MONASH University

Information Technology

FIT2100 Operating Systems

MEMORY MANAGEMENT - PART 2

Week 10 - Part 1
Semester 2 2024
(Reading: Tanenbaum: Chapter 3 and Stallings: Chapter 7, 8)

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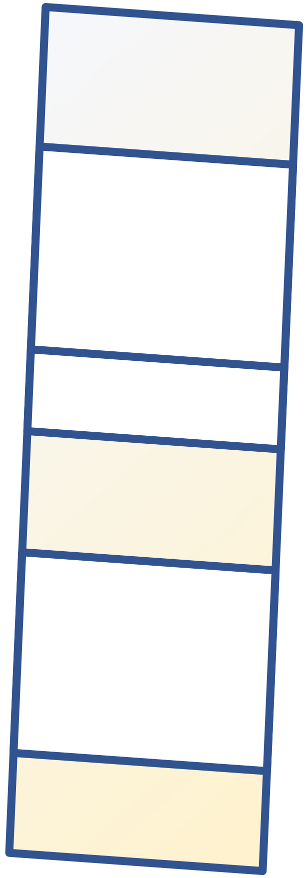
OUTLINE

- Swapping
- Shared Memory
- Virtual Memory
- Paged Virtual Memory
- Page Replacement Algorithms
- Segmented Virtual Memory
- Segment Placement Algorithms

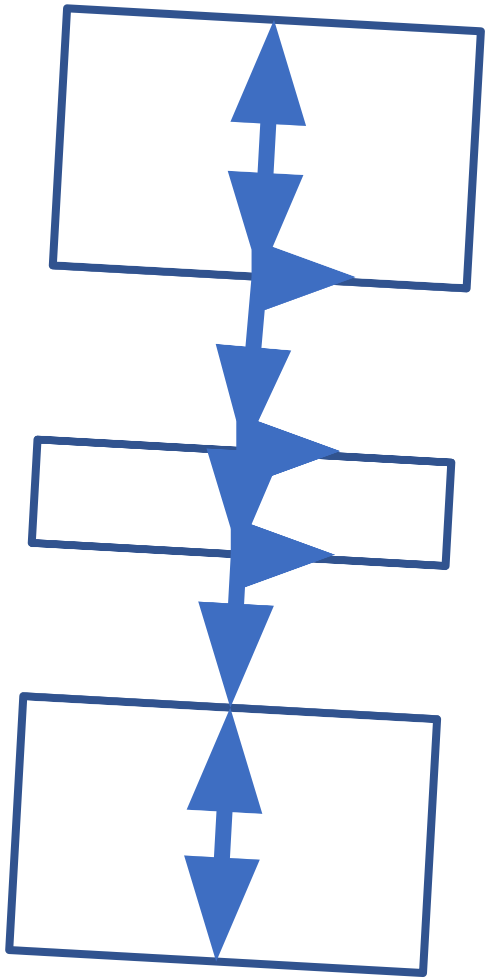
SEGMENTED VIRTUAL MEMORY



SEGMENTED VIRTUAL MEMORY

WHAT IS A SEGMENT?

- A process is allocated one or more logical **segments** of memory.
- A segment can be copied in or out, just like a page.
- Segments can **vary** in size, up to a defined **maximum** size.
- There are no fixed ‘frames’ in physical memory: segments are placed where space is available.
- Moving out a segment leaves a **‘hole’** where another smaller or equal in size segment may fit.



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SEGMENTED VIRTUAL MEMORY

WHAT IS A SEGMENT?

- Instead of page faults, segmented systems have “segment faults”, during which a whole segment is copied from disk into memory.
- If the main memory is sparsely occupied, the segment can be copied into unused memory.
- If the main memory is largely occupied, then one or more whole segments must be copied back to disk to make space for the new segment.
- When a segment fault arises, enough contiguous memory must be freed to fit the new segment in.
- This always requires more effort than a page fault.
- It is unlikely that the space freed by removing one or more existing segments will be exactly the right size to fit the new segment.
- This usually results in gaps between segments, wasting memory → “external fragmentation”.
- In a paged VM system, only portions of a file need be in memory at any time, the rest may be on disk.
- In a segmented VM system, the whole file must be in memory at any time.
- Segments must always be smaller than the physical memory, and the total size of all segments must also be smaller than the physical memory.
- Segment tables are usually smaller than page tables.

SEGMENTED VIRTUAL MEMORY

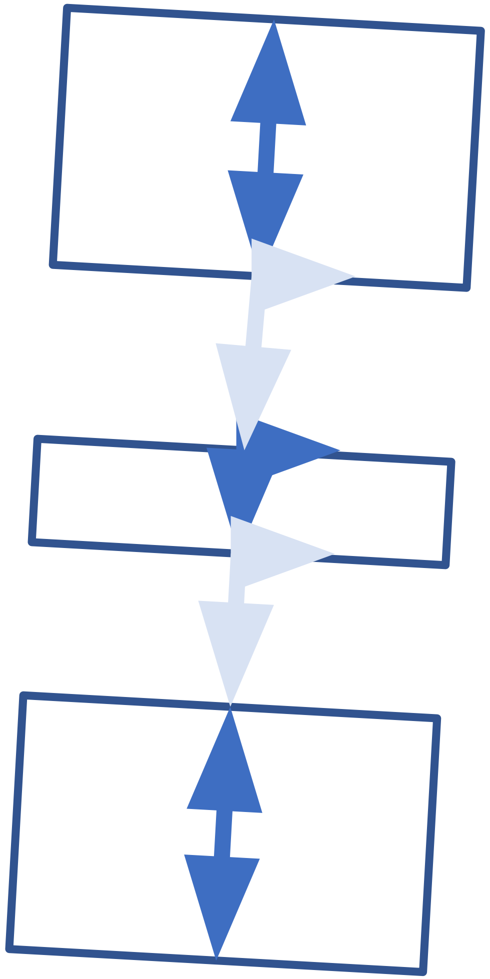
FRAGMENTATION

NO INTERNAL FRAGMENTATION

- A segment may grow or shrink dynamically depending on required size. There is no ‘wasted’ space within a segment that cannot be used.

EXTERNAL FRAGMENTATION

- Can space **between** segments be wasted? **YES**.
  - A small segment may be copied out (or a small process may exit the system).
  - The **hole** left behind may be too small to reasonably fit another segment
  - Even though the space is available, it is not used.
- **Compaction** is the technique of periodically re-arranging segments to remove gaps. Like all “garbage collection” schemes it is computationally expensive.



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SEGMENTED VIRTUAL MEMORY
LOGICAL ADDRESSES

- The memory address contains a **segment number** and an **offset** (just like paging)

Example:

`0000000001100000000000000010001`

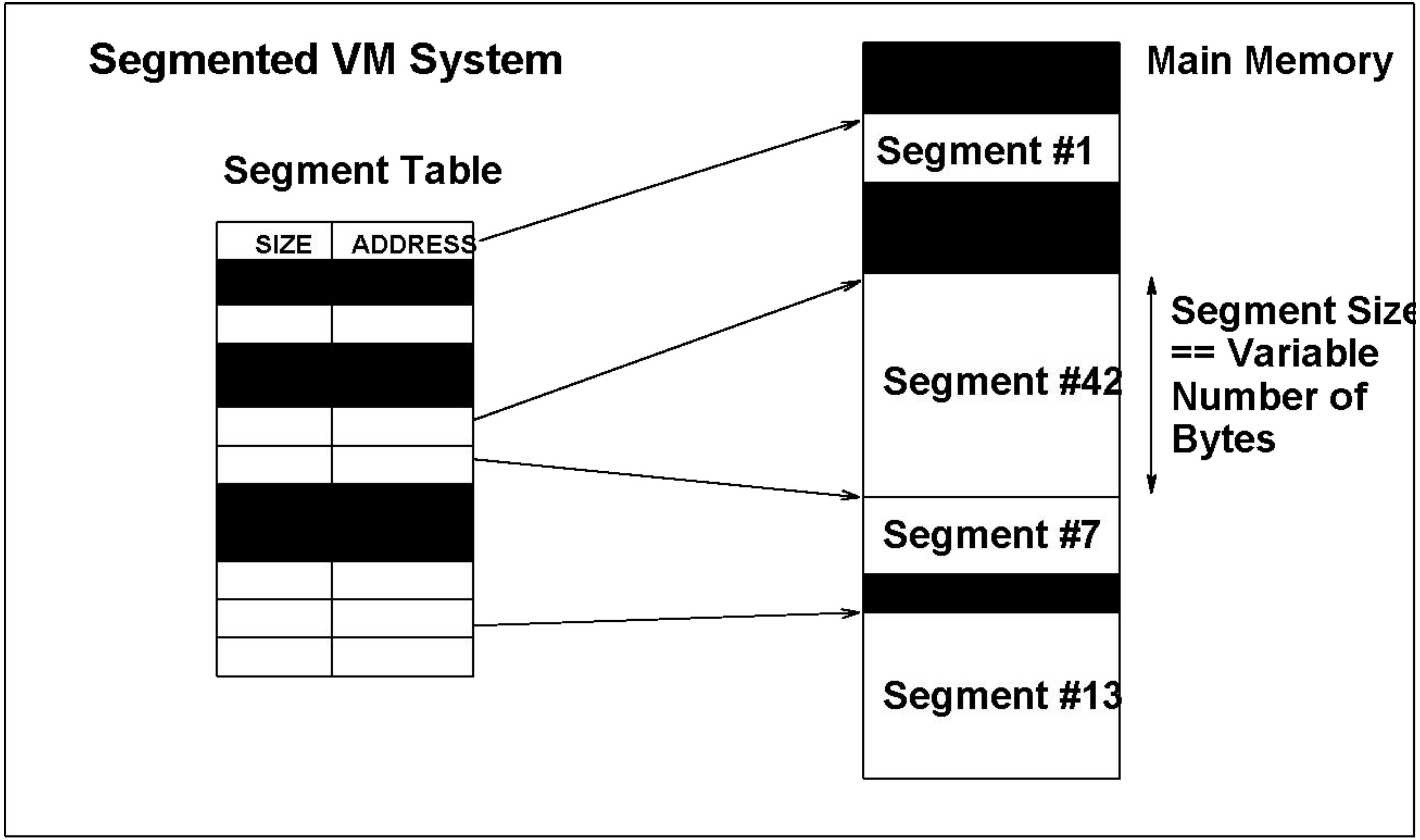
Seg number 12 Offset 17 bytes

- The most significant bits in the **logical address** are used for the **segment number**. The remaining bits are an **offset** from the **start** of the segment in physical memory.
- Segments can be different sizes. **If the offset goes past the end of a segment**, the logical address is invalid.

'SEGMENTATION FAULT'!!! **Analogous to page fault**

SEGMENTED VIRTUAL MEMORY

WHAT IS A SEGMENT TABLE?



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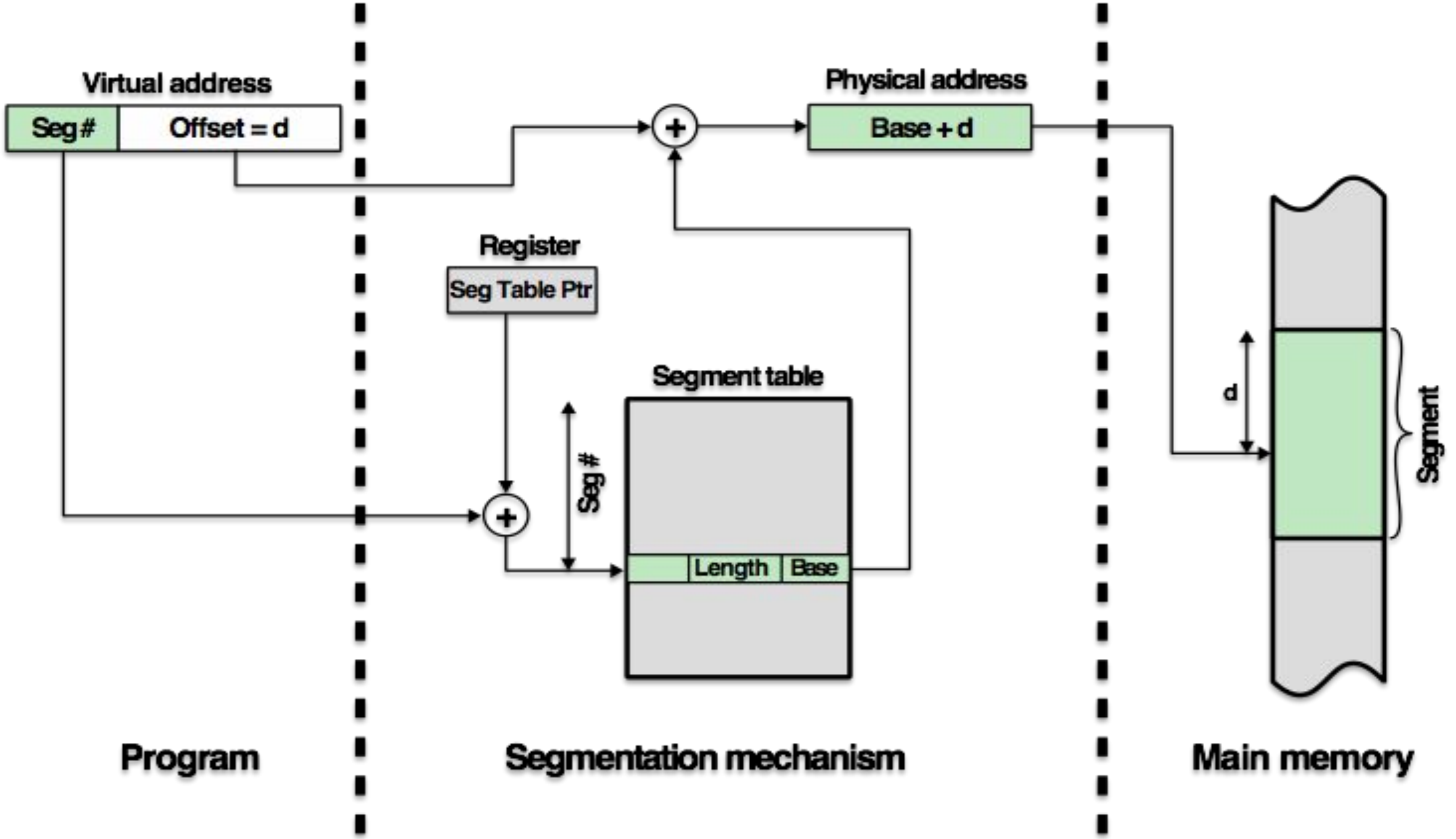
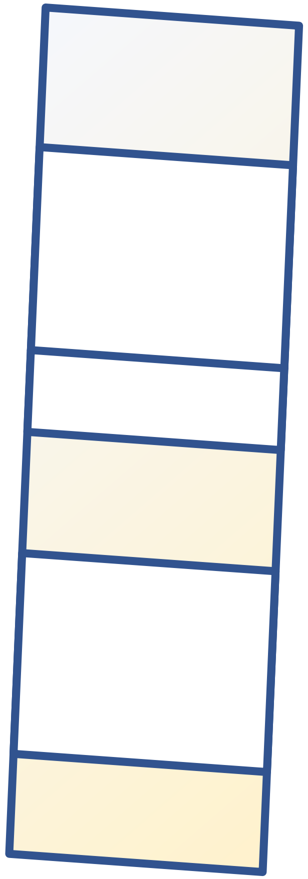
SEGMENTED VIRTUAL MEMORY

ADDRESS TRANSLATION (SEGMENTATION)



SEGMENT PLACEMENT ALGORITHMS



SEGMENT PLACEMENT ALGORITHMS

FOUR APPROACHES

Best-fit	First-fit	Next-fit	Worst-fit
• chooses the block that is **closest in size** to the request	• begins to **scan memory from the beginning** and chooses the first available block that is large enough	• begins to **scan memory from the location of the last placement** and chooses the next available block that is large enough	• chooses the **largest available block** for placement of the segment

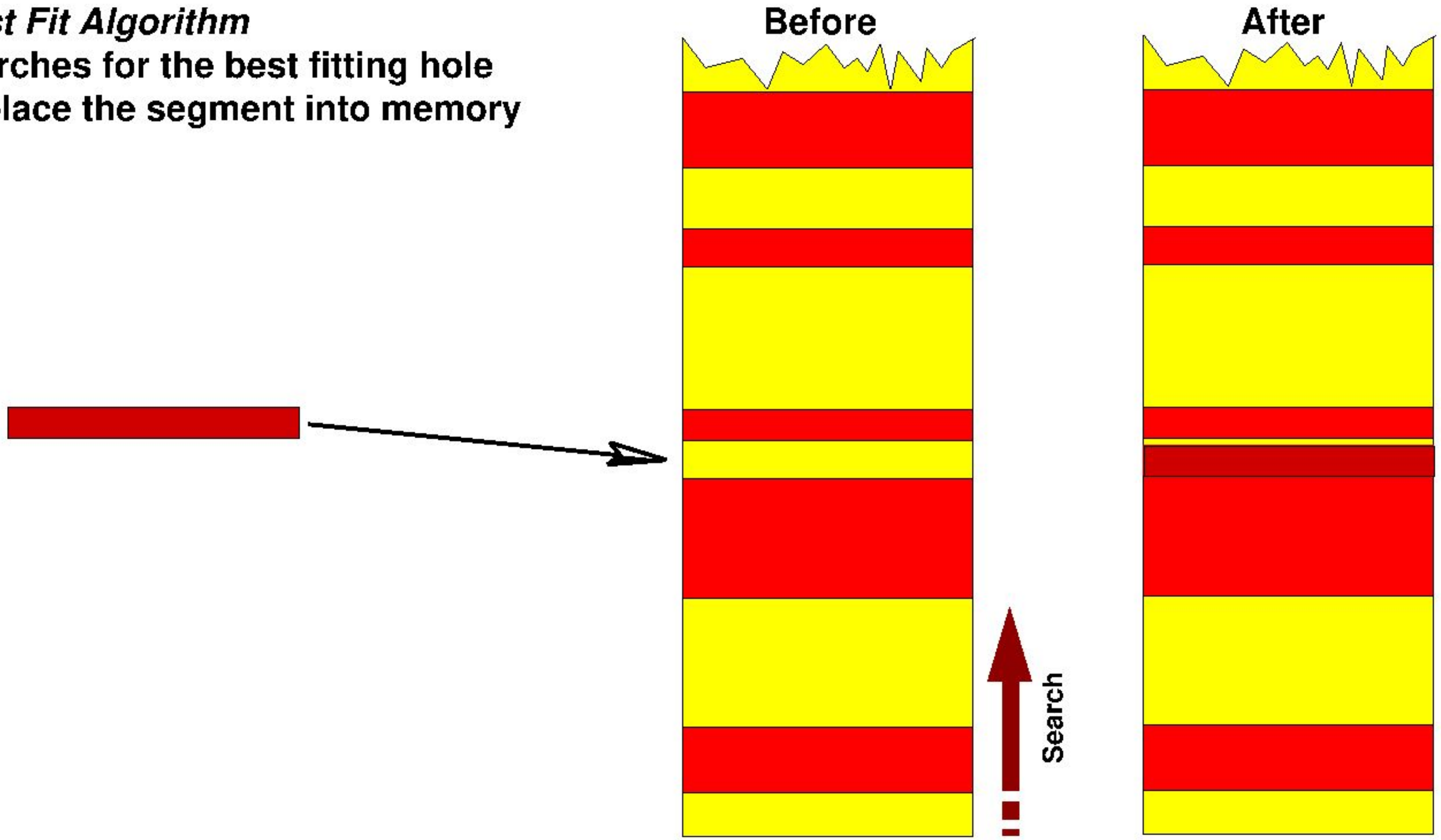
SEGMENTED VIRTUAL MEMORY

Best Fit Algorithm

- Using this algorithm, the available free areas in memory are scanned to find the "hole" that is both larger and nearest in size to the segment to be copied in
- The segment is then copied into this hole – unless the unlikely case of an exact fit occurs, the effect will be to leave a much smaller hole in free memory
- The advantage of the *Best Fit* algorithm is that if the population of segments and holes are on average similar in size, utilization of memory is good (fragments are on average small in size)
- One disadvantage of the *Best Fit* algorithm is that sorting the holes in memory by size to find the best fitting candidates can be slow, depending on the sort algorithm used, the size of the memory, and the number of holes to be sorted
- Another disadvantage of the Best Fit algorithm is that depending on the statistics of the populations of segments and holes, it can produce a large number of small holes that increases the fragmentation problem

SEGMENTED VIRTUAL MEMORY

Best Fit Algorithm
searches for the best fitting hole to place the segment into memory



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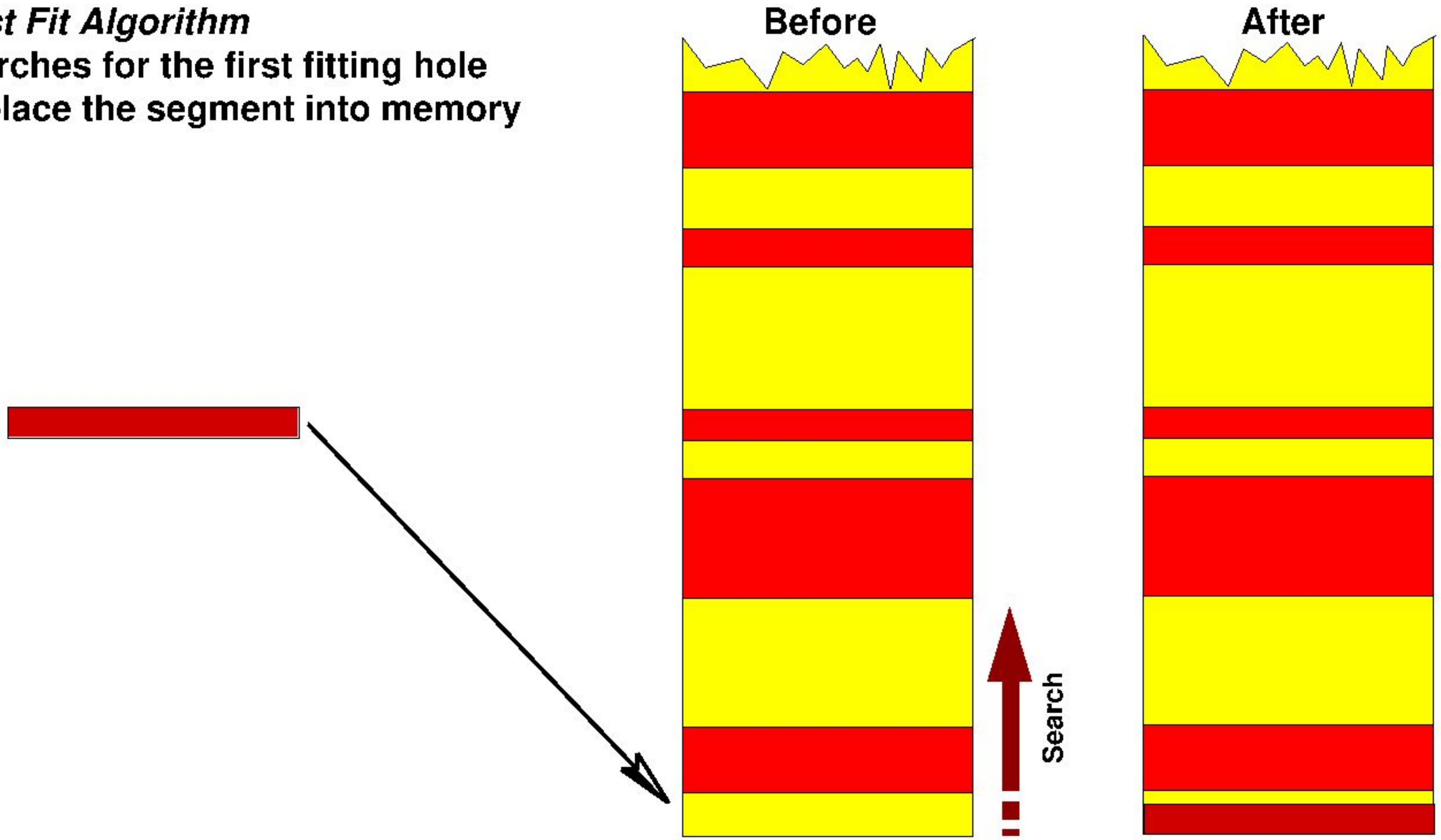
SEGMENTED VIRTUAL MEMORY

First Fit Algorithm

- Using this algorithm, the available free areas in memory are scanned to find the first "hole" that is larger than the segment to be copied in
- The segment is then copied into this hole – unless the unlikely case of an exact fit occurs, the effect will be to leave a hole of arbitrary size in free memory
- The advantage of the *First Fit* algorithm is that it is cheap in computational effort if the memory is not heavily fragmented
- A major disadvantage of the *First Fit* algorithm is that scanning the holes in memory to find the first fitting candidate can be very slow if the memory is heavily fragmented and a large proportion of holes are smaller than the segment to be copied
- Another disadvantage of the *First Fit* algorithm is that depending on the statistics of the populations of segments and holes, it can make a bad fragmentation problem worse

SEGMENTED VIRTUAL MEMORY

First Fit Algorithm
searches for the first fitting hole to place the segment into memory



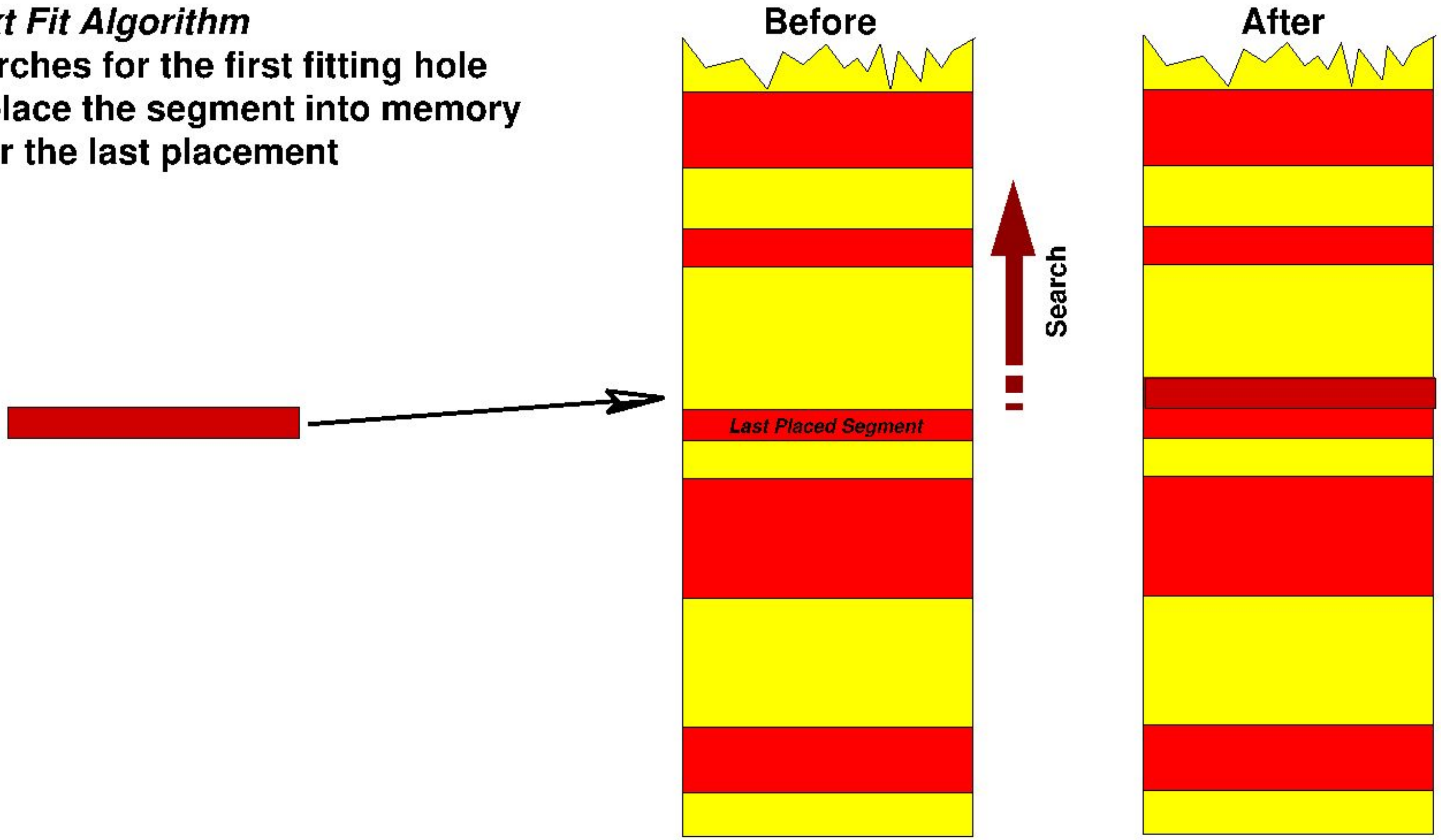
SEGMENTED VIRTUAL MEMORY

Next Fit Algorithm

- Using this algorithm, the available free areas in memory consecutive to the last segment placement are scanned to find the first “hole” that is larger than the segment to be copied in
- The segment is then copied into this hole – unless the unlikely case of an exact fit occurs, the effect will be to leave a hole of arbitrary size in free memory
- The advantage of the *Next Fit* algorithm is that it is cheaper than the *First Fit* algorithm in computational effort if the memory is not heavily fragmented
- A major disadvantage of the *Next Fit* algorithm is that scanning the holes in memory by size to find the first fitting candidate can still be very slow if the memory is heavily fragmented and a large proportion of holes are smaller than the segment to be copied
- Another disadvantage of the *Next Fit* algorithm is that depending on the statistics of the populations of segments and holes, it can also make a bad fragmentation problem worse

SEGMENTED VIRTUAL MEMORY

Next Fit Algorithm
searches for the first fitting hole to place the segment into memory after the last placement



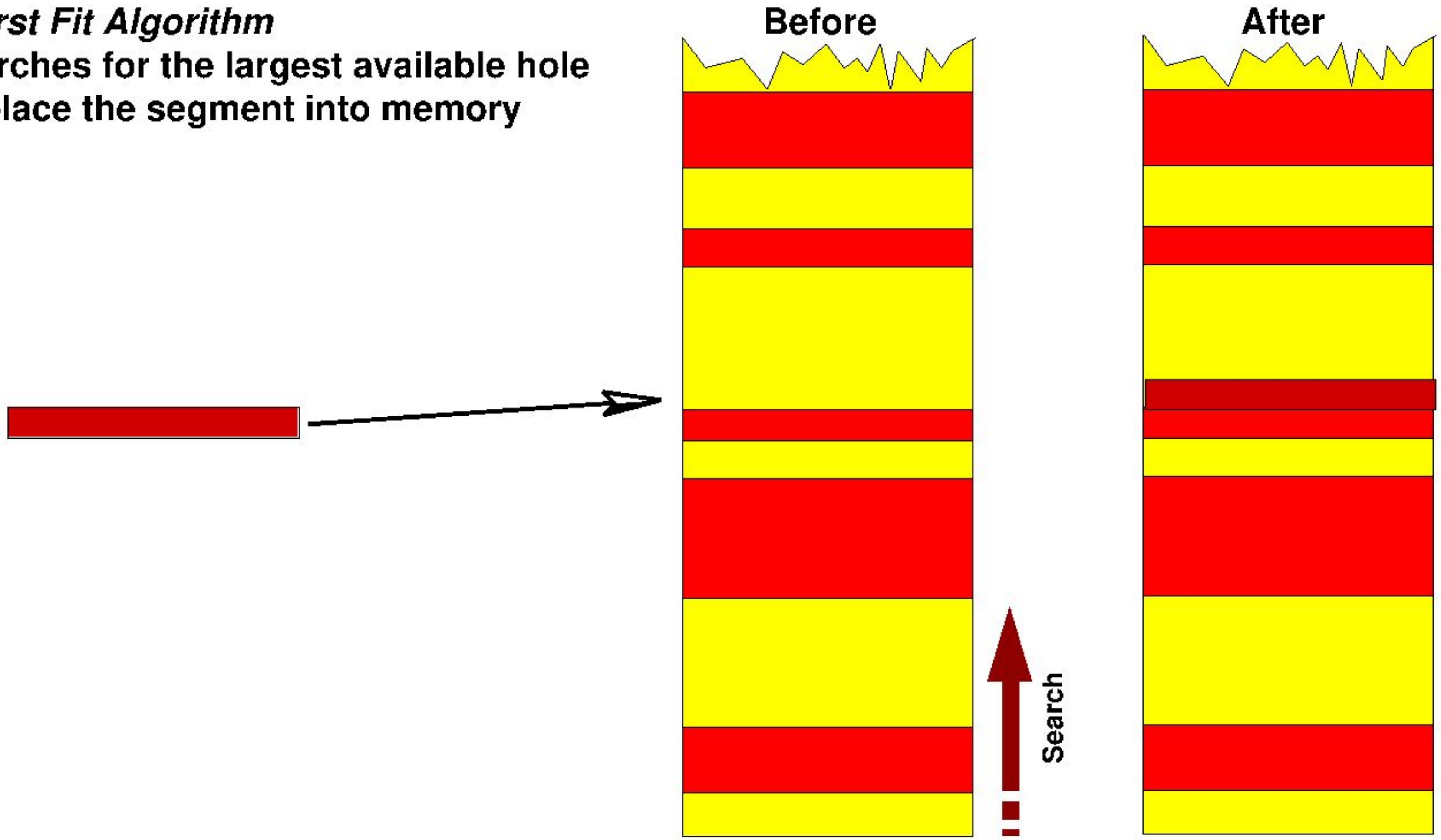
SEGMENTED VIRTUAL MEMORY

Worst Fit Algorithm

- Using this algorithm, the available free areas in memory are scanned to find the largest available “hole” in memory
- The segment is then copied into this hole – leaving a hole that may be large depending on the size of the fragment
- The advantage of the *Worst Fit* algorithm is that it creates large holes that can be more easily allocated if the memory is not heavily fragmented
- A major disadvantage of the *Worst Fit* algorithm is that sorting the holes in memory by size to find the largest candidate can be very slow if the memory is heavily fragmented and a large proportion of holes are small

SEGMENTED VIRTUAL MEMORY

Worst Fit Algorithm
searches for the largest available hole to place the segment into memory



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MEMORY MANAGEMENT EXAMPLES

Netdata Disk / RAM / Swap (Tsaousis et al 2019)

Core i7 6700K / 8 GB RAM
FreeBSD 11.2-RELEASE
Very light load

Disk Throughput [MB/s]

DRAM Occupancy [GB]

Swap Usage [MB]

Swap I/O [MB/s]

Netdata Disk / RAM / Swap (Tsaousis et al 2019)

Core i7 4578U / 8 GB RAM
OSX 10.10.5 Yosemite
Heavy load (80-90% CPU)

Disk Throughput [MB/s]

DRAM Occupancy [GB]

Swap Usage [MB]

Swap I/O [MB/s]

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Summary

- So far we have discussed
  - Why virtualised memory is useful
  - Paging and segmentation.
  - How to translate a logical memory address into a physical address
  - Four different segment placement algorithms.
- Next Section
  - Inter Process Communication (IPC)
- Reading
  - Stallings, Chapter 7 & 8 (7th Edition)