CIS 447/544: Computer and Network Security

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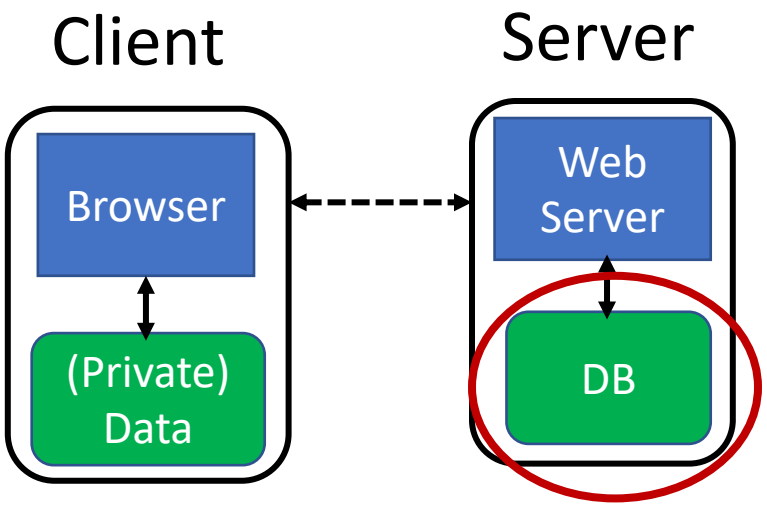
SQL databases

- There are different kinds of DBMSes, differing in
  - organization of data
  - structure of transactions
  - etc.
- SQL DBMS are the most common
  - SQL: Structured Query Language
    - data is organized in **tables** (aka **relations**)
    - transactions work with the rows and columns of tables
    - Newer types of DBMSes
      - data remains unstructured
      - We're not looking at these

SQL Injection

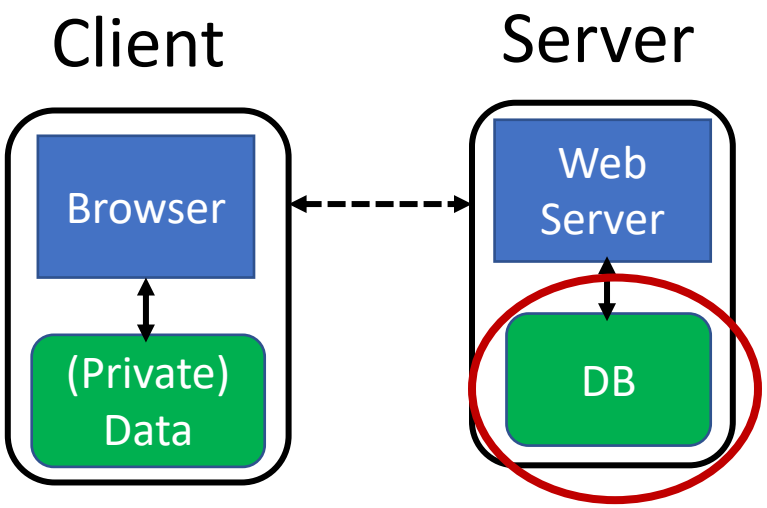


Server-side data

Database: provides long-lived data storage and manipulation

- Database Management System (DBMS) provides
  - **Transactions**: add / retrieve / modify / restructure data
  - **ACID** properties
    - **A**tomicity: transaction completes entirely or not at all
    - **C**onsistency: database stays in a valid state
    - **I**solation: transaction's effects visible only upon completion
    - **D**urability: once committed, its effects persist, eg, despite power failures

Server-side data



Long-lived state, stored in a separate database

Need to protect this state from illicit access and tampering

SQL (Structured Query Language)

Users

Name	Gender	Age	Email	Password
Connie	F	12	connie@bc.com	j3i8g8ha
Steven	M	14	steven@bc.com	a0u23bt
Greg	M	34	greg@bc.com	0aergja
Cindy	F	35	cindy@bc.com	1bjb9a93

Get Records

```
SELECT *
FROM Users
WHERE name ='Steven'
```

Update Records

```
Update Users
SET email='s@bc.com'
WHERE name ='Steven'
```

Insert Records

```
INSERT INTO Users
Values('Ed', 'M',
'15','ed@bc.com','pass123')
```

SQL (Structured Query Language)

Table

Users **Table name**

Name	Gender	Age	Email	Password
Connie	F	12	connie@bc.com	j3i8g8ha
Steven	M	14	steven@bc.com	a0u23bt
Greg	M	34	greg@bc.com	0aergja
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Row (Record)

Column

Database transactions

Transactions are the unit of work on a database

"Give me everyone in the User table who is listed as taking CIS447 in the Classes table"

2 reads

1 transaction

"Deduct $100 from Alice; Add $100 to Bob"

2 writes

SQL (Structured Query Language)

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SELECT Age FROM Users WHERE Name='Greg';

SQL (Structured Query Language)

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Cindy	F	35	cindy@bc.com	1bjb9a93

SELECT Age FROM Users WHERE Name='Greg'; 34

SQL (Structured Query Language)

Users

Name	Gender	Age	Email	Password
Connie	F	12	connie@bc.com	j3i8g8ha
Steven	M	14	steven@bc.com	a0u23bt
Greg	M	34	mr.uni@bc.com	0aergja
Cindy	F	35	cindy@bc.com	1bjb9a93

```
SELECT Age FROM Users WHERE Name='Greg';   34

UPDATE Users SET Email='mr.uni@bc.com'
    WHERE Age=34; -- this is a comment

SELECT  * FROM Users WHERE Age > 25
        /* this is also a comment */ AND Gender='M';
```

SQL (Structured Query Language)

Users

Name	Gender	Age	Email	Password
Connie	F	12	connie@bc.com	j3i8g8ha
Steven	M	14	steven@bc.com	a0u23bt
Greg	M	34	mr.uni@bc.com	0aergja
Cindy	F	35	cindy@bc.com	1bjb9a93
Pearl	F	10000	pearl@bc.com	ziog9gga

SELECT Age FROM Users WHERE Name='Greg'; 34

UPDATE Users SET Email='mr.uni@bc.com'
WHERE Age=34; -- this is a comment

INSERT INTO Users Values('Pearl, 'F',...);

SQL (Structured Query Language)

Users

Name	Gender	Age	Email	Password
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```
SELECT Age FROM Users WHERE Name='Greg';   34

UPDATE Users SET Email='mr.uni@bc.com'
        WHERE Age=34; -- this is a comment
INSERT INTO Users Values('Pearl, 'F',...);

DROP TABLE Users;
```

SQL (Structured Query Language)

```
SELECT Age FROM Users WHERE Name='Greg';   34
UPDATE Users SET Email='mr.uni@bc.com'
    WHERE Age=34; -- this is a comment
INSERT INTO Users Values('Pearl, 'F',…);
DROP TABLE Users;
```

Example 1

```
<?php
   $sql = "SELECT id, name, salary
           FROM credential
           WHERE eid='$eid'";
   $result = $conn->query($sql);
?>
```

If you do not know any eid, can you get the database to return some records?

eid [ ]

What do you put here?

Example 1

```
<?php
   $sql = "SELECT id, name, salary
           FROM credential
           WHERE eid='$eid'";
   $result = $conn->query($sql);
?>
```

If you do not know any eid, can you get the database to return some records?

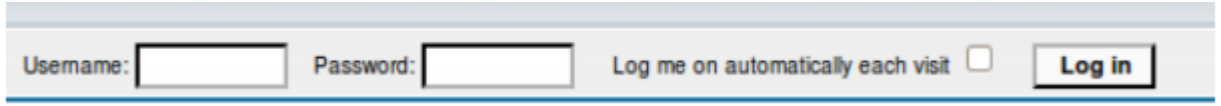
What do you put here?

' XYZ' OR 1=1 -- '

eid

Example 2

Website



"Login code" (PHP)

In class exercise

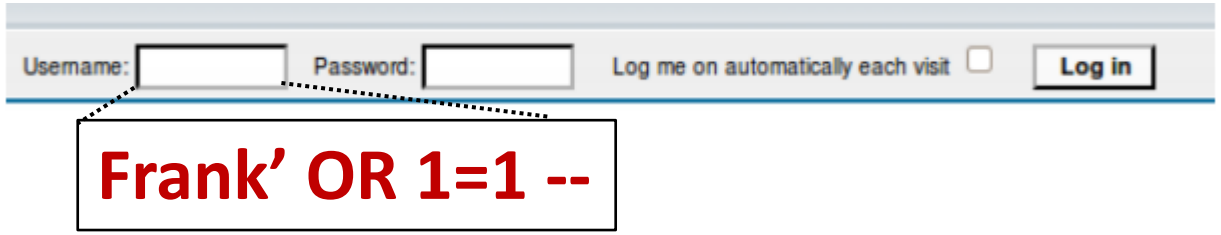
```
$sql = "select * from Users
where name='$user' and password='$pass'";
$result = $conn->query($sql);
```

How do you log into this website?

How could you exploit this?

Example 2

Website




```
$sql = "select * from Users
where name='$user' and password='$pass'";
$result = $conn->query($sql);
```

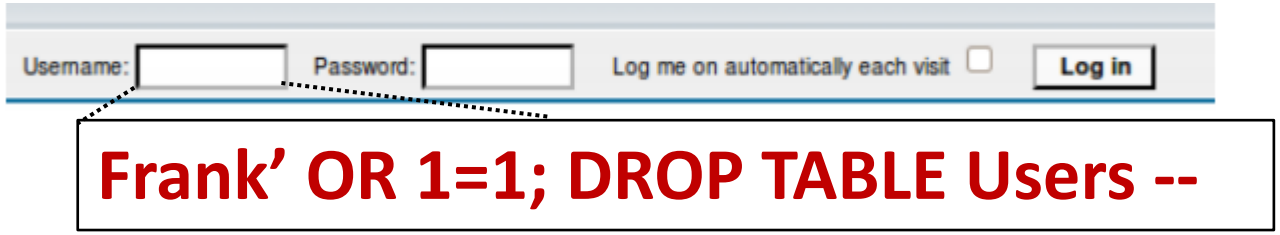
```
$sql = "select * from Users
where name='frank' OR 1=1 -- and
password='whocares'";
```

Login successful!

Problem: Data and code mixed up together

SQL injection: Worse

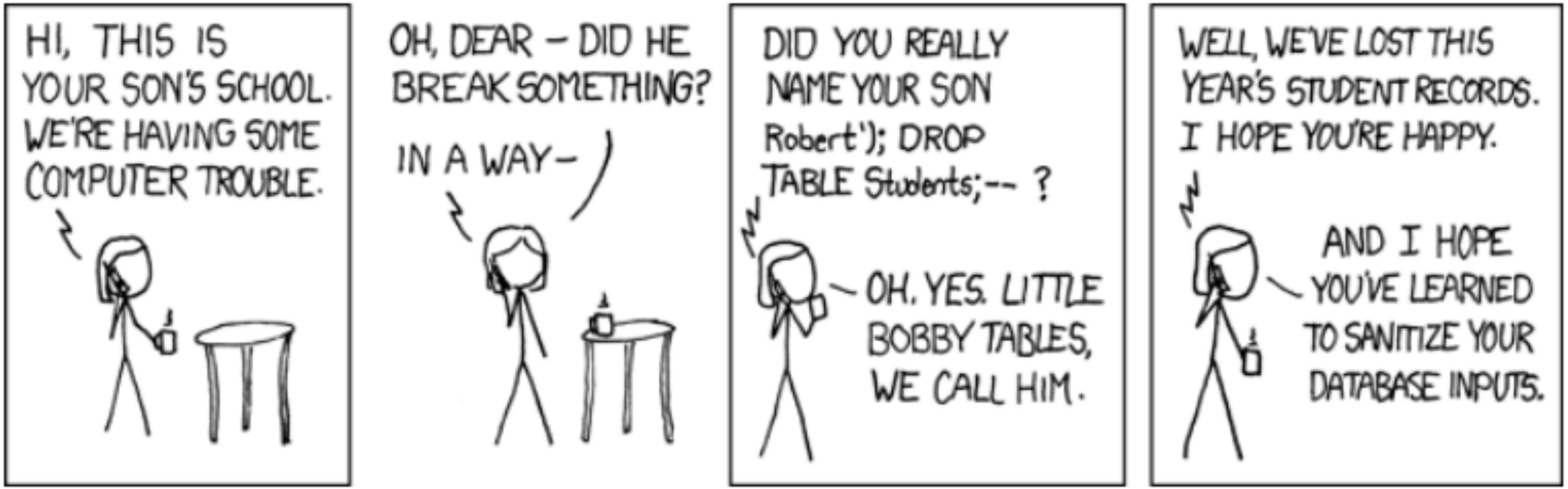
Website



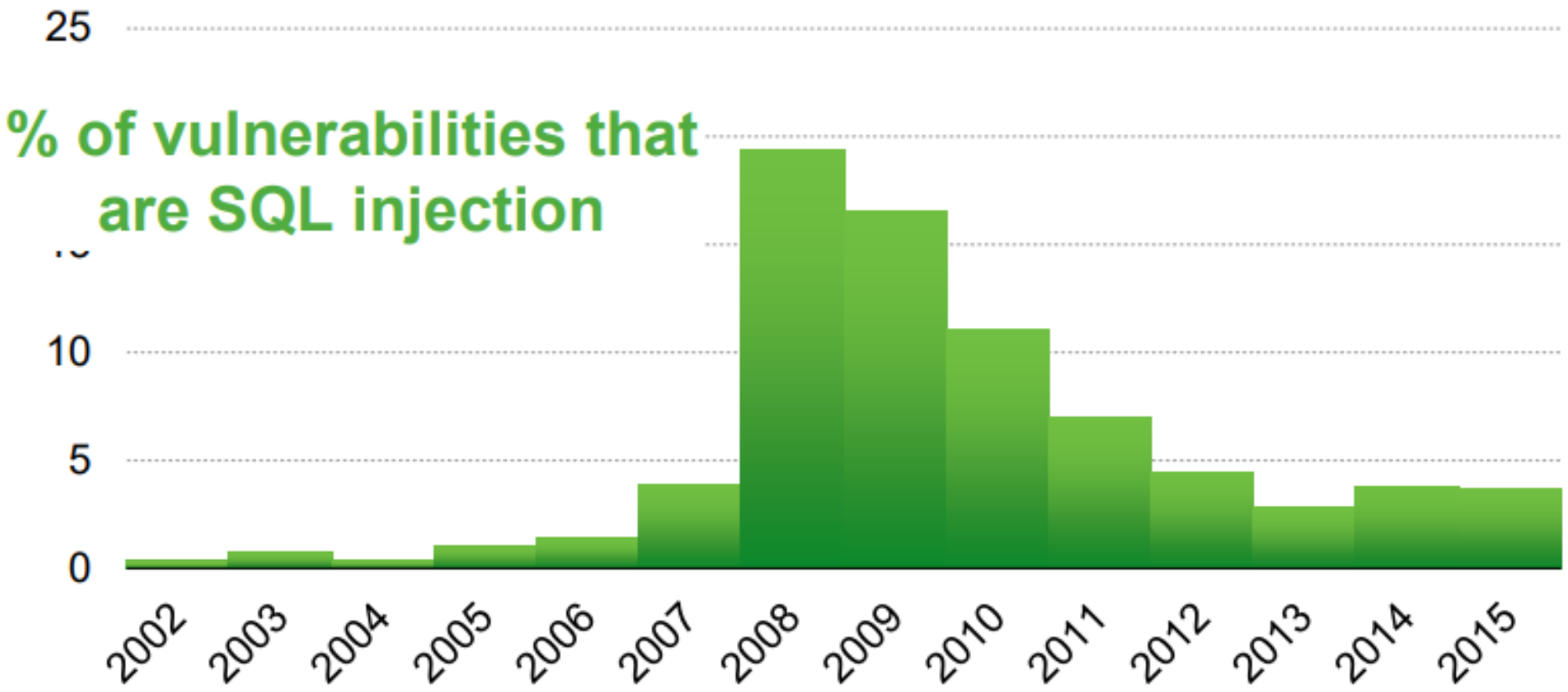

```
$sql = "select * from Users
where name='$user' and password='$pass'";
$result = $conn->query($sql);
```

```
$sql = "select * from Users
where name='frank' OR 1=1;
DROP TABLE Users -- and password='whocares'";
```

Can chain together statements with semicolon: STATEMENT 1 ; STATEMENT 2


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.

SQL injection attacks are common



https://nvd.nist.gov/view/vuln/statistics

SQL Injection Countermeasures

The underlying issue

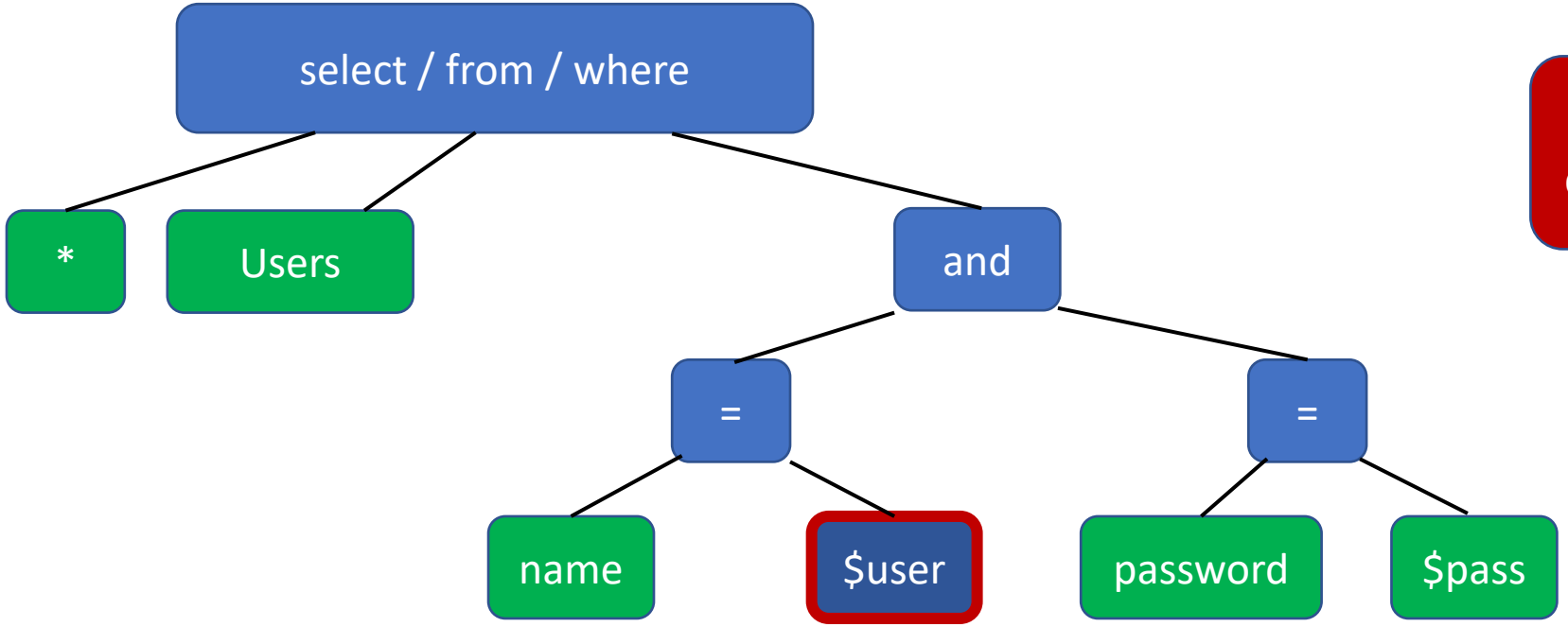
```
$sql = “select * from Users
where name=‘$user’ and password=‘$pass’”;
$result = $conn->query($sql);
```

- This one string combines the code and the data
  - Similar to buffer overflows

When the boundary between code and data blurs, we open ourselves up to vulnerabilities

The underlying issue

```
$sql = “select * from Users
where name=‘$user’ and password=‘$pass’”;
$result = $conn->query($sql);
```



Should be data, not code

Prevention: Input validation

- We require input of a certain form, but we cannot guarantee it has that form, so we must validate it
  - Just like we do to avoid buffer overflows
- Making input trustworthy
  - **Check** it has the expected form, reject it if not
  - **Sanitize** by modifying it or using it such that the result is correctly formed

Sanitization: Blacklisting

‘ ; --

- **Delete** the characters you don’t want

- **Downside**: “Peter O’Connor”
  - You want these characters sometimes!
  - How do you now if/when the characters are bad?

- **Downside:** How to know you’ve ID’d all the bad characters

Sanitization: Escaping

- **Replace** problematic characters with safe ones
  - Change ‘ to \’
  - Change ; to \;
  - Change - to \-
  - Change \ to \\
- Hard by hand, there are many libs & methods
  - magic_quotes_gpc = On
  - mysql_real_escape_string()

- **Downside:** Sometimes you want these in your SQL

Checking: Whitelisting

- Check that the user input is **known to be safe**
  - E.g., integer within the right range

- Rationale: Given invalid input, **safer to reject than fix**
  - “Fixes” may result in wrong output, or vulnerabilities
  - Principle of fail-safe defaults

- **Downside**: Hard for rich input!
  - How to whitelist usernames? First names?

Sanitization via escaping, whitelisting, blacklisting is HARD

Can we do better?

Sanitization: Prepared statements

- Treat user data according to its *type*
- Decouple the code and the data

```
$sql = "select * from Users
where name='$user' and password='$pass'";
$result = $conn->query($sql);
```

connect to DB

```
$conn = new mysql("localhost", "user", "pass", "DB");
```

Prepare statement

```
$statement = $conn->prepare("select * from Users
                where name=? and password=? ");
```

bind variables to typed data

```
$statement->bind_param("ss", $user, $pass);
```

s for string

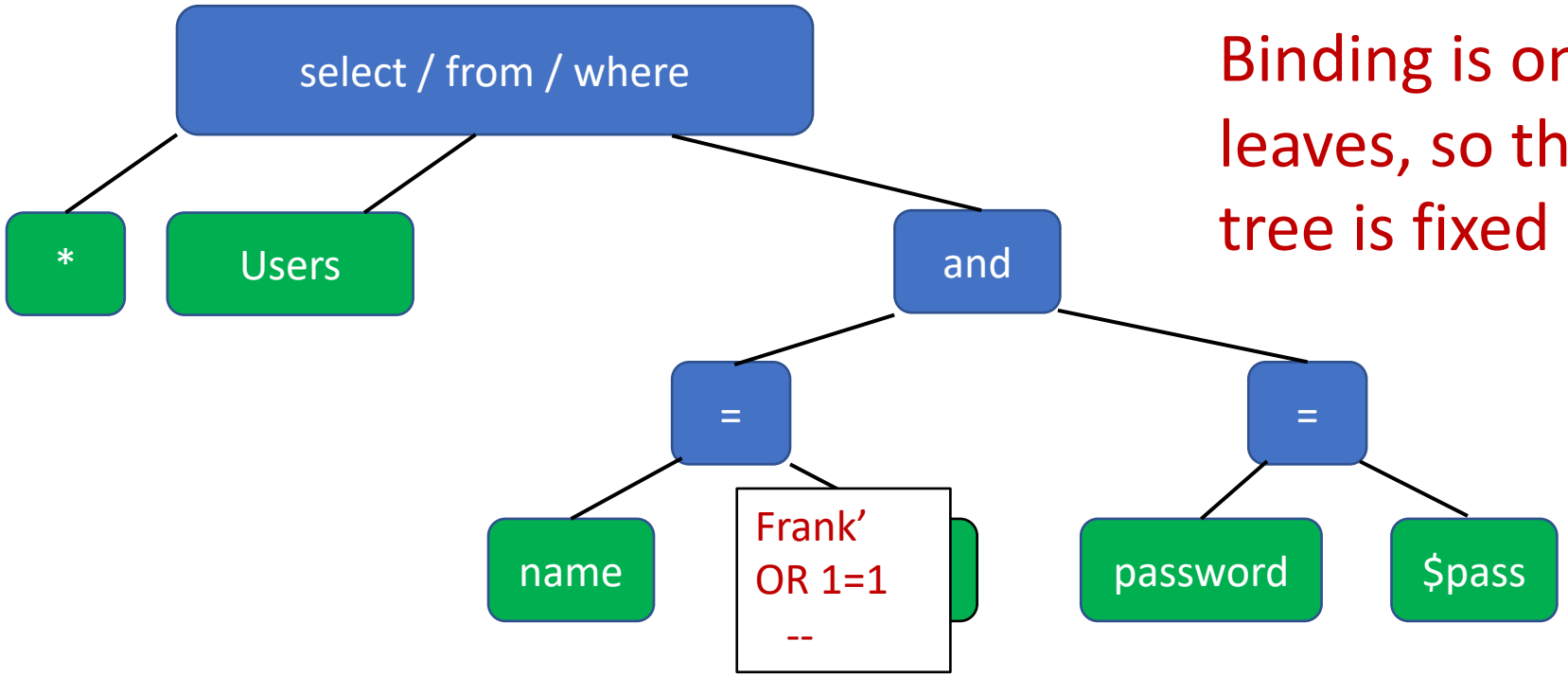
i for integer

```
$statement->execute();
```

Decoupling lets us compile now, before binding the data

The underlying issue

```
$statement = $conn->prepare("select * from Users
        where name=? and password=?";
$statement->bind_param("ss", $user, $pass);
```



Binding is only applied to the leaves, so the structure of the tree is fixed

Additional mitigation

- For defense in depth, also try to mitigate any attack
  - Should always do input validation in any case!

- **Limit privileges**: reduces power of exploitation
  - Limit commands and/or tables a user can access
  - e.g., allow SELECT on Orders but not Creditcards

- **Encrypt sensitive data:** less useful if stolen
  - May not need to encrypt Orders table
  - But certainly encrypt creditcards.cc_numbers

SQL Injection Examples

- Check the following for SQLi examples:
  - http://www.unixwiz.net/techtips/sql-injection.html

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