Asynchronicity: concurrency. A tale of

(a.k.a: the subtle art of making a PB&J sandwich)

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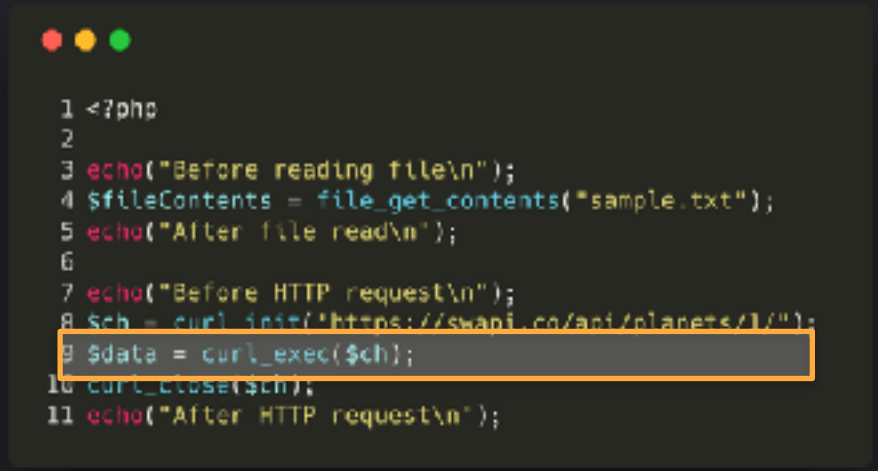

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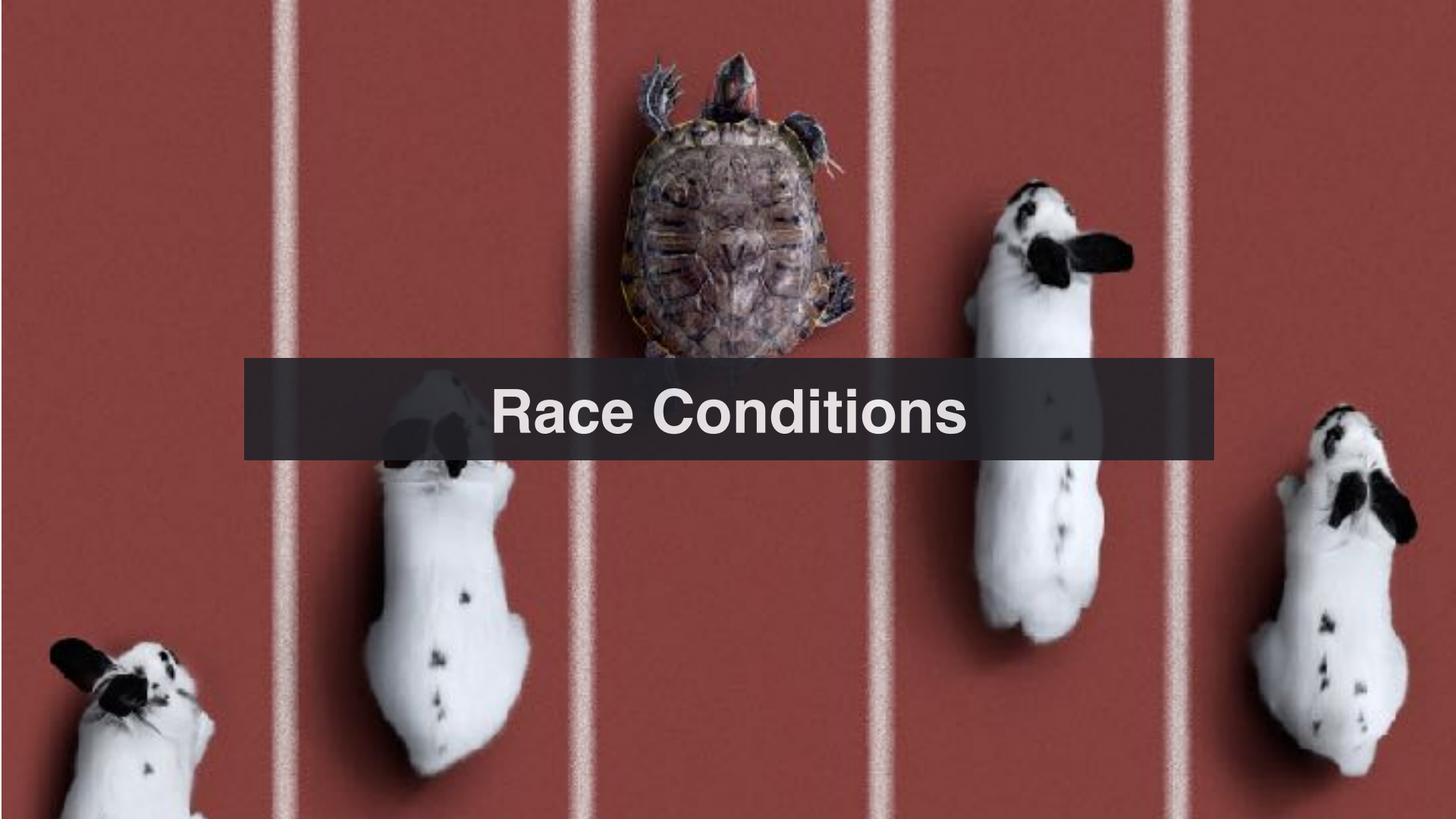
Race Conditions

About Me

@joel__lord

joellord

Our Agenda

- Event Loop
- Callbacks
- Promises
- Generators
- Await/Async
- Events
- Reactive Events


How to make a PB&J sandwich

PB&J Sandwich

- Get the ingredients
  - Get some bread
  - Get some PB
  - Get some J
- Prepare the sandwich
  - Spread PB
  - Spread J
- Close it
- Eat it!

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The Event Loop

Classic Architecture (PHP, Java)

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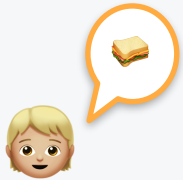
- I want a sandwich!



Classic Architecture (PHP, Java)

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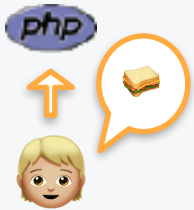
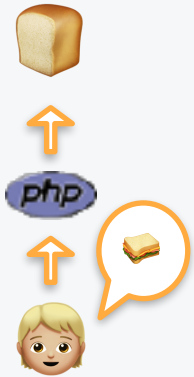
- Process start



Classic Architecture (PHP, Java)

- I want a sandwich!
- Process start
  - Fetches the ingredients



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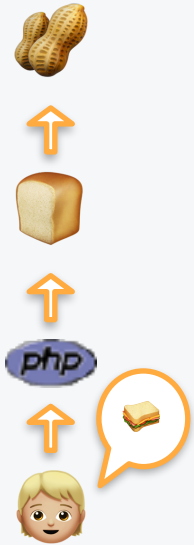

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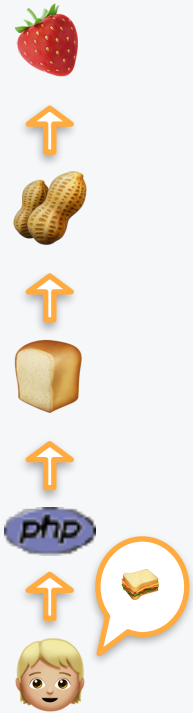

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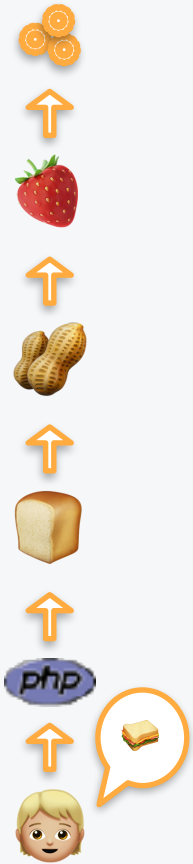
- I want a sandwich!
- Process start
  - Fetches the ingredients
  - Prepares the sandwich



Classic Architecture (PHP, Java)

- I want a sandwich!
- Process start
  - Fetches the ingredients
  - Prepares the sandwich
  - Here's your sandwich

Classic Architecture (PHP, Java)

- I want a sandwich!
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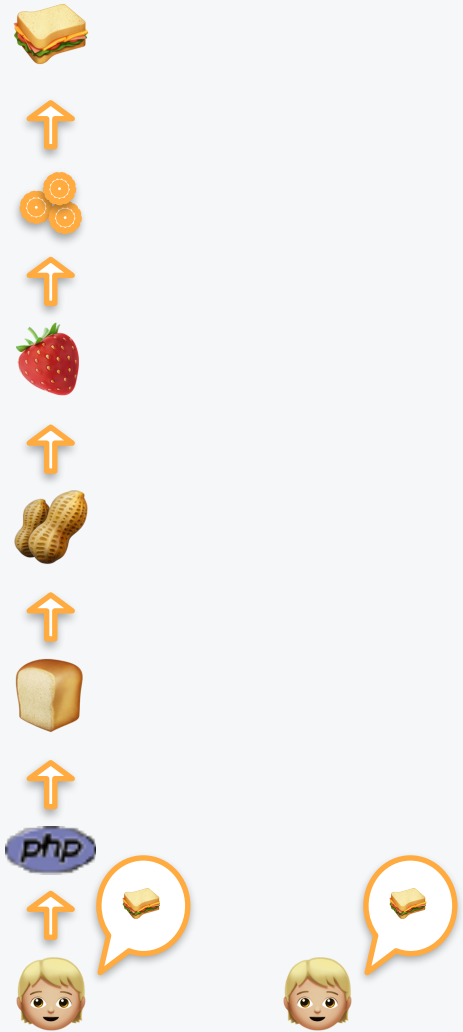
- A new customer arrives: I want a sandwich!



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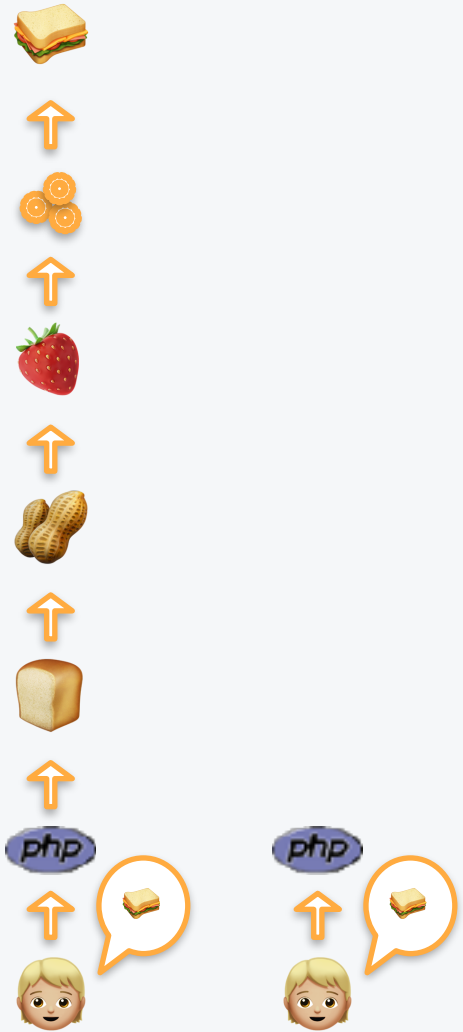
- Another process starts



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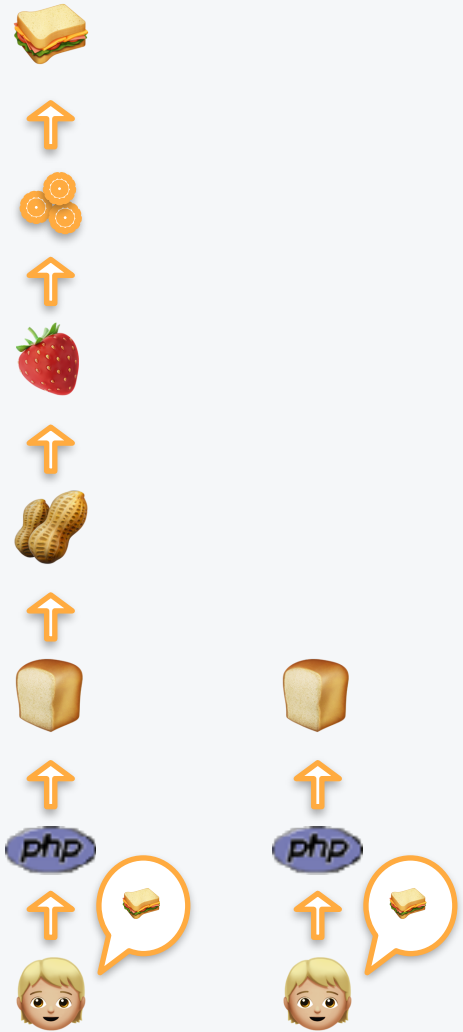

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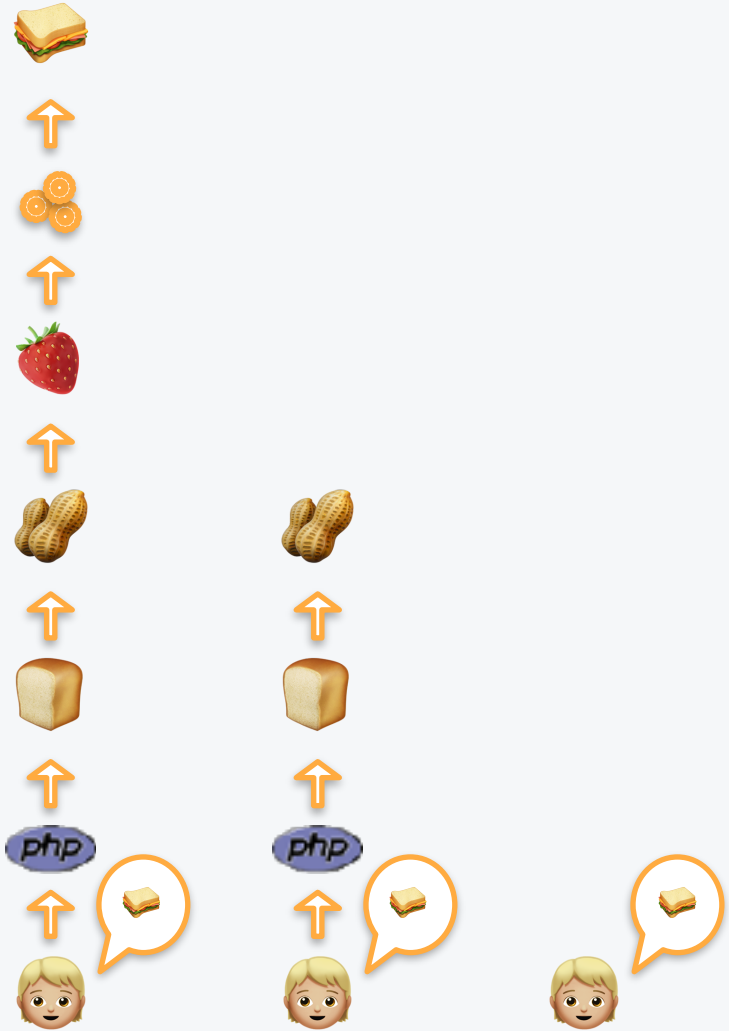

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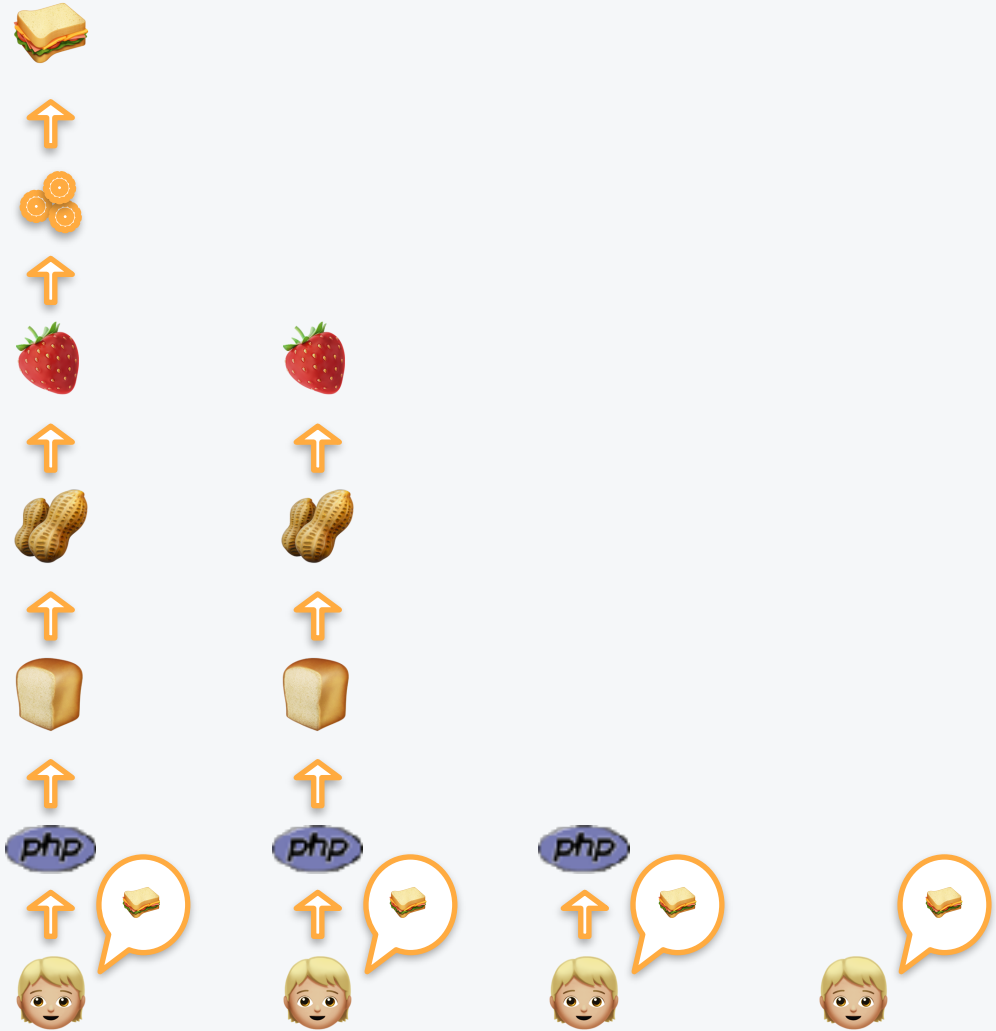

Classic Architecture (PHP, Java)

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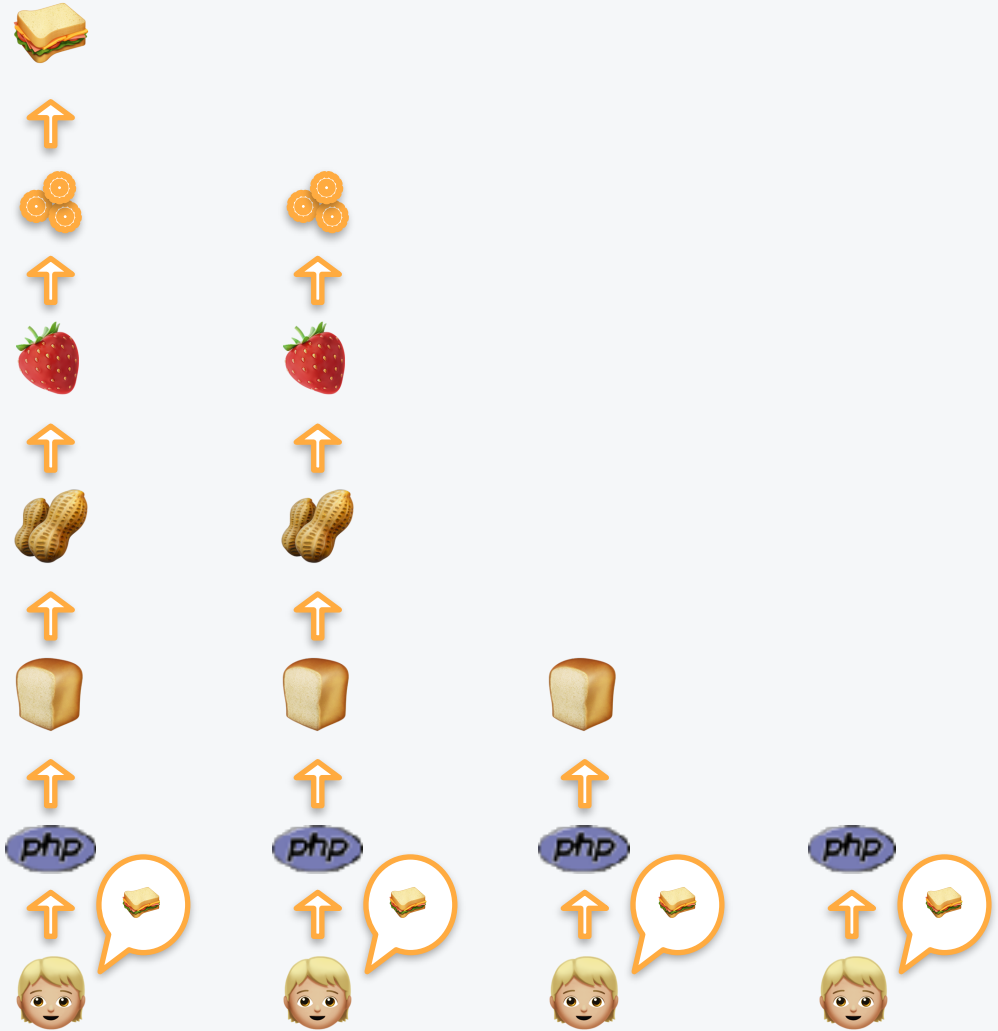

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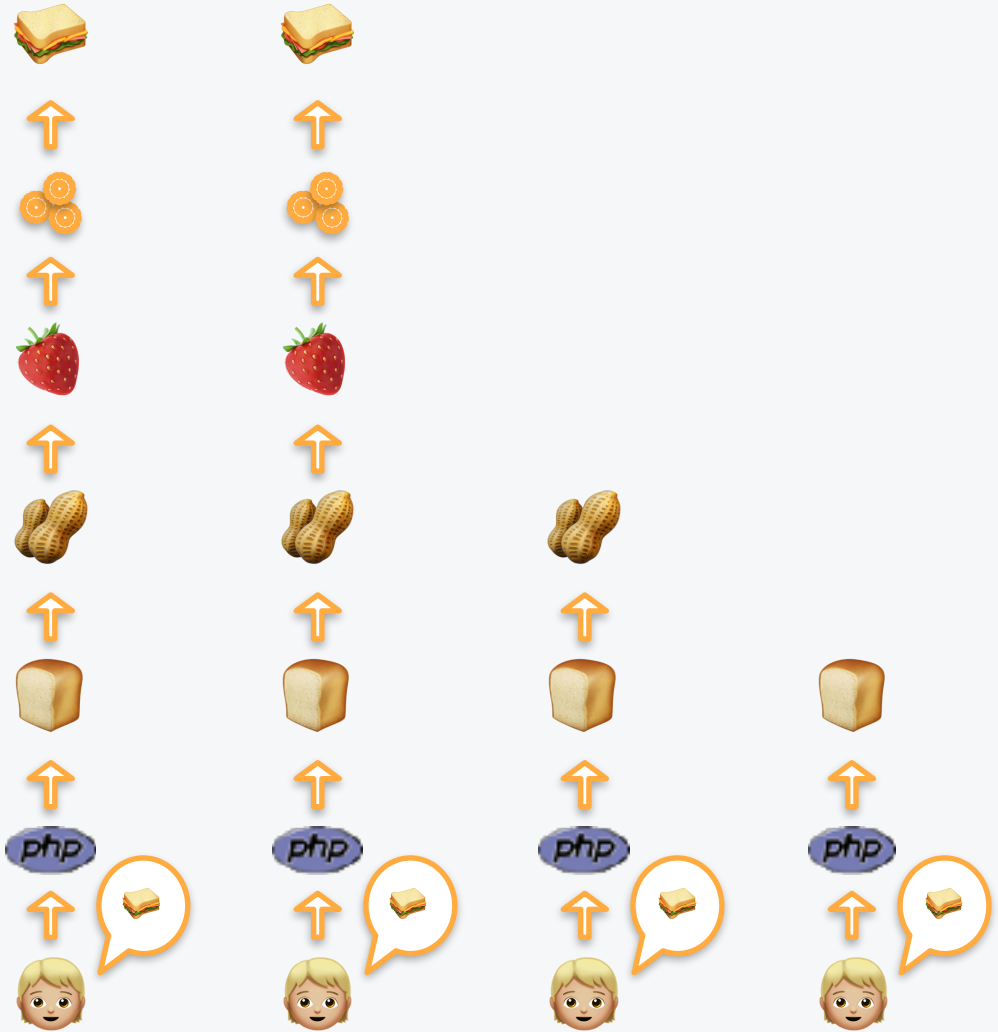

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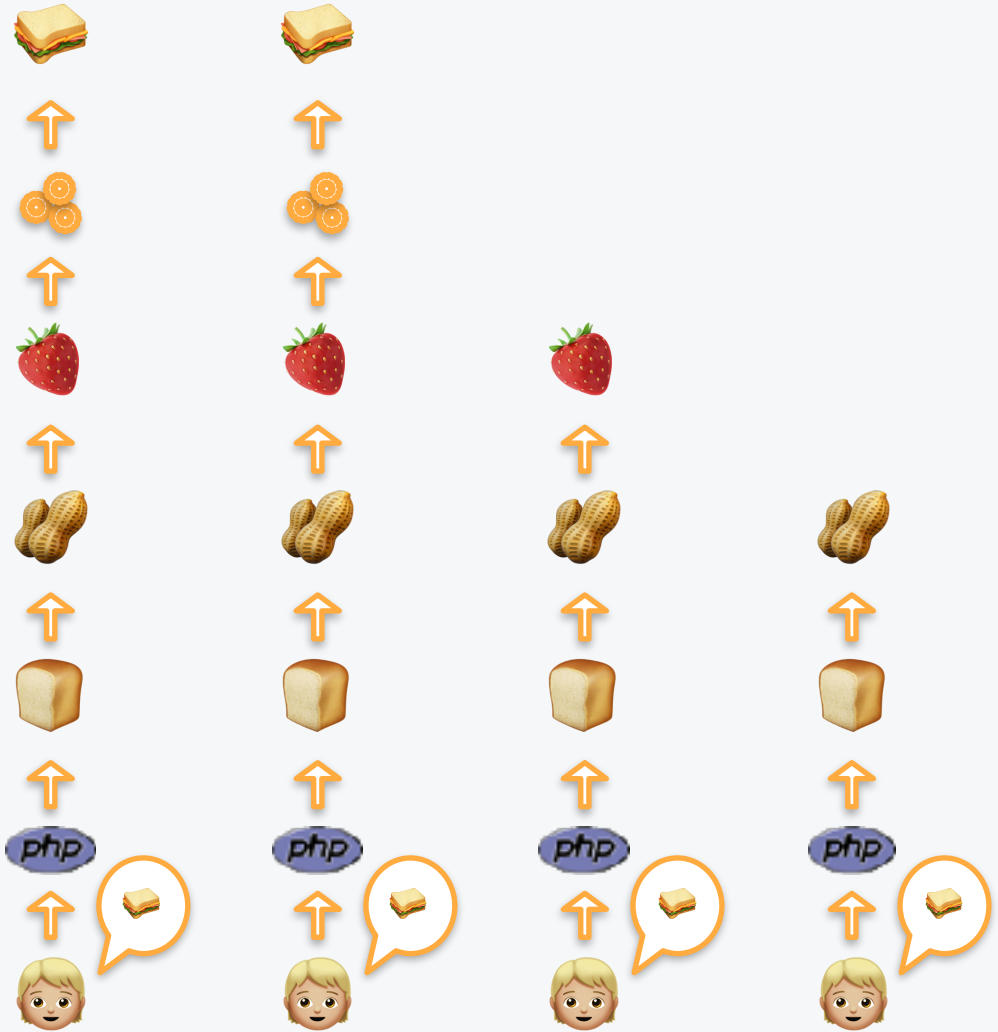

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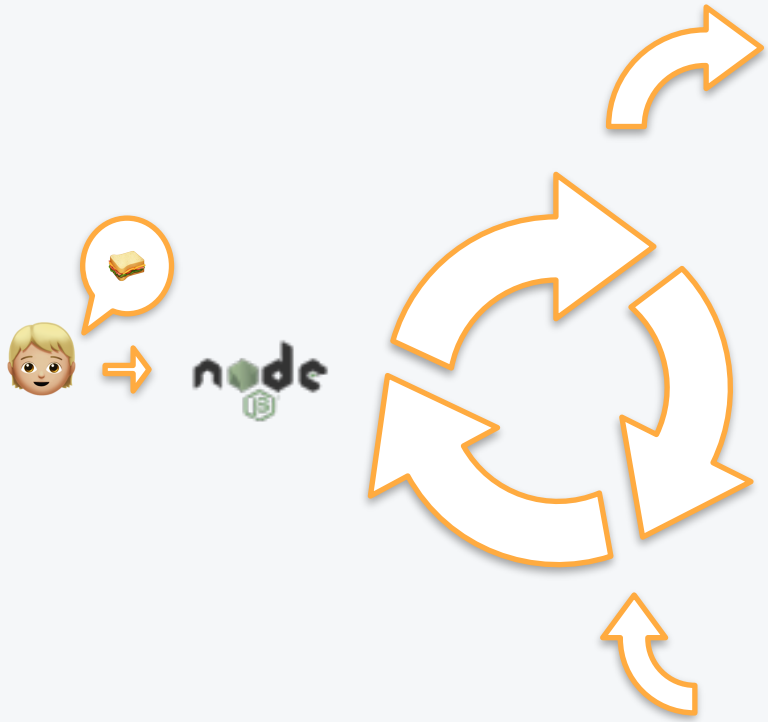

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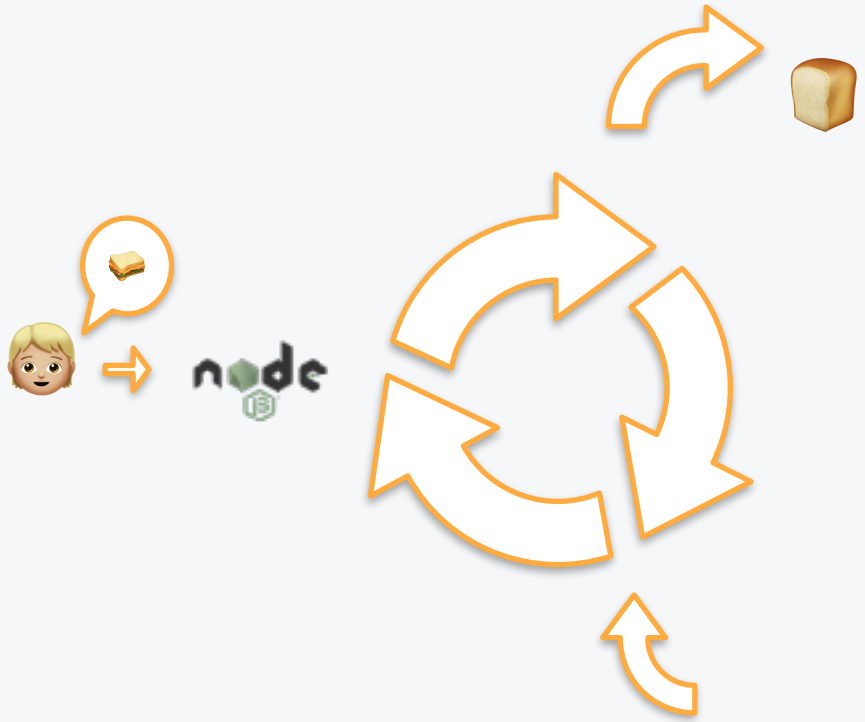

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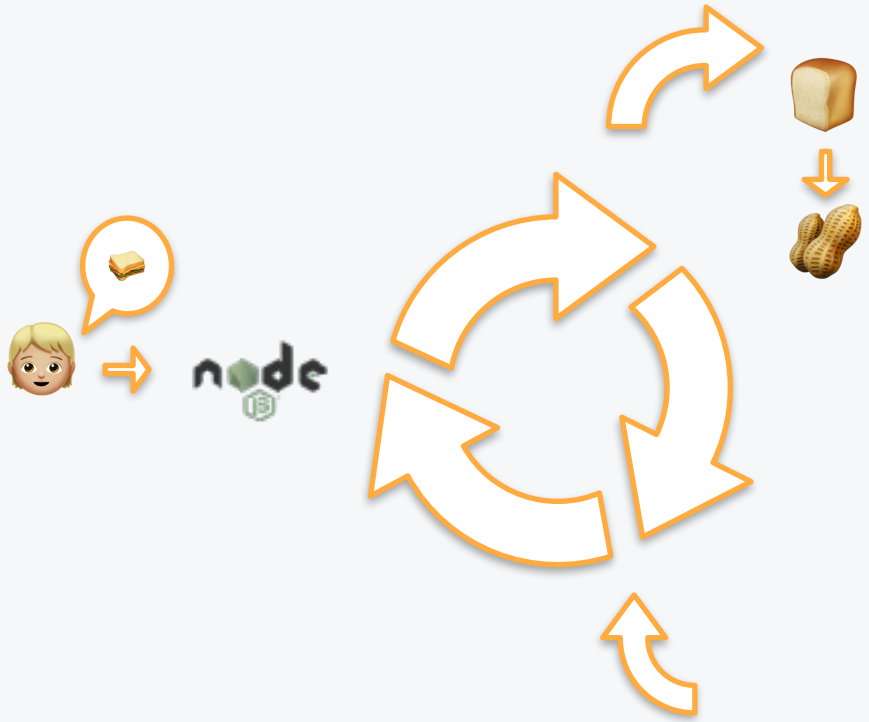

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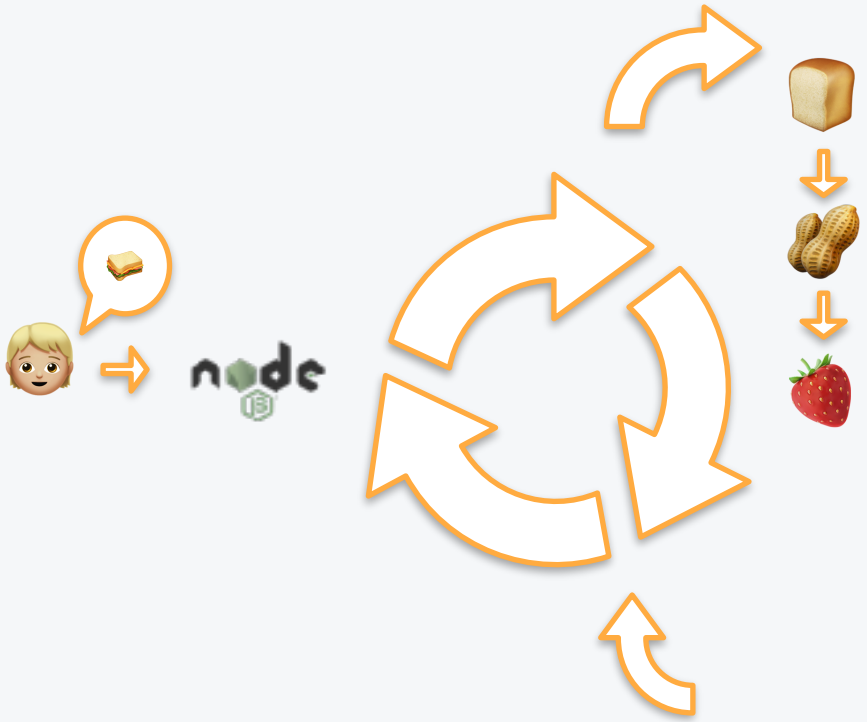

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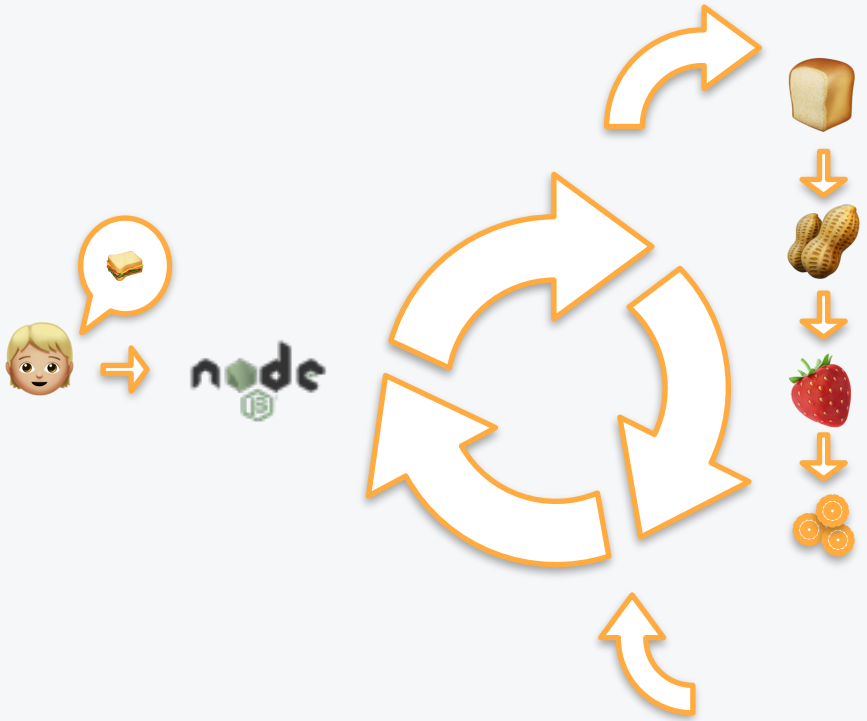

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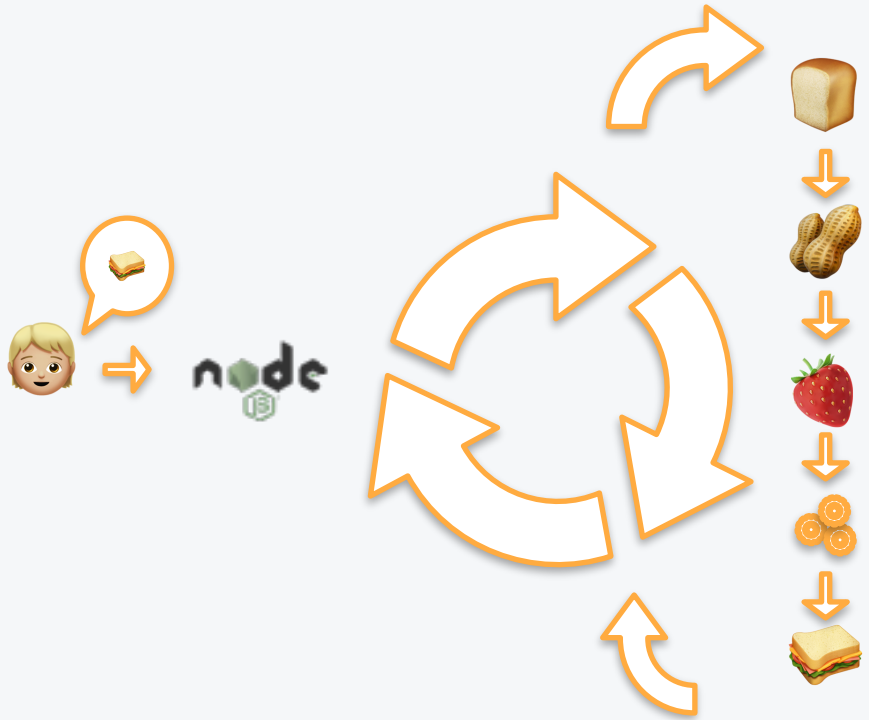

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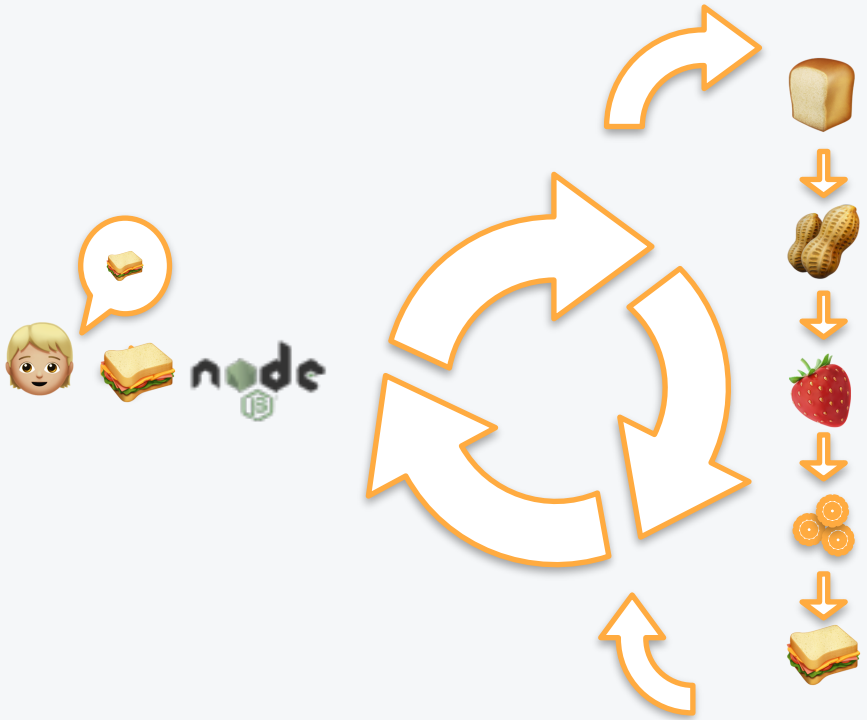

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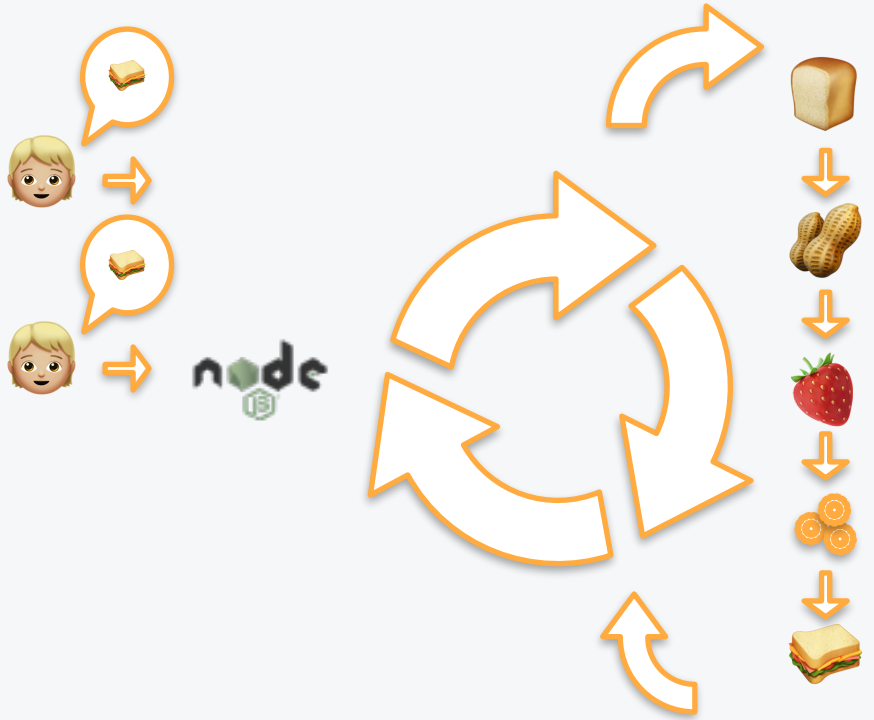

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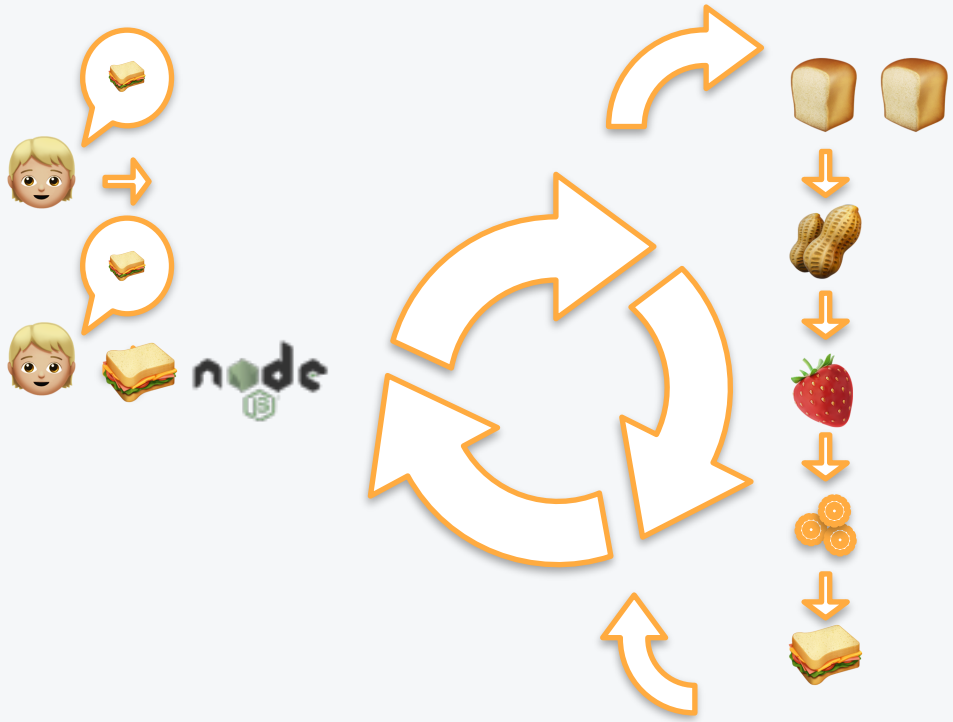

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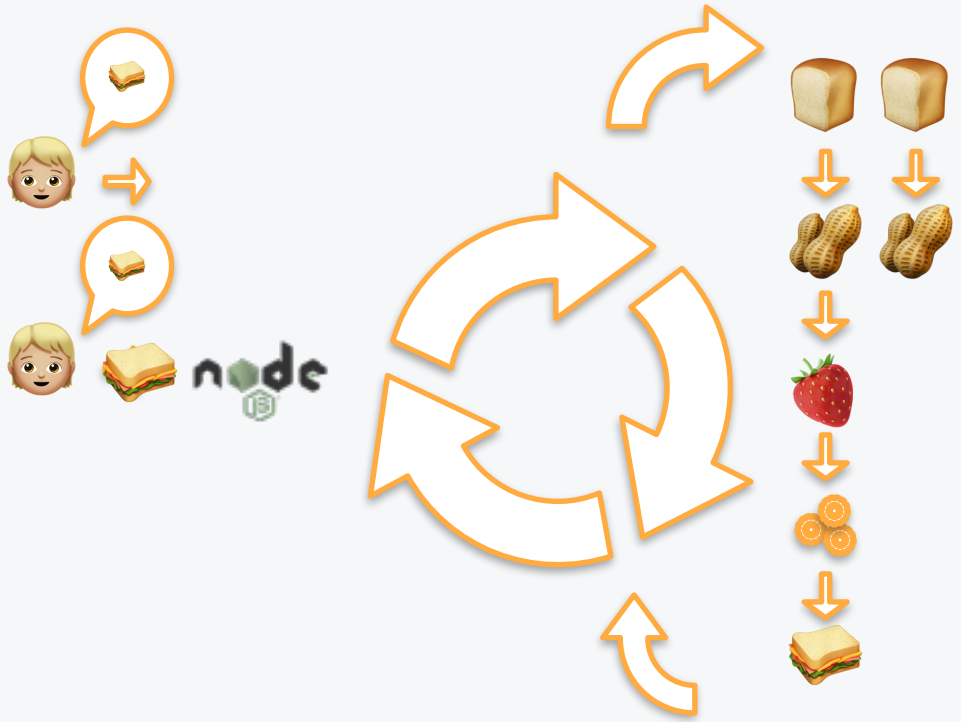

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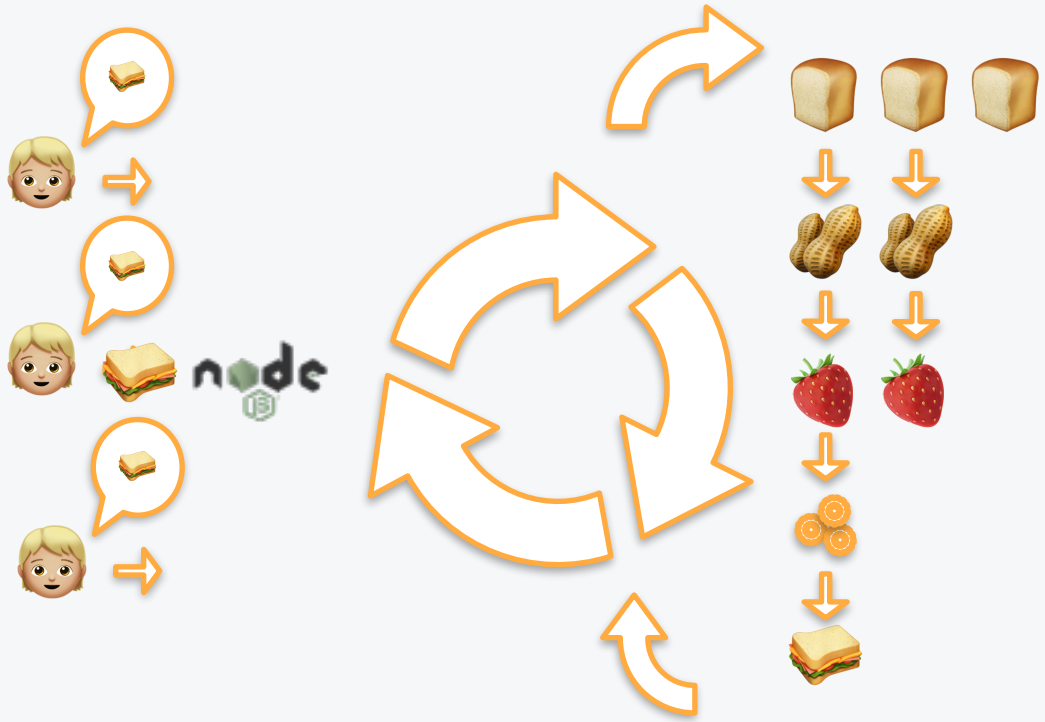

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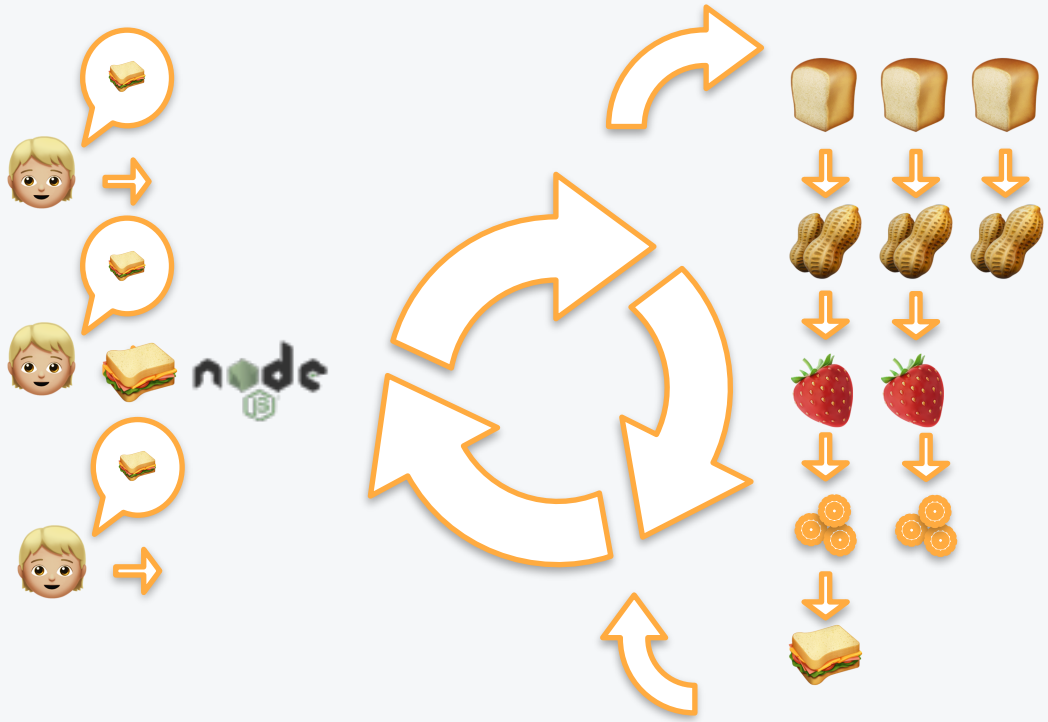

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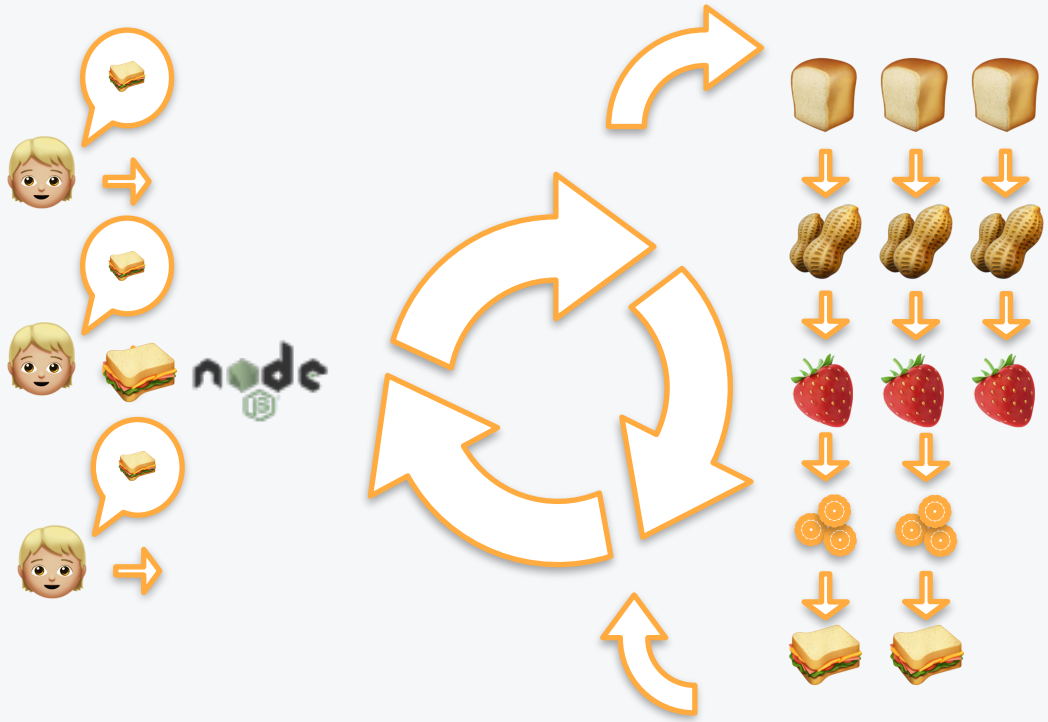

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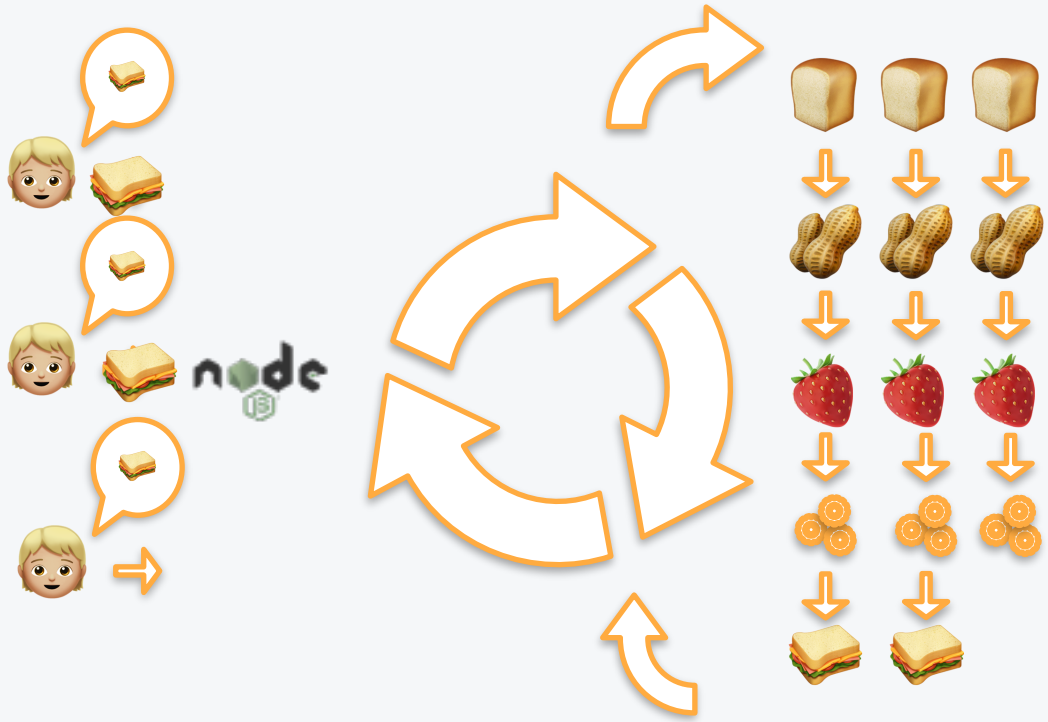

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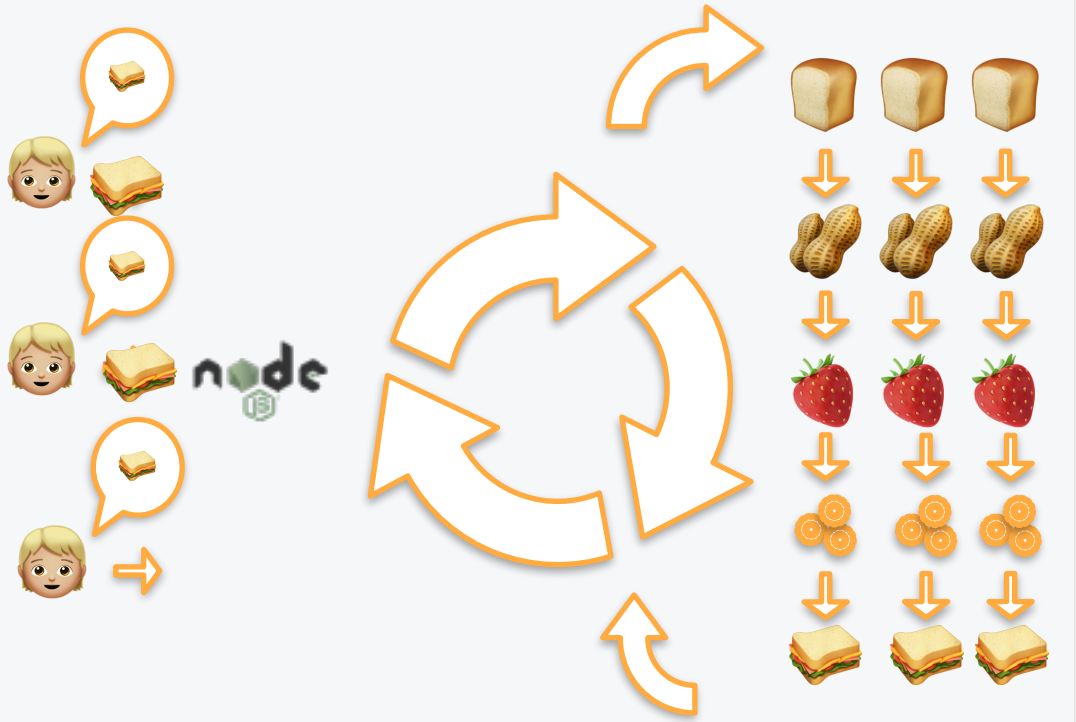

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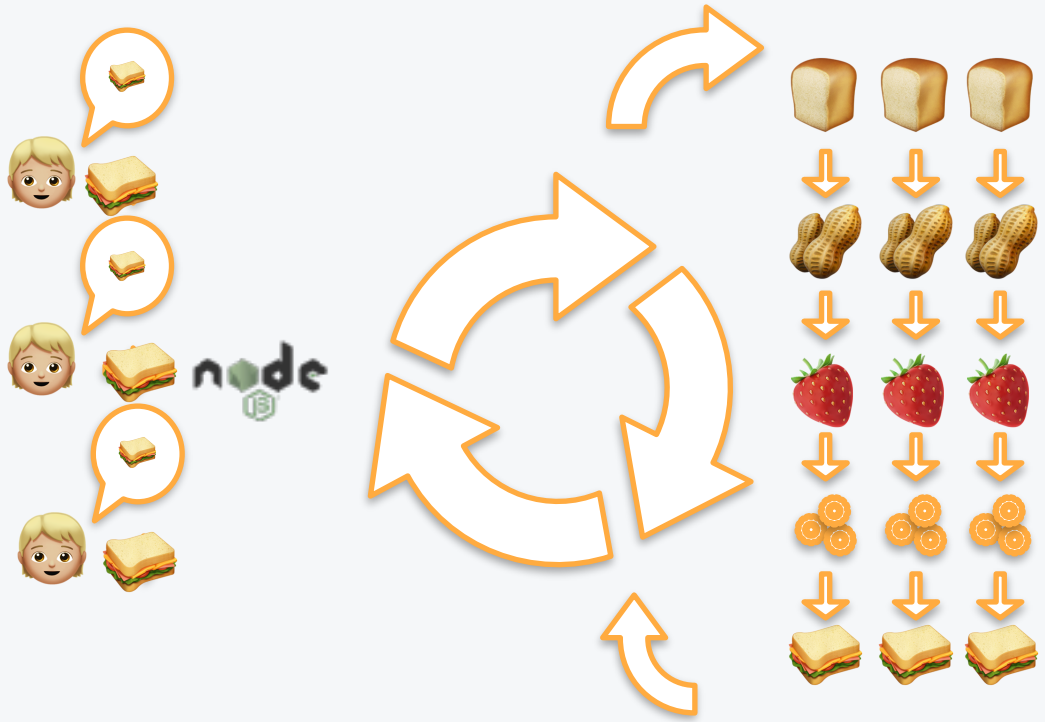
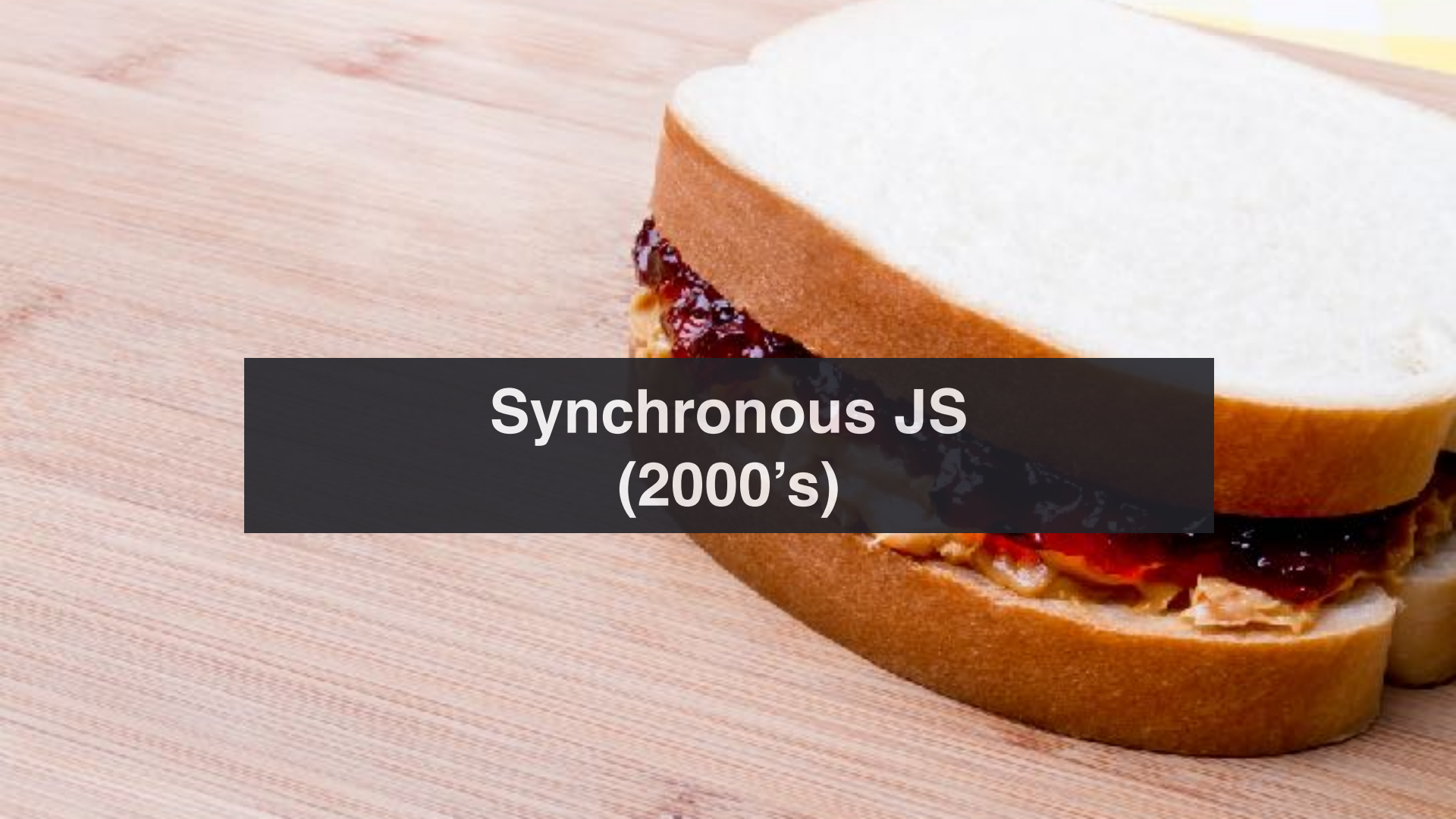


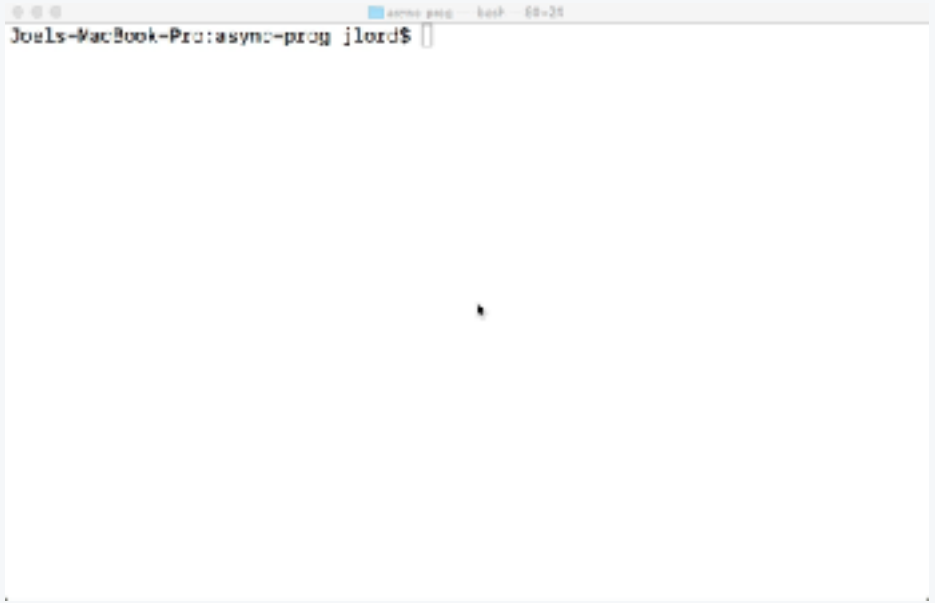

Synchronous JS
(2000’s)

Code

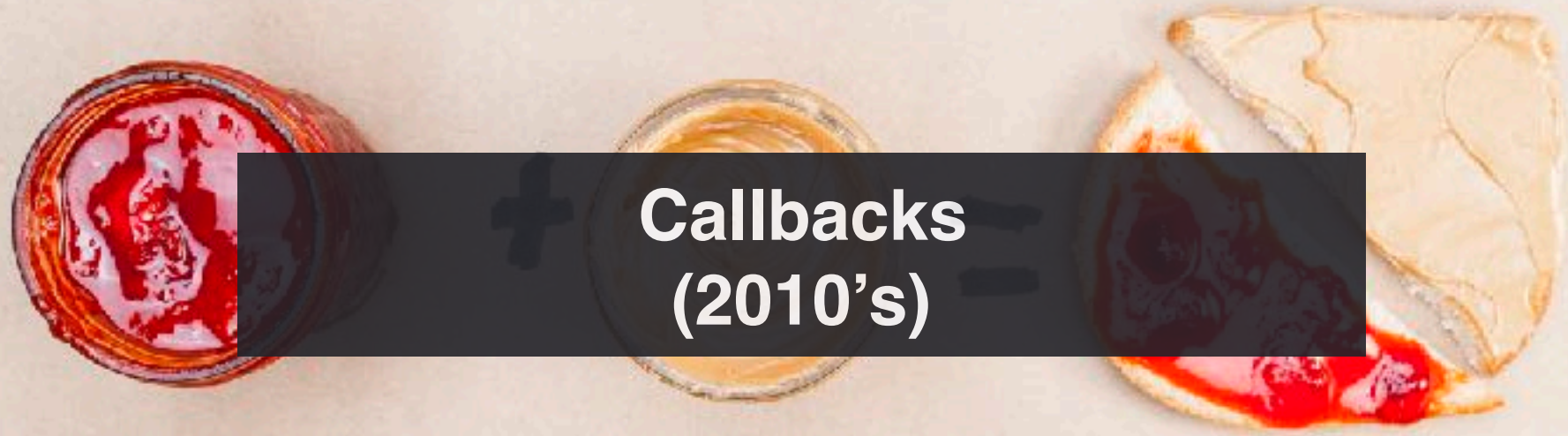
```
let PBnJMaker = require("./pbnjmaker");

PBnJMaker.fetchBread();
PBnJMaker.fetchPeanutButter();
PBnJMaker.fetchJam();
PBnJMaker.spreadPeanutButter();
PBnJMaker.spreadJam();
let result = PBnJMaker.closeSandwich();
console.log("Eat that " + result);
```

Result



@joel__lord
#confoo

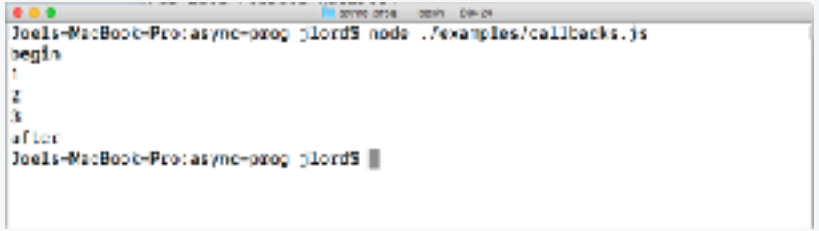


Callbacks (2010's)

What is a callback

- Simply a function as an argument to a function
- Could be synchronous or asynchronous

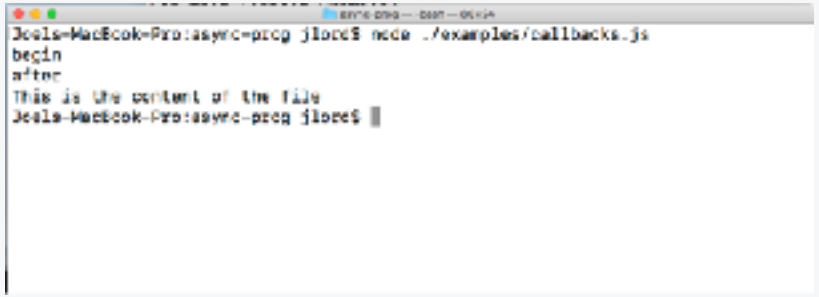
```
1 //Synchronous
2 let array = [1,2,3];
3 console.log("begin");
4 array.map((i) => {console.log(i)});
5 console.log("after");
```



What is a callback

- Simply a function as an argument to a function
- Could be synchronous or asynchronous

```
1 //Asynchronous
2 console.log("begin");
3 fs.readFile("./cb.txt", (err, data) => {
4     console.log(data);
5 });
6 console.log("after");
```



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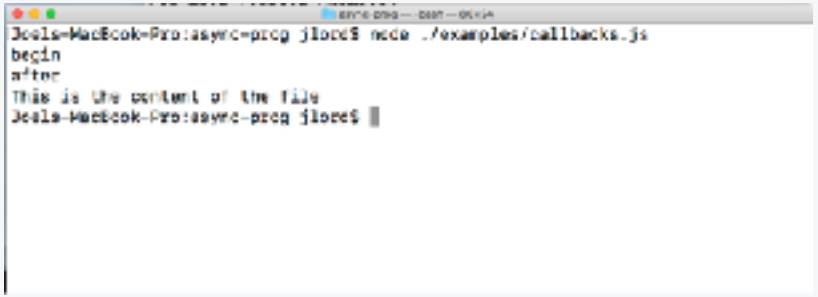

What is a callback

Asynchronous callback and the event loop

```
console.log("begin");

fs.readFile("./cb.txt",
(err, data) => {
    console.log(data);
});

console.log("after");
```

```
Joels-MacBook-Pro:async-prog jlord$ node ./examples/callbacks.js
```

What is a callback

Asynchronous callback and the event loop

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    console.log(data);
});

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```

```
Joels-MacBook-Pro:async-prog jlord$ node ./examples/callbacks.js
begin
```

@joel__lord
#confoo

What is a callback

Asynchronous callback and the event loop

```
console.log("after");
```

```
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    console.log(data);
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```

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@joel__lord
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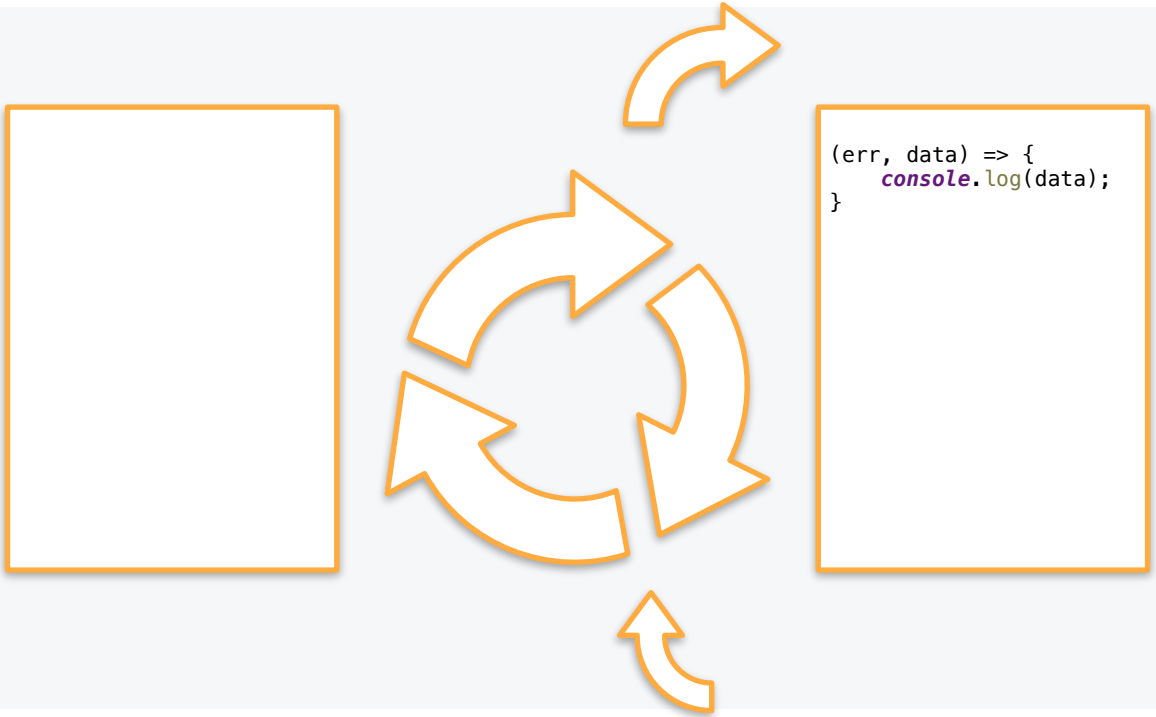

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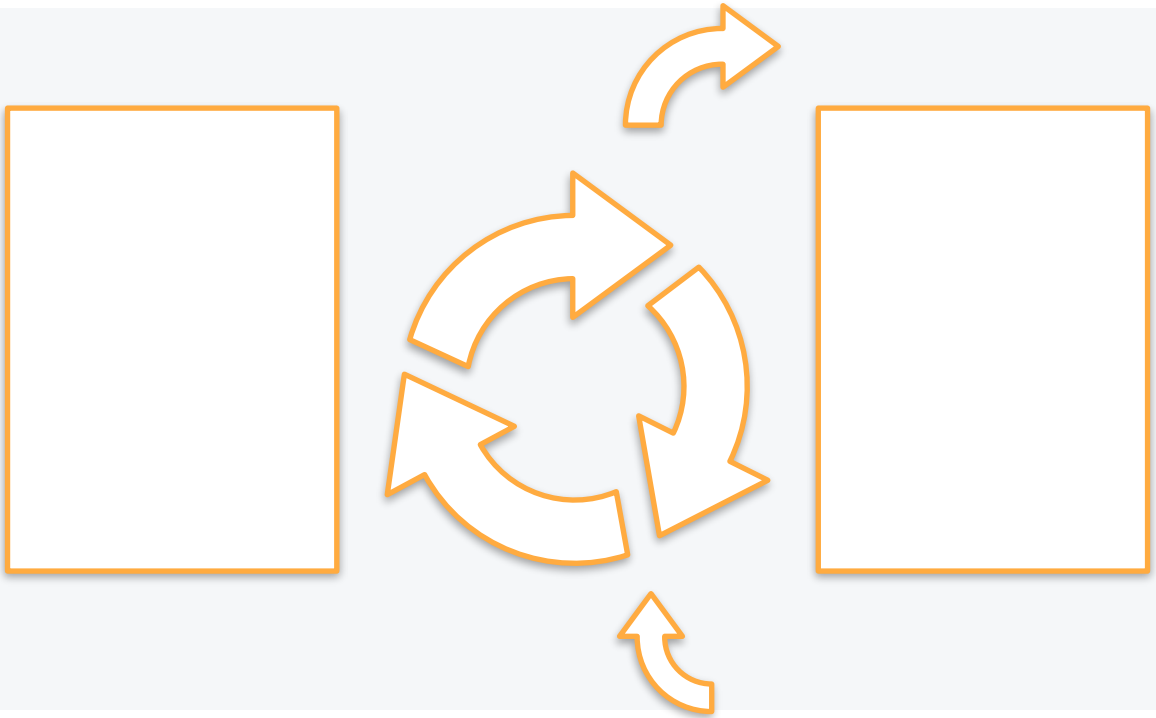


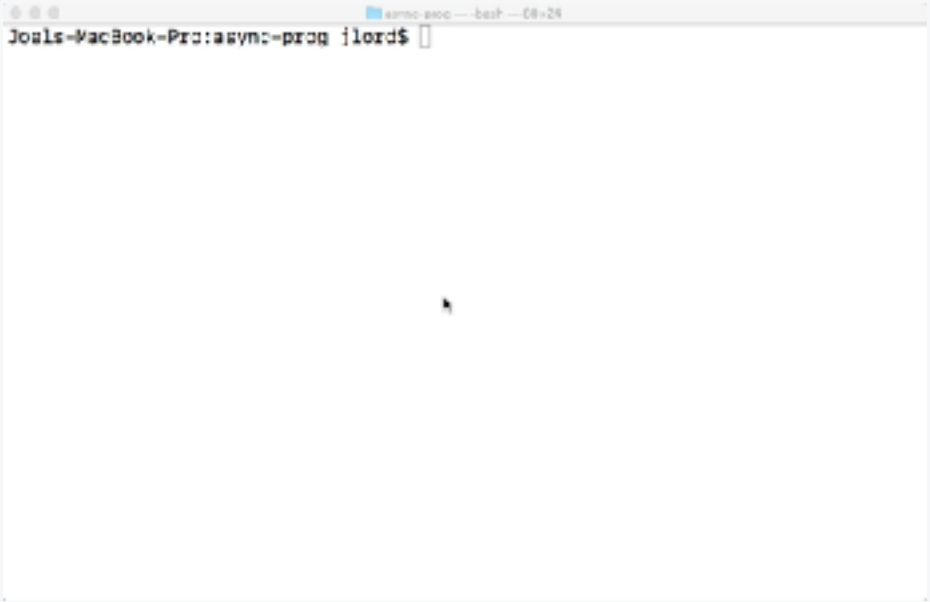
```
Joels-MacBook-Pro:async-prog jlord$ node ./examples/callbacks.js
begin
after
This is the content of the file
Joels-MacBook-Pro:async-prog jlord$
```

Code

```
let PBnJMaker = require("./pbnjmaker");

PBnJMaker.fetchBread(() => {
    PBnJMaker.fetchPeanutButter(() => {
        PBnJMaker.fetchJam(() => {
            PBnJMaker.spreadPeanutButter(() => {
                PBnJMaker.spreadJam(() => {
                    PBnJMaker.closeSandwich((err, output) =>
                        console.log("Eat that " + output);
                    });
                });
            });
        });
    });
});
```

Result



@joel__lord
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Callbacks

- It works!
- but…

```
let PBnJMaker = require("./pbnjmaker");

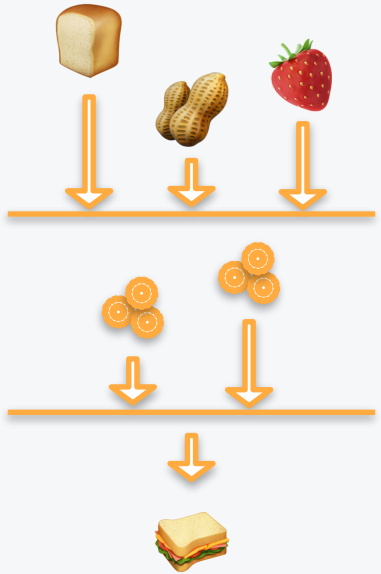
PBnJMaker.simulateError();

PBnJMaker.fetchBread((err) => {
    if (err) {
        console.log("An error occurred while fetching the ingredients");
    } else {
        PBnJMaker.fetchPeanutButter((err) => {
            if (err) {
                console.log("An error occurred while fetching the ingredients");
            } else {
                PBnJMaker.fetchJam((err) => {
                    if (err) {
                        console.log("An error occurred while fetching the ingredients");
                    } else {
                        PBnJMaker.spreadPeanutButter((err) => {
                            if (err) {
                                console.log("An error occurred while preparing the sandwich");
                            } else {
                                PBnJMaker.spreadJam((err) => {
                                    if (err) {
                                        console.log("An error occurred while preparing the sandwich");
                                    } else {
                                        PBnJMaker.closeSandwich((err, result) => {
                                            if (err) {
                                                console.log("An error occurred");
                                            } else {
                                                console.log("Eat that " + result);
                                            }
                                        });
                                    }
                                });
                            }
                        });
                    }
                });
            }
        });
    }
});
```

Parallel events

Step by step

Parallel events



@joel__lord
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Code

```
var PBnJMaker = require('./pbnjmaker');

var steps = 0;
// PBnJMaker.simulateError();

function fetchIngredients() {
    PBnJMaker.fetchBread(handleIngredients);
    PBnJMaker.fetchPeanutButter(handleIngredients);
    PBnJMaker.fetchJam(handleIngredients);
}

function handleIngredients(err) {
    if (err) return console.log("An error occurred while fetching the ingredients");
    ingredients++;
    if (ingredients === 3) {
        prepareSandwich();
    }
}

function prepareSandwich() {
    PBnJMaker.spreadPeanutButter(preparationStepCompleted);
    PBnJMaker.spreadJam(preparationStepCompleted);
}

function preparationStepCompleted(err) {
    if (err) return console.log("An error occurred while preparing the sandwich");
    steps++;
    if (steps === 4) {
        completeSandwich();
    }
}

function completeSandwich() {
    PBnJMaker.classSandwich(function (err, result) {
        if (err) {
            console.log("An error occurred");
        } else {
            console.log("Eat that " + result);
        }
    });
}

fetchIngredients();
```

Result

```
Joels-MacBook-Pro:async-prog jlord$
```

@joel__lord
#confoo

Code

```
var ingredients = 0;
var steps = 0;

function fetchIngredients() {
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function prepareSandwich() {
    PBnJMaker.spreadPeanutButter(preparationStepCompleted);
    PBnJMaker.spreadJam(preparationStepCompleted);
}

function preparationStepCompleted(err) {
    if (err) return console.log("An error occurred while preparing the sandwich");
    steps++;
    if (steps === 4) {
        completeSandwich();
    }
}

function completeSandwich() {
    PBnJMaker.classSandwich((err, result) => {
        if (err) {
            console.log("An error occurred");
        } else {
            console.log("Eat that " + result);
        }
    });
}

fetchIngredients();
```

Result

```
Joels-MacBook-Pro:async-prog jlord$
```

@joel__lord
#confoo

Code

```
1 let PBnJMaker = require('./pbnjmaker');
2 let ingredients = 0;
3 let steps = 0;
4 // PBnJMaker.simulateError();
5
6 function fetchIngredients() {
7     PBnJMaker.fetchPeanutButter(handleIngredients);
8     PBnJMaker.fetchJam(handleIngredients);
9 }
10
11 function handleIngredients(err) {
12     if (err) return console.log("An error occurred while fetching the ingredients");
13     ingredients++;
14     if (ingredients === 2) {
15         prepareSandwich();
16     }
17 }
18
19 function prepareSandwich() {
20     PBnJMaker.spreadPeanutButter(preparationStepCompleted);
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22 }
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32 function completeSandwich() {
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35             console.log("An error occurred");
36         } else {
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38         }
39     });
40 }
41
42 fetchIngredients();
```

Result

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Joels-MacBook-Pro:async-prog jlord$
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@joel__lord
#confoo

Code

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let PBnJMaker = require('./pbnjmaker');
let ingredients = 0;
let steps = 0;
// PBnJMaker.simulateError();

function fetchIngredients() {
    PBnJMaker.fetchBread(handleIngredients);
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}

function handleIngredients(err) {
    if (err) return console.log("An error occurred while fetching the ingredients");
    ingredients++;
    if (ingredients === 3) {
        prepareSandwich();
    }
}

function prepareSandwich() {
    PBnJMaker.spreadPeanutButter(preparationStepCompleted);
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    });
}

fetchIngredients();
```

Result

```
Joels-MacBook-Pro:async-prog jlord$
```

@joel__lord
#confoo

Code

```
var PBnJMaker = require('./pbnjmaker');
var ingredients = 4;
var steps = 0;
// PBnJMaker.simulateError();

function fetchIngredients() {
    PBnJMaker.fetchBread(handleIngredients);
    PBnJMaker.fetchPeanutButter(handleIngredients);
    PBnJMaker.fetchJam(handleIngredients);
}

function handleIngredients(err) {
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    ingredients++;
    if (ingredients === 3) {
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Joels-MacBook-Pro:async-prog jlord$
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@joel__lord
#confoo

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fetchIngredients();
```

Result

```
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```

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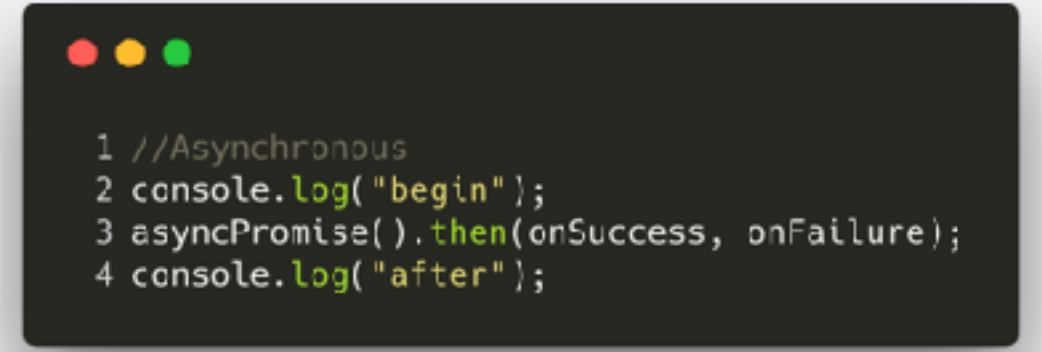
Promises
(2014)

What is a promise?

- A representation of a callback
- Returns a .then() method
- Error handling simplified



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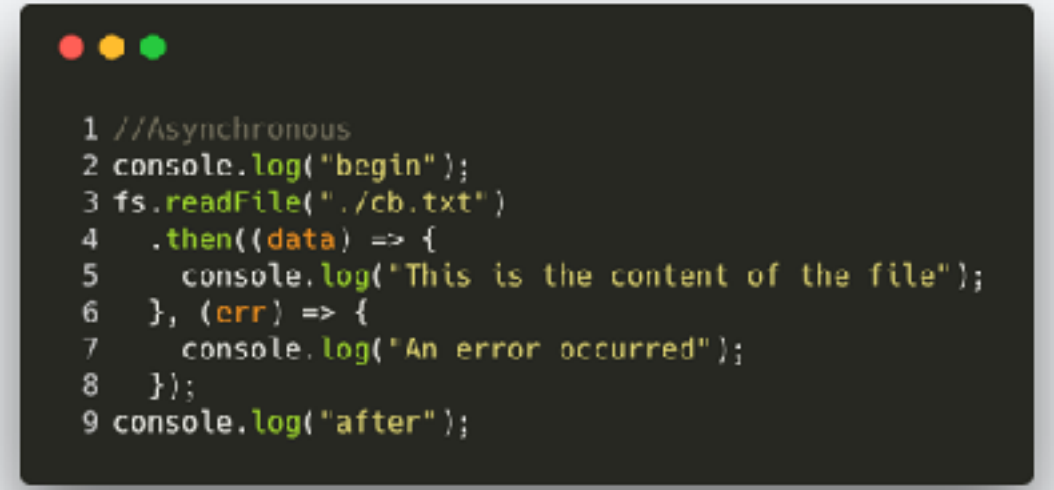
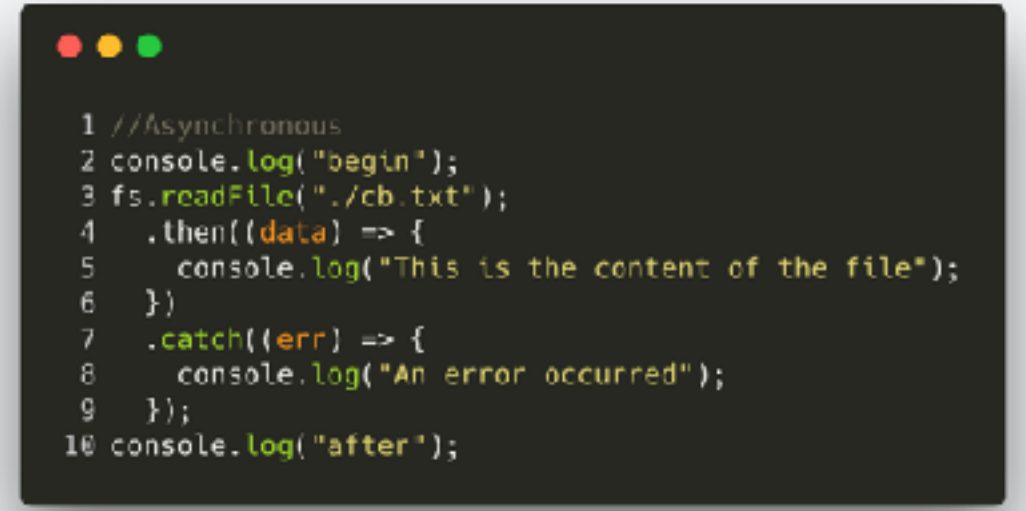


```
1 //Asynchronous
2 console.log("begin");
3 fs.readFile("./cb.txt")
4   .then((data) => {
5     console.log("This is the content of the file");
6   }, (err) => {
7     console.log("An error occurred");
8   });
9 console.log("after");
```

What is a promise?

- A representation of a callback
- Returns a .then() method
- Error handling simplified



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3 fs.readFile("./cb.txt");
4   .then((data) => {
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6   })
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Code

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let PBnJMaker = require("./pbnjmaker");

PBnJMaker.fetchBread().then(() => {
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    return PBnJMaker.spreadPeanutButter();
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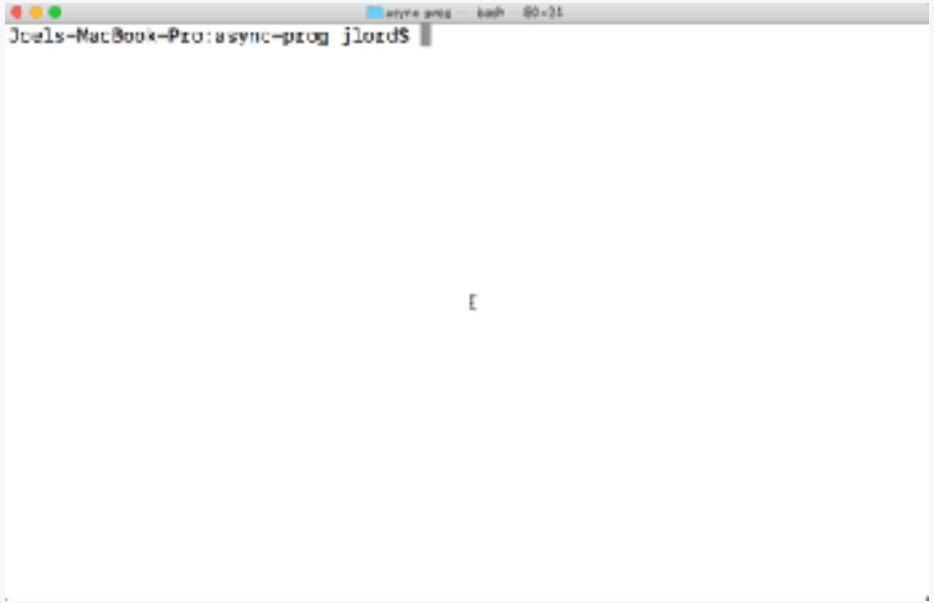
}).then(() => {
    return PBnJMaker.closeSandwich();
}).then((result) => {
    console.log("Eat that " + result);
});
```

Result



@joel__lord
#confoo

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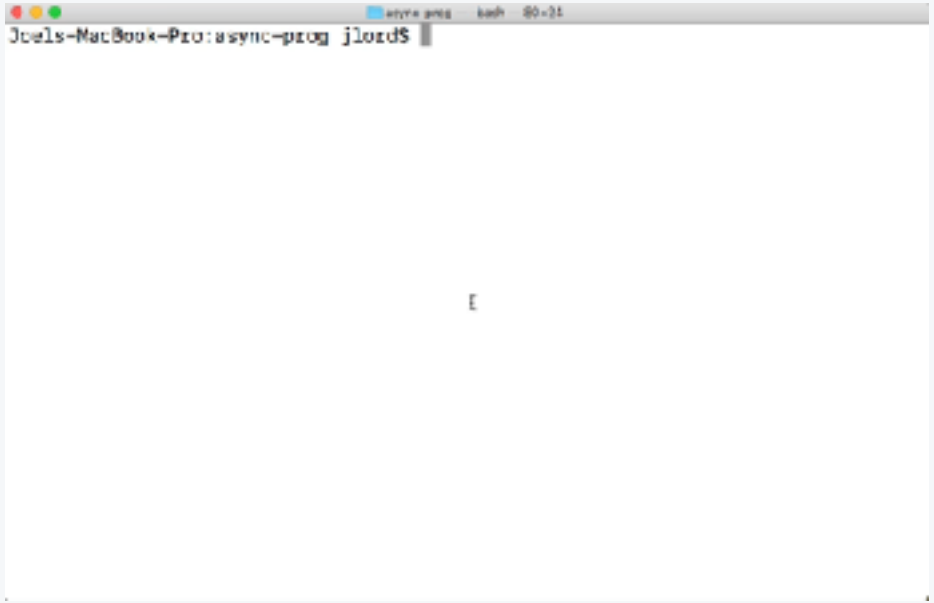

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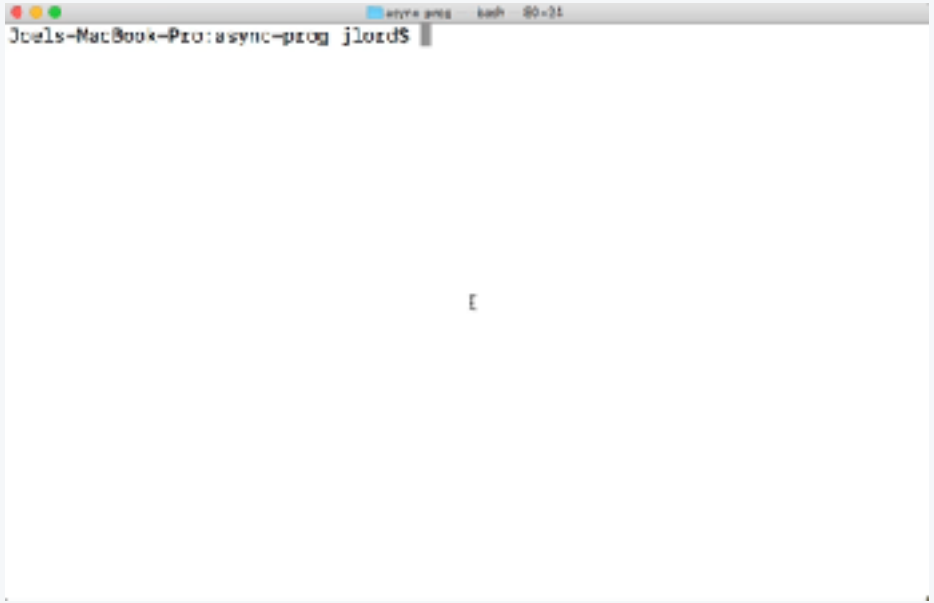

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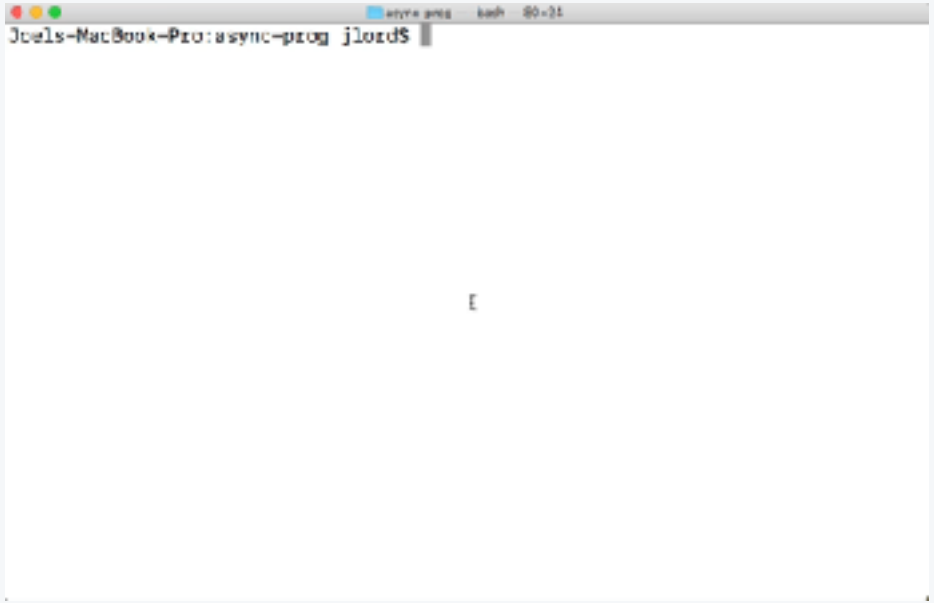

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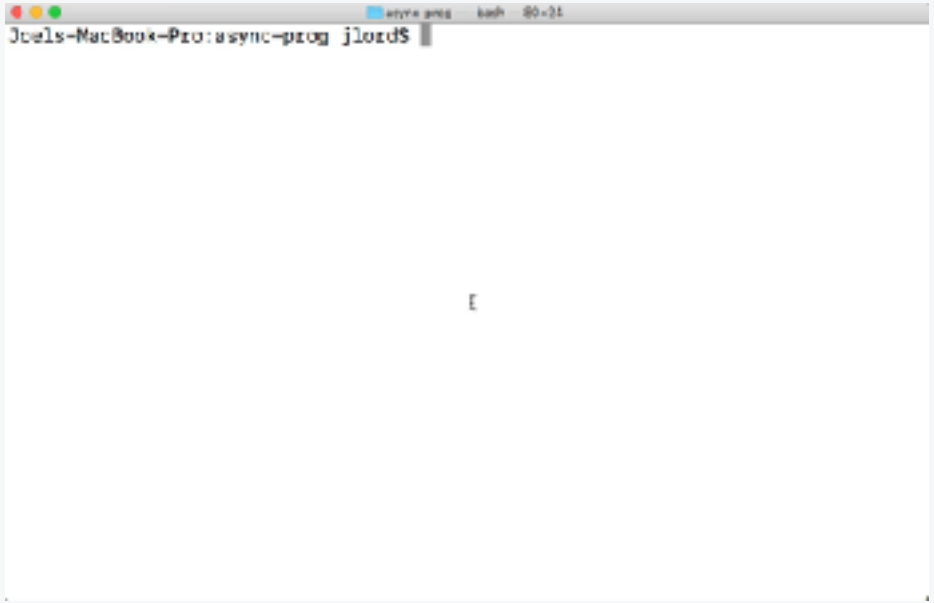

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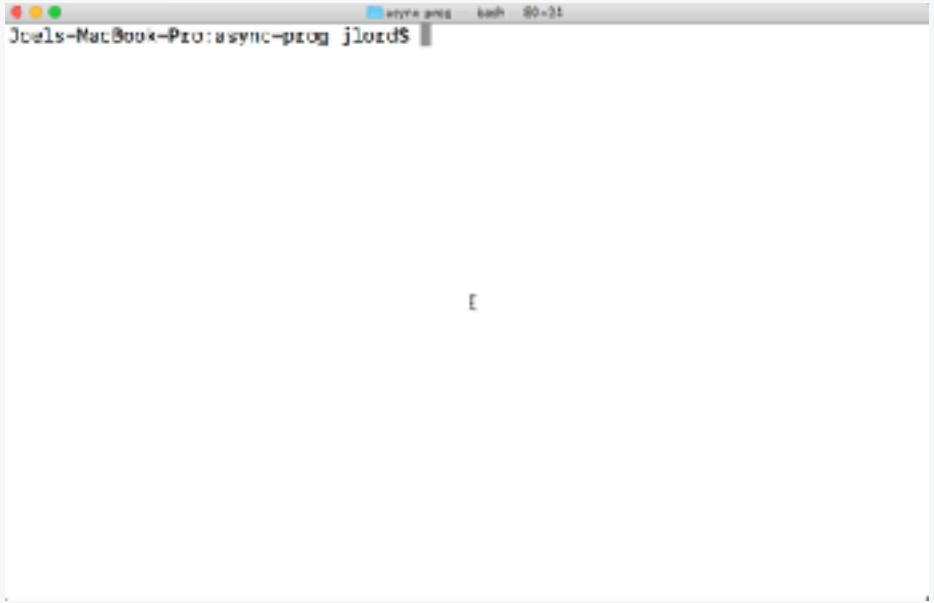

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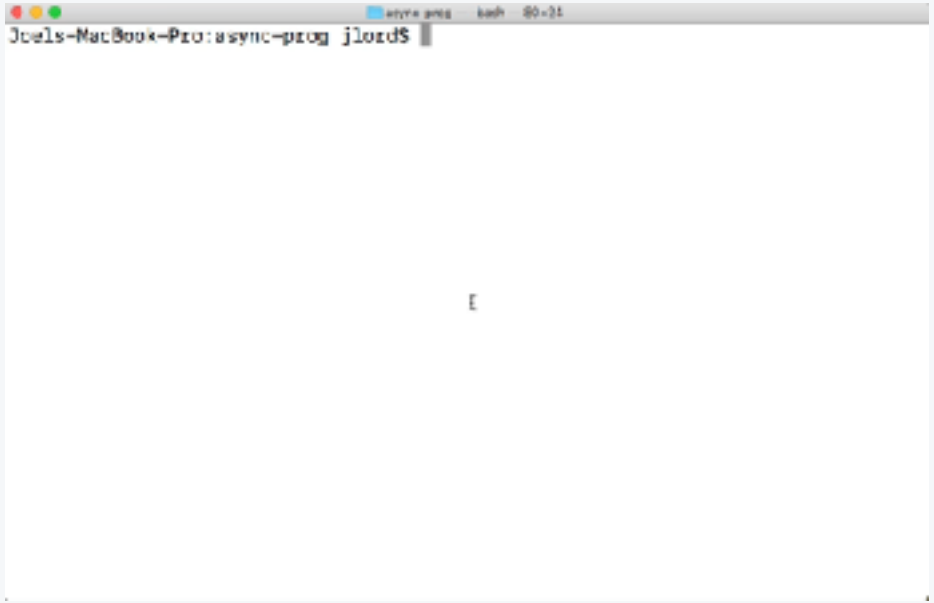

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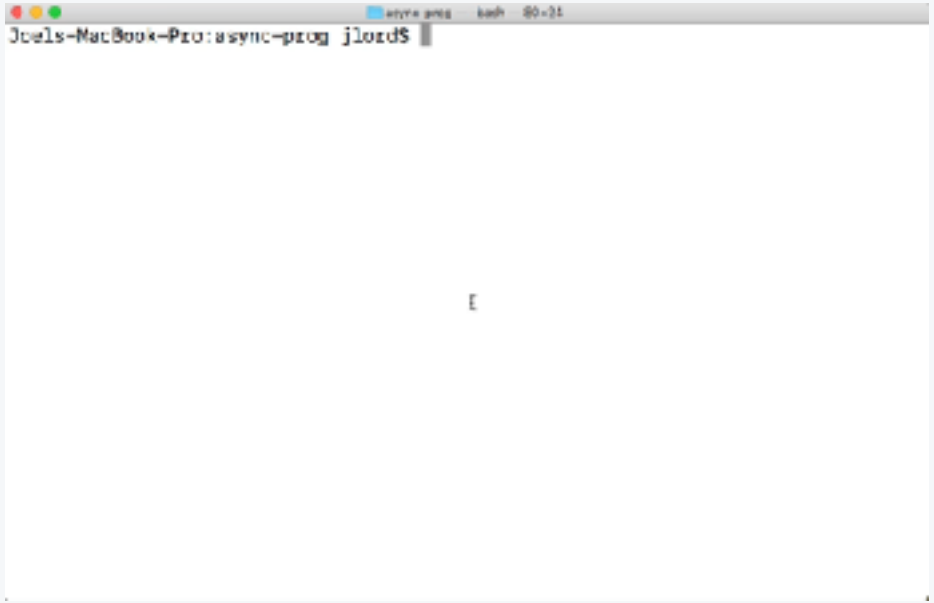

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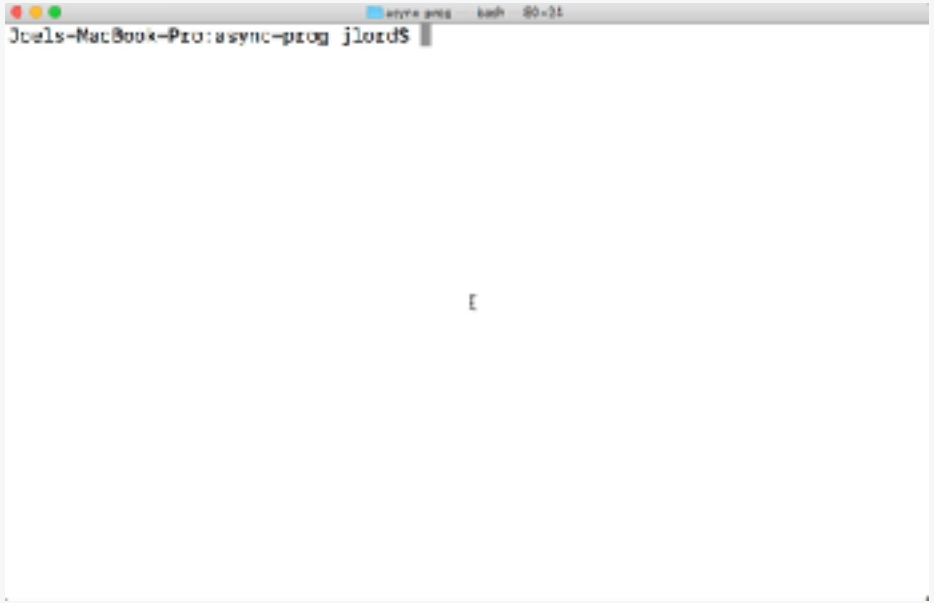

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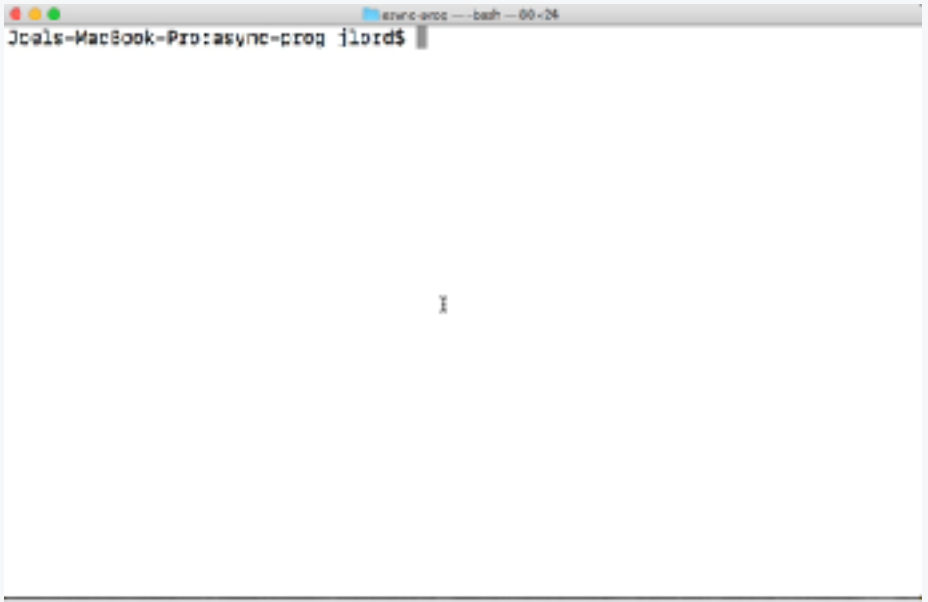

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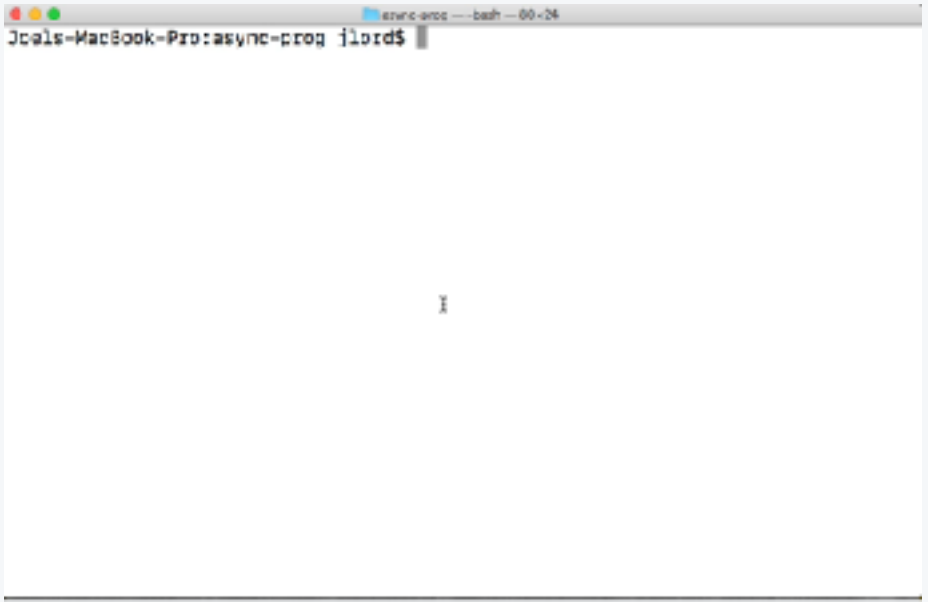

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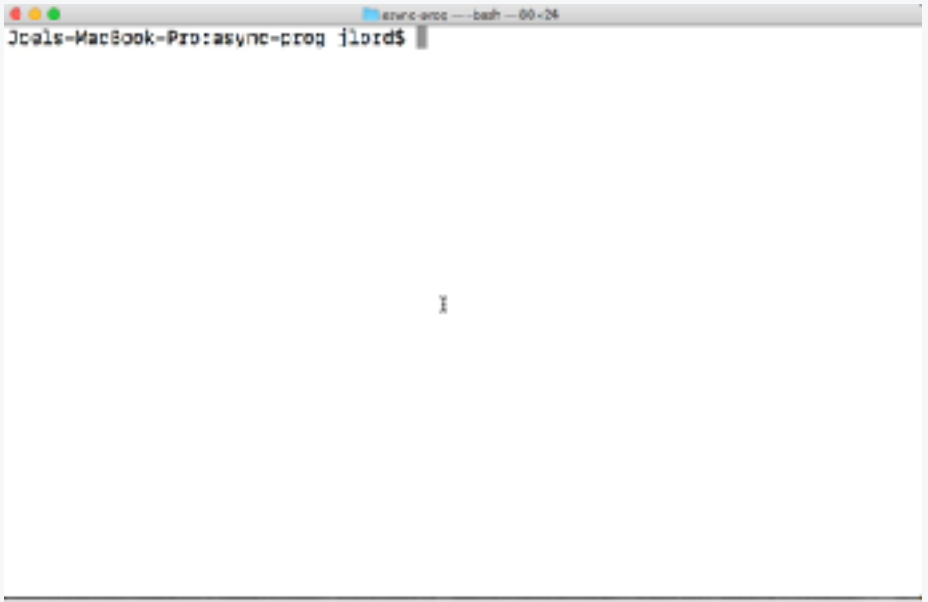

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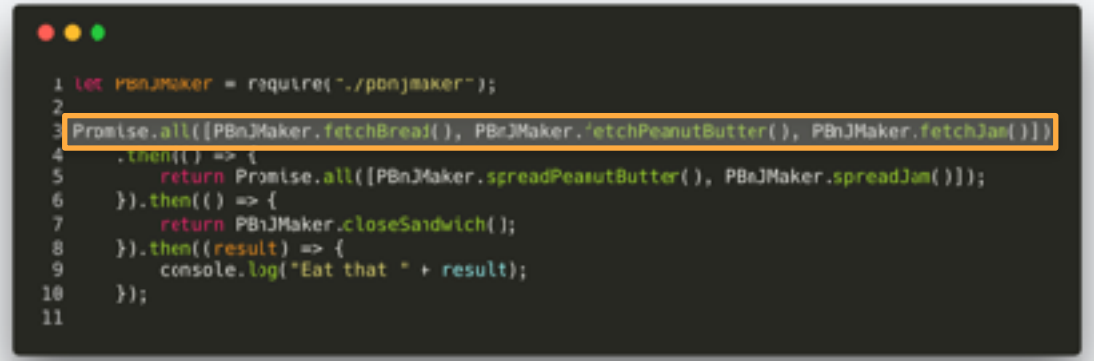
Aggregate functions

- .all()
- .race()

Aggregate functions

- .all()
- .race()



Aggregate functions

- .all()
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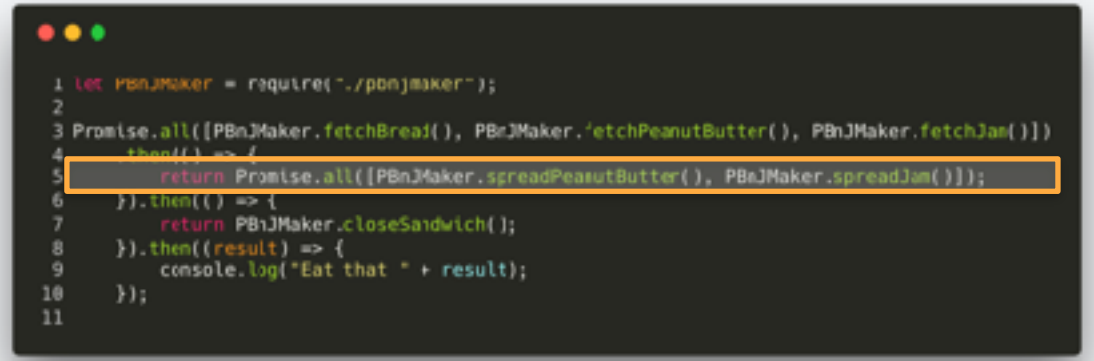
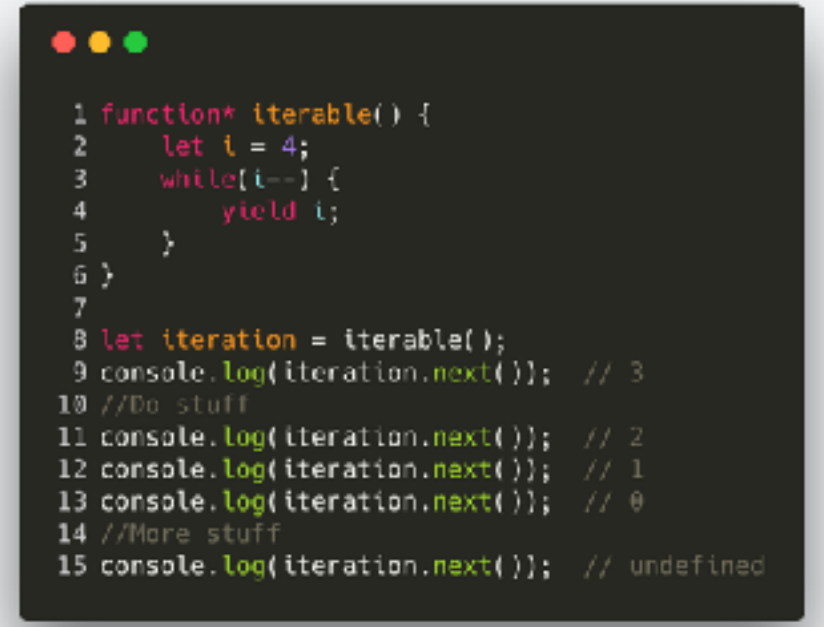



Generators
(2015)

What is a generator?

- An iterable function
- “Pauses” the execution of a function



```
function* iterable() {
    let i = 4;
    while(i--) {
        yield i;
    }
}

let iteration = iterable();
console.log(iteration.next()); // 3
//Do stuff
console.log(iteration.next()); // 2
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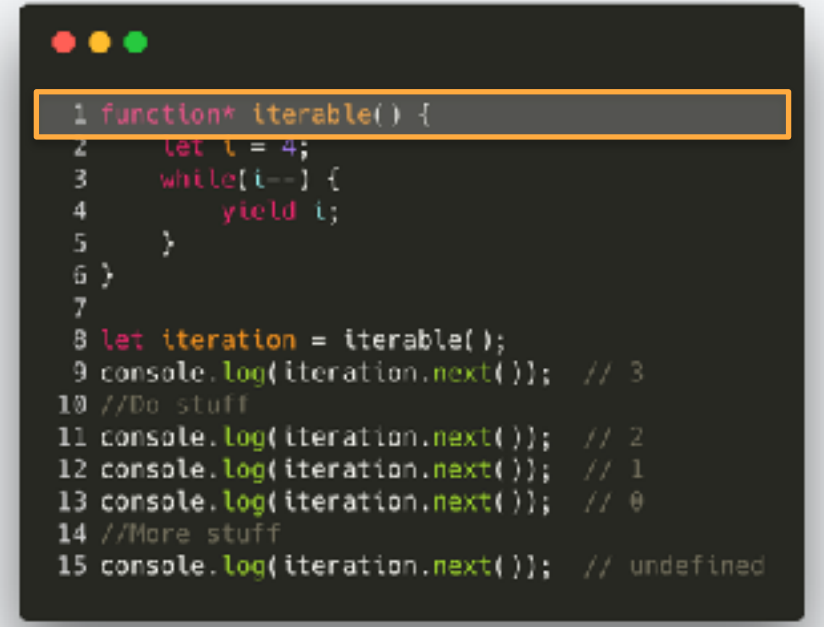

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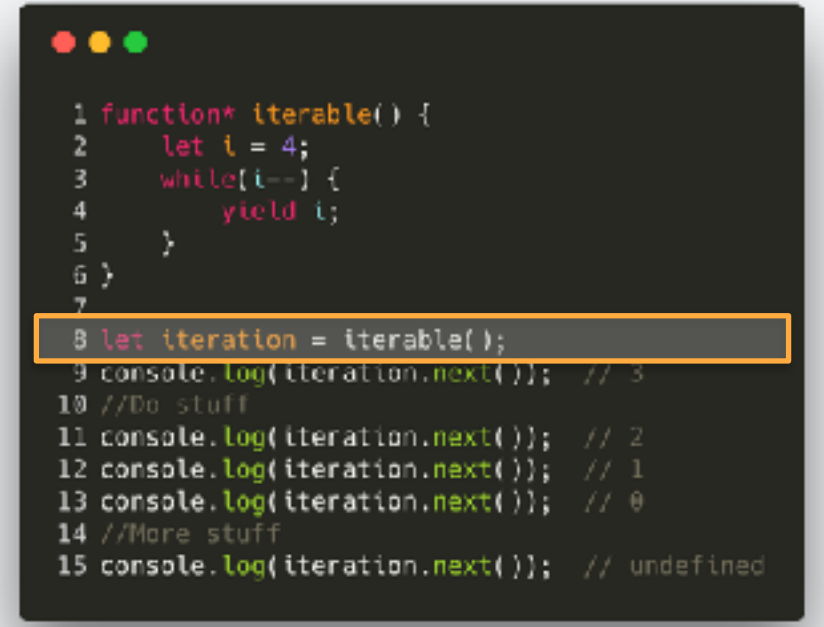

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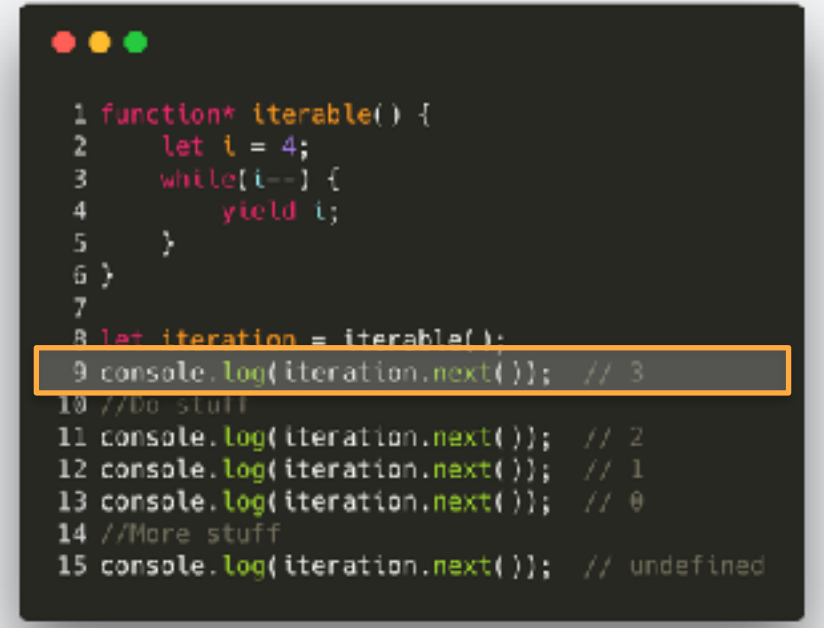

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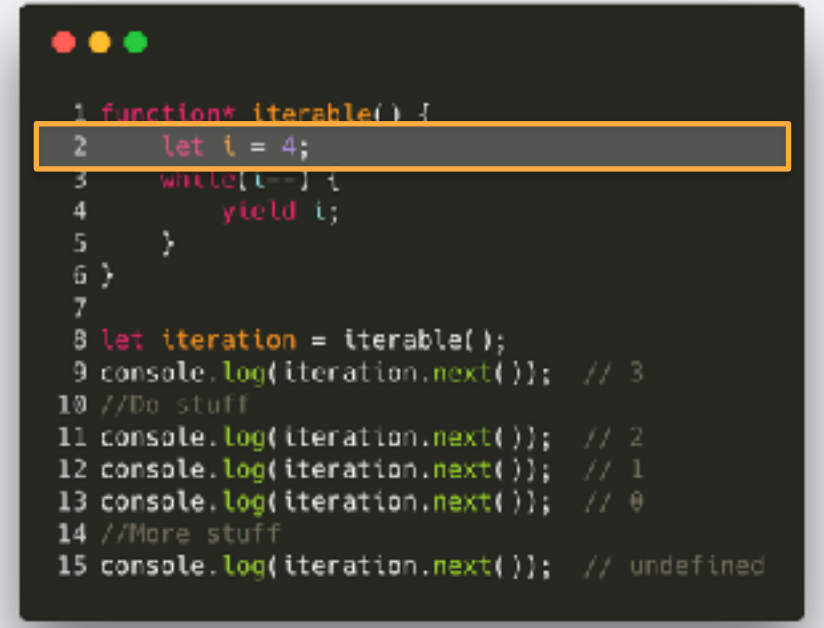

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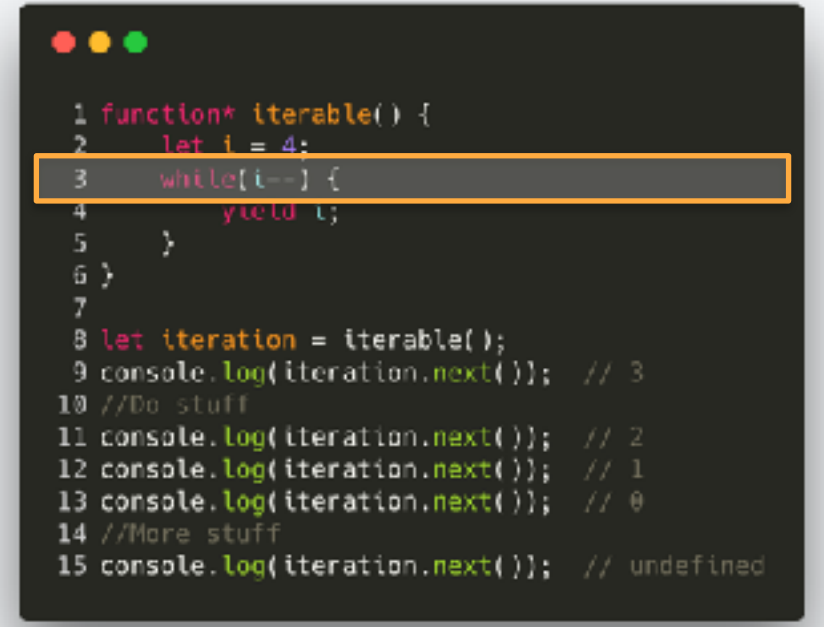

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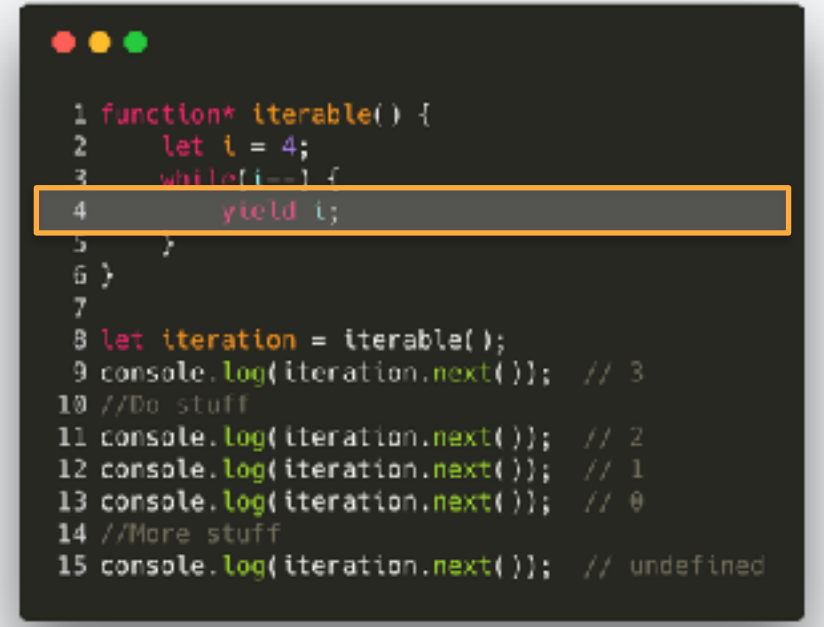

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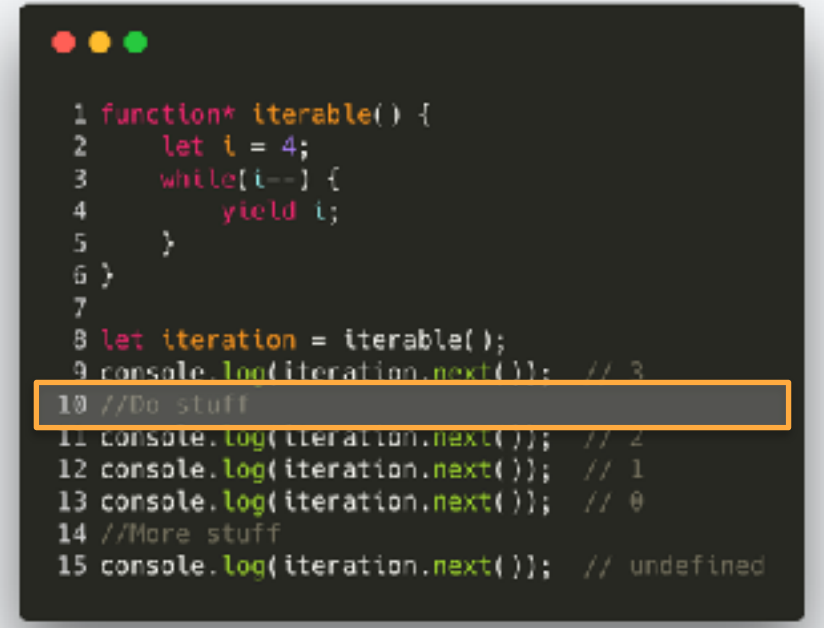

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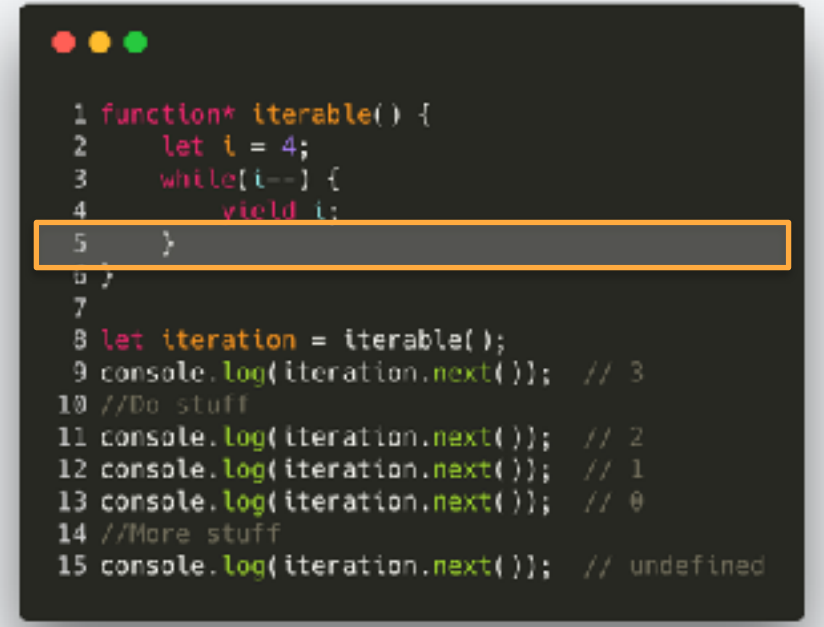

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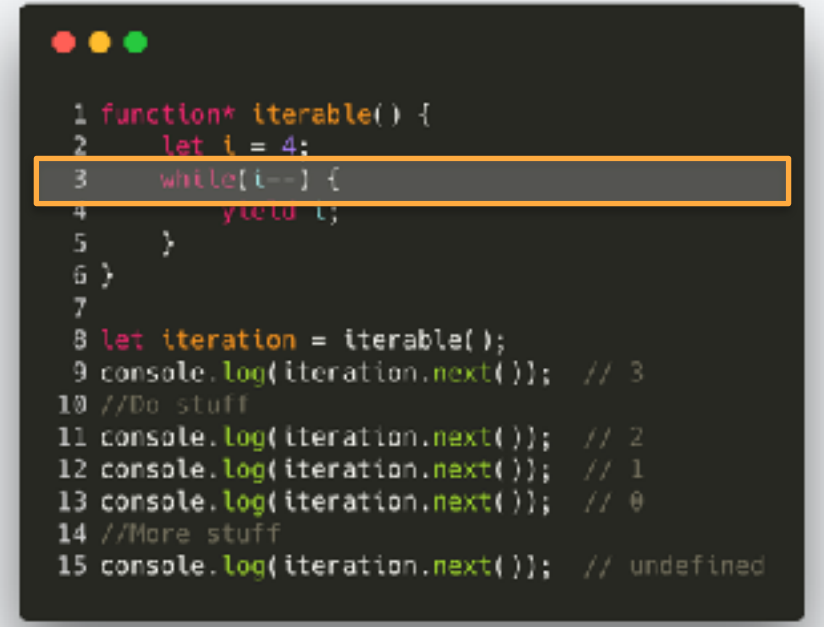

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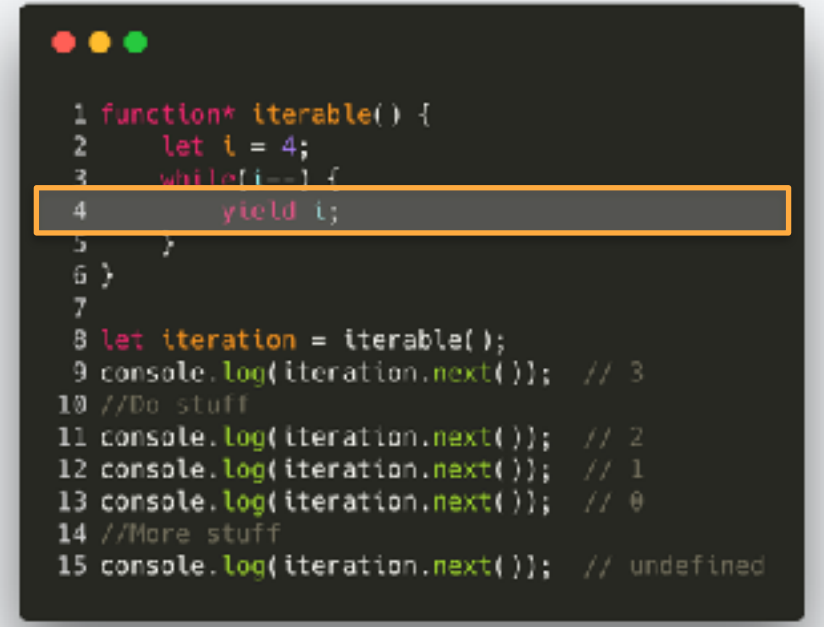

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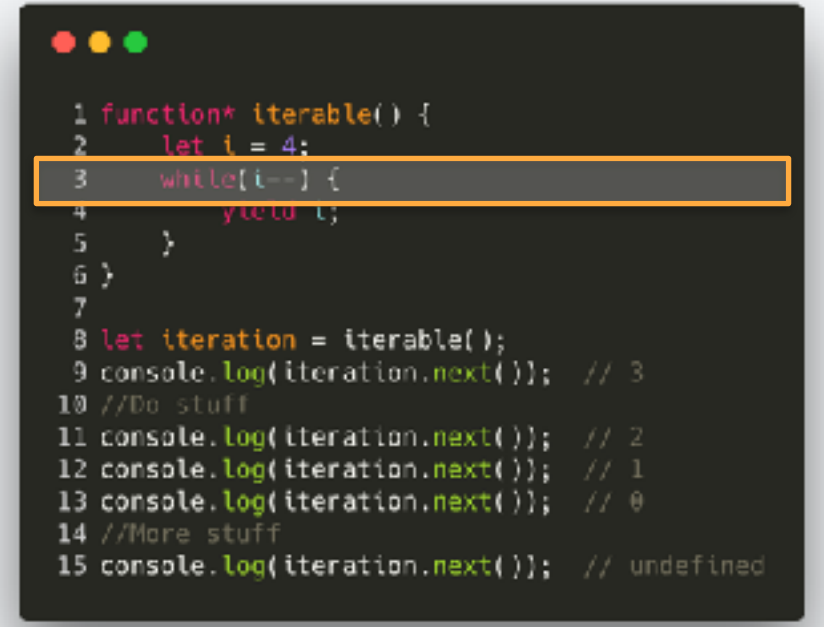

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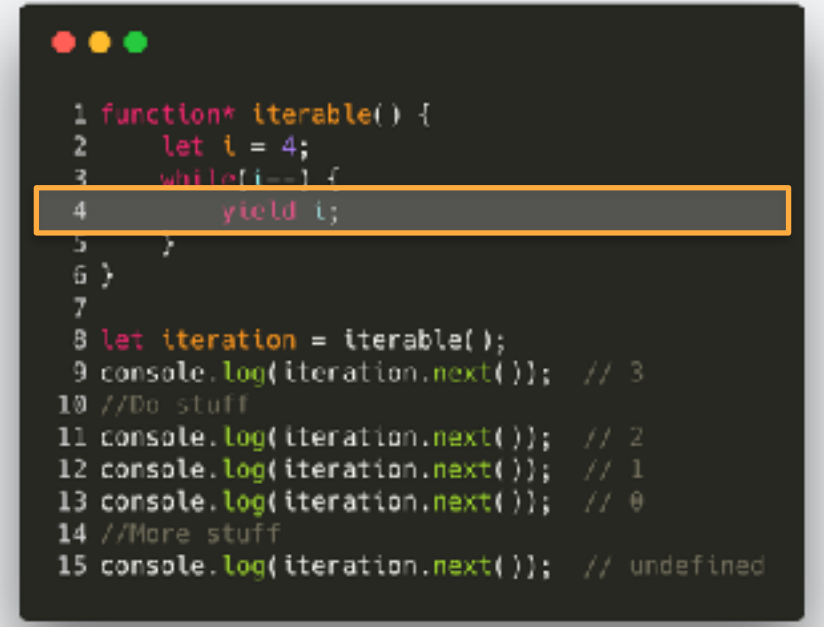

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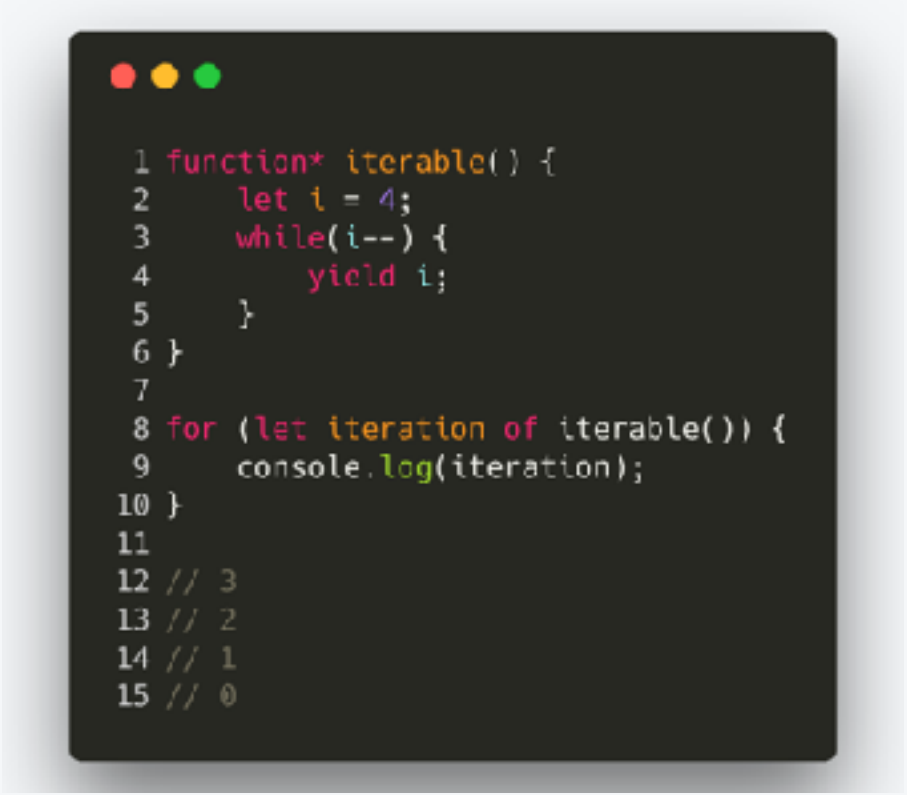
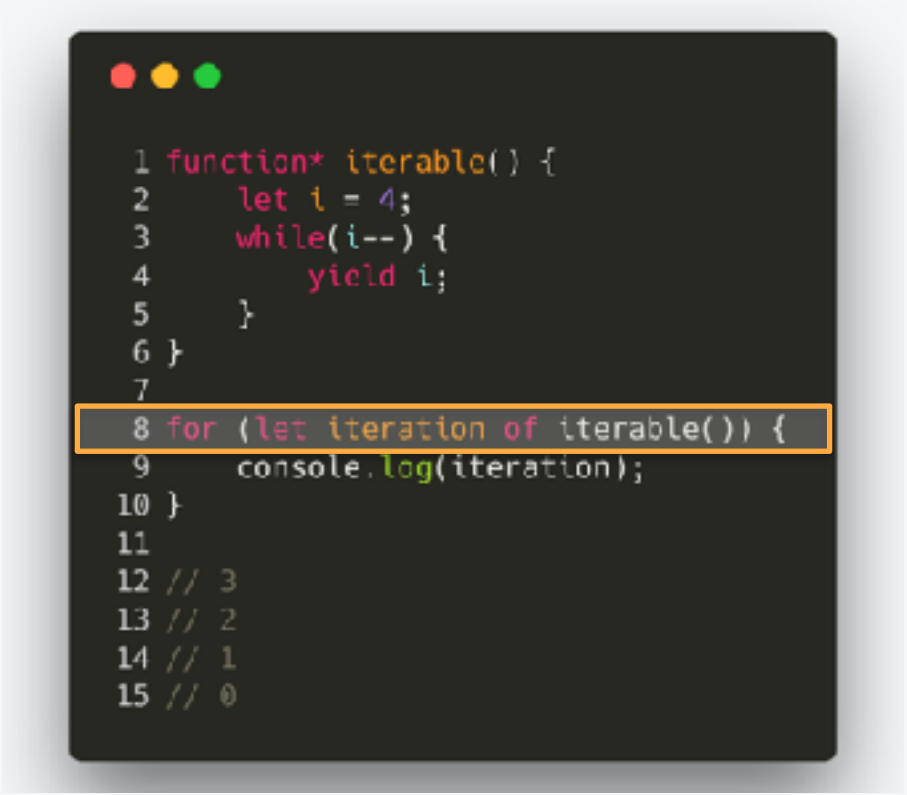


```
function* iterable() {
    let i = 4;
    while(i--) {
        yield i;
    }
}

for (let iteration of iterable()) {
    console.log(iteration);
}

// 3
// 2
// 1
// 0
```

What is a generator?

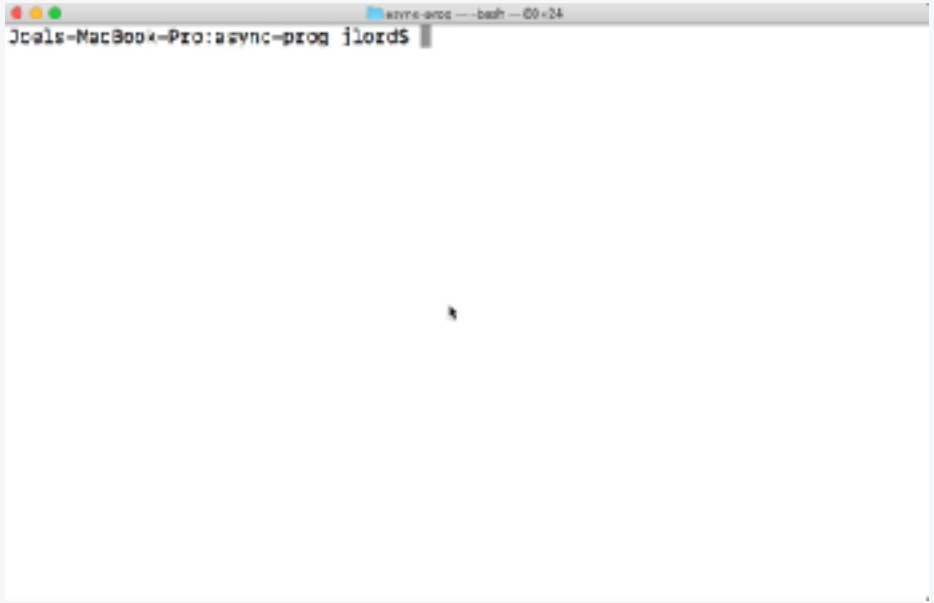
- An iterable function
- “Pauses” the execution of a function



Code

```
let PBnJMaker = require("./pbnjmaker");

PBnJMaker.verbose();

function* makePBnJ() {
    yield PBnJMaker.fetchBread;
    yield PBnJMaker.fetchPeanutButter;
    yield PBnJMaker.fetchJam;
    yield PBnJMaker.spreadPeanutButter;
    yield PBnJMaker.spreadJam;
    yield PBnJMaker.closeSandwich;
}

for (let step of makePBnJ()) {
    step();
}

console.log("Eat that sandwich");
```

Result



@joel__lord
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Async Generators

- Combining the power of promises and generators

```
module.exports = (makeGenerator) => {
    let generator = makeGenerator.apply(this, arguments);

    function handle(result) {
        // A generator returns an object
        // {done: [Boolean], value: [Any]}
        if (result.done) return Promise.resolve(result.value);
        return Promise.resolve(result.value).then(function(res) {
            return handle(generator.next(res));
        }, function(err) {
            return handle(generator.throw(err));
        });
    }

    try {
        return handle(generator.next());
    } catch(e) {
        return Promise.reject(e);
    }
};
```

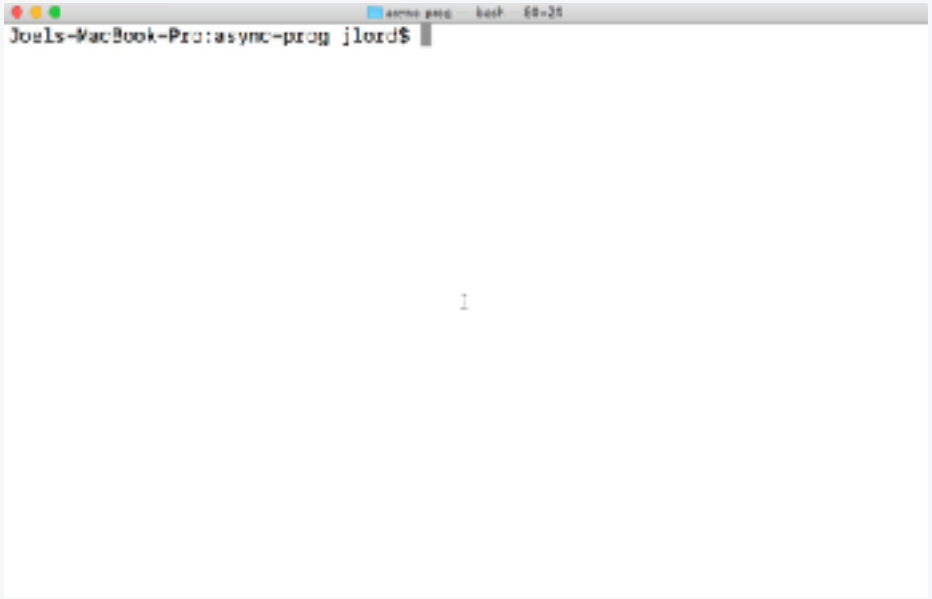
Code

```
let PBnJMaker = require("./pbnjmaker");
let async = require("./async");

function* makePBnJ() {
    yield PBnJMaker.fetchBread();
    yield PBnJMaker.fetchPeanutButter();
    yield PBnJMaker.fetchJam();
    yield PBnJMaker.spreadPeanutButter();
    yield PBnJMaker.spreadJam();
    return PBnJMaker.closeSandwich();
}

async(makePBnJ).then((result) => console.log("Eat that " + result));
```

Result



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Code

```
let PBnJMaker = require("./pbnjmaker");
let async = require("./async");

function* makePBnJ() {
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}

async(makePBnJ).then((result) => console.log("Eat that " + result));
```

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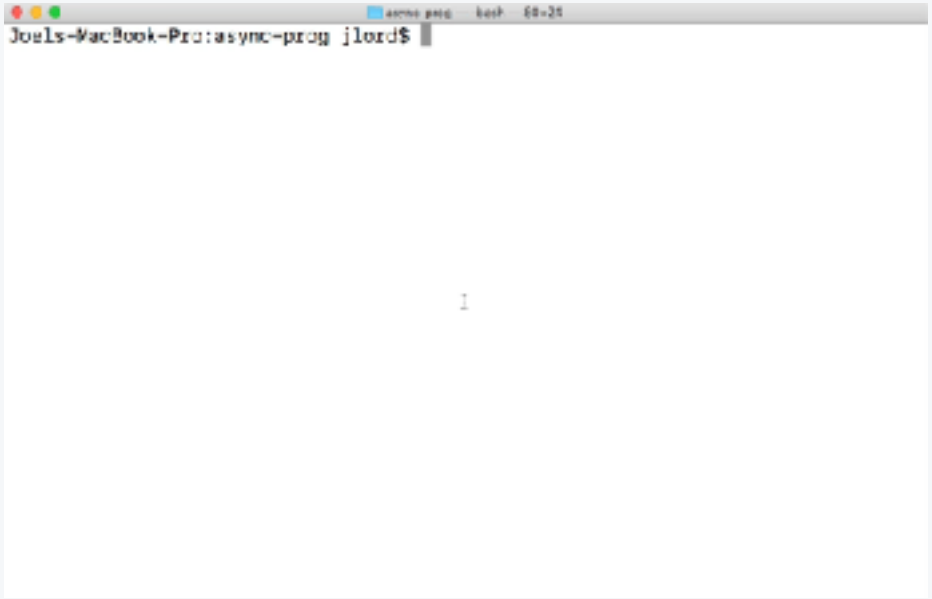

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Async / Await
(2017)

What is async/await?

- Newly introduced in ES8 (ES2017)
- Natural evolution of generators and promises

```
let PBnJMaker = require('./pbnjmaker');

async function makePBnJ() {
    await PBnJMaker.fetchBread();
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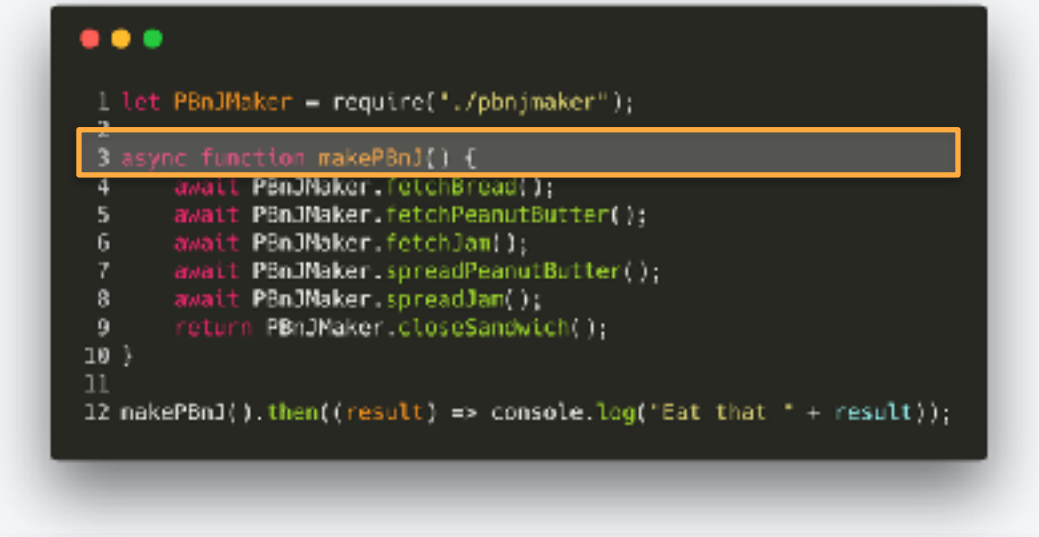

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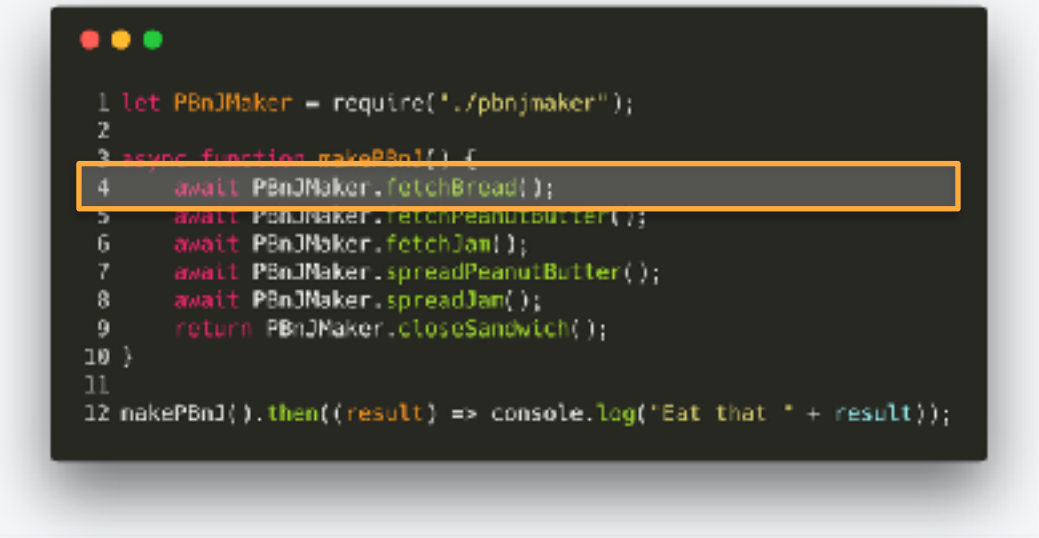

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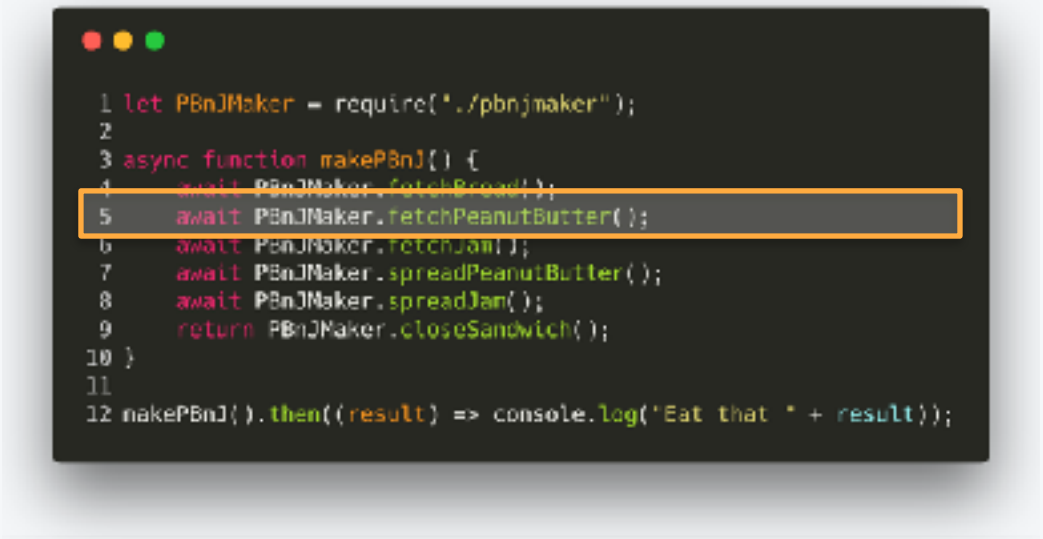

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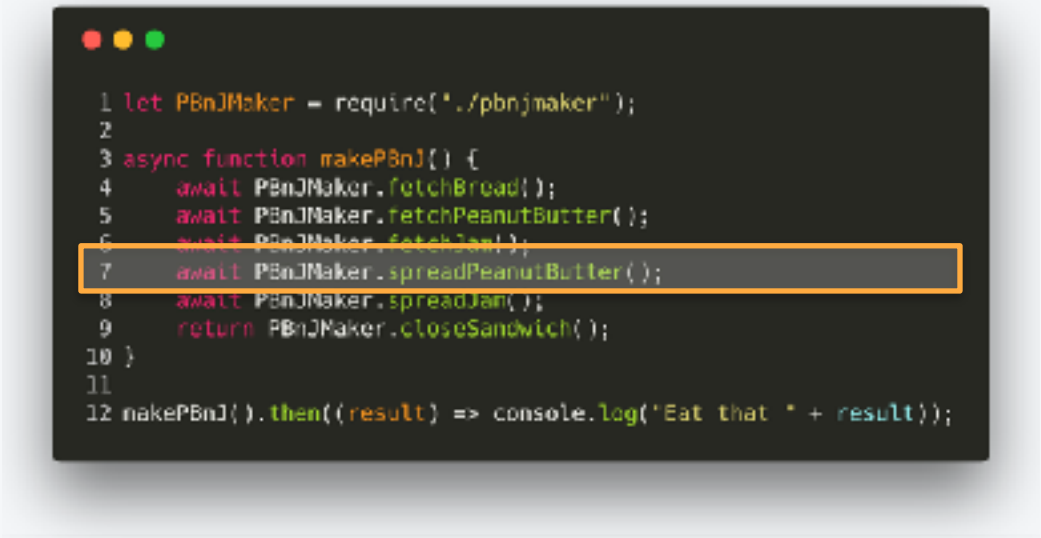

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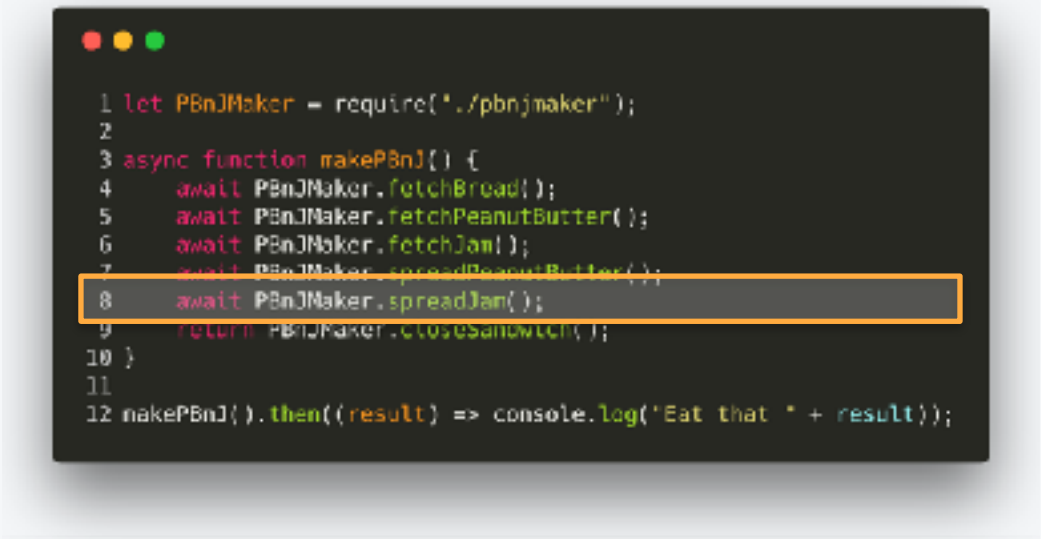

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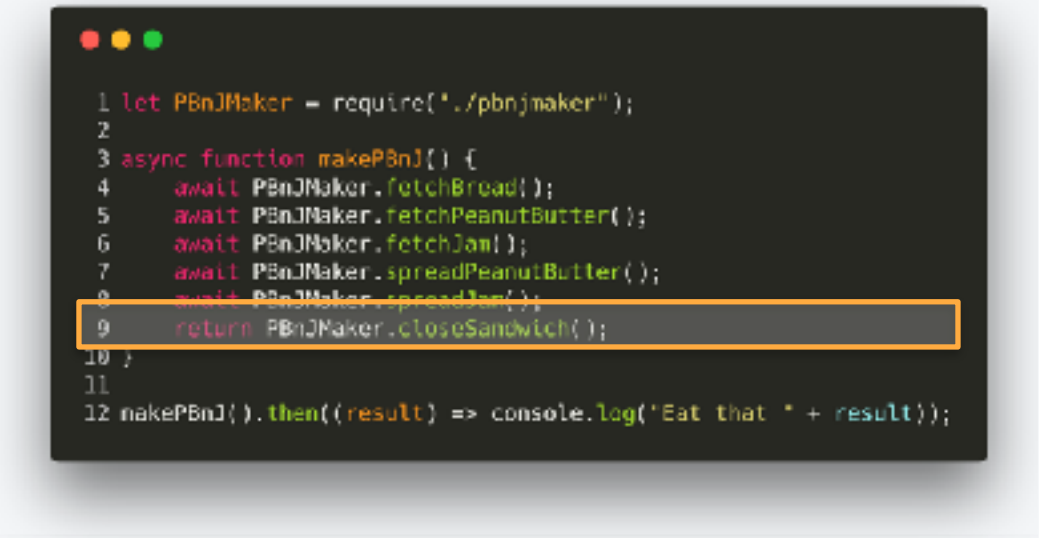

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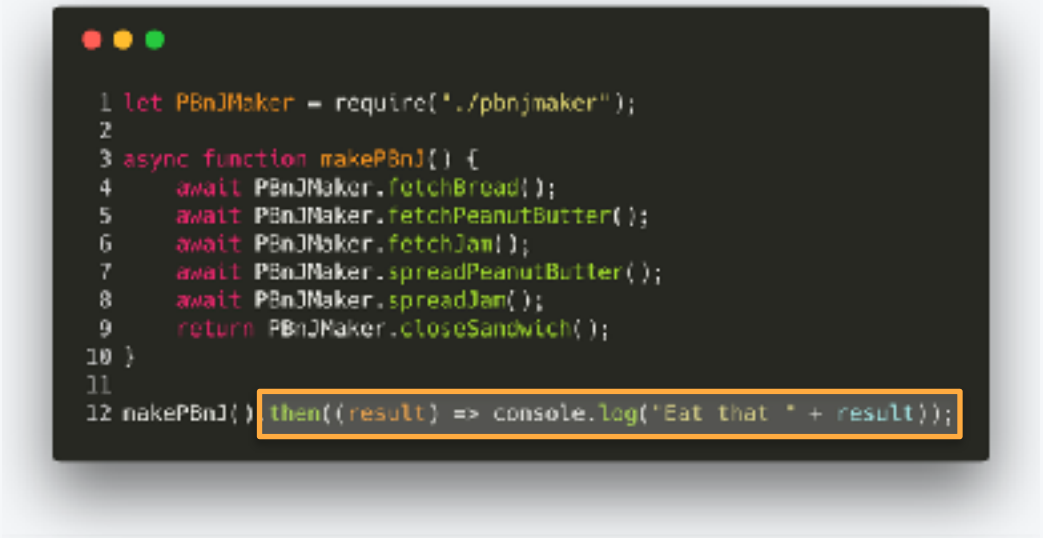

What is async/await?

- Very easy to parallelize processes

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let PBnJMaker = require("./pbnjmaker");

async function getIngredients() {
    let p1 = PBnJMaker.fetchBread();
    let p2 = PBnJMaker.fetchPeanutButter();
    let p3 = PBnJMaker.fetchJam();
    return await p1 + await p2 + await p3;
}

async function prepareSandwich() {
    let p1 = PBnJMaker.spreadPeanutButter();
    let p2 = PBnJMaker.spreadJam();
    return await p1 + await p2;
}

async function makePBnJ() {
    await getIngredients();
    await prepareSandwich();
    return PBnJMaker.closeSandwich();
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makePBnJ().then((result) => console.log("Eat that " + result));

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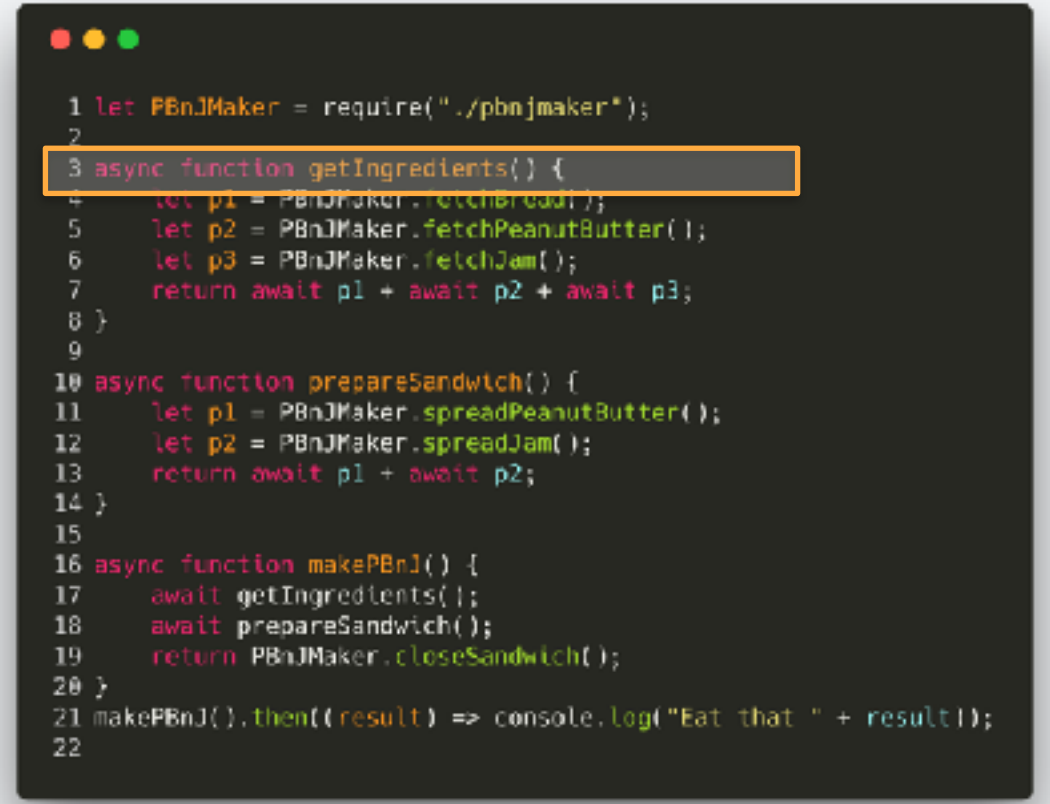

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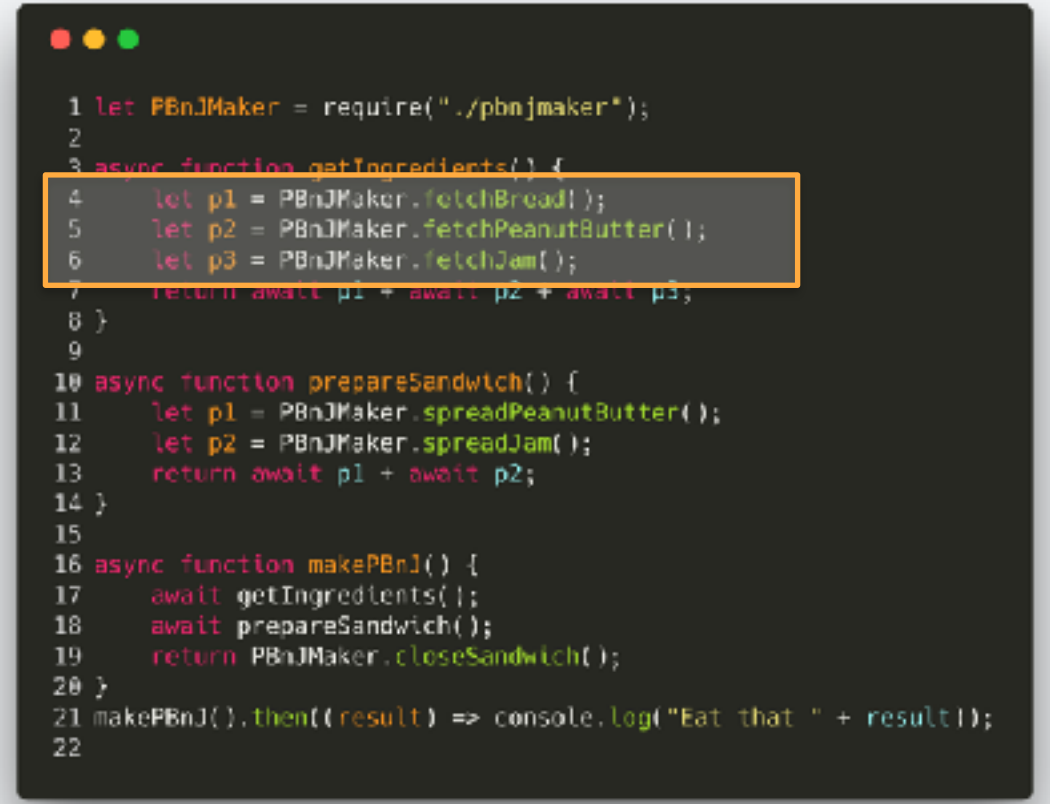

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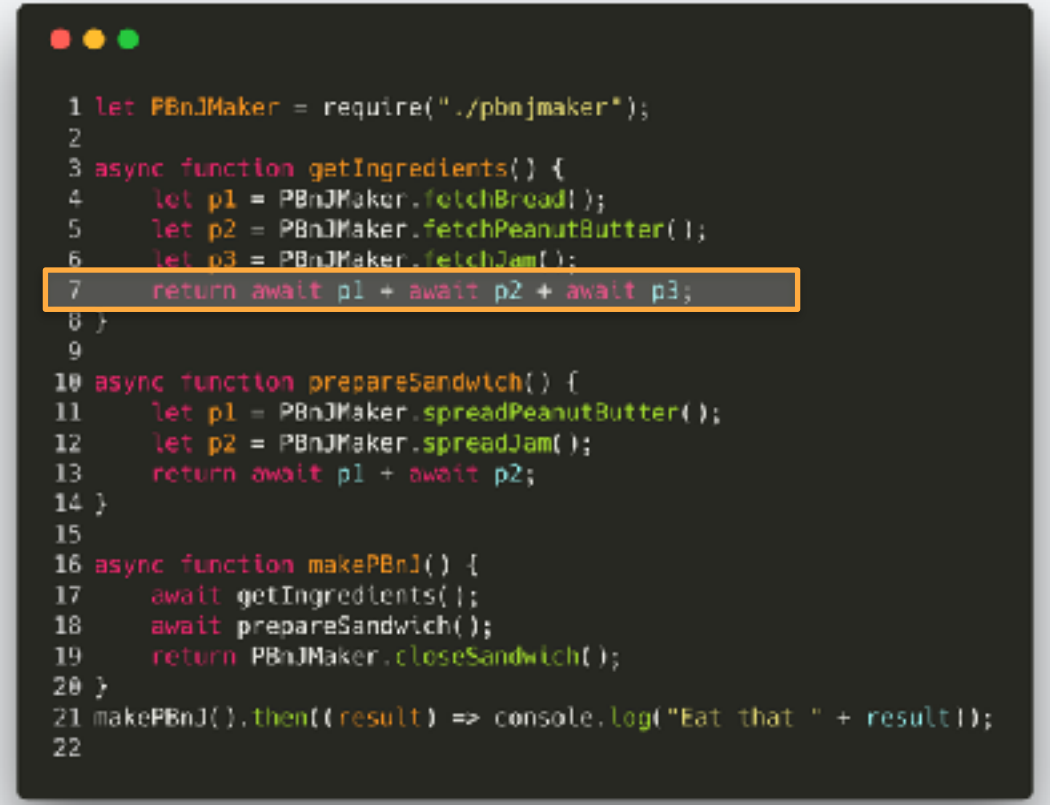

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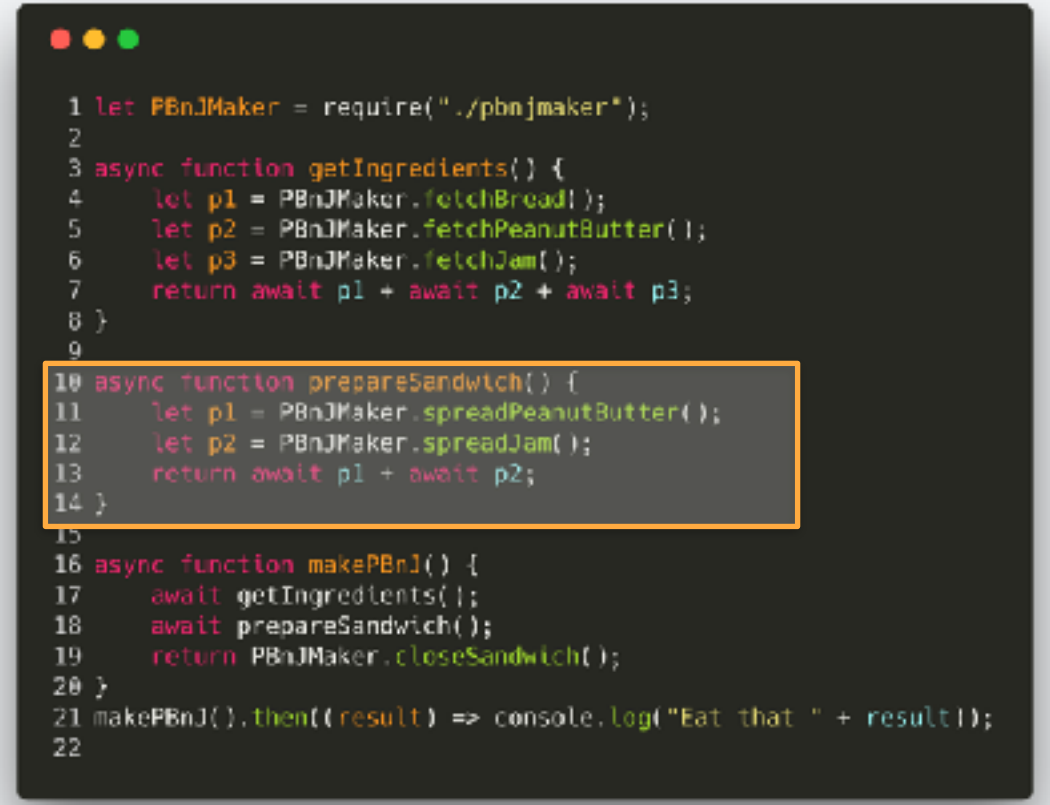

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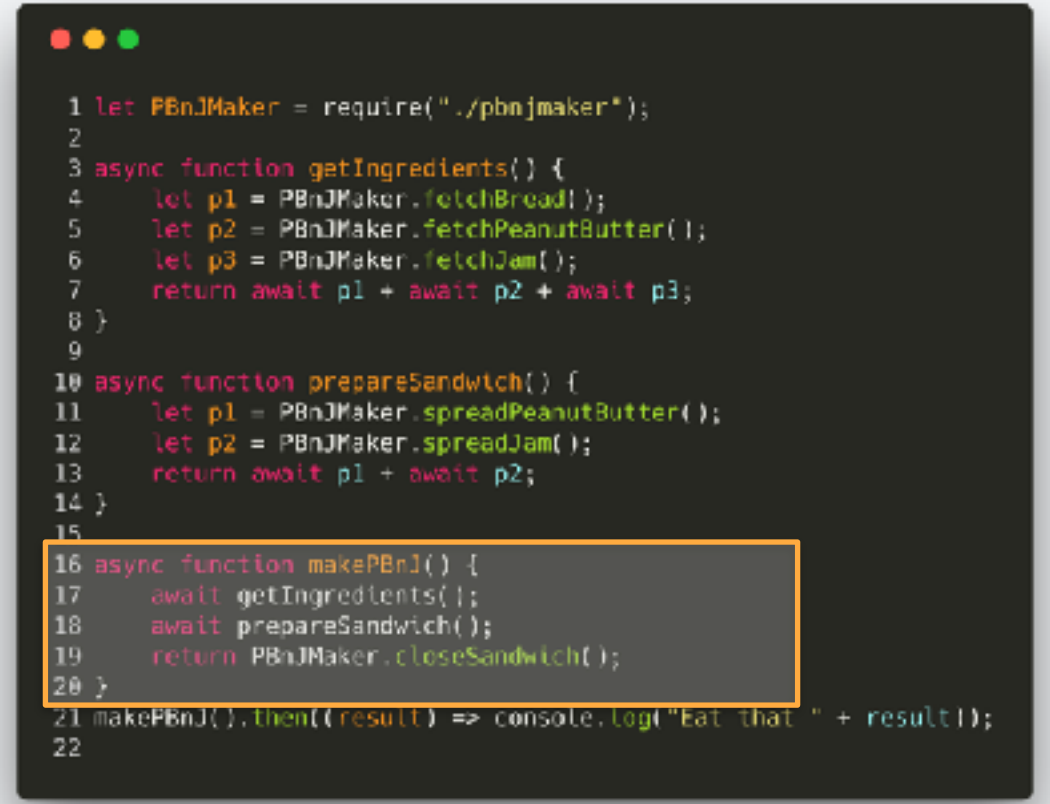

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    let p1 = PBnJMaker.fetchBread();
    let p2 = PBnJMaker.fetchPeanutButter();
    let p3 = PBnJMaker.fetchJam();
    return await p1 + await p2 + await p3;
}

async function prepareSandwich() {
    let p1 = PBnJMaker.spreadPeanutButter();
    let p2 = PBnJMaker.spreadJam();
    return await p1 + await p2;
}

async function makePBnJ() {
    await getIngredients();
    await prepareSandwich();
    return PBnJMaker.closeSandwich();
}
makePBnJ().then((result) => console.log("Eat that " + result));
```
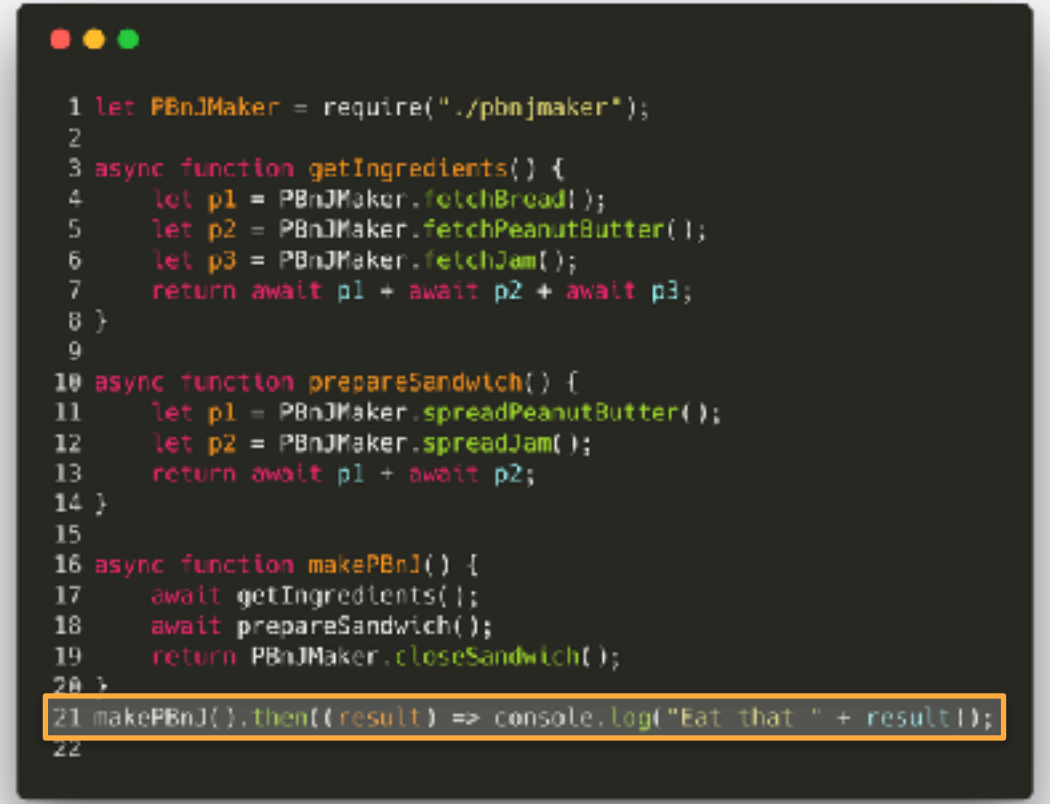

What is async/await?

- Very easy to parallelize processes



```
1 let PBnJMaker = require("./pbnjmaker");
2
3 async function getIngredients() {
4     let p1 = PBnJMaker.fetchBread();
5     let p2 = PBnJMaker.fetchPeanutButter();
6     let p3 = PBnJMaker.fetchJam();
7     return await p1 + await p2 + await p3;
8 }
9
10 async function prepareSandwich() {
11     let p1 = PBnJMaker.spreadPeanutButter();
12     let p2 = PBnJMaker.spreadJam();
13     return await p1 + await p2;
14 }
15
16 async function makePBnJ() {
17     await getIngredients();
18     await prepareSandwich();
19     return PBnJMaker.closeSandwich();
20 }
21 makePBnJ().then((result) => console.log("Eat that " + result));
22
```

Async / Await

Programatically define your steps

```
let PBnJMaker = require("./pbnjmaker");

let ingredients = ["Bread", "PeanutButter", "Jam"];
let steps = ingredients.map((i) => `fetch${i}`);
steps.push(...["spreadPeanutButter", "spreadJam"]);

async function makePBnJ(todo) {
    for (var i = 0; i < todo.length; i++) {
        await PBnJMaker[todo[i]]();
    }
    return PBnJMaker.closeSandwich();
}

makePBnJ(steps).then((result) => console.log('Eat that ' + result));
```

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Events (1990's)

Events in the browser

- At the core of the original Javascript
- window.onready = …
- button.onclick = …

```html
<html>
<body>
    <button id="btn1">Click me</button>
</body>

<script>
    let btn = document.querySelector("#btn1");
    btn.onclick = () => alert("Clicked");
</script>
</html>
```

Node Event Emitter

- In node, you can use the event emitter
- Create you own events for a library

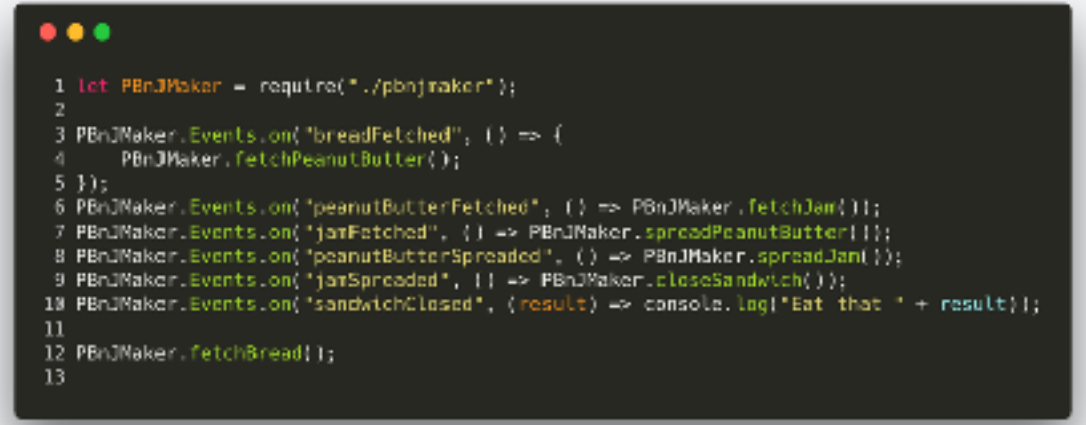
```
const EventEmitter = require('events');
class MyEmitter extends EventEmitter {}
const eventEmitter = new MyEmitter();

let fetchBread = function(options) {
    return axios.get(SERVER + "/fetchBread").then((response) => {
        eventEmitter.emit("breadFetched", response);
    });
};

exports.Events = eventEmitter;
```

Node Event Emitter

- In node, you can use the event emitter
- Create you own events for a library



```
let PBnJMaker = require("./pbnjmaker");

PBnJMaker.Events.on("breadFetched", () => {
    PBnJMaker.fetchPeanutButter();
});
PBnJMaker.Events.on("peanutButterFetched", () => PBnJMaker.fetchJam());
PBnJMaker.Events.on("jamFetched", () => PBnJMaker.spreadPeanutButter());
PBnJMaker.Events.on("peanutButterSpreaded", () => PBnJMaker.spreadJam());
PBnJMaker.Events.on("jamSpreaded", () => PBnJMaker.closeSandwich());
PBnJMaker.Events.on("sandwichClosed", (result) => console.log("Eat that " + result));

PBnJMaker.fetchBread();

```

Code

```
let PBnJMaker = require("./pbnjmaker");

PBnJMaker.Events.on("breadFetched", () => {
    PBnJMaker.fetchPeanutButter();
});
PBnJMaker.Events.on("peanutButterFetched", () => PBnJMaker.fetchJam());
PBnJMaker.Events.on("jamFetched", () => PBnJMaker.spreadPeanutButter());
PBnJMaker.Events.on("peanutButterSpreaded", () => PBnJMaker.spreadJam());
PBnJMaker.Events.on("jamSpreaded", () => PBnJMaker.closeSandwich());
PBnJMaker.Events.on("sandwichClosed", (result) => console.log('Eat that ' + result));

PBnJMaker.fetchBread();
```

Demo

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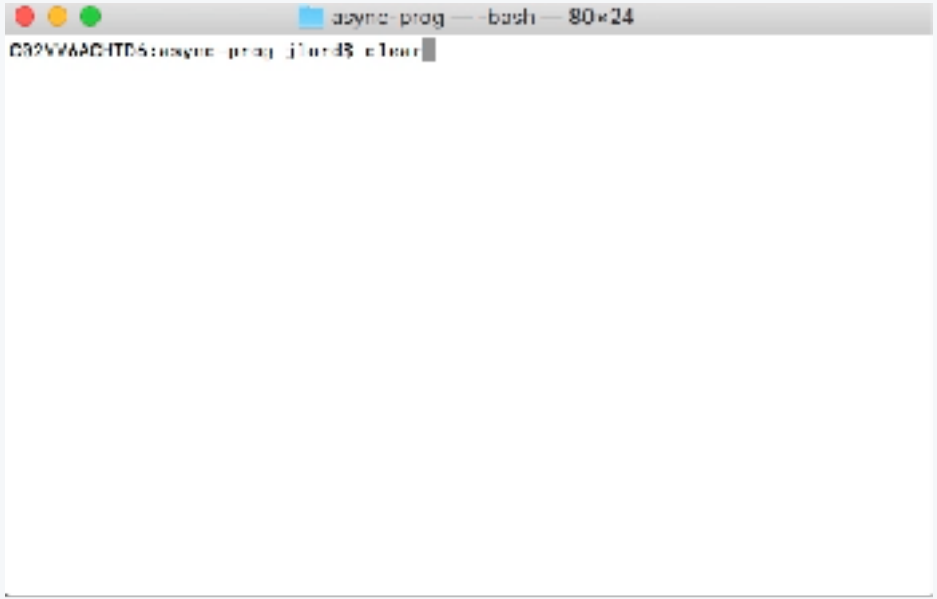
Code

```
const PBnJMaker = require("./pbnjmaker");

let ingredientsFetched = 0;
let ingredientsSpreaded = 0;

let ingredientFetched = () => {
    ingredientsFetched++;
    if (ingredientsFetched === 3) {
        PBnJMaker.Events.emit("ingredientsFetched");
    }
};

let spreaded = () => {
    ingredientsSpreaded++;
    if (ingredientsSpreaded === 2) {
        PBnJMaker.Events.emit("ingredientsSpreaded");
    }
};

PBnJMaker.Events.on("breadFetched", ingredientFetched);
PBnJMaker.Events.on("peanutButterFetched", ingredientFetched);
PBnJMaker.Events.on("jamFetched", ingredientFetched);

PBnJMaker.Events.on("ingredientsFetched", () => {
    PBnJMaker.spreadPeanutButter();
    PBnJMaker.spreadJam();
});

PBnJMaker.Events.on("peanutButterSpreaded", spreaded);
PBnJMaker.Events.on("jamSpreaded", spreaded);

PBnJMaker.Events.on("ingredientsSpreaded", () => {
    PBnJMaker.closeSandwich();
});

PBnJMaker.Events.on("sandwichClosed", (result) => console.log("Eat this " + result));

PBnJMaker.fetchBread();
PBnJMaker.fetchPeanutButter();
PBnJMaker.fetchJam();
```

Demo



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Reactive Stream
(2017)

RxJS

- Manipulate data, synchronous or asynchronous as streams
- Manipulate streams like arrays

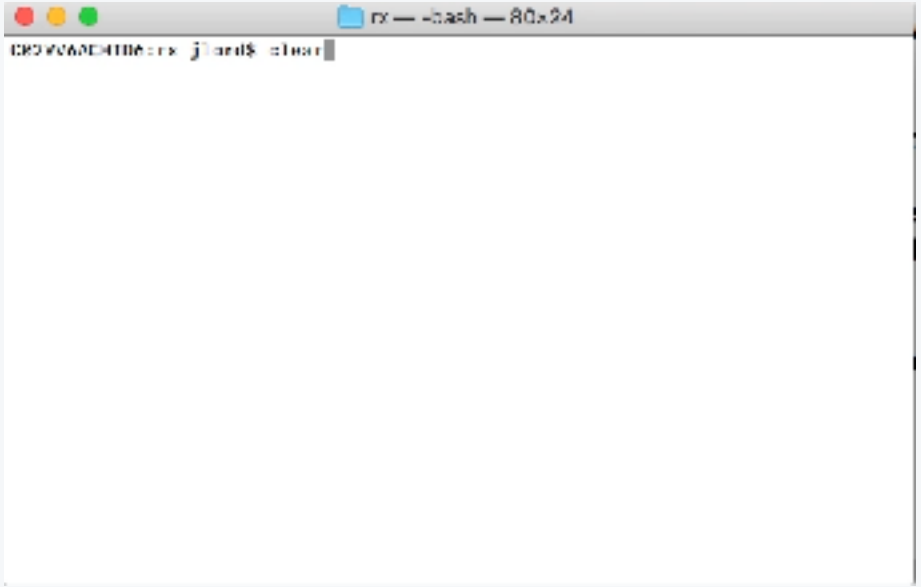
```
getDataFromLocalMemory()
    .filter (s => s != null)
    .map(s => `${s} transformed`)
    .forEach(s => console.log(`next => ${s}`))
```

```
getDataFromNetwork()
    .filter (s => s != null)
    .map(s => `${s} transformed`)
    .subscribe(s => console.log(`next => ${s}`))
```

Code

```
const Rx = require("rxjs");
let PBnJMaker = require("../pbnjmaker");

const ingredients = ["bread", "peanutButter", "jam"];

const ingredientEvents = ingredients.map((ingredient) => {
    return Rx.Observable.fromEvent(PBnJMaker.Events, `${ingredient}Fetched`);
});

const ingredientEvents$ = Rx.Observable.merge(...ingredientEvents);

const subscription = ingredientEvents$.subscribe(() => {
    console.log("Just fetched an ingredient");
});
```

Demo



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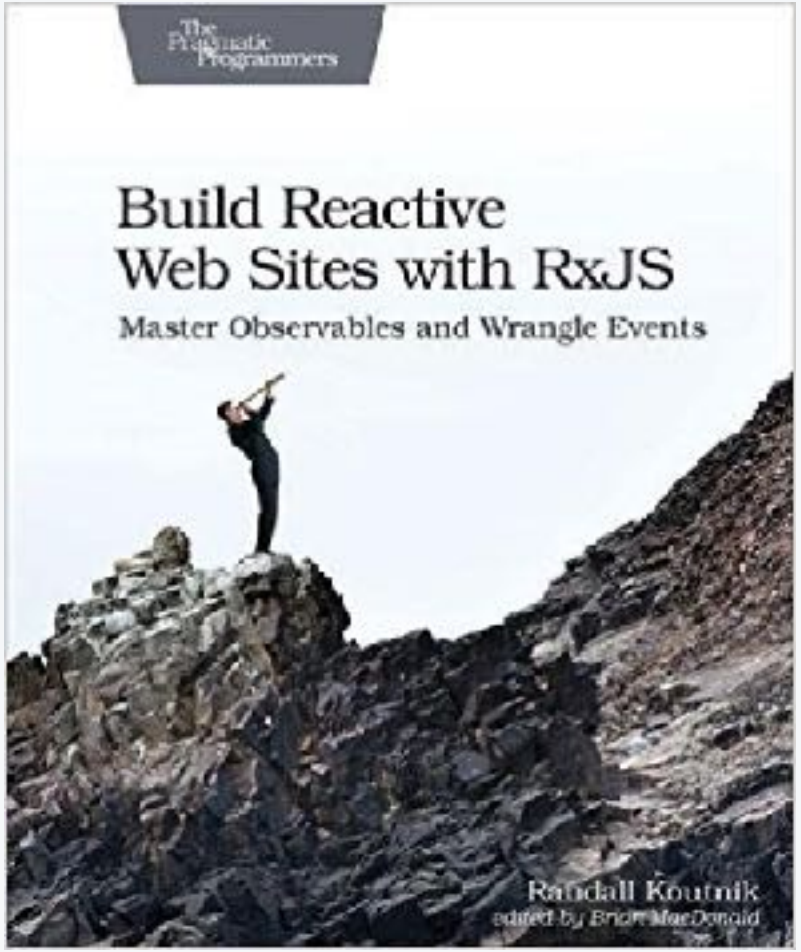
RxJS

- RTFM


The Pragmatic Programmers
Build Reactive Web Sites with RxJS
Master Observables and Wrangle Events
Randall Koutnik
edited by Brian MacDonald


In Conclusion
(c’est presque la faim)

Summary

Asynchronous patterns

- The Event Loop
- Callbacks
- Promises
- Generators
- Async/Await
- Events
- Reactive Stream

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

Summary

Asynchronous patterns

- The Event Loop
- Callbacks
- Promises
- Generators
- Async/Await
- Events
- Reactive Stream
- …. How to make a PBnJ sandwich!

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

Asynchronicity: concurrency. A tale of

Confoo - Montreal, Canada
March 7, 2018

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