- In general, faster memory is more expensive than slower memory

- Different types of memory can be arranged in a hierarchy

- Small fast storage elements (registers) are kept in the CPU

- Cache is slightly slower than registers and kept close to the CPU

- Larger slower main memory is accessed through the bus

- Even larger and much slower storage (disks, tapes, network drives) are farther from the CPU
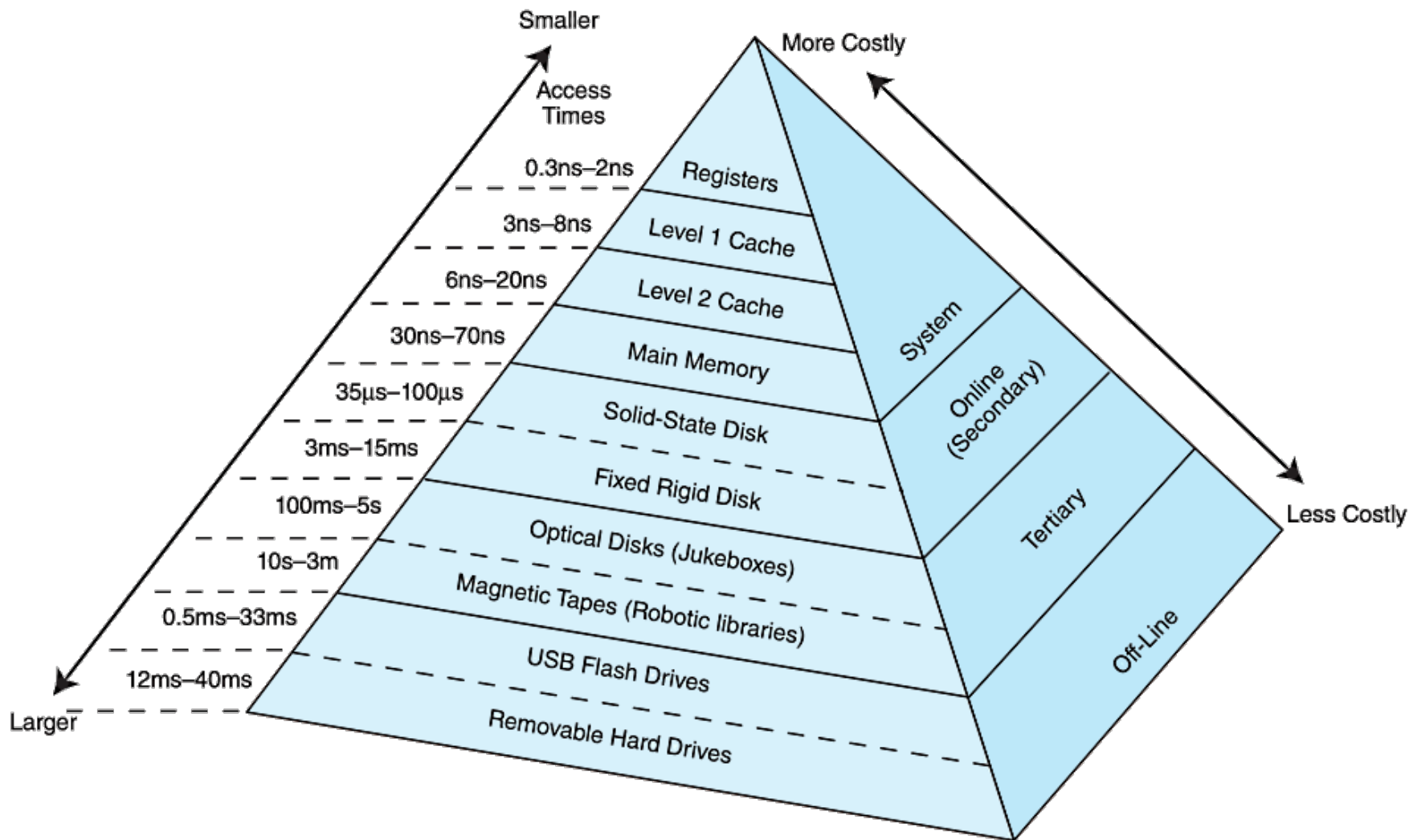
- Most systems are byte addressable

  - Each 8-bit byte is assigned a unique number (address)

  - Addresses range from 0 to some maximum

  - Consecutive byte addresses differ by 1

- Maximum address depends on address register width

- Larger storage units consist of multiple bytes

  - Words (4 bytes), half words (2 bytes)

  - Word size matches the CPU register size

- Some systems may be word addressable

  - Each word contains multiple bytes

  - Consecutive word addresses differ by 1

- MIPS processor uses 32-bit registers and addresses

  - Addresses range from 0 to $2^{32} - 1$

  - Registers and words contain 4 bytes

- SW instruction copies a register into memory

  - Leftmost byte is stored at the lowest address

  - Next lower byte is stored at the next higher address

  - This "big endian" storage order is used by the MIPS

- Example: if 0x12345678 is stored at address 200:

Address	200	201	202	203
contents	0x12	0x34	0x45	0x78

- Other systems use "little endian" memory storage

  - Rightmost byte is stored at the lowest address

  - Next higher byte is stored at next higher address

  - Intel systems use this memory storage order

- Example: if 0x12345678 is stored at address 200:

Address	200	201	202	203
contents	0x78	0x56	0x34	0x12

- Byte order matters when exchanging data
  - Network order is big endian
  - Little endian systems must reorder network bytes received
- Registers always contain bytes in high to low order
  - High byte on left, low byte on right
- Character strings are arrays of bytes
  - Individual bytes are accessed
  - Characters in string are ordered from first to last
  - Address of string = address of leading character
- Byte order matters when accessing multi-byte items

- We will examine registers, cache, main memory, and virtual memory.

- Registers are accessed directly by the processor
  - Instructions contain register numbers (rs, rt and rd)
  - Registers are contained within the CPU

- Virtual memory extends the address space from RAM (main memory) to the secondary storage (hard drive)

- Virtual memory provides more space: Cache memory provides speed