# Operating Systems
# Project 5:
# Processes & Multiprogramming

# Multiprogramming Requirements

- Memory Management
  - Ability to load multiple programs into memory
- Time Sharing
  - Ability to periodically stop the running process and transfer control to an ISR in the OS
- Process Management
  - Ability to keep track of and change between executing processes.
    - Context switching
    - Ready queue

# New Files

- New versions of:
  - `kernel.asm`
  - `lib.asm`
  - `bootload.asm`
- New files:
  - `proc.h`
  - `proc.c`
  - `testproc.h`

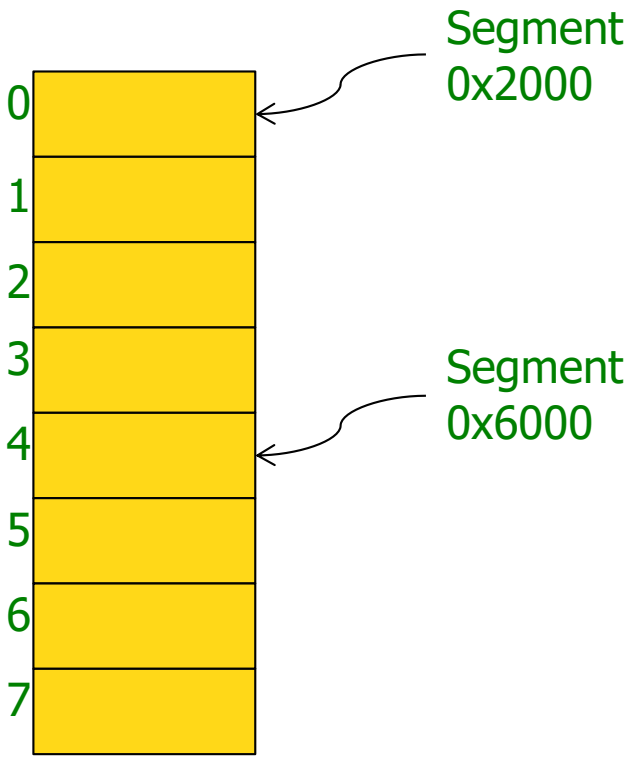
# Segment-Based Memory Management

- Allow one process to be loaded into each segment
  - Segments: 0x0000, 0x1000, 0x2000, … 0x9000
    - 0x0000 reserved for interrupt vector
    - 0x1000 reserved for kernel
    - → **8 segments available for user programs**
      - 0x2000 – 0x9000

- Maximum program + data + stack?
  - 0x1000 bytes = 65536 bytes = 64kB

# Tracking Free Memory

- Memory segment map:
  - Each index corresponds to one memory segment.
    - segment = (index+2)*0x1000
    - index = (segment/0x1000)-2
  - Marked as:
    - FREE or USED



# Time Sharing: Programmable Interrupt Timer

- Generates interrupt 0x08
- Will generate approximately 12 interrupts / second
- ISR for interrupt 0x08 will do context switching and scheduling
  - Assembly language code is given
  - Write a C function that gets called on each interrupt
    - Similar to `handleInterrupt21` for interrupt `0x21`.

# Interrupt 0x08 ISR Details

- `makeTimerInterrupt()`
  - Sets entry 0x08 in interrupt vector to point to timer_ISR assembly routine in kernel.asm.
- `timer_ISR()`
  - Pushes context (GP registers + PC) onto stack of interrupted program.
  - Invokes handleTimerInterrupt with segment & stack pointer of interrupted program

# Interrupt 0x08 ISR Details

- `handleTimerInterrupt(int segment, int stackPointer)`
  - C function that you add to your *kernel*
  - Does process management and short term scheduling
- `returnFromTimer(int segment, int stackpointer)`
  - Assembly routine in kernel.asm
  - Called at end of handleTimerInterrupt to return to program in segment.
    - Pops context of program from its stack
    - Transfers control to program in segment
  - Call does not return

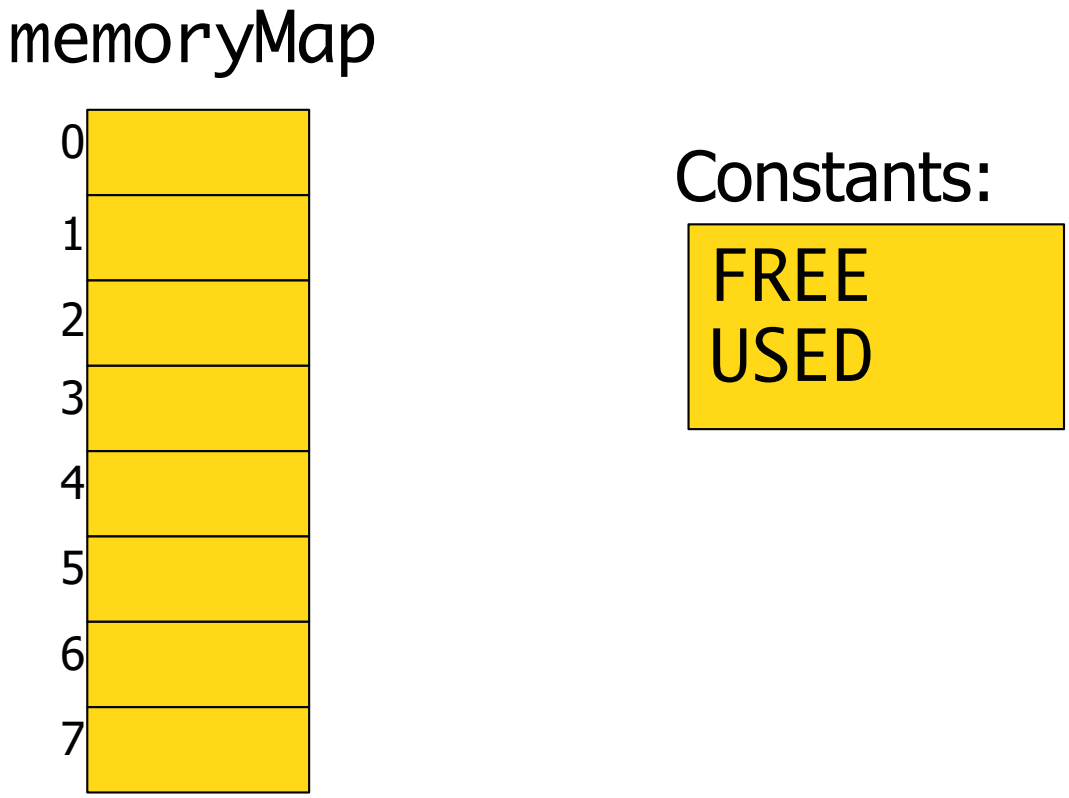
# Process Management Responsibilities

- Starting a new process (`executeProgram`)
  - Obtain process control block (PCB) for the process
  - Load program into free segment
  - Add PCB onto ready queue
- Short-term scheduling (`handleTimerInterrupt`)
  - Save stack pointer of interrupted process in PCB
  - Pick new process from ready queue
  - Start new process by calling `returnFromTimer`
- Terminating a processes (`terminate`)
  - Release memory segment
  - Release PCB

# Process Management: proc.*

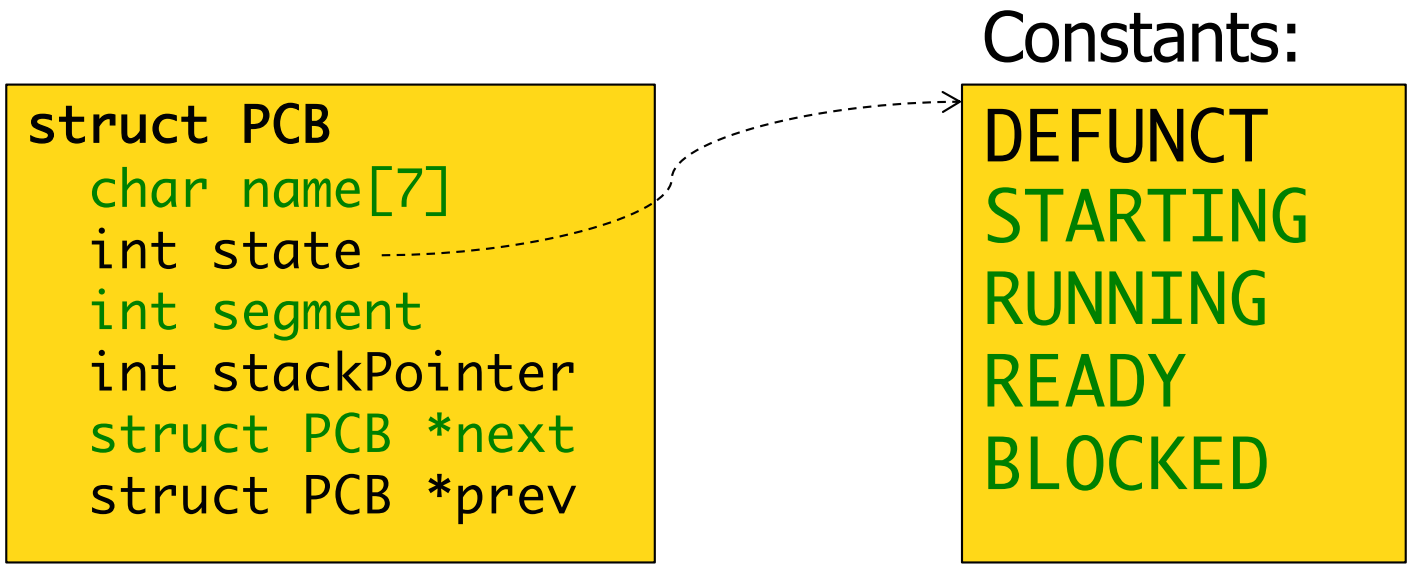
- `proc.h` defines constants, data structures, global variables, and functions that you will use for memory and process management
  - Provided for you
- You need to write (most of) `proc.c` to implement the defined functions
- `testproc.c`
  - Provided to help you test your implementation

# proc.h Data Structures: memoryMap



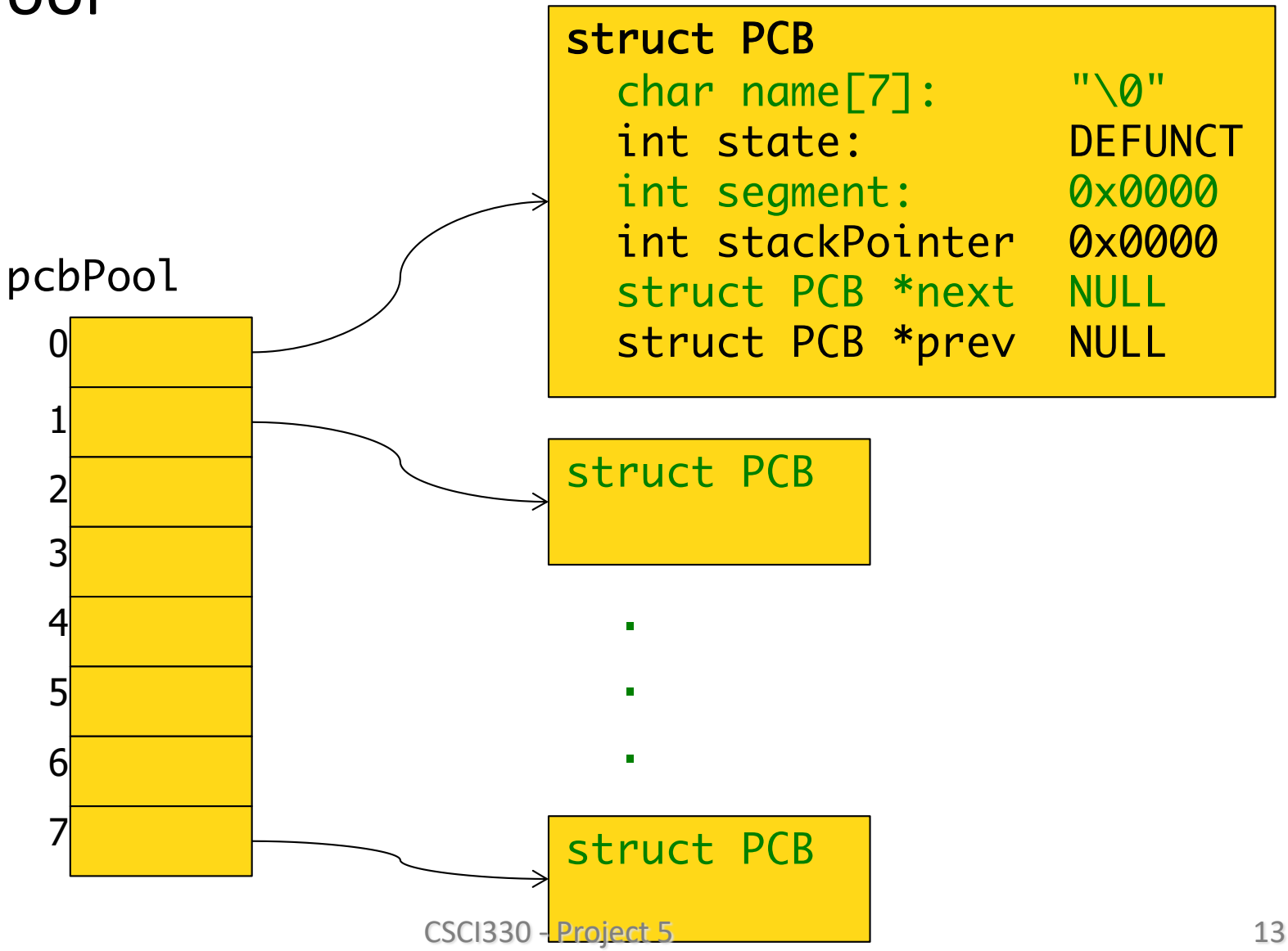
# proc.h Data Structures: PCB

- Process Control Block:



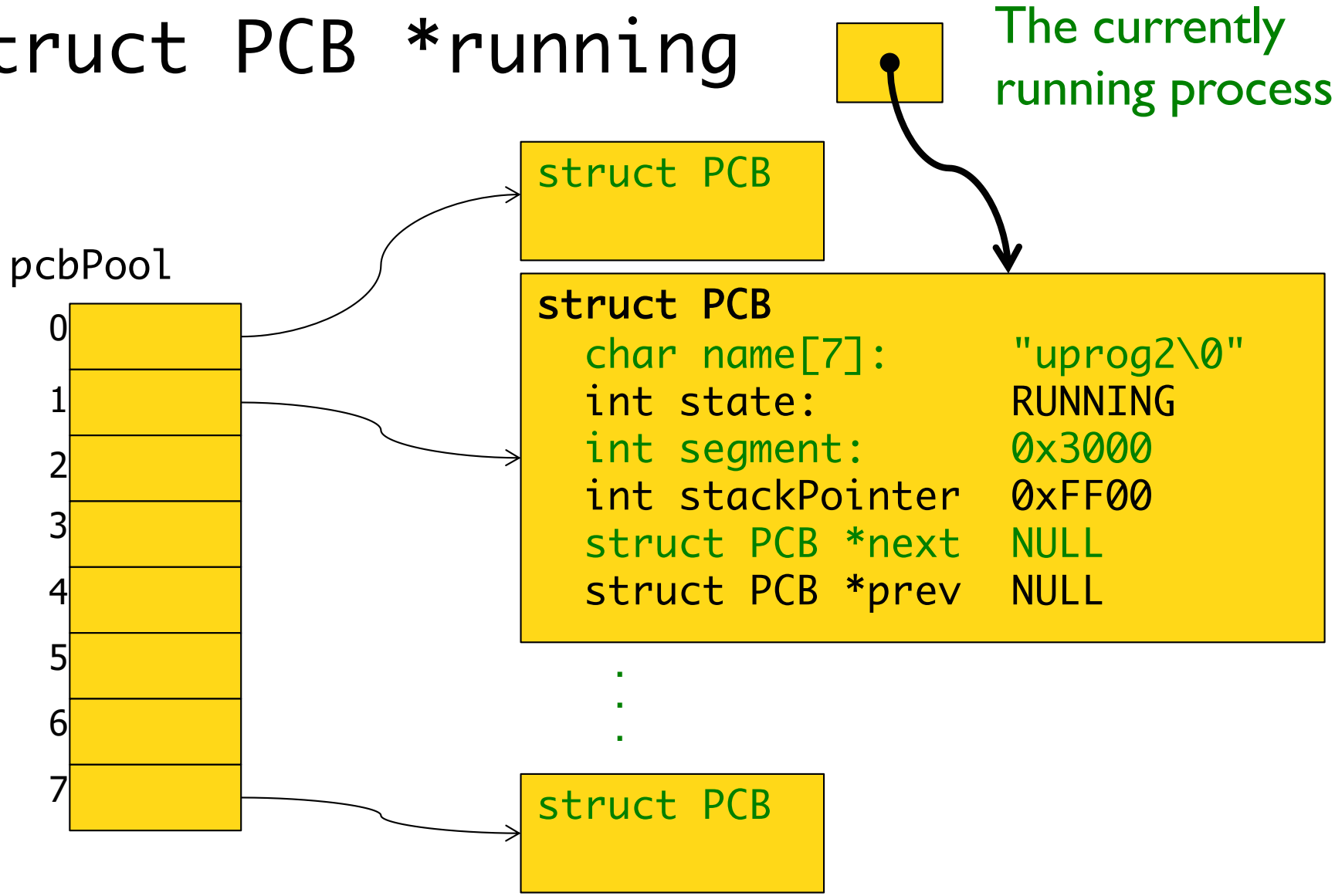
# proc.h Data Structures: pcbPool

- PCB Pool



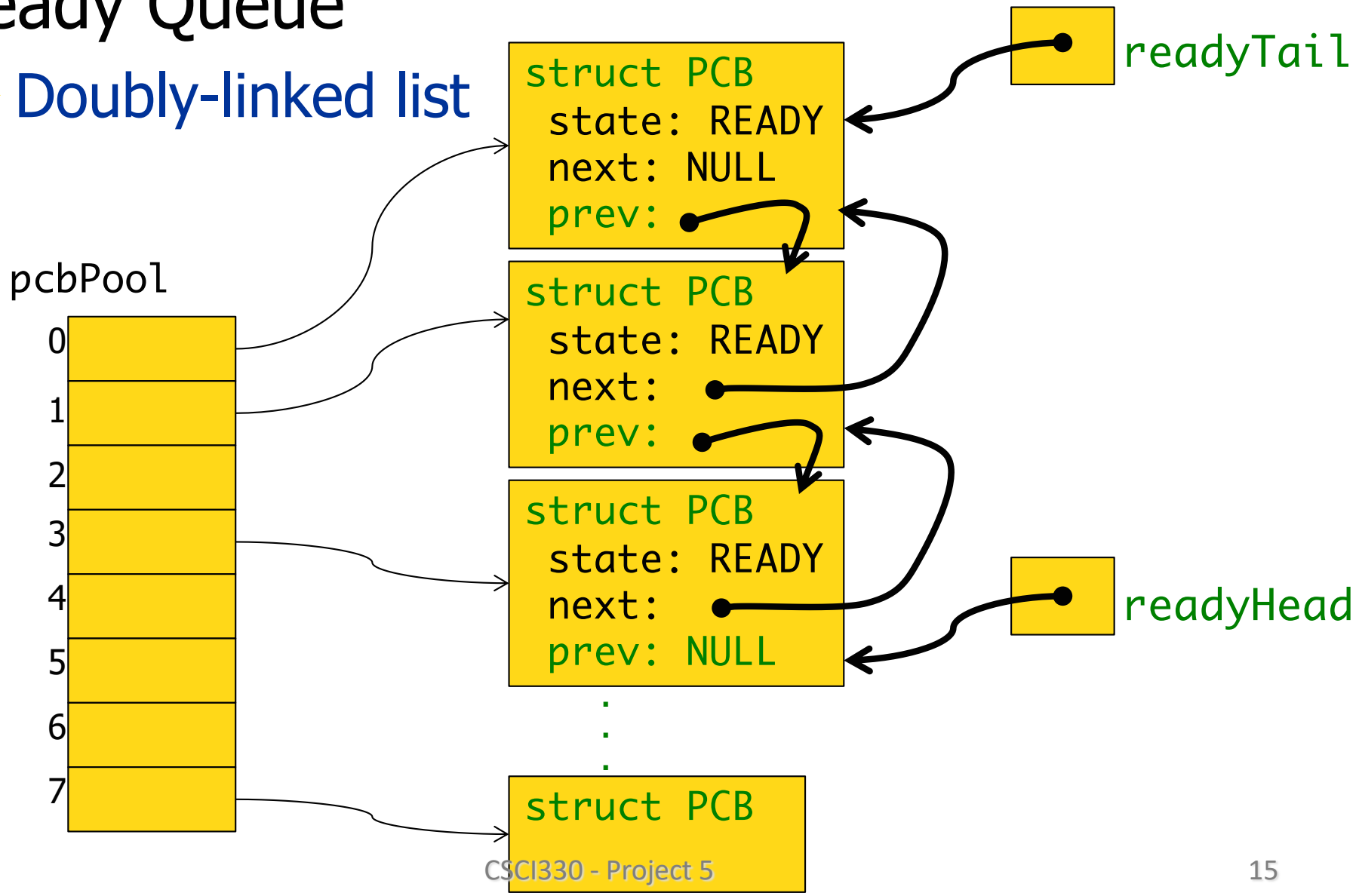
# proc.h Data Structures

- struct PCB *running



# proc.h Data Structures

- Ready Queue
  - Doubly-linked list



# proc.h Data Structures

- Initially the running process will be the Idle Process

```
struct PCB *running
```

idleProc

```
struct PCB
  char name[7]:      "IDLE\0"
  int state:         READY
  int segment:       0x1000
  int stackPointer   0x????
  struct PCB *next   NULL
  struct PCB *prev   NULL
```

If no processes in the ready queue to be run, run idle process

# proc.h Functions

- proc.h defines functions for manipulating these data structures:
  - `void initializeProcStructures();`
  - `int getFreeMemorySegment();`
  - `void releaseMemorySegment(int seg);`
  - `struct PCB *getFreePCB();`
  - `void releasePCB(struct PCB *pcb);`
  - `void addToReady(struct PCB *pcb);`
  - `struct PCB *removeFromReady();`

# proc.c && testproc.c

- Implement those functions in `proc.c`
- Use and extend `testproc.c` to test your implementations before trying to use them in the kernel.
  - Compile with gcc:
    - `gcc –o testproc testproc.c proc.c`
  - Run on local machine:
    - `./testproc`

# Using proc.h and proc.c

- To use the variables in proc.h and the functions in proc.c:
  - In kernel.c:
    - #define MAIN
    - #include "proc.h"
    - Need to link proc.o when creating kernel
  - In any other files that use proc.h (e.g., proc.c)
    - #include "proc.h"

# Accessing the Kernel's Data Segment

- The global variables defined in `proc.h` are put into the kernel's data segment by the compiler
- Variables in the data segment are addressed by offset into the data segment.
  - If `readyHead = 0x0450`,
  - then the PCB pointed to by `readyHead` is stored at memory address:

```
ds*0x10 + 0x0450
```

# Accessing the Kernel's Data Segment

- When `handleTimerInterrupt` is called, `ds` register will contain address of the interrupted process' data segment.
  - If `readyHead = 0x0450`,
    when the kernel attempts to access the PCB pointed to by `readyHead`, it looks at memory address:
    `ds*0x10 + 0x0450`
    which is now in the interrupted process' data segment not the kernel's data segment!

# Accessing the Kernel's Data Segment

- `kernel.asm` provides functions to deal with this situation:
  - `setKernelDataSegment()`
    - Invoke this in your kernel ***before*** accessing any global variables defined in `proc.h` and before calling any functions from `proc.h` that access those variables!
  - `restoreDataSegment()`
    - Invoke this in your kernel after you are finished accessing the global variables

# Copying Data to the Kernel's Data Segment

- In `executeProgram(char *fname)` you need to copy the name from `fname` into the PCB
- But…
  - `fname` is addressed relative to *shell's* stack segment
  - The PCB is addressed relative to *kernel's* data segment
  - Use the `kStrCopy` function given in project description when running in shell's data segment
    - Not between `setKernelDataSegment` and `restoreDataSegment`