Processes - A System View

Waiting for a child to finish – `wait()`

```
#include <sys/types.h>
#include <wait.h>
pid_t wait(int *status);
```

- Suspend calling process until child has finished
- Allow parent to reap child
- Returns:
  - Process ID of terminated child on success
  - -1 on error, sets **`errno`**
- Parameters:
  - **`status`**: status information set by **`wait`** and evaluated using specific macros defined for **`wait`**.

Waiting for a child to finish – `wait()`

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#include <wait.h>
pid_t wait(int *status);
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- Allow parent to reap child
- Returns:
  - Process ID of ter
  - -1 on error, sets
- Parameters:
  - **`status`**: status information set by **`wait`** and evaluated using specific macros defined for **`wait`**.

Instead of waiting, you can use a signal handler (later lecture) for signal **`SIGCHLD`** which issues a **`wait()`** call

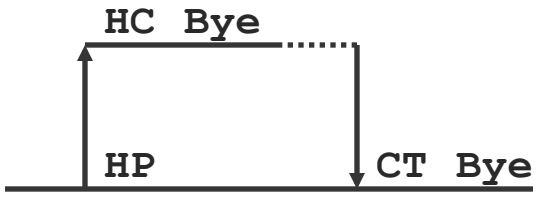
`wait()` syscall

- Allows parent process to wait (block) until child finishes
- Causes the caller to suspend execution until child's status is available

`errno`	cause
`ECHILD`	Caller has no unwaited-for children
`EINTR`	Function was interrupted by signal
`EINVAL`	Options parameter of waitpid was invalid

Waiting for a child to finish

```
void fork9() {
    int child_status;

    if (fork() == 0) {
        printf("HC: hello from child\n");
    }
    else {
        printf("HP: hello from parent\n");
        wait(&child_status);
        printf("CT: child has terminated\n");
    }
    printf("Bye\n");
    exit();
}
```



If parent has multiple children, wait will return when one of them (order not known!) completes

`execv`: Loading and Running Programs

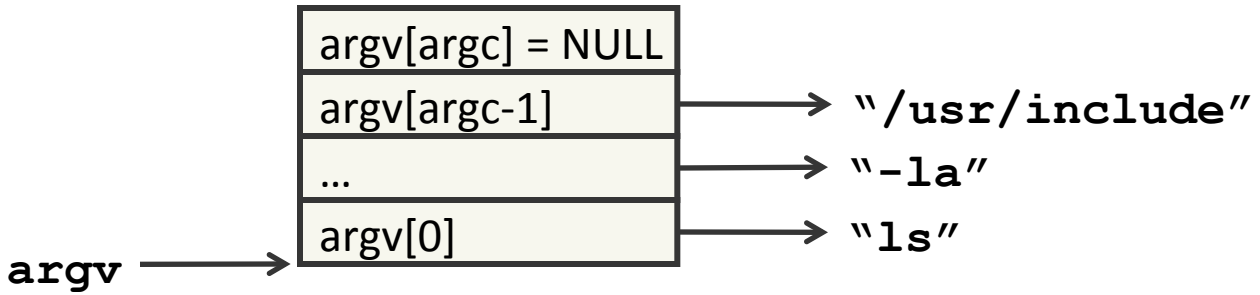
```
int execv(char *filename, char *argv[])
```

- transforms the calling process into a new process
  - Runs executable **`filename`**
  - With argument list **`argv`**
- Does not return (unless error)
- Overwrites code, data, and stack
  - keeps pid, open files and signal context

execv: Loading and Running Programs

```
int execv(char *filename, char *argv[])
```

- argv is a pointer to the argument list to be made available to the new process



- To pass arguments and environment, use:

```
int execve(char *filename, char *argv[], char *envp[])
```


execv Example

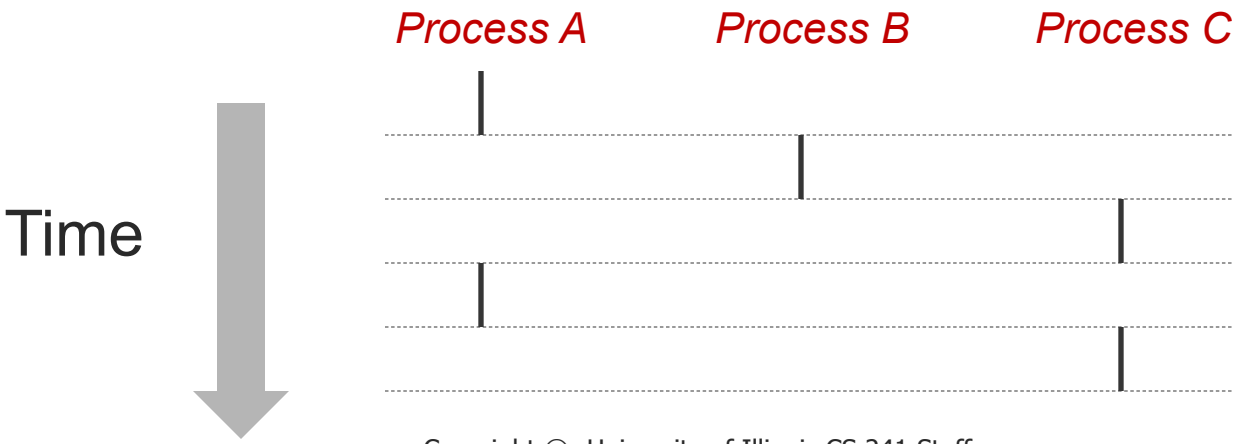
```
#include <fcntl.h>
#include <unistd.h>
#include <stdio.h>

int main(int argc, char **argv)
{
  int fd;

  fd = open(argv[1],O_RDWR|O_CREAT,S_IRWXU); //???
  dup2(fd, 1);                               //???
  close(fd);                                 //???

  char* array[] = {"ls", "-la", NULL};
  execv("/bin/ls", array);

  printf("This string should not be printed!\n");
}
```

execv Example

```
#include <fcntl.h>
#include <unistd.h>
#include <stdio.h>

int main(int argc, char **argv)
{
  int fd;

  fd = open(argv[1],O_RDWR|O_CREAT,S_IRWXU); //create an output file
  dup2(fd, 1);                               //redirect output to file
  close(fd);                                 //free unused file descriptor

  char* array[] = {"ls", "-la", NULL};
  execv("/bin/ls", array);

  printf("This string should not be printed!\n");
}
```

Concurrent Processes

- Two processes run concurrently (are concurrent) if their flows overlap in time
  - Otherwise, they are sequential
- Examples (running on single core)
  - Concurrent: A & B, A & C
  - Sequential: B & C



What is fork good for?

- What does concurrency gain us?
  - The appearance that multiple actions are occurring at the same time
  - If done right, your program can improve throughput (#instr./second)
- `fork()` creates a new process that runs concurrently

What is fork good for?

```
#include <stdio.h>
#include <sys/types.h>
#include <unistd.h>

int main() {
    pid_t pid;
    int i;


        if(pid = fork()) {          /* parent */
            parentProcedures();
        }
        else {                      /* child */
            childProcedures();
        }


    return 0;
}
```

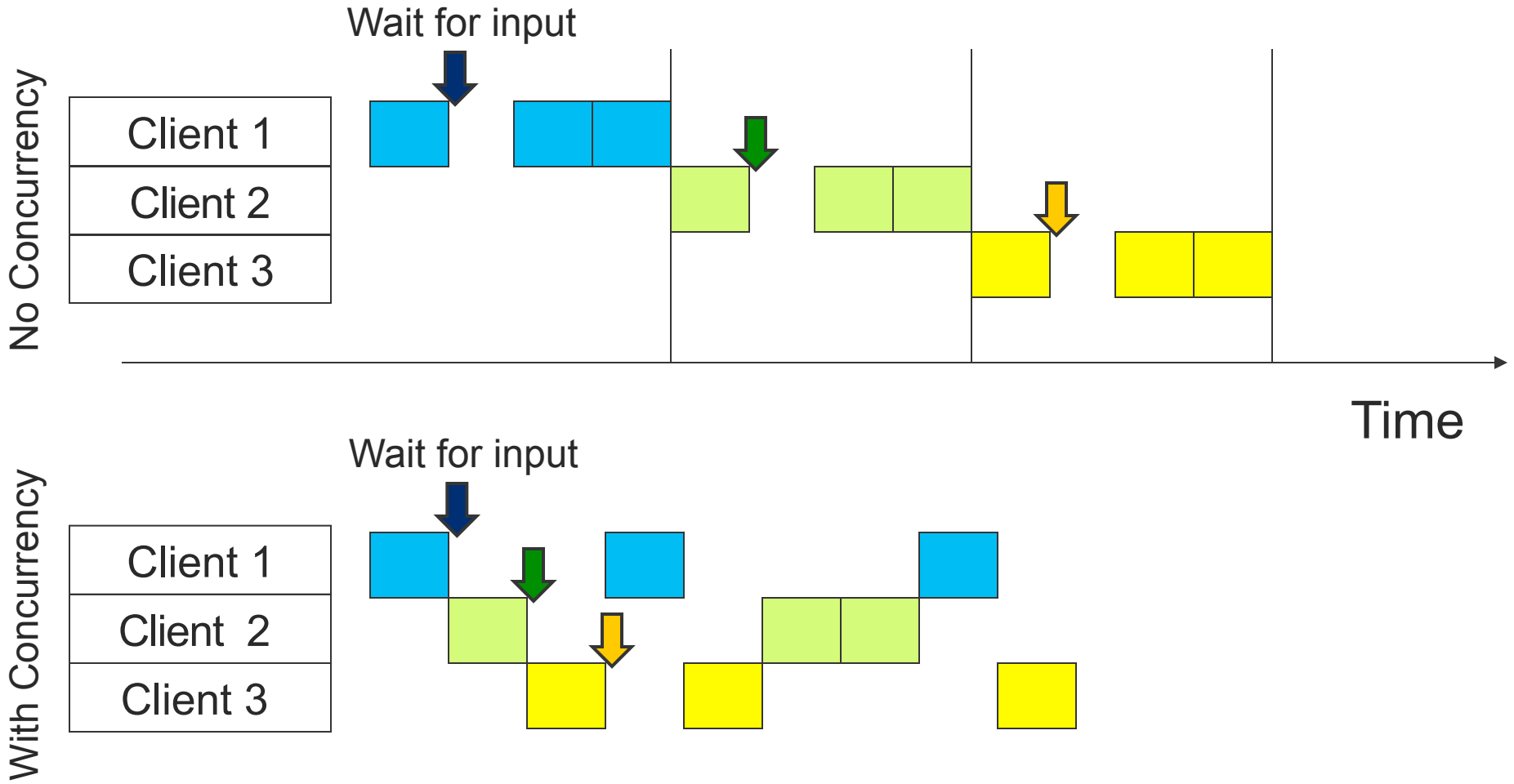

What is fork good for?

```
#include <stdio.h>
#include <sys/types.h>
#include <unistd.h>

int main() {
    pid_t pid;
    int i;
    while (1) {
        /* wait for new clients */
        if(pid = fork()) {          /* parent */
            /* reset server */
        }
        else {                      /* child */
            /* handle new client */
            exit(0);
        }
    }
    return 0;
}
```


Why Concurrency?

- Exploit natural concurrent structure of an application
  - The world is not sequential!
  - Easier to program multiple independent and concurrent activities
- Better resource utilization
  - Resources unused by one application can be used by the others
- Better average response time
  - No need to wait for other applications to make progress

Benefits of Concurrency

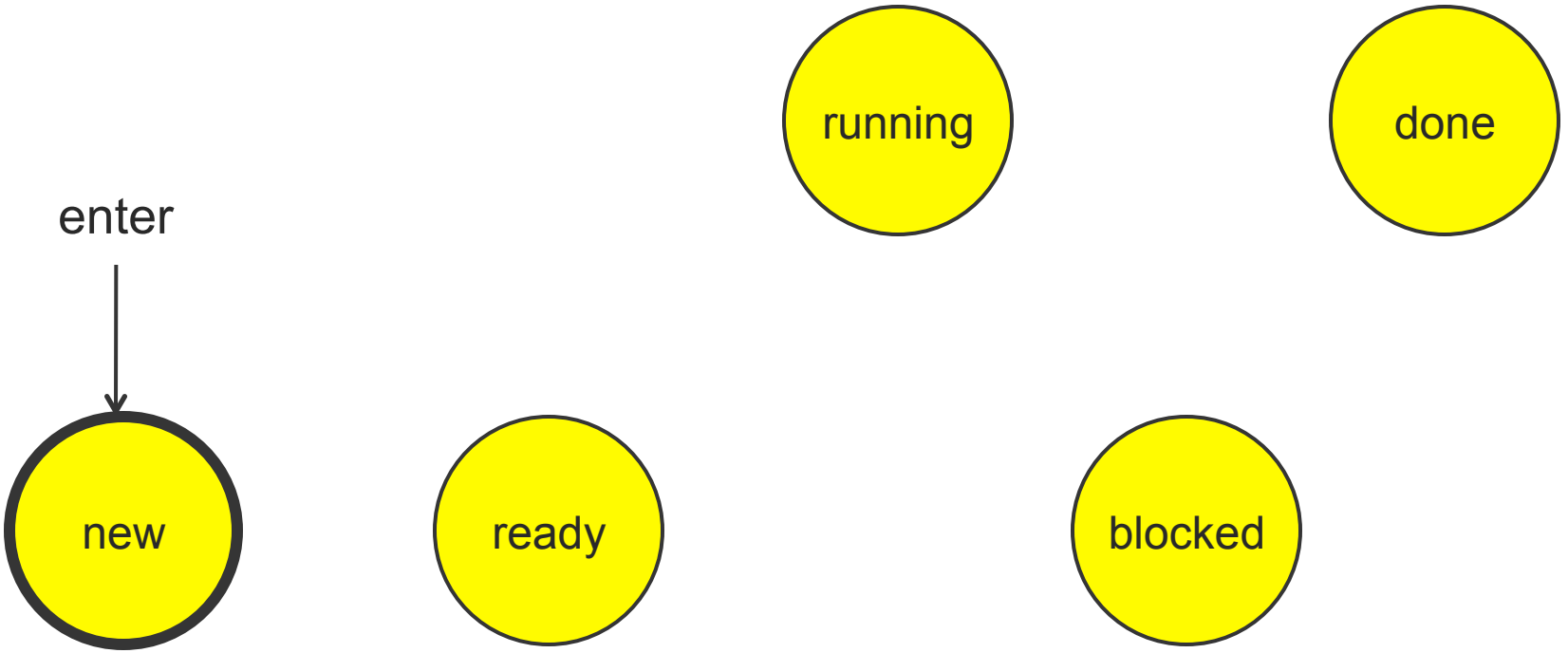


Five State Process Model

- New
  - New process is created
- Ready
  - Available to execute
- Running
  - Currently executing
  - On a single processor machine, at most one process in the "running" state
- Blocked
  - Waiting on some event
- Done
  - Process terminates

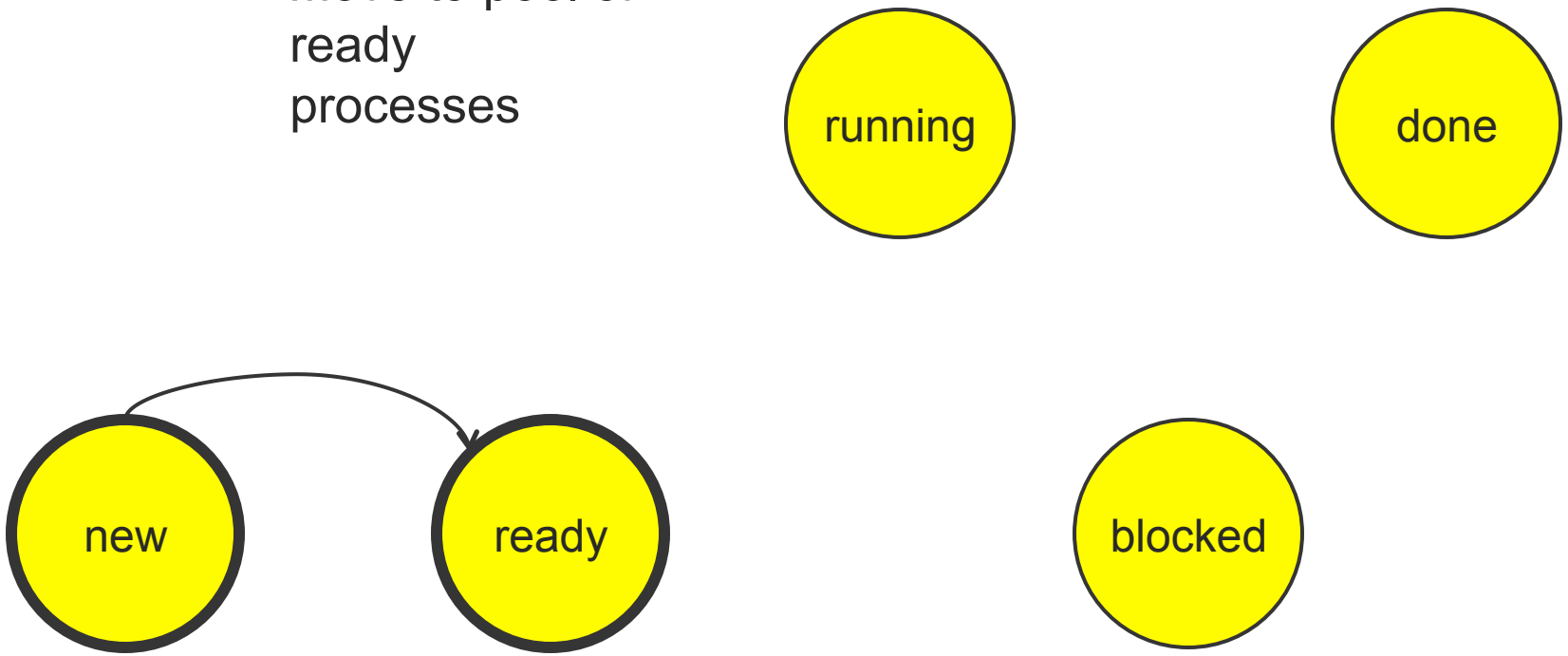
5 State Model - Transitions

- New process creation



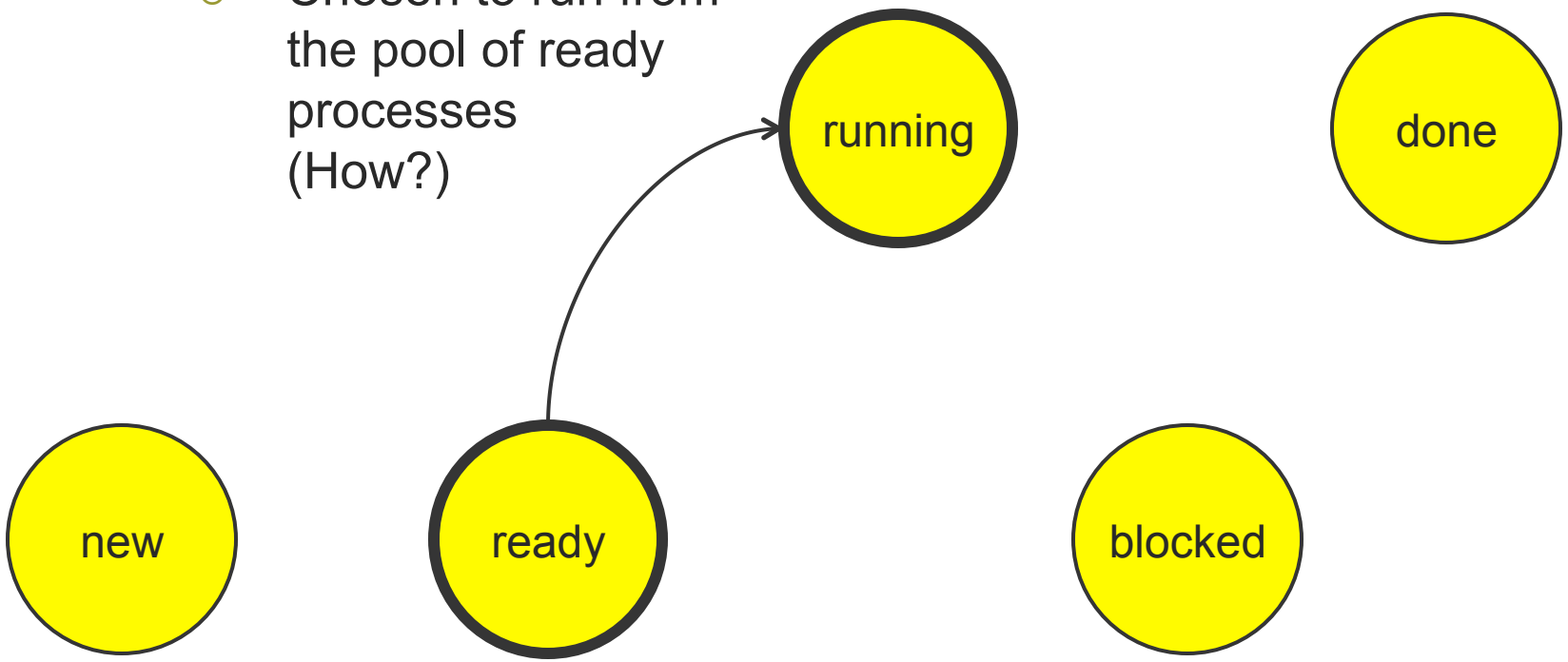
5 State Model - Transitions

- New to Ready
  - Move to pool of ready processes



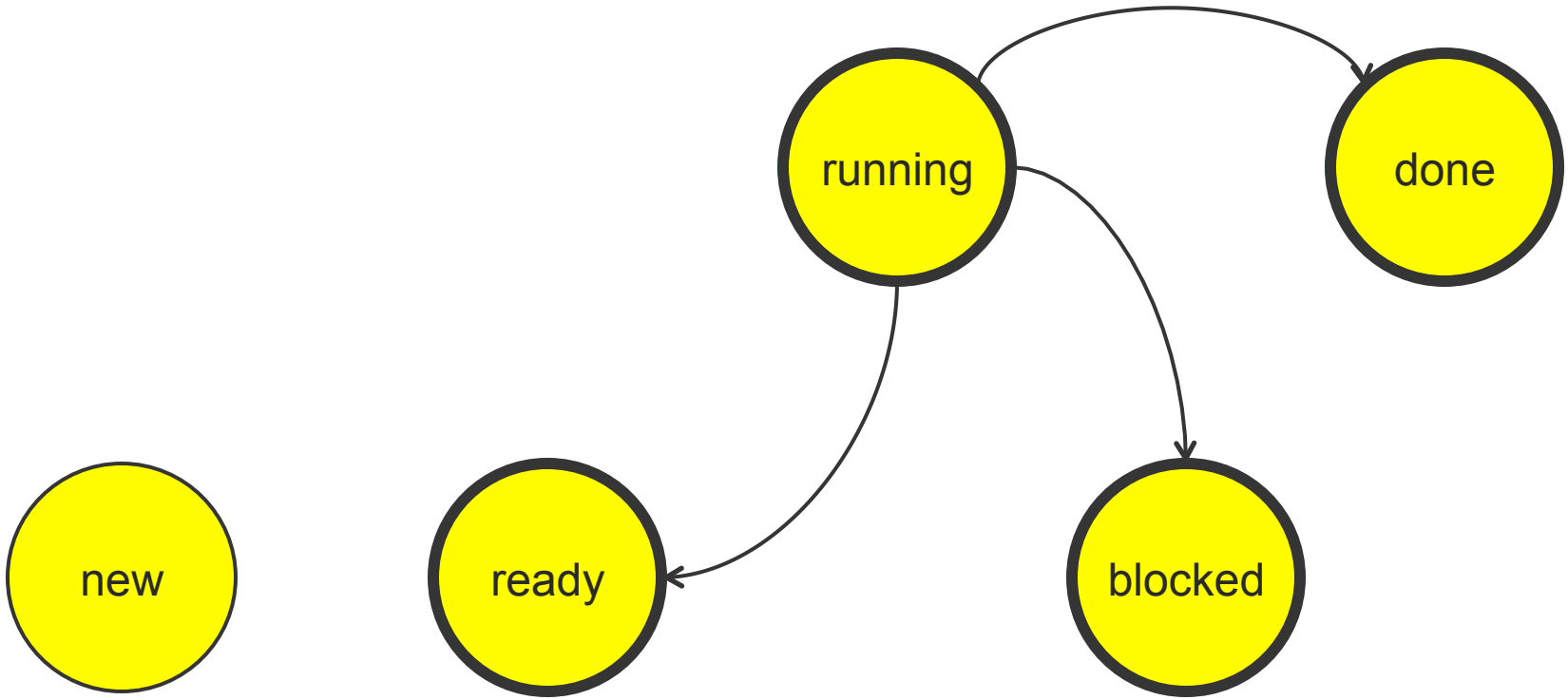
5 State Model - Transitions

- Ready for Running
  - Chosen to run from the pool of ready processes (How?)



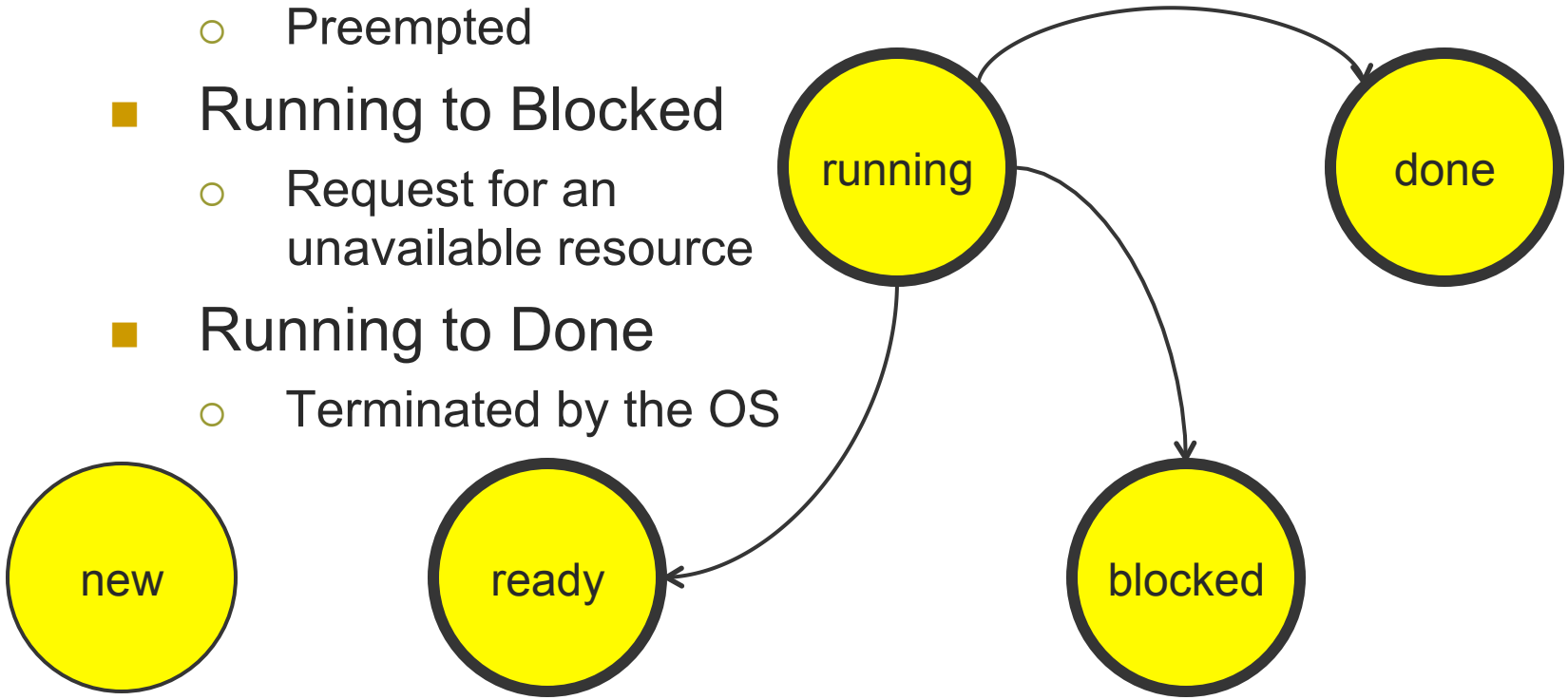
5 State Model - Transitions

What events cause these transitions?



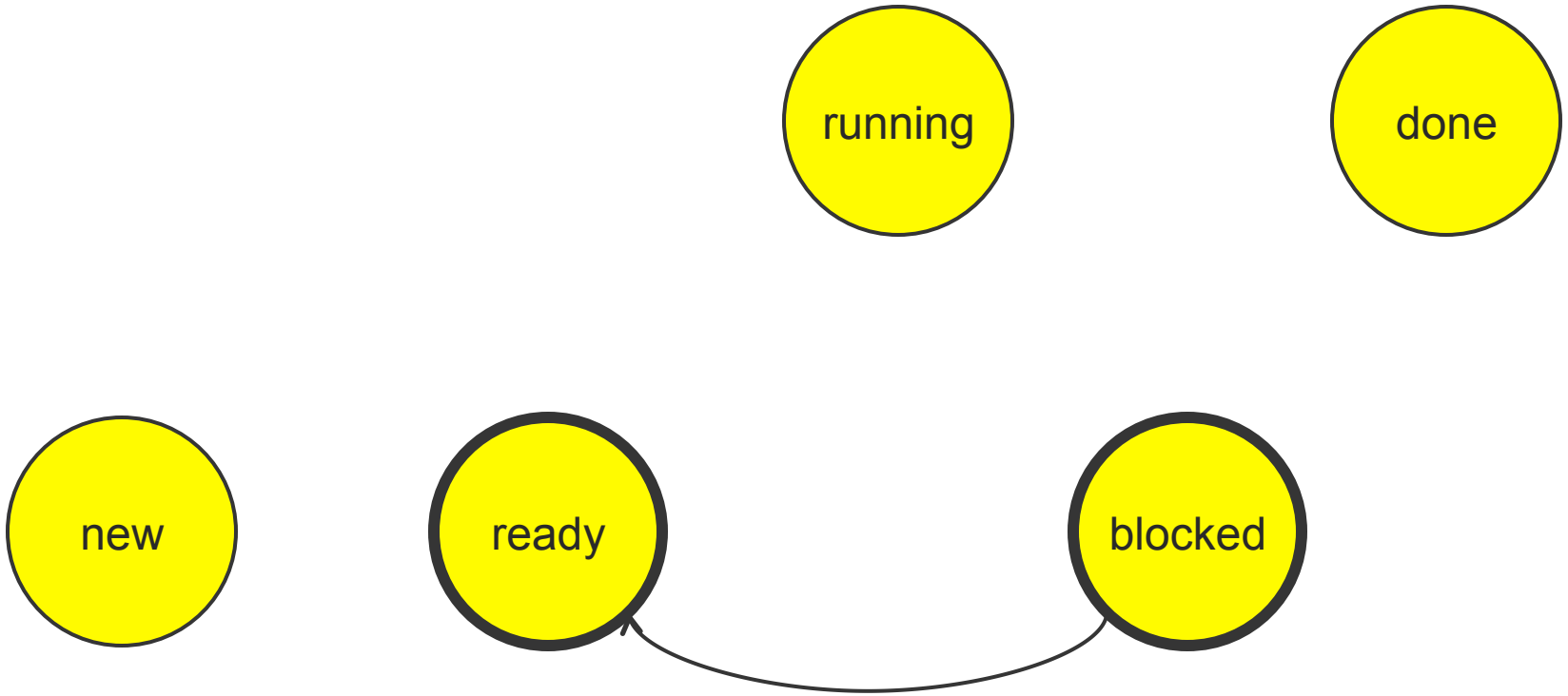
5 State Model - Transitions

- Running to Ready
  - Preempted
- Running to Blocked
  - Request for an unavailable resource
- Running to Done
  - Terminated by the OS



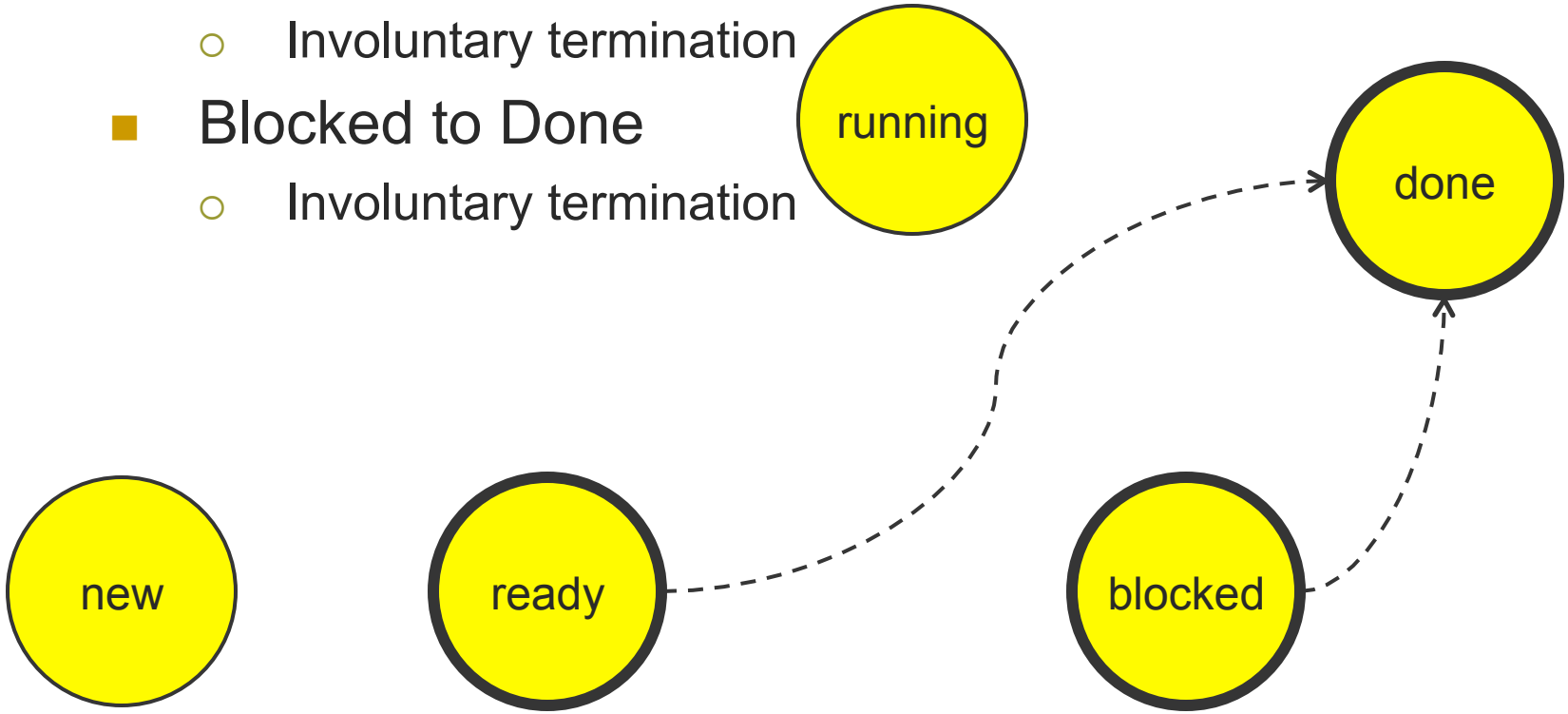
5 State Model - Transitions

- Blocked to Ready
  - Resource is now available



5 State Model - Transitions

- Ready to Done
  - Involuntary termination
- Blocked to Done
  - Involuntary termination



5 State Model - Transitions