Computer Organization and Application

Lecture 1 - all

Introduction to Computer system Organization

Dr Mohammed Fadhil
Email: mohammed.fadhil1@uomus.edu.iq

Computer Organization & Architecture

- **Architecture** is those attributes visible to the programmer
  - **Instruction set**: Defines the operations the computer can perform.
  - **Number of bits**: Determines how data types like numbers and characters are represented.
  - **I/O mechanisms**: Handles communication between the computer and external devices.
  - **Memory addressing techniques**: Dictates how the system accesses and locates data in memory.
  - e.g. Is there a multiply instruction?
- **Organization** is how features are implemented
  - **Control signals**: Manage the flow of data within the system.
  - **Interfaces**: Connect the computer to peripherals (e.g., printers, storage devices).
  - **Memory technology**: The hardware used for storing and retrieving data.
  - e.g. Is there a hardware multiply unit or is it done by repeated addition

Computer Organization & Architecture

- Many computer manufacturers offer a family of models with the same ***architecture*** but different ***organization***.

- As a result, these models vary in ***price*** and ***performance***. A particular architecture may last for many years, while its organization changes with changing technology.

- All Intel x86 family share the same basic architecture
- The IBM System/370 family share the same basic architecture

- This gives code compatibility
  - At least backwards
- **Organization** differs between different versions

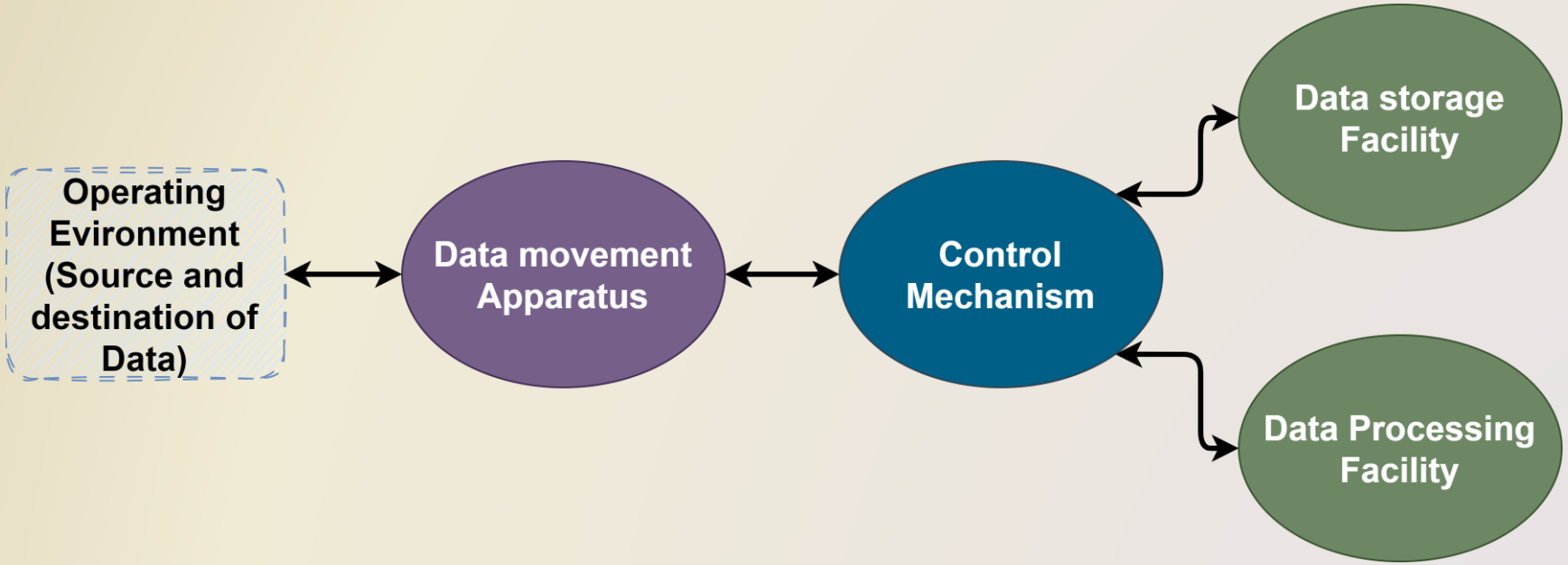
Structure & Function

- **Computers** are complex systems with millions of electronic components. How, then, can one clearly describe them? The key is to recognize the hierarchical nature of most complex systems.
  - a **hierarchical approach**, where each system is made up of smaller subsystems, and those subsystems can be broken down further until we reach the basic components.
- The hierarchical design allows a **designer** to focus on one level at a time, understanding how components interact. At each level, ***two*** *main aspects are important*:
  - **Structure** the way in which the components are interrelated.
  - **Function** is the operation of each individual component as part of the structure.

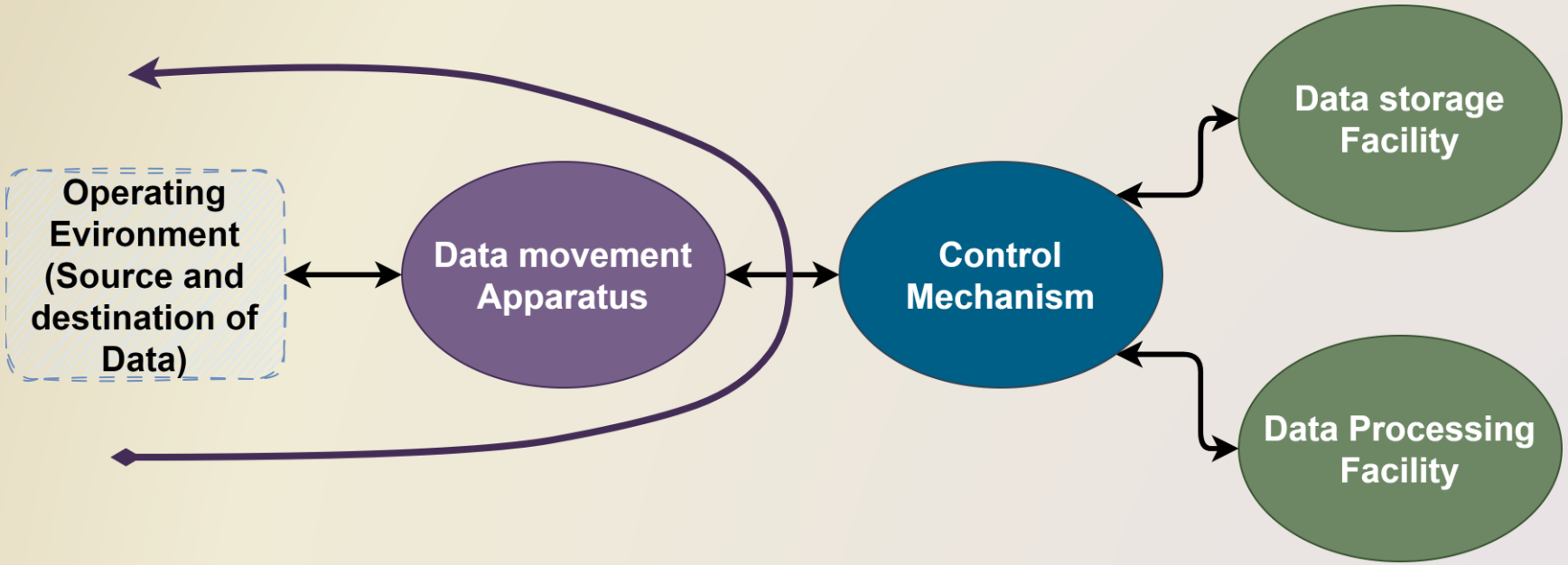
Function

- In general terms, there are only four basic functions that a computer can perform:
  - **Data processing:** can involve various forms of data and a wide range of processing needs. However, there are only a few fundamental methods or types of data processing.
  - **Data storage:** computers must temporarily store data being processed in real time for short-term use. They also provide long-term storage for saving files for future retrieval and updates.
  - **Data movement:** the computer's operating environment includes devices that act as sources or destinations for data. The computer must be able to move data between itself and the outside world.
    - **Input–Output (I/O)**: This refers to the process of receiving data from or delivering data to directly connected devices, known as peripherals.
    - **Data Communications**: This involves moving data over longer distances to or from remote devices
  - **Control:** the control unit within a computer manages resources and coordinates the performance of functional parts based on instructions.

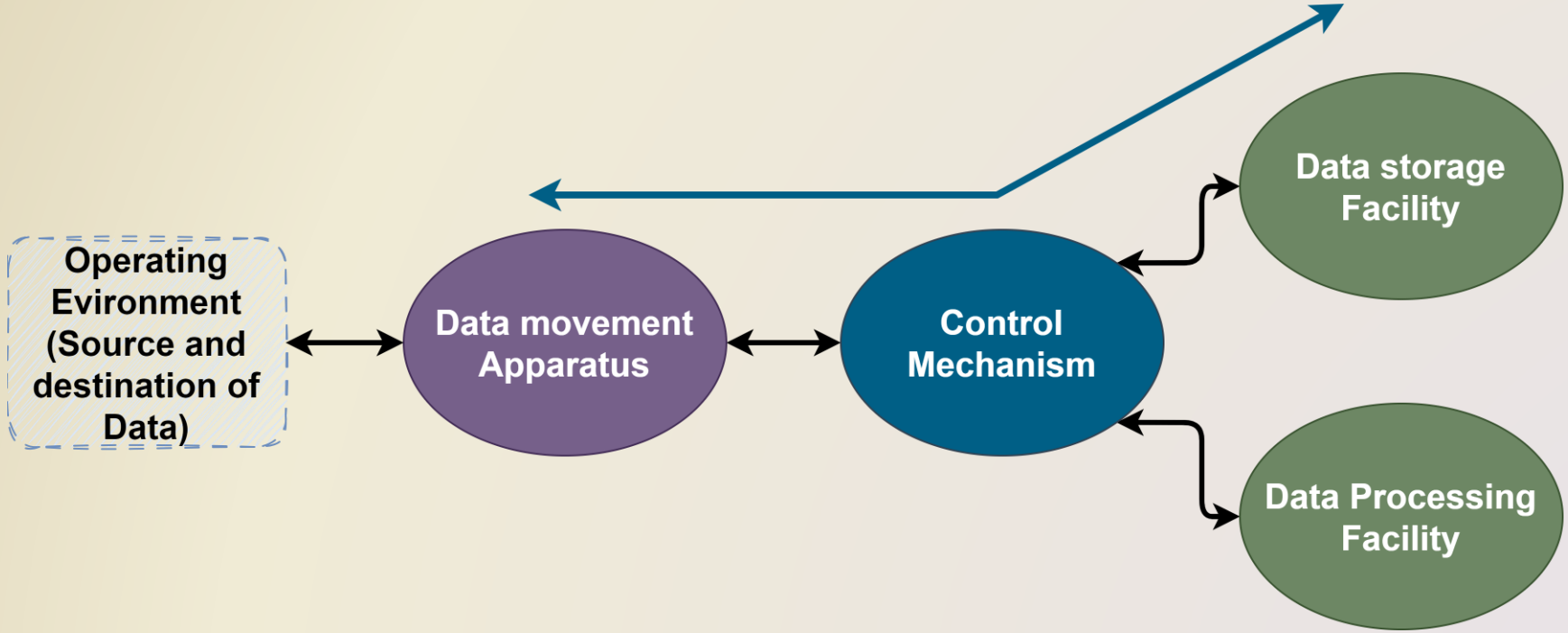
Functional view



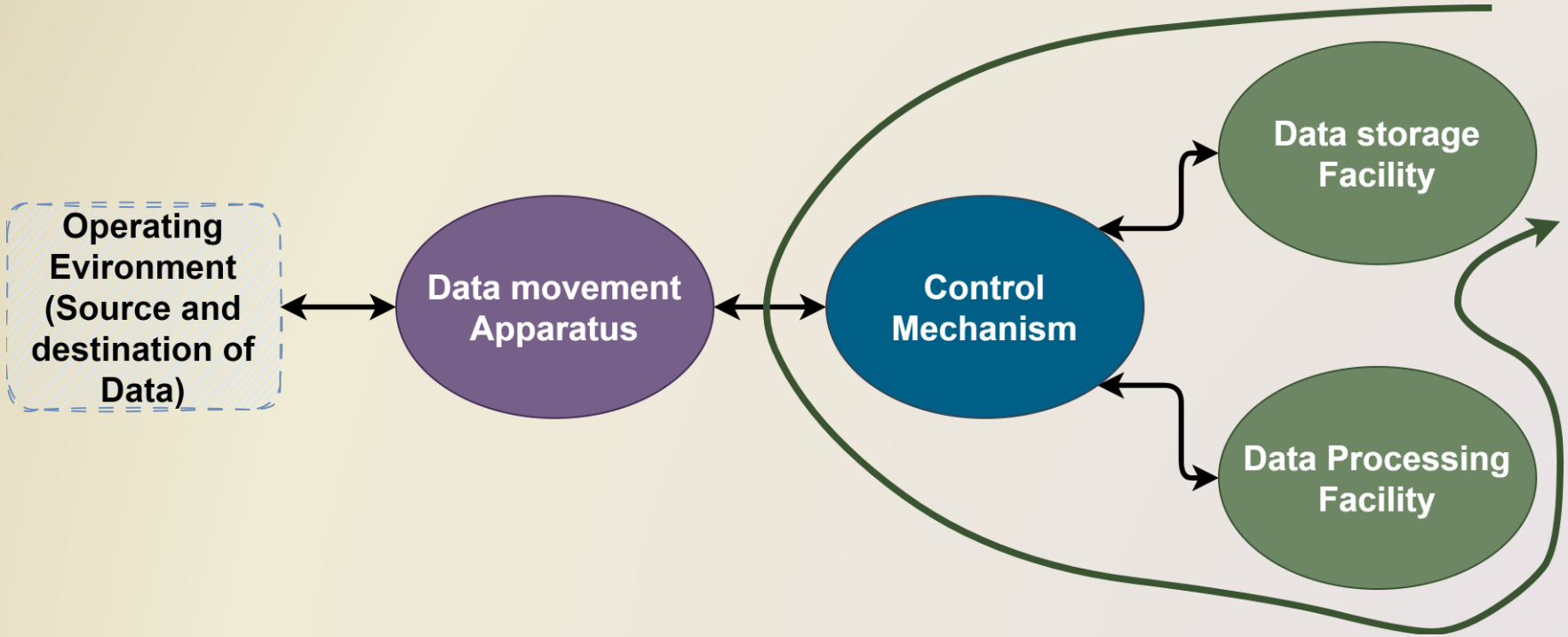
Operations (1) Data Movement



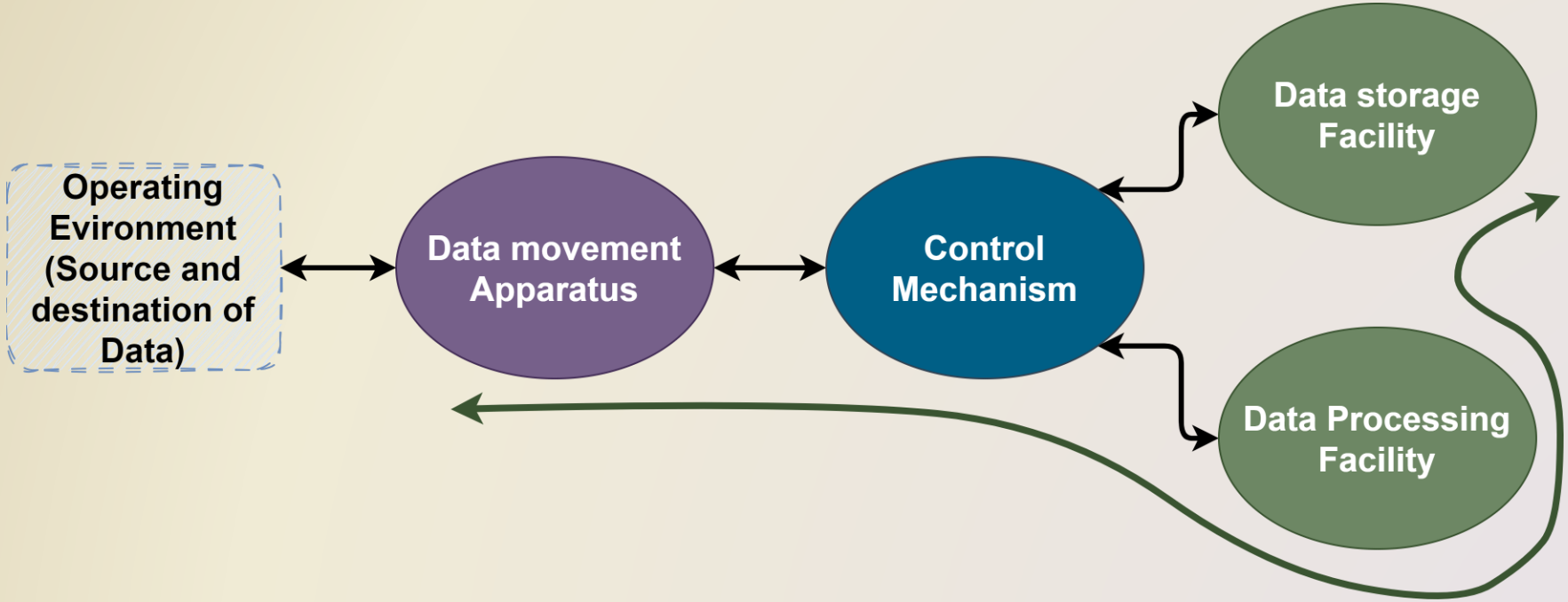
Operations (2) Storage



Operations (3) Processing from/to storage



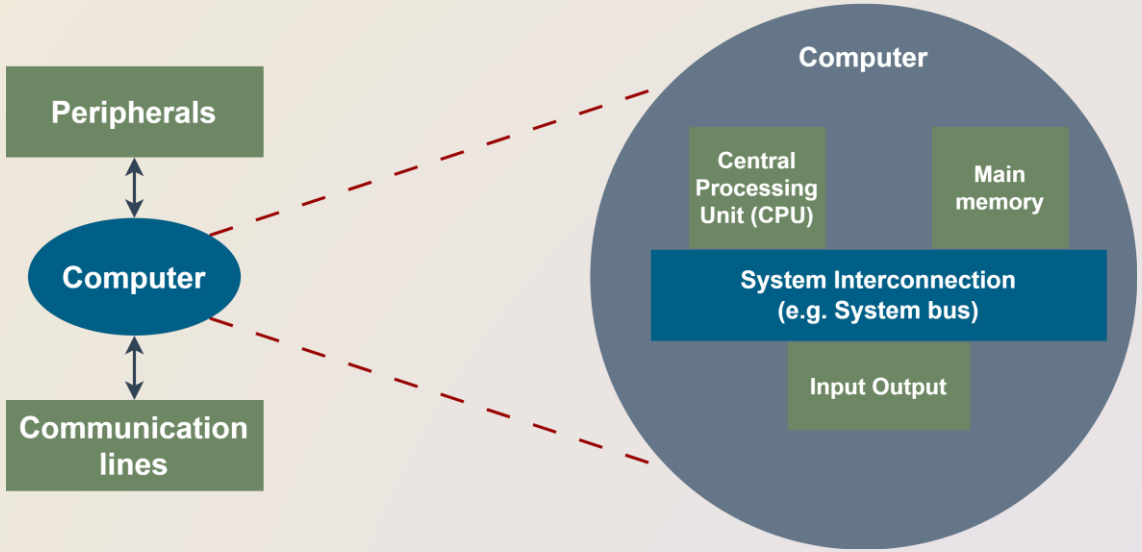
Operations (4) Processing from storage I/O



Structure – Top level

- There are **four main structural components**:
  - **Central processing unit (CPU):** Controls the operation of the computer and performs its data processing functions; often simply referred to as **processor**.
  - **Main memory**: Stores data.
  - **I/O**: Moves data between the computer and its external environment.
  - **System interconnection**: Some mechanism that provides for communication among CPU, main memory, and I/O. A common example of system interconnection is by means of a **system bus**.

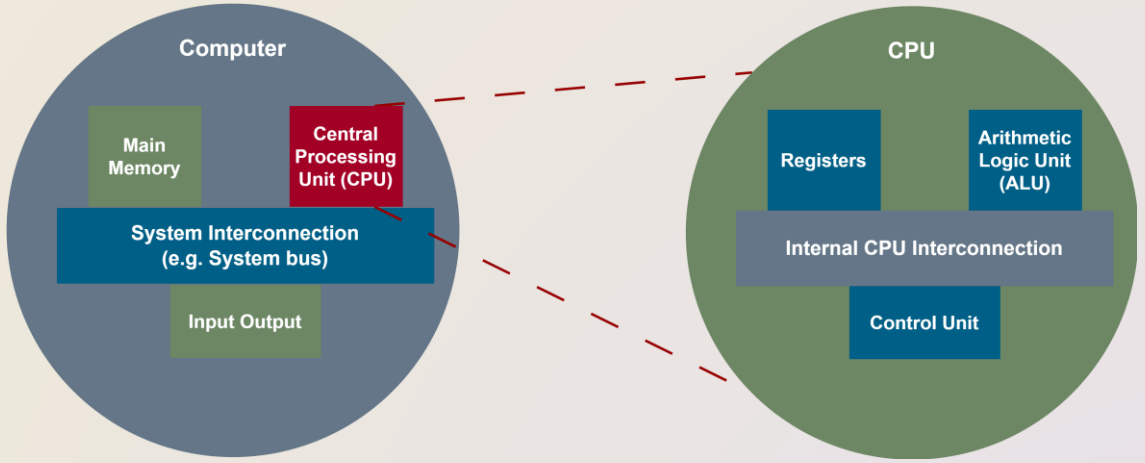
The following figures provide a hierarchical view of the internal structure of a traditional single-processor computer.



I. The computer

Structure – The CPU

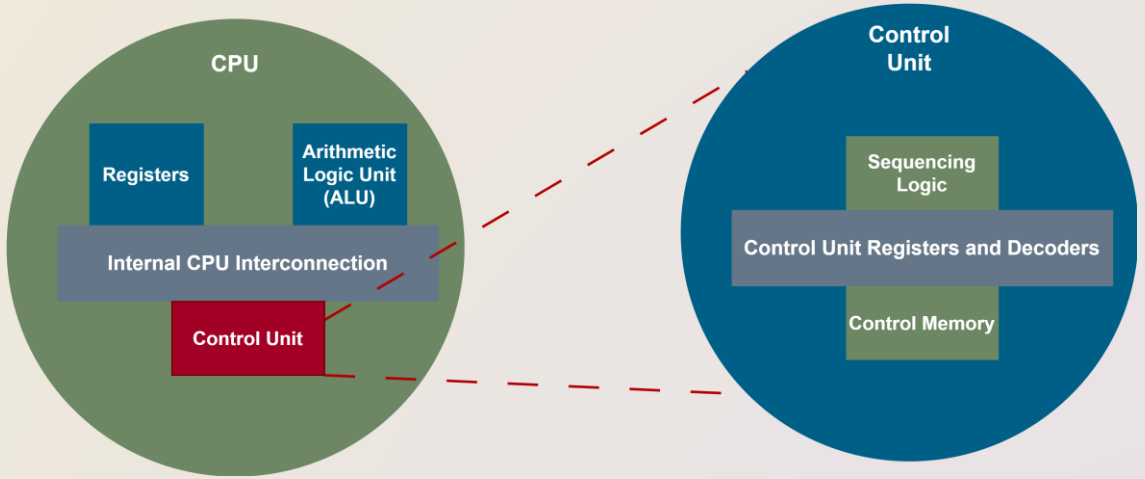
- **CPU** major structural components are as follows:
  - **Control unit**: Controls the operation of the CPU and hence the computer.
  - **Arithmetic and logic unit (ALU)**: Performs the computer's data processing functions.
  - **Registers**: Provides storage internal to the CPU.
  - **CPU interconnection**: Some mechanism that provides for communication among the control unit, ALU, and registers.



II. The CPU

Structure – The Control Unit

- The **Control Unit** component:
  - **Sequencing logic** : dictates the order in which instructions are executed by the processor.
  - **CU decoders and registers**: **decoders** in the CU translate instructions into control signals, while **registers** temporarily hold data and instructions during processing.
  - **Control memory**: a specialized memory in the CU that stores microinstructions which define how the processor's control signals are generated and executed.



III. The Control Unit

Structure and Function

- **Multicore Computer Structure:** a type of computer where **multiple processors** are integrated on a single chip.
- **Core**: Each processor within a multicore computer, containing:
  - Control unit
  - Arithmetic Logic Unit (ALU)
  - Registers
  - Perhaps **cache**
- Computers that are used or produced in the present day typically have **multiple processors** (**multicore structure**).

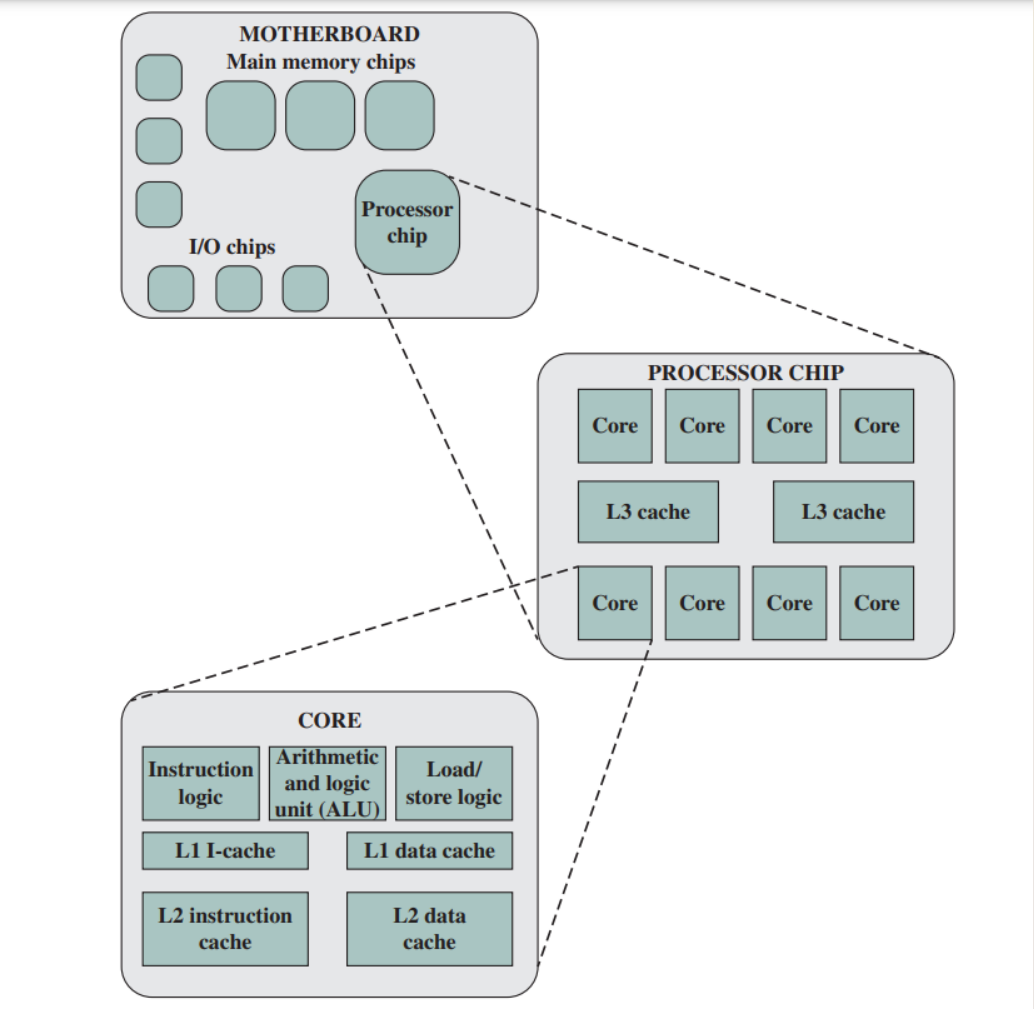
Structure and Function

To clarify the terminology, we use the following definitions;

- **Central Processing Unit (CPU)**:
  - The part of a computer that fetches and executes instructions.
  - Consists of the an ALU, a Control Unit, and Registers.
  - In a system with a single processing unit, it is simply called a **processor**.
- **Core**:
  - A single processing unit within a processor chip.
  - Functions similarly to a CPU on a single-CPU system.
  - Specialized cores may handle specific tasks such as **vector or matrix operations**.
- **Processor**:
  - A physical chip (piece of silicon) containing one or more cores.
  - Interprets instructions and executes them.
  - If it has **multiple cores**, it is called **a multicore processor**.

- **Cache Memory**:
  - Modern computers use **multiple layers of memory**, called **cache memory**, between the processor and main memory to speed up data access.
  - **Cache memory** is smaller and faster than the main memory.
  - Its purpose is **to speed up memory access** by storing data from the main memory that will likely be used soon.
  - Multiple levels of cache (L1, L2, L3, etc.) can further improve performance:
    - **L1 cache is the fastest and is closest to the CPU core.**
    - **Each subsequent level (L2, L3, etc.) is slower and larger than the previous one.**

Structure and Function



Simplified View of Major Elements of a Multicore Computer

Structure and Function

- **Motherboard**:
  - The main board in most computers, including smartphones, tablets, laptops, and workstations, that houses the main components.
- **Printed Circuit Board (PCB)**:
  - A flat, rigid board that connects electronic components. It has multiple layers, usually 2 to 10, with copper pathways to link components.
- **System Board**:
  - Another name for the motherboard, the main PCB in a computer.
- **Expansion Boards**:
  - Smaller boards that plug into the motherboard to add extra functionality.
- **Chips**:
  - Made from semiconducting material (usually silicon), these chips house circuits and logic gates, creating **integrated circuits**.
- **Processor Slot**:
  - The motherboard has a slot for the processor chip, typically a multicore processor with multiple cores.
- **Memory and Controller Slots**:
  - It includes slots for memory chips and I/O controller chips, along with other essential components.
- **Expansion Slots**:
  - Desktop motherboards have expansion slots that allow the addition of more components through expansion boards.
- **Chip Connections**:
  - Modern motherboards connect only a few chip components, each containing thousands to hundreds of millions of transistors.

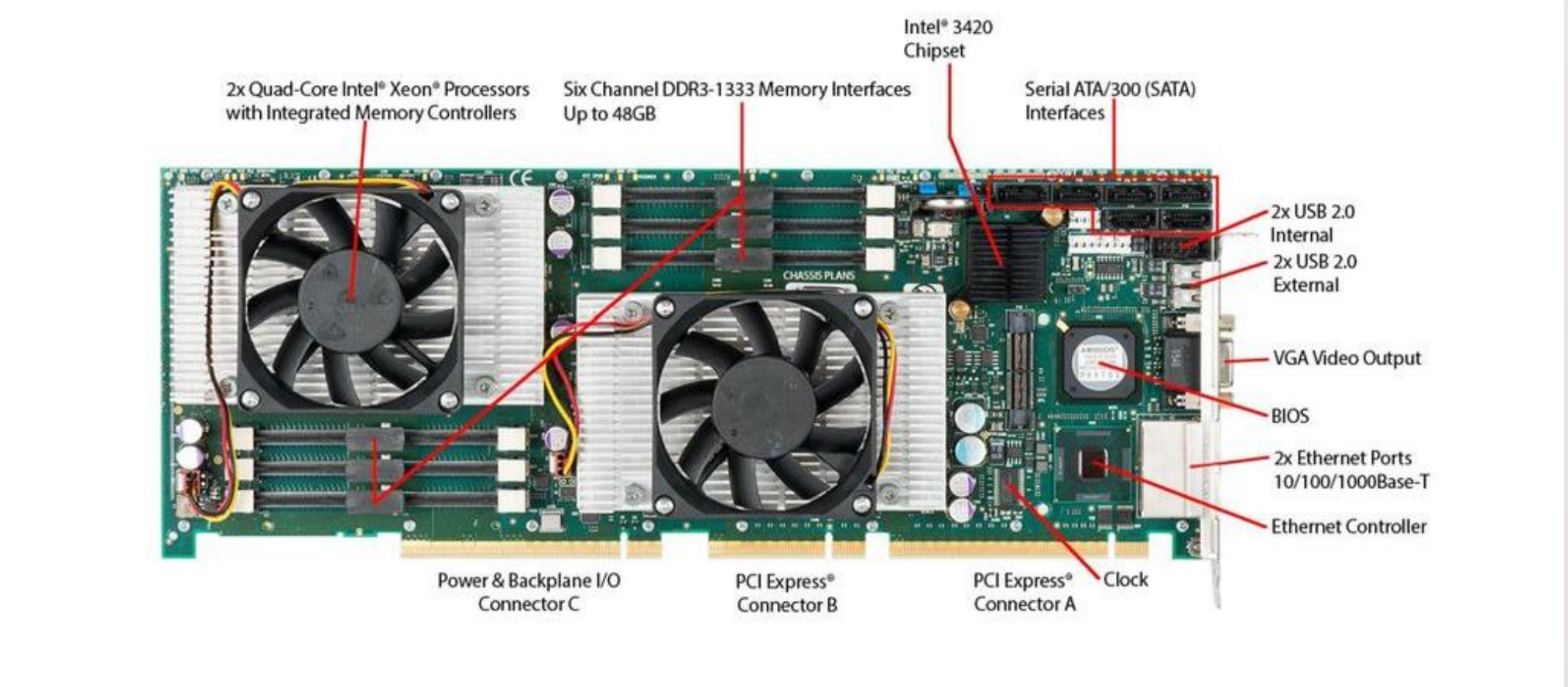
Structure and Function

- Next, we zoom in on the structure of a single core, which occupies a portion of the processor chip. In general terms, the functional elements of a core are:
  - **Instruction Logic**: This involves fetching and decoding instructions to understand their operations and the memory locations of any operands.
  - **Arithmetic and Logic Unit (ALU)**: This unit carries out the operations specified by the instructions.
  - **Load/store logic**: Manages the transfer of data to and from main memory via cache.

Structure and Function

- **L1 Cache**: Each core has an L1 cache, divided into:
  - **Instruction Cache (I-cache):** Transfers instructions to and from main memory.
  - **Data Cache (L1 Data Cache):** Transfers operands and results.
- **L2 Cache**: Most modern processor chips also include an L2 cache as part of the core.
  - **Split or Combined:** The L2 cache can be split between instruction and data caches or be a single, combined cache.

Structure and Function

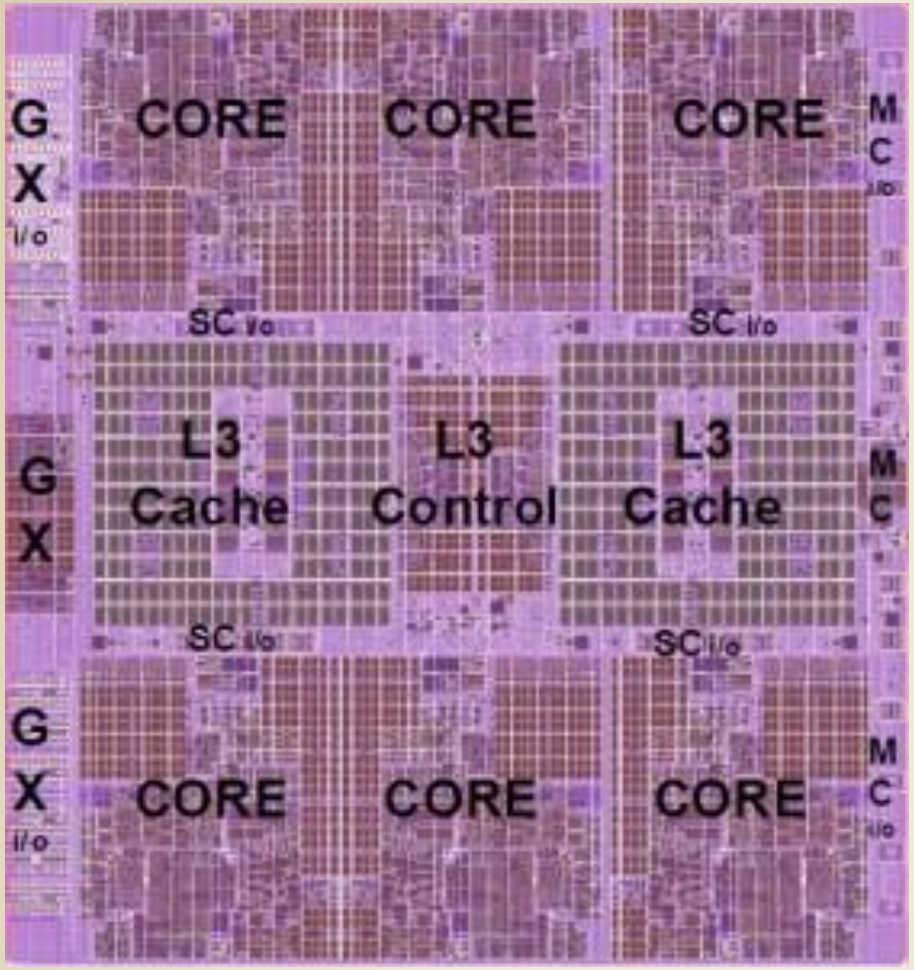


Motherboard with Two Intel Quad-Core Xeon Processors

Structure and Function

- Here, we mention the most important, in addition to the processor
  - **PCI-Express slots:** For high-end display adapters and peripherals.
  - **Ethernet controller/ports:** For network connections.
  - **USB sockets:** For peripheral devices.
  - **SATA sockets:** For connecting to disk memory.
  - **DDR interfaces:** For main memory chips.
  - **Intel 3420 chipset:** I/O controller for direct memory access between peripherals and main memory.

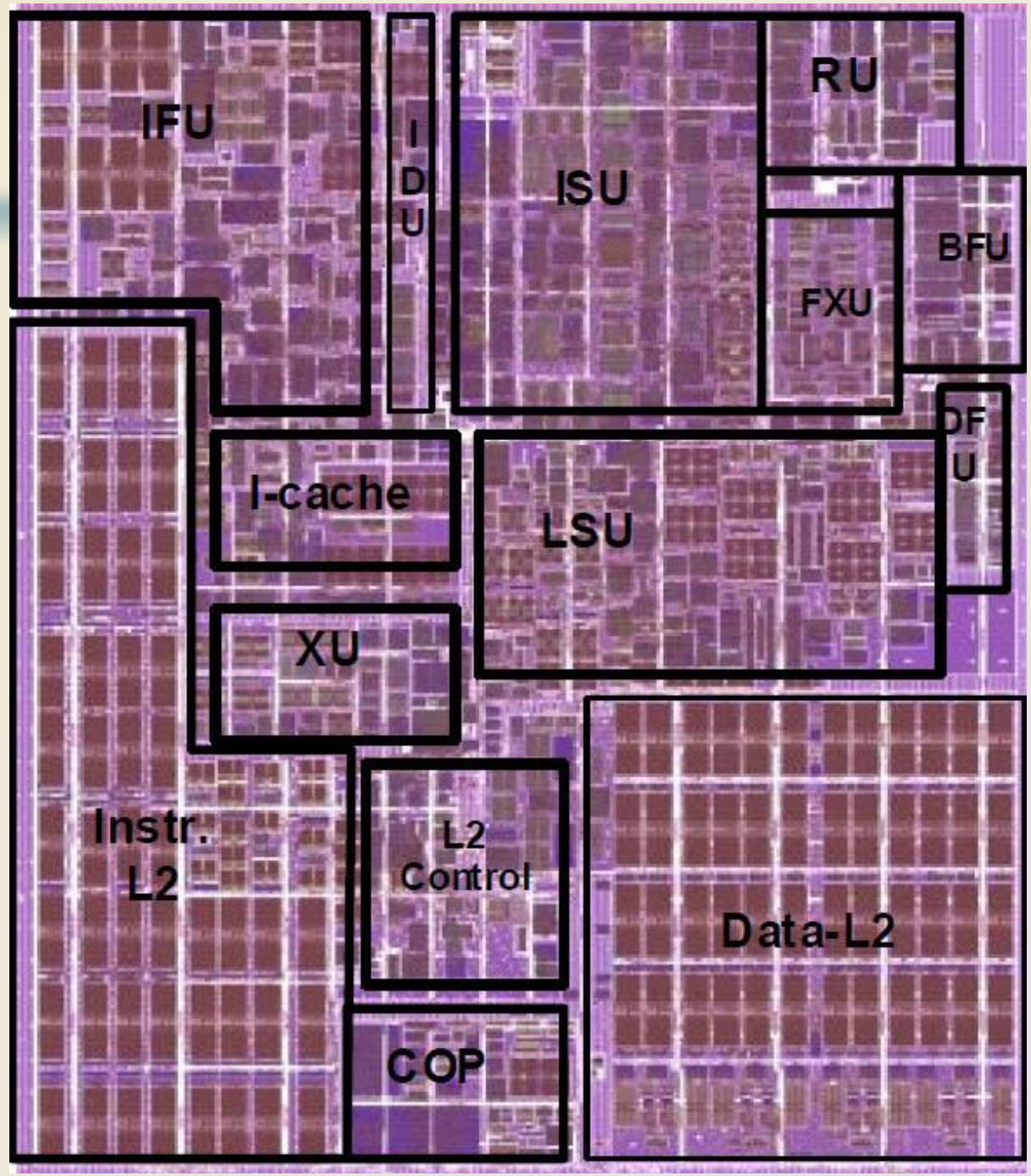
Structure and Function



zEnterprise EC12 Processor Unit (PU) chip diagram

- **IBM zEnterprise EC12 Processor Chip:**
  - Contains 2.75 billion transistors.
  - Composed of six cores (processors).
- **L3 Cache:**
  - Two large areas of L3 cache, shared by all six cores.
  - L3 control logic manages traffic between:
    - The L3 cache and the cores.
    - The L3 cache and the external environment.
- **Additional Logic and Controllers:**
  - Storage control (SC) logic: Positioned between the cores and the L3 cache.
  - Memory controller (MC): Manages access to external memory.
  - GX I/O bus: Controls the interface for channel adapters handling I/O (input/output) operations.

zEnterprise EC12 Core layout



The Main Sub- areas within a Single Core

- **ISU (Instruction Sequence Unit):** Determines the order of instruction execution in a superscalar architecture.
- **IFU (Instruction Fetch Unit):** Fetches instructions.
- **IDU (Instruction Decode Unit):** Decodes instructions from the IFU.
- **LSU (Load-Store Unit):** Manages data between the L1 (96 KB) and L2 caches, handling all types of operand accesses.
- **XU (Translation Unit):** Translates logical addresses to physical ones and includes a Translation Lookaside Buffer (TLB).
- **FXU (Fixed-Point Unit):** Executes fixed-point arithmetic.
- **BFU (Binary Floating-Point Unit):** Handles binary/hexadecimal floating-point operations and fixed-point multiplication.
- **DFU (Decimal Floating-Point Unit):** Performs decimal fixed-point and floating-point operations.
- **RU (Recovery Unit):** Maintains system state and manages hardware fault recovery.
- **COP (Co-Processor):** Handles data compression and encryption for each core.
- **I-Cache:** A 64 KB L1 cache for prefetching instructions.
- **L2 Control:** Manages traffic through L2 caches.
- **Data-L2:** A 1 MB L2 data cache for non-instruction memory traffic.
- **Instr-L2:** A 1 MB L2 instruction cache.

Thank You ☺