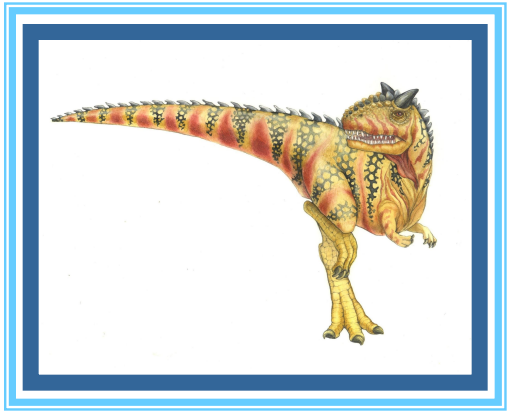
Chapter 3: Processes

Lecture 09



Recap

- Schedulers
  - Short term scheduler
  - Long term scheduler
  - Medium term scheduler
- Multiprogramming
- Context Switch
- Operations on processes
  - Process creation
  - Process Termination

Objectives

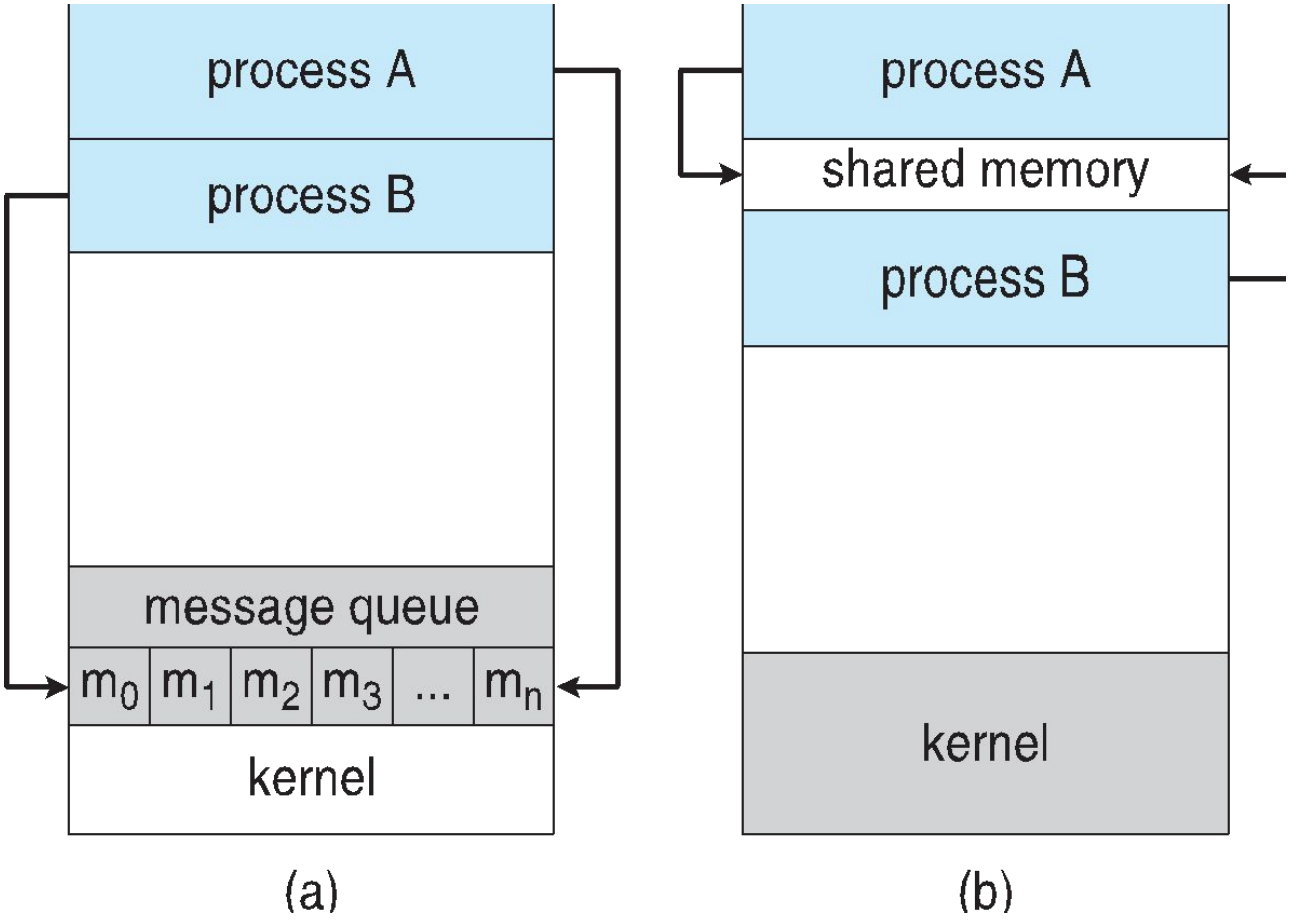
- Inter-process Communication
  - Shared memory
    - Producer-consumer problem
  - Message Passing
    - Direct or indirect communication
    - Synchronous or Asynchronous Communication
    - Automatic or explicit buffering

Interprocess Communication

- Processes within a system may be ***independent*** or ***cooperating***
- Cooperating process can affect or be affected by other processes, including sharing data
- Reasons for cooperating processes:
  - Information sharing
  - Computation speedup
  - Modularity
  - Convenience
- Cooperating processes need **inter-process communication** (**IPC**)
- Two models of IPC
  - **Shared memory**
  - **Message passing**

Communications Models

(a) Message passing. (b) shared memory.



Shared memory vs Message passing

- Message passing is useful for exchanging smaller amounts of data, because no conflicts need to be avoided.
- Message passing is also easier to implement than is shared memory for inter-process communication.
- Shared memory is faster than message passing because message passing systems are typically implemented using system calls and thus require the more time consuming task of kernel intervention.
- In contrast, in shared memory systems, system calls are required only to establish shared memory regions. Once shared memory is established, a;; accesses are treated as routine memory accesses and no assistance from kernel is required.

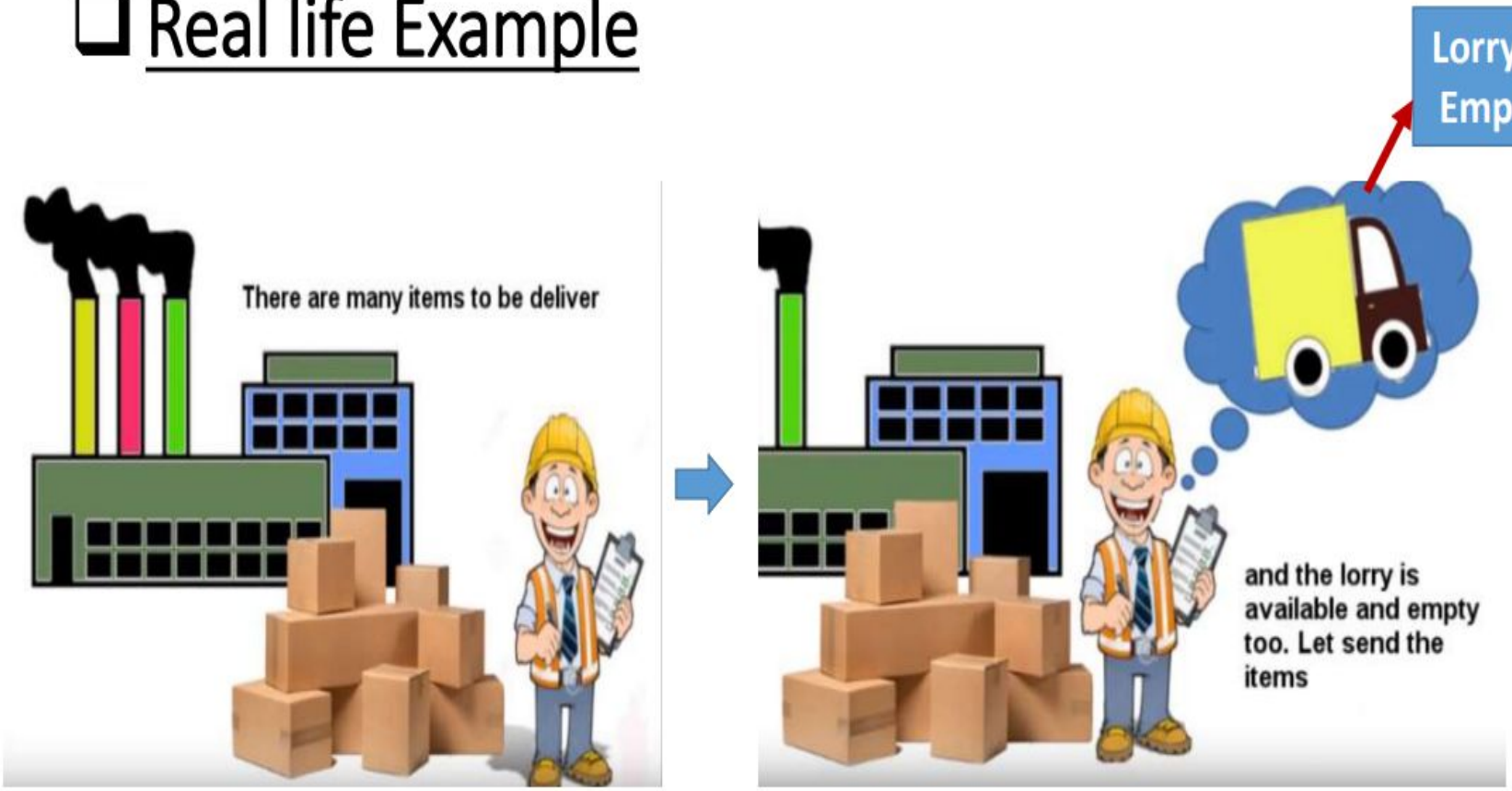
Cooperating Processes

- ***Independent*** process cannot affect or be affected by the execution of another process
- ***Cooperating*** process can affect or be affected by the execution of another process
- Advantages of process cooperation
  - Information sharing
  - Computation speed-up
  - Modularity
  - Convenience

Producer-Consumer Problem

- Paradigm for cooperating processes, *producer* process produces information that is consumed by a *consumer* process
- Is a multi-process synchronization problem
- Also known as the bounded-buffer problem Two processes share a common buffer
  - Producer : One of them is producer puts information in the buffer
  - Consumer : One of them is consumer takes information out of the buffer
- The problem is to make sure that the producer won't try to add data into the buffer if it's full and that the consumer won't try to remove data from an empty buffer.
- **unbounded-buffer** places no practical limit on the size of the buffer
- **bounded-buffer** assumes that there is a fixed buffer size

❑ Real life Example

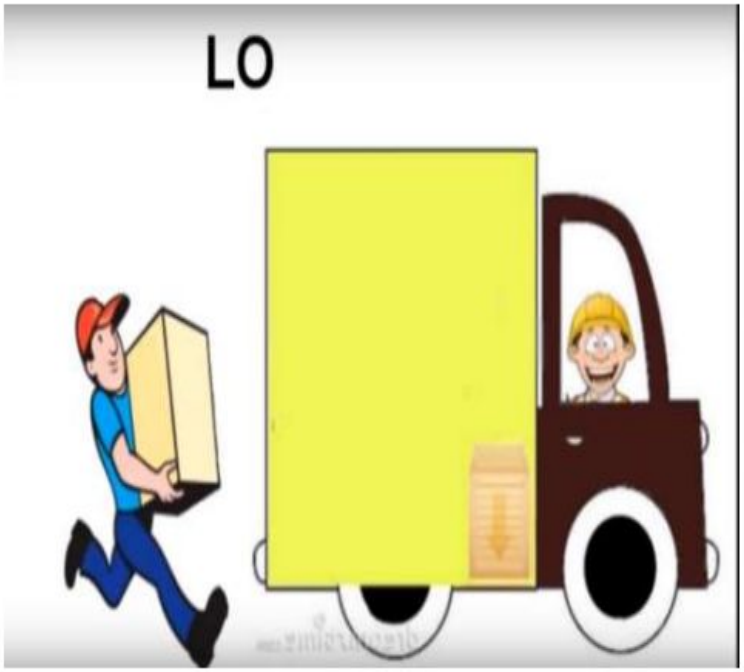


Picture 1: Full of items

Picture 2: Lorry is empty

❑ Real life Example

Picture 3 : Working for load



Picture 4 : Loading

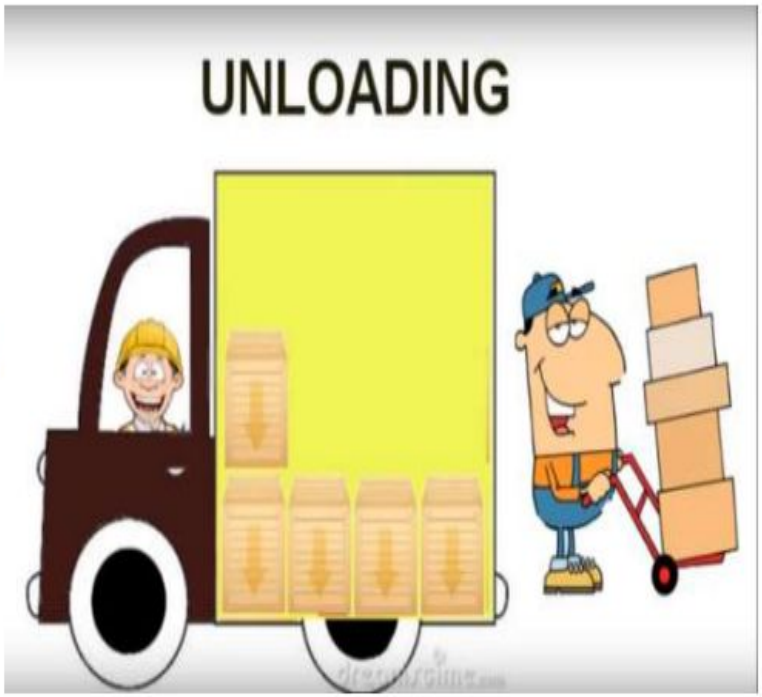
❑ Real life Example

Picture 5 : Truck is full

Picture 6 : Still many items

❑ Real life Example

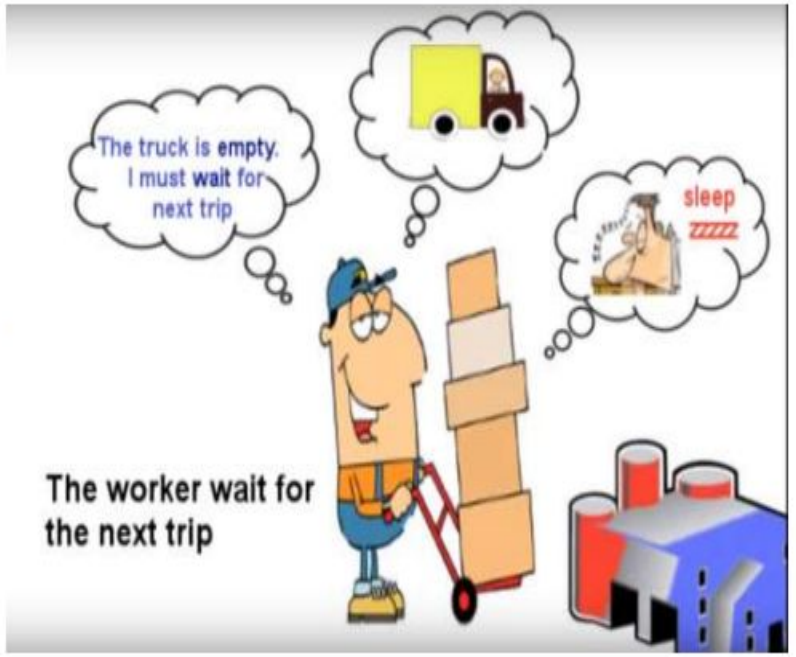
Picture 7 : Truck is full & unloaded



Picture 8 : Uloading

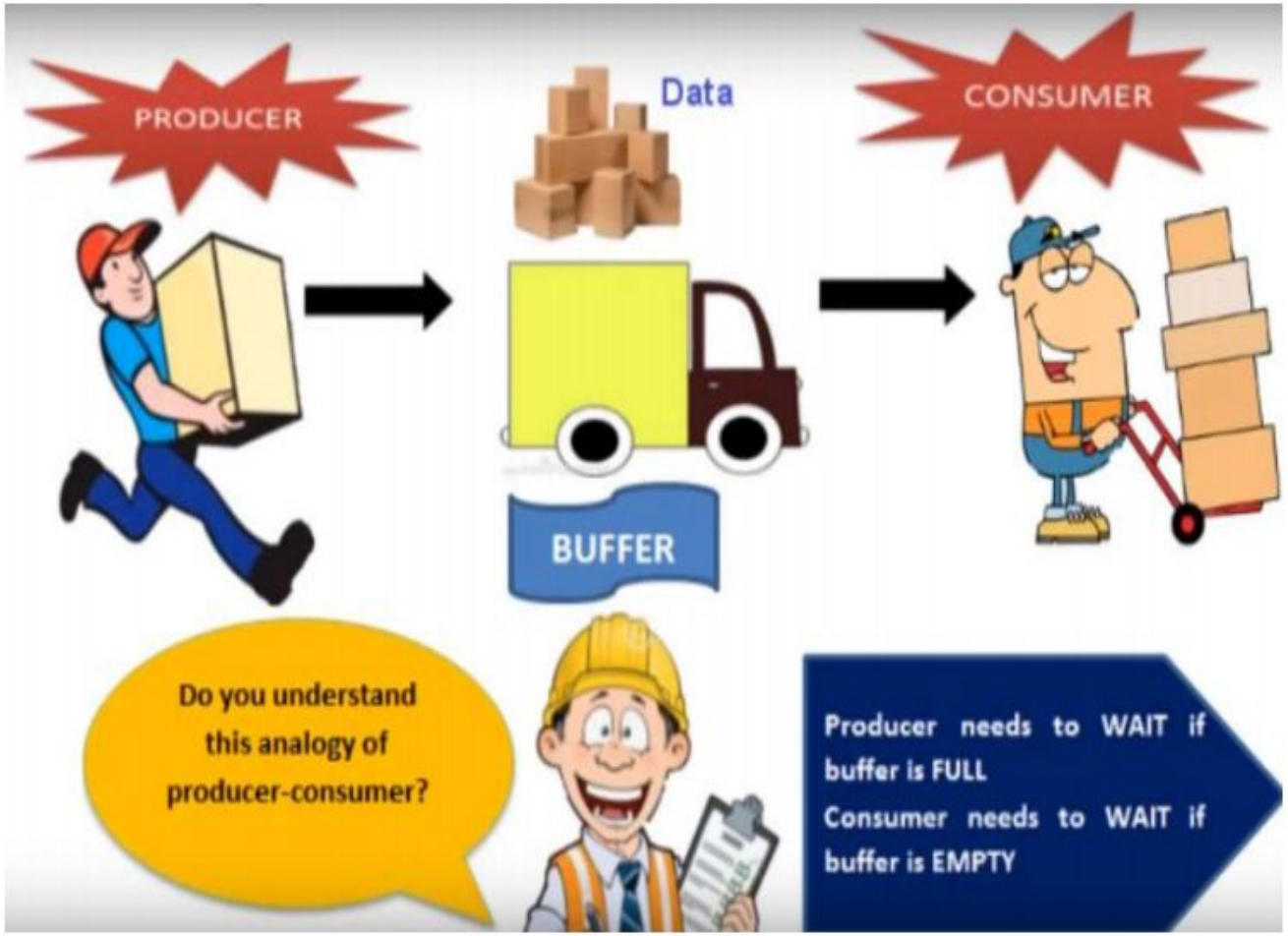
❑ Real life Example

Picture 9 : Truck is empty



Picture 10 : Waiting

❑ Real life Example



Picture: All Process

What's the problem here?

- The following are the problems that might occur in the Producer-Consumer:
  - The producer should produce data only when the buffer is not full. If the buffer is full, then the producer shouldn't be allowed to put any data into the buffer.
  - The consumer should consume data only when the buffer is not empty. If the buffer is empty, then the consumer shouldn't be allowed to take any data from the buffer.
  - The producer and consumer should not access the buffer at the same time.

Interprocess Communication – Shared Memory

- An area of memory shared among the processes that wish to communicate
- The communication is under the control of the users processes not the operating system.
- Major issues is to provide mechanism that will allow the user processes to synchronize their actions when they access shared memory.
- Synchronization is discussed in great details in Chapter 5.

Interprocess Communication – Message Passing

- Mechanism for processes to communicate and to synchronize their actions
- Message system – processes communicate with each other without resorting to shared variables
- IPC facility provides two operations:
  - **`send`**(*message*)
  - **`receive`**(*message*)
- The *message* size is either fixed or variable

Message Passing (Cont.)

- If processes *P* and *Q* wish to communicate, they need to:
  - Establish a ***communication link*** between them
  - Exchange messages via send/receive
- Implementation issues:
  - How are links established?
  - Can a link be associated with more than two processes?
  - How many links can there be between every pair of communicating processes?
  - What is the capacity of a link?
  - Is the size of a message that the link can accommodate fixed or variable?
  - Is a link unidirectional or bi-directional?

Message Passing (Cont.)

- Implementation of communication link
  - Physical:
    - Shared memory
    - Hardware bus
    - Network
  - Logical:
    - Direct or indirect
    - Synchronous or asynchronous
    - Automatic or explicit buffering

Direct Communication

- Symmetric and asymmetric

Symmetric:

In the Direct Communication, each process that wants to communicate must explicitly name the recipient or sender of the communication. In this scheme, the **send and receive** primitives are defined as follows :

- Processes must name each other explicitly:
  - **`send`** (*P, message*) – send a message to process P
  - **`receive`**(*Q, message*) – receive a message from process Q
- Properties of communication link
  - Links are established automatically
  - A link is associated with exactly one pair of communicating processes
  - Between each pair there exists exactly one link
  - The link may be unidirectional, but is usually bi-directional

Direct Communication

- In *asymmetry* only the sender names the recipient; the recipient is not required to name the sender. In this scheme, the send and receive primitives are defined as follows:
- *Send(P, message): Send a message to process P.*
- *receive(id, message):Receive a message from any process; the variable id is set to the name of the process with which communication has taken place.*
- Disadvantage of symmetric and asymmetric schemes
  - The disadvantage in both symmetric and asymmetric schemes is the limited modularity of the resulting process definitions. Changing the name of a process may necessitate examining all other process definitions.

Indirect Communication

- Messages are directed and received from mailboxes (also referred to as ports)
  - Each mailbox has a unique id
  - Processes can communicate only if they share a mailbox
- Properties of communication link
  - Link established only if processes share a common mailbox
  - A link may be associated with many processes
  - Each pair of processes may share several communication links
  - Link may be unidirectional or bi-directional

Indirect Communication

- Operations
  - create a new mailbox (port)
  - send and receive messages through mailbox
  - destroy a mailbox
- Primitives are defined as:

  `send`(*A, message*) – send a message to mailbox A

  `receive`(*A, message*) – receive a message from mailbox A

Indirect Communication

- Mailbox sharing
  - P_1, P_2, and P_3 share mailbox A
  - P_1, sends; P_2 and P_3 receive
  - Who gets the message?
- Solutions
  - Allow a link to be associated with at most two processes
  - Allow only one process at a time to execute a receive operation
  - Allow the system to select arbitrarily the receiver. Sender is notified who the receiver was.

Indirect Communication

- A mailbox may be owned either by a process or by the operating system. If the mailbox is owned by a process (that is, the mail box is part of the address space of the process), then we distinguish between the owner (which can only receive messages through this mailbox) and the user (which can only send messages to the mailbox).
- Since each mailbox has a unique owner, there can be no confusion about which process should receive a message sent to this mailbox. When a process that owns a mailbox terminates, the mailbox disappears. Any process that subsequently sends a message to this mailbox must be notified that the mail box no longer exists.

Indirect Communication

- In contrast, a mailbox that is owned by the operating system has an existence of its own. It is independent and is not attached to any particular process. The operating system then must provide a mechanism that allows a process to do the following:
  - Create a new mailbox.
  - Send and receive messages through the mailbox.
  - Delete a mailbox.
- The process that creates a new mailbox is that mailbox's owner by default. Initially, the owner is the only process that can receive messages through this mailbox. However, the ownership and receiving privilege may be passed to other processes through appropriate system calls. Of course, this provision could result in multiple receivers for each mailbox.

Synchronization

- Message passing may be either blocking or non-blocking
- **Blocking** is considered **synchronous**
  - **Blocking send** -- the sender is blocked until the message is received
  - **Blocking receive** -- the receiver is blocked until a message is available
- **Non-blocking** is considered **asynchronous**
  - **Non-blocking send** -- the sender sends the message and continue
  - **Non-blocking receive** -- the receiver receives:
    - A valid message, or
    - Null message
- Different combinations possible
  - If both send and receive are blocking, we have a **rendezvous**

Synchronization (Cont.)

- Producer-consumer becomes trivial

```
message next_produced;
while (true) {
        /* produce an item in next produced */
send(next_produced);
}
```

```
message next_consumed;
while (true) {
   receive(next_consumed);

   /* consume the item in next consumed */
}
```

Buffering

- Queue of messages attached to the link.
- implemented in one of three ways
- **Zero capacity:** The queue has maximum length 0; thus, the link cannot have any messages waiting in it. In this case, the sender must block until the recipient receives the message.
- The zero-capacity case is sometimes referred to as a message system with no buffering;
- **Bounded capacity:** The queue has finite length n thus, at most n messages can reside in it. If the queue is not full when a new message is sent, the latter is placed in the queue (either the message is copied or a pointer to the message is kept), and the sender can continue execution without waiting. The link has a finite capacity, however. If the link is full, the sender must block until space is available in the queue. It is also known as automatic buffering.
- **Unbounded capacity:** The queue has potentially infinite length; thus, any number of messages can wait in it. The sender never blocks. It is also known as automatic buffering.

End of Chapter 3