TK2100: Informasjonssikkerhet Lesson 11: SQLi and Passwords

Dr. Andrea Arcuri
Westerdals Oslo ACT
University of Luxembourg

Goals

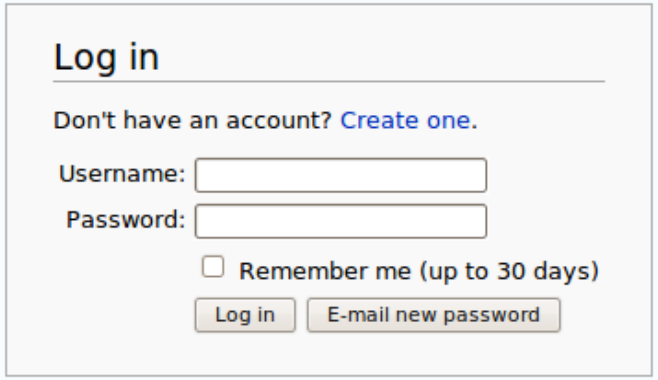
- Understand the bases of how SQL Injection is carried out
- Learn how passwords should be stored in a secure way

SQL Injection

Database Access

- Relational databases are the most common type of database
- Data can be queried with *SQL* (Structured Query Language)
- Typical SQL query: *SELECT * FROM x WHERE p*
  - SELECT: specify one, more or all columns/fields
  - FROM: the database tables from which data is read from
  - WHERE: a Boolean predicate to select just a subset of the data
    - i.e., only some specific rows, and not the whole tables
- SQL can be based on user inputs (eg HTML forms)

Example: Login



- "*Users*" table with "*username*" and "*password*"
- *String sql = "SELECT * FROM Users WHERE username=""+ username + "" and password="" + password+""";*
  - the variables "username" and "password" contain data from user inputs
- If query result is not empty, then the given user for that username is authenticated
- This works, but *can you see the problem here?*

SQL Injection: Tautologies

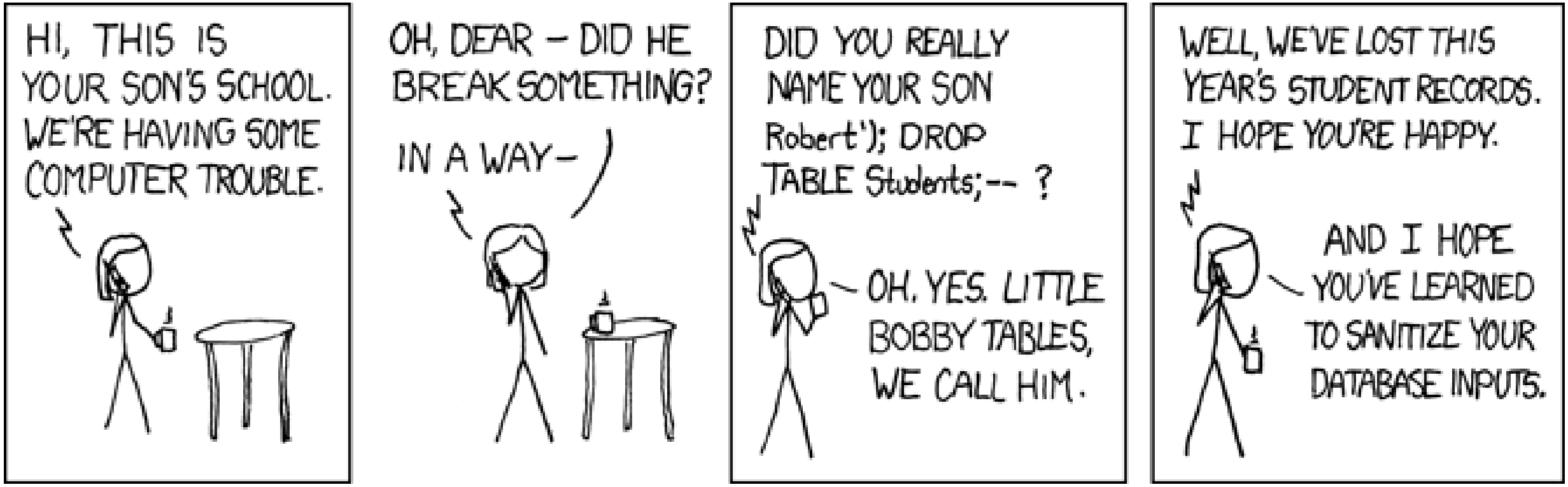
- Eve wants to login as Alice, but she does not know the password
- Not a problem! Can inject a tautology with the password, eg "*whatever' or '1'='1*"
  - note the first ' after "*whatever*", and last string for 1 missing the closing '
- The resulting SQL would become: *"SELECT * FROM Users WHERE username='Alice' and password='whatever' or '1'='1';*
- The WHERE clause would always be true (ie, a tautology)

SQL Injection: Cont.

- Injection is the ***most common*** type of security vulnerability
  - See Top 10 from *www.owasp.org*
- Problem: creating SQL commands by concatenating string *without* sanitizing user inputs
  - can alter the structure of the SQL queries
  - non-escaped single quote ‘ was the problem in previous example
  - this is the same kind of issue as in XSS attacks
- SQL Injection allows attackers to access data without authorization by either turning the WHERE clauses into tautologies, or turn them in non-executed comments (**--**)

NEVER TRUST USER INPUTS!!!

Always Sanitize/Escape Inputs!



https://xkcd.com/327/

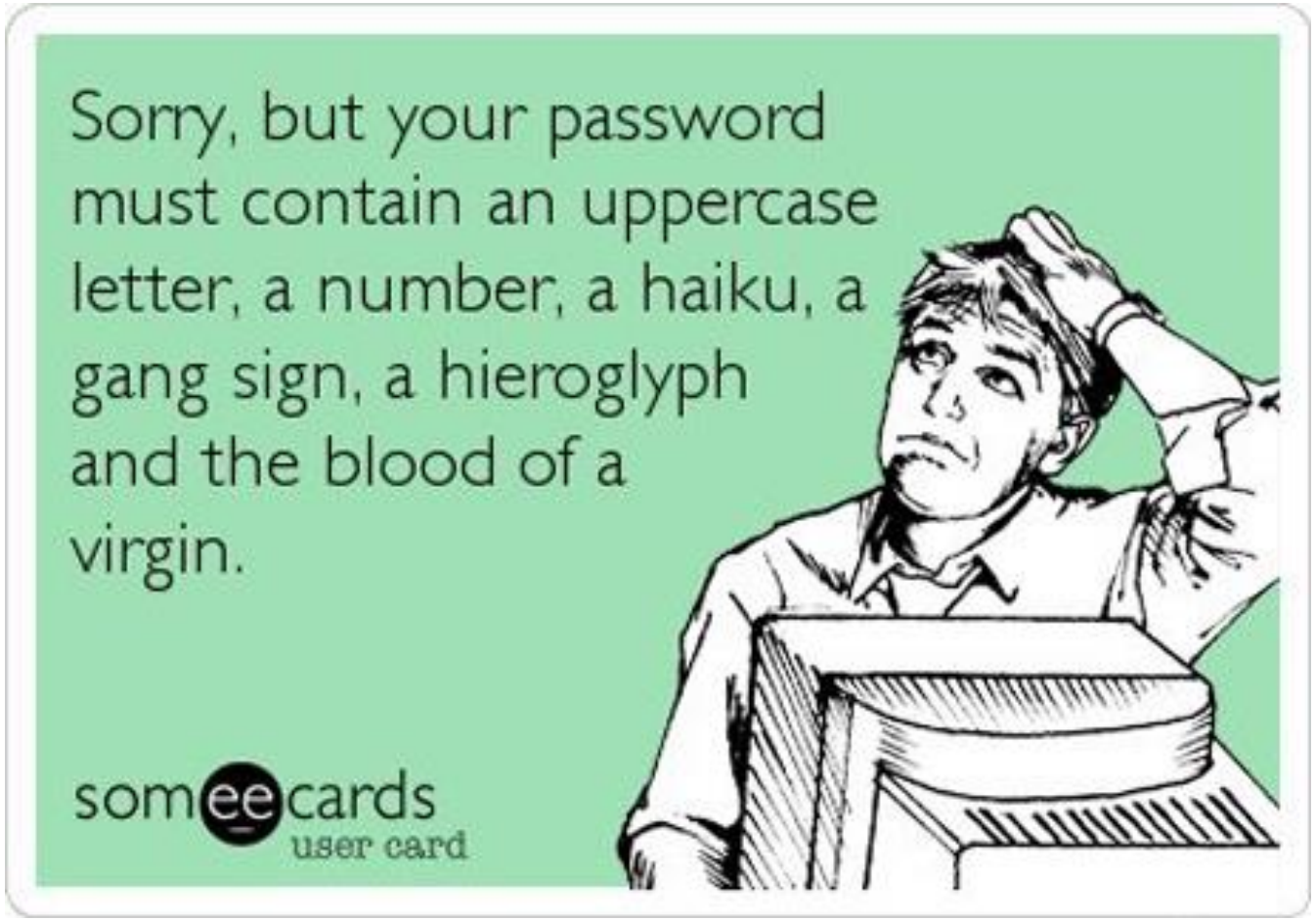
What info to steal?

- Any sensitive data… but most commons are:
- 1) Credit Card Numbers
- 2) Passwords
  - Hacker can then login an impersonate a specific user
  - People often re-use the same password for different web sites

Passwords

Passwords

- Needed to verify identity of a user
- Not too short nor simple, otherwise too easy to crack with brute-force
- *Security* vs *Usability:* hard to get a good balance
  - eg, ideally would have different passwords for each different site, and change them often, eg every week… but who the heck is going to do that???

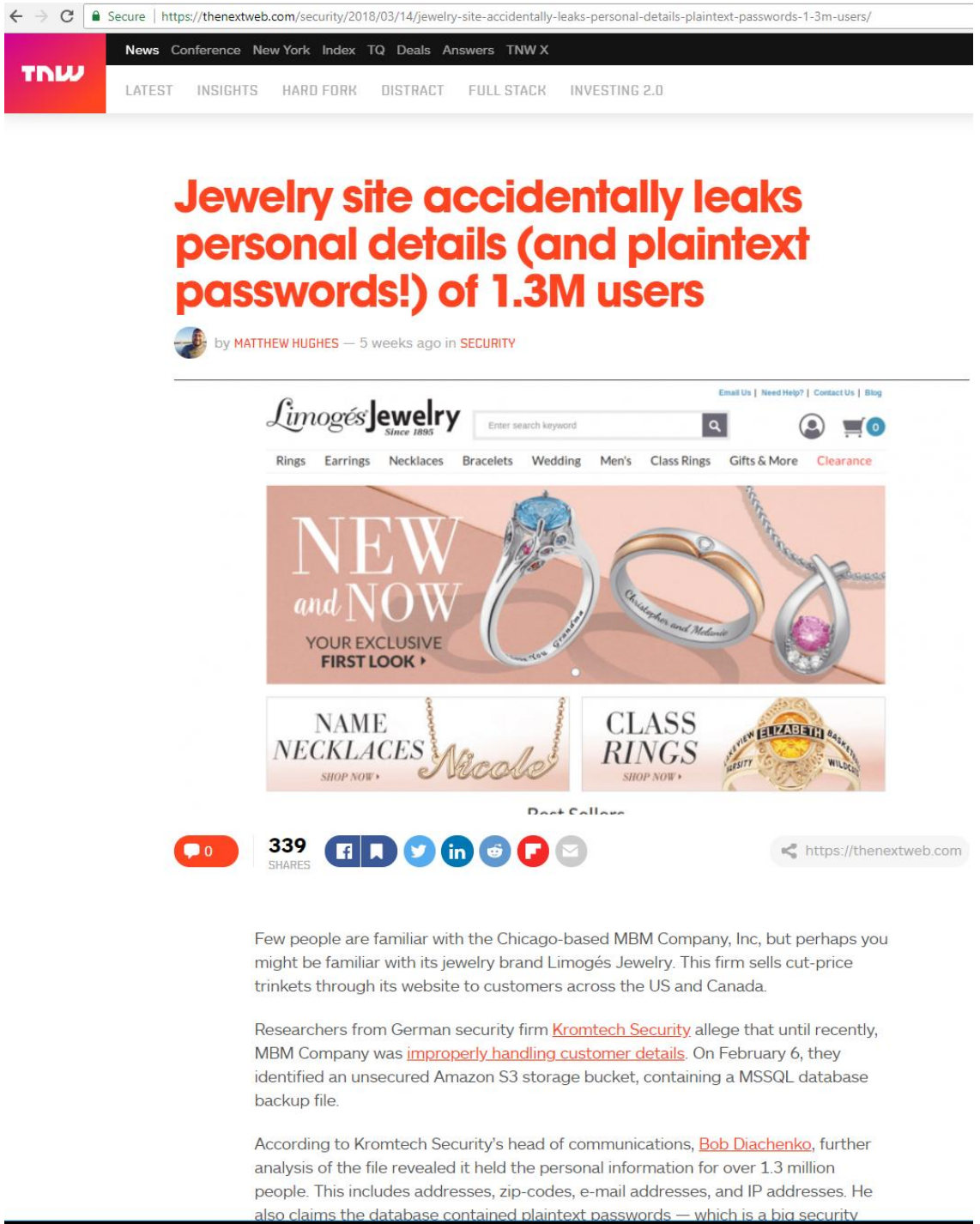


Password Storage

- When creating new user, need to save password somewhere, usually a database
- **NEVER SAVE A PASSWORD IN CLEAR TEXT**
- Passwords need to be *hashed*
- Even if an hacker has full access to database, should **NOT** be able to get the passwords
  - Typical case is a successful SQL Injection attack
  - But many more cases: eg disgruntled employee, recovery from broken thrown away hard-drive, etc.
- Besides being able to impersonate a user, hacker can try the same password on other sites (Amazon/Facebook/etc)

- Thousands of examples…
- Eg, 2018, **1.3 million** plain-text passwords leaked from a web jewelry store

- On a different topic, look at the “shares” icons, and how such companies can keep track of me visiting that page…



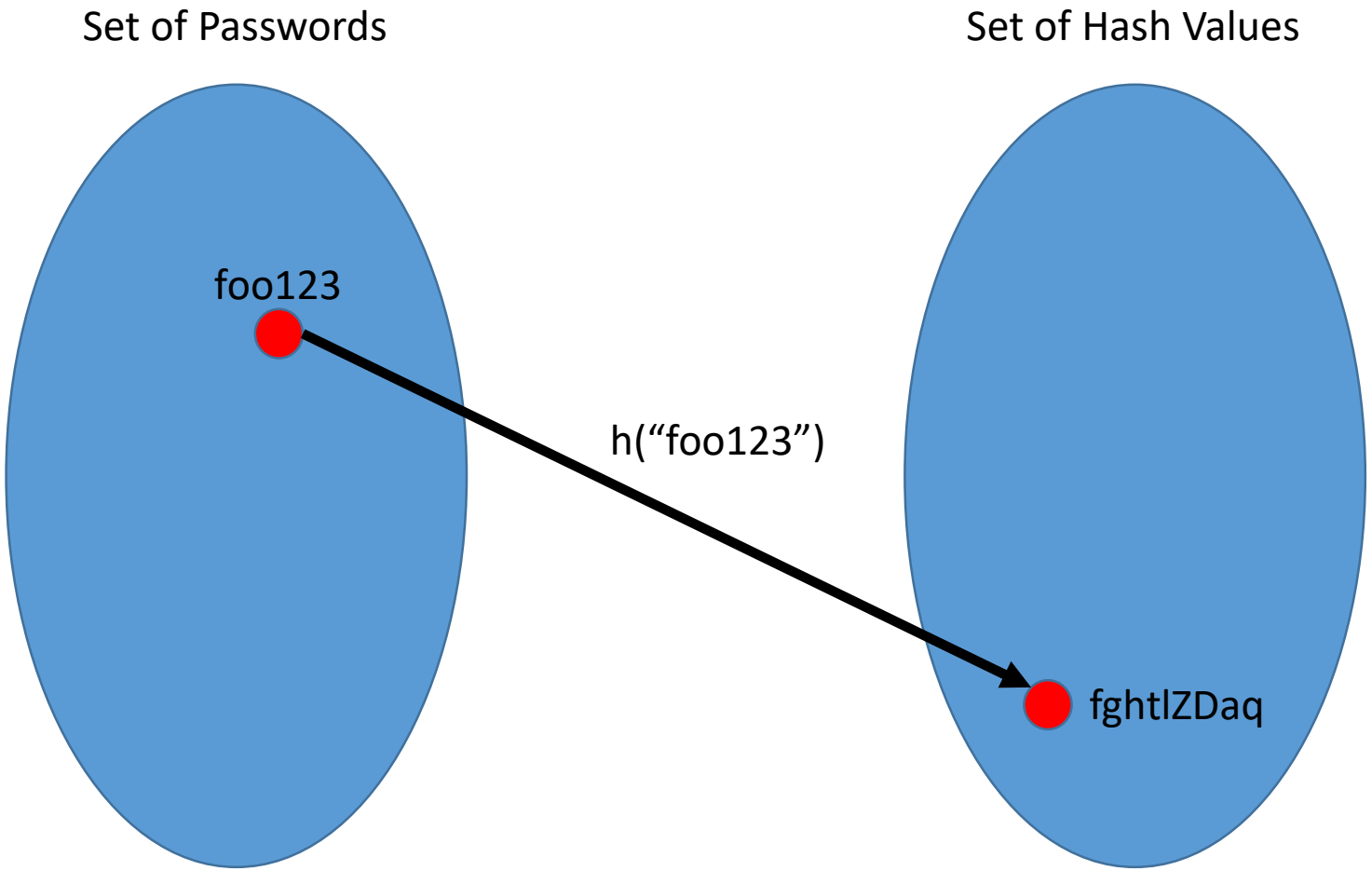
NEVER SAVE A PASSWORD IN CLEAR TEXT!!!

- If password is "*foo123*", then such string should NEVER be saved in the database
- *But how to do authentication then?*

Hash Functions

- $h(x) = y$
- It is just a mathematical function from x to y
  - In our case, x is the password, and y is its hashed value
- Deterministic: always same y from same input x
- Shouldn't be able to recover x from y, even if you have full knowledge of how $h()$ is implemented
- Small change x' to x should lead to big different between y and y'
  - ie, y and y' should look uncorrelated, and so cannot say if x and x' are similar
- For security, want no collisions: no two values should have same hash, ie $h(x) = y = h(z)$

- h(“foo123”) = “fghtlZDaq”
- Should not be possible to recompute “foo123” if a hacker knows “fghtlZDaq”



Login with Hashed Passwords

- How can server verify the login of user A with password X, if the server does not know the password X, but only the hash Y=h(X)?
- Server needs to retrieve from database the hash Y for given user A, recompute the hash h(X) from the input password X, and then verify that the new hash does match Y, ie Y == h(X)

Database table for Users

UserName	Hashed Password
…	…
foo	fghtlZDaq
…	…

- Logging in with *foo/whatever* would fail, because *h(“whatever”) != “fghtlZDaq”*
- Logging in with *foo/foo123* would work, as *h(“foo123”) == “fghtlZDaq”*

Salted Passwords

- Cannot expect users to have long passwords
- If hacker has access to DB, from a hash Y, can calculate *h(K)* for all strings K up to certain length N, eg N=8, and check if any *h(K)* does match Y
- For small N, this is doable. Do not even need to run *h(),* as those values can be pre-computed, ie *Rainbow Tables*
- Further issue: two users with same passwords will have same hash Y
- Solution: add a random *salt* S (eg a random long string) to the password before hashing, and store the salt together with the hash in the database
- *h(X+S)=Y*
- Each user will have its own random salt

Database table for Users

UserName	Hashed Password	Salt
…	…	…
foo	sfdsgIII	SGFNSDSasdfs
bar	Hnjnvrs	dsfsfewaaa
…	…	…

- Both users *foo* and *bar* have the same password *foo123*
- The *hashed* values are different, because the *salt* is different
- h(“foo123SGFNSDSasdfs”) == “sfdsgIII”
- h(“foo123dsfsfewaaa”) == “Hnjnvrs”

Pepper

- If hacker has access to the database, s/he can read the *salt* values
- Still non-trivial to break the hash code, but doable
- *Pepper*: yet another random string added before calculating the hash
- NOT stored in the database, just somewhere else
  - files, remote server, hardcoded in the source code, etc
- One single pepper string for whole application (and not per user)
- Help mitigating if hacker gets access to the database (eg via SQL Injection), as would not be able to read the pepper

Hash Function Speed

- In security, you want hash functions that are *slow,* to make it difficult for the hackers to break them
  - but still manageable time on server to do authentication, eg within 1 second
- *BCrypt* is the most used hash function for passwords
- However, you can make *slow* any hash function (eg SHA256) by using a loop, in which the output is re-hashed N times
  - *eg, N=6* and so *h(h(h(h(h(h(x))))))* = *y*
  - Note, SHA stands for Secure Hash Algorithm, but it is not really secure on its own, as too fast

Implications of Hashing

- A web site should not be able to tell you what was your password
- If can give it to you, or even just some hints (eg first 2 letters), or tell you if too similar to a previous password, then *BE WORRIED*…
- Note: comic has a mistake… passwords must be hashed, and NOT encrypted

Password Recovery

- Should **NOT** be possible to recover a password
- If one forgets it, can have a password *reset*
- Email sent to user, with link to create a new password
- This is a typical approach, but only works as long as email is not compromised

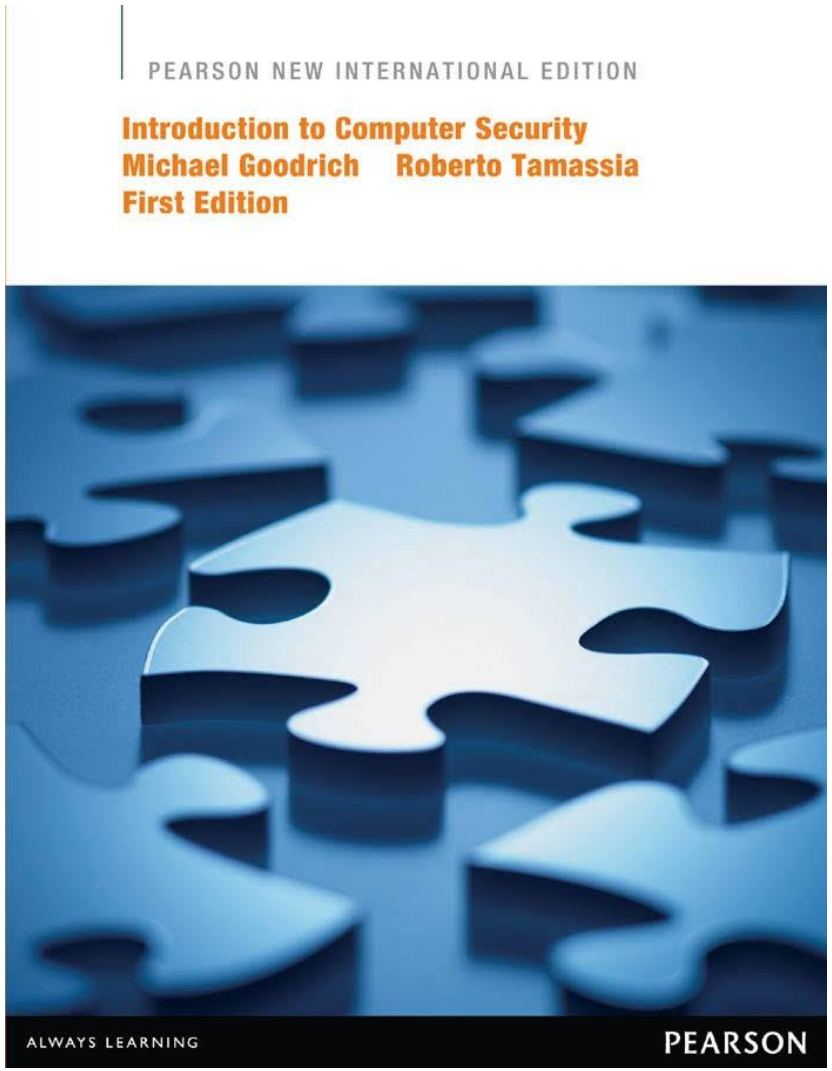
Failed Login

- A failed login should not provide any further info
- Eg, should not tell if password is close to correct one, or if user even exists
- No unnecessary info should be leaked, as *hacker could use it*
- Example: if user does not exist, still need to compute hash for password… *why???*

Cont.

- Assume login with *foo/foo123*
- Assume user *foo* does not exist
- Computing hash *h("foo123")* takes time, so one could just immediately state tht login did fail, as *foo* not in the database
- Computing *h("foo123")* would be a waste of CPU time, but still necessary
  - Recall, *h()* is slow
- If not computing *h()*, then login for non-existing users would be much *faster*, and hacker can use such info to determine if a user exists
  - i.e, check how long it takes for server to state failed login
  - i.e., leaked info based on response time of the HTTP requests

For Next Week



- Book pages: 41-42, 137-138, 372-377, 417
- Note: when I tell you to **study** some specific pages in the book, it would be good if you also *read* the other pages in the same chapter at least once