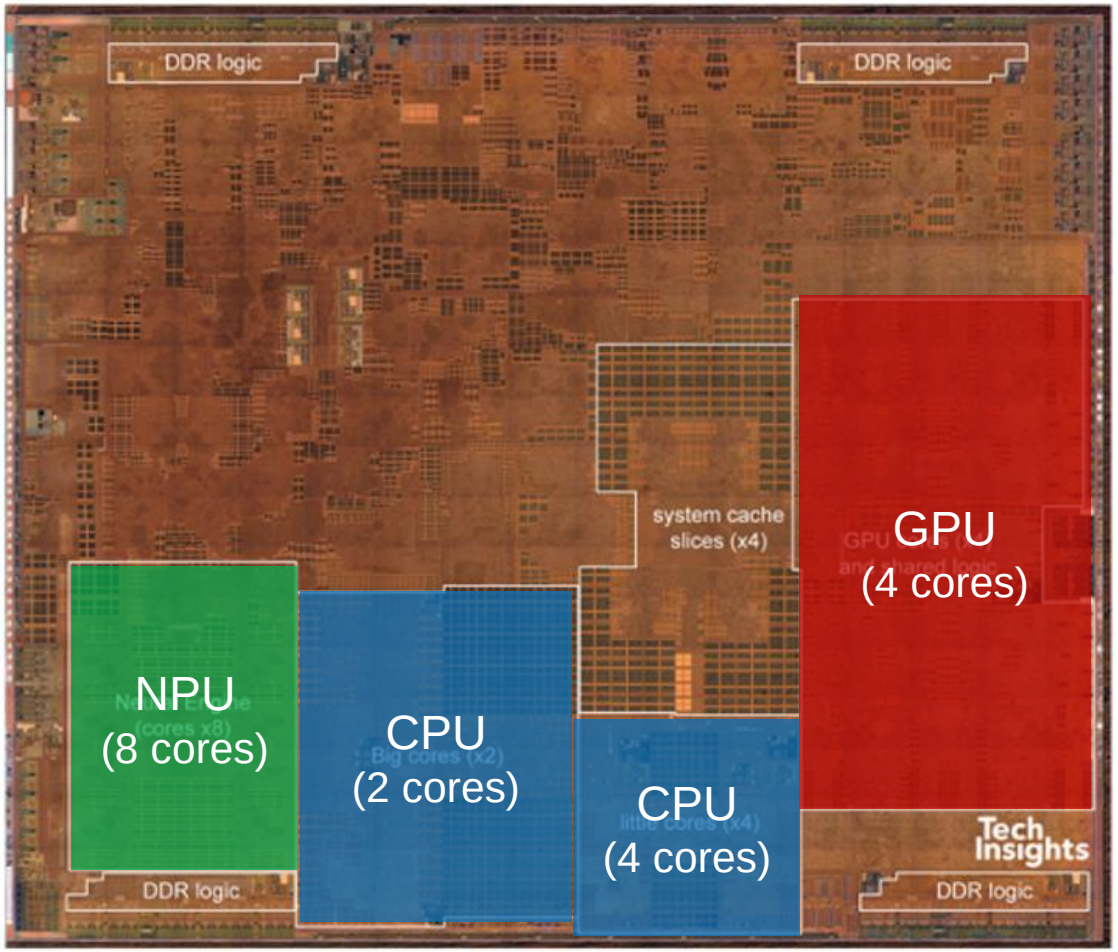
Processor SoC

Anatomia di un Tablet

E cosa c'è dentro al **Processor SoC?**

- Apple A12 Bionic *system-on-chip*
  - **83,27 mm²**
    - (8,42 mm x 9,89 mm)
  - **Processo a 7nm**
  - **6,9 miliardi di transistor**
  - **Hexa-Core (6) CPU**
    - 2 (Vortex) @2,49GHZ
    - 4 (Tempest) @1,49GHz
  - **4-Core GPU**
  - **8-Core NPU**

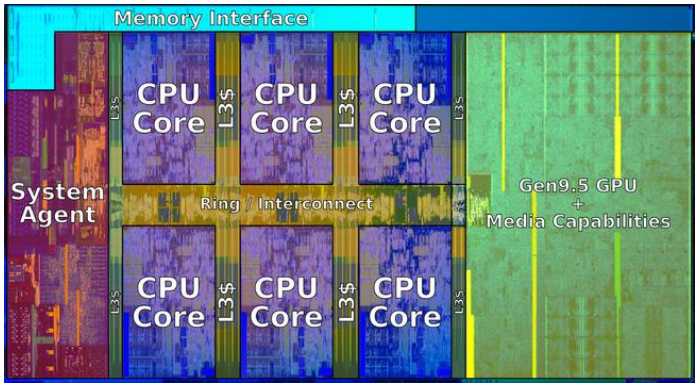




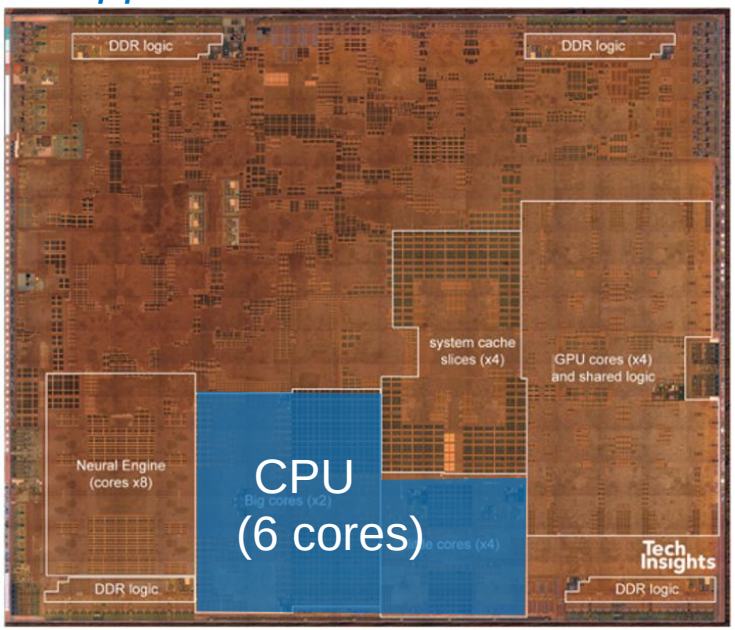
La CPU: l'implementazione dell'ISA

- Vi ricordate i **Processor SoC** del PC e del Tablet?
  - Ognuno con tante CPU

Intel i7 Coffee Lake SoC



Apple A12 Bionic SoC



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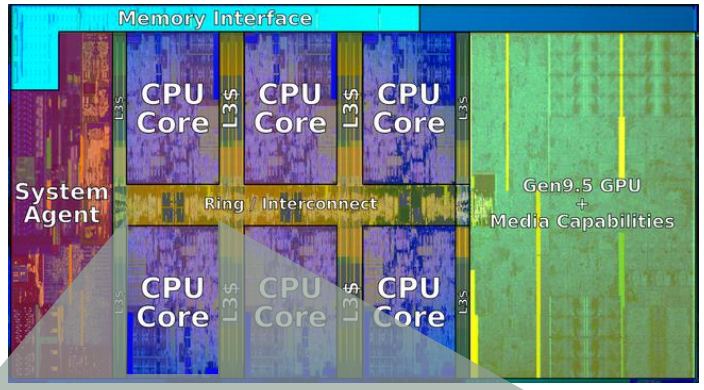

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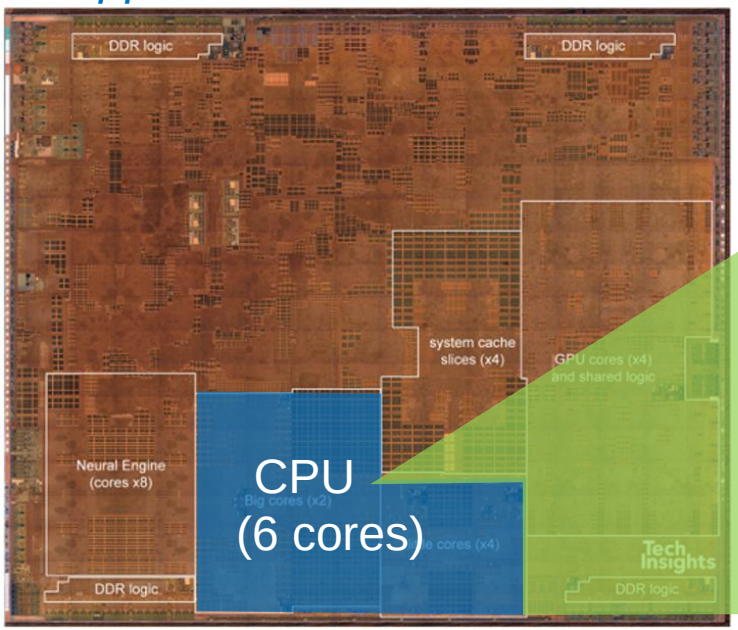
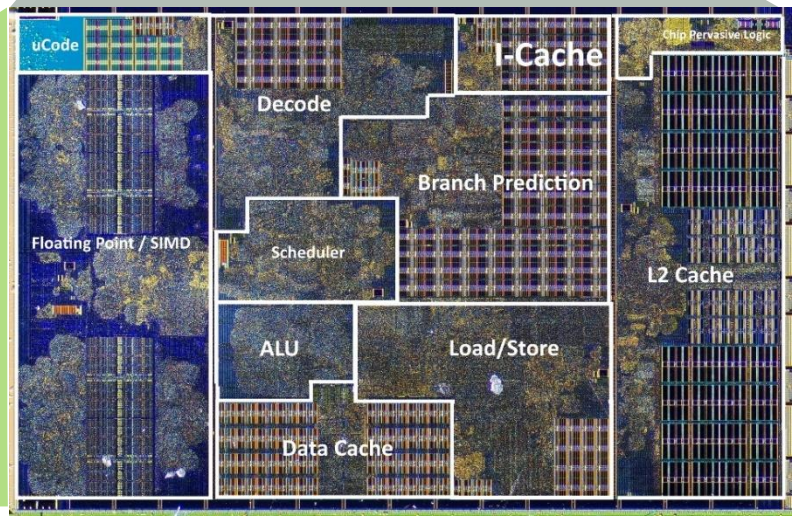


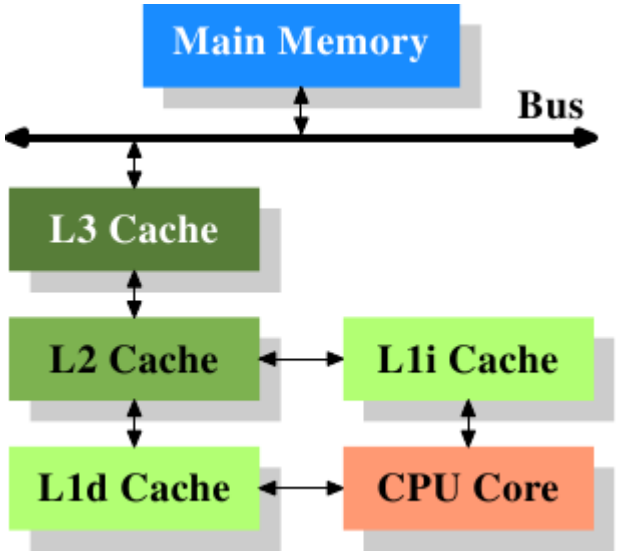


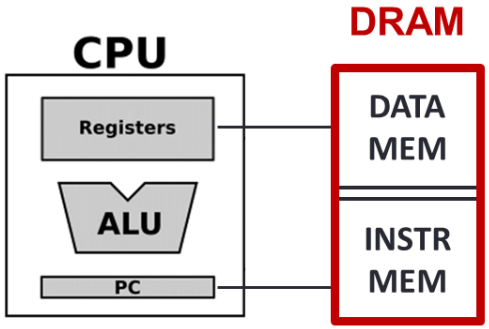
AMD Zen2 core

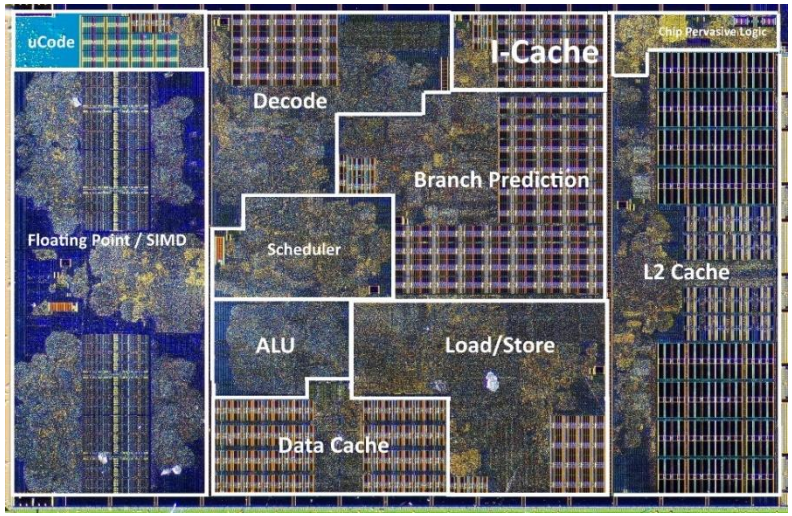
ATTENZIONE: non è la CPU di nessuno dei SoC

La CPU: l'implementazione dell'ISA

- E vi ricordate la **gerarchia di memoria**?







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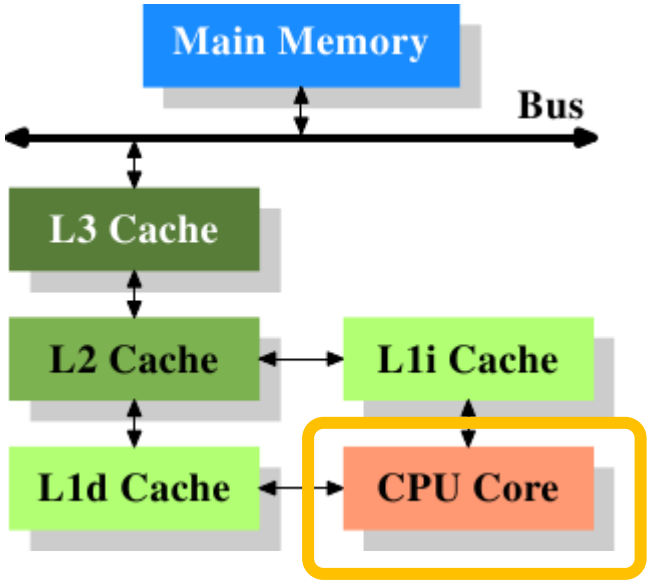

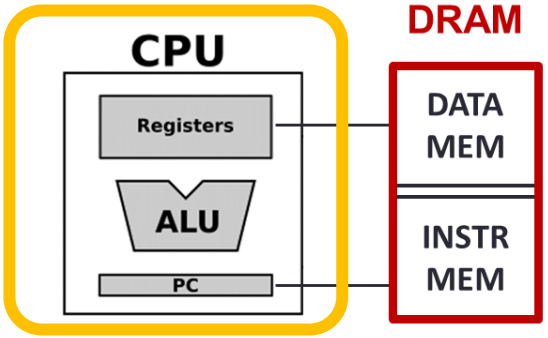

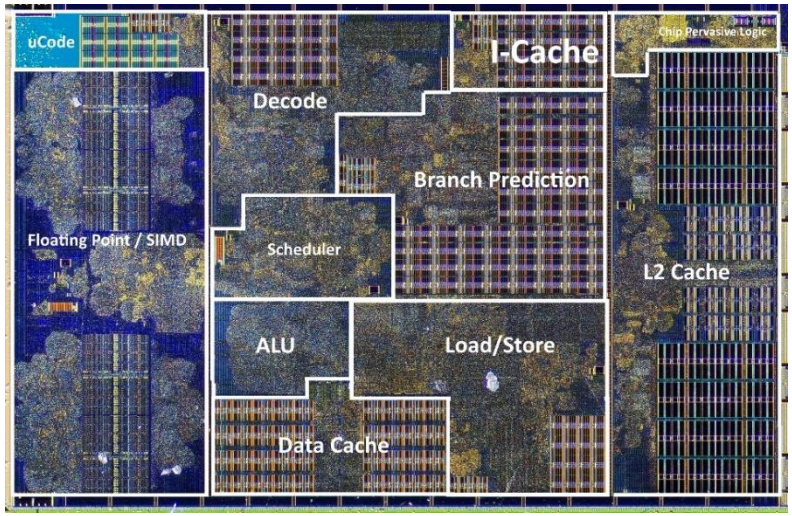

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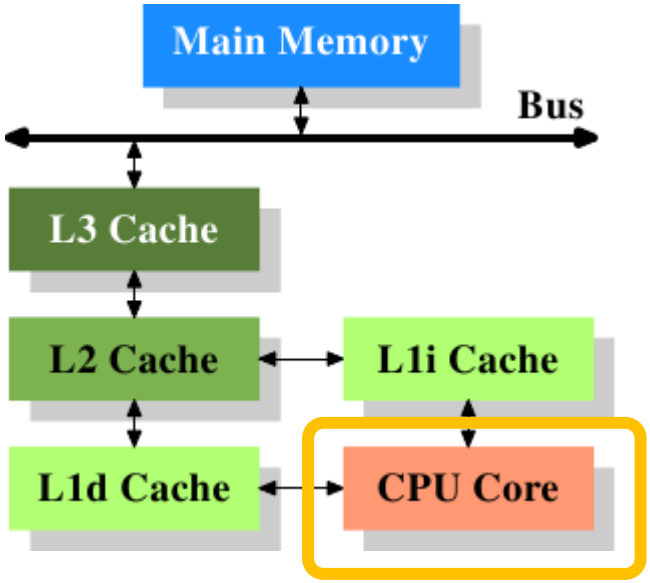

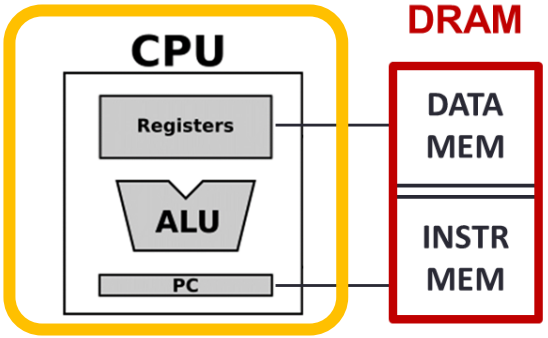

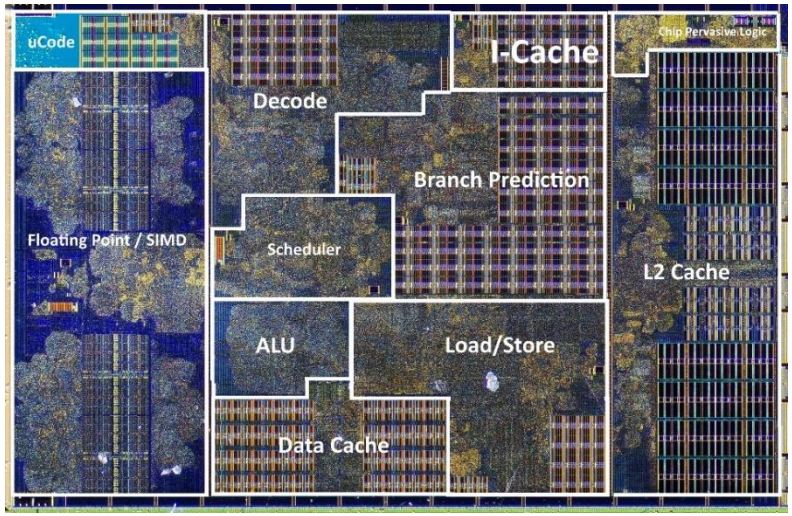

AMD Zen2 core

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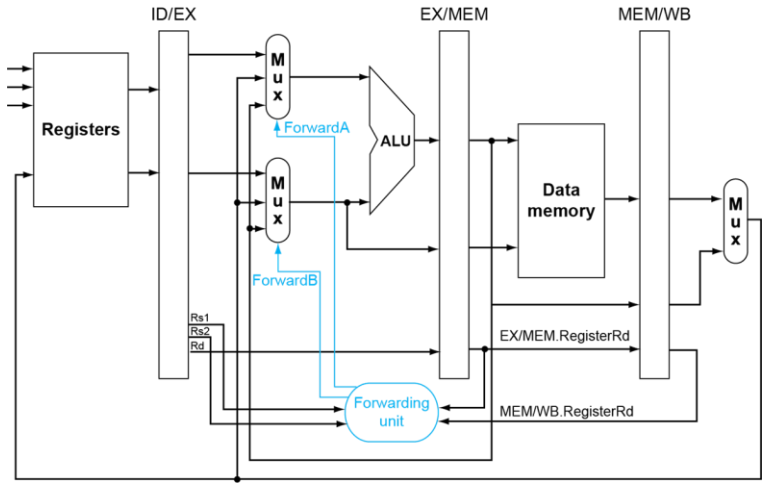
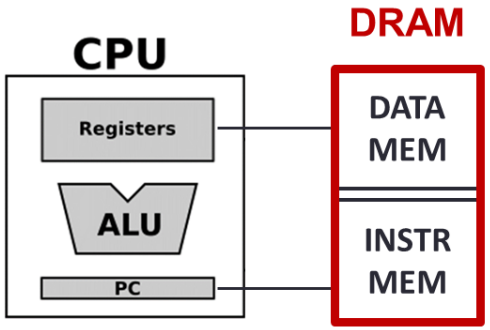
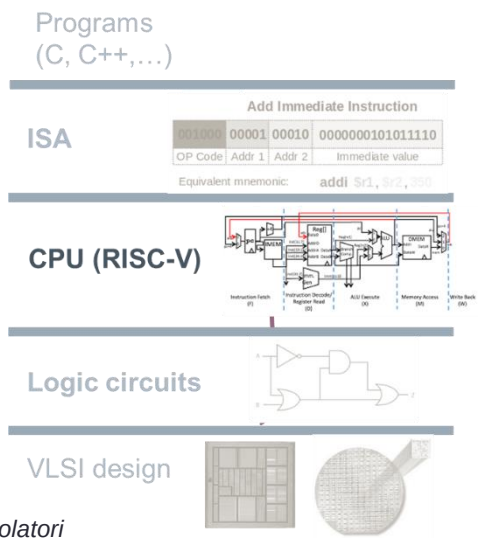
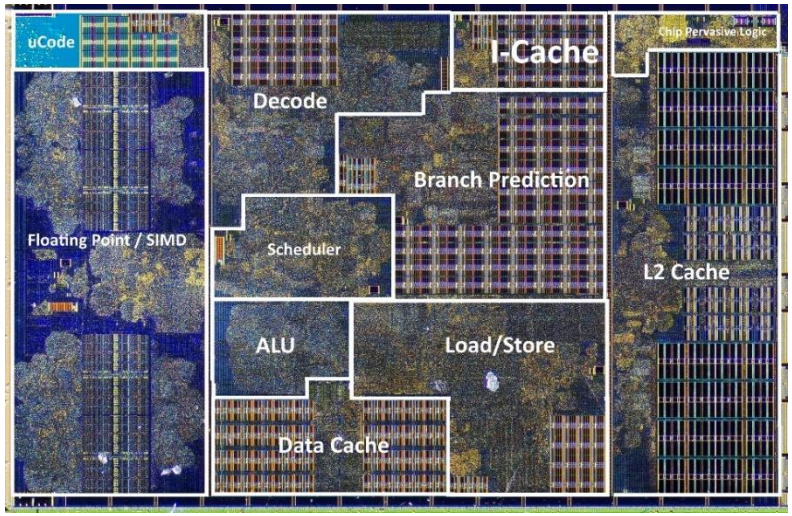


- **CPU PIPELINE**
  - ALU
  - Registers
  - Data mem







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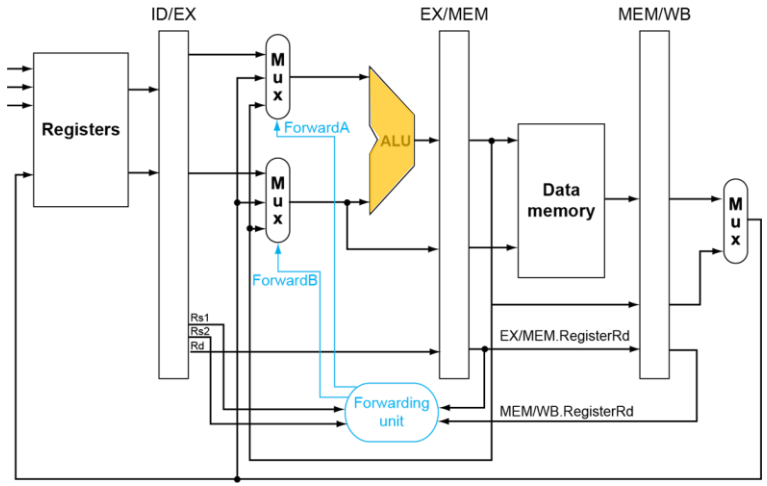

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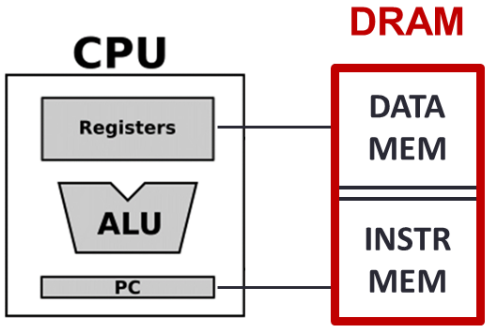
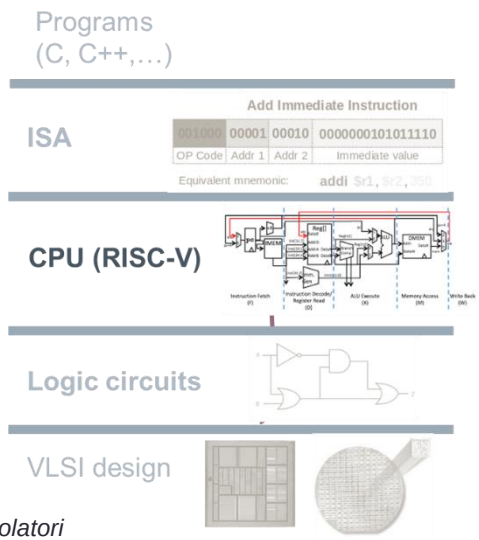
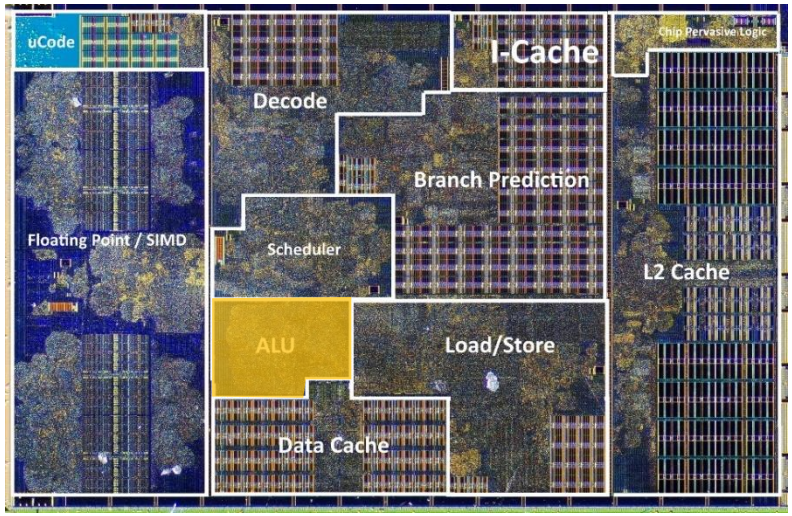
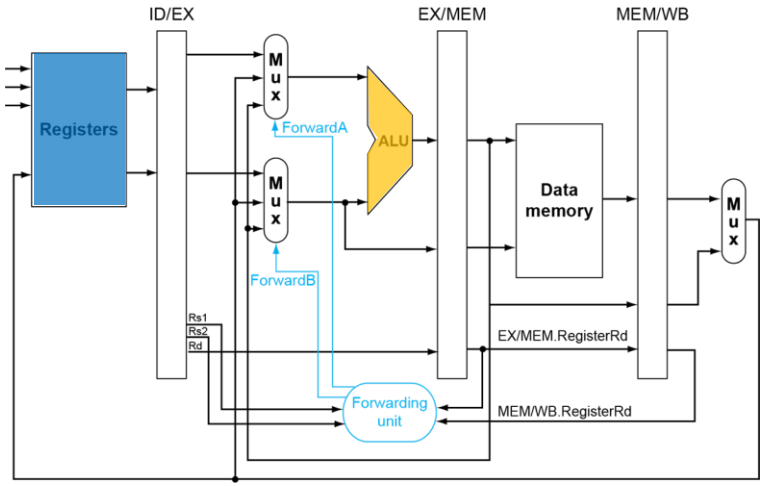




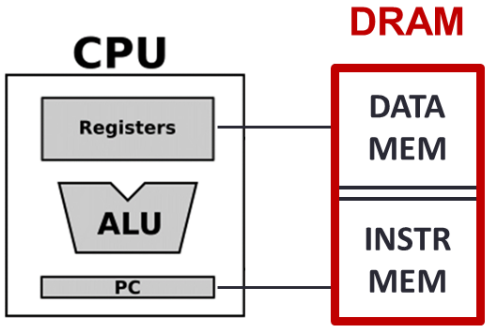


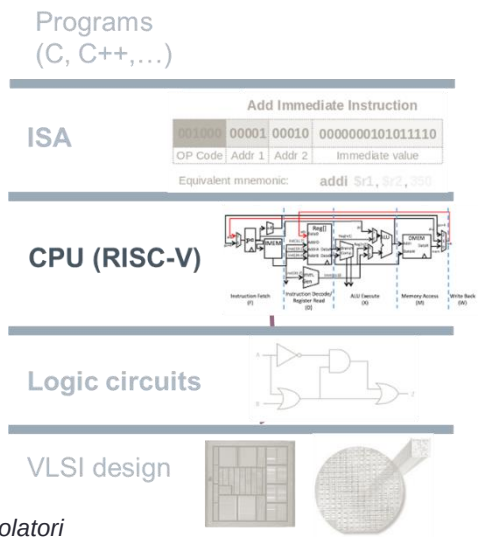
AMD Zen2 core

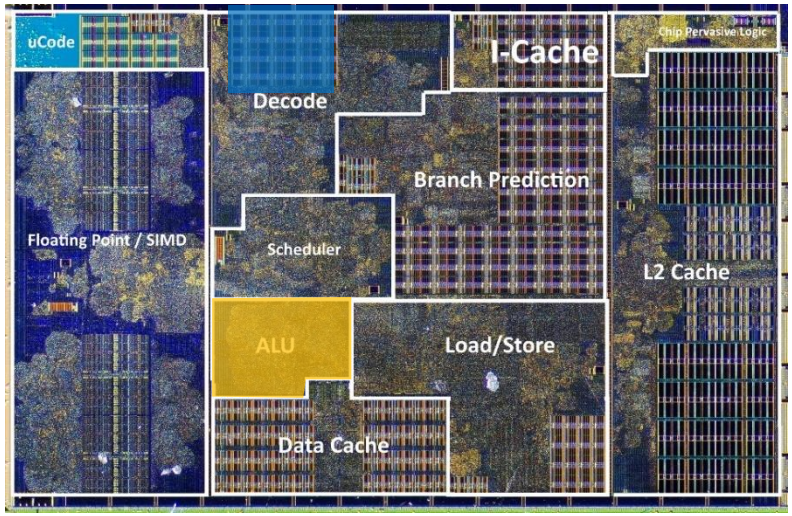
La CPU: l'implementazione dell'ISA



- **CPU PIPELINE**
  - ALU
  - Registers
  - Data mem







AMD Zen2 core

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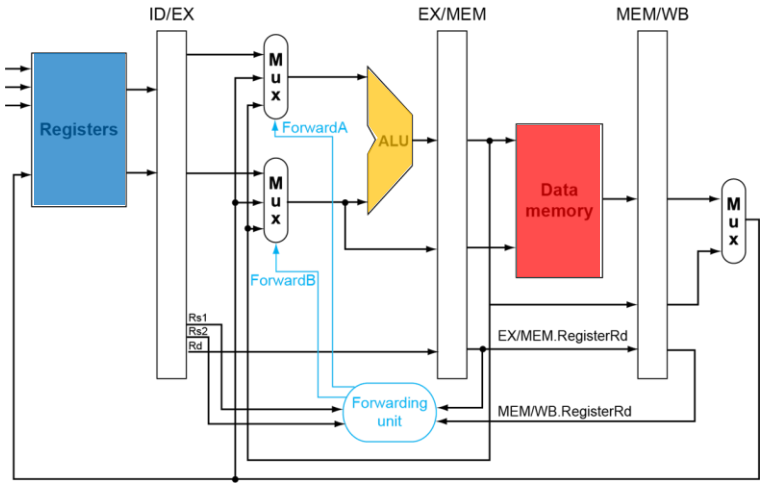

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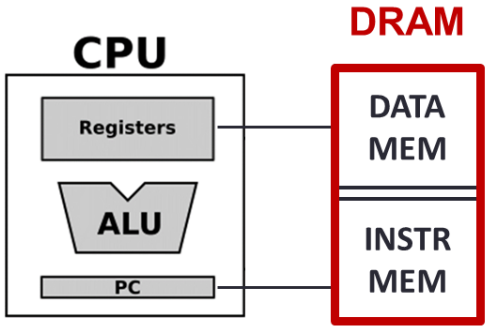
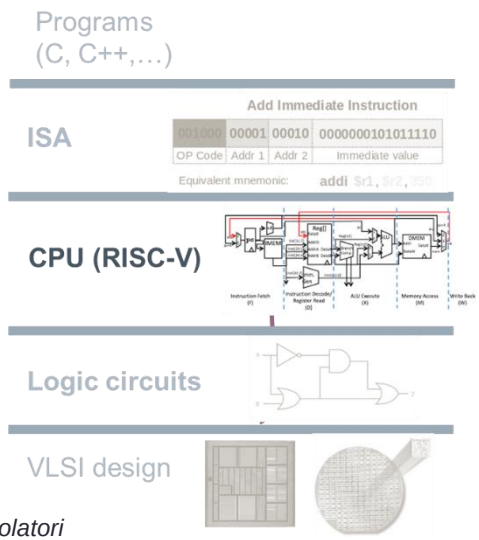
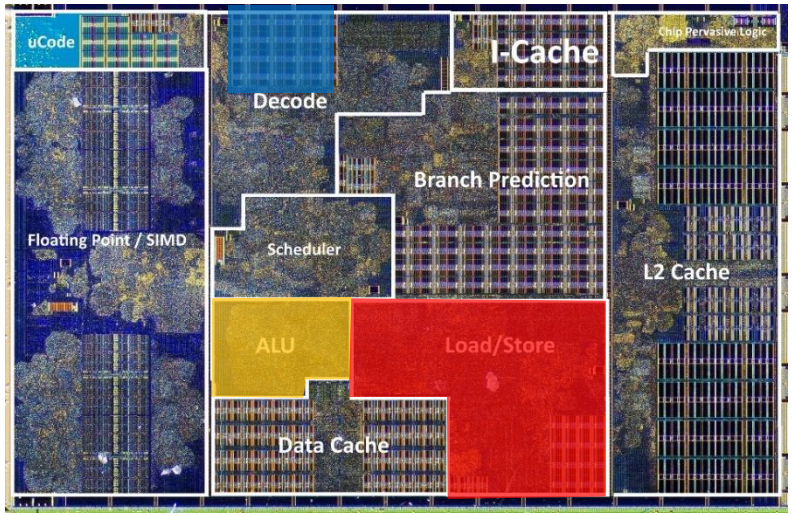


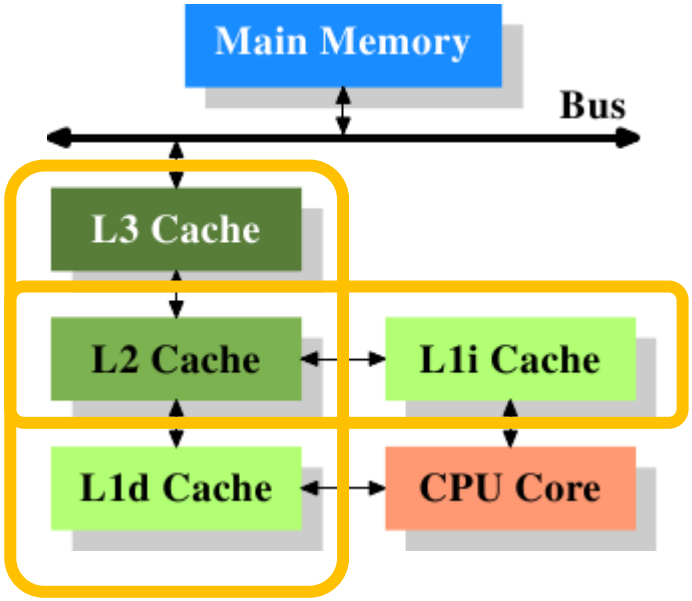


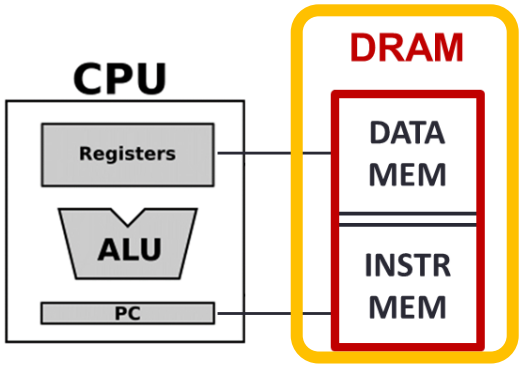


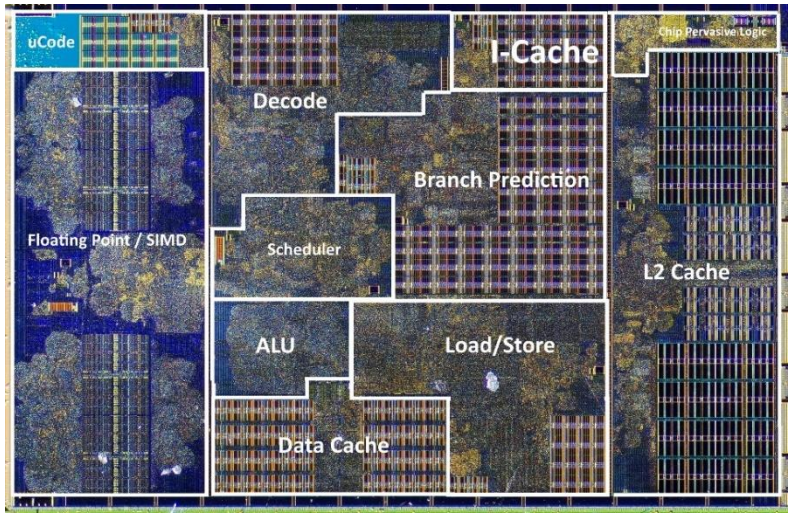
AMD Zen2 core

La CPU: l'implementazione dell'ISA

- E vi ricordate la **gerarchia di memoria**?







AMD Zen2 core

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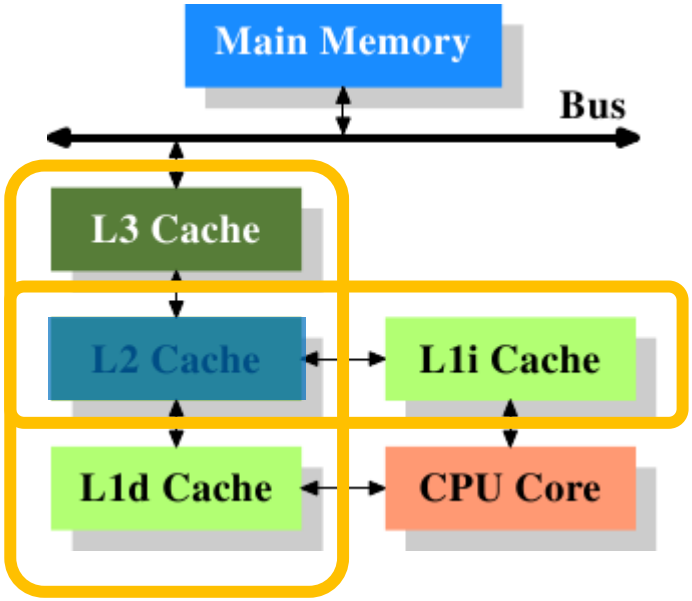

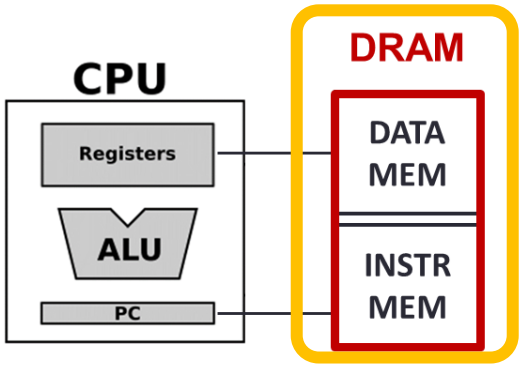

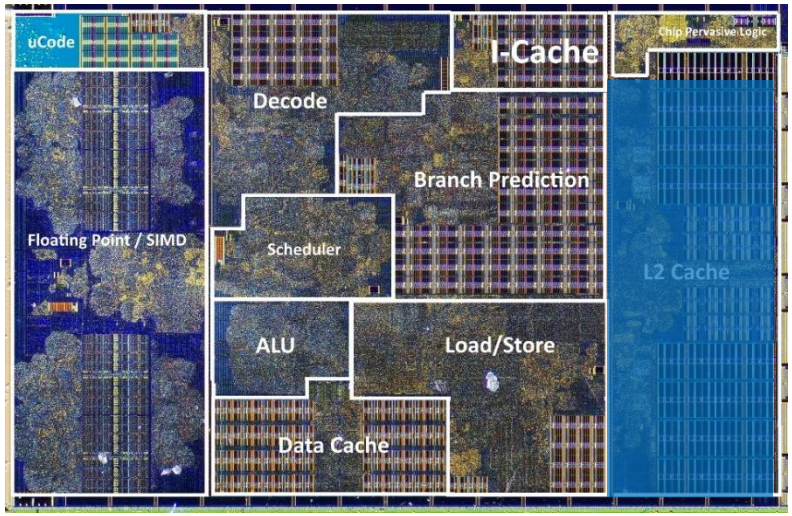

AMD Zen2 core

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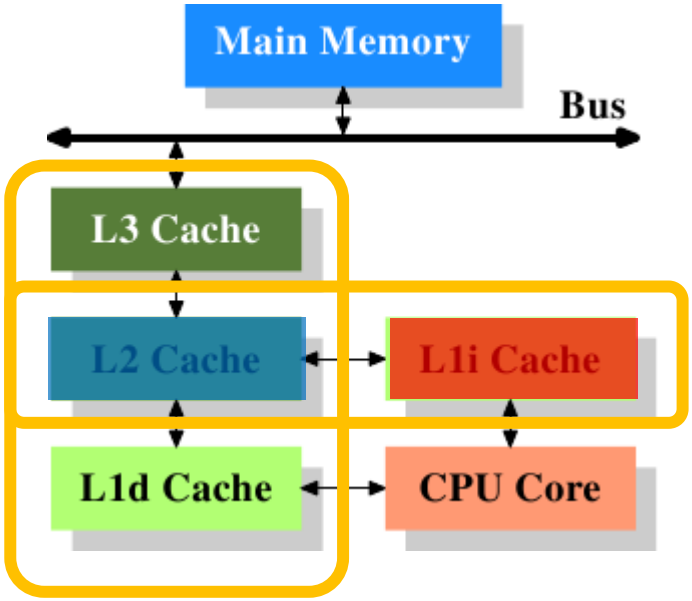

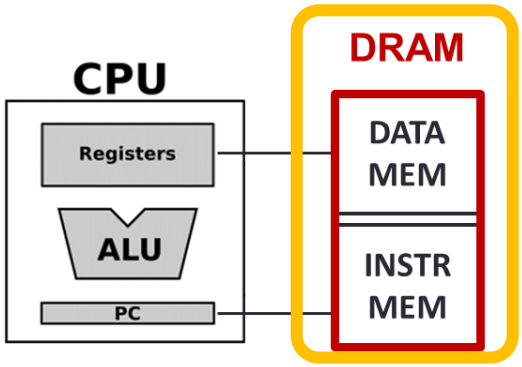

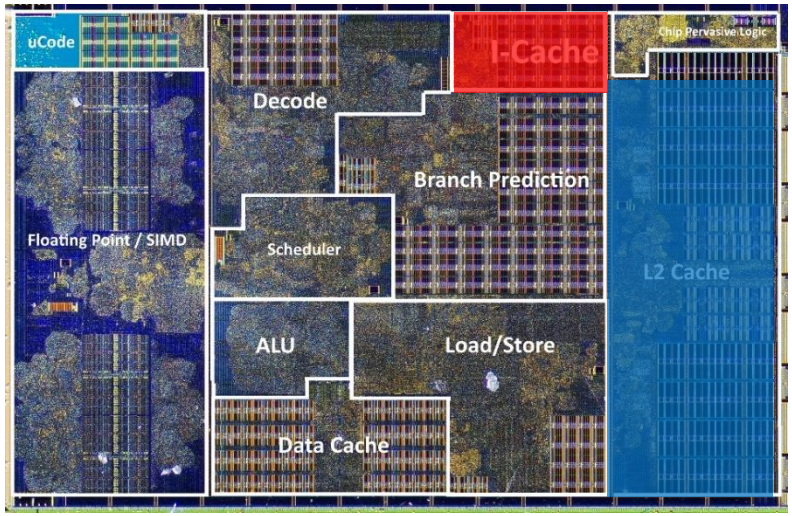

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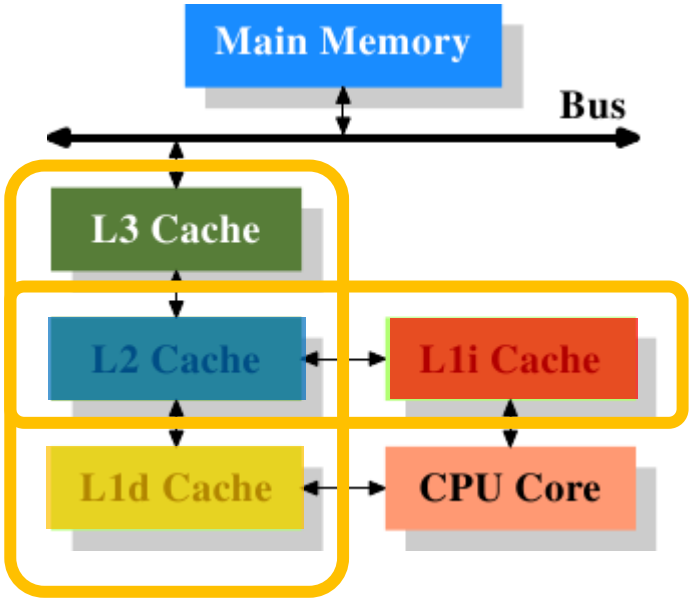

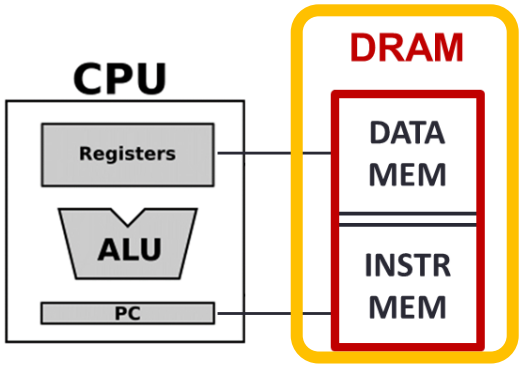

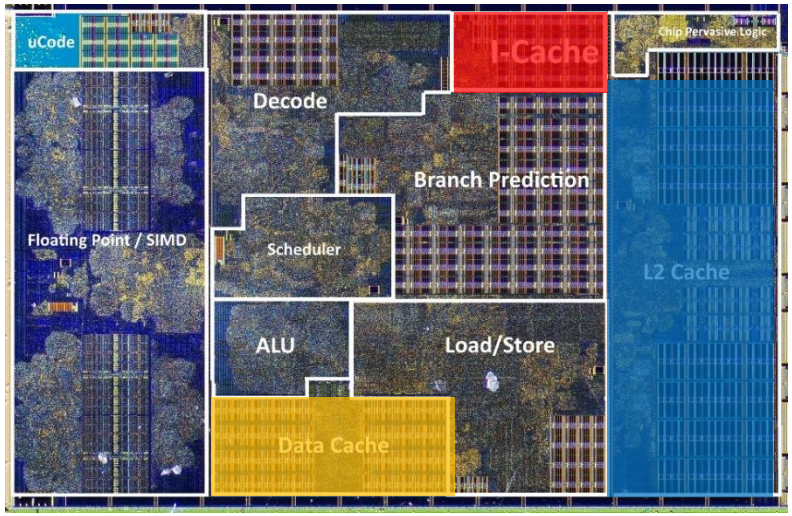

AMD Zen2 core