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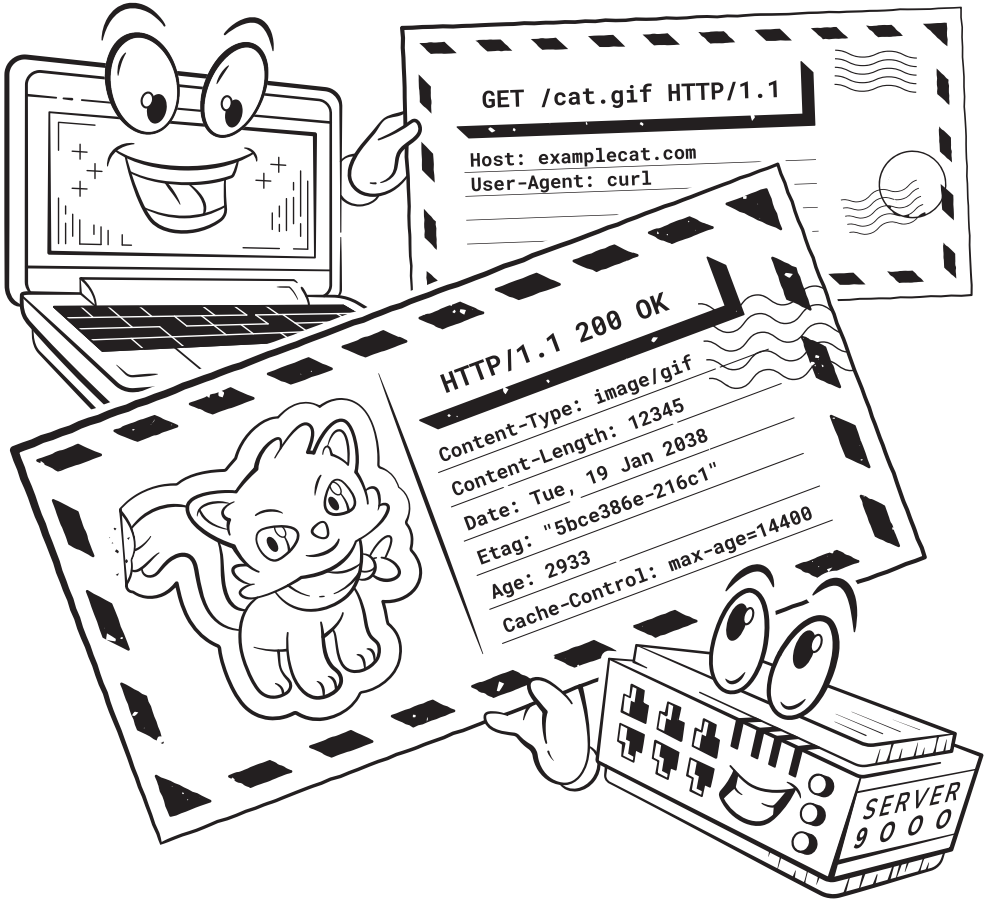
HTTP

learn your browser's language

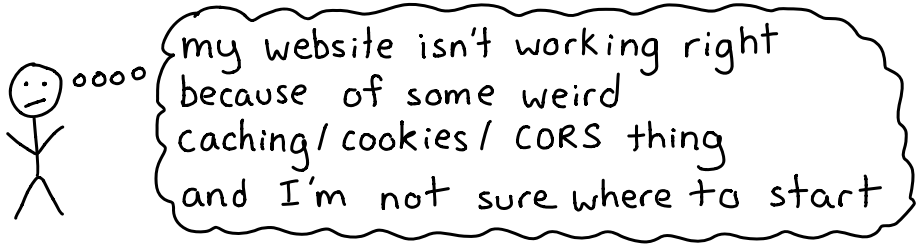


by Julia Evans

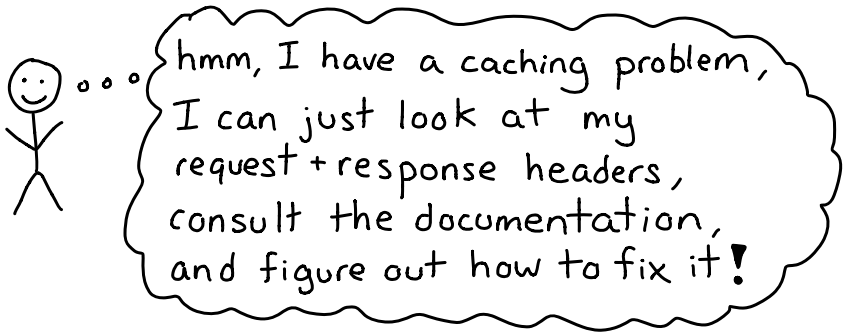
about this zine

Your browser uses HTTP every time it visits a website.

This zine's goal is to take you from:



to



credits

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Editing: Dolly Lanuza, Kamal Marhubi

Copy editing: Courtney Johnson

special thanks to Marco Rogers for suggesting the idea of a HTTP zine

how to learn more

♥ Mozilla Developer Network

`https://developer.mozilla.org`

MDN is a fantastic wiki maintained by Mozilla. It has tutorials and reference documentation for HTML, CSS, HTTP, Javascript. It's the best place to start for reference documentation.

♥ OWASP

`https://cheatsheetseries.owasp.org`

OWASP is an organization that publishes security best practices. If you have a question about web security, they've probably published a cheat sheet or guide to help you.

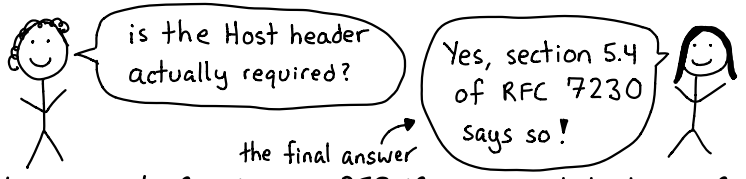
♥ httpstatuses.com

Nice little site that explains all the HTTP status codes.

♥ RFCs

`https://tools.ietf.org/html/rfcXXXX` ← put RFC number here

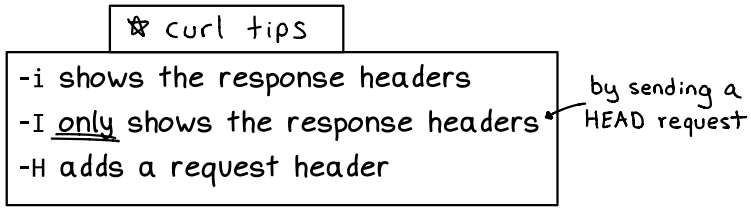
RFCs are numbered documents (like "RFC 2631"). Every Internet protocol (like TLS or HTTP) has an RFC. These are where you go to find the Official Final Answers to technical questions you have about any internet standard. The HTTP standard is mostly documented in 6 RFCs numbered 7230 to 7235.



Don't be scared of using an RFC if you want to know for sure!

HTTP exercises

Making HTTP requests with curl to real internet websites and trying different headers is my favourite way to play around with HTTP & learn.



Try the `Range` header:

```
curl -i https://examplecat.com/cat.txt -H "Range: bytes=8-17"
```

Request (and print out!) a compressed response:

```
curl -i https://examplecat.com
   -H "Accept-Encoding: gzip" -- output -
```

Get a webpage in Spanish:

```
curl -i https://twitter.com -H "Accept-Language: es-ES"
```

Get redirected to another URL:
(hint: look at the `Location` header!)

```
curl -i http://examplecat.com
```

Guess what content delivery network Github is using:
(hint: it's in a header starting with `X-`)

```
curl -I https://github.githubassets.com
```

Find out when `example.com` was last updated:
(hint: `Last-Modified`)

```
curl -I example.com
```

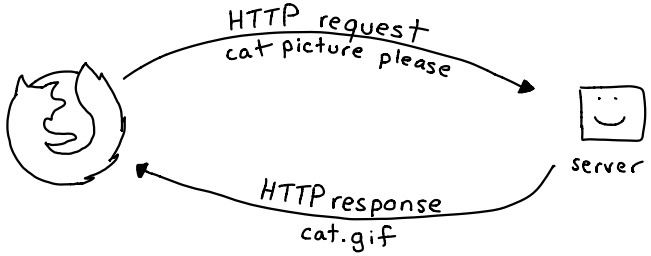
Get a 404 not found:

```
curl -i examplecat.com/bananas
```

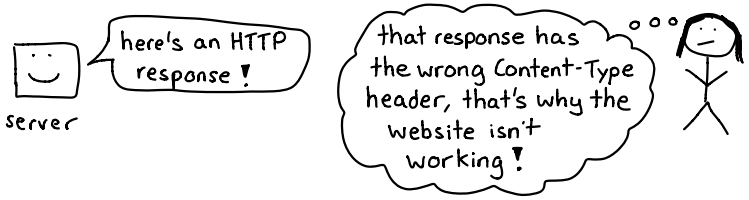

Table of Contents

what's HTTP?

HTTP is the protocol (Hypertext Transfer Protocol) that's used when you visit any website in your browser.



The exciting thing about HTTP is that even though it's used for literally every website, HTTP requests and responses are easy to look at and understand:



Example of what an HTTP request and response might look like:

request

request line: `GET / HTTP/1.1`

headers:
```
Host: examplecat.com
User-Agent: curl
Accept: */*
```

response

status: `HTTP/1.1 200 OK`

headers:
```
Cache-Control: max-age=604800
Content-Type: text/html
Etag: "1541025663+ident"
Server: ECS (nyb/1D0B)
Vary: Accept-Encoding
X-Cache: HIT
Content-Length: 1270
```

body:
```
<!doctype html>
<title>Example Cat</title>

...
```

All that text is a lot to understand, so let's get started learning what all of it means!

security headers

These are headers your server can set. They ask the browser to protect your users' data against attackers in different ways:

Content-Security-Policy

often called CSP

Only allow CSS / Javascript from certain domains you choose to run on your website. Helps protect against cross-site-scripting (aka XSS) attacks.

Referrer-Policy

Control how much information is sent to other sites in the `Referer` header. Example: `Referrer-Policy: no-referrer`. (spelling is inconsistent with Referer header !!)

Strict-Transport-Security

often called HSTS

Require HTTPS. If you set this the client (browser) will never request a plain HTTP version of your site again. Be careful! You can't take it back!

Expect-CT

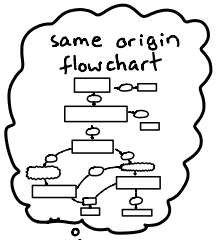
Certificate Transparency (CT) is a system that can help find malicious SSL certificates issued for your site. This header gives the browser a URL to use to report bad certificates to you.

X-XSS-Protection

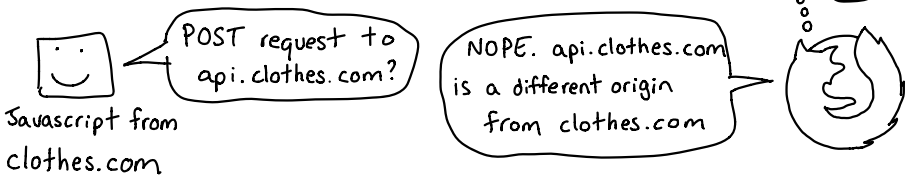
Another way to protect against XSS attacks. It's not supported by all browsers, and `Content-Security-Policy` is more powerful.

CORS

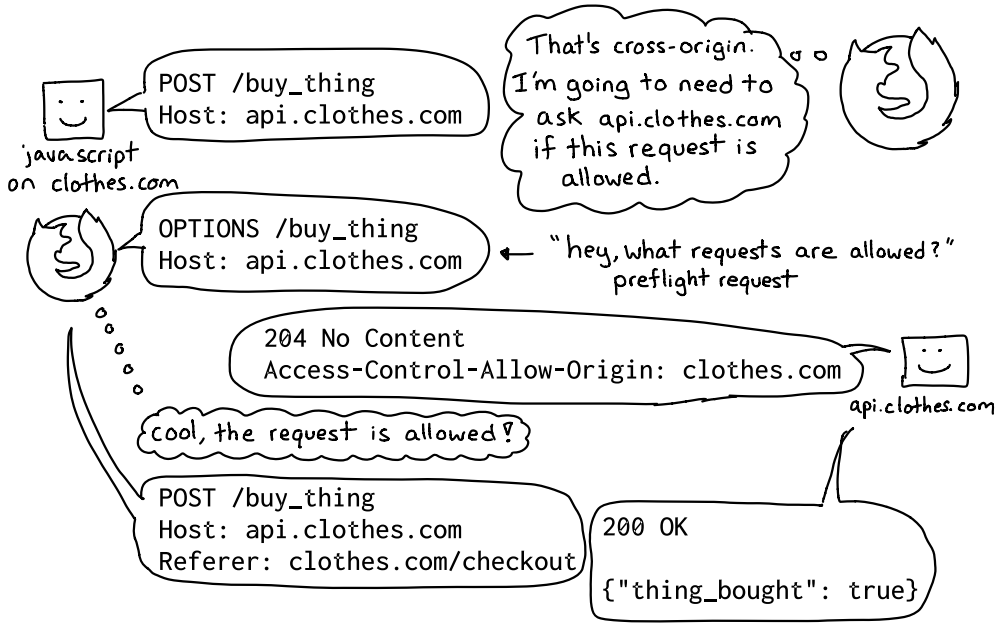
cross-origin resource sharing



Cross-origin requests are not allowed by default, because of the same origin policy.



If you run api.clothes.com, you can allow clothes.com to make requests to it using the `Access-Control-Allow-Origin` header. Here's what happens:



This OPTIONS request is called a "preflight" request and it only happens for some requests, like we described in the diagram on the same-origin policy page. Most GET requests will just be sent by the browser without a preflight request first, but POST requests that send JSON need a preflight.

how URLs work

`https://examplecat.com:443/cats?color=light%20gray#banana`

Scheme · domain · port · path · query string · fragment id

scheme `https://`
Protocol to use for the request. Encrypted (`https`), insecure (`http`), or something else entirely (`ftp`).

domain `examplecat.com`
Where to send the request. For HTTP(s) requests, the Host header gets set to this (`Host: example.com`)

port `:443`
Defaults to 80 for HTTP and 443 for HTTPS.

path `/cats`
Path to ask the server for. The path and the query parameters are combined in the request, like: `GET /cats?color=light%20gray HTTP/1/1`

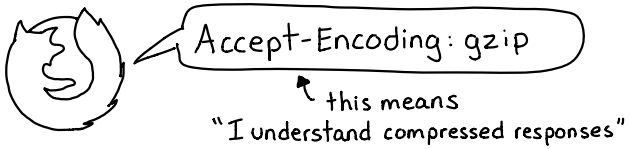
query parameters `color=light gray`
Query parameters are usually used to ask for a different version of a page ("I want a light gray cat!"). Example:
`hair=short&color=black&name=mr%20darcy`
name = value, separated by &

URL encoding `%20`
URLs aren't allowed to have certain special characters like spaces, @, etc. So to put them in a URL you need to percent encode them as % + hex representation of ASCII value.
space is `%20`, `%` is `%25`, etc.

fragment id `#banana`
This isn't sent to the server at all. It's used either to jump to an HTML tag (`<a id="banana"..>`) or by Javascript on the page.

what's a header?

Every HTTP request and response has headers. Headers are a way for the browser or server to send extra information!



Headers have a name and a value.

Accept-Encoding: gzip
(name: Accept-Encoding; value: gzip)

Header names aren't case sensitive:

totally valid → aCcEpT-eNcOdIng : gzip

There are a few different kinds of headers:

Describe the body:

```
Content-Type: image/png      Content-Encoding: gzip
Content-Length: 12345        Content-Language: es-ES
```

Ask for a specific kind of response:

```
Accept: image/png            Accept-Encoding: gzip
Range: bytes=1-10            Accept-Language: es-ES
```

Every Accept- header has a corresponding Content- header

Manage caches:

```
ETag: "abc123"               If-Modified-Since: 3 Aug 2019 13:00:00 GMT
If-None-Match: "abc123"      Last-Modified: 3 Feb 2018 11:00:00 GMT
Vary: Accept-Encoding        Expires: 27 Sep 2019 13:07:49 GMT
                             Cache-Control: public, max-age=300
```

Say where the request comes from:

```
User-Agent: curl             Referer: https://examplecat.com
```

Cookies:

```
Set-Cookie: name=julia; HttpOnly   (server → client)
Cookie: name=julia                 (client → server)
```

and more!

why the same origin policy matters

Browsers work hard to make sure that `evil.com` can't make requests to `other-website.com`. But `evil.com` can request `other-website.com` from its own server. So what's the big deal?

Here are 2 reasons it's important to prevent Javascript code from making arbitrary requests from your browser:

Reason 1: cookies

Browsers often send your cookies with HTTP requests. You don't want `evil.com` to be able to make requests using your login cookies. They'd be logged in as you!

Reason 2: network access

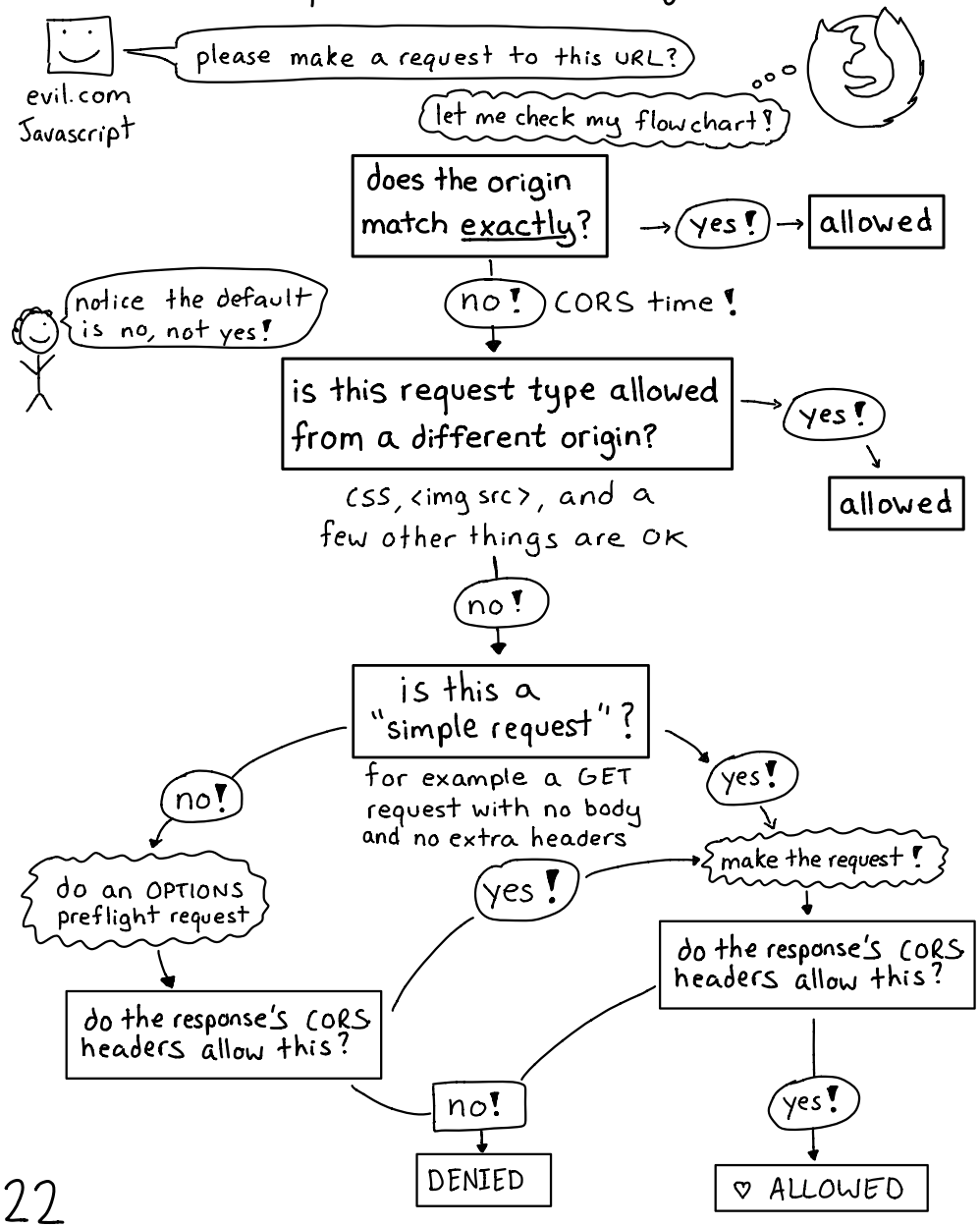
You might be on a private network (for example your company's corporate network) that `evil.com` doesn't have access to, but your computer does.

the same origin policy

An origin is the protocol + domain including subdomains + port.

example: https://tabby.examplecat.com:443

The same origin policy is one way browsers protect you from malicious Javascript code. Here's basically how it works:



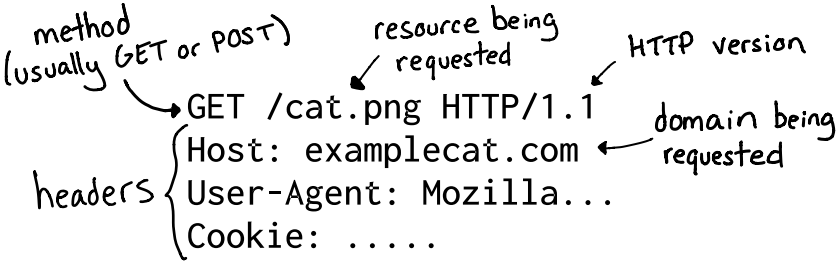
anatomy of an ★ HTTP request ★

HTTP requests always have:

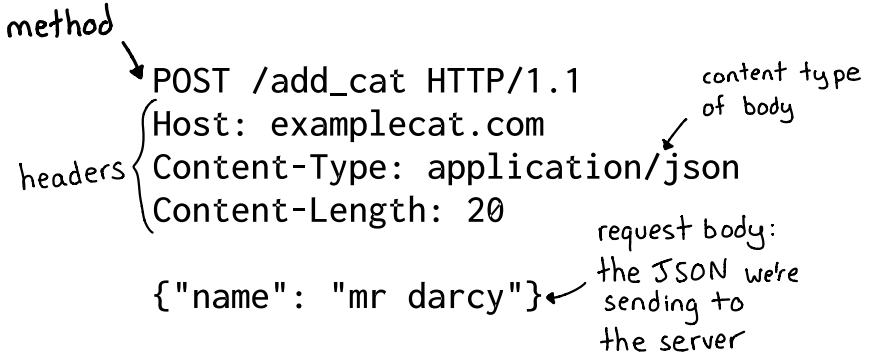
- → a domain (like examplecat.com)
- → a resource (like /cat.png)
- → a method (GET, POST, or something else)
- → headers (extra information for the server)

There's an optional request body. GET requests usually don't have a body, and POST requests usually do.

This is an HTTP 1.1 request for examplecat.com/cat.png. It's a GET request, which is what happens when you type a URL in your browser. It doesn't have a body.



Here's an example POST request with a JSON body:



request methods

Every HTTP request has a method. It's the first thing in the first line:

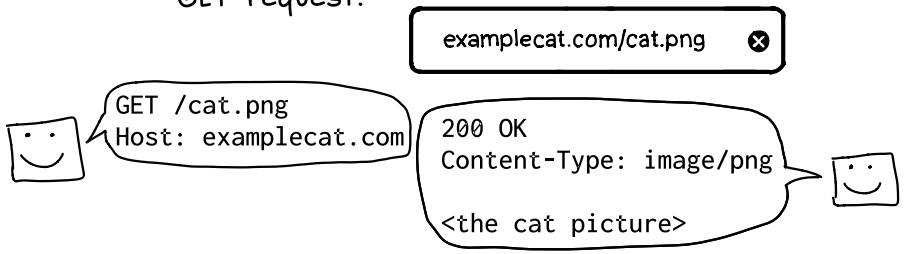
this means it's a GET request

```
GET /cat.png HTTP/1.1
```

There are 9 methods in the HTTP standard. 80% of the time you'll only use 2 (GET and POST).

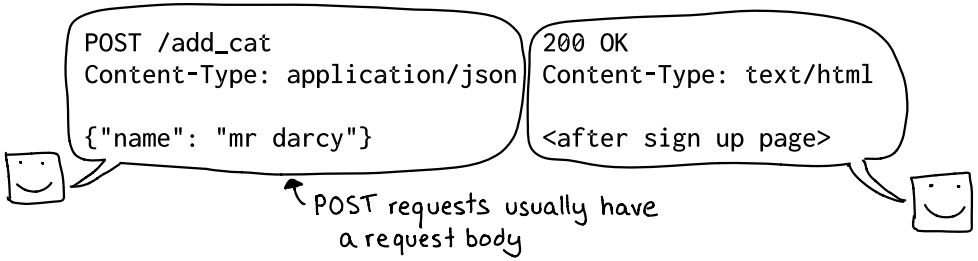
GET

When you type an URL into your browser, that's a GET request.



POST

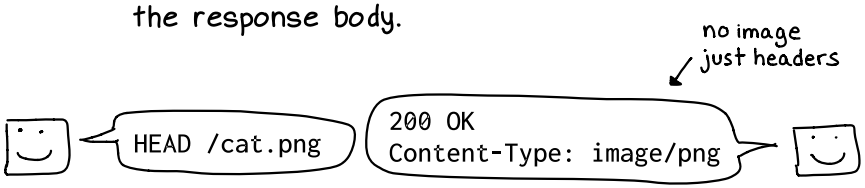
When you hit submit on a form, that's (usually) a POST request.



The big difference between GET and POST is that GETs are never supposed to change anything on the server.

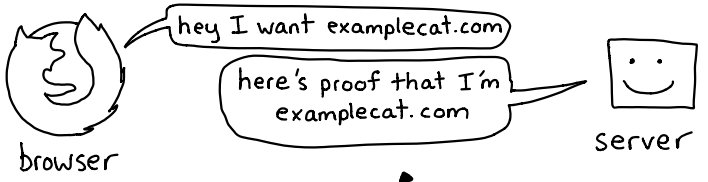
HEAD

Returns the same result as GET, but without the response body.



certificates

To establish an HTTPS connection to examplecat.com, the client needs proof that the server actually is examplecat.com .



the proof is called a certificate.

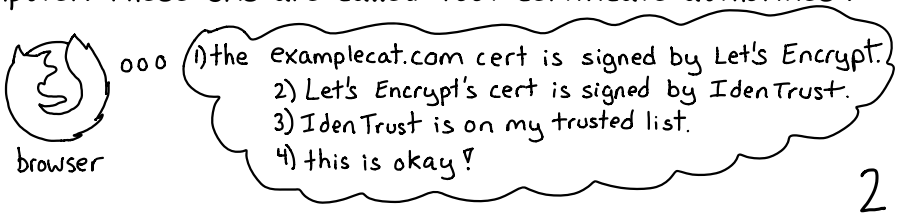
A TLS certificate has:

- a set of domains it's valid for (eg examplecat.com)
- a start and end date (example: july 1 2019 to oct 1 2019)
- a secret private key that only the server has
- a public key to use when encrypting
- a cryptographic signature from someone trusted

this is the only secret part, the rest is public

The trusted entity that signs the certificate is called a ★ Certificate Authority ★ (CA) and they're responsible for verifying that you actually own the domain:

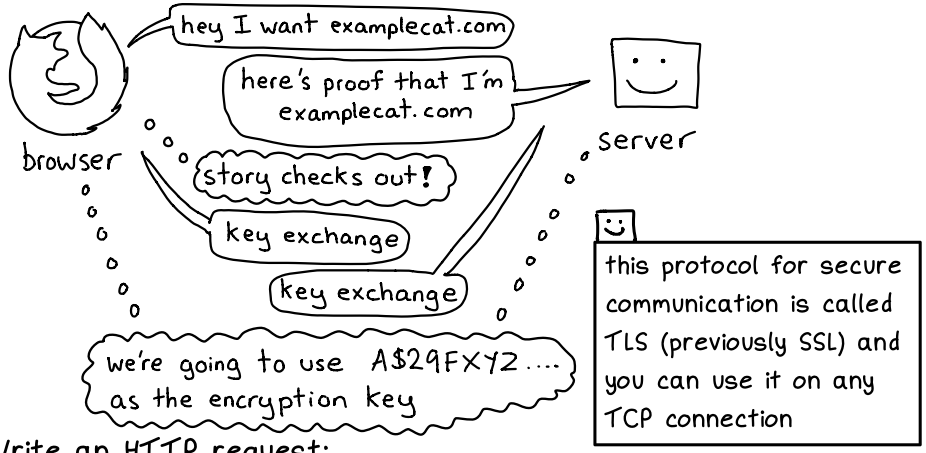
When your browser connects to examplecat.com, it validates the certificates using a list of trusted CAs installed on your computer. These CAs are called "root certificate authorities".



HTTPS: HTTP + secure

Here's what your browser does when it asks for `https://examplecat.com/cat.png`:

① Negotiate an encryption key (AES symmetric key) to use for this connection to `examplecat.com`. The browser and server use the same key to encrypt/decrypt content. Here's a simplified version of how picking the encryption key works:

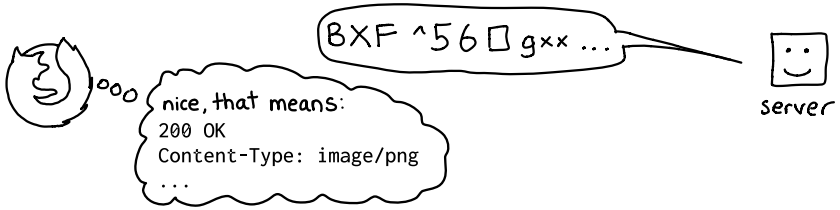


② Write an HTTP request:

```
GET /cat.png HTTP/1.1
Host: examplecat.com
User-Agent: Mozilla/...
```

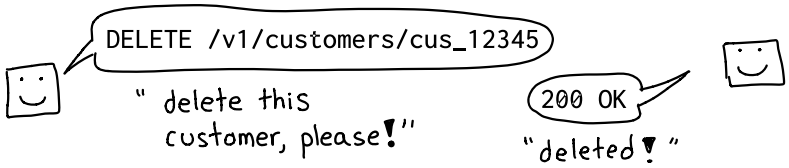
③ Encrypt the HTTP request with AES & send it to examplecat.com:

④ Receive encrypted HTTP response:



OPTIONS OPTIONS is mostly used for CORS requests. Page 24 has more about CORS. It also tells you which methods are available.

DELETE Used in many APIs (like the Stripe API) to delete resources.



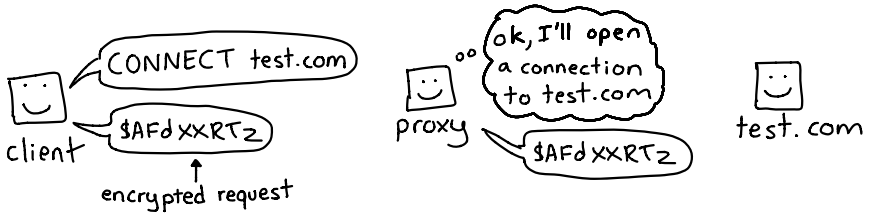
PUT Used in some APIs (like the S3 API) to create or update resources. `PUT /cat/1234` lets you `GET /cat/1234` later.

PATCH Used in some APIs for partial updates to a resource ("just change this 1 field").

TRACE I've never seen a server that supports this, you probably don't need to know about it.

CONNECT Different from all the others: instead of making a request directly to a server, it asks for a proxy to open a connection.

If you set the `HTTPS_PROXY` environment variable to a proxy server, many HTTP libraries will use this protocol to proxy your requests.



request headers

These are the most important request headers:

Host

The domain. The only required header.

```
Host: examplecat.com
```

User-Agent

name + version of your browser and OS

```
User-Agent: curl 7.0.2
```

Referer

website that linked or included the resource

```
Referer: https://examplecat.com
```

(yes, it's misspelled!)

Authorization

eg a password or API token

base64 encoded user:password

```
Authorization: Basic YXZ
```

Cookie

Send cookies the server sent earlier. Keeps you logged in.

```
Cookie: user=b0rk
```

Range

lets you continue downloads ("get bytes 100-200")

```
Range: bytes=100-200
```

Cache-Control

"max-age=60" means cached responses must be less than 60 seconds old

If-Modified-Since

only send if resource was modified after this time

```
If-Modified-Since: Wed, 21 Oct...
```

If-None-Match

only send if the ETag doesn't match those listed

```
If-None-Match: "e7ddac"
```

Accept

MIME type you want the response to be

```
Accept: image/png
```

Accept-Encoding

set this to "gzip" and you'll probably get a compressed response

```
Accept-Encoding: gzip
```

Accept-Language

set this to "fr-CA" and you might get a response in French

```
Accept-Language: fr-CA
```

Content-Type

MIME type of request body, e.g. "application/json"

Content-Encoding

will be "gzip" if the request body is gzipped

Connection

"close" or "keep-alive". Whether to keep the TCP connection open

HTTP/2

HTTP/2 is a new version of HTTP.

Here's what you need to know:

★ A lot isn't changing

All the methods, status codes, request/response bodies, and headers mean exactly the same thing in HTTP/2.

before (HTTP/1.1)

```
method: GET
path: /cat.gif
headers:
  - Host: examplecat.com
  - User-Agent: curl
```

one change: Host header => authority

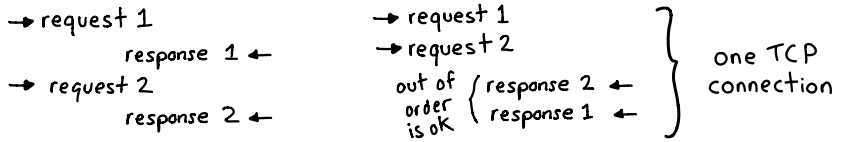
after (HTTP/2)

```
method: GET
path: /cat.gif
authority: examplecat.com
headers:
  - User-Agent: curl
```

★ HTTP/2 is faster

Even though the data sent is the same, the way HTTP/2 sends it is different. The main differences are:

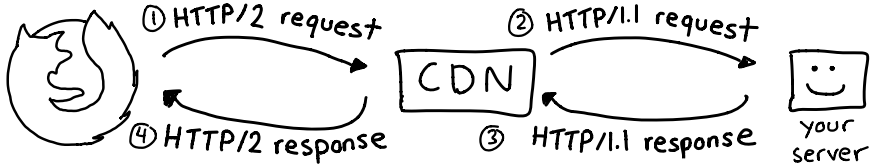
- It's a binary format (it's harder to `tcpdump` traffic and debug)
- Headers are compressed
- Multiple requests can be sent on the same connection at a time



All these changes together mean that HTTP/2 requests often take less time than the same HTTP/1.1 requests.

★ Sometimes you can switch to it easily

A lot of software (CDNs, nginx) let clients connect with HTTP/2 even if your server still only supports HTTP/1.1.

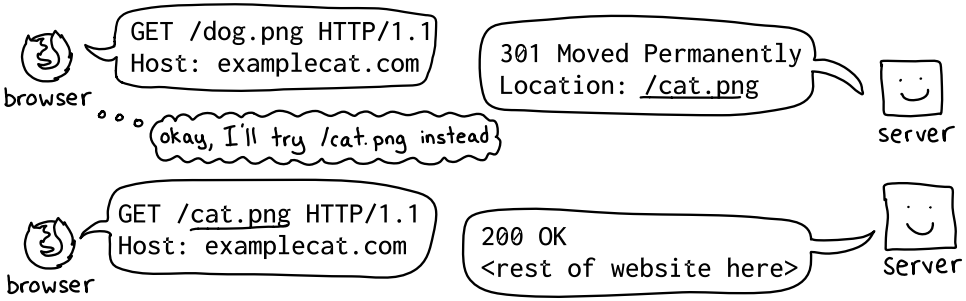


redirects

Sometimes you type a URL into your browser like this:

but you end up at a slightly different URL, like this:

Here's what's going on behind the scenes:



The `Location` header tells the browser what new URL to use. The new URL doesn't have to be on the same domain: `examplecat.com/panda` can redirect to `pandas.com`. Setting up redirects is a great thing to do if you move your site to a new domain!

! Warning !

`301 Moved Permanently` redirects are PERMANENT: after a browser sees one once, it'll always use `examplecat.com/cat.png` when someone types `examplecat.com/dog.png`, forever. You can't take it back and decide to not to redirect. If you're not sure you want to redirect your site for eternity, use `302 Found` to redirect instead.

using HTTP APIs

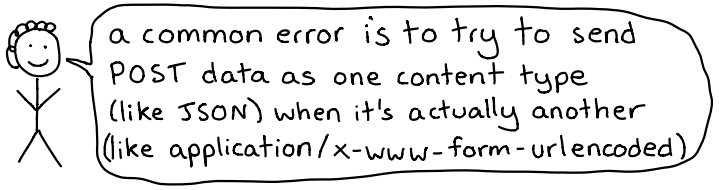
Lots of services (Twitter! Twilio! Google!) let you use them by sending them HTTP requests. If an HTTP API doesn't come with a client library, don't be scared! You can just make the HTTP requests yourself. Here's what you need to remember:

→ Set the right `Content-Type` header

Often you'll be sending a POST request with a body, and that means you need a `Content-Type` header that matches the body. The 2 main options are:

* `application/json` ← JSON!
* `application/x-www-form-urlencoded` ← same as what a HTML form does

If you don't set the `Content-Type`, your request won't work.



→ Identify yourself

Most HTTP APIs require a secret API key so they know who you are. Here's how that looks for the Twilio API:

```
curl
https://api.twilio.com/2010-04-01/Accounts/ACCOUNT_ID/Messages.json
   -H "Content-Type: application/json"
   -u ACCOUNT_ID:AUTH_TOKEN
   -d '{
      "from": "+15141234567",
      "to": "+15141234567",
      "body": "a text message"
   }'
```

-u sends the username/password in the Authorization header

this sends a POST request

anatomy of an HTTP response

HTTP responses have:

- a status code (200 OK! 404 not found!)
- headers
- a body (HTML, an image, JSON, etc)

Here's the HTTP response from `examplecat.com/cat.txt`:

```
HTTP/1.1 200 OK                                          } status code
Accept-Ranges: bytes
Cache-Control: public, max-age=0
Content-Length: 33
Content-Type: text/plain; charset=UTF-8                  } headers
Date: Mon, 09 Sep 2019 01:57:35 GMT
Etag: "ac5affa59f554a1440043537ae973790-ssl"
Strict-Transport-Security: max-age=31536000
Age: 0
Server: Netlify

\    /\                                                  } body
 )  ( ')
(  /  )
 \(__)|
```

(status: the 200 in the status line; cat! ☺: the ASCII cat)

There are a few kinds of response headers:

- when the resource was sent/modified:

```
Date: Mon, 09 Sep 2019 01:57:35 GMT
Last-Modified: 3 Feb 2017 13:00:00 GMT
```

- about the response body:

```
Content-Language: en-US   Content-Type: text/plain; charset=UTF-8
Content-Length: 33 Content-Encoding: gzip
```

- caching:

```
ETag: "ac5affa..." Age: 255
Vary: Accept-Encoding Cache-Control: public, max-age=0
```

- security: (see page 25)

```
X-Frame-Options: DENY Strict-Transport-Security: max-age=31536000
X-XSS-Protection: 1 Content-Security-Policy: default-src https:
```

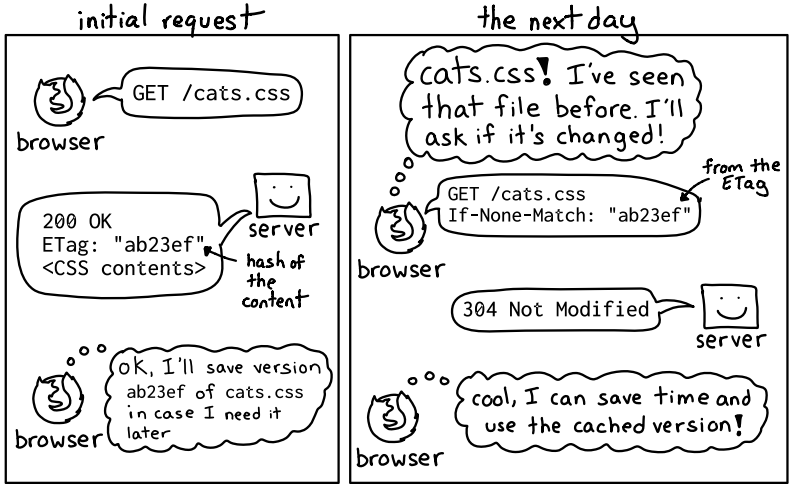
- and more:

```
Connection: keep-alive Accept-Ranges: bytes
Via: nginx
Set-Cookie: cat=darcy; HttpOnly; expires=27-Feb-2020 13:18:57 GMT;
```


caching headers

ETag response header and **If-None-Match** request header

These 3 headers let the browser avoid downloading an unchanged file a second time.



If-Modified-Since is similar to If-None-Match but with Last-Modified instead of ETag

Vary response header

Sometimes the same URL can have multiple versions (Spanish, compressed or not, etc). Caches categorize the versions by request header like this:

Accept-Language	Accept-Encoding	content
en-US	–	hello
es-ES	–	hola
en-US	gzip	f∫xx99æef^.. (compressed gibberish)

The `Vary` header tells the cache which request headers should be the columns of this table.

Cache-Control request AND response header

Used by both clients and servers to control caching behaviour. For example:

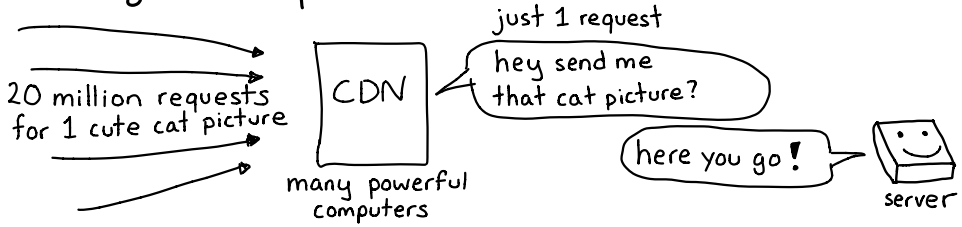
`Cache-Control: max-age=99999999999`

from the server asks the CDN or browser to cache the thing for a long time.

content delivery networks

In 2004, if your website suddenly got popular, often the webserver wouldn't be able to handle all the requests.

A CDN (content delivery network) can make your site faster and save you money by caching your site and handling most requests itself.



Today, there are many free or cheap CDN services available, which means if your site gets popular suddenly you can easily keep it running!

This is great but caching can cause problems too!

Next, we'll explain the HTTP headers your CDN or browser uses to decide how to do caching.

response headers

Age

how many seconds response has been cached

`Age: 355`

Date

when response was sent

`Date: Mon, 09 Sep 2019...`

Last-Modified

when content was last modified (not always accurate)

ETag

Version of response body

`Etag: "ac5affa.."`

Cache-Control

various caching settings

`Cache-Control: max-age=300`

Vary

request headers that response will vary based on

Via

added by proxy servers

`Via: nginx`

Expires

The response is stale and should be re-requested after this time.

Connection

"close" or "keep-alive" Whether to keep the TCP connection open

Set-Cookie

Sets a cookie.

`Set-Cookie: name=value; HttpOnly`

Access-Control-*

Called CORS headers. These allow cross-origin requests.

Content-Type

MIME type of body

`Content-Type: text/plain`

Content-Length

length of body in bytes

`Content-Length: 33`

Content-Language

Language of body

`Content-Language: en-US`

Content-Encoding

Whether body is compressed

`Content-Encoding: gzip`

Location

URL to redirect to

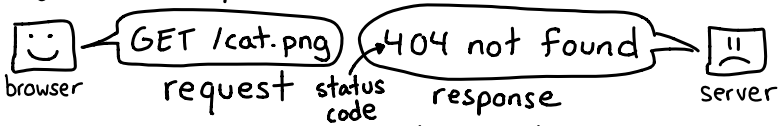
`Location: /cat.png`

Accept-Ranges

Whether Range request header is supported for this resource

HTTP status codes

Every HTTP response has a ★status code★



There are 50ish status codes, and these are the most common ones in real life:

2xxs mean ★success★

200 OK

3xxs aren't errors, just redirects to somewhere else

301 Moved Permanently

302 Found
temporary redirect

304 Not Modified
the client already has the latest version, "redirect" to that

4xx errors generally mean the client made an invalid request

400 Bad Request

403 Forbidden
API key/OAuth/something needed

404 Not Found
we all know this one :)

429 Too Many Requests
you're being rate limited

5xx errors generally mean something's wrong with the server

500 Internal Server Error
the server code has an error

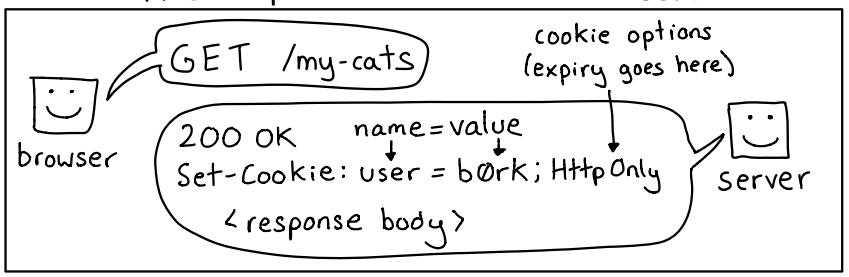
503 Service Unavailable
could mean nginx (or whatever proxy) couldn't connect to the server

504 Gateway Timeout
the server was too slow to respond

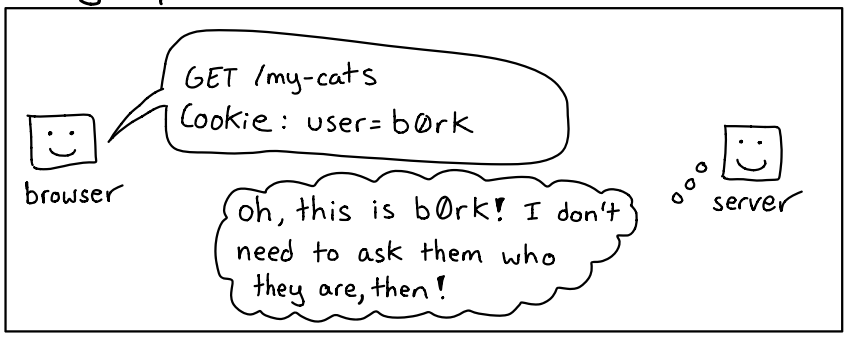
how cookies work

Cookies are a way for a server to store a little bit of information in your browser.
They're set with the `Set-Cookie` response header, like this:

first request: server sets a cookie



Every request after: browser sends the cookie back



Cookies are used by many websites to keep you logged in. Instead of `user=b0rk` they'll set a cookie like `sessionid=long-incomprehensible-id`. This is important because if they just set a simple cookie like `user=b0rk`, anyone could pretend to be `b0rk` by setting that cookie!

Designing a secure login system with cookies is quite difficult. To learn more about it, google "OWASP Session Management Cheat Sheet".