Memory

Language Support for Dynamic Allocation

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- Explicit memory management, e.g., C. Where the programmer controls the creation and deletion of objects (`malloc` and `free`)

And several other approaches!

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Physical Memory

Dynamic Partitioning

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A lot more complicated to implement, but this allows the process (i.e., the job submission) to say how big a partition it needs and the OS allocates just that

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Physical Memory

We can allocate sequentially, moving up memory

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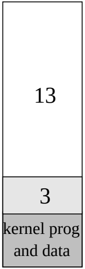

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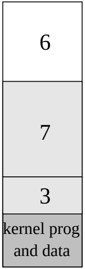

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kernel prog and data

Memory

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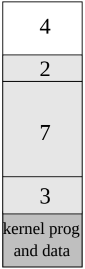

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kernel prog
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The problem is when a process ends and we get memory back: it creates holes

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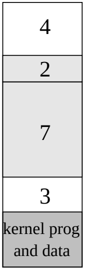

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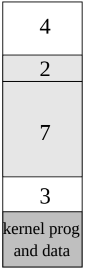

We have space enough to run a process of size 5, but nowhere to put it

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This is a general problem, called *fragmentation* and is very difficult to solve effectively

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The more processes come and go, the worse the fragmentation gets

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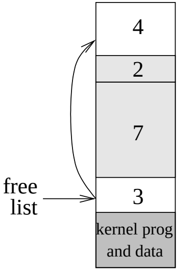

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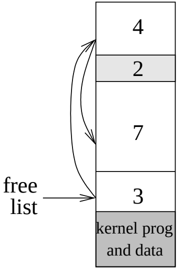
When a block is freed, put it in the freelist. It helps to keep the freelist sorted in address order:



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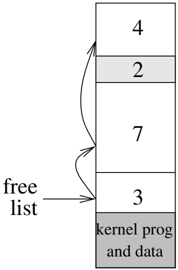

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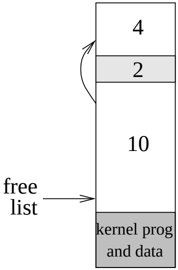
Slightly more clever is to *coalesce* physically adjacent blocks



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But there might be several blocks on the freelist that we could use: which one to choose?

Strategies for choosing blocks include:

- Best Fit. Find the *smallest* available big enough hole. Slow as we always have to search the entire freelist and results in lots of small fragments that are effectively useless as they are too small to be allocated

Memory

Physical Memory

- First Fit. Use the *first* available big enough hole. Initially faster than Best Fit and tends to leave larger and more useful fragments. But fragments tend to be created near the front of the freelist, so we have to search further and further each time

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- First Fit. Use the *first* available big enough hole. Initially faster than Best Fit and tends to leave larger and more useful fragments. But fragments tend to be created near the front of the freelist, so we have to search further and further each time
- Worst Fit. Find the *biggest* available big enough hole. Strangely this works out better than you think. Slicing chunks off bigger blocks tends to leave larger fragments that are more likely to be useful. Marginally faster than Best Fit as we have larger and therefore fewer blocks in the freelist to search through

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Allocation is **still a problem** in current machines where certain kinds of hardware need large contiguous chunks of physical memory, e.g., GPUs

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The second generally gives us larger fragments, but both need to be addressed

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The OS stops all running processes (i.e., stops scheduling processes); shifts their code and data around to close up the gaps; then lets the processes continue (i.e., starts scheduling again)

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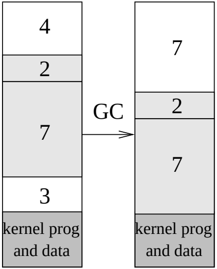
Physical Memory



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- the pause while things are moved is bad for interactive and real-time behaviour
- the erratic nature of when GCs are needed leads to unpredictable behaviour from the OS
- given the right kind of hardware support, better solutions completely avoiding the need for GC are possible

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There are ways of implementing GC to avoid the stop-and-copy (ephemeral GC), or mitigating the overhead (generational GC) but even so it is not popular for OSs

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These issues develop when we move to *virtual* memory later, but in general code should not assume it lives in a given place in memory

□