OSLab: Threads

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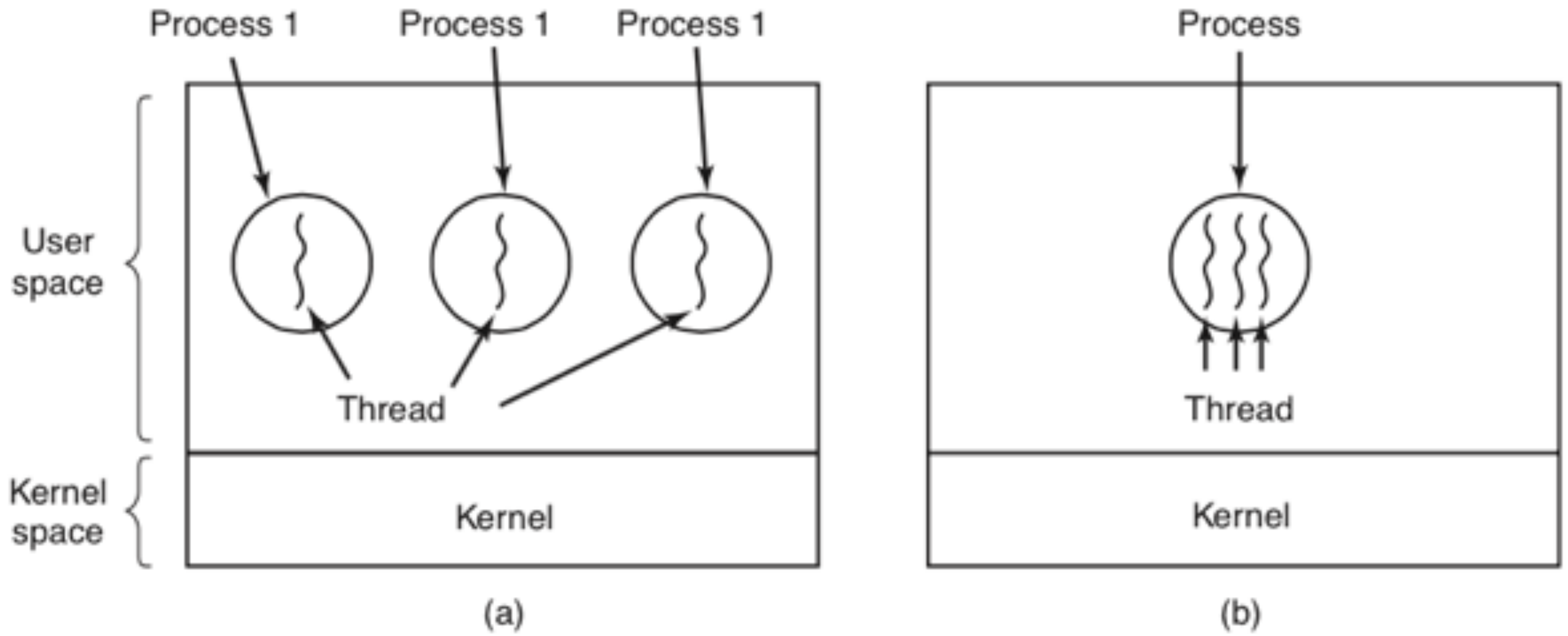
What are threads ?

- **Wikipedia:** 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.
- “Processes within processes”
- “Lightweight processes”

Process vs Thread

a single-threaded process = resource + execution
a multi-threaded process = resource + executions



- A process =a unit of resource ownership, used to group resources together

- A thread = a unit of scheduling, scheduled for execution on the CPU.

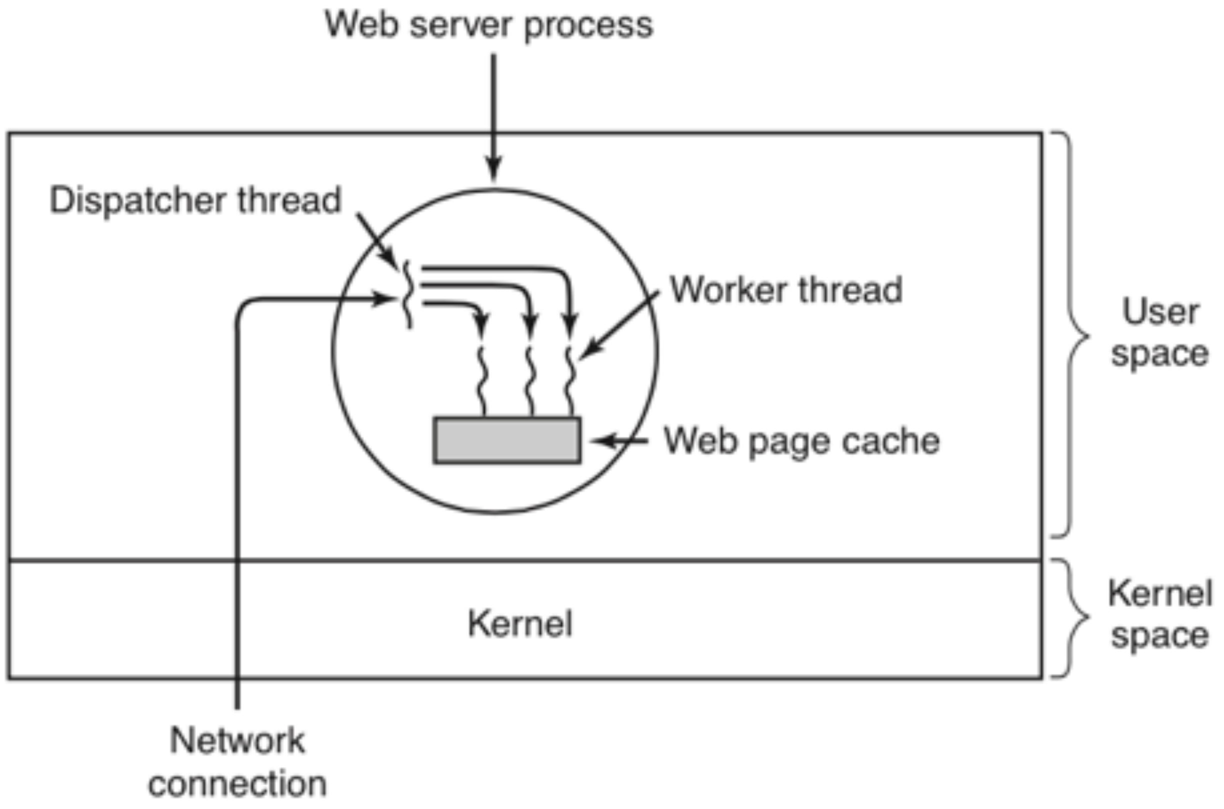
Process vs Thread

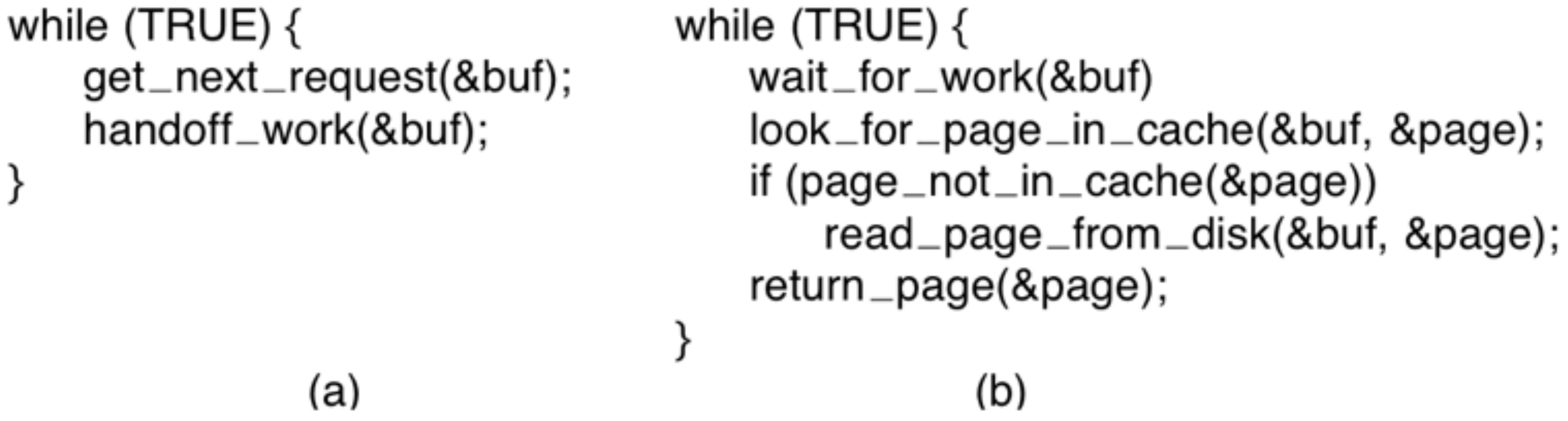
Threads share resources	Processes share devices
Memory space	CPU, disk,
File pointers	memory, printers
…	…

Threads own	Processes Own
Program counter	Threads +
Registers	Memory space
Stack	File pointers
…	…

- All threads of a process have same user. Hence no protection among threads.

Multi-threaded web server





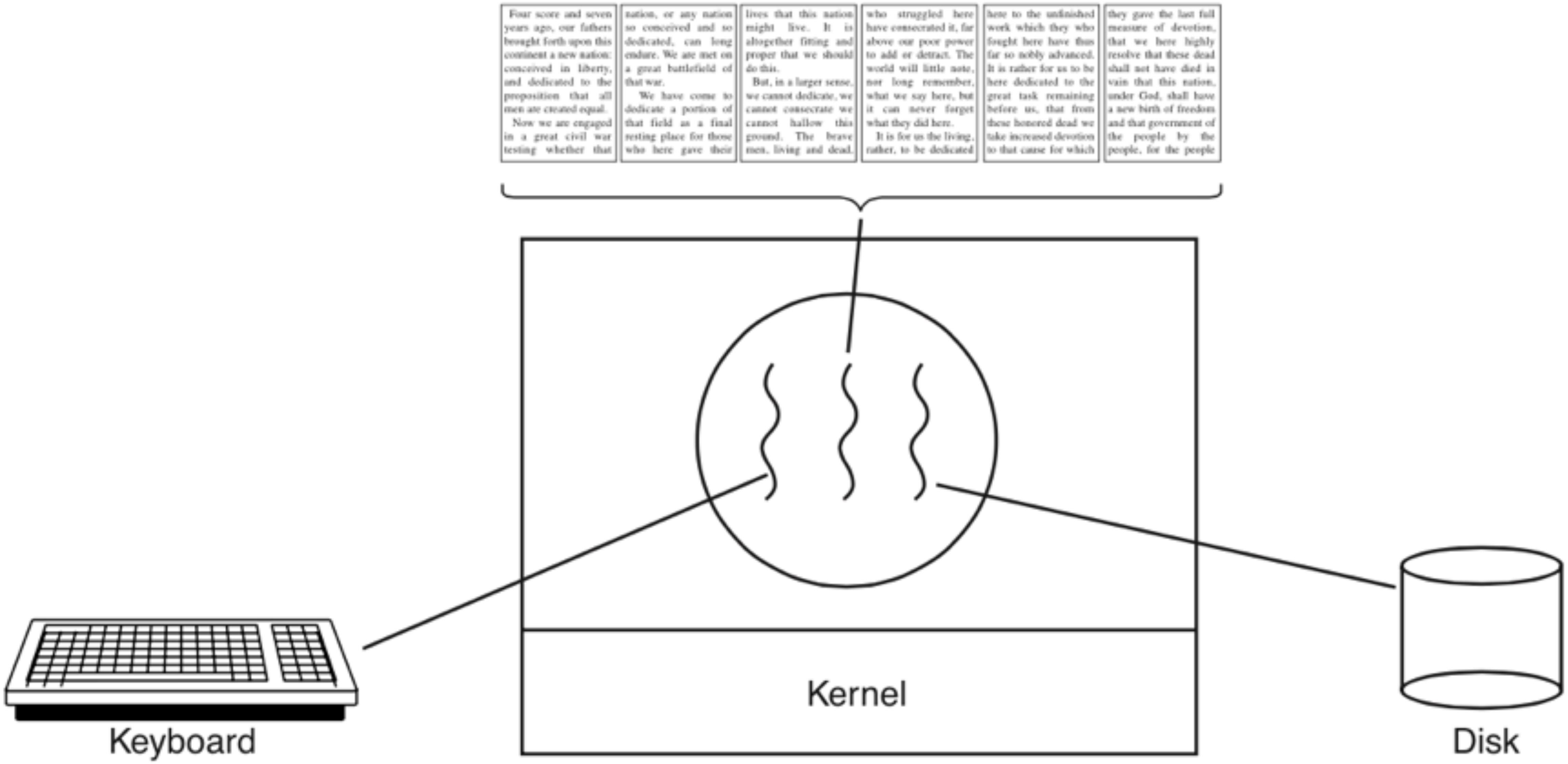
```
while (TRUE) {
    get_next_request(&buf);
    handoff_work(&buf);
}
```

(a)

```
while (TRUE) {
    wait_for_work(&buf)
    look_for_page_in_cache(&buf, &page);
    if (page_not_in_cache(&page))
        read_page_from_disk(&buf, &page);
    return_page(&page);
}
```

(b)

Multi-threaded editor



Four score and seven years ago, our fathers brought forth upon this continent a new nation: conceived in liberty, and dedicated to the proposition that all men are created equal.

Now we are engaged in a great civil war testing whether that nation, or any nation so conceived and so dedicated, can long endure. We are met on a great battlefield of that war.

We have come to dedicate a portion of that field as a final resting place for those who here gave their lives that this nation might live. It is altogether fitting and proper that we should do this.

But, in a larger sense, we cannot dedicate, we cannot consecrate we cannot hallow this ground. The brave men, living and dead, who struggled here have consecrated it, far above our poor power to add or detract. The world will little note, nor long remember, what we say here, but it can never forget what they did here.

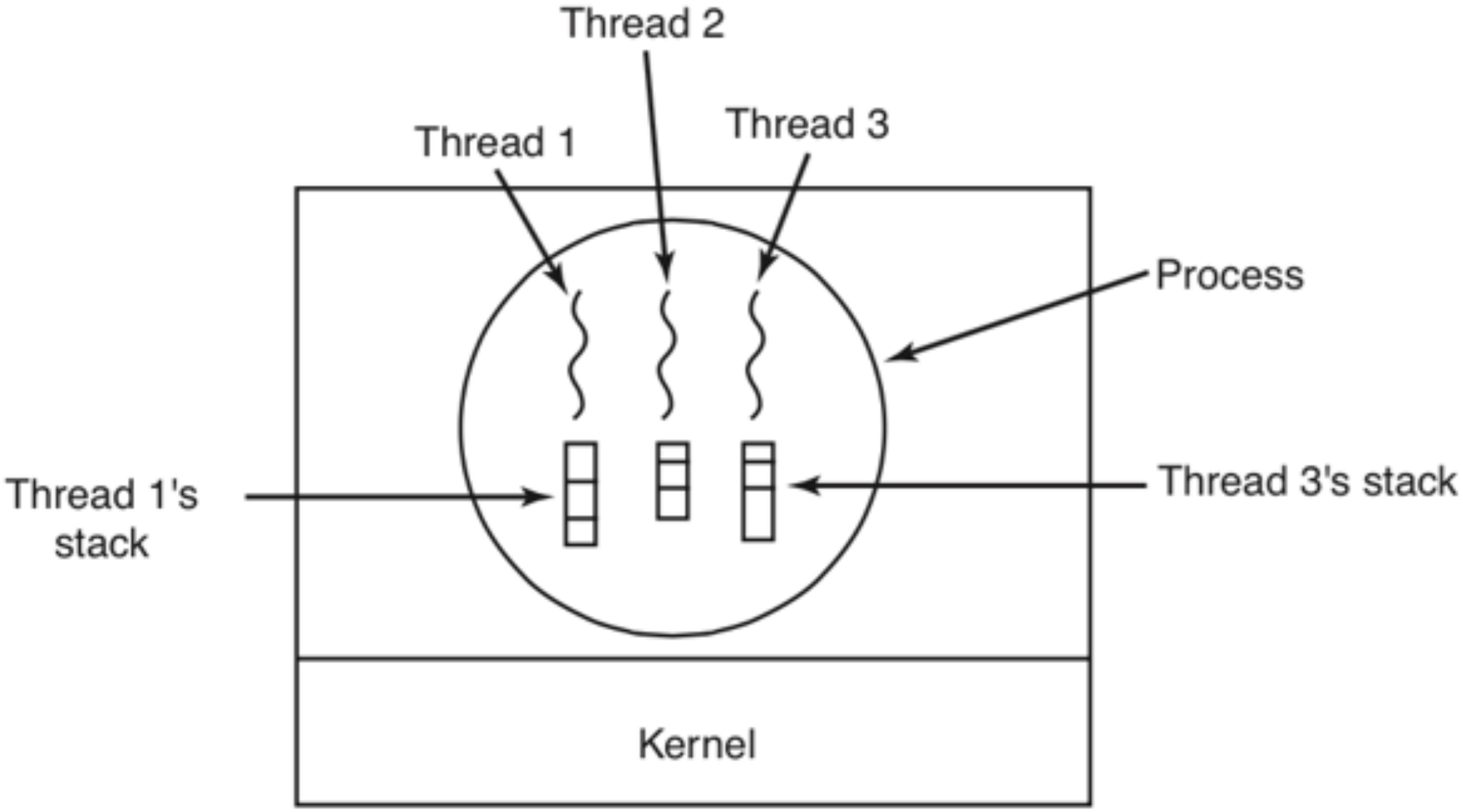
It is for us the living, rather, to be dedicated here to the unfinished work which they who fought here have thus far so nobly advanced. It is rather for us to be here dedicated to the great task remaining before us, that from these honored dead we take increased devotion to that cause for which they gave the last full measure of devotion, that we here highly resolve that these dead shall not have died in vain that this nation, under God, shall have a new birth of freedom and that government of the people by the people, for the people

Advantages of multi-threading

- Parallelisation: Use multiple cores / cpus. e.g. multithreaded matrix multiplication.
- Responsiveness: Longer running tasks can be run in a worker thread. The main thread remains responsive e.g. editor.
- Cheaper: Less resource intensive than processes both memory and time.
- Simpler sharing: IPC harder and more time consuming.
- Better system utilisation: jobs finish faster.

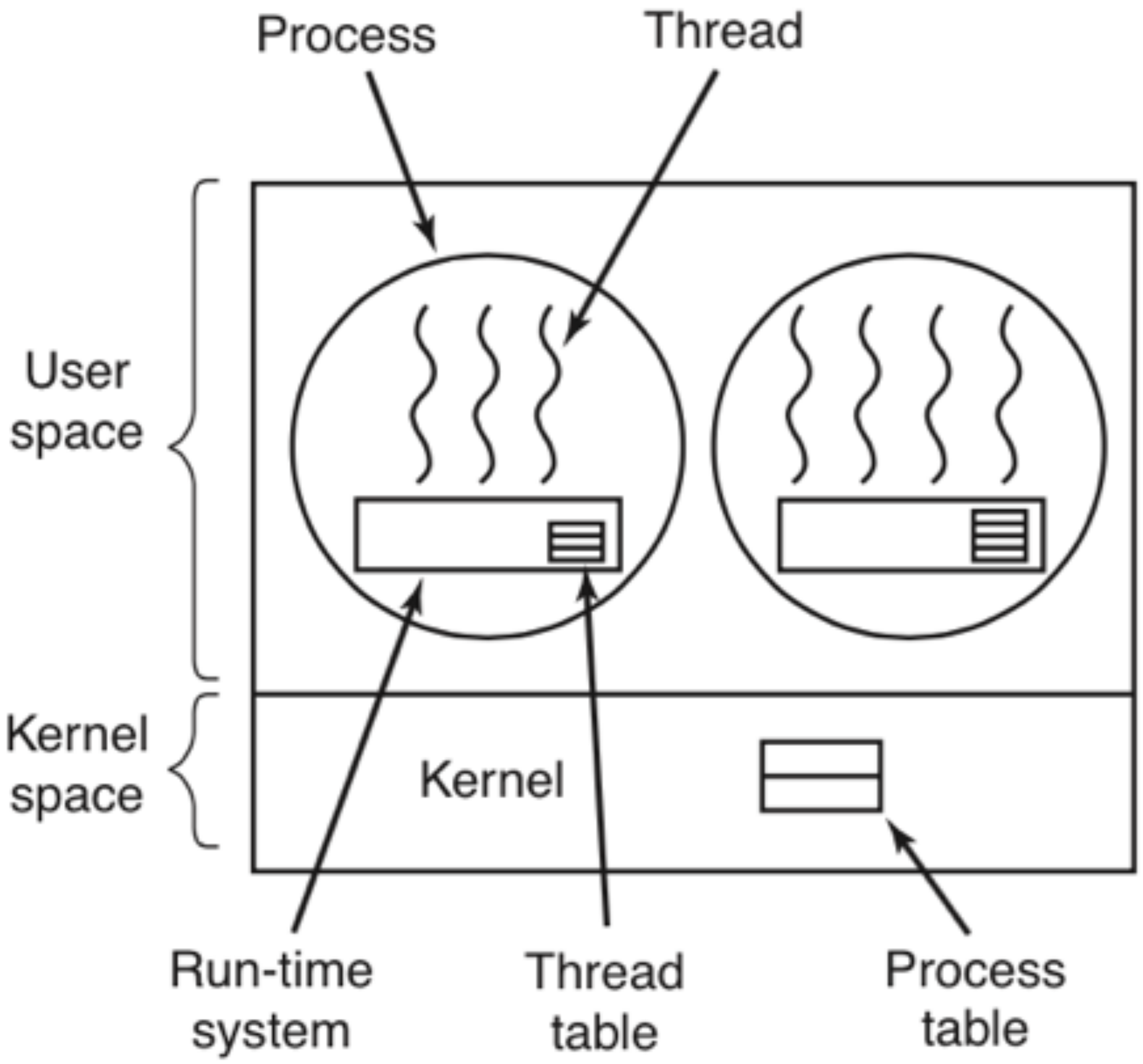
Each thread has own stack

- Stores data local to function. Can take advantage of functions, recursion, etc.
- Stack is destroyed when the thread exits.

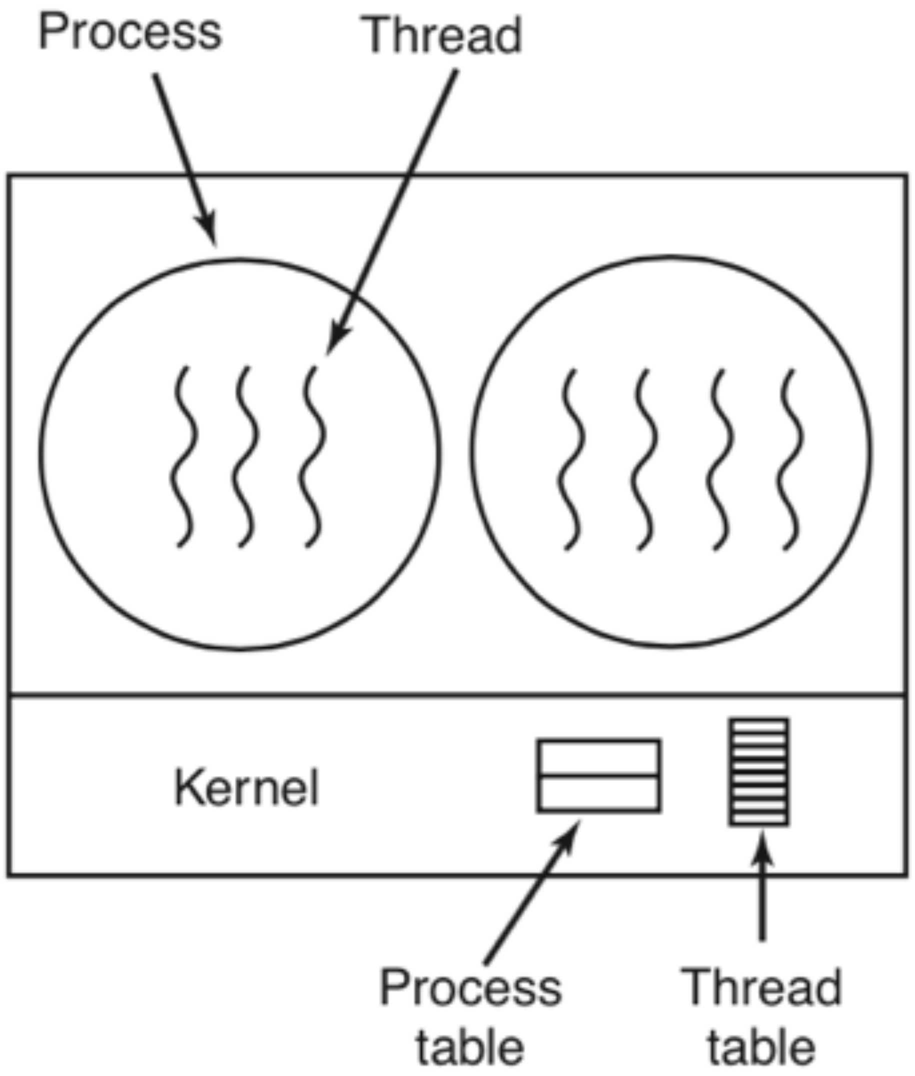


Thread implementation

User-level threads



Kernel-level threads



User-level threads

Advantages:

- No dependency on OS - uniform behaviour.
- Application specific thread scheduling.
- Simple and fast - creation, switching, etc.

Disadvantages:

- Entire process gets one time schedule.
- Entire process gets blocked if one thread is blocked - requires non-blocking system calls.
- Page fault in one thread can cause blocking, even though data for other threads are in memory.

Kernel-level threads

- Advantage: Kernel schedules threads independently - all above disadvantages are gone.

Disadvantages:

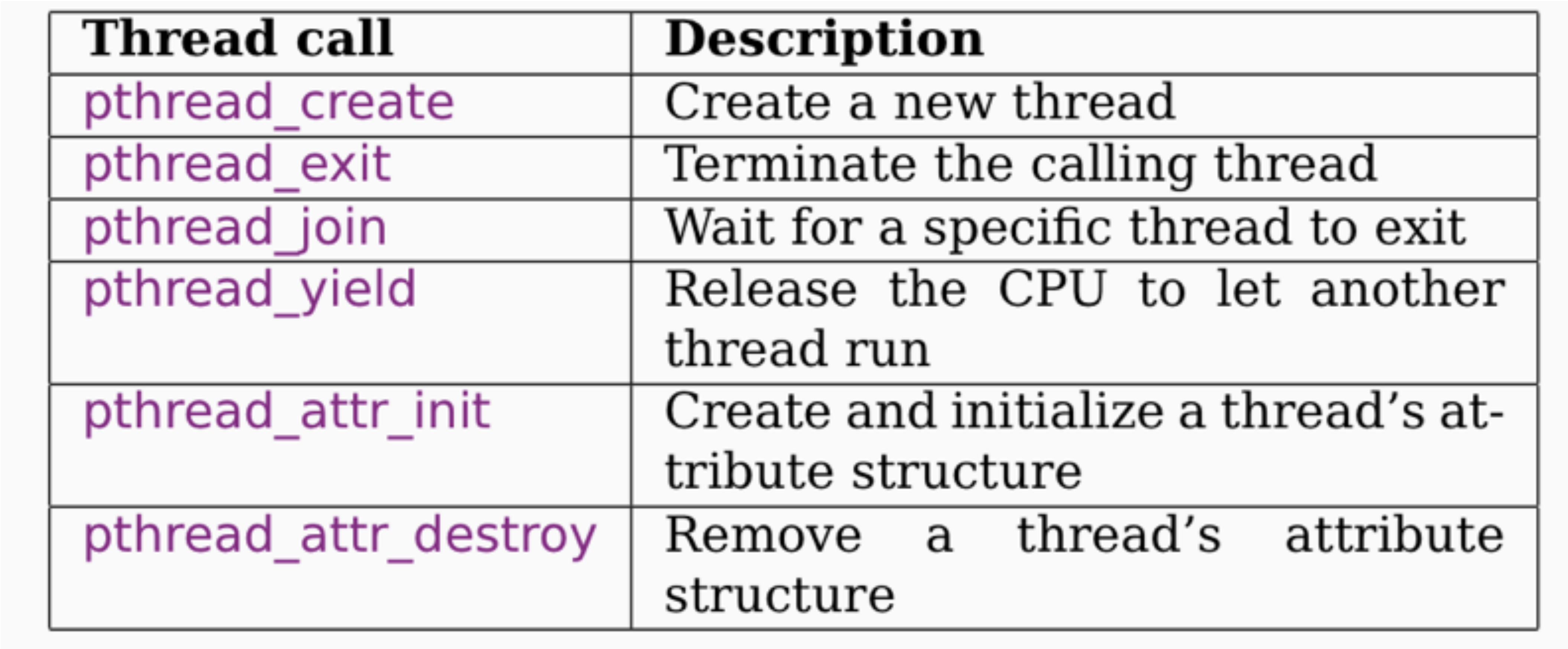
★ Overhead: more information per thread needs to be stored. Context switch is also slower.

★ Complexity: Kernel becomes more complex. Needs to handle thread scheduling, etc.

Hybrid implementations are possible !!

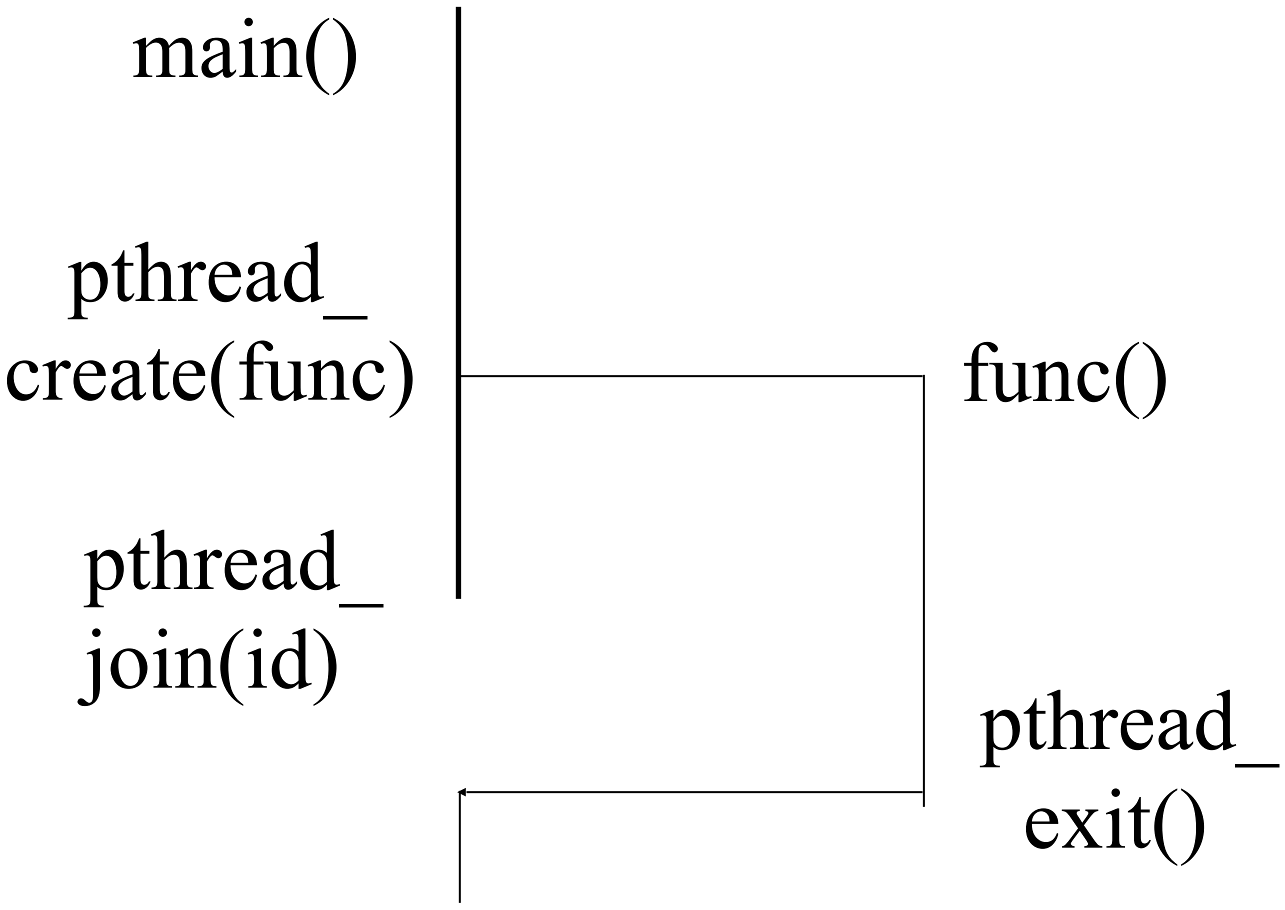
POSIX Threads

- IEEE 1003.1 c: The standard for writing portable threaded programs. The threads package it defines is called Pthreads, including over 60 function calls, supported by most UNIX systems.
- Some functions:



Thread call	**Description**
pthread_create	Create a new thread
pthread_exit	Terminate the calling thread
pthread_join	Wait for a specific thread to exit
pthread_yield	Release the CPU to let another thread run
pthread_attr_init	Create and initialize a thread's attribute structure
pthread_attr_destroy	Remove a thread's attribute structure

Typical structure



main()

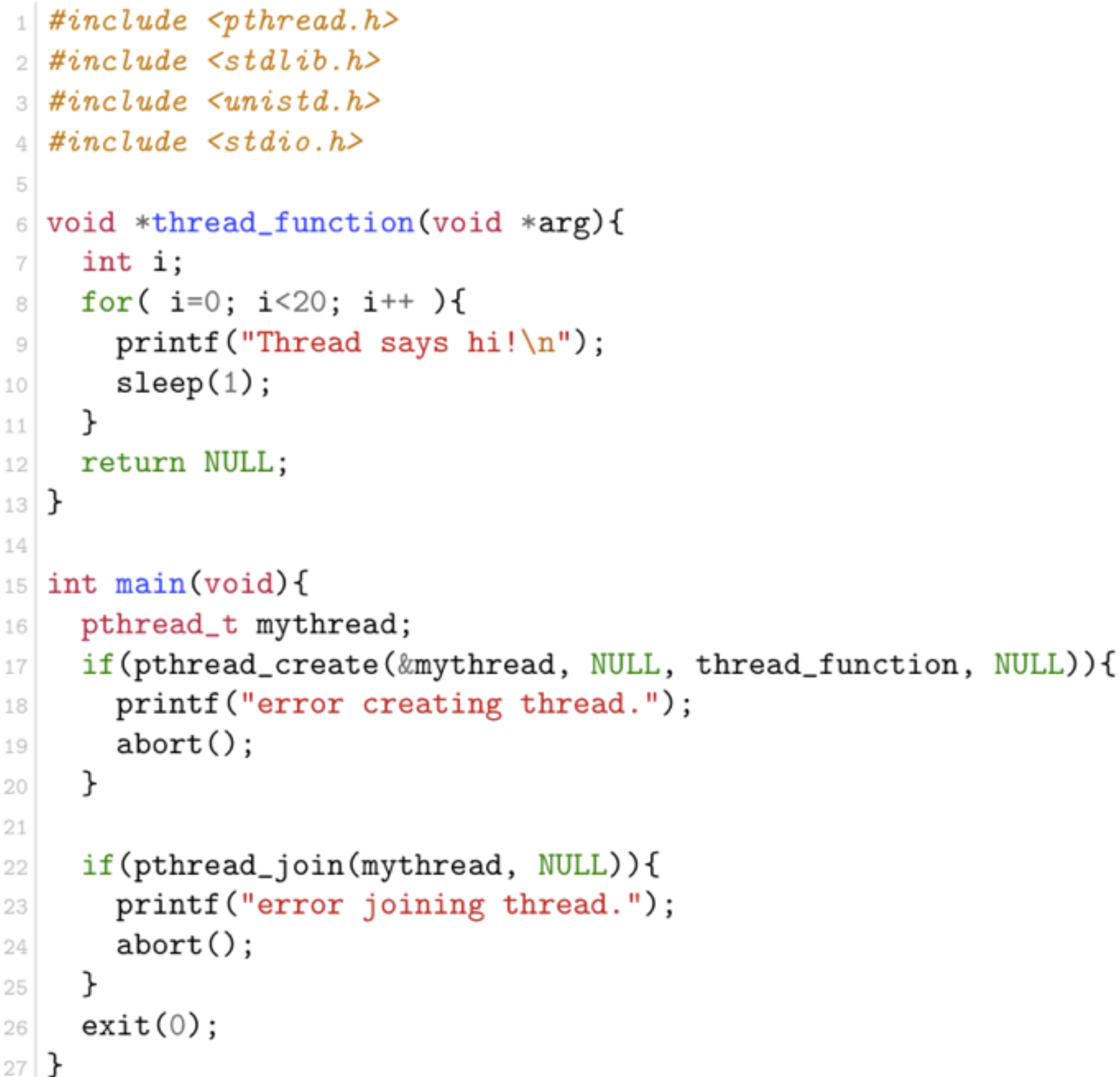
pthread_create(func)

func()

pthread_join(id)

pthread_exit()

POSIX Threads Example



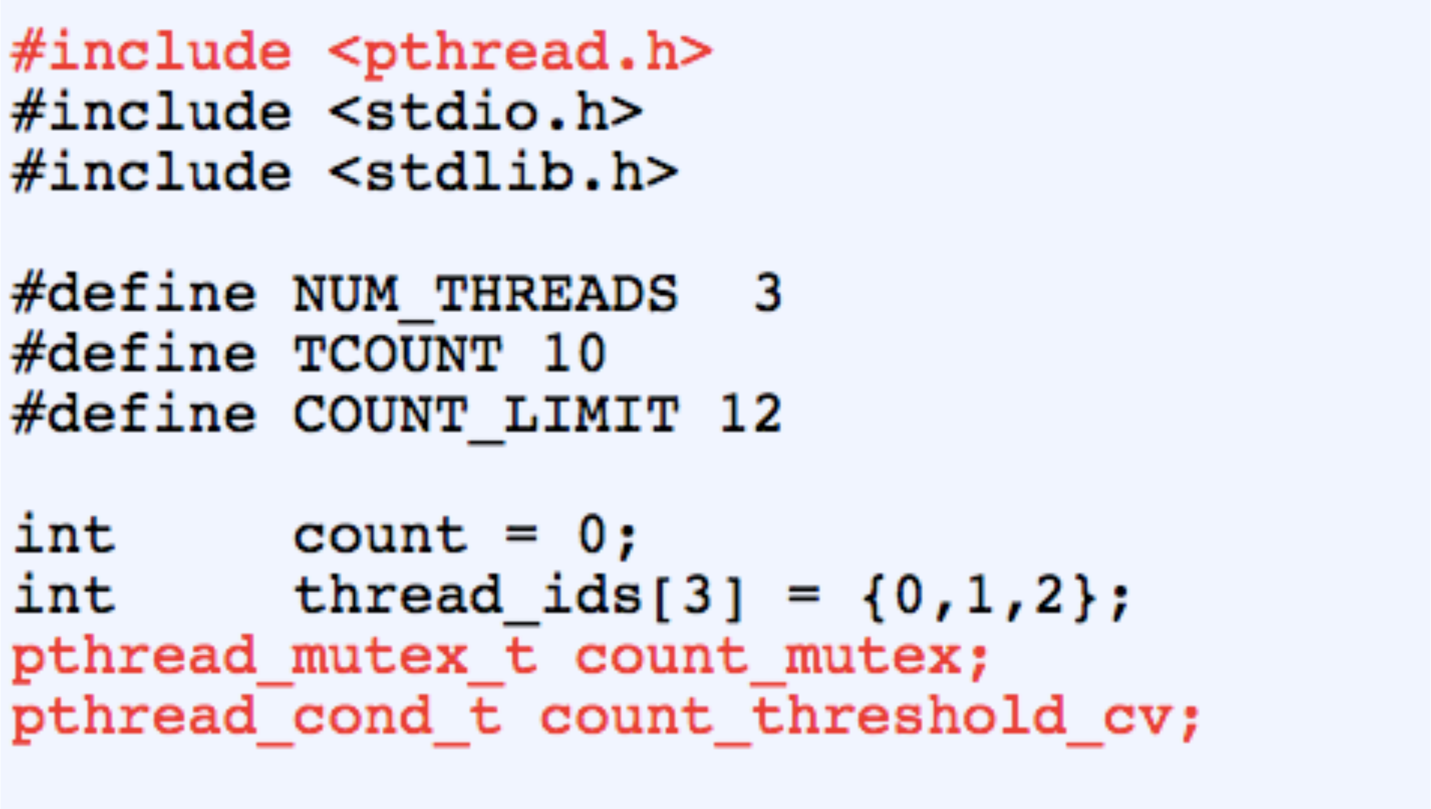
```c
#include <pthread.h>
#include <stdlib.h>
#include <unistd.h>
#include <stdio.h>

void *thread_function(void *arg){
  int i;
  for( i=0; i<20; i++ ){
    printf("Thread says hi!\n");
    sleep(1);
  }
  return NULL;
}

int main(void){
  pthread_t mythread;
  if(pthread_create(&mythread, NULL, thread_function, NULL)){
    printf("error creating thread.");
    abort();
  }

  if(pthread_join(mythread, NULL)){
    printf("error joining thread.");
    abort();
  }
  exit(0);
}
```

Pthread Mutex

- Access shared data in a thread safe manner.
- Typical sequence:
  - Create and initialize a mutex variable
  - Several threads attempt to lock the mutex
  - Only one succeeds and that thread owns the mutex
  - The owner thread performs some set of actions
  - The owner unlocks the mutex
  - Another thread acquires the mutex and repeats the process
  - Finally the mutex is destroyed

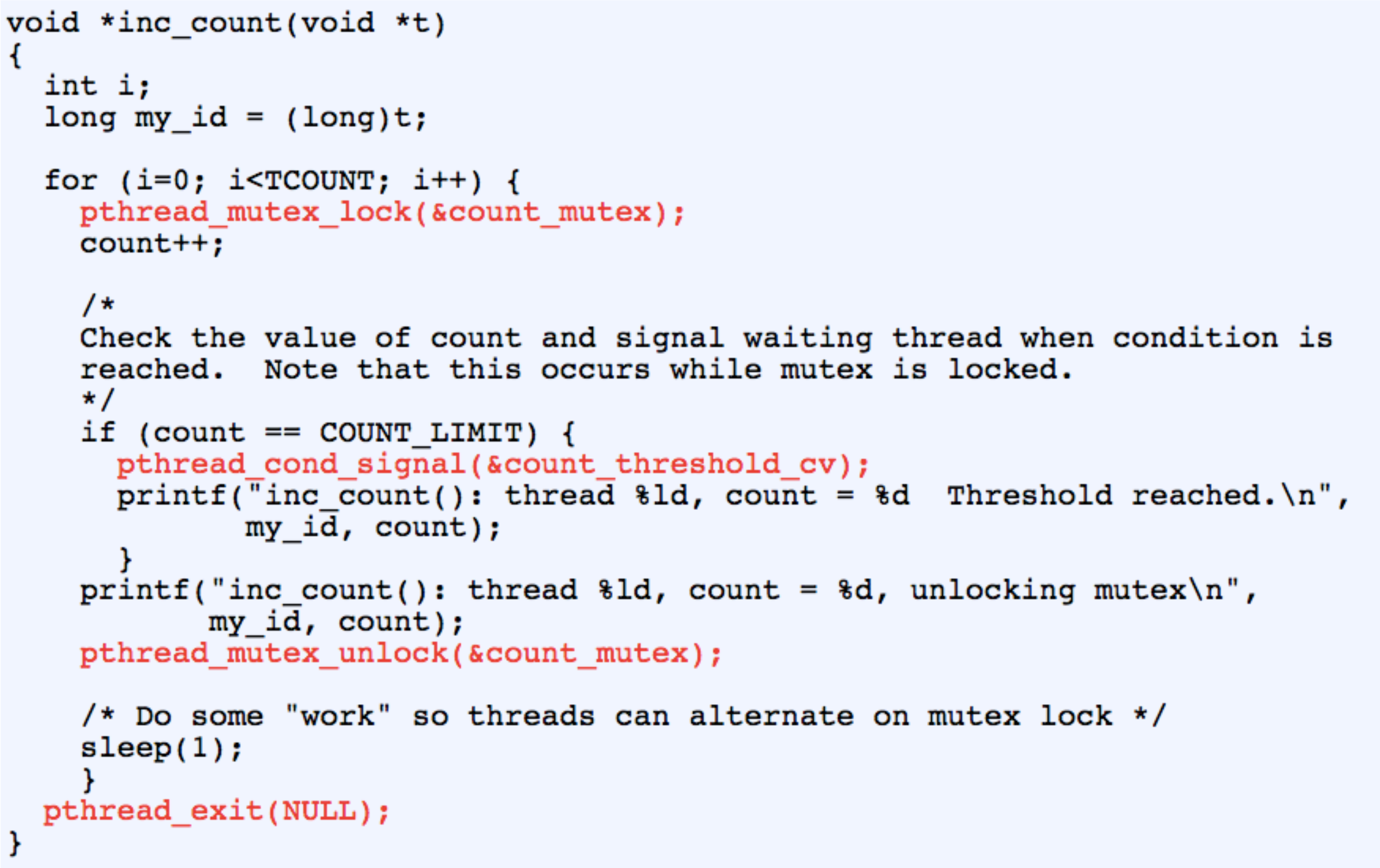
Pthread Sync Example

- Preamble



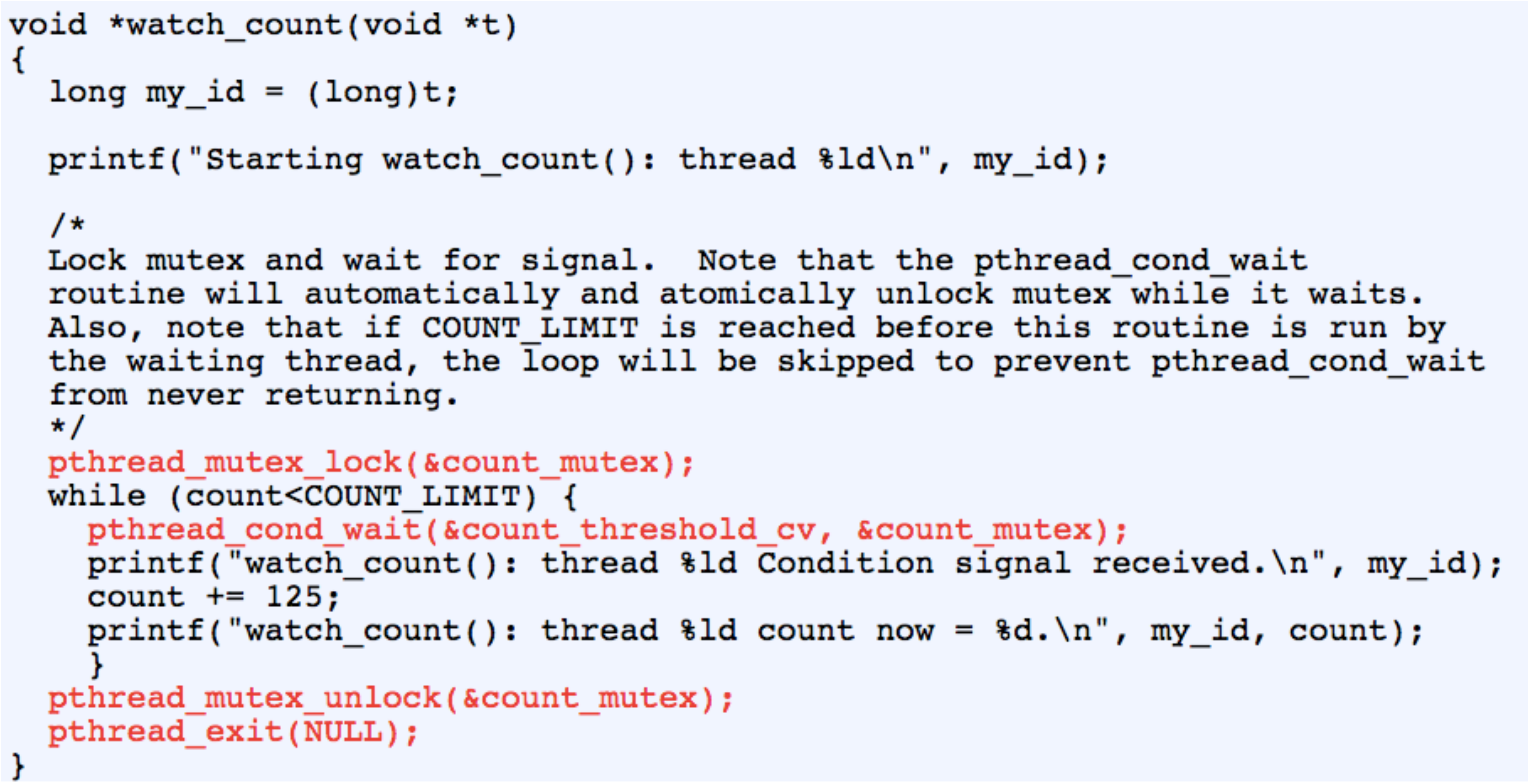
```
#include <pthread.h>
#include <stdio.h>
#include <stdlib.h>

#define NUM_THREADS  3
#define TCOUNT 10
#define COUNT_LIMIT 12

int     count = 0;
int     thread_ids[3] = {0,1,2};
pthread_mutex_t count_mutex;
pthread_cond_t count_threshold_cv;
```

Pthread Sync Example



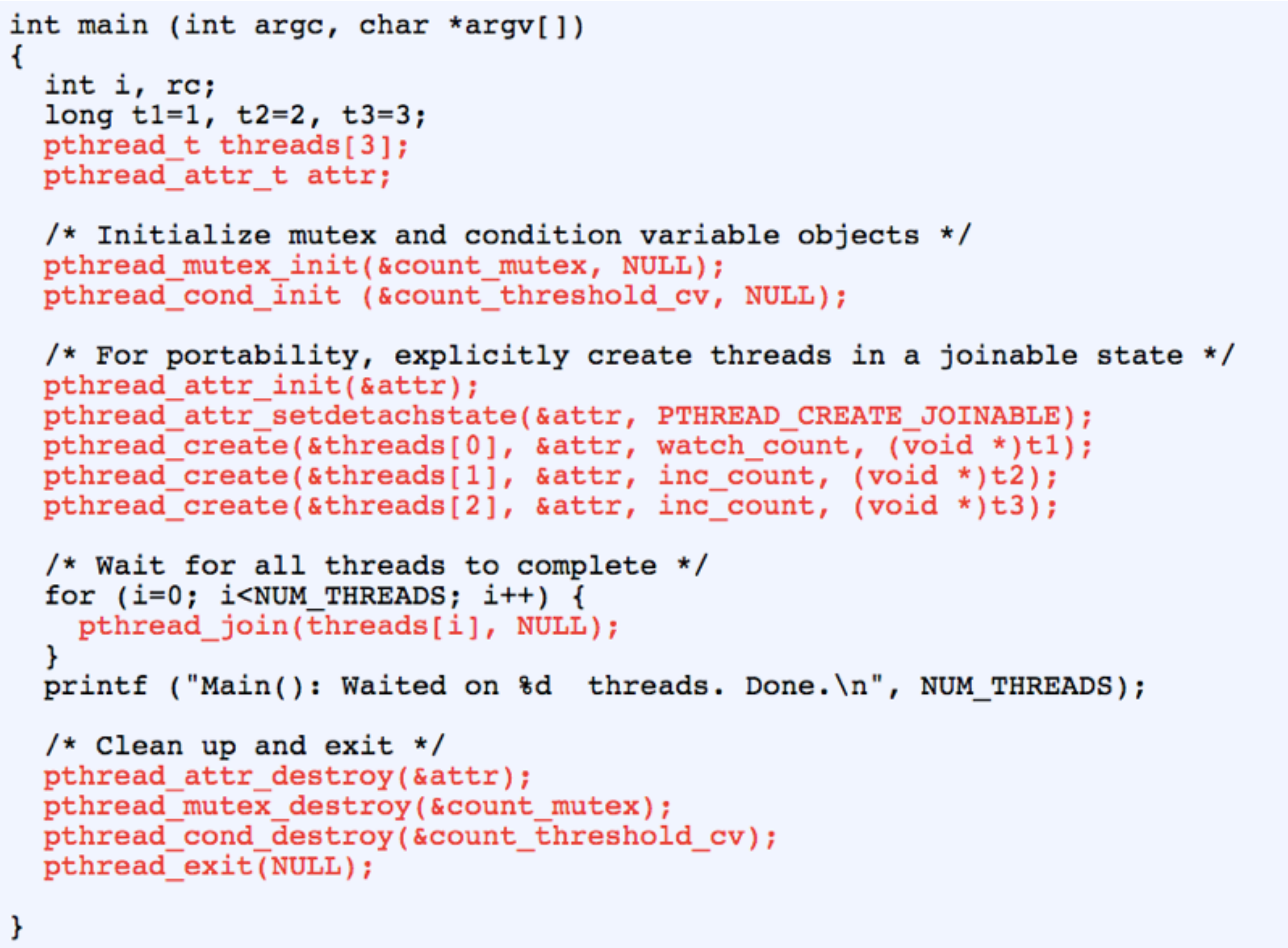
```
void *inc_count(void *t)
{
  int i;
  long my_id = (long)t;

  for (i=0; i<TCOUNT; i++) {
    pthread_mutex_lock(&count_mutex);
    count++;

    /*
    Check the value of count and signal waiting thread when condition is
    reached.  Note that this occurs while mutex is locked.
    */
    if (count == COUNT_LIMIT) {
      pthread_cond_signal(&count_threshold_cv);
      printf("inc_count(): thread %ld, count = %d  Threshold reached.\n",
             my_id, count);
      }
    printf("inc_count(): thread %ld, count = %d, unlocking mutex\n",
           my_id, count);
    pthread_mutex_unlock(&count_mutex);

    /* Do some "work" so threads can alternate on mutex lock */
    sleep(1);
    }
  pthread_exit(NULL);
}
```

Pthread Sync Example



```
void *watch_count(void *t)
{
  long my_id = (long)t;

  printf("Starting watch_count(): thread %ld\n", my_id);

  /*
  Lock mutex and wait for signal.  Note that the pthread_cond_wait
  routine will automatically and atomically unlock mutex while it waits.
  Also, note that if COUNT_LIMIT is reached before this routine is run by
  the waiting thread, the loop will be skipped to prevent pthread_cond_wait
  from never returning.
  */
  pthread_mutex_lock(&count_mutex);
  while (count<COUNT_LIMIT) {
    pthread_cond_wait(&count_threshold_cv, &count_mutex);
    printf("watch_count(): thread %ld Condition signal received.\n", my_id);
    count += 125;
    printf("watch_count(): thread %ld count now = %d.\n", my_id, count);
    }
  pthread_mutex_unlock(&count_mutex);
  pthread_exit(NULL);
}
```

Pthread Sync Example



```
int main (int argc, char *argv[])
{
  int i, rc;
  long t1=1, t2=2, t3=3;
  pthread_t threads[3];
  pthread_attr_t attr;

  /* Initialize mutex and condition variable objects */
  pthread_mutex_init(&count_mutex, NULL);
  pthread_cond_init (&count_threshold_cv, NULL);

  /* For portability, explicitly create threads in a joinable state */
  pthread_attr_init(&attr);
  pthread_attr_setdetachstate(&attr, PTHREAD_CREATE_JOINABLE);
  pthread_create(&threads[0], &attr, watch_count, (void *)t1);
  pthread_create(&threads[1], &attr, inc_count, (void *)t2);
  pthread_create(&threads[2], &attr, inc_count, (void *)t3);

  /* Wait for all threads to complete */
  for (i=0; i<NUM_THREADS; i++) {
    pthread_join(threads[i], NULL);
  }
  printf ("Main(): Waited on %d  threads. Done.\n", NUM_THREADS);

  /* Clean up and exit */
  pthread_attr_destroy(&attr);
  pthread_mutex_destroy(&count_mutex);
  pthread_cond_destroy(&count_threshold_cv);
  pthread_exit(NULL);

}
```