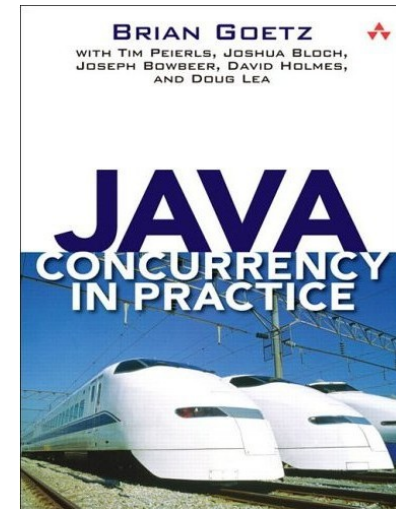# Chapter 4
Threads

Images from Silberschatz
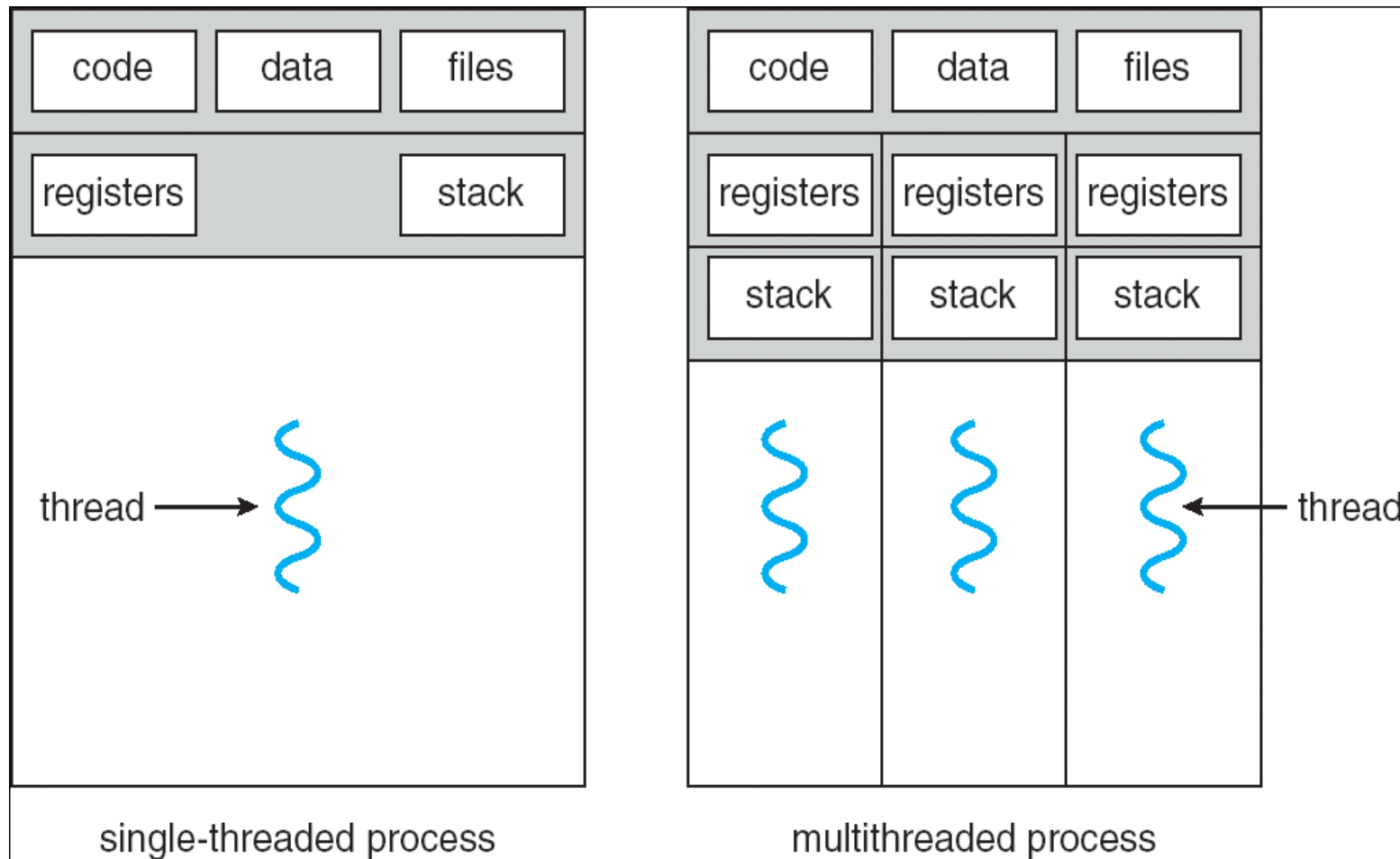
Java Concurrency in Practice,
Goetz, Peierls, Josh **Bloch**, Bowbeer,
Holmes, Doug **Lea**

http://jcip.net/

Threads

- Multiple lines of control *inside one process*

- What is shared?

- How many PCBs?

code	data	files

registers		stack

thread →

single-threaded process

code	data	files

registers	registers	registers
stack	stack	stack

← thread

multithreaded process

Typical Usages

- Word Processor

- Web Server

Benefits

- Why multithread?

Risks

- Scheduling

- Synchronization

- Hazards

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Safety

- An entity (class, method, function, ...) is thread-safe if it behaves correctly when accessed from multiple threads, regardless of the scheduling/interleaving of those threads, with no additional synchronization on the part of the calling code.[1]

- Synchronization:

Atomic
Race Condition

[1] Adapted from Goetz, et al, page 18.

thread safe function calls

*name*_r()

- strtok_r()

- strtok() - non-thread safe
    - exactly, why is this?
    - what data is shared?
    - who has access to it?

Multicore

- More people have multicores

    - pressure on developers to write multithreaded code

- Multithreaded coding challenges:
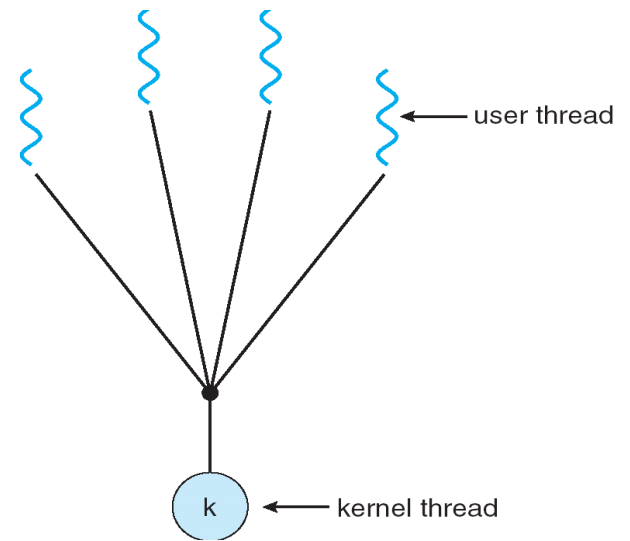
User vs Kernel Threads

- User:

- Kernel:

	User Level Threads	Kernel Level Threads	Processes
Create Time	34	948	11,300

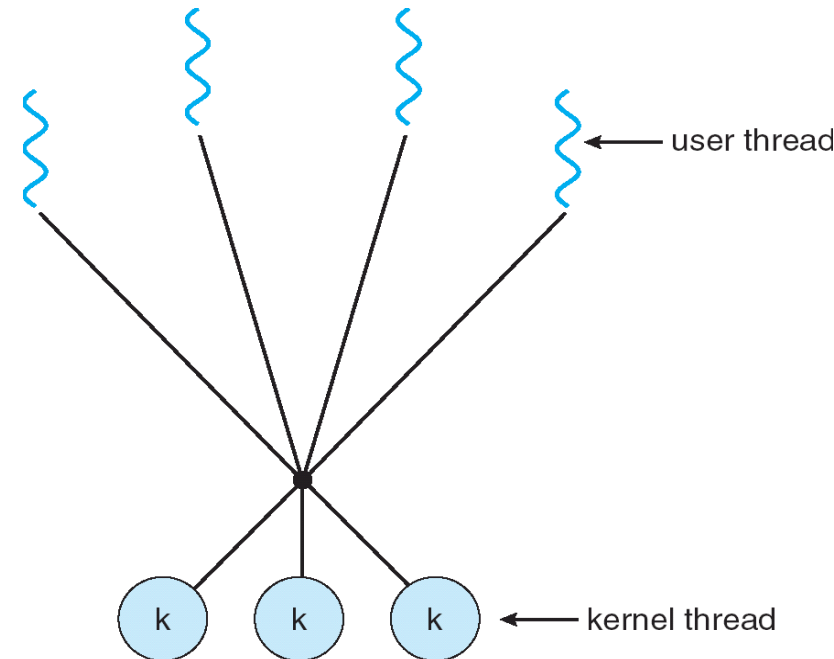(chart from Stallings, W., *Operating Systems Internals and Design Principles*, 5th Edition, page 169.)

Models

- Many-to-One

- One-to-One

- Many-to-Many

blocking system call?

user thread

kernel thread

k

user thread

kernel thread

k   k   k

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Thread Libraries

- User vs Kernel

- POSIX Pthreads

- Win32

- Java

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Pthreads

- Linux, cygwin, Solaris, etc.

    - gcc -g -o appName appname.c -lpthread

    - what shared library contains the PThread implementation?

```c
/* This code works on Zeus!
 * link with -lpthread
 * gcc -o app -g app.o -lpthread
 */
#include <pthread.h>
#include <stdio.h>

int gSum; /* this data is shared by the thread(s) */

void *runner(void *param); /* the thread */

int main(int argc, char *argv[])
{
  pthread_t tid; /* the thread identifier */
  pthread_attr_t attr; /* set of attributes for the thread */
  int *pResult;

  if (argc != 2)
  {
    fprintf(stderr,"usage: a.out <integer value>\n");
    /*exit(1);*/
    return -1;
  }

/* page 133 of Silberschatz */
```

```c
  if (atoi(argv[1]) < 0)
  {
    fprintf(stderr,"Argument %d must be nonneg\n",atoi(argv[1]));
    /*exit(1);*/
    return -1;
  }
  gSum = 0;

  /* get the default attributes */
  pthread_attr_init(&attr);

  /* create the thread */
  pthread_create(&tid,&attr,runner,argv[1]);

  /* now wait for the thread to exit */
  pthread_join(tid,  &pResult); // why a handle?

  printf("sum = %d OR %d\n",gSum, *pResult);
}
/* page 133 of Silberschatz */
```

```c
/**
 * The thread will begin control
 * in this function
 */
void *runner(void *param)
{
  int i, upper = atoi(param);


  if (upper > 0)
  {
    for (i = 1; i <= upper; i++)
    {
      gSum += i;
    }
  }


  pthread_exit((void*) &gSum);
}
/* page 133 of Silberschatz */
```

Mutex!

```c
/* This code works on Zeus!
 * link with -lpthread
 * gcc -o app -g app.o -lpthread
 */
#include <pthread.h>
#include <stdio.h>

int gSum; /* this data is shared by the thread(s) */
pthread_mutex_t gMutex;

void *runner(void *param); /* the thread */

int main(int argc, char *argv[])
{
  pthread_t tid1, tid2; /* the thread identifier */
  pthread_attr_t attr; /* set of attributes for the thread */
  const int THREAD_PARAM_ONE = 5;
  const int THREAD_PARAM_TWO = 6;

  gSum = 0;


/* adapted from page 133 of Silberschatz */
```

```c
    /* init the mutex */
    pthread_mutex_init(&gMutex, NULL);

    /* get the default attributes */
    pthread_attr_init(&attr);

    /* create the threads */
    pthread_create(&tid1, &attr, runner, &THREAD_PARAM_ONE);
    pthread_create(&tid2, &attr, runner, &THREAD_PARAM_TWO);

    /* now wait for the threads to exit */
    pthread_join(tid1, NULL);
    pthread_join(tid2, NULL);

    pthread_mutex_destroy(&gMutex);
    pthread_attr_destroy(&attr);

    printf("sum = %d\n",gSum);
}

/* adapted from page 133 of Silberschatz */
```

```c
/**
 * The thread will begin control in this function
 */
void *runner(void *param)
{
  int i;
  // gSum = 0; // ???

  for (i = 1; i <= *(int*)param; i++)
  {
    pthread_mutex_lock(&gMutex);
    gSum += i;
    //nanosleep(100);
    pthread_mutex_unlock(&gMutex);
  }

  pthread_exit((void*) &gSum);
}
/* page 133 of Silberschatz */
```

Pthread Functions

- pthread_create
- pthread_cond_init
- pthread_mutex_init
- pthread_attr_init
- pthread_mutex_lock / unlock
- pthread_cond_wait / pthread_cond_timedwait
- pthread_cond_signal / pthread_cond_broadcast
- pthread_mutex_destroy
- pthread_attr_destroy
- pthread_cond_destroy
- pthread_exit/pthread_join
- pthread_kill / pthread_detach
- pthread_setaffinity_np   sched_setaffinity

Typical usage

- Message Queues, thread safe/concurrent

- Cancellation

  - asynchronous

  - deferred

- Thread Pools

- Scheduler

Java Threads

- http://java.sun.com/docs/books/tutorial/essential/concurrency/index.html

- Startup/creation

- Synchronization

Threads

```java
public class MyThread implements Runnable
{

    @Override
    public void run()
    {
    }

}

MyThread myThread = new MyThread();
Thread listenThread = new Thread(myThread);

listenThread.start(); // call run
```

Synchronization

- Some data structures are thread safe:

    - ConcurrentHashMap<K, V>

    - ConcurrentLinkedQueue<E>

- Often threads will pass messages to each other through Queues

```
ConcurrentLinkedQueue<String> messageQueue =
    new ConcurrentLinkedQueue<String>();
```

Sychronization

- synchronized method
  ```
  public synchronized void once()
  {
      // only one thread can be executing this
      // method, per object!
  }
  ```

- synchronized block

  ```
  synchronized(this) // every object contains a lock
  {
      this.x++;
  }
  ```

Producer/Consumer

- Design Pattern

- One thread produces data,
  the other consumes data.

```
public void consume()
{
    synchronized (queue)
    {
        while(queue.isEmpty())
        {
            queue.wait();
            // wait releases the lock until
            // notify is used
        }
        msg = queue.remove();
    }
    // do work with msg
}
```

```
public void produce(msg)
{
    synchronized (queue)
    {
        queue.add(msg);
        queue.notify()
    }
}
```

pthreads

- pthread_cond_wait() / pthread_cond_timedwait()

- pthread_cond_signal() / pthread_cond_broadcast()

- pthread_cond_t

pthreads

- pthread_rwlock_t

- pthread_rwlock_rdlock / pthread_rwlock_wrlock

- pthread_relock_unlock