9 Debugging Processes

This chapter covers the following topics

- Turning on internal debug flags
- Instrumenting code with debug logs
- Using Chrome Devtools to debug Node
- Enhancing stack traces
- Improve stack trace presentation
- Tracing asynchronous operations
- Postmortems

Introduction

One to two paragraph intro to chapter

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.

On 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:

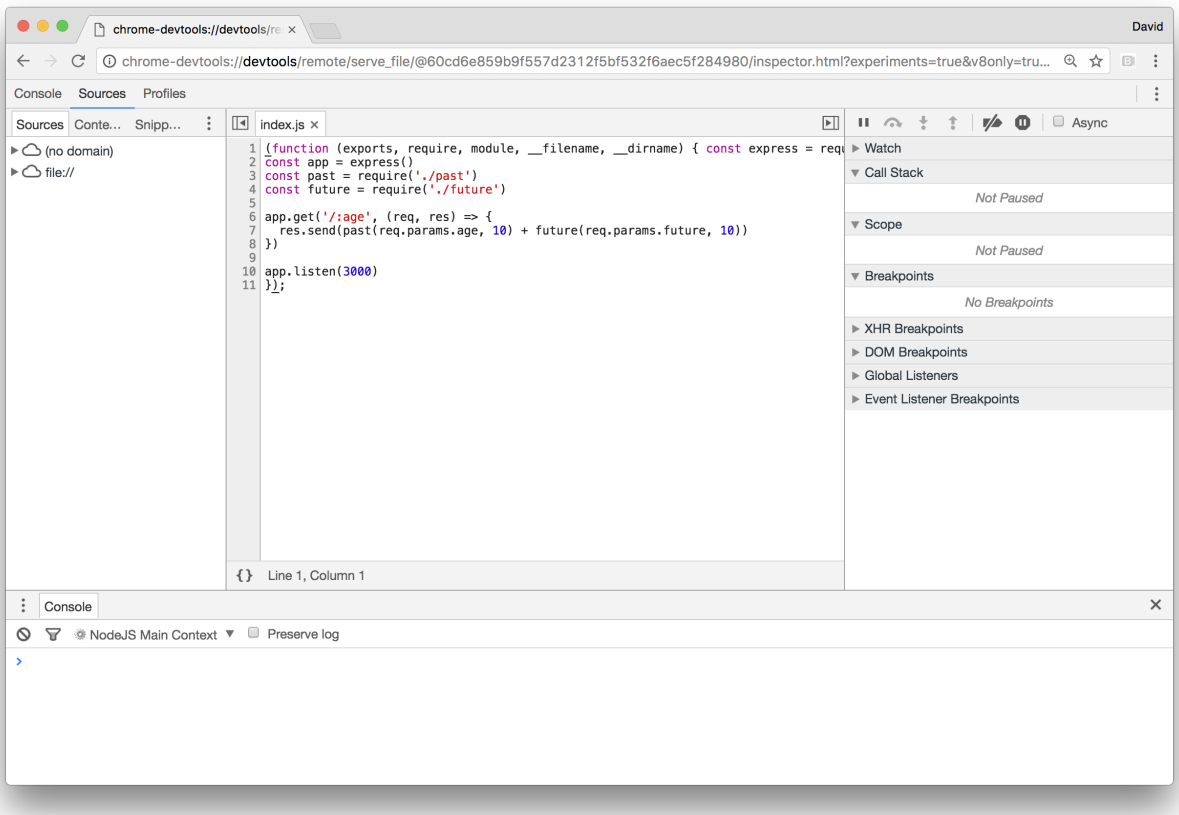
```
$ node --inspect index.js
```

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

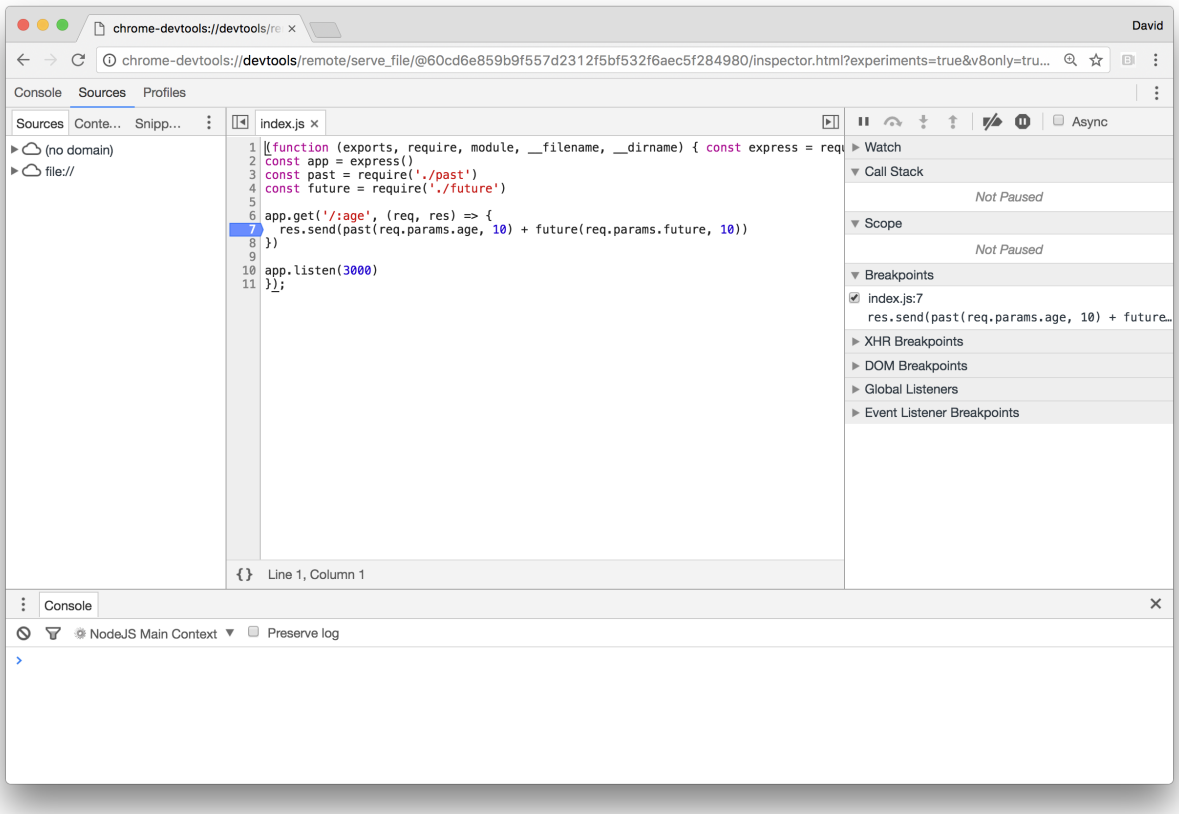
The Module Wrapper 

> 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.

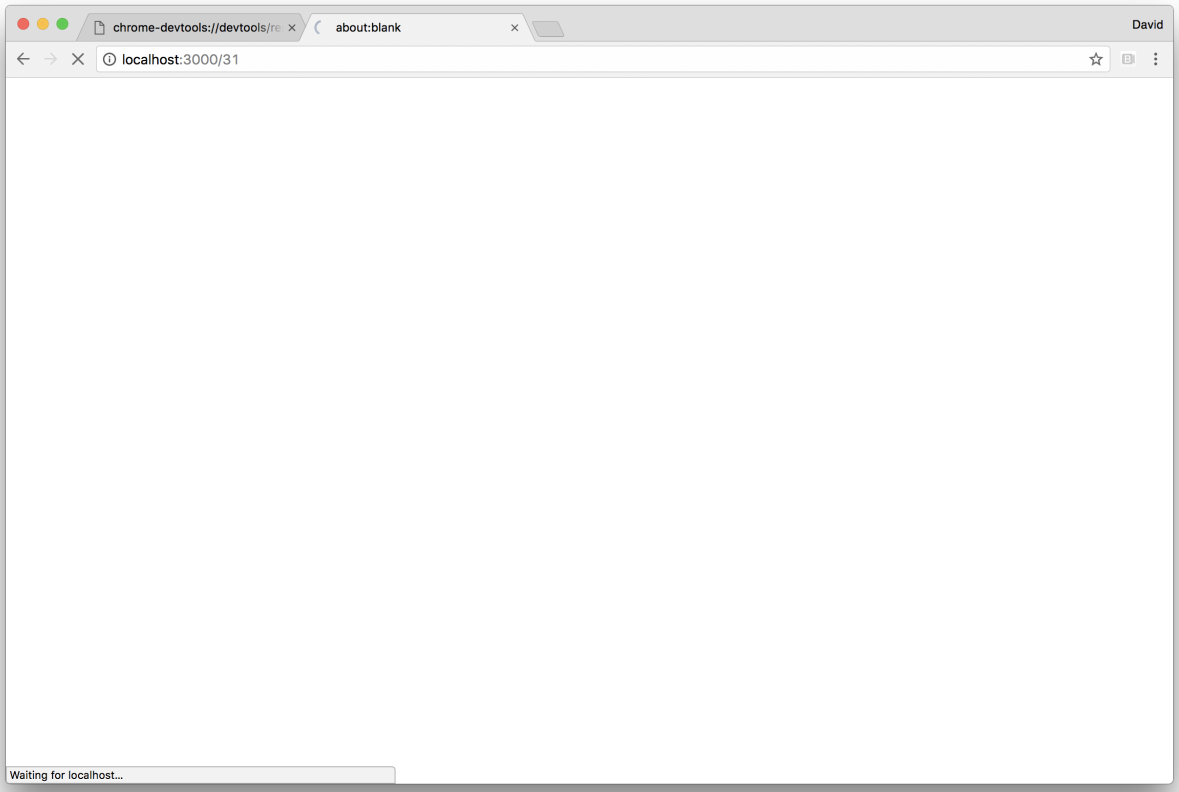
Now let's set a break inside our route handler, on line 7.

If we click the number 7 in the LOC column to the left of the code, it should an arrow like shape over and around the number, also making color the color of the 7 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 something look like the following:

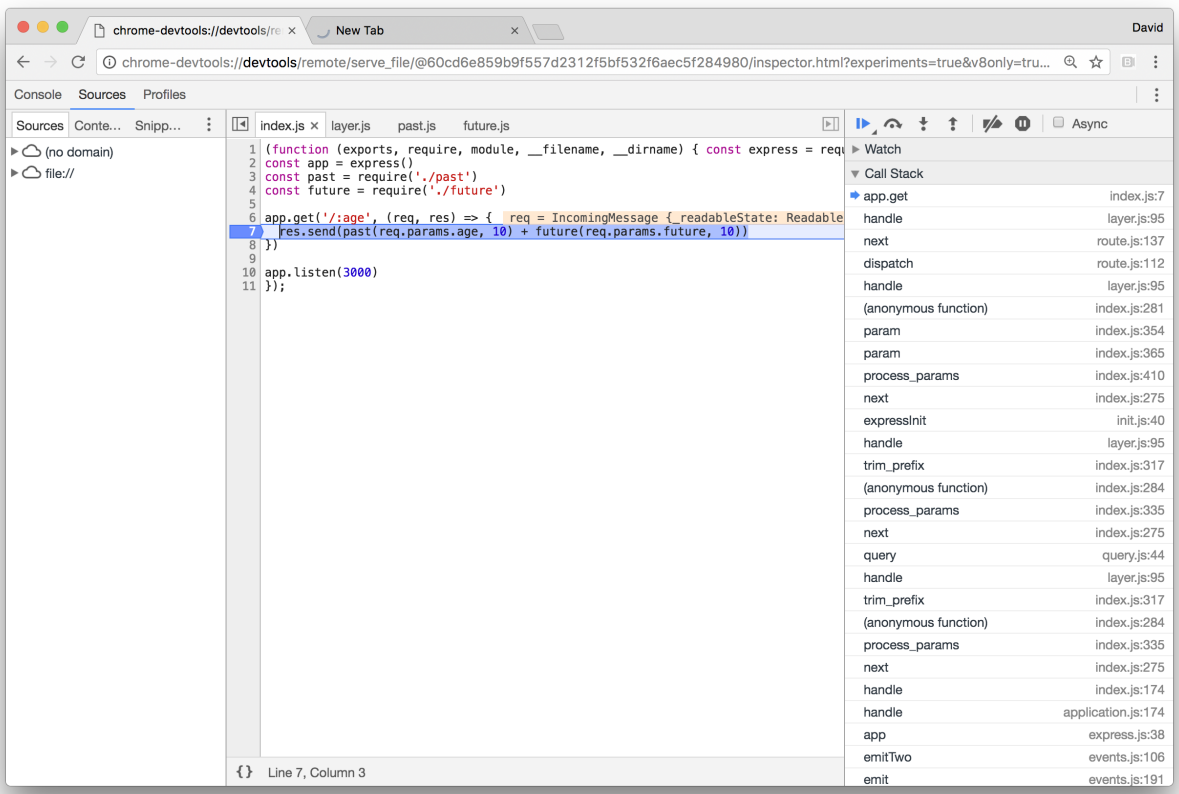


Now let's open a new tab, and navigate to `http://localhost:3000/31`



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

The next thing we see should look like the following:



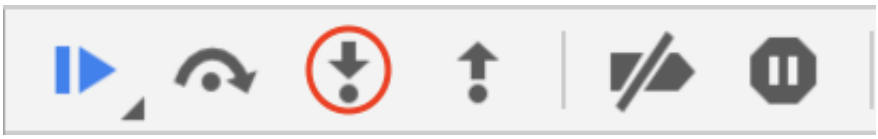
We can see line 7 is now highlighted, and there's a sort of tooltip showing us the

values of of the `req` and `res` objects on the line above.

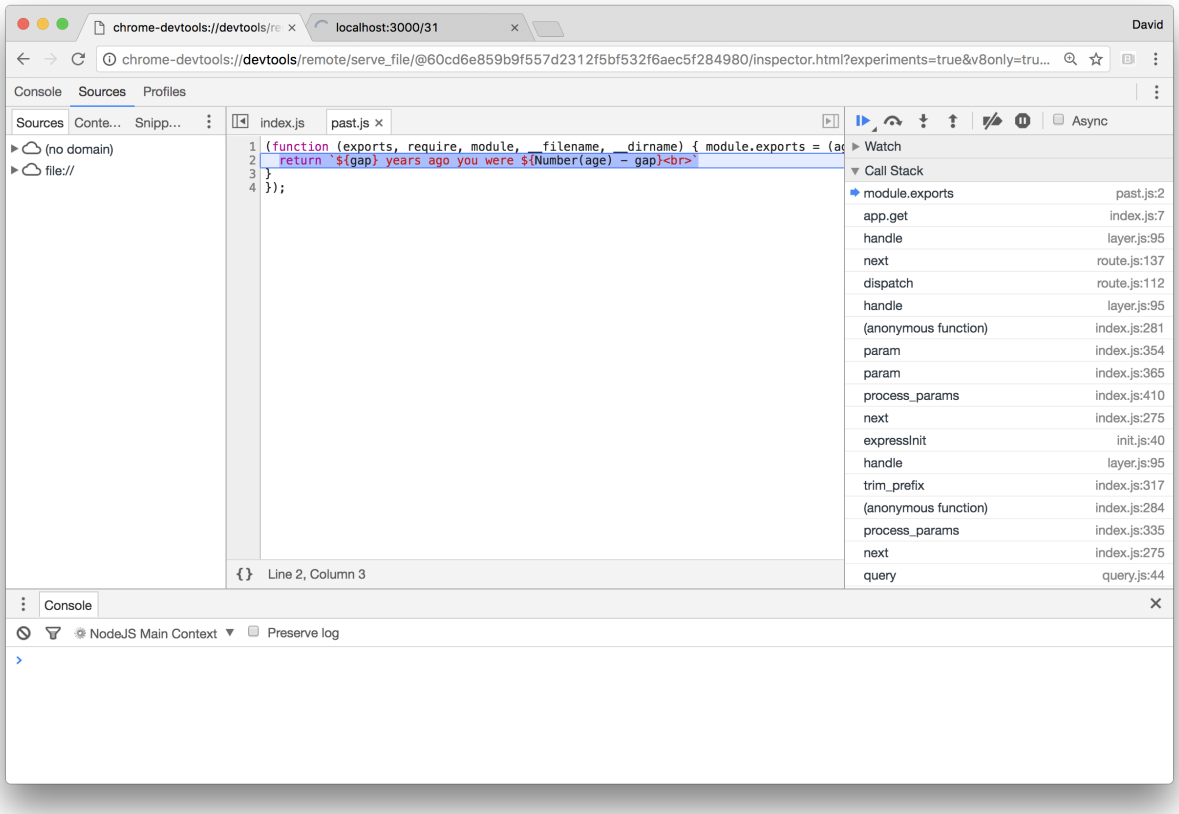
Over in the right column the Call Stack panel is full of Call Frames (the functions in the stack), and there's now a blue play button in the control icons at the top of the right column. If we we're to scroll the right column, we'd also see the Scope pane is populated with references.

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:



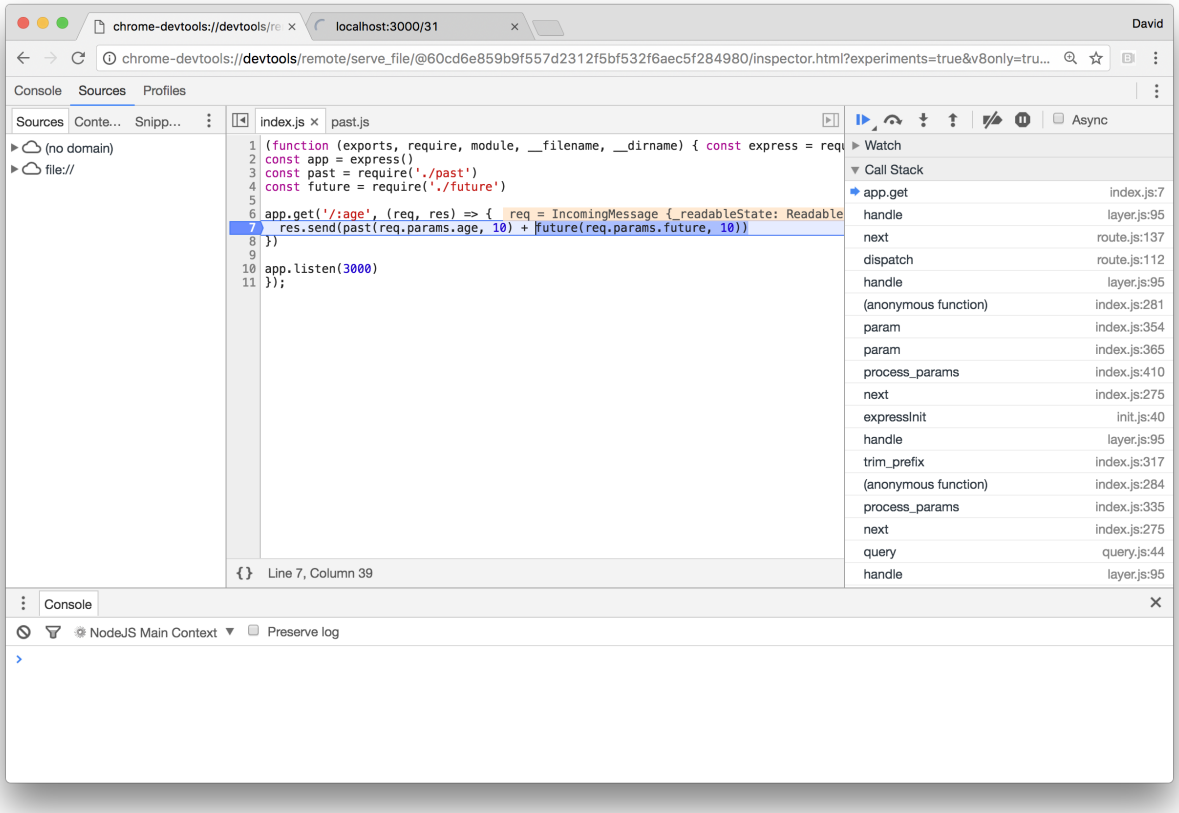
When we press this, we step into the `past` function, which is in the `past.js` file, so Devtools will open a new tab in the above center code panel, and highlight the line which is about to execute (in our case, line 2).



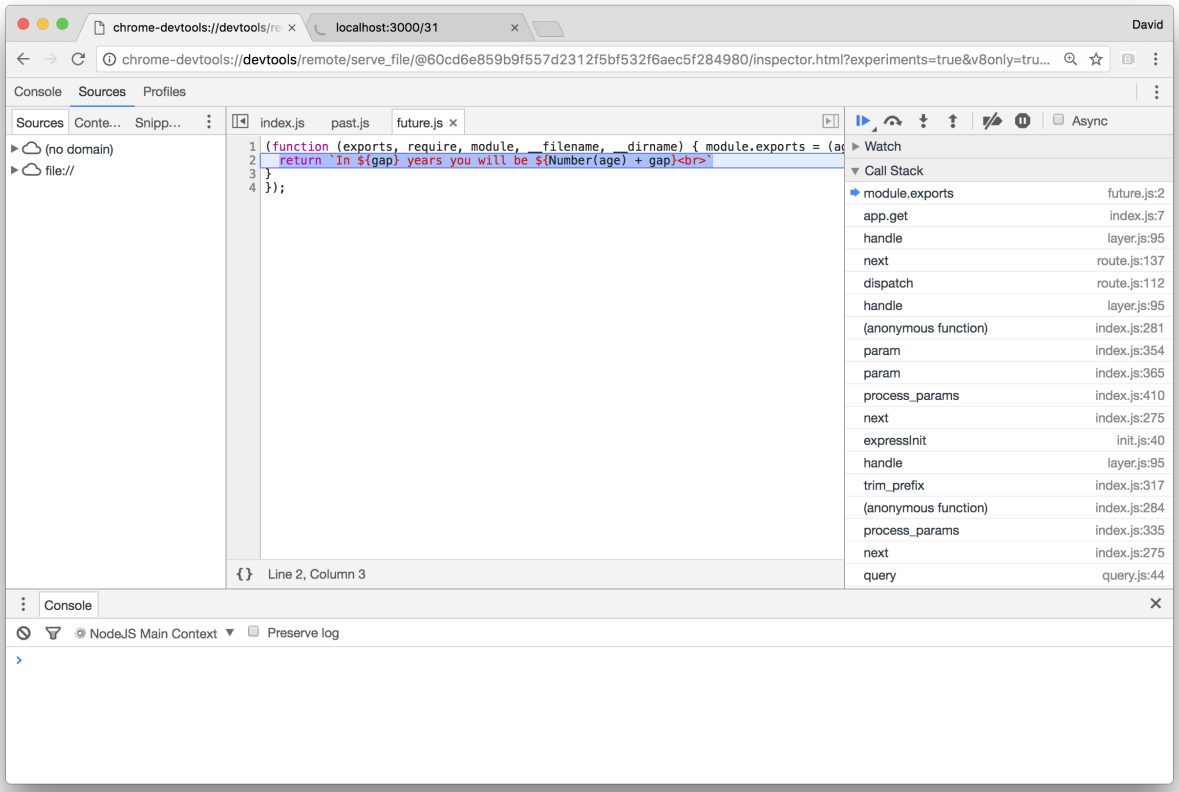
So let's step out of the `past` function, by pressing the arrow pointing up and away from a dot, next to the step in icon:

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:

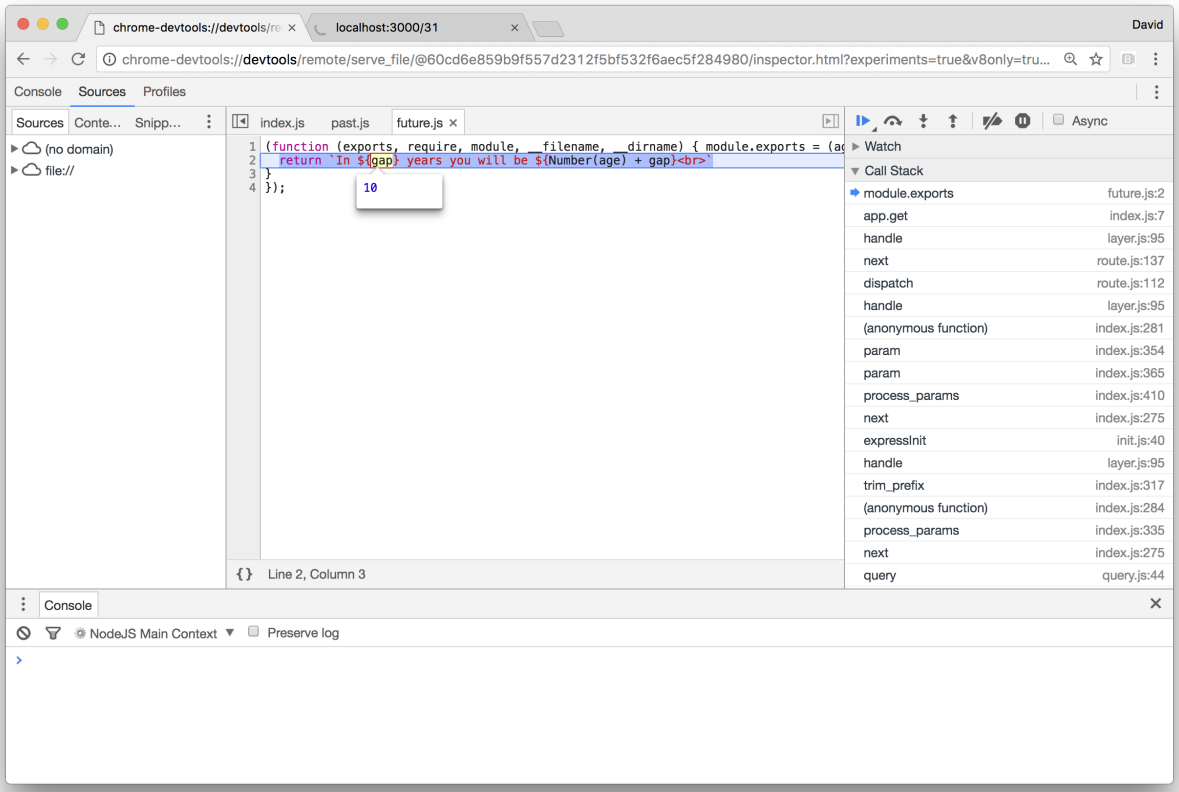


Then we'll press the step in icon again, which will take us into the `future` function in the `future.js` file:

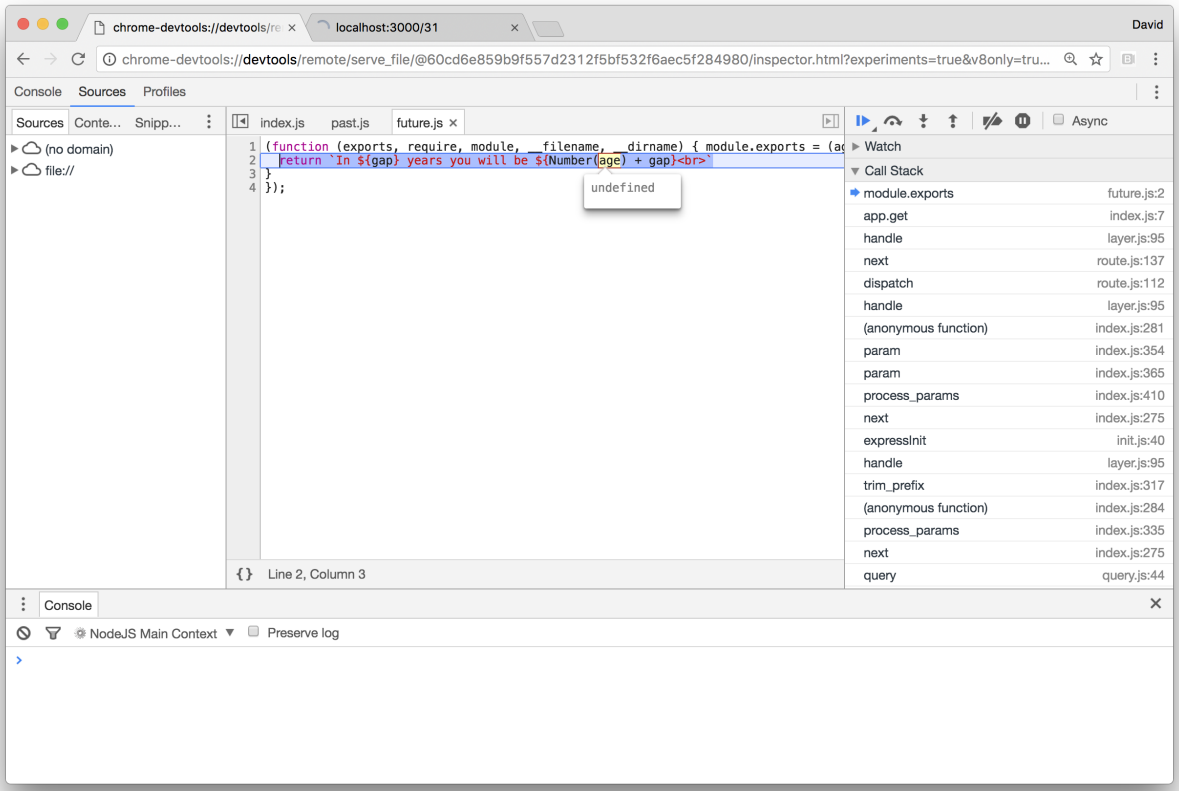


Okay, this is the function that generates that particular sentence with the `NaN` in it. A `NaN` can be generated for all sort of reasons, dividing zero by itself, substracting `Infinity` from `Infinity` trying coerce a string to a number when the string does not hold a valid number, to name a few. At 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:

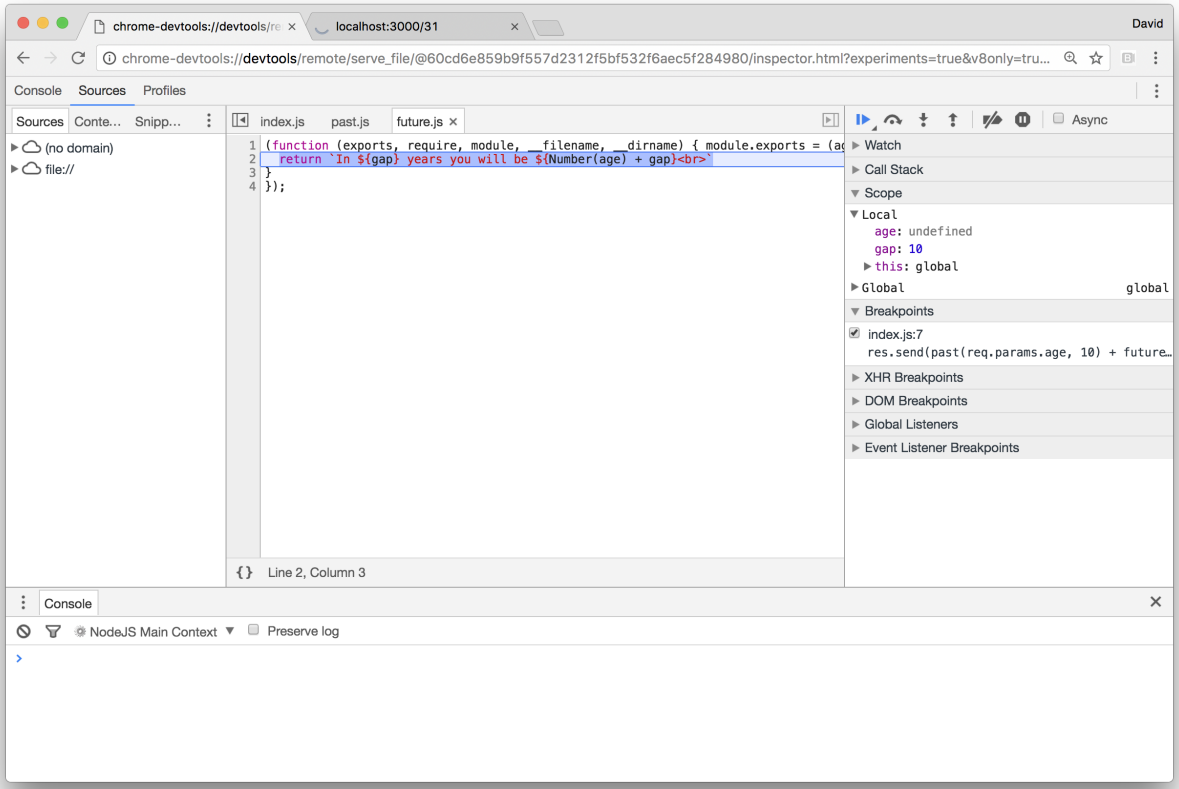


Seems fine, now let's hover over the `age` variable:



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:

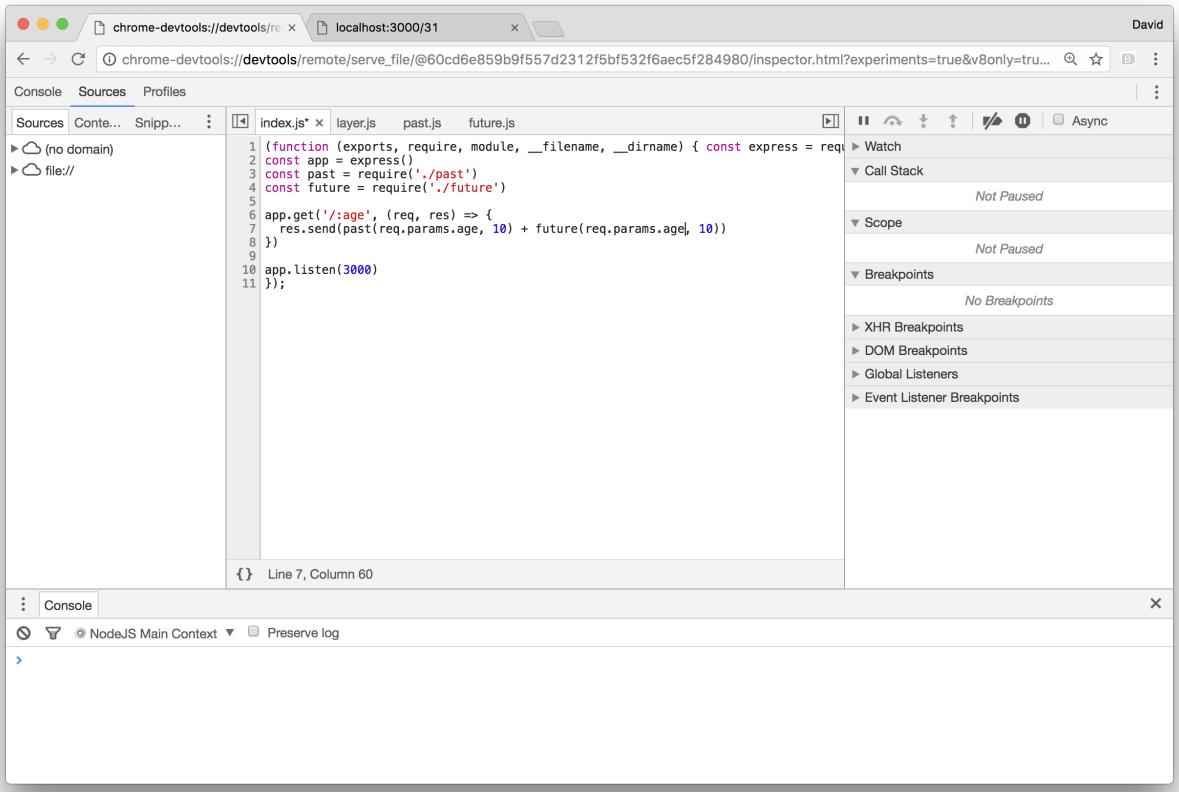


Well `Number(undefined)` is `NaN`, and `NaN + 10` is also `NaN`.

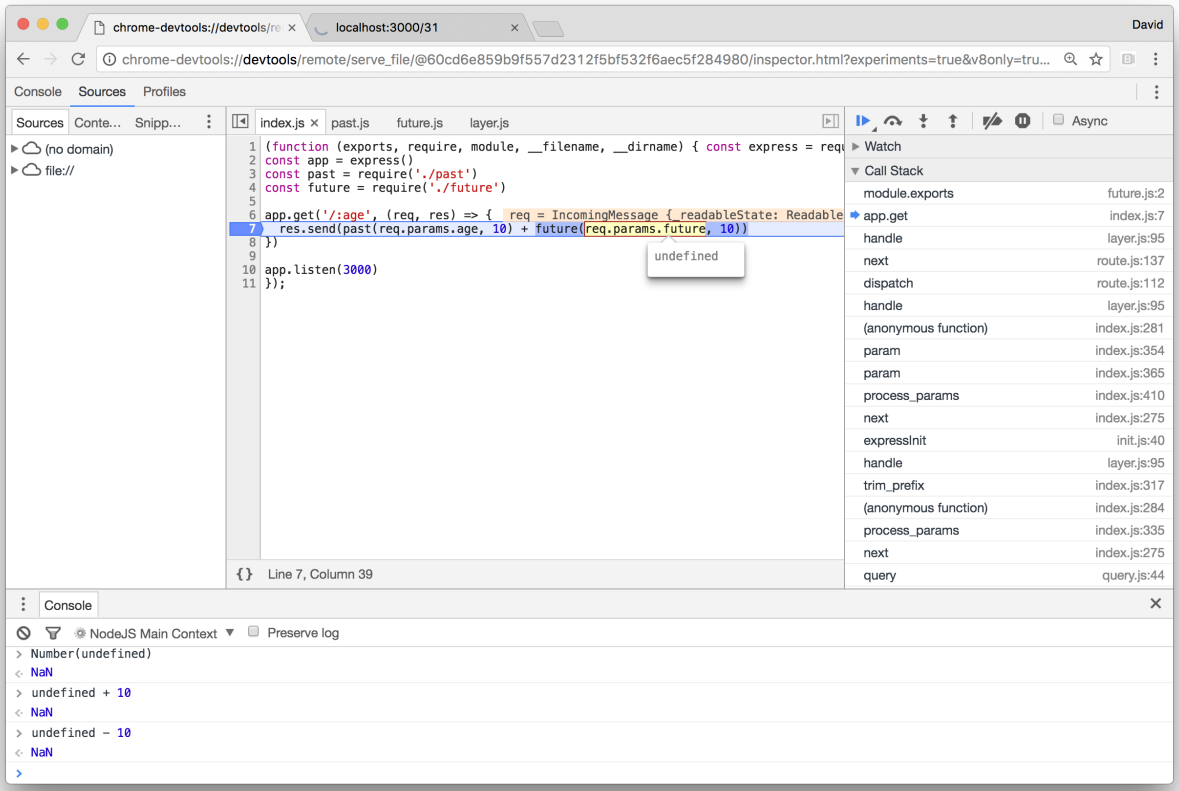
Why is `age` set to `undefined`?

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:



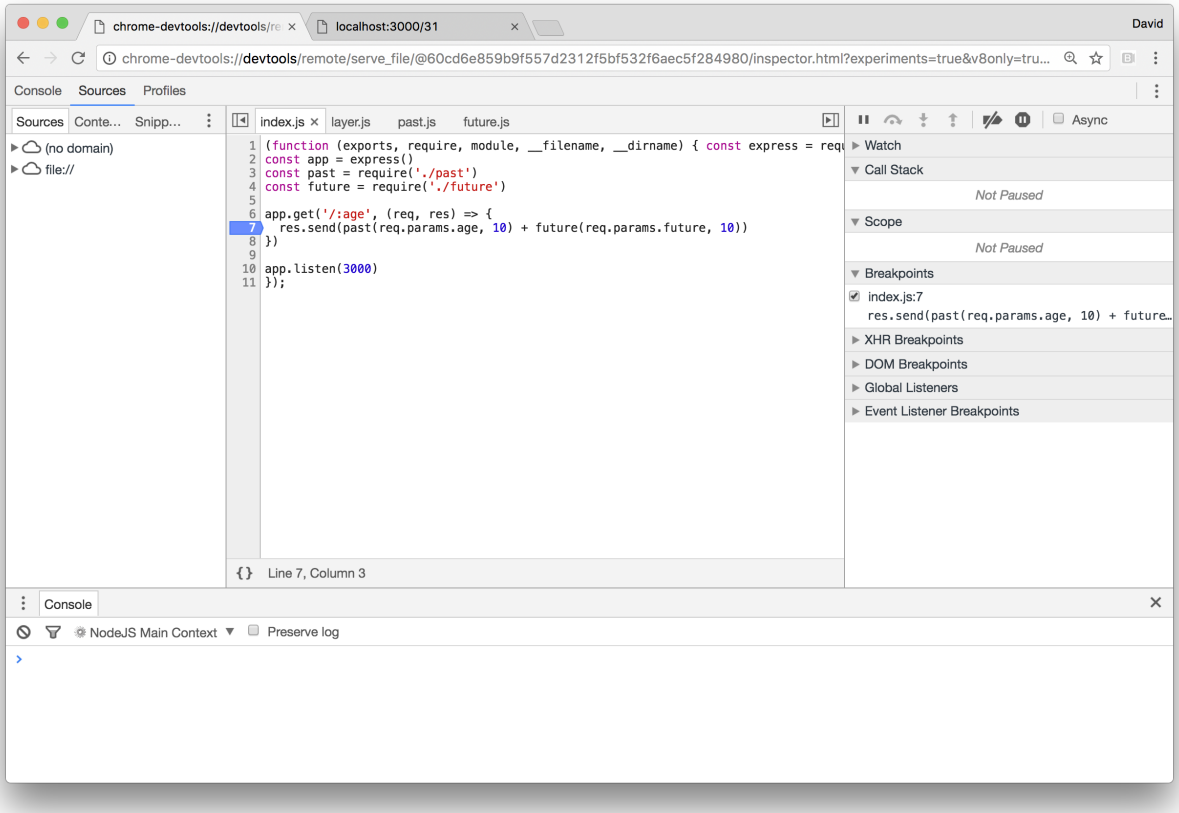
Now let's hover over the value we're passing in to `future`:



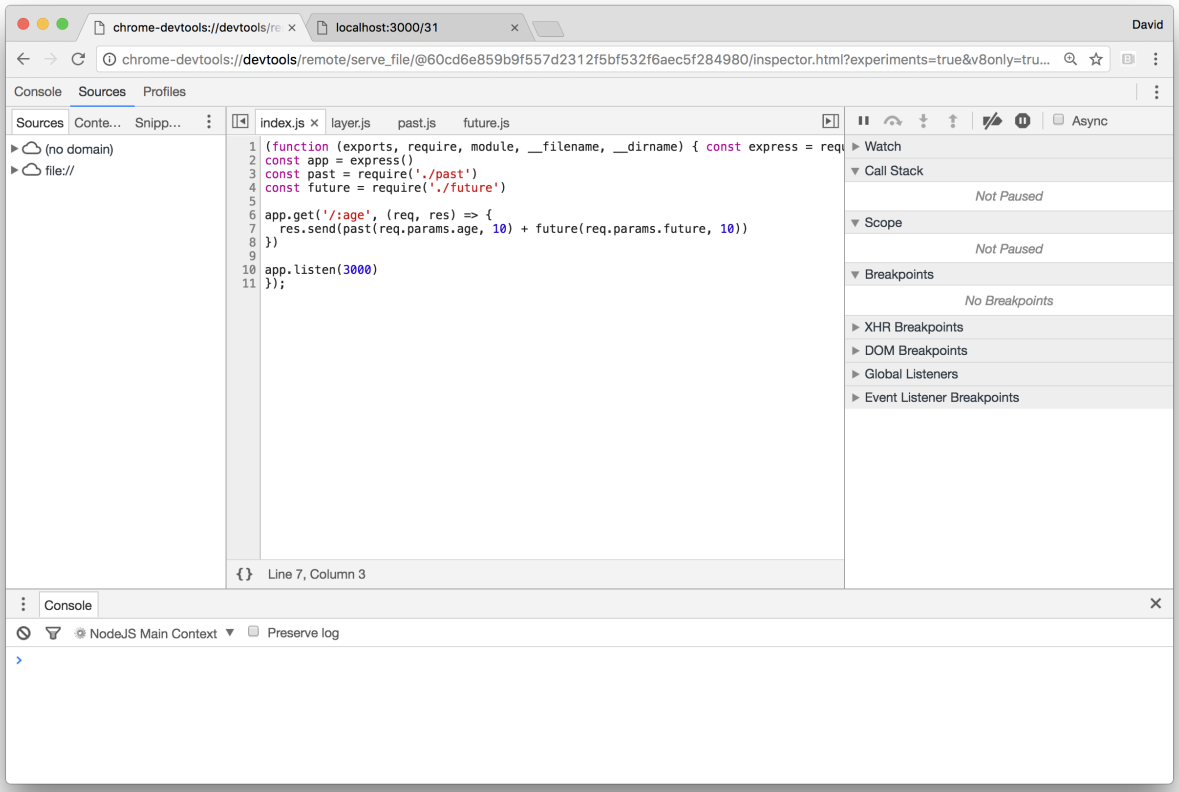
That's `undefined` too, why is it `undefined`?!

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

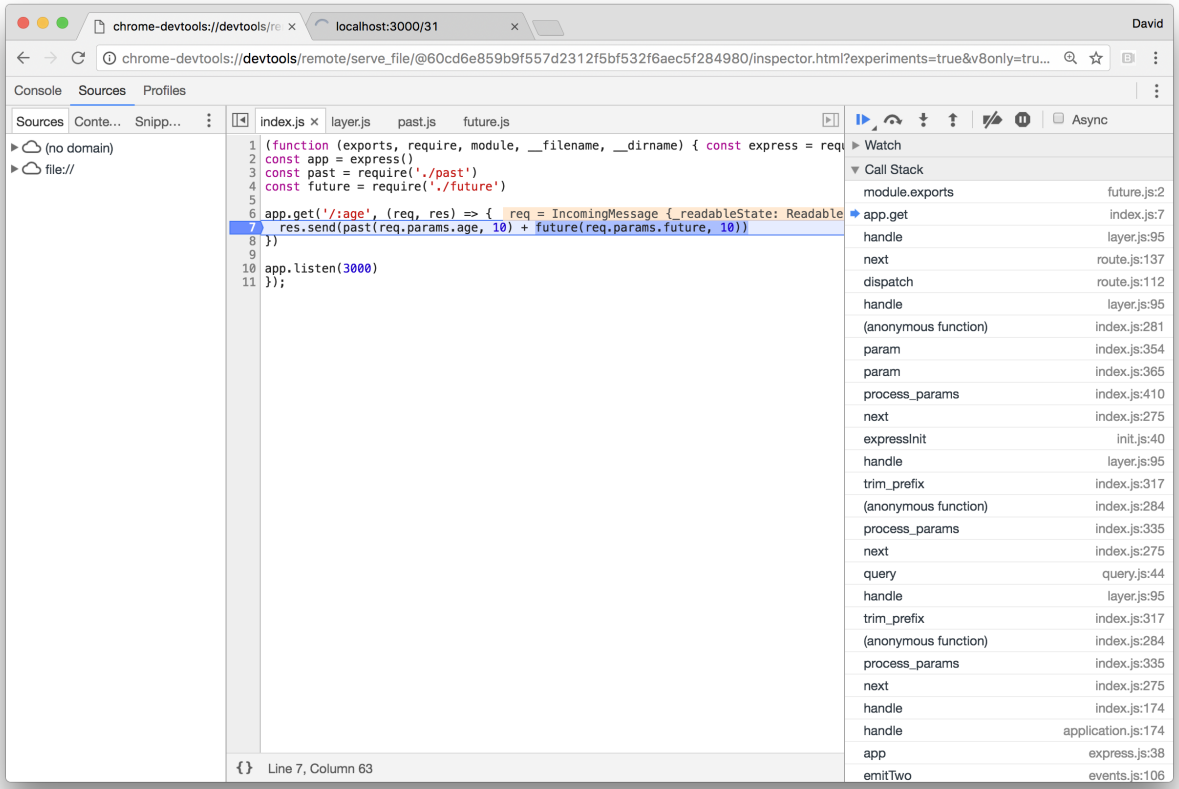
To be absolutely sure, let's fix it while the server is running, if we hit the blue play button twice we should see something like:



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

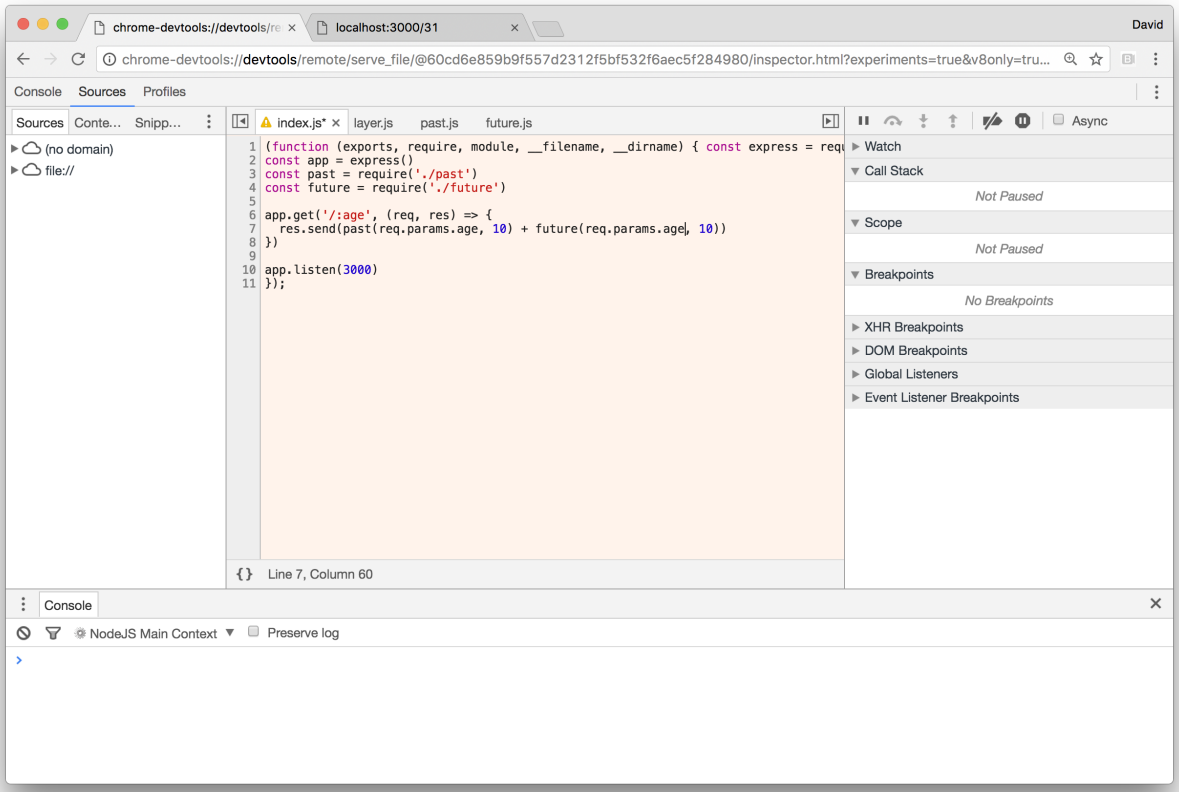


Now if we click immediately after the `e` in `req.params.future` we should get a blink cursor, we backspace out the word `future` and type the word `age`, making our code look like so:

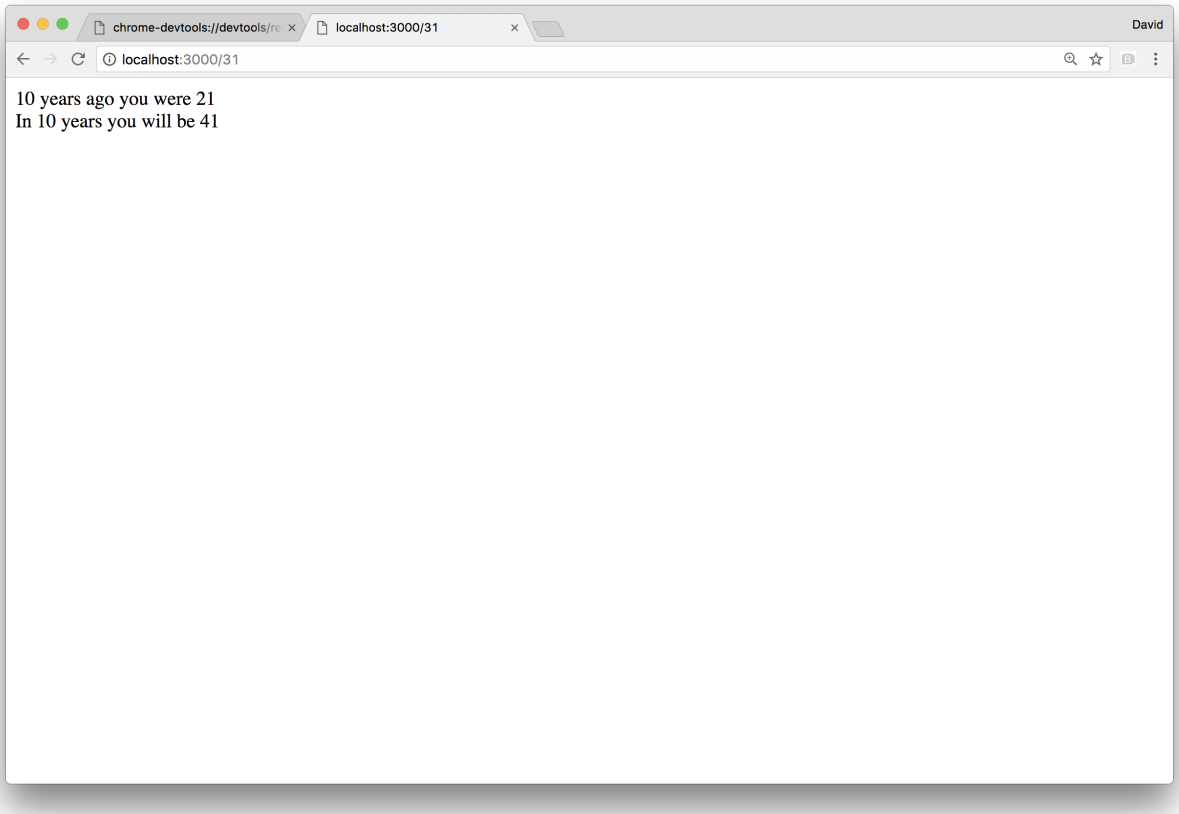


Finally we can live save those changes in our running server by pressing CMD + s on MacOS or Ctrl + s on Windows and Linux.

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 happens.

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**)

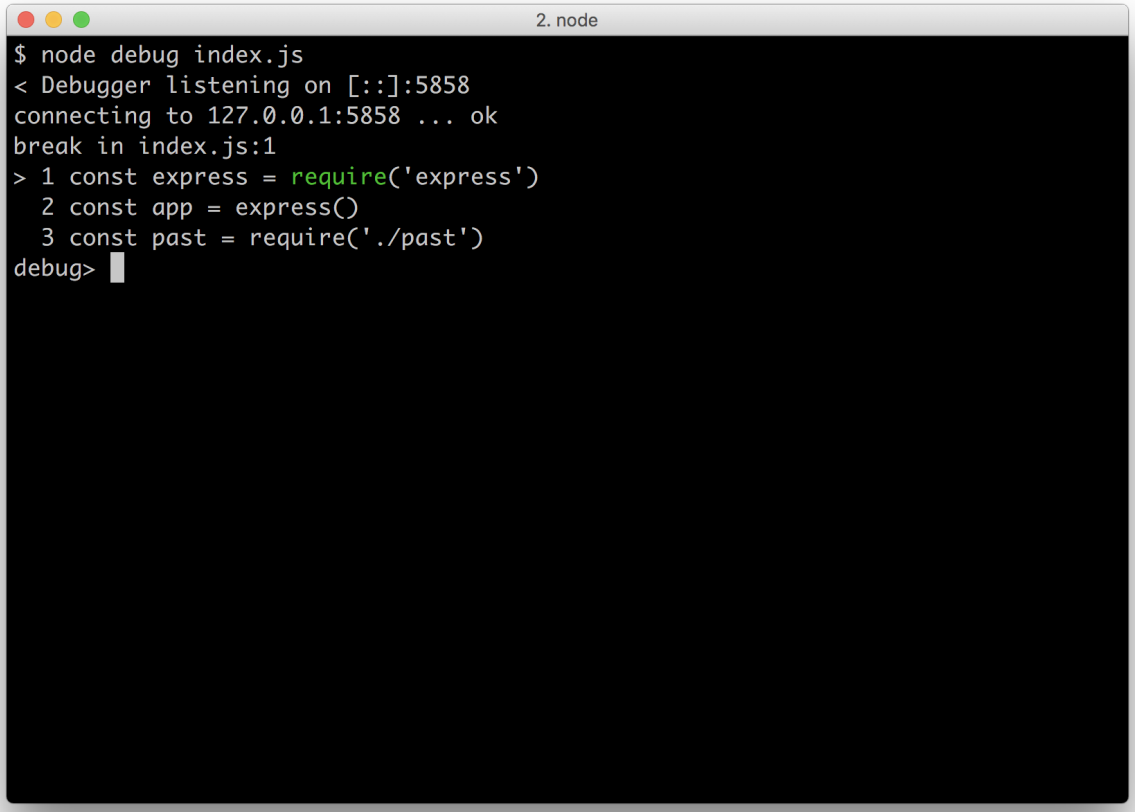
node debug

There may be rare occasions when 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
```



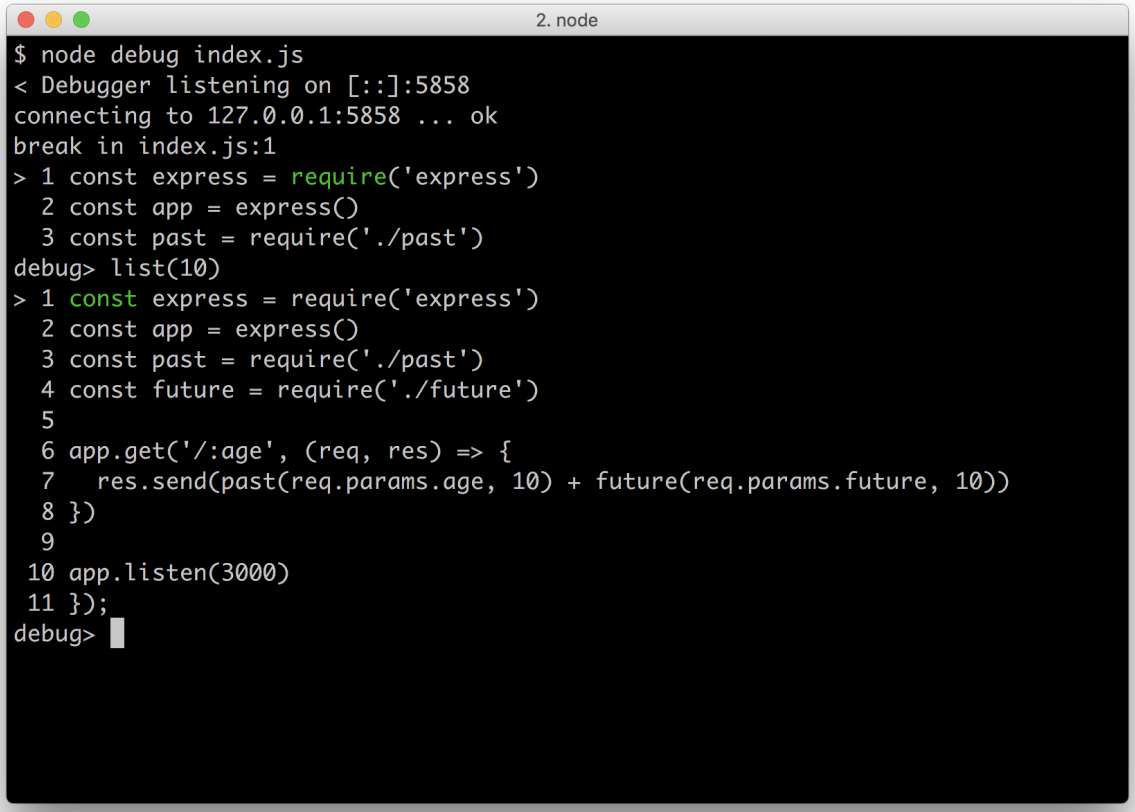
When we enter debug mode, we see the first three lines of our entry point (`index.js`).

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).

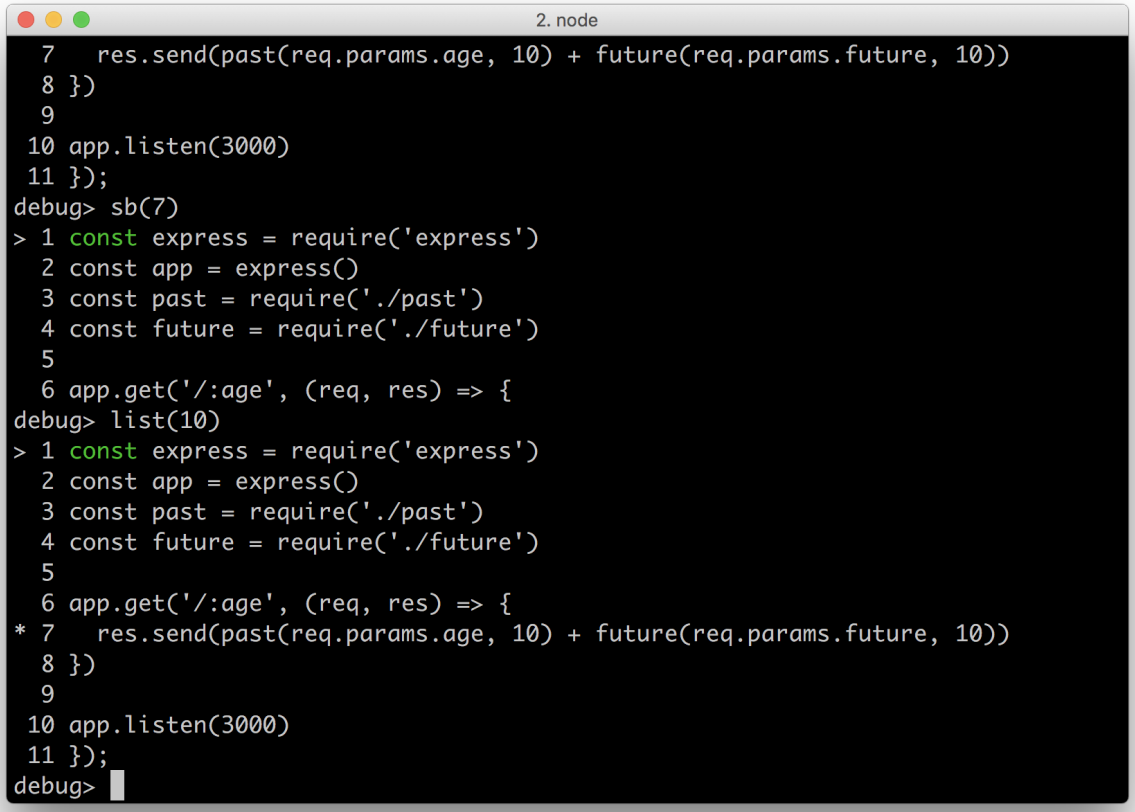
We're interested in the 7th line, because this is the code that's executed when the server receives a request.

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.

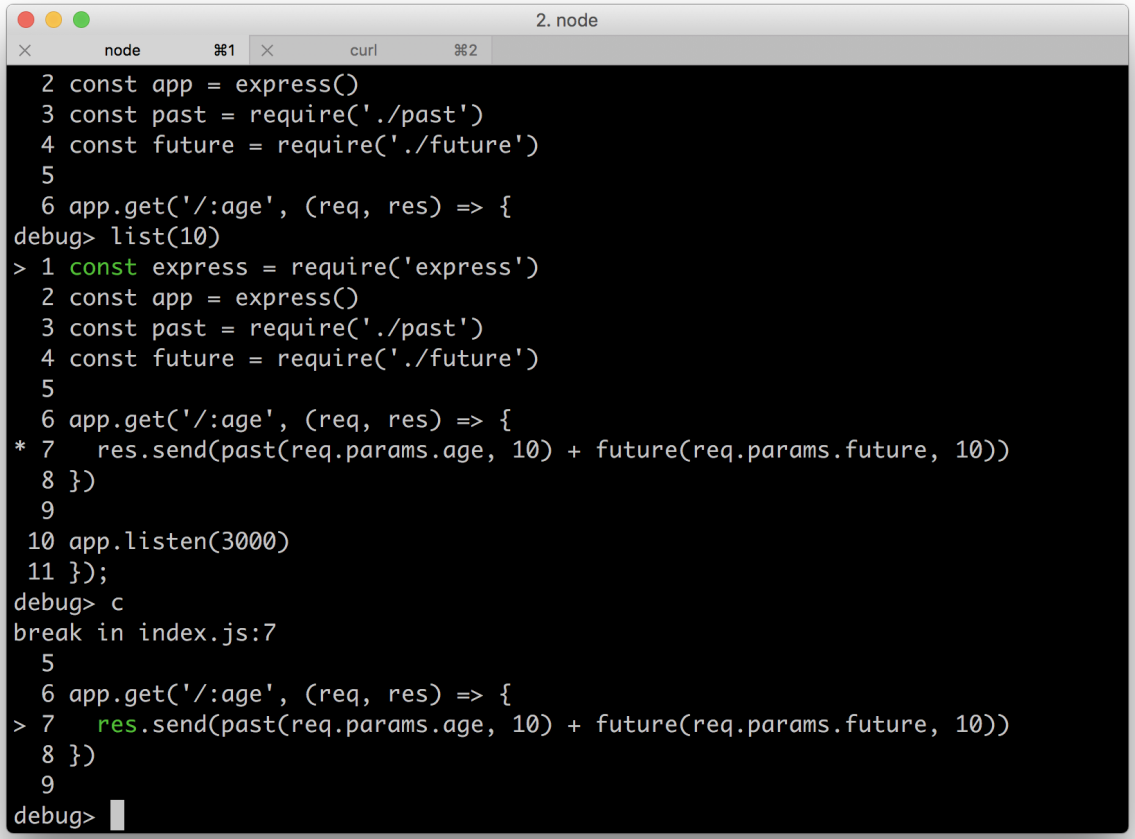
We use the `c` command to tell the process to continue, like so:

```
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:

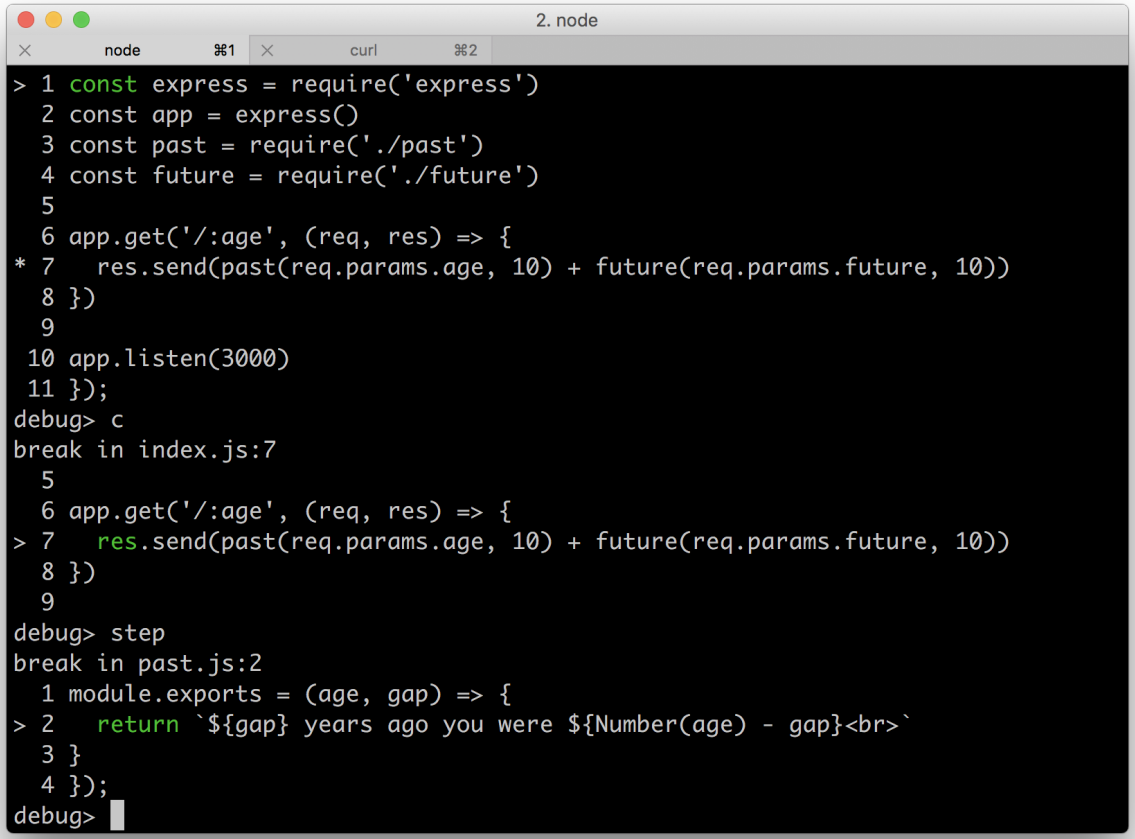
```
$ curl http://localhost:3000/31
```

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
```

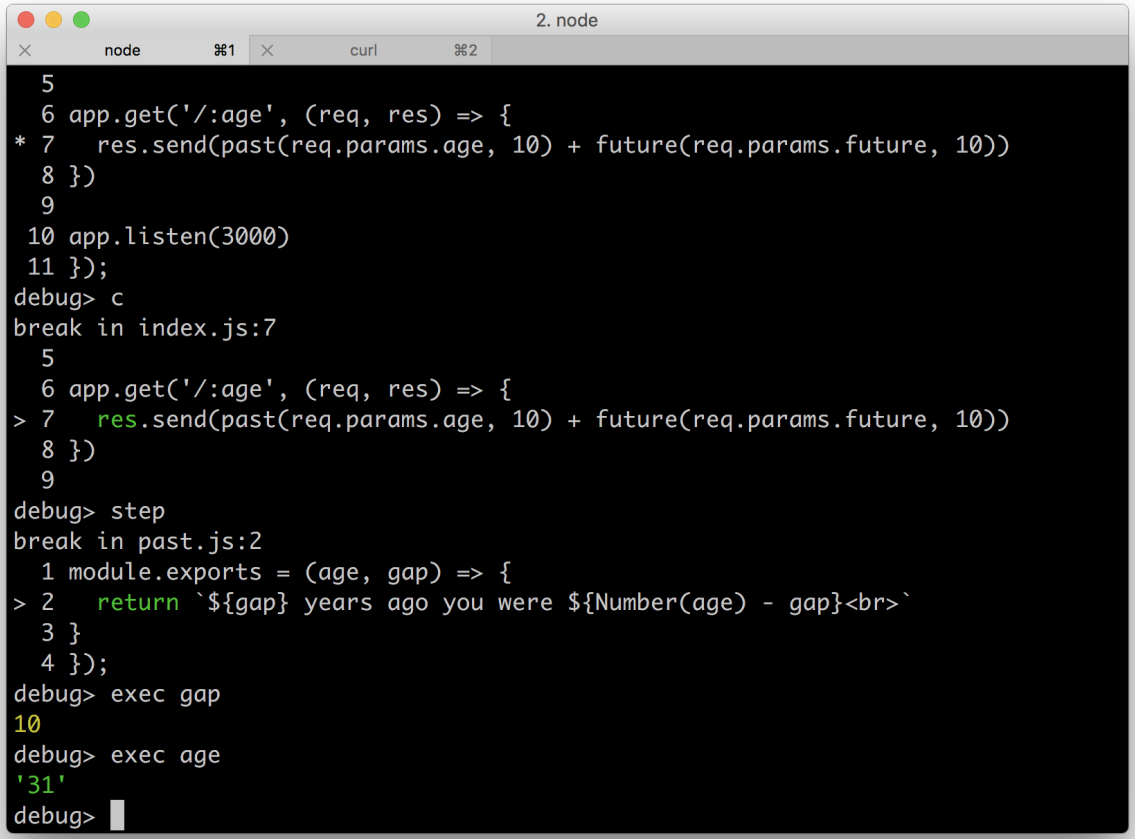


This enters our `past.js` file, with the current break on line 2.

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
```

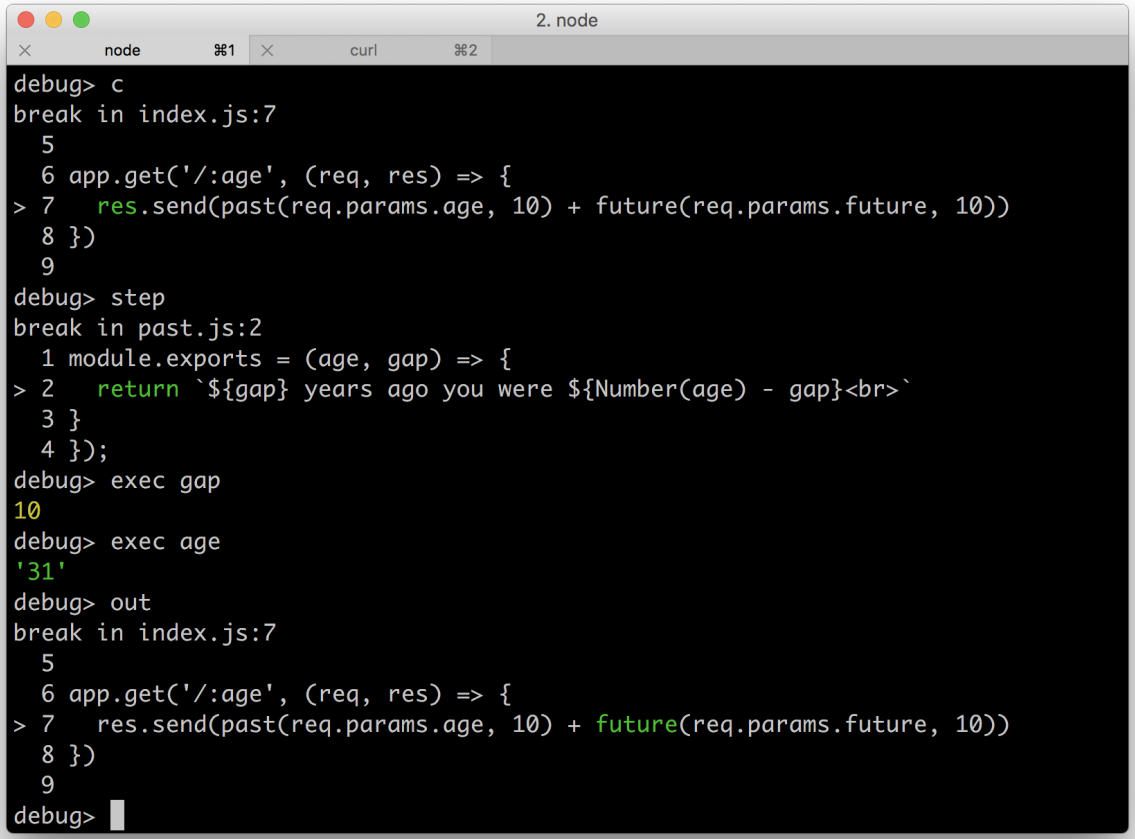
```
debug> exec age
```



Everything seems to be in order here.

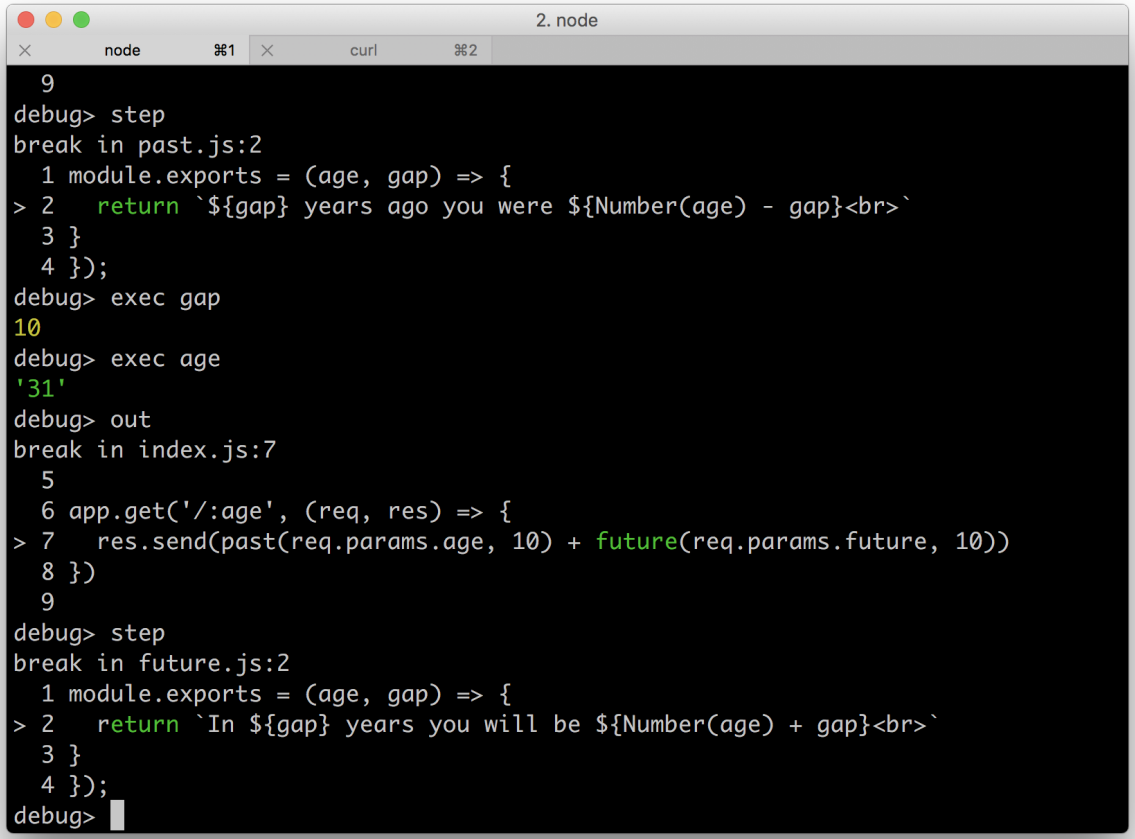
Now let's step back out of the `past` function, we use the `out` command to do this, like so:

```
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.

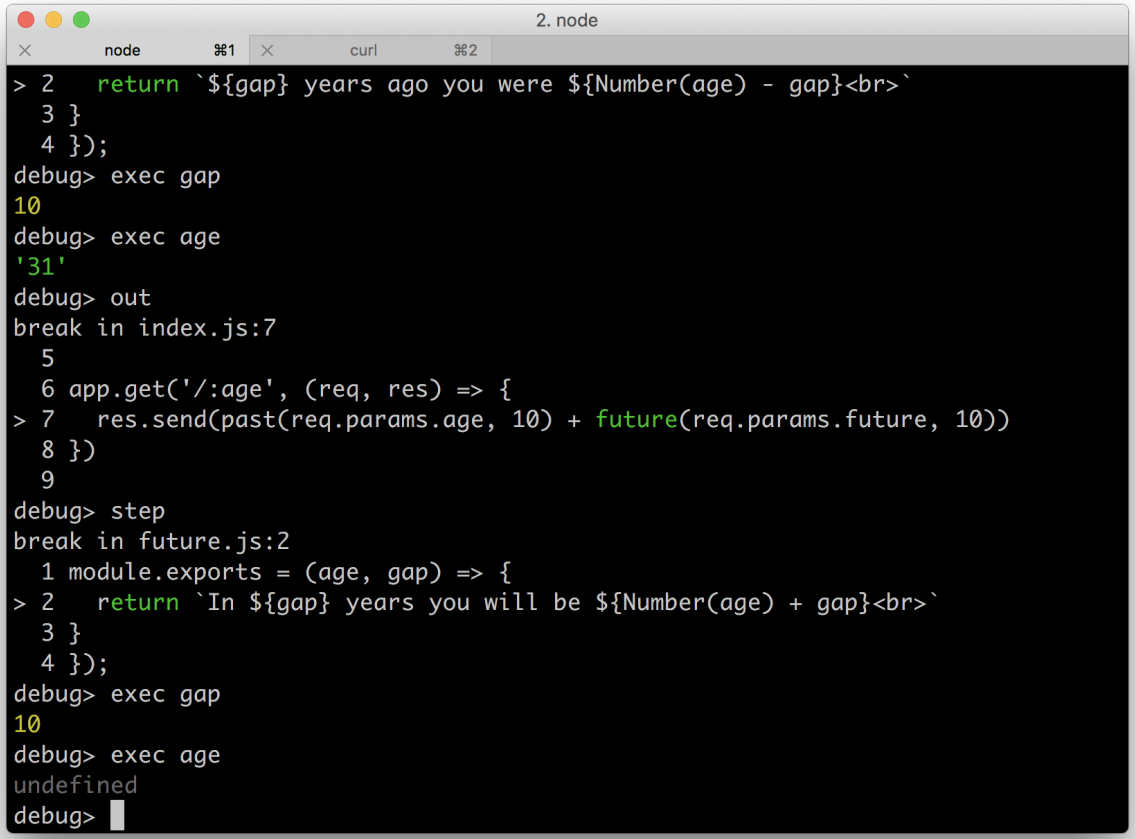
```
debug> step
```



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
```



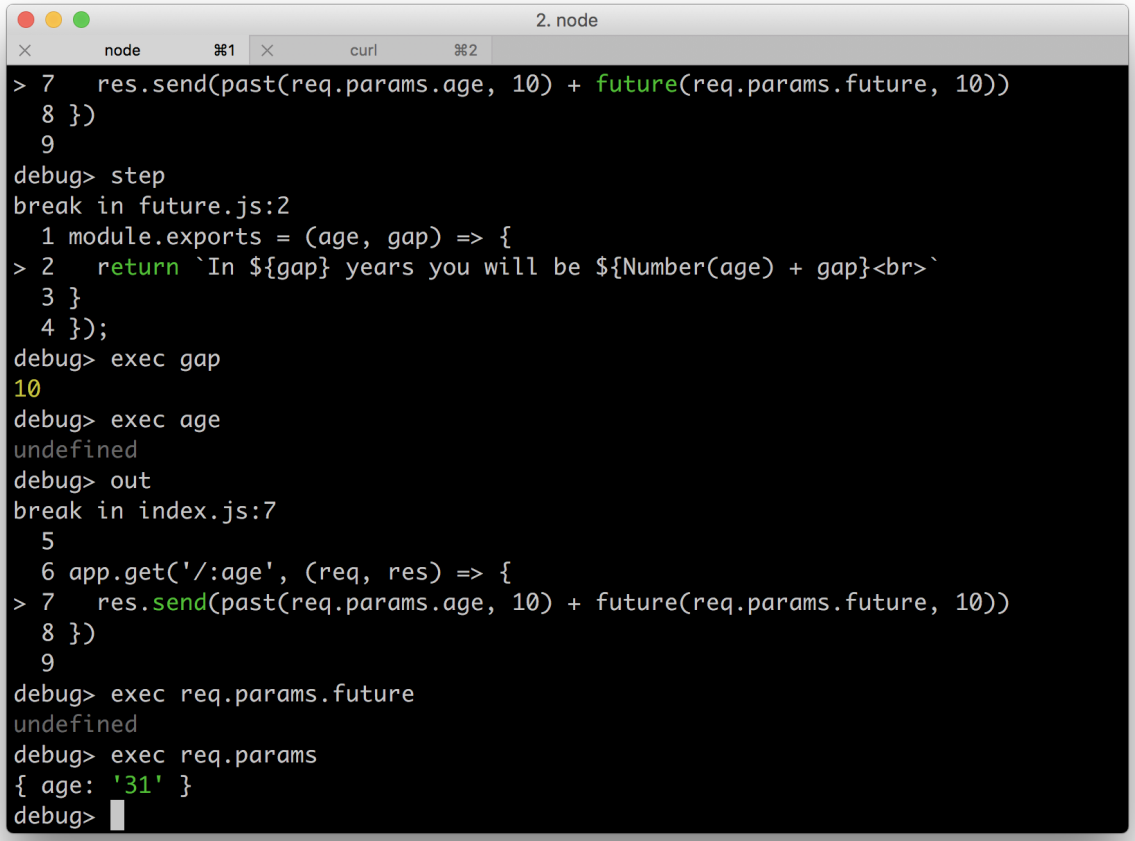
Aha, we can see that `age` is `undefined`, let's step back up into the router function using the `out` command:

```
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

Enhancing Stack Trace Output

[cute stack]

Getting Ready

How to do it

How it works

There's more

Increasing Stacksize

Asynchronous Stack Traces

Error.prepareStackTrace

See also

Enabling Debug Logs

Getting Ready

How to do it

How it works

There's more

pino-debug

####

See also

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**

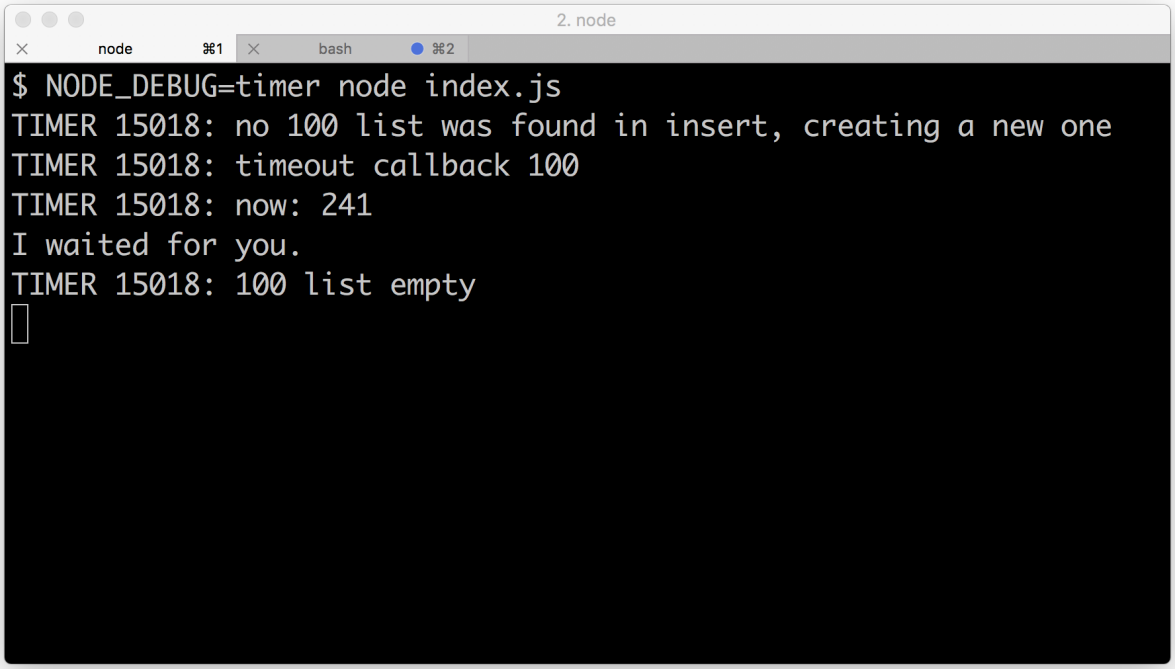
How to do it

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

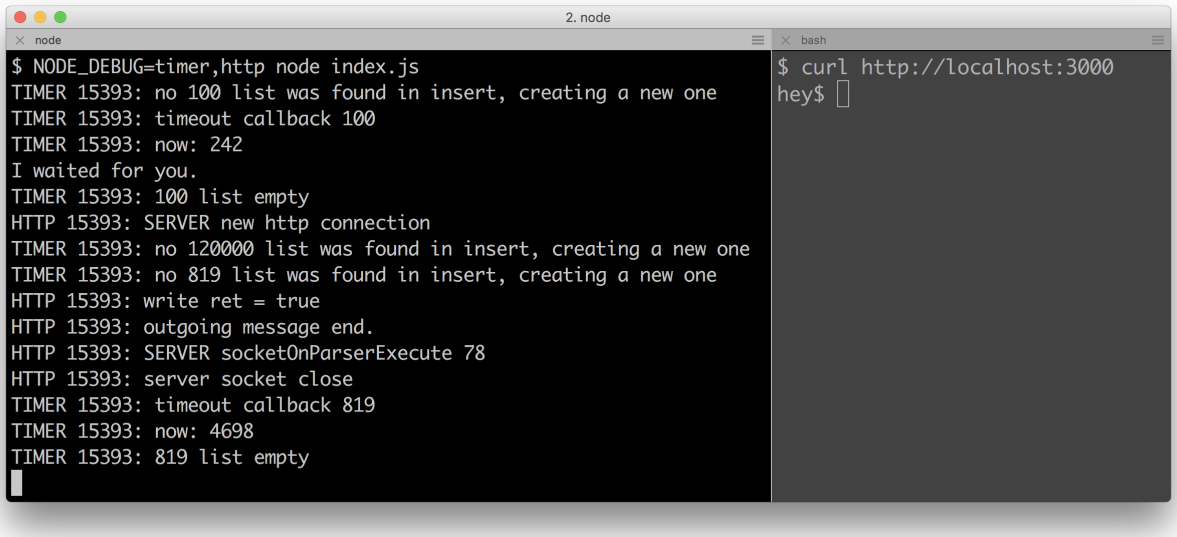
Let's try running the process again with both `timer` and `http` flags enabled:

```
$ 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 out own core like log messages

[how to etc]

[tip box recommending `debug` module instead]

Debugging Node Core Libraries

- run with --node-inspect and --debug-brk (point to previous recipe dealing with general usage of node--inspect)
- navigate to (no domain) files
- find util.js
- find exports.debuglog
- set breakpoint in function created by debuglog
- press run
- cycle through messages until message is odd number (like 819)
- use stack inspector to find the utcDate function
- understand timers.enroll and unrefActive
- understand what utcDate is doing

See also

- TBD

Tracing Asynchronous Operations

Getting Ready

How to do it

How it works

There's more

See also

Postmortem Debugging

Getting Ready

How to do it

How it works

There's more

See also