Operating System Concepts

Lecture 8: Interprocess Communication

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MWF 12:00-12:50 VVC 2 215

Today's class

- Interprocess communication
  - Shared memory
  - Message Passing

Cooperating processes

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  - improve program structure/modularity
    - each cooperating process is smaller than a single monolithic program
- cooperating processes need to share information
  - OS makes this happen using interprocess communication mechanisms

What are IPC mechanisms in UNIX?

IPC type	SUS	FreeBSD 8.0	Linux 3.2.0	Mac OS X 10.6.8	Solaris 10
half-duplex pipes	•	(full)	•	•	(full)
FIFOs	•	•	•	•	•
full-duplex pipes	allowed	•, UDS	UDS	UDS	•, UDS
named full-duplex pipes	obsolescent	UDS	UDS	UDS	•, UDS
XSI message queues	XSI	•	•	•	•
XSI semaphores	XSI	•	•	•	•
XSI shared memory	XSI	•	•	•	•
message queues (real-time)	MSG option	•	•		•
semaphores	•	•	•	•	•
shared memory (real-time)	SHM option	•	•	•	•
sockets	•	•	•	•	•
STREAMS	obsolescent				•

Two fundamental approaches

- Message passing
  - kernel intervention (through system calls) is required in every send/receive operation
  - extensible to communication in distributed systems
  - **positive aspects:** all sharing is explicit; less chance for error
  - **negative aspects:** high overhead. data copying, cross protection domains

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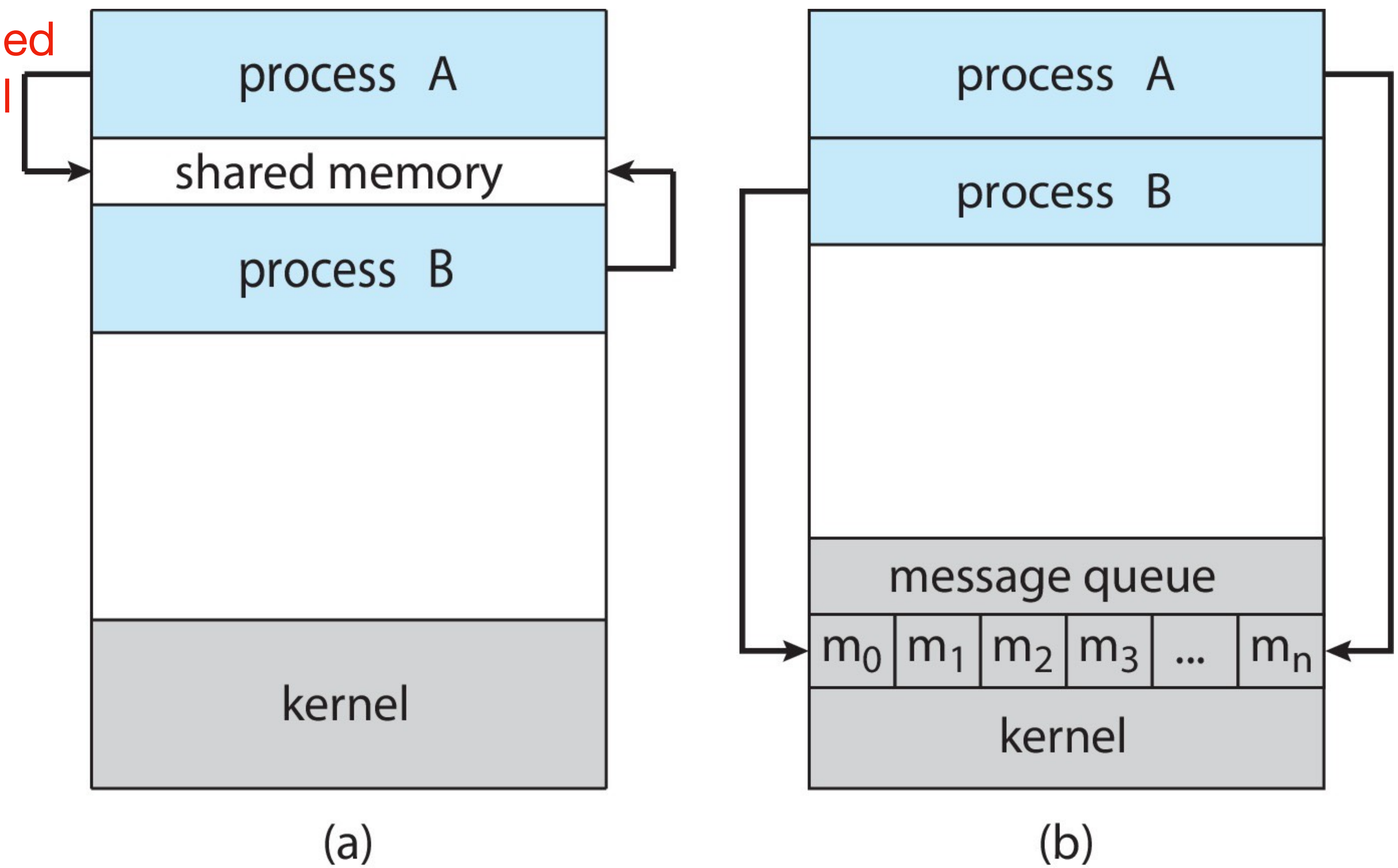
- Shared memory: processes (or threads) can read and write a set of shared memory locations
  - system calls are only required to establish shared memory regions
  - processes are responsible for ensuring that they do not access a location concurrently (synchronization is explicit)
  - difficult to provide across machine boundaries
  - **positive aspects:** faster: set up shared memory once, then access w/o crossing protection domains
  - **negative aspects:** things might change behind your back; error prone

Two fundamental approaches

processes read/write data from/to this shared memory region established by the mmap system call



Communication using message passing

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  - this identifier is shared between the processes to access to the queue (**HOW?**)
- OS keeps track of messages
  - copies them, notifies receiving process, etc.

Properties of message passing systems

- Direction
  - simplex (one-way)
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- Reliability
  - messages can get lost, corrupted, or reordered

Message passing issues

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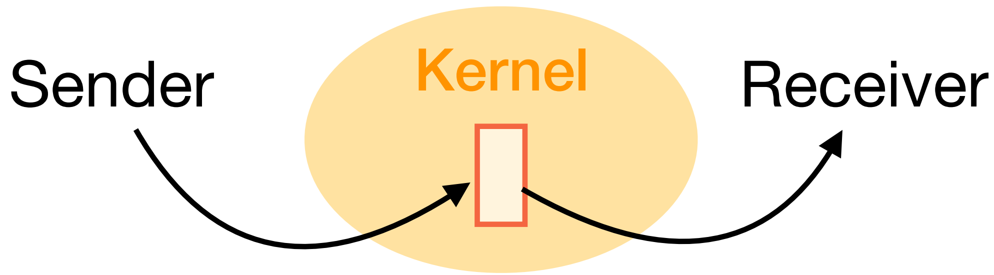
- blocking operations



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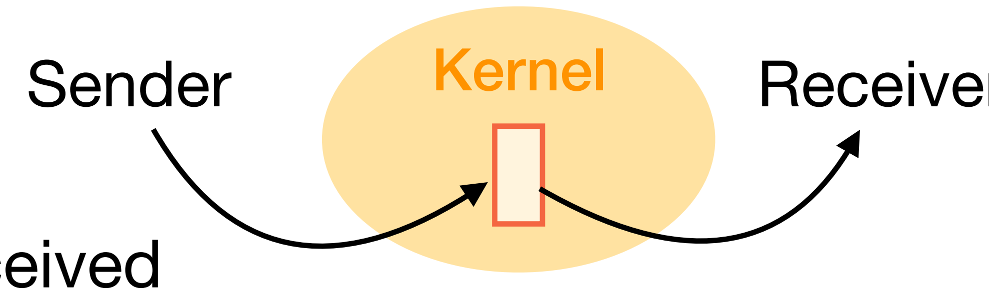

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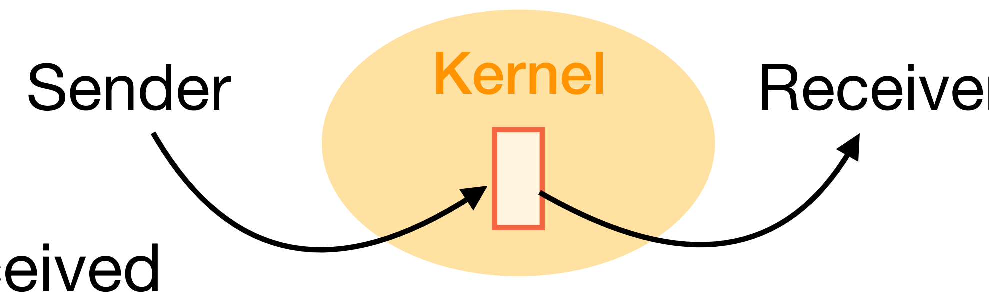
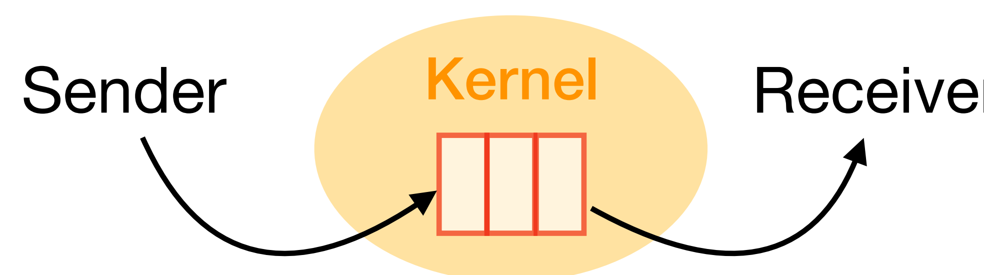


- non-blocking operations



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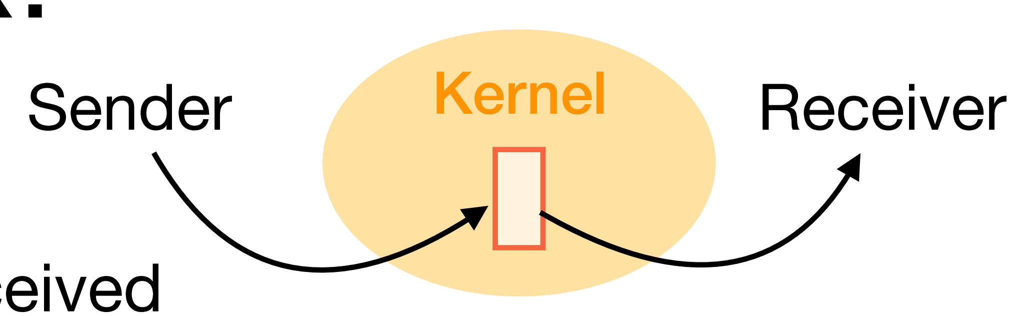

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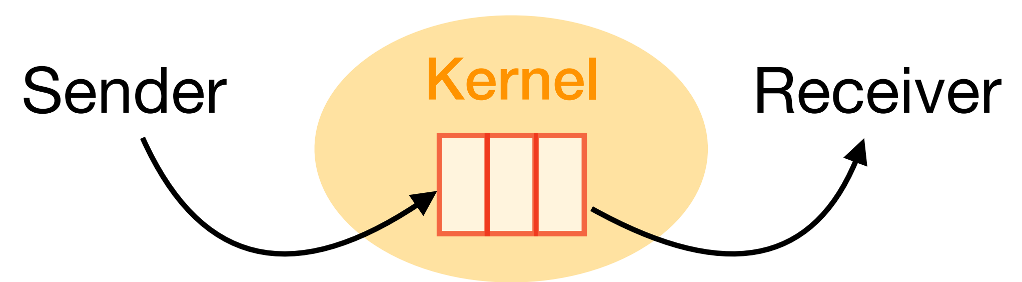

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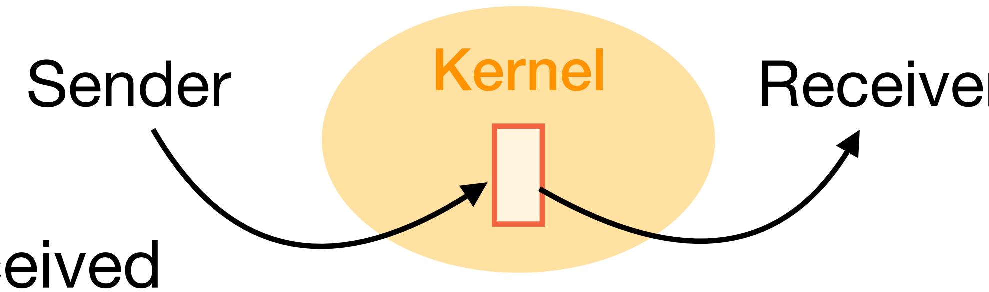

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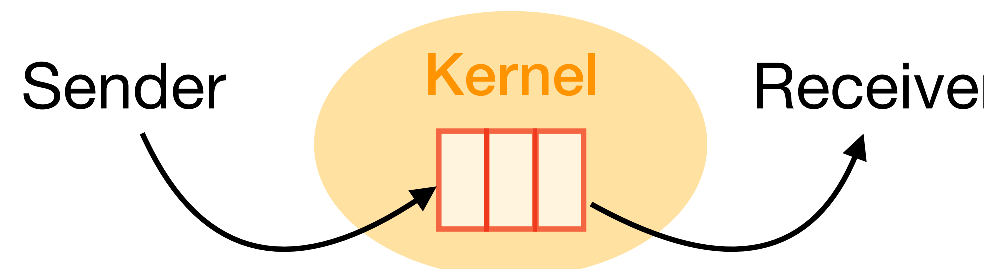

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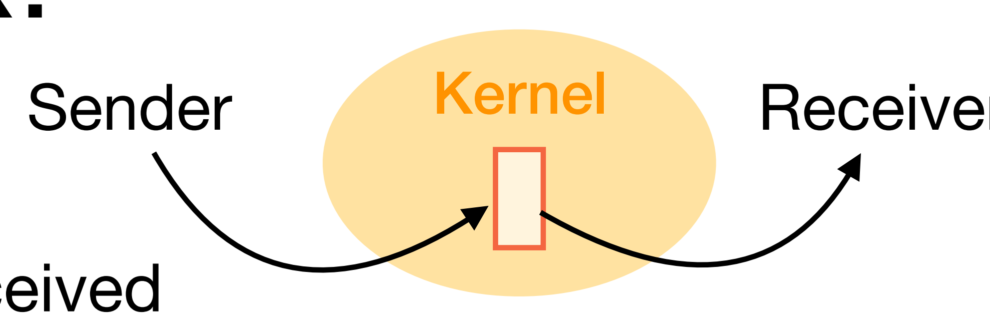

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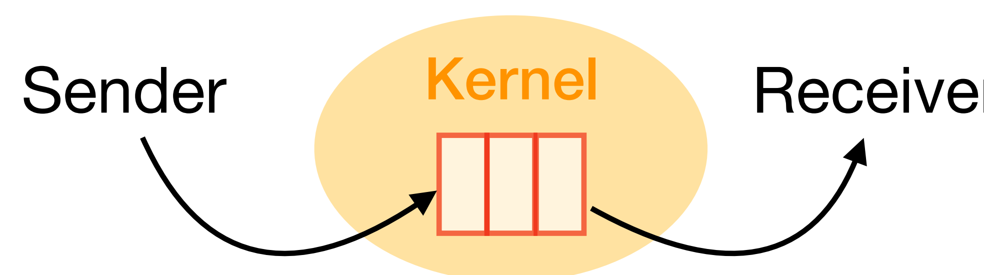

- partially blocking/non-blocking
  - send( )/receive( ) with timeout

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- the `mmap( )` systems call performs this function
- can fork processes that need to share the data structure so that they know the name of the shared object
    - **any other solution?**

Producer-Consumer problem

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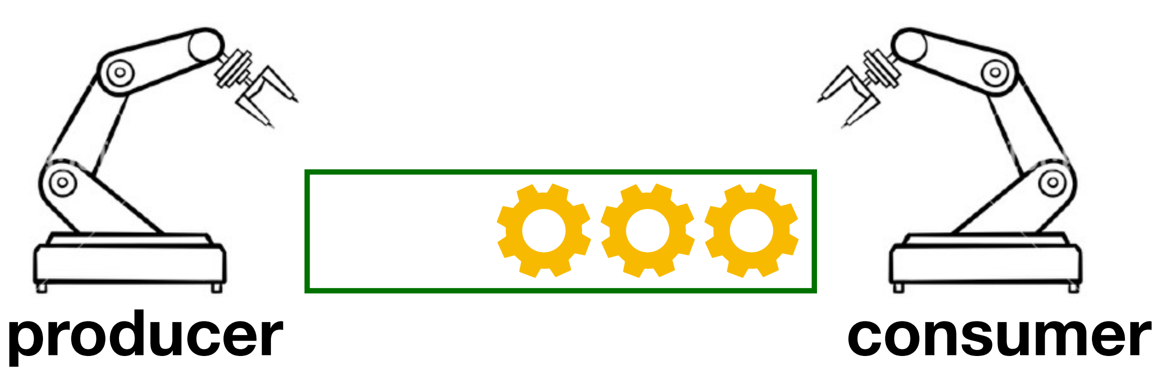

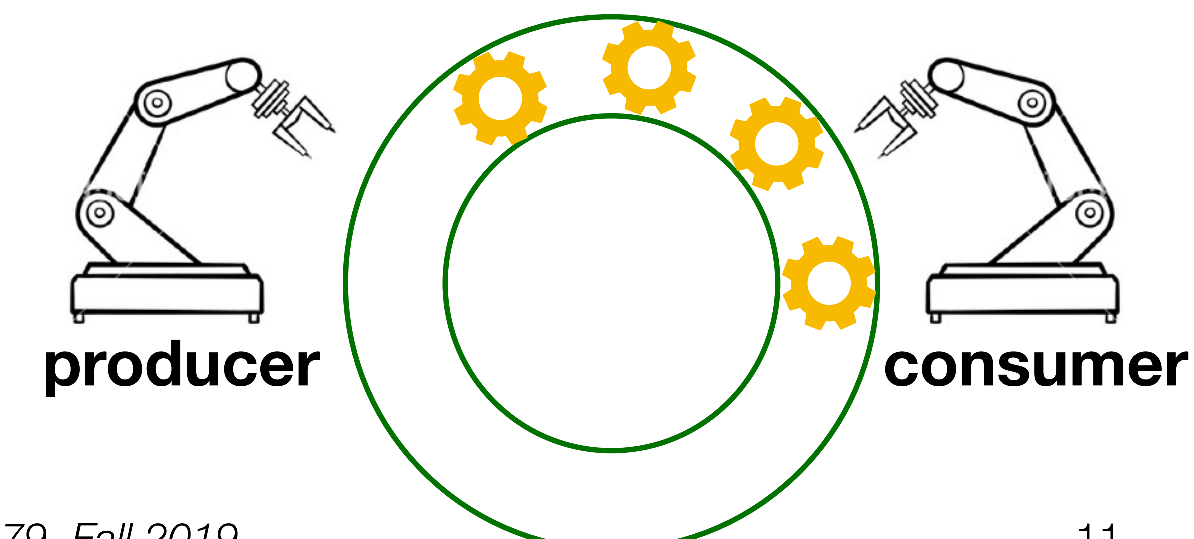

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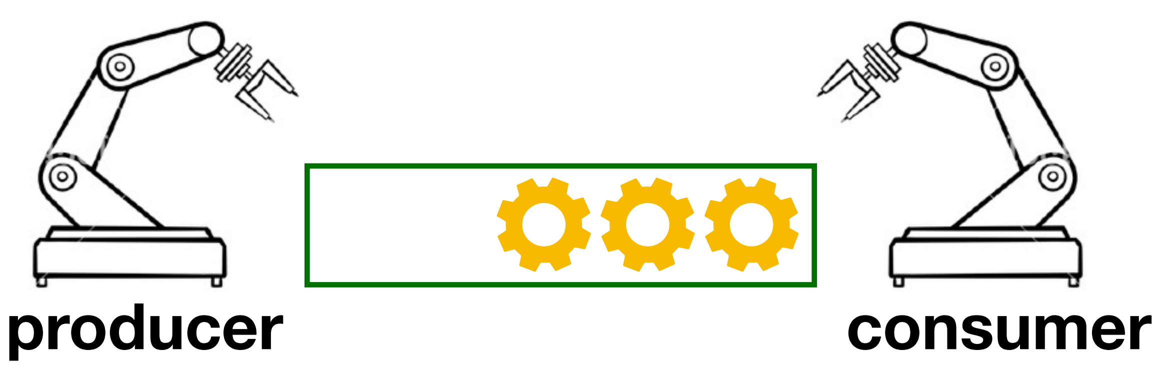

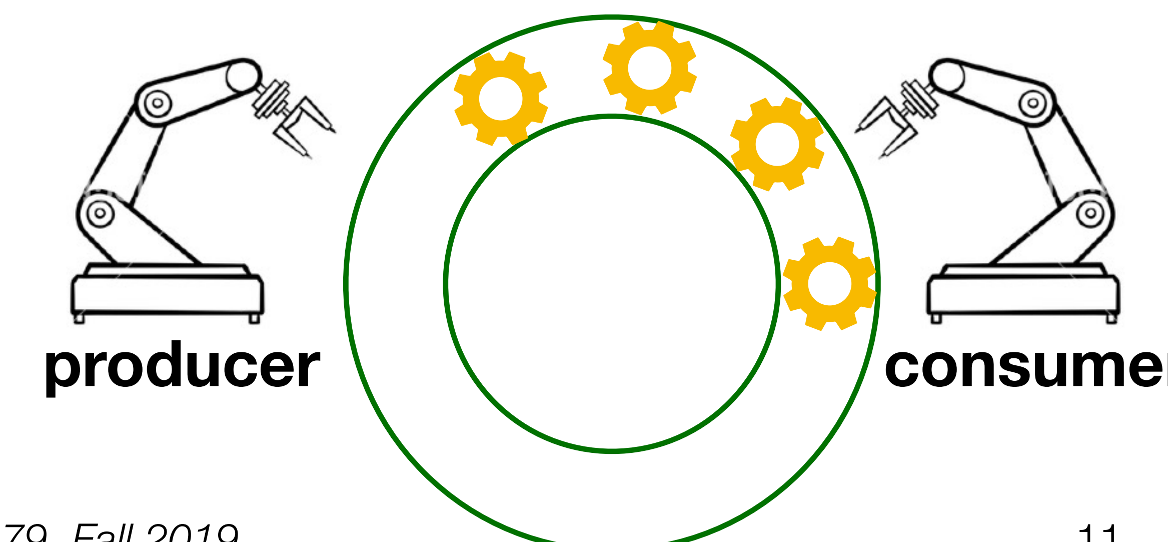

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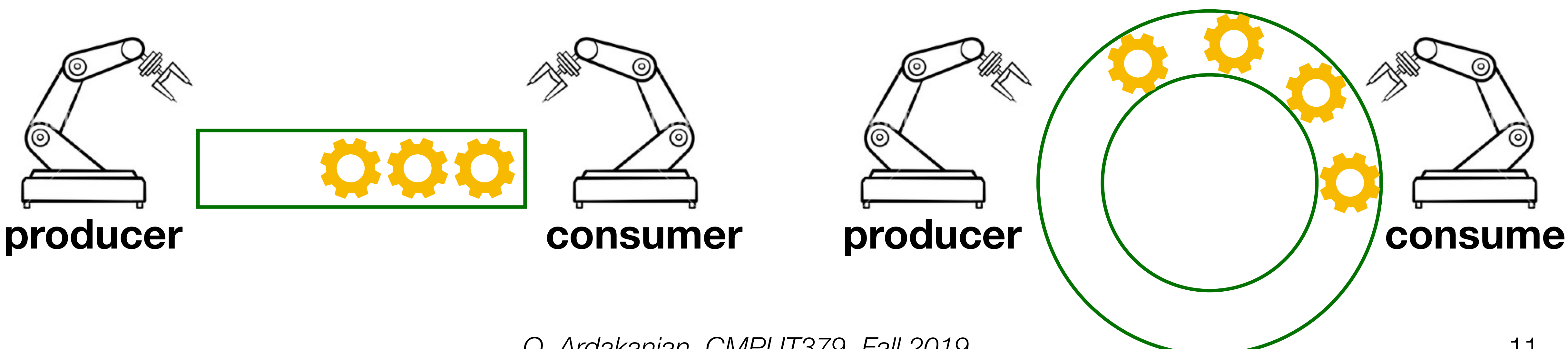

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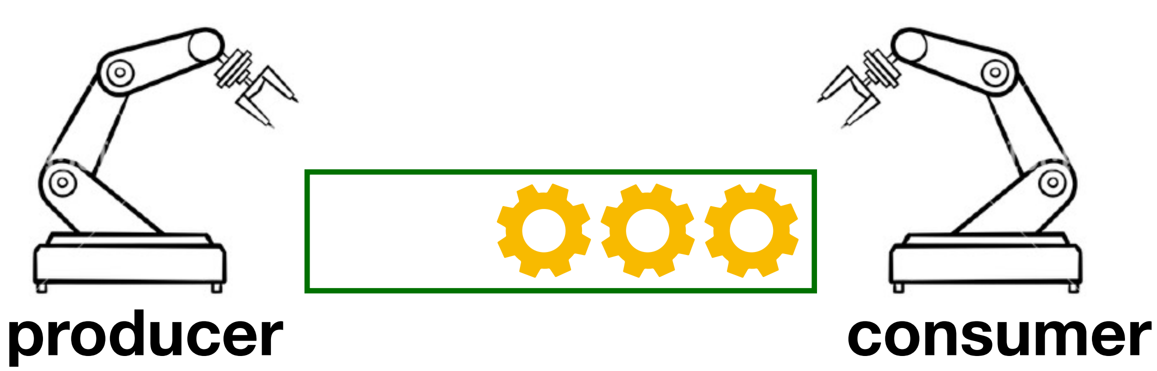

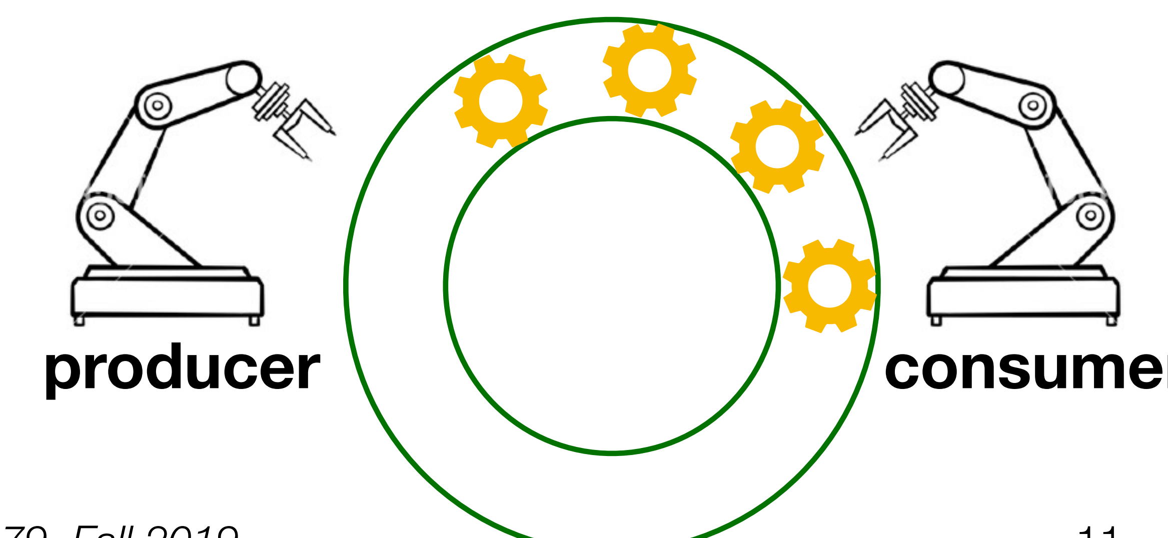

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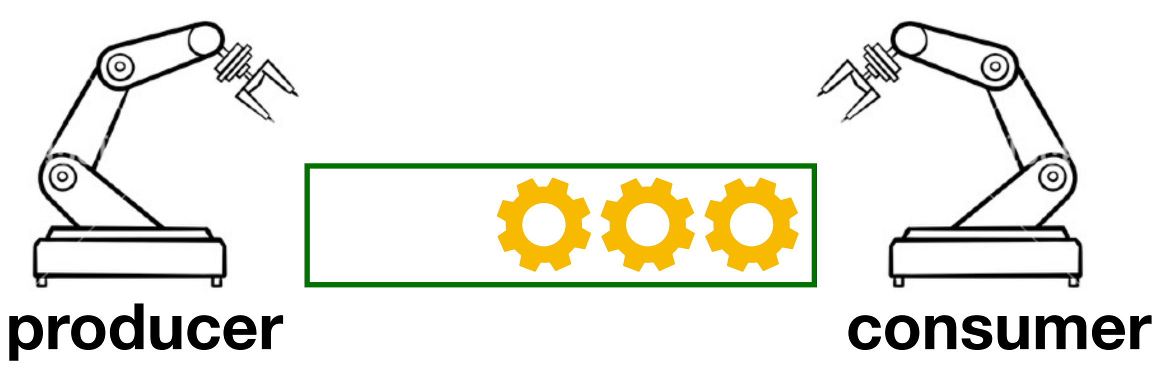

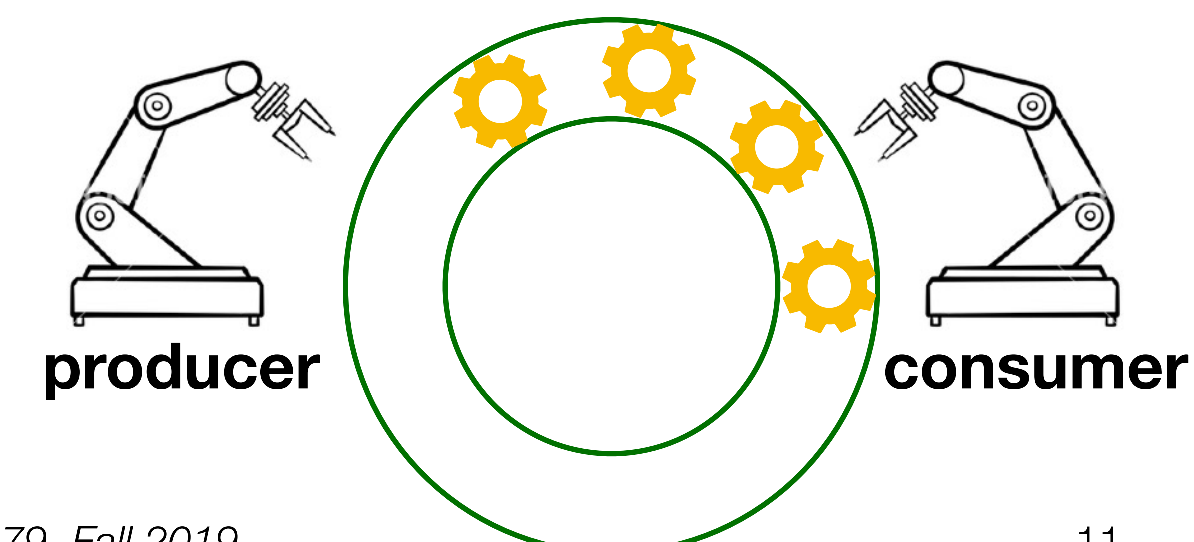

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- What should the producer do when the buffer is full?
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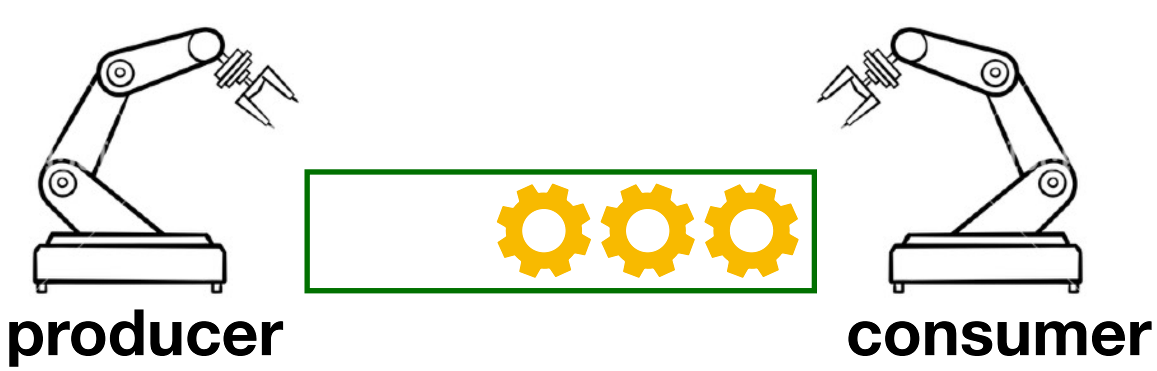
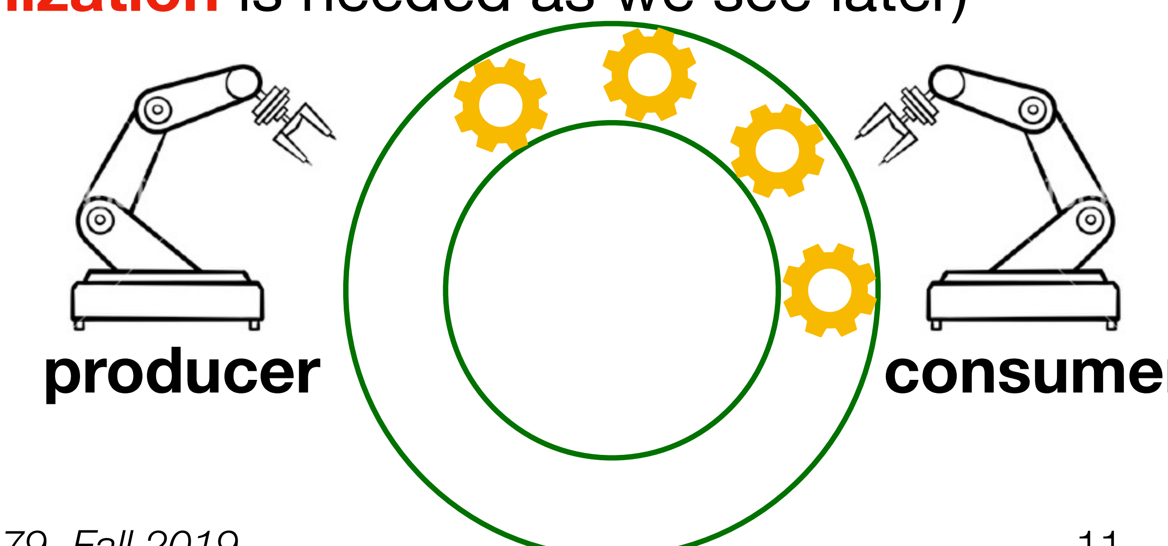
- How to maintain data integrity? (**synchronization** is needed as we see later)





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  - `n` is the size of the buffer
  - `in` points to the next free location
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  - this way we can have at most `n - 1` items in the buffer (**WHY?**)

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    while (in+1 mod n == out) {}
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Consumer

```
int consumer( ) {
  …
  while(true) {
    …
    while (in == out) {}
    nextc = buffer[out]
    out = out+1 mod n
    consume nextc
  }
}
```

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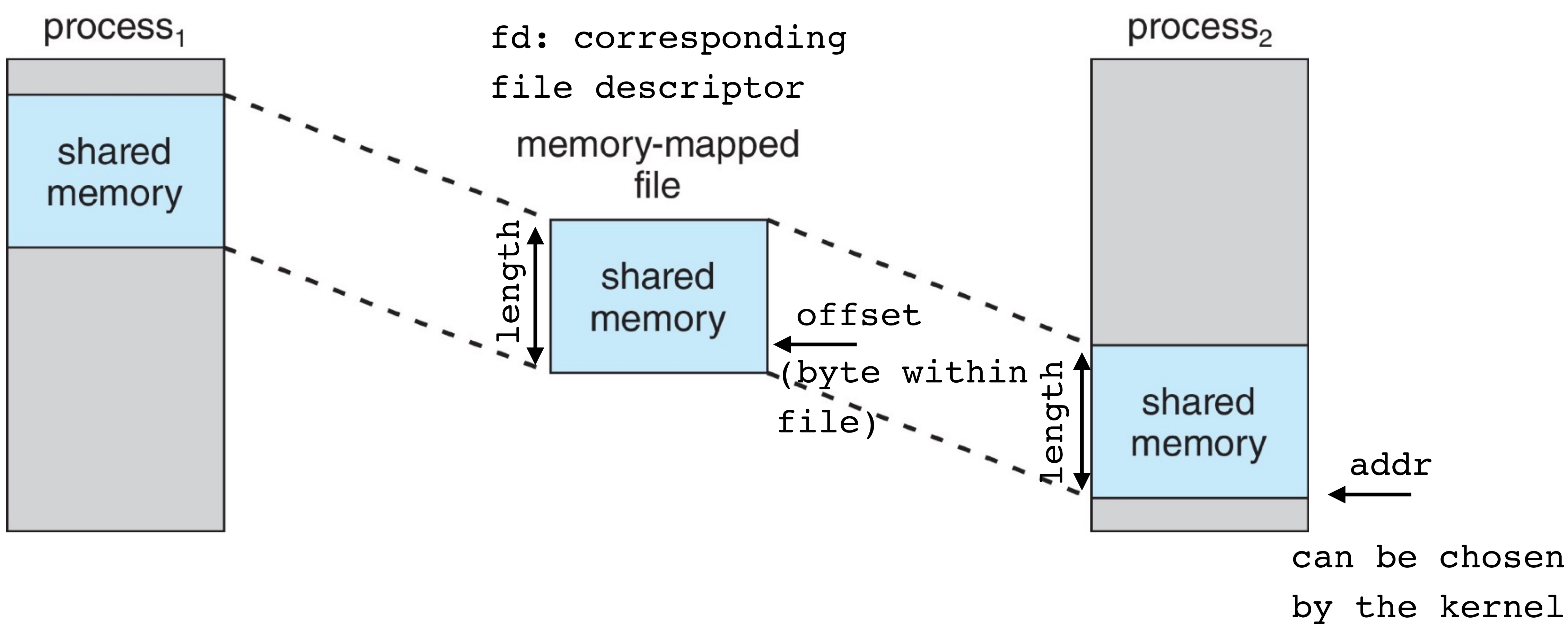
  - the file pointer is used to write to or read from this shared memory object
- the `shm_unlink( )` system call removes the shared memory object
  - once all processes have unmapped the object, it de-allocates and destroys the contents of the associated memory region

the mmap system call

```
void *mmap(void *addr, size_t length, int prot, int flags, int fd, off_t offset)
```



POSIX producer

```
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <unistd.h>
#include <fcntl.h>
#include <sys/shm.h>
#include <sys/stat.h>
#include <sys/mman.h>

int main() {
  const int SIZE = 4096;                                   /* size (B) of shared memory object */
  const char* name = “/prog-shm";                          /* name of the shared memory object */

  const char* message_0 = "Hello";
  const char* message_1 = "World!";

  int shm_fd;                                              /* shared memory file descriptor */
  void* ptr;                                               /* pointer to shared memory object */

  shm_fd = shm_open(name, O_CREAT | O_RDWR, 0666);         /* create the shared memory object */
  ftruncate(shm_fd, SIZE);                                 /* configure size of the shared memory object */
  ptr = mmap(0, SIZE, PROT_WRITE, MAP_SHARED, shm_fd, 0); /* memory map the shared memory object */

  sprintf(ptr, "%s", message_0);                           /* write to the shared memory object */
  ptr += strlen(message_0);
  sprintf(ptr, "%s", message_1);
  ptr += strlen(message_1);

  return 0;
}
```

POSIX consumer

```
#include <stdio.h>
#include <stdlib.h>
#include <fcntl.h>
#include <sys/shm.h>
#include <sys/stat.h>
#include <sys/mman.h>

int main() {
  const int SIZE = 4096;                    /* size (B) of shared memory object */
  const char* name = "/prog-shm";           /* name of the shared memory object */

  int shm_fd;                               /* shared memory file descriptor */
  void* ptr;                                /* pointer to shared memory object */

  shm_fd = shm_open(name, O_RDONLY, 0666); /* open the shared memory object */

  /* memory map the shared memory object */
  ptr = mmap(0, SIZE, PROT_READ, MAP_SHARED, shm_fd, 0);

  printf("%s", (char*)ptr);                 /* read from the shared memory object */
  shm_unlink(name);                         /* remove the shared memory object */

  return 0;
}
```

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- `msgrcv( )` retrieves messages from a queue
- `msgctl( )` performs various operations on a queue.
  - is generally used to destroy message queue

Example — writer.c

```
#include <stdio.h>
#include <sys/ipc.h>
#include <sys/msg.h>

// structure for message queue
struct mesg_buffer {
    long mesg_type;
    char mesg_text[100];
} message;

int main()
{
    key_t key;
    int msgid;

    key = ftok("progfile", 65);             // generates a unique key
    msgid = msgget(key, 0666 | IPC_CREAT); // creates a message queue
    message.mesg_type = 1;

    printf("Write Data: ");
    scanf("%s", message.mesg_text);

    msgsnd(msgid, &message, sizeof(message), 0); // sends the message

    printf("Data sent is: %s \n", message.mesg_text);

    return 0;
}
```

Example — reader.c

```
#include <stdio.h>
#include <sys/ipc.h>
#include <sys/msg.h>

// structure for message queue
struct mesg_buffer {
    long mesg_type;
    char mesg_text[100];
} message;

int main()
{
    key_t key;
    int msgid;

    key = ftok("progfile", 65);                        // generates a unique key

    msgid = msgget(key, 0666 | IPC_CREAT);             // creates a message queue

    msgrcv(msgid, &message, sizeof(message), 1, 0); // receives the message

    printf("Data Received is : %s \n”, message.mesg_text);

    msgctl(msgid, IPC_RMID, NULL);                     // destroys the message queue

    return 0;
}
```