April 19

- Four Classes to Go!
- Save the Forest
- VM and Making Programs Go

Operating System

- The OS is JUST A PROGRAM
  - but it runs in SUPERVISOR state
    - access any of memory
    - all IO devices, etc.
  - whereas ordinary programs run in USER state
    - only access memory through page tables set up by OS
    - normally no access to IO devices
- Programs ask the OS for services (syscall)
  - give me more memory
  - read/write data from/to disk
  - put pixel on screen
  - give me the next character from the keyboard
- The OS may choose to “map” devices such as the screen into USER space

Shell

- You normally interact with a SHELL
- It provides the command prompt, or GUI (graphical user interface)
- It is JUST A PROGRAM
- It runs in USER state just like your programs
- It interprets your mouse clicks or typed commands and asks the OS to implement your requests

- Suppose you “double-click” on a program icon

  What happens?

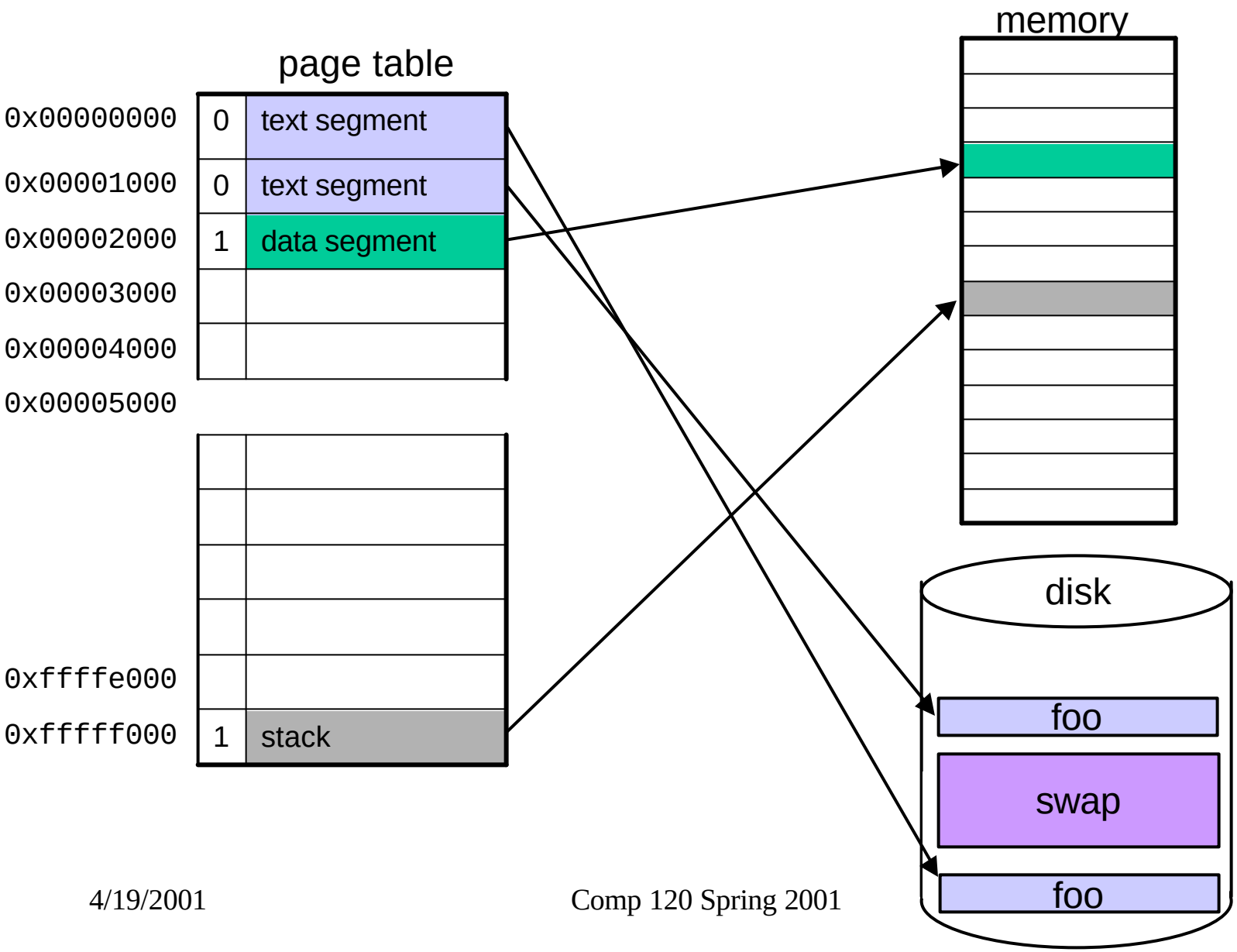
Program Startup in SHELL

- First the SHELL finds the file indicated by the icon
- It checks some permissions and such
- Finally it calls the EXEC system call with the file name and possibly some arguments
- Now the OS takes over

OS Exec

- The OS keeps a PROCESS TABLE of all running programs
  - disk location of executable
  - memory location of page tables
  - priority
  - current status (running, waiting ready, waiting on an event, etc.)
  - PID (process ID) a number assigned to the process
- A PROCESS is an independent program running in its own memory space
- The OS allocates a new entry in the PROCESS TABLE
- And sets up the PAGE TABLE for the new process

Initial Page Table



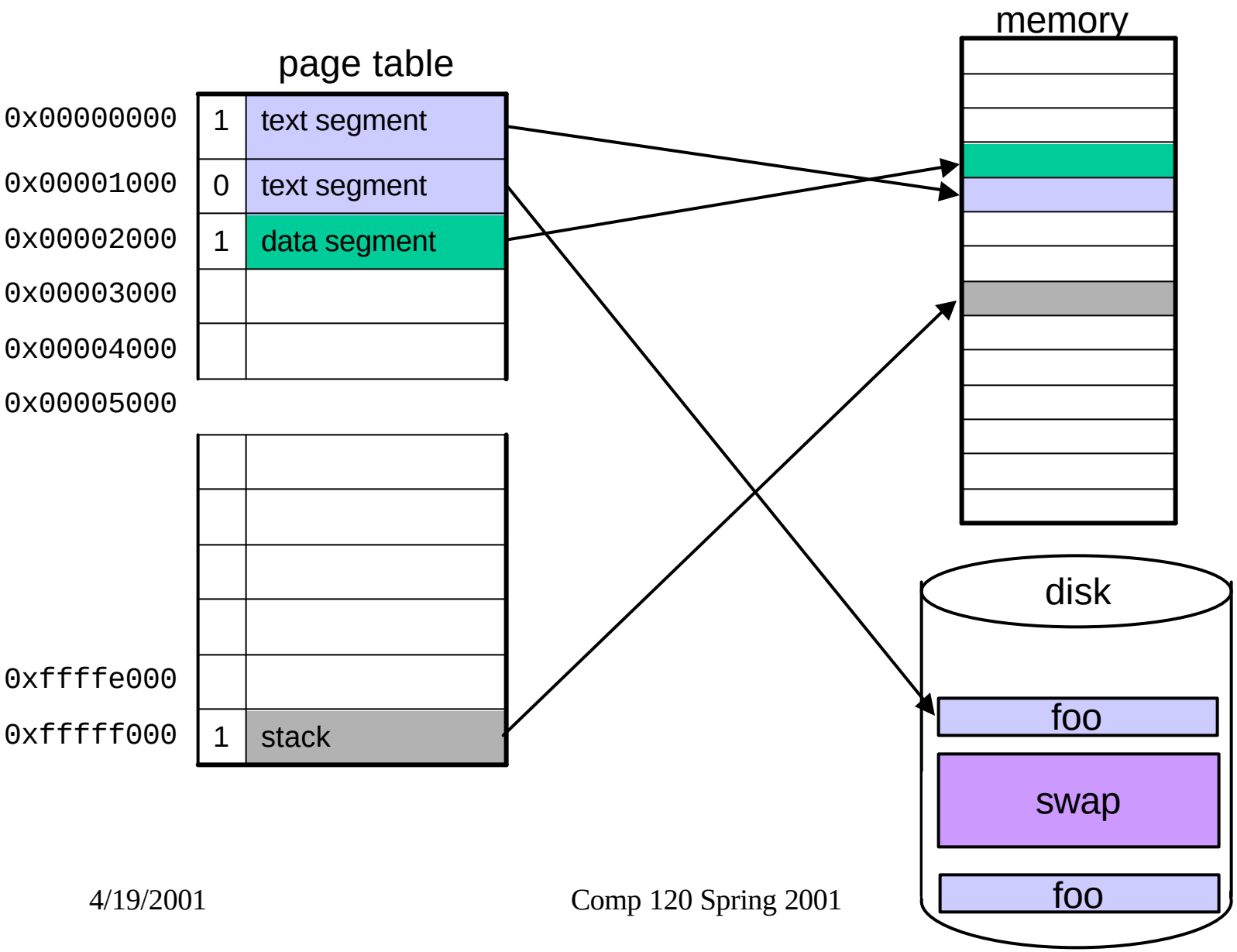
Program Startup

- Now everything is ready
  - The PROCESS TABLE entry has been set up
  - The PAGE TABLE for the process has been initialized
  - The TEXT SEGMENT is out on disk
  - The DATA SEGMENT is in memory
  - The STACK SEGMENT has been allocated 1 PAGE
- The OS is ready to take the leap of faith
- ONLY ONE program runs at a time
- When your program is running the OS is not
- To run your program and maintain control the OS must trust that is will eventually get control again
  - when the program asks for a service
  - when the program does something illegal
  - when a timer goes off

Fault in the Text

- When we branch to the beginning of “main” we get a page fault
- So the OS copies the first page of the TEXT of main to a free page in memory

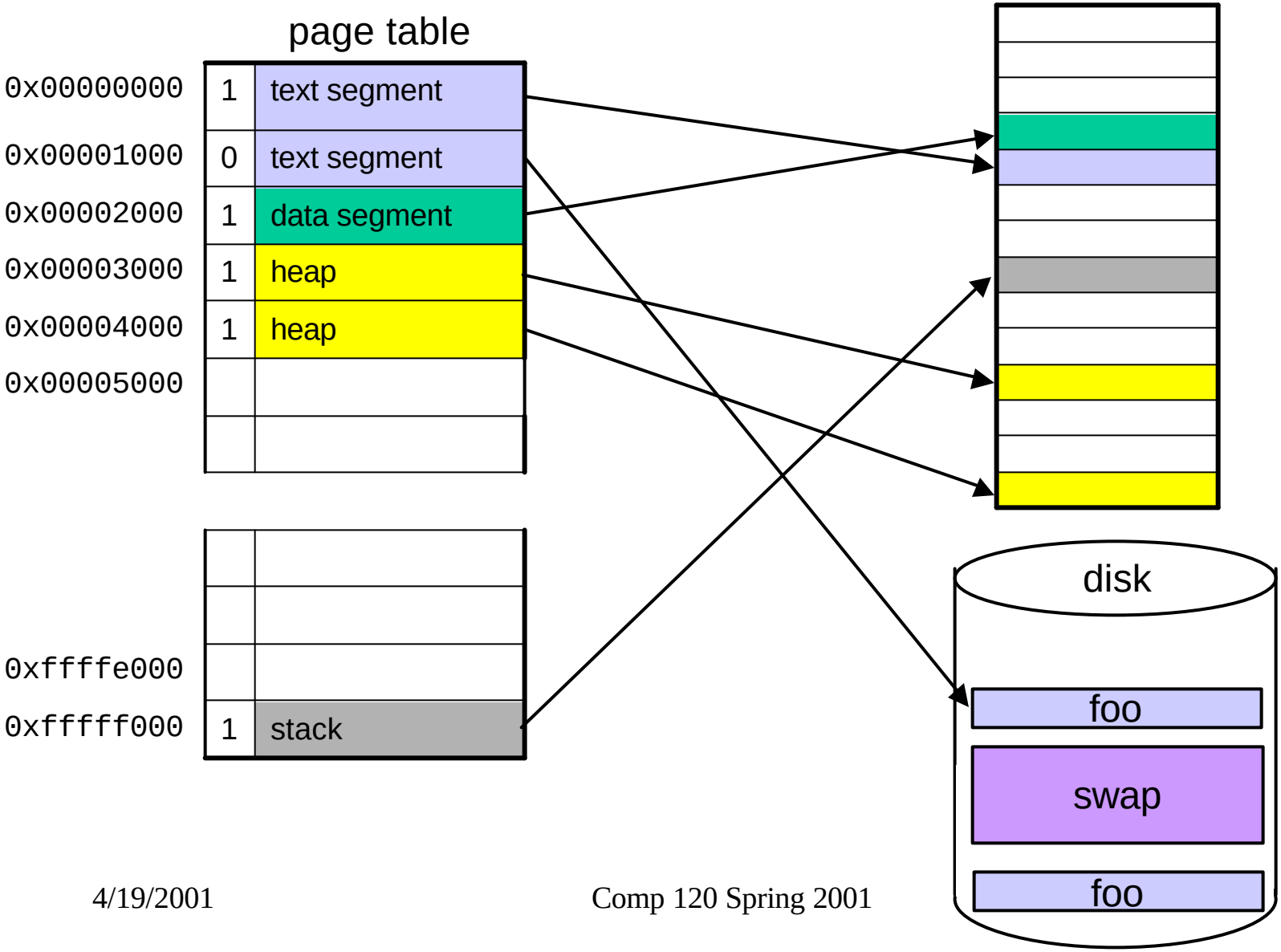
Fault in the Text



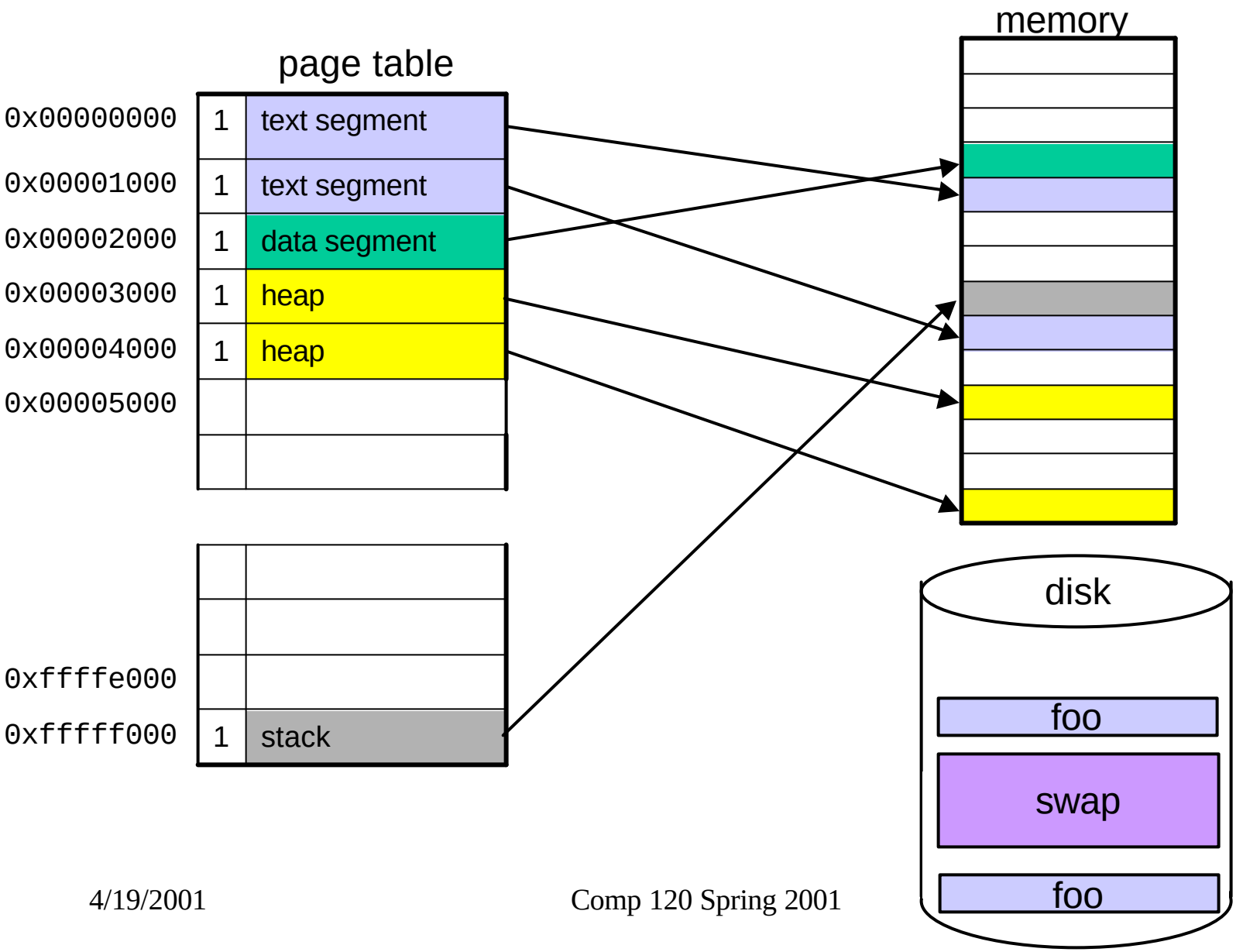
Allocate a block of memory

- Now suppose the first thing our program needs to do is get 6k of memory for an array
- The program uses “new” to make an array
- Down inside “new” it calls “malloc”
- Down inside “malloc” it uses a system call to ask the OS for memory
- The OS will have to find 2 pages to hold 6k

Allocate a block of memory



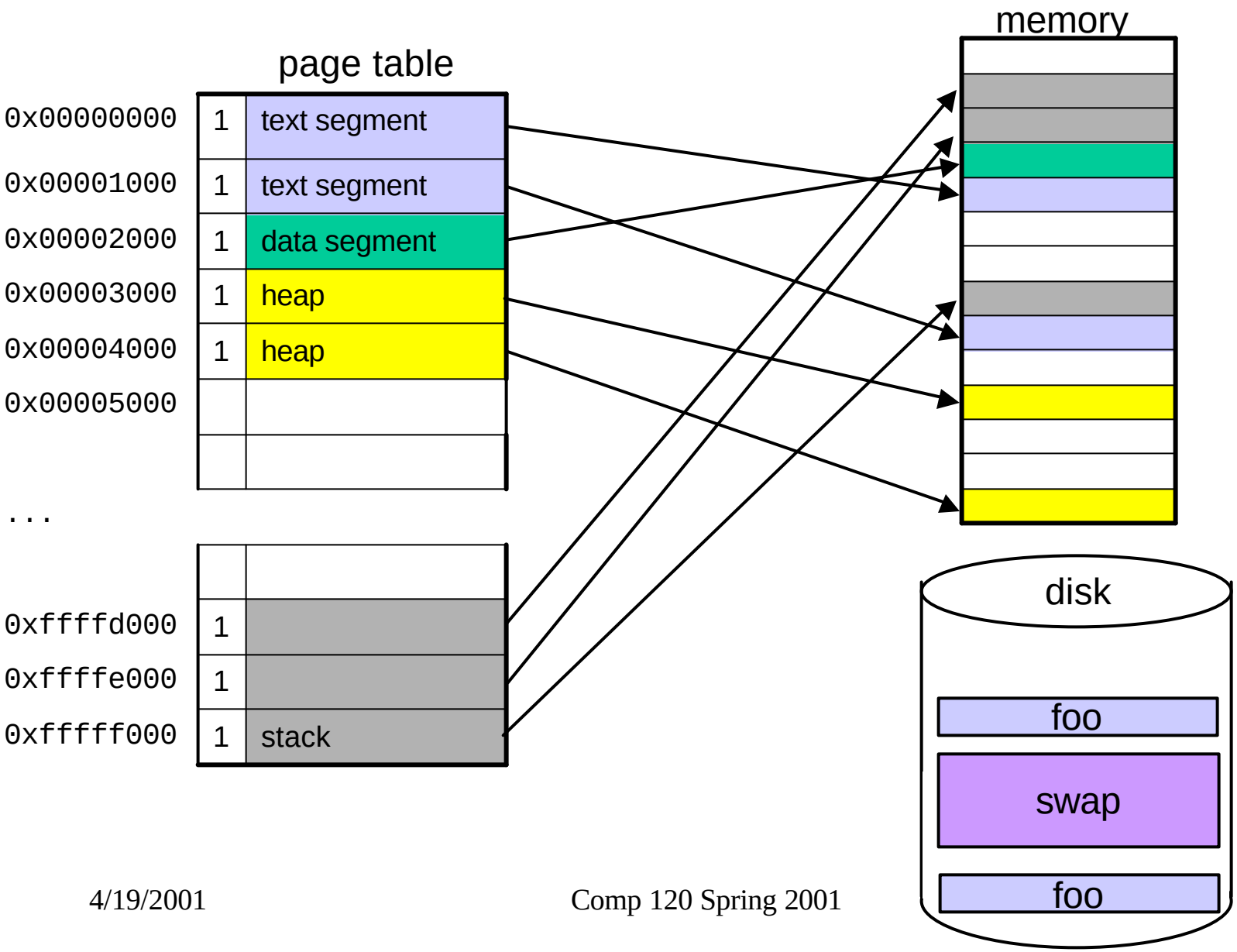
Fault in the other page of TEXT



Grow the stack

- Now our program needs more stack space
- Perhaps it has to call a recursive function to transverse a complex data structure
- Or perhaps the user declares an “automatic” array like
  double work[4000];
  which needs 8000 bytes of memory

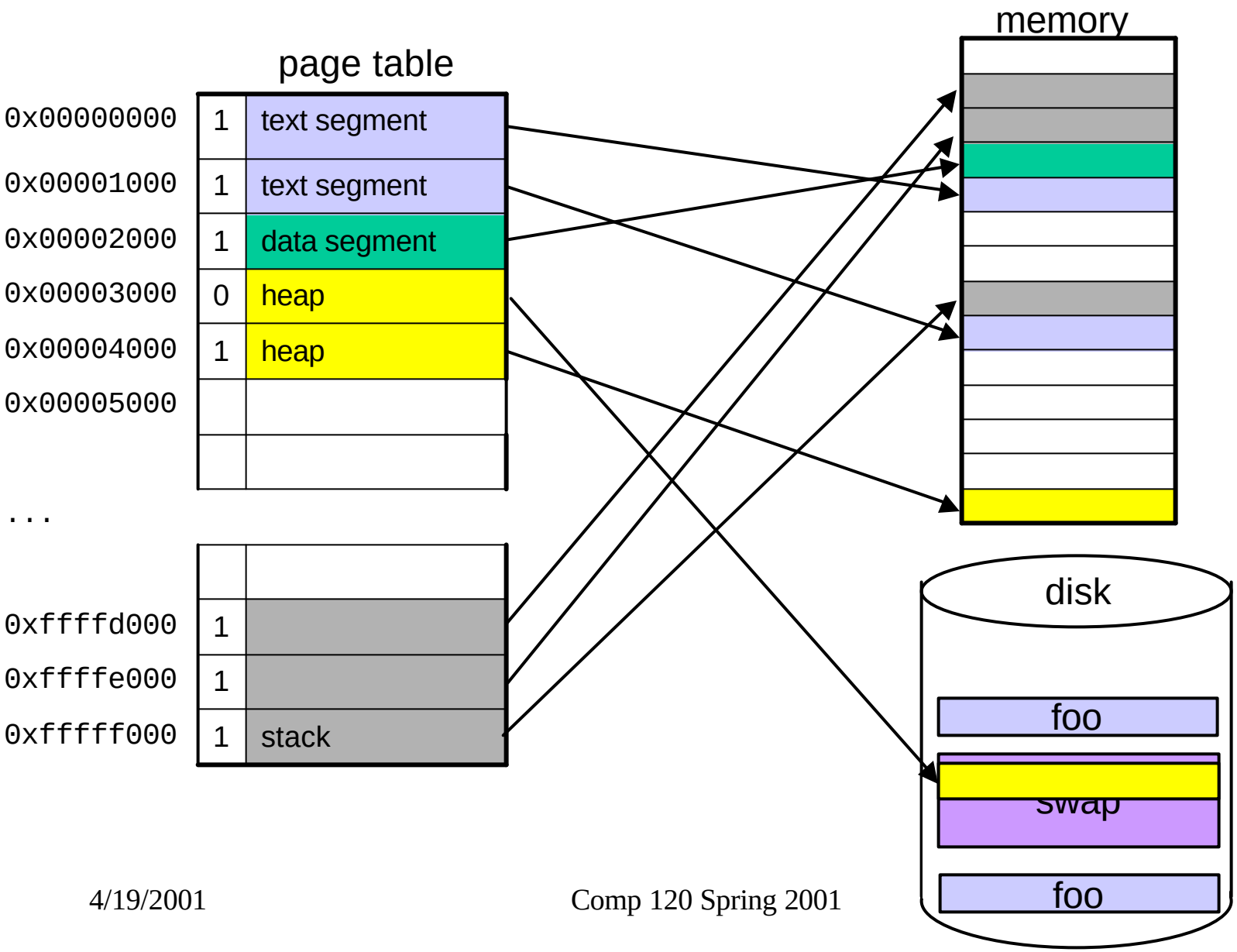
Grow the stack



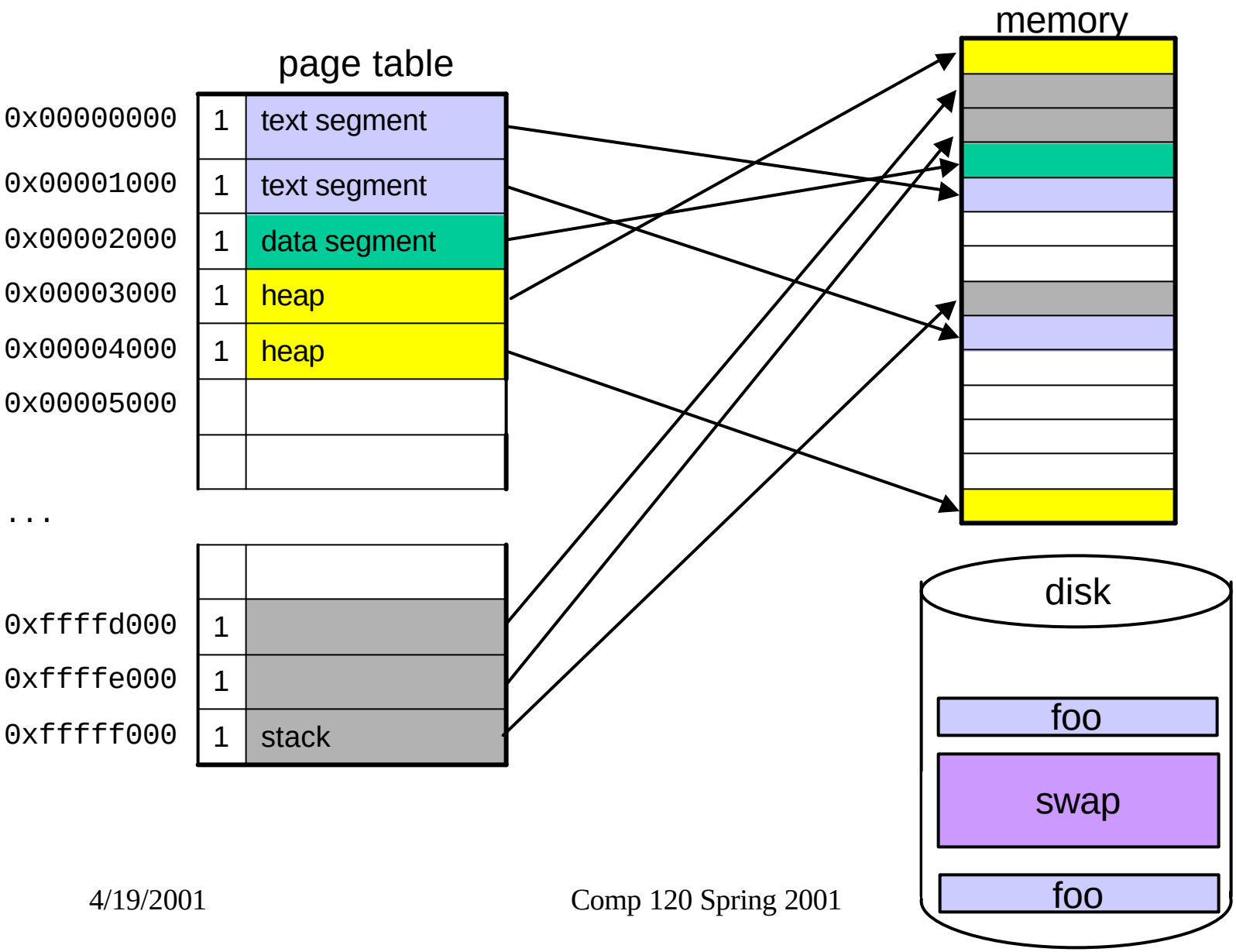
Get partially paged out

- Sometime later, some other program running on the system needs more memory
- It asks the OS
- The OS realizes that not enough physical memory remains available
- So the OS chooses to PAGE OUT one page from our program
- It would choose one that hasn't been used for a while
  - like possibly one of the heap segments

Partially Paged Out



Later we need that page



Exit

- Finally our program exits
- It calls the “exit” system call to notify the OS that it is done
- The OS cleans puts the memory back on the free list
- Cleans up the PAGE TABLE and PROCESS TABLE
- And goes on about its business...

- What does the OS do when no programs are ready?

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