# Multithreading in Rust: Synchronization

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# Link Explorer

- You and your friends are bored so you decided to play a game where you go to a random Wikipedia page and try to find a link to another wikipedia page that is the longest (by length of the html)
  - Trust me, it’s fun!
- You decide to enlist Rust (along with the reqwest and select crates) to help you.

# Sequential Link Explorer

- The most straightforward approach
- No threads => no race conditions :^)
- Let’s see how fast it is…
- (code)

# Multithreaded Link Explorer

- The web requests are network bound, so we can easily overlap the wait times for these requests by running them in separate threads.
- You can see this runs considerably faster!
- Problems
  - We have this funky batching thing going on — **What's wrong with it?**
  - We can easily reuse threads (really, we should be using a **threadpool** which you will implement in assignment 6 of CS110)

```
real    2m55.927s
user    0m7.964s
sys     0m1.722s
```

Sequential

```
real    0m9.932s
user    0m6.843s
sys     0m1.926s
```

Multithreaded

# Can we do better than batching…?

- First of all, why did we need batching?
  - What happens if I just make the batch size really big…
- What's a more effective way to limit the number of active threads/outgoing connections?
  - You saw in CS110 lecture that we can use condition variables and semaphores to impose a limit on the number of "permission slips"
  - You will see this again in Assignment 5 (News Aggregator) — as an exercise, you may wish to upgrade the link explorer example to impose limits in this way!

# Condition Variables in C++

## Lecture 10: Multithreading and Condition Variables

- The **semaphore** constructor is so short that it's inlined right in the declaration of the **semaphore** class.
- **semaphore::wait** is our generalization of **waitForPermission**.

```
void semaphore::wait() {
  lock_guard<mutex> lg(m);
  cv.wait(m, [this] { return value > 0; })
  value--;
}
```

- Why does the capture clause include the **this** keyword?
  - Because the anonymous predicate function passed to **cv.wait** is just that—a regular function. Since functions aren't normally entitled to examine the **private** state of an object, the capture clause includes **this** to effectively convert the **bool**-returning function into a **bool**-returning **semaphore** method.
- **semaphore::signal** is our generalization of **grantPermission**.

```
void semaphore::signal() {
  lock_guard<mutex> lg(m);
  value++;
  if (value == 1) cv.notify_all();
}
```

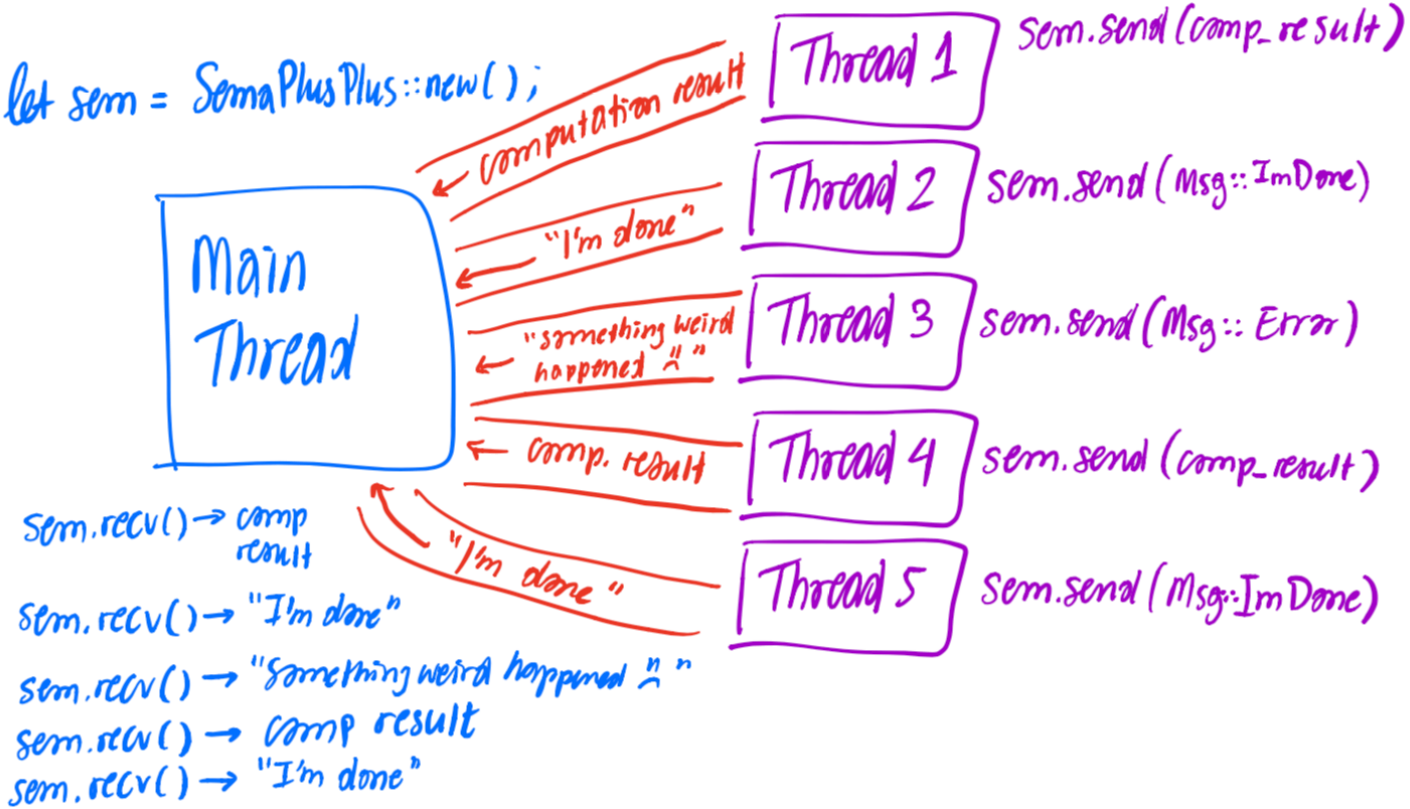
# Condition Variables in Rust

- Idiomatic to associate a condition variable with a mutex by putting them in a pair together and wrapping that pair in an Arc.
- We clone this pair before we move it into a thread.
  - Recall: we are NOT cloning the mutex, but rather a (reference-counted) pointer to it!
- You pass in the return value of mutex.lock().unwrap() to cv.wait(…) (or cv.wait_while(…))
- The Mutex<T> and Condvar interfaces in Rust enable us to write shorter, safer, and more legible code.
- We'll see this in today's live-coding example.

# SemaPlusPlus

- Semaphores can mediate access to a limited resource through giving out a limited number of “permission slips.” They can also synchronize threads to wait until a piece of data is ready (see producer/consumer) — we’ll focus on this second use case in the following example.
- But they only let you increment and decrement — let’s do something more interesting.
- Instead of just sema.signal — let’s do sema.send (msg)
- Instead of just sema.wait — lets’ do sema.recv() (which returns a msg that was previously sent)
- Why might we want an abstraction like this?

# SemaPlusPlus



# SemaPlusPlus Implementation

- Starter code
- Finished Example