R

بسم الله الرحمن الرحیم

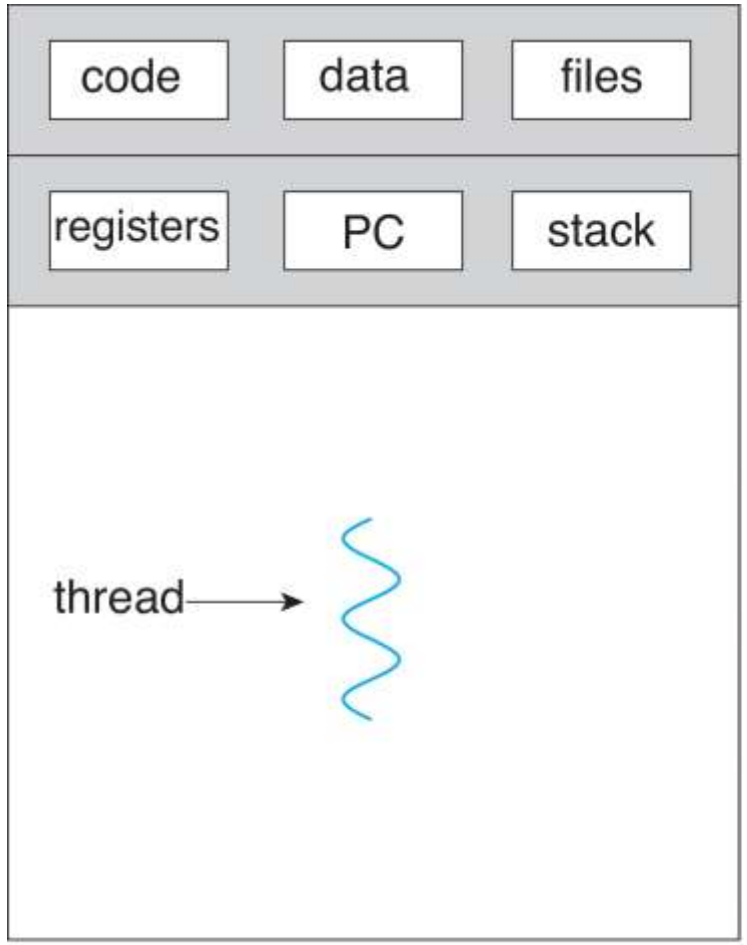
سیستم عامل

جلسه پنجم – ادامه‌ی ریسمان، همزمانی

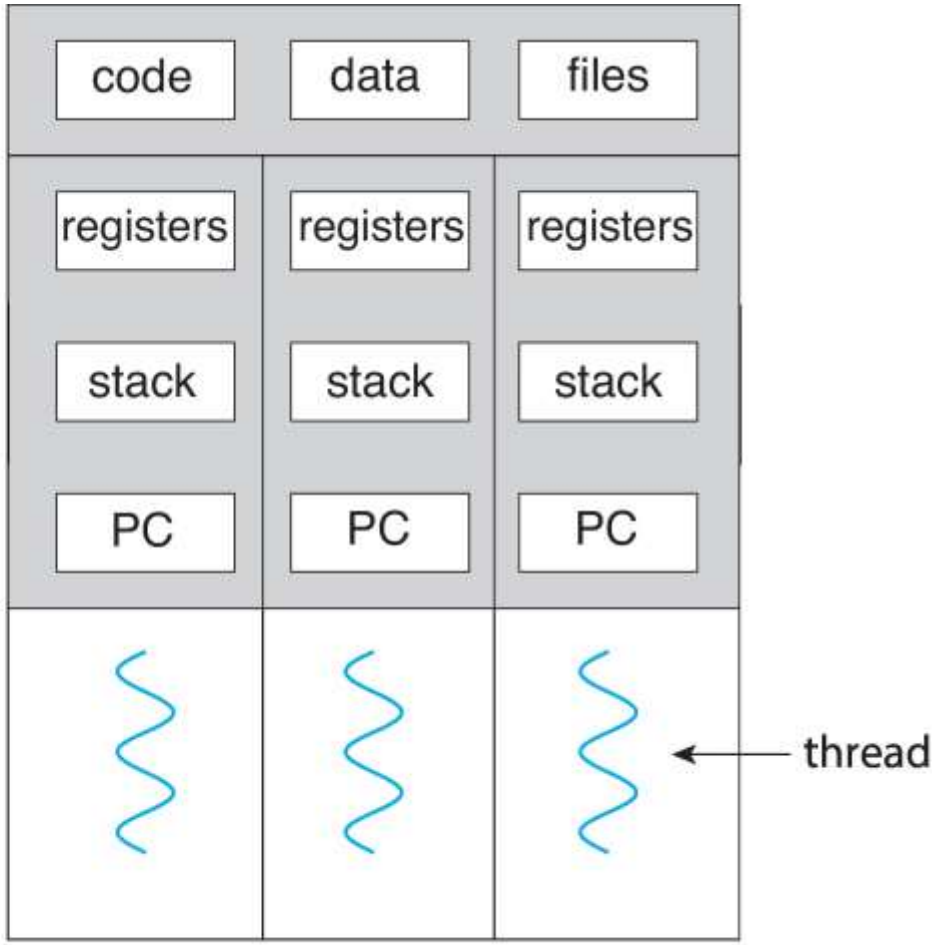
آنچه گذشت

جلسه‌ی قبل، ریسمان

ریسمان



single-threaded process



multithreaded process

Why Use Threads?

- **Utilize** multiple CPU's concurrently
- **Low cost** communication via shared memory
- Overlap computation and blocking on a single CPU
  - *Blocking due to I/O*
  - *Computation and communication*
- Handle asynchronous events

جلسه‌ی جدید

ادامه‌ی ریسمان

استراتژی‌های استفاده از ریسمان

Common Thread Strategies

- Manager/worker
  - *Manager thread handles I/O*
  - *Magaer assigns work to worker threads*
  - *Worker threads created dynamically*
  - *... or allocated from a thread-pool*
- Pipeline
  - *Each thread handles a different stage of an assembly line*
  - *Threads hand work off to each other in a producer-consumer relationship*

Manager / Worker

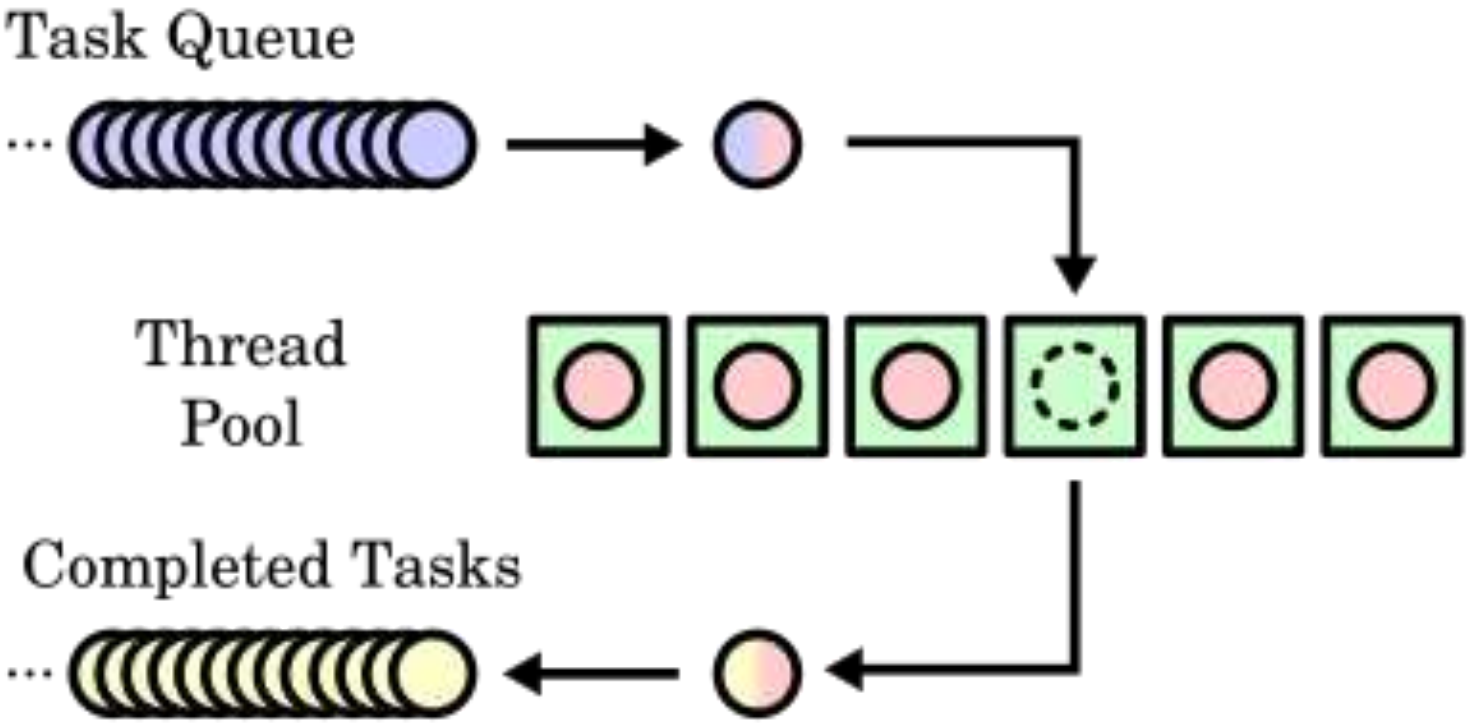


Image from https://en.wikipedia.org/wiki/Thread_pool

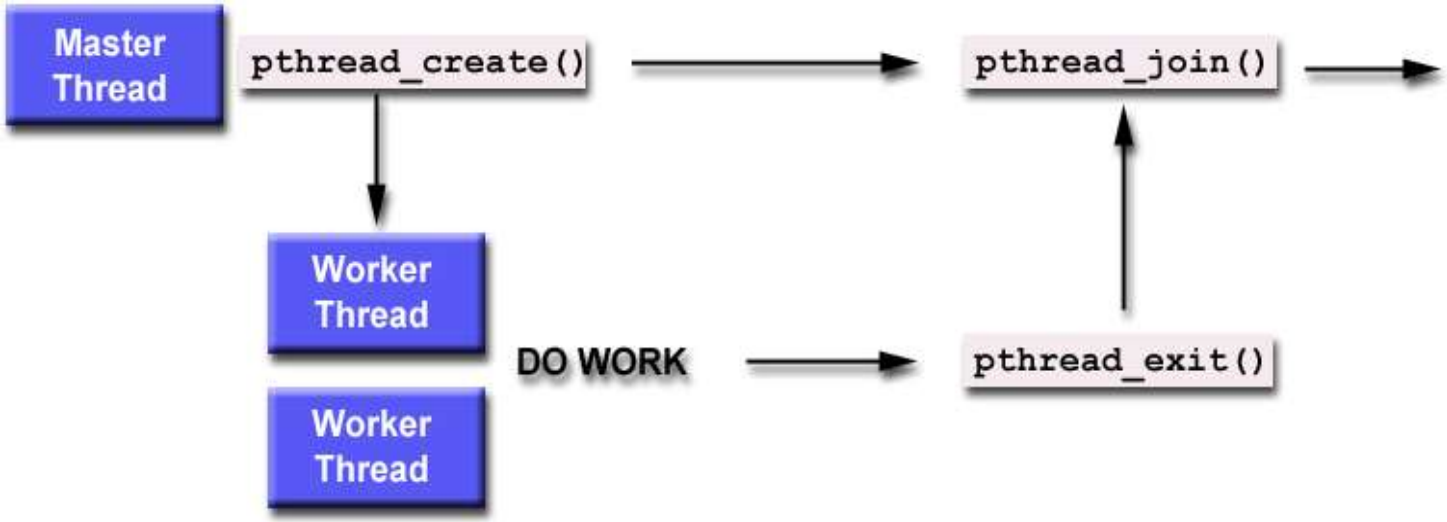
Java Thread Pools

- Three factory methods for creating thread pools in Executors class:
  - `static ExecutorService newSingleThreadExecutor()`
  - `static ExecutorService newFixedThreadPool(int size)`
  - `static ExecutorService newCachedThreadPool()`

Pthreads (continued)

- pthread_exit (status)
  - *Terminates the thread and returns "status" to any joining thread*
- pthread_join (threadid,status)
  - *Blocks the calling thread until thread specified by "threadid" terminates*
  - *Return status from pthread_exit is passed in "status"*
  - *One way of synchronizing between threads*
- pthread_yield ()
  - *Thread gives up the CPU and enters the run queue*

Using Create, Join and Exit



Pros & Cons of Threads

- Pros:
  - *Overlap I/O with computation!*
  - *Cheaper context switches*
  - *Better mapping to multiprocessors*
- Cons:
  - *Potential thread interactions*
  - *Complexity of debugging*
  - *Complexity of multi-threaded programming*
  - *Backwards compatibility with existing code*

پیاده‌سازی ریسمان

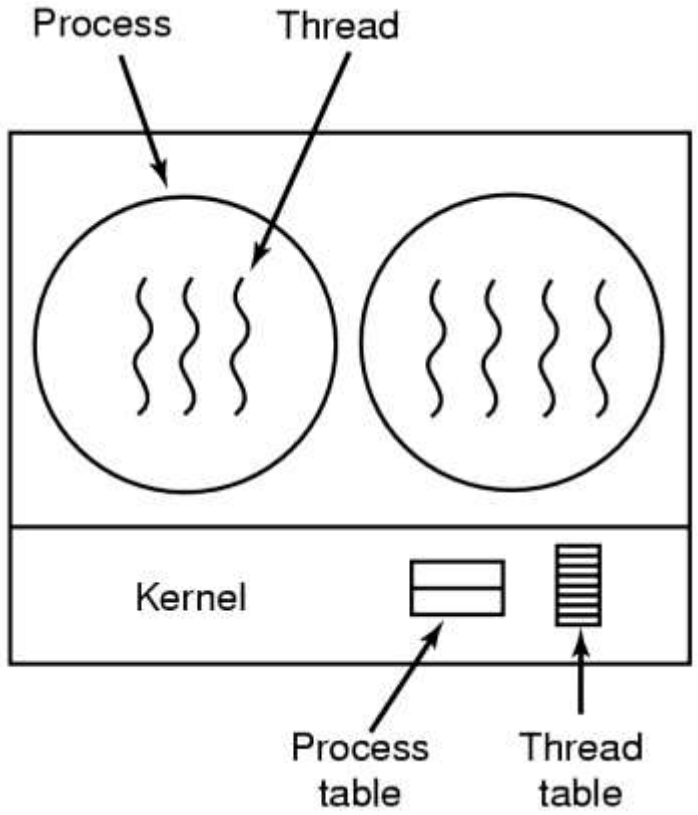
در سیستم عامل یا در کتاب‌خانه‌ی برنامه؟

Thread

- The idea of managing multiple abstract program counters above a single real one can be implemented using privileged or non-privileged code.
  - *Threads can be implemented in the OS or at user level*
- User level thread implementations
  - *Thread scheduler runs as user code (thread library)*
  - *Manages thread contexts in user space*
  - *The underlying OS sees only a traditional process above*

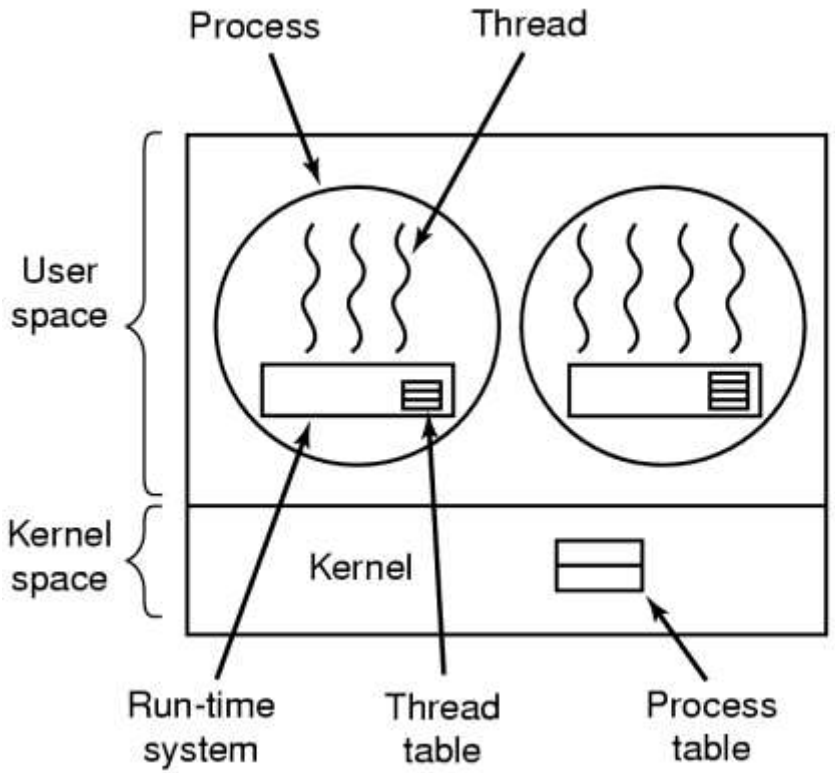
Kernel-Level Threads

Thread-switching
code is in the kernel



User-Level Threads

The thread-switching code is in user space



User-level threads (Green Threads)

- Advantages
  - *Cheap context switch costs among threads in the same process!*
  - *Calls are procedure calls not system calls!*
  - *User-programmable scheduling policy*
- Disadvantages
  - *How to deal with blocking system calls!*
  - *How to overlap I/O and computation!*

مسائل همزمانی

Concurrency

- *Two or more threads*
- *Parallel or pseudo parallel execution*
- *Can’t predict the relative execution speeds*
- *The threads access shared variables*

Concurrency Vs. Parallelism

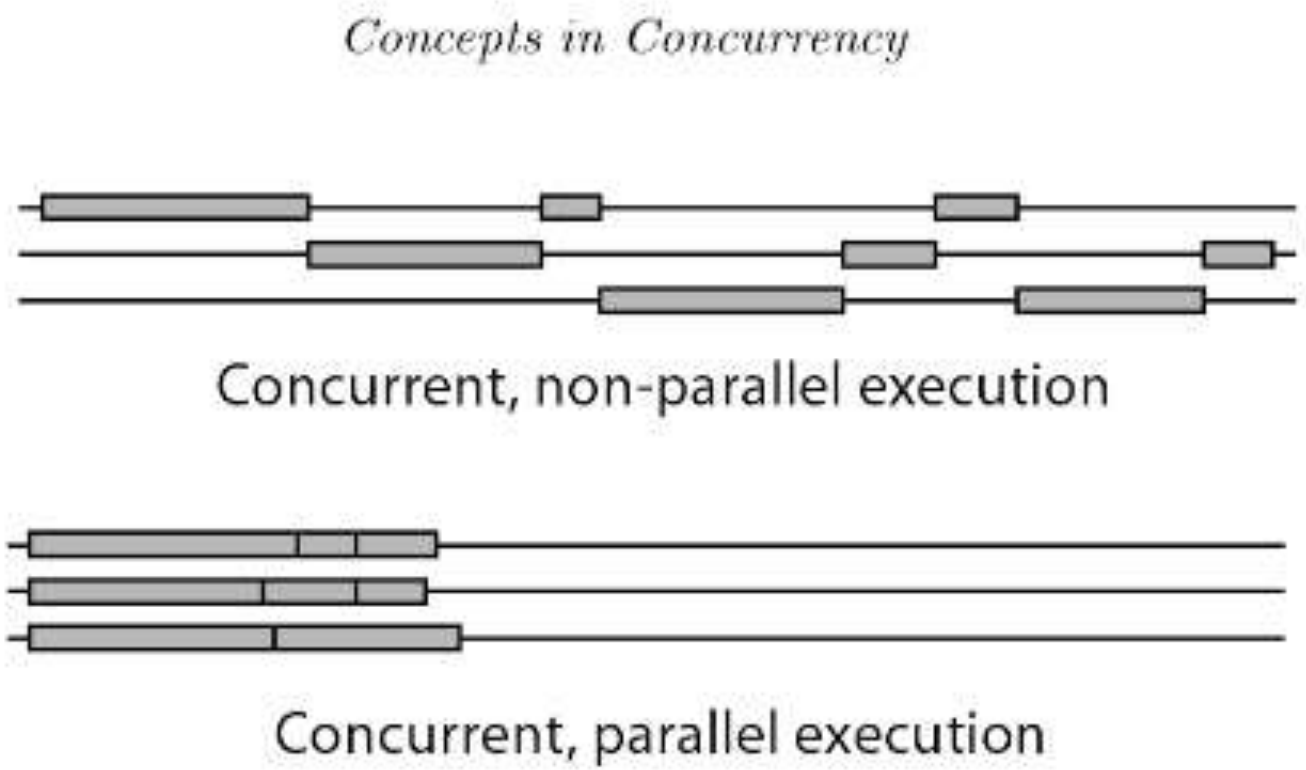


Image from: https://stackoverflow.com/a/53215726

Concurrency

Example: One thread writes a variable that another thread reads

- Problem – non-determinism:
- *The relative order of one thread's reads and the other thread's writes may determine the outcome!*

وضعیت رقابتی

Race Condition

Race Conditions

- What is a race condition?
- Why do race conditions occur?

Race Conditions

- A simple multithreaded program with a race:

i++;

Race Conditions

- A simple multithreaded program with a race:

...
load i to register;
increment register;
store register to i;
...

آیا مسئله‌ی وضعیت رقابتی مهم است؟

- مثال: بانک!
- فرض کنید یک متغیر برای میزان مانده حساب دارید.
- remainingMoney -= 100000
- اگر همزمان چندین برداشت از حساب کنید.

Race Conditions

- Why did this race condition occur?
  - *two or more threads have an inconsistent view of a shared memory region (ie., a variable)*
  - *values of memory locations are replicated in registers during execution*
  - *context switches at arbitrary times during execution*
  - *threads can see stale memory values in registers*

Race Conditions

- Race condition: whenever the result depends on the precise execution order of the threads!
- What solutions can we apply?
  - *prevent context switches by preventing interrupts*
  - *make threads coordinate with each other to ensure mutual exclusion in accessing critical sections of code*

- Mutual Exclusion?
- Critical Section?

Critical Section

a part of a program where shared resources (like variables or memory) are accessed and modified

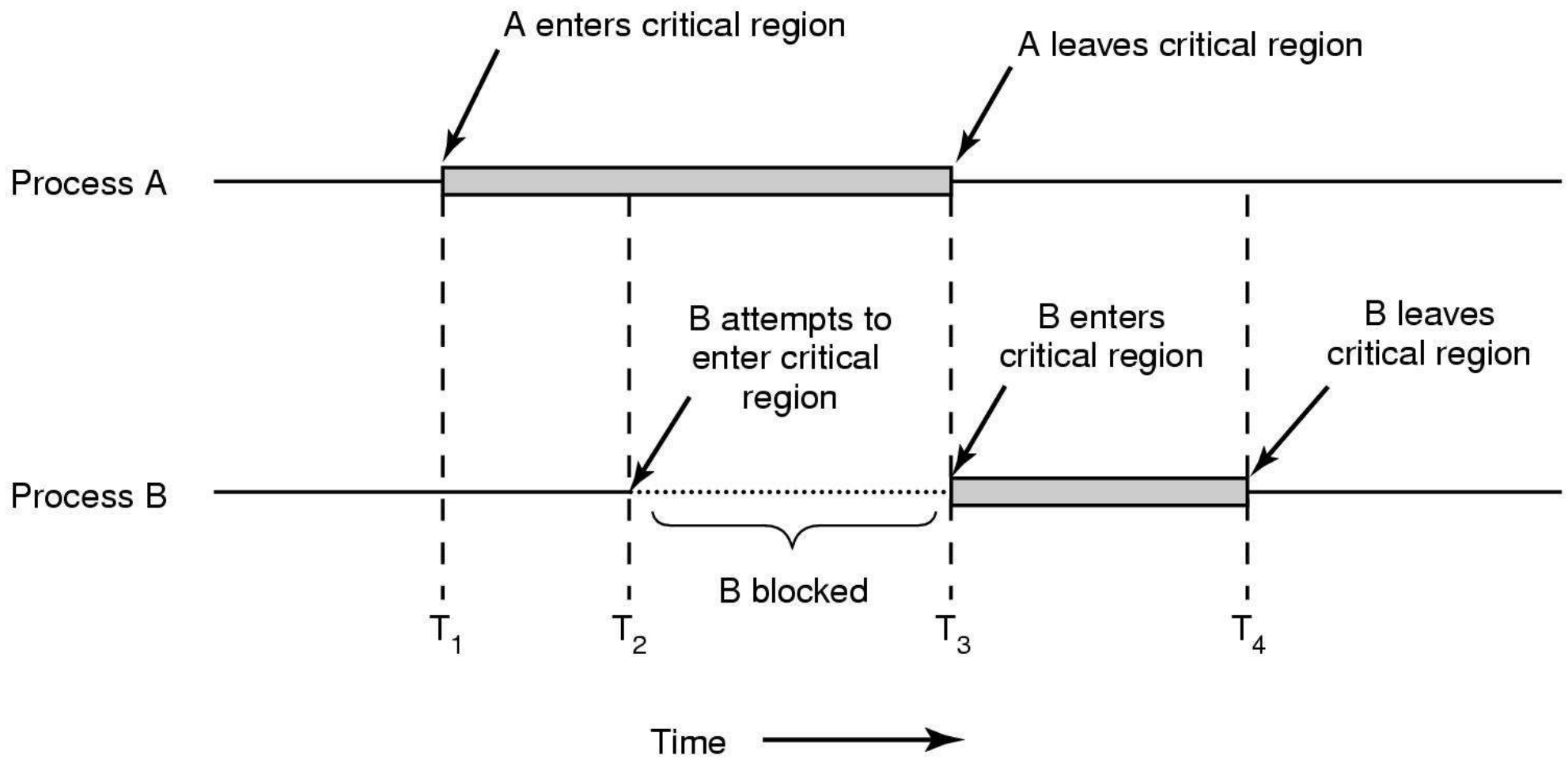
```
...
load i to register;
increment register;
store register to i;
...
```

Critical Section

Mutual Exclusion Conditions

- No two processes simultaneously in critical section
- No assumptions about speeds or numbers of CPUs
- No process running outside its critical section may block another process
- No process waits forever to enter its critical section

Mutual Exclusion Example

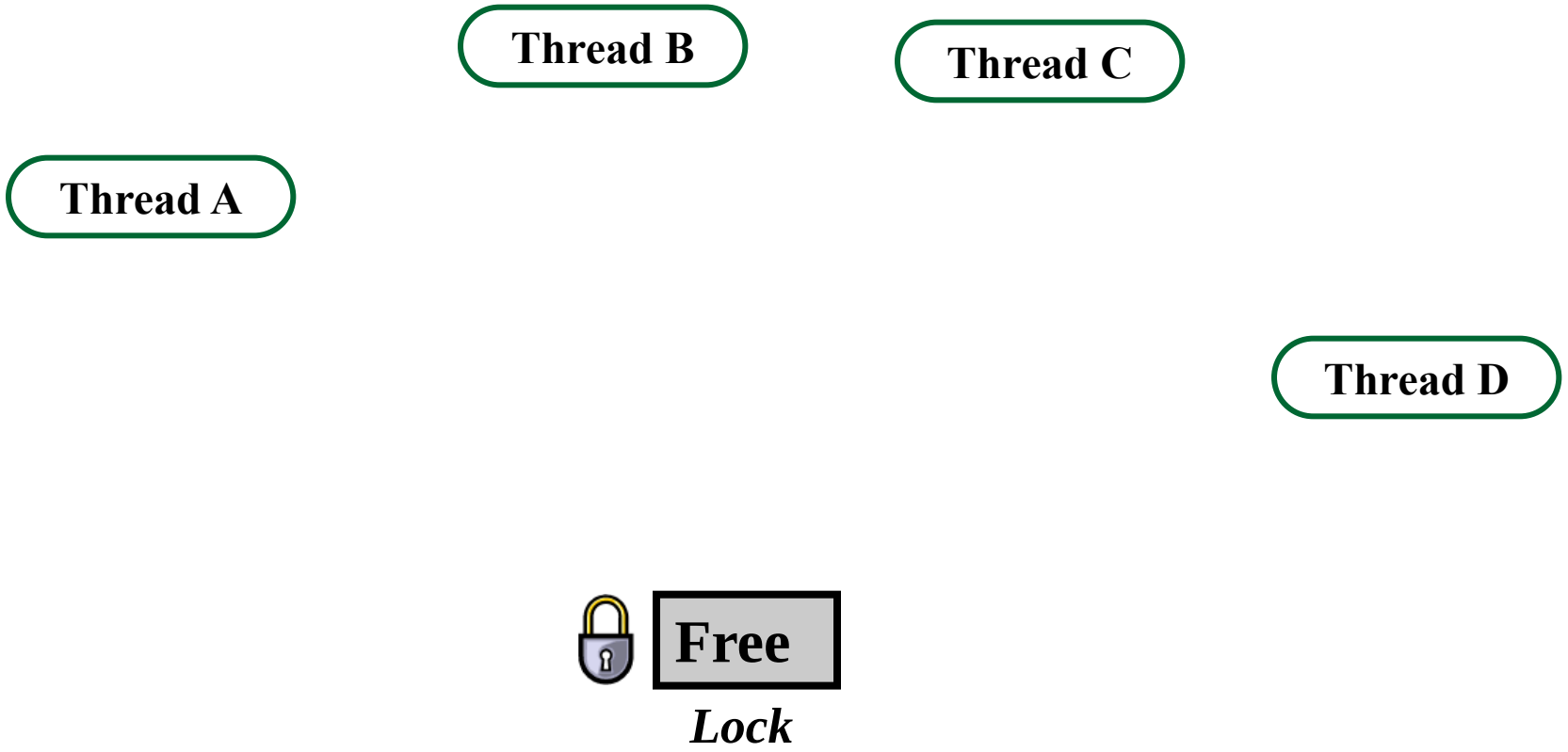


چطوری MUTUAL EXCLUSION؟

Enforcing Mutual Exclusion

- What about using ***locks****?*
- Locks can ensure exclusive access to shared data.
  - *Acquiring a lock prevents concurrent access*
  - *Expresses intention to enter critical section*
- Assumption:
  - *Each shared data item has an associated lock*
  - *All threads set the lock before accessing the shared data*
  - *Every thread releases the lock after it is done*

Acquiring and Releasing Locks



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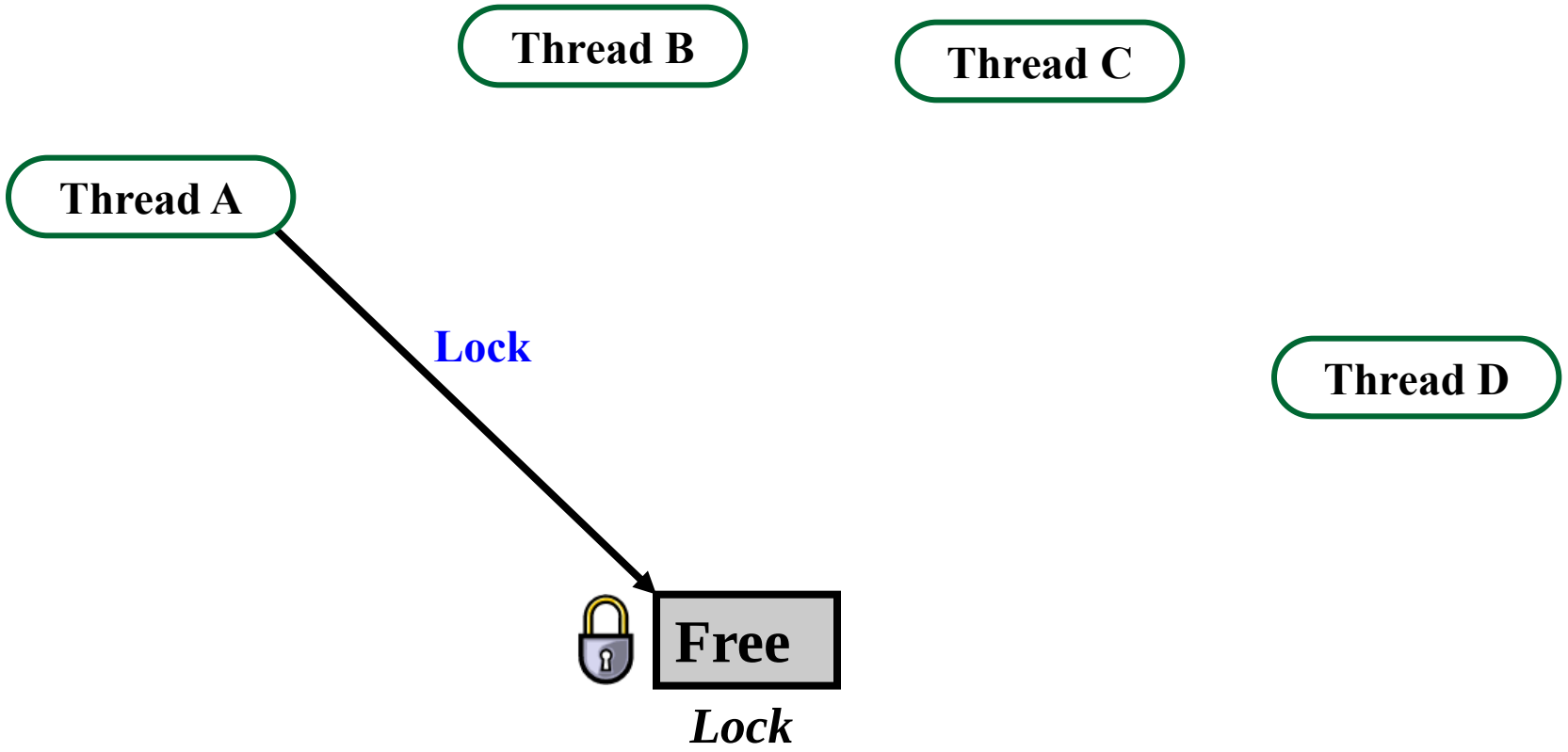

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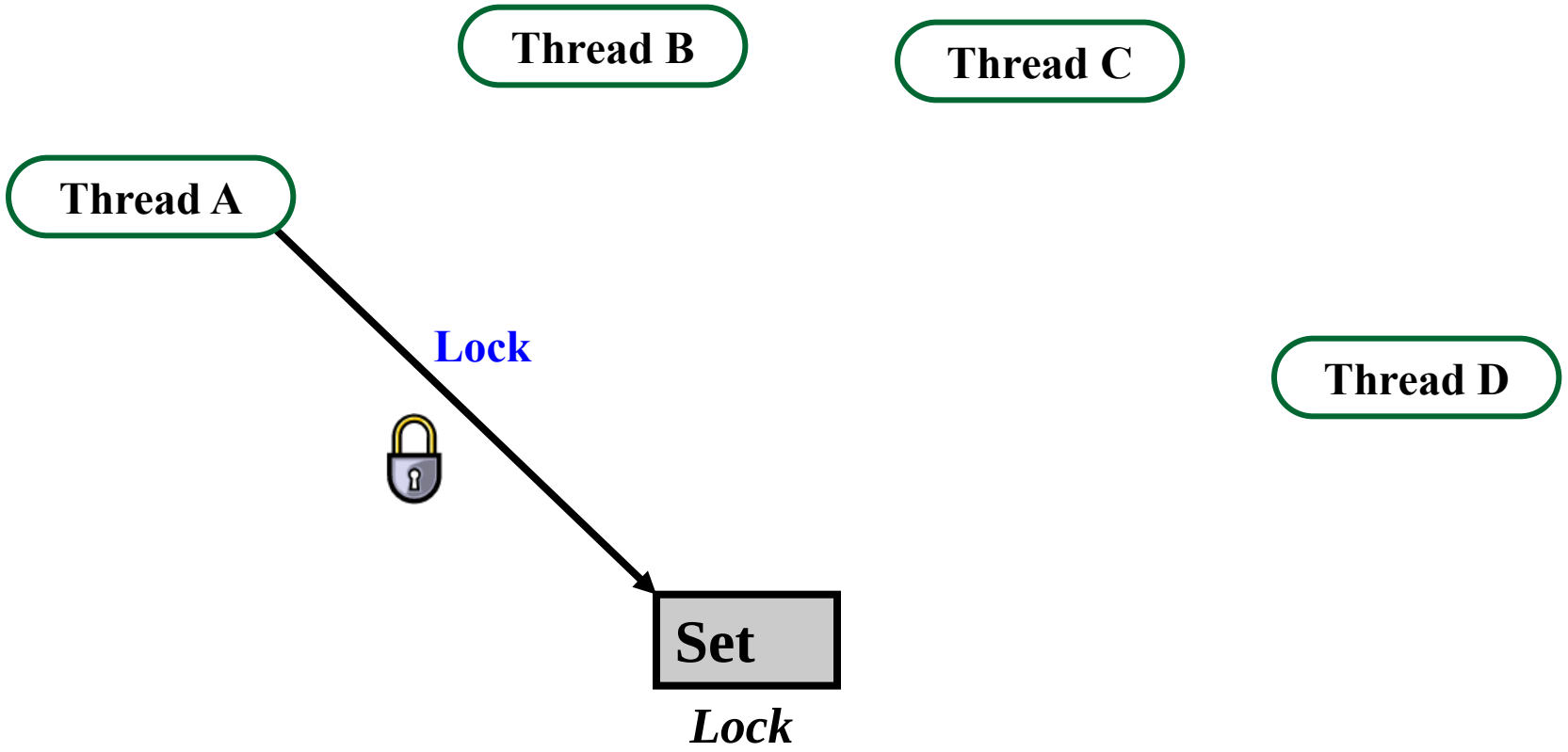

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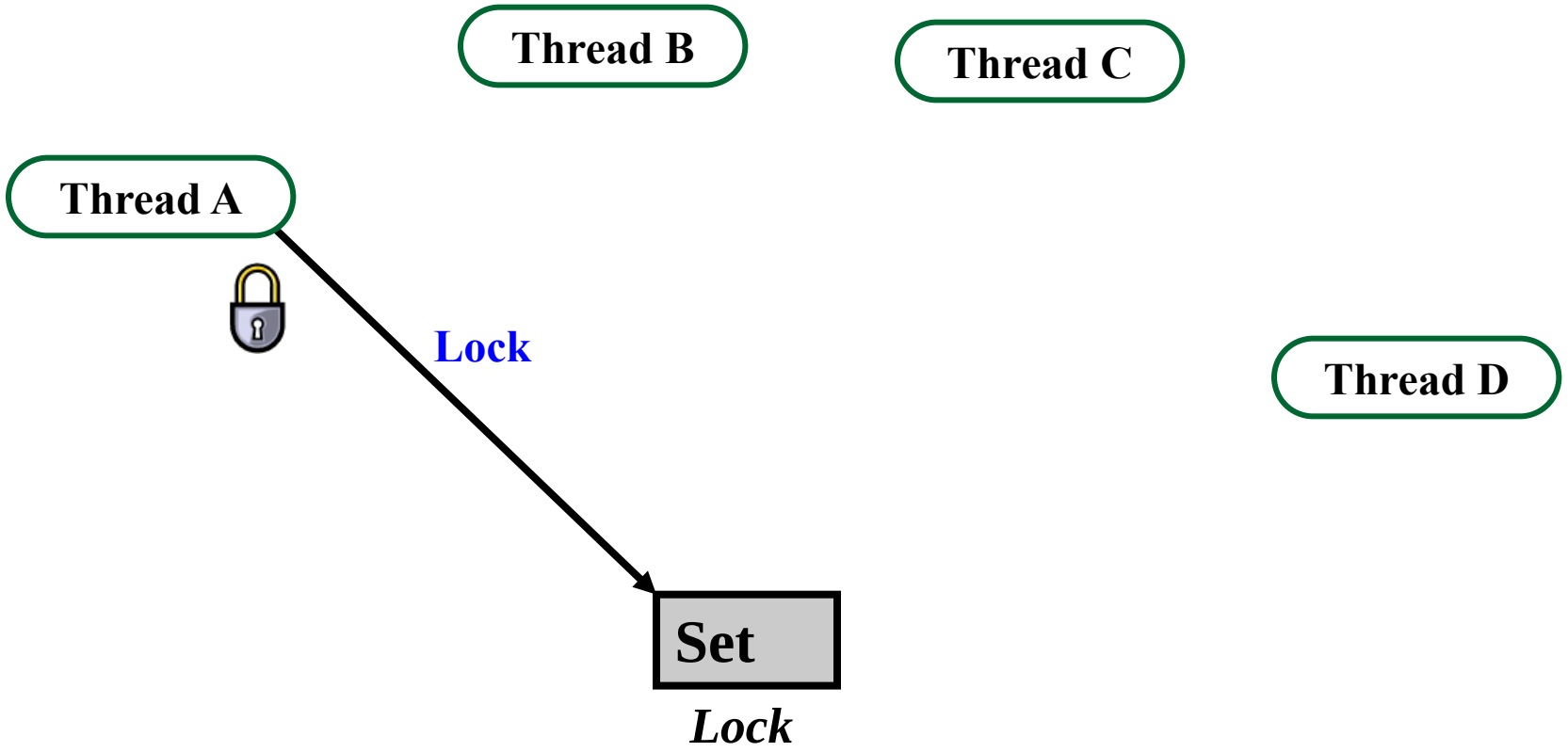

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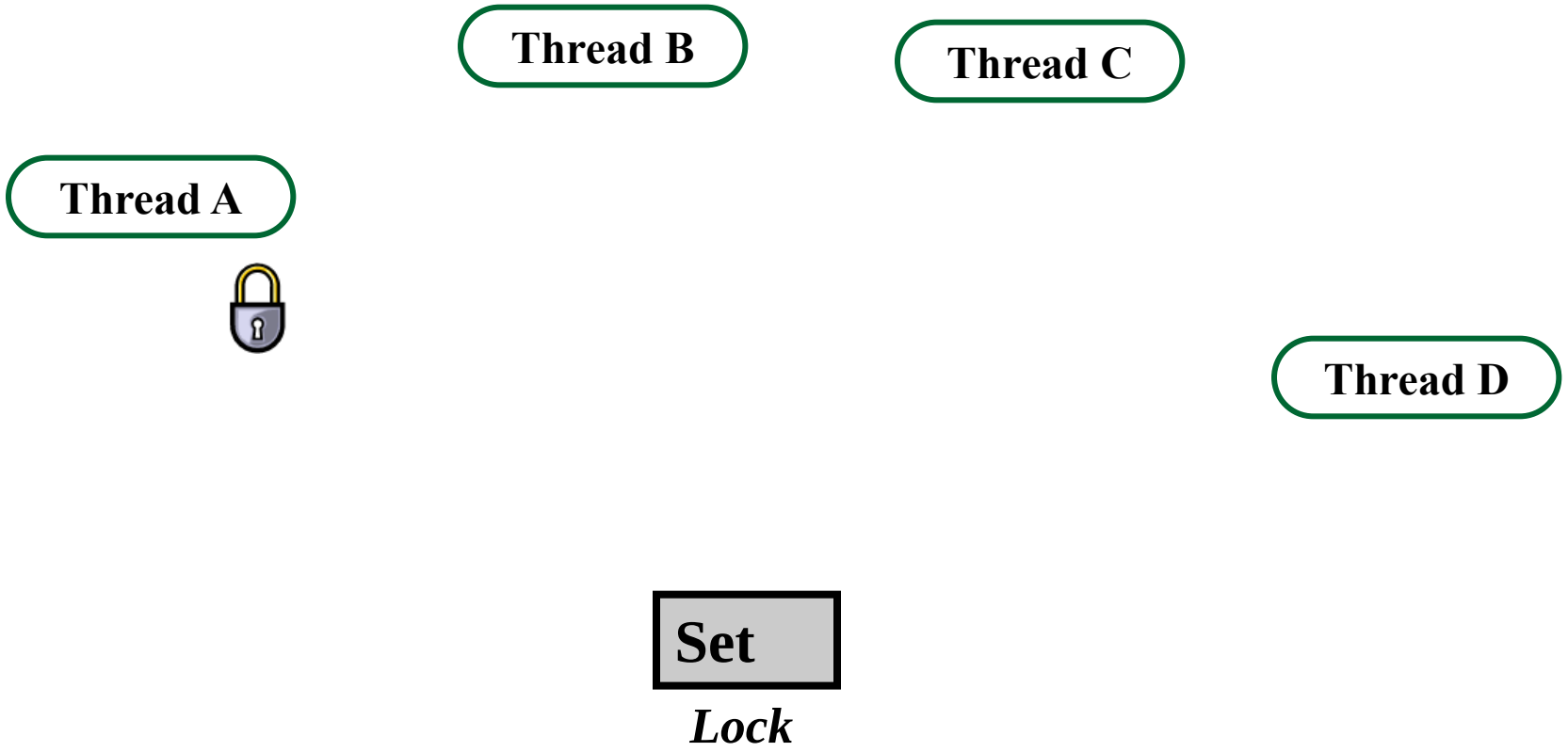

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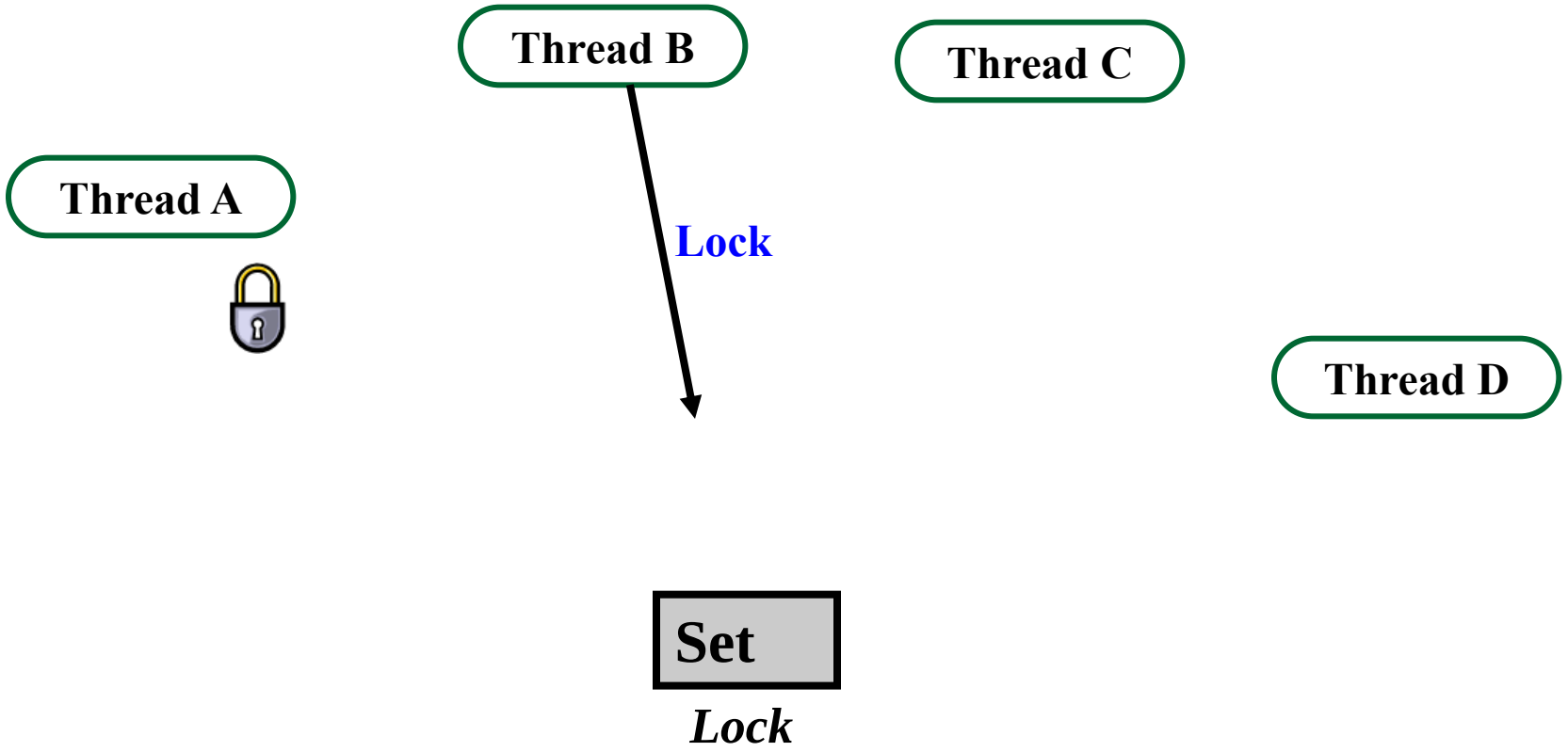

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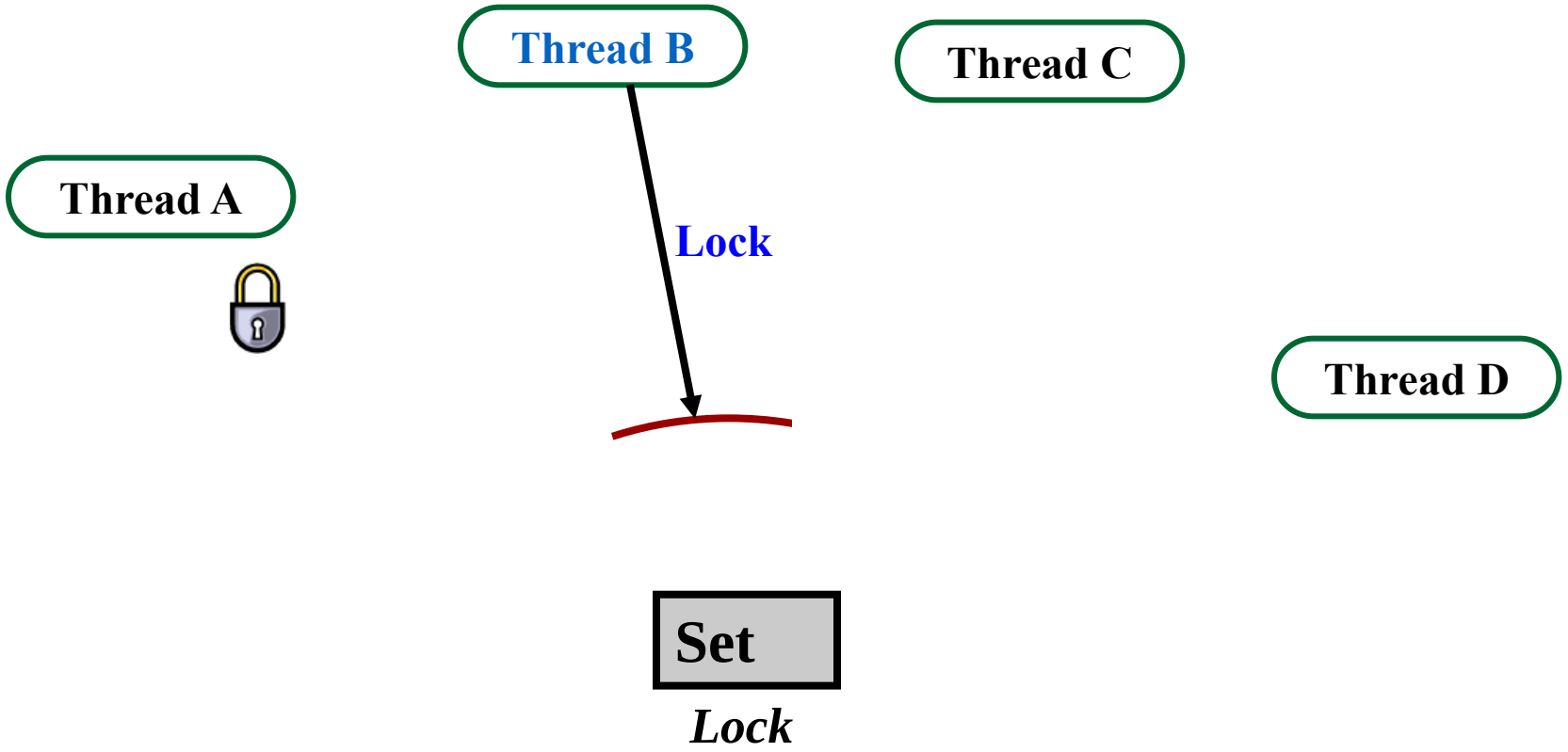

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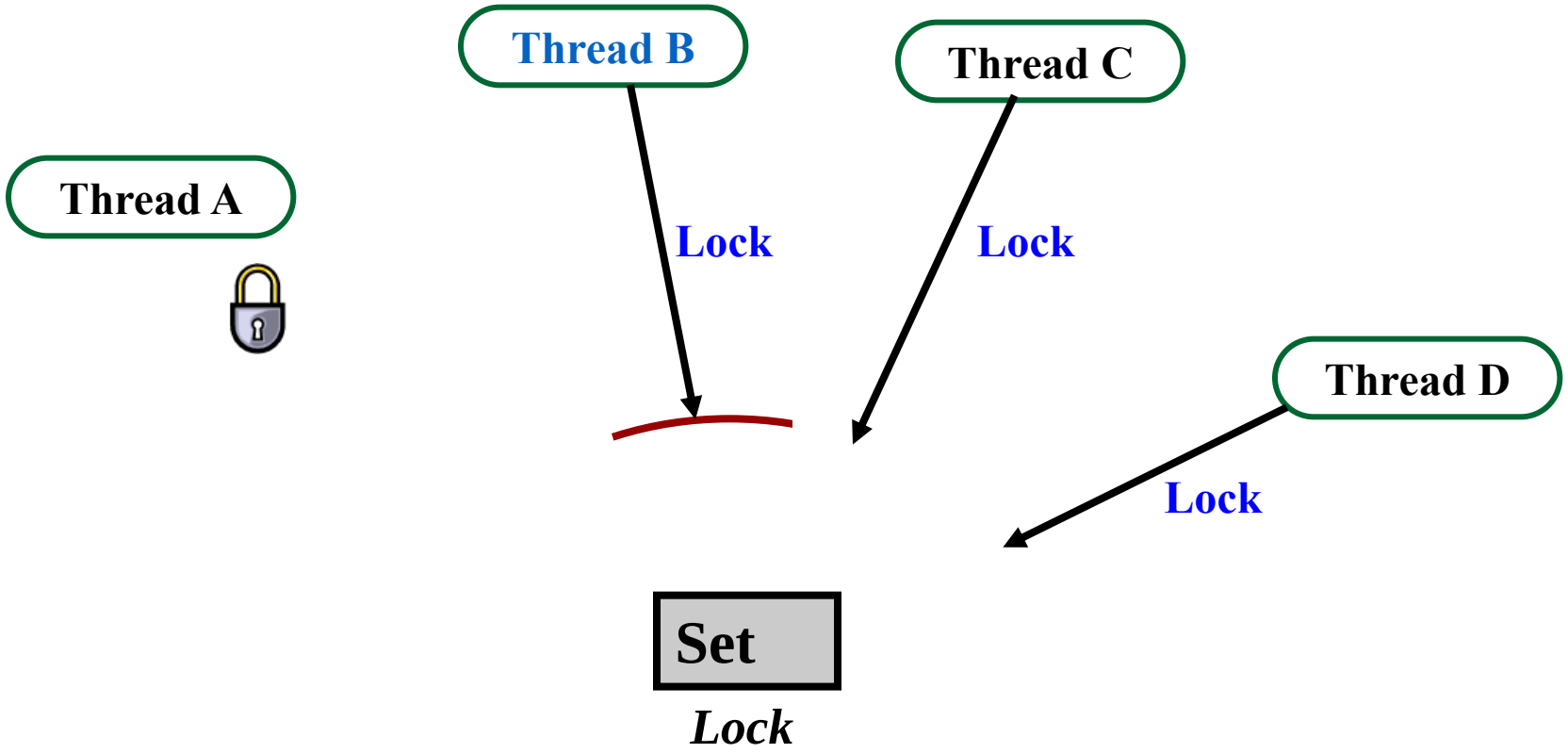

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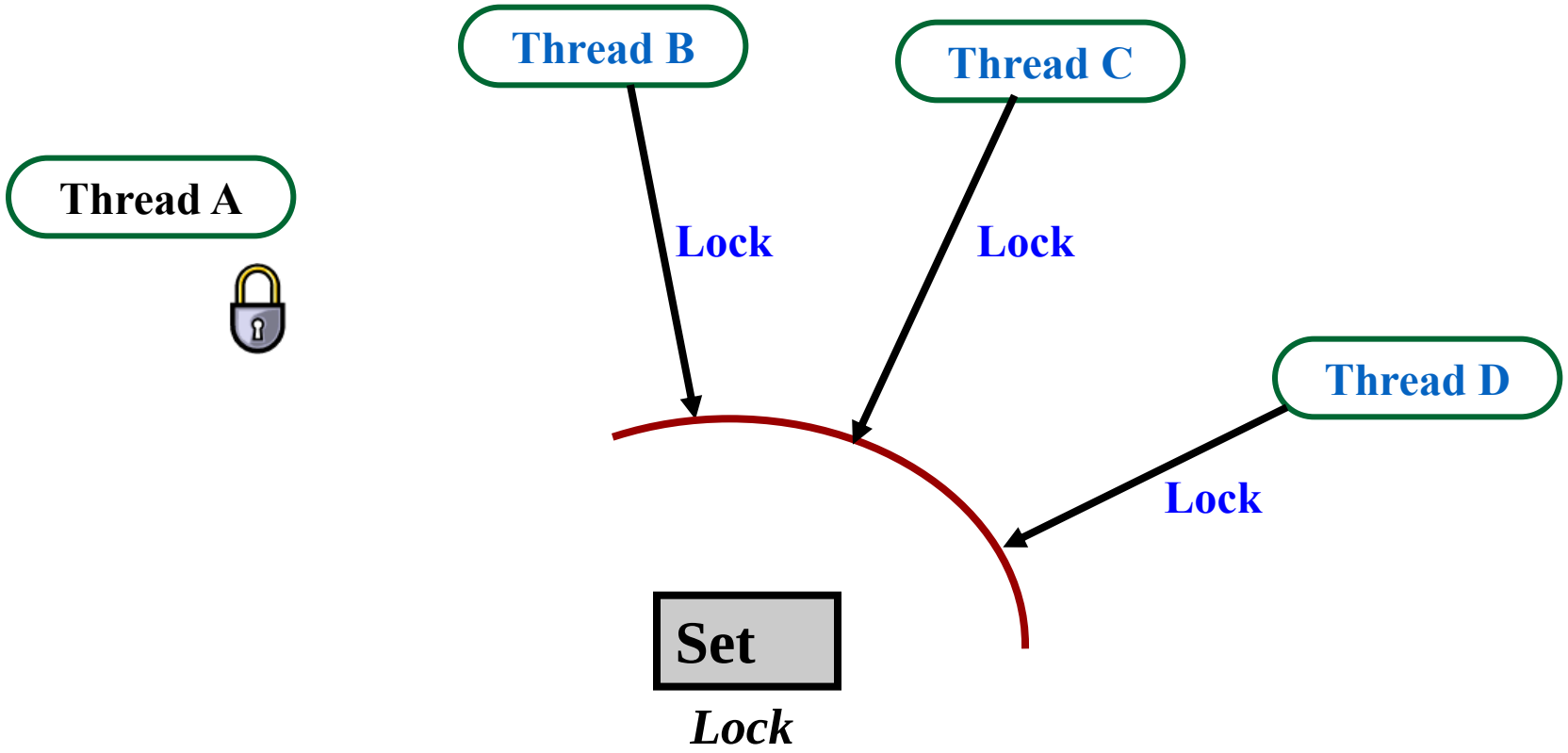

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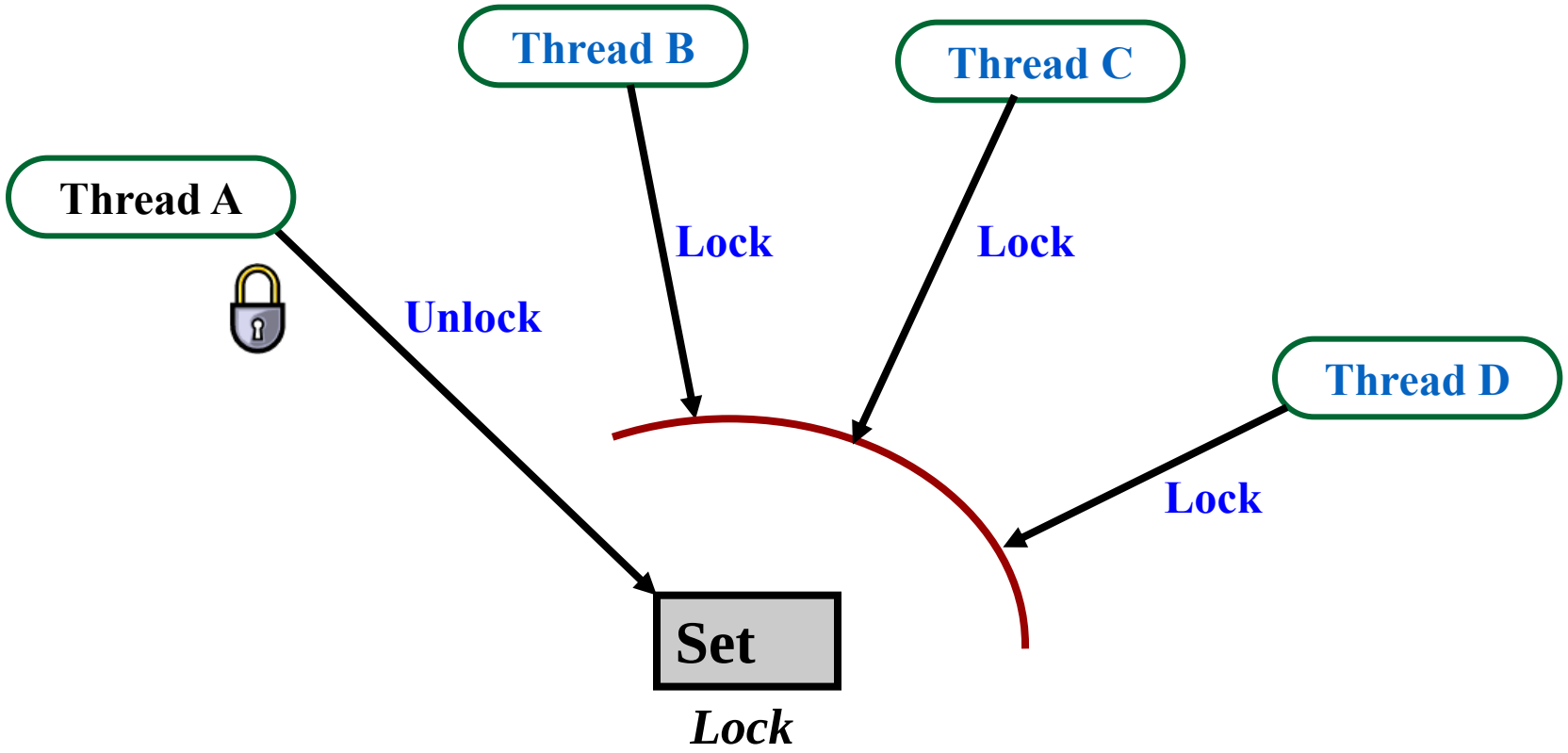

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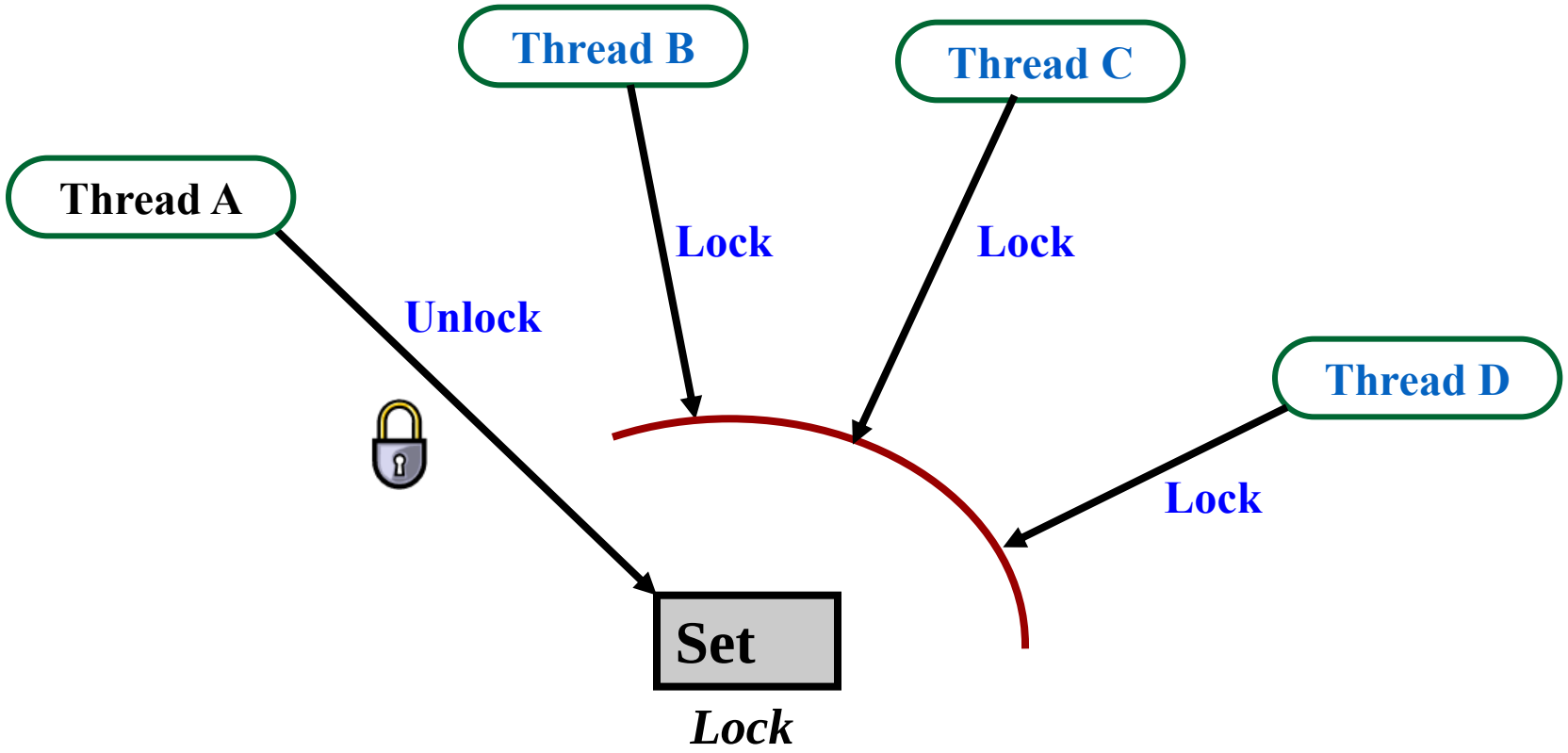

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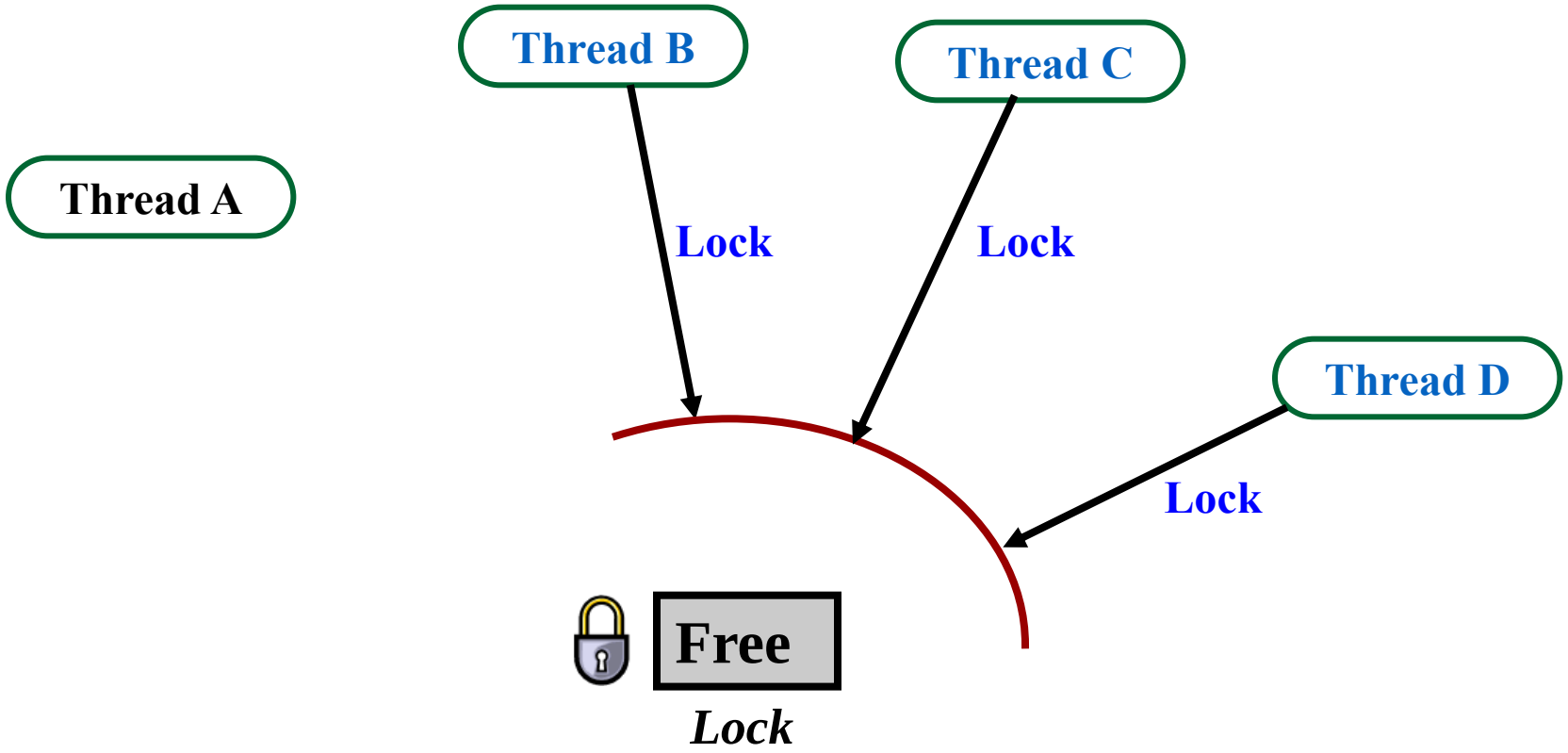

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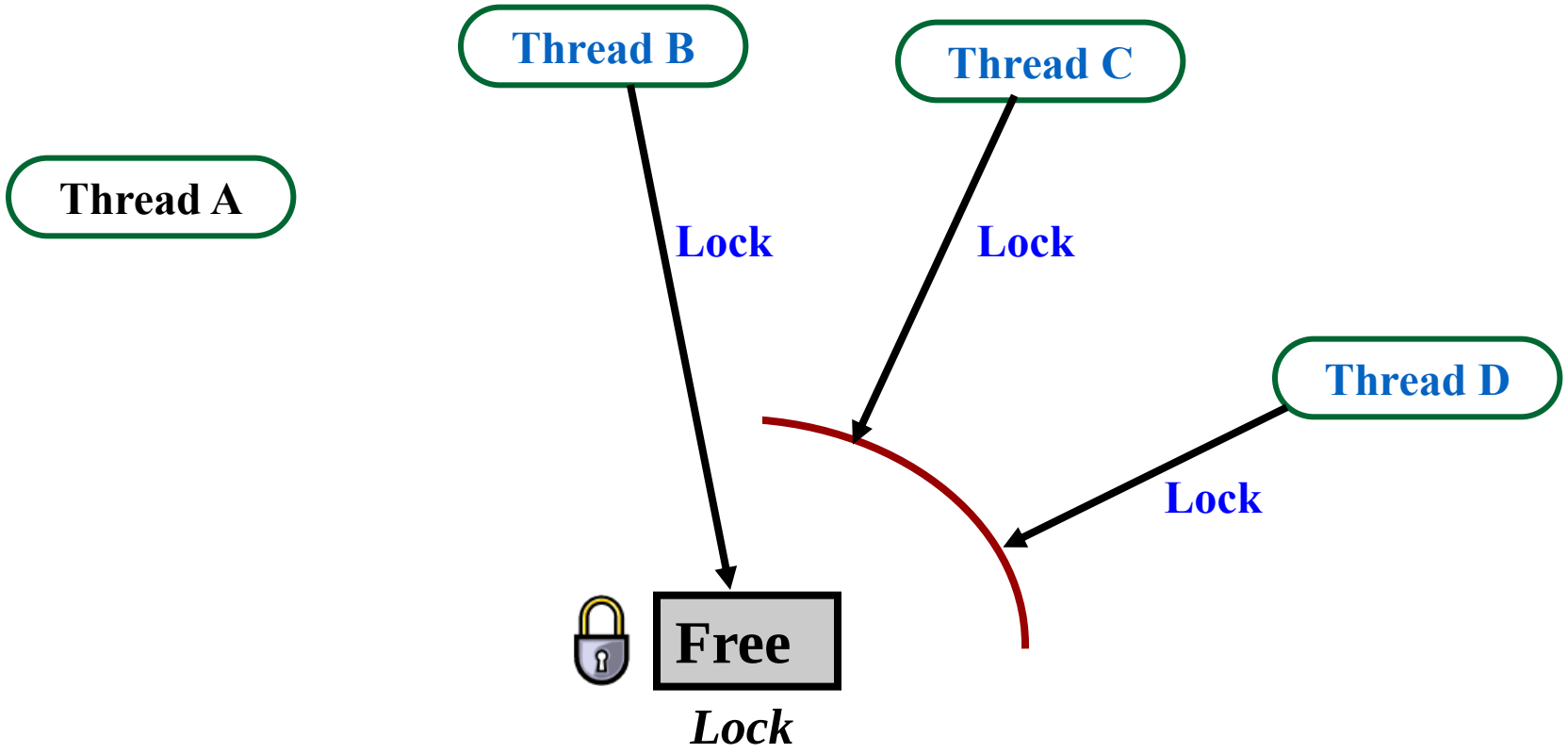

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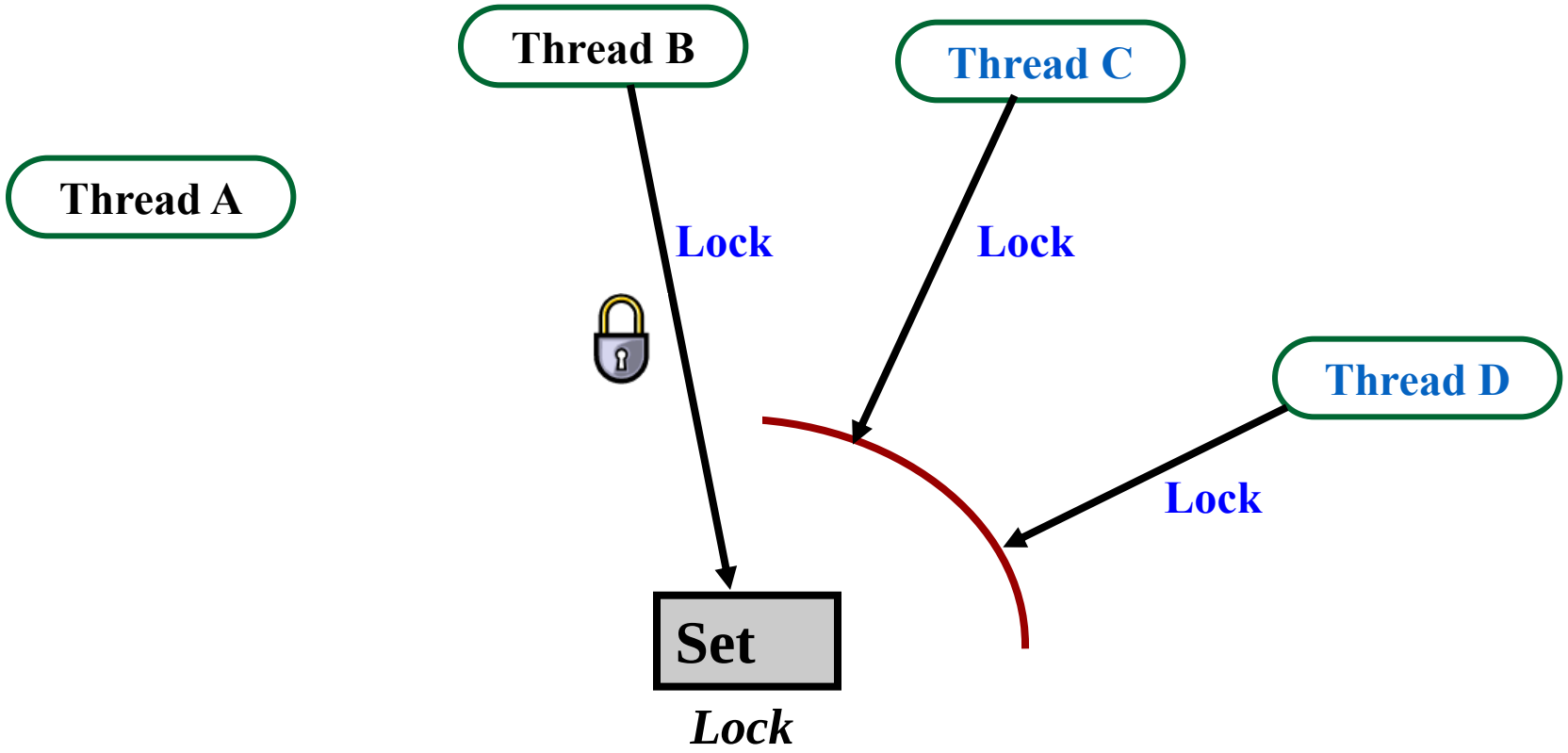

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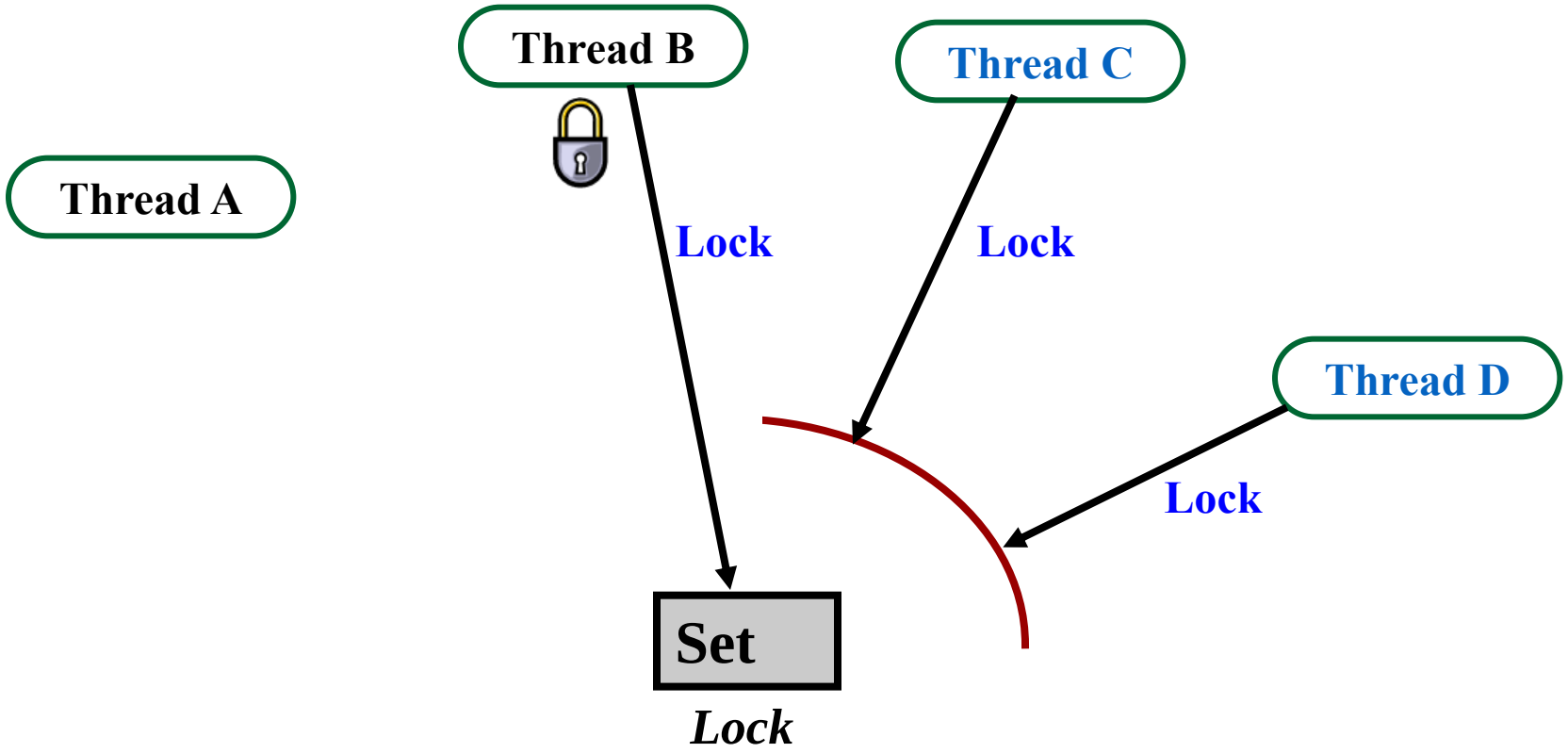

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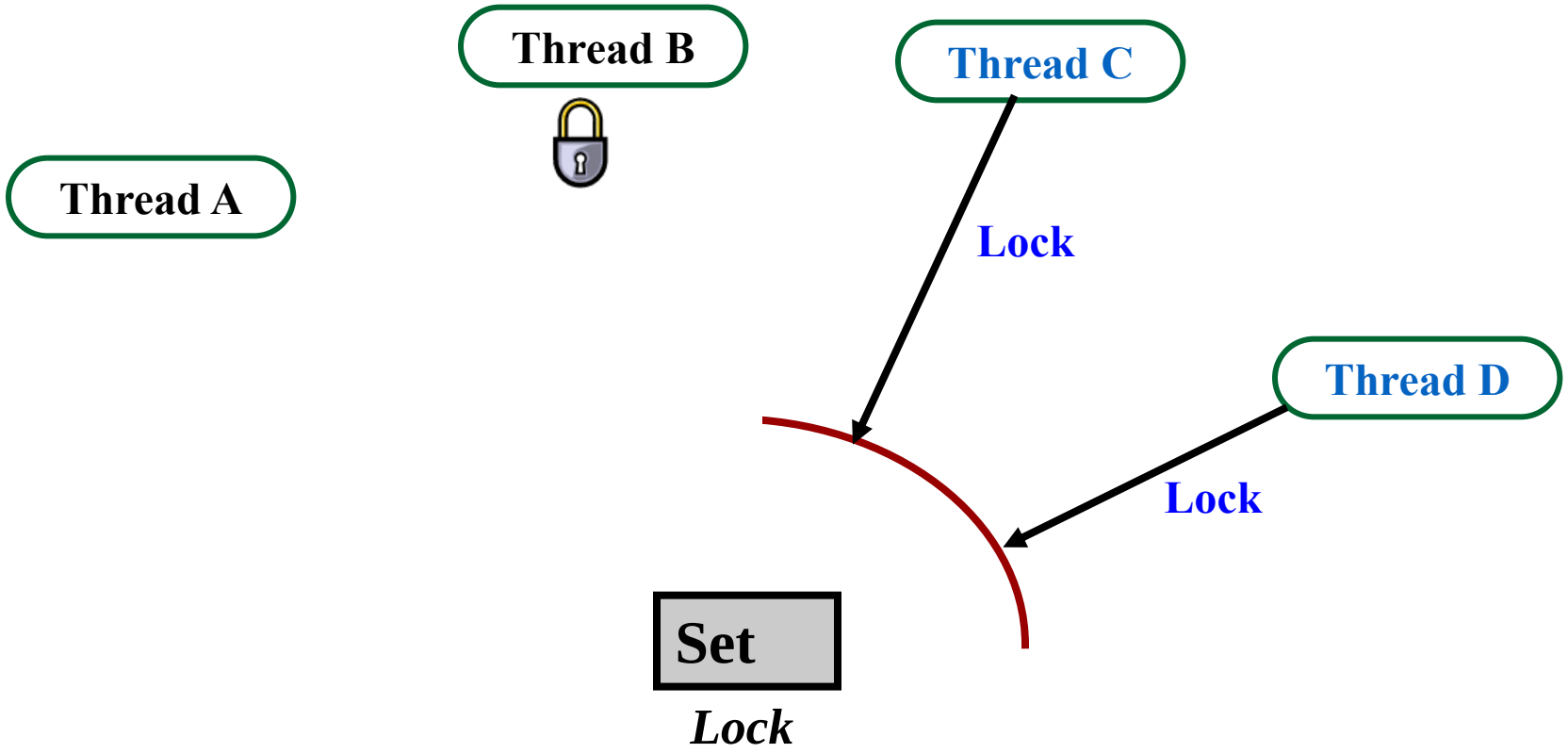

Mutual Exclusion (mutex) Locks

- An abstract data type used for synchronization
- The mutex is either:
  - *Locked* (*"the lock is held"*)
  - *Unlocked* (*"the lock is free"*)

Mutex Lock Operations

- Lock (*mutex*)
  - *Acquire the lock if it is free … and continue*
  - *Otherwise wait until it can be acquired*
- Unlock (*mutex*)
  - *Release the lock*
  - *If there are waiting threads wake one up*

Using a Mutex Lock

Shared data:

```
Mutex myLock;
```

```
1 repeat
2    Lock(myLock);
3    critical section
4    Unlock(myLock);
5    remainder section
6 until FALSE
```

```
1 repeat
2    Lock(myLock);
3    critical section
4    Unlock(myLock);
5    remainder section
6 until FALSE
```

جلسه‌ی بعد

- چگونگی پیاده‌سازی Mutex
- Semaphoreها
- مسائل مشهور هم‌زمانی

آزمونک

زمان: ۲۰ دقیقه