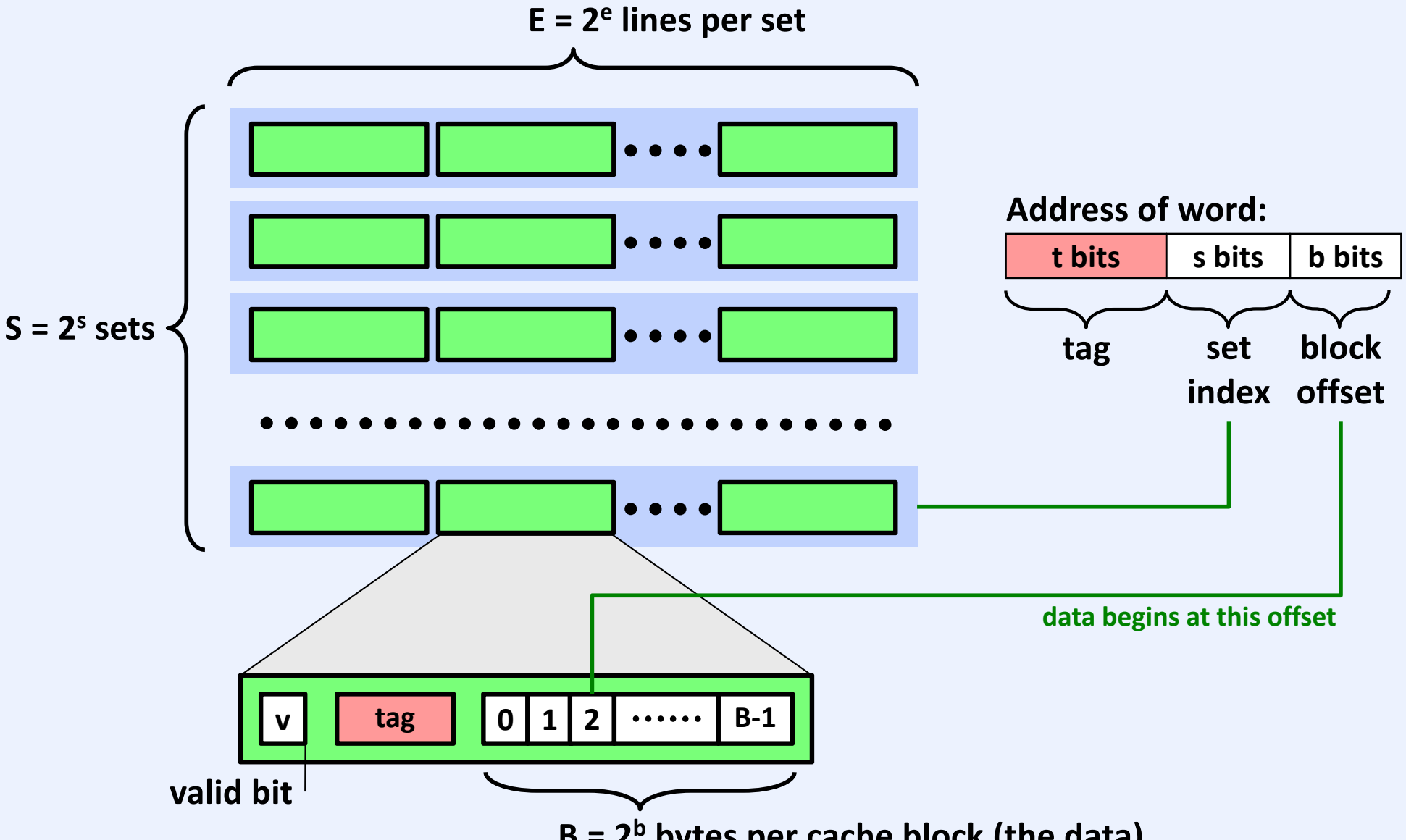
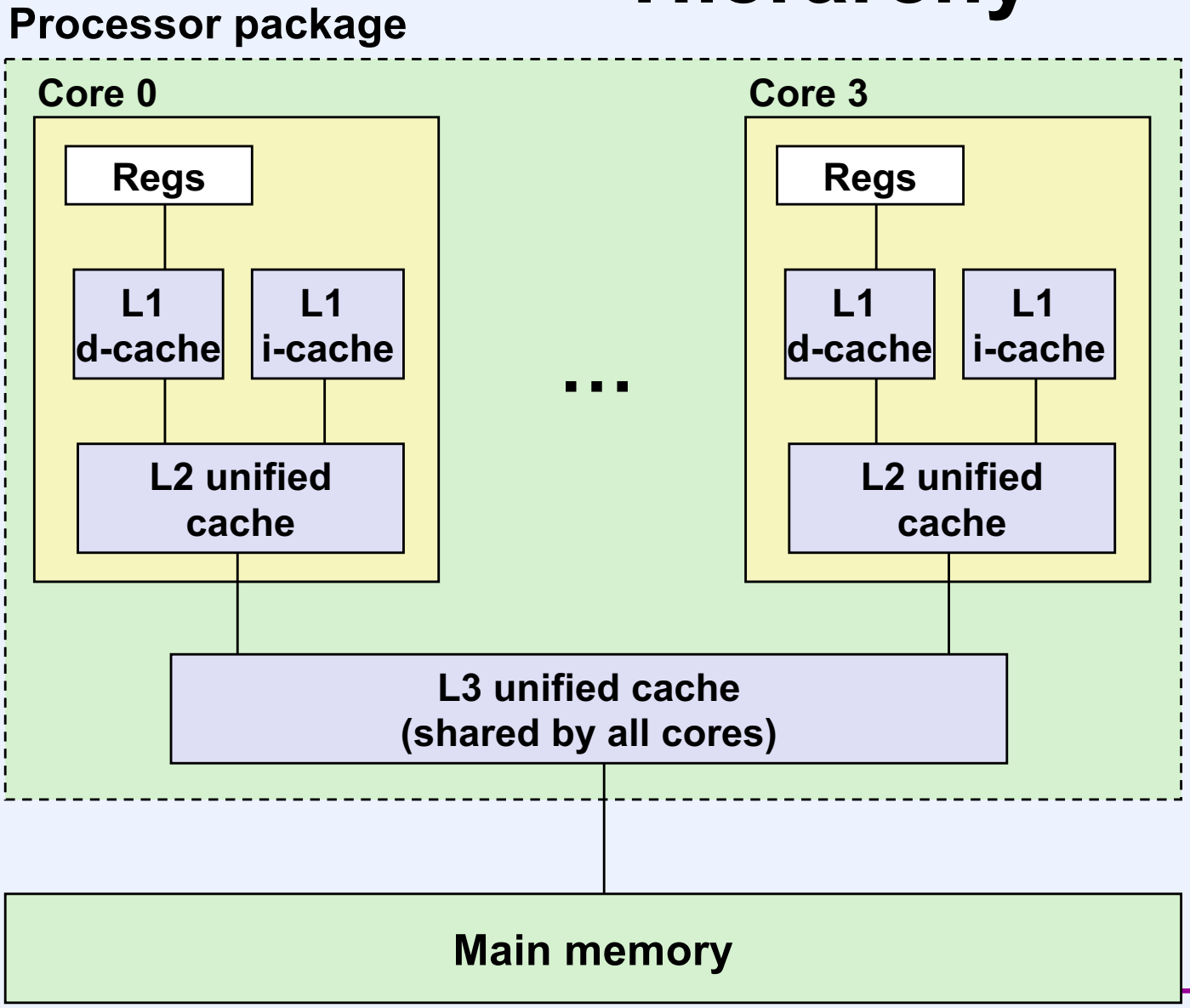
Memory Management Part 5

E-Way Set-Associative Cache



Intel Core i5 and i7 Cache Hierarchy



L1 i-cache and d-cache:
32 KB, 8-way,
Access: 4 cycles

L2 unified cache:
256 KB, 8-way,
Access: 11 cycles

L3 unified cache:
8 MB, 16-way,
Access: 30-40 cycles

Block size: 64 bytes for all caches

Quiz 1

You're designing the algorithm for allocating an often-used and -allocated kernel data structure that fits within a cache line. We'd like to make sure that a number of these data structures can coexist in the hardware caches. Which one of the following would help make this happen (and is doable)?

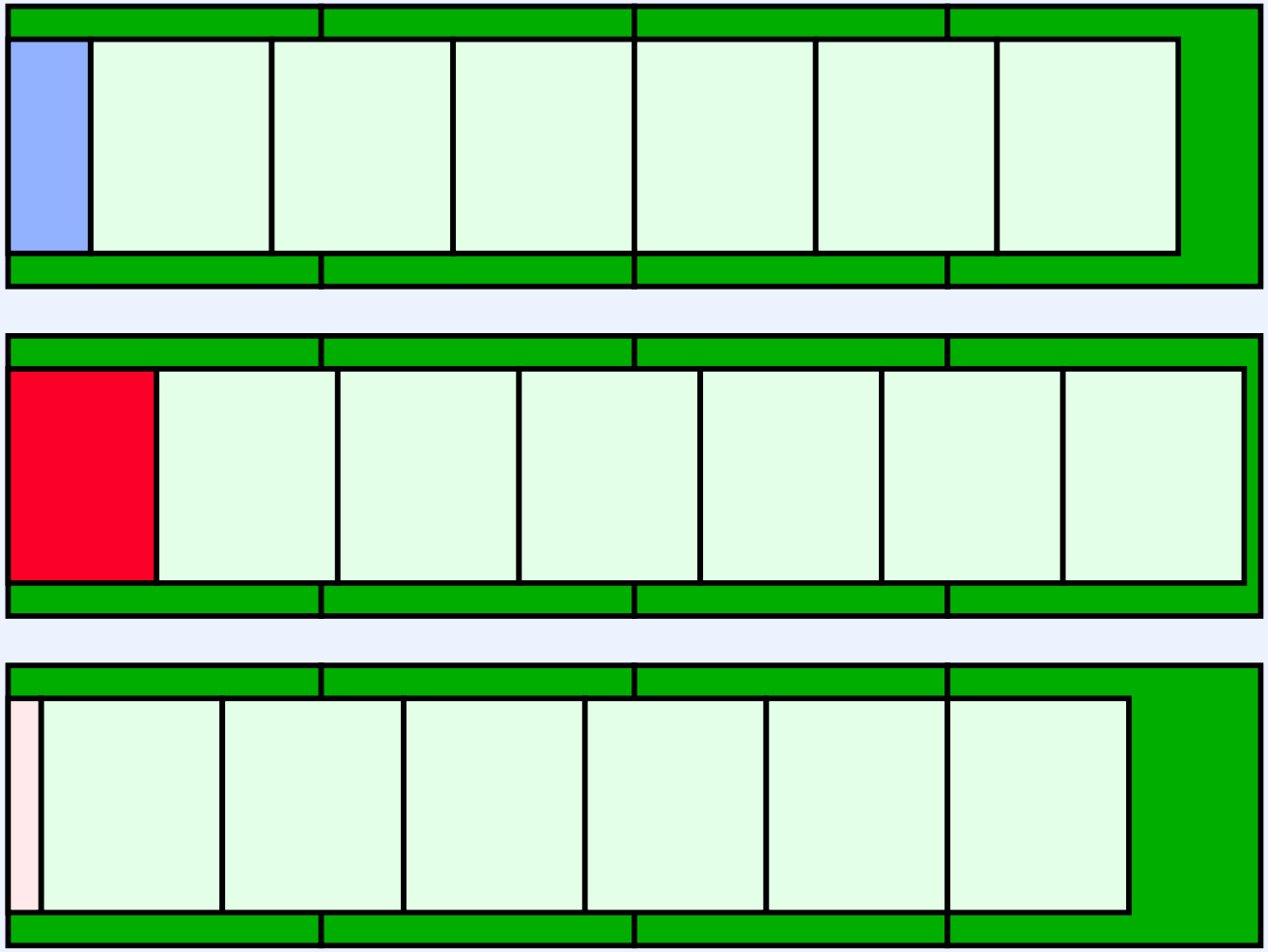
a) Rounding the size of the data structure up to a power of 2

b) Making sure all reside in the same cache set

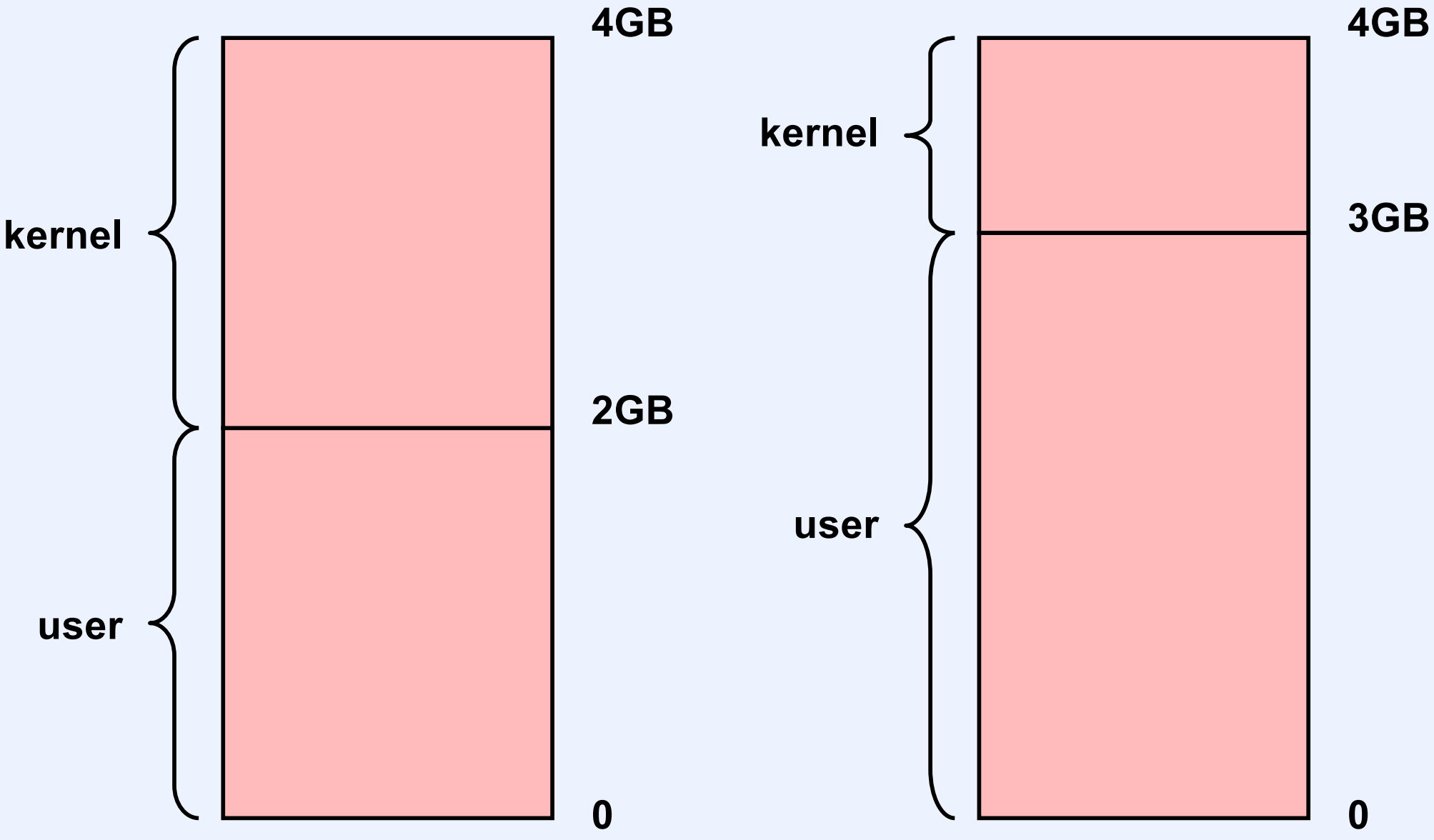
c) Making sure they are distributed across cache sets

d) Nothing would help

Slab Allocation



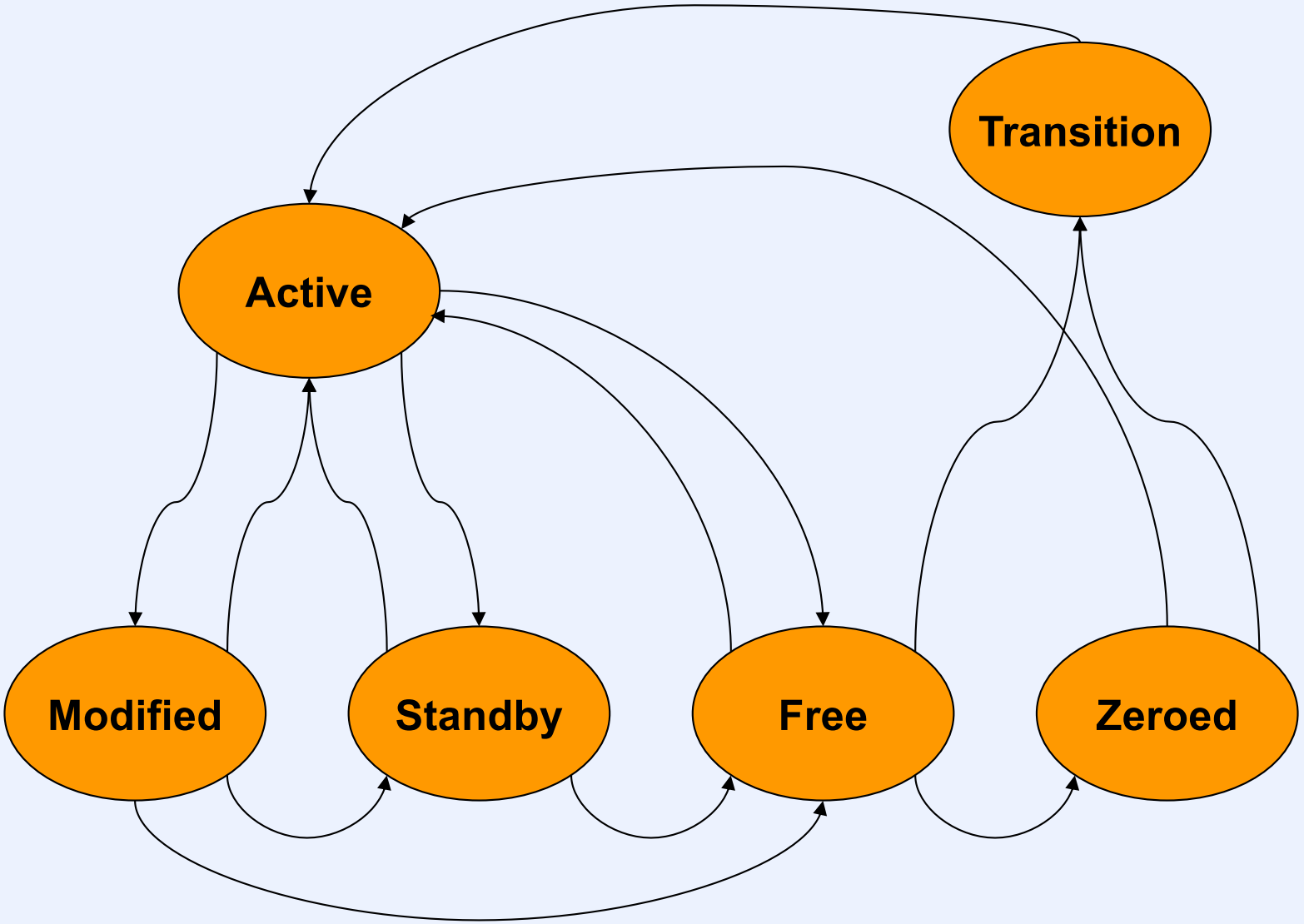
Windows x86 Layout



Windows Paging Strategy

- All processes guaranteed a "working set"
  - lower bound on page frames
- Competition for additional page frames
- "Balance-set" manager thread maintains working sets
  - one-handed clock algorithm
- Swapper thread swaps out idle processes
  - first kernel stacks
  - then working set
- Some of kernel memory is paged
  - page faults are possible

Windows Page-Frame States



Unix and Virtual Memory: The *fork/exec* Problem

- Naive implementation:
  - fork actually makes a copy of the parent's address space for the child
  - child executes a few instructions (setting up file descriptors, etc.)
  - child calls exec
  - result: a lot of time wasted copying the address space, though very little of the copy is actually used

vfork

- Don't make a copy of the address space for the child; instead, give the address space to the child
  - the parent is suspended until the child returns it
- The child executes a few instructions, then does an *exec*
  - as part of the *exec* (or *exit*), the address space is handed back to the parent
- Advantages
  - very efficient
- Disadvantages
  - works only if child does an *exec* (or *exit*)
  - child shouldn't do anything to the address space

Quiz 2

Will the assertion evaluate to true?

```
volatile int A = 6;
…
if (vfork() == 0) {
  A = 7;
  exit(0);
}
sleep(1); // sleep for one second
assert(A == 7);
…
```

a) yes

b) no

Lazy Evaluation

- Always put things off as long as possible
- If you wait long enough, you might not have to do them

A Better *fork*

- Parent and child share the pages comprising their address spaces
  - if either party attempts to modify a page, the modifying process gets a copy of just that page
- Advantages
  - semantically equivalent to the original *fork*
  - usually faster than the original *fork*
- Disadvantages
  - slower than *vfork*

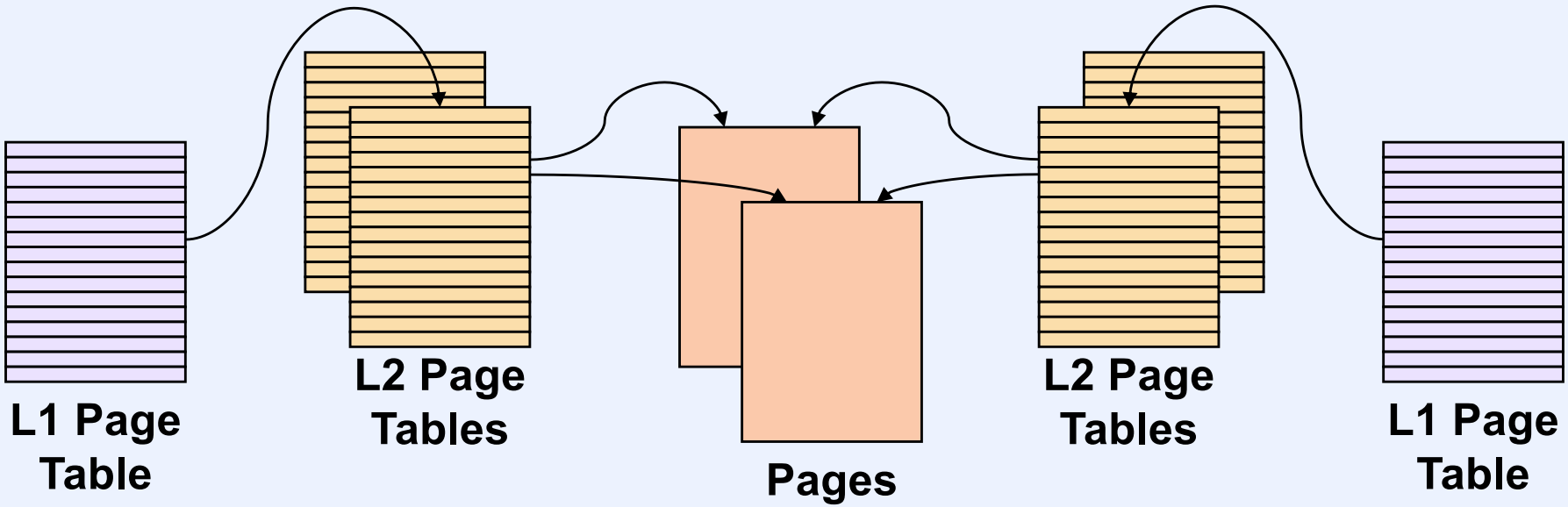
Quiz 3

How many pages of virtual memory must be copied from the parent to the child in the following code?

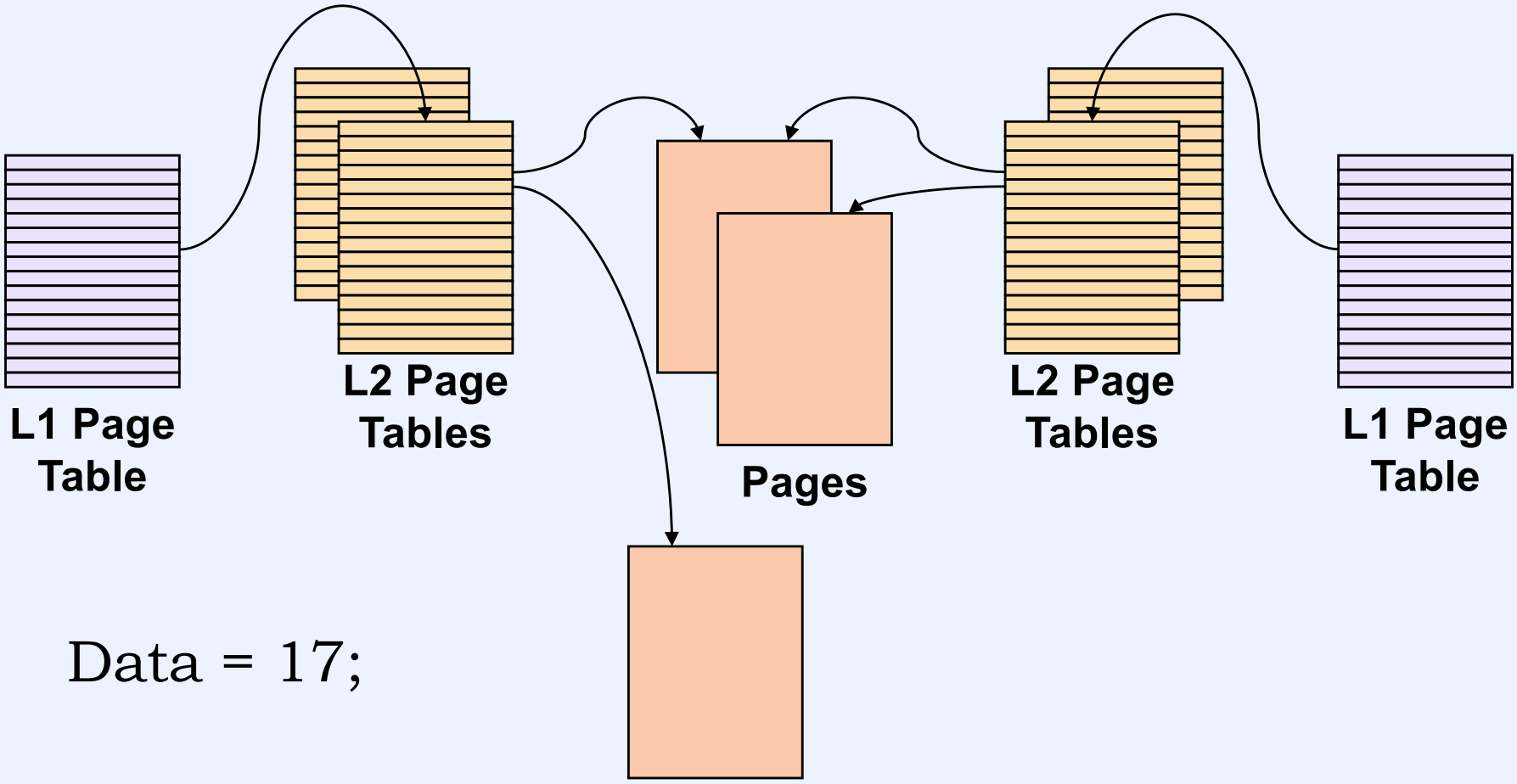
```
if (fork() == 0) {
  close(0);
  dup(open("input_file", O_RDONLY));
  execv("newprog", 0);
}
```

a) 0
b) 1-2
c) 4-8
d) lots

Copy on Write (1)



Copy on Write (2)



Data = 17;

Quiz 4

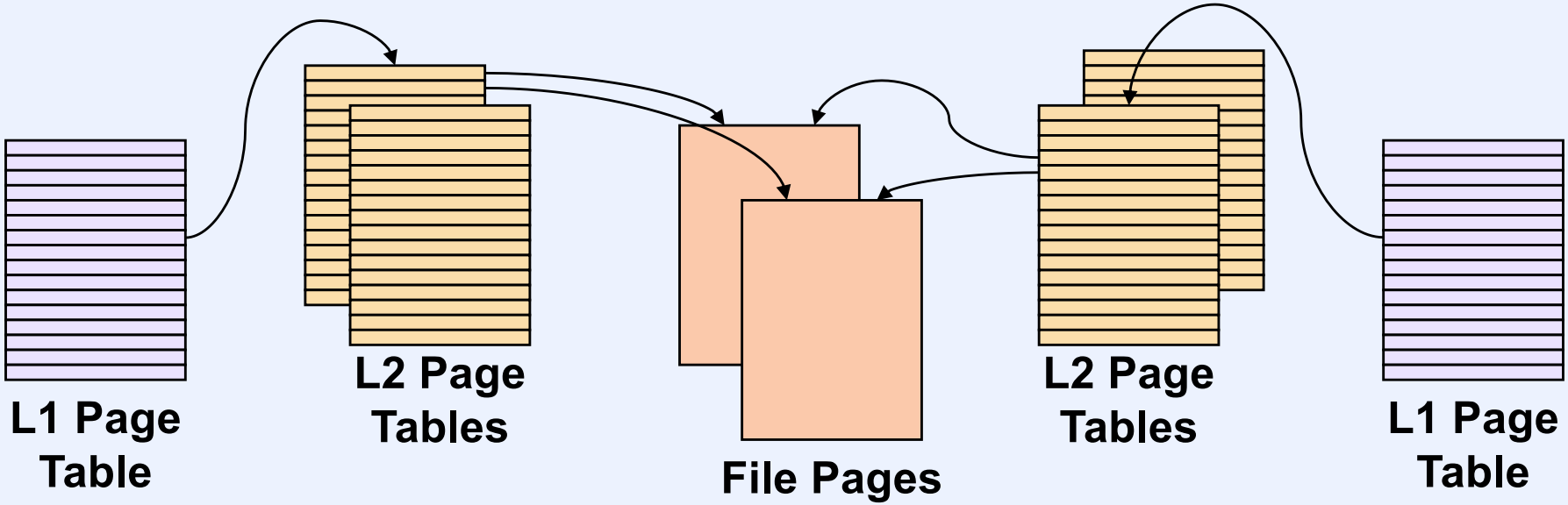
We have a file that contains one billion 64-bit integers. We are writing a program to read in the file and add up all the integers. Which approach will be fastest:

a) read the file 8 bytes at a time, adding to a running total what is read in

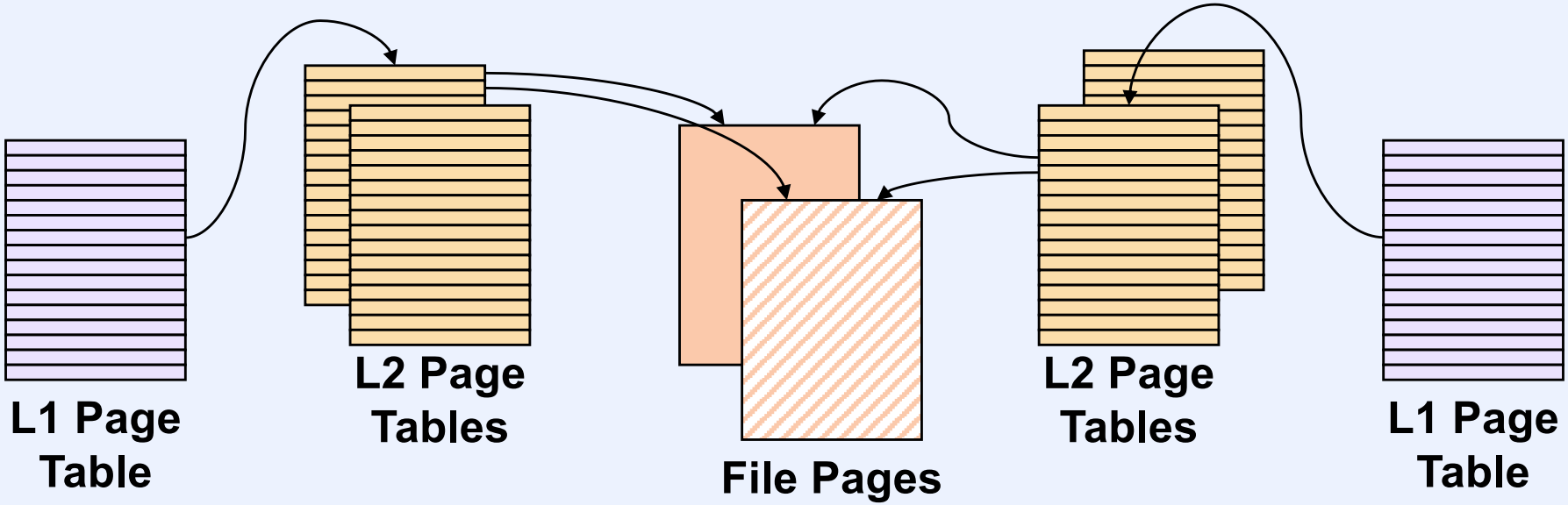
b) read the file 8k bytes at a time, then add each of the integers contained in that block to the running total

c) *mmap* the file into the process's address space, then sum up all the integers in this mapped region of memory

The *mmap* System Call

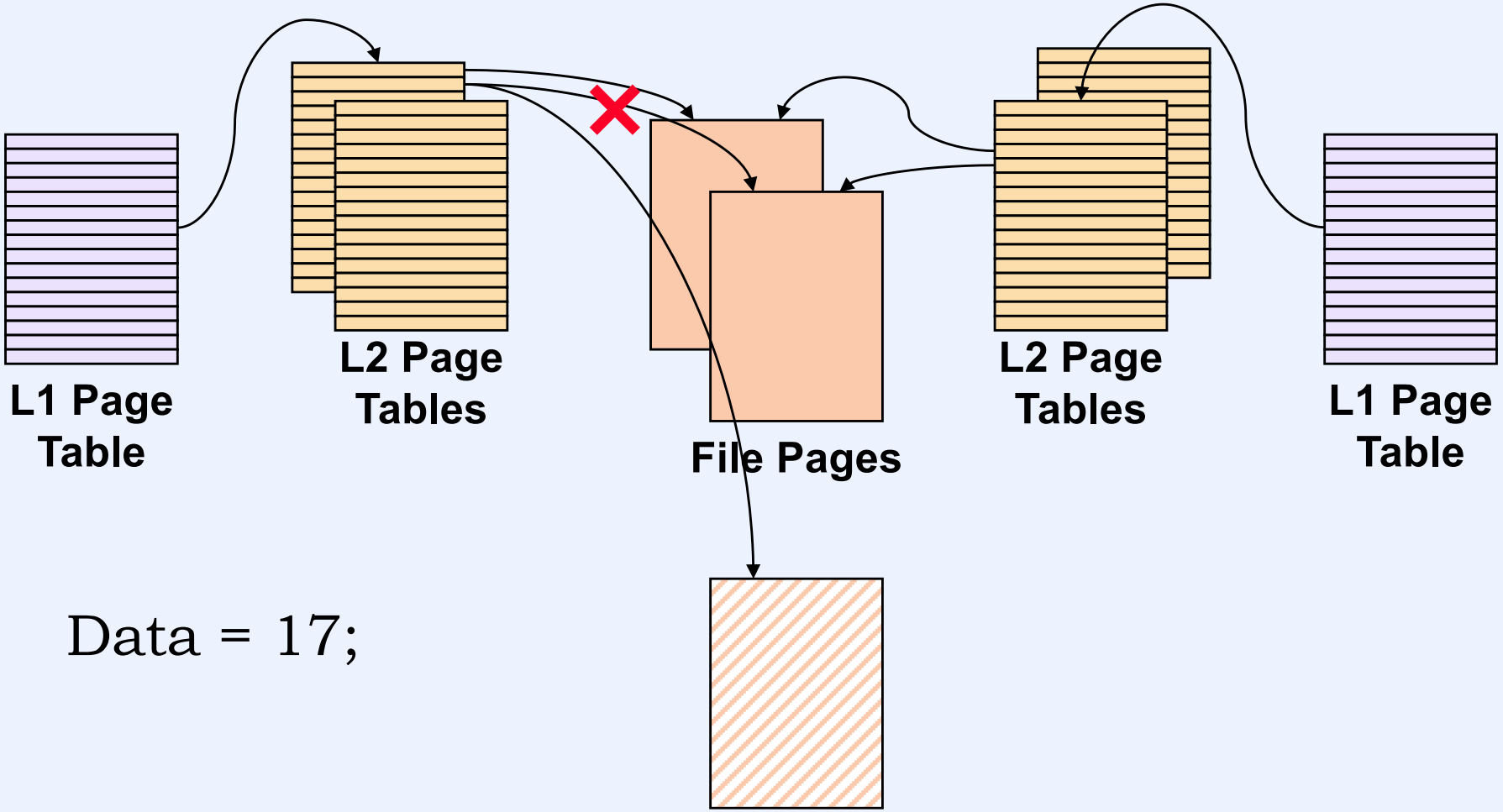


Share-Mapped Files

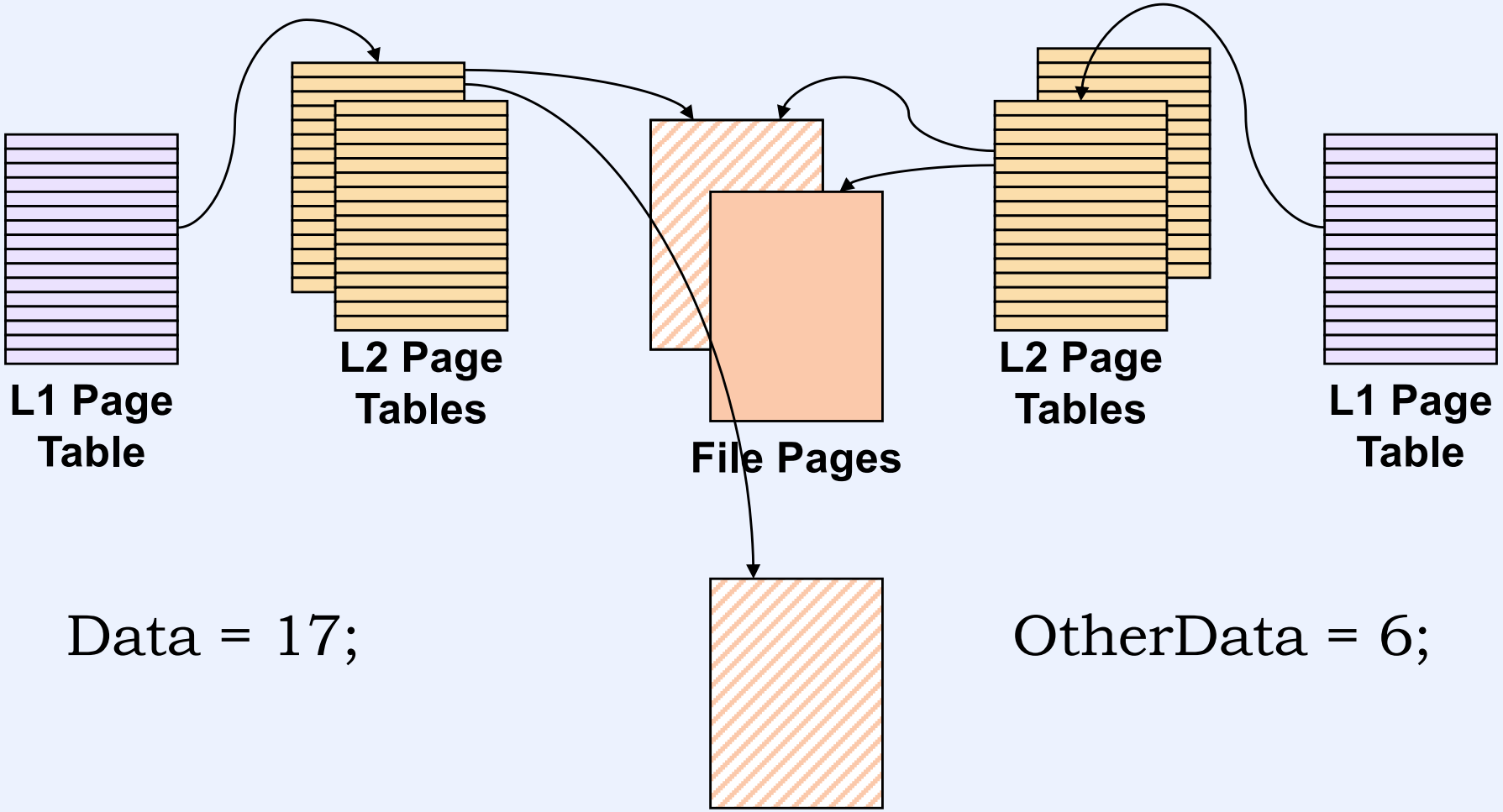


Data = 17;

Private-Mapped Files



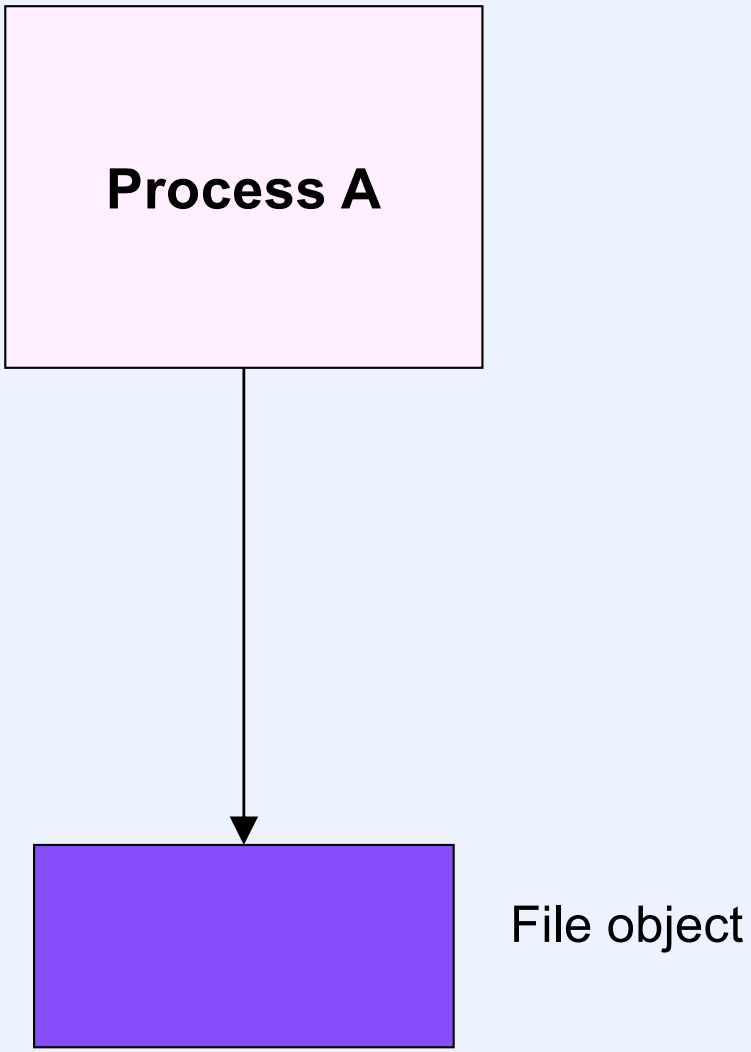
A Private-Mapped File Changes



Virtual Copy

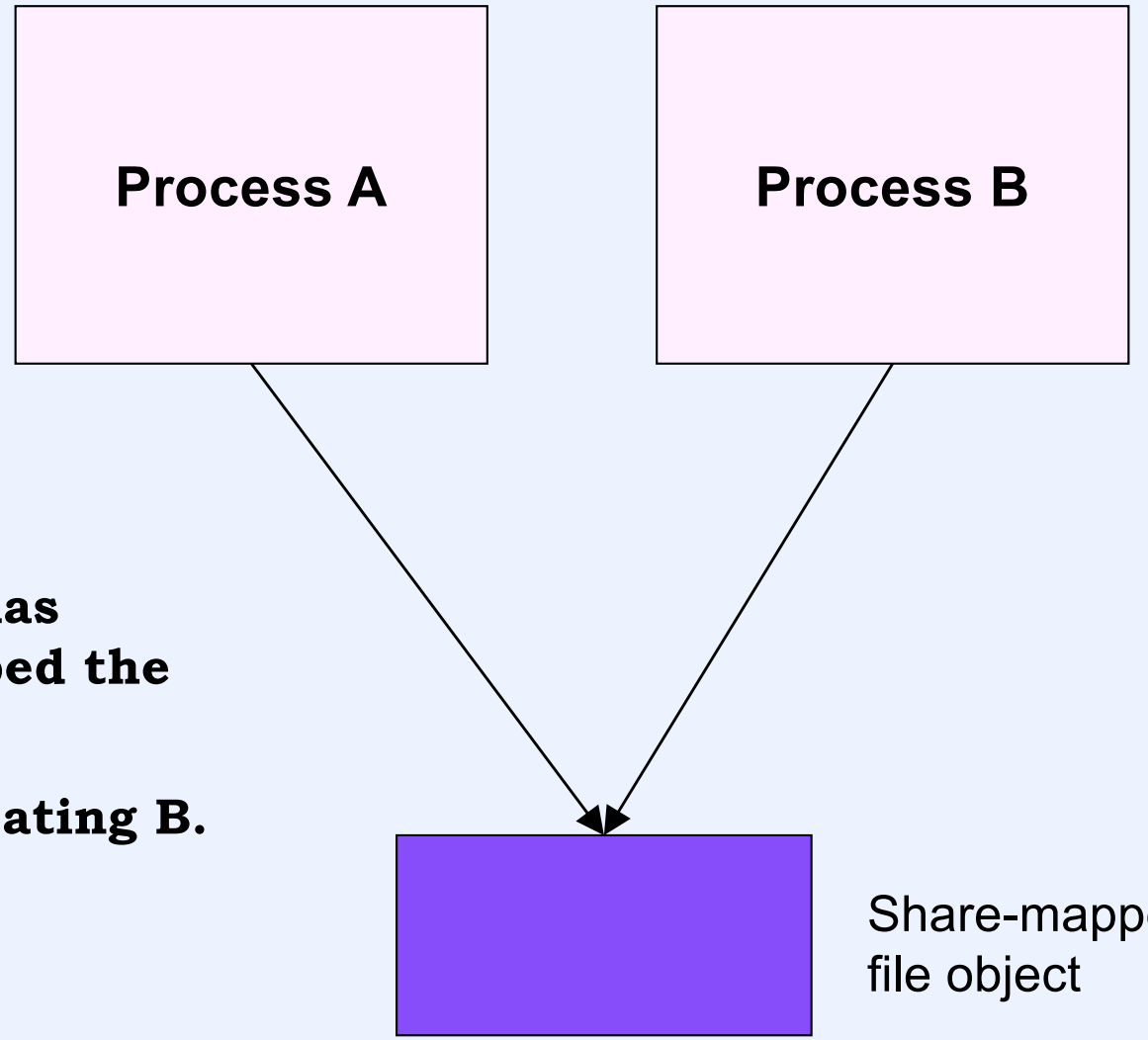
- Local RPC
  - "copy" arguments from one process to another
    - assume arguments are page-aligned and page-sized
    - map pages into both caller and callee, copy-on-write

Share Mapping (1)



Process A has share mapped the file object.

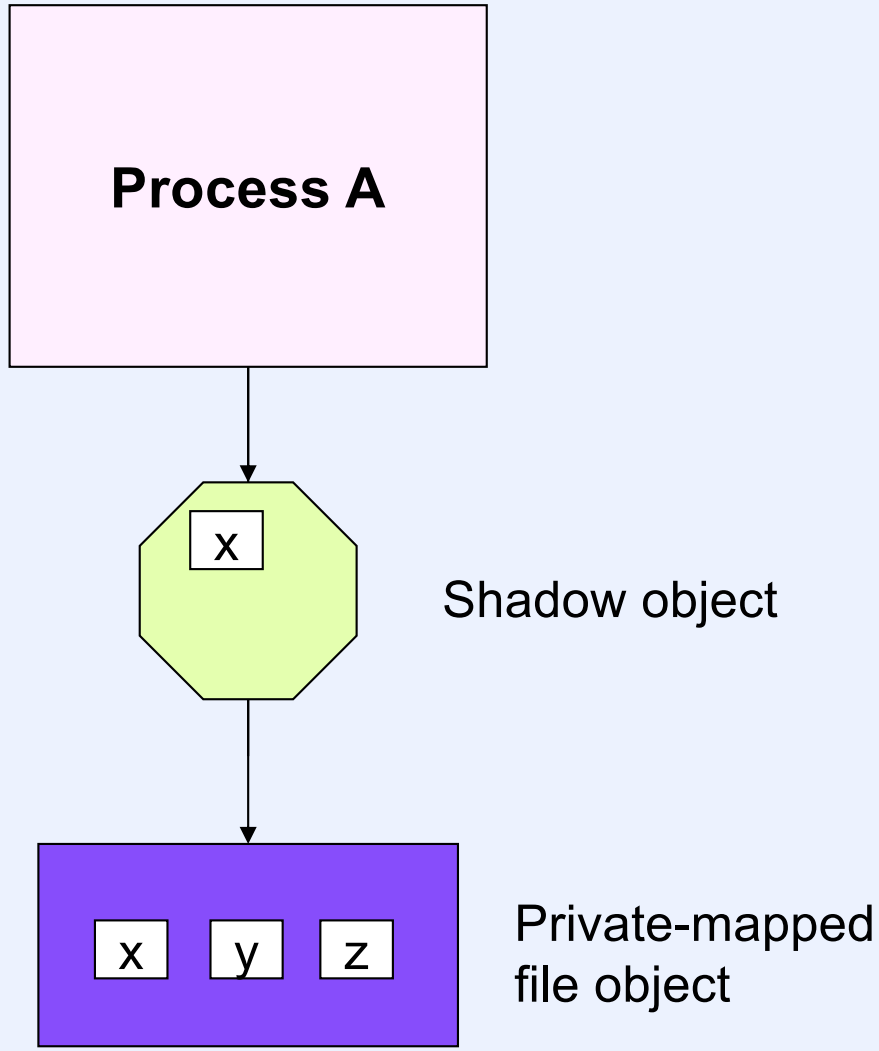
Share Mapping (2)



Process A has share-mapped the file object.

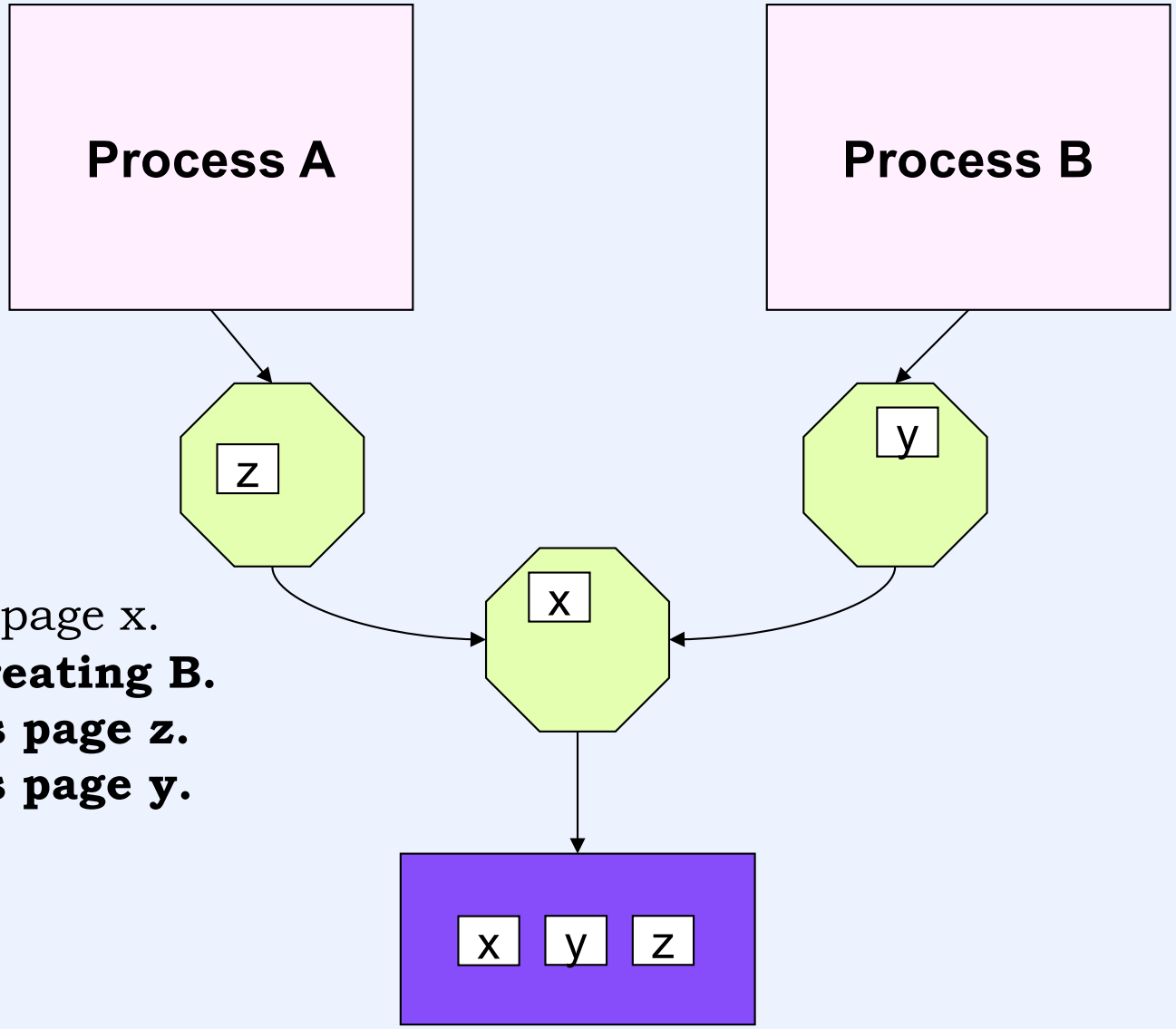
A forks, creating B.

Private Mapping (1)



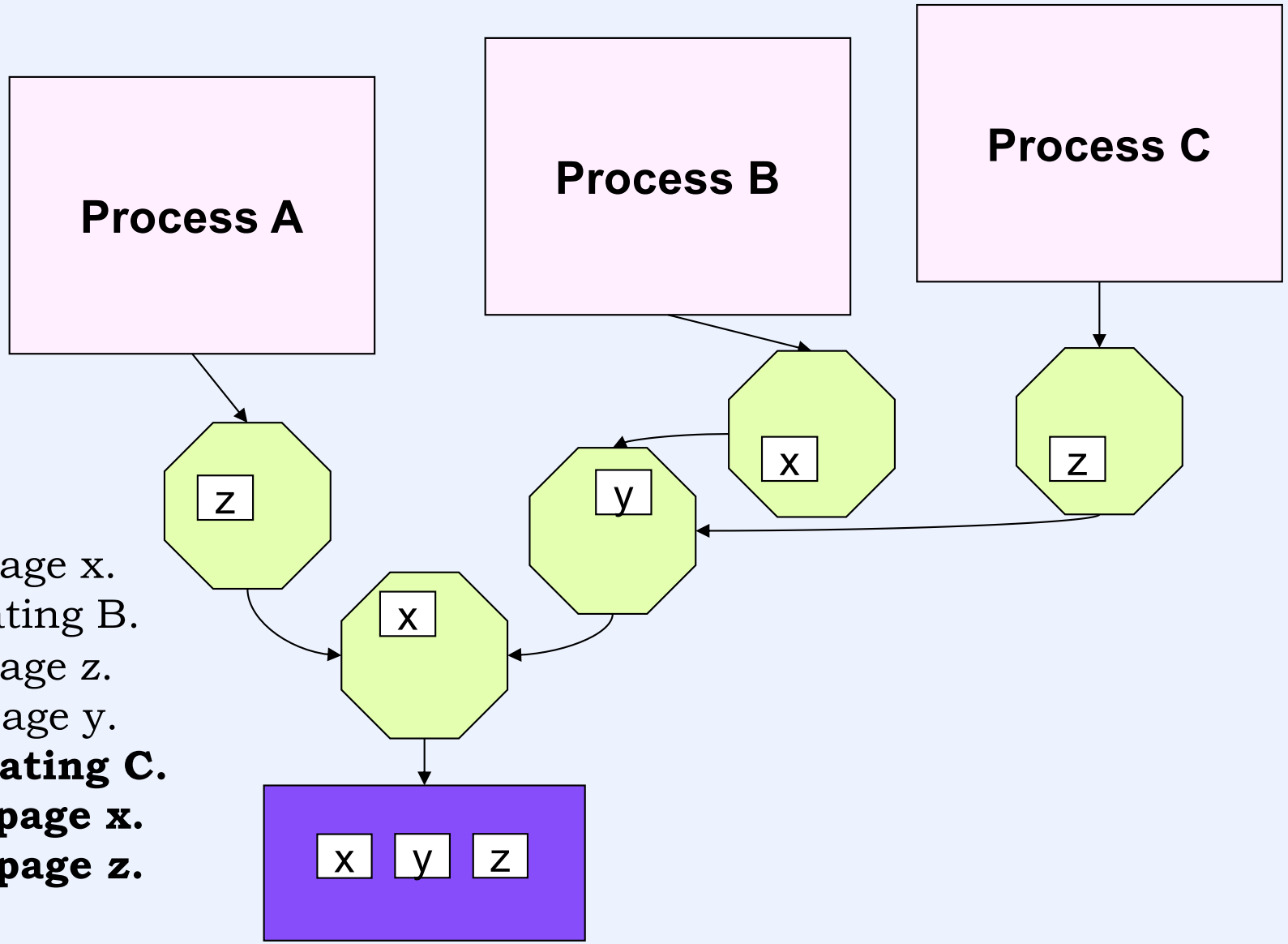
A modifies page x.

Private Mapping (2)



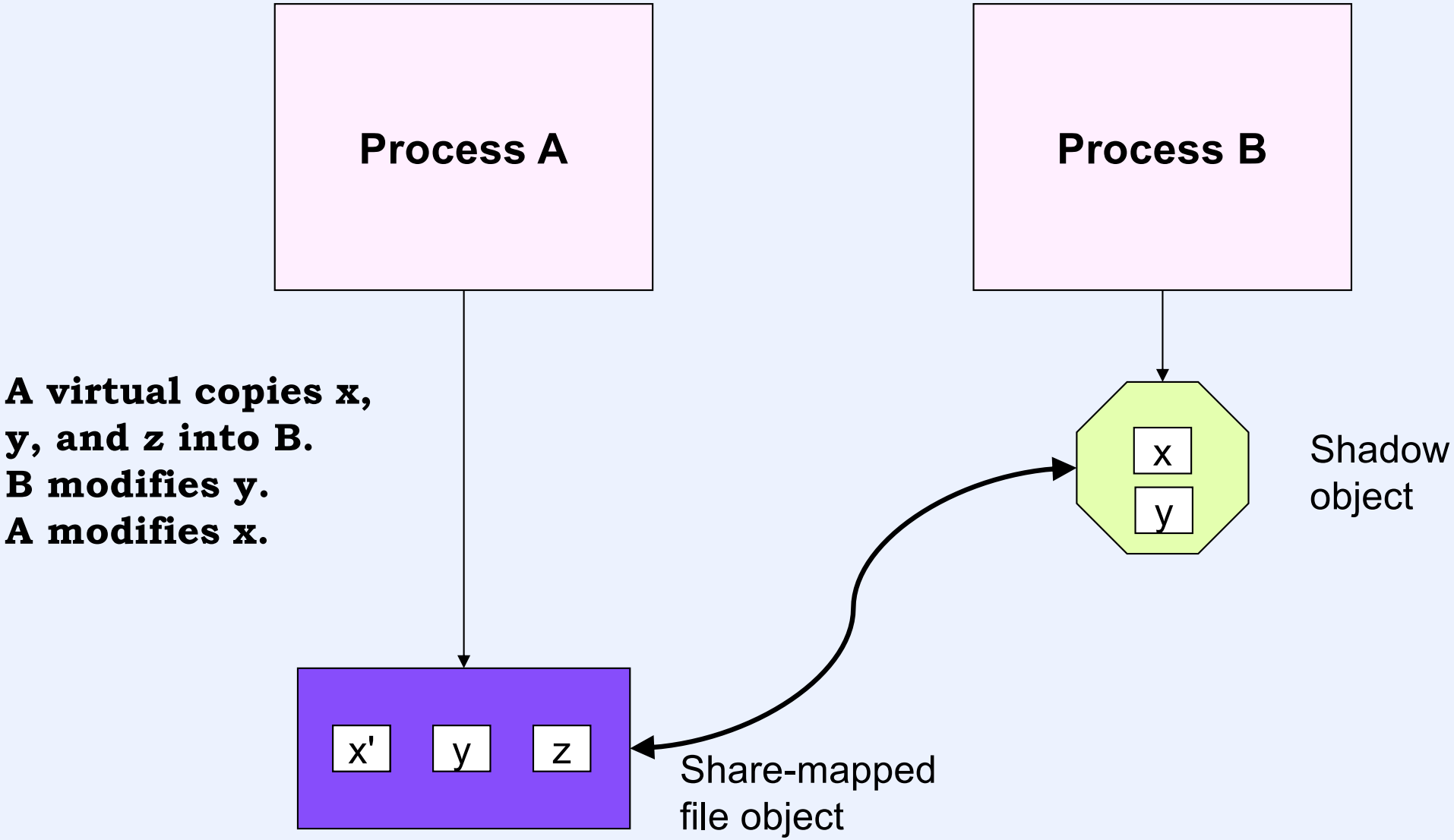
A modifies page x.
A forks, creating B.
A modifies page z.
B modifies page y.

Private Mapping (3)



A modifies page x.
A forks, creating B.
A modifies page z.
B modifies page y.
B forks, creating C.
B modifies page x.
C modifies page z.

Share and Private Mapping



Quiz 5

Unix process X has private-mapped a file into its address space. Our system has one-byte pages and the file consists of four pages. The pages are mapped into locations 100 through 103. The initial values of these pages are all zeroes.

1) X stores a 1 into location 100
2) X forks, creating process Y
3) X stores a 1 into location 101
4) Y stores a 2 into location 102
5) Y forks, creating process Z
6) X stores 111 into location 100
7) Y stores 222 into location 103
8) Z sums the contents of locations 100, 101, and 102, and stores them into location 103

What value did Z store into 103?

Answer:

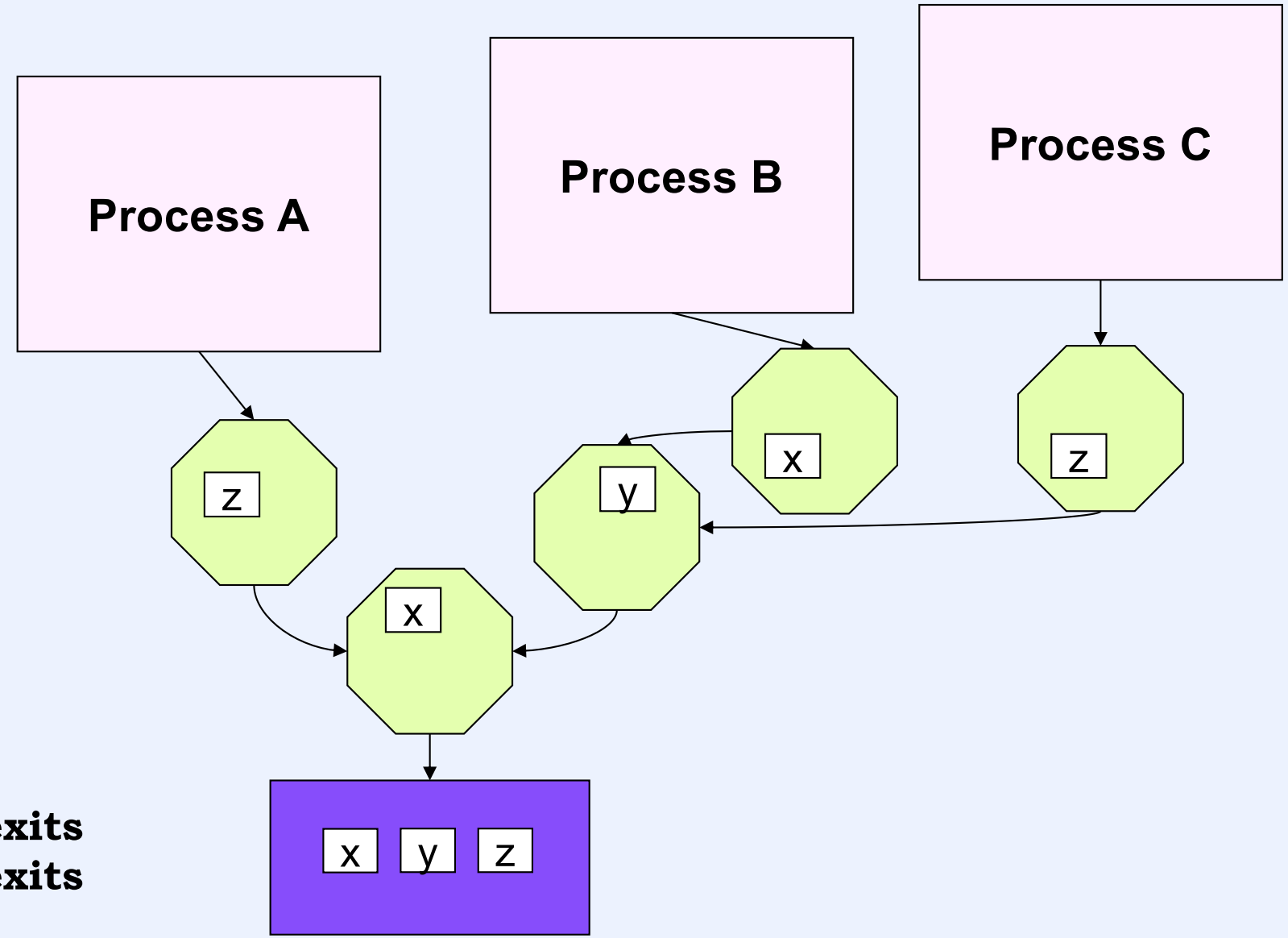
a) 0
b) 3
c) 4
d) 113

Fork Bomb!

```
int main() {
  while (1) {
    if (fork() <= 0)
      exit(0);
  }
  return 0;
}
```

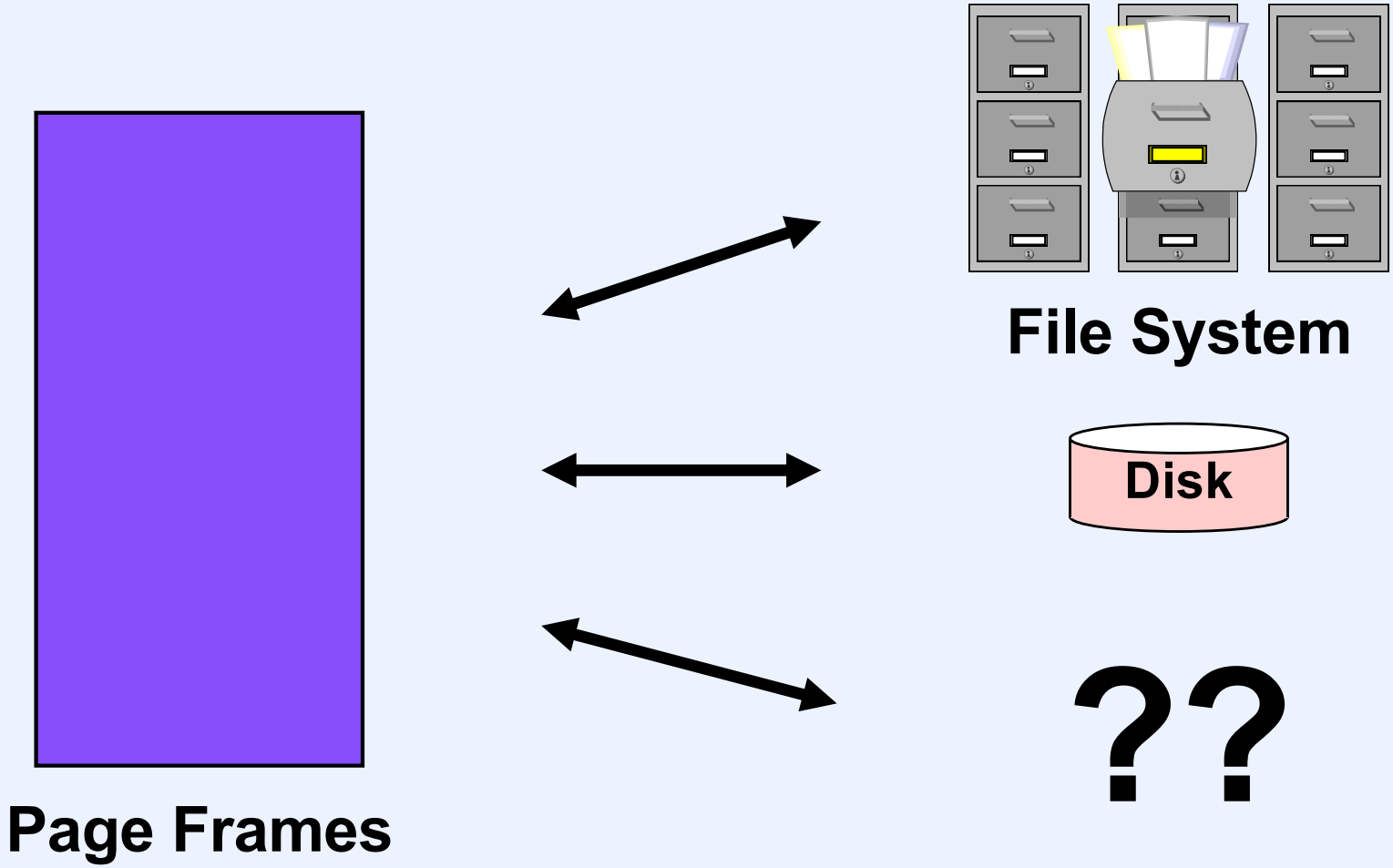
```
int main() {
  while (1) {
    if (fork() > 0)
      exit(0);
  }
  return 0;
}
```

Private Mapping (Continued)



Process B exits
Process A exits

The Backing Store



Backing Up Pages (1)

- Read-only mapping of a file (e.g. text)
  - pages come from the file, but, since they are never modified, they never need to be written back
- Read-write shared mapping of a file (e.g. via *mmap* system call)
  - pages come from the file, modified pages are written back to the file

Backing Up Pages (2)

- Read-write private mapping of a file (e.g. the data section as well as memory mapped private by the *mmap* system call)
  - pages come from the file, but modified pages, associated with shadow objects, must be backed up in swap space
- Anonymous memory (e.g. bss, stack, and shared memory)
  - pages are created as *zero fill on demand*; they must be backed up in swap space

Swap Space

- Space management possibilities
  - radical-conservative approach: pre-allocation
    - backing-store space is allocated when virtual memory is allocated
    - page outs always succeed
    - might need to have much more backing store than needed
  - radical-liberal approach: lazy evaluation
    - backing-store space is allocated only when needed
    - page outs could fail because of no space
    - can get by with minimal backing-store space

Space Allocation in Linux

- Total memory = primary + swap space
- System-wide parameter: *overcommit_memory*
  - three possibilities
    - maybe (default)
    - always
    - never
- mmap has MAP_NORESERVE flag
  - don't worry about over-committing

Space Allocation in Windows

- Space reservation
  - allocation of virtual memory
- Space commitment
  - reservation of physical resources
    - paging space + physical memory
- *MapViewOfFile* (sort of like *mmap*)
  - no over-commitment
- Thread creation
  - creator specifies both reservation and commitment for stack pages