Server-side Web Security: SQL Injection Attacks & XSS

CS 161: Computer Security

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SQL Injection Scenario

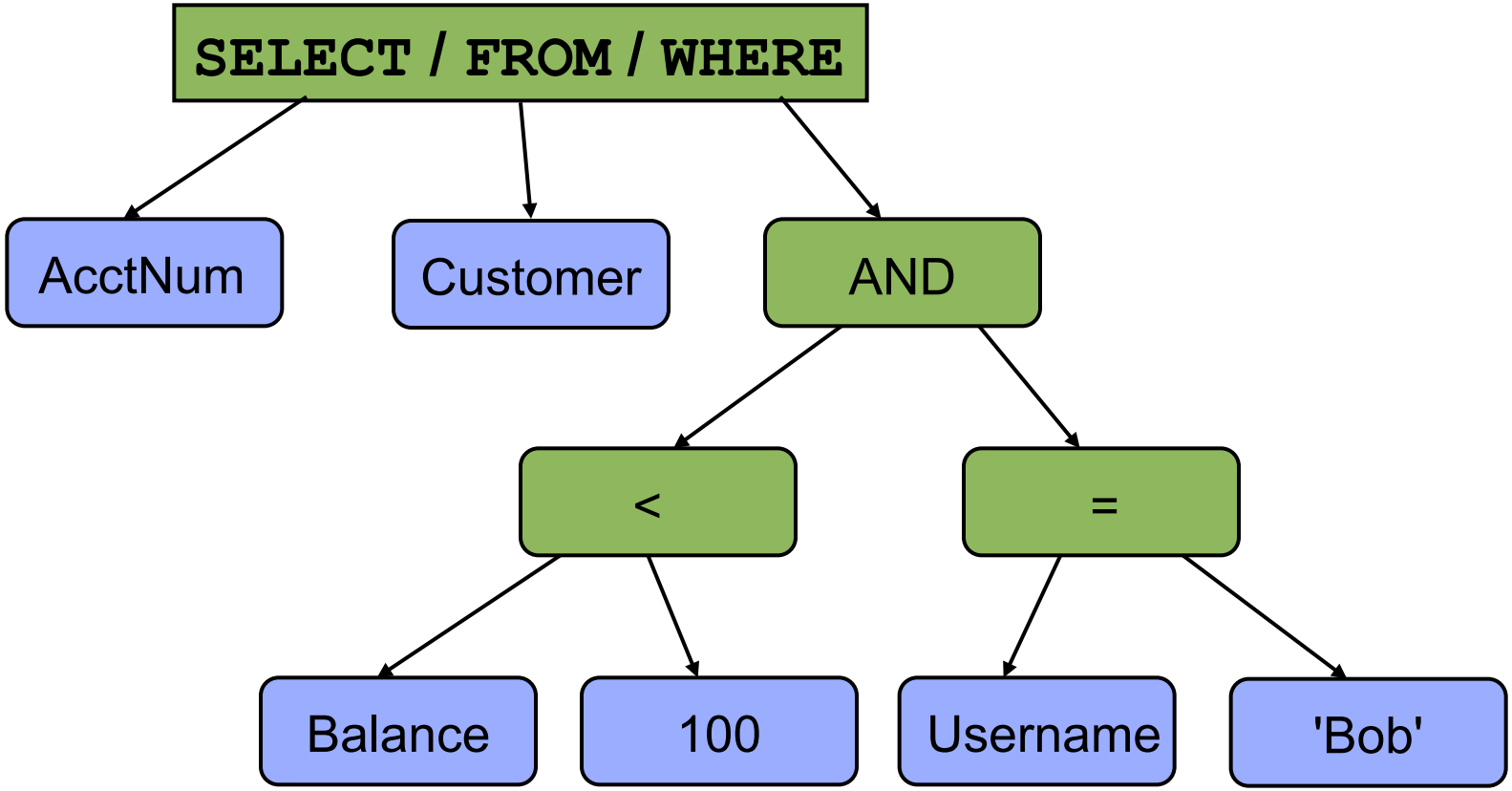
- Suppose web server front end stores URL parameter "`recipient`" in variable `$recipient` and then builds up a string with the following SQL query:

```
$sql = "SELECT AcctNum FROM Customer
        WHERE Balance < 100 AND
         Username='$recipient' ";
```

- So for "?recipient=Bob" the SQL query is:

```
"SELECT AcctNum FROM Customer
        WHERE Balance < 100 AND
         Username='Bob' "
```

Parse Tree for SQL Example




```
SELECT AcctNum FROM Customer
   WHERE Balance < 100 AND Username='Bob'
```

SQL Injection Scenario

- Suppose web server front end stores URL parameter "`recipient`" in variable `$recipient` and then builds up a string with the following SQL query:

```
$sql = "SELECT AcctNum FROM Customer
        WHERE Balance < 100 AND
         Username='$recipient' ";
```

- How can $recipient cause trouble here?
  - How can we see anyone's account?
    - Even if their balance is >= 100

SQL Injection Scenario, cont.

```
WHERE Balance < 100 AND
        Username='$recipient'
```

- Conceptual idea (doesn't quite work): Set `recipient` to "foo' OR 1=1" …

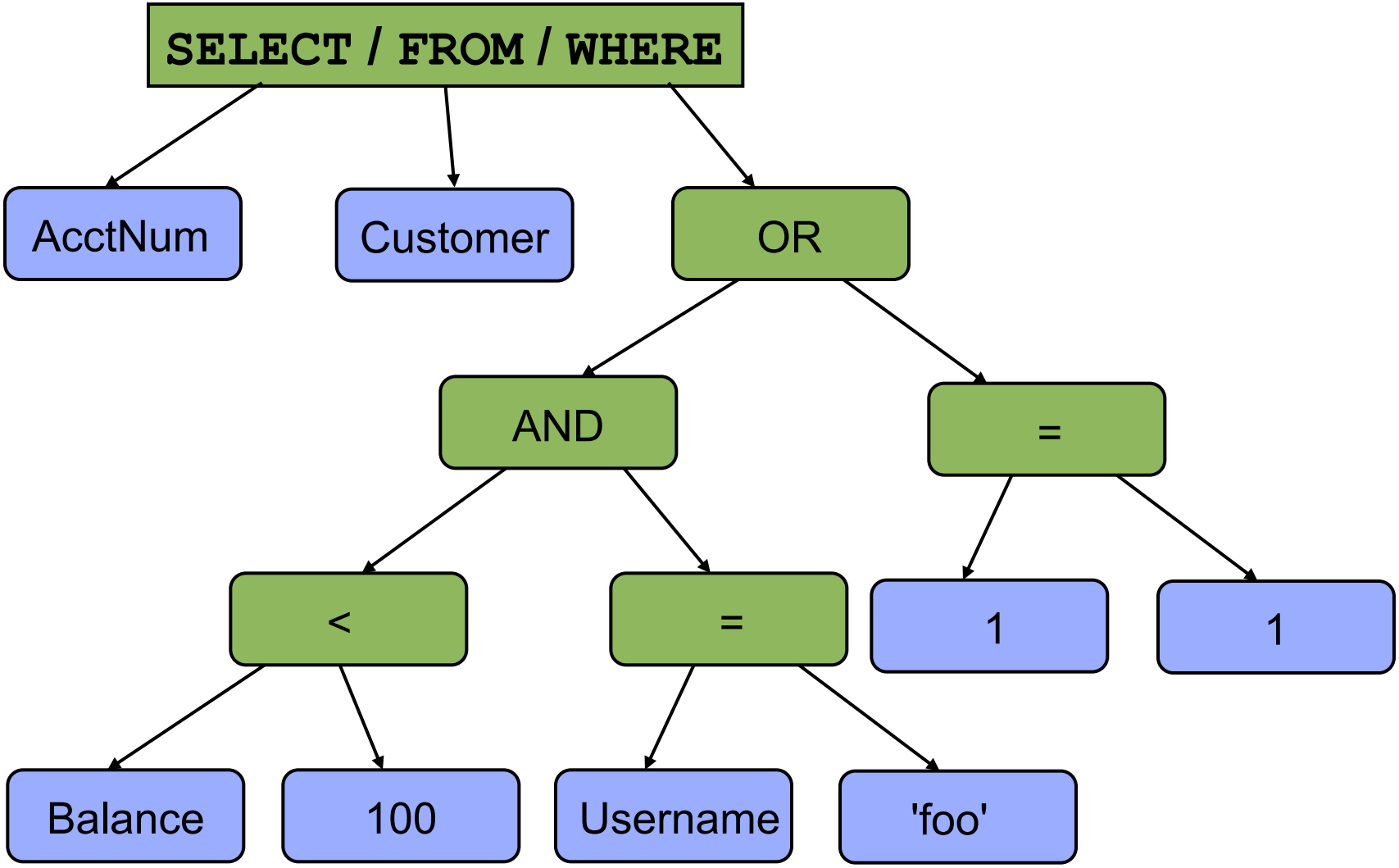
```
WHERE Balance < 100 AND
        Username='foo' OR 1=1'
```

- *Precedence* makes this:

```
WHERE (Balance < 100 AND
        Username='foo') OR 1=1
```

- Always true!

Parse Tree for *SQL Injection*




```
SELECT AcctNum FROM Customer
 WHERE (Balance < 100 AND  Username='foo') OR 1=1
```

SQL Injection Scenario, cont.

- Why "foo' OR 1=1" doesn't quite work:

  WHERE Balance < 100 AND
  Username='foo' OR 1=1'

Syntax error: quotes aren't balanced

SQL server will reject command as ill-formed

SQL Injection Scenario, cont.

- Why "foo' OR 1=1" doesn't quite work:

  WHERE Balance < 100 AND
  Username='foo' OR 1=1'

- Sneaky fix: use "foo' OR 1=1--"

  Begins SQL comment …

SQL Injection Scenario, cont.

- Why "foo' OR 1=1" doesn't quite work:

```
WHERE Balance < 100 AND
        Username='foo' OR 1=1'
```

- Sneaky fix: use "foo' OR 1=1 --"
- SQL server sees:

```
WHERE Balance < 100 AND
        Username='foo' OR 1=1 --'
```

When parsing SQL query, SQL server ignores all of this since it's a comment …

So now it finds the quotes balanced; no syntax error; **successful injection**!

SQL Injection Scenario, con't

```
WHERE Balance < 100 AND
        Username='$recipient'
```

- How about $recipient =
  foo'; DROP TABLE Customer -- ?
- Now there are two separate SQL commands, thanks to ';' command-separator.
- Can *change database* however you wish

SQL Injection: Summary

- Target: web *server* that uses a back-end database
- Attacker goal: inject or modify database commands to either read or alter web-site information
- Attacker tools: ability to send requests to web server (e.g., via an ordinary browser)
- Key trick: web server allows characters in attacker's input to be interpreted as SQL control elements rather than simply as data

Welcome to the Amazing World Of Squigler …

Some Squigler Database Tables

Squigs		
`username`	`body`	`time`
ethan	*My first squig!*	2013-02-27 21:51:52
cathy	*@ethan: borrr-ing!*	2013-02-27 21:52:06
…	…	…

```
def post_squig(user, squig):
    if not user or not squig: return
    conn = sqlite3.connect(DBFN)
    c    = conn.cursor()
    c.executescript("INSERT INTO squigs VALUES
          ('%s', '%s', datetime('now'));" %
                                (user, squig))
    conn.commit()
    c.close()
```

Server code for posting a “squig”

```
INSERT INTO squigs VALUES
     (dilbert, 'don't contractions work?',
      date);
```

Syntax error

Squigler Database Tables

Accounts		
`username`	`password`	`public`
dilbert	funny	‘t’
alice	kindacool	‘f’
…	…	…

```
INSERT INTO squigs VALUES
     (dilbert, '' || (select (username || '␣' || password) from
accounts where username='bob') || '',
      date);
```

```
INSERT INTO squigs VALUES
     (dilbert, '' || (select (username || '␣' || password) from
accounts where username='bob') || '',
      date);
```

Empty string literals

```
INSERT INTO squigs VALUES
     (dilbert, '' || (select (username || ' ' || password) from
accounts where username='bob') || '',
      date);
```

A blank separator, just for tidiness

```
INSERT INTO squigs VALUES
     (dilbert, '' || (select (username || '␣' || password) from
accounts where username='bob') || '',
      date);
```

Concatenation operator.

Concatenation of string **S** with empty string is just **S**

```
INSERT INTO squigs VALUES
     (dilbert, (select (username || '␣' || password) from
accounts where username='bob'),
      date);
```

Value of the squig will be Bob's username and password!

Defenses

Language support for constructing queries

Specify query structure independent of user input:

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```
ResultSet getProfile(Connection conn, String arg_user)
{
   String query = "SELECT AcctNum FROM Customer WHERE
                        Balance < 100 AND Username = ?";
   PreparedStatement p = conn.prepareStatement(query);
   p.setString(1, arg_user);
   return p.executeQuery();
}
```

"Prepared Statement"

Defenses

Language support for constructing queries

Specify query structure independent of user input:

```
ResultSet getProfile(Connection conn, String arg_user)
{
   String query = "SELECT AcctNum FROM C
                        Balance < 100 AND Username = ?";
   PreparedStatement p = conn.prepareStatement(query);
   p.setString(1, arg_user);
   return p.executeQuery();
}
```

Untrusted user input

Defenses

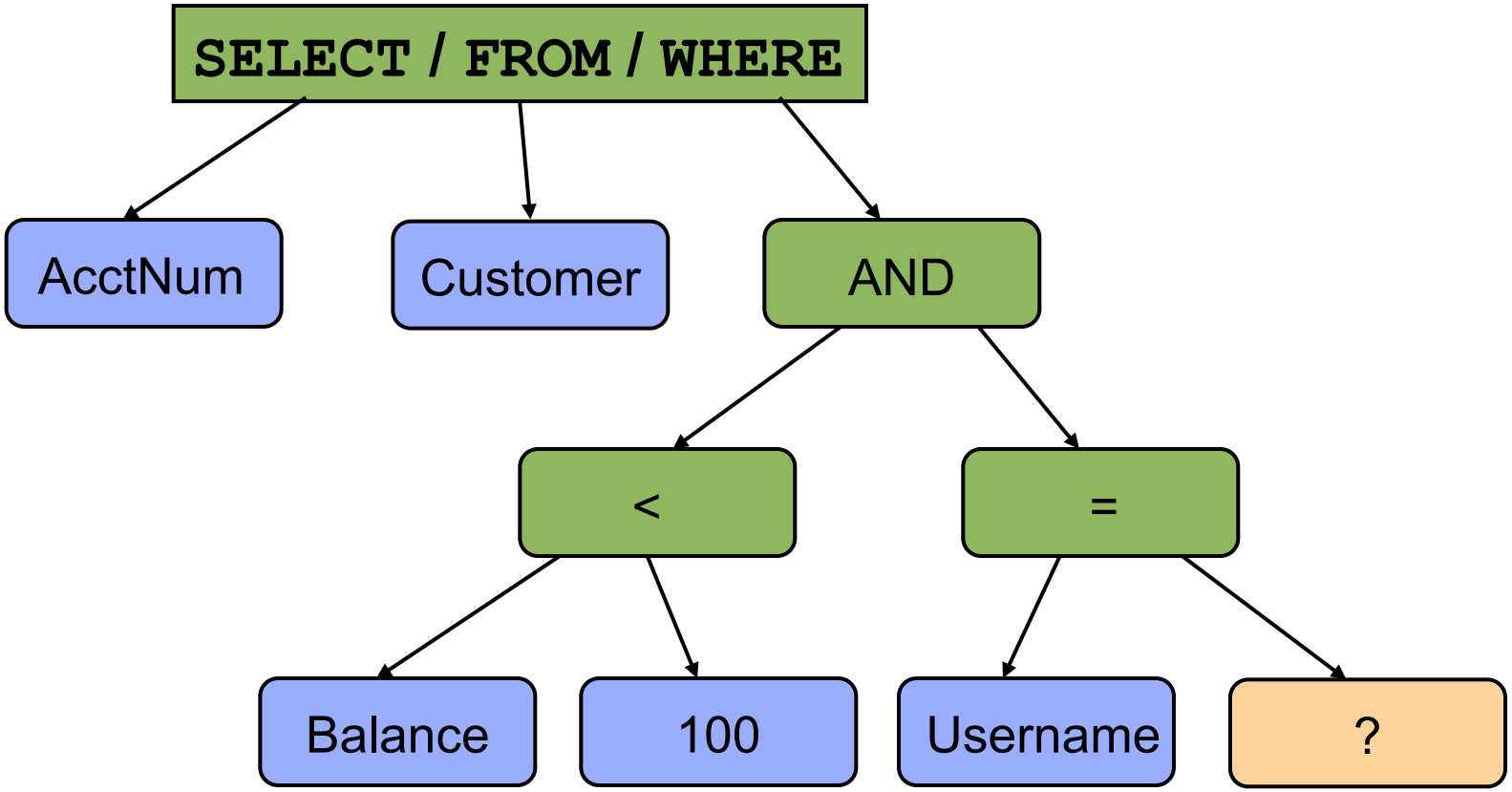
Language support for constructing queries

Specify query structure independent of user input:

```
ResultSet getProfile(Connection conn, String arg_user)
{
   String query = "SELECT AcctNum FROM Customer WHERE
                        Balance < 100 AND Username = ?";
   PreparedStatement p = conn.prepareStatement(query);
   p.setString(1, arg_user);
   return p.executeQuery();
}
```

Input is confined to a single SQL atom

Parse Tree Template Constructed by `Prepared` Statement



Note: **`prepared`** statement only allows ?'s for leaves, not internal nodes. So *structure* of tree is *fixed*.

Defenses

Language support for constructing queries

Specify query structure independent of user input:

```
ResultSet getProfile(Connection conn, String arg_user)
{
   String query = "SELECT AcctNum FROM Customer WHERE
                        Balance < 100 AND Username = ?";
   PreparedStatement p = conn.prepareStatement(query);
   p.setString(1, arg_user);
   return p.executeQuery();
}
```

Binds the value of arg_user to '?' atom

Defenses

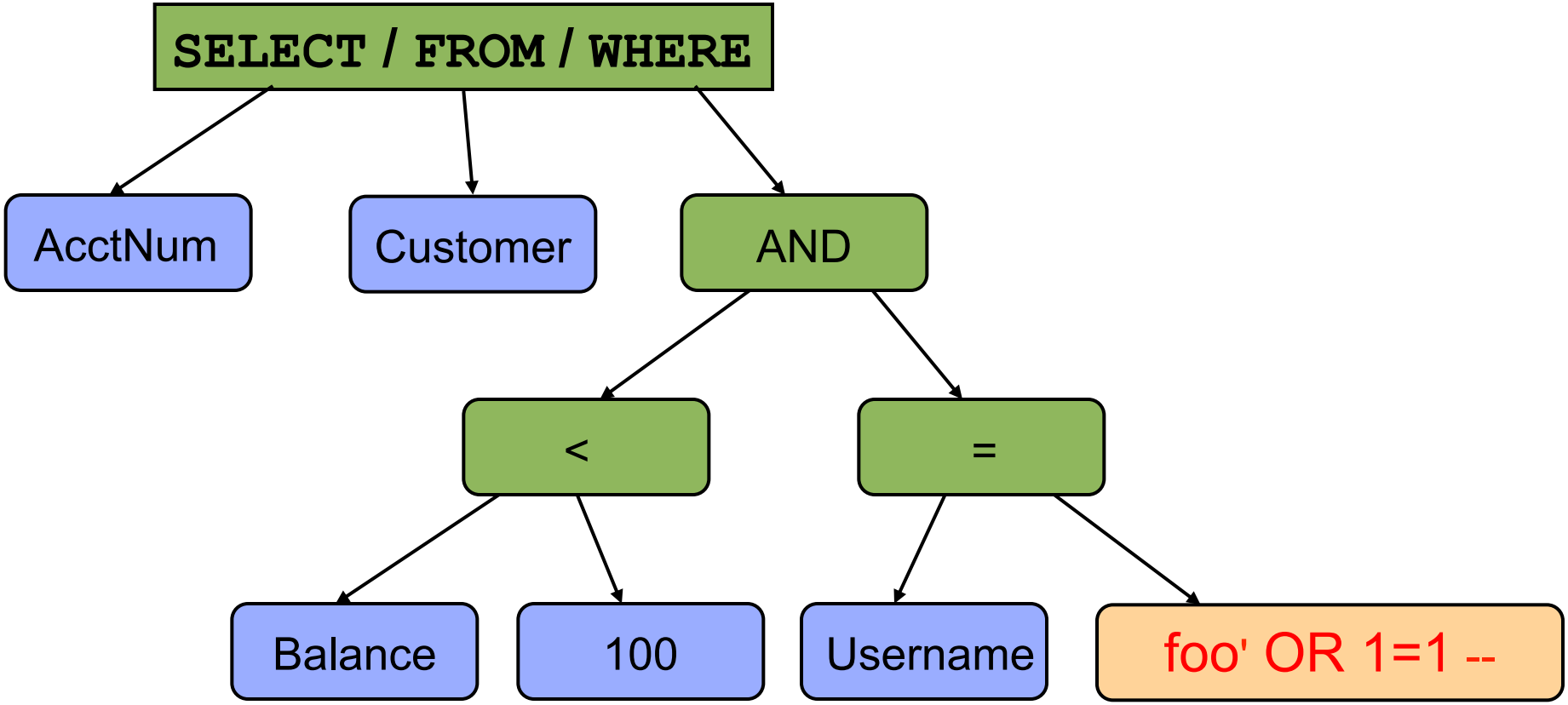
Language support for constructing queries

Specify query structure independent of user input:

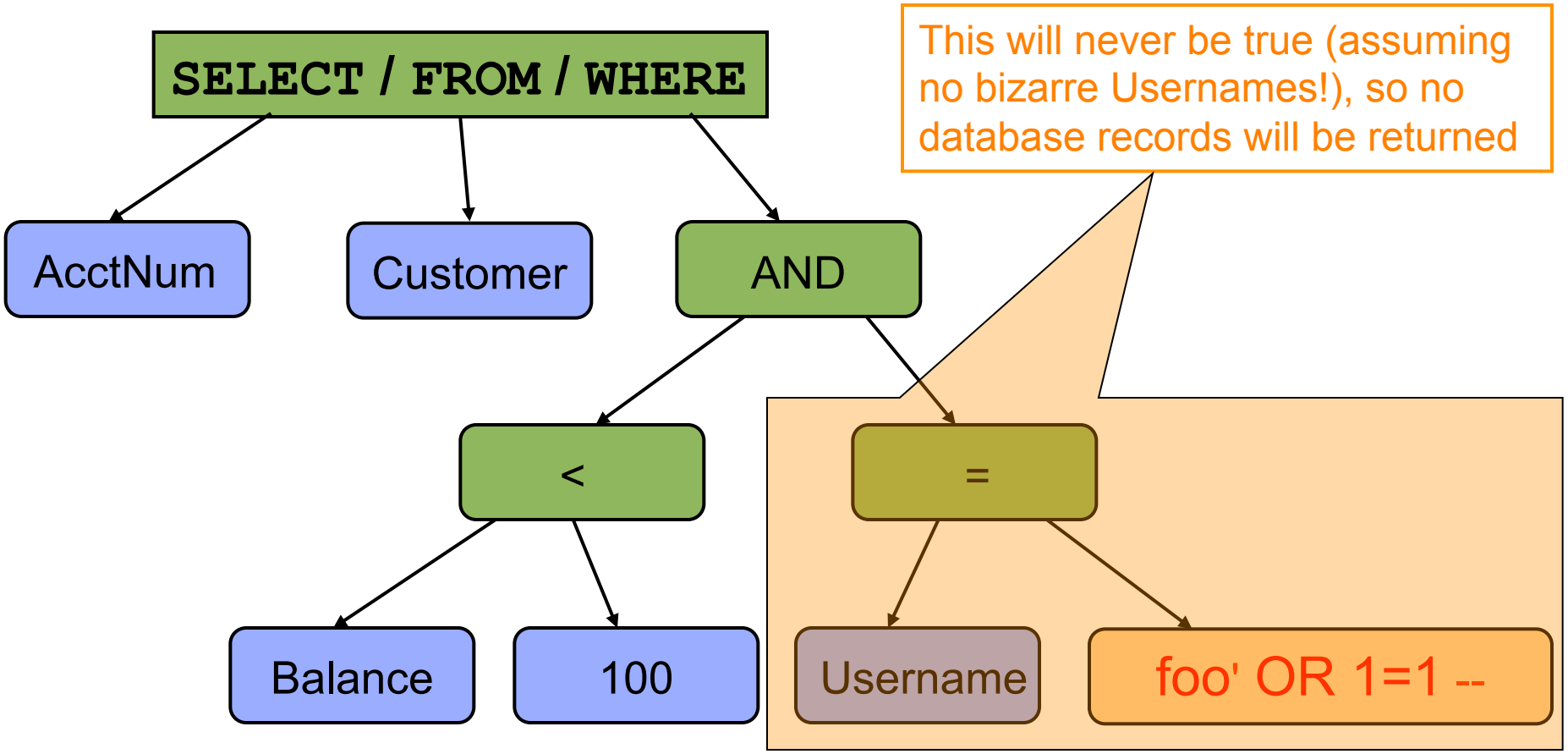
```
ResultSet getProfile(Connection conn, String arg_user)
{
   String query = "SELECT AcctNum FROM Customer WHERE
                        Balance < 100 AND Username = ?";
   PreparedStatement p = conn.prepareStatement(query);
   p.setString(1, arg_user);
   return p.executeQuery();
}
```

No matter what input user provides, Prepared Statement ensures it will be treated as a single SQL datum

Parse Tree Template Constructed by Prepared Statement



Parse Tree Template Constructed by Prepared Statement




ZU 0666', 0, 0); DROP DATABASE TABLICE;

XSS

- Cross-site scripting (**XSS**): tricking browsers into giving undue access to attacker's Javascript
  - *Stored* XSS: attacker leaves Javascript lying around on benign web service for victim to stumble across
  - *Reflected* XSS: attacker gets user to click on specially-crafted URL with script in it, web service reflects it back

Dynamic Web Pages

- Rather than static HTML, web pages can be expressed as a program, say written in *Javascript*:

```
<title>Javascript demo page</title>

<font size=30>
Hello, <b>
<script>
var a = 1;
var b = 2;
document.write("world: ", a+b, "</b>");
</script>
```

Javascript

- Powerful web page *programming language*
- Scripts are embedded in web pages returned by web server
- Scripts are executed by browser. Can:
  - Alter page contents
  - Track events (mouse clicks, motion, keystrokes)
  - Read/set cookies
  - Issue web requests, read replies
- *(Note: despite name, has nothing to do with Java!)*

Confining the Power of Javascript Scripts

- Given all that power, browsers need to make sure JS scripts don't abuse it
- For example, don't want a script sent from `hackerz.com` web server to read cookies belonging to `bank.com` …
- … or alter layout of a `bank.com` web page
- … or read keystrokes typed by user while focus is on a `bank.com` page!

Same Origin Policy

- Browsers provide isolation for JS scripts via the Same Origin Policy (**SOP**)
- Simple version:
  - Browser associates web page elements (layout, cookies, events) with a given **origin** ≈ web server that provided the page/cookies in the first place
    - Identity of web server is in terms of its hostname, e.g., `bank.com`
- SOP = *only scripts received from a web page's origin have access to page's elements*

XSS: Subverting the Same Origin Policy

- It'd be **Bad** if an attacker from `evil.com` can fool your browser into executing script of their choice …
  - … with your browser believing the script's origin to be some other site, like `bank.com`
- One nasty/general approach for doing so is trick the server of interest (e.g., `bank.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 all that powerful/nasty access
- Such attacks are termed *Cross-Site Scripting* (**XSS**)

Syndicate

R Domains already xss'ed.
S Famous and Government web sites.
F Status: Fixed/Unfixed.
PR Pagerank by Alexa®.

You can subscribe to our mailing list to receive alerts by mail.

Date	Author	Domain	R	S	F	PR	Category	Mirror
21/02/11	LostBrilliance	audience.cnn.com	R	★	✗	53	XSS	mirror
21/02/11	db	freedns.afraid.org		★	✗	8834	XSS	mirror
19/02/11	h3rcul3s	cwg2010.indianexpress.com		★	✗	2942	XSS	mirror
18/02/11	Yeyah	app.email.skype.com		★	✗	189	XSS	mirror
17/02/11	warvector	www.level3.com		★	✗	53575	XSS	mirror
17/02/11	SeeMe	api.screenname.aol.com		★	✗	51	XSS	mirror

Two 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 `bank.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 `bank.com` server