1 Debugging Processes

This chapter covers the following recipes

- Debugging Node with Chrome Devtools
- Enhancing Stack Trace output
- Enabling Debug Logs
- Enabling Core Debug Logs

Introduction

Debugging JavaScript has traditionally been non-trivial, this is partly to do with evented asynchronous paradigms inherent in the programming model and partly to do with tooling (and the difficulties in creating tooling that is well matched to JavaScripts programming model).

In recent years, however, as JavaScript usage has exponentially increased in both browser and server side development, tooling has improved and continues to improve.

In this chapter, we talk about how to use fundamental debugging tools, discuss helpful techniques, introduce some additional useful introspection resources and delve deeper into advanced production debugging tools and techniques such as async tracing and postmortems.

Debugging Node with Chrome Devtools

Node 6.3.0 onwards provides us with the `--inspect` flag which we can use to debug the Node runtime with Google Chrome's Devtools.

> ### Debugging Legacy Node 
>
> This recipe can be followed with older versions of Node prior to Node 6.3.0 - it just requires a little more set up. To follow this recipe in a legacy Node version, jump to **Using `node-inspector` with Older Node Versions** in the **There's More** section of this recipe first.

In this recipe we're going to diagnose and solve a problem in a simple Express application.

Getting Ready

We're going to debug a small web server, so let's create that real quick.


the command line we execute the following commands:

```
$ mkdir app
$ cd app
$ npm init -y
$ npm install --save express
$ touch index.js future.js past.js
```

Our `index.js` file should contain the following:

```
const express = require('express')
const app = express()
const past = require('./past')
const future = require('./future')

app.get('/:age', (req, res) => {
  res.send(past(req.params.age, 10) + future(req.params.future, 10))
})

app.listen(3000)
```

Our `past.js` should look like:

```
module.exports = (age, gap) => {
  return `${gap} years ago you were ${Number(age) - gap}<br>`
}
```

And our `future.js` file should be:

```
module.exports = (age, gap) => {
  return `In ${gap} years you will be ${Number(age) + gap}<br>`
}
```

> **Web Frameworks** 

> We're only using express here as an example, to learn more about Express and other Frameworks see **Chapter 7 Working With Web Frameworks**

How to do it

When we run our server (which we created in the Getting Ready section) normally, and navigate our browser to (for instance) `http://localhost:3000/31` the output is as follows:

```
10 years ago you were 21
In 10 years you will be NaN
```

Looks like we have a Not a Number problem.

Let's start our server in inspection mode:

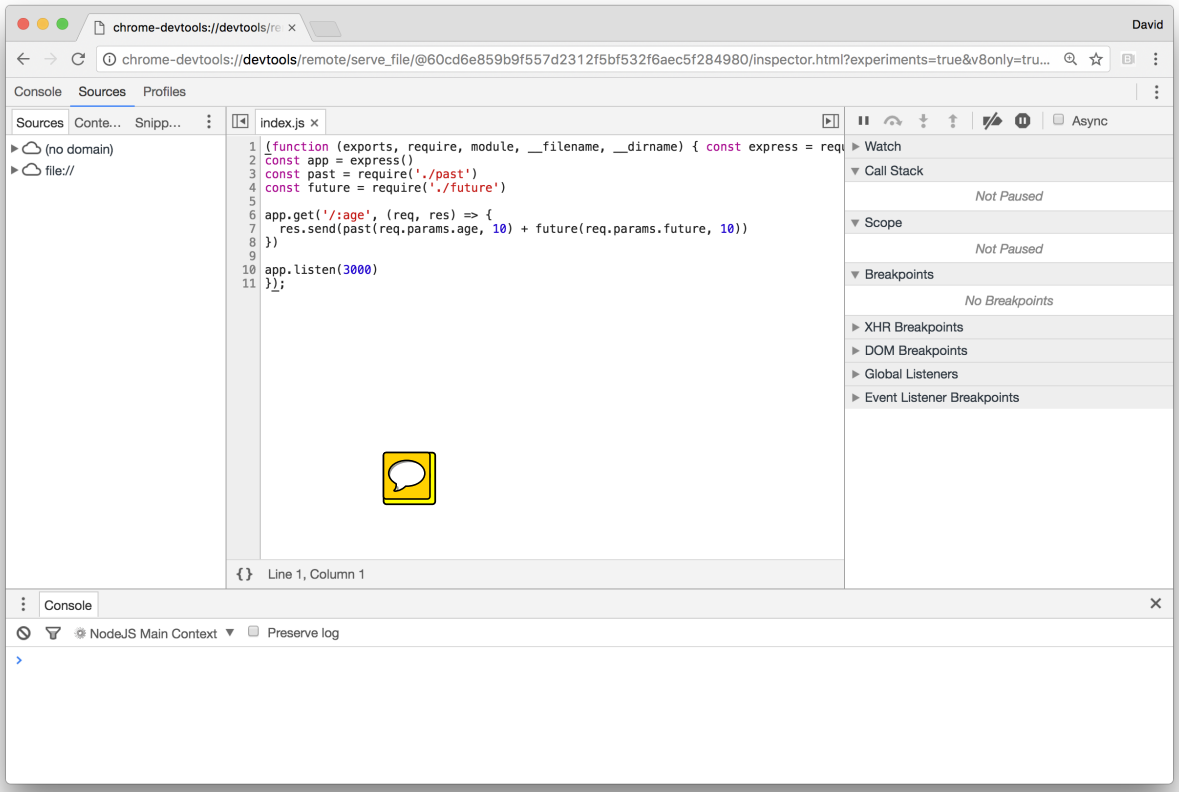
```
$ node --inspect index.js
```

We should see output that's something like the following:

```
Debugger listening on port 9229.
To start debugging, open the following URL in Chrome:
    chrome-devtools://devtools/remote/serve_file/@60cd6e859b9f557d2312f
```

Let's copy and paste full the URL with the `chrome-devtools://` protocol, into you Chromes location bar.

We should then see something like the following:



Chrome Devtools Running in Chrome Browser

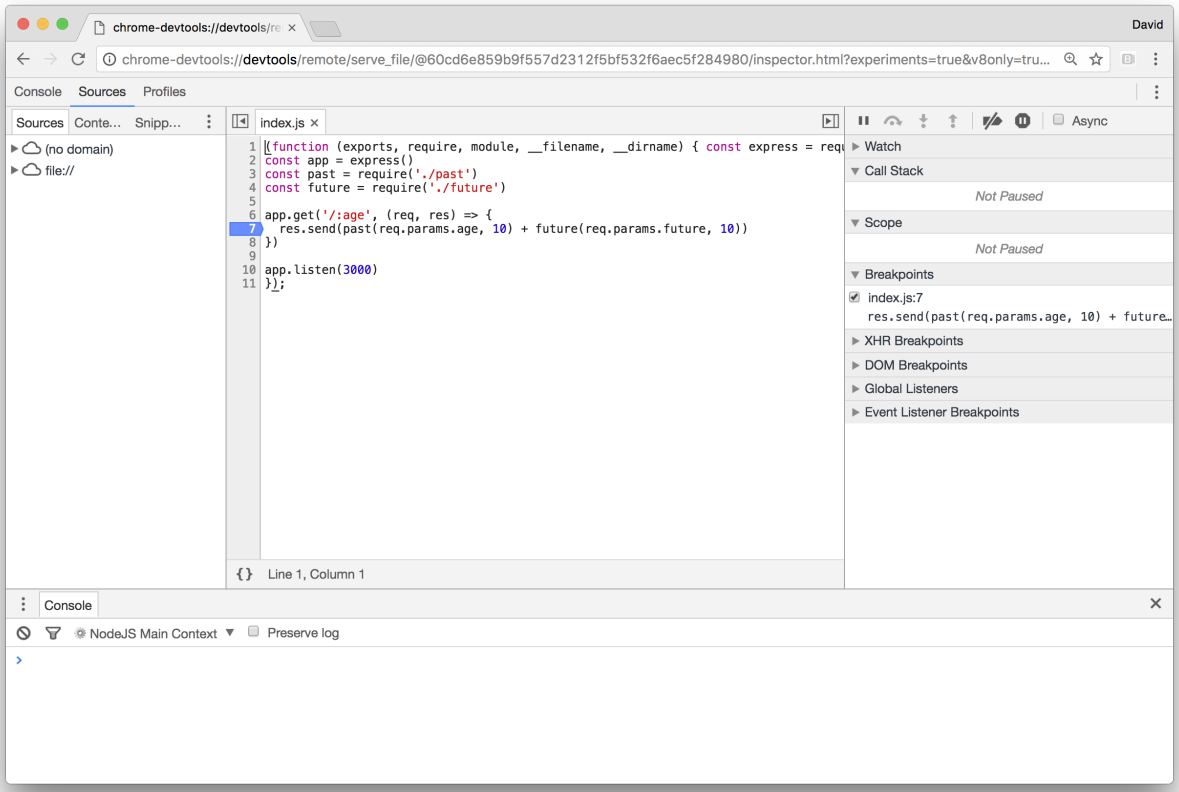
The Module Wrapper 

> Notice that the Devtools Code section shows an additional outer function wrapping the code we placed into `index.js`. This outer function is added at run time to each code file loaded into the process (either by directly starting the file with `node` or by using `require` to load it). This outer function is the Module Wrapper, it's the mechanism Node uses to supply local references like `module` and `__filename` that are unique to our module without polluting global scope.

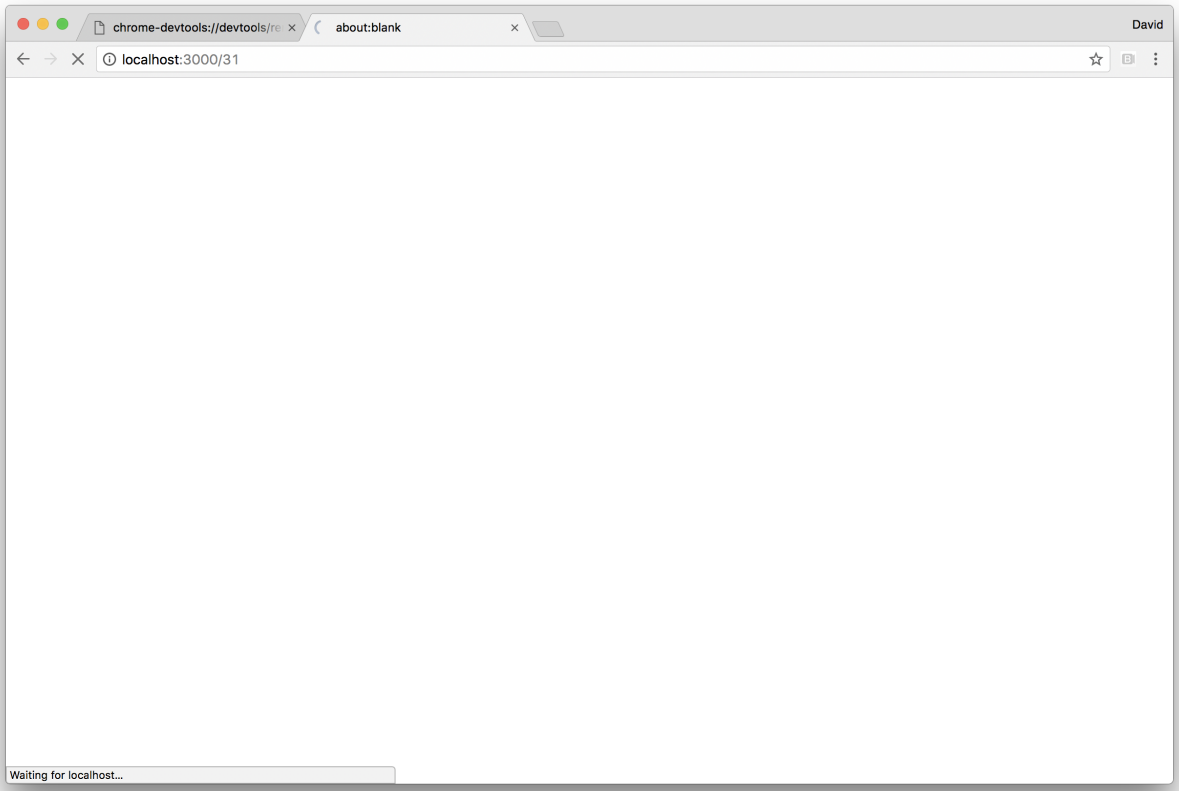
Now let's set a break inside our route handler, on line 7.

If we click the number 7 in the LOC column to the left of the code, an arrow like shape will appear over and around the number (which will turn white). Over on the right hand column, in the Breakpoints pane we should also see a checkbox with "index.js:7" next to it, while beneath that is the code from the line we've set a breakpoint on.

In short, the Devtools GUI should now look something like the following:

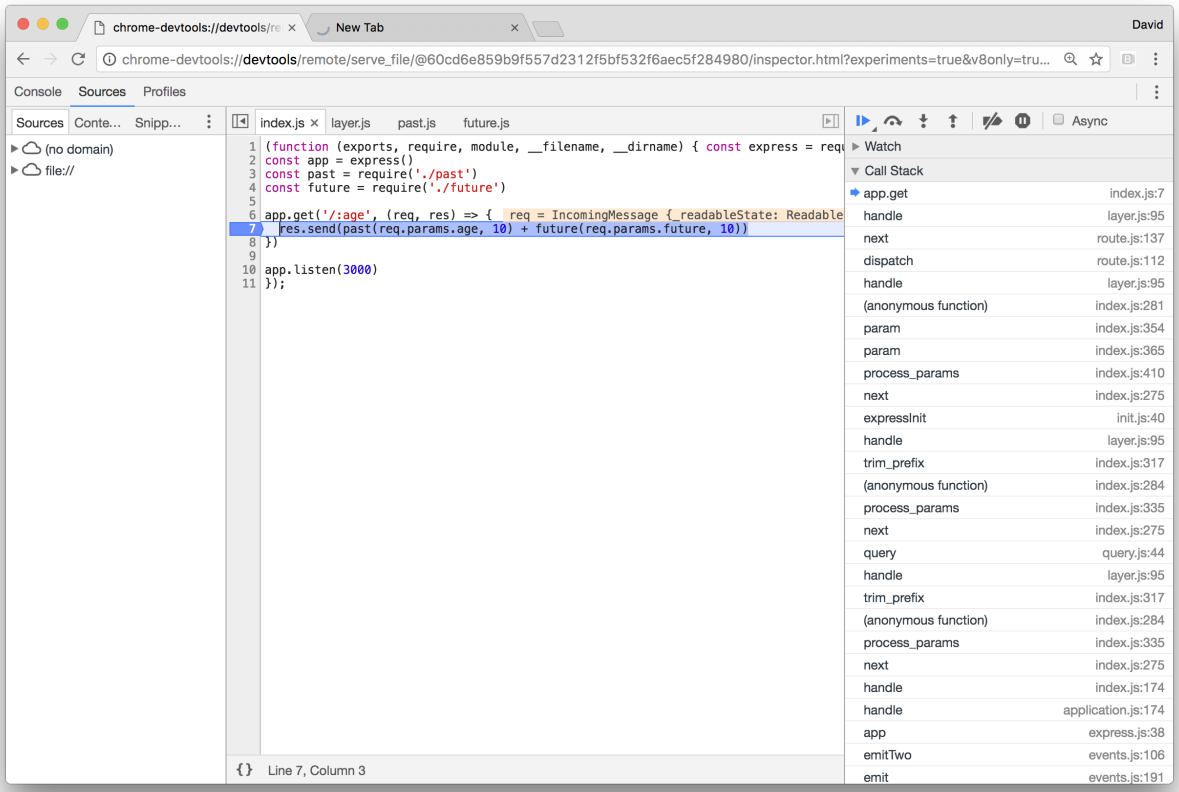


Now let's open a new tab, and navigate to `http://localhost:3000/31`



This will cause the breakpoint to trigger, and Devtools will immediately grab focus.

The next thing we see should look like the following:

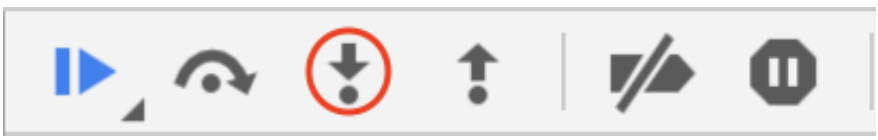


We can see line 7 is now highlighted, and there's a sort of tooltip showing us the values of of the `req` and `res` objects on the line above.

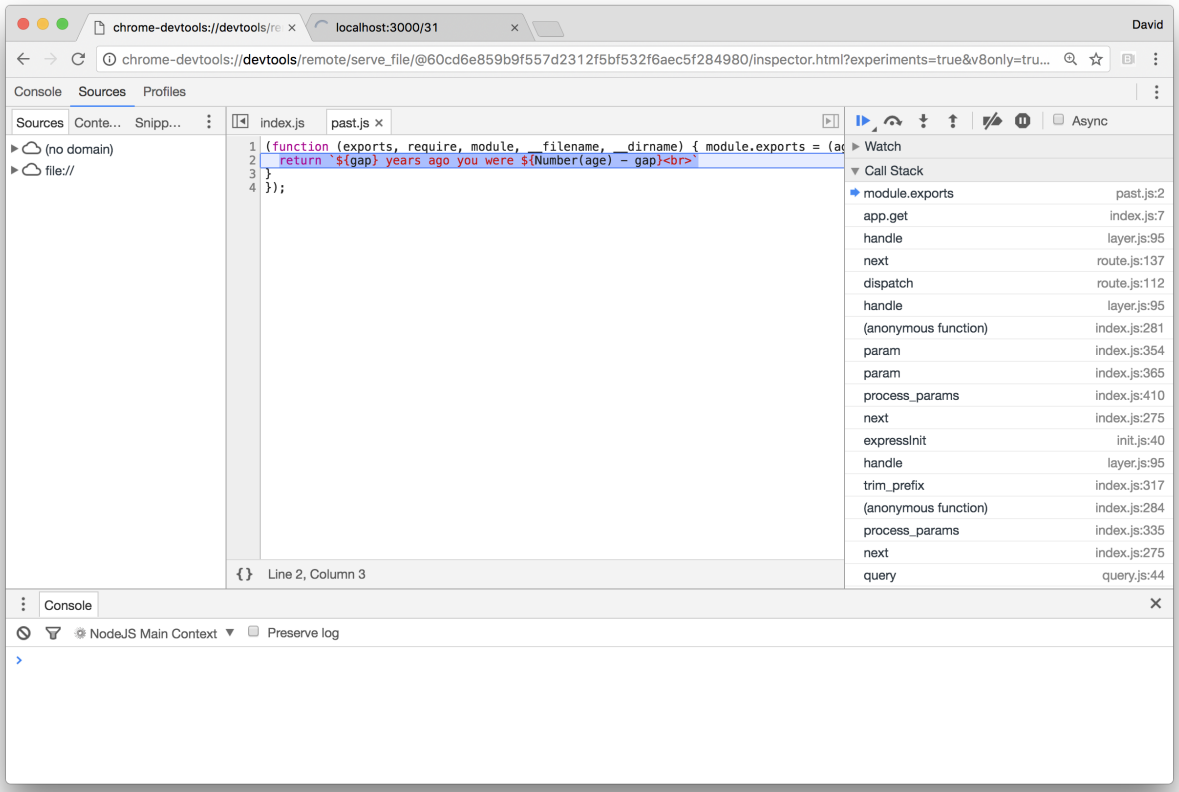
Over in the right column the Call Stack panel is full of Call Frames (the functions in the stack), and there's now a blue play button in the control icons at the top of the right column. If we we're to scroll the right column, we'd also see the Scope pane is populated with references.

The debugger is waiting for us to allow execution to proceed, and we can chose whether to step over, in or out of the next instruction.

Let's try stepping in, this is the down arrow pointing to a dot, third icon from the left in the controls section:



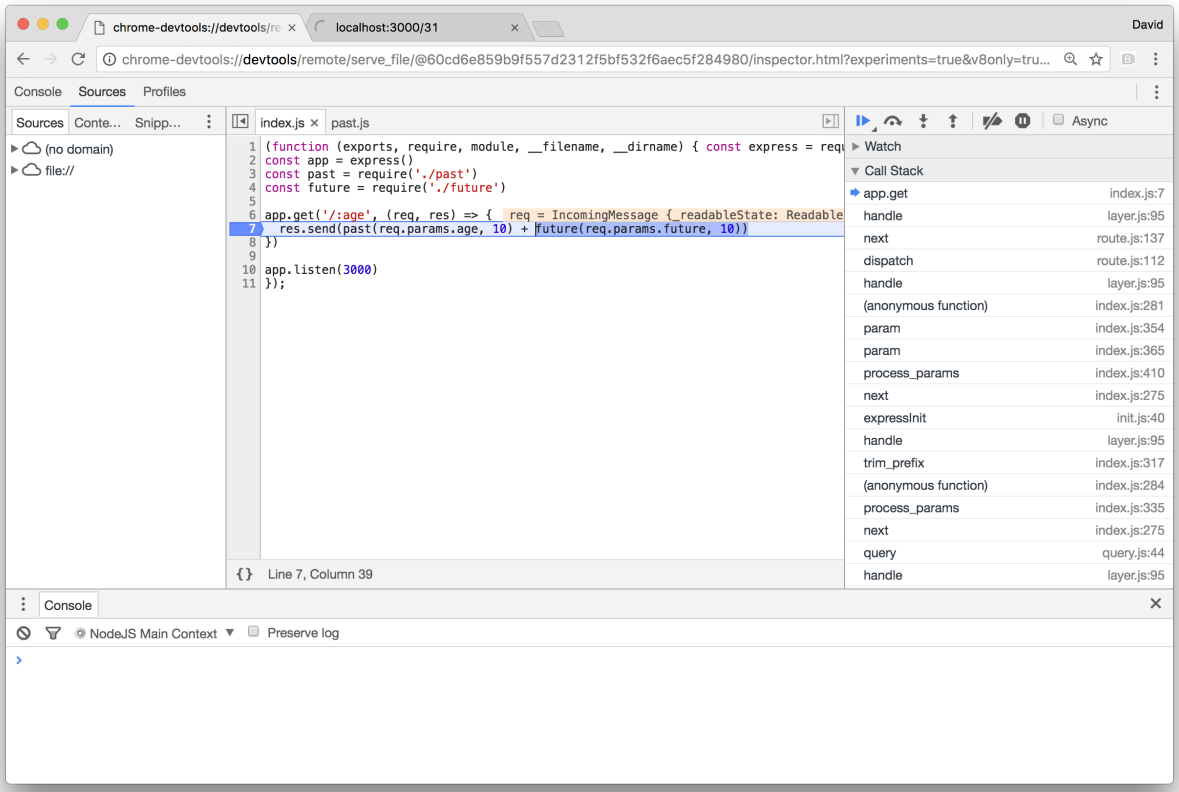
When we press this, we step into the `past` function, which is in the `past.js` file, so Devtools will open a new tab in the above center code panel, and highlight the line which is about to execute (in our case, line 2).



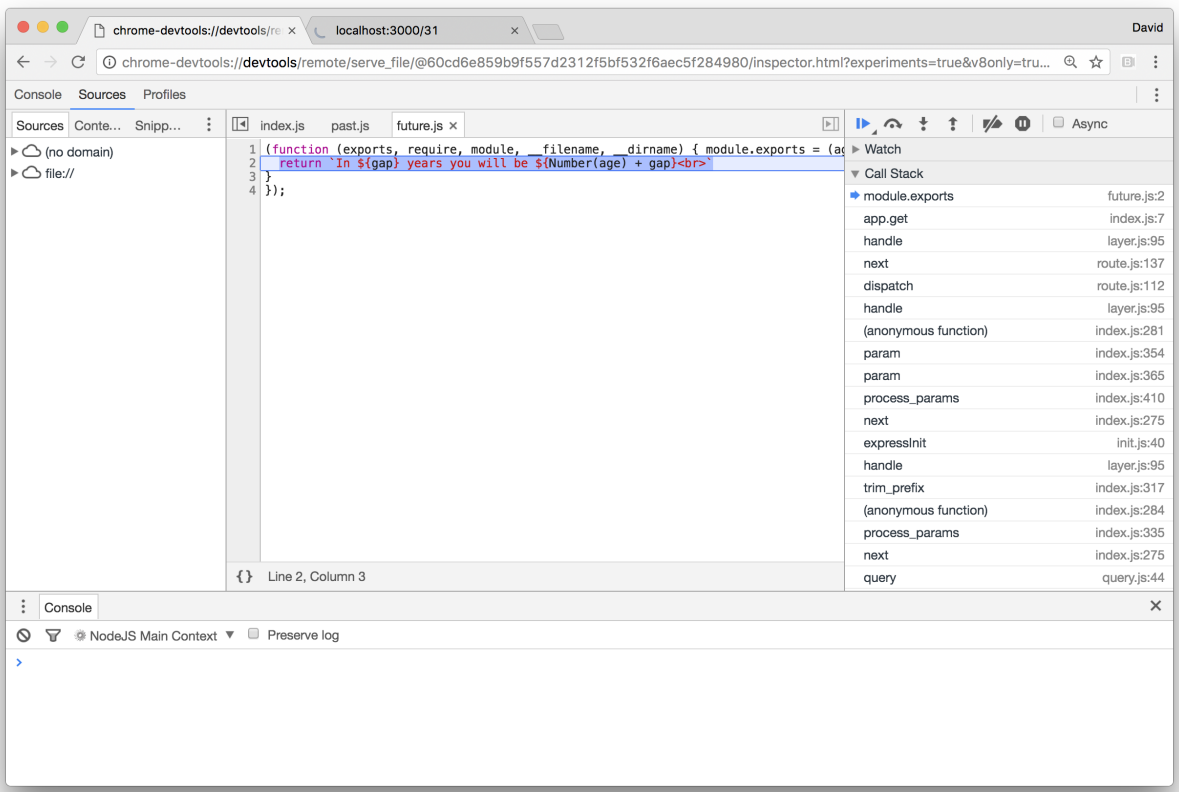
So let's step out of the `past` function, by pressing the arrow pointing up and away from a dot, next to the step in icon:

The second line of the output seems to have the issue, which is our `future` function.

Now that we've stepped out, we can see that the call to `future` is highlighted in a darker shade of blue:



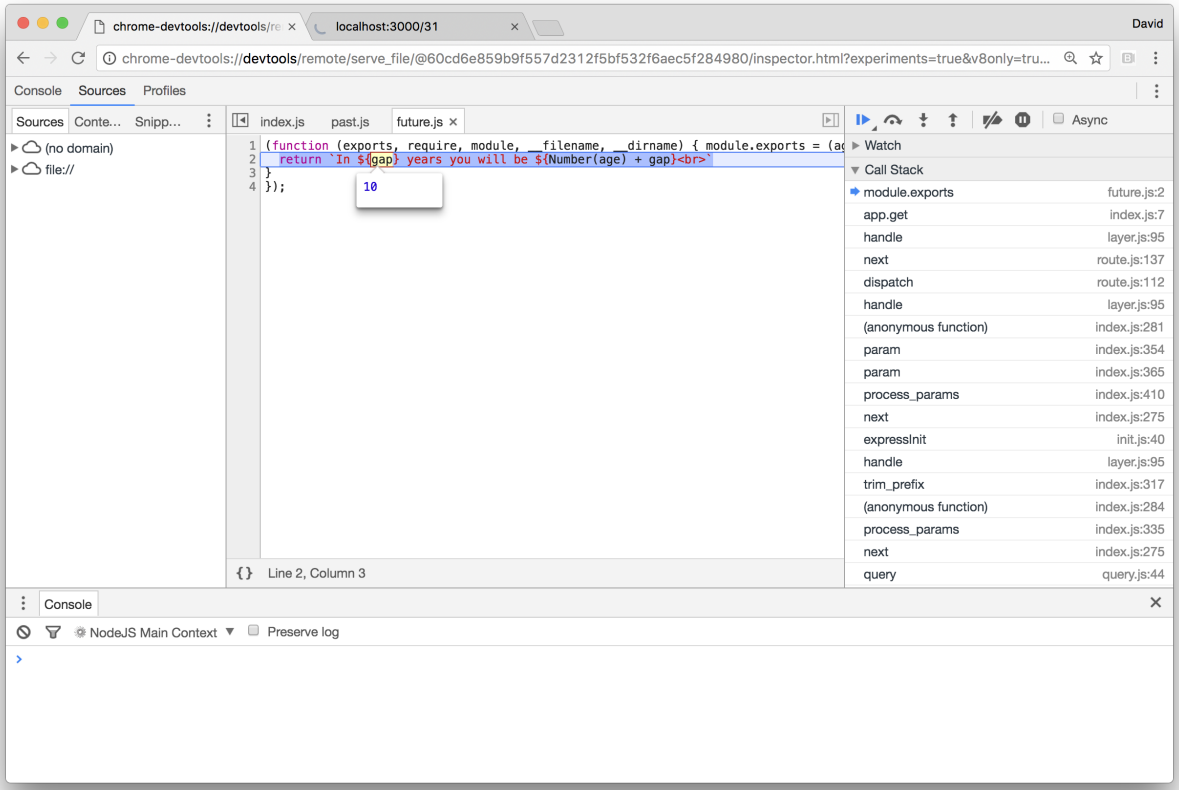
Then we'll press the step in icon again, which will take us into the `future` function in the `future.js` file:



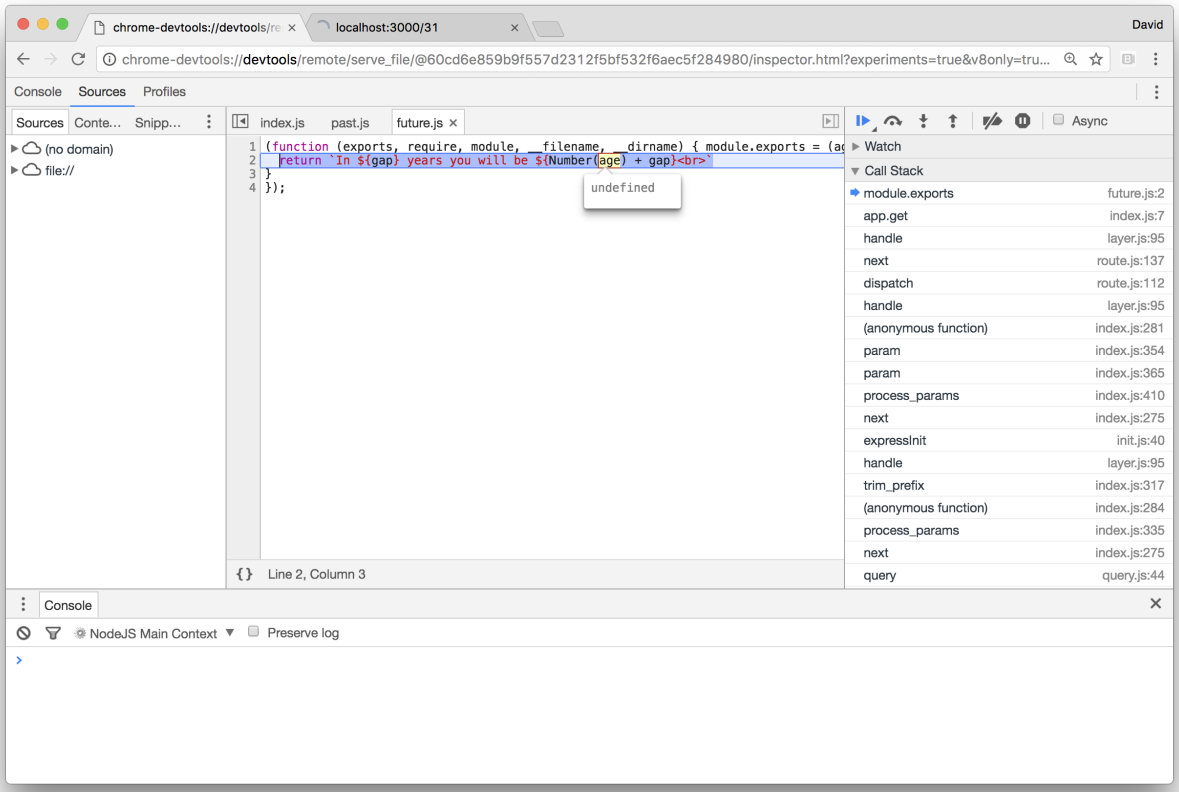
Okay, this is the function that generates that particular sentence with the `NaN` in it. A `NaN` can be generated for all sort of reasons, dividing zero by itself, substracting

`Infinity` from `Infinity` trying coerce a string to a number when the string does not hold a valid number, to name a few. At any rate, it's probably something to do with the values in our `future` function.

Let's hover over the `gap` variable, we should see:

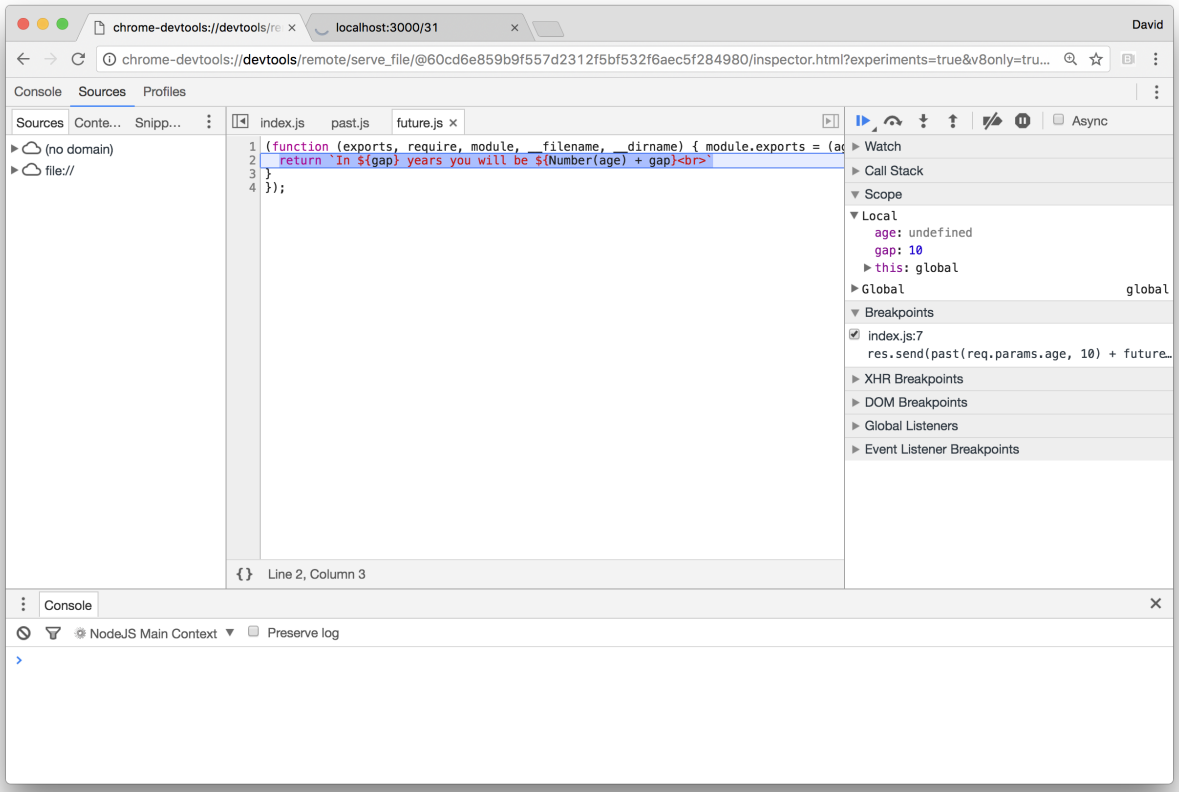


Seems fine, now let's hover over the `age` variable:



Wait why does that say `undefined`, we vicariously passed `31` by navigating to the `http://localhost:3000/31`.

To be sure our eyes aren't deceiving us, we can double check by collapsing the Call Stack column (by clicking the small downwards arrow next to the C of Call Stack). We should see:

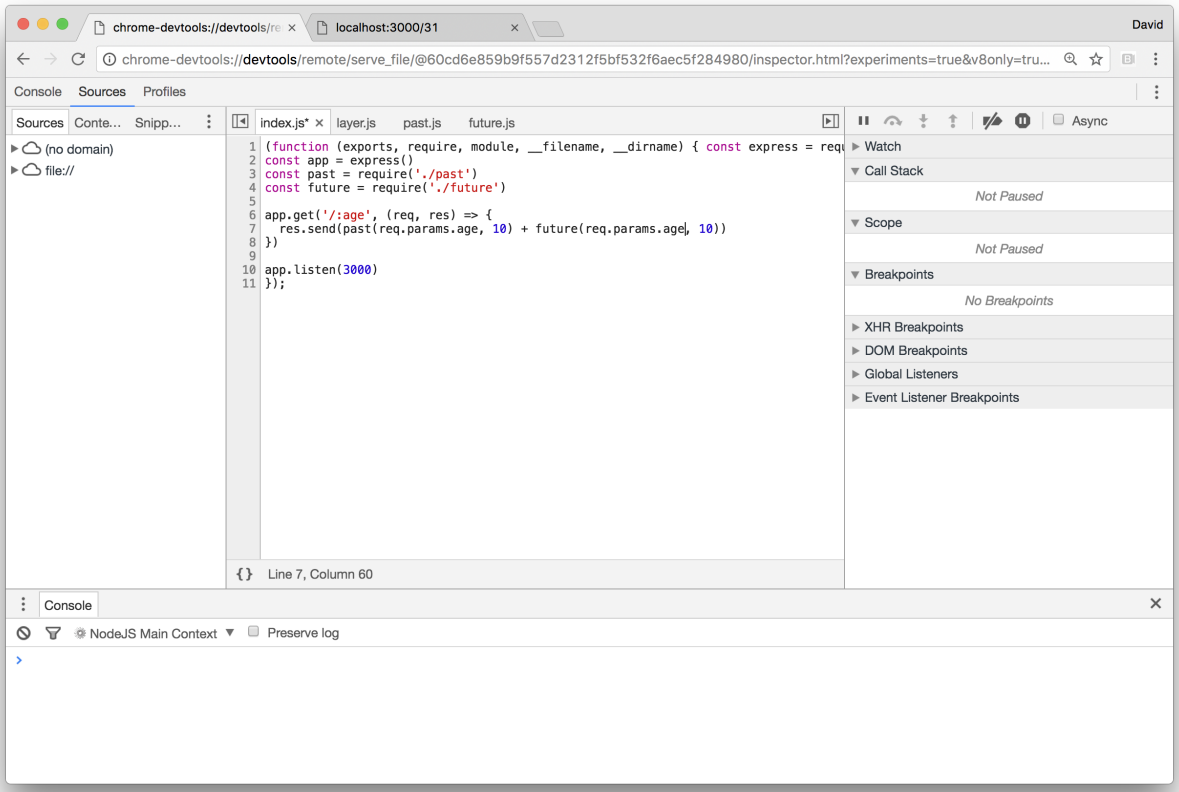


Well `Number(undefined)` is `NaN`, and `NaN + 10` is also `NaN`.

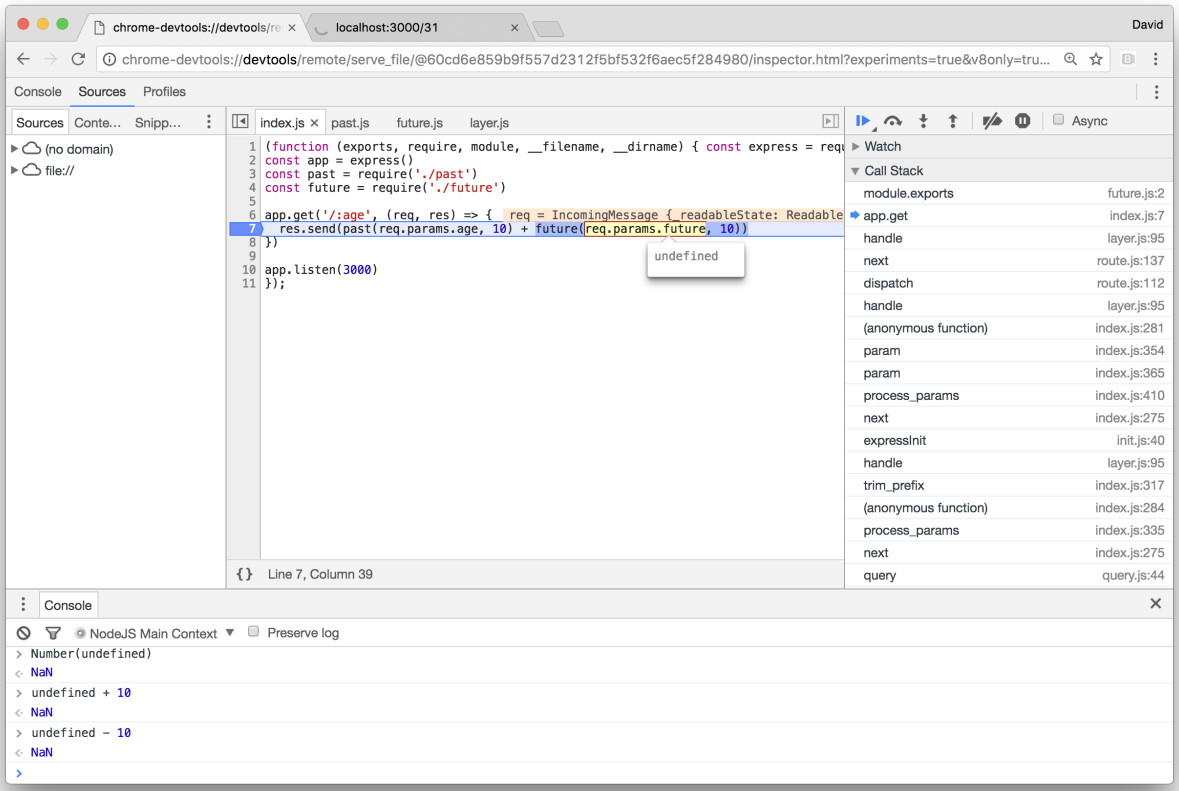
Why is `age` set to `undefined`?

Let's open up the Call Stack bar again, and click the second row from the top (which says `app.get`).

We should be back in the `index.js` file again (but still frozen on line 2 of `future.js`). Like so:



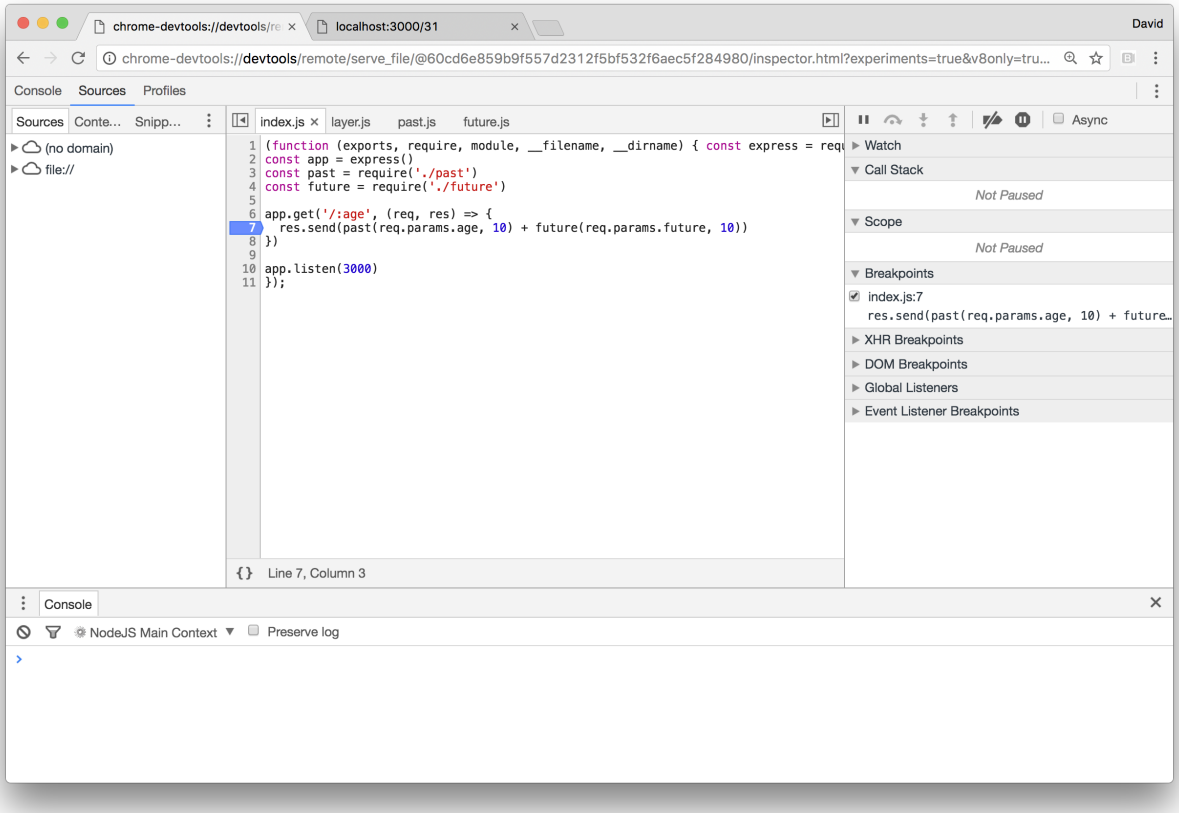
Now let's hover over the value we're passing in to `future`:



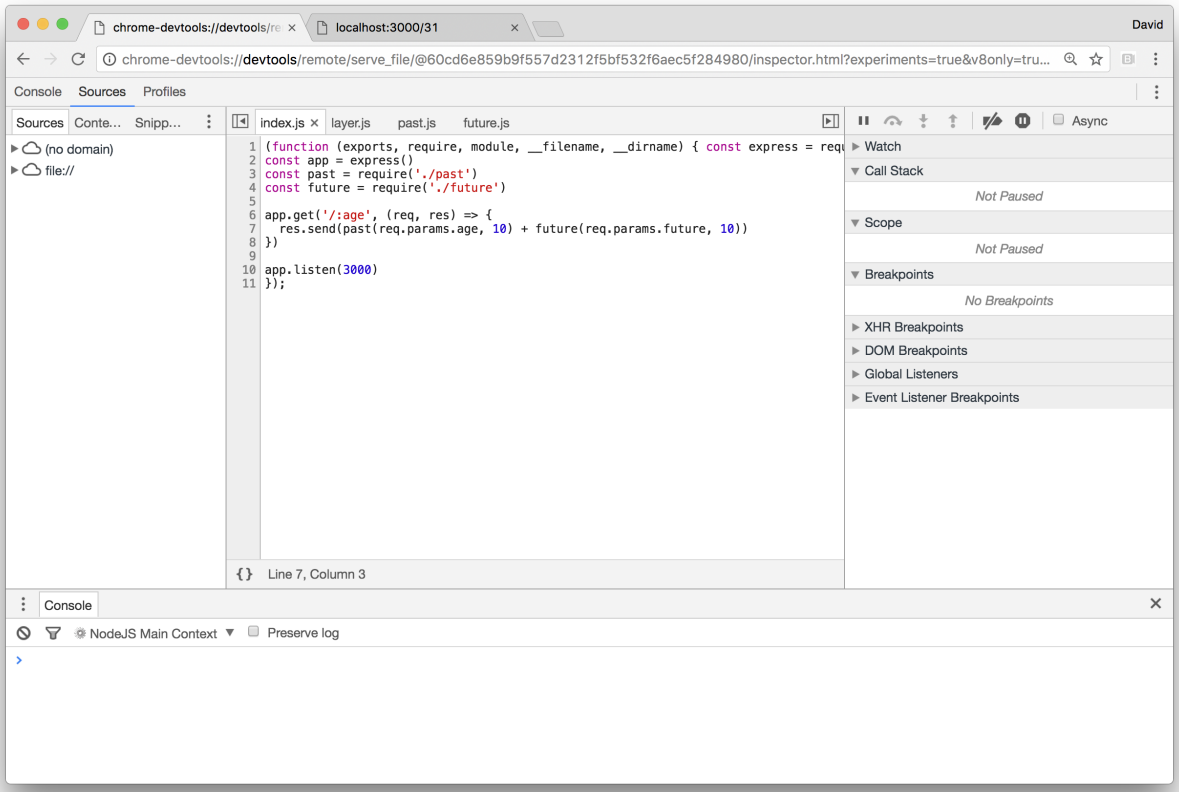
That's `undefined` too, why is it `undefined`?!

Oh. That should be `req.params.age` not `req.params.future`. Oops.

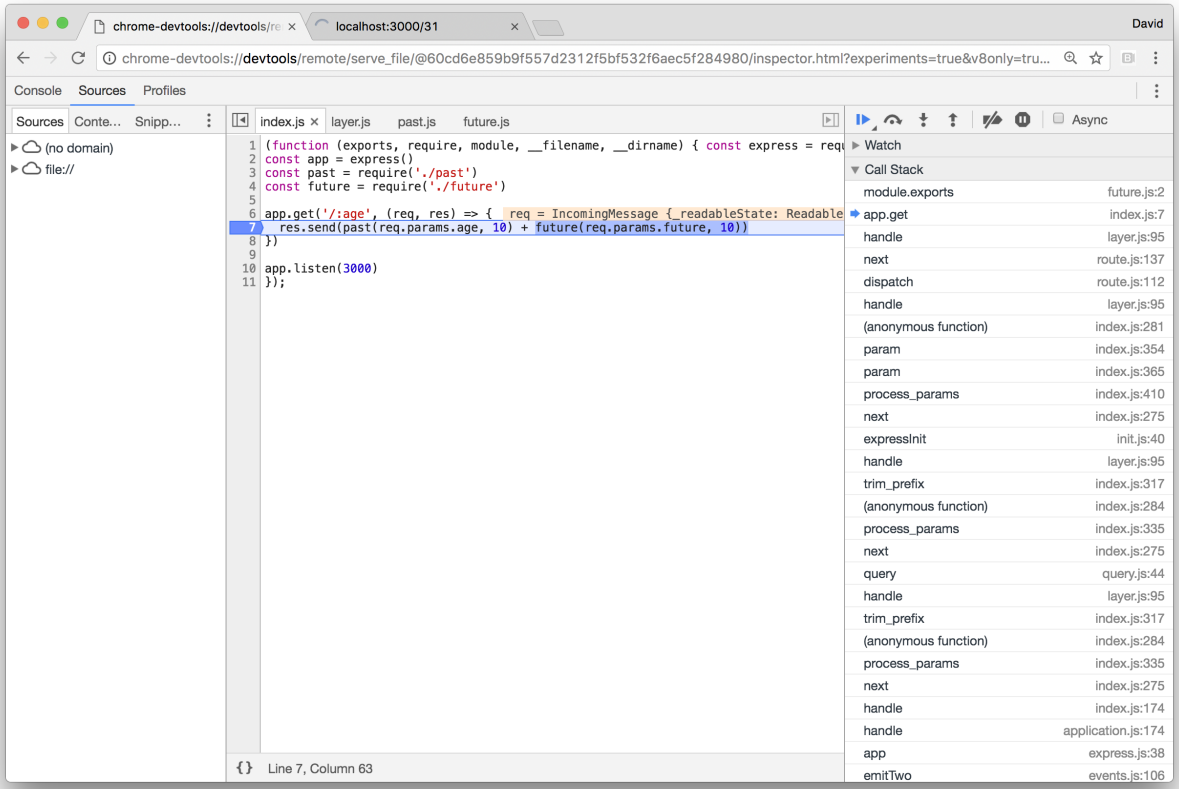
To be absolutely sure, let's fix it while the server is running, if we hit the blue play button twice we should see something like:



Now let's click line 7 again to remove the breakpoint, we should be seeing:

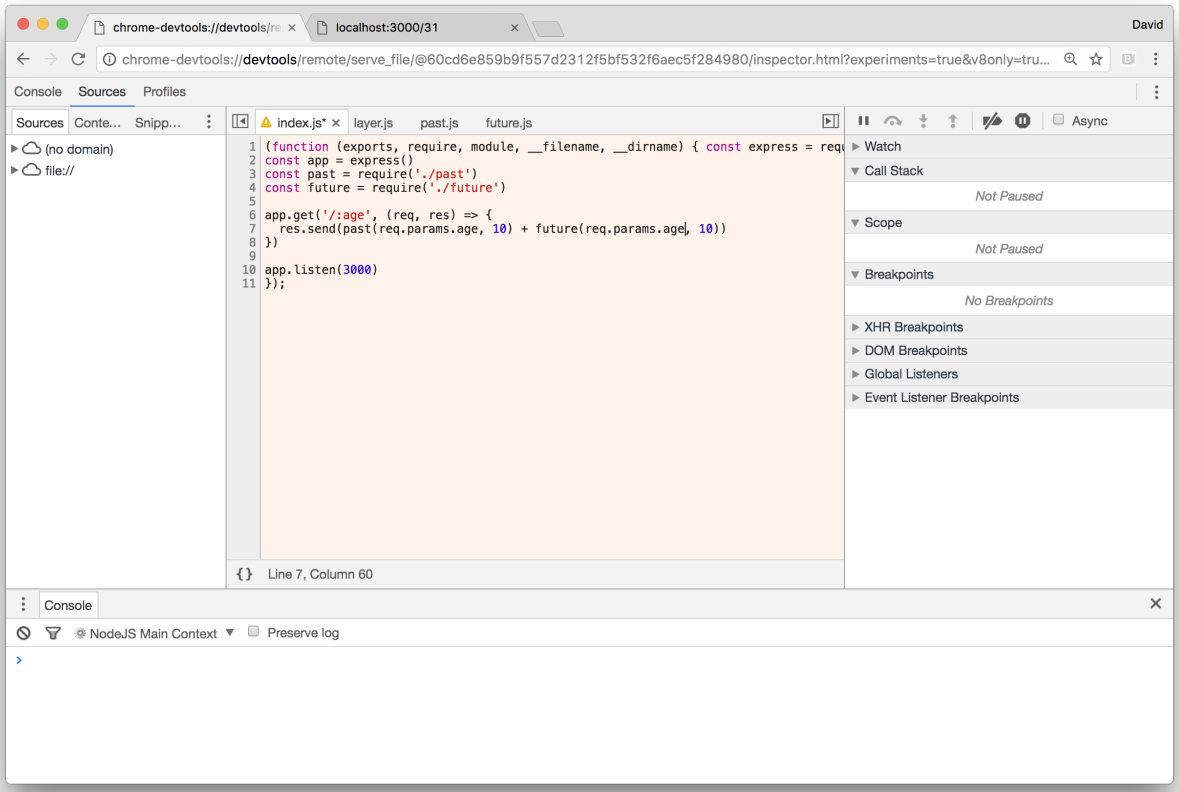


Now if we click immediately after the `e` in `req.params.future` we should get a blink cursor, we backspace out the word `future` and type the word `age`, making our code look like so:

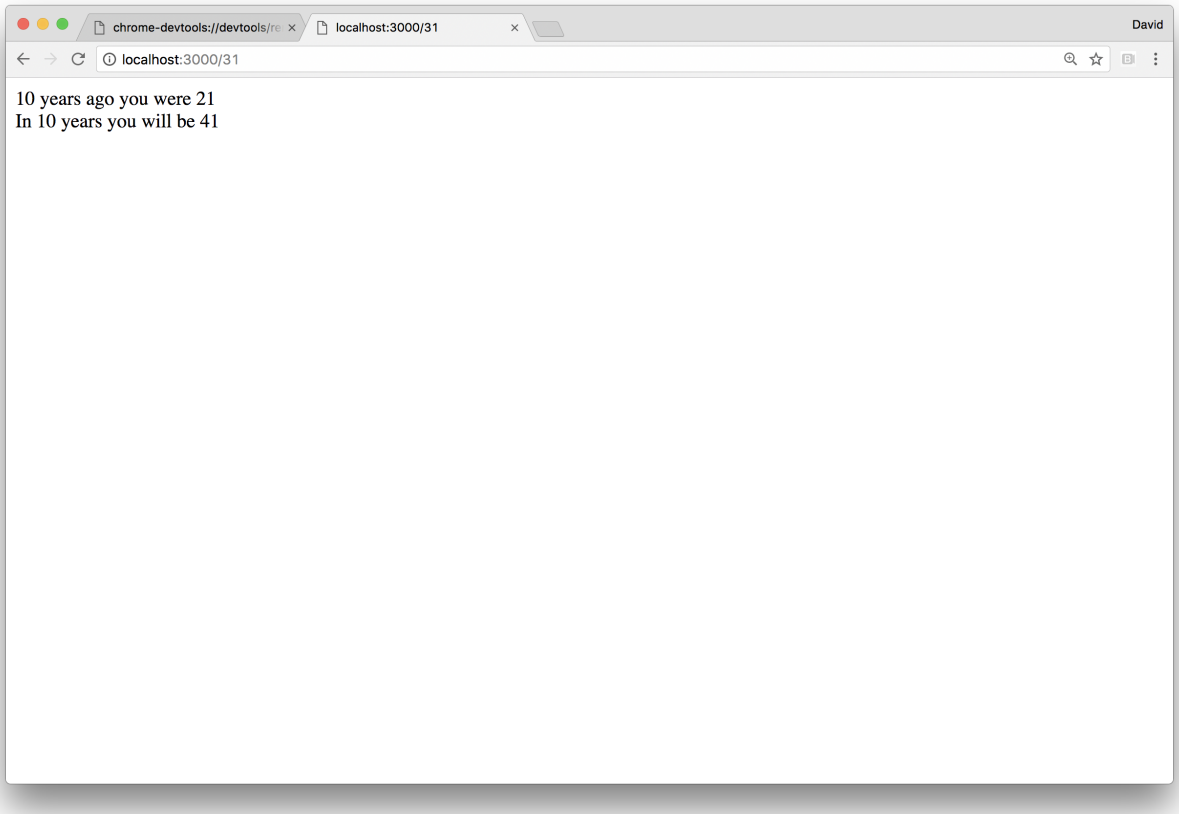


Finally we can live save those changes in our running server by pressing CMD + s on MacOS or Ctrl + s on Windows and Linux.

The code panel will then change background color, like so:



Finally, let's check our route again:



Ok we've definitely found the problem, and verified a solution.

How it works

We don't really need to know how debugging Node with devtools is made possible in order to avail of the tool, however, for the curious here's a high level overview.

Debugging ability is ultimately provided by v8, the JavaScript engine used by Node. When we run `node` with the `--inspect` flag the v8 inspector opens a port, that accepts WebSocket connections. Once a connection is established commands in the form of JSON packets are sent back and forth between the inspector and a client.

The `chrome-devtools://` URI is a special protocol recognized by the chrome browser that loads the Devtools UI (which is written in HTML, CSS and JavaScript, so can be loaded directly into a normal browser tab). The Devtools UI is loaded in a special mode (remote mode), where a WebSocket endpoint is supplied via the URL.

The WebSocket connection allows for bi-directional communication between the inspector and the client. The tiny Inspector WebSocket server is written entirely in C and runs on a separate thread so that when the process is paused, the inspector can continue to receive and send commands.

In order to achieve the level of control we're afforded in debug mode (ability to pause, step, inspect state, view callstack, live edit) v8 operations are instrumented throughout with Inspector C++ functions that can control the flow, and change state in place.

For instance, if we've set a breakpoint, once that line is encountered a condition will match in the C++ level that triggers a function which pauses the event loop (the JavaScript thread). The Inspector then sends a message to the client over the WebSocket connection telling it that the process is paused on a particular line and the client updates its state. Like wise, if the user chooses to "step into" a function, this command is sent to the Inspector, which can briefly unpause and repause the event loop in the appropriate place, then sends a message back with the new position and state.

There's more

Let's find out how to debug older versions of Node, make a process start with a paused runtime and learn to use the builtin command line debugging interface.

Using `node-inspector` with Older Node Versions

The `--inspect` flag and protocol were introduced in Node 6.3.0, primarily because the v8 engine had changed the debugging protocol. In Node 6.2.0 and down, there's a legacy debugging protocol enabled with the `--debug` flag but this isn't compatible with the native Chrome Devtools UI.

Instead we can use the `node-inspector` tool, as a client for the legacy protocol.

The `node-inspector` tool essentially wraps an older version of Devtools that interfaces with the legacy debug API, and then hosts it locally.

Let's install `node-inspector`:

```
$ npm i -g node-inspector
```

This will add a global executable called `node-debug` which we can use as shorthand to start out process in debug mode.

If we run our process like so

```
$ node-debug index.js
```

We should see output something like the following:

```
Node Inspector v0.12.10
Visit http://127.0.0.1:8080/?port=5858 to start debugging.
Debugging `index.js`

Debugger listening on [::]:5858
```

When we load the url http://127.0.0.1:8080/?port=5858 in our browser we'll again see the familiar Devtools interface.

By default, the `node-debug` command start our process in a paused state, after pressing run (the blue play button), we should now be able to follow the main recipe in it's entirety using a legacy version of Node.

Immediately pausing a process on start

In many cases we want to debug a process from initialization, or we may want to set up breakpoints before anything can happen 

From Node 8 onwards we use the following to start Node in an immediately paused state:

```
$ node --inspect-brk index.js
```

In Node 6 (at time of writing 6.10.0), `--inspect` is supported but `--inspect-brk` isn't. Instead we can use the legacy `--debug-brk` flag in conjunction with `--inspect` like so:

```
$ node --debug-brk --inspect index.js
```

In Node v4 and lower, we'd simply use `--debug-brk` instead of `--debug` (in conjunction with another client, see **Using Node Inspector with Older Node Versions**)

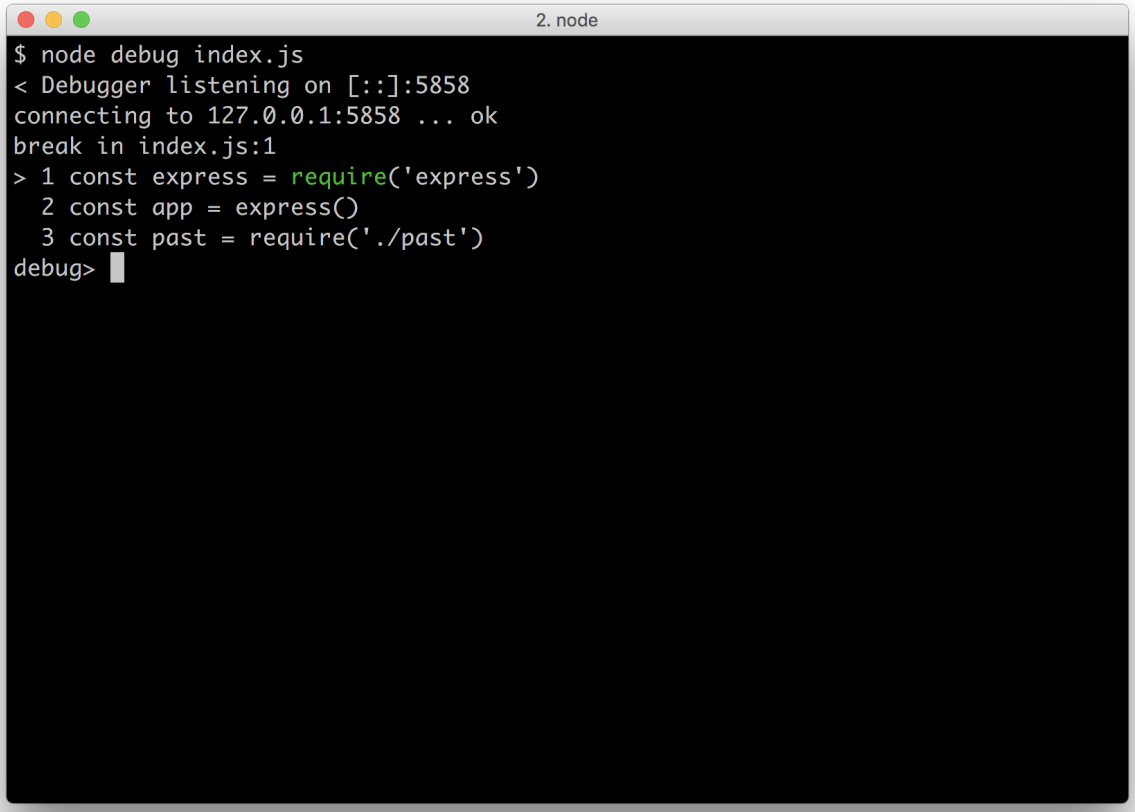
node debug

There may be rare occasions when we don't have easy access to a GUI, in these scenarios command line abilities become paramount.

Let's take a look at Nodes built in command line debugging interface.

Let's run our app from the main recipe like so:

```
$ node debug index.js
```



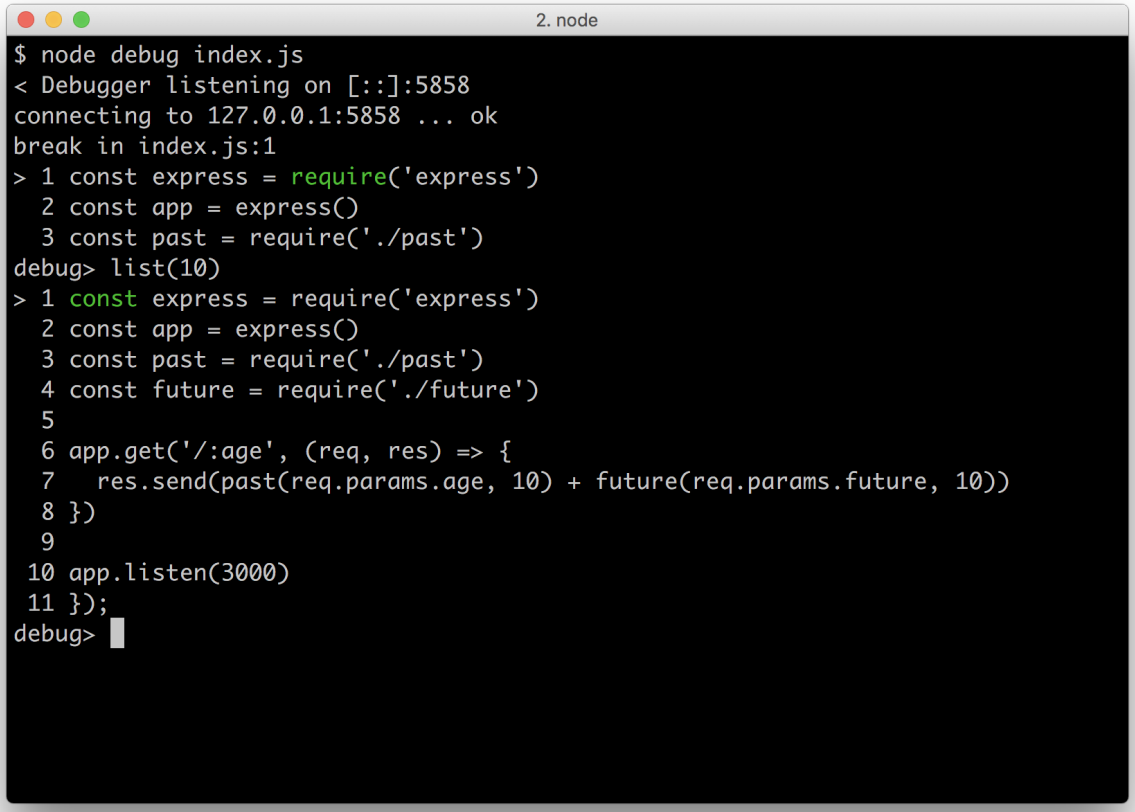
When we enter debug mode, we see the first three lines of our entry point (`index.js`).

Upon entering debug mode, the process is paused on the first line of the entry point. By default, when a breakpoint occurs the debugger shows 2 lines before and after the current line of code, since this is the first line we only see two lines after.

The debug mode provides several commands in the form of functions, or sometimes as magic getter/setters (we can view these commands by typing `help` and hitting enter)

Let's get a little context using the `list` function,

```
debug> list(10)
```



This provides 10 lines after our current line (again it would also include 10 lines before, but we're on the first line so there's no prior lines to show).

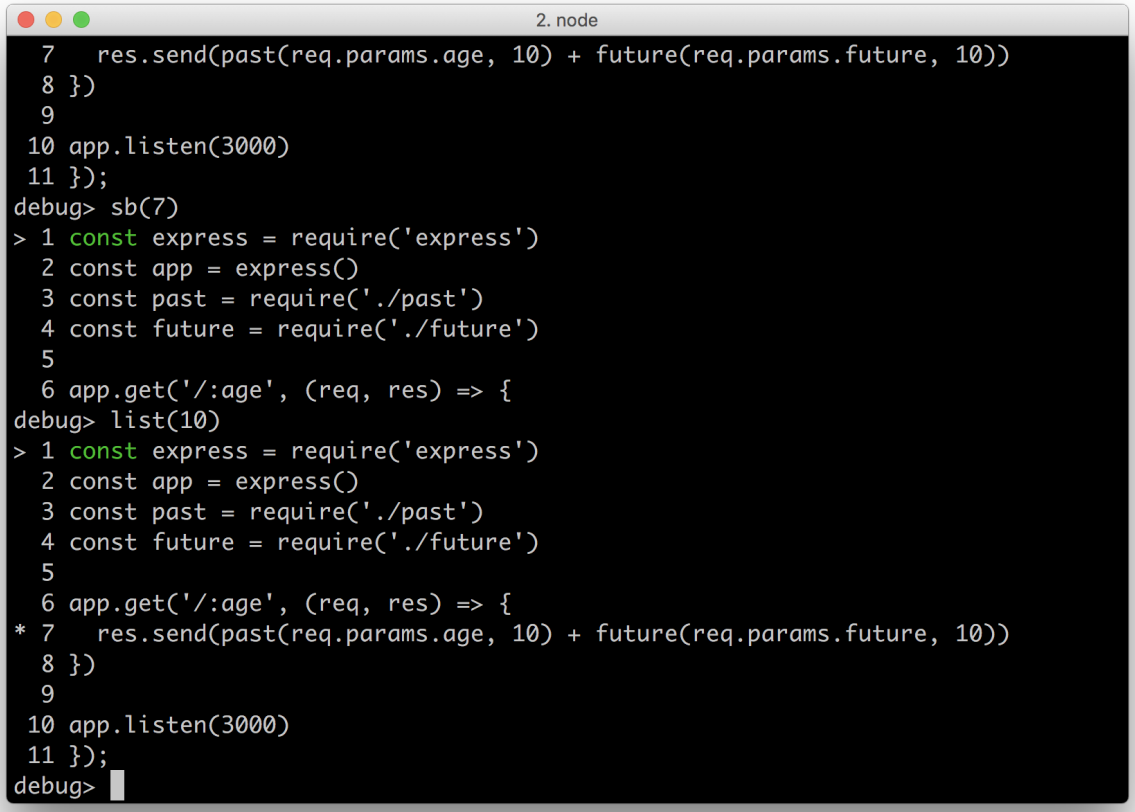
We're interested in the 7th line, because this is the code that's executed when the server receives a request.

We can use the `sb` function (which stands for Set Breakpoint), to set a break point on line 7, like so:

```
debug> sb(7)
```

Now if we use `list(10)` again, we should see an asterisk (`*`) adjacent to line 7.

```
debug> list(10)
```



Since our app began in paused mode, we need to tell the process to begin running as normal so we can send a request to it.

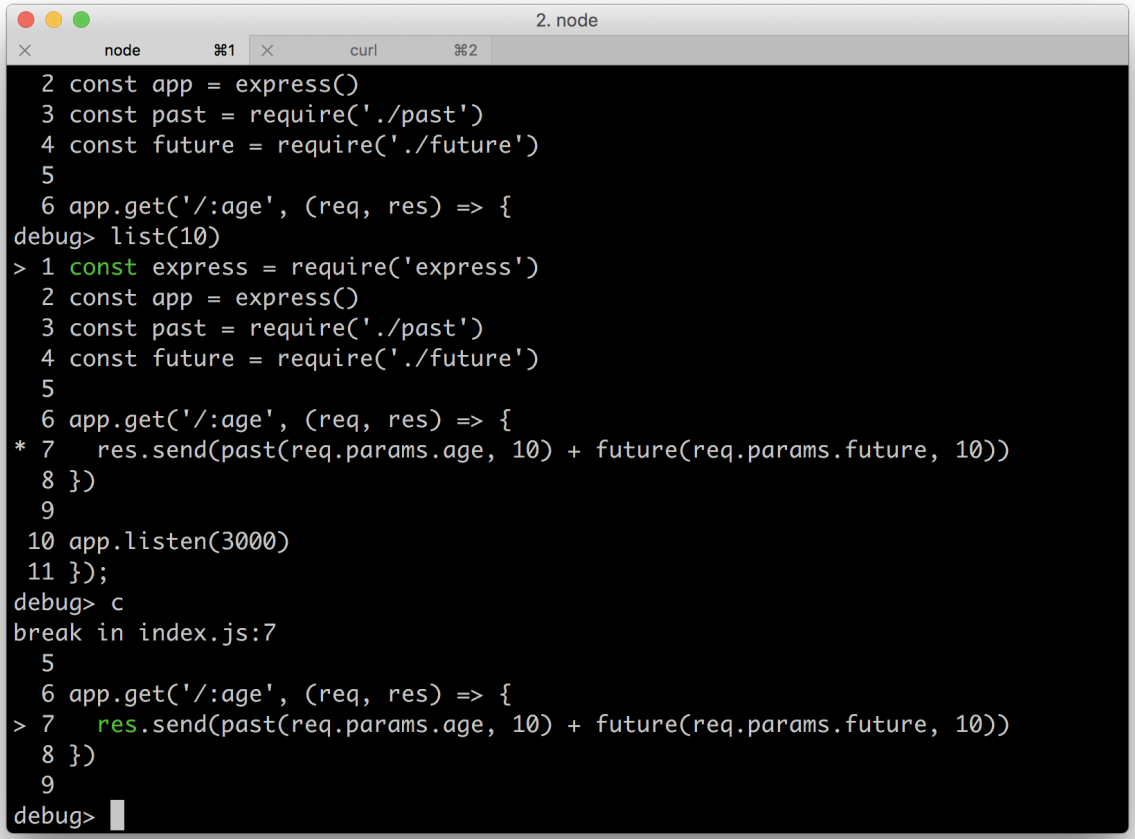
We use the `c` command to tell the process to continue, like so:

```
debug> c
```

Now let's make a request to our server, we could use a browser to do this, or if we have `curl` on our system, in another terminal we could run the following:

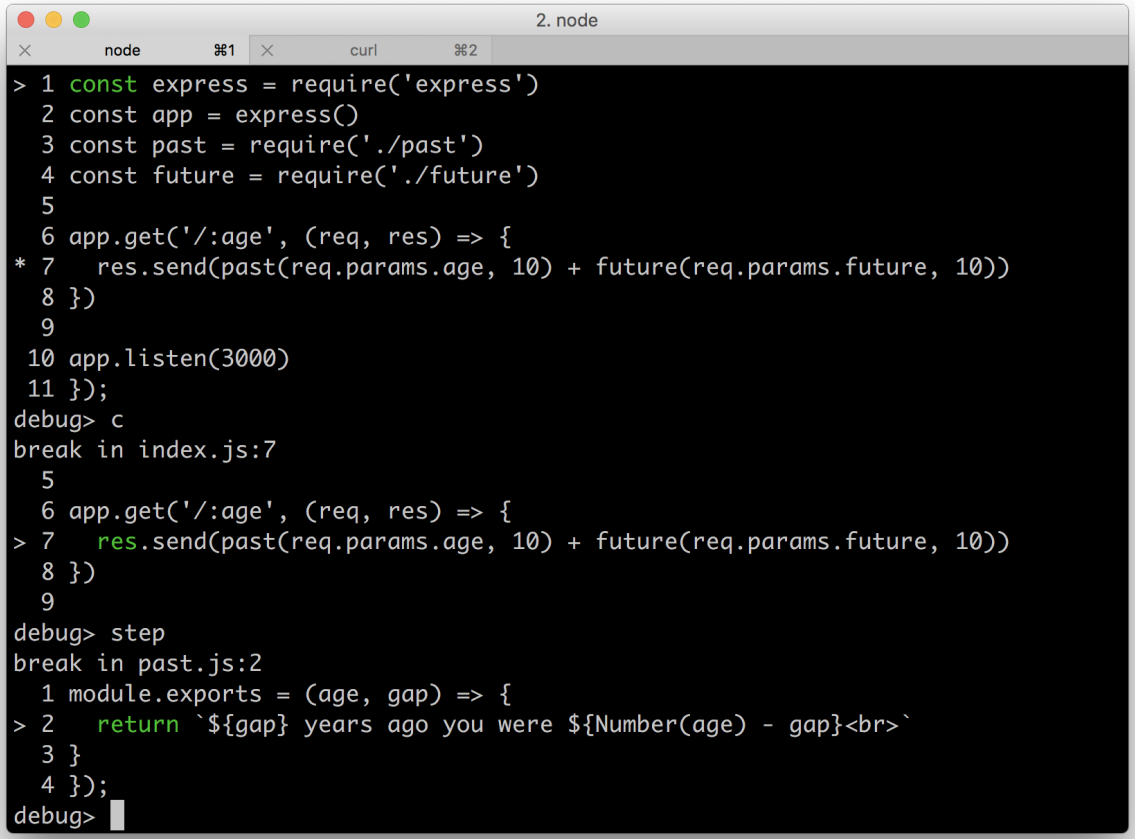
```
$ curl http://localhost:3000/31
```

This will cause the process to hit our breakpoint and the debugger console should print out "break in index.js:7" along with the line our code is currently paused on, with 2 lines of context before and after. We can see a right caret (`>`) indicating the current line.



Now let's step in to the first function, to step in we use the `step` command:

```
debug> step
```

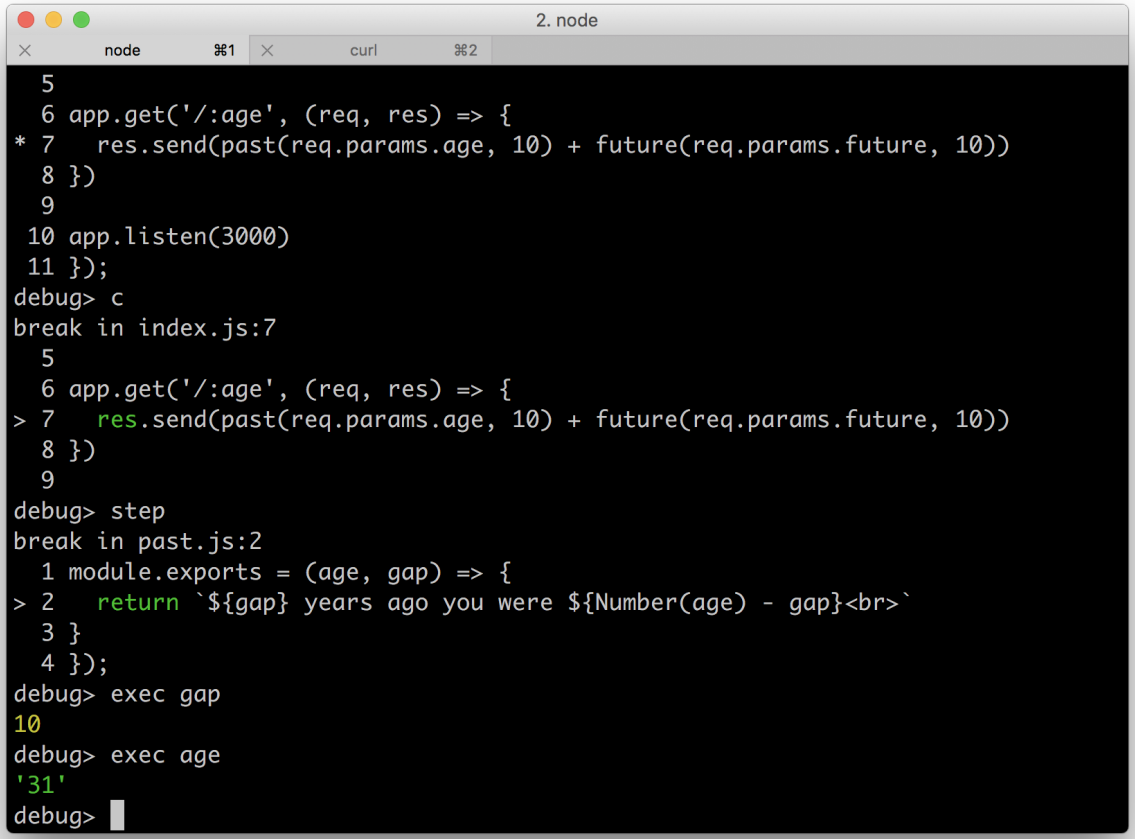


This enters our `past.js` file, with the current break on line 2.

We can print out references in the current debug scope using the `exec` command, let's print out the values of the `gap` and `age` arguments:

```
debug> exec gap
```

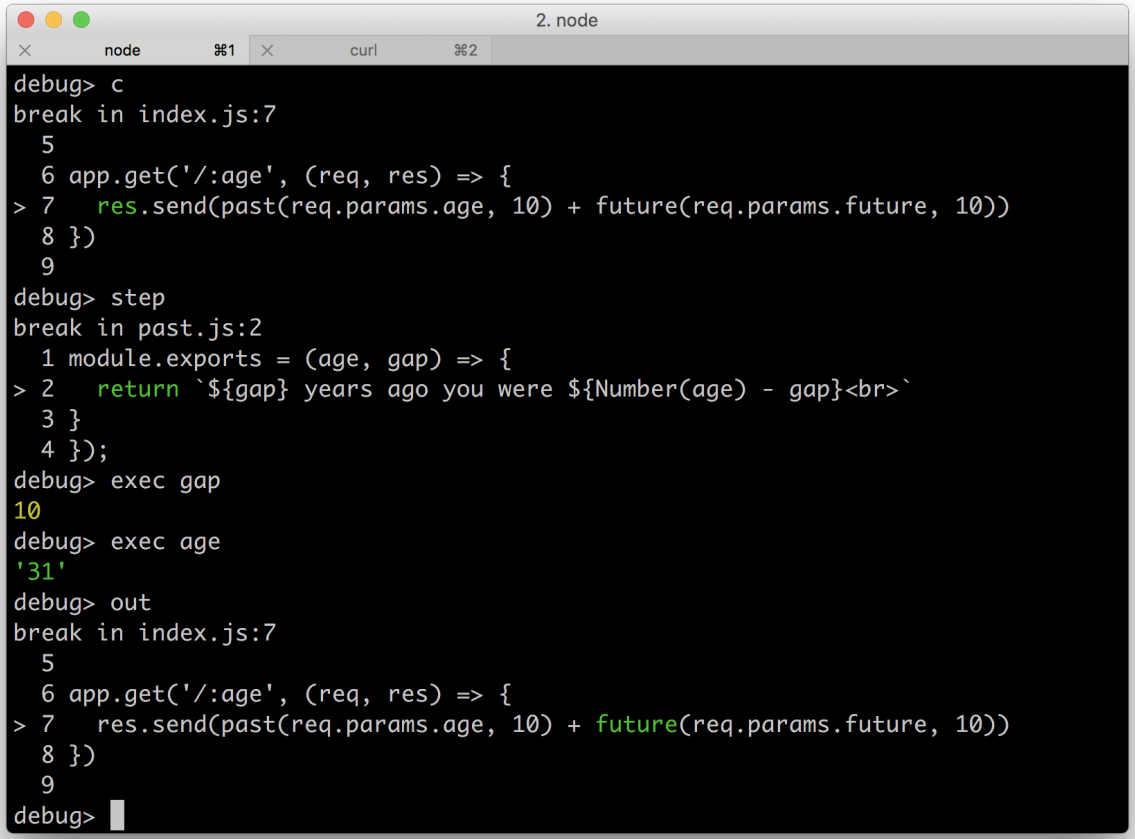
```
debug> exec age
```



Everything seems to be in order here.

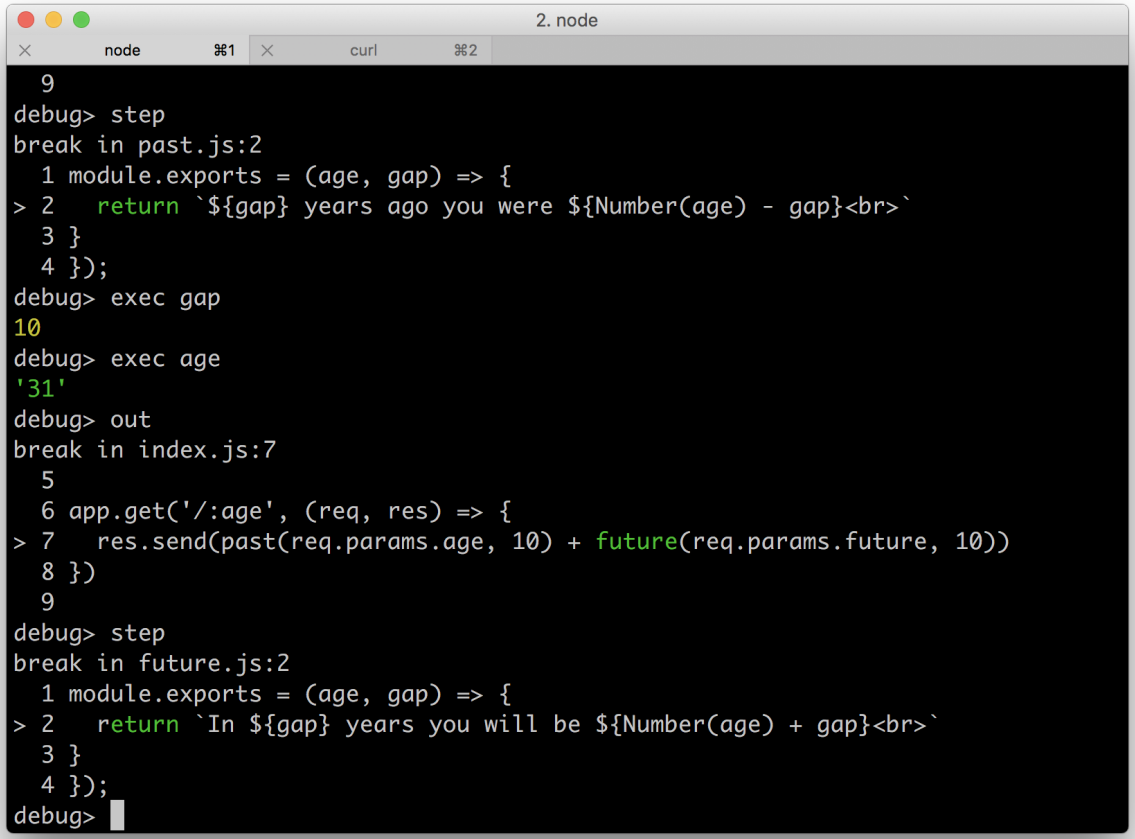
Now let's step back out of the `past` function, we use the `out` command to do this, like so:

```
debug> out
```



We should now see that the `future` function is a different color, indicating that this is the next function to be called. Let's step into the `future` function.

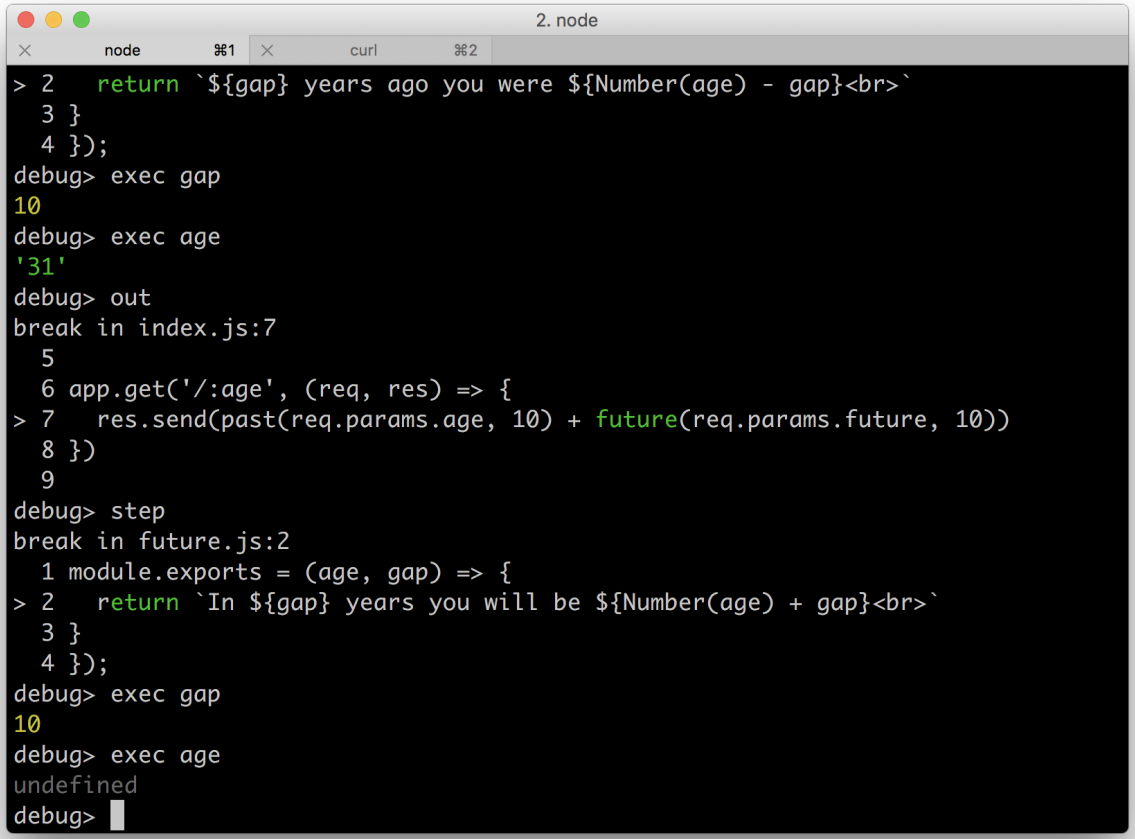
```
debug> step
```



Now we're in out `future.js` file, again we can print out the `gap` and `age` arguments using `exec`:

```
debug> exec gap
```

```
debug> exec age
```



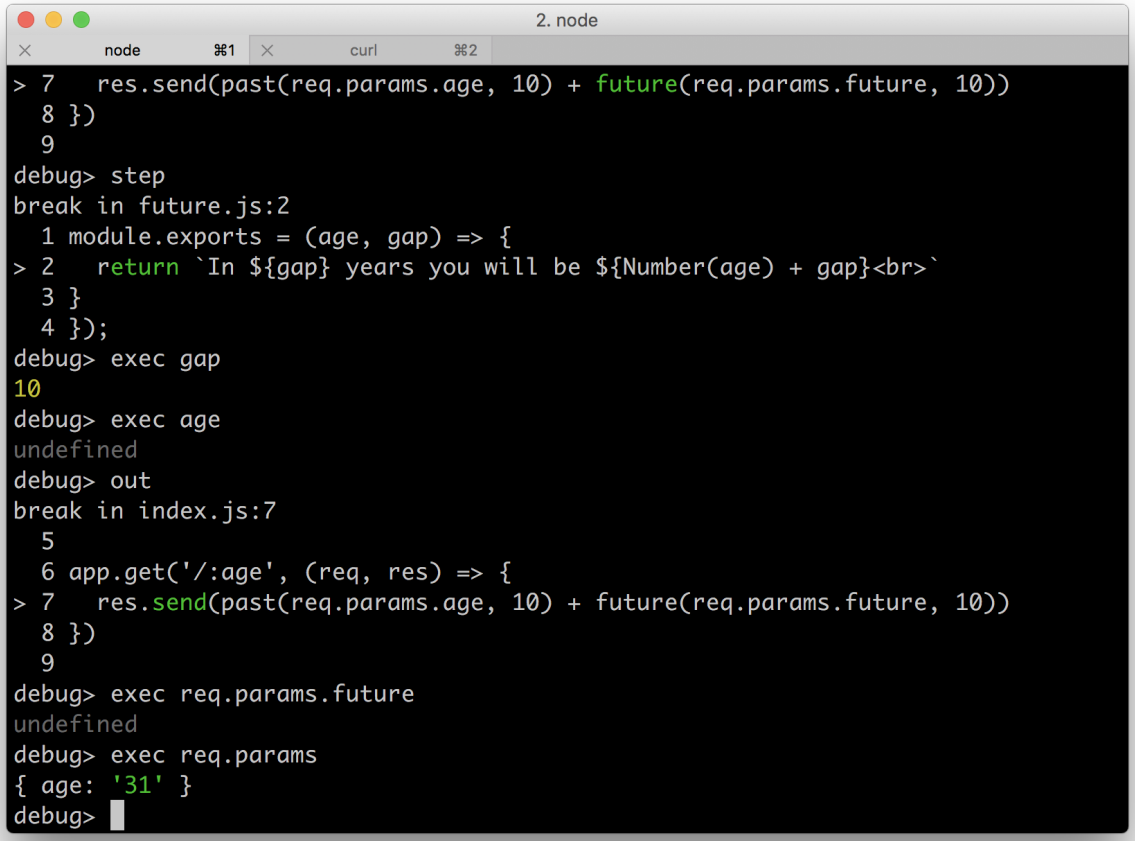
Aha, we can see that `age` is `undefined`, let's step back up into the router function using the `out` command:

```
debug> out
```

Let's inspect `req.params.future` and `req.params`:

```
debug> req.params.future
```

```
debug> req.params
```



It's now (again) obvious where the mistake lies, there is no `req.params.future`, that input should be `req.params.age`.

See also

- *Creating an Express Web App* in **Chapter 7 Working With Web Frameworks**
- *Writing Module Code* in **Chapter 2 Writing Modules**
- *Profiling Memory* in **Chapter 9 Optimizing Performance**
- *CPU Profiling with Chrome Devtools* in the *There's More* section of *Finding Bottlenecks with Flamegraphs* in **Chapter 9 Optimizing Performance**

Enhancing Stack Trace output

When a Node process experiences an error, the function where the error occurred, and the function that called that function (and so on) is written to STDERR as the final output of the application.

This is called a stack trace. By default Node's JavaScript engine (v8) retains a total of ten frames (references to functions in a stack).

However, in many cases we need far more than ten frames to understand the context from a stack for trace when performing root-cause analysis on a faulty process. On the other hand, the larger the stack trace, the more memory and CPU process has to use to keep track of the stack.

In this recipe we're going to increase the size of the stack trace, but only in a development environment.

Getting Ready

Let's prepare for the recipe by making a small application, that causes an error creating a long stack trace.

We'll create a folder called app, initialize it as a package, install express and create three files, `index.js`, `routes.js` and `content.js`:

```
$ mkdir app
$ cd app
$ npm init -y
$ npm install express
$ touch index.js routes.js content.js
```

Our `index.js` file should look like this:

```
const express = require('express')
const routes = require('./routes')
const app = express()

app.use(routes)

app.listen(3000)
```

The `routes.js` file like the following:

```
const content = require('./content')
const {Router} = require('express')
const router = new Router()

router.get('/', (req, res) => {
  res.send(content())
})

module.exports = router
```

And the `content.js` file like so:

```
function content (opts, c = 20) {
  return --c ? content(opts, c) : opts.ohoh
}

module.exports = content
```

How to do it

Let's begin by starting our server:

```
$ node index.js
```

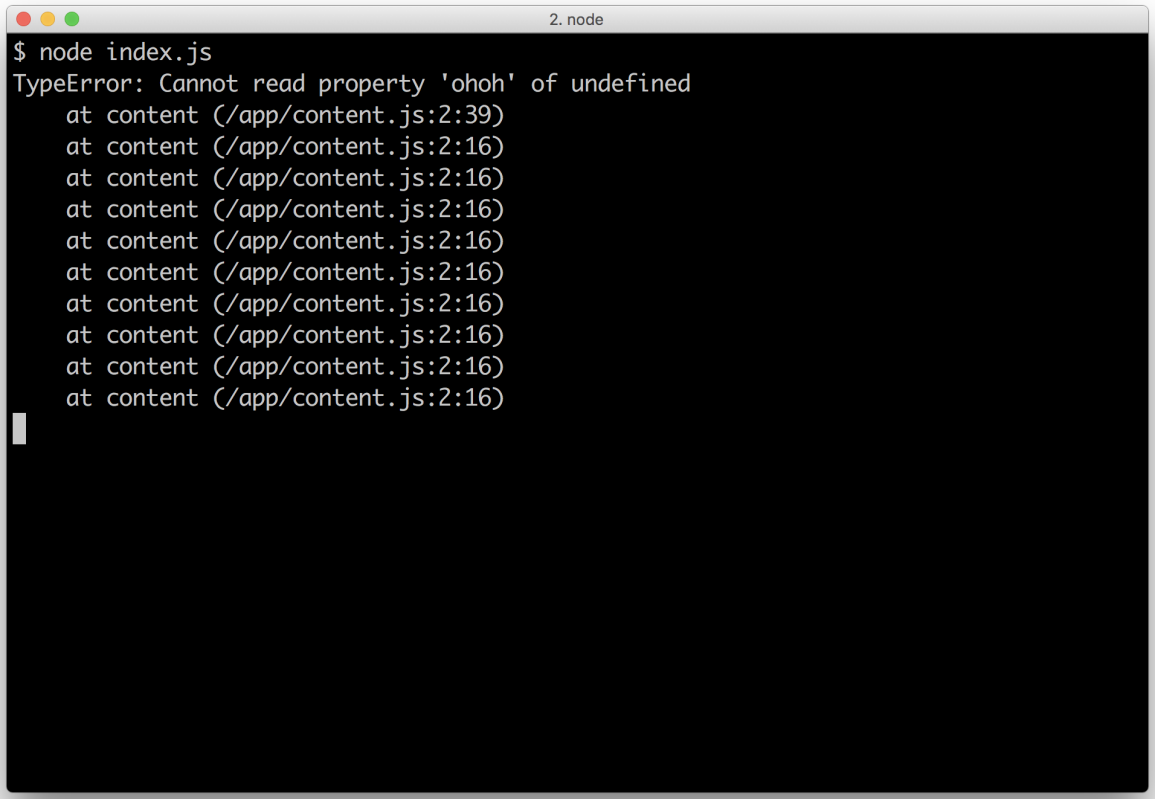
All good so far, ok let's send a request to the server, we can navigate a browser to `http://localhost:8080` or we can use `curl` (if installed) like so:

```
$ curl http://localhost:3000/
```

That should spit out some error HTML output, containing a stack trace.

Even though an error has been thrown, the process hasn't crashed because `express` catches errors in routes to keep the server alive.

The terminal window that's running our server will also have a stack trace.



We can see (in this case) that the `content` function is being calling itself recursively (but not too many times otherwise there would be a Maximum Call Stack size exceed error).

The content function looks like this:

```
function content (opts, c = 20) {
  return --c ? content(opts, c) : opts.ohoh
}
```

The error message is "Cannot read property 'ohoh' of undefined".

It should be fairly clear, that for whatever reason the `opts` argument is being input as `undefined` by a function calling the `content` function.

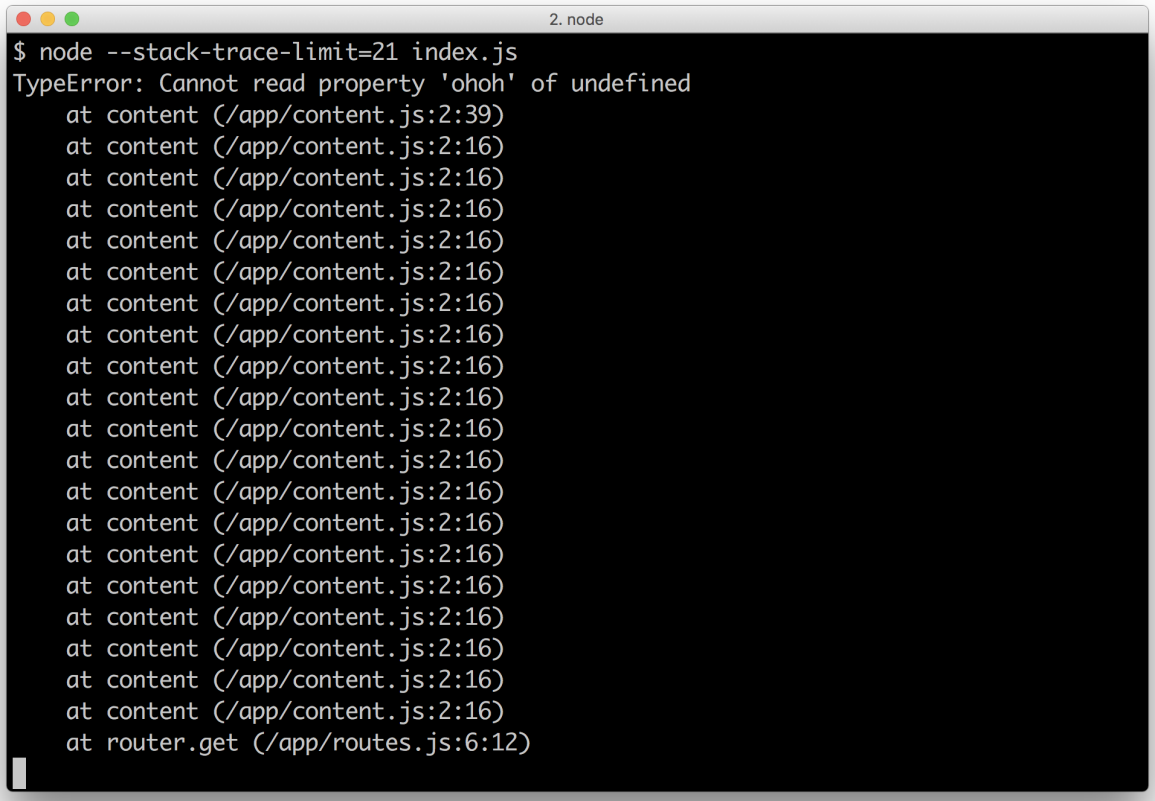
But, because our stack is limited at ten frames, we can't see what originally called the first iteration of the `content` function.

One way to address this is to use the `--stack-trace-limit` flag.

We can see that `c` defaults to `20`, so if we set the limit to 21, maybe we'll see what originally called the `c` function:

```
$ node --stack-trace-limit=21 index.js
```

This should result in something like the figure below:



Now we can see that the original call is made from `router.get` in the `routes.js` file, line 6, column 12.

Line 6 is:

```
  res.send(content())
```

Ah it looks like we're calling `content` without any inputs, of course that means the arguments default to `undefined`.

How it works

The `--stack-trace-limit` flag instructs the V8 JavaScript engine to retain more stacks on each tick of (each time round) the event loop.

When an error occurs, a stack trace is generated that traces back through the antecedent function calls as far as the defined limit allows.

There's more

Can we set the stack limit in process? What if we want a different stack trace limit in production versus development environments? We can track and trace asynchronous function calls? Is it possible to have nicer looking stack traces? We'll answer all these questions, right now.

Infinite Stack Trace Limit in Development

A lot of the time, in development we want as much context as we can get, but we don't want to have to type out a long flag every time we run a process.

But in production, we want to save precious resources.

Let's copy the `app` folder to `infinite-stack-in-dev-app`

```
$ cp -fr app infinite-stack-in-dev-app
```

Now at very the top of `index.js` we simply write:

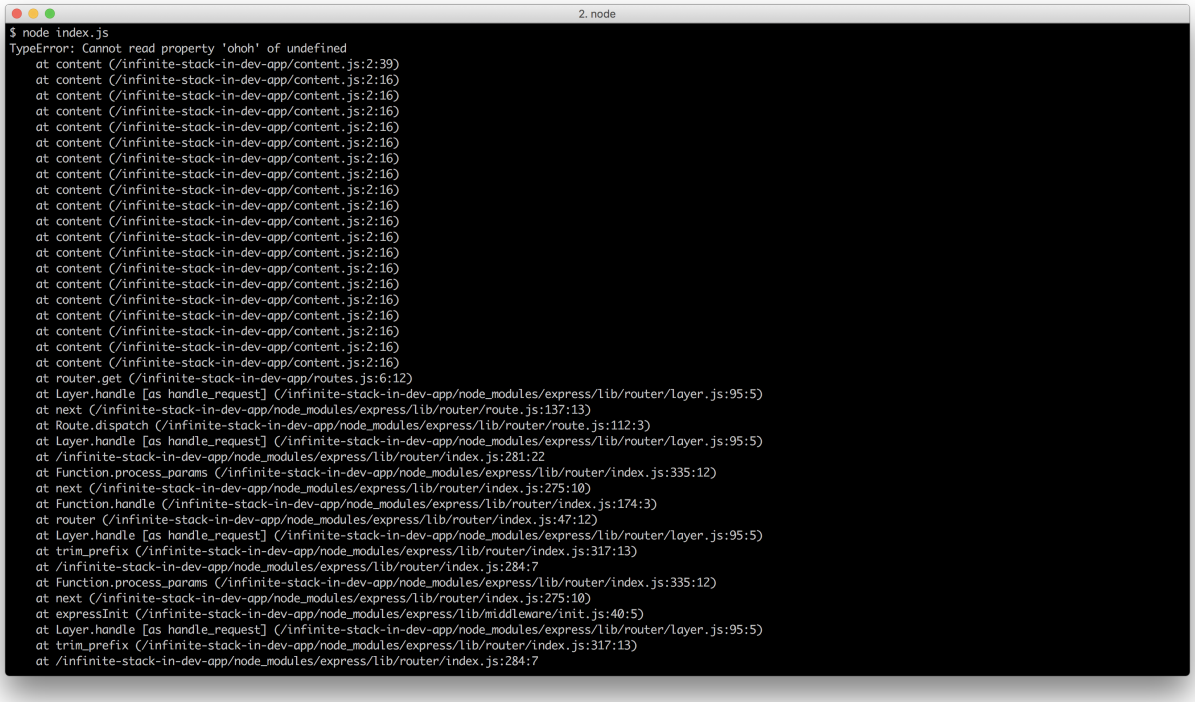
```
if (process.env.NODE_ENV !== 'production') {
  Error.stackTraceLimit = Infinity
}
```

Now if we run our server:

```
$ node index.js
```

Then make a request with `curl` (or, optionally, some other method like a browser):

```
$ curl http://localhost:3000/
```



Our stack trace will be limitless.

Stack Trace Layout

The default stack trace could definitely stand to be more human friendly.

Enter `cute-stack`, a tool for creating prettified stack traces.

Let's copy our `app` folder to `pretty-stack-app`, and install `cute-stack`:

```
$ cp -fr app pretty-stack-app
$ cd app
$ npm install --save cute-stack
```

Now let's place the following at the very top of the `index.js` file:

```
require('cute-stack')()
```

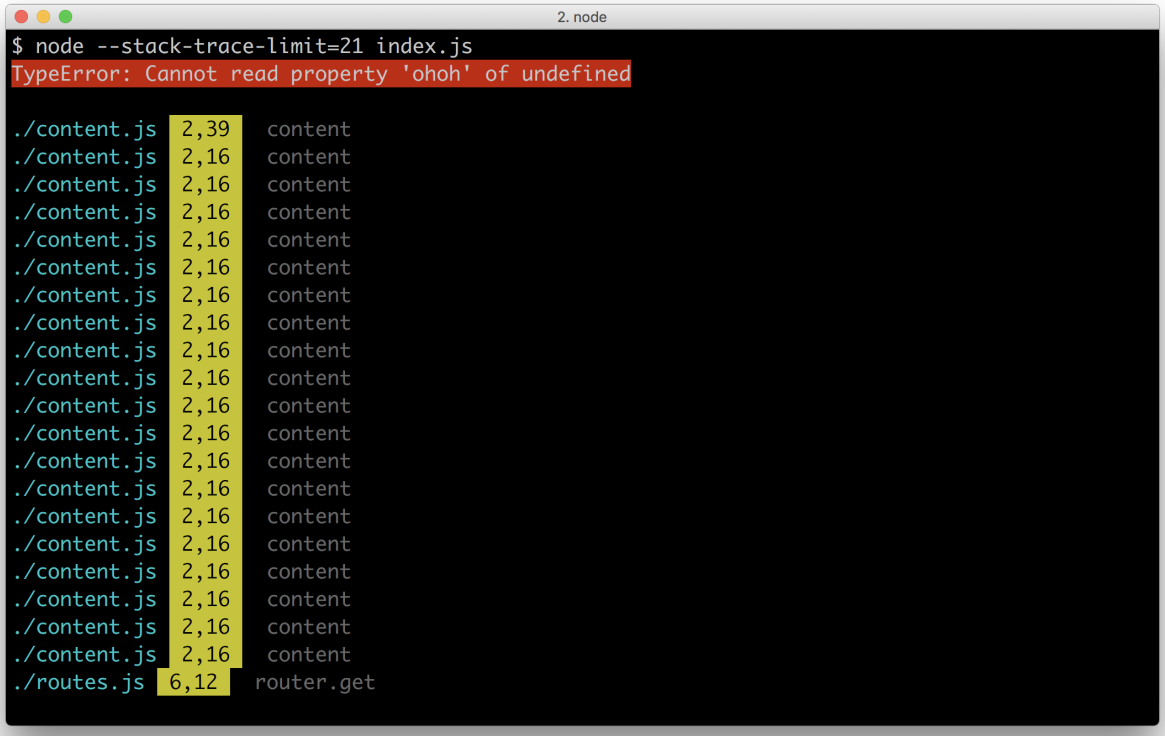
Now let's run our process, with a larger stack trace limit (as in the main recipe),

```
$ node --stack-trace-limit=21 index.js
```

Make a request, either with a browser, or if installed, `curl`:

```
$ curl http://localhost:3000/
```

As a result we should see a beautified stack trace, similar to the following figure:



> **Alternative Layouts** 
>
> `cute-stack` has additional layouts, such as table, tree, and json as well as plugin system for creating your own layouts see the `cute-stack` readme for more.

The `cute-stack` tool takes advantage of a proprietary V8 API, `Error.prepareStackTrace` which can be assigned a function, that receives `error` and `stack` inputs. This function can then process the `stack` and return a string which becomes the stack trace output.

> **Error.prepareStackTrace** 
>
> See https://github.com/v8/v8/wiki/Stack-Trace-API for more on `Error.prepareStackTrace`

Asynchronous Stack Traces

The asynchronous nature of JavaScript effects the way a stack trace works. In

JavaScript, each "tick" (each time the JavaScript event-loop iterates) has a new stack.

Let's copy our `app` folder to `async-stack-app`:

```
$ cp -fr app async-stack-app
```

Now let's alter `content.js` to like so:

```
function content (opts, c = 20) {
  function produce (cb) {
    if (--c) setTimeout(produce, 10, cb)
    cb(null, opts.ohoh)
  }
  return produce
}

module.exports = content
```

Then let's alter `routes.js` in the following way:

```
const content = require('./content')
const {Router} = require('express')
const router = new Router()

router.get('/', (req, res) => {
  content()((err, html) => {
    if (err) {
      res.send(500)
      return
    }
    res.send(html)
  })
})

module.exports = router
```

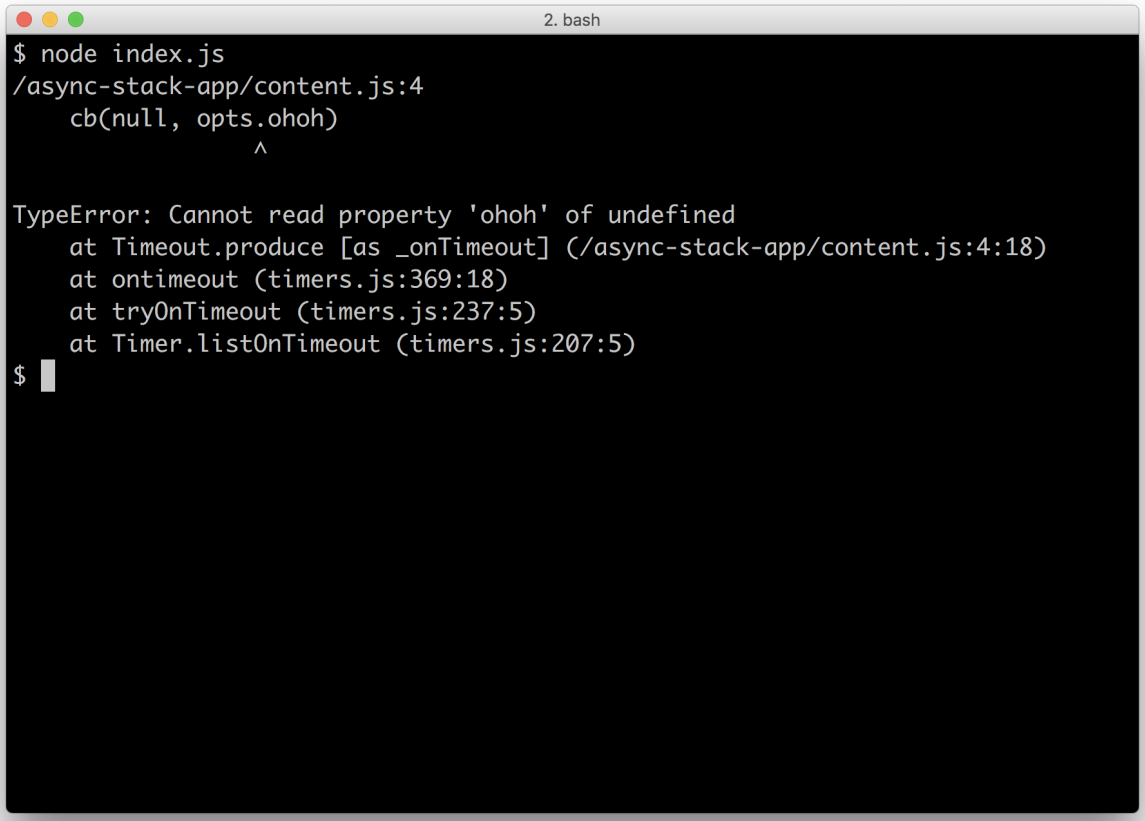
Now if we start our server

```
$ node index.js
```

And make a request :

```
$ curl http://localhost:3000/
```

We'll see only a small stack trace, descending from timeout specific internal code, as in the following figure:



We can obtain asynchronous stack traces with the `longjohn` module, let's install is as a development dependency:

```
$ npm install --save-dev longjohn
```

Now we can add the following the very top of the `index.js` file:

```
if (process.env.NODE_ENV !== 'production') {
  require('longjohn')
}
```

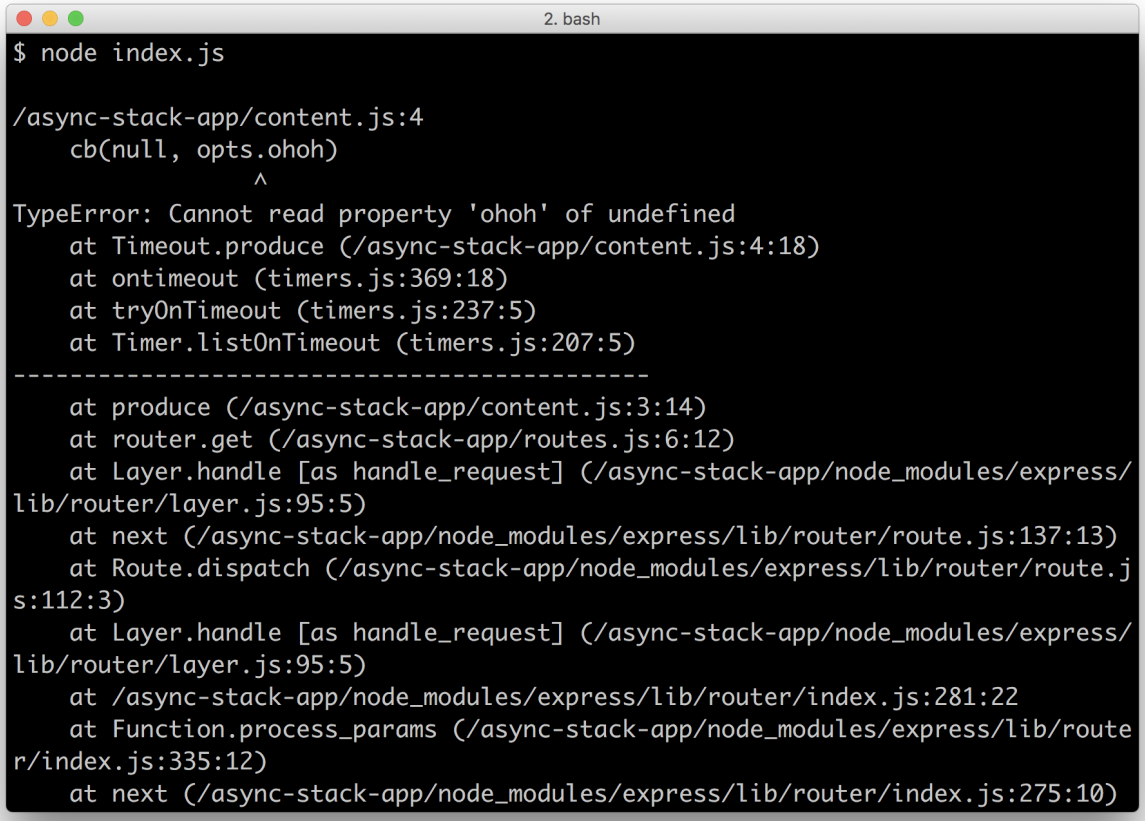
Let's run our server again:

```
$ node index.js
```

And make a request:

```
$ curl http://localhost:3000/
```

Now we should see the original stack, followed by a line of dashes, followed by the previous stack, which furnishes with additional stack context (like `produce` and `router.get` function.



See also

- *Creating an Express Web App* in **Chapter 7 Working With Web Frameworks**
- *Interfacing with standard I/O* in **Chapter 3 Coordinating I/O**

Enabling Debug Logs

More than 13450 modules directly depend on the third party `debug` module (at time of writing). Many other modules indirectly use the `debug` module by the use of those 13450. Some highly notable libraries, like Express, Koa and Socket.io also use the `debug` module.

In many code bases there's a wealth of often untapped tracing and debugging logs that we can use to infer and understand how our application is behaving.

In this recipe we'll discover how to enable and effectively analyse these log messages

Getting Ready

Let's create a small Express app which we'll be debugging.

On the command line we execute the following commands:

```
$ mkdir app
$ cd app
$ npm init -y
$ npm install --save express
$ touch index.js
```

Our `index.js` file should contain the following:

```
const express = require('express')
const app = express()
const stylus = require('stylus')

app.get('/some.css', (req, res) => {
  const css = stylus(`
    body
      color:black
  `).render()
  res.send(css)
})

app.listen(3000)
```

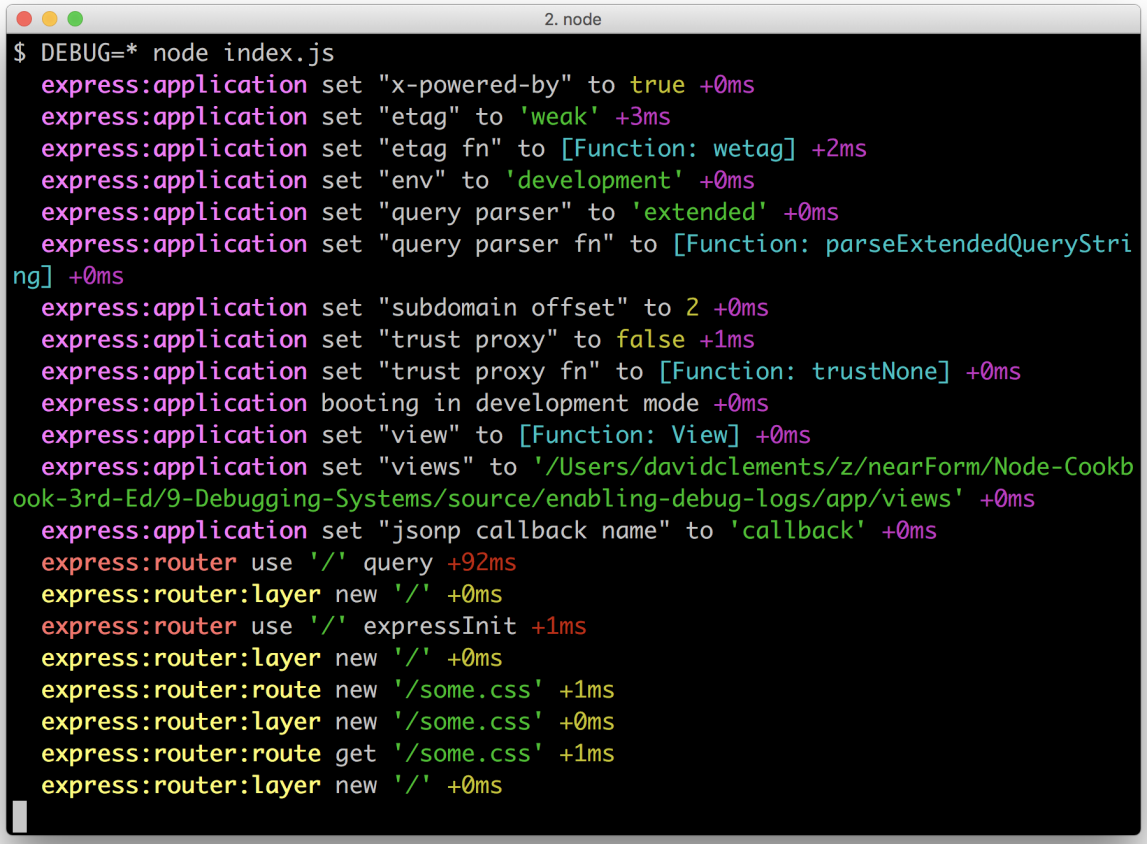
> ### Web Frameworks 
>
> We're only using Express here as an example, to learn more about Express and other Frameworks see **Chapter 7 Working With Web Frameworks**

How to do it

Let's turn on all debug logging:

```
DEBUG=* node index.js
```

As soon as we start the server, we see some debug output that should be something like the following image.



The first message is

```
  express:application set "x-powered-by" to true +0ms
```

Let's make a mental note to add `app.disable('x-powered-by')` since it's much better for security to not publicly announce the software a server is using.

> ### Security 
>
> For more on Security and server hardening see **Chapter 8 Dealing with Security**

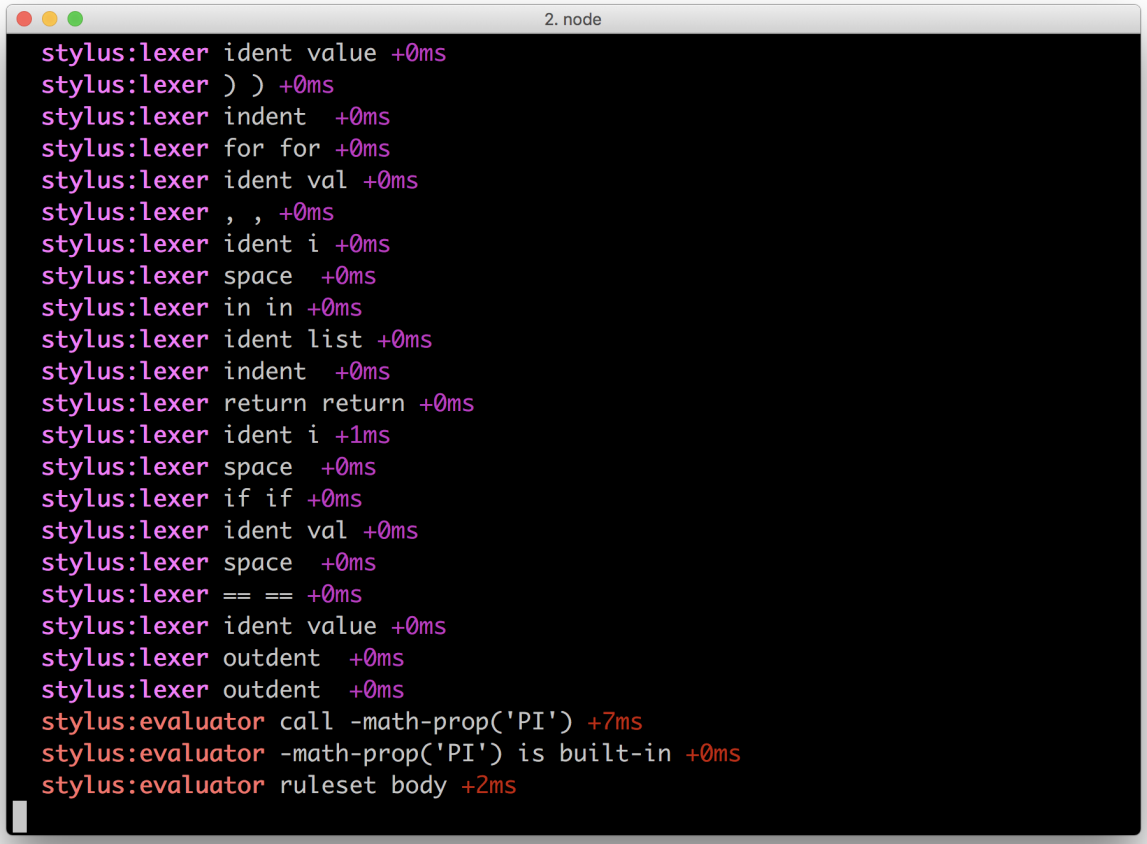
This debug log line has helped us to understand how our chosen framework actually behaves, and allows us to mitigate any undesired behavior in an informed manner.

Now let's make a request to the server, if we have `curl` installed we can do:

```
$ curl http://localhost:3000/some.css
```

(Or otherwise we can simply use a browser to access the same route).

This results in more debug output, mostly a very large amount of `stylus` debug logs.

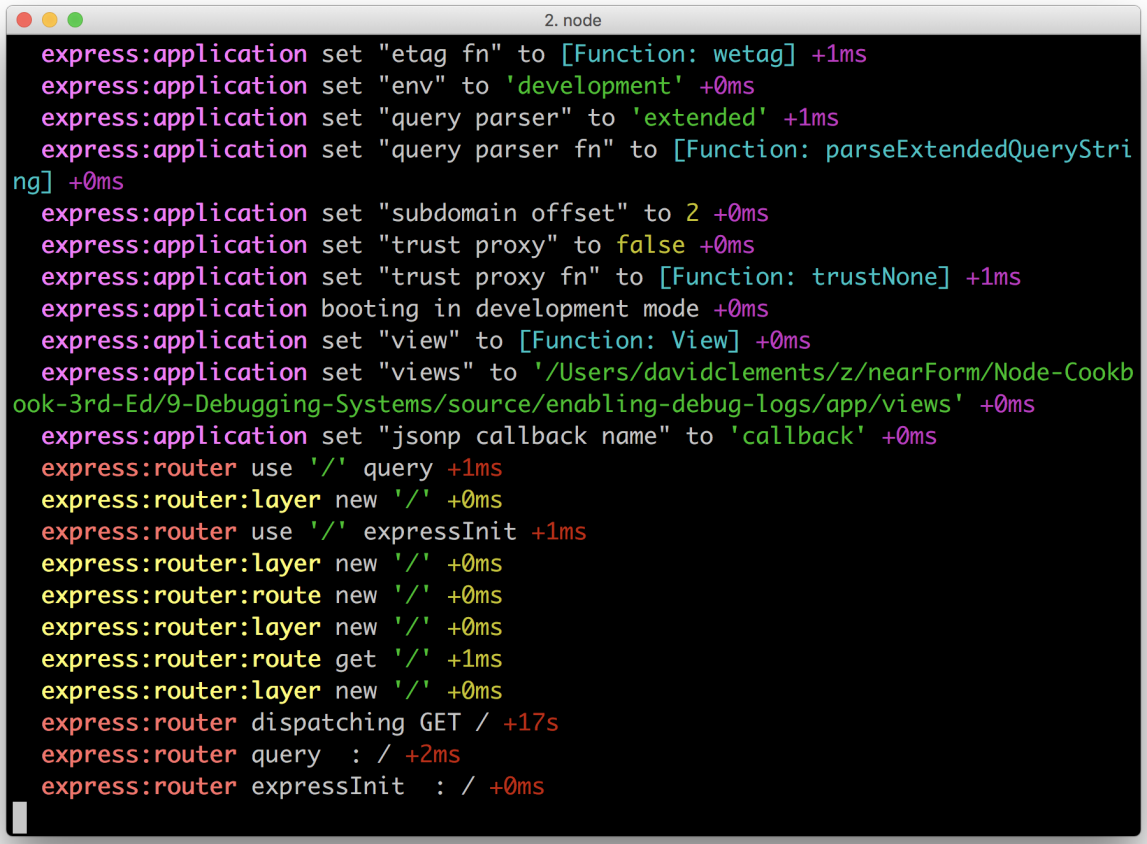


While it's interesting to see the Stylus parser at work, it's a little overwhelming, so let's try just looking at `express` logs:

```
$ DEBUG=express:* node index.js
```

And we'll make a request again (we can use `curl` or a browser as appropriate):

```
$ curl http://localhost:3000/some.css
```



This time our log filtering enabled us to easily see the debug messages for an incoming request.

How it works

In our recipe, we initially set `DEBUG` to `*`, which means enable all logs. Then we wanted to zoom in explicitly on express related log messages. So we set `DEBUG` to `express:*`, which means enable all logs that begin with the characters `express:`. By convention, modules and frameworks delimit sub-namespaces with the `:` colon.

At an internal level, the `debug` module reads from the `process.env.DEBUG`, splits the string by whitespace or commas, and then converts each item into a regular expression.

When a module uses the `debug` module, if will require `debug` and call it with a namespace representing that module to create a logging function that it then uses to output messages when debug logs are enabled for that module.

Using the `debug` module 

> For more on using `debug` module in our own code see **Instrumenting code with `debug`** in the *There's More* section

Each time a module registers itself with the `debug` module the list of regular expressions (as generated from the `DEBUG` environment variable) are tested against the namespace provided by the registering module.

If there's no match the resulting logger function is a no-op (that is, an empty function). So the cost of the debug logs in production is minimal.

If there is a match, the returned logging function will accept input, decorate it with ANSI codes (for terminal coloring), and create a time stamp on each call to the logger.

There's more

Let's find out how to use `debug` in our own code, and some best practices around enabling debug logs in production scenarios.

Instrumenting code with `debug`

We can use the `debug` module in our own code, to create logs that relate to the context of our application or module.

Let's copy our `app` folder from the main recipe, and call it `instrumented-app`, and install the `debug` module:

```
$ cp -fr app instrumented-app
$ cd instrumented-app
$ npm install --save debug
```

Next, we'll make `index.js` look like so:

```
const express = require('express')
const app = express()
const stylus = require('stylus')
const debug = require('debug')('my-app')

app.get('/some.css', (req, res) => {
  debug('css requested')
  const css = stylus(`
    body
      color:black
```

```
  `).render()
  res.send(css)
})

app.listen(3000)
```

We've required `debug`, created a logging function (called `debug`) with the namespace `my-app` and then used it in our route handler.

Now let's start our app, and just turn on logs for the `my-app` namespace:

```
$ DEBUG=my-app node index.js
```

Now let's make a request to http://localhost:3000/some.css, either in browser, or with `curl` we could do:

```
$ curl http://localhost:3000/some.css
```

This should create the following log message:

```
  my-app css requested +0ms
```

Using Debug in production

The default `debug` logs are not suited to production logging. The logging output is human readable rather than machine readable output, it uses colors which are enabled with terminal ANSI codes (which will essentially pollute the output when saved to file or database).

In production, if we wanted to turn on debug logs we can produce more standard logging output with the following

```
$ DEBUG_COLORS=no DEBUG=* node index.js
```

JSON Logging with `pino-debug`

The `pino-debug` module passes `debug` messages through `pino` so that log output is in newline delimited JSON (a great compromise between machine and human readability and common log format).

> ### About `pino` 
>
> `pino` is a high performance logger, that's up to 8-9 times faster than other popular loggers (see the benchmarks for more information.)

Due to the performant techniques used by `pino` using `pino-debug` leads to a performance increase in log writing (and therefore leaves more room for other activities in process, like serving requests) even though there's more output per log message!

Let's copy our `app` folder to `logging-app`, and install `pino-debug`:

```
$ cp -fr app logging-app
$ npm install --save pino-debug
```

We'll add two npm scripts, one for development and one for production, let's edit `package.json` like so:

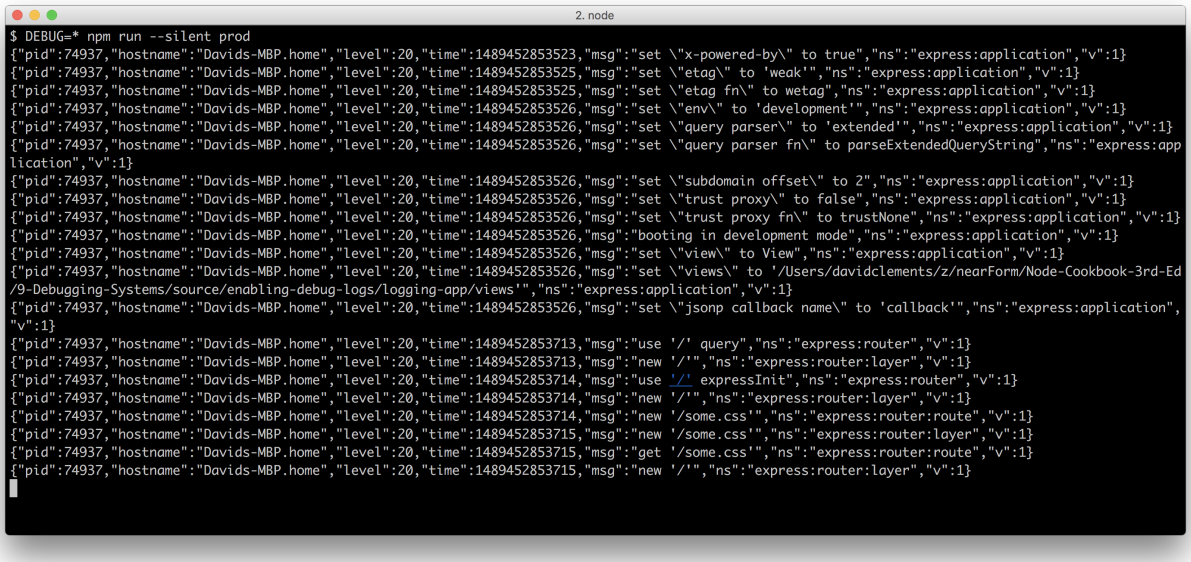
```
{
  "name": "app",
  "version": "1.0.0",
  "description": "",
  "main": "index.js",
  "scripts": {
    "test": "echo \"Error: no test specified\" && exit 1",
    "dev": "node index.js",
    "prod": "node -r pino-debug index.js"
  },
  "keywords": [],
  "author": "",
  "license": "ISC",
  "dependencies": {
    "express": "^4.15.0",
    "pino-debug": "^1.0.3",
    "stylus": "^0.54.5"
  }
}
```

Now if we run the following:

```
$ DEBUG=* npm run --silent prod
```

We'll should see the express logs in JSON form, where the `msg` field contains the

log contents and the `ns` field contains the relevant debug message. Additionally `pino` adds a few other useful fields, like `time`, `pid`, `hostname`, `level` (the log level, defaults to 20 which is debug level) and `v` (this log format version).



Debug Namespace to Log Level Mapping 

See the `pino-debug` readme for mapping namespaces to custom log levels.

See also

- *Creating an Express Web App* in **Chapter 7 Working With Web Frameworks**
- *Interfacing with standard I/O* in **Chapter 3 Coordinating I/O**
- *Adding Logging* in **Chapter 7 Working With Web Frameworks**

Enabling Core Debug Logs

It can be highly useful to understand what's going on in Node's core, there's a very easy way to get this information.

In this recipe we're going to use a special environment variable to enable various debugging flags that cause Node Core debug logging mechanisms to print to STDOUT.

Getting Ready

We're going to debug a small web server, so let's create that real quick.

On the command line we execute the following commands:

```
$ mkdir app
$ cd app
$ npm init -y
$ npm install --save express
$ touch index.js
```

Our `index.js` file should contain the following:

```
const express = require('express')
const app = express()

app.get('/', (req, res) => res.send('hey'))

setTimeout(function myTimeout() {
   console.log('I waited for you.')
}, 100)

app.listen(3000)
```

> ### Web Frameworks 
>
> We're only using express here as an example, to learn more about Express and other Frameworks see **Chapter 7 Working With Web Frameworks**

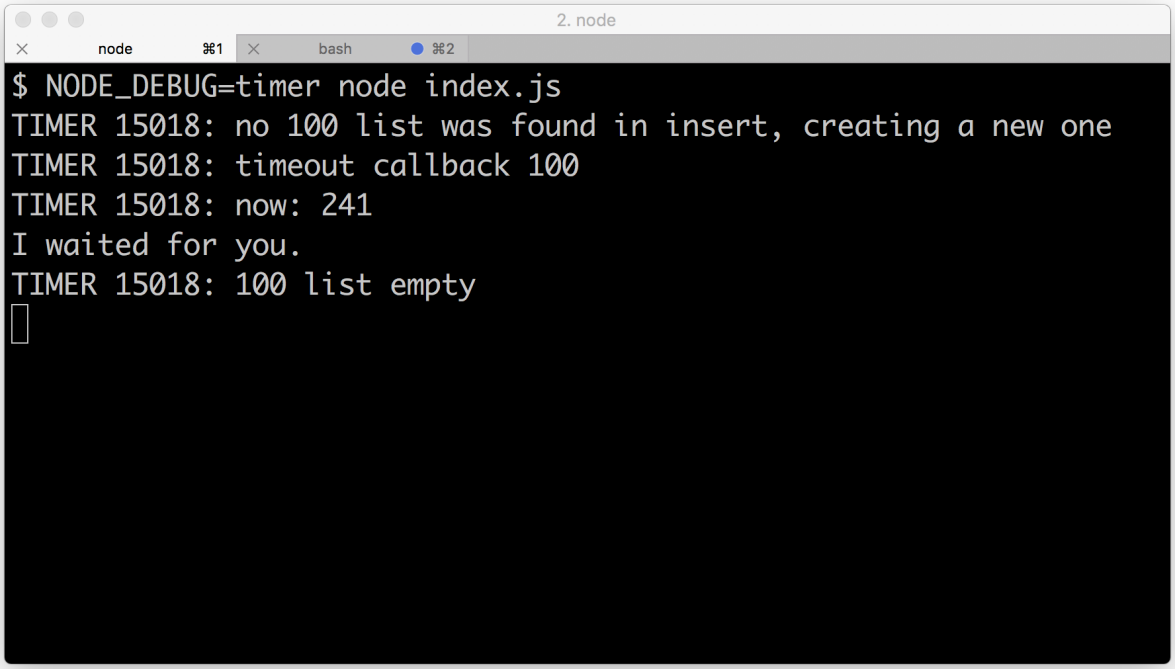
How to do it

We simply have to set the `NODE_DEBUG` environment variable to one or more of the supported flags.

Let's start with the `timer` flag by running our app like so:

```
$ NODE_DEBUG=timer node index.js
```

This should show something like the following figure:



Core timer debug output

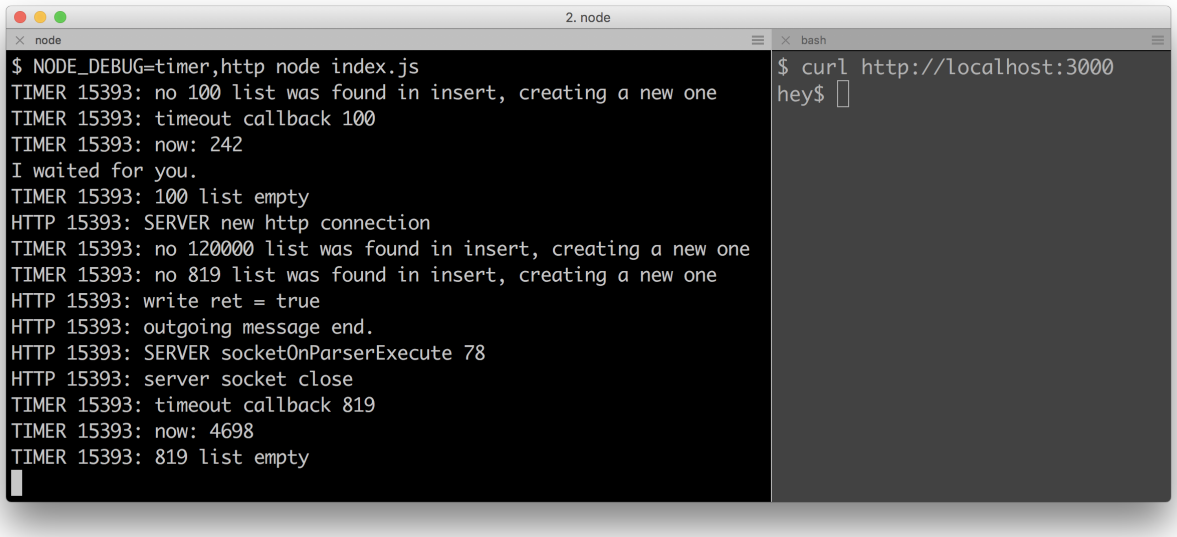
Let's try running the process again with both `timer` and `http` flags enabled:

```
$ NODE_DEBUG=timer,http node index.js
```

Now we need to trigger some HTTP operations to get any meaningful output, so let's send a request to the HTTP server using `curl` (our an alternative favoured method, such as navigating to `http://localhost:3000` in the browser).

```
$ curl http://localhost:3000
```

This should give output similar to the following image:



Core timer and http debug output

How it works

The `NODE_DEBUG` environment variable can be set to any combination of the following flags:

- `http`
- `net`
- `tls`
- `stream`
- `module`
- `timer`
- `cluster`
- `child_process`
- `fs`

The `fs` debug flag

> The quality of output varies for each flag. At time of writing, the `fs` flag in particular doesn't actually supply any debug log output, but when enabled will cause a useful stack trace to be added to any unhandled error events for asynchronous I/O calls. See https://github.com/nodejs/node/blob/cccc6d8545c0ebd83f934b9734f5605aaeb000f2/lib/fs.js#L76-L94 for context.

In our recipe we were able to enable core timer and HTTP debug logs, by setting the `NODE_DEBUG` environment variable to `timers` in the first instance and then `timers,http` in the second.

We use a comma to delimit the debug flags, however the delimiter can be any character.

Each line of output consists of the namespace, the process ID (PID), and the log message.

When we set `NODE_DEBUG` to `timer`, the first log message indicates that it's creating a list for `100`. Our code passes `100` as the second argument passed to `setTimeout`, internally the first argument (the timeout callback) is added to a queue of callbacks that should run after `100` millisecond. Next we see a message "timeout callback 100" which means every 100ms timeout callback will now be called. The following message (the "now" message) \ indicates the current "time" as the internal `timers` module sees it, this is milliseconds since the `timers` module was initialized. The "now" message can be useful to see the time drift between timeouts and intervals, because a timeout of 10ms will rarely (if ever) be exactly 10 ms. More like 14ms, because of 4ms of execution time for other code in a given tick (time around the event loop). While 4ms drift is acceptable, a 20ms drift would indicate potential performance problems - a simple `NODE_DEBUG=timer` prefix could be used for a quick check. The final debug message shows that the `100` list is now empty, meaning all callback functions set for that particular interval have now been called.

Most of the HTTP output is self explanatory, we can see when a new connection has been made to the server, when a message has ended and when a socket has closed. The remaining two cryptic messages are `write ret = true` and `SERVER socketOnParserExecute 78`. The `write ret = true` relates to when the server attempted to write to a socket, if the value was false it would mean the socket had closed and the (again internally) the server would begin to handle that scenario. As for the `socketOnParserExecute` message, this has to do with Nodes internal HTTP parser (written in C), the number (78) is the string length of the headers sent from the client to the server.

Combining multiple flags can be useful, we set `NODE_DEBUG` to `timer,http` we were able to how the `http` module interacts with the internal `timer` module. We can see after a the "SERVER new http connection" message, that two timers are set (based on the timeout lists being created), one for 120000 milliseconds (two minutes, the default socket timeout) and one (in the example case) for 819 milliseconds.

This second interval (819) is to do with an internal caching mechanism for the HTTP `Date` header. Since the smallest unit in the `Date` header is seconds, a timeout is

set for the amount of milliseconds left before the next second and the `Date` header is provided the same string for the remainder of that second.

> ### Core Mechanics 
>
> For a deeper understanding of our discussion here, see the There's More section where we use debugging tools to step through code in Node core to show how to fully pick apart the log messages in this recipe.

There's more

Let's look at the way Node Core triggers the debug log messages, and see if we can use this knowledge to gain greater understanding of Node's internal workings.

Creating our own NODE_DEBUG flags

Core modules tend to use the `util` modules `debuglog` method to generate a logging function that defaults to a no-op (an empty function) but writes log messages to STDOUT when the relevant flag appears in the `NODE_DEBUG` environment variable.

We can use `util.debuglog` to create our own core like log messages.

Let's take our `app` folder we created in the main recipe and copy it to `instrumented-app`,

```
$ cp -fr app instrumented-app
```

Now let's make `index.js` look like so:

```
const util = require('util')
const express = require('express')
const debug = util.debuglog('my-app')
const app = express()

app.get('/', (req, res) => {
  debug('incoming request on /', req.route)
  res.send('hey')
})

setTimeout(function myTimeout() {
   debug('timeout complete')
   console.log('I waited for you.')
```

```
}, 100)

app.listen(3000)
```

Now we can turn on our custom debug logs like so:

```
$  NODE_DEBUG=my-app node index.js
```

If we make a request to http://localhost:3000 the output of our process should like something like this:

```
MY-APP 30843: timeout complete
I waited for you.
MY-APP 30843: incoming request on / Route {
  path: '/',
  stack:
   [ Layer {
       handle: [Function],
       name: '<anonymous>',
       params: undefined,
       path: undefined,
       keys: [],
       regexp: /^\/?$/i,
       method: 'get' } ],
  methods: { get: true } }
```

> ### Prefer the `debug` module 
>
> In many cases, using the third party `debug` module instead of `util.debuglog` is preferable. The `debug` modules supports wildcards, and the output is time stamped and color coded, while the production cost of using it is negligible. See the **Enabling Debug Logs** recipe in this chapter for more.

Debugging Node Core Libraries

The core libraries that come bundled with the Node binary are written in JavaScript. Which means we can debug them the same way we debug our own code. This level of introspection means we can understand internal mechanics to a fine level of detail.

Let's use the Devtools to pick apart how `util.debuglog` works.

Devtools 

> To understand how to use Devtools, see the first recipe in this chapter **Debugging Node with Chrome Devtools**

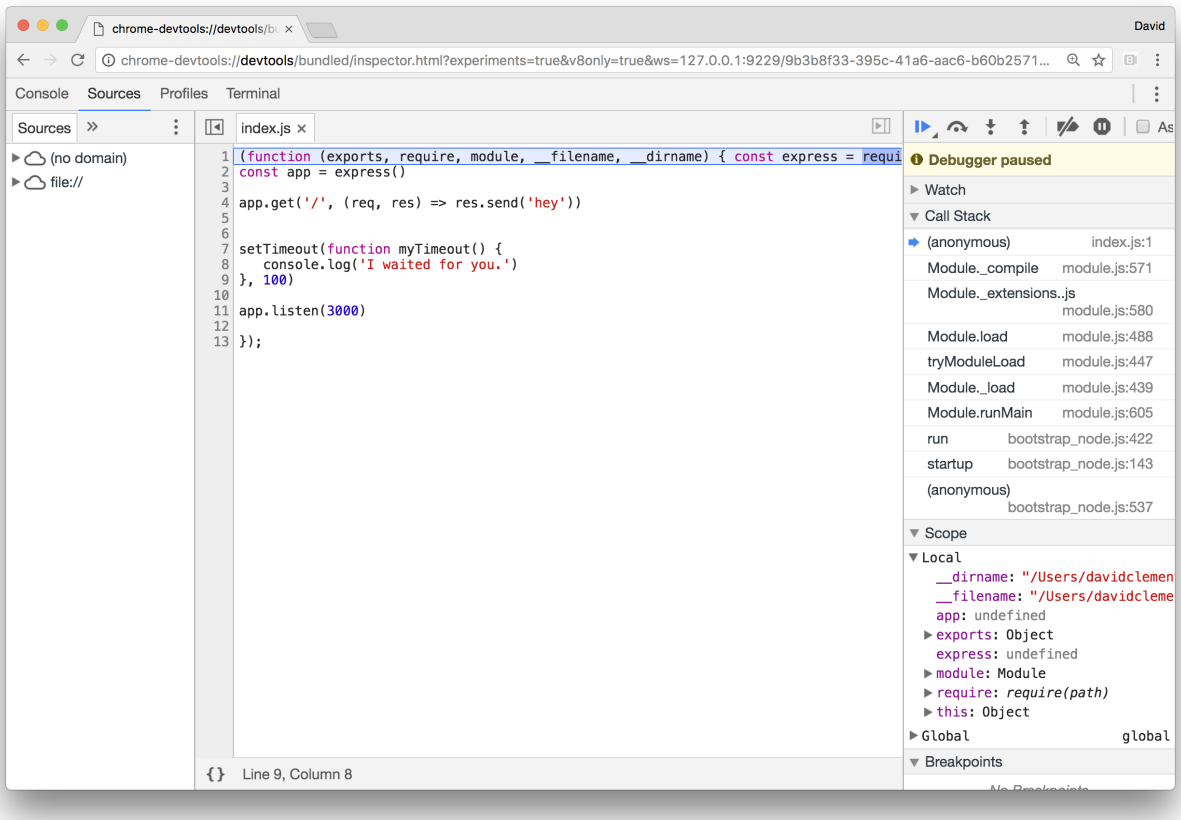
We'll run our code we prepared in the **Getting Ready** section like so (Node 8+):

```
$ NODE_DEBUG=timer node --inspect-brk index.js
```

Or if we're using Node 6.3.0+

```
$ NODE_DEBUG=timer node --debug-brk --inspect index.js
```

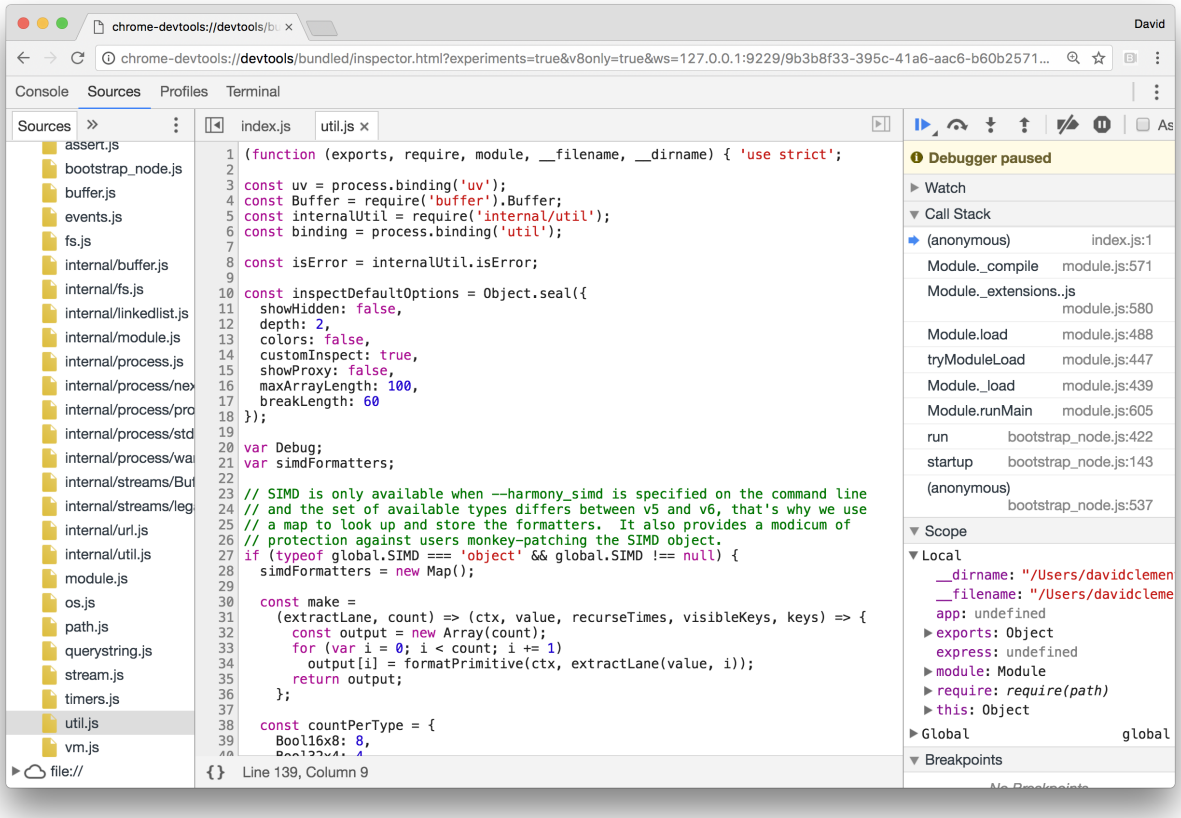
Next we copy and paste the `chrome-devtools://` URI into Chrome, and we should see something like the following:



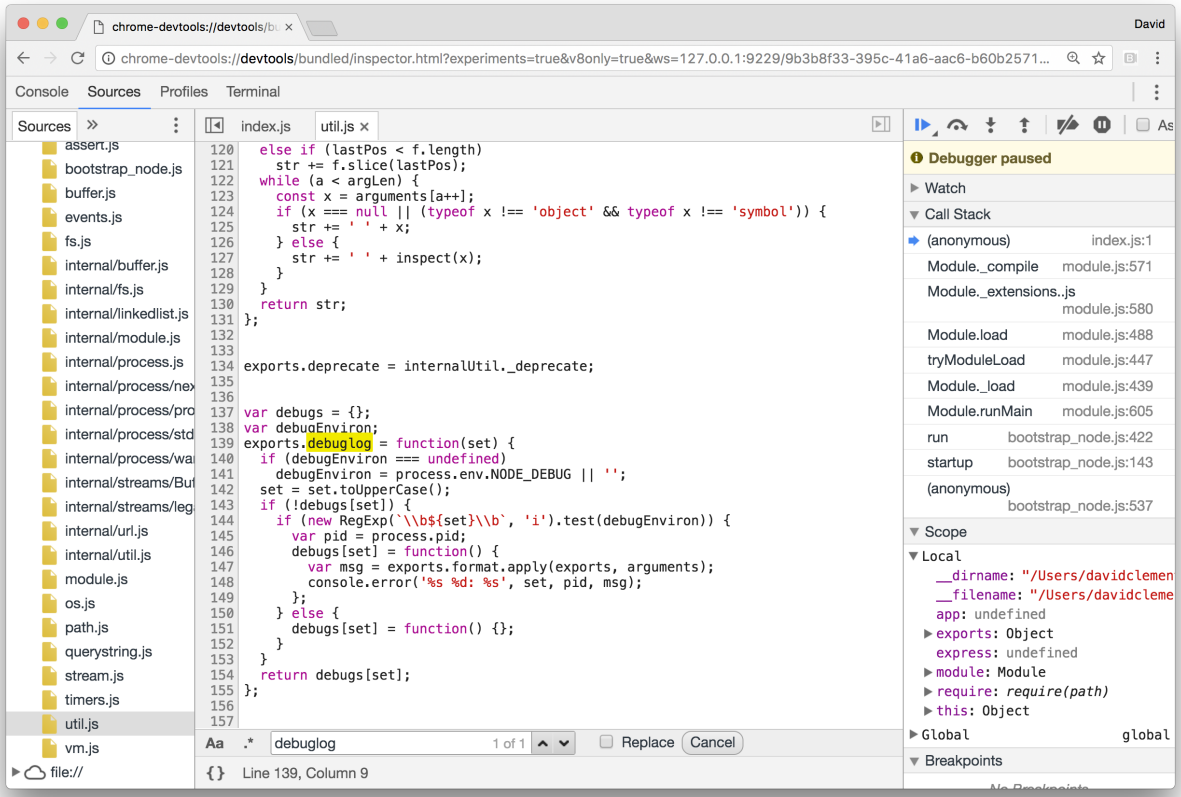
Now in left hand pane (the Navigation pane), we should see two drop down tree, `(no domain)` and `file://`. The `(no domain)` files are files that came compiled into Node.

Let's click the small right facing triangle next to `(no domain)`, to expand the list. Then locate the `util.js` file and double click to open. At this point we should see

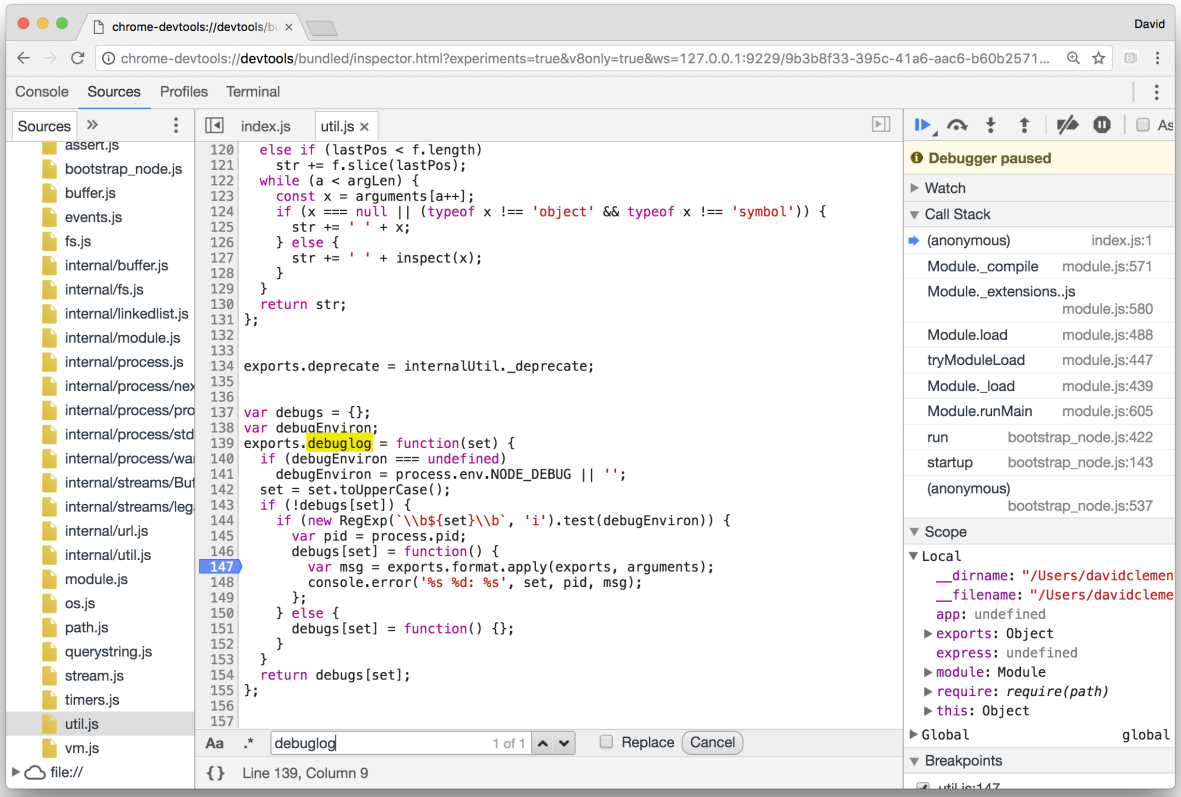
something like the following:



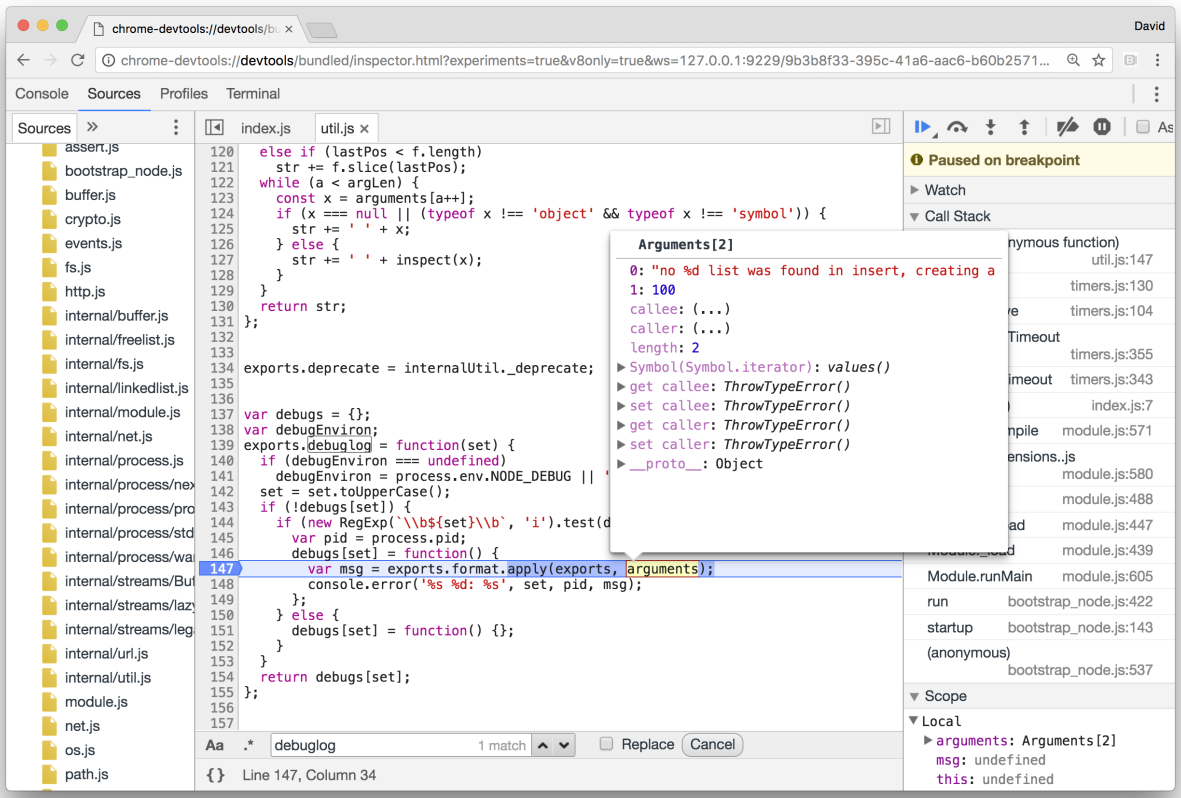
Next we want to find the `debuglog` function, an easy way to do this is to press Cmd+F on macOs or Ctrl+F on Linux and Windows, to bring up the small find dialog, then type "debuglog", this should highlight the exported `debuglog` method.



If we read the exported function, we should be able to ascertain that given the right conditions (e.g. if the flag is set on `NODE_DEBUG`), a function is created and associated to a namespace. Different Node versions could have differences in their `util.js`, in our case the first line of this generated function is line 147, so we set a breakpoint on line 147 (or wherever the first line of the generated function may be).



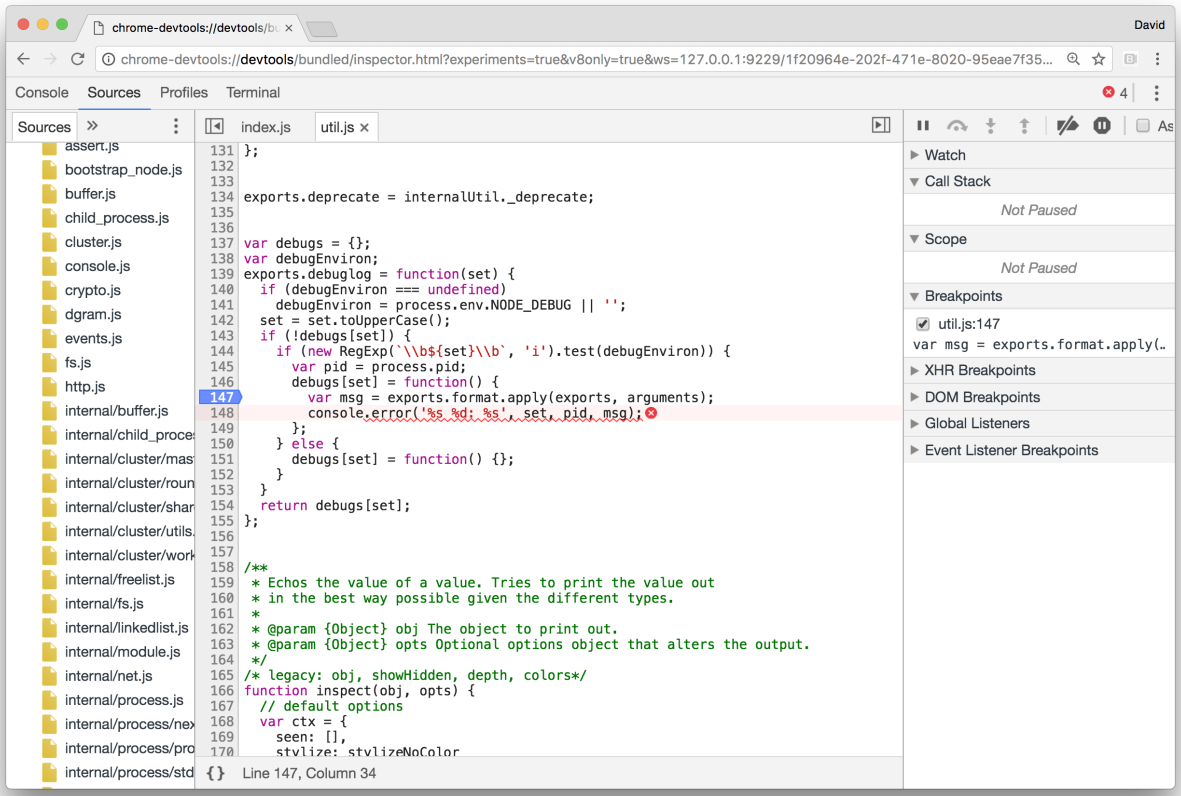
Now if we press run, our breakpoint should be triggered almost immediately. Let's hover over the `arguments` object referenced in the generated function



We should see that the second argument passed to the generated debug function

is `100` this relates to the millisecond parameter we pass to `setTimeout` in our `index.js` and is part of the first debug message ("no 100 list was found...").

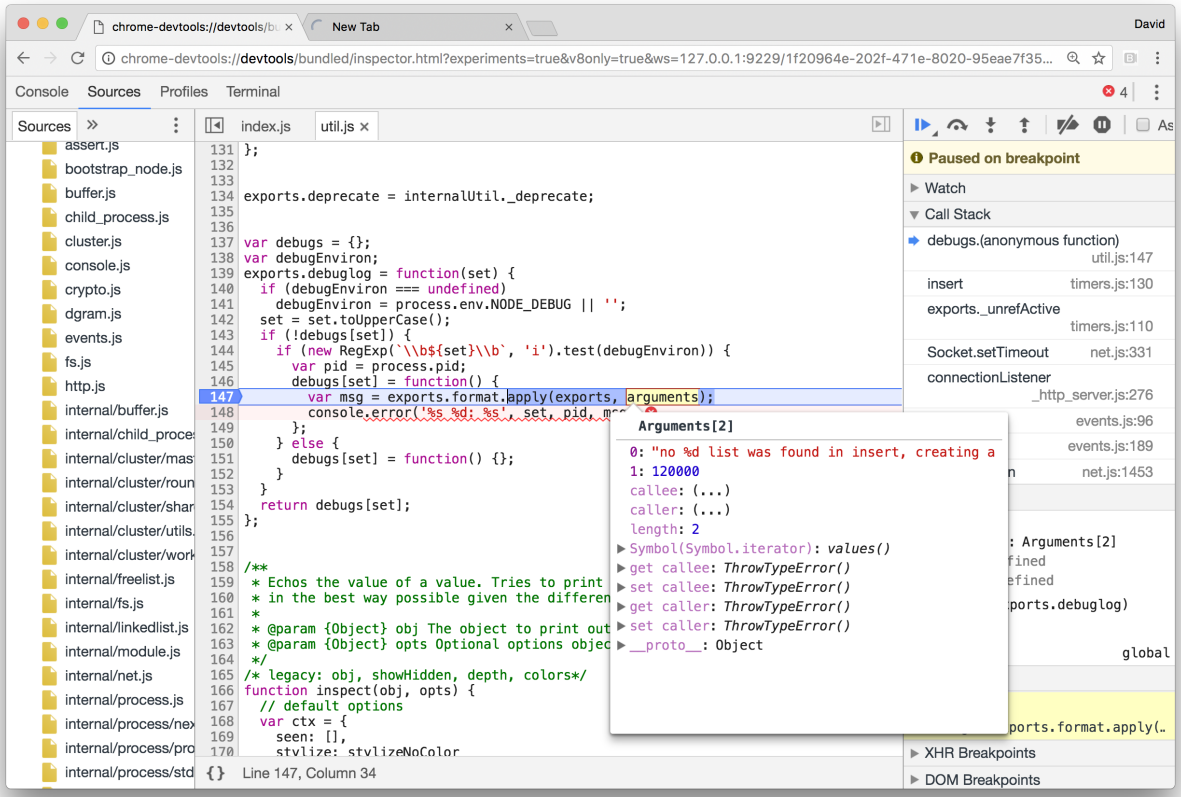
Now let's hit the play button three more times, until the blue play button no longer shows (and there's a pause button) in it's place and there's a "error" count in the top right corner of 4, as demonstrated in the following:



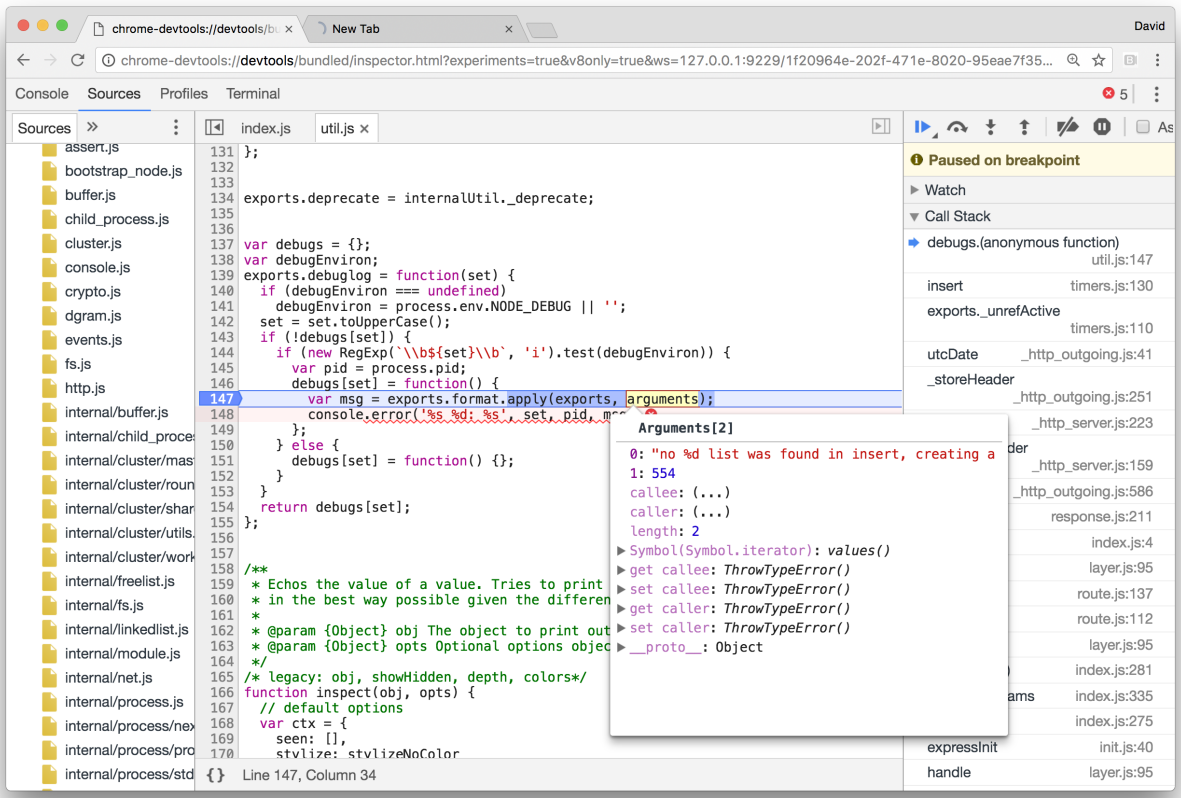
Devtools perceives each log errors because the debug messages are written to STDERR, this is why the error count in the top right corner is 4.

Now let's open a new browser tab and navigate to http://localhost:3000.

Devtools should have paused again at our breakpoint, if we hover over the `arguments` object in the generated function we should see that the second argument is `12000`, this relates to the default 2 minute timeout on sockets (as discussed in the main recipe).

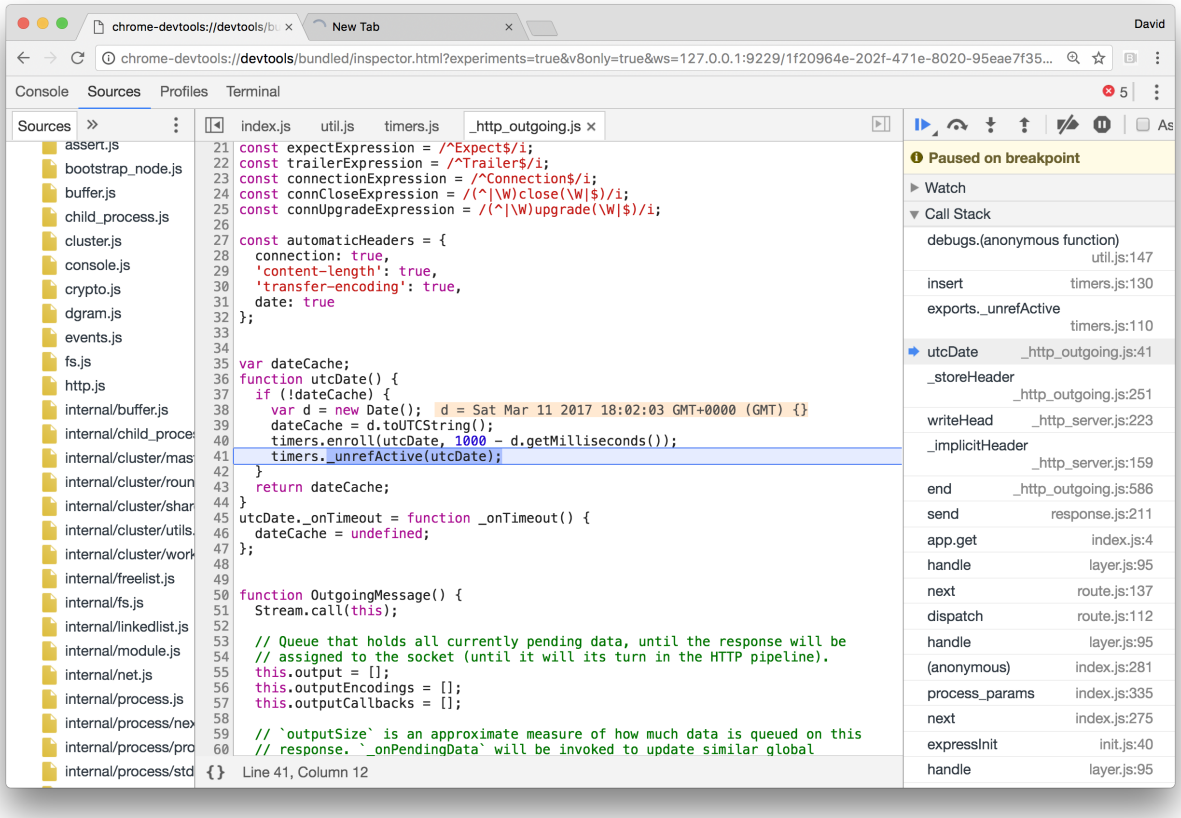


If we hit the play button again, and inspect the `arguments` object we should see the second argument is a number that's less than 1000.



Over on the right hand side, in the Call Stack there's a frame called `utcDate`, let's

select that frame to view the function.



This function is in a library that's only for internal core use called `_http_outgoing.js`.

We can see that it's currently within the an `if` block that checks whether `dateCache` is falsey. If `dateCache` is falsey, it creates a new date, and assigns the output of `toUTCString` to `dateCache`. Then it uses `timers.enroll`, this is a way of creating a `setTimeout`, where the provided object represents the timeout reference. It sets the time to `1000` minus the millisecond unit in the date object which effectively measures how long there's is left of the current second. Then it calls `timers._unrefActive` which activates the timer without allowing the timer to keep the event loop open. The `utcDate._onTimeout` method sets `dateCache` to `undefined`, so at the end of the timeout, `dateCache` is cleared.

If we look down the Call Stack, we should be able to infer that the `utcDate` function is called when a request is made, and is to do with HTTP header generation (specifically the `Date` HTTP header).

The net effect is that a process may receive, say, 10000 requests in a second, and only the first of those 10000 has to perform the relatively expensive Date generation, while the following 9999 requests all use the cached date.

And that's the sort of things we can learn by debugging core.

See also

- *Creating an Express Web App* in **Chapter 7 Working With Web Frameworks**
- *Working with Files* in **Chapter 3 Coordinating I/O**
- *Communicating over sockets* in **Chapter 3 Coordinating I/O**