[544] Caching

Tyler Caraza-Harter

Outline

Challenge: Latency

Cache Hierarchy

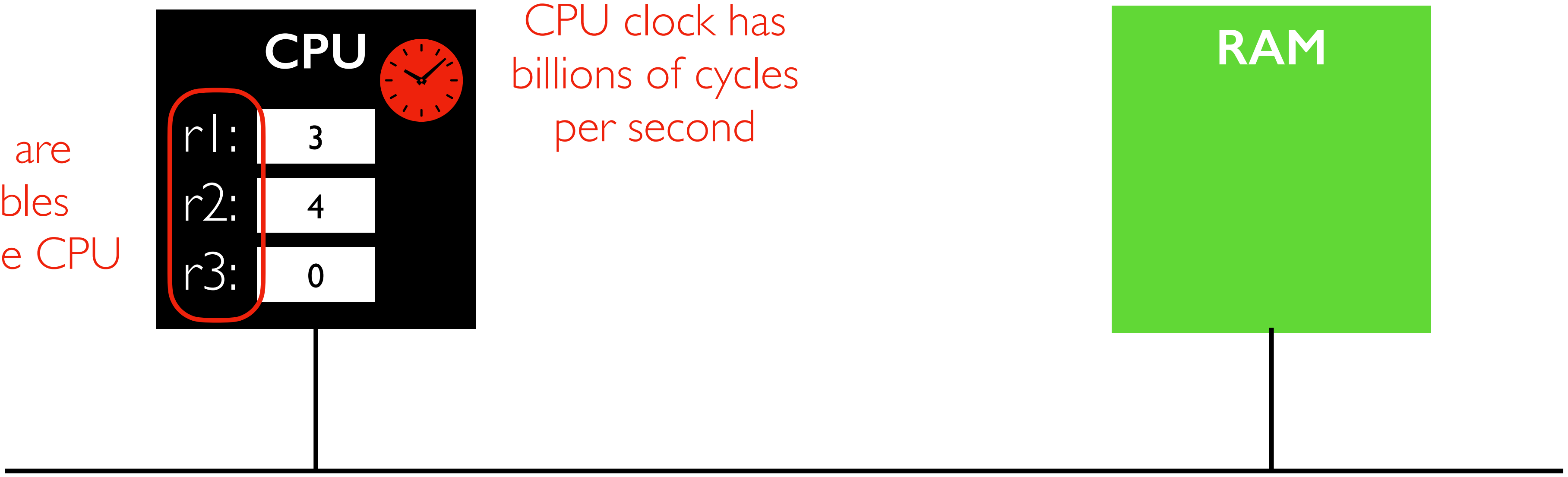
- CPU, RAM, SSD, Disk, Network
- Tradeoffs

What data should be cached?

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

Practice

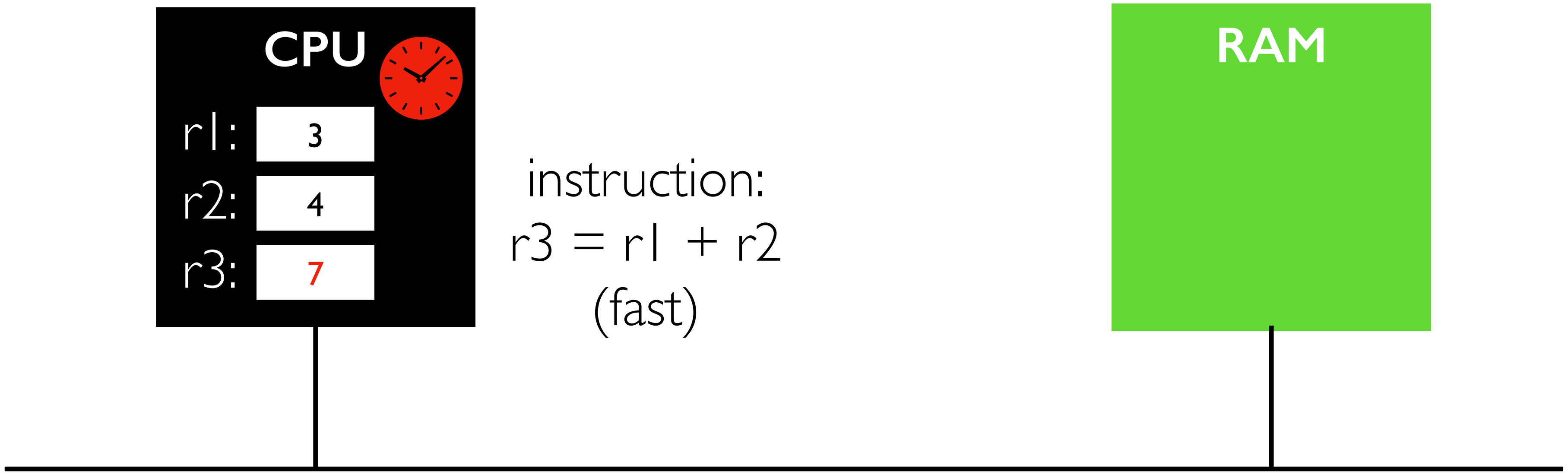
CPU and RAM



registers are
like variables
built into the CPU

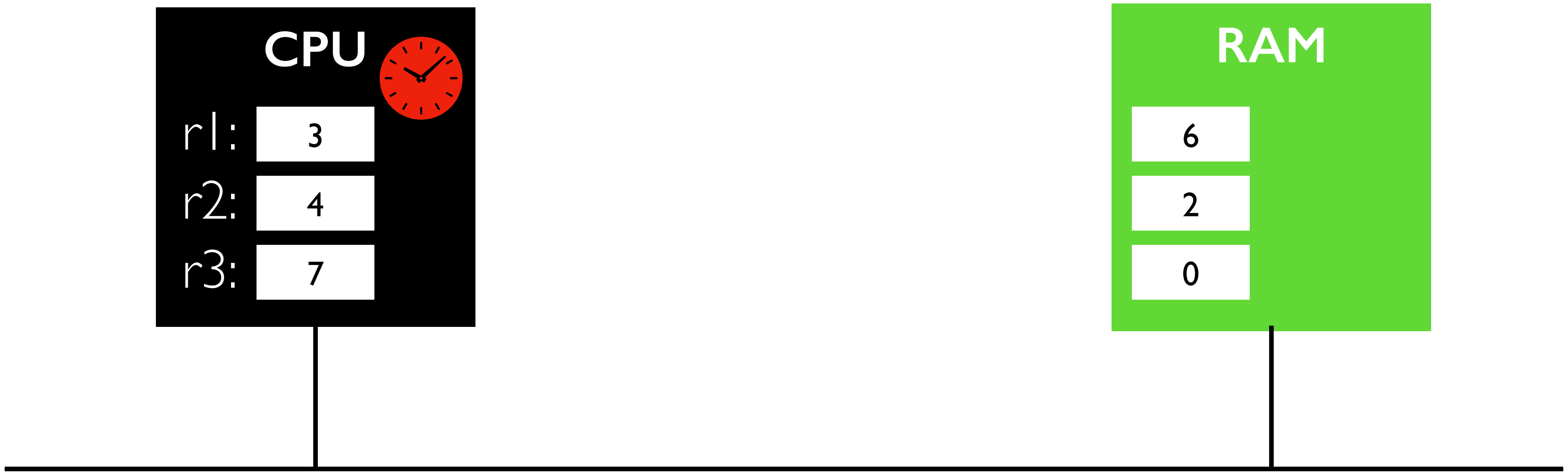
CPU clock has
billions of cycles
per second

CPU and RAM



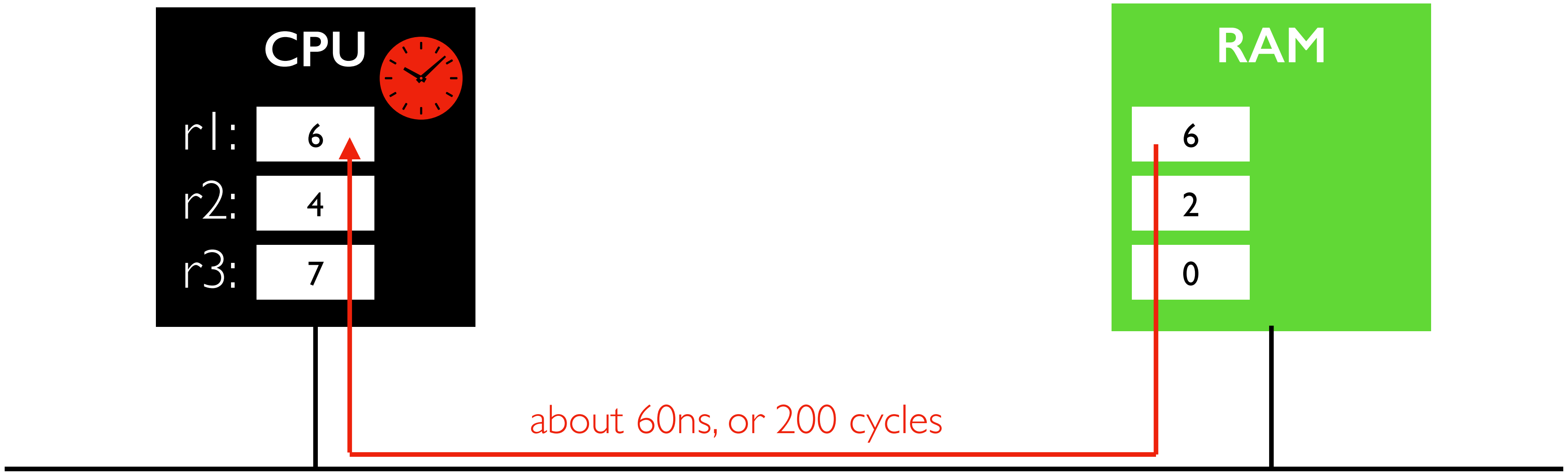
instruction:
r3 = r1 + r2
(fast)

Load and Store



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

Latency



CPU

r1: 6

r2: 4

r3: 7

RAM

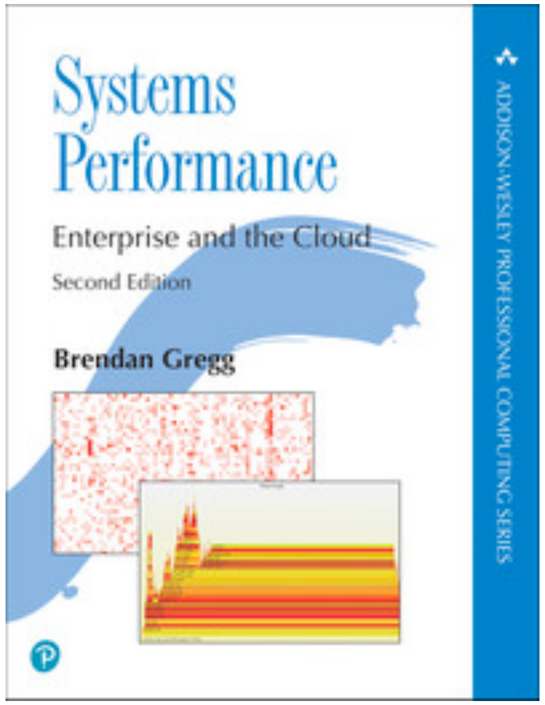
6

2

0

about 60ns, or 200 cycles

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



Systems Performance

Enterprise and the Cloud

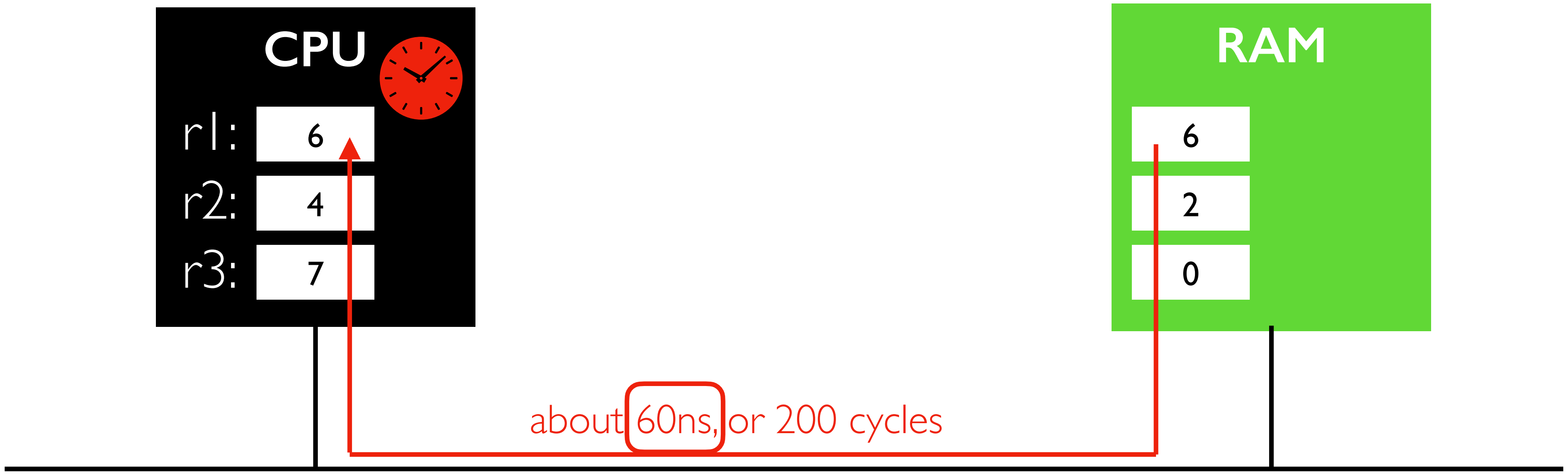
Second Edition

Brendan Gregg

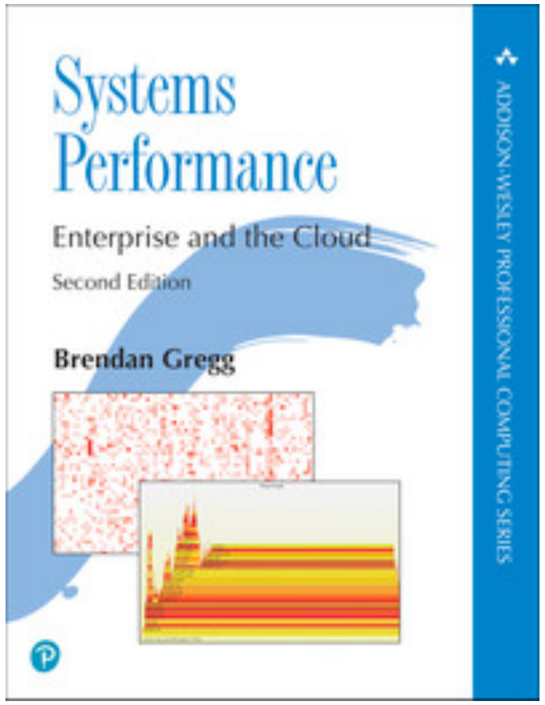
ADDISON-WESLEY PROFESSIONAL COMPUTING SERIES

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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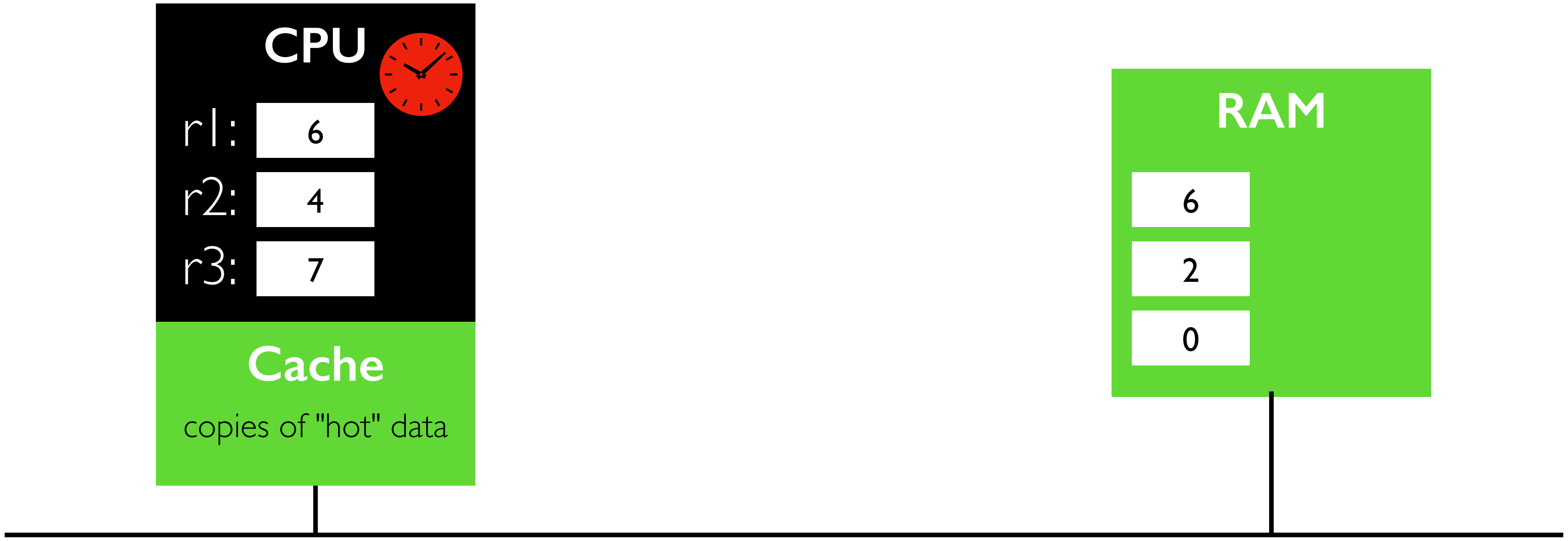
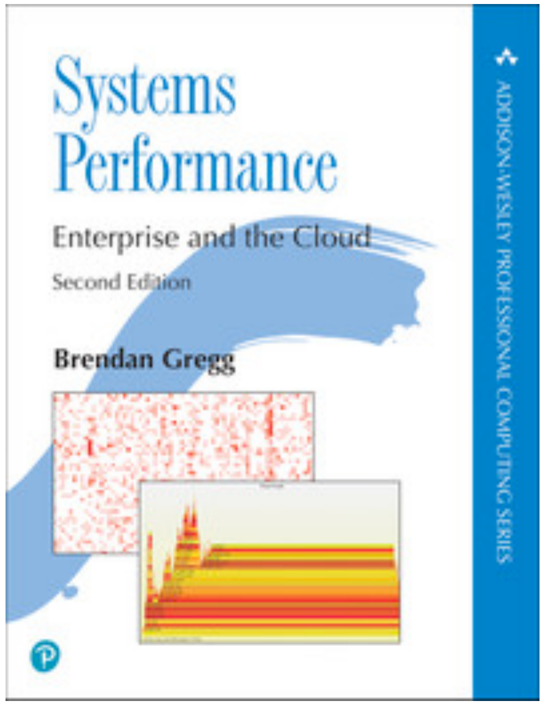
Cache



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



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Latency Measurements

Metrics

- 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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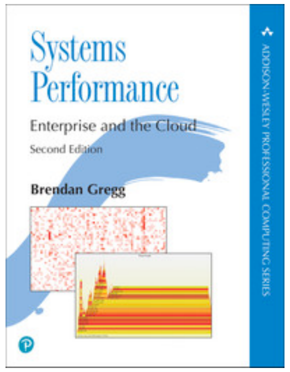

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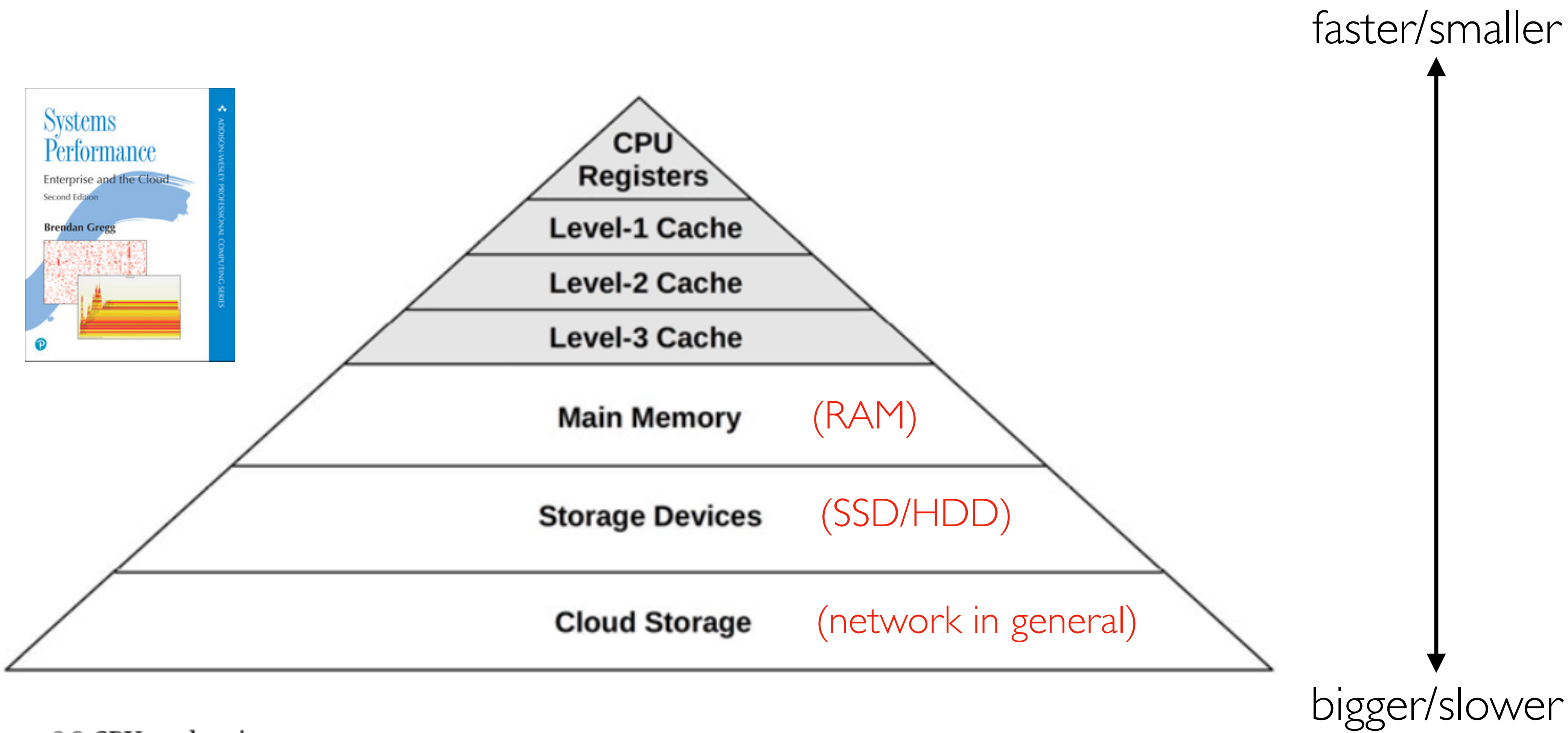


faster/smaller

CPU Registers

Level-1 Cache

Level-2 Cache

Level-3 Cache

Main Memory (RAM)

Storage Devices (SSD/HDD)

Cloud Storage (network in general)

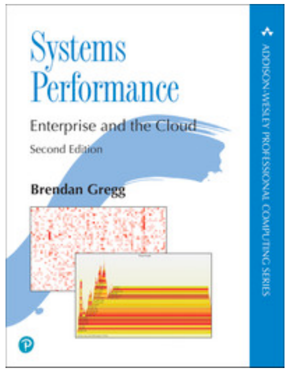
bigger/slower

Figure 6.2 CPU cache sizes

Example: Intel Xeon Platinum 9282 (2019)

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

Cache Hierarchy



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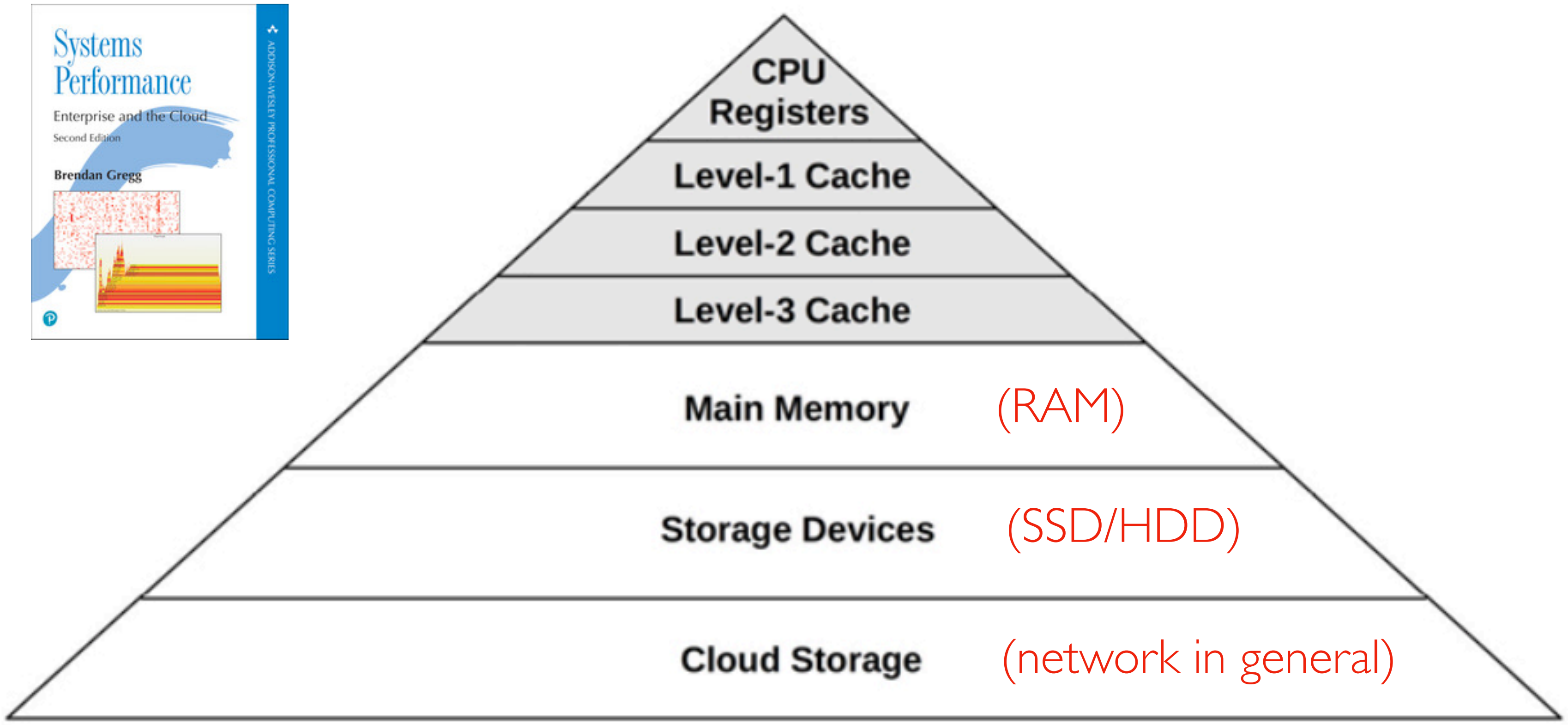

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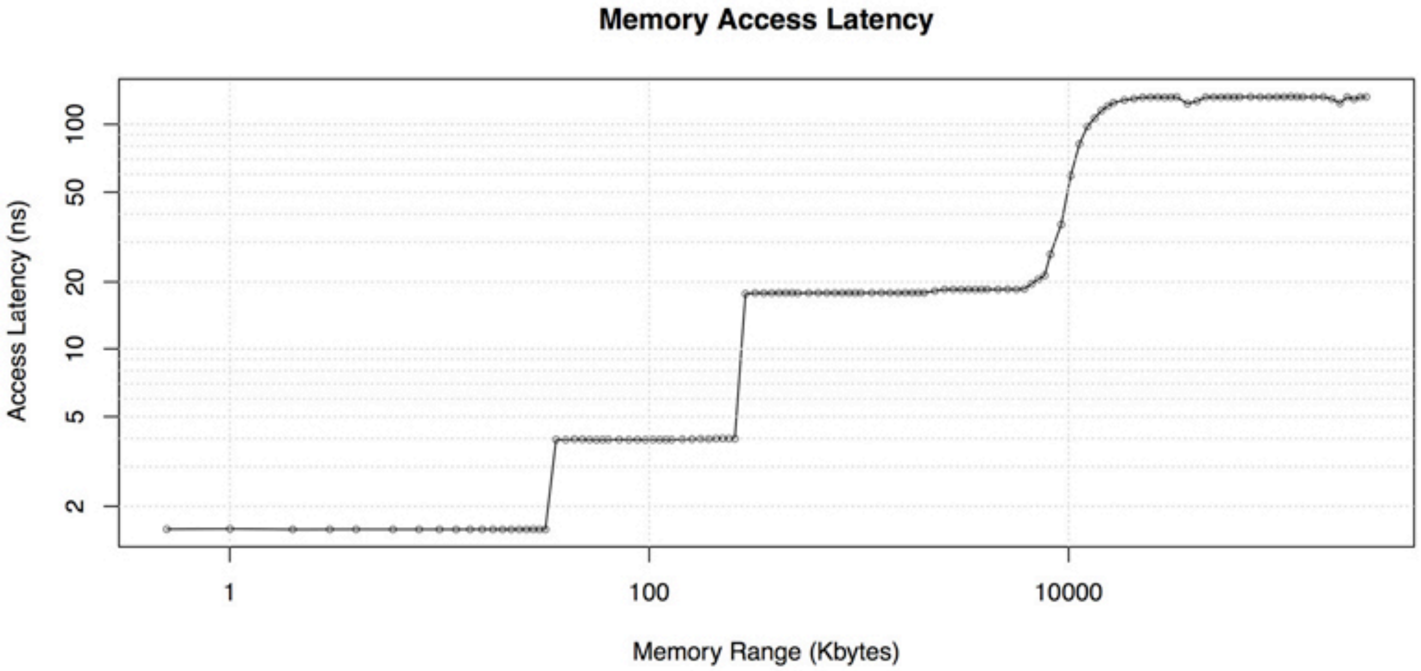
Figure 6.2 CPU cache sizes



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

- 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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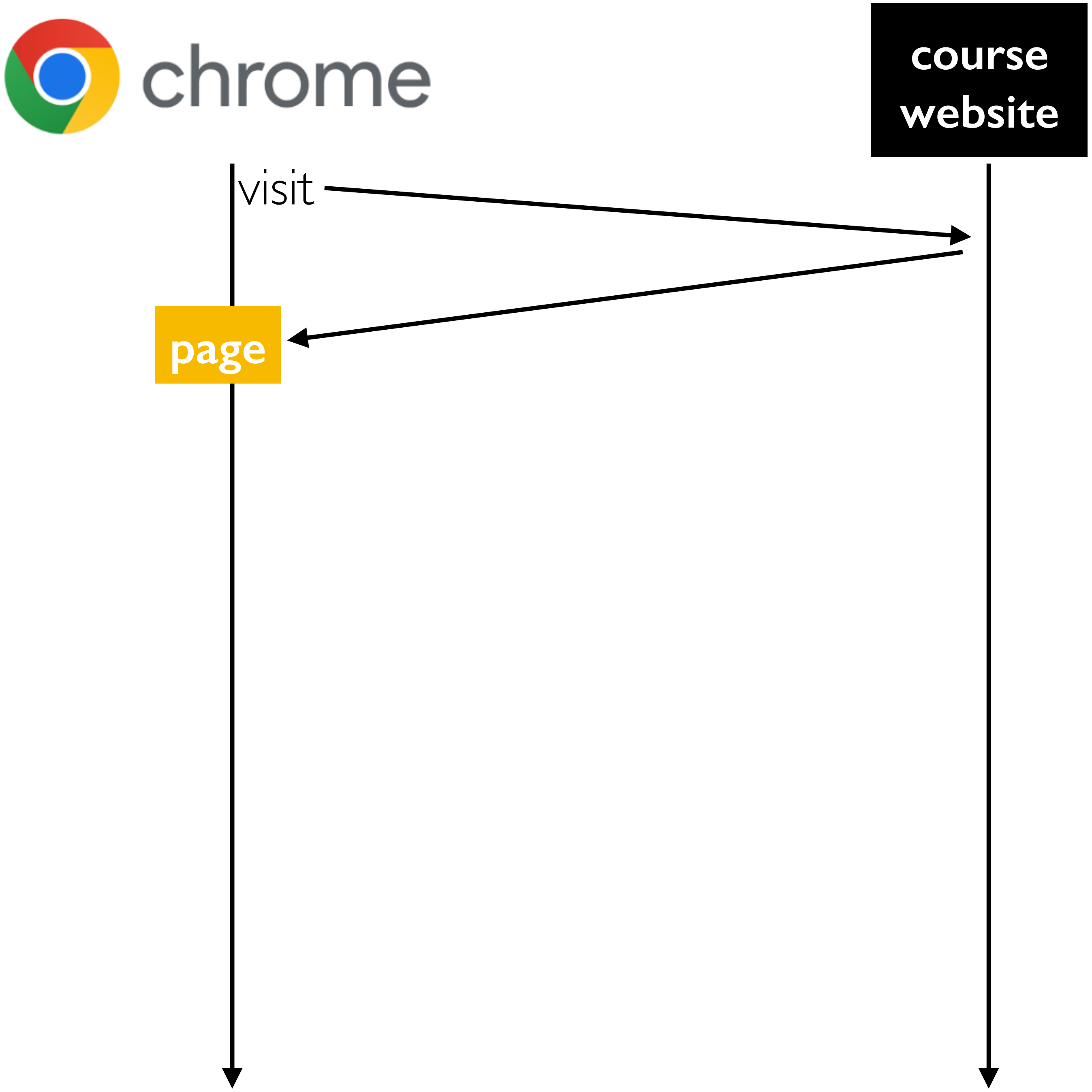
Practice

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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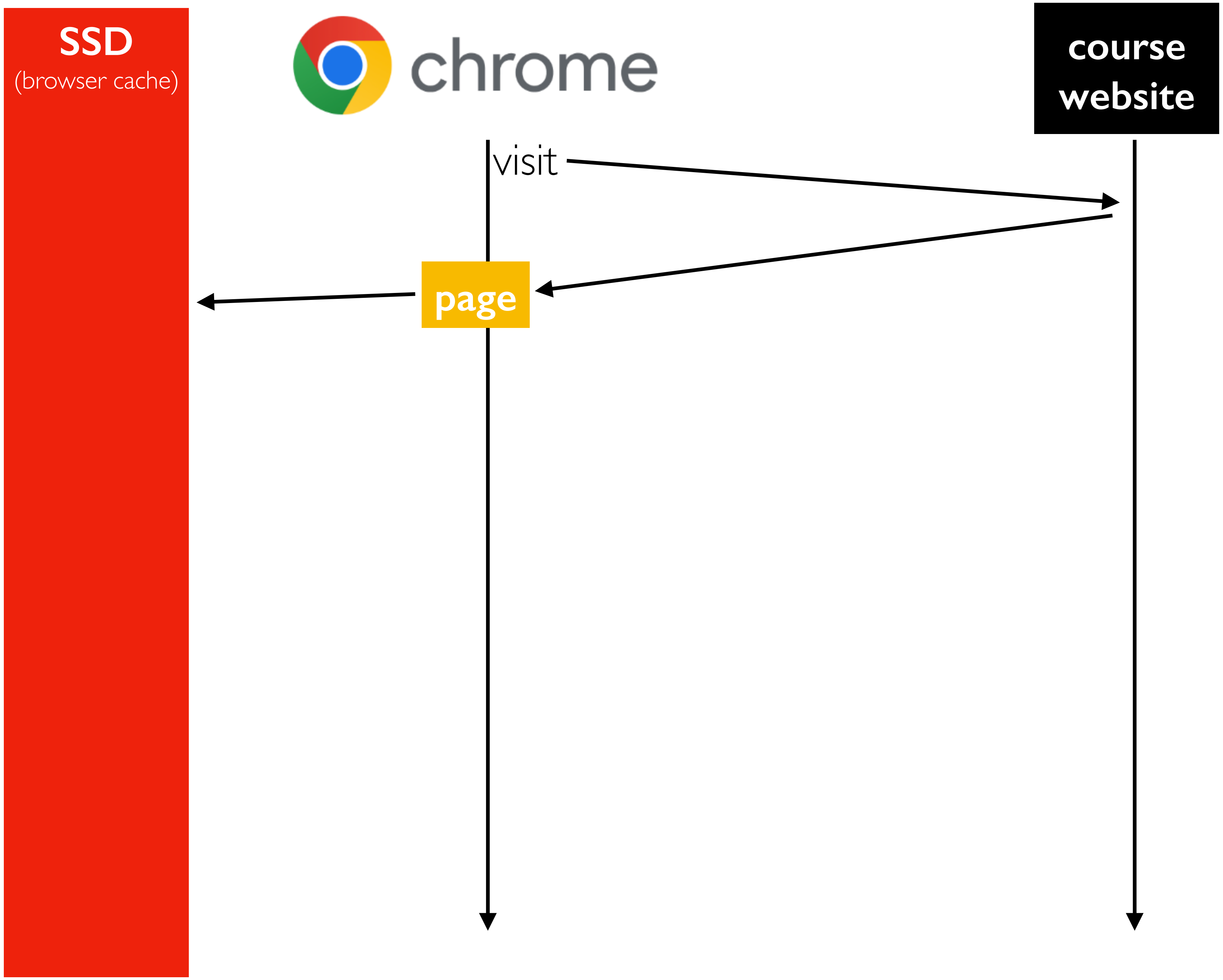

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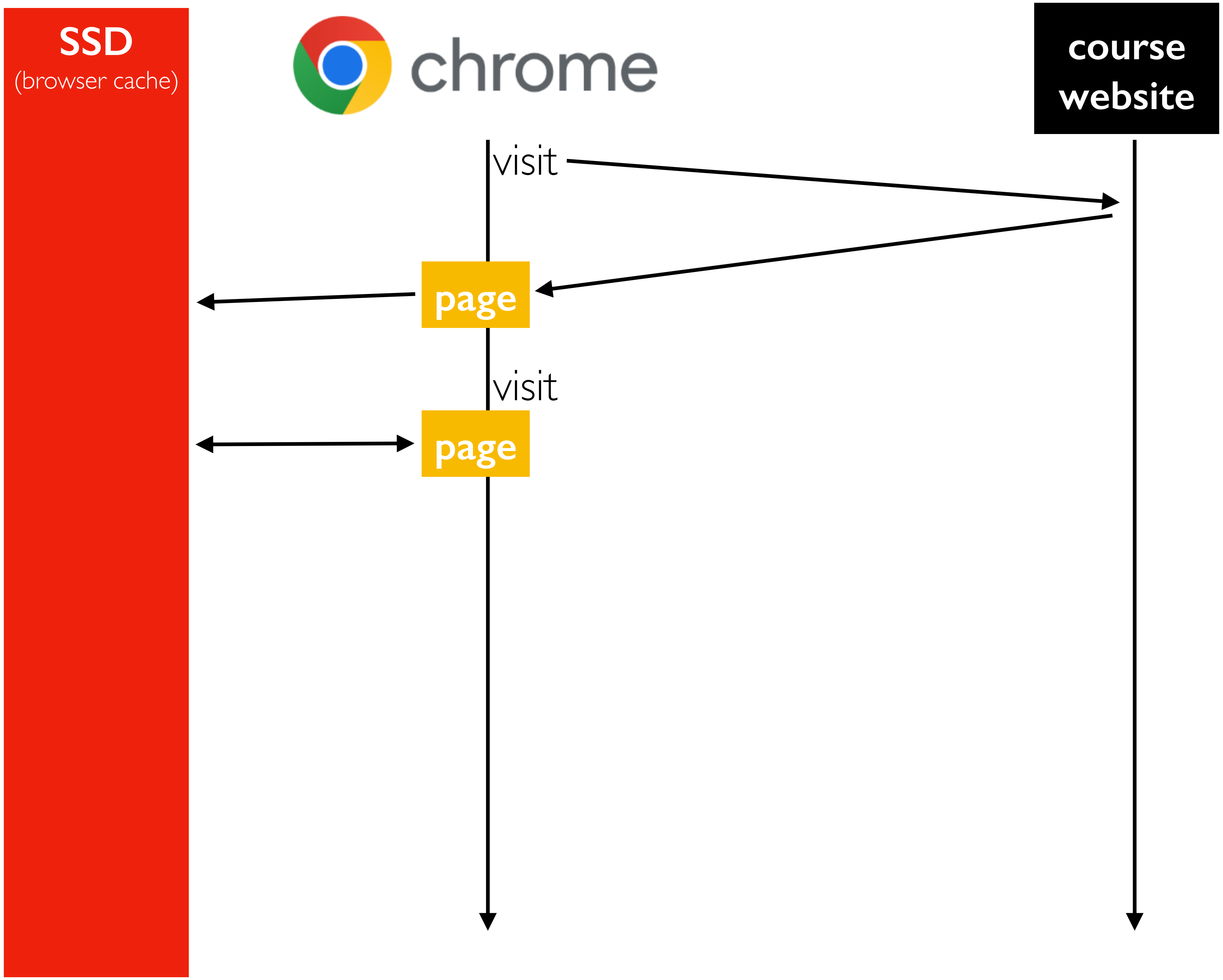

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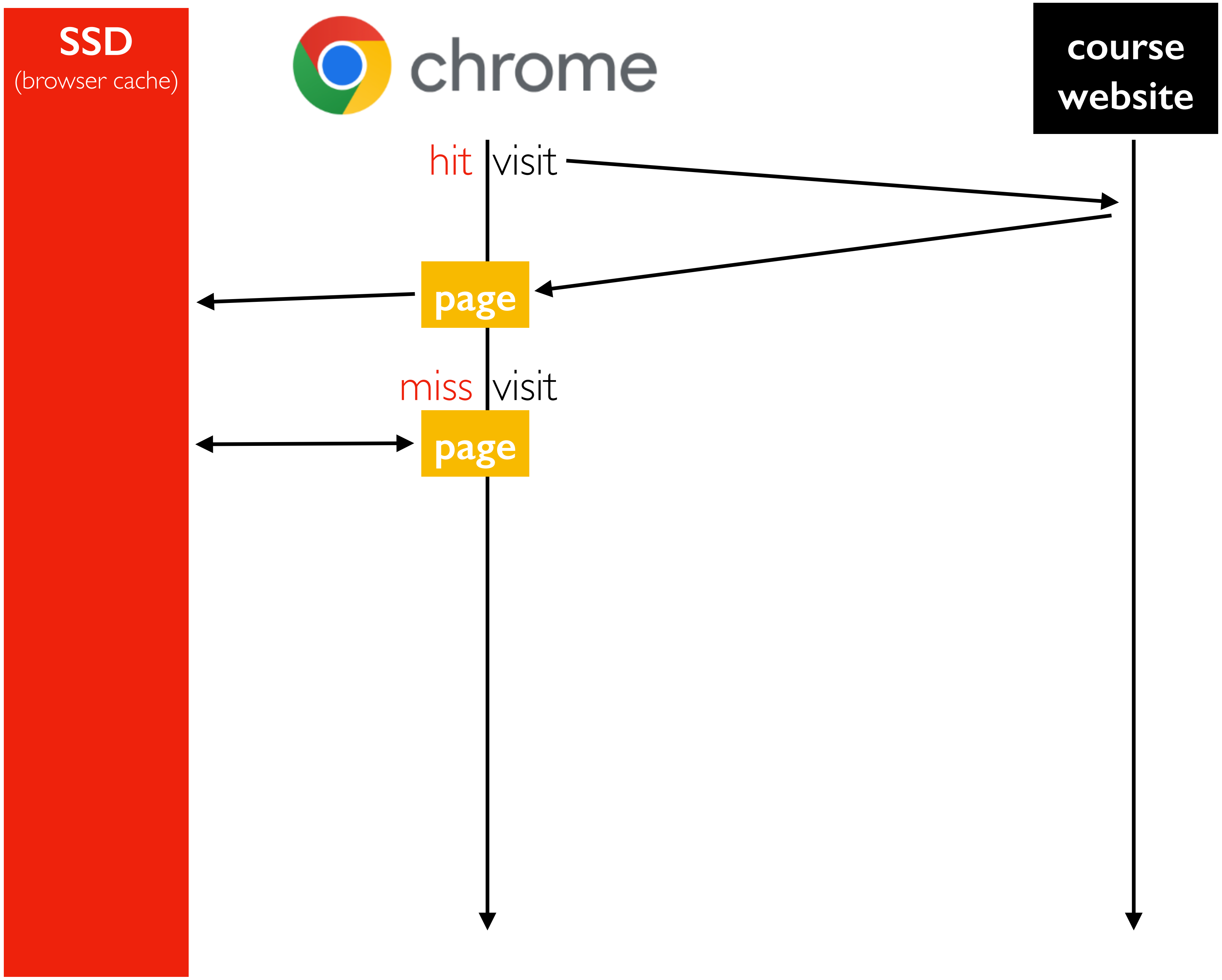

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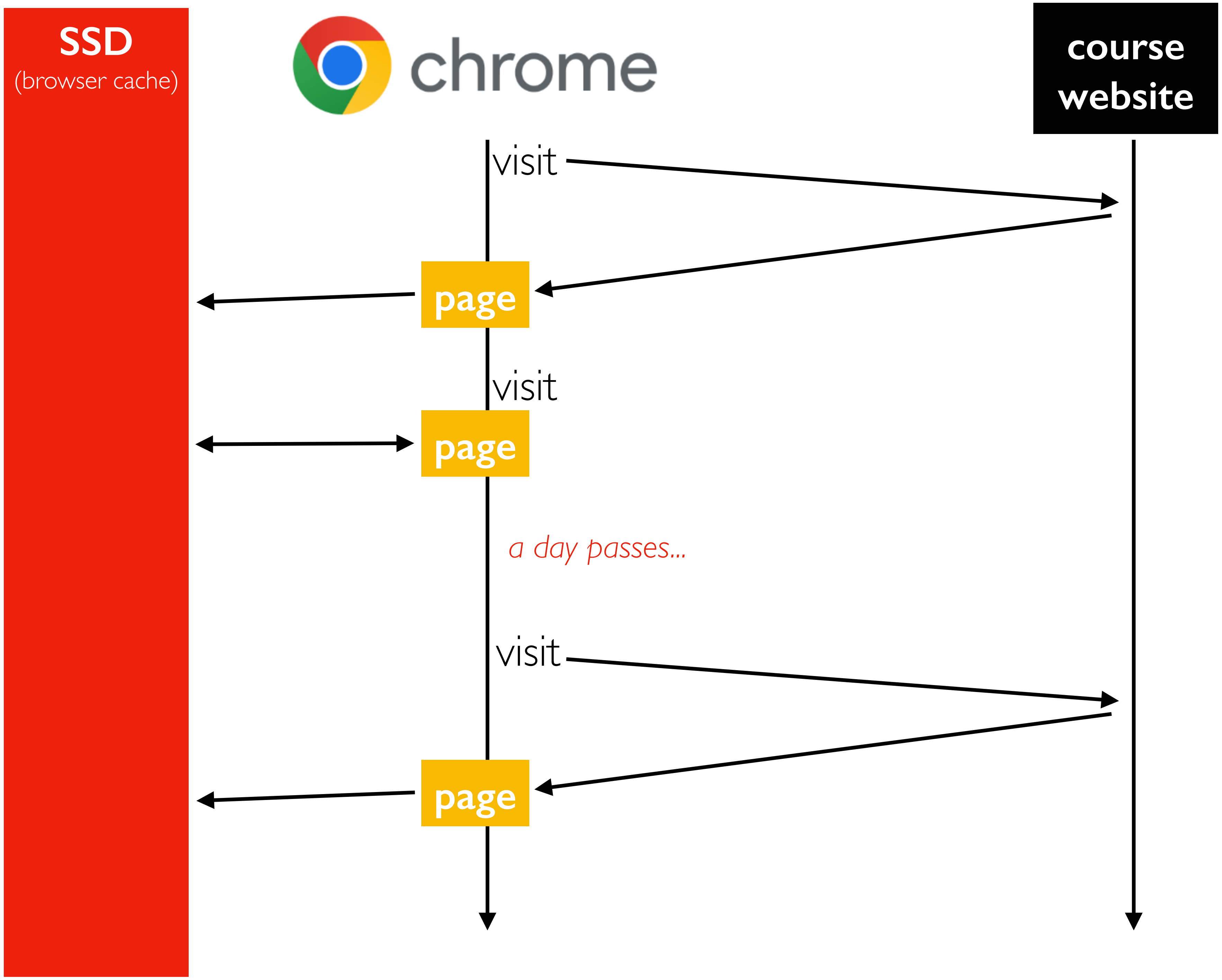

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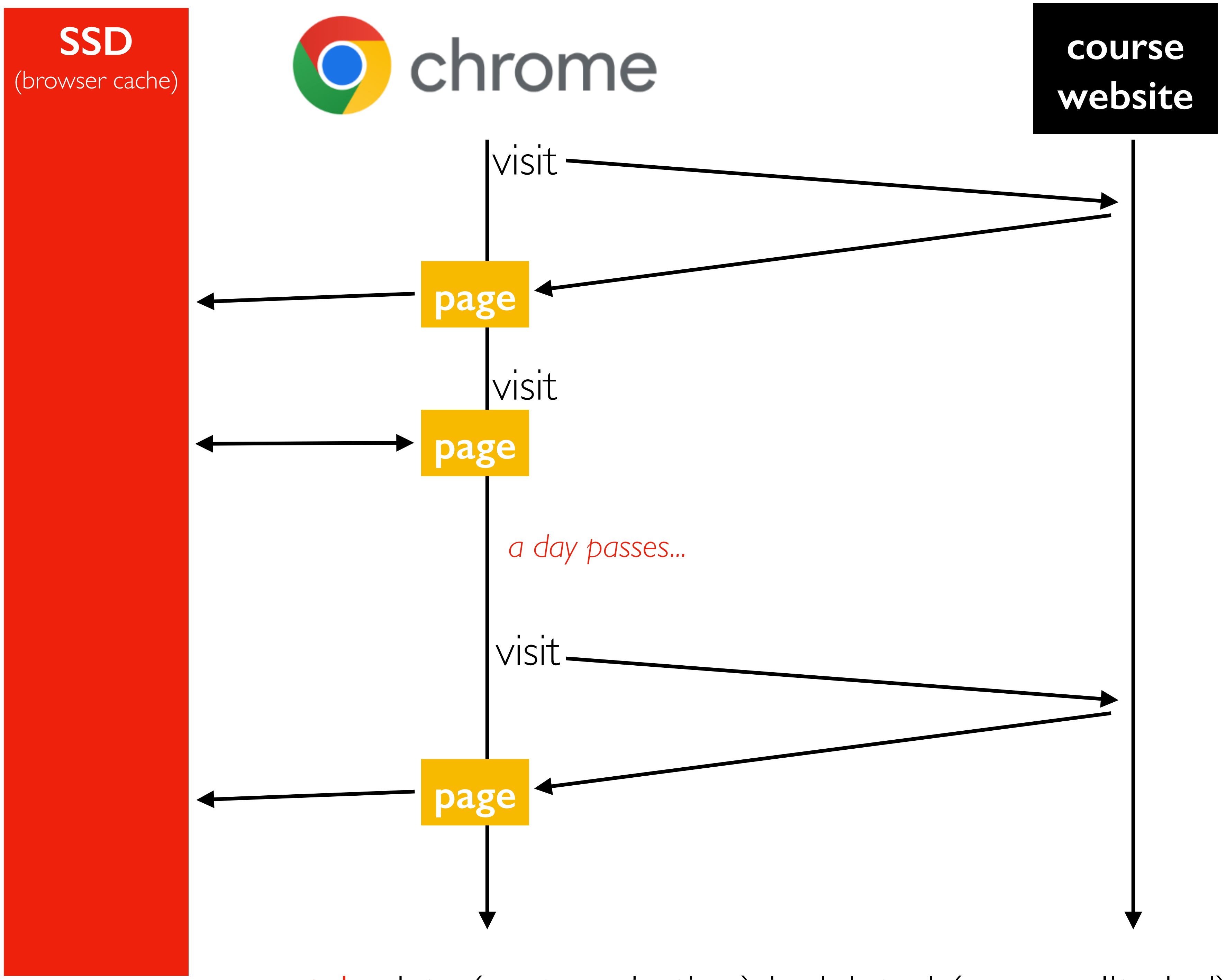

stale data (past expiration) is deleted (or re-valitaded).
SSD is large so freshness is more important than space.

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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 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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