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**Which concept has given you the most difficulty so far in the context of Homework 3?**

- A. Understanding the index file layout
- B. C++ Classes & Inheritance
- C. C++ STL
- D. Query Processor Algorithm
- E. Debugging/GDB
- F. Style considerations
- G. Prefer not to say

*Different Link (again)*

# Hypertext Transfer Protocol

## CSE 333 Winter 2023

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# Relevant Course Information

- ❖ Midterm grades have been released
  - Regrades are open until Wednesday (3/1)
- ❖ Exercise 10 due Wednesday (3/1)
  - Client-side programming
- ❖ Exercise 11 due Friday (3/3)
  - Server-side programming
  - Can use ex10 client solution to send messages to ex11 server
- ❖ Homework 4 due next Thursday (3/09)
  - **Can still use 2 late days for hw4 (hard deadline of 3/12)**
  - Part of section this week will cover tools for debugging hw4

# Homework 4 Summary

- ❖ Build a Multithreaded Web Server (333gle)
  - You will host the querying service that you built in your previous homework on a web server
- ❖ Running your server
  - *careful w/ collisions!*  
`./http333d <port> <static files> <unit indices>`  
*files on disk sent to client*  
*HW3 .idx*
  - Static files are the files on disk corresponding to our index files
  - You (and others) can access it on any browser now!  
*↳ use http:// not https://*
- ❖ Implementation
  - Using network protocols to communicate between client/server
  - Handling some additional security flaws
  - Note: Multithreading is already implemented for you

# Client and Server Communication

- ❖ Lecture 20 (Client-side and Server-side Networking) has already shown how to do this in C/C++
  - `sendreceive.cc` and `server_accept_rw_close.cc`
- ❖ This is what actually happens on the web!
  - Clients establish a stable TCP connection to the server
  - Lots of bytes are interchanged/processed between each other



# Case Study of Protocols: HTTP

- ❖ A **protocol** defines a set of rules governing the **format** and **exchange** of messages (in a computing system)
  - Syntax: The formatting or grammar of the system
  - Semantics: What messages are being exchanged
  - Allows everyone be on the same page of communication
- ❖ **Hypertext Transfer Protocol: Request/Response Protocol**
  - HTTP defines how we should send information between a client and a server
  - A **request** will send a message to the server (about anything)
  - A **response** will process and respond to that message
  - And it's human readable!

# Requests: Client Sending Messages

- ❖ A client wants to talk to a server about something
  - Initiates a conversation (establish or using existing connection)
  - Generally, this is for retrieving a resource, using **Uniform Resource Identifier (URI)**

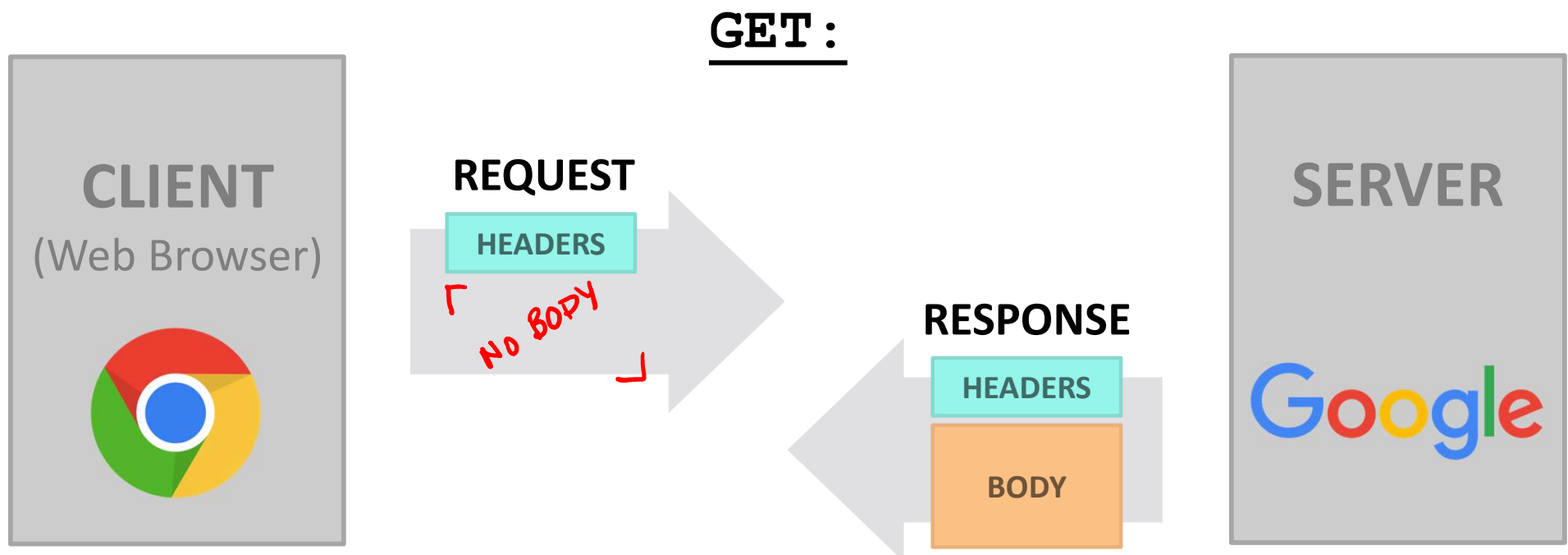
*www.google.com/index.html*  
URI

- ❖ Standard Syntax:

- [METHOD] *→ /index.html* [request-uri] HTTP/*→ 1.1* [version] \r\n  
[headerfield1]: [fieldvalue1] \r\n  
[headerfield2]: [fieldvalue2] \r\n  
[...]  
[headerfieldN]: [fieldvalueN] \r\n  
\r\n  
[request body, if any] *2x CRLF split headers*

# HTTP Methods

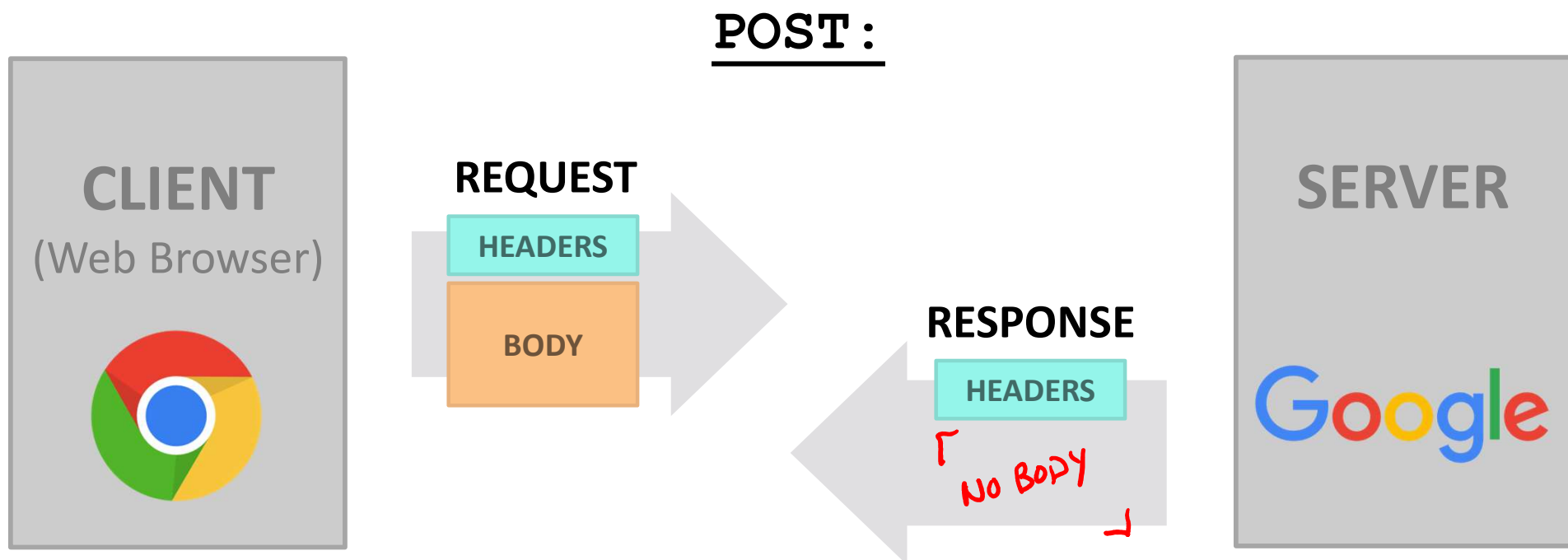
- ❖ There are three commonly-used HTTP methods:
  - **GET**: “Please send me the named resource”





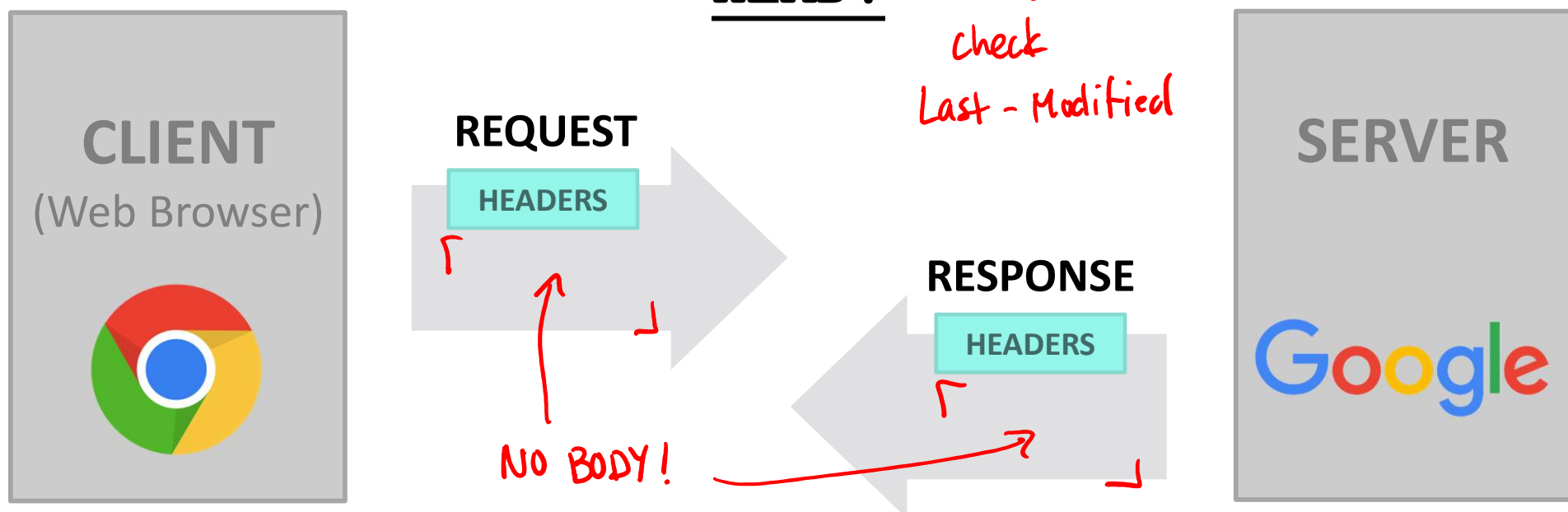
# HTTP Methods

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    - Doesn’t send resource; often to check if cached copy is still valid



# 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)
  - **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, . . .
    - For instance: TRACE – “show any proxies or caches in between me and the server”
  - <https://developer.mozilla.org/en-US/docs/Web/HTTP/Methods>

Web Programming

↑  
Mozilla Docs

# 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 → Good for multi-homing
  - `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 → e.g. login token
  - <https://www.rfc-editor.org/rfc/rfc2616.html#section-5.3>

↑ HTTP Standard (Dense)

# 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
Cookie:
SESS0c8e598bbe17200b27e1d0a18f9a42bb=5c18d7ed6d369d56b69a1
c0aa441d
...
```

- ❖ Demo: use nc to see a real HTTP request

*↳ nc -l <port num>*

*connect w/ browser*

# Response: Server Responding

- ❖ A server parses and sends a response to a user
  - Indicate how the server processed the request (accepted or not)
  - Send requested resource back to the client

- ❖ General form:

*1.1* →

```
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]
```

*linked* ↷

# Status Codes and Reason

- ❖ *Code*: numeric outcome of the request – easy for computers to interpret
  - A 3-digit integer with the 1<sup>st</sup> 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"

Ex:

404 old webpage

200 success

403 No perms

# 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 → *size of response body*
- `Last-Modified`: a date indicating the last time the request object was modified
- <https://developer.mozilla.org/en-US/docs/Web/HTTP/Headers>

*HW4* ✱ [https://developer.mozilla.org/en-US/docs/Web/HTTP/Basics\\_of\\_HTTP/MIME\\_types](https://developer.mozilla.org/en-US/docs/Web/HTTP/Basics_of_HTTP/MIME_types)

*MIME  
Type*

*size of  
response  
body*

# 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_publiccookie/3.3.4a mod_uwa/3.2.1
Phusion_Passenger/3.0.11
Last-Modified: Mon, 21 May 2018 07:58:05 GMT
Content-Length: 82
Content-Type: text/html
...
<html><body>
<font color="chartreuse" size="18pt">Awesome!!</font>
</body></html>
```

❖ Demo: Use telnet to see real HTTP responses

└ telnet <hostname> <port num>



# Poll Everywhere

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## Which statement is FALSE about the HTTP/1.1 Protocol?

- ~~A.~~ **HTTP** is a standard communication protocol for the web  
*True, P for protocol*
- ~~B.~~ A client always sends a message first before the server  
*True, Request - Response protocol*
- ~~C.~~ An HTTP Request can only request one resource at a time  
*True, only 1 URI*
- D.** An HTTP Response needs to have a response body  
*False, see HEAD or POST Response*
- E. I'm not really sure...

# HTTP/1.1 Protocol

- ❖ HTTP / 1.1 (1997) – The protocols accepted by **all current browsers and servers**
  - Built after HTTP/0.9 (1991) and HTTP/1.0 (1996)
  - Better performance, richer caching features, better support for multihomed servers, and much more
- ❖ “Chunked Transfer-Encoding” – Send responses in multiple pieces (Transfer-Encoding: chunked)
  - [https://en.wikipedia.org/wiki/List\\_of\\_HTTP\\_header\\_fields#transfer-encoding-response-header](https://en.wikipedia.org/wiki/List_of_HTTP_header_fields#transfer-encoding-response-header)
- ❖ Persistent Connections: TCP connections can handle multiple requests (Connection: keep-alive)
  - ↳ No need to re-connect

# Improvements: HTTP/2 and HTTP/3

- ❖ Human-readable text protocols can only go so far
- ❖ HTTP/2 (2015) was a push to optimize HTTP/1.1
  - Built off Google Project SPDY which aimed to reduce latency
  - Compressed headers and message body
  - Many larger companies quickly transitioned
  - <https://en.wikipedia.org/wiki/HTTP/2>
- June 6th 2022
- ❖ HTTP/3 (2022) builds even more on HTTP/2
  - Mainly using UDP-based protocol called QUIC (holds a standard connection like TCP)
  - <https://en.wikipedia.org/wiki/HTTP/3>

# Slow to Change: HTTP Protocols

- ❖ HTTP/1.1 is still used today (1997 – Present)
  - <https://almanac.httparchive.org/en/2022/http#fig-1>
  - ~20% of requests still use HTTP/1.1
  - <https://almanac.httparchive.org/en/2019/http#fig-3>
  - Down from ~50% of requests 4 years ago
- ❖ Why is the transition taking so long?
  - Lack of knowledge about HTTP/2+
  - A good portion of web servers are still using HTTP/1.1
  - It takes engineering work to support a new HTTP protocol
  - HTTP/1.1 is human readable → *Time and Money*
  - Amongst more...

# Thanks Everyone for Listening to my Lectures!

- ❖ Honestly super cool to be able to lecture to a bunch of students. Wish time permitted for more guest lectures!
- ❖ I will be the Summer Instructor for CSE 333 (23su), so if you are interested in working with me, please contact me:
  - Email: [tzyang2@cs.uw.edu](mailto:tzyang2@cs.uw.edu)
  - I will probably send an Ed post in Spring quarter
- ❖ Best of luck with the rest of the quarter! You got this! 😊  
↳ Exercises, HW4, Final

# 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