# [544] Caching

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# Learning Objectives

- describe the cache hierarchy
- trace through access patterns with LRU and FIFO policies
- calculate cache performance metrics

# Outline

Challenge: Latency

Cache Hierarchy

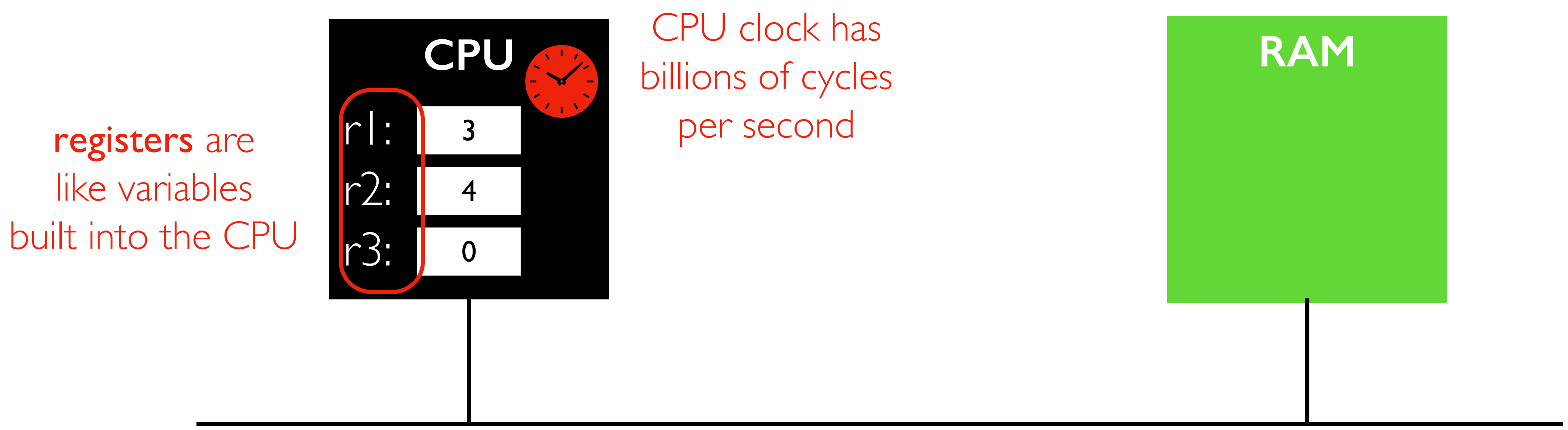
- CPU, RAM, SSD, Disk, Network
- Tradeoffs

Policy: what data should be cached?

- manual
- expiration
- eviction policies: random, FIFO, LRU

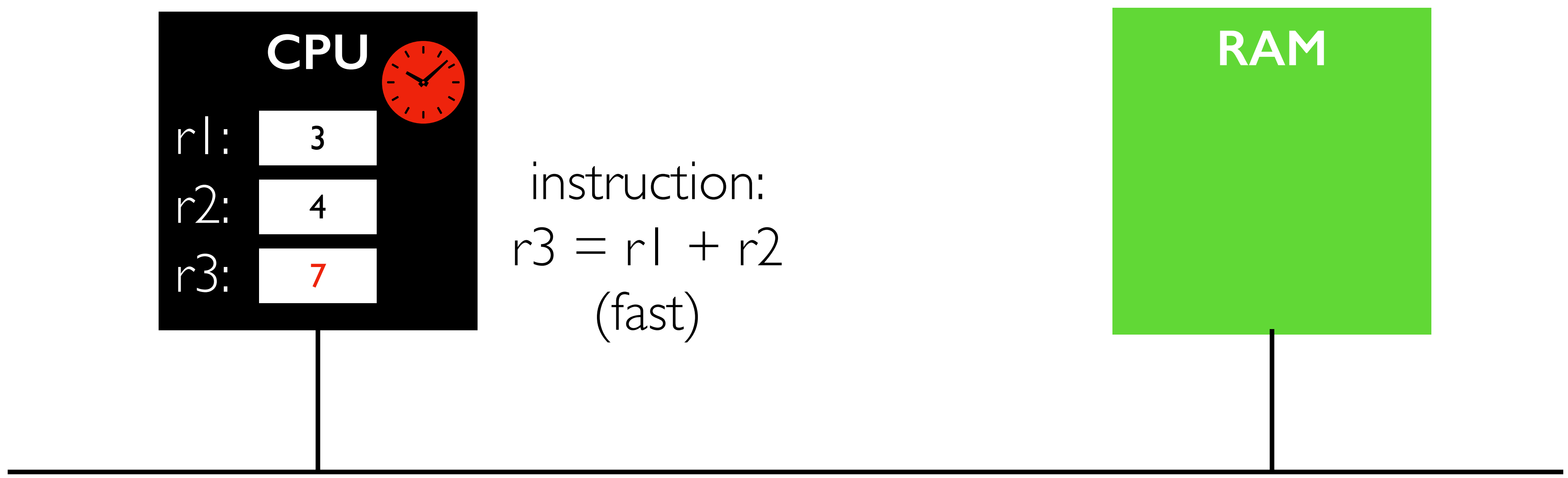
Practice

# CPU and RAM



registers are
like variables
built into the CPU
CPU
r1:
3
r2:
4
r3:
0
CPU clock has
billions of cycles
per second
RAM

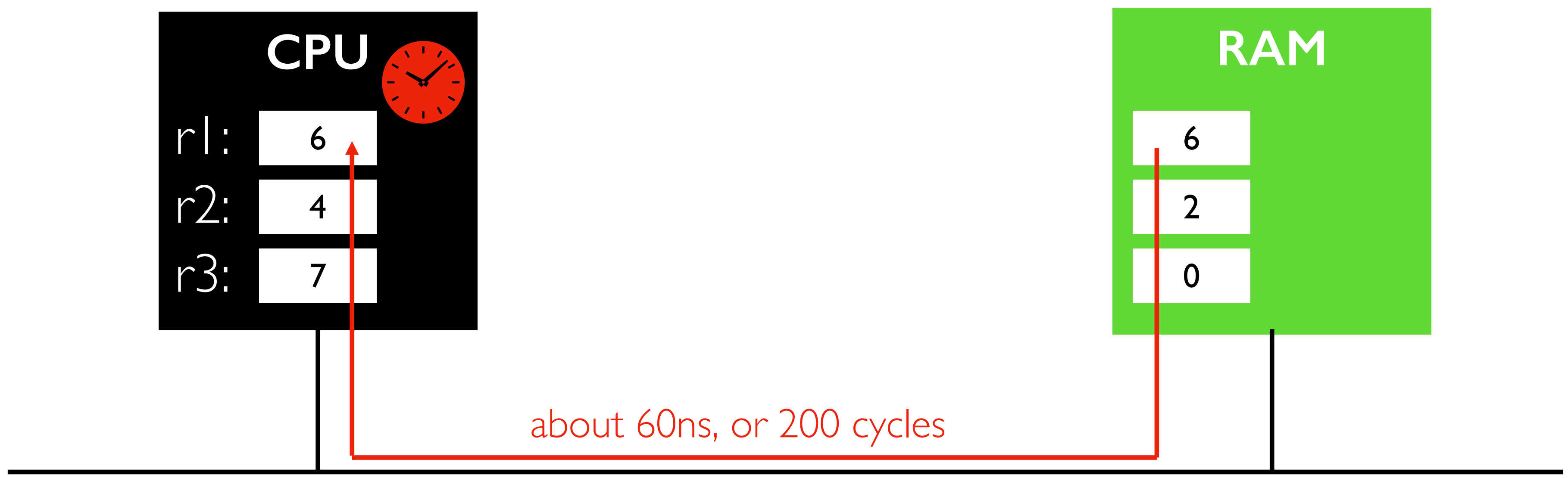
# CPU and RAM



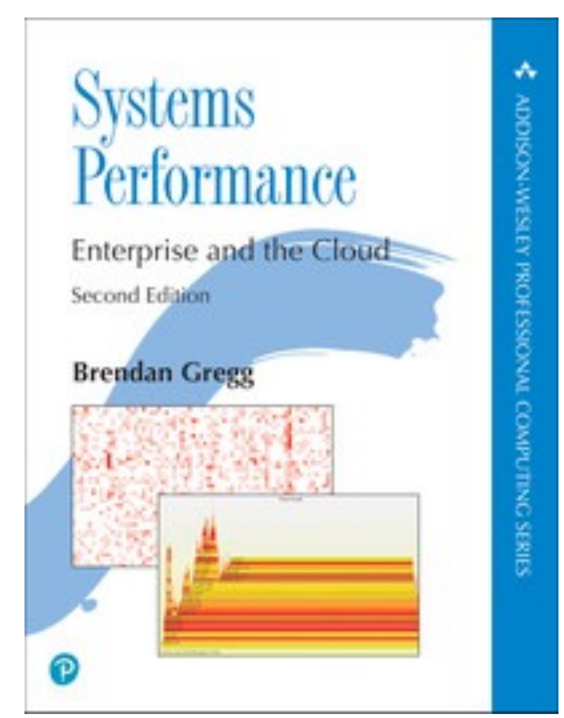
# Load and Store


**challenge**: if we want to add some numbers stored in RAM, we need to **load** before adding and **store** after

# Latency

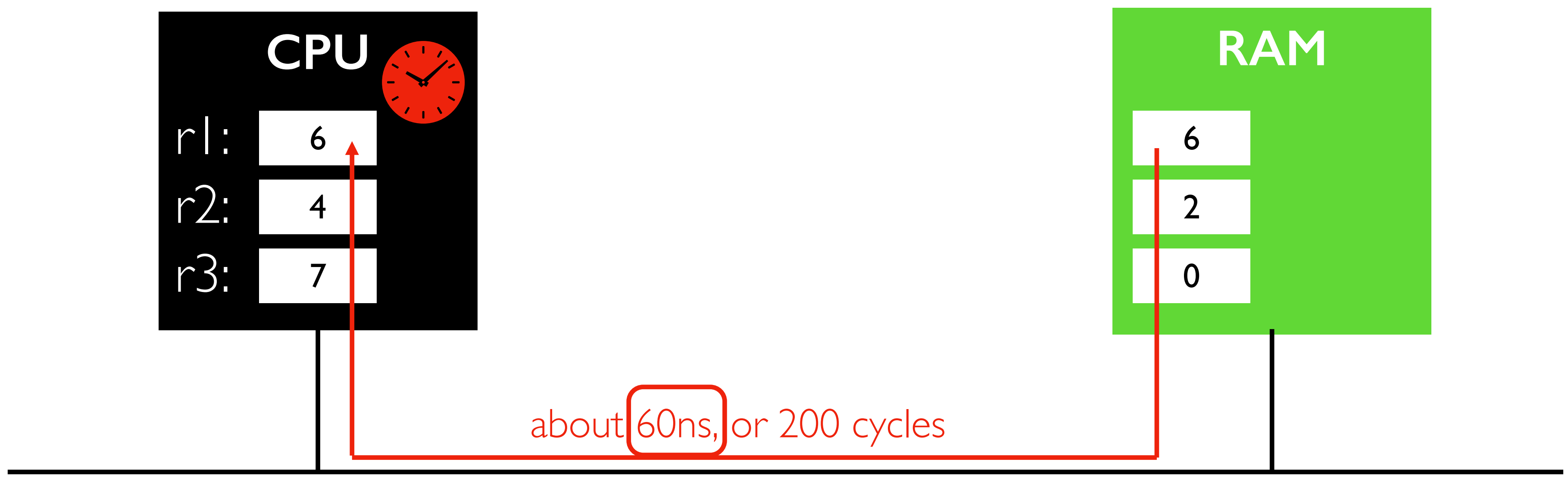



very slow, but not long enough to
switch to a different process...

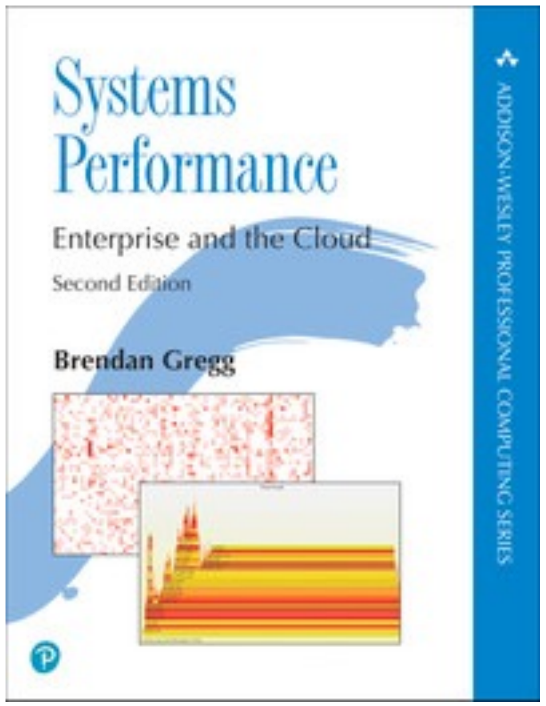



source: visuals, estimates

# Latency




"how much time" is a latency measure.
Throughput (bytes/second) would depend on how many loads like these we can do simultanously.

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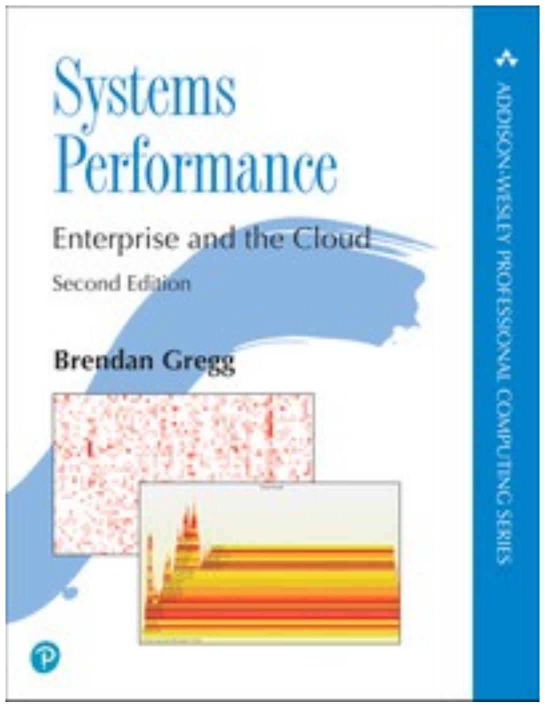
# Cache


**Idea**: CPUs can have a small/fast memory built in for data that is accessed frequently




source: visuals, estimates

# Latency Measurements

Metrics

- throughput
- average latency
- median latency
- "tail" latency (99th percentile, 99.9th percentile, etc).

Which metrics do we expect caching to help with the most?

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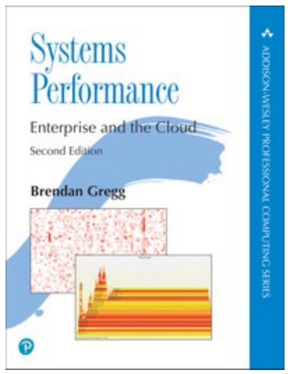
# Cache Hierarchy



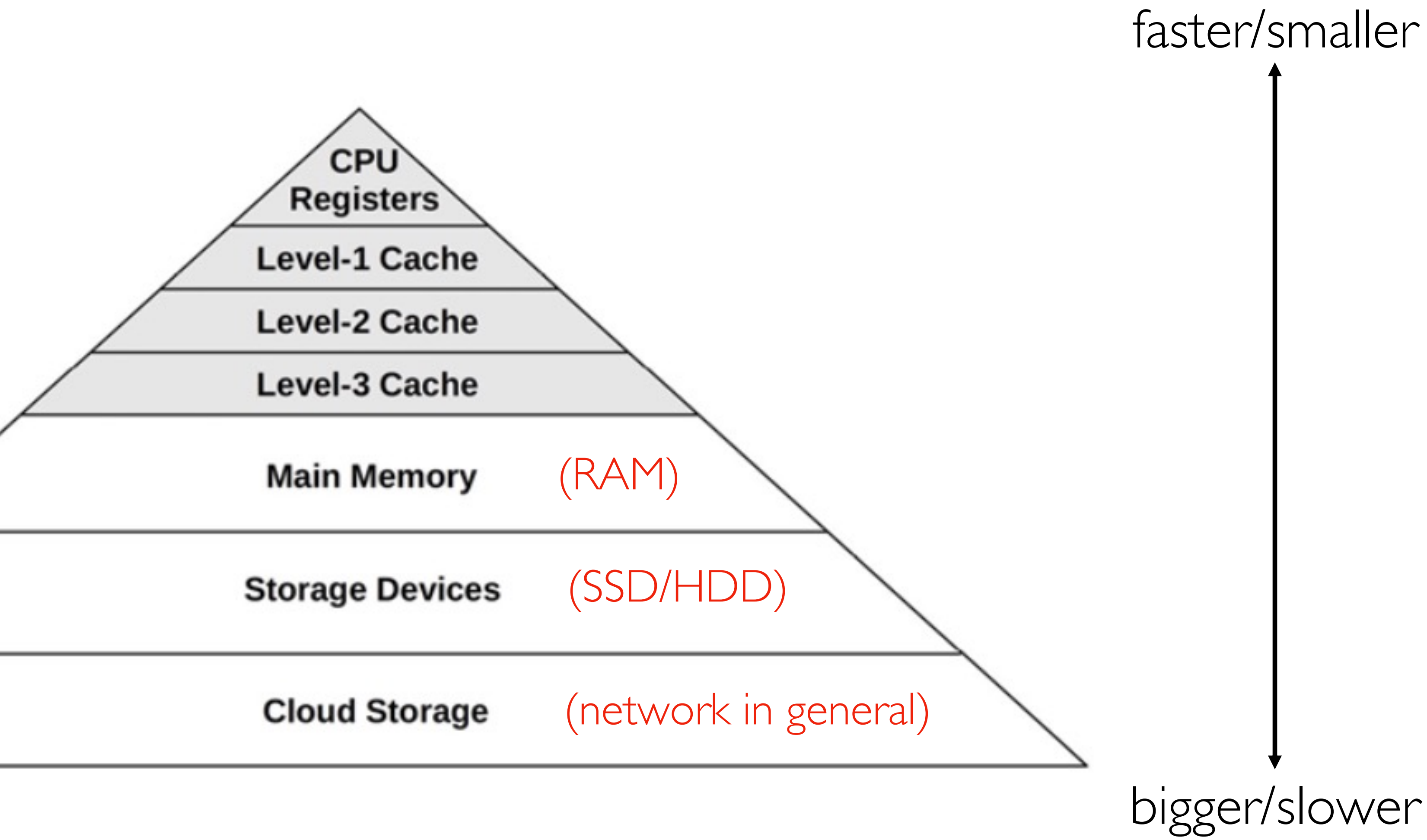



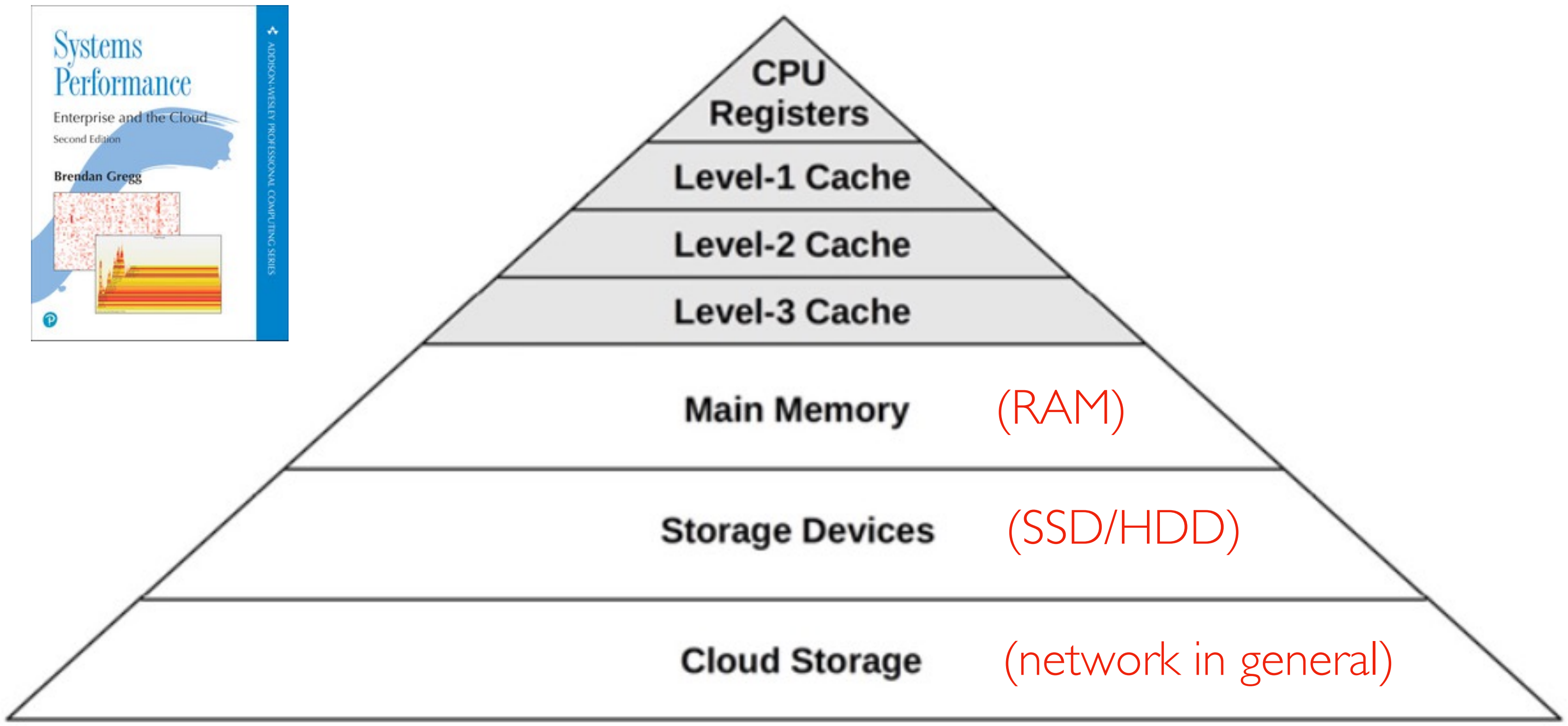

Figure 6.2 CPU cache sizes

Example: Intel Xeon Platinum 9282 (2019)

- L1: 64 KB
- L2: 1 MB
- L3: 77 MB

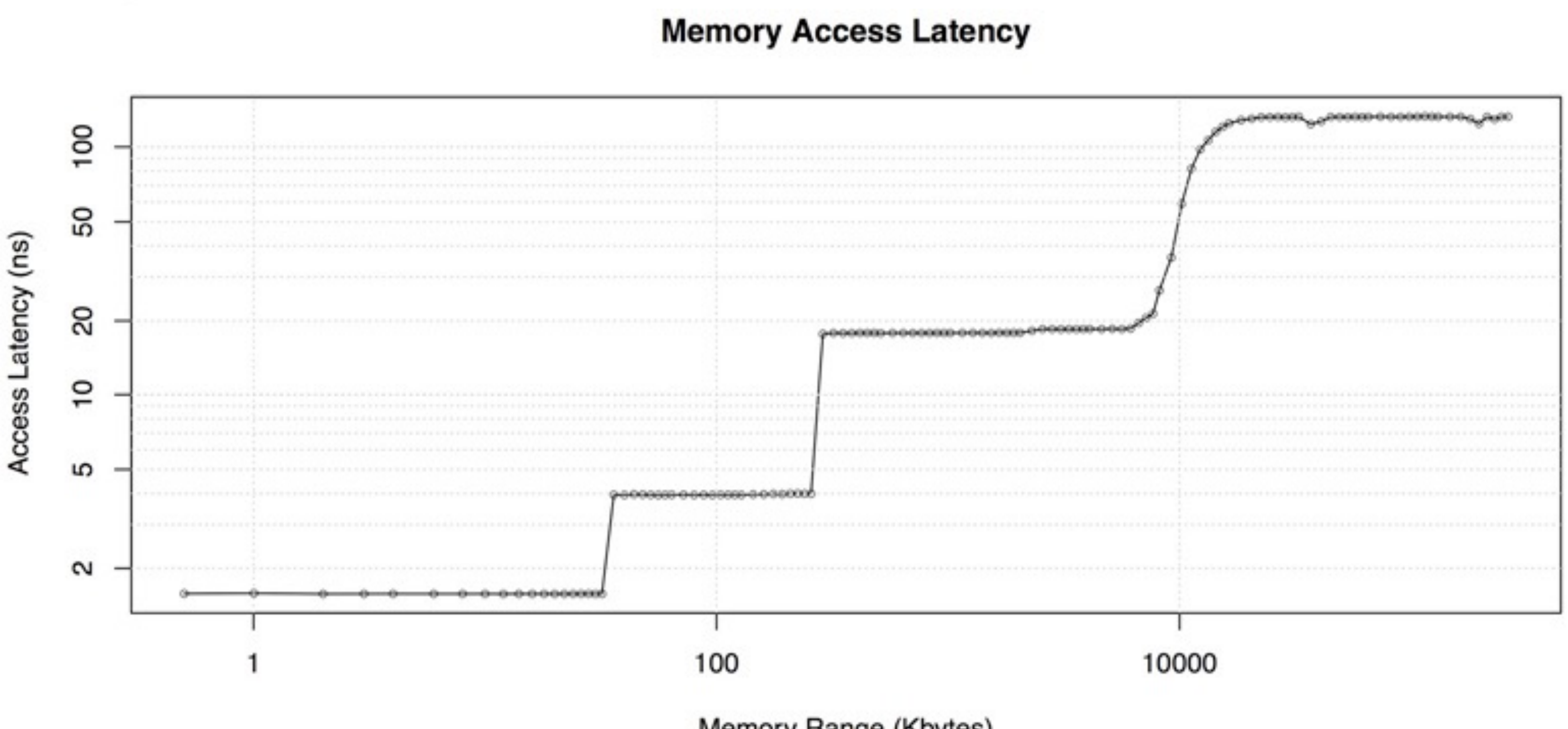
# Cache Hierarchy

faster/smaller




bigger/slower

Figure 6.2 CPU cache sizes




about how big is the L3 cache?
what is the latency for an L3 cache access?

# Resource Tradeoffs

File system caches file data in RAM

- use memory
- avoid storage reads

Browser caches recently visited page as file

- uses storage space
- avoid network transfers

Python dictionary caches return values in a dict (key=args, val=return)

- uses memory space
- avoid repeated compute

```
cache = {}
def f(x):
    if not x in cache:
        cache[x] = g(x)
    return cache[x]
```

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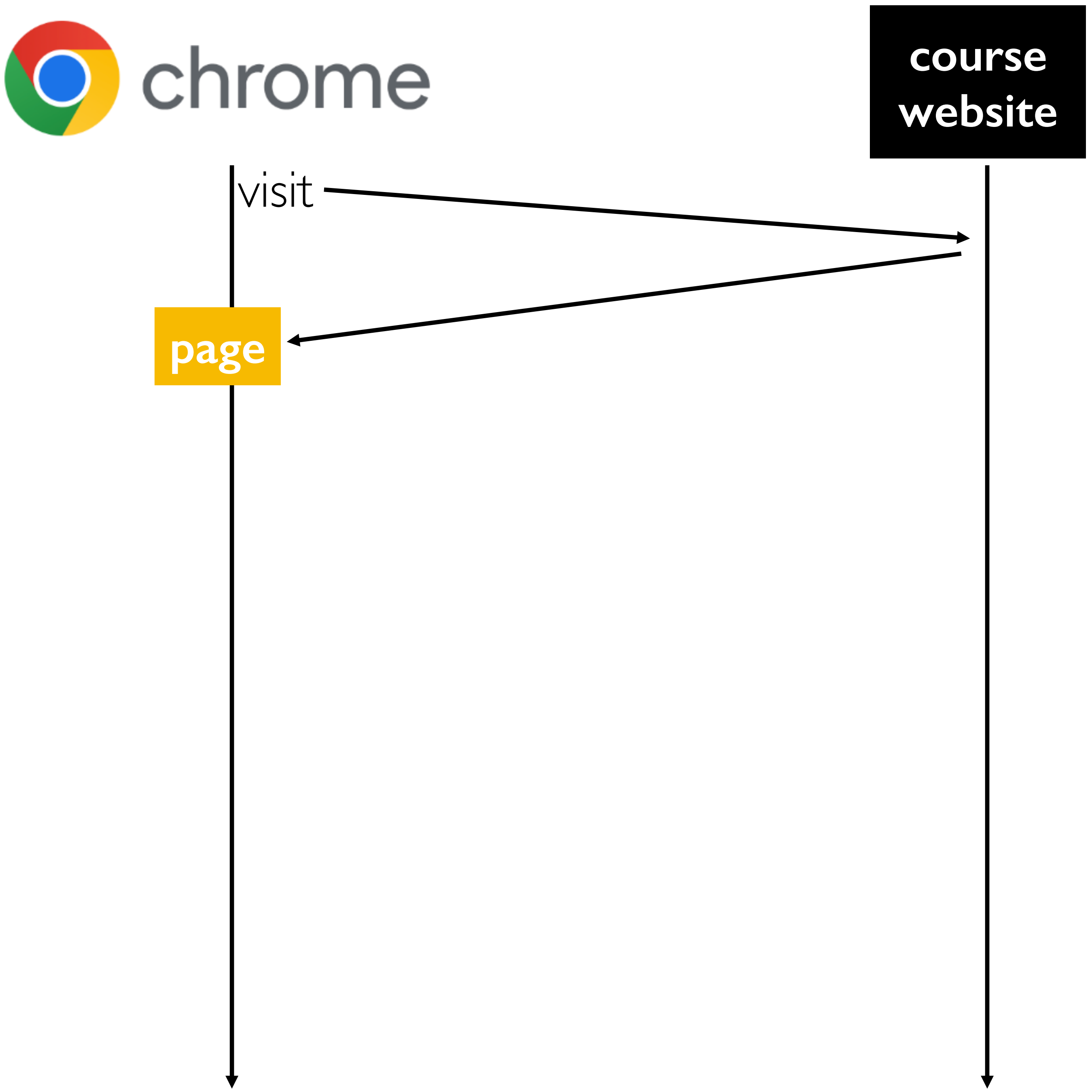
Practice

# Manual Caching: Spark Example

```
spark_df = ???? # not usually in memory

spark_df.cache() # put it in memory

# use spark_df for a lot of calculations

spark_df.unpersist() # free up memory
```

we'll be spending lots of time on Spark later in the semester

# Expiration: Browser Example



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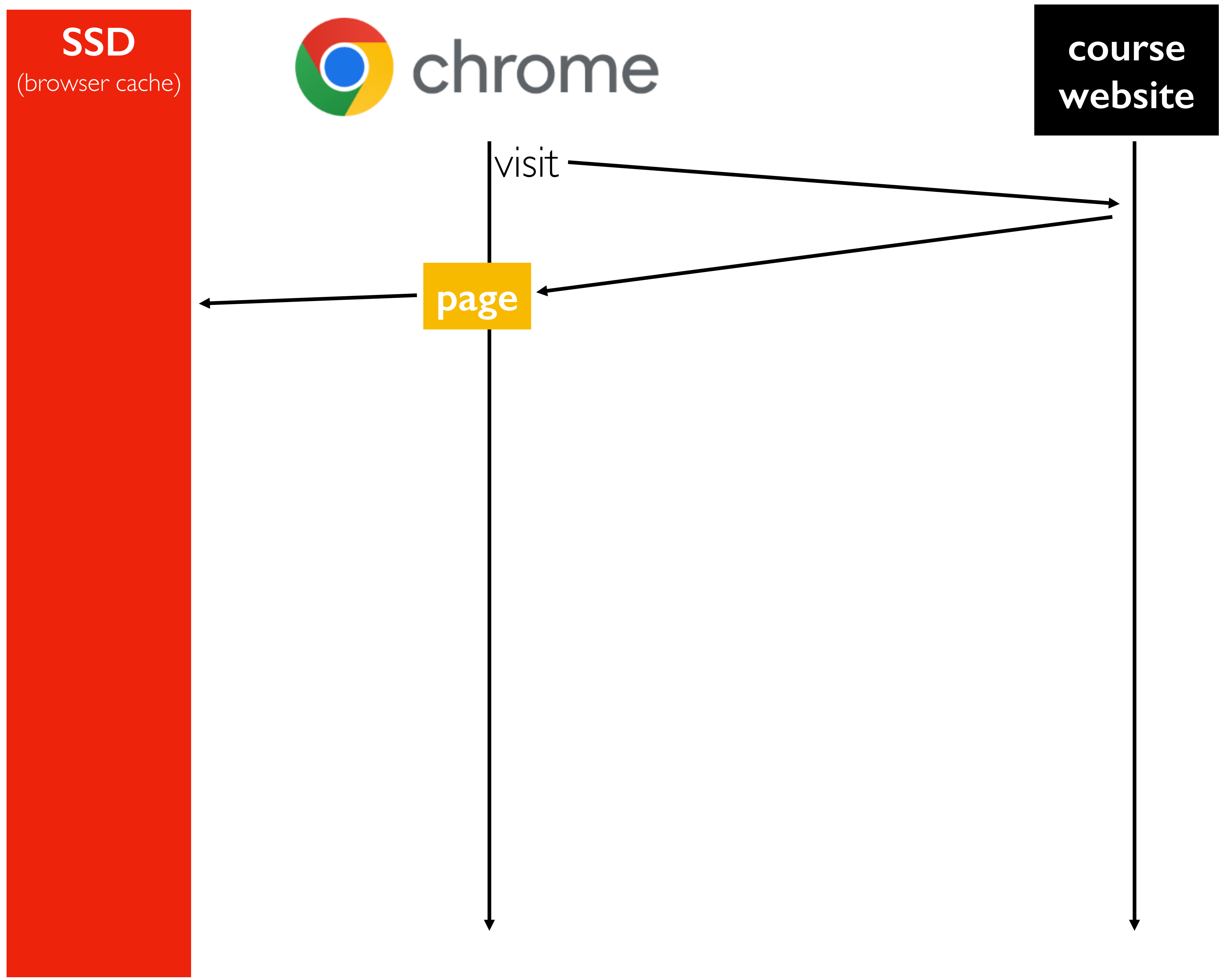

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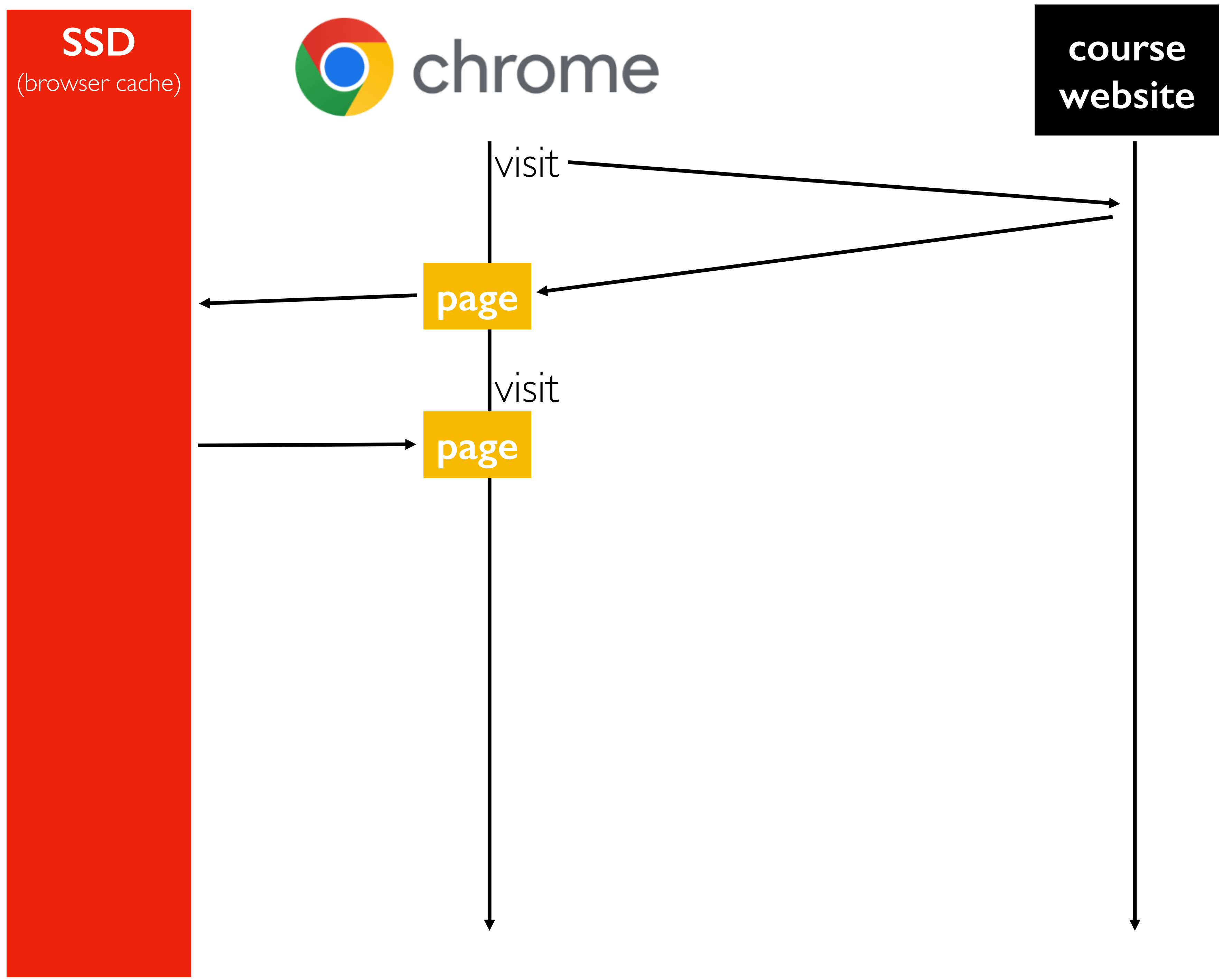

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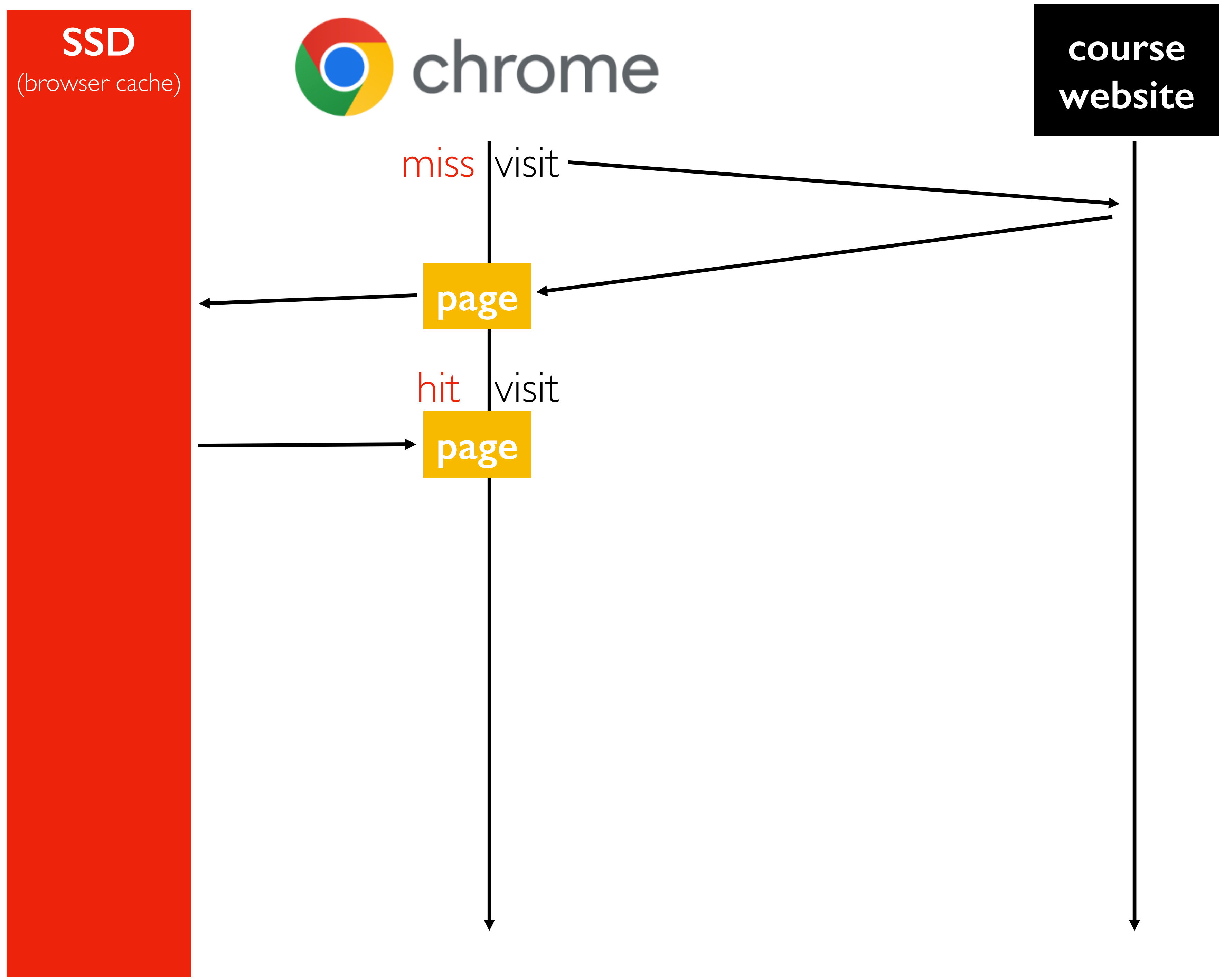

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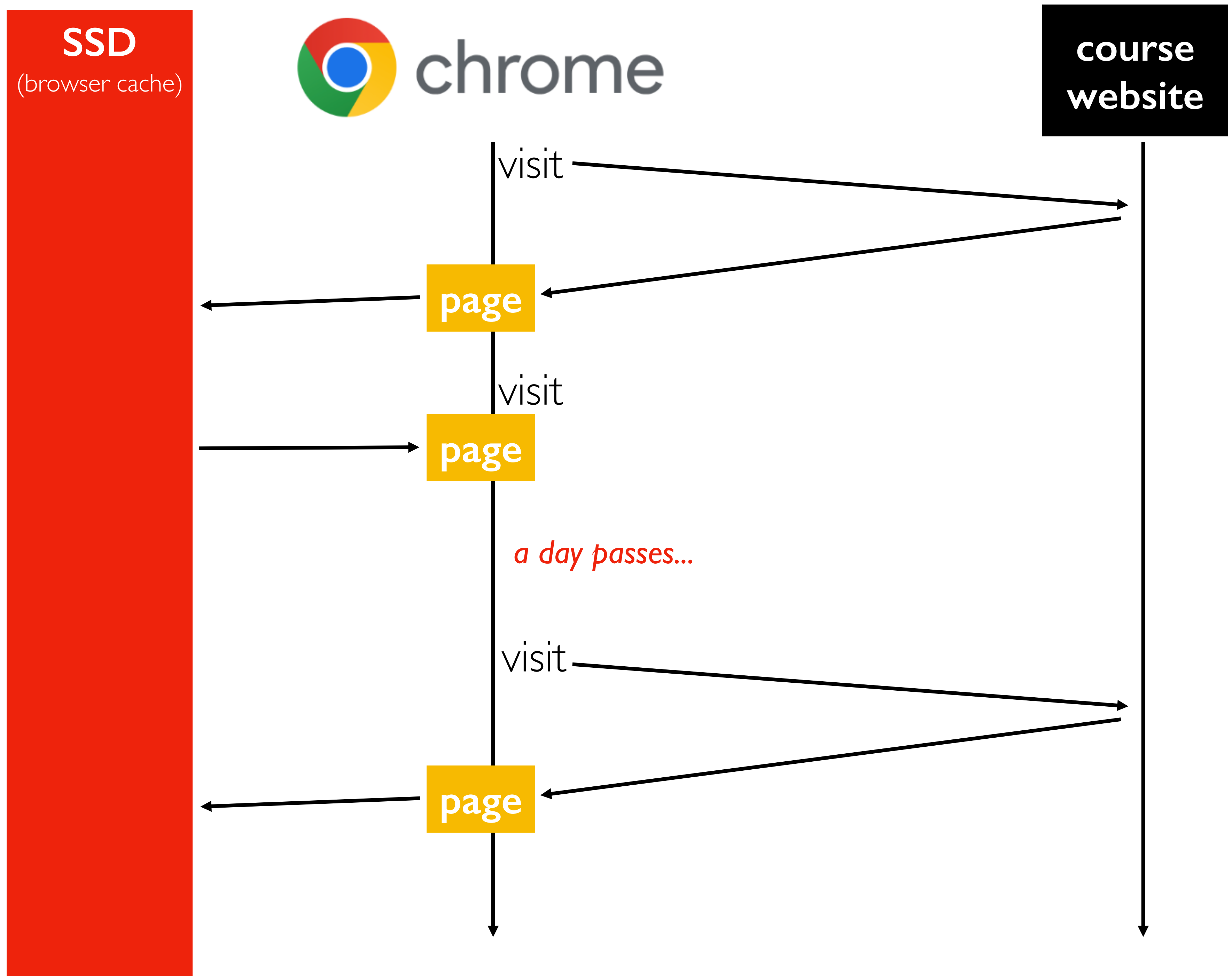


stale data (past expiration) is deleted (or re-valitaded).
SSD is large so freshness is more important than space.

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# Cache Policies

When to load data to a cache?

- whenever we read something, add it
- special exception: programmer knows it will never be read again
  - for example, F_NOCACHE option in Linux

When to evict data to a cache? Several policies

- random
  - select any entry at random as victim for eviction
- FIFO (first in, first out)
  - evict whichever entry has been in the cache the longest
- LRU (least recently used)
  - evict whichever entry has been used the least recently

Worksheet

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