

Concurrency: Processes

CSE 333 Winter 2019

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Administrivia

- ❖ hw4 due Thur. night
 - (Plus late days – max 2 – if you have them)

- ❖ Please fill out course evals while they are available

- ❖ Final exam Wed. 3/20, 2:30-4:20
 - Some review in sections Thur.; review Q&A Tue. 3/19, 4:30
 - Topic list and old finals on Exams page
 - Summer final exams are 1 hour; regular quarters are usual 2 hours

- ❖ Lecture Wednesday: System calls, buffering, libraries & more
 - (no slides – be here!)

Outline

- ❖ searchserver
 - Sequential
 - Concurrent via forking threads – `pthread_create()`
 - **Concurrent via forking processes – `fork()`**
 - Concurrent via non-blocking, event-driven I/O – `select()`
 - We won't get to this ☹

- ❖ Reference: *Computer Systems: A Programmer's Perspective*, Chapter 12 (CSE 351 book)

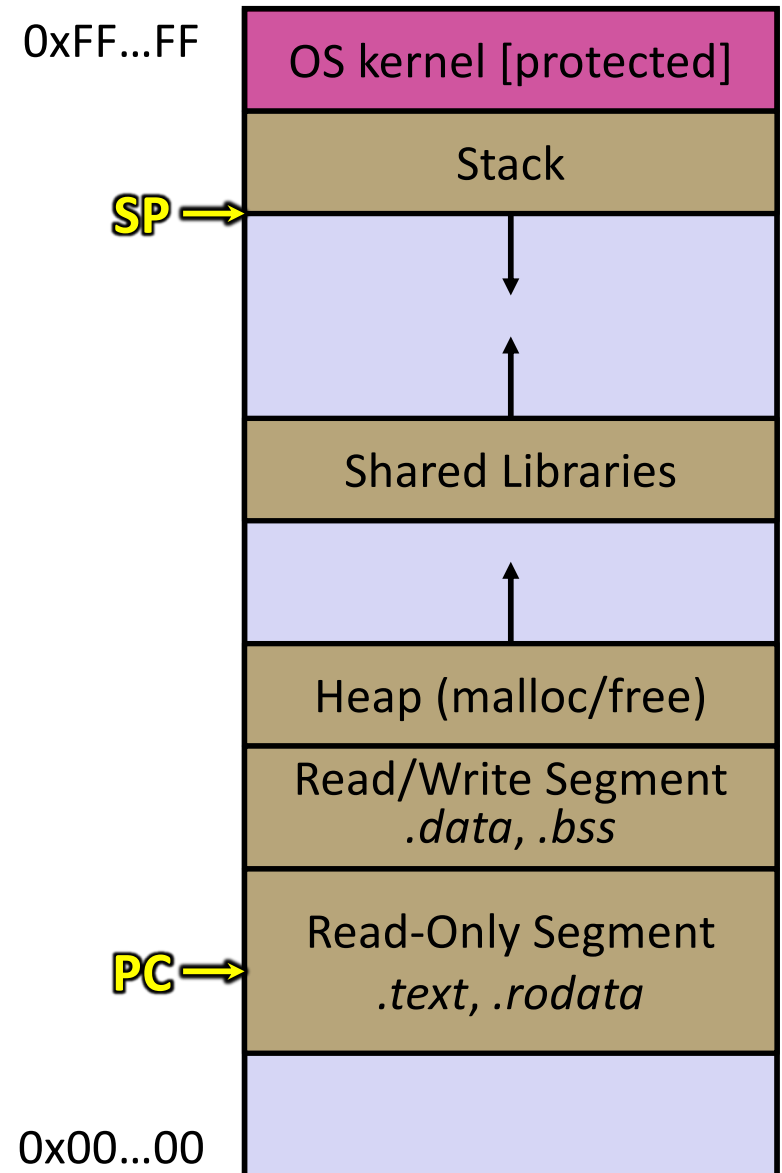
Creating New Processes

❖ `pid_t fork(void);`

- Creates a new process (the “child”) that is an *exact clone** of the current process (the “parent”)
 - *Everything is cloned except threads: variables, file descriptors, open sockets, the virtual address space (code, globals, heap, stack), etc.
- Primarily used in two patterns:
 - Servers: fork a child to handle a connection
 - Shells: fork a child that then `exec`'s a new program

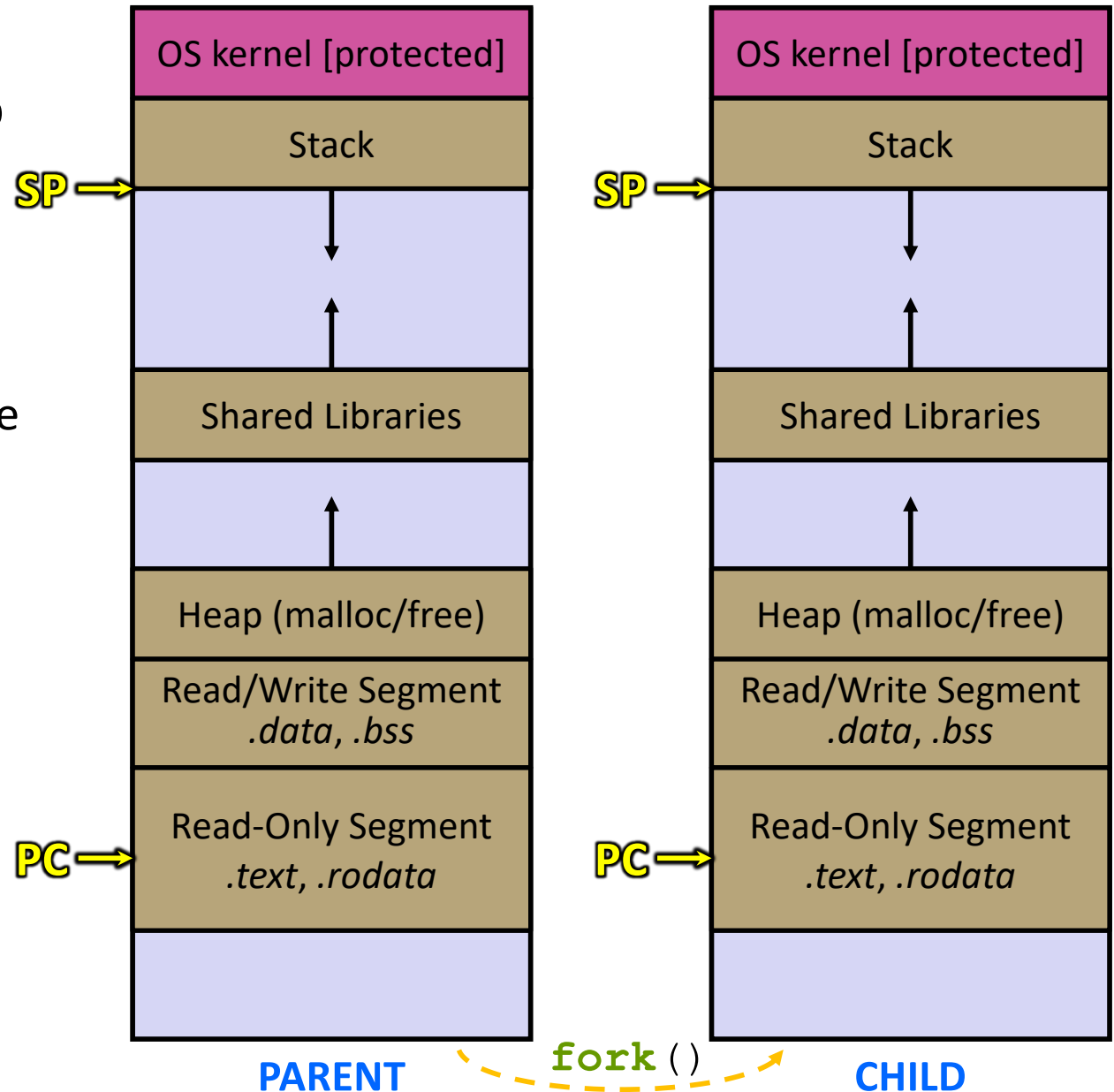
fork () and Address Spaces

- ❖ A process executes within an *address space*
 - Includes segments for different parts of memory
 - Process tracks its current state using the **stack pointer** (SP) and **program counter** (PC)



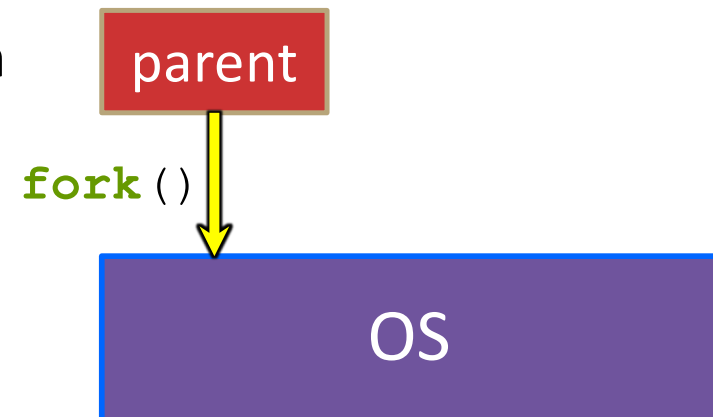
fork () and Address Spaces

- ❖ Fork cause the OS to clone the address space
 - The *copies* of the memory segments are (nearly) identical
 - The new process has *copies* of the parent's data, stack-allocated variables, open file descriptors, etc.



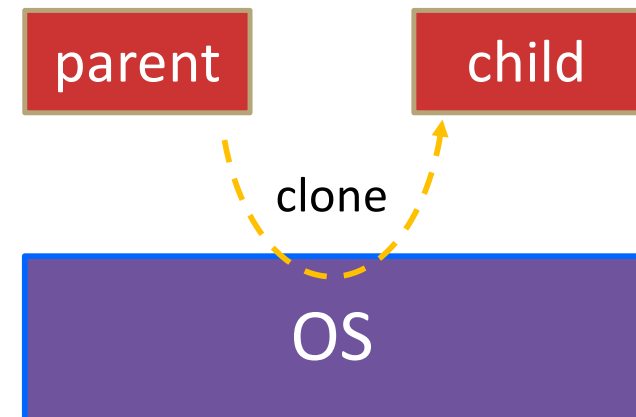
fork ()

- ❖ **fork ()** has peculiar semantics
 - The parent invokes **fork ()**
 - The OS clones the parent
 - *Both* the parent and the child return from fork
 - Parent receives child's pid
 - Child receives a 0



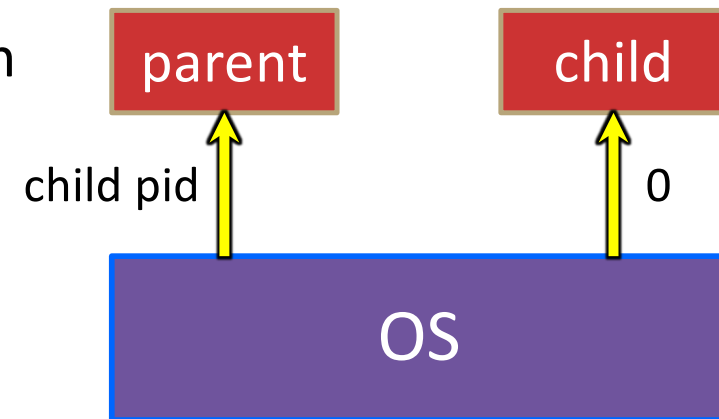
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- ❖ See `fork_example.cc`

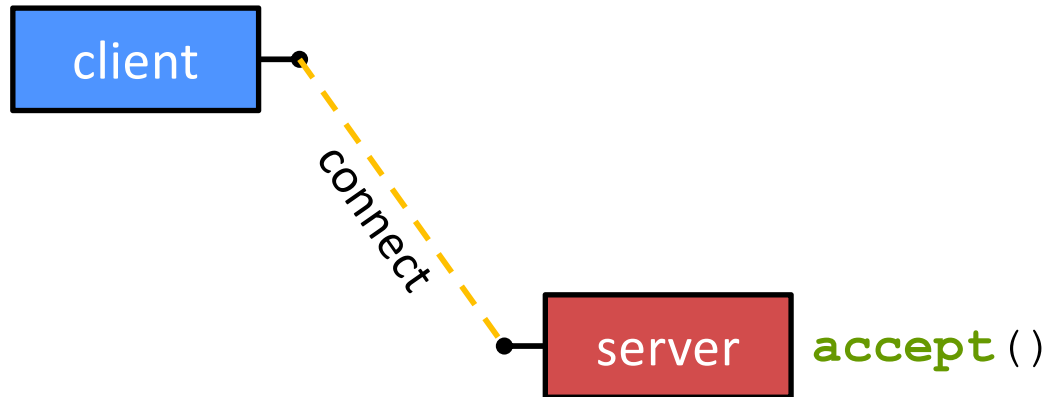
Concurrent Server with Processes

- ❖ The **parent** process blocks on **accept** () , waiting for a new client to connect
 - When a new connection arrives, the parent calls **fork** () to create a **child** process
 - The child process handles that new connection and **exit** () 's when the connection terminates
- ❖ Remember that children become “zombies” after death
 - Option A: Parent calls **wait** () to “reap” children
 - Option B: Use a **double-fork trick**

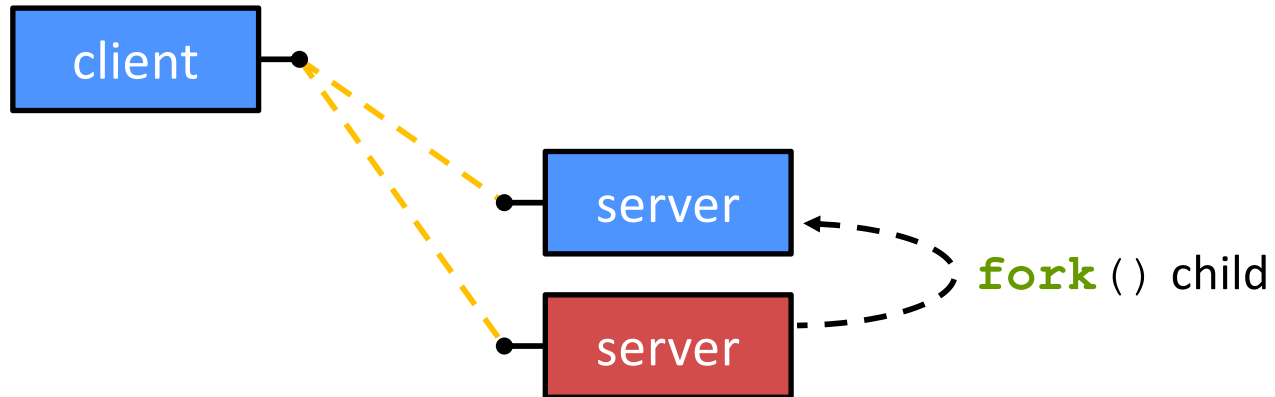
Double-fork Trick



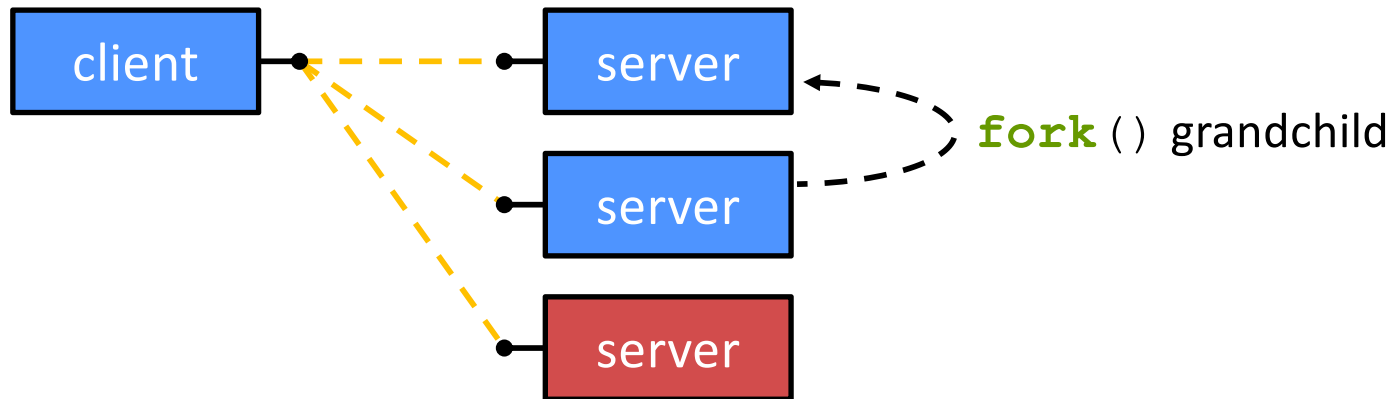
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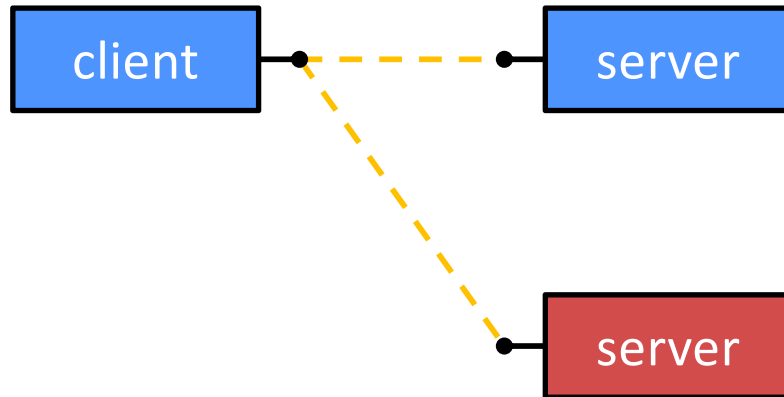
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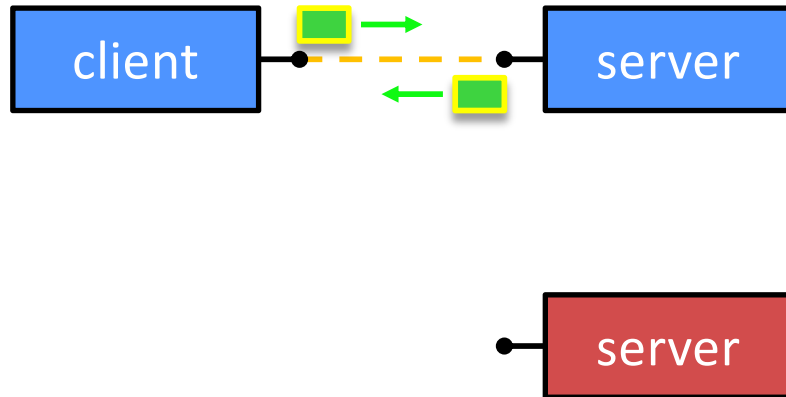


child `exit()`'s / parent `wait()`'s

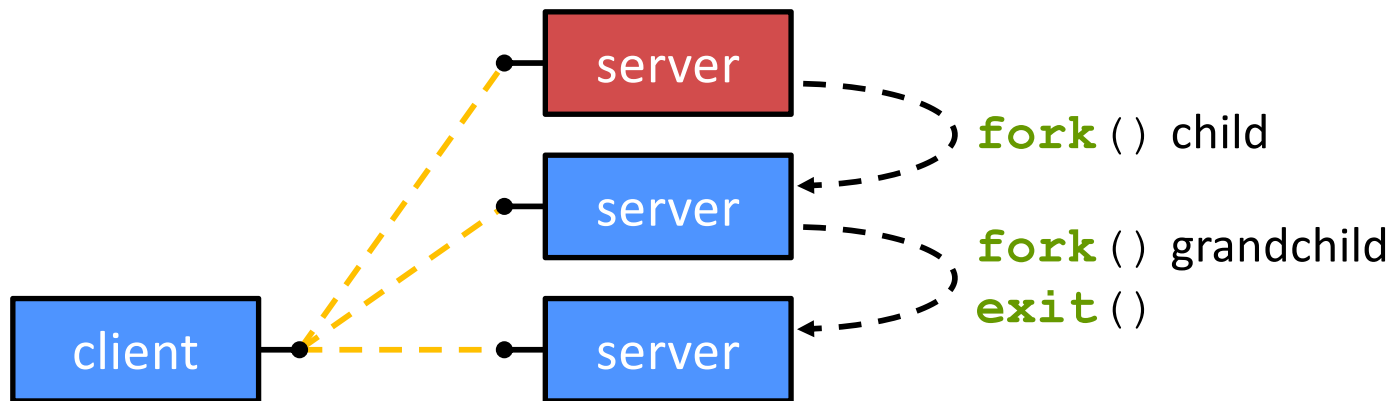
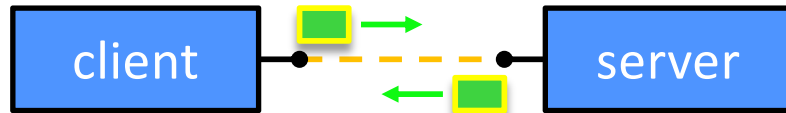
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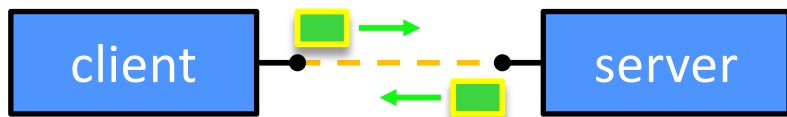
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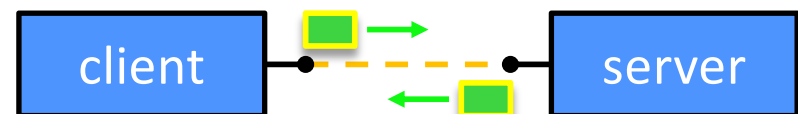
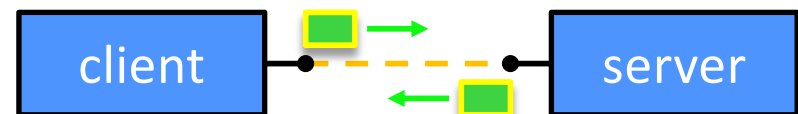
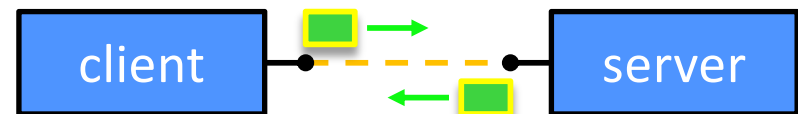
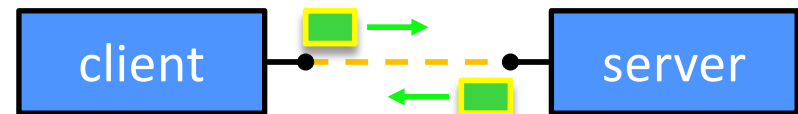
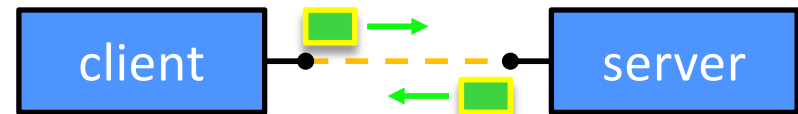
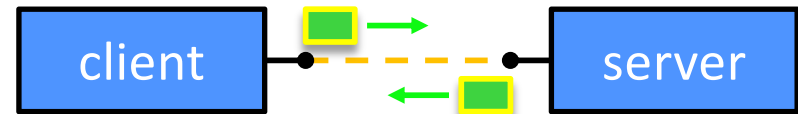
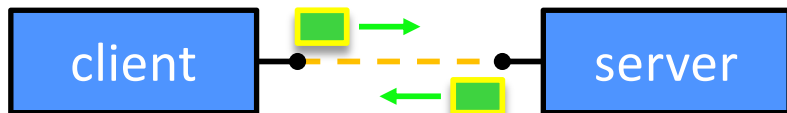
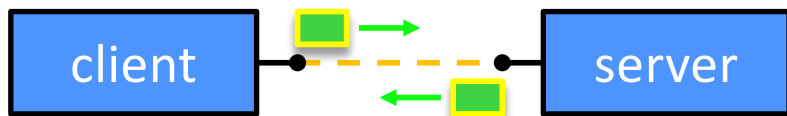
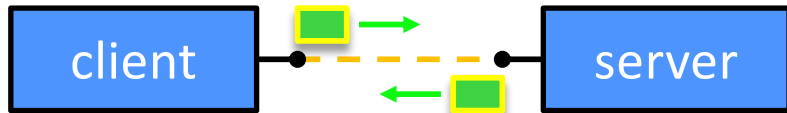
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Concurrent with Processes

❖ See `searchserver_processes/`

Whither Concurrent Processes?

❖ Advantages:

- Almost as simple to code as sequential
 - In fact, most of the code is identical!
- Concurrent execution leads to better CPU, network utilization

❖ Disadvantages:

- Processes are heavyweight
 - Relatively slow to fork
 - Context switching latency is high
- Communication between processes is complicated

How Fast is `fork()` ?

- ❖ See forklatency.cc

- ❖ ~ **0.25 ms** per fork*
 - ∴ maximum of $(1000/0.25) = 4,000$ connections/sec/core
 - ~350 million connections/day/core
 - This is fine for most servers
 - Too slow for super-high-traffic front-line web services
 - Facebook served ~ 750 billion page views per day in 2013!
Would need 3-6k cores just to handle `fork()`, *i.e.* without doing any work for each connection

- ❖ *Past measurements are not indicative of future performance – depends on hardware, OS, software versions, ...

How Fast is `pthread_create()` ?

- ❖ See threadlatency.cc
- ❖ **~0.036 ms per thread creation***
 - ~10x faster than `fork()`
 - ∴ maximum of $(1000/0.036) = 28,000$ connections/sec
 - ~2.4 billion connections/day/core
- ❖ Much faster, but writing safe multithreaded code can be serious voodoo
- ❖ *Past measurements are not indicative of future performance – depends on hardware, OS, software versions, ..., but will typically be an order of magnitude faster than `fork()`

Aside: Thread Pools

- ❖ In real servers, we'd like to avoid overhead needed to create a new thread or process for every request

- ❖ Idea: Thread Pools:
 - Create a fixed set of worker threads or processes on server startup and put them in a queue
 - When a request arrives, remove the first worker thread from the queue and assign it to handle the request
 - When a worker is done, it places itself back on the queue and then sleeps until dequeued and handed a new request