Node.js - the core

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Overview

- "Node's goal is to provide an easy way to build scalable network programs."
  - http://nodejs.org/#about
- A full programming environment, not just for building "servers"
- "The official name of Node is "Node".
  The unofficial name is "Node.js" to disambiguate it from other nodes."
  - https://github.com/joyent/node/wiki/FAQ
- Event-based rather than thread-based; can use multiple processes
- Assumes most time consuming operations involve I/O
  - invoked asynchronously; non-blocking
  - a callback function is invoked when they complete
- Created by Ryan Dahl at Joyent

passed control of the project to Isaac Schlueter on 1/30/12

- Runs on top of Chrome V8 (see next slide)
- Implemented in C++ and JavaScript
- Supported on Linux, Mac OS X and Windows

a cartoon from substack

Should You Use It?

- Reasons To Use
  - application can benefit from asynchronous, non-blocking I/O
  - application is not compute-intensive
  - V8 engine is fast enough
  - prefer callback or actor models of concurrency
    - over thread-based approach with synchronized access to mutable state
  - same language on client and server
  - like dynamically typed languages
  - large number of JavaScript developers
- Some issues being addressed
  - finding packages - there are a large number of them and finding the best ones isn't easy enough
  - debugging - stack traces from asynchronously executed code are incomplete
  - event loop - sometimes difficult to determine why a program isn't exiting
    - typically due to open connections

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Multiple Threads & Processes

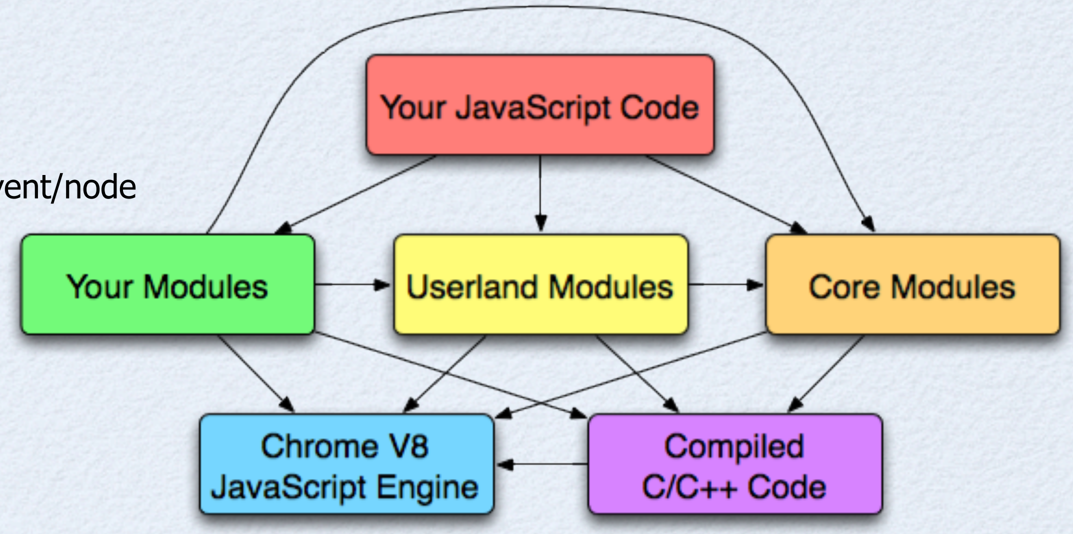
- Node uses multiple threads internally
  - to simulate non-blocking file I/O
- You can’t create new threads
  - unless you use “Threads A GoGo”
    - https://github.com/xk/node-threads-a-gogo
    - “provides an asynchronous, evented and/or continuation passing style API for moving blocking/longish CPU-bound tasks out of Node's event loop to **JavaScript threads that run in parallel** in the background and that **use all the available CPU cores automatically**; all **from within a single Node process**”
- Can use multiple, cooperating processes
  - see “Child Processes” core module
    - processes created with `fork` function can emit and listen for messages
  - see “Clusters” core module
    - “easily create a network of processes that all share server ports”

Chrome V8

- From Google
- Used by Chrome browser and Node.js
- Implemented in C++
- Currently supports ECMAScript 5
- Node adopts the JavaScript syntax supported by V8
  - so will support ES6 when V8 supports it

Where To Look For Functionality

1. JavaScript
   - core classes: **`Arguments`**, **`Array`**, **`Boolean`**, **`Date`**, **`Error`**, **`Function`**, **`Global`**, **`JSON`**, **`Math`**, **`Number`**, **`Object`**, **`RegExp`**, **`String`**
2. Core Modules
   - included with Node
   - http://nodejs.org/docs/latest/api/
   - view source at https://github.com/joyent/node
     - JavaScript is in **`lib`** directory
     - C++ code is in **`src`** directory
3. Userland Modules (third party)
   - typically installed using NPM tool
   - http://search.npmjs.org/
   - 8802 NPM packages on 4/12/12
4. Write yourself



Packages have JavaScript APIs,
but can be partially implemented in C++.

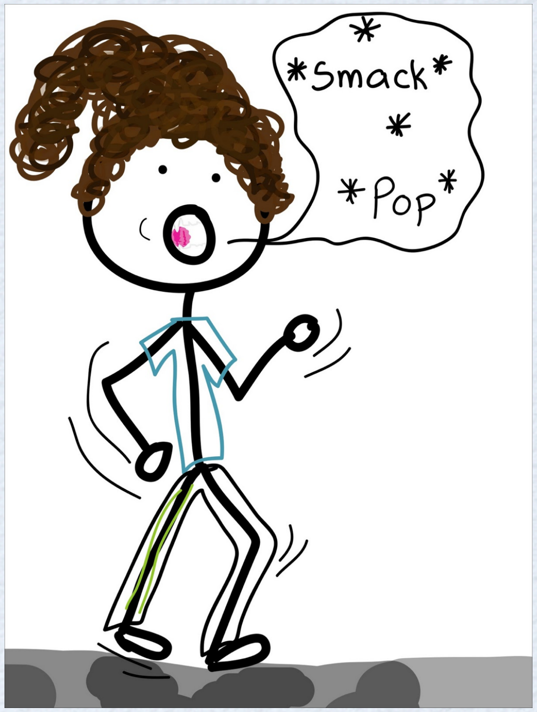
Event Loop

- When a Node program starts,
  it automatically starts an event loop
  - `node name.js`
- The currently running function, or the main script,
  can add function calls to the event queue
  - one way is by passing a function to `process.nextTick`
- When the currently running function completes
  - next function in event queue is removed from queue and run
- Most asynchronous functions, such as those that perform I/O
  - take a callback function as an argument
  - add a call to that function to the event queue when their work completes
- Program ends when event queue is empty
  - and there are no open network connections

U.K. roller coaster
(1930 to 2007)

Synchronous vs. Asynchronous

- Asynchronous functions
  - preferred over synchronous in most cases,
    especially when time to complete is long or unpredictable
  - take a callback function, typically as last argument
  - invoke it, passing an error description as first argument
    and possibly additional arguments
- Synchronous functions
  - can make application unresponsive if long running
  - do not take a callback function
  - if an error occurs, throw an error description
    - either a string or an Error object
    - throwing an Error is preferred because when strings are thrown, no stacktrace is available



Callbacks

- Functions passed to asynchronous functions
  - often anonymous
- Invoked any number of times,
  but often just once when operation completes
- Parameter that accepts callback
  - by convention, last parameter
  - by convention, named **`cb`** or **`callback`**
- Callback parameters
  - typically an object describing an error, if any, and a result
  - by convention, error is first argument and is named **`err`**
- Some libraries require following these conventions
  - ex. Async.js
- See example on next slide

Callback Example

JavaScript

```
var fs = require('fs');

function readObject(filePath, cb) {
  fs.readFile(filePath, function (err, buf) {
    var obj = null;
    if (!err) {
      try {
        obj = JSON.parse(buf); // can throw
      } catch (e) {
        err = e;
      }
    }
    cb(err, obj);
  });
}

readObject('demo.json', function (err, obj) {
  if (err) {
    console.error(err);
  } else {
    console.log(obj);
  }
});
```

demo.json

```
{
  "name": "Mark Volkmann",
  "address": {
    "street": "644 Glen Summit",
    "city": "St. Charles",
    "state": "Missouri",
    "zip": 63304
  },
  "hobby": "running"
}
```

CoffeeScript

```
fs = require 'fs'

readObject = (filePath, cb) ->
  fs.readFile filePath, (err, buf) ->
    if !err
      try
        obj = JSON.parse(buf) # can throw
      catch e
        err = e
    cb err, obj

readObject 'demo.json', (err, obj) ->
  if err
    console.error err
  else
    console.log obj
```

Node Globals

(other than standard JavaScript globals)

- Variables defined outside functions
  - are global in browsers
  - are local to current module in Node

- Node global variables
  - **`console`** - used to write to stdout and stderr
  - **`global`** - object that holds most global properties and functions
    - can use to share properties across modules; values can be functions
  - **`process`** - has methods that get info about and interact with current process; extends **`EventEmitter`**

    more on this later
  - **`require`** - has property **`cache`** (see next slide)
  - **`Buffer`** - constructor function for creating objects that read and write data, especially binary data
- Node global functions
  - **`require`**, **`setTimeout`**, **`clearTimeout`**, **`setInterval`**, **`clearInterval`**

    ☆

Node Local Variables

- Node variables that are local to current module
  - **`__dirname`**
    - full path to directory that contains the module source file
  - **`__filename`**
    - full path to source file name that defines the module
  - ☆ **`module`**
    - object that holds information about the current module
    - shared by all instances of current module
    - main property of interest is **`exports`**
  - ☆ **`exports`**
    - object used to export properties from a module; values can be functions
    - same as **`module.exports`**
  - **`require.cache`**
    - a property on the **`require`** function
    - holds required modules so each is only loaded once
    - delete a property to allow a module to be reloaded by a subsequent call to **`require`**
      - property is full path to module, ex. **`delete require.cache[__dirname + '/mymodule.js'];`**

The **`require`** function has other properties, but they are rarely used directly.
They include: **`extensions`**, **`main`**, **`registerExtension`** and **`resolve`**.

console Methods

similar to methods supported in browsers

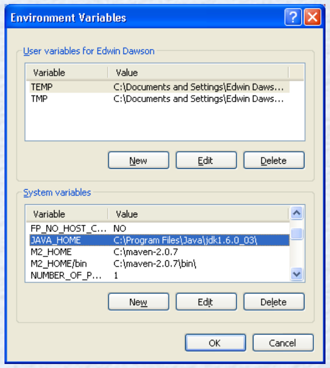
- ☆ **`console.log(`*`args`*`)`** - writes to stdout with a newline
  - first arg can be a string containing formatting directives
  - if not, **`util.inspect`** is called on each argument (returns string representation of object)
  - formatting directives: **`%s`** - String, **`%d`** - Number, **`%j`** - JSON, **`%%`** - single percent sign
- **`console.info`** - same as **`console.log`**
- **`console.warn`** - same as **`console.log`**, but writes to stderr
- **`console.error`** - same as **`console.warn`**
- **`console.dir(`*`obj`*`)`** - writes result of **`util.inspect(`*`obj`*`)`** to stdout
- **`console.time(`*`label`*`)`** - marks start time
- **`console.timeEnd(`*`label`*`)`** - marks end time and outputs label and duration
- ☆ **`console.trace`** - writes stack trace to stderr
- **`console.assert(`*`boolean, msg`*`)`**
  - same as **`assert.ok()`**; throws **`AssertionError`** with ***msg*** if false

multiple arguments are output with a space between each

Process Properties

- ☆ **`process.argv`** - array containing **`'node'`**, main script absolute file path, and command-line arguments
- ☆ **`process.env`** - object containing environment variables
- **`process.pid`** - process id
- **`process.stdin`** - non-blocking readable stream; paused by default
  - emits **`'data'`** event when return key is pressed and **`'end'`** event when ctrl-d is pressed

  see upcoming example
- **`process.stdout`** and **`process.stderr`** - blocking, writable streams
  - important so output from asynchronous functions isn't interspersed
- **`process.title`** - get/set name displayed by **`ps`** command; defaults to "node" doesn't work on Mac OS X
- **`process.version`** - Node version
- and more



User variables for Edwin Dawson

Variable	Value
TEMP	C:\Documents and Settings\Edwin Daws...
TMP	C:\Documents and Settings\Edwin Daws...

System variables

Variable	Value
FP_NO_HOST_C...	NO
JAVA_HOME	C:\Program Files\Java\jdk1.6.0_03\
M2_HOME	C:\maven-2.0.7
M2_HOME/bin	C:\maven-2.0.7\bin\
NUMBER_OF_P...	1

Process Methods

- **`process.chdir(`*`directory`*`)`** - changes current working directory
- **`process.cwd()`** - returns current working directory
- ☆ **`process.exit(`*`code`*`)`** - exits process with given status code
- **`process.memoryUsage()`**
  - returns object with **`heapTotal`** and **`heapUsed`** properties
- ☆ **`process.nextTick(`*`function`*`)`**
  - places given function at end of event loop queue so it runs in next iteration of event loop
  - one way to break up a long running function that avoids blocking event loop

see upcoming example

- **`process.uptime()`**
  - returns number of seconds (integer, not float) process has been running
- more

Process Events

- **`exit`** - process is about to exit; event loop is no longer running
- **`uncaughtException`** - error has bubbled to top
  - if a listener is registered, uncaught exceptions will not cause a stack trace to print and program to exit
- POSIX signals - ex. SIGINT emitted when ctrl-c is pressed

```
process.on(event-name, function () {
  ...
});
```

for more detail on listening for events, see slides on **`EventEmittter`** later

Buffers

- For reading and writing data, including binary data
  - some read and write functions in the "file system" module work with **`Buffer`** objects
- Must specify encoding when converting between strings and **`Buffer`** objects
  - **`'ascii'`**, **`'base64'`**, **`'binary'`**, **`'hex'`**, **`'ucs2'`**, **`'utf8'`**
- To create a **`Buffer`**
  - **`new Buffer(`*`size-in-bytes`*`)`**
  - **`new Buffer(`*`array`*`)`**
  - **`new Buffer(`*`string`*`, `*`encoding`*`='utf8')`**
- **`Buffer`** properties
  - **`length`** in bytes

"If you pass a **`Buffer`** to a function,
it's no longer your buffer!
Reading from it or writing to it
at that point is entering the
territory of undefined behavior."
Issac Schlueter on
Node.js mailing list, 3/15/12

Buffer Writing Methods ...

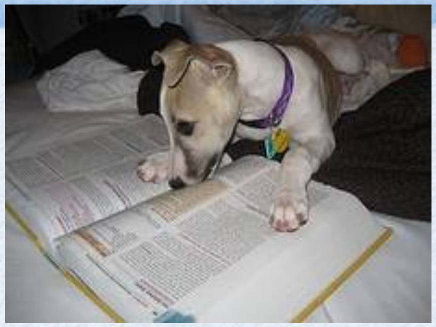
- ***buffer[index] = value;***
  - sets a given byte
- ***buffer.write(string,*** ***offset*=0, *length*=buffer.length, encoding='utf8')**
  - length is the number of bytes to write
  - if not enough room, will write as many bytes as will fit
  - returns number of bytes written
- ***buffer.writetype(value, offset, noAssert*=false)**
  - where type is **Int8**, **Int16BE**, **Int16LE**, **Int32BE**, **Int32LE**, **UInt8**, **UInt16BE**, **UInt16LE**, **UInt32BE**, **UInt32LE**, **FloatBE**, **FloatLE**, **DoubleBE**, **DoubleLE**
  - when **noAssert** is **true**, it doesn't verify that there is enough space from the offset to the end of the buffer to write the type
  - no return value since the number of bytes written is known from the method name

LE = Little Endian
BE = Big Endian

... Buffer Writing Methods

- **`buffer.copy(`*`targetBuffer`*`, `*`targetStart`*`=0, `*`sourceStart`*`=0, `*`sourceEnd`*`=buffer.length)`**
  - copies data from one buffer (the method receiver) to another
- **`buffer.fill(`*`value`*`, `*`offset`*`=0, `*`end`*`=buffer.length)`**
  - ***`value`*** is used for each byte
  - ***`value`*** should be an integer (0 to 255) or a string (only first byte is used)
  - if only ***`value`*** is specified, the entire buffer is filled

Buffer Reading Methods



- ***buffer*[*index*]**
  - returns a given byte
- ***buffer*.toString(*encoding*, *start*=0, *end*=buffer.length)**
- ***buffer*.read*type*(*offset*, *noAssert*=false)**
  - where type is **Int8**, **Int16BE**, **Int16LE**, **Int32BE**, **Int32LE**, **UInt8**, **UInt16BE**, **UInt16LE**, **UInt32BE**, **UInt32LE**, **FloatBE**, **FloatLE**, **DoubleBE**, **DoubleLE**
  - when **noAssert** is **true**, it doesn't verify that there are enough bytes from the offset to the end of the buffer to read the type
  - returns a **Number**

LE = Little Endian
BE = Big Endian

Other Buffer Methods/Functions

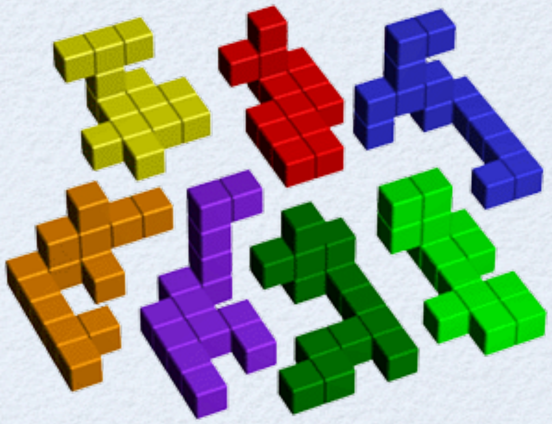
- Other **`Buffer`** methods
  - **`buffer.slice(`*`start`*`, `*`end`*`=buffer.length)`**
    - returns a new buffer that shares memory with the receiver
    - **`start`** is the offset and **`end`** is the length of the new buffer
- **`Buffer`** functions
  - **`Buffer.byteLength(`*`string`*`, `*`encoding`*`='utf8')`**
    - returns byte length of a given string which isn’t always the same as **`string.length`**
  - **`Buffer.isBuffer(`*`obj`*`)`**
    - determines if an object is a **`Buffer`**

Buffer Example

```
var buf = new Buffer(100);

buf.writeUInt16BE(12345, 0);

buf.writeFloatLE(Math.PI, 16);

var number = buf.readUInt16BE(0);
console.log('number =', number);

var pi = buf.readFloatLE(16);
console.log('pi =', pi);
```

Modules

- Defined by a single JavaScript file
  - may "require" others that are their own modules
- Top-level variables and functions defined in them are local to the module
  - not global in the entire runtime like in a browser environment
  - not visible to other modules unless exported
- Each module has it's own local variable named "**`module`**" that refers to an object with these properties
  - ☆ **`exports`** - initially set to `{}`; see next slide
  - **`parent`** - module object of module that required this one
  - **`filename`** - full path to file that defines this module
  - **`loaded`** - false until first **`require`** of the module completes; defaults to **`false`**
  - **`paths`** - array of filepaths that would be searched to find this module
  - **`exited`** - no longer used
  - **`children`** - no longer used



Defining Modules

- A module can expose functions to other modules by exporting them
  - not visible outside module if not exported

can also export non-function values, including objects and arrays, but that isn't as common

- To export many functions
  - **`exports.`*`name`* `=`** ***`some-function`*****`;`**
  - repeat to export additional things
- To export a single function
  - **`module.exports =`** ***`some-function`*****`;`**

can be a constructor function

  - replaces the default **`exports`** object
  - exports only one thing from the module
  - not used in conjunction with previous kind of exports
- Should also create **`package.json`** and **`README.md`**

used by npm

used by GitHub

A **Node package** is a collection of one or more JavaScript modules, optional C++ source files, optional shell scripts and a package.json file that describes the contents of the package and identifies the main module (or uses **`index.js`** by default).

Using Modules

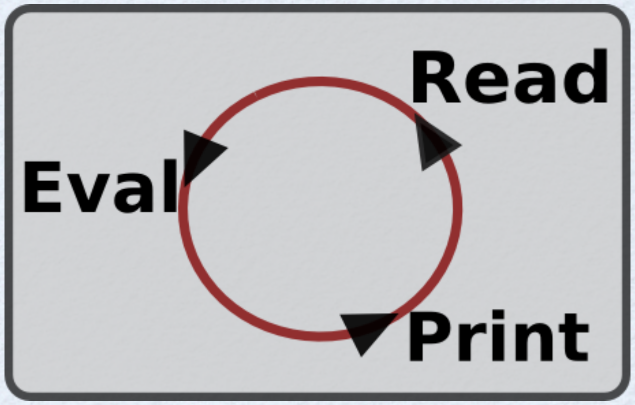
- `var name = require('module-name');`
  1. searches core modules
  2. searches directories listed in `NODE_PATH` environment variable
     - delimited with `:` in Linux and Mac or `;` in Windows
  3. searches upward in path for "node_modules" subdirectories
- `var name = require('module-path');`
  1. only reads from specified path; typically start with `./` or `../`
- Object returned is typically
  - an object with many properties that are the exported functions
  - a constructor function
  - a single, non-constructor function
- Caches result
  - subsequent requires for same module return cached object without re-reading the file that defines the module
    - unless `require.cache` property matching full path to module is deleted

searches for specified name, then tries these file extensions: `.js`, `.json`, `.node`

for more detail, see http://nodejs.org/docs/latest/api/modules.html

REPL

- Provides a Read-Eval-Print-Loop
  - launched from a terminal window by entering "**`node`**"
  - result of last expression is held in variable _
- Other than entering standard JavaScript code, the following REPL commands are supported
  - **`.help`** - lists these commands
  - **`.break`** - discards a partially entered multi-line expression (ctrl-c does same)
  - **`.exit`** - exits REPL (ctrl-d does same)
  - **`.save {`*`file-path`*`}`** - saves every line entered in REPL to specified file
  - **`.load {`*`file-path`*`}`** - loads a JavaScript file, even if it has already been loaded; picks up changes



Please Use A Lint Tool!

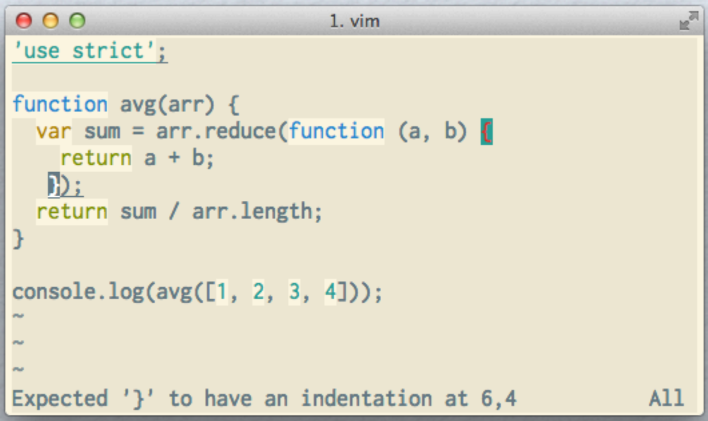
- Find coding errors and style violations, including incorrect indentation
- JSLint
  - from Douglas Crockford
  - very strict and opinionated - “Warning! JSLint will hurt your feelings.”
  - http://jslint.com/
  - nodelint is an npm module that allows JSLint to be run from command line
    - https://github.com/tav/nodelint

- JSHint
  - a fork of JSLint from Anton Kovalyov, Wolfgang Kluge and Josh Perez
  - more configurable, so less opinionated
  - http://www.jshint.com/
  - node-jshint is an npm module that allows JSHint to be run from command line
    - https://github.com/jshint/node-jshint
    - `npm install -g jshint`

for more detail, see http://nodejs.org/docs/latest/api/modules.html

Lint Tool Editor Integration

- Highlights errors/violations as you type!
- Emacs
  - https://github.com/daleharvey/jshint-mode
- Vim
  - jslint.vim - https://github.com/hallettj/jslint.vim
  - jshint.vim - https://github.com/manalang/jshint.vim
- Sublime
  - subline-jslint - https://github.com/fbzhong/sublime-jslint
  - sublime-jshint - https://github.com/uipoet/sublime-jshint
  - Sublime Linter - http://rondevera.github.com/jslintmate/



```
'use strict';

function avg(arr) {
  var sum = arr.reduce(function (a, b) {
    return a + b;
   });
  return sum / arr.length;
}

console.log(avg([1, 2, 3, 4]));
~
~
~
Expected '}' to have an indentation at 6,4          All
```

Core Modules

Overview

- Core modules are “modules and bindings that are compiled into Node”
- “In general, Node is based on the philosophy that it should not come with batteries included.”
- “One goal of Node's minimal core library is to encourage people to implement things in creative ways, without forcing their ideas onto everyone.”
- “With a tiny core and a vibrant user space, we can all flourish and experiment without the onerous burden of having to always agree”
- See links in API doc at http://nodejs.org/docs/latest/api/

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Utilities ...

```
var util = require('util');
```

- **`util.debug(`*`string`*`)`** - writes to stderr preceded by "**`DEBUG: `**"
- **`util.log(`*`string`*`)`** - writes to stdout preceded by timestamp and "**` - `**"
- **`util.format(`*`fmt-string`*`, `*`args`*`)`**
  - returns a formatted string
  - formatting directives: `%s` - String, `%d` - Number, `%j` - JSON, `%%` - single percent sign
  - excess arguments are converted to strings using `util.inspect(`*`arg`*`)`
- **`util.inspect(`*`object`*`, `*`hidden`*`=false, `*`depth`*`=2)`**
  - returns string representation of an object
  - includes non-enumerable properties only if ***`hidden`*** is true
  - traverses objects to default or specified ***`depth`***; pass **`null`** for infinite

... Utilities ...

- **`util.isArray(value)`** - determines if an object is an **`Array`**
  - in ES5, can use **`Array.isArray(value)`**
- **`util.isDate(value)`** - determines if an object is a **`Date`**
- **`util.isError(value)`** - determines if an object is an **`Error`**
- **`util.isRegExp(value)`** - determines if an object is a **`RegExp`**
- Use **`typeof`** operator for other tests
  - `typeof(value) === 'boolean'|'number'|'string'|'object'|'function'|'undefined'`

Why not just use the instanceof operator in place of these?

JavaScript's **`instanceof`** operator doesn't work across contexts, including those created with Node's "vm" module and created in different browser windows or frames.

The **`util.is*`** functions provide a more reliable way to determine if an object is of one of these fundamental types.

Here's the implementation of **`util.isDate`**:

```
function isDate(d) {
  return typeof d === 'object' &&
    objectToString(d) === '[object Date]';
}
```

... Utilities

- **`util.inherits(`*`ctor`*`, superCtor)(`*`obj`*`)`**
  - inherits prototype methods from one constructor into another
  - prototype of ***`ctor`*** is set to a new object created from ***`superCtor`***
  - adds **`super_`** property to ***`ctor`***

```
var util = require('util');

function MySuper() {}

MySuper.prototype.foo = function () {
  console.log('MySuper foo entered');
};

function MySub() {
  MySuper.call(this);
}

util.inherits(MySub, MySuper);

MySub.prototype.foo = function () {
  MySub.super_.prototype.foo();
  console.log('MySub foo entered');
};

var sub = new MySub();
sub.foo();
```

can pass arguments to superclass ctor here

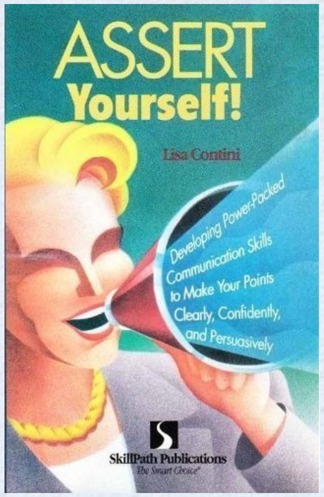
calls superclass method

Output:
```
MySuper foo entered
MySub foo entered
```

Assertion Testing ...

```
var assert = require('assert');
```

- Basic assertions that throw an **`Error`** if a condition isn't met
- Used by some unit test frameworks
- Actual and expected values are specified in opposite order of many other testing APIs
- Call functions on this **`assert`** object that are listed on the next slide
  - ex. `assert.equal(score, 100, 'perfect score');`


ASSERT
Yourself!
Lisa Contini
Developing Power-Packed Communication Skills to Make Your Points Clearly, Confidently, and Persuasively
SkillPath Publications
The Smart Choice

... Assertion Testing

- Functions
  - `ok(`*`value`*`, [`*`message`*`])` or *`assert`*`(`*`value`*`, [`*`message`*`])`
    - verifies that *`value`* is truthy; *`value`* can be a boolean condition
  - `equal(`*`actual`*`, `*`expected`*`, [`*`message`*`])` - uses `==`, so performs type conversions
  - `notEqual(`*`actual`*`, `*`expected`*`, [`*`message`*`])` - uses `!=`, so performs type conversions
  - `deepEqual(`*`actual`*`, `*`expected`*`, [`*`message`*`])` - also compares nested properties and array elements
  - `notDeepEqual(`*`actual`*`, `*`expected`*`, [`*`message`*`])` - ditto
  - `strictEqual(`*`actual`*`, `*`expected`*`, [`*`message`*`])` - uses `===`, so no type conversions
  - `notStrictEqual(`*`actual`*`, `*`expected`*`, [`*`message`*`])` - uses `!==`, so no type conversions
  - `throws(`*`fn`*`, [`*`error`*`], [`*`message`*`])` - succeeds if *`fn`* throws any error or a specified one
  - `doesNotThrow(`*`fn`*`, [`*`error`*`], [`*`message`*`])` - succeeds if *`fn`* does not throw any error or a specified one
  - `ifError(value)` - throws if value is truthy; useful for testing first parameter in callbacks
  - `fail(`*`actual`*`, `*`expected`*`, `*`message`*`, `*`operator`*`)`
    - throws `AssertionError` with *`message`*, ignoring other arguments
    - if *`message`* is null, the error message *`actual`* `+ ' ' +` *`operator`* `+ ' ' +` *`expected`* and *`message`* isn't used

see Node.js
issue #2993

Assertion Examples

```
var assert = require('assert');
var fs = require('fs');

assert(1 < 2, 'math works');

var actual = [1, [2, 3], 4];
var expected = [1, [2, 3], 4];
assert.deepEqual(actual, expected);

assert.throws(
  fs.readFileSync.bind(null, '/does/not/exist'),
  Error);

assert.doesNotThrow(
  function () {
    fs.readFileSync('demo.js');
  },
  Error);

console.log('calling fs.readFile');
fs.readFile('/does/not/exist', function (err, data) {
  assert.ifError(err);
  console.log('data =', data);
});

assert.fail(null, null, 'did not expect to be here');
```

OS

```
var os = require('os');
```

- Retrieves information about the operating environment
  - processor architecture (ex. x64 or ia32 which are specific Intel processor architectures)
  - host name
  - load average over last 1, 5 and 15 minutes
  - OS platform (ex. 'darwin')
  - OS type (ex. 'Darwin')
  - OS release number
  - uptime in seconds
  - free and total memory in bytes
  - information about each network interface
  - information about each CPU
- Get number of processors with **`os.cpus().length`**

OS Example

```
var os = require('os');

console.log('arch =', os.arch());
console.log('hostname =', os.hostname());
console.log('loadavg =', os.loadavg()); // 1, 5 and 15 minute load averages
console.log('platform =', os.platform());
console.log('release =', os.release());
console.log('type =', os.type());
console.log('uptime =', os.uptime(), 'seconds');

console.log('\nfreemem =', os.freemem(), 'bytes');
console.log('totalmem =', os.totalmem(), 'bytes');
var pctFree = os.freemem() / os.totalmem() * 100;
console.log('% free =', pctFree.toFixed(2) + '%');

// Returns object where keys are interface names and
// values are arrays of objects, 1 per address for the interface,
// that have address, family and internal properties.
console.log('\nnetworkInterfaces =', os.networkInterfaces());

// Returns array of objects, 1 per CPU,
// that have model, speed (in MHz) and times
// (# of CPU ticks spent in user, nice, sys, idle and irq) properties.
console.log('\ncpus =', os.cpus());
```

percentages with values between 0 and 1

user - milliseconds executed at user level without nice priority
nice - milliseconds executed at user level with nice priority
system - milliseconds executed at system level
idle - milliseconds doing nothing
irq - milliseconds servicing interrupts (includes waiting on I/O?)

OS Example Output

```
arch = ia32
hostname = Mark-Volkmanns-MacBook-Pro-17.local
loadavg = [ 0.8515625, 0.67724609375, 0.64111328125 ]
platform = darwin
release = 11.2.0
type = Darwin
uptime = 15954 seconds

freemem = 3607273472 bytes
totalmem = 8589934592 bytes
```

`lo0` is the "virtual loopback interface".
Packets sent to this are routed **internally**
to the network loopback.
This bypasses local network interface hardware,
reducing load on network resources.

```
networkInterfaces = { lo0:
   [ { address: 'fe80::1', family: 'IPv6', internal: true },
     { address: '127.0.0.1', family: 'IPv4', internal: true },
     { address: '::1', family: 'IPv6', internal: true } ],
  en0:
   [ { address: 'fe80::5ab0:35ff:fef3:d095', family: 'IPv6', internal: false },
     { address: '192.168.0.5', family: 'IPv4', internal: false } ],
  en1:
   [ { address: 'fe80::5ab0:35ff:fe6a:23e4', family: 'IPv6', internal: false },
     { address: '192.168.0.6', family: 'IPv4', internal: false } ] }
```

```
cpus = [ { model: 'MacBookPro6,1',
    speed: 2660,
    times: { user: 730150, nice: 0, sys: 569300, idle: 14654330, irq: 0 } },
  { model: 'MacBookPro6,1',
    speed: 2660,
    times: { user: 279490, nice: 0, sys: 126060, idle: 15548110, irq: 0 } },
  { model: 'MacBookPro6,1',
    speed: 2660,
    times: { user: 985960, nice: 0, sys: 616860, idle: 14350840, irq: 0 } },
  { model: 'MacBookPro6,1',
    speed: 2660,
    times: { user: 254950, nice: 0, sys: 115040, idle: 15583670, irq: 0 } } ]
```

Readline ...

```
var rl = require('readline');
```

- Reads streams one line at a time
- Supports many control keys when reading from stdin
  - see **`_ttwrite`** method in **`readline.js`**
- Functions
  - **`createInterface(`*`input`*`, `*`output`*`, `*`completer`*`)`**
    - **`input`** and **`output`** are streams
      - typically **`process.stdin`** and **`process.stdout`** (should probably be the defaults)
      - can be a file streams
    - **`completer`** is a function that provides tab completion; can omit; see example ahead
  - **`setPrompt(`*`prompt`*`, [`*`length`*`])`**
    - sets prompt displayed when **`prompt()`** is called
    - if **`length`** is specified, the prompt will be right-padded with spaces to meet it
  - **`prompt()`**
    - outputs prompt specified in **`setPrompt()`**
    - user can enter a line without a prompt

Key	Action
ctrl-c	emits SIGINT
ctrl-z	emits SIGTSTP
ctrl-b	back one char
ctrl-f	forward one char
ctrl-left	go to left word boundary
ctrl-right	got to right word boundar
ctrl-a	go to start
ctrl-e	go to end
ctrl-h	delete char to left of cursor
ctrl-d	delete char under cursor
ctrl-u	delete entire line
ctrl-k	delete to end
ctrl-w	delete back to word boundary
ctrl-backspace	same as ctrl-w
ctrl-delete	delete forward to word boundary
ctrl-p	previous in history
ctrl-n	next in history

... Readline

- More Functions
  - **`question(`*`text, callback`*`)`**
    - outputs **`text`** instead of the specified prompt
    - passes line entered by user to callback
    - does not emit **`'line'`** event, but if additional lines are entered, **`'line'`** events are generated for those
  - **`write(`*`text`*`)`** - writes string to input as if user typed it
  - **`pause()`** - used internally for tab completion
  - **`resume()`** - used internally for tab completion
  - **`close()`** - marks interface as closed and emits **`'close'`** event, but doesn't close input stream
- Events
  - **`'line'`** - when user presses enter key or there is a newline in the stream
  - **`'close'`** - when **`close()`** is called or ctrl-c or ctrl-d are pressed

```
var rl = require('readline');

var intf = rl.createInterface(
  process.stdin, process.stdout);

intf.on('line', function (line) {
  // Only invoked if more than one line is entered.
  // The question method doesn't emit this event.
  console.log('line event: got ' + line);
});

intf.question('What is your name? ',
  function (name) {
    console.log('Hello, ' + name + '!');
  });
```

Readline Guess Example

```
var rl = require('readline');

// Generate a random number between 1 and 10.
var answer = Math.floor(Math.random() * 10) + 1;
console.log('A number between 1 and 10 has been selected.');

var intf = rl.createInterface(process.stdin, process.stdout);
function prompt(msg) {
  intf.setPrompt(msg);
  intf.prompt();
}

intf.on('line', function (line) {
  var number = parseInt(line, 10);
  if (isNaN(number)) {
    prompt('Enter a number: ');
  } else if (number < answer) {
    prompt('Too low: ');
  } else if (number > answer) {
    prompt('Too high: ');
  } else {
    console.log('CORRECT!');

    // Allow the program to terminate.
    intf.close();
    process.stdin.destroy();
  }
});

prompt('Guess the number: ');
```

Readline Completion Example

gets fruits that start with entered text

```
var rl = require('readline');
var fruits = ('apple banana blackberry blueberry cherry grape grapefruit ' +
  'lemon lime orange peach pear plum strawberry').split(' ');

function completer(partial) {
  var options = fruits.filter(function (word) {
    return word.indexOf(partial) === 0;
  });
  return [options, partial];
}

console.log('Enter names of fruits.');
console.log('Press tab for completion.');
console.log('To exit, enter "exit" or press ctrl-c or ctrl-d.');
var intf = rl.createInterface(process.stdin, process.stdout, completer);
intf.setPrompt('fruit: ');
intf.prompt();
intf.on('line', function (line) {
  if (line === 'exit') {
    intf.close();
    process.stdin.destroy(); // allows program to terminate
  } else {
    console.log('got ' + line);
    intf.prompt();
  }
});
```

```
// Asynchronous version
function completer(partial, cb) {
  var options = fruits.filter(function (word) {
    return word.indexOf(partial) === 0;
  });
  cb(null, [options, partial]);
}
```

TTY

```
var tty = require('tty');
```

- Intercepts terminal keystrokes
  - including whether shift, ctrl and meta keys were down
- Important for intercepting certain keystrokes before the operating system acts on them
  - for example, ctrl-c normally sends an interrupt signal (SIGINT) that causes a Node program to stop

TTY Example

```
var tty = require('tty');

process.stdin.resume(); // must do before entering raw mode
tty.setRawMode(true); // can't intercept key presses without this

// char string is only set for normal characters.
// key object is set for all key presses.
// Properties of key include name, ctrl, meta and shift.
process.stdin.on('keypress', function (char, key) {
  console.log('char =', char);
  if (key) {
    console.log('key =', key);
    var name = '';
    if (key.shift) key.name = key.name.toUpperCase();
    if (key.meta) name += 'meta ';
    if (key.ctrl) name += 'ctrl ';
    name += key.name;
    console.log('You pressed ' + name);
    if (key.ctrl && key.name == 'c') {
      console.log('exiting');
      process.exit()
    }
  }
});
```

On Mac OS X, neither the option nor the command key cause the `meta` property to be set!

Events

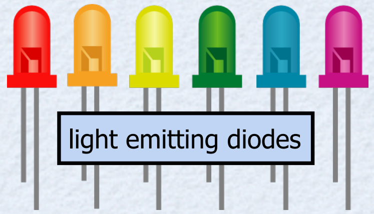
- Many Node classes inherit from **`EventEmitter`**
- Custom classes can also
- Objects that are event emitters
  - always emit **`'newListener'`** when listeners are added
  - often emit **`'error'`** when an error occurs in one of their methods
- Event listeners
  - functions that are invoked when events are emitted
  - passed any data emitted with the event
  - not passed the event name unless **`EventEmitter`** subclasses are specifically written to do so

EventEmitter Methods ...

```
var EventEmitter = require('events').EventEmitter;
```

only property exported

- **`setMaxListeners(`*`n`*`)`**
  - sets the maximum number of listeners that can be registered for a given event
  - default is 10; set to zero for unlimited
  - useful for finding bugs where an excessive number listeners are being registered
  - outputs warning using **`console.error`** and calls **`console.trace`**, but does not throw
- **`on(`*`event, listener`*`)`** or **`addListener(`*`event, listener`*`)`**
  - registers a listener function for a given event
- **`once(`*`event, listener`*`)`**
  - registers a listener function for a given event and removes it after its first invocation
- **`emit(`*`event, args`*`)`**
  - invokes listener functions for the event in the order they registered; passes all args to them
  - synchronous! - listener functions are run immediately, not added to event loop queue
  - workaround
    - listener functions can add a function to event loop queue by passing it to **`process.nextTick`**



... EventEmitter Methods

- **`removeListener(`*`event, listener`*`)`**
  - unregisters a listener function for a given event
- **`removeAllListeners([`*`event`*`])`**
  - unregisters all listener functions for a given event or all events
- **`listeners(`*`event`*`)`**
  - returns a live array of all listener functions for a given event
  - can delete function elements to unregister
  - can push function elements to register

Event Example

```
var EventEmitter = require('events').EventEmitter;
var util = require('util');

function Thermostat() {}
util.inherits(Thermostat, EventEmitter);

Thermostat.prototype.set = function (temperature) {
  this.temperature = temperature;
  if (temperature < 32) {
    this.emit('cold', temperature);
  } else if (temperature > 100) {
    this.emit('hot', temperature);
  }
};

var t = new Thermostat();
t.on('cold', function (temp) {
  console.log(temp + ' is too cold!');
});
t.on('hot', function (temp) {
  console.log(temp + ' is too hot!');
});

t.set(50);
t.set(0); // outputs "0 is too cold!"
t.set(110); // outputs "110 is too hot!"
```

Path

`var path = require('path');`

- Methods

  p parameters are string file paths

  - **`normalize(`*`p`*`)`** - returns a new path after resolving `..` and `.`, and replacing consecutive slashes with one, in path ***p***
  - **`join(`*`path-parts`*`)`** - returns a path created by joining any number of path parts and normalizing
  - **`resolve([`*`from`*`...], `*`to`*`)`** - resolves relative path ***to*** to an absolute path by prefixing with the ***from*** values from right to left, using the first combination found to exist or the current directory if none exist

    also normalizes

    why right to left?
  - **`relative(`*`from`*`, `*`to`*`)`** - returns a relative path that can be used to cd from ***from*** to ***to***
  - **`dirname(`*`p`*`)`** - returns the directory portion of path ***p***
  - **`basename(`*`p`*`, [`*`ext`*`])`** - returns the filename portion of path ***p***, removing the extension ***ext*** if supplied
  - **`extname(`*`p`*`)`** - returns the extension of path ***p***, including a leading dot
  - **`exists(`*`p`*`, `*`callback`*`)`** - passes a boolean to callback indicating whether the path ***p*** exists
  - **`existsSync(`*`p`*`)`** - returns a boolean indicating whether the path ***p*** exists

  moved to the “File System” module in Node version 7

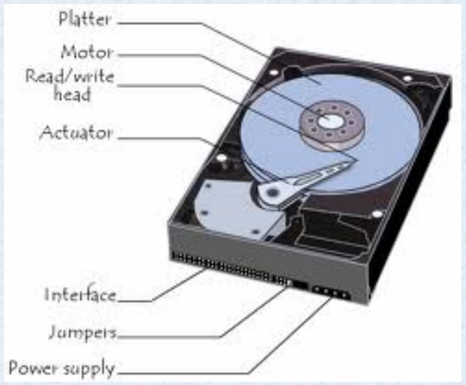
Path Examples

```
var path = require('path');

console.log(path.normalize('../fs/../console///demo.js'));
// ../console/demo.js

var dirs = ['../url', '../vm', '../zlib'];
var args = dirs.concat('demo.js');
console.log(path.resolve.apply(null, args));
// /Users/Mark/Documents/OCI/SVN/training/Node.js/labs/zlib/demo.js

var absPath = path.resolve('../foo.txt');
// Recall that __dirname holds the absolute path to the current directory.
// var absPath = __dirname + /foo.txt'; // same as above

console.log(path.dirname(absPath)); // parent of current directory
console.log(path.basename(absPath, '.txt')); // foo
console.log(path.extname(absPath)); // .txt

path.exists(absPath, function (existsP) {
  console.log(absPath + ' exists? ' + existsP); // false
});
```

File System

```
var fs = require('fs');
```

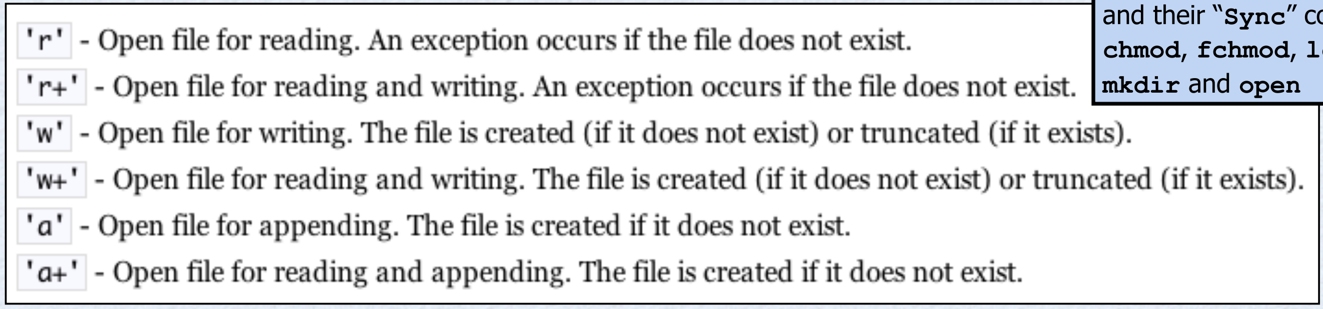
- Wraps access to POSIX file I/O functions
- Provides asynchronous (preferred) and synchronous versions of most functions
  - asynchronous functions take a callback function as their last argument
    - callback functions take an error description as their first argument
  - synchronous functions can throw errors
- Contains many more functions than any other core module
  - buckle up, six slides worth coming next!
  - for parameter details, see http://nodejs.org/docs/latest/api/fs.html



File System Functions ...

Use of async functions instead of sync functions is strongly encouraged to avoid blocking the event loop with long-running I/O operations.

- Open/Close
  - **`open`**/**`openSync`** - takes a path and returns a file descriptor
  - **`close`**/**`closeSync`** - takes a file descriptor
- Reading
  - **`read`**/**`readSync`** - takes a file descriptor and a **`Buffer`**; reads specified range of bytes from file into **`Buffer`**
  - **`readFile`**/**`readFileSync`** - takes a file path; reads entire file; returns data in a **`Buffer`**
- Writing
  - **`write`**/**`writeSync`** - takes a file descriptor and a **`Buffer`**;
    writes specified range of bytes from **`Buffer`** into file starting at a given position
  - **`writeFile`**/**`writeFileSync`** - takes a file path and a string or **`Buffer`**;
    writes bytes in string or **`Buffer`** to file, replacing existing content



- `'r'` - Open file for reading. An exception occurs if the file does not exist.
- `'r+'` - Open file for reading and writing. An exception occurs if the file does not exist.
- `'w'` - Open file for writing. The file is created (if it does not exist) or truncated (if it exists).
- `'w+'` - Open file for reading and writing. The file is created (if it does not exist) or truncated (if it exists).
- `'a'` - Open file for appending. The file is created if it does not exist.
- `'a+'` - Open file for reading and appending. The file is created if it does not exist.

modes are used by these functions and their "**`Sync`**" counterparts: **`chmod`**, **`fchmod`**, **`lchmod`**, **`mkdir`** and **`open`**

... File System Functions ...

- Streams
  - **`createReadStream`** - returns an **`fs.ReadStream`** object
  - **`createWriteStream`** - returns an **`fs.WriteStream`** object
  - see detail on stream objects later
- Directories
  - **`mkdir/mkdirSync`** - takes file path and optional access permissions mode (ex. '755') and creates a directory
  - **`readdir/readdirSync`** - takes file path and gets array of directory contents
  - **`rmdir/rmdirSync`** - takes directory path and deletes directory only if empty
- Links
  - **`link/linkSync`** - creates a file that is a link (a.k.a. hard link) to another
  - **`symlink/symlinkSync`** - creates a file that is a symbolic link (a.k.a. soft link) to another
  - **`readLink/readLinkSync`** - gets info. about the file referred to by a link
  - **`unlink/unlinkSync`** - deletes a link or file; note there is no **`rm`** function

For more on **hard links**, see http://en.wikipedia.org/wiki/Hard_link

For more on **symbolic links**, see http://en.wikipedia.org/wiki/Symbolic_link

... File System Functions ...

- Statistics
  - **`stat`**/**`statSync`** - takes a file path; returns an **`fs.Stats`** object that provides details about the file
  - **`fstat`**/**`fstatSync`** - same as **`stat`** versions, but takes a file descriptor object instead of a file path
  - **`lstat`**/**`lstatSync`** - same as **`stat`** versions, but if file path is to a link, describes the link instead of the target file
  - all return an **`fs.Stats`** object
    - methods: **`isFile`**, **`isDirectory`**, **`isBlockDevice`**, **`isCharacterDevice`**, **`isSymbolicLink`**, **`isFIFO`**, **`isSocket`**
    - properties: **`dev`**, **`ino`**, **`mode`**, **`nlink`**, **`uid`**, **`gid`**, **`rdev`**, **`size`**, **`blksize`**, **`blocks`**, **`atime`**, **`mtime`**, **`ctime`**
    - **`atime`**, **`mtime`** and **`ctime`** are **`Date`** objects

`atime` is time of last access
`mtime` is time of last content modification
`ctime` is time of last content, owner or permission change

- Timestamps
  - **`utimes`**/**`utimesSync`** - takes a file path, atime and mtime; changes atime and mtime values for the file
  - **`futimes`**/**`futimesSync`** - same as **`utimes`** versions, but takes a file descriptor object instead of a file path

... File System Functions ...

- Change owner
  - **`chown/chownSync`** - takes a file path, user id and group id
  - **`fchown/fchownSync`** - same as **`chown`** versions, but takes a file descriptor instead of a file path
  - **`lchown/lchownSync`** - same as **`chown`** versions, but if file path is to a link, changes the link instead of the target file

- Change mode (access permissions)
  - **`chmod/chmodSync`** - takes a file path and a mode (an octal number or a string) ex. 0755 or '755'
    - octal literals are not allowed in ES5 strict mode
  - **`fchmod/fchmodSync`** - same as **`chmod`** versions, but takes a file descriptor instead of a file path
  - **`lchmod/lchmodSync`** - same as **`chmod`** versions, but if file path is to a link, changes the link instead of the target file

... File System Functions ...

- Watching
  - **`watchFile`** - takes a file path, optional options and a callback
    - file path cannot be to a directory
    - calls callback every time the file is accessed (not under Mac OS X!) or modified
    - default options are typically good; see doc for detail
    - callback is passed current and previous **`fs.Stats`** objects
    - to detect file modification, compare current mtime value to previous one
  - **`unwatchFile`** - takes a file path; stops watching for file access
  - **`watch`** - takes a file path, optional options and a callback
    - file path can be to a directory (typical case)
    - does not detect changes in nested directories
    - default options are typically good; see doc for detail
    - callback is invoked when the file or directory being watched has a change
      - passed an event string (always 'change') and
        the associated file path (useful when watching a directory and a file in it changes)
    - returns an **`fs.FSWatch`** object that emits **`'change'`** and **`'error'`** events and has a **`close`** method

Currently the file path isn't consistently passed to the callback. It never is under Mac OS X because that OS doesn't provide the information.

When **`watch`** indicates that the content of a directory has changed, **`fs.readdir`** can be used to determine which files have changed. See the **`watch`** example coming up.

From Ben Noordhuis ... "**`fs.watch`** on OS X and the BSDs is backed by the **kqueue** event mechanism. It has a couple of known shortcomings, lack of *time updates being one of them.

Linux and Windows use the **inotify** and **ReadDirectoryChangesW** interfaces respectively, which are more robust.

Use **`fs.watchFile`** if you want consistent behavior across Unices. It's not nearly as efficient as **`fs.watch`** though, and it isn't supported on Windows."

... File System Functions

- Other
  - **`fsync/fsyncSync`** - synchronizes in-memory data with data on disk
  - **`realpath/realpathSync`** - resolves relative file paths to absolute paths
  - **`rename/renameSync`** - renames and/or moves a file
    - takes “from path” and “to path”; “to path” must include file name, not just directory
  - **`truncate/truncateSync`** - truncates or extends a file to a given byte length

Reading Files - Three Ways

```
var async = require('async');
var fs = require('fs');
var filePath = 'foo.txt';

fs.readFile(filePath, function (err, buf) {
  if (err) throw err;
  console.log(buf.toString());
});

var rs = fs.createReadStream(filePath);
rs.on('data', function (buf) {
  console.log(buf.toString());
});

var maxSize = 100;
var buf = new Buffer(maxSize);
var openFile = fs.open.bind(null, filePath, 'r');
var readFile = function (fd, cb) {
  fs.read(fd, buf, 0, buf.length, 0, function (err, bytesRead) {
    console.log(buf.toString());
    cb(err, fd);
  });
};
async.waterfall([openFile, readFile, fs.close], function (err) {
  if (err) throw err;
});
```

can be called multiple times for large files

can also listen for `'error'` events

This approach has the following advantages:
- can read from a specified chunk of the file
- can read into a specified chunk of the `Buffer`

Disadvantages include:
- all the things above MUST be specified
- the code is longer and more complicated

see more on **async** module in "Userland Modules" section

Writing Files - Three Ways

```
var async = require('async');
var fs = require('fs');

var filePath = 'foo.txt';
var data = 'red\ngreen\nblue\n';

// If file already exists, content is replaced.
fs.writeFile(filePath, data, function (err) {
  if (err) throw err;
});

var ws = fs.createWriteStream(filePath);
ws.write(data);
ws.end();

var buf = new Buffer(data);
var open = fs.open.bind(null, filePath, 'w');
var write = function (fd, cb) {
  fs.write(fd, buf, 0, buf.length, 0, function (err) {
    cb(err, fd);
  });
};
async.waterfall([open, write, fs.close], function (err) {
  if (err) throw err;
});
```

can listen for `'error'` events

This approach has the following advantages:
- can write into a specified chunk of the file
- can write from a specified chunk of the **`Buffer`**

Disadvantages include:
- all the things above MUST be specified
- the code is longer and more complicated

Watch Example ...

```
var async = require('async');
var fs = require('fs');
var dir = '.';

function getStats(dir, cb) {
  fs.readdir(dir, function (err, files) {
    if (err) return cb(err);

    var stats = {};

    // This function is passed to async.every below.
    var iterator = function (file, cb) {
      // Skip hidden files (start with a period).
      if (/^\./.test(file)) return cb(true);
      // Skip Vim backup files (end with a tilde).
      if (/~$/.test(file)) return cb(true);

      fs.stat(file, function (statErr, stat) {
        if (statErr) {
          err = statErr;
        } else {
          stats[file] = stat;
        }
        cb(!err); // stops async.every when there is an error
      });
    };
    async.every(files, iterator, function (result) {
      cb(err, stats);
    });
  });
}
```

Gets an **`fs.Stats`** object for every file in a given directory.
`dir` is a directory path.
`cb` is a callback that is passed **`err`** and an array of **`fs.Stats`** objects.

... Watch Example ...

```
function report(name, oldStat, newStat) {
  if (!oldStat && newStat) {
    console.log(name, 'was created');
    return;
  }

  var modified = newStat.mtime > oldStat.mtime;
  if (modified) {
    var diff = newStat.size - oldStat.size;
    var suffix = Math.abs(diff) === 1 ? 'byte' : 'bytes';
    var desc =
      diff > 0 ? 'increased by ' + diff + ' ' + suffix :
      diff < 0 ? 'decreased by ' + -diff + ' ' + suffix :
      'did not change';
    console.log(name, 'content modified, size', desc);
  }
}

var oldStats;
getStats(dir, function (err, stats) {
  oldStats = stats;
});
```

Reports activity for a single file.
`name` is a file name.
`oldStat` and `newStat` are `fs.Stats` objects.

... Watch Example

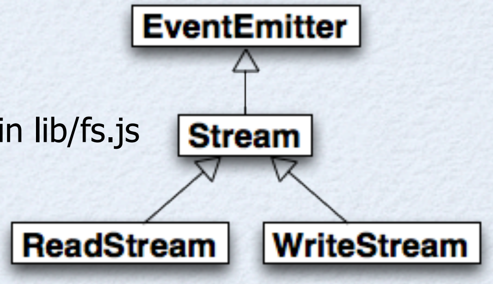
```
fs.watch(dir, function () {
  getStats(dir, function (err, newStats) {
    if (err) {
      return console.error(err);
    }

    Object.keys(oldStats).forEach(function (name) {
      if (!newStats[name]) {
        console.log(name, 'was deleted');
      }
    });

    Object.keys(newStats).forEach(function (name) {
      report(name, oldStats[name], newStats[name]);
    });

    oldStats = newStats;
  });
});
```

Under Mac OS X, `null` is always passed to the callback for `filePath`.
The callback is invoked when any file in the directory is created, deleted, or has its contents modified.
It is not invoked when

- a file is merely accessed
- the owner of a file is changed
- the permissions on a file are changed

Streams

- Two types
  - readable streams - created by **`fs.createReadStream(`*`file-path, [options]`*`)`**
  - writable streams - created by **`fs.createWriteStream(`*`file-path, [options]`*`)`**
  - options include **`flags`** (a mode at bottom of slide 11) and **`encoding`** (**`'ascii'`**, **`'base64'`**, **`'binary'`**, **`'hex'`**, **`'ucs2'`** or **`'utf8'`**)
- A stream can be one or both (duplex) types
- Classes
  - **`Stream`** inherits from **`EventEmitter`** defined in lib/stream.js
  - **`ReadStream`** and **`WriteStream`** inherit from **`Stream`** defined in lib/fs.js



There are several ways to create duplex streams in the core modules including:
the **`Stream`** pipe method,
the **`net.createServer`** and **`net.connect`** functions
(both return a **`net.Socket`** object which is a duplex stream)
and the **`tls.connect`** function.

Examples of non-duplex streams include:
`http.ServerRequest`, **`http.ServerResponse`**,
`fs.ReadStream` and **`fs.WriteStream`**.

Custom streams of both types can also be created.
For an example, see https://github.com/dominictarr/event-stream.

Readable Streams ...

- Events
  - **`open`** - when stream is ready; callback is passed a file descriptor object
  - **`data`** - when data has been read
    - callback is passed a **`Buffer`** object or a string if **`setEncoding`** was called on the stream
  - **`end`** - when end of stream is reached
    - no more **`'data'`** events will be emitted
  - **`error`** - when a read error occurs
  - **`close`** - when underlying file descriptor is closed
- Properties
  - **`readable`** - boolean indication of whether the stream can be read
    - changes to false if an **`error`** or **`end`** event is delivered or the **`destroy`** method is called on the stream

... Readable Streams

- Methods
  - `setEncoding(`*`encoding`*`)` - sets character encoding used
    - valid values are `'ascii'`, `'base64'`, `'binary'`, `'hex'`, `'ucs2'` and `'utf8'`
  - `pause()` - temporarily stops `'data'` events
  - `resume()` - resumes `'data'` events
  - `destroy()` - closes underlying file descriptor
    - no more events will be emitted after `close`
  - `destroySoon()` - closes underlying file descriptor
    - only after writes complete if the stream is also writable
  - `pipe(`*`destination`*`, [`*`options`*`])` - connects this stream to a writable stream
- See example on slide 17

everything read from the file is written to stdout

```
var fs = require('fs');
var rs = fs.createReadStream('TaleOfTwoCities.txt');
rs.pipe(process.stdout);
```

Reading a File By Lines

```
var fs = require('fs');

function readLines(filePath, cb) {
  var rs = fs.createReadStream(filePath, {bufferSize: 80});
  var leftover = '';

  rs.on('data', function (buf) {
    var lines = buf.toString().split('\n');
    lines[0] = leftover + lines[0];
    leftover = lines.pop(); // chunk at end
    lines.forEach(function (line) {
      cb(line);
    });
  });

  rs.on('end', function () {
    if (leftover.length > 0) {
      cb(leftover);
    }
  });
}

readLines('./story.txt', console.log);
```

callback is invoked once for each line

See slightly better implementation in node-liner userland module.

`npm install liner`

Writable Streams ...

- Events
  - **`open`** - when stream is ready; callback is passed a file descriptor object
  - **`drain`** - when “kernel buffer” is empty meaning it is safe to write again
  - **`error`** - when write error occurs
  - **`close`** - when underlying file descriptor has been closed
  - **`pipe`** - when stream is passed to **`pipe`** method of a **`ReadStream`**
- Properties
  - **`bytesWritten`** - number of bytes written so far
  - **`writable`** - boolean indication of whether stream can be written
    - changes to **`false`** if an **`error`** event is delivered or
      the **`end`** or **`destroy`** method is called on the stream (see next slide)

Kernel buffers are used internally by Node to buffer output in case destination streams cannot keep up.

... Writable Streams

- Methods
  - **`write(`*`string`*`, `*`encoding`*`='utf8', [`*`fd`*`])`** - writes a string to stream
    - **`fd`** parameter is a UNIX-only, rarely used option
  - **`write(`*`buffer`*`)`** - writes contents of **`Buffer`** to stream

---

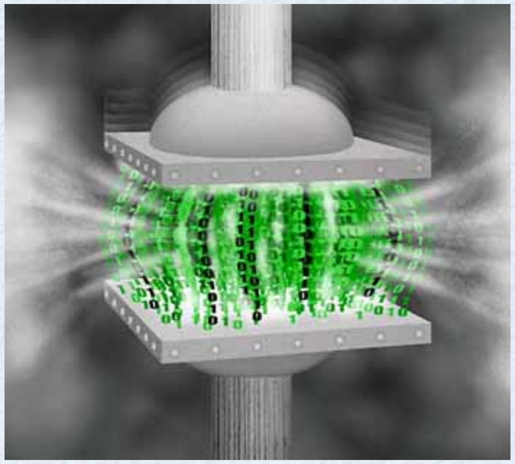
  - **`end()`** - terminates stream
  - **`end(`*`string`*`, [`*`encoding`*`])`** - writes a string to stream and then terminates it
  - **`end(`*`buffer`*`)`** - writes contents of **`Buffer`** to stream and then terminates it

---

  - **`destroy()`** - closes underlying file descriptor
    - no more events will be emitted after **`close`**
  - **`destroySoon()`** - closes underlying file descriptor
    - only after writes complete if stream is also writable
- See example on slide 18

Zlib

```
var zlib = require('zlib');
```



- Supports three kinds of compression and decompression
  - Deflate - from Wikipedia, "Deflate is a lossless data compression algorithm that uses a combination of the LZ77 algorithm and Huffman coding."
  - Deflate Raw - same as Deflate, but doesn't append a zlib header
  - GZIP - based on the Deflate algorithm
- Highly configurable
- Seven classes - create instances with **`zlib.createName([options]);`**
  - **`Gzip`**, **`Deflate`** and **`DeflateRaw`** are writeable streams that compress
  - **`Gunzip`**, **`Inflate`** and **`InflateRaw`** are readable streams that decompress
  - **`Unzip`** is a readable stream that detects the compression type and decompresses
- Convenience functions
  - perform seven operations corresponding to the seven classes without streams
    - **`deflate`**, **`deflateRaw`**, **`gzip`**, **`gunzip`**, **`inflate`**, **`inflateRaw`** and **`unzip`**
  - each takes a string or **`Buffer`** object and
    a callback function that is passed an **`Error`**, if any, and the result as a **`Buffer`**

Zlib Example

```
var fs = require('fs');
var zlib = require('zlib');

function zipToFile(data, filePath, cb) {
  zlib.gzip(data, function (err, buffer) {
    if (err) return cb(err);
    fs.writeFile(filePath, buffer, cb);
  });
}

function unzipFromFile(filePath, cb) {
  fs.readFile(filePath, function (err, buffer) {
    if (err) return cb(err);
    zlib.gunzip(buffer, function (err, buffer) {
      cb(err, buffer.toString());
    });
  });
}

var filePath = 'message.gz';
var data = 'This is a message';
zipToFile(data, filePath, function (err) {
  if (err) throw err;
  unzipFromFile(filePath, function (err, result) {
    if (err) throw err;
    console.log('result =', result);
  });
});
```

String Decoder

```
var StringDecoder = require('string_decoder').StringDecoder;
```

- Not documented yet
- Handles writing data from buffers that do not end in a complete multi-byte character
- Used by
  - core modules **`fs`**, **`http`**, **`net`**, **`repl`** and **`tls`**
  - npm's **`read`** module
    - which it uses for "**`npm init`**" to prompt for **`package.json`** information

Net ...

`var net = require('net');`

- Provides methods for implementing TCP servers and clients
- Methods
  - **`createServer([`*`options`*`], [`*`callback`*`])`**
    - typically used server-side
    - returns a **`net.Server`** object
    - callback is passed a **`net.Socket`** object
    - register listeners for events on socket in callback
  - **`connect(`*`port`*`, [`*`host`*`], [`*`callback`*`])`** - for TCP
    `connect(`*`path`*`, [`*`callback`*`])` - for Unix socket ← for communicating between processes on same host
    - asynchronously creates a new connection
    - typically used client-side
    - returns a **`net.Socket`** object and passes nothing to callback
    - **`host`** defaults to localhost
  - **`createConnection(`*`args`*`)`**
    - alias for **`connect`** method

... Net

- Methods
  - **`isIP(`*`s`*`)`** - returns 0 if **`s`** is not an IP address string, 4 if IPv4, and 6 if IPv6
  - **`isIPv4(`*`s`*`)`** - returns boolean indicating whether **`s`** is a version 4 IP address string
    - pattern is **`d.d.d.d`** where **`d`** is an integer between 0 and 255
    - can be represented in 32 bits
  - **`isIPv6(`*`s`*`)`** - returns boolean indicating whether **`s`** is a version 6 IP address string
    - pattern is **`h:h:h:h:h:h:h:h`** where each **`h`** is a 4 character hex value
    - can be represented in 128 bits
    - leading zeros in an **`h`** value may be omitted
    - **`h`** values that are all zeros can be replaced by a single zero or omitted
    - all colons must be retained, except more than two consecutive colons can be replaced by only two colons once within an address
      - ex. `1:2:0:0:0:0:7:8` is equivalent to `1:2:::::7:8` and `1:2::7:8`

net.Server Class ...

- Kind of object returned by **`net.createServer`** function
- Methods
  - **`listen(`*`port`*`, [`*`host`*`], `*`callback`*`)`** - for TCP
    `listen(`*`path`*`, `*`callback`*`)` - for Unix socket
    - listens for new connections
    - if **`host`** is omitted, will listen for connections from any host
    - returns nothing and passes nothing to callback
  - **`pause(`*`ms`*`)`**
    - stop accepting new connections for **`ms`** milliseconds, perhaps for throttling
  - **`close()`**
    - asynchronously stop accepting new connections permanently
    - a 'close' event is emitted when complete
  - **`address()`**
    - returns an object containing **`port`** and **`address`** (IP) properties

... net.Server Class

- Events

  register for these with
  `server.on(event-name, callback);`

  - `listening` - emitted when server is ready to accept connections
  - `connection` - emitted when a connection is made
    - `net.Socket` object is passed to callback
  - `close` - emitted when server is no longer accepting connections
  - `error` - emitted when an error occurs
    - `Error` object is passed to callback
- Properties
  - `maxConnections` - set to limit number of connections
  - `connections` - will be set to current number of connections

net.Socket Class ...

- Represents a TCP or Unix socket
- Kind of object returned by **`net.connect`** function
- Properties
  - **`remoteAddress`** - remote IP address
  - **`remotePort`** - remote port number
  - **`bufferSize`** - size of **`Buffer`** that holds data to be written before it is sent
  - **`bytesRead`** - number of bytes read
  - **`bytesWritten`** - number of bytes written

... net.Socket Class ...

- Methods
  - **`connect(`*`port`*`, [`*`host`*`], `*`callback`*`)`** - for TCP
    `connect(`*`path`*`, `*`callback`*`)` - for Unix socket
    - usually **`net.connect`** is used instead of this
    - might use this to implement a custom socket (by writing a new class that inherits **`net.Socket`**) or to reuse a closed **`Socket`** to connect to a different server
    - asynchronously opens a new connection
    - **`host`** defaults to localhost
    - returns nothing and passes nothing to callback
  - **`setEncoding(`*`encoding`*`)`** - options are 'ascii', 'base64' and 'utf8' (default)
  - **`write(`*`data`*`, [`*`encoding`*`], [`*`callback`*`])`**
    - encoding defaults to **`'utf8'`**, callback is invoked after all data has been written
  - **`end(`*`data`*`, [`*`encoding`*`])`**
    - optionally writes more data; closes socket; server will receive **`'end'`** event

... net.Socket Class ...

- Methods
  - **`pause()`** - pauses reading of data; for throttling an upload
  - **`resume()`** - resumes reading of data after a call to **`pause()`**
  - **`setTimeout(`*`ms`*`, [`*`callback`*`])`**
    - invokes callback once if no reads or writes within ms
    - set to zero (default) for no timeout to wait forever and never invoke a callback
  - **`address()`**
    - returns IP address and port of socket in a object with **`address`** and **`port`** properties
  - **`destroy()`** - advanced
  - **`setNoDelay(`*`bool`*`)`** - advanced
  - **`setKeepAlive(`*`enable`*`, [`*`initialDelay`*`])`** - advanced

… net.Socket Class

- Events
  - **`connect`** - when connection is established
  - **`data`** - when data is received
    - callback is passed a **`Buffer`** or string containing the data
  - **`end`** - when **`end()`** has been called on socket on other end
  - **`timeout`** - when timeout occurs (see **`setTimeout`** method)
  - **`drain`** - when write **`Buffer`** becomes empty
  - **`error`** - when any socket-related error occurs
    - callback is passed an **`Error`** object
  - **`close`** - when fully closed
    - callback is passed boolean indicating whether it was closed due to an error

net Example

Server

```
var net = require('net');
var PORT = 8019;

var server = net.createServer(function (socket) {
  console.log('client connected'); 2

  socket.on('data', function (data) {
5   console.log('received "' + data + '"');
  });

  socket.on('end', function () {
    console.log('client disconnected'); 7
    server.close();
  });

  socket.write('hello');
});

server.on('error', function (err) {
  console.error(err.code === 'EADDRINUSE' ?
    'port ' + PORT + ' is already in use' :
    err);
});

server.listen(PORT, function () {
1 console.log('listening on ' + PORT);
});
```

Client

```
var net = require('net');

var socket = net.connect(8019, function () {
  console.log('connected to server'); 3
});

socket.on('data', function (data) {
  console.log('received "' + data + '"'); 4
  socket.write('goodbye');
  socket.end();
});

socket.on('end', function (data) {
  console.log('disconnected from server'); 6
});
```

Output from server

```
1) listening on 8019
2) client connected
5) received "goodbye"
7) client disconnected
```

Output from client

```
3) connected to server
4) received "hello"
6) disconnected from server
```

Datagram

```
var dgram = require('dgram');
```

"I have a UDP joke to tell you, but you might not get it" ... unknown

- User Datagram Protocol (UDP)
  - supports datagram sockets
- Datagram overview
  - messages are broken into packets
  - packets are separately addressed and routed
  - faster because it foregoes the handshaking overhead of TCP
  - doesn't guarantee reliability, packet ordering or data integrity
  - suitable when error checking and correction isn't needed or is provided by the application
  - suitable when dropping packets is better than waiting for them
- To create a datagram socket
  - **`var dgs = createSocket(`*`type`*`, [`*`callback`*`])`**
    - creates a datagram socket of a given type (**`'udp4'`** or **`'udp6'`**)
    - optional callback gets **`'message'`** events (more in two slides)

Packet size varies based on the Maximum Transmission Unit (MTU) of the transmission technology used.

For **IPv4** the minimum size is 68 bytes and the recommended size is 576 bytes.

For **IPv6** the minimum size is 1280 bytes.

Typically the actual packet size is at least 1500 bytes.

Datagram Socket Methods

- ***dgs*.send(*buffer*, *offset*, *length*, *port*, *address*, [*callback*])**
  - sends a message that is in a specified chunk of a **`Buffer`** object
  - callback is passed **`err`** and number of bytes sent
- ***dgs*.bind(*port*, [*address*])**
  - starts listening on a given **`port`**
  - if **`address`** is specified, only listens on specified network interface instead of all
- ***dgs*.close()**
  - closes the datagram socket
- ***dgs*.address()**
  - gets address of socket in an object with **`address`** and **`port`** properties
- and more

see output from **`os.networkInterfaces()`** later

Datagram Events

- **`'message'`**
  - when a message is received
  - callback is passed a **`Buffer`** and rinfo object with **`address`** and **`port`** properties
- **`'listening'`**
  - when socket begins listening
- **`'close'`**
  - when call to **`close`** method completes
- **`'error'`**
  - when an error occurs
  - callback is passed an **`Error`** object

Datagram Server Example

```
var dgram = require('dgram');

var type = 'udp4'; // or 'udp6'
var server = dgram.createSocket(type);

server.on('message', function (msg, rinfo) {
  console.log('got "' + msg + '" from ' +
    rinfo.address + ':' + rinfo.port);

  msg = new Buffer('pong');
  server.send(msg, 0, msg.length, rinfo.port, rinfo.address, function (err, bytes) {
    console.log('bytes sent: ', bytes);
    server.close();
  });
});

server.on('error', function (err) {
  console.error(err);
});

server.on('listening', function () {
  var addr = server.address();
  console.log('listening on ' + addr.address + ':' + addr.port);
});

var PORT = 1234;
server.bind(PORT);
```

Datagram Client Example

```
var dgram = require('dgram');

var type = 'udp4'; // or 'udp6'
var client = dgram.createSocket('udp4');

client.on('message', function (msg, rinfo) {
  console.log('got "' + msg + '" from ' +
    rinfo.address + ':' + rinfo.port);
  client.close(); // only expecting on message
});

client.on('error', function (err) {
  console.error(err);
});

client.on('listening', function () {
  var addr = client.address();
  console.log('listening on ' + addr.address + ':' + addr.port);
});

var msg = new Buffer('ping');
var HOST = 'localhost';
var PORT = 1234;
client.send(msg, 0, msg.length, PORT, HOST, function (err, bytes) {
  console.log('bytes sent: ', bytes);
});
```

Server Output

```
listening on 0.0.0.0:1234
got "ping" from 127.0.0.1:49617
bytes sent:  4
```

Client Output

```
listening on 0.0.0.0:49617
bytes sent:  4
got "pong" from 127.0.0.1:1234
```

automatically selected port

Domain Name System (DNS)

```
var dns = require('dns');
```

- Resolves IP address from a domain name
  - **`lookup`** function
- Resolves domain name from an IP address
  - **`reverse`** function
- Retrieves many types of DNS records from a domain name
  - supported DNS record types are
    A (IPv4), AAAA (IPv6), CNAME (canonical name), MX (mail exchange),
    NS (name server), PTR (reverse IP lookup), TXT (text), SRV (service locator)
  - **`resolve`** function takes an array of DNS record types to retrieve
  - these functions return a specific type of DNS record:
    `resolve4`, **`resolve6`**, **`resolveCname`**, **`resolveMx`**, **`resolveNs`**, **`resolveTxt`**, **`resolveSrv`**
- For information on DNS record types,
  see http://en.wikipedia.org/wiki/List_of_DNS_record_types

DNS Example

```
var dns = require('dns');

var domain = 'www.google.com';

dns.lookup(domain, function (err, address, family) {
  if (err) {
    throw err;
  }
  console.log(domain, address, 'IPv' + family);

  dns.reverse(address, function (err, domains) {
    if (err) {
      console.error('reverse lookup failed');
    } else {
      console.log(domains);
    }
  });
});
```

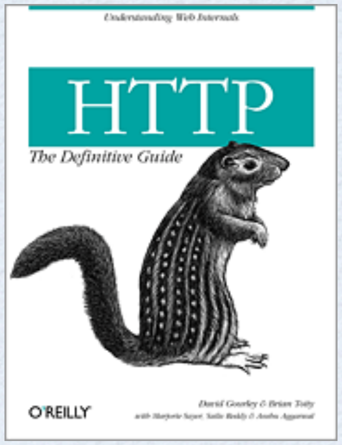
Output

```
www.google.com 74.125.65.106 IPv4
[ 'gx-in-f106.1e100.net' ]
```

HTTP

```
var http = require('http');
```

- Low-level API
- Typically the **`express`** module is used which builds on the **`connect`** module which builds on this
  - so we'll just cover the basics
- Supports streaming of requests and responses
  - rather than buffering until all the data is ready
- Use **`querystring`** core module to parse query parameters
  - covered in more detail later
- Can send HTTP requests with **`http.request`** function
  - userland module **`request`** is often used instead



HTTP Example ...

```
var http = require('http');
var qs = require('querystring');

var PORT = 3002;

// Create an HTTP server and give it a 'request' listener.
var srv = http.createServer(function (req, res) {
  var url = req.url;

  // Many browsers, including Chrome, ask for this first.
  if (url === '/favicon.ico') {
    res.statusCode = 404;
    res.end(); // could also return an icon file and 200 status
    return;
  }

  console.log('method =', req.method);
  console.log('url =', url);
  console.log('headers =', req.headers);
  console.log('HTTP version =', req.httpVersion);

  var index = url.indexOf('?');
  var path = url.substring(0, index);
  console.log('path =', path);
  var queryString = url.substring(index + 1);
  var params = qs.parse(queryString); // can't pass entire URL
  console.log('query parameters =', params);
```

Sample output is based on browsing `http://localhost:3002/foo/bar?month=April&color=yellow`

see output two slides ahead

... HTTP Example ...

```
// Decide what to write in response based on path and query parameters.
// Express supports defining “routes” which makes this easier.

// If there is data in the request body, it can be received in chunks.
var data = '';
req.on('data', function (chunk) {
  data += chunk;
});
req.on('end', function () {
  // All the data has been received now.
  console.log('data =', data);
});

var status = 200;
var responseHeaders = {
  'Content-Type': 'text/plain'
};
// Can set response status and other headers in one call.
//res.writeHead(status, responseHeaders);

// Can set response status and each header separately.
res.statusCode = status;
res.setHeader('Content-Type', 'text/plain');
```

chunk size is limited by TCP packet size

... HTTP Example

```
  // Write the response body after all headers have been written.

  // Can write response body in one call.
  //res.end('Hello, World!');

  // Can write response body in chunks.
  res.write('Hello');
  res.write(', ');
  res.write('Chunks!');
  res.end();
});

srv.listen(PORT, function () {
  console.log('ready');
});
```

Output

```
ready
connection created
method = GET
url = /foo/bar?month=April&color=yellow
headers = { host: 'localhost:3002',
  'user-agent': 'Mozilla/5.0 (Macintosh; Intel Mac OS X 10.7; rv:9.0.1) Gecko/20100101 Firefox/9.0.1',
  accept: 'text/html,application/xhtml+xml,application/xml;q=0.9,*/*;q=0.8',
  'accept-language': 'en-us,en;q=0.5',
  'accept-encoding': 'gzip, deflate',
  'accept-charset': 'ISO-8859-1,utf-8;q=0.7,*;q=0.7',
  connection: 'keep-alive',
  'cache-control': 'max-age=0' }
HTTP version = 1.1
path = /foo/bar
query parameters = { month: 'April', color: 'yellow' }
data =
```

nothing in request body

Uniform Resource Locator (URL) ...

`var url = require('url');`

- Contains methods to resolve and parse URL strings
- **`URL`** object properties

All examples below assume the full URL is **`'http://username:password@company.com:3000/foo/bar?month=April&color=yellow#baz'`**

  - **`protocol`** - ex. **`'http:'`**
  - **`auth`** - ex. **`'username:password'`**
  - **`host`** - includes port; ex. **`'company.com:3000'`**
  - **`port`** - port number; ex. **`'3000'`**
  - **`hostname`** - ex. **`'company.com'`**
  - **`query`** - query object; ex. **`{month: 'April', color: 'yellow'}`**
  - **`search`** - query prepended with **`?`**; ex. **`'?month=April&color=yellow'`**
  - **`pathname`** - portion after **`host`** and before **`search`**; starts with a slash; ex. **`'/foo/bar'`**
  - **`path`** - **`pathname`** plus **`search`**; ex. **`'/foo/bar?month=April&color=yellow'`**
  - **`hash`** - fragment identifier; ex. **`'#baz'`**
  - **`href`** - entire URL string;
    ex. **`'http://username:password@company.com:3000/foo/bar?month=April&color=yellow#baz'`**

... URL

- Functions
  - **`parse(`*`urlString`*`, `*`parseQueryString`*`=false, `*`slashesDenoteHost`*`=false)`**
    - creates and returns a **`URL`** object from a URL string
    - if **`parseQueryString`** is true, **`query`** property will be an object where keys are query parameter names and values are query parameter values; ex. **`{ month: 'April', color: 'yellow' }`**
      - otherwise **`query`** property value is just the query string portion as a string without leading **`?`**
    - if **`slashesDenoteHost`** is true, host will be obtained from first slashed part after //; ex. **`url.parse('http://foo/bar/baz', false, true)`** returns a URL object where **`host = 'foo'`**, **`path = '/bar/baz'`**, and **`pathname`** is the same
  - **`format(`*`urlObject`*`)`**
    - takes a URL object and returns a URL string
  - **`resolve(`*`from`*`, `*`to`*`)`**
    - returns a URL string created by treating **`from`** as the base URL and **`to`** as a relative URL
    - see example on next slide

URL Example

```
'use strict';
var url = require('url');

var urlString =
  'http://username:password@company.com:3000/' +
  'foo/bar?month=April&color=yellow#baz';
var urlObj = url.parse(urlString, true, true);
console.log('urlObj =', urlObj);

urlObj.auth = 'fred:wilma';
urlObj.query.month = 'September';
urlObj.query.color = 'blue';
urlObj.hash = '#barney';
urlString = url.format(urlObj);
console.log('urlString =', urlString);

var baseUrl = 'http://www.ociweb.com/mark';
var relativeUrl = 'knowledge-sharing/tech-com/sett';
var resolvedUrl = url.resolve(baseUrl, relativeUrl);
console.log('resolvedUrl =', resolvedUrl);
```

```
urlObj = { protocol: 'http:',
  slashes: true,
  auth: 'username:password',
  host: 'company.com:3000',
  port: '3000',
  hostname: 'company.com',
  href: 'http://username:password@company.com:3000/foo/bar?month=April&color=yellow#baz',
  hash: '#baz',
  search: '?month=April&color=yellow',
  query: { month: 'April', color: 'yellow' },
  pathname: '/foo/bar',
  path: '/foo/bar?month=April&color=yellow' }
urlString = http://fred:wilma@company.com:3000/foo/bar?month=April&color=yellow#barney
resolvedUrl = http://www.ociweb.com/knowledge-sharing/tech-com/sett
```

Output

Query Strings

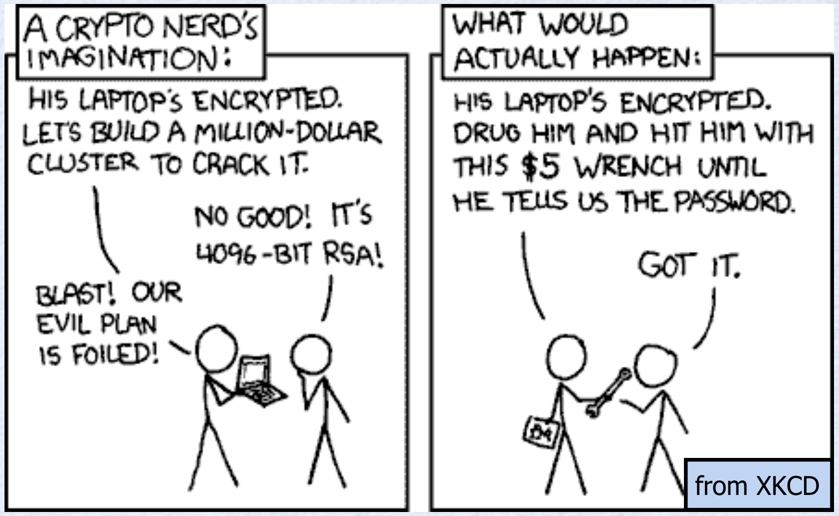
`var qs = require('querystring');`

- Contains methods to parse and create query strings
  - part of URLs from `?` to end
- Used by "url" module
- Functions
  - `stringify(`*`obj`*`, `*`sep`*`='&', `*`eq`*`='=')`
    - creates a query string from key/value pairs in obj
    - why would different delimiter characters ever be desired?
    - ex. `qs.stringify({month: 'April', color: 'yellow'})` returns `'month=April&color=yellow'`
  - `parse(`*`str`*`, `*`sep`*`='&', `*`eq`*`='=')`
    - creates an object containing key/value pairs from a query string
    - ex. `qs.parse('month=April&color=yellow')` returns `{ month: 'April', color: 'yellow' }`
  - other functions are mainly for internal use

Crypto

```
var crypto = require('crypto');
```

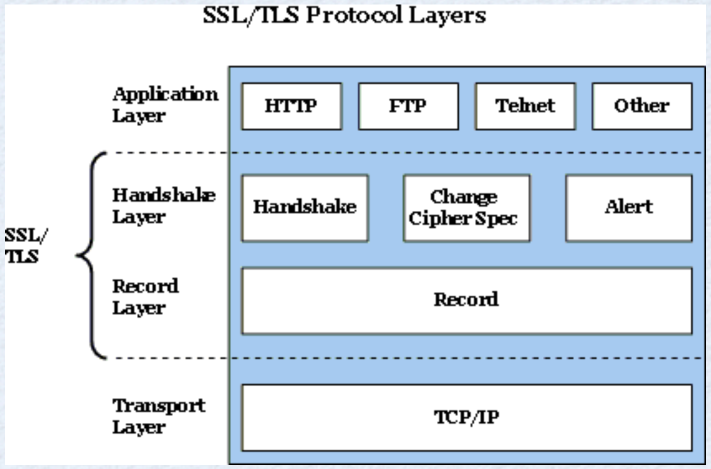
- Provides functions for working with security credentials that are used with HTTP and HTTPS
- Works with concepts such as
  - Privacy Enhanced Email (PEM) credential
  - cryptographic hash
  - digest
  - Hash-based Message Authentication Code (HMAC)
  - cipher / decipher
  - signer object
  - verification object
  - Diffie-Hellman key exchange
  - asynchronous PBKDF2
- Relies on OS **`openssl`** command
- Beyond my knowledge to say anything further


A CRYPTO NERD'S IMAGINATION:
HIS LAPTOP'S ENCRYPTED. LET'S BUILD A MILLION-DOLLAR CLUSTER TO CRACK IT.
NO GOOD! IT'S 4096-BIT RSA!
BLAST! OUR EVIL PLAN IS FOILED!
WHAT WOULD ACTUALLY HAPPEN:
HIS LAPTOP'S ENCRYPTED. DRUG HIM AND HIT HIM WITH THIS $5 WRENCH UNTIL HE TELLS US THE PASSWORD.
GOT IT.
from XKCD

TLS/SSL

```
var tls = require('tls');
```

- Secure Socket Layer (SSL)
- Transport Layer Security (TLS) - an upgrade to SSL 3.0
- Both are cryptographic protocols for secure internet communication
  - public/private key infrastructure
  - prevents eavesdropping and tampering with message content
- Functions
  - **`tls.createServer(`*`options`*`, [`*`connectionListener`*`])`**
    - called by server code
    - options include key, certificate and certificate authority (CA) file contents
      - can also set **`rejectUnauthorized`** option to **`true`** to reject connections not authorized by a CA in list of authorized CAs
    - returns a **`tls.Server`** object (see next slide)
  - **`tls.connect(`*`port`*`, [`*`host`*`], [`*`options`*`], [`*`connectionListener`*`])`**
    - called by client code
    - options include key, certificate and certificate authority (CA) file contents
    - returns a **`tls.CleartextStream`** object (see next slide)



TLS Classes

- **`tls.Server`**
  - type of object returned by **`tls.createServer()`**
  - "a subclass of **`net.Server`** and has the same methods"
    - including **`listen(`*`port`*`)`**
  - "Instead of accepting just raw TCP connections, this accepts encrypted connections using TLS or SSL."
- **`tls.CleartextStream`**
  - type of object returned by **`tls.connect()`**
  - has same methods and events as readable and writable streams
  - "a stream on top of the encrypted stream that makes it possible to read/write an encrypted data as a cleartext data"

TLS Example Server

```
var fs = require('fs');
var tls = require('tls');

var opts = {
  key: fs.readFileSync('mykey.pem'),
  cert: fs.readFileSync('mycert.pem'),
};

var server = tls.createServer(opts, function (cts) {
  console.log('server connected',
    cts.authorized ? 'authorized' : 'unauthorized');

  cts.setEncoding('utf8');

  cts.write('ping');
  cts.on('data', function (data) {
    console.log('got', data, 'from client');
    server.close();
    process.exit(0);
  });
  cts.on('end', function () {
    console.log('got end event from client');
  });
});

server.listen(8000, function() {
  console.log('ready');
});
```

see HTTPS section (slide 51) for command to generate key and certificate .pem files

will only get `'authorized'` if `rejectUnauthorized` option is `true`

if encoding isn't specified then `data` will be a `Buffer` instead of a string (no default encoding)

TLS Example Client

```
var fs = require('fs');
var tls = require('tls');

var opts = {
  key: fs.readFileSync('mykey.pem'),
  cert: fs.readFileSync('mycert.pem'),
};

var cts = tls.connect(8000, opts);
cts.setEncoding('utf8');
cts.on('secureConnect', function () {
  console.log('client connected',
    cts.authorized ? 'authorized' : 'unauthorized');
});
cts.on('data', function (data) {
  console.log('got', data, 'from server');
  cts.write('pong');
});
cts.on('end', function () {
  console.log('got end event from server; process will exit');
});
cts.on('error', function (e) {
  var msg = e.code === 'ECONNREFUSED' ?
    'failed to connect; is server running?' : e.toString();
  console.error(msg);
});
```

can also pass this callback to `tls.connect()`; `this` will be set to the `cts` object inside it

if encoding isn't specified then `data` will be a `Buffer` instead of a string (no default encoding)

TLS/SSL Advanced Functionality

- Start a TLS session on an existing TCP connection
- Next Protocol Negotiation (NPN)
  - TLS handshake extension to use one TLS server
    for multiple protocols (HTTP and SPDY)
- Server Name Indication (SNI)
  - TLS handshake extensions to use one TLS server
    for multiple hostnames with different SSL certificates

HTTPS

```
var https = require('https');
```

- HTTP over SSL/TLS
  - Secure Socket Layer (SSL) preceded Transport Layer Security (TLS)
  - these are cryptographic protocols
  - from Wikipedia, "encrypt the segments of network connections above the Transport Layer, using asymmetric cryptography for key exchange, symmetric encryption for privacy, and message authentication codes for message integrity"
- Need .pem files for key and certificate
  - "Privacy Enhanced Mail"
  - one way to create is to run following command and answer prompts

```
openssl req -x509 -nodes -days 365 -newkey rsa:2048 -keyout mykey.pem -out mycert.pem
```

`req -x509`: type of certificate signing request

`-nodes`: makes key unencrypted — no password required to use

`-days 365`: valid for this many days

`rsa:2048`: type of key management and size in bits

- **`https.Server`** is a subclass of **`tls.Server`**
- **`https.request`** function sends a request to a secure web server
  - supports same options as **`http.request`** function
  - userland module **`request`** is often used instead

HTTPS Example

```
var fs = require('fs');
var https = require('https');

var PORT = 3002;
var opts = {
  key: fs.readFileSync('mykey.pem'),
  cert: fs.readFileSync('mycert.pem')
};

var srv = https.createServer(opts, function (req, res) {
  // Many browsers, including Chrome, ask for this first.
  if (req.url === '/favicon.ico') {
    res.statusCode = 404;
    res.end(); // could also return an icon file and 200 status
    return;
  }

  res.statusCode = 200;
  res.end('Hello, World!');
});

srv.listen(PORT, function () {
  console.log('ready');
});
```

browse with https://localhost:3002 or
run "`curl -k https://localhost:3002`"
(`-k` allows SSL connections without certificates

Virtual Machine (VM) ...

```
var vm = require('vm');
```

- Compiles a string of JavaScript code and runs it or saves it so it can be run later without recompiling
- The code does not have access to variables in local scope, regardless of the **`vm`** function used
  - to run code that can access variables in local scope, use the JavaScript **`eval`** function
- Syntax errors in the code string passed to these functions are reported to stderr and an **`Error`** is thrown
- Functions in this module that run code return the value of the last expression evaluated
  - **`return`** statements cannot be used in the top-level of a code string, only inside function definitions within a code string

... VM

- Functions

The optional filename arguments appear in stack traces to help with debugging.

  - **`runInThisContext(code, [filename])`**
    - global object for code is current global object; assign properties to **`global`** to make them accessible
  - **`runInNewContext(code, [sandbox], [filename])`**
    - global object for code is sandbox object
    - creates a new context which has overhead
  - **`createContext([sandbox])`**
    - creates a **`Context`** object that can be passed to **`vm.runInContext()`**
  - **`runInContext(code, context, [filename])`**
    - context must be created by calling **`vm.createContext(sandbox)`** (see next slide)
    - global object for code is sandbox object passed to **`createContext`**
    - context object also holds built-in objects and functions
    - **more efficient than `runInNewContext` when the same context will be used multiple times**
  - **`createScript(code, [filename])`**
    - compiles code and returns a **`Script`** object that can be used execute the code later
    - see **`Script`** methods on next slide

VM `Script` Class

- Objects created by calling **`vm.createScript(`*`code`*`)`**
- Methods
  - **`runInThisContext()`**
    - global object for code is current global object
    - assign properties to **`global`** to make them accessible
  - **`runInNewContext([`*`sandbox`*`])`**
    - global object for code is sandbox object

VM Example

```
var assert = require('assert');
var vm = require('vm');

var code = "Math.pow(x, y)";
var code2 = "console.log('z =', z); " + code;

console.log('global =', global); // has lots of variables and functions
global.x = 3;
global.y = 2;
global.z = 19;
// Note how global functions (in this case just console)
// are explicitly being made available in the sandbox and context.
var sandbox = {x: 2, y: 3, z: 19, console: console};
var context = vm.createContext({x: 2, y: 4, z: 19, console: console});

assert.equal(vm.runInThisContext(code), 9); // 3 ^ 2
assert.equal(vm.runInNewContext(code2, sandbox), 8); // 2 ^ 3
assert.equal(vm.runInContext(code2, context), 16); // 2 ^ 4

var script = vm.createScript(code);
assert.equal(script.runInThisContext(), 9); // 3 ^ 2
assert.equal(script.runInNewContext(sandbox), 8); // 2 ^ 3
assert.equal(script.runInContext(context), 16); // 2 ^ 4
```

Child Processes

`var cp = require('child_process');`

- Functions — all of these return a **`ChildProcess`** object
  - **`spawn(`*`command, args`*`=[], [`*`options`*`])`**
    - starts a new process that runs a given command and returns a **`ChildProcess`** object
    - **`args`** holds command-line flags and arguments
    - **`cwd`** option specifies directory in which command runs (defaults to current)
    - **`env`** option specifies environment variables available in child process (defaults to **`process.env`**)
    - to obtain output, listen for **`data`** events on **`stdout`** and **`stderr`** properties
  - **`exec(`*`command, args`*`=[],`*`options, callback`*`)`**
    - runs a command in a shell, buffers output to stdout and stderr,
      and passes it to a callback function of the form **`function (err, stdout, stderr)`**
    - supports a **`timeout`** option
    - callback is passed status code, stdout **`Buffer`** and stderr **`Buffer`**
  - **`execFile(`*`file-path, args`*`=[], [`*`options`*`],`*`callback`*`)`**
    - executes commands in specified file in current process
    - callback is passed status code, stdout **`Buffer`** and stderr **`Buffer`**
  - **`fork(`*`script-path, args`*`=[],`*`options`*`)`**
    - similar to **`spawn`**, but returned object has a **`send`** method that emits **`'message'`** events

process doesn't end when end of script is reached; must call **`process.exit()`** in script

`ChildProcess` Class

- Inherits from **`EventEmitter`**
- Events
  - **`exit`** - emitted after child process ends
    - callback function takes a status code and a signal
    - a code is passed on normal termination
    - a signal is passed if terminated by a signal
- Properties
  - **`stdin`** - standard input stream
  - **`stdout`** - standard output stream
  - **`stderr`** - standard error stream
  - **`pid`** - process id
- Methods
  - **`send(`*`message`*`)`**
    - sends message to child process
  - **`kill(`*`signal`*`='SIGTERM')`**
    - sends a given signal to the child process

Child Process Example #1

```
var child_process = require('child_process');

var cp = child_process.spawn(
  'ls', ['-l', '..']);
console.log('pid =', cp.pid);

cp.stdout.on('data', function (data) {
  console.log('data =', data.toString());
});

cp.on('exit', function (code, signal) {
  console.log('exit code =', code);
  console.log('exit signal =', signal);
});
```

runs the "`ls -l`" command in the parent directory

Output

```
pid = 16511
total 0
drwxr-xr-x  7 Mark  staff  238 Jan 28 18:36 addons
drwxr-xr-x  4 Mark  staff  136 Dec  7 20:52 async
drwxr-xr-x  3 Mark  staff  102 Nov 21 08:50 buffers
drwxr-xr-x  5 Mark  staff  170 Nov 15 15:03 callbacks
drwxr-xr-x  8 Mark  staff  272 Feb 18 14:04 child_process
...
drwxr-xr-x  5 Mark  staff  170 Jan  8 13:19 vm
drwxr-xr-x  4 Mark  staff  136 Feb 15 18:38 zlib

exit code = 0
exit signal = null
```

Child Process Example #2

finds every required module in the `.js` files in a below the parent directory

```
#!/bin/bash
# Finds all files with a given file extension
# in and below the current directory
# that contain a given string.
# For example, myFind java "implements Foo"

if [ $# -ne 2 ]; then
  echo usage: myFind {file-extension} {search-string}
  exit 1
fi

find . -name "*.$1" | xargs grep "$2"
```

```
var child_process =
  require('child_process');

var args = ['js', 'require('];
var opts = {cwd: '..'};
var file = 'child_process/myFind.sh';
var cp = child_process.execFile(file, args, opts, function (err, data) {
  if (err) {
    return console.error(err);
  }

  var re = /require\(['"](.*)['"]\)/;
  var requires = {};
  data.split('\n').forEach(function (line) {
    var matches = re.exec(line);
    if (matches) {
      requires[matches[1]] = true;
    }
  });
  Object.keys(requires).sort().forEach(function (req) {
    console.log(req);
  });
});
```

Output

```
../lib/math
./build/Release/demo
./build/Release/hello
./demo1
./helper
assert
async
child_process
...
util
vm
zlib
```

Cluster

```
var cluster = require('cluster');
```

- “easily create a network of processes that all share server ports”
  - works with any TCP-based server, including HTTP and HTTPS
- Builds on “Child Processes” module
- Initial process is called “master”
  - only process that listens on selected port
  - uses inter-process communication (IPC) pipes to communicate with workers
- Forked processes are called “workers”
  - typically want to fork a number of workers not greater than number of processors
  - get number of processors with **`os.cpus().length`**
  - no guarantees about order of selection of workers to handle requests
    - distributes connections across workers, but doesn’t distribute requests
    - once a client gets a connection, all their requests will go to the same worker

“The difference between **`cluster.fork()`** and **`child_process.fork()`** is simply that cluster allows TCP servers to be shared between workers.

`cluster.fork` is implemented on top of **`child_process.fork`**.

The message passing API that is available with **`child_process.fork`** is available with cluster as well.”

“The Jewel Box (also known as NGC 4755, the Kappa Crucis **Cluster** and Caldwell 94) is an open cluster in the constellation of Crux.” ... Wikipedia

Cluster Masters

- Can fork workers
- Can send messages to workers
  - `worker.send('message');`
- Can listen for messages from workers
  - `worker.on('message', function (obj) {...});`
- Can listen for death of workers
  - `cluster.on('death', function (worker) {...});`
  - anything that kills the process triggers this,
    including OS `kill` command and throwing an uncaught exception
  - can optionally fork replacement workers
    - typically the only job of master after it forks workers

Cluster Workers

- Have a unique id
  - in `process.env.NODE_WORKER_ID` within their process
- Typically start a server such as an HTTP server
- Can send messages to their master
  - `process.send(obj);`
- Can listen for messages from master
  - `process.on('message', function (msg) {...});`
- Cannot send messages to other workers
- Cannot fork more workers
- Are killed if their master dies

Cluster Example ...

```
var cluster = require('cluster');

if (cluster.isMaster) { // cluster.isWorker is also set
  var requestCount = 0;
  var handleMsg = function (msg) {
    if (msg.cmd === 'gotRequest') {
      requestCount++;
      console.log('requestCount =', requestCount);
    }
  };

  cluster.on('death', function (worker) {
    console.log('worker with pid', worker.pid, 'died - starting new worker');
    worker = cluster.fork();
    worker.on('message', handleMsg);
  });

  // Fork worker processes.
  var cpuCount = require('os').cpus().length;
  for (var i = 1; i < cpuCount; i++) {
    var worker = cluster.fork();
    worker.on('message', handleMsg);
  }
```

same code is run for the master and each worker

... Cluster Example

1. browse http://localhost:8000
2. kill the process that handled the request
3. refresh the page and note that
   a different process handles the request

```
} else { // for workers
  // Start an HTTP server in worker processes.
  var http = require('http');
  var PORT = 8000;
  http.Server(function (req, res) { // not a constructor function
    if (req.url === '/favicon.ico') {
      res.writeHead(404);
      res.end(); // could also return an icon file and 200 status
      return;
    }

    // Simulate taking a while to process request.
    setTimeout(function () {
      res.statusCode = 200;
      res.end('Hello from process ' + process.pid + '!\n');

      console.log('worker with pid', process.pid, 'handled a request');

      // Send message to master process.
      process.send({cmd: 'gotRequest'});
    }, 1000); // one second
  }).listen(PORT);

  var workerId = process.env.NODE_WORKER_ID; // numbered starting from 1
  console.log('worker server', workerId, 'ready, pid', process.pid);
}
```

Node.js Resources

- Main site - http://nodejs.org/
- API doc - http://nodejs.org/docs/latest/api/
- NPM Registry Search - http://search.npmjs.org/
- How To Node - http://howtonode.org/
- node-toolbox - http://toolbox.no.de/
- NodeUp podcast - http://nodeup.com/
- Felix Geisendoerfer’s guide - http://nodeguide.com