Systems and Networking I

Applied Computer Science and Artificial Intelligence

2024-2025

SAPIENZA
UNIVERSITÀ DI ROMA

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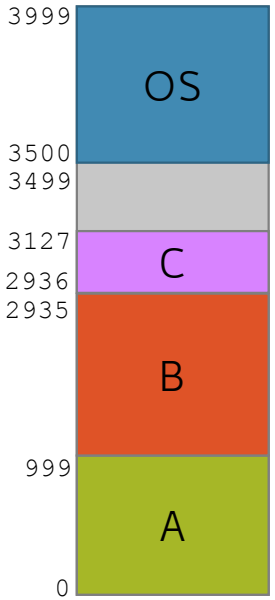

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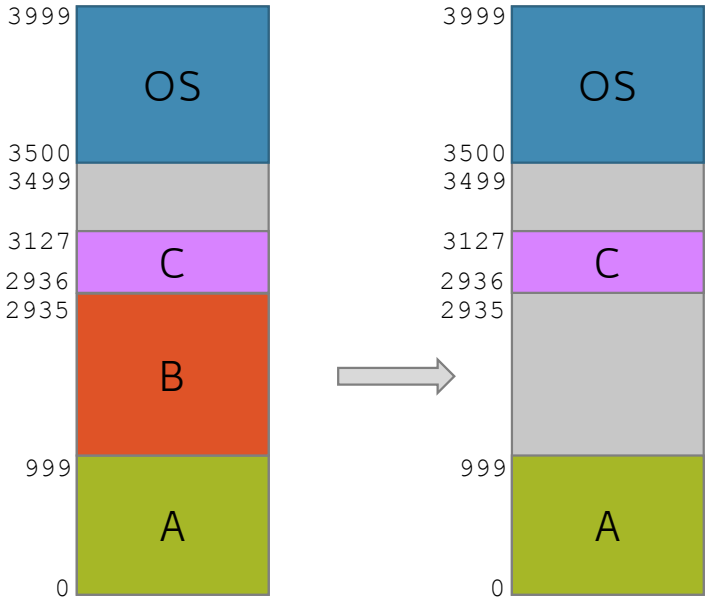

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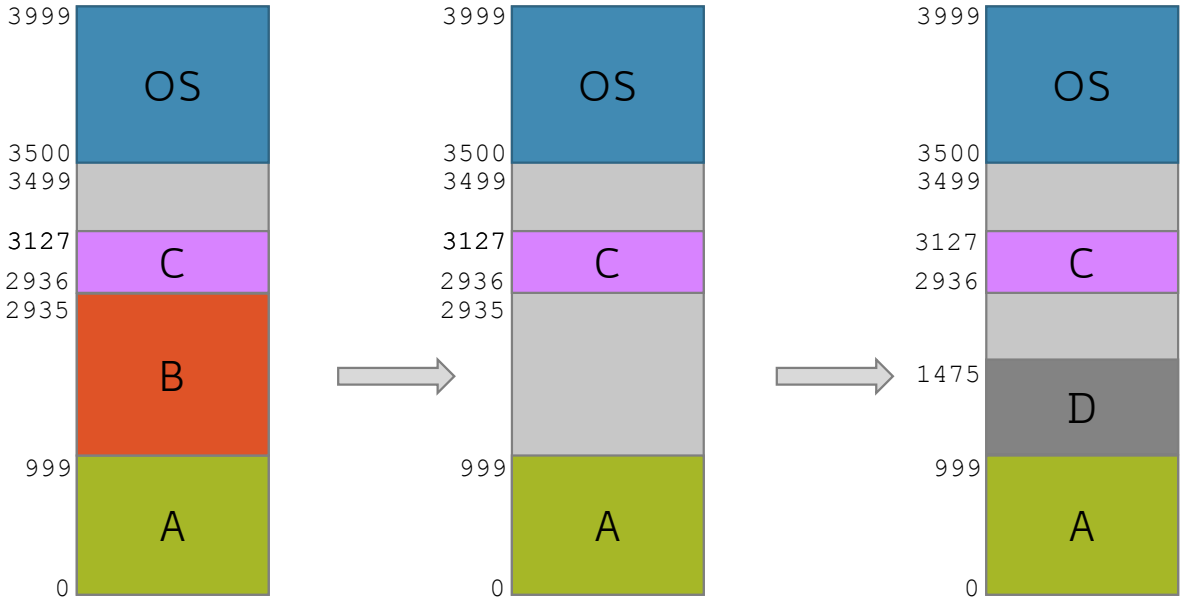

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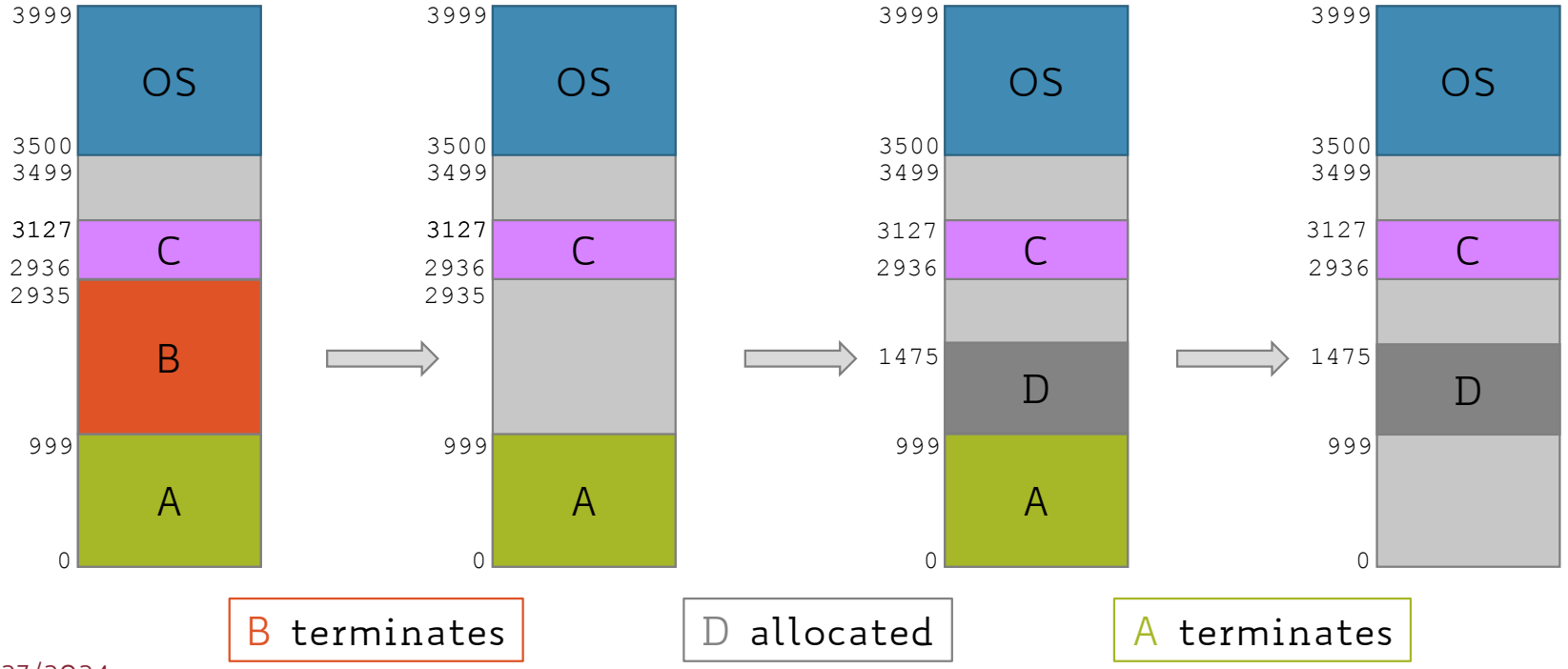

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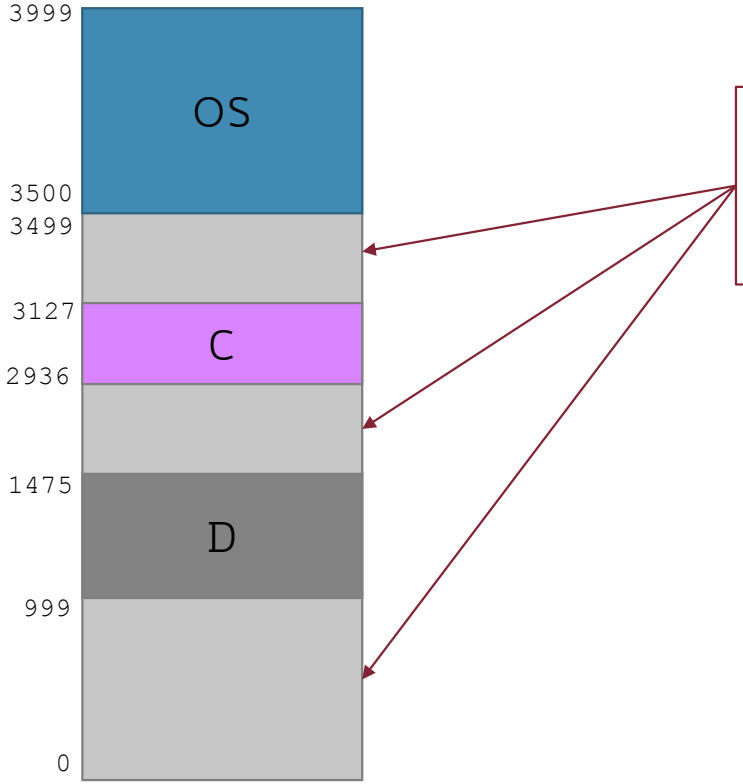

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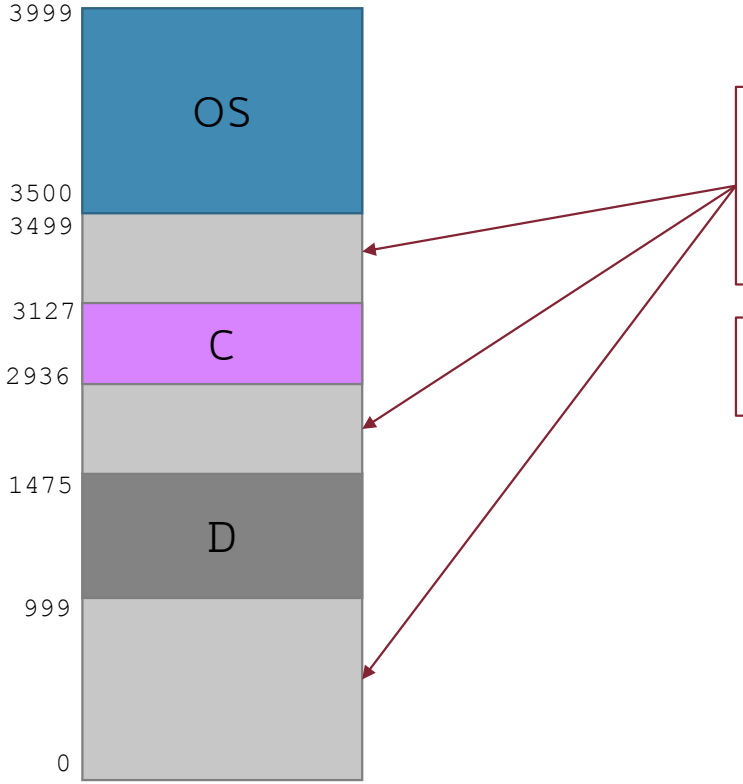

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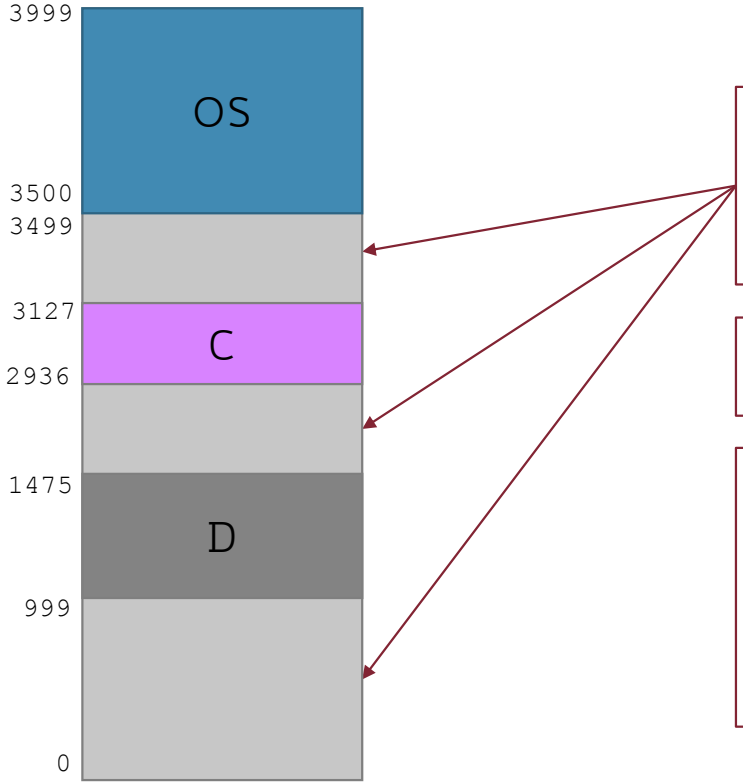

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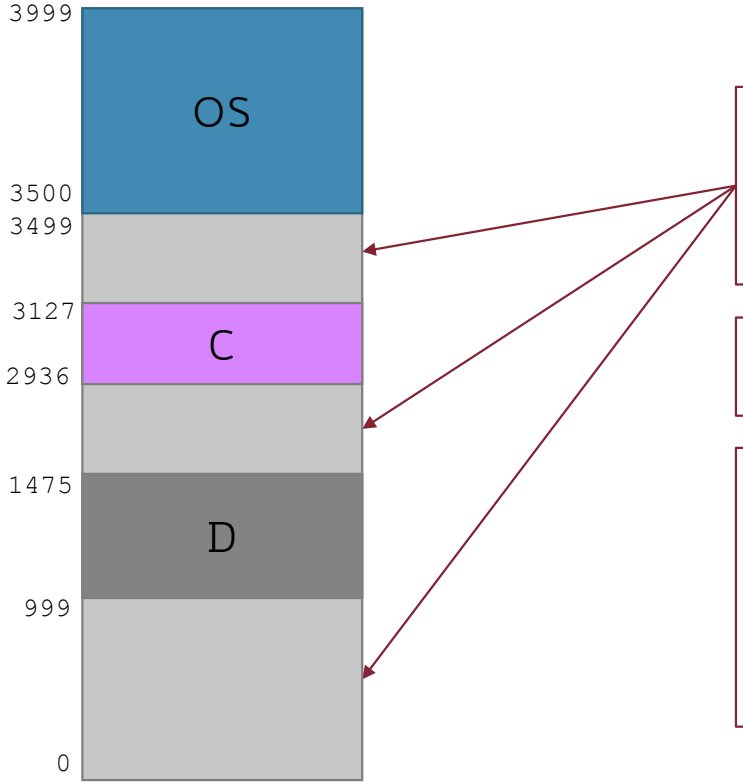

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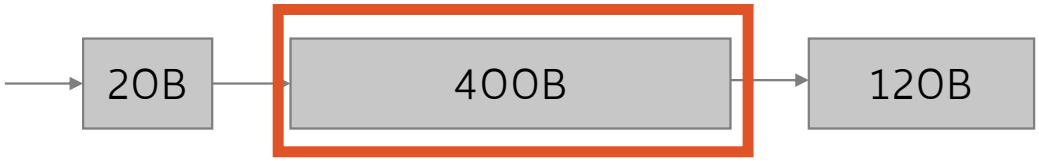

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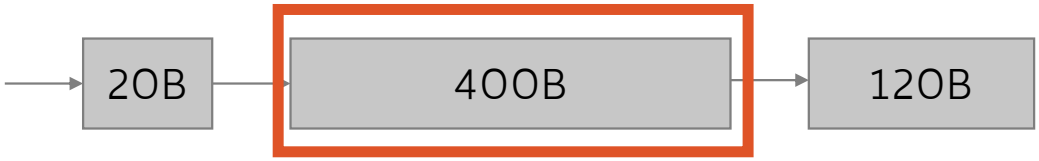

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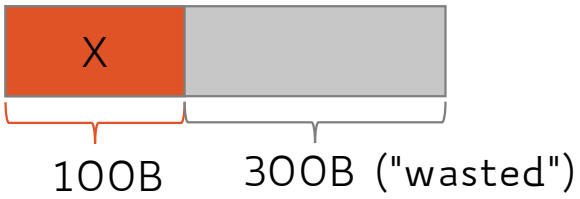

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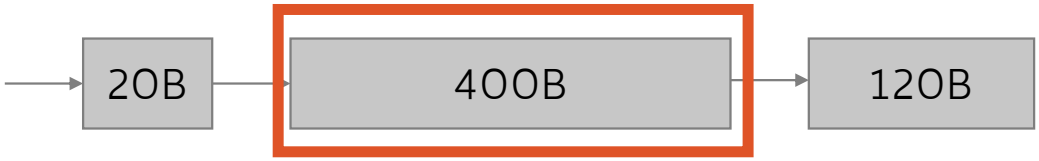

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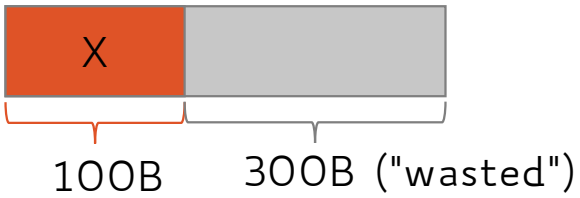

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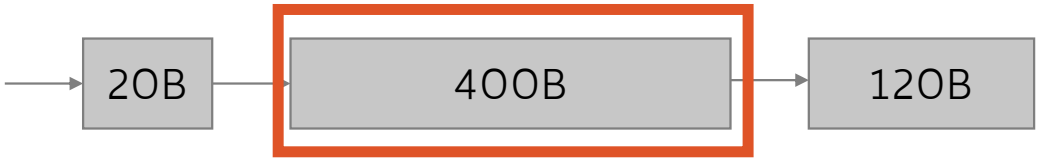

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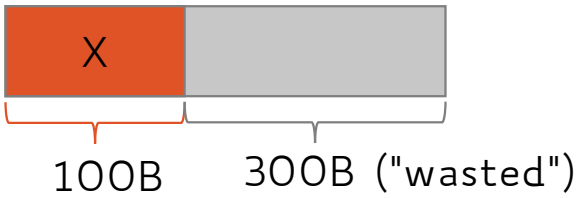

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We will not be able to satisfy this request even if theoretically we could

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Binary Search Tree (BST)

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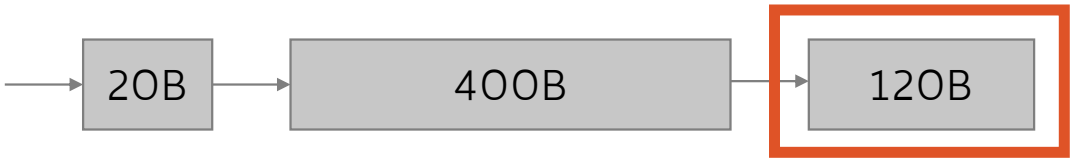

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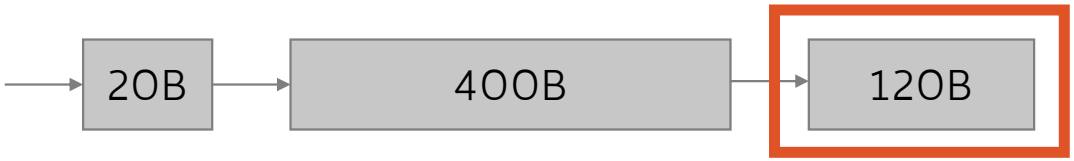

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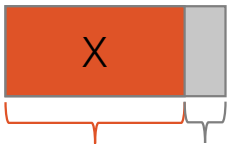

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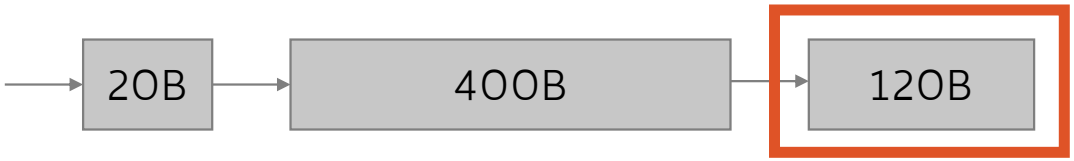

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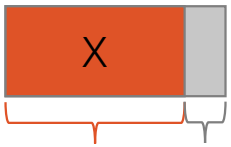

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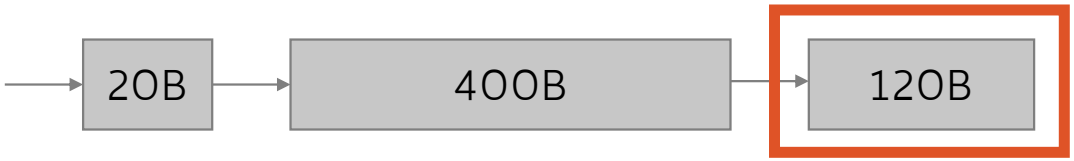

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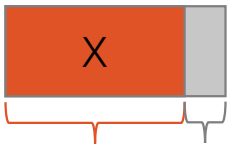

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We can now assign it the second available hole segment (400B)

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- First-Fit is also generally faster than Best-Fit

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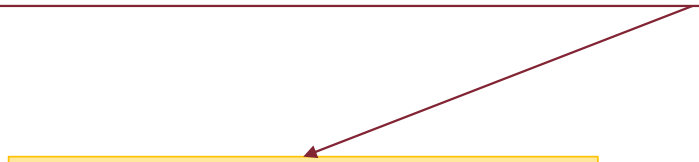

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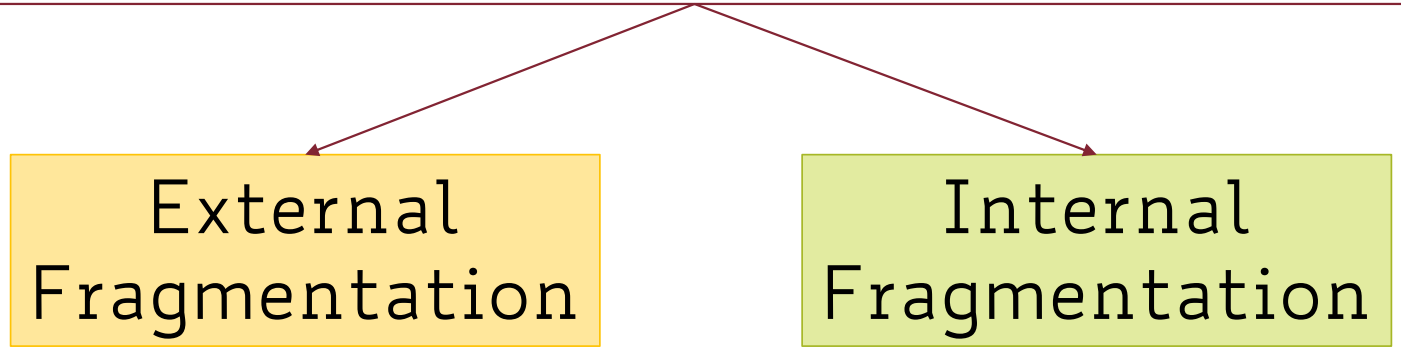

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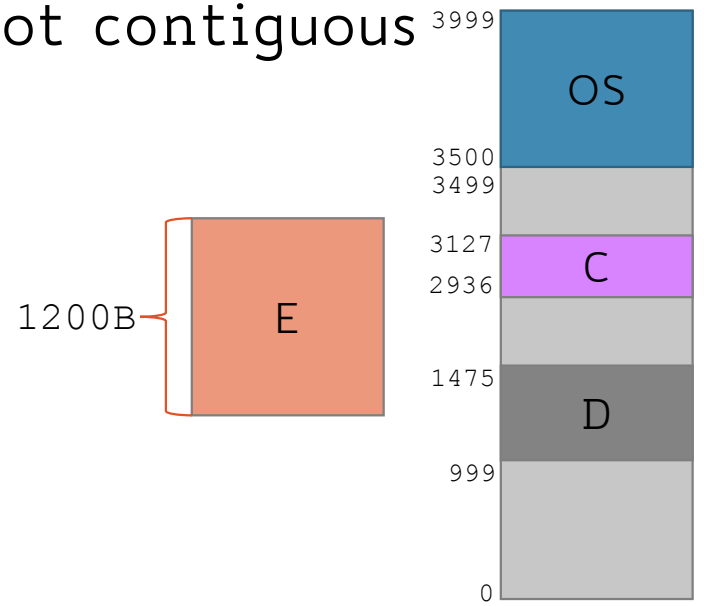

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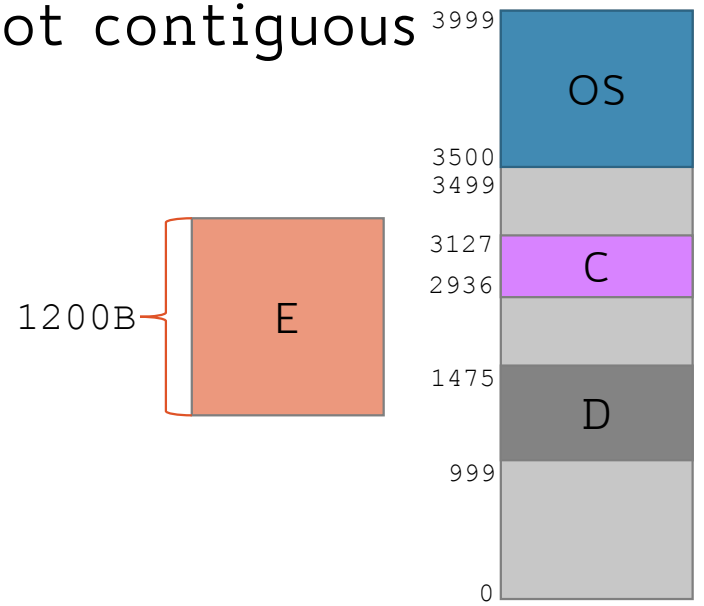

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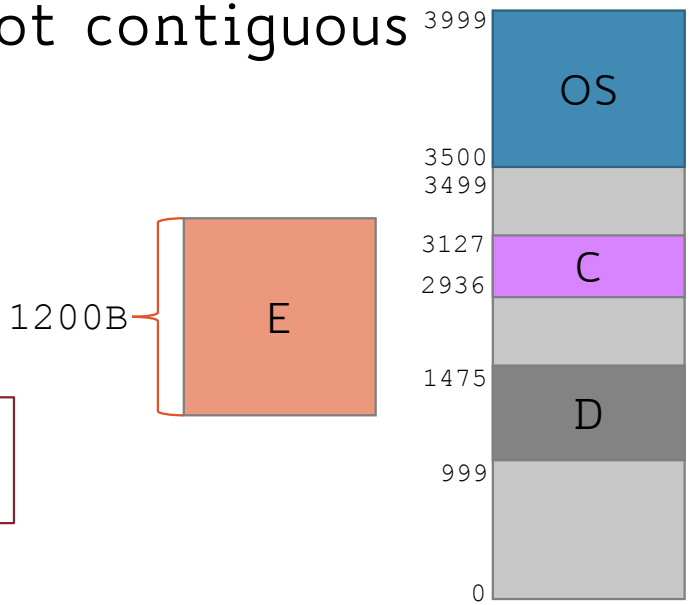
Goal:
Allocation policy that minimizes wasted space!



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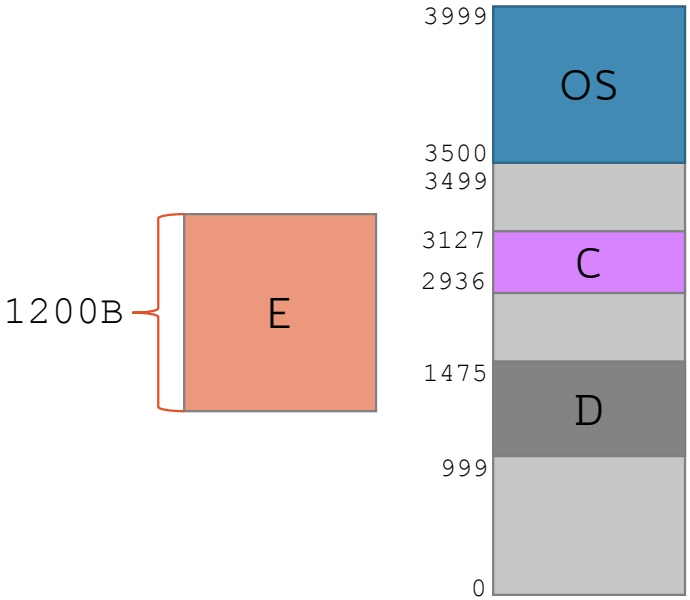
- For example, consider a process whose size is 8,846B and a hole of size 8,848B
- It may be much more efficient to allocate the process the whole block (and waste 2B) rather than keep track of a tiny 2B hole

Solution to Fragmentation: Full Compaction



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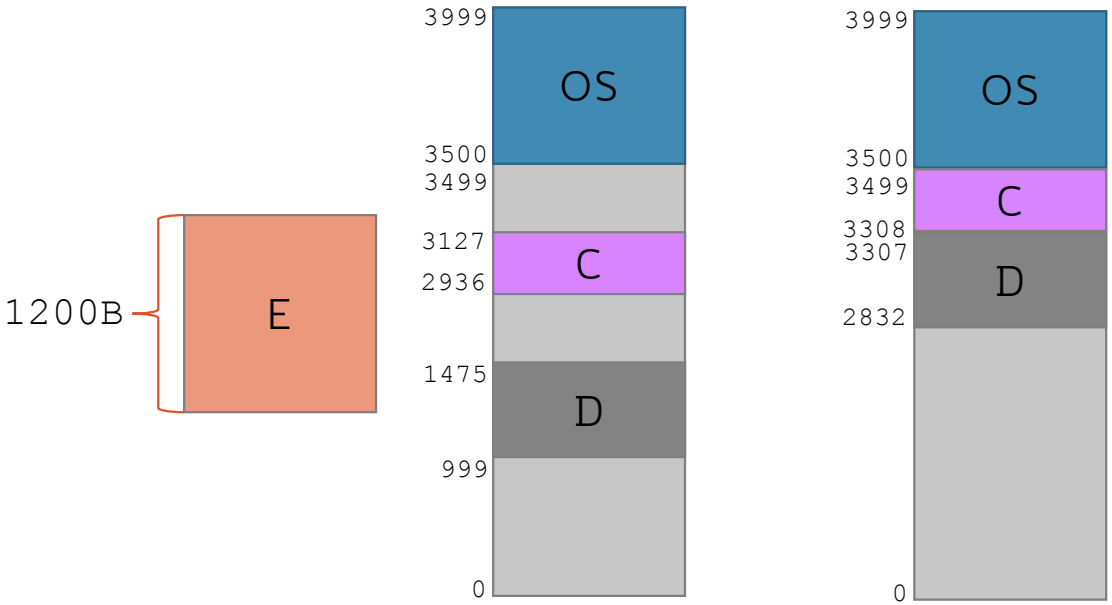

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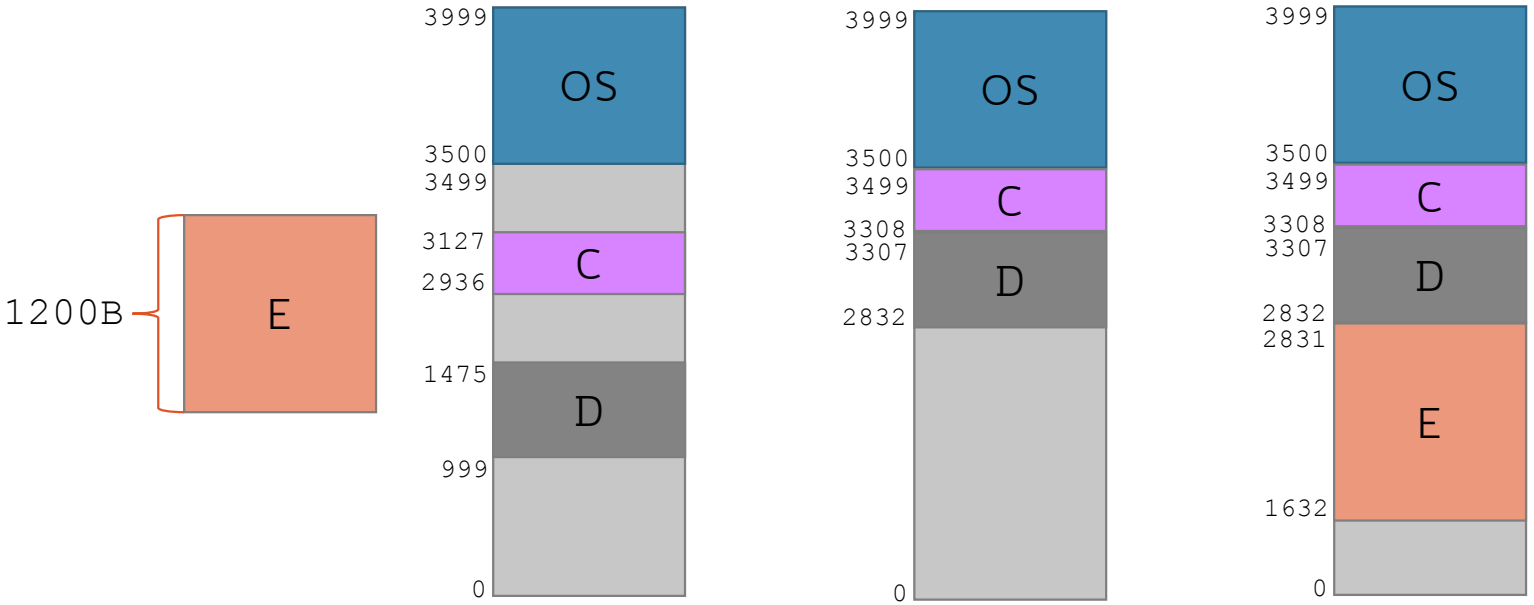

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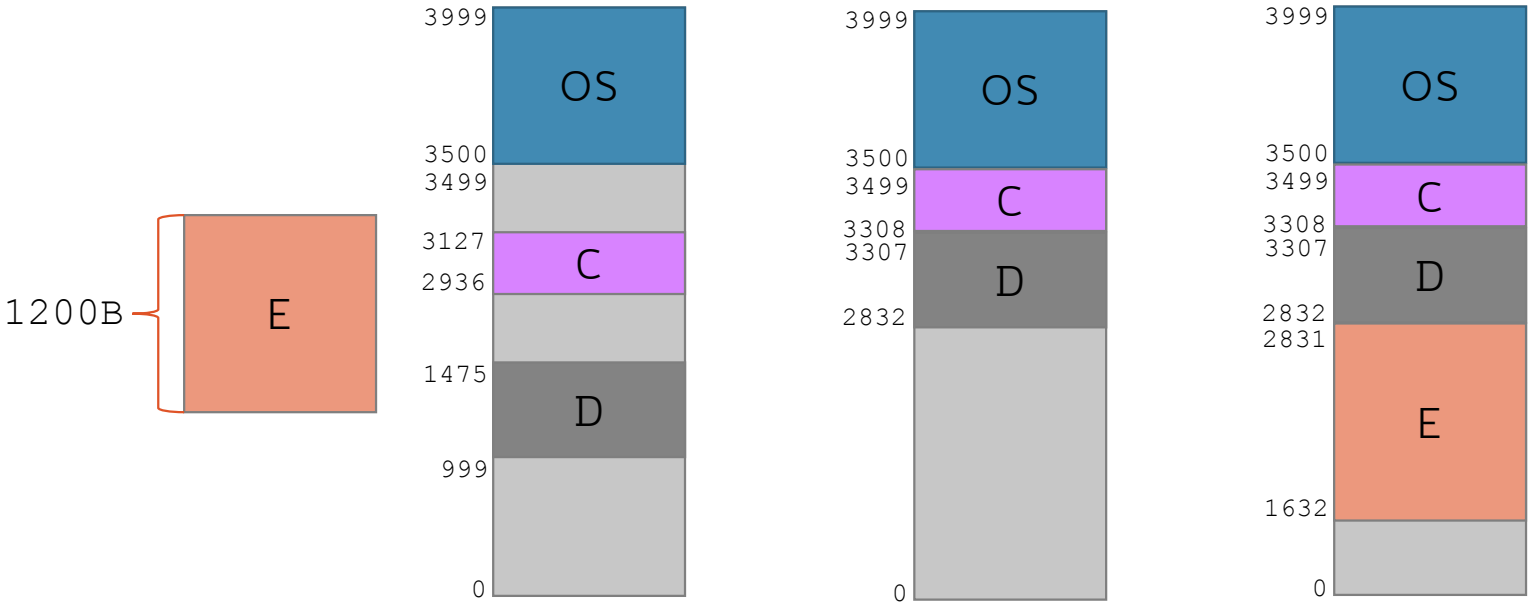

Only one hole is left but two processes need to be moved (C and D)

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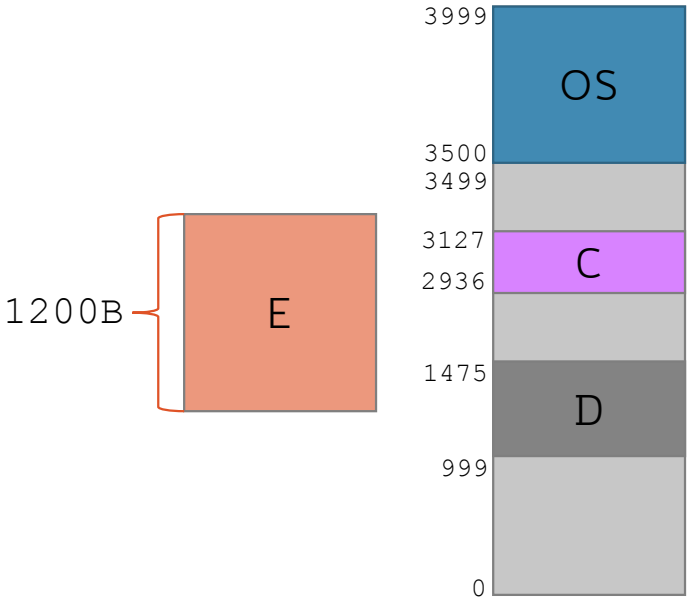

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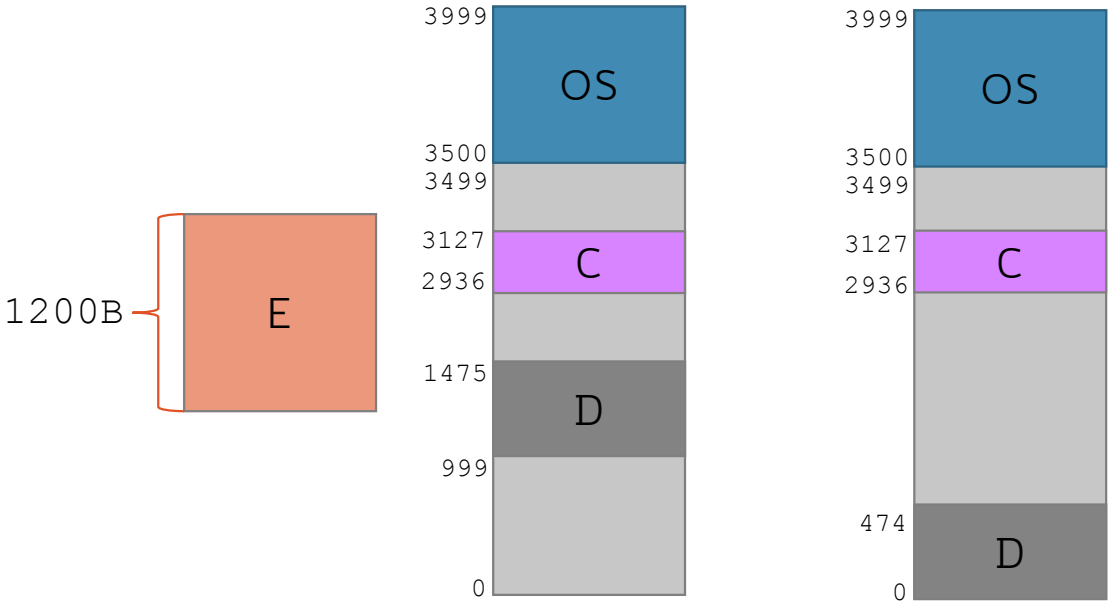

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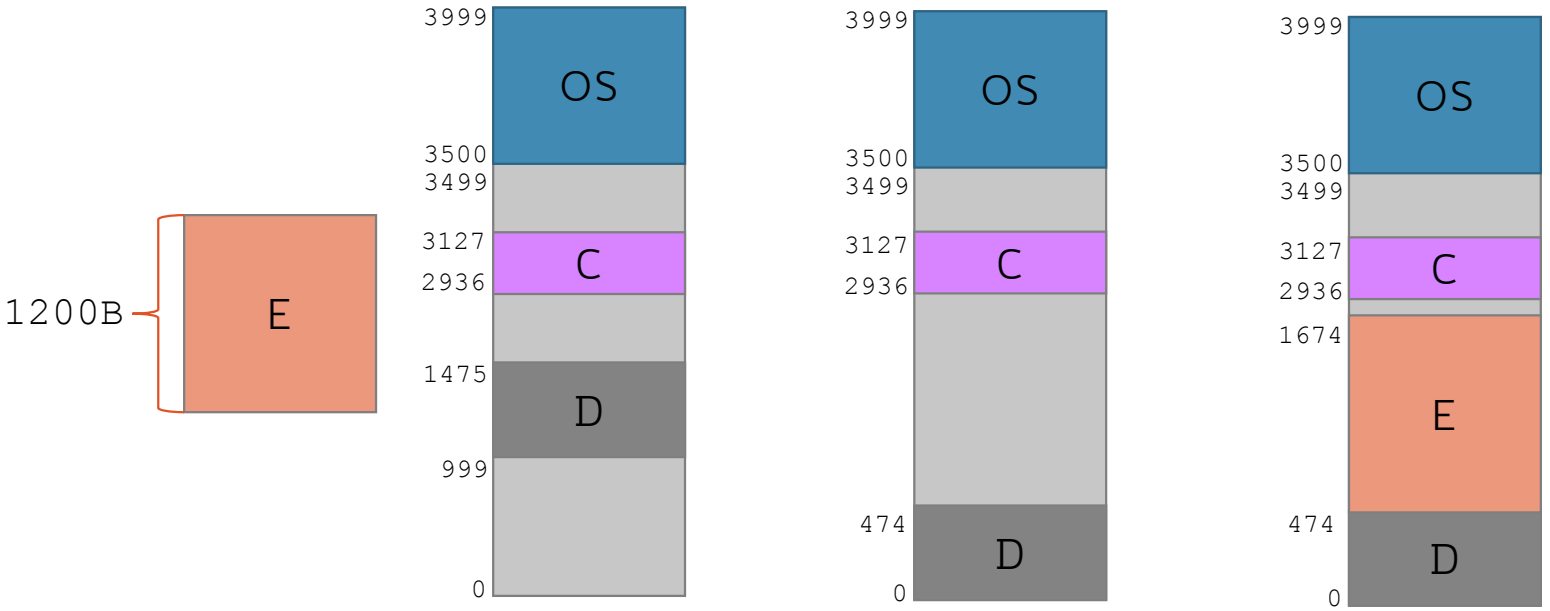

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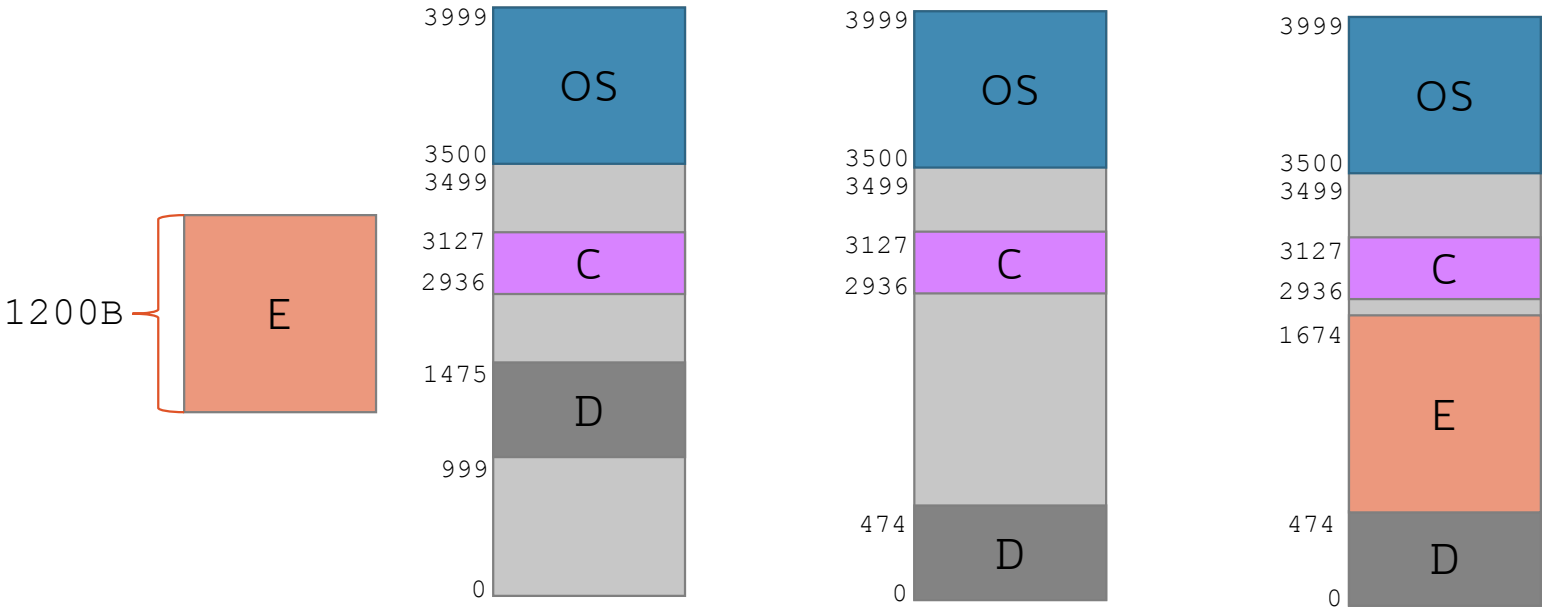

Still some holes left but only one process is moved (D) rather than two

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- That process can be "swapped out" from memory to disk to make room for other processes

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- Using swapping, fragmentation can be tackled easily
  - Just run compaction before swapping-in a process

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  - disk transfer rate = 40 MB/sec (250 msec just to do the data transfer)
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Swapping: Example

- Swapping is a very slow process compared to other operations due to the interaction with hard disk
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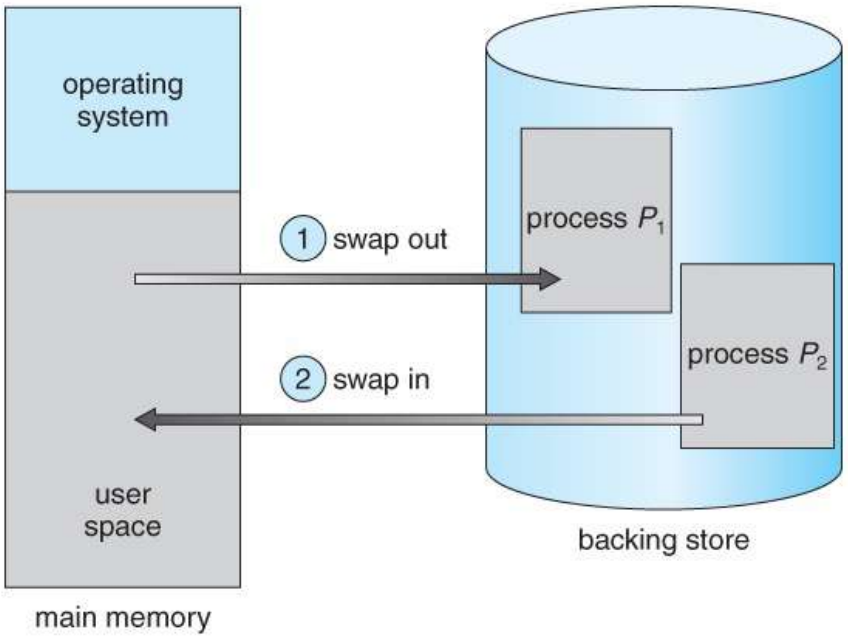
  - 10 MB user process
  - disk transfer rate = 40 MB/sec (250 msec just to do the data transfer)
- Since swap-in may involve swapping-out another process, the overall time required will be ~500 msec
- Time slice is usually way smaller than that!

Swapping



Most modern OSs no longer use swapping, because it is too slow and there are faster alternatives available (e.g., paging)

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  - Hard to grow or shrink process memory
- Fragmentation
  - Frequent compaction needed
- Process entirely loaded
  - Swapping helps but it may be too inefficient

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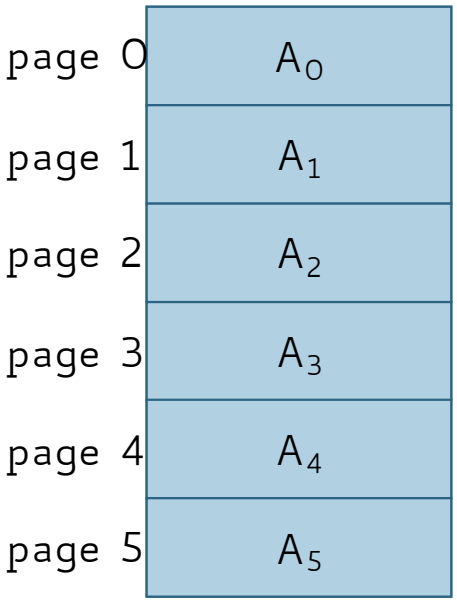
90/10 Rule

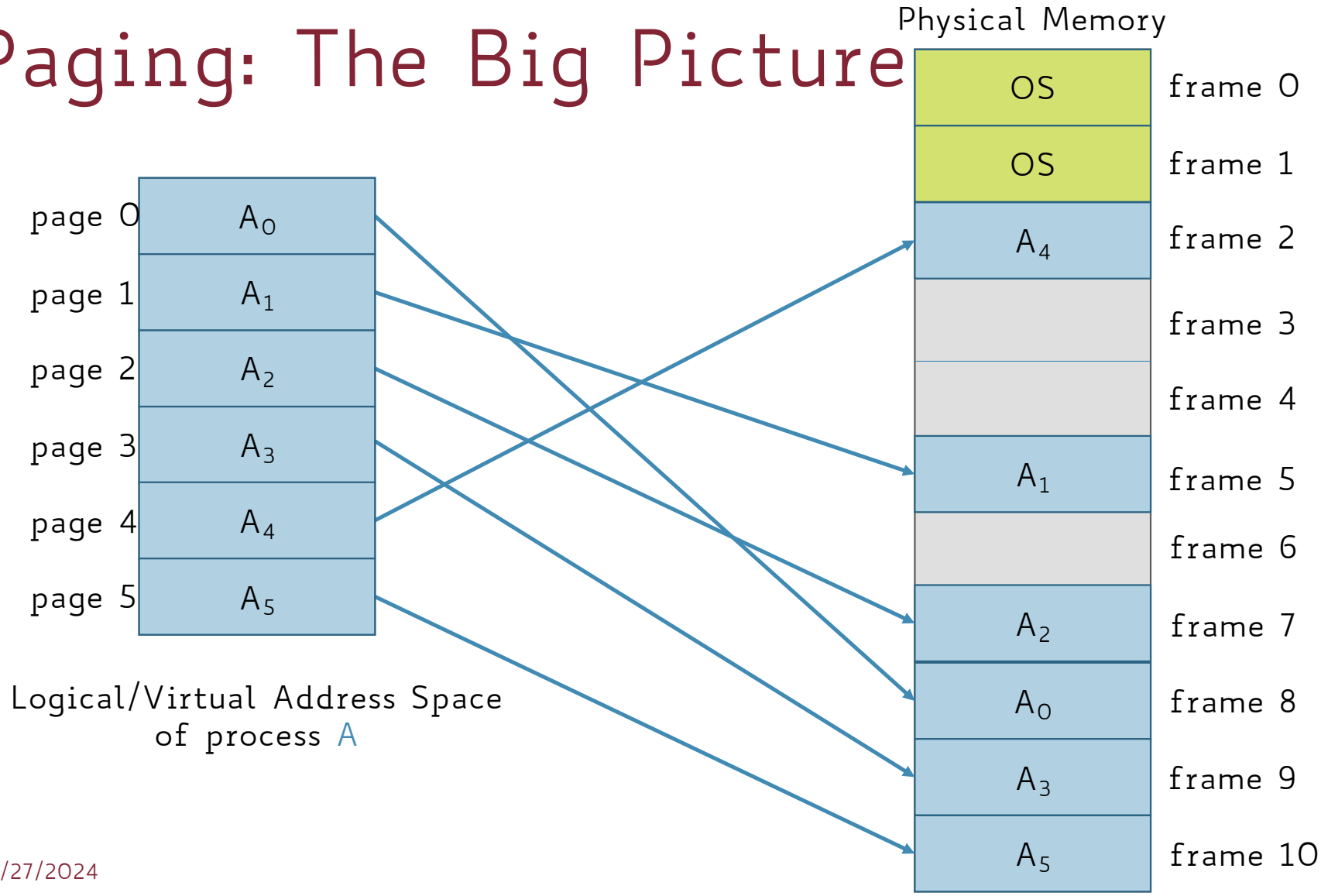
Processes spend 90% of their time accessing only 10% of their allocated memory space

Paging: The Big Picture



Logical/Virtual Address Space
of process A

Paging: The Big Picture



Basic OS Responsibilities for Paging

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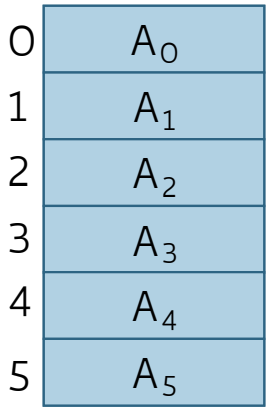
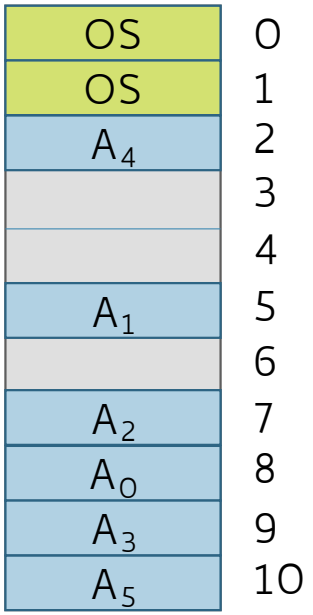
- OS needs dedicated support for doing it → Page Table

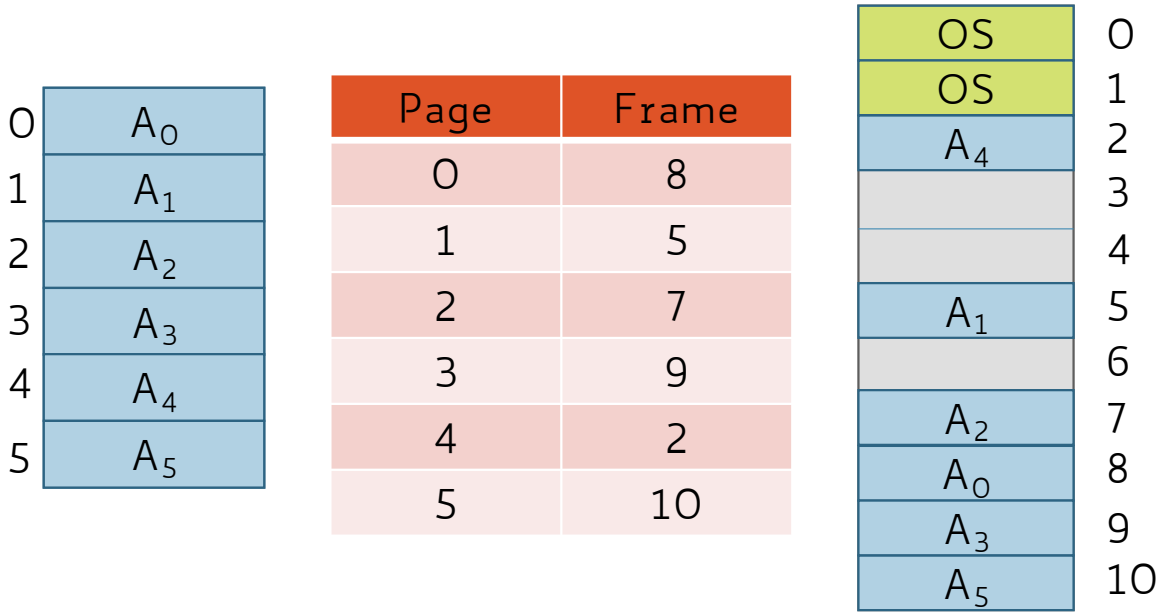
Page Table: Mapping Pages to Frames





Page Table: Mapping Pages to Frames

Lookup table to retrieve what frame a page is stored in



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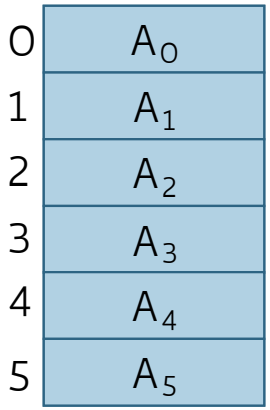
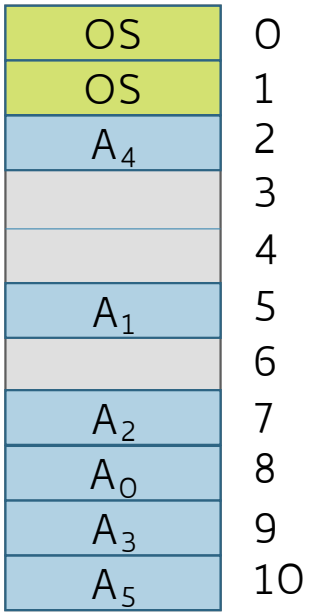


Page	Frame
0	8
1	5
2	7
3	9
4	2
5	10



We have assumed all pages of a process are mapped to physical frames, but this is not always the case

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- Contiguous memory allocation may cause fragmentation
  - External vs. Internal Fragmentation
- Existing countermeasures (compaction) exist but they are costly
- We may want to relax the constraint on having an entire process loaded in main memory
- Paging solves all these issues!