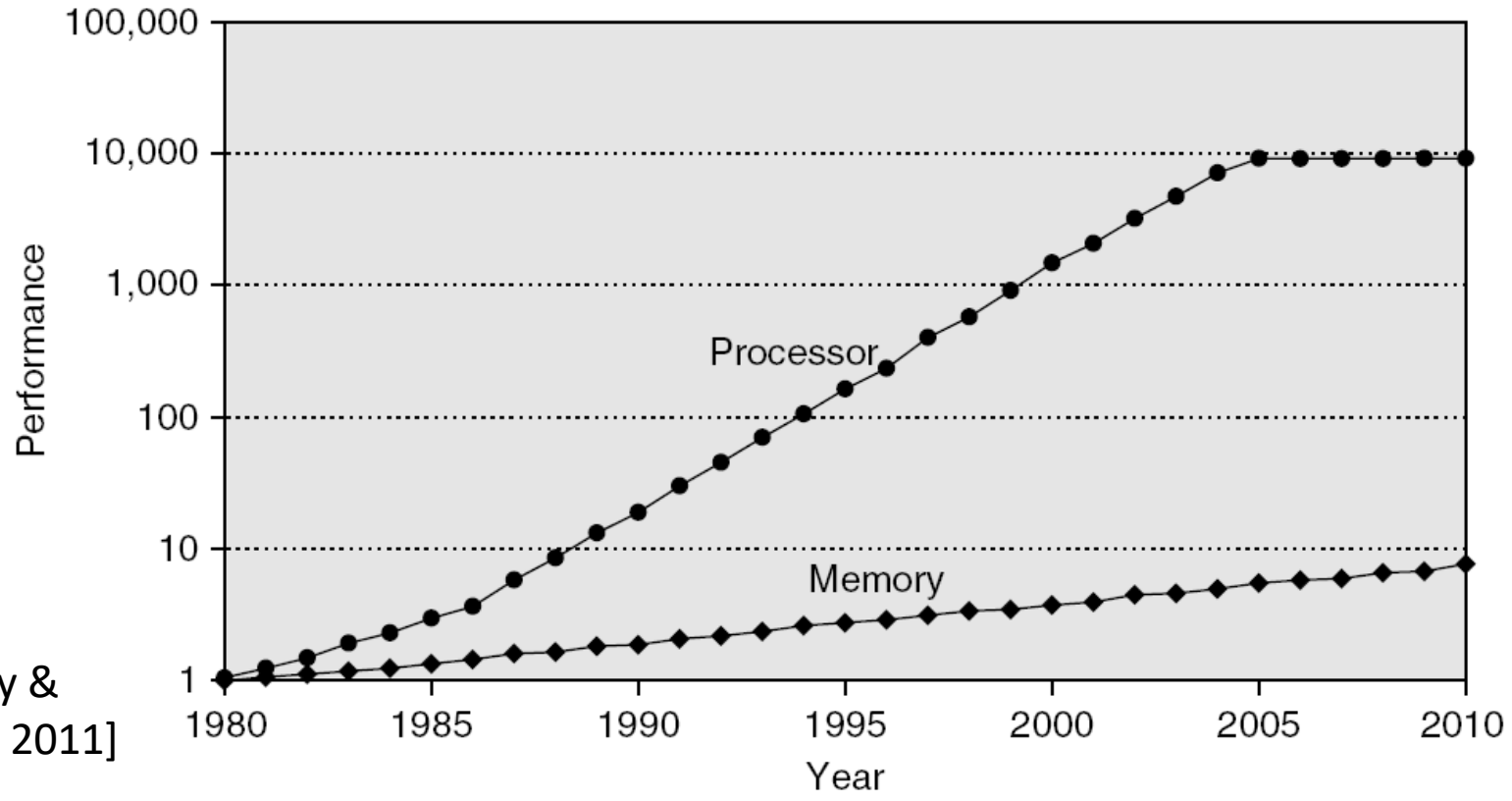
CSE 112: Computer Organization

Instructor: Sujay Deb

Lecture 22

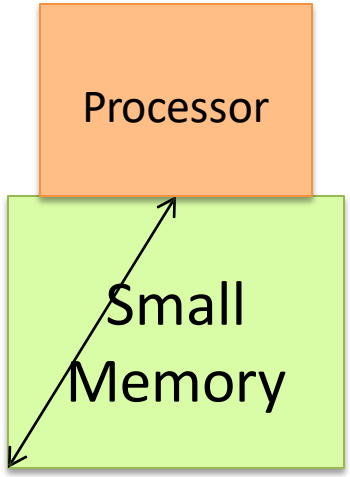
Processor-DRAM Latency Gap

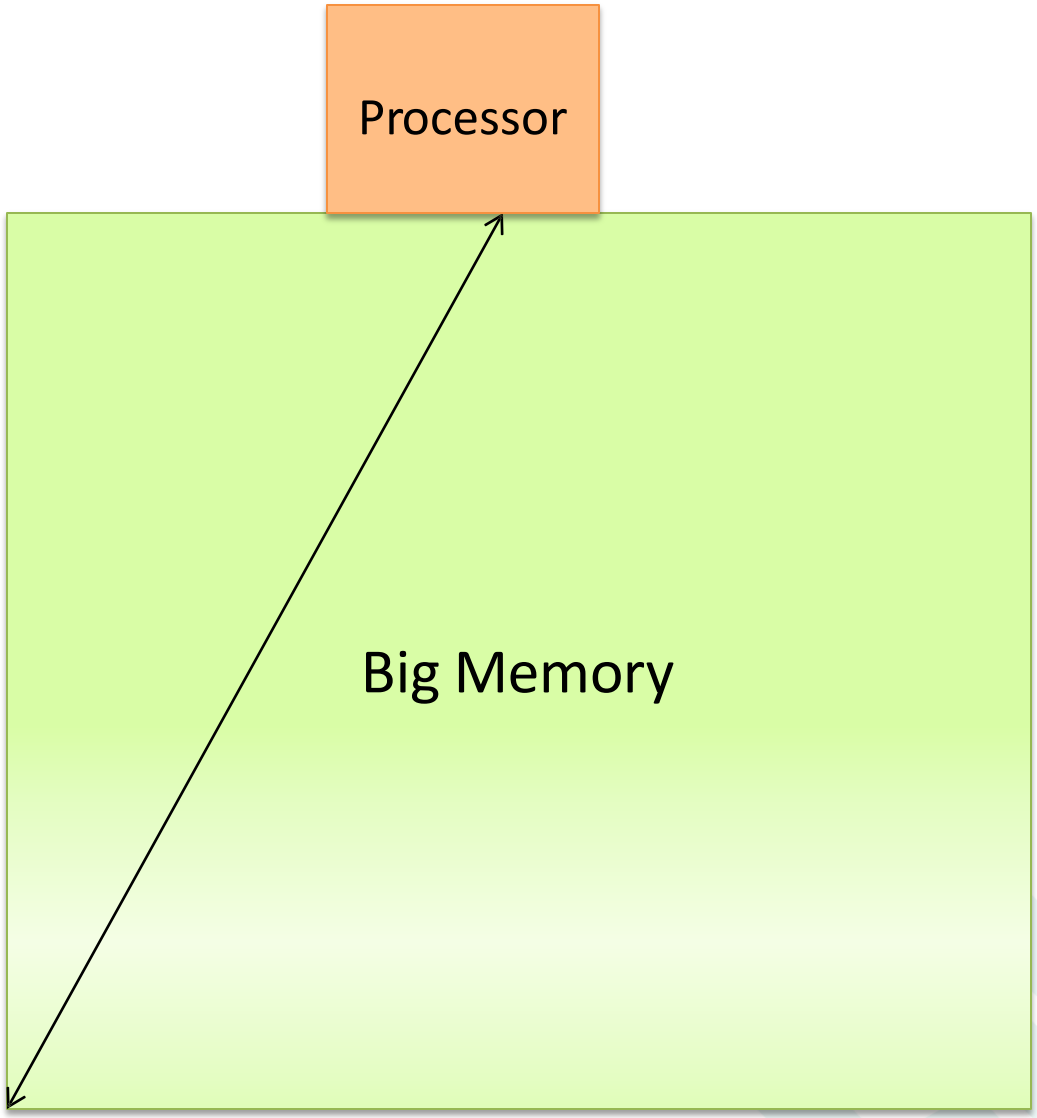


[Hennessy & Patterson 2011]

- Four-issue 2 GHz superscalar accessing 100 ns DRAM could execute 800 instructions during the time for one memory access!
- Long latencies mean large bandwidth-delay products which can be difficult to saturate, meaning bandwidth is wasted

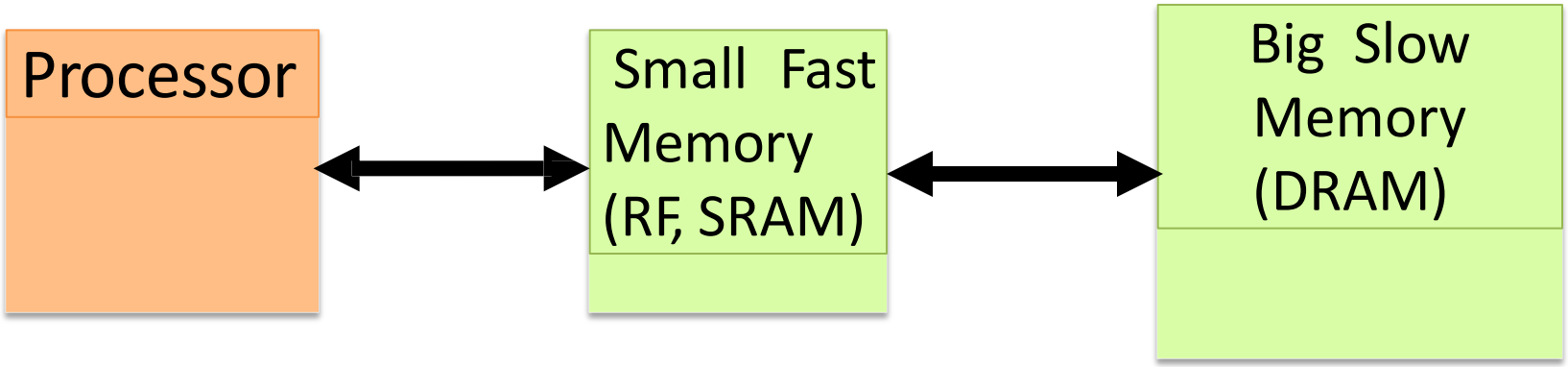
Physical Size Affects Latency





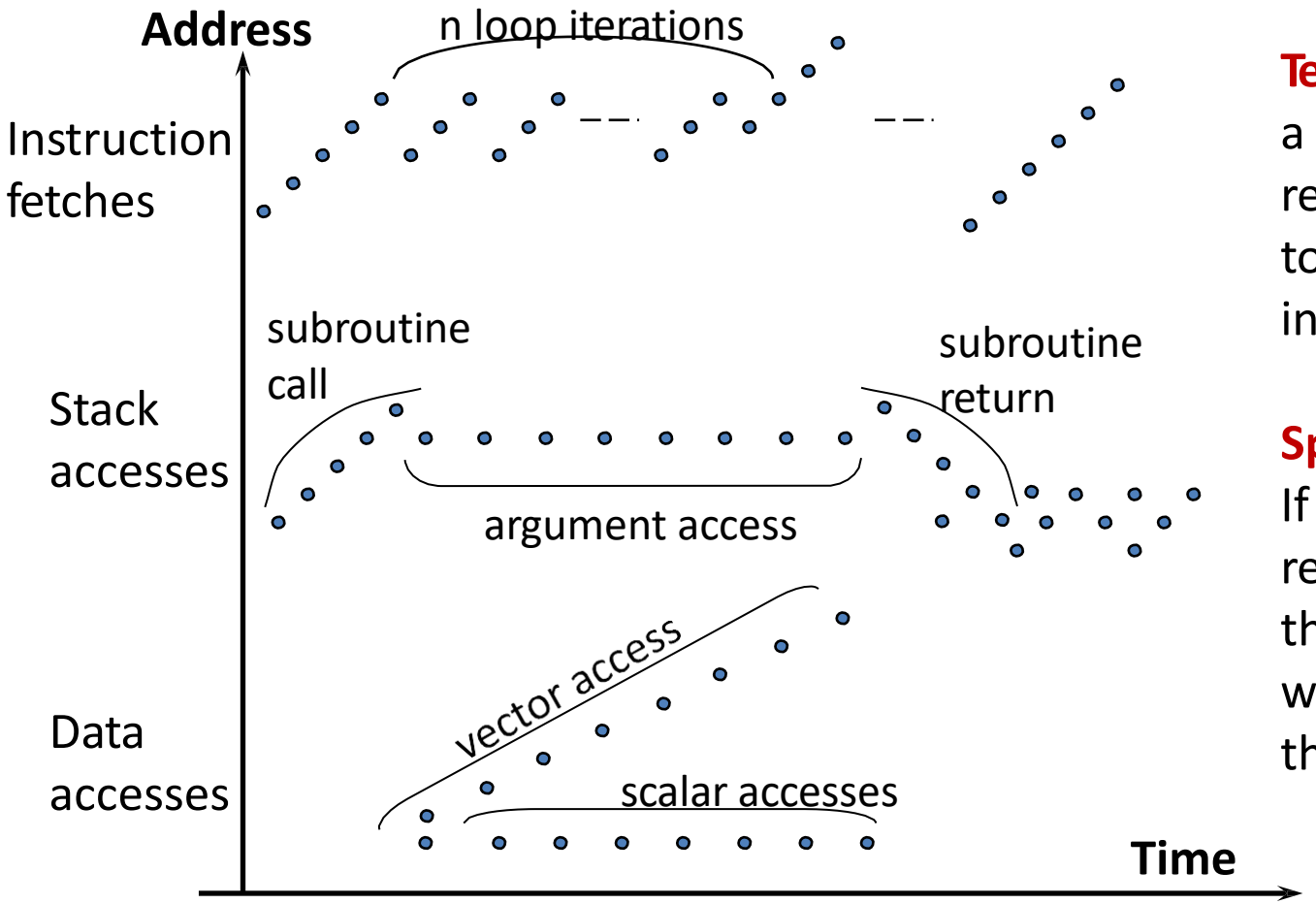
- Signals have further to travel
- Fan out to more locations

Memory Hierarchy



- Capacity: Register << SRAM << DRAM
- Latency: Register << SRAM << DRAM
- Bandwidth: on-chip >> off-chip
- On a data access:
  - if data is in fast memory -> low-latency access to SRAM
  - if data is not in fast memory -> long-latency access to DRAM
- Memory hierarchies only work if the small, fast memory actually stores data that is reused by the processor

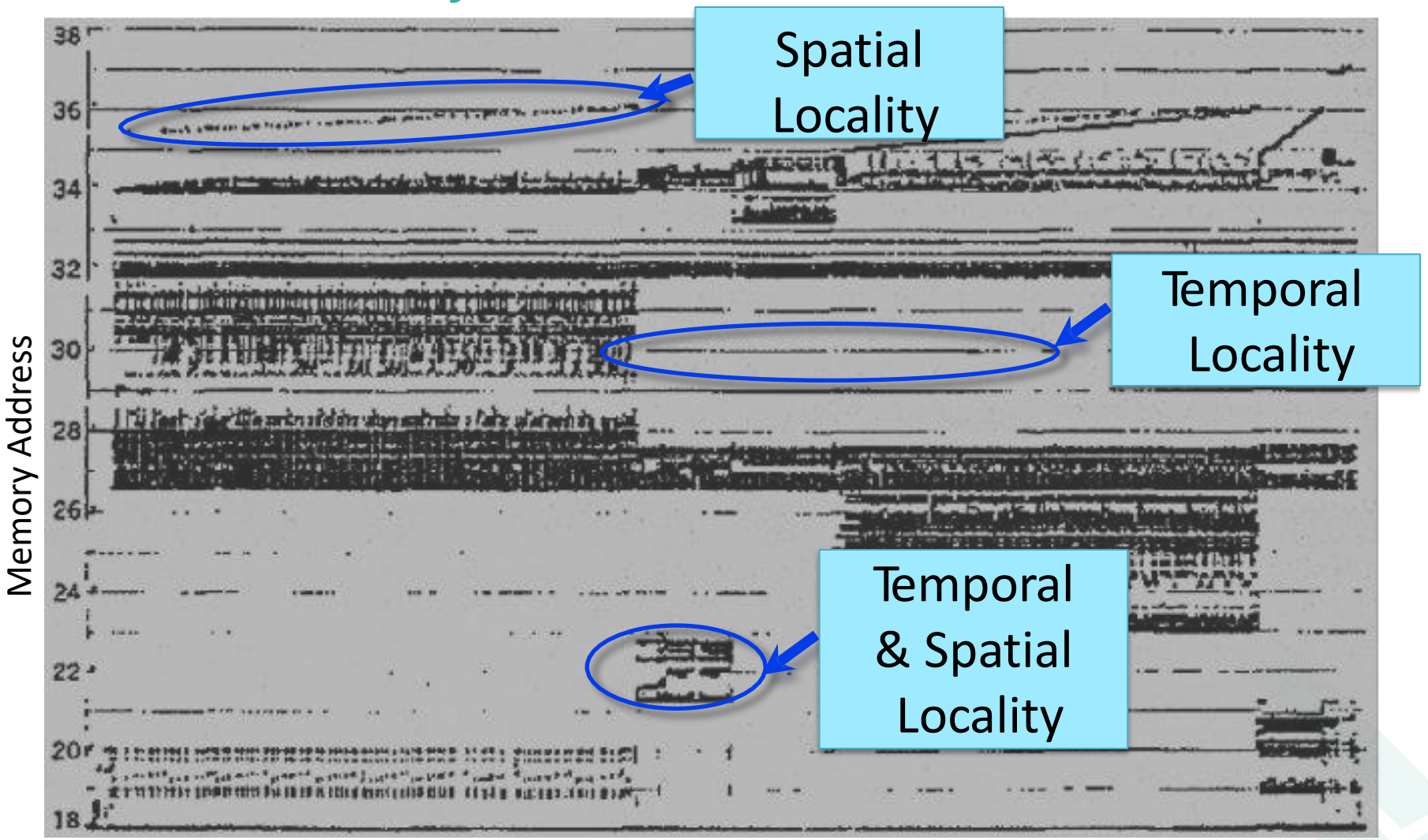
Common And Predictable Memory Reference Patterns



Temporal Locality: If a location is referenced it is likely to be referenced again in the near future

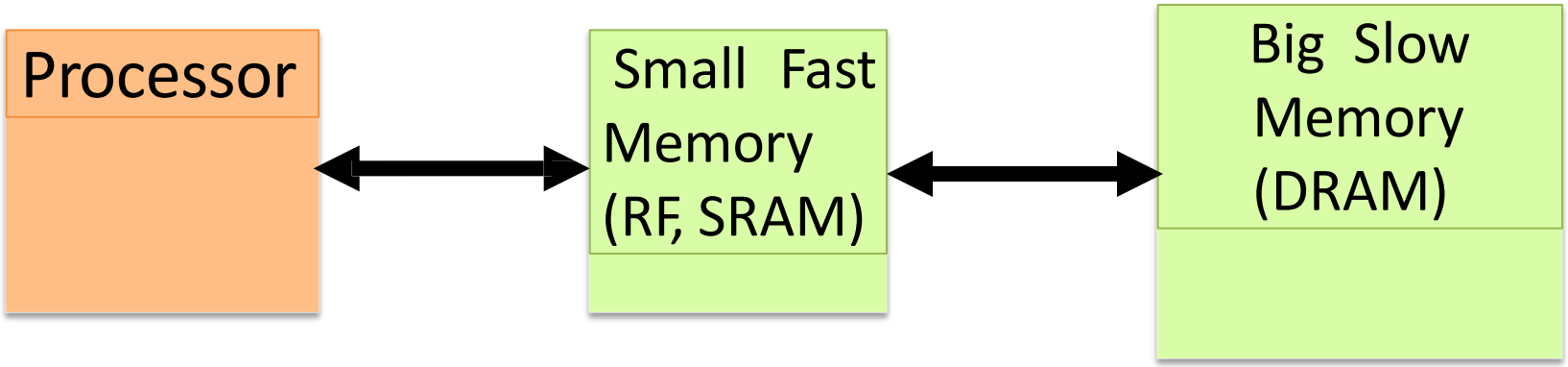
Spatial Locality: If a location is referenced it is likely that locations near it will be referenced in the near future

Real Memory Reference Patterns



[From Donald J. Hatfield, Jeanette Gerald: Program Restructuring for Virtual Memory. IBM Systems Journal 10(3): 168-192 (1971)]

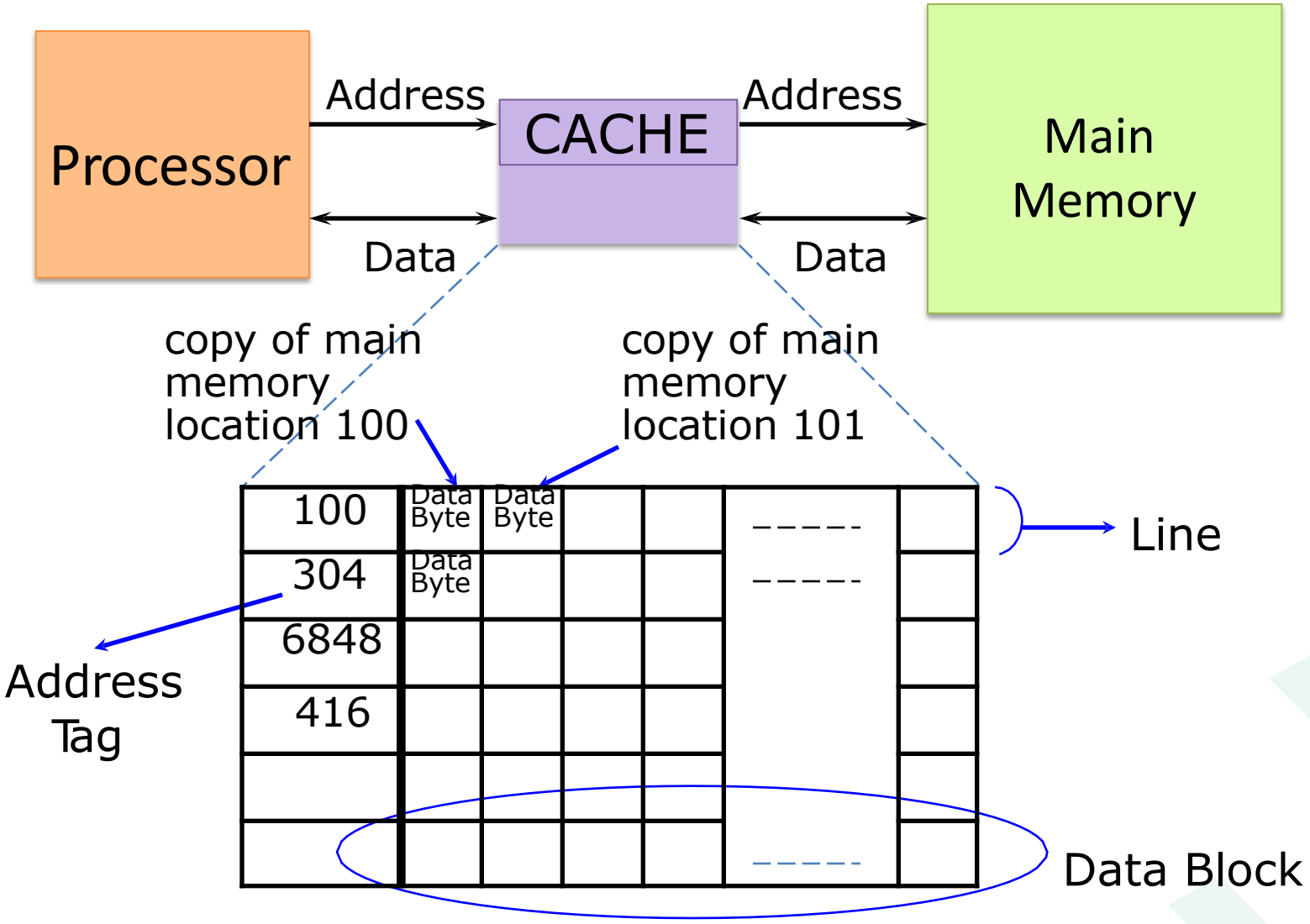
Caches Exploit Both Types of Locality



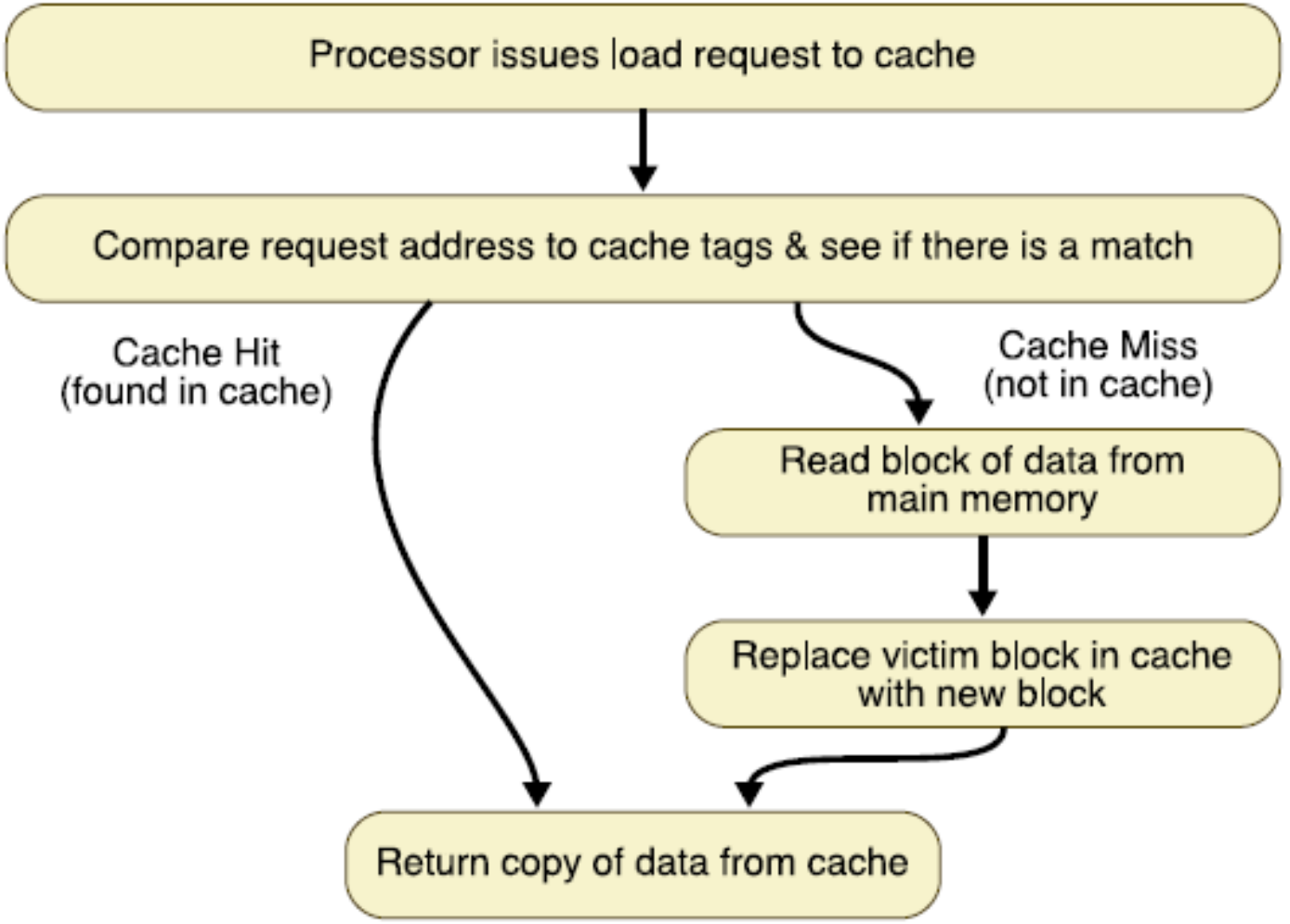
- Exploit temporal locality by remembering the contents of recently accessed locations
- Exploit spatial locality by fetching blocks of data around recently accessed locations

Classifying Caches

Inside a Cache

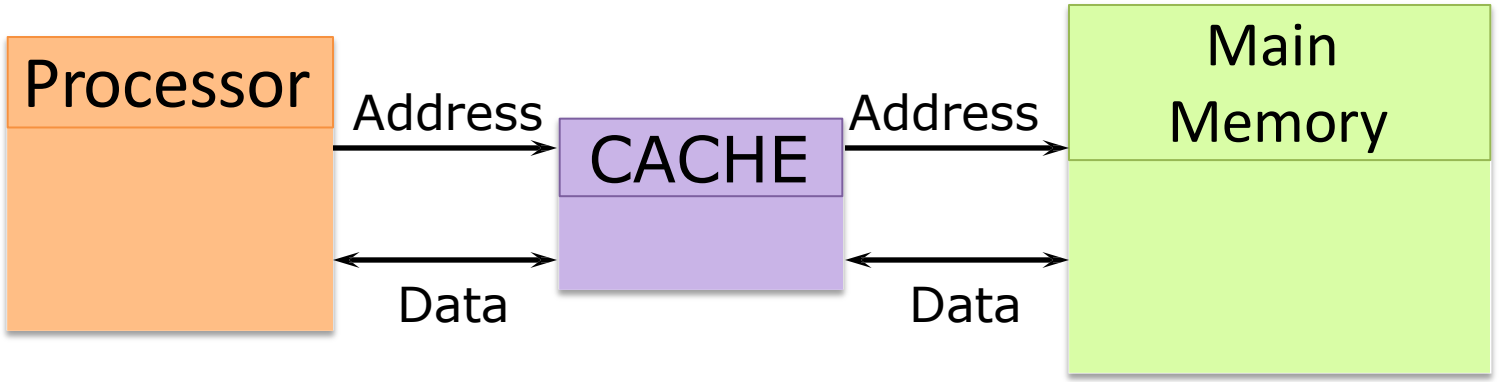


Basic Cache Algorithm for a Load



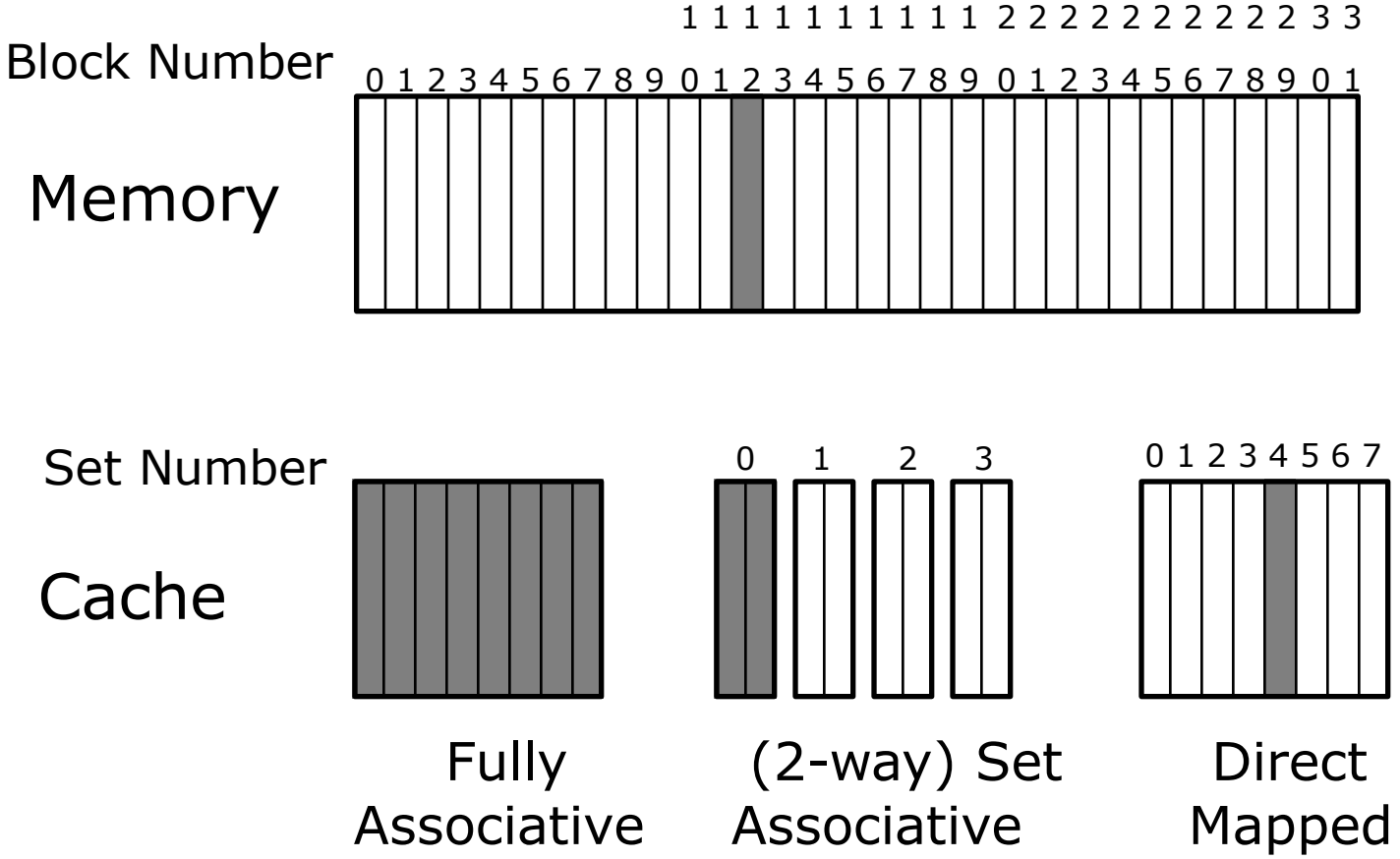
Class Interaction # 25

Classifying Caches



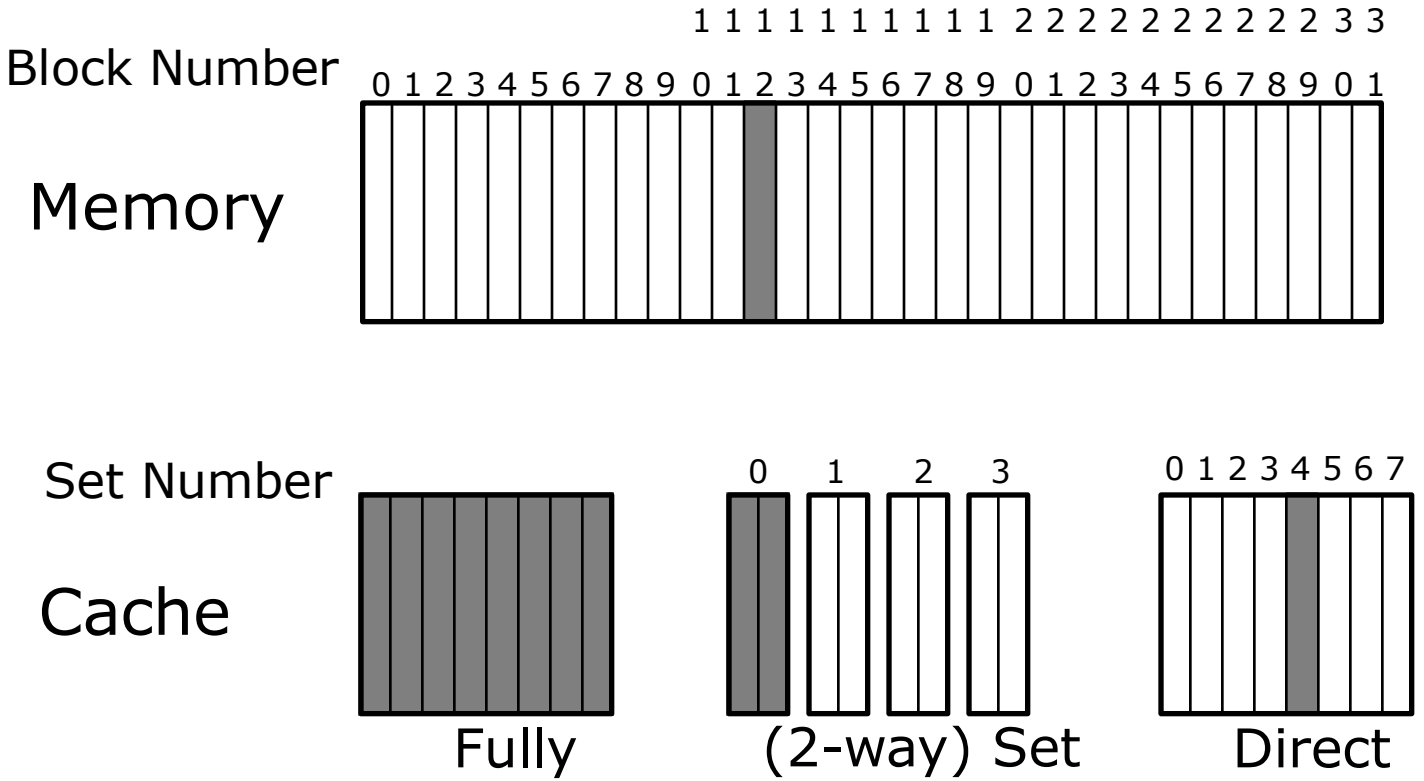
- **Block Placement**: Where can a block be placed in the cache?
- **Block Identification**: How a block is found if it is in the cache?
- **Block Replacement**: Which block should be replaced on a miss?
- **Write Strategy**: What happens on a write?

Block Placement: Where to Place Block in Cache?



block 12
can be placed

Block Placement: Where to Place Block in Cache?



block 12 can be placed

Associative	Associative	Mapped
anywhere	anywhere in set 0 *(12 mod 4)*	only into block 4 *(12 mod 8)*