Advanced Programming in the UNIX Environment

Week 08, Segment 2:
System V IPC

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System V IPC

There are three types of *asynchronous* IPC originating from System V:

- Semaphores
- Shared Memory
- Message Queues

All three use IPC structures, referred to by an *identifier* and a *key*; all three are (necessarily) limited to communication between processes on one and the same host.

Since these structures are not known by name, special system calls (`msgget(2)`, `semop(2)`, `shmat(2)`, etc.) and special userland commands (`ipcrm(1)`, `ipcs(1)`, etc.) are necessary.

System V IPC: Semaphores

A semaphore is a counter used to provide access to a shared data object for multiple processes. To obtain a shared resource a process needs to do the following:

1. Test semaphore that controls the resource.
2. If value of `semaphore` > 0, decrement semaphore and use resource; increment semaphore when done.
3. If `value` == 0 sleep until `value` > 0

Semaphores are obtained using `semget(2)`, properties controlled using `semctl(2)`, operations on a semaphore performed using `semop(2)`.

System V IPC: Semaphores

Terminal — 130×24

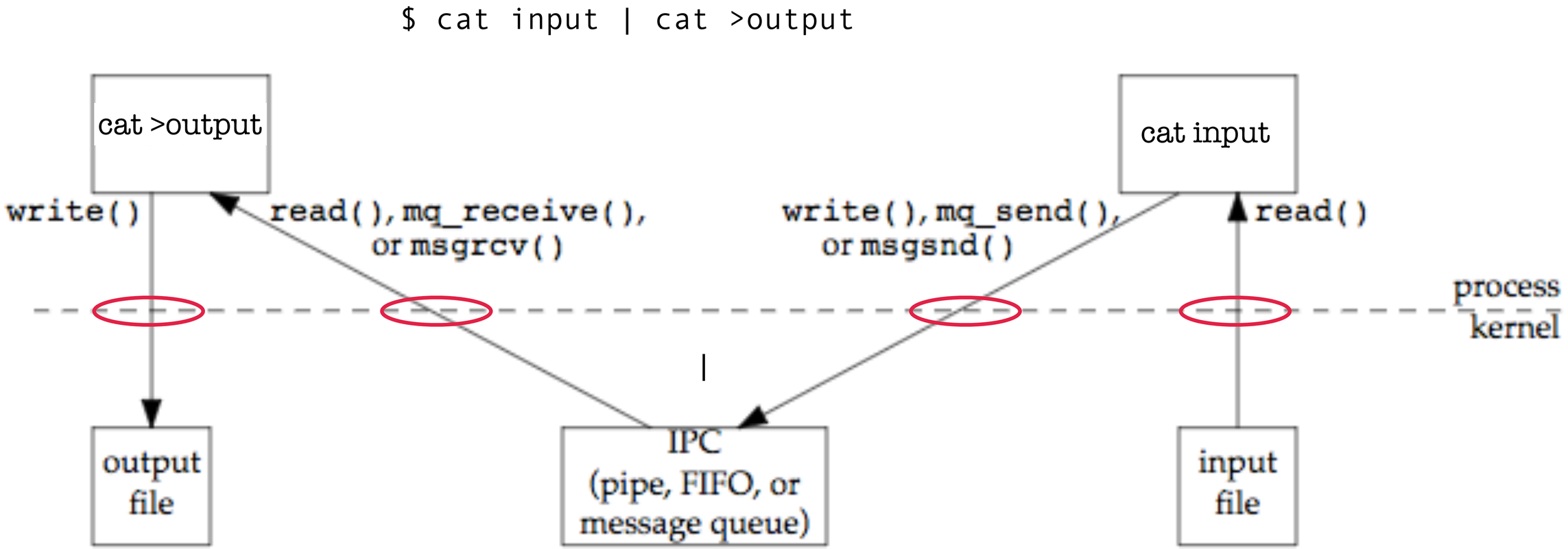
```
Press return to unlock:
Unlocked.
jschauma@apue$ ipcs -s
IPC status from <running system> as of Mon Oct 19 01:38:29 2020

Semaphores:
T         ID     KEY        MODE       OWNER    GROUP
s     720896  704662389 --rw-rw-rw- jschauma    users

jschauma@apue$ ./a.out
Press return to lock:
Trying to lock...
Locked.
Press return to unlock:
Unlocked.
jschauma@apue$ ipcrm -s 720896
jschauma@apue$ ipcs -s
IPC status from <running system> as of Mon Oct 19 01:39:47 2020

Semaphores:
T         ID     KEY        MODE       OWNER    GROUP

jschauma@apue$
```

0 sh

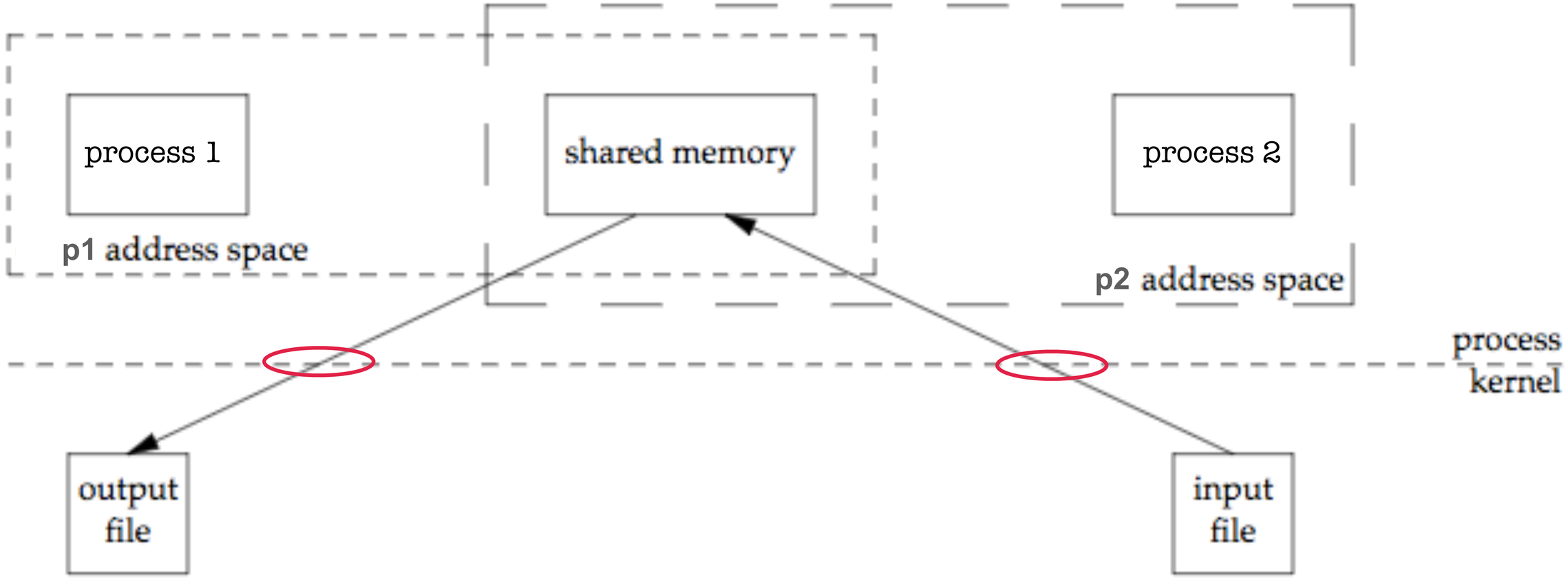
```
Locked.
Press return to unlock:
Unlocked.
jschauma@apue$ sudo su - fred
fred@apue$ whoami
fred
fred@apue$ cd ~jschauma/08
fred@apue$ ./a.out
Press return to lock:
Trying to lock...
Locked.
Press return to unlock:
Unlocked.
fred@apue$ ipcs -s
IPC status from <running system> as of Mon Oct 19 01:39:20 2020

Semaphores:
T         ID     KEY        MODE       OWNER    GROUP
s     720896  704662389 --rw-rw-rw- jschauma    users

fred@apue$ ipcrm -s 720896
ipcrm: semid(720896): : Operation not permitted
fred@apue$
```

1 sh

IPC Data Flow



System V IPC: Shared Memory



System V IPC: Shared Memory

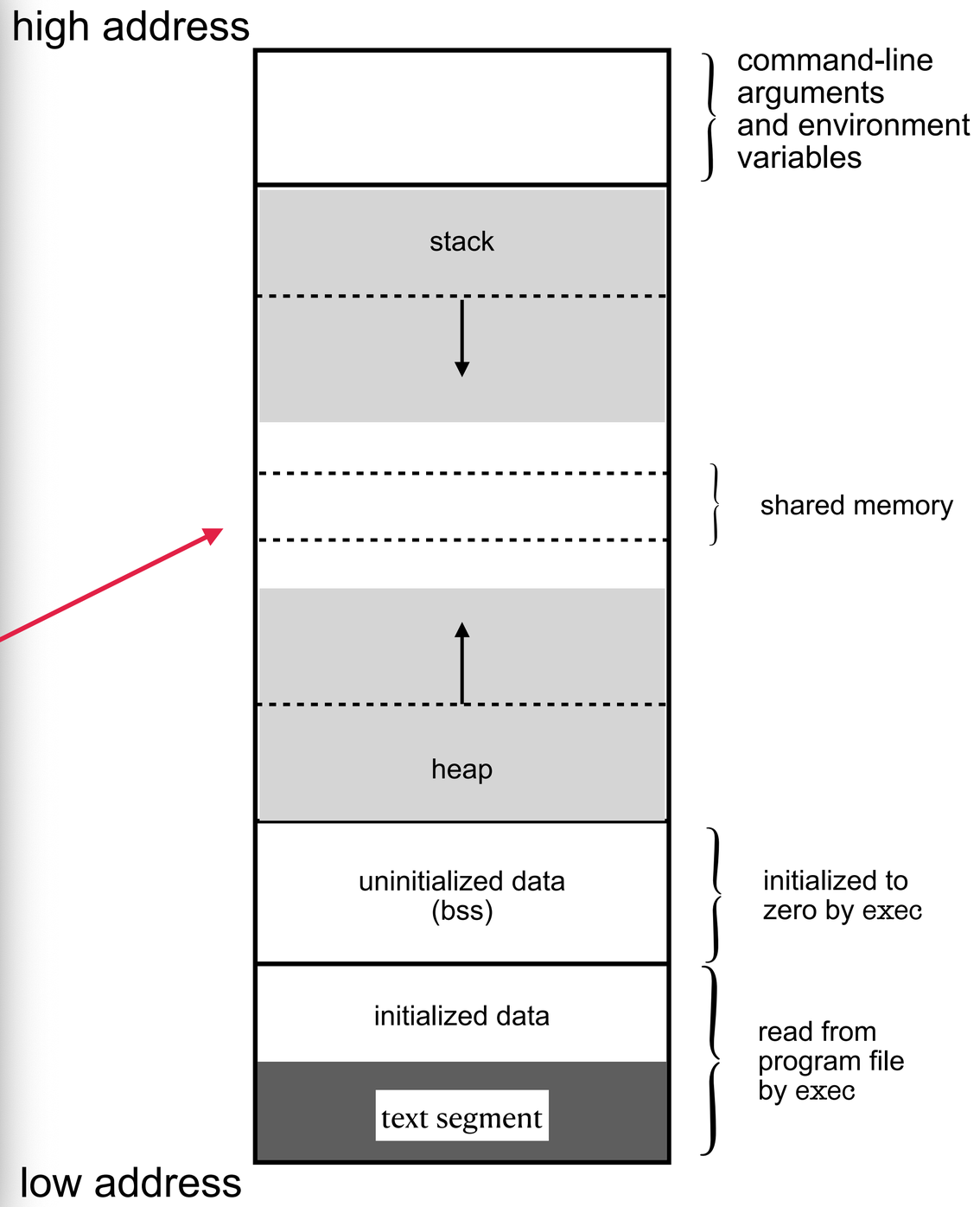
- fastest form of IPC
- access to shared region of memory often controlled using semaphores
- obtain a shared memory identifier using `shmget(2)`
- attach shared memory segment to a processes address space by calling `shmat(2)`
- detach it using `shmdt(2)`
- catch-all for shared memory operations: `shmctl(2)`

System V IPC: Shared Memory

Terminal — 130×24

```
m    327681  704662386 --rw-rw-rw- jschauma    users jschauma    users      0    1024  1074  1074  2:23:10  2:23:10  2:23:10

jschauma@apue$ ./a.out
1359: segment contains: "The cow says 'moo'."
jschauma@apue$ ./a.out
1579: segment contains: "The cow says 'moo'."
jschauma@apue$ ipcs -ma
IPC status from <running system> as of Mon Oct 19 02:23:52 2020

Shared Memory:
T         ID     KEY        MODE       OWNER    GROUP  CREATOR   CGROUP NATTCH    SEGSZ  CPID  LPID    ATIME    DTIME    CTIME
m    327681  704662386 --rw-rw-rw- jschauma    users jschauma    users      0    1024  1074  1579  2:23:48  2:23:48  2:23:10

jschauma@apue$ ipcrm -m 327681
jschauma@apue$ ./a.out
1751: segment contains: ""
jschauma@apue$ ipcs -ma
IPC status from <running system> as of Mon Oct 19 02:25:06 2020

Shared Memory:
```

```
Terminal — 81×44
jschauma@apue$ ./a.out
High address (args and env):
----------------------------
envp[16] at                                          : 0x7F7FFF2279D8
environ[16] at                                       : 0x7F7FFF2279D8
envp[0] at                                           : 0x7F7FFF227958
environ[0] at                                        : 0x7F7FFF227958
last arg at                                          : 0x7F7FFF227950
first arg at                                         : 0x7F7FFF227948

Stack:
------
First variable inside main at                        : 0x7F7FFF2278DC
func_array[] ends at                                 : 0x7F7FFF2278D0
func_array[] (like 'array[]', but on stack) begins at : 0x7F7FFF2278C0
argc at                                              : 0x7F7FFF2278BC
argv at                                              : 0x7F7FFF2278B0
envp at                                              : 0x7F7FFF2278A8
func2 (from main): frame at                          : 0x7F7FFF22788C
func frame at                                        : 0x7F7FFF227884
static int n within func at                          : 0x      601EEC
func (called     1 times): frame at                  : 0x7F7FFF227884
func2 (from func): frame at                          : 0x7F7FFF22785C

Shared Memory:
-----
shared memory area ends at                           : 0x7F7FF7EFE6A0
shared memory area begins at                         : 0x7F7FF7EE6000

Heap:
-----
malloced area ends at                                : 0x7926986E5020
malloced area begins at                              : 0x7926986E5000

Uninitialized Data (BSS):
-------------------------
array[] ends at                                      : 0x      601F70
array[] (uninitialized, fixed-size char * on BSS) from : 0x      601F60
num2 (uninitialized global int) at                   : 0x      601F58
string2 (uninitialized global char *) at             : 0x      601F50
extern **environ at                                  : 0x      601F40

Initialized Data:
-----------------
```



System V IPC: Message Queues

- linked list of messages stored in kernel space
- create or open existing queue using `msgget(2)`
- add message at end of queue using `msgsnd(2)`
- receive messages from queue using `msgrcv(2)`
- control queue properties using `msgctl(2)`

The message itself is contained in a user-defined structure such as

```
struct mymsg {
        long mtype;       /* message type */
        char mtext[512]; /* body of message */
};
```

System V IPC: Message Queues

Terminal — 130×24

```
q    393216          1 --rw-r--r-- jschauma    users jschauma    users       0     0   2048   1652    952 20:11:20 20:12:01 20:10:48

jschauma@apue$ ./rcv 1
Who will get this?
jschauma@apue$ ./send "Unblock thyself."
Usage: msgsend key message
jschauma@apue$ ./send 1 "Unblock thyself."
jschauma@apue$ ipcs -qa
IPC status from <running system> as of Mon Oct 19 20:13:28 2020

Message Queues:
T        ID     KEY        MODE       OWNER    GROUP  CREATOR   CGROUP CBYTES  QNUM QBYTES LSPID LRPID    STIME    RTIME    CTIME
q    393216          1 --rw-r--r-- jschauma    users jschauma    users       0     0   2048   225  1620 20:13:20 20:13:20 20:10:48

jschauma@apue$ ./rcv 2
msgget: No such file or directory
jschauma@apue$ ipcrm -q 393216
jschauma@apue$ ipcs -qa
IPC status from <running system> as of Mon Oct 19 20:13:48 2020

Message Queues:
T        ID     KEY        MODE       OWNER    GROUP  CREATOR   CGROUP CBYTES  QNUM QBYTES LSPID LRPID    STIME    RTIME    CTIME

jschauma@apue$
```

POSIX Message Queues

`mq(3)` provides a real-time IPC interface similar to System V message queues. Notably:

- message queues are identified by a named identifier (no `ftok(3)` needed)
- message queues may or may not be exposed in the filesystem (e.g., `/dev/mqueue`)
- `mq_send(3)` and `mq_receive(3)` allow both blocking and non-blocking calls
- `mq_send(3)` lets you specify a priority; equal priority messages are queued as a FIFO, but higher priority messages are inserted before those of a lower priority
- `mq(3)` provides an asynchronous notification mechanism: `mq_notify(3)`

POSIX Message Queues

Terminal — 130×24

```
Number of messages in queue: 1
Message of priority 1: TUNA
Message of priority 0: avocado
Message of priority 0: onion
Message of priority 0: tomato

Number of messages in queue: 1
Message of priority 0: avocado
Number of messages in queue: 1
Message of priority 0: onion
Number of messages in queue: 1
Message of priority 0: tomato
Number of messages in queue: 1
Message of priority 1: TUNA

Number of messages in queue: 1
Message of priority 0: avocado
Number of messages in queue: 1
Message of priority 0: onion
Number of messages in queue: 1
Message of priority 0: tomato
Number of messages in queue: 1
Message of priority 1: TUNA
```

```
jschauma@apue$ ./mqsend avocado onion tomato
jschauma@apue$ ./mqsend -w avocado onion tomato
jschauma@apue$ ./mqsend avocado onion tomato
jschauma@apue$ ./mqsend avocado onion tomato
jschauma@apue$
```

0 sh 1 sh

System V IPC

- *asynchronous* IPC between processes on the same system
- old, but not obsolete
- semaphores are useful to guard access to shared resources
- shared memory allows for fast IPC
- message queues as a service are a popular way to implement "pub sub" models
  - Amazon Simple Queue Service
  - Apache Kafka
  - Java Message Service
  - RabbitMQ
  - ...