# CSCE 313-200
# Introduction to Computer Systems
# Spring 2024

## Processes

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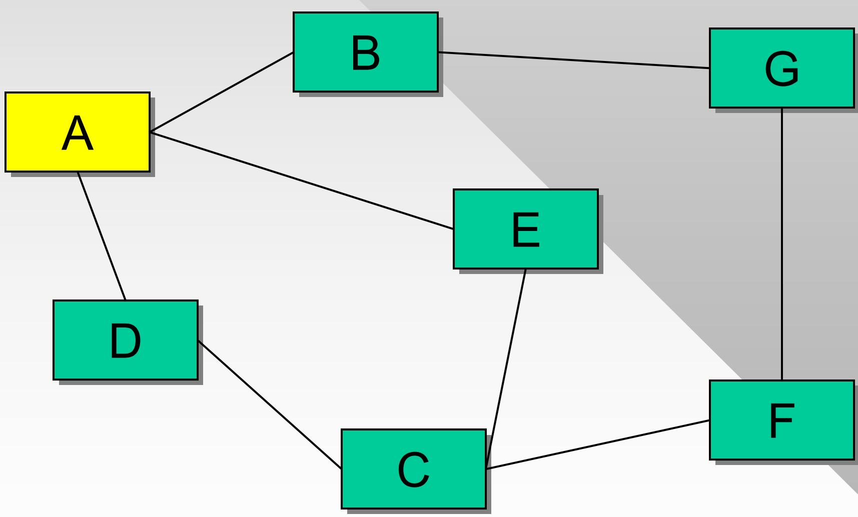
# Homework #1

q = L + (float)w / (d+1)

- When running A*
  - Incorrect # of nodes if weight is integer in q = L + w / (d+1)
- Basic BFS and DFS
  - Order of traversal on this graph?




```
Adjacency list
A: E, D, B
B: A, G
C: E, D, F
D: A, C
E: A, C
F: C, G
G: B, F
```

# Homework #1

- Refresh the concept of search
  - Assume an undirected graph G = (V,E)
  - Start node $s \in V$
- Maintain two structures
  - Unexplored set U
  - Discovered set D
- Approach #1:

```
U.add (s)
while ( U.notEmpty () )
    x = U.removeNextNode ()          // node to explore
    if ( D.find(x) == true )         // if already explored, ignore
        continue
    N = G.getNeighbors (x)           // N is a set of nodes
    if ( N.size() == 0 ) break       // exit?
    for each y in N
        U.add (y)
```

Any problems?

# Homework #1

- This code fails to actually insert anything into D
- Correct version:

```
U.add (s)
while ( U.notEmpty () )
    x = U.removeNextNode ()
    if ( D.find(x) == true )        // if already explored, ignore
         continue
    D.add (x)
    N = G.getNeighbors (x)
    if ( N.size() == 0 ) break      // exit?
    for each y in N
            U.add (y)
```

Any drawbacks?

- Requires huge storage as each node may be pushed into U as many times as there are links to it
  - Not advisable in practice

# Homework #1

- Approach #2 inserts a single copy of each node in U:

```
U.add (s); D.add (s);                  // s = source node
while ( U.notEmpty () )
    x = U.removeNextNode ()
    N = G.getNeighbors (x)
    if ( N.size() == 0 ) break     // exit?
    for each y in N
        if ( D.find (y) == false ) // has been pushed in U?
            U.add (y)
            D.add (y)
```

Always use this version!

- For most types of non-trivial exploration, approach #2 is far superior to #1
- What if D has a function that combines find/add?
  - Can directly use STL set's insert() function

# Homework #1

- When you find the exit, how far is it from s?
- Idea: make U keep track of tuples (nodeID, distance)

```
U.add (s, 0); D.add (s);
while ( U.notEmpty () )
    t = U.removeNextTuple ()       // t is a tuple
    N = G.getNeighbors (t.ID)
    if ( N.size() == 0 )
         printf (“Found at distance %d\n”, t.distance)
         break
    for each y in N
        if ( D.find (y) == false )          // new node?
            U.add (y, t.distance + 1)
            D.add (y)
```

- Note that U.add() also needs light intensity for bFS/A*
  - See the handout for details

# Homework #1

- Reusing the search algorithm
  - Create a base class

```
class Ubase {
          virtual void Add (uint64 ID, int distance, float intensity) = 0;
          virtual UnexploredRoom RemoveNextTuple (void) = 0;
          ...
}
```

  - Inherit four classes

```
class Ubreadth : public Ubase {
          // implement a queue here
}
class Udepth : public Ubase {
          // implement a stack here
}
...
```

```
Ubase *ptr;
if (searchType == BFS)
    ptr = new Ubreadth;
else if ...

Search (ptr);
```

  - Create base pointer to a specific class, then send it to search()

```
Search (Ubase *U)
{
    while (U->size() > 0)
          ...
}
```

# Chapter 3: Roadmap

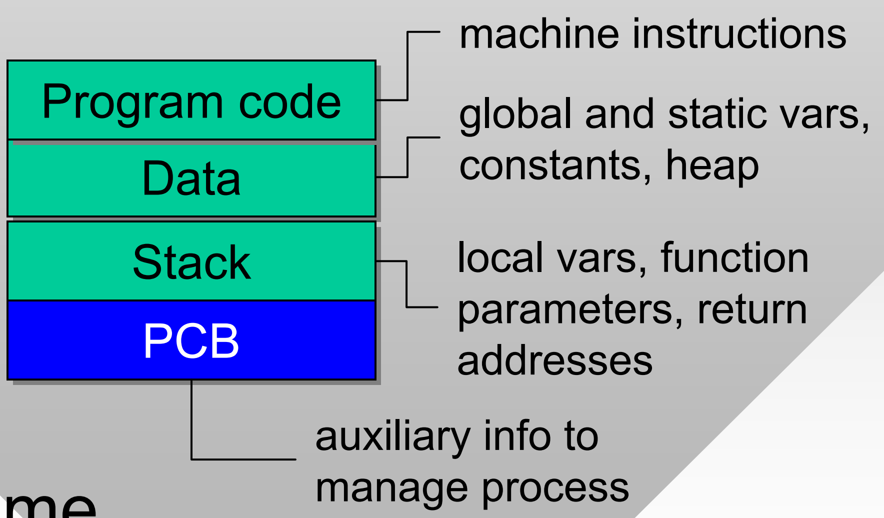
- 3.1 What is a process?
- 3.2 Process states
- 3.3 Process description
- 3.4 Process control
- 3.5 Execution of the OS
- 3.6 Security issues
- 3.7 Unix process management

Part II

| |
|---|
| Chapter 3: Processes |
| Chapter 4: Threads |
| Chapter 5: Concurrency |
| Chapter 6: Deadlocks |

# Processes

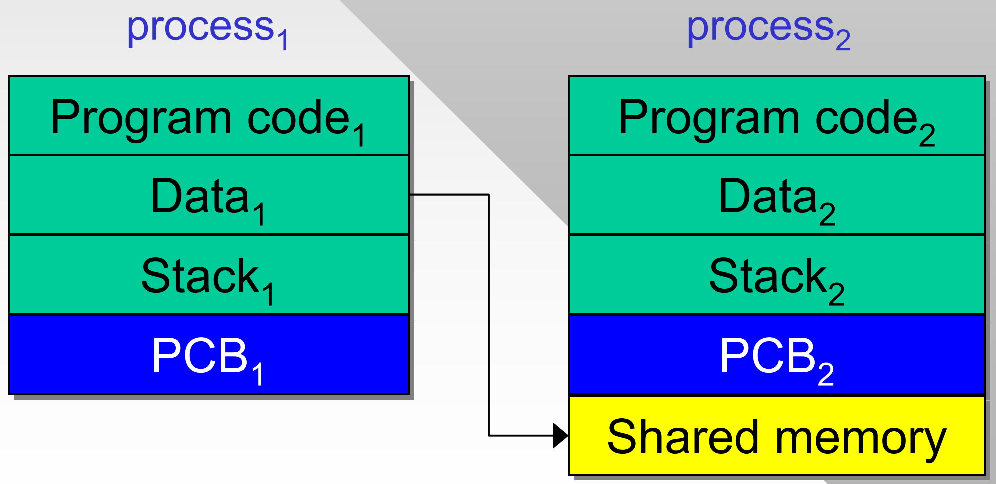

- From the 1960s, jobs were described by a special data structure that allowed the OS to systematically monitor, control, and synchronize them
- This became known as a process, which consists of:
  - Program in execution
  - Data
  - Stack
  - Process Control Block (PCB)




- Note that programs stored on disk do not become processes until they are started

# Processes

- Processes with shared memory
  - If shared memory is created by a process, it can be accessed in other processes in the system
  - This is called *memory mapping*
  - Just like named pipes, shared memory in Windows is addressable using some unique name



# Chapter 3: Roadmap

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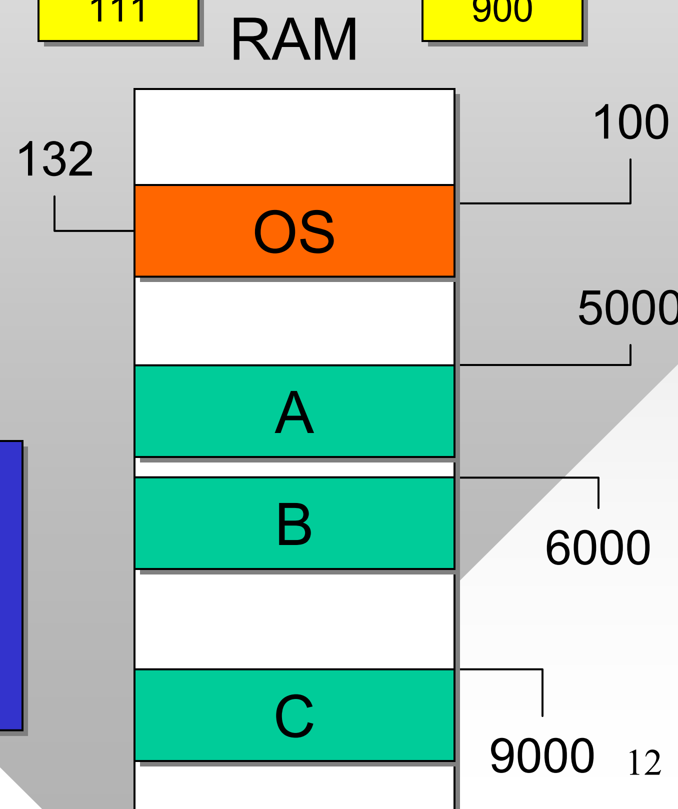
# Process States

- Process trace
  - Offsets (i.e., relative addresses) of instructions executed by a process
- CPU trace
  - Sequence of absolute addresses executed by the CPU
  - Suppose OS allows 6 CPU instructions in a slice, needs 3 to perform a process switch

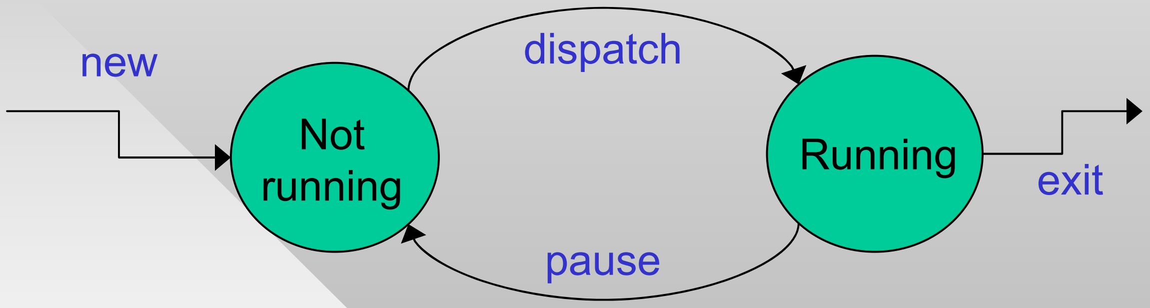
| A | B | C |
|---|---|---|
| 0 | 0 | 0 |
| 1 | 1 | 900 |
| 2 | 2 | 901 |
| 503 | 3 | 902 |
| 504 | | 903 |
| 505 | | 904 |
| 506 | | 900 |
| 507 | | 901 |
| 108 | | 902 |
| 109 | | 903 |
| 110 | | 904 |
| 111 | | 900 |



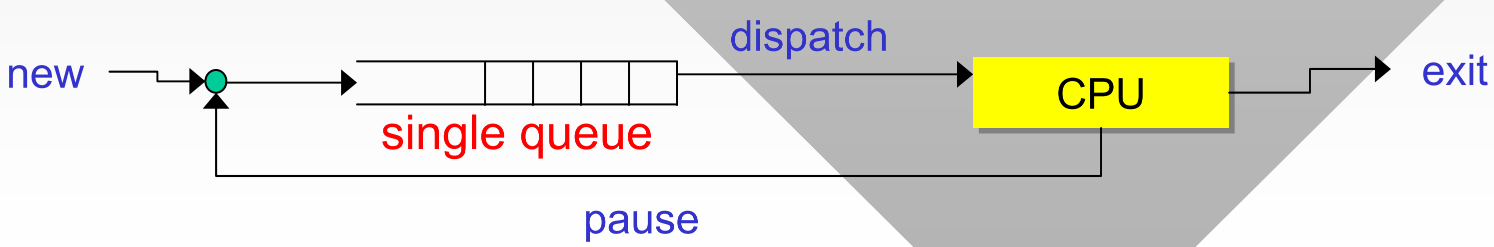

| CPU | | | | |
|---|---|---|---|---|
| 5000 | 100 | 6003 | 9901 | 102 |
| 5001 | 101 | 100 | 9902 | 5506 |
| 5002 | 102 | 101 | 9903 | 5507 |
| 5503 | 6000 | 102 | 9904 | 5108 |
| 5504 | 6001 | 9000 | 100 | 5109 |
| 5505 | 6002 | 9900 | 101 | 5110 |

# Process States

- This brings us to the issue of how the OS keeps track of processes and what runs next
- Simple *2-state model*:



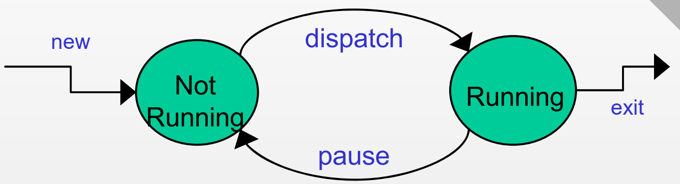

- Implementation:



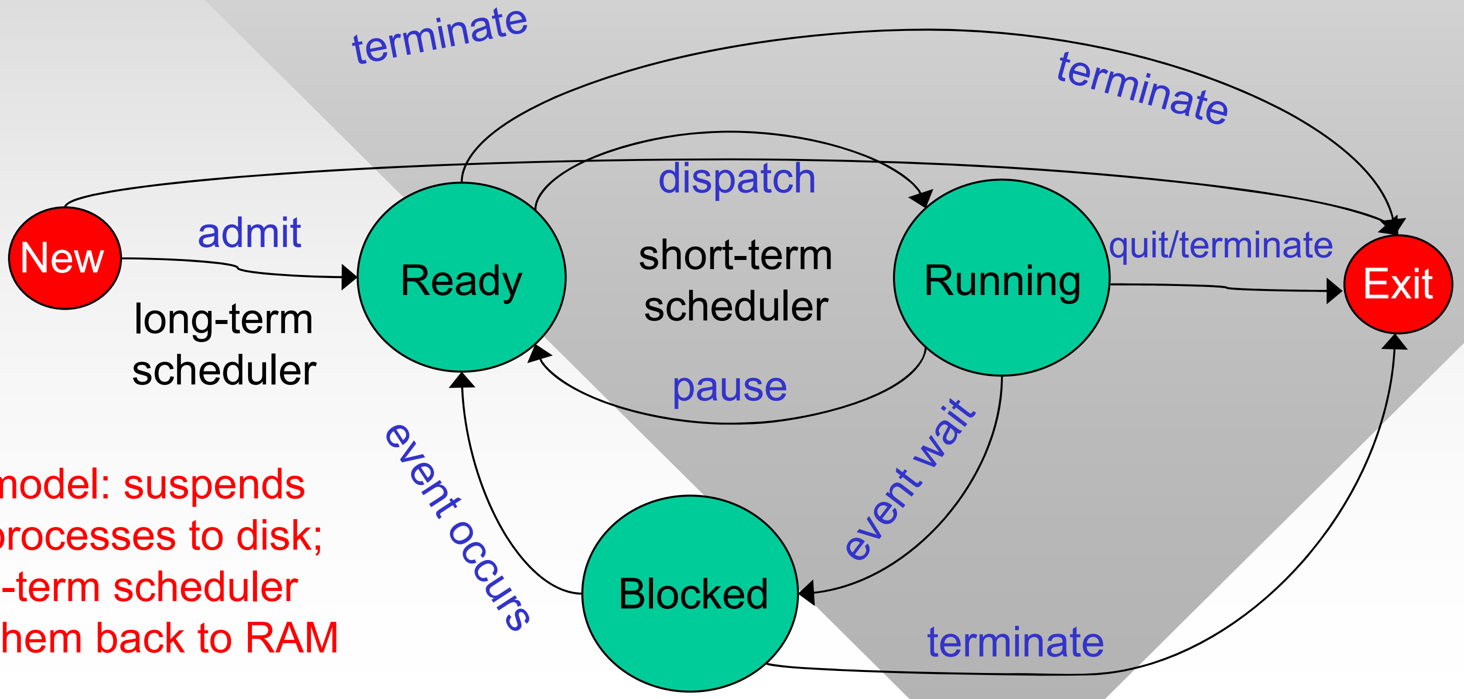
# Process States

- Process termination
  - Normal completion
  - User request (e.g., Ctrl-C)
  - Request from another process
  - Access violation
  - Arithmetic error (division by zero)
  - Invalid instruction
  - Privileged instruction
  - Not enough RAM (bad_alloc exception)
- Stealthy crashes
  - Severe stack corruption may cause program to quit without any warning or error
- If code crashes in Release mode, will it crash in Debug?
  - Not necessarily
  - Some bugs can be seen only in release mode
  - Reasons?
- What about vice versa?

# Process States




- Notice that 2-state model has no simple way of selecting the next ready process
  - Some might be blocked on I/O or events
- Next version, called *5-state model*, solves this:




7-state model: suspends blocked processes to disk; medium-term scheduler activates them back to RAM

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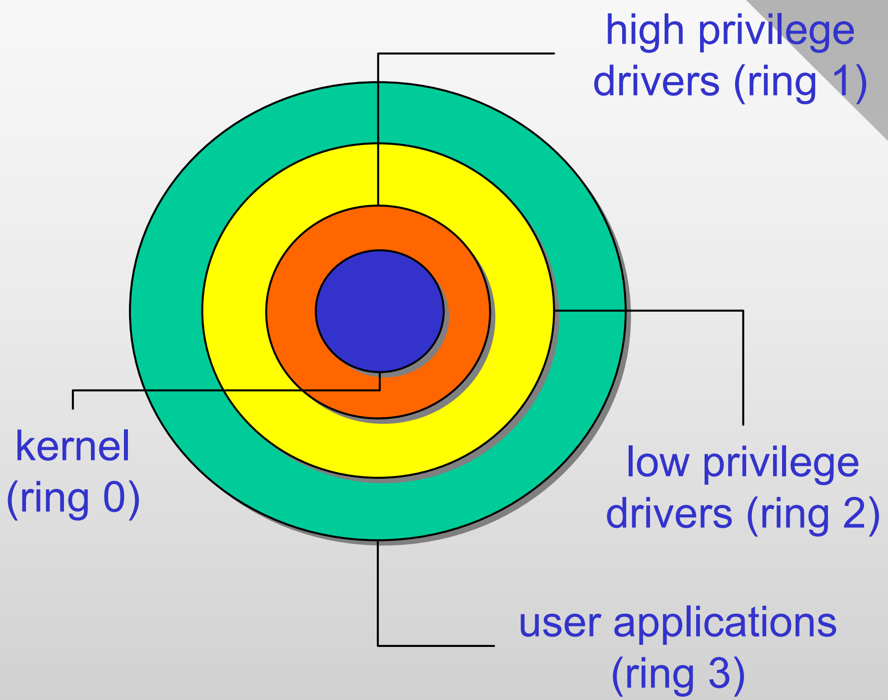
# Execution Modes

- CPU provides at least 2 execution modes
  - User mode prohibits all I/O instructions, virtual table manipulation, access to blocks of RAM not owned by process, and modification of certain registers
  - Kernel mode has no restrictions
- Some architectures allow more than 2 modes
  - These are often called protection rings
  - More granularity to allow "intermediate" privileges to certain processes (e.g., printer driver should be able to perform I/O, but not modify virtual-memory tables)
- Intel/AMD CPUs support 4 execution levels
  - Some older supercomputers had 8

# Execution Modes




- Consider a hypothetical 4-ring system:
  - Ring 3 always user mode
  - Ring 0 always kernel
  - Rings 1 and 2 depend on the implementation
- Windows and Linux support only rings 0 and 3
  - Partly because other architectures these can run on (e.g., PowerPC and MIPS) traditionally had only 2 modes
  - Partly to reduce complexity
- Main drawback of 2-level systems
  - Any driver crash bluescreens the system and forces a reboot

# Execution Modes

- Microsoft virtualization server (Hyper-V) is an exception
  - Virtual machines (VM) allow multiple guest OSes to run transparently on the CPU
- Guest OSes are managed by the virtual machine monitor (VMM) called hypervisor
  - In contrast to normal kernels that are called supervisors
- Hypervisor runs in ring 0, guest OS in ring 1
  - AMD-V was supported starting with Athlon 64 (2006) and Intel VT-x starting with Pentium 4 (2005)