Hypertext Transfer Protocol

CSE 333 Autumn 2019

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Administrivia

- Ex16 extended until *Friday*
- No exercise assigned today!
- HW4 due two Thursdays from now (12/05)
  - You can use at most ONE late day

Lecture Outline

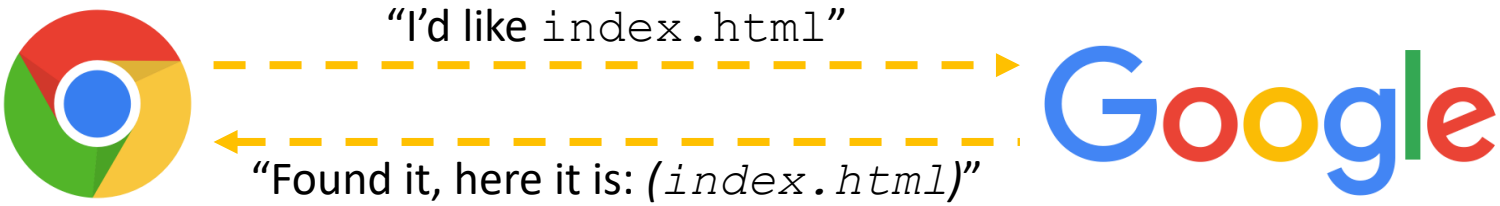
- **HTTP: Hypertext Transfer Protocol**
  - Client Requests
  - Server Responses
- Advanced features and HTTP/2

Learning Objectives

- Be able to *implement* a basic version of the HTTP protocol
  - i.e. Understand what components make up HTTP requests and responses
  - You will do this on HW4

- See an example of a protocol that is well-designed for its purpose, and understand *why*
  - C, POSIX, and now HTTP: all have aged well due to *programmer discipline*

HTTP Basics



- A client establishes one or more TCP connections to a server
  - The client sends a request for a web object over a connection and the server replies with the object's contents
- We have to figure out how to let the client and server communicate their intentions to each other clearly
  - We have to define a *protocol*

Protocols

- A protocol is a set of rules governing the format and exchange of messages in a computing system
  - What messages can a client exchange with a server?
    - What is the syntax of a message?
    - What do the messages mean?
    - What are legal replies to a message?
  - What sequence of messages are legal?
    - How are errors conveyed?

- A protocol is (roughly) the network equivalent of an API

HTTP: Hypertext Transport Protocol

- A request / response protocol
  - A client (web browser) sends a request to a web server
  - The server processes the request and sends a response
- Typically, a **request** asks a server to retrieve a resource
  - A *resource* is an object or document, named by a Uniform Resource Identifier (**URI**)
- A **response** indicates whether or not the server succeeded
  - If so, it provides the content of the requested response
- https://en.wikipedia.org/wiki/Hypertext_Transfer_Protocol

Lecture Outline

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HTTP Requests

- General form:
  - `[METHOD] [request-uri] HTTP/[version]\r\n`
    `[headerfield1]: [fieldvalue1]\r\n`
    `[headerfield2]: [fieldvalue2]\r\n`
    `[...]`
    `[headerfieldN]: [fieldvalueN]\r\n`
    `\r\n`
    `[request body, if any]`

Arbitrary K/V strings

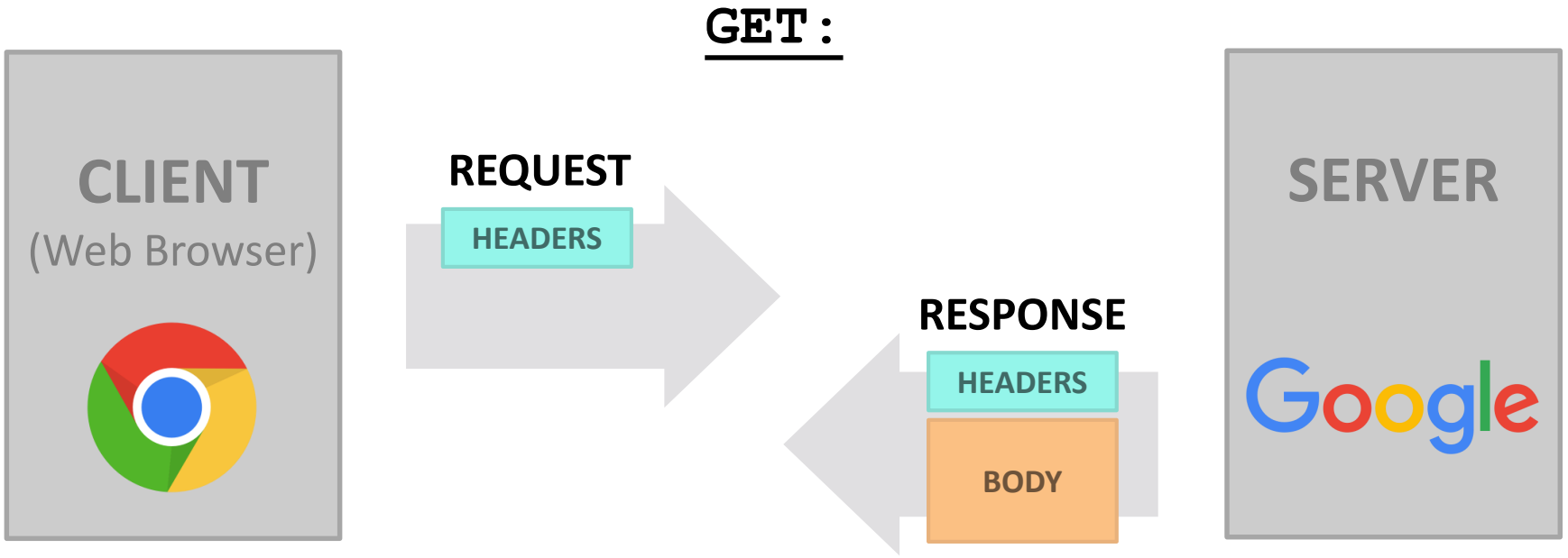
By default, Linux uses "\n" to represent "newline"

Must send TWO newlines to indicate "no more headers"

- Demo: use `nc -l` to see a real request

HTTP Methods

- There are three commonly-used HTTP methods:
  - **`GET`**: "Please send me the named resource"



HTTP Methods

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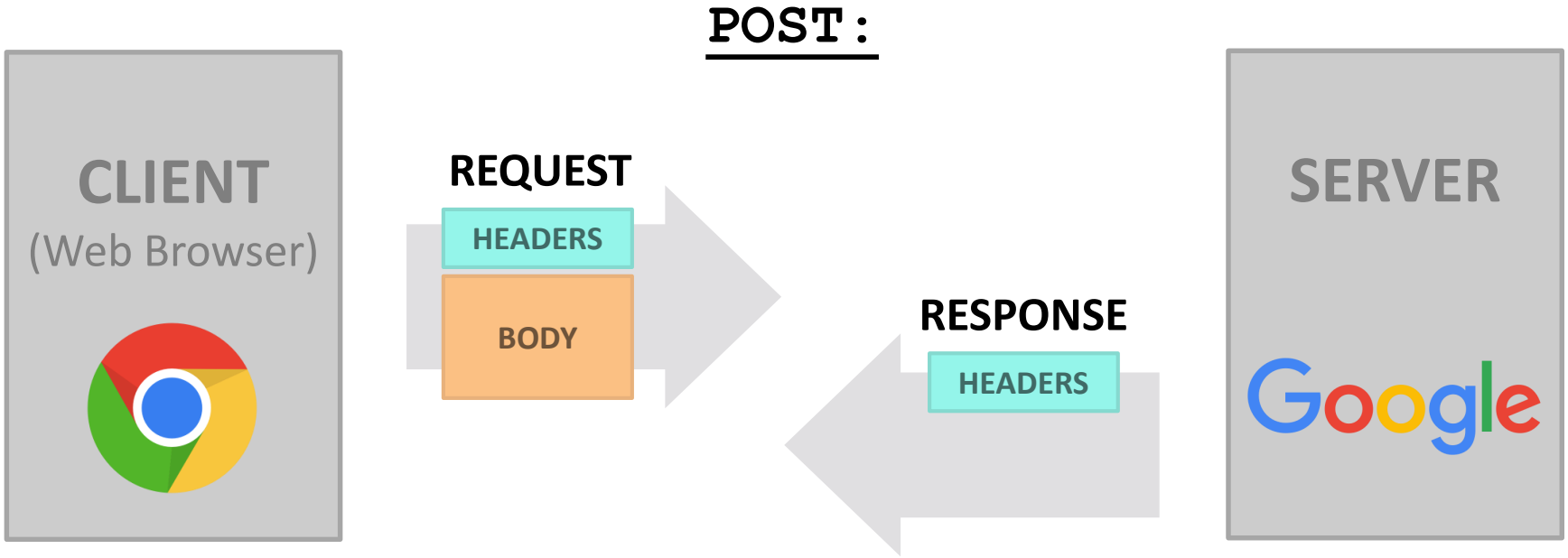
  - `GET`: "Please send me the named resource"
  - **`POST`**: "I'd like to submit data to you" (*e.g.* file upload)



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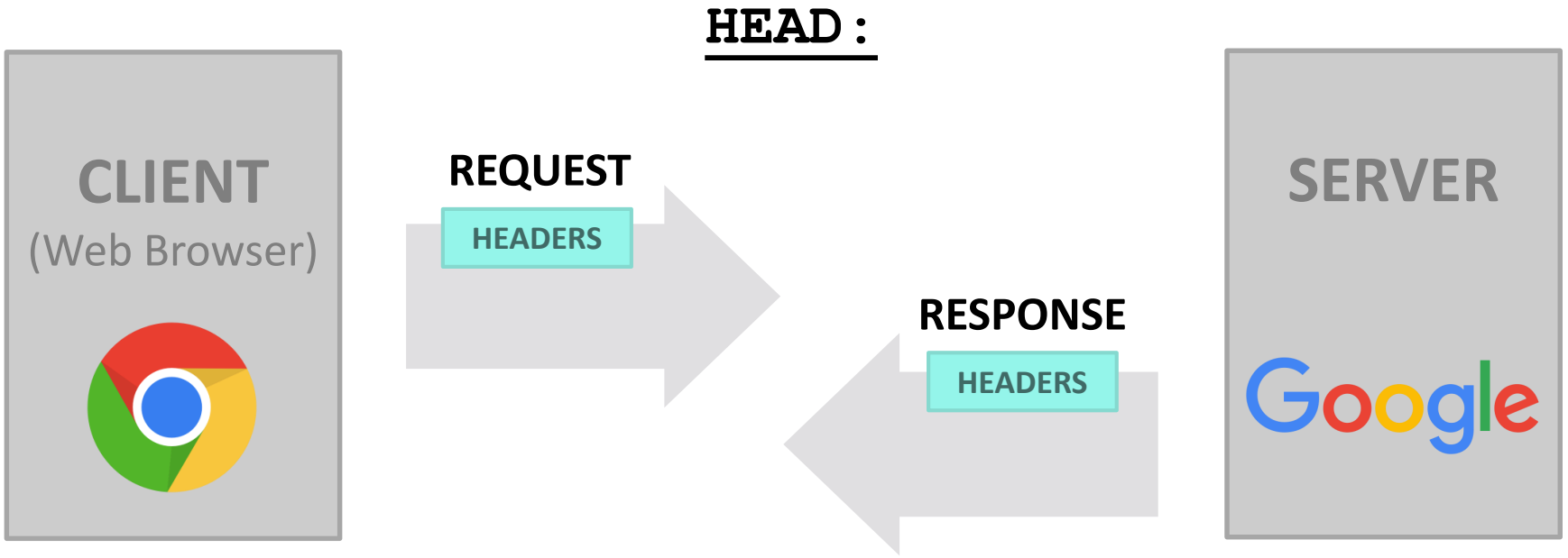
  - **`HEAD`**: "Send me the headers for the named resource"



HTTP Methods

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  - `GET`: "Please send me the named resource"
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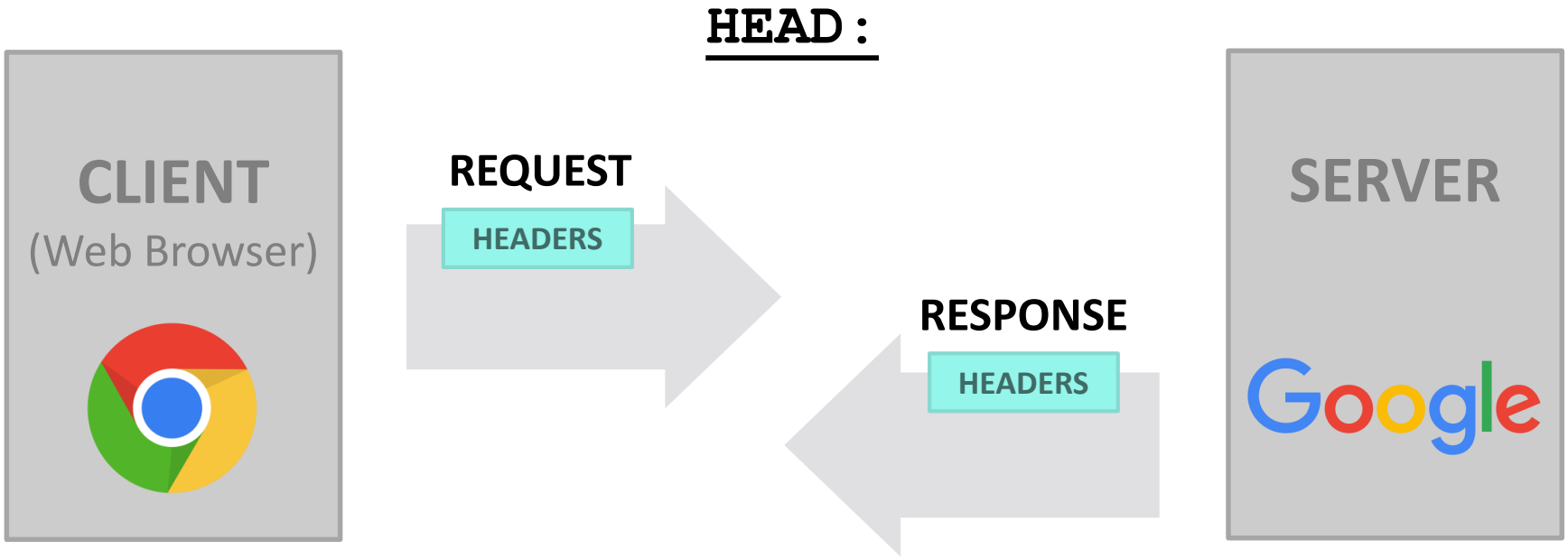
  - **`HEAD`**: "Send me the headers for the named resource"
    - Doesn't send resource; often to check if cached copy is still valid



HTTP Methods

- There are three commonly-used HTTP methods:
  - `GET`: "Please send me the named resource"
  - `POST`: "I'd like to submit data to you" (*e.g.* file upload)
  - `HEAD`: "Send me the headers for the named resource"
    - Doesn't send resource; often to check if cached copy is still valid

- Other methods exist, but are much less common:
  - `PUT`, `DELETE`, `TRACE`, `OPTIONS`, `CONNECT`, `PATCH`, `...`
    - Eg: `TRACE` is "show any proxies or caches in between me and the server"

Client Headers

- The client can provide one or more request "headers"
  - These provide information to the server or modify how the server should process the request

- You'll encounter many in practice
  - `Host:` the DNS name of the server
  - `User-Agent:` an identifying string naming the browser
  - `Accept:` the content types the client prefers or can accept
  - `Cookie:` an HTTP cookie previously set by the server
  - https://www.w3.org/Protocols/rfc2616/rfc2616-sec5.html

A Real Request

```
GET / HTTP/1.1
Host: attu.cs.washington.edu:3333
Connection: keep-alive
Upgrade-Insecure-Requests: 1
User-Agent: Mozilla/5.0 (Windows NT 10.0; Win64; x64) AppleWebKit/537.36
(KHTML, like Gecko) Chrome/66.0.3359.181 Safari/537.36
Accept: text/html,application/xhtml+xml,application/xml;q=0.9,image/webp,
image/apng,*/*;q=0.8
DNT: 1
Accept-Encoding: gzip, deflate
Accept-Language: en-US,en;q=0.9
Cookie: SESS0c8e598bbe17200b27e1d0a18f9a42bb=5c18d7ed6d369d56b69a1c0aa441d7
8f; SESSd47cbe79be51e625cab059451de75072=d137dbe7bbe1e90149797dcd89c639b1;
_sdsat_DMC_or_CCODE=null; _sdsat_utm_source=; _sdsat_utm_medium=; _sdsat_ut
m_term=; _sdsat_utm_content=; adblock=blocked; s_fid=50771A3AC73B3FFF-3F18A
ABD559FFB5D; s_cc=true; prev_page=science.%3A%2Fcontent%2F347%2F6219%2F262%
2Ftab-pdf; ist_usr_page=1; sat_ppv=79; ajs_anonymous_id=%229225b8cf-6637-49
c8-8568-ecb53cfc760c%22; ajs_user_id=null; ajs_group_id=null; __utma=598078
07.316184303.1491952757.1496310296.1496310296.1; __utmc=59807807; __utmc=80
...
```

Lecture Outline

- HTTP: Hypertext Transfer Protocol
  - Client Requests
  - **Server Responses**
- Advanced features and HTTP/2

HTTP Responses

- General form:
  - `HTTP/[version] [status code] [reason]\r\n`
    `[headerfield1]: [fieldvalue1]\r\n`
    `[headerfield2]: [fieldvalue2]\r\n`
    `[...]`
    `[headerfieldN]: [fieldvalueN]\r\n`
    `\r\n`
    `[response body, if any]`

different form request

same syntax as request, but different k/v pairs and different semantics

- Demo: use `nc -C` to see a real response
  - On Mac, use `nc -c` instead . 👎 for lack of standards ☹

Status Codes and Reason

- *Code*: numeric outcome of the request – easy for computers to interpret
  - A 3-digit integer with the 1st digit indicating a response category
    - `1xx`: Informational message
    - `2xx`: Success
    - `3xx`: Redirect to a different URL
    - `4xx`: Error in the client's request
    - `5xx`: Error experienced by the server

- *Reason*: human-readable explanation
  - *e.g.* "OK" or "Moved Temporarily"

Common Statuses

- `HTTP/1.1 200 OK`
  - The request succeeded and the requested object is sent
- `HTTP/1.1 404 Not Found`
  - The requested object was not found
- `HTTP/1.1 301 Moved Permanently`
  - The object exists, but its name has changed
    - The new URL is given as the "`Location:`" header value
- `HTTP/1.1 500 Server Error`
  - The server had some kind of unexpected error

Server Headers

- The server can provide zero or more response "headers"
  - These provide information to the client or modify how the client should process the response

- You'll encounter many in practice
  - `Server:` a string identifying the server software
  - `Content-Type:` the type of the requested object
  - `Content-Length:` size of requested object
  - `Last-Modified:` a date indicating the last time the request object was modified
  - https://www.w3.org/Protocols/rfc2616/rfc2616-sec6.html

A Real Response

```
HTTP/1.1 200 OK
Date: Mon, 21 May 2018 07:58:46 GMT
Server: Apache/2.2.32 (Unix) mod_ssl/2.2.32 OpenSSL/1.0.1e-fips
mod_pubcookie/3.3.4a mod_uwa/3.2.1 Phusion_Passenger/3.0.11
Last-Modified: Mon, 21 May 2018 07:58:05 GMT
ETag: "2299e1ef-52-56cb2a9615625"
Accept-Ranges: bytes
Content-Length: 82
Vary: Accept-Encoding,User-Agent
Connection: close
Content-Type: text/html
Set-Cookie:
bbbbbbbbbbbbbbb=DBMLFDMJCGAOILMBPIIAAIFLGBAKOJNNMCJIKKBKCDMDEJHMPONHCILPIBL
ADEAKCIABMEEPAOPMMKAOLHOKJMIGMIDKIHNCANAPHMFMBLBABPFENPDANJAPIBOIOOOD;
HttpOnly

<html><body>
<font color="chartreuse" size="18pt">Awesome!!</font>
</body></html>
```

Poll Everywhere

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- Are the following statements True or False?

	Q1	Q2
A.	False	False
B.	False	True
C.	True	False
D.	True	True
E.	I'm not sure …	

Q1: A protocol *only* defines the "syntax" that clients and servers can communicate with.

Q2: Clients and servers use the same header fields.

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HTTP/1.1 Feature: Chunked Transfer Encoding

- A server might not know how big a response object is
  - *e.g.* dynamically-generated content in response to a query or other user input
- How do you send Content-Length?
  - Could wait until you've finished generating the response, but that's not great in terms of *latency* – we want to start sending the response right away
- Chunked message body: response is a series of chunks

HTTP/1.1 Feature: Persistent connections

- Establishing a TCP connection is costly
  - Multiple network round trips to set up the TCP connection
  - TCP has a feature called "slow start"; slowly grows the rate at which a TCP connection transmits to avoid overwhelming networks

- A web page consists of multiple objects and a client probably visits several pages on the same server
  - Bad idea: separate TCP connection for each object
  - Better idea: single TCP connection, multiple requests

HTTP/1.1 "Warts"

- World has changed since HTTP/1.1 was adopted
  - Web pages were a few hundred KB with a few dozen objects on each page, now several MB each with hundreds of objects (JS, graphics, …) & multiple domains per page
  - Much larger ecosystem of devices (phones especially)

- Many hacks used to increase HTTP/1.1 performance
  - Multiple TCP sockets from browser to server
  - Caching tricks; JS/CSS ordering and loading tricks; cookie hacks
  - Compression/image optimizations; splitting/sharding requests
  - etc., etc. …

HTTP/2 (1 of 3)

- All current browsers and servers "speak" HTTP/1.1
  - Version 1.1 of the HTTP protocol
    - https://www.w3.org/Protocols/rfc2616/rfc2616.html
  - Standardized in 1997 and meant to fix shortcomings of HTTP/1.0
    - Better performance, richer caching features, better support for multihomed servers, and much more

- HTTP/2 standardized in 2015
  - Doesn't change the basic web request/response model
  - Will coexist with HTTP/1.1 for a long time

HTTP/2 (2 of 3)

- Based on Google SPDY (2010) ; standardized in 2015

- Features:
  - Same core request/response model (GET, POST, OK, …)
  - Binary protocol
    - Easier parsing by machines (harder for humans)
    - Sizes in headers, not discovered as requests are processed
    - Headers compressed and deduplicated by default!
  - Multiple data steams multiplexed on single TCP connection
    - Fixes “head-of-line blocking”
    - With priorities on the streams!
  - Server push and more…

HTTP/2 (3 of 3)

- Security
  - HTTPS bolted onto HTTP in 2000 (TLS-encrypted HTTP)
  - Most HTTP/2 servers only support TLS encryption requests
- Status
  - Used now by most major web sites
  - Coexists with HTTP/1.1
  - HTTP/2 used automatically when browser and server both support it
- Flaws
  - Standardization process was “fast”
  - Encryption not part of the standard
  - TCP-level head-of-line blocking

Poll Everywhere

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- Which HTTP status code family do you think the following Reasons belong to?

	Q1	Q2
A.	4xx	2xx
B.	4xx	3xx
C.	5xx	2xx
D.	5xx	3xx
E.	I'm not sure …	

Q1: Gateway Time-out

Q2: No Content

Extra Exercise #1

- Write a program that:
  - Creates a listening socket that accepts connections from clients
  - Reads a line of text from the client
  - Parses the line of text as a DNS name
  - Connects to that DNS name on port 80
  - Writes a valid HTTP request for "/"

```
GET / HTTP/1.1\r\n
Host: <DNS name>\r\n
Connection: close\r\n
\r\n
```

  - Reads the reply and returns it to the client