POSIX Threads programming (pthread)

Operating System

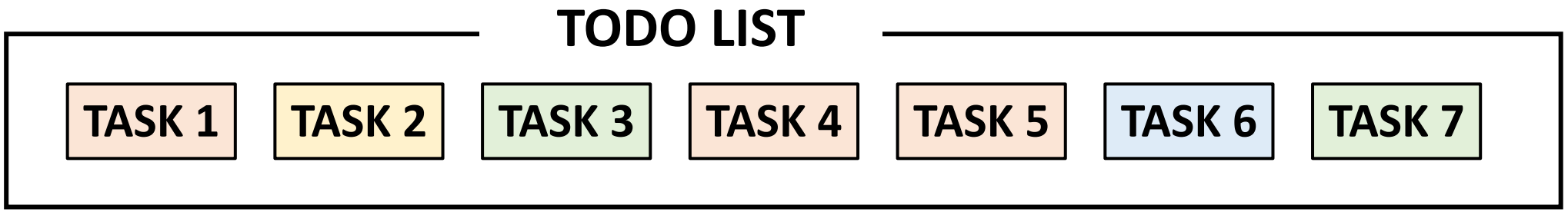
Introduction

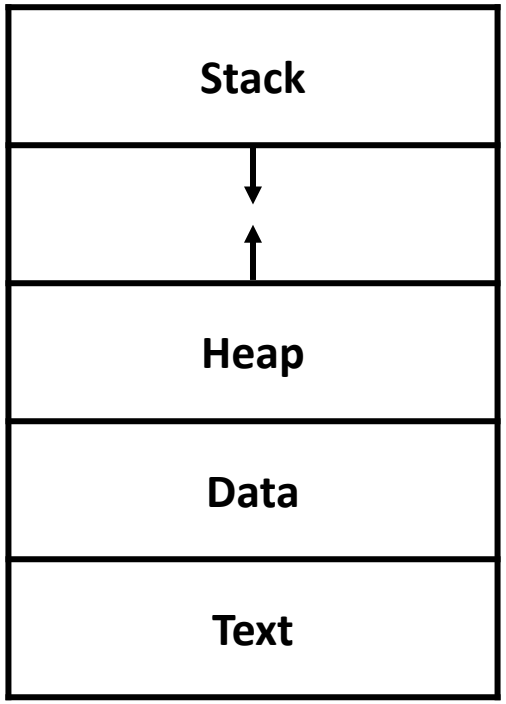
- What is a thread?
- POSIX Thread(Pthread) Overview
- The Pthread API
- Compile pthread program
- Thread Management
- Mutex variables
- Condition variables

What is a thread?

- A thread of execution is **the smallest sequence of programmed instructions** that can be managed **independently** by a scheduler, which is typically a part of the operating system.
- Threads exist **within a process** as **subsets of a process.**
- Threads may share and use the process resources.
- Thread has its **own independent flow of control** as long as its parent process exists and the OS supports it
- Thread **duplicates only the essential resources** it needs to be independently schedulable
- Thread is "**lightweight**" because most of the overhead has already been accomplished through the creation of its process.

Process model





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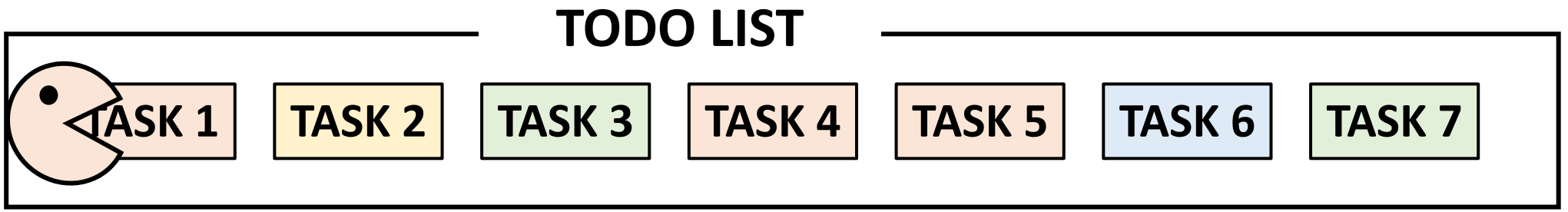

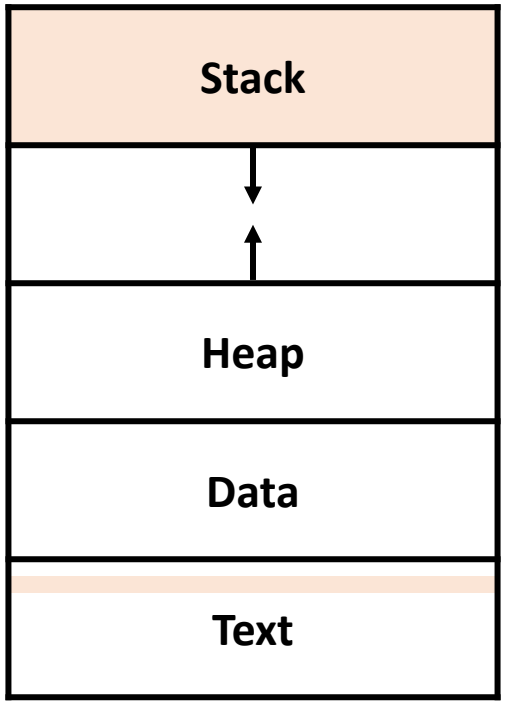

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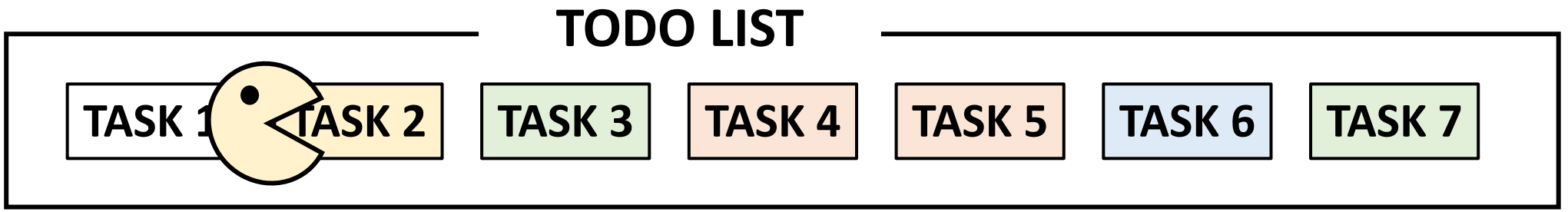

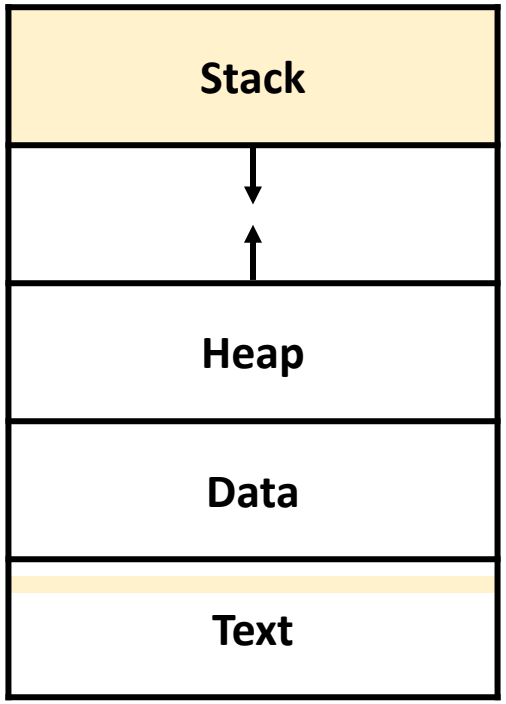

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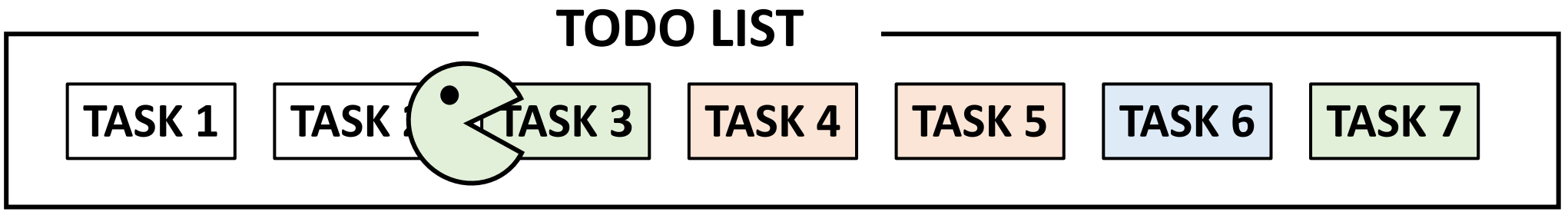

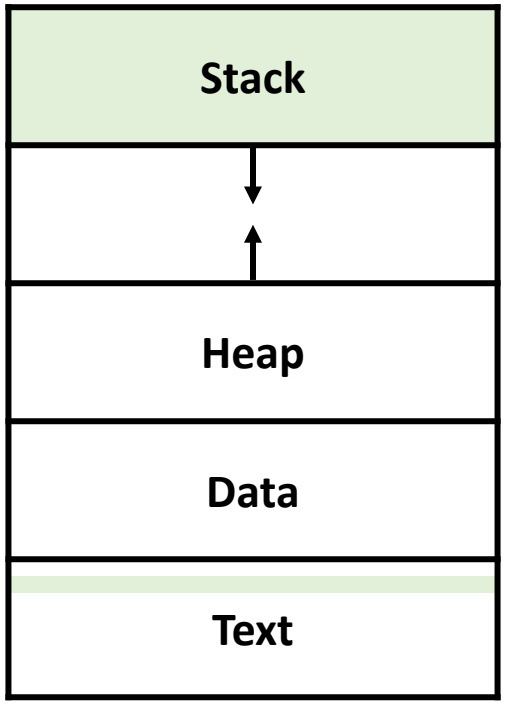

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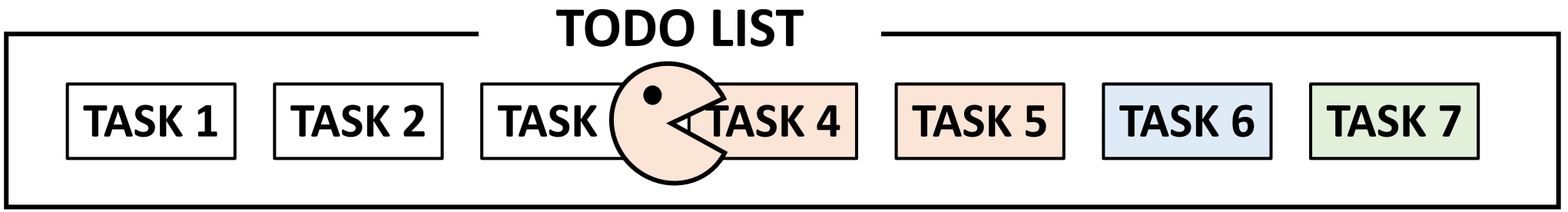

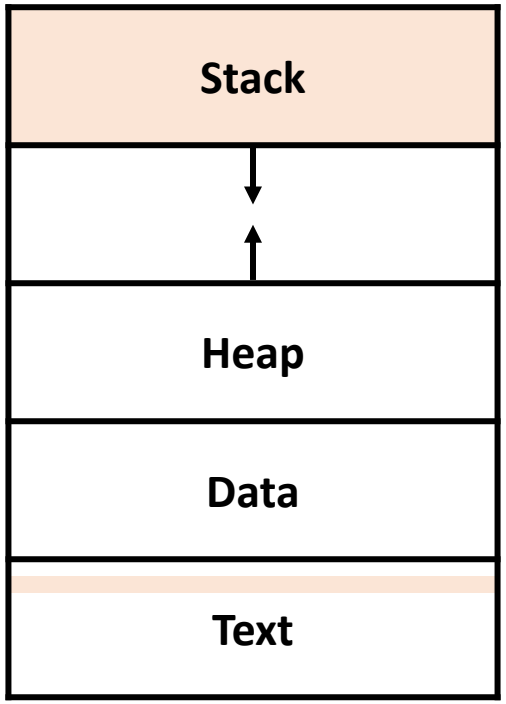

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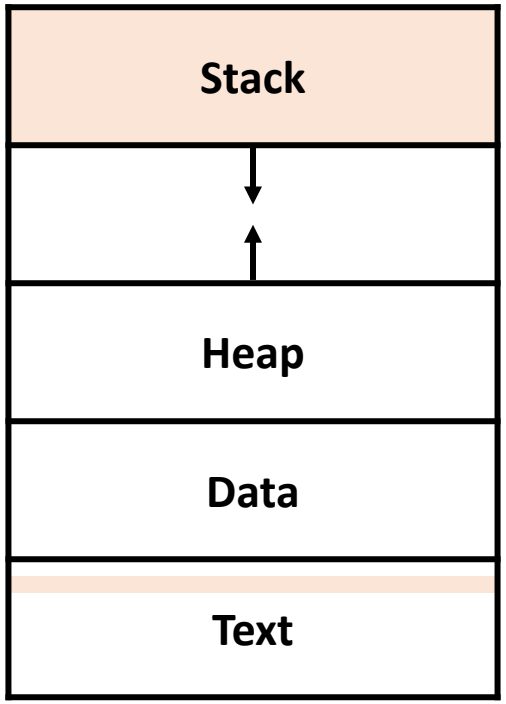

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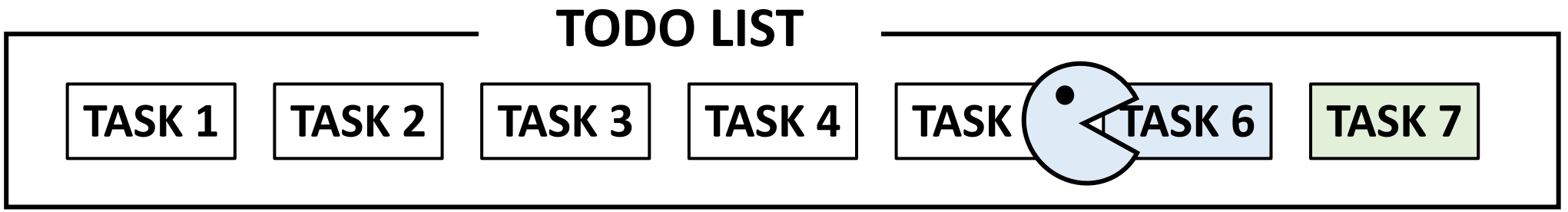

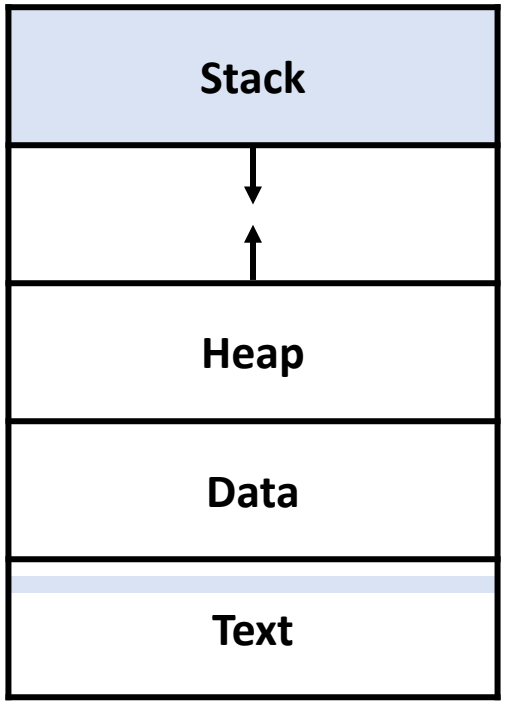

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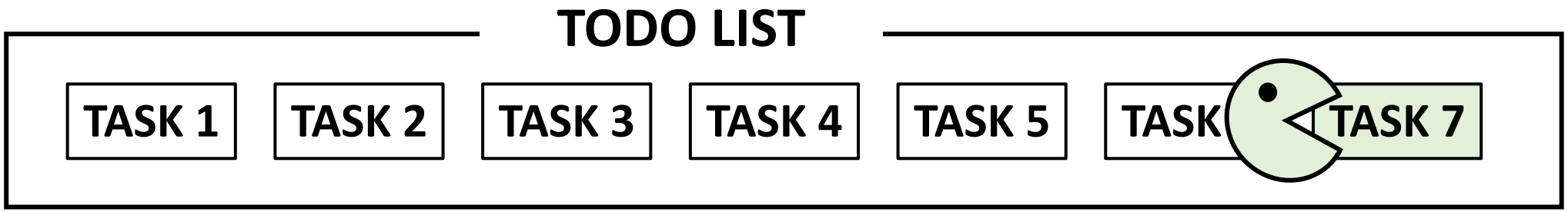
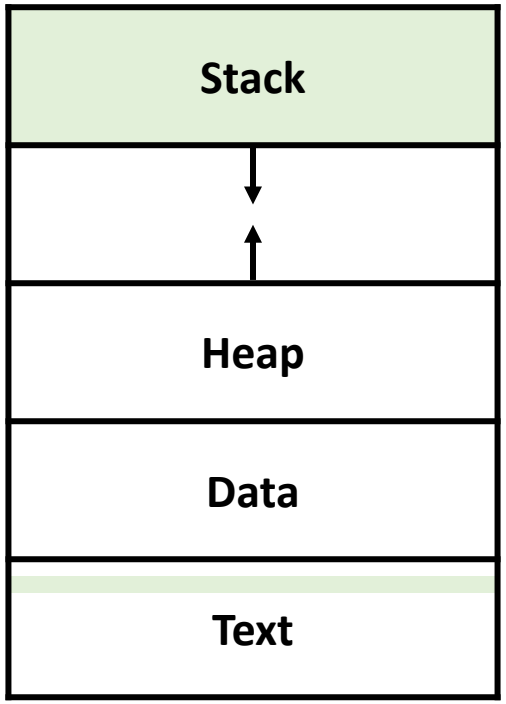
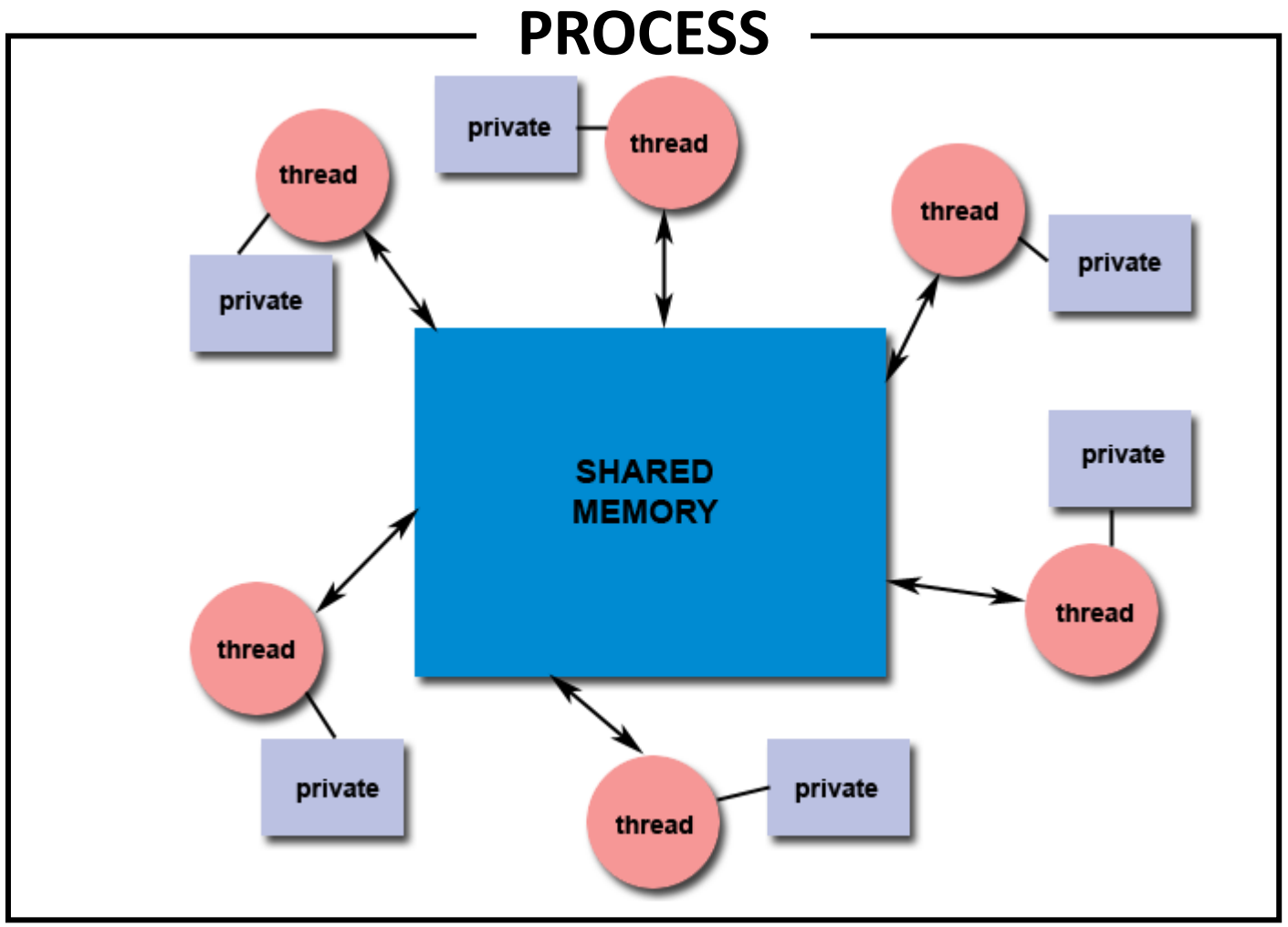
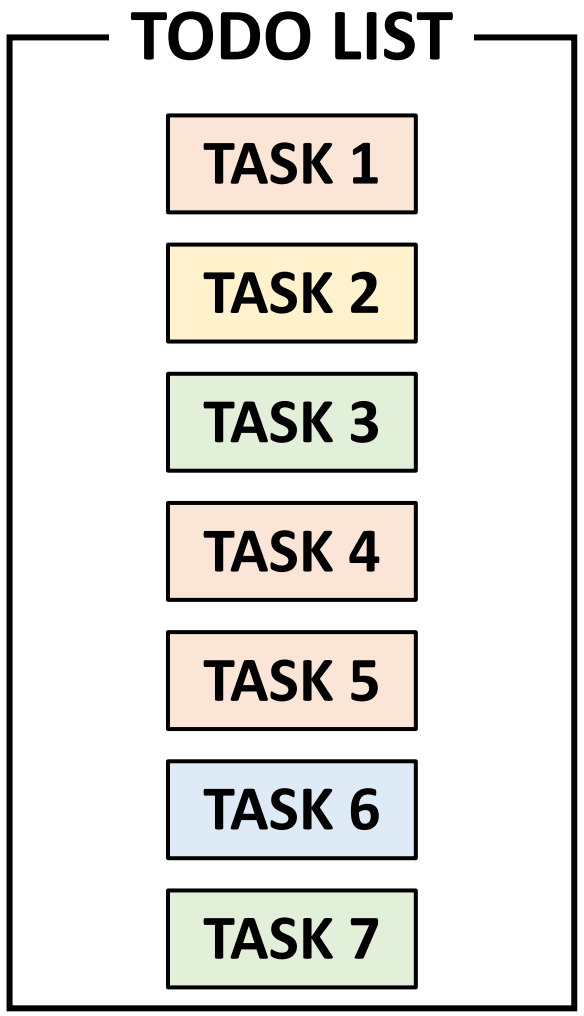




Thread model





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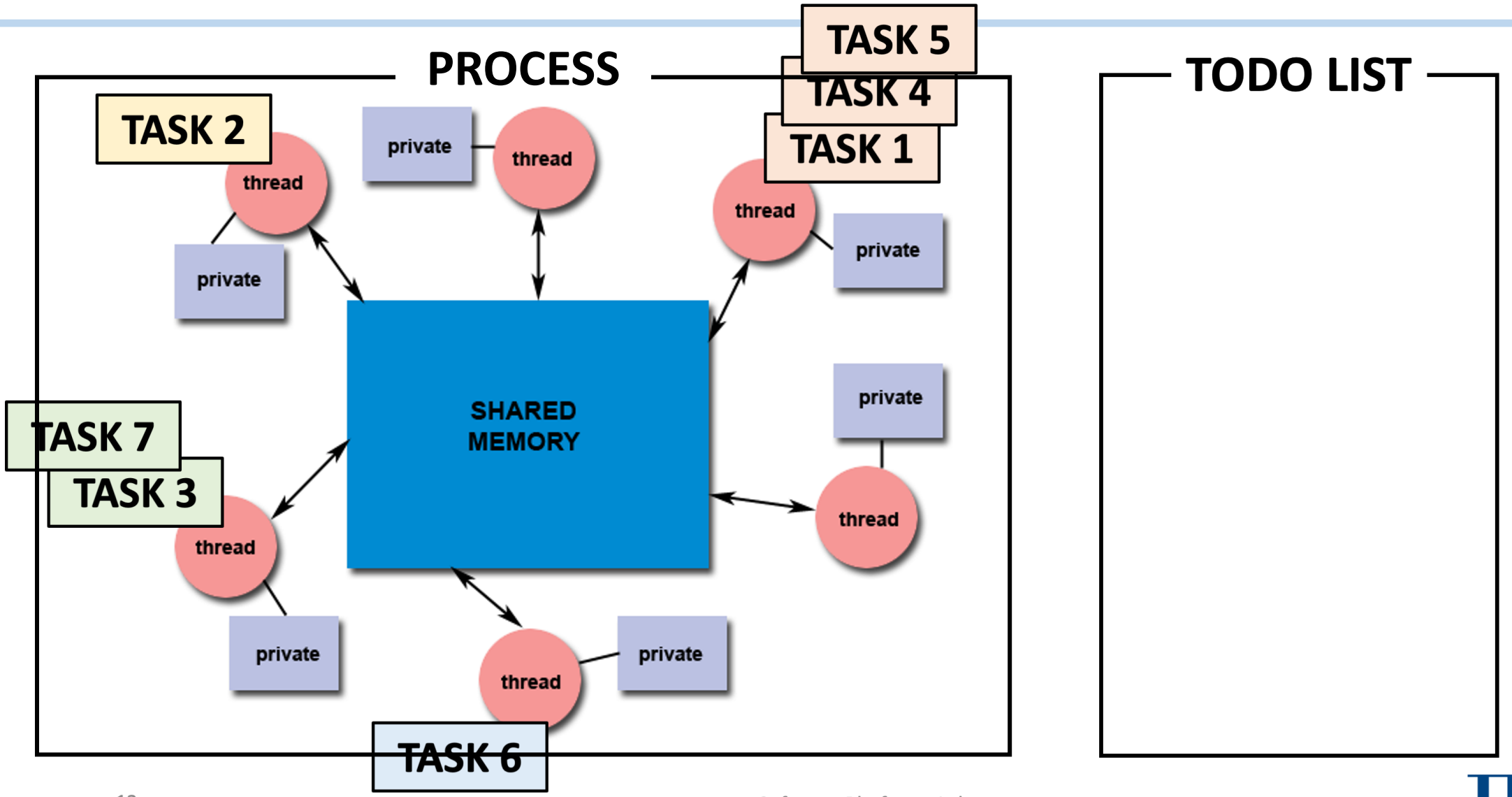
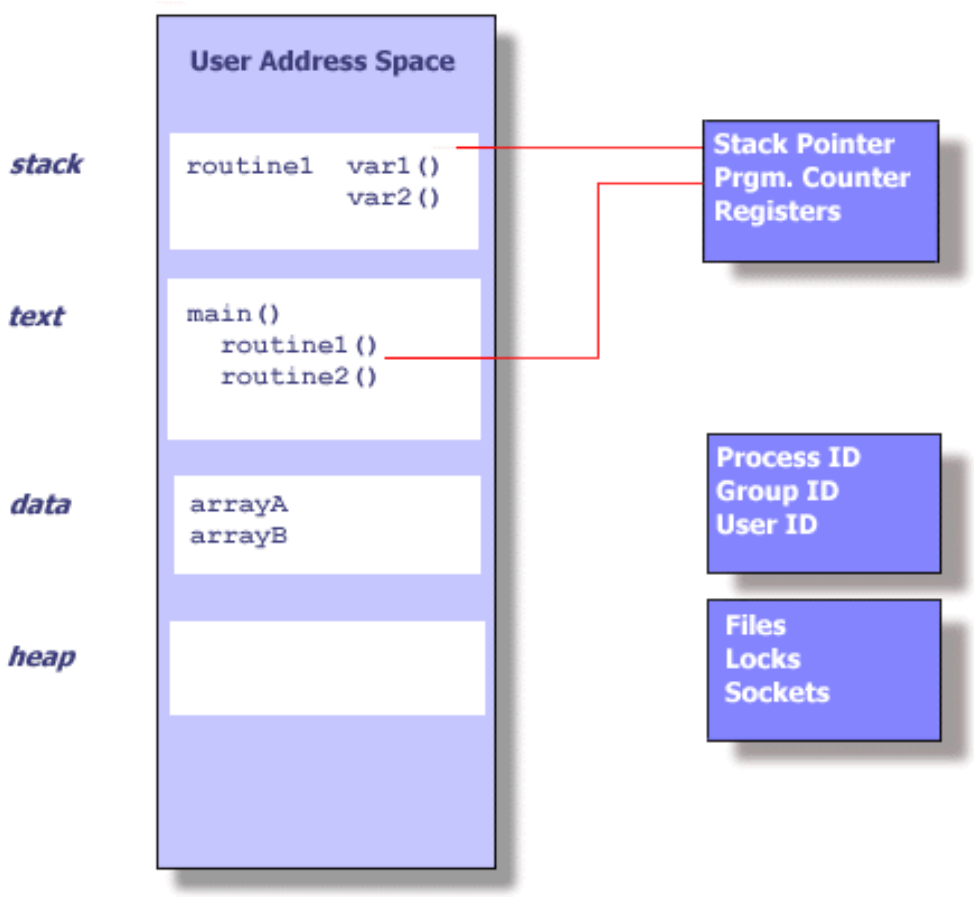
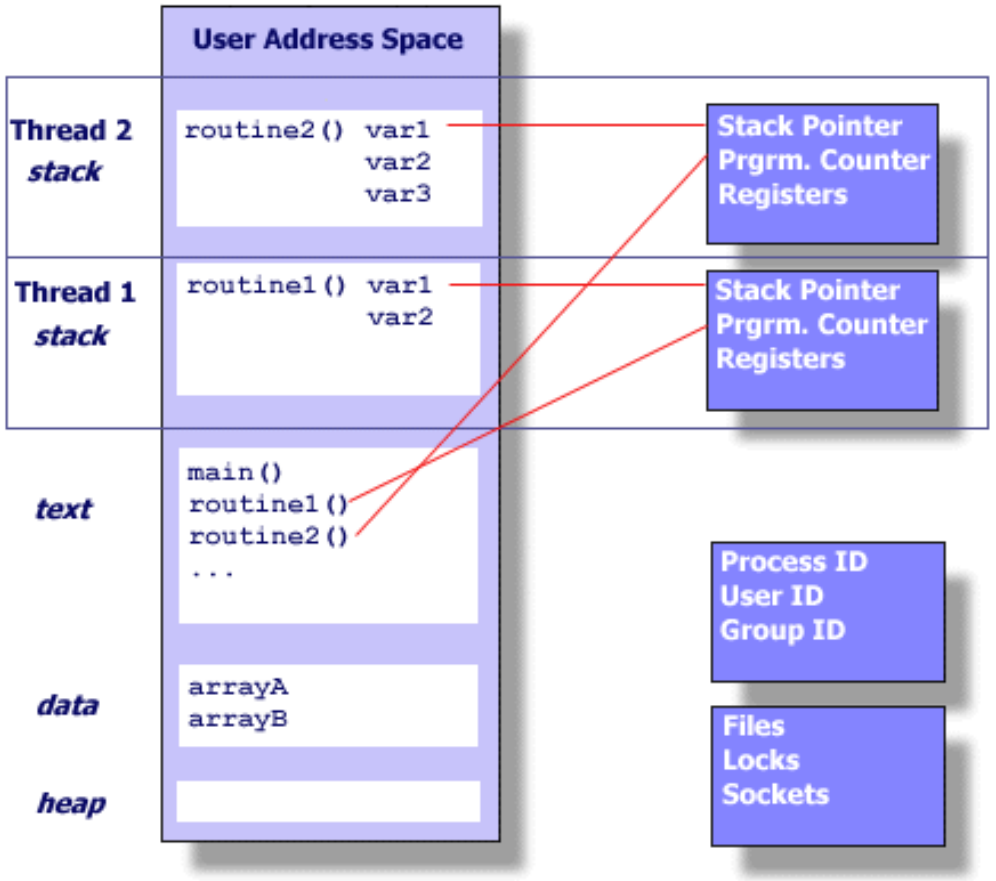


Process vs. Thread

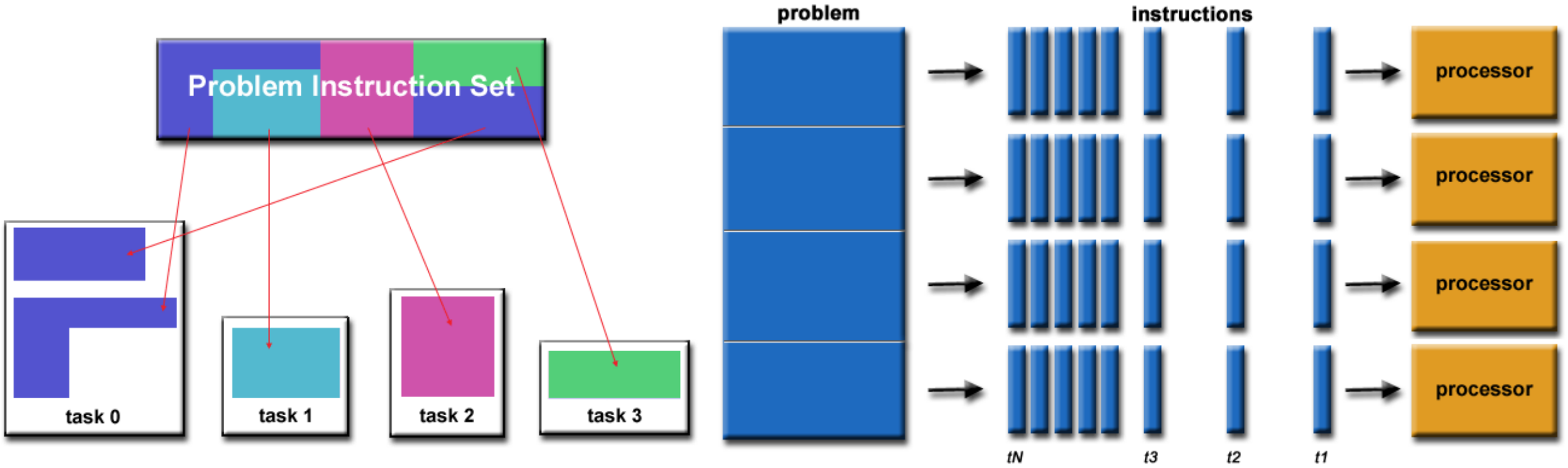


UNIX PROCESS

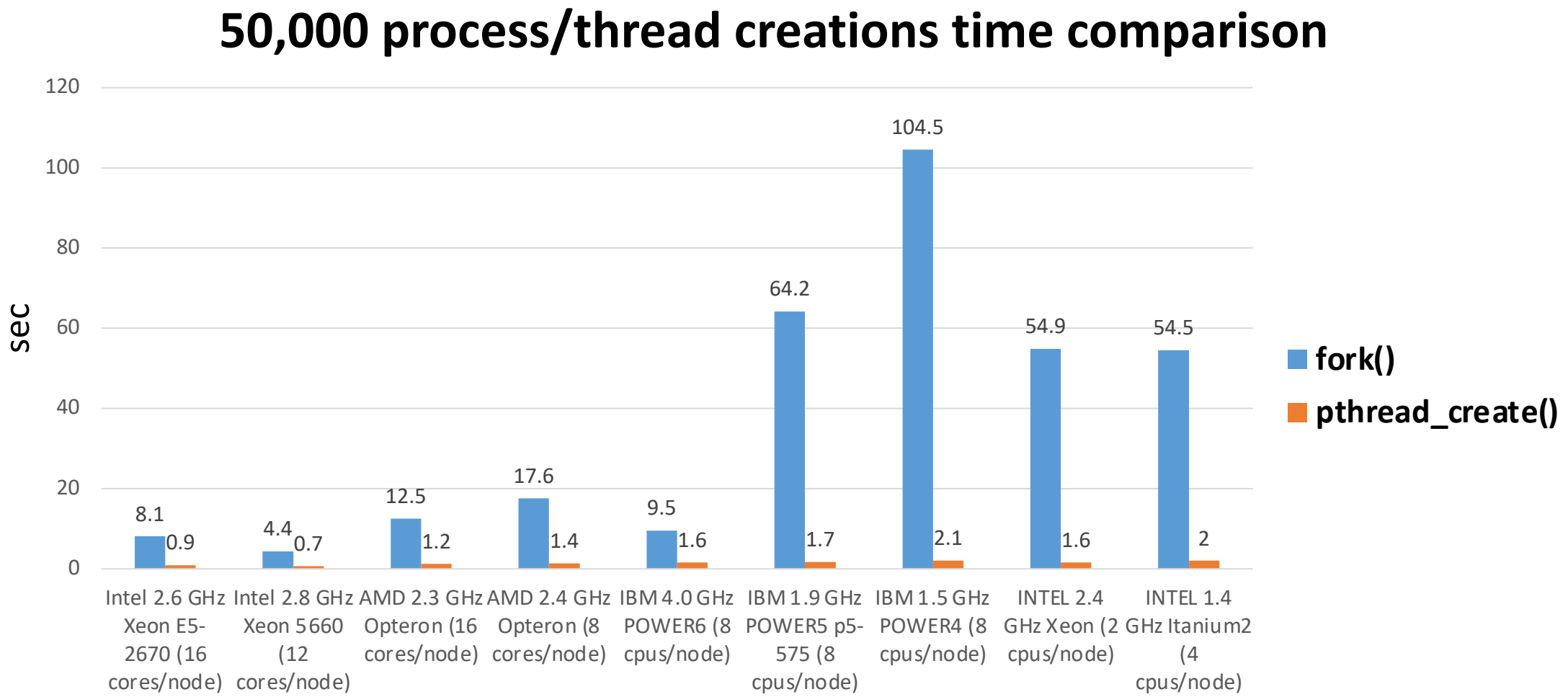


THREADS WITHIN A UNIX PROCESS

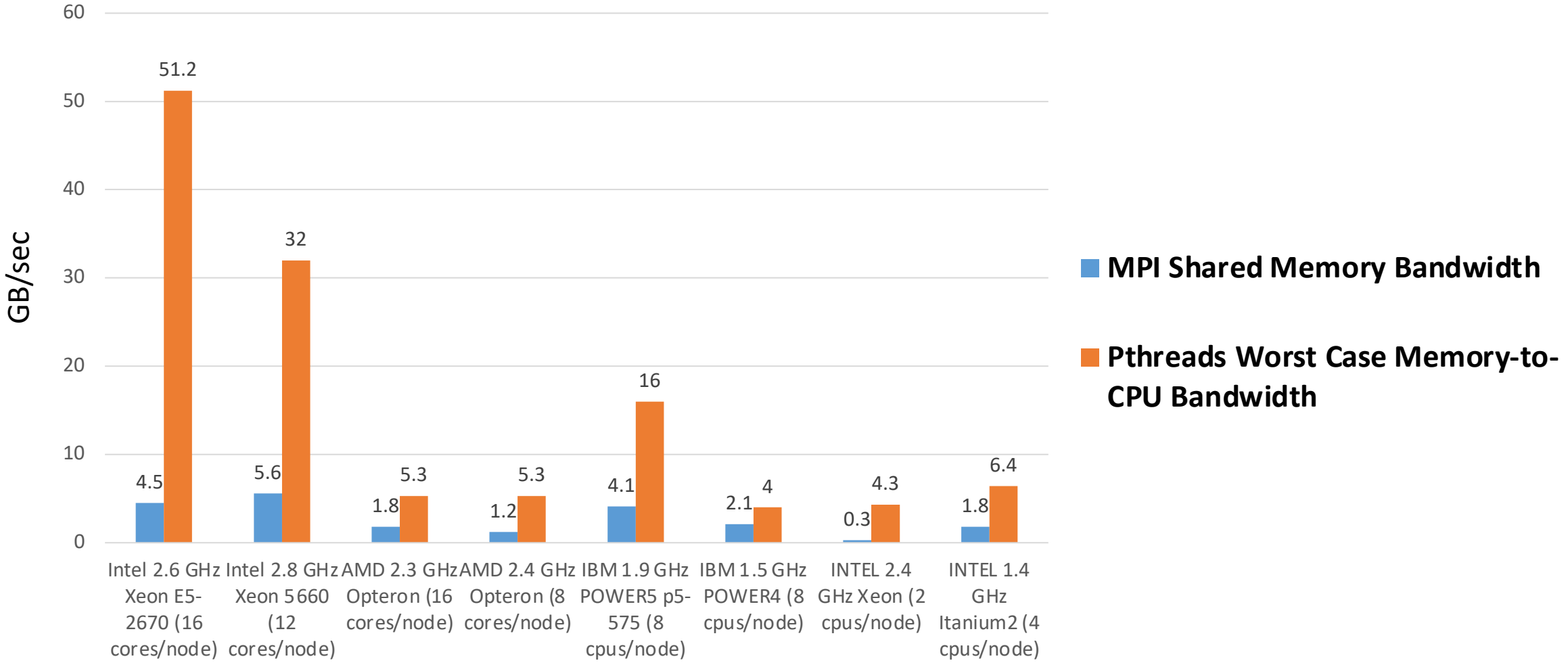
1. Parallel Programming



2. Light Weight



3. Efficient Communications/Data Exchange



The Pthread API

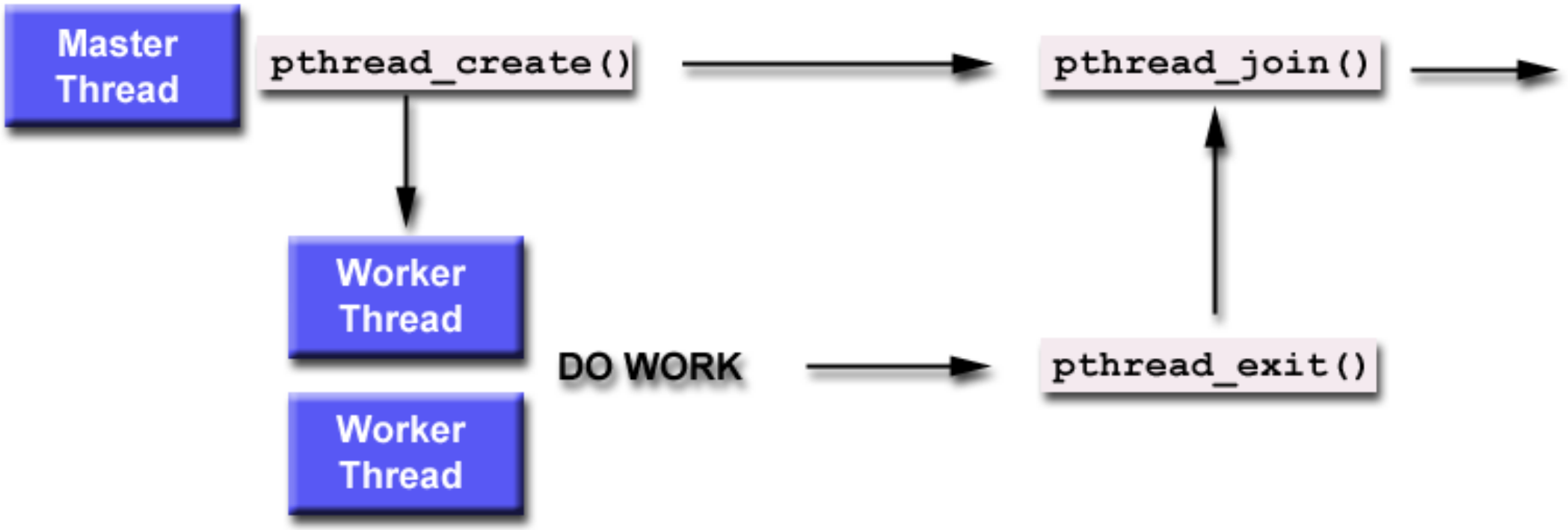
1. **Thread management:** Routines that work directly on threads - creating, detaching, joining, etc.
2. **Mutexes:** Routines that deal with synchronization, called a "mutex", which is an abbreviation for "**mut**ual **ex**clusion". Mutex functions provide for creating, destroying, locking and unlocking mutexes.
3. **Condition variables:** Routines that address communications between threads that share a mutex. Based upon programmer specified conditions. This group includes functions to create, destroy, wait and signal based upon specified variable values.

Compile pthread program

- For portability, the **pthread.h header file** should be included in each source file using the Pthreads library.

Compiler / Platform	Compiler Command	Description
INTEL Linux	icc -pthread	C
	icpc -pthread	C++
PGI Linux	pgcc -lpthread	C
	pgCC -lpthread	C++
GNU Linux, Blue Gene	gcc -pthread	GNU C
	g++ -pthread	GNU C++
IBM Blue Gene	bgxlc_r / bgcc_r	C (ANSI / non-ANSI)
	bgxlC_r, bgxlc++_r	C++

Thread Management



Pthread API – pthread_create

```
int pthread_create(pthread_t *thread,
                   const pthread_attr_t *attr,
                   void *(*start_routine)(void *),
                   void  *arg);
```

- Create a new thread.

@param [out]	thread_t	ID of new thread
@param [in]	attr	Thread attribute configuration (e.g.,Stack size)
@param[in]	start_routine	Thread function to execute (main function of new thread)
@param[in]	arg	argument(s) pass(es) to start_routine
@return		If success 0, else error num

Pthread API – pthread_join

```
int pthread_join(pthread_t thread,
                 void **ret_val);
```

- Waits for the termination of a specific thread.
  - Return immediately if the target thread already terminated.

@param [in]	thread_t	Thread ID of target thread which would terminate
@param [out]	ret_val	Return value of terminated thread
@return		If success 0

Pthread API – pthread_exit

```
void pthread_exit(void *ret_val);
```

- Terminates the thread.
  - Return call in thread start function is implicit call of pthread_exit().

@param [in] ret_val	Return value of terminated thread. Another thread which waits for the thread by pthread_join can get this value.

Mutex variables

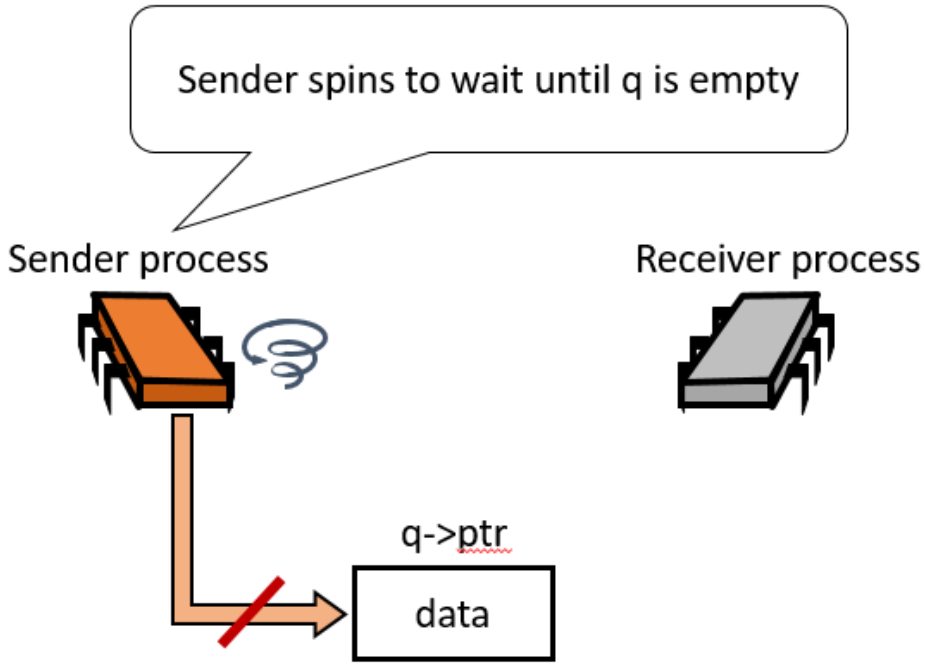
- Race condition

Thread 1	Thread 2	Balance
Read balance: $1000		**$1000**
	Read balance: $1000	**$1000**
	Deposit $200	**$1000**
Deposit $200		**$1000**
Update balance $1000+$200		**$1200**
	Update balance $1000+$200	**$1200**

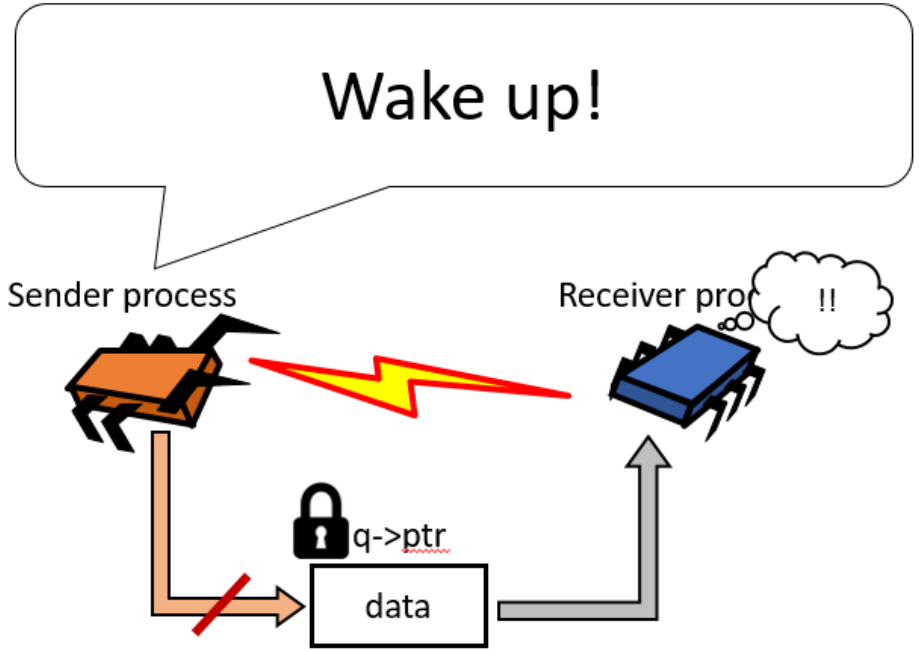
Mutex variables caution

Condition variables

- Spin wait (Spin Lock)

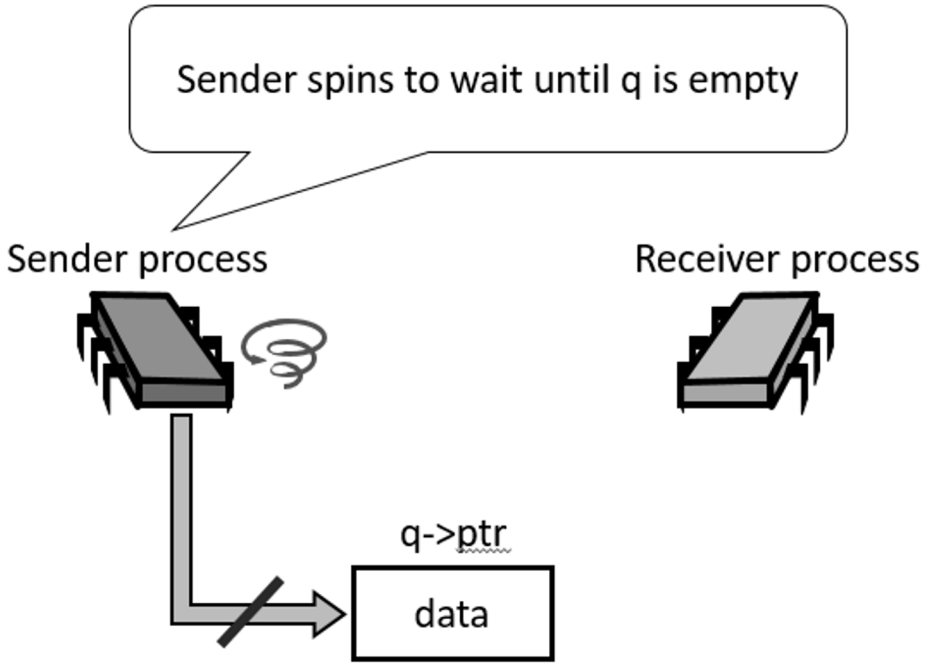


- Sleep – and – WakeUp



Condition variables

- Spin wait (Spin Lock)



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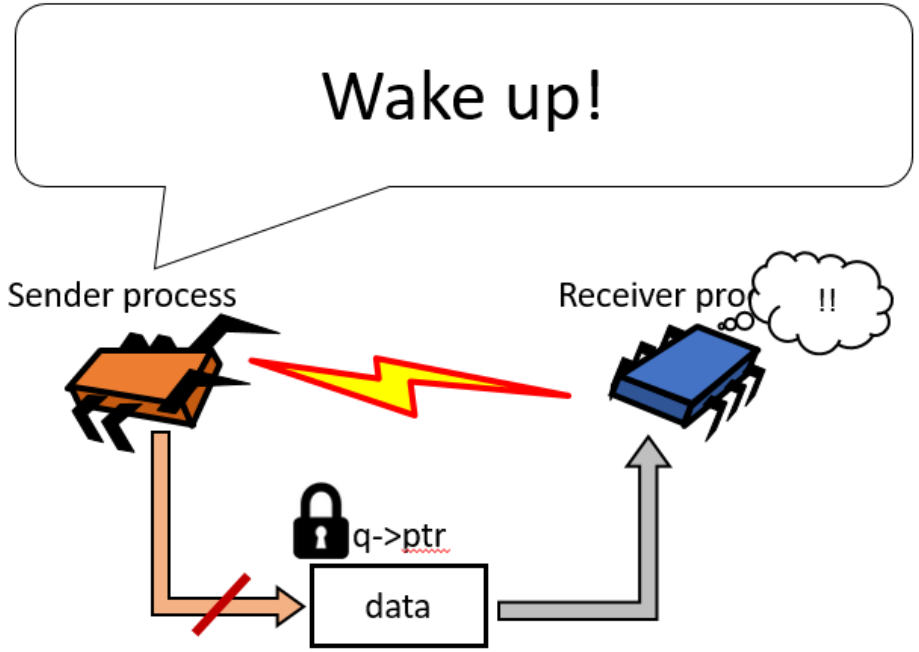

Practice

- Normally, performing a merge sort on a single thread takes a long time.
- Implement merge sort with 4 threads executing on 4 different parts. i.e. each thread sorts ¼ of all elements.
- After all child threads are done, the master thread should merge them again to make the whole elements sorted.

- Make sure that multiple processors (at least 4) are assigned to the virtual machine.
- Compare execution time using ‘time’ command.
  - Ex) time ./prac_pthread
- Tip: Use –O3 option to make it significantly faster

Thank you.