Asynchronous JavaScript

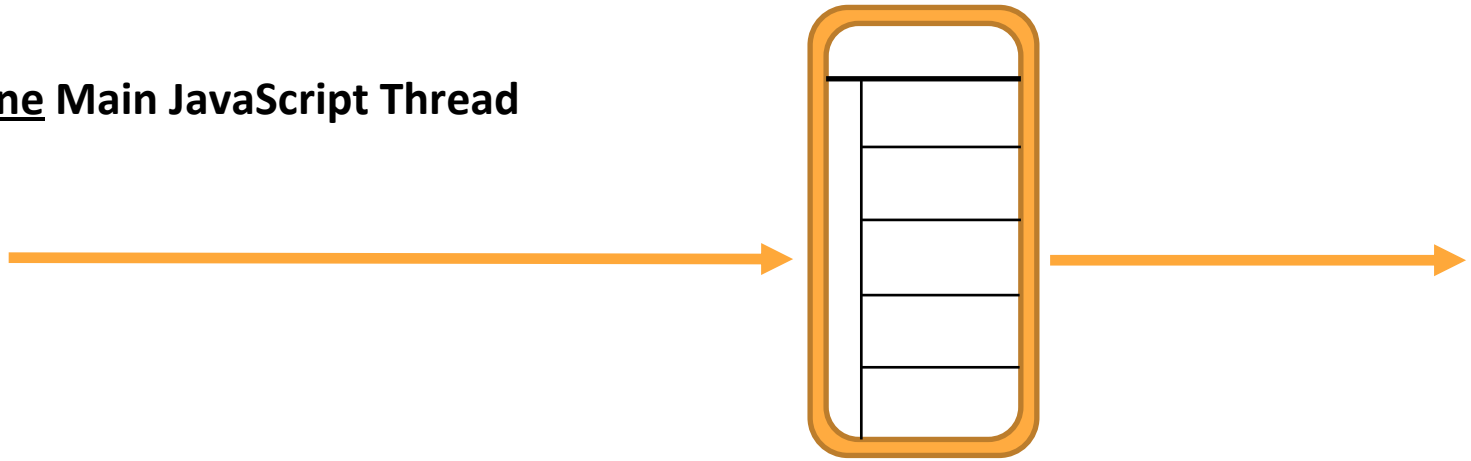
Callbacks

Promises

async/await

Avoid Long Running Tasks on the Main Thread

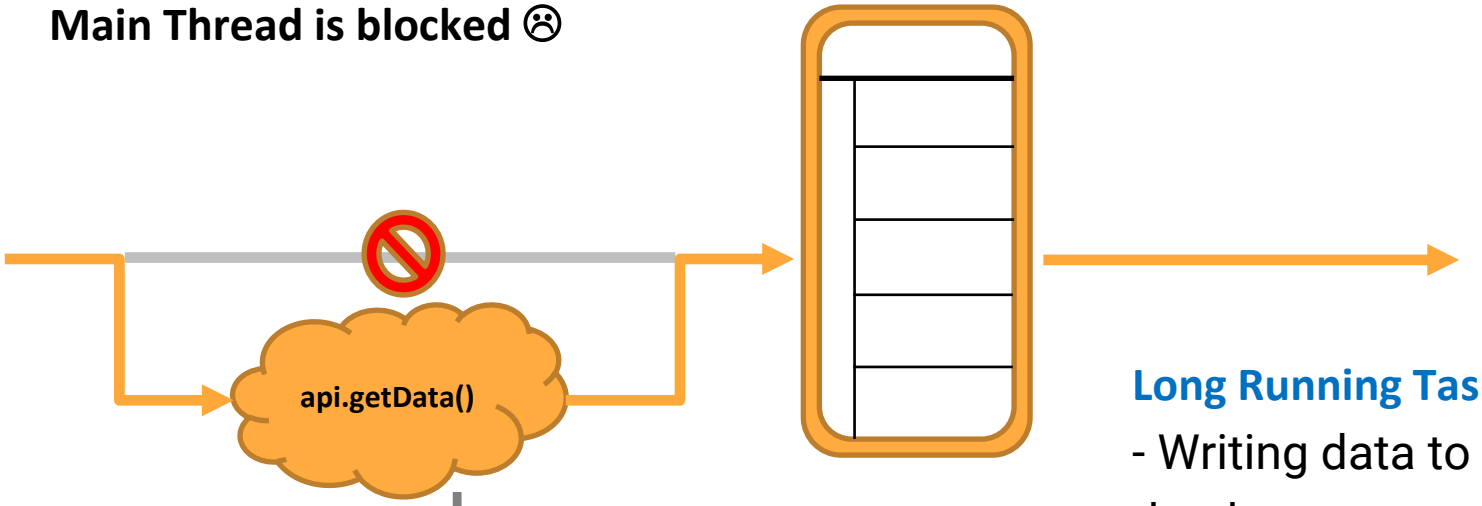
One Main JavaScript Thread



To guarantee a great user experience, it's essential to **avoid blocking the main thread** as it used to handle UI events on client-side (or handles incoming requests on the server-side)

Long Running Task on the Main Thread

Main Thread is blocked ☹




```
const data = api.getData()
display(data)
```

Synchronous long running code **blocks** the Main thread

Long Running Tasks include:

- Writing data to a file / database
- Parsing large JSON file
- Fetching data from Web API
- Executing CPU demanding task (e.g., compress an image)

Need to use Asynchronous programming to avoid blocking the main thread

Synchronous vs. Asynchronous

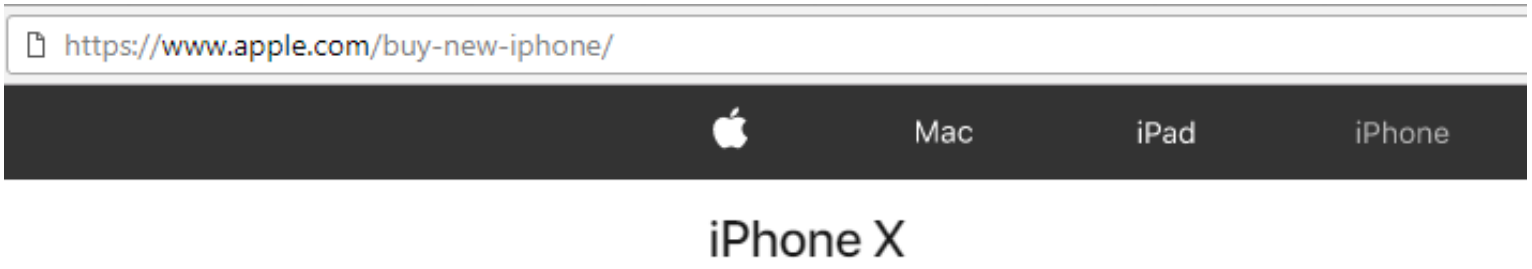
Buying newly released iPhone

- **Synchronous**:
  - You go to an Apple store
  - Wait impatiently in a queue, then pay for the phone and take it home

Synchronous vs. Asynchronous

Buying newly released iPhone

- **Asynchronous**:
  - You order the phone online from apple.com,
  - Then get on with other things in your life.
  - At some point in the future, the phone will be shipped. The postman will raise a knocking event on your door so that the phone can be delivered to you.



Sync Programming is Easy

```
function getStockPrice(name) {
 const symbol = getStockSymbol(name);
 const price = getStockPrice(symbol);
 return price;
}
```

Call a function,
suspend the caller
and wait for the return value to arrive

Synchronous Programming Problems

- I/O and CPU demanding tasks delay execution of all other tasks => **UI may become unresponsive**
- Especially problematic with accessing web resources
  - Resource may be large
  - Server may hang
  - Slow connection means slow loading causing UI blocks

Why use Async Programming?

- JavaScript is single-threaded
  - Long-running operations block other operations
- Async Programming is required to **prevent blocking** on long-running operations
- Benefits:
  - ***Responsiveness**: prevent blocking of the UI*

    => Doesn't lock UI on long-running computations
  - Better server-side ***Scalability**: prevent blocking of request-handling threads*

Asynchronous programming techniques

How to execute a long running tasks without blocking the Main thread?

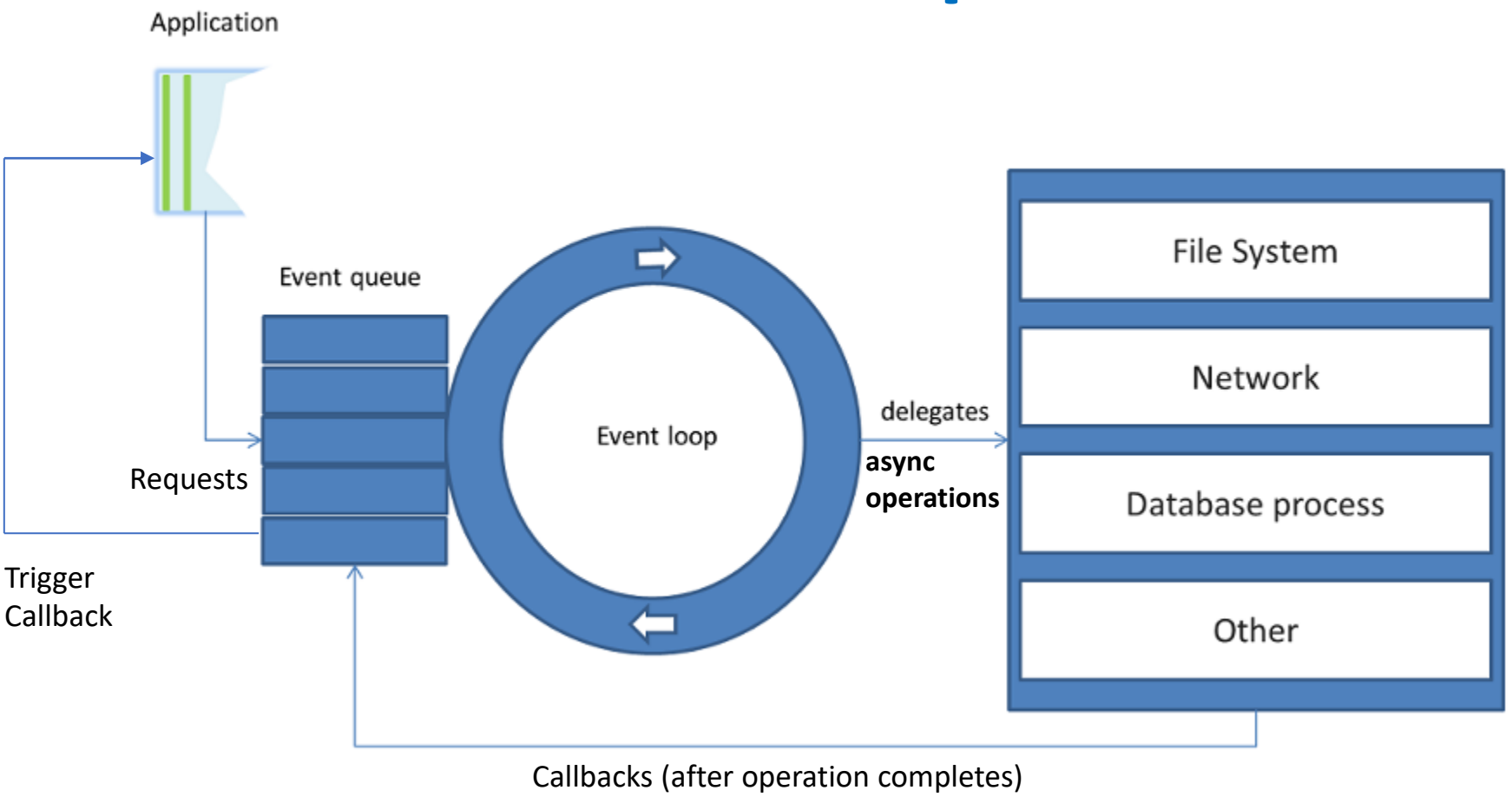
=> Async JavaScript programming using either:

- Callbacks
- Promises
- async/await

Key benefit of Async Programming = ***Responsiveness***

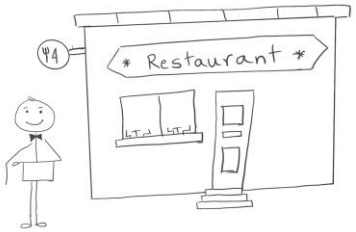
prevent blocking the main thread on long-running operations

Event Loop

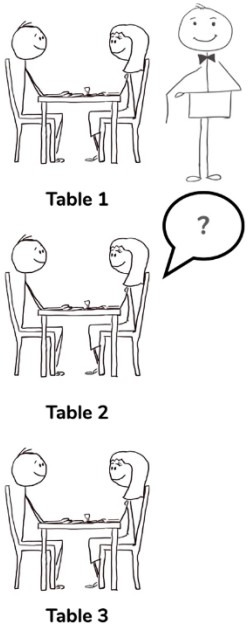


Delegate async operations (e.g., I/O tasks) and manage callbacks to avoid blocking main thread

Watch https://www.youtube.com/watch?v=8aGhZQkoFbQ



Analogy - Restaurant with a Single Waiter



Waiter acts as the Event Loop

Event Queue

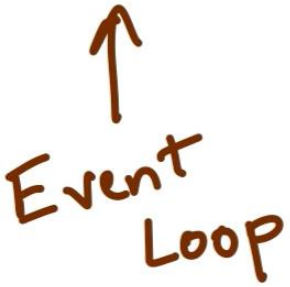
When the dish is ready then place a callback on the events queue

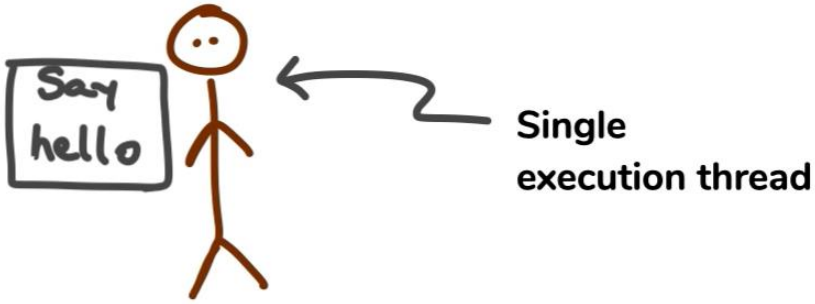
```
let order1 = takeOrder(table1);
chef.handOver(order, dish => serveTable(dish)); ✓
let order2 = takeOrder(table2);
```

Source: https://www.youtube.com/watch?v=EI7sN1dDwcY

Event Queue & Event Loop

```
while isNotEmpty(eventQueue)
   pull out first item from event queue
   execute it
```

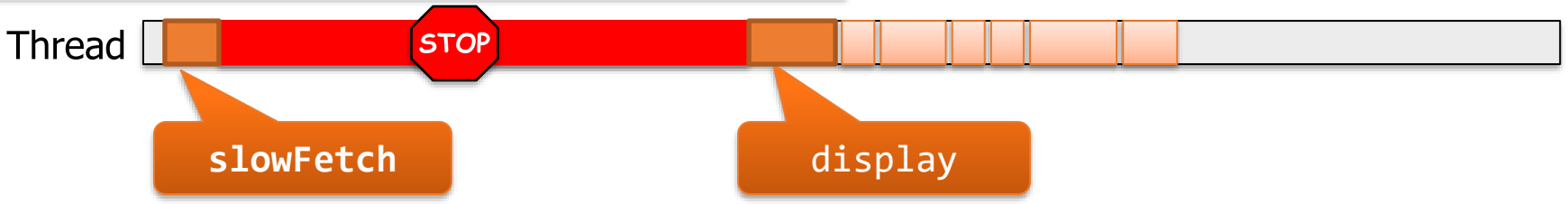




Synchronous vs. Asynchronous Functions

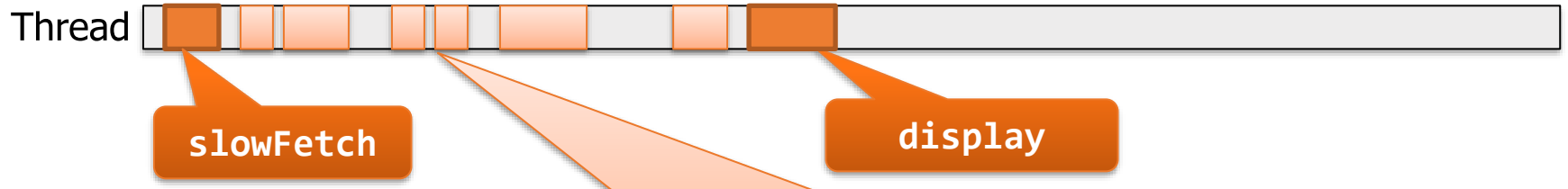
Synchronous → Wait for result before returning

```
const result = slowFetch(...) // UI Thread
display(result)  // UI Thread
```




```
// Slow request with callbacks
fun makeNetworkRequest(display) {
    // The slow network request runs on another thread
    slowFetch { result =>
       // When the result is ready, this callback will get the result
       display(result)
    }
}
```

Asynchronous → do an **asynchronous** call to slowFetch using backgroud thread, then update UI with the result



UI not blocked

While waiting for a result, **the main thread is unblocked** so other functions can run

Callbacks

- A callback function is a function passed into another function as an argument, which is then invoked inside the outer function
  - The outer function can pass arguments
- Examples of callbacks:
  - E.g., **`navigator.geolocation.getCurrentPosition`** takes a callback argument
- Problems:
  - Heavily nested functions are hard to understand => **Callback hell** i.e., non-trivial to follow path of execution
  - Errors and exceptions are a hard to handle

Callback Example

```
function getLocation() {
    navigator.geolocation.getCurrentPosition(showPosition);
}

function showPosition(position) {
    const p = document. querySelector("#demo");
    p.innerHTML += `Latitude: ${position.coords.latitude}
       <br>Longitude: ${position.coords.longitude} <BR>`;
}
```

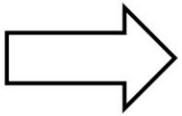
Callback Hell…

```
function getStockPrice(name, cb) {
    getStockSymbol(name, (error, symbol) => {
        if (error) {
            cb(error);
        }
        else {
            getStockPrice(symbol, (error, price) => {
                if (error) {
                    cb(error);
                }
                else {
                    cb(price);
                }
            })
        }
    })
}
```

Promises solves the Callback Hell…

CALLBACK

```
getData(a ⇒ {
    getMoreData(a, b ⇒ {
        getMoreData(b, c ⇒ {
            getMoreData(c, d ⇒ {
                getMoreData(d, e ⇒ {
                    console.log(e);
                });
            });
        });
    });
});
```



PROMISES

```
getData()
.then(a ⇒ getMoreData(a))
.then(b ⇒ getMoreData(b))
.then(c ⇒ getMoreData(c))
.then(d ⇒ getMoreData(d))
.then(e ⇒ console.log(e));
```

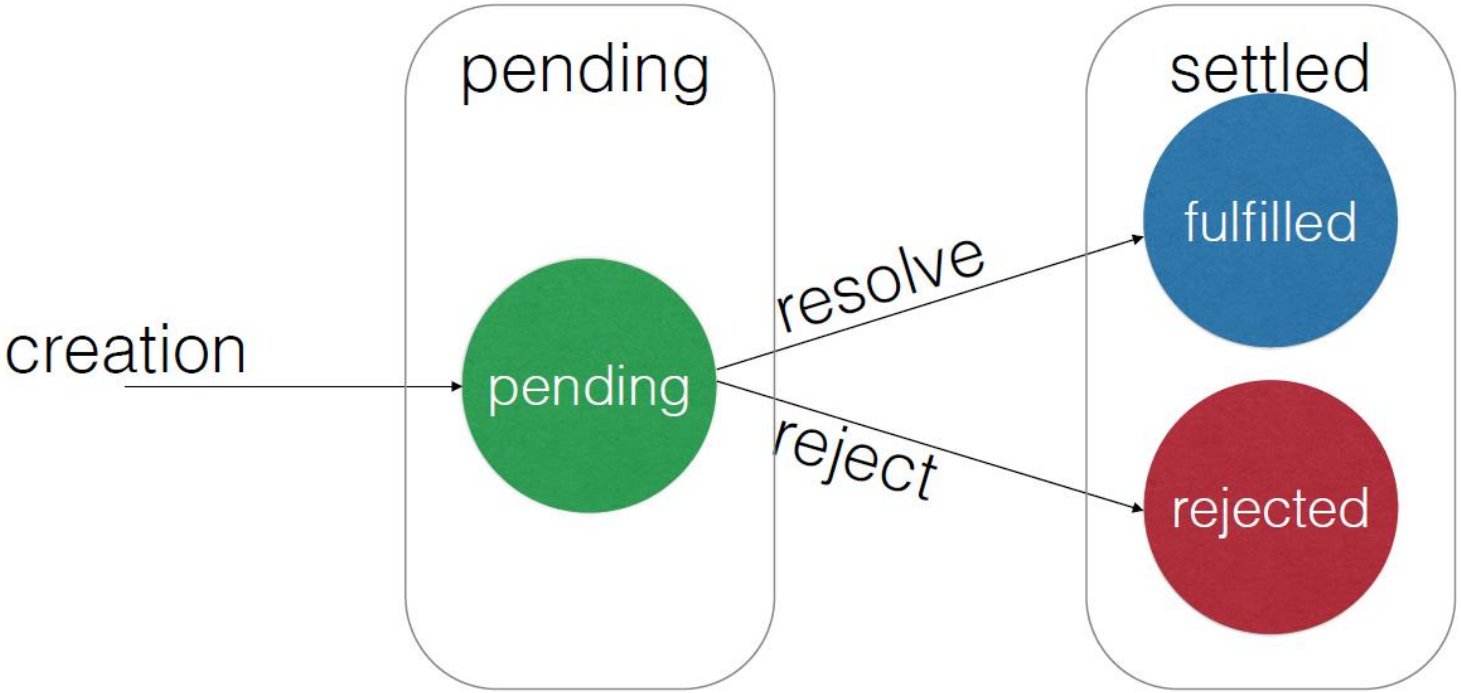
Promises

- Promise = object that represents an eventual (future) value
  - Is a way of promising that a work will be done (or might fail if the work could not be completed)
  - A producer returns a promise which it can later fulfill or reject
- Promise has one of three states: pending, fulfilled, or rejected
- Consumers listen for state changes with **.then** method:

```
promise.then(onFulfilled)
       .catch(onRejected)
       .finally(() => console.log('done!'));
```

- onFulfilled is function to process the received results
- onRejected is a function to handle errors

State of a Promise



- **Pending** - Not settled yet
- **Fulfilled** - When a promise is resolved successfully.
- **Rejected** - When a promise failed.
- **Settled** - an *umbrella term* to describe that a promise is either fulfilled or rejected

How to create a Promise

```
const promise = new Promise((resolve, reject) =>
{
    try {
        …
        resolve(value);
    } catch(e)  {
        reject(e);
     }
});
```

Example: Writing a Promise

- Wrapping **fs.readFile** in a promise

```
function getStudent(studentId) {
    return new Promise( (resolve, reject) => {
        fs.readFile('data/student.json', function (err, data) {
                if (err) {
                    reject(err);
                } else {
                    const students = JSON.parse(data);
                    const student = students.find(s => s.studentId === studentId);
                    resolve(student);
                }
            }
        );
    });
}
```

Example - Getting a resource from Url using node-fetch API

- Fetch content from the server

```
const url = "https://api.github.com/users/github";
fetch(url).then(response => response.json())
          .then(user => {
              console.log(user);
           })
           .catch(err => console.log(err));
```

- Fetch returns a Promise. Promise-fulfilled event (**.then**) receives a response object.
- **.json()** method is used to get the response body into a JSON object

sync vs. async

- **sync**

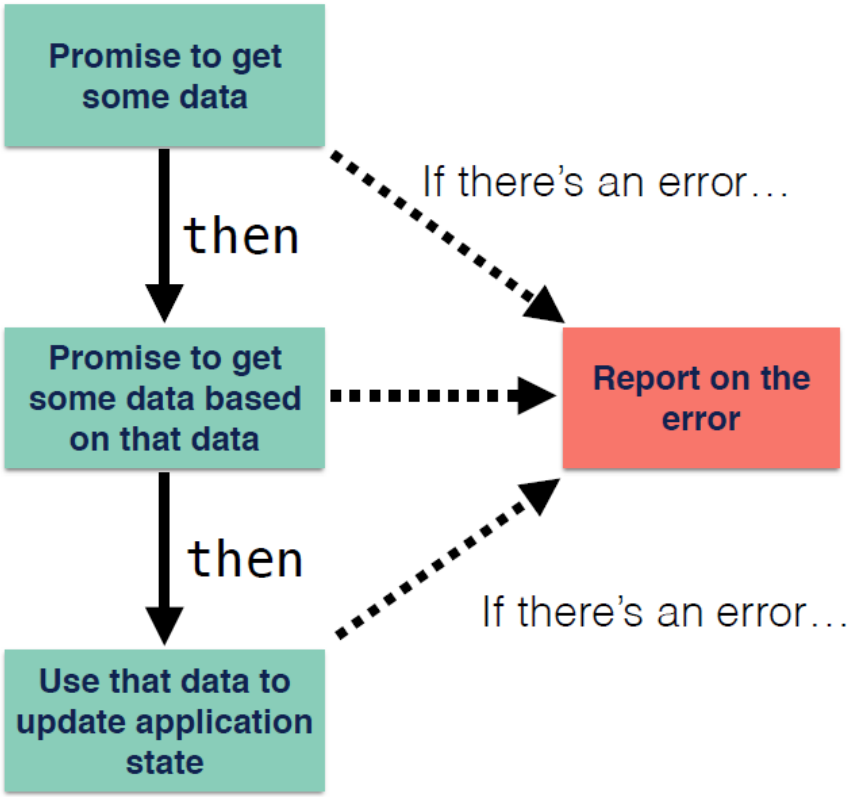
```
function getStockPrice(name) {
    const symbol = getStockSymbol(name);
    const price = getStockPrice(symbol);
    return price;
}
```

- **async**

```
function getStockPrice(name) {
    return getStockSymbol(name).
     then(symbol => getStockPrice(symbol));
}
```

Chaining Promises

Chaining Promises organize many steps that need to happen in order, with each step happening asynchronously



- See example @ http://jsfiddle.net/erradi/cxg5exox/

Chaining Promises

```
getUser()
  .then(function(user) {
    return getRights(user);
  })
  .then(function(rights) {
    updateMenu(rights);
  })
```

Better Syntax

```
getUser()
  .then(user => getRights(user))
  .then(rights => updateMenu(rights))
```

What distinguishes promises?

1. Easier **exception handling**
2. Easier to **run promises in parallel** to improve the app performance
3. Easier **asynchronous** programming
    - Replace callback-based code with sequential **`async / await`** to handle asynchronous long-running tasks without blocking

Promise combinator methods

Promise combinator methods

- **Promise.all** calls many promises and returns only when all the specified promises have completed or been rejected. The result returned is an array of values returned by the completed promises.

```
Promise.all([p1, p2, ..., pN]).then(allResults =>
{ ... });
```

- **Promise.race** calls two or more promises and returns the first response received (and ignores the remaining ones)

```
Promise.race([p1, p2, ..., pN]).then(firstResult
=> { ... });
```

Differences

⚙ Promise.all vs. Promise.allSettled

- `Promise.all` rejects as soon as a promise in the list is rejected.
- `Promise.allSettled` resolves regardless of rejected promise(s) within the list.

⚙ Promise.race vs. Promise.any

- `Promise.race` short-circuits on the first settled (fulfilled or rejected) promise within the list.
- `Promise.any` short-circuits on the first fulfilled promise and continues to resolve regardless of rejected promises unless all within the list reject.

	Short-circuit?	Short-circuits on?	Fulfilled on?	Rejected on?
Promise.all	✅	First rejected promise	All promise fulfilled	First rejected promise
Promise.allSettled	❌	N/A	Always	N/A
Promise.race	✅	First settled	First promise fulfilled	First rejected promise
Promise.any	✅	First fulfilled	First promise fulfilled	All rejected promises

Source: https://sung.codes/blog/2019/05/18/promise-race-vs-promise-any-and-promise-all-vs-promise-allsettled/

async / await

- Allows easier composition of promises compared to chaining using **.then**
  - Due to its sequential style, it's **easier** to understand

```
async function getStudent(studentId) {
    const student = await getStudent(studentId);
    student.courses = await getCourses(student.courseIds);
    return student;
}

try {   const studentId = 2015002;
        const student = getStudent(studentId);
        console.log( JSON.stringify(student, null, 2));
}
catch(err) { console.log(err); }
```

How await works?

- When a function awaits a result of a call, it does NOT block instead the runtime:
  - **suspends** the function execution, removes it from the thread, and stores the state and the remaining function statements in memory until the result is ready then
  - **resumes** the function execution where it left off
- While it's suspended waiting for a result, **it unblocks the thread that it's running on**, so that the thread is free to be used for other tasks

Summary

- Async/await allows easier **asynchronous** programming
  - Replace callback-based code with sequential code to handle asynchronous long-running tasks without blocking
  - Structure of asynchronous code is the same as synchronous code