ECE560
Computer and Information Security

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Database Security

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Relational Databases

- Table of data consisting of rows and columns
  - Each column holds a particular type of data
  - Each row contains a specific value for each column
  - Ideally has one column where all values are unique, forming an identifier/key for that row

- Enables the creation of multiple tables linked together by a unique identifier that is present in all tables

- Use a relational query language to access the database
  - Allows the user to request data that fit a given set of criteria

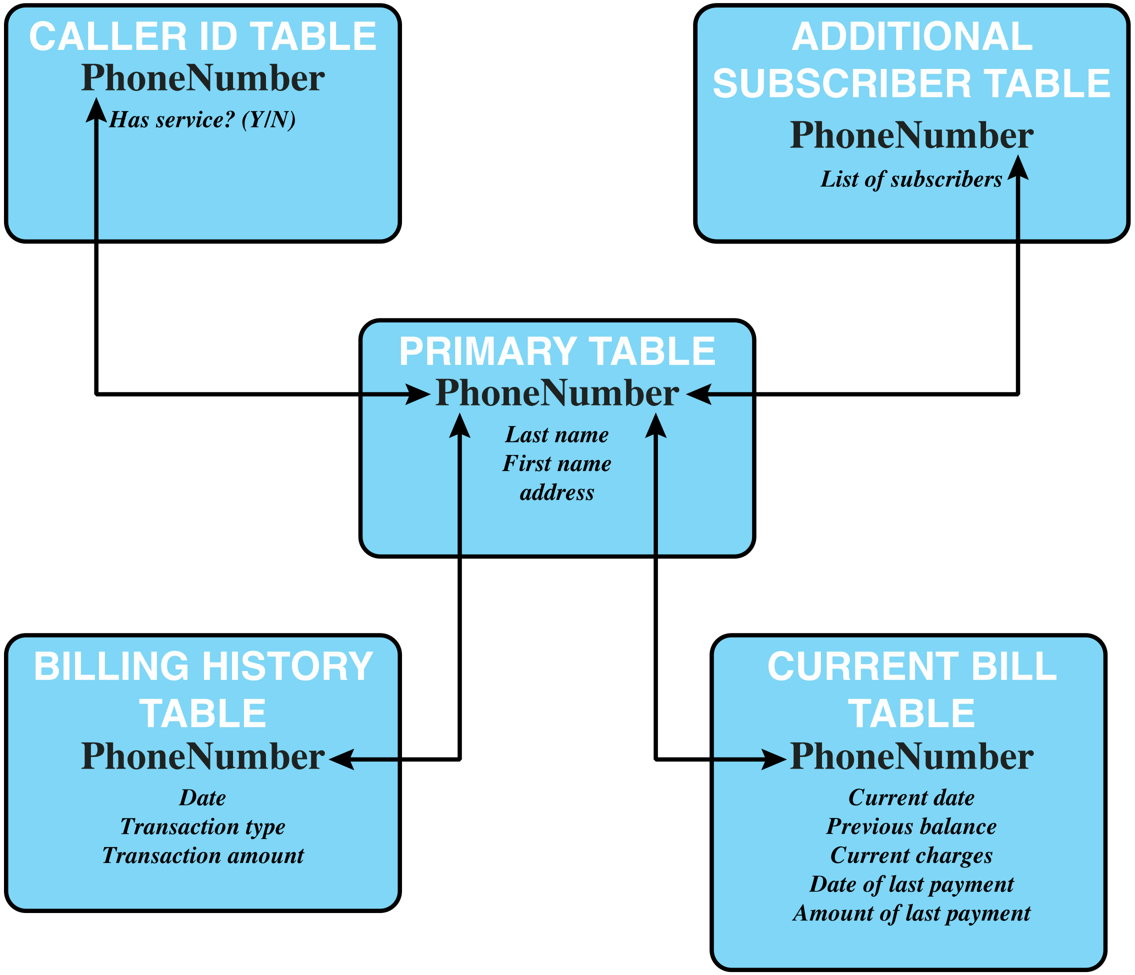


Figure 5.2 Example Relational Database Model. A relational database uses multiple tables related to one another by a designated key; in this case the key is the PhoneNumber field.

Relational Database Elements

- Relation/table/file
- Tuple/row/record
- Attribute/column/field

Primary key

- Uniquely identifies a row
- Consists of one or more column names

Foreign key

- Links one table to attributes in another

View/virtual table

- Result of a query that returns selected rows and columns from one or more tables

Department Table

Did	Dname	Dacctno
4	human resources	528221
8	education	202035
9	accounts	709257
13	public relations	755827
15	services	223945

primary key

Employee Table

Ename	Did	Salarycode	Eid	Ephone
Robin	15	23	2345	6127092485
Neil	13	12	5088	6127092246
Jasmine	4	26	7712	6127099348
Cody	15	22	9664	6127093148
Holly	8	23	3054	6127092729
Robin	8	24	2976	6127091945
Smith	9	21	4490	6127099380

foreign key

primary key

(a) Two tables in a relational database

Dname	Ename	Eid	Ephone
human resources	Jasmine	7712	6127099348
education	Holly	3054	6127092729
education	Robin	2976	6127091945
accounts	Smith	4490	6127099380
public relations	Neil	5088	6127092246
services	Robin	2345	6127092485
services	Cody	9664	6127093148

(b) A view derived from the database

Figure 5.4 Relational Database Example

Structured Query Language (SQL)

- Standardized language to define schema, manipulate, and query data in a relational database
- Several similar versions of ANSI/ISO standard
- All follow the same basic syntax and semantics

SQL statements can be used to:

- Create tables
- Insert and delete data in tables
- Create views
- Retrieve data with query statements

SQL Injection Attacks (SQLi)

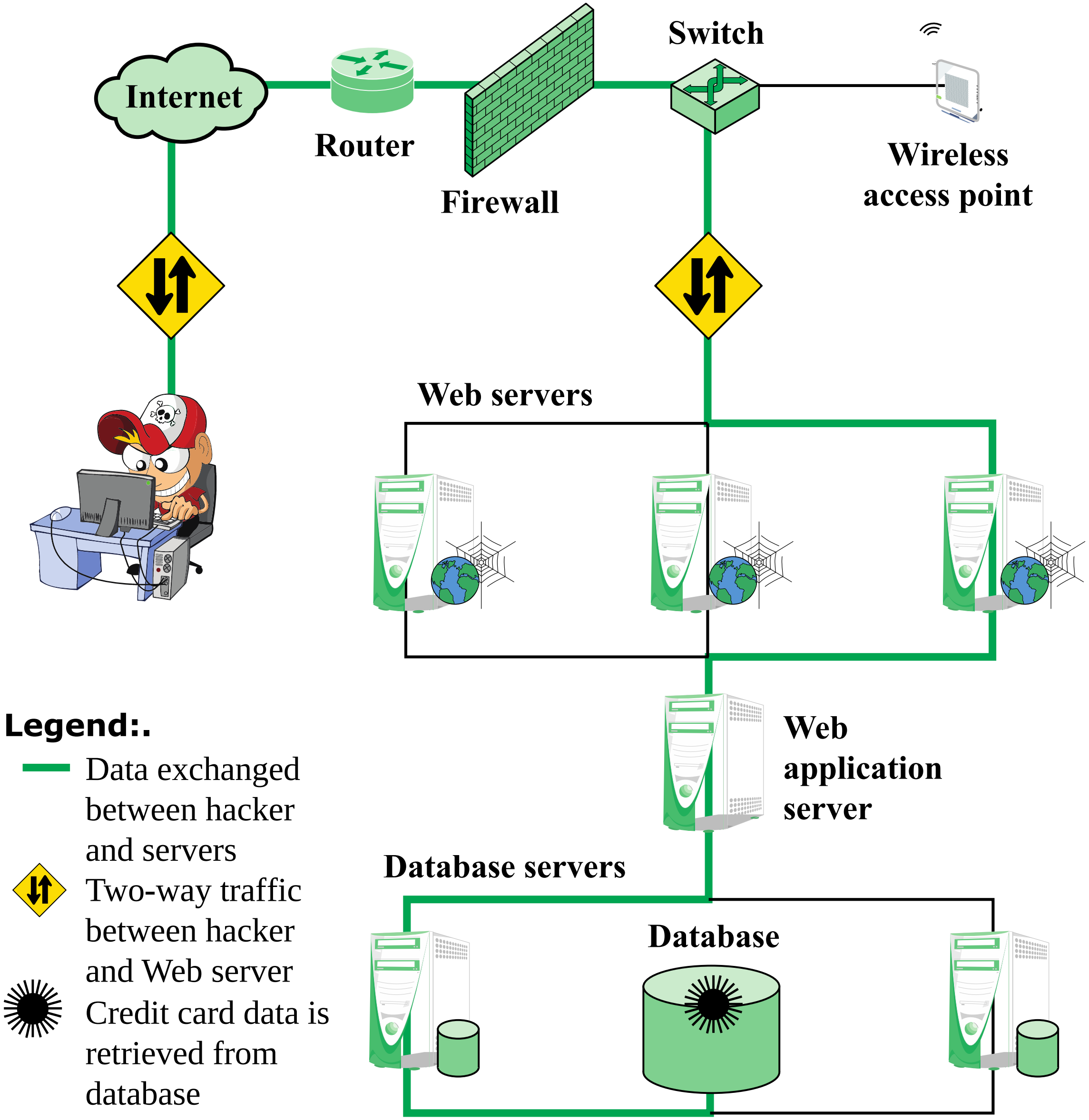
- One of the most prevalent and dangerous network-based security threats

- Designed to exploit the nature of Web application pages

- Sends malicious SQL commands to the database server

- Most common attack goal is bulk extraction of data

- Depending on the environment SQL injection can also be exploited to:
  - Modify or delete data
  - Execute arbitrary operating system commands
  - Launch denial-of-service (DoS) attacks

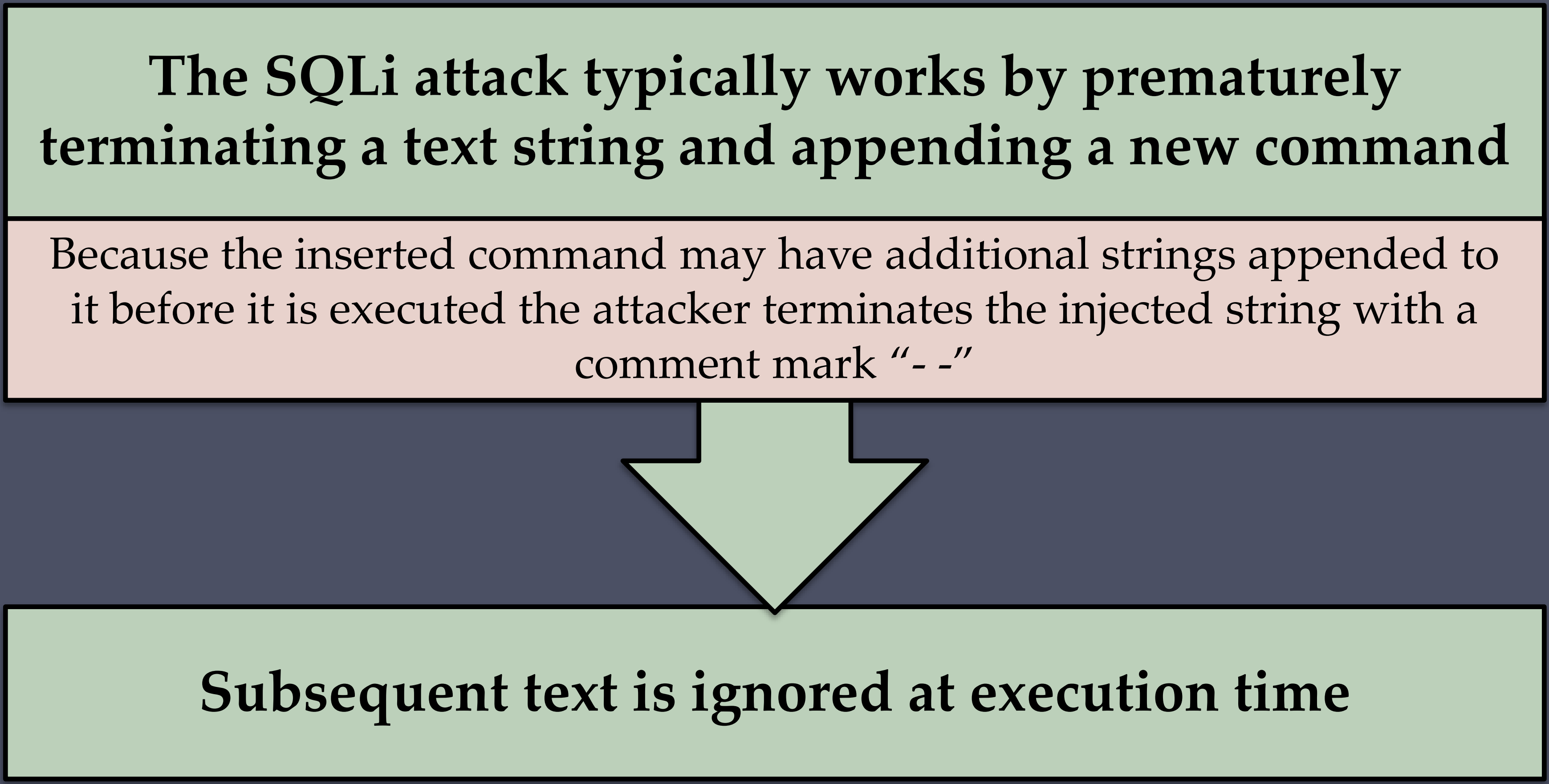


Legend:.

- 🟩 Data exchanged between hacker and servers
- ⇅ Two-way traffic between hacker and Web server
- ✸ Credit card data is retrieved from database

Figure 5.5 Typical SQL Injection Attack

Injection Technique



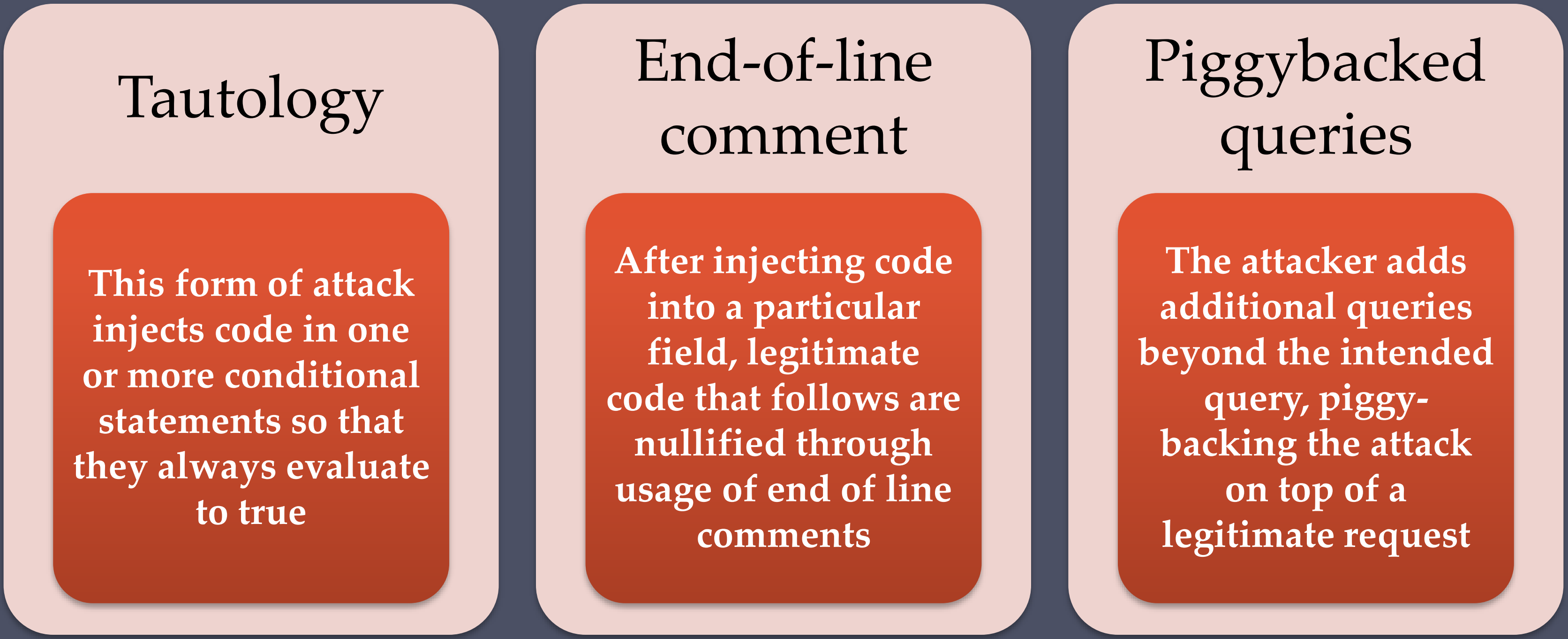
The SQLi attack typically works by prematurely terminating a text string and appending a new command

Because the inserted command may have additional strings appended to it before it is executed the attacker terminates the injected string with a comment mark “- -”

Subsequent text is ignored at execution time

Inband Attacks

- Uses the same communication channel for injecting SQL code and retrieving results
- The retrieved data are presented directly in application Web page
- Include:



Tautology

This form of attack injects code in one or more conditional statements so that they always evaluate to true

End-of-line comment

After injecting code into a particular field, legitimate code that follows are nullified through usage of end of line comments

Piggybacked queries

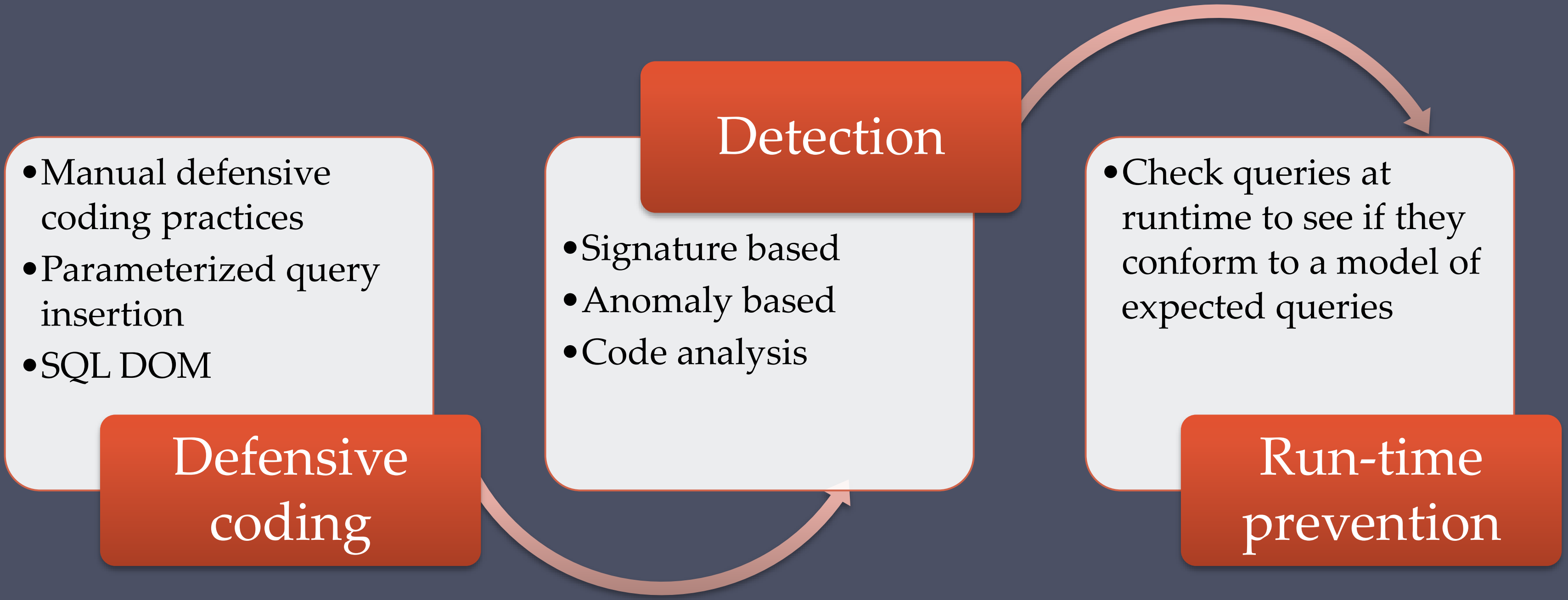
The attacker adds additional queries beyond the intended query, piggy-backing the attack on top of a legitimate request

Out-of-Band Attack

- Data are retrieved using a different channel
- This can be used when there are limitations on information retrieval, but outbound connectivity from the database server is lax

SQLi Countermeasures

- Three types:



Defensive coding

- Manual defensive coding practices
- Parameterized query insertion
- SQL DOM

Detection

- Signature based
- Anomaly based
- Code analysis

Run-time prevention

- Check queries at runtime to see if they conform to a model of expected queries

SQL injection examples

See here:

http://www.w3schools.com/sql/sql_injection.asp

Proper database coding practices

- Escaping special characters ← Better than nothing…

```
$query = sprintf("SELECT * FROM users WHERE user='%s'",
            mysql_real_escape_string($user));
```

- Parameterized queries ← Decent, if you have to…

```
$stmt = $pdo->prepare('SELECT * FROM employees WHERE
name = :name');
$stmt->execute(array('name' => $name));
```

- **FRAMEWORKS**: NOT DOING SQL YOURSELF! ← That’s where it’s at.

```
new_guy = User.create(
 username = 'foo',
 email = 'foo@bar.com',
 age = 25,
 lang = ['en', 'fr']
)
new_guy.commit();
```

Object Relational Mapper (ORM)

- The most common form of database framework.
- Programmer writes class definitions, framework creates whole database automatically
- Classes integrate with database with no extra code.
- Less work, no SQL injection

Inferential Attack

- There is no actual transfer of data, but the attacker is able to reconstruct the information by sending particular requests and observing the resulting behavior of the Website/database server
- Include:
  - Illegal/logically incorrect queries
    - This attack lets an attacker gather important information about the type and structure of the backend database of a Web application
    - The attack is considered a preliminary, information-gathering step for other attacks
  - Blind SQL injection
    - Allows attackers to infer the data present in a database system even when the system is sufficiently secure to not display any erroneous information back to the attacker

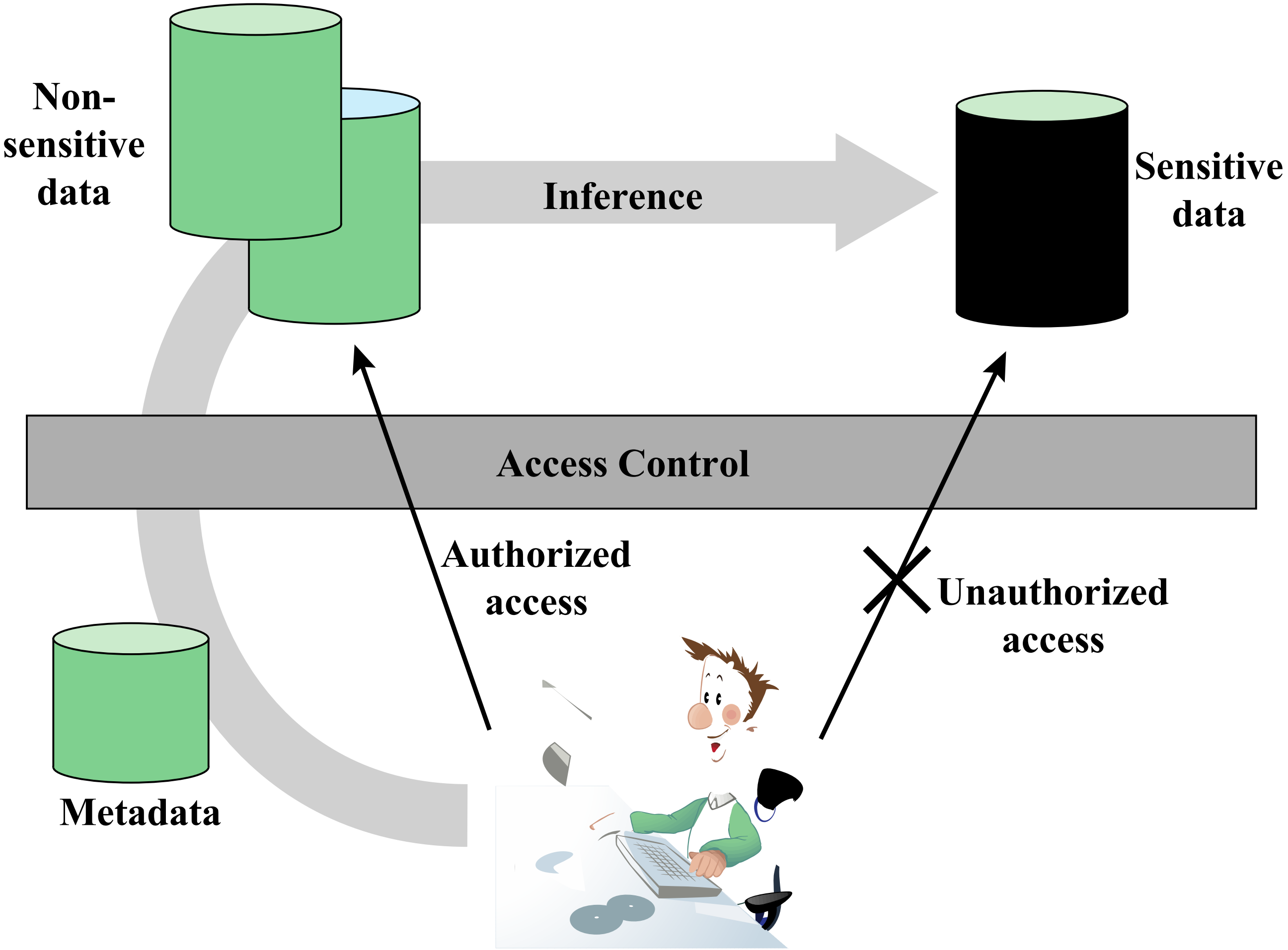


Figure 5.7 Indirect Information Access Via Inference Channel

Name	Position	Salary ($)	Department	Dept. Manager
Andy	senior	43,000	strip	Cathy
Calvin	junior	35,000	strip	Cathy
Cathy	senior	48,000	strip	Cathy
Dennis	junior	38,000	panel	Herman
Herman	senior	55,000	panel	Herman
Ziggy	senior	67,000	panel	Herman

(a) Employee table

Position	Salary ($)
senior	43, 000
junior	35,000
senior	48,000

Name	Department
Andy	strip
Calvin	strip
Cathy	strip

(b) Two views

(Assume order is preserved)

Name	Position	Salary ($)	Department
Andy	senior	43,000	strip
Calvin	junior	35,000	strip
Cathy	senior	48,000	strip

(c) Table derived from combining query answers

Figure 5.8 Inference Example

SQL Access Controls

- **Access control system** determines what access rights the user has (create, insert, delete, update, read, write)

- Two commands for managing access rights:
    - Grant
        - Used to grant one or more access rights or can be used to assign a user to a role
    - Revoke
        - Revokes the access rights

- Typical access rights are:
    - Select
    - Insert
    - Update
    - Delete
    - References

Database Encryption

- The database is typically the most valuable information resource for any organization
    - Protected by multiple layers of security
        - Firewalls, authentication, general access control systems, DB access control systems, database encryption
        - Encryption becomes the last line of defense in database security
    - Can be applied to the entire database, at the record level, the attribute level, or level of the individual field
- Disadvantages to encryption:
    - Key management
        - Authorized users must have access to the decryption key for the data for which they have access
    - Inflexibility
        - When part or all of the database is encrypted it becomes more difficult to perform record searching

Database security summary

- Don’t do dumb coding practices that allow SQL injection
  - **Object Relational Mapper (ORM)** = good

- Think carefully about different views of data and what they could reveal if combined

- Apply **principle of least privilege** to database permissions

- Keep your database credentials secret!
  - *Don’t put them into git*

- Database encryption *may* be applicable, if you can deal with key management (don’t put key next to data!)