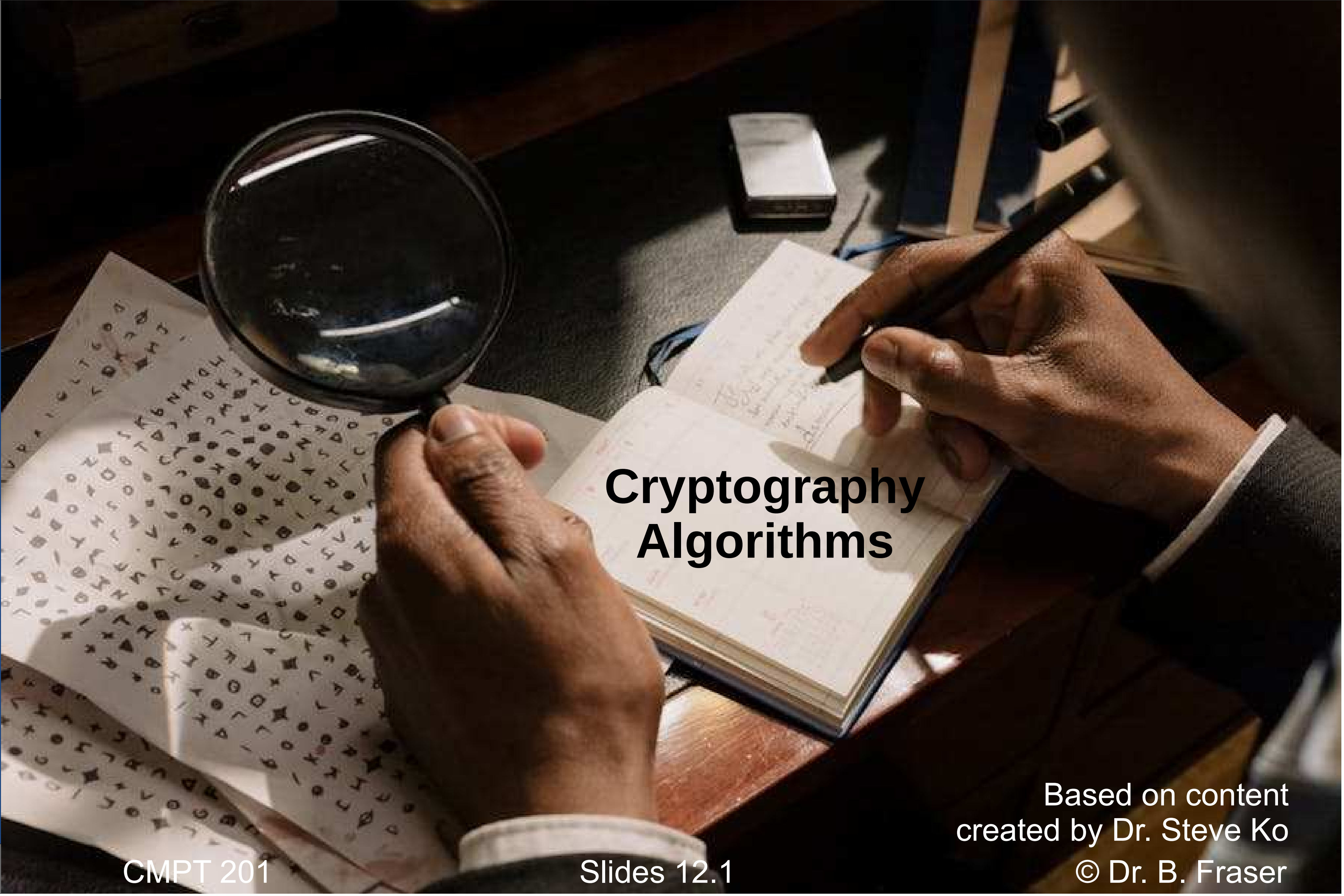


Cryptography Algorithms

Based on content
created by Dr. Steve Ko

CMPT 201

Slides 12.1

Topics

- What is cryptography?
- What are the basics of cryptographic algorithms?
  - What are cryptographic hashes?
  - What is a secret key encryption?
  - What is public-key encryption?

Cryptography:
The absolute basics

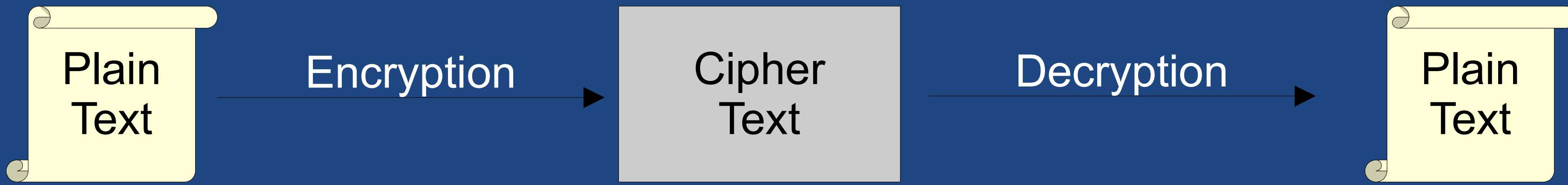
Context

- Cryptography
  - A very broad area.
  - We'll focus on how to *use* cryptography.
  - We just touch on the basics!

The CIA Model

- CIA model: the classic security model.
  - Confidentiality:
    ..
  - Integrity:
    ..
    and only by authorized parties.
  - Availability:
    ..
- Threat examples
  - Against confidentiality: classified information leak
  - Against integrity: fake images/videos
  - Against availability: Denial-of-Service (DoS) attacks

General Cryptography Process



- Cryptographers invented secret codes
  to hide messages from unauthorized observers.
- Challenges:
  - How can you hide a message from everyone but the intended recipient?
  - How can the recipient know the message is authentic?

ABCD: Traditional Cryptography

- Traditional Cryptography:
  - Secret codes, which are secret algorithms.
  - E.g., Caesar Cipher: ..

    For +1 ‘A’ becomes ‘B’.
- ABCD: Which of the following is the cipher text from using a 3-letter shift Caesar Cipher on the plain text “Hello world”?

```
a) EBIIL TLOIA
b) KHOOR ZRUOG
c) IFMMP XPSME
d) LOWOR LDHEL
```

- What is the problem with a secret algorithm?
  - When your algorithm (or code book) is compromised, ..

Modern Encryption

- Algorithms are Public
  - ..
  - May be symmetric (secret key) or asymmetric (public key).
- Why is this better?
  - If algorithm or code is secret,
    then if it falls into the wrong hands it means code is useless.
  - If only key is private,
    then if it falls into the wrong hands then
    ..

Crypto Algorithm Goals

- Choose an encryption algorithm such that:
  - Given a key, it should be

    ..
  - Without a key, it should be

    ..
- Strength of security often based on length of key:

  Longer key is more difficult to guess (by brute-force).

Window of Validity

- Window of Validity
  ..
  - Must only use algorithm that have not been compromised.
- Problem:
  Window of validity of your crypto function
  ..
  - Design systems so you can replace the crypto function easily.
- Example Windows of Validity
  - 1993: SHA-0 was published.
  - 1995: Possible weakness was found in the SHA-0 algorithm; replaced with SHA-1.
  - 2004: Published way to compromise SHA-0
  - 2017: Published way to compromise SHA-1
  - ????: Published way to compromise SHA-256?

Three Types

- Types of cryptography algorithms based on their keys:
  - Zero keys: ..
  - One key: ..
  - Two keys: ..

Cryptographic Hash Functions
(Zero Keys)

Cryptographic Hash Functions

- Suppose we have a cryptographic hash function *h()*
  - It takes a message *m* of arbitrary length as input and ..
- Toy example:

  $h(m) = (m^2)$ % 4321

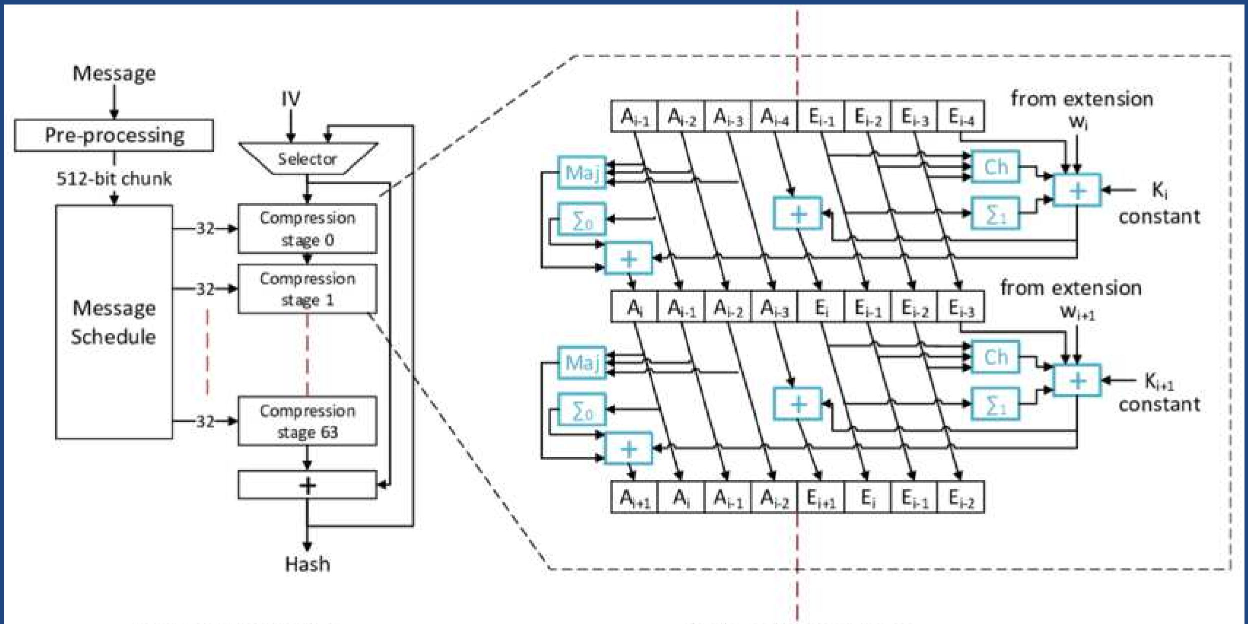
m	m in hex		h(m)
AAAA	(0x41414141)	-->	2242
BBBB	(0x42424242)	-->	893
CCCC	(0x43434343)	-->	2558
DDDD	(0x44444444)	-->	2916
EEEE	(0x45454545)	-->	1967
FFFF	(0x46464646)	-->	4032
GGGG	(0x47474747)	-->	469
HHHH	(0x48484848)	-->	4241
IIII	(0x49494949)	-->	2385
JJJJ	(0x4A4A4A4A)	-->	3543
KKKK	(0x4B4B4B4B)	-->	3394
LLLL	(0x4C4C4C4C)	-->	1938

Hash Function Properties

- ..
  - It should be easy to compute $h(m)$
- ..
  - Given $h(x)$, it should be difficult to find x.
  - i.e., the reverse of $h()$ should be difficult to compute.
- ..
  - Given x, it should be difficult to find x' where $h(x') == h(x)$
  - i.e., Given a value and a hash function, it should be difficult to find another value that produces the same hash.
- ..
  - It should be difficult to find two messages x and x' where $h(x) == h(x')$
  - i.e., given a hash function, it should be difficult to find *any* two values that produce the same hash.

Ideal Hash

- Ideally, we want all these properties
  for a strong cryptographic hash function.
  - However, not all hash functions provide all these properties.
- Example good crypto hash function: SHA-256.



(a) SHA-256 Function (b) Compression Stages

https://www.researchgate.net/figure/SHA-256-algorithm-block-diagram-a-SHA-256-execution-flow-including-the-preprocessing_fig3_371457507

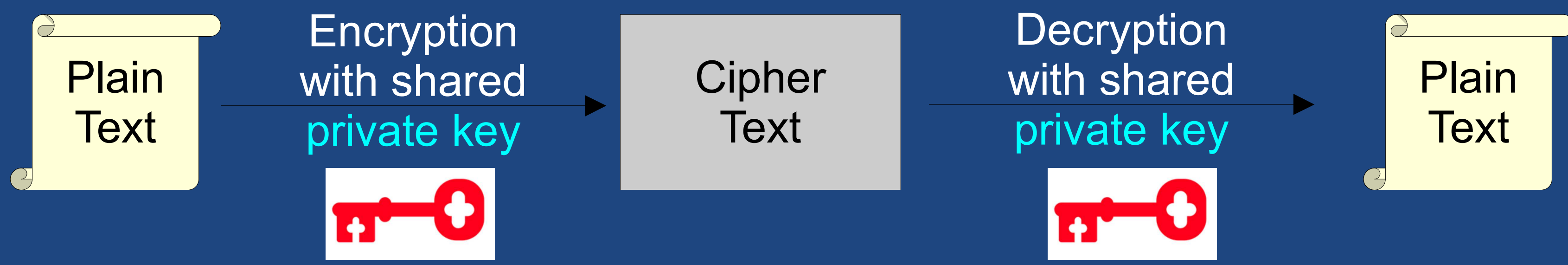
Private Key Cryptography

or

Symetric Key Cryptography

(One key)

Private (Symmetric) Key Crypto



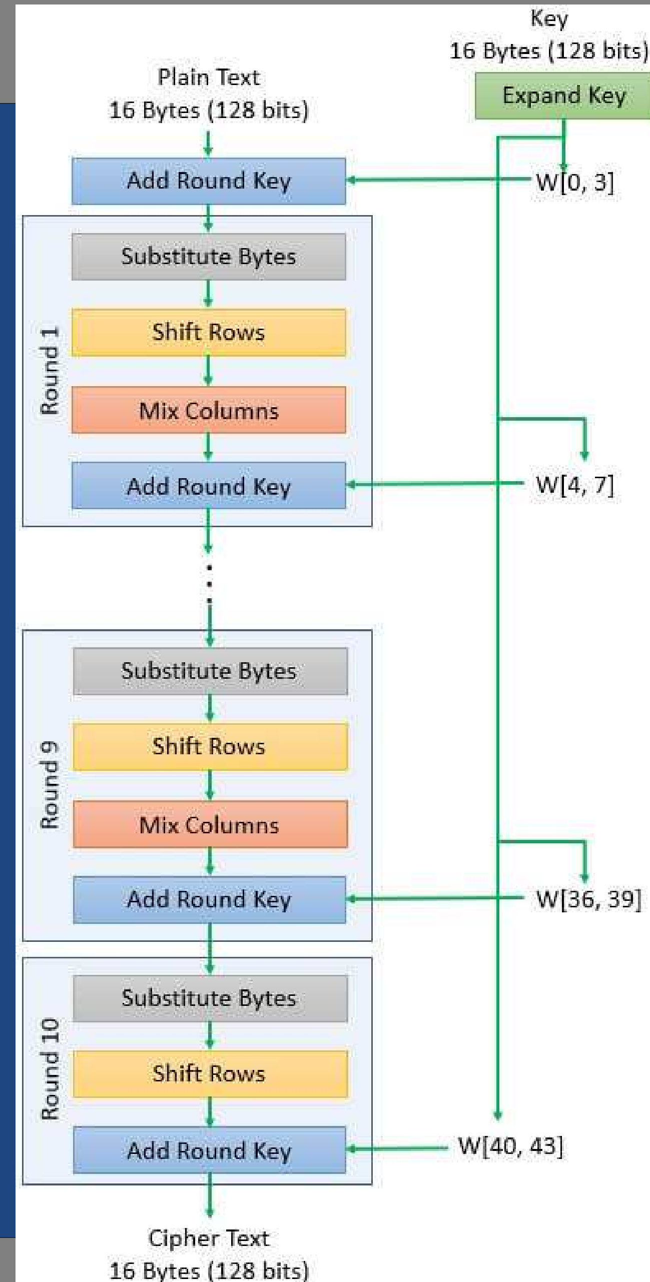
- One key:

  ..

  - ..
  - This was the only type of encryption prior to invention of public-key in 1970's.

Private Key Crypto: AES

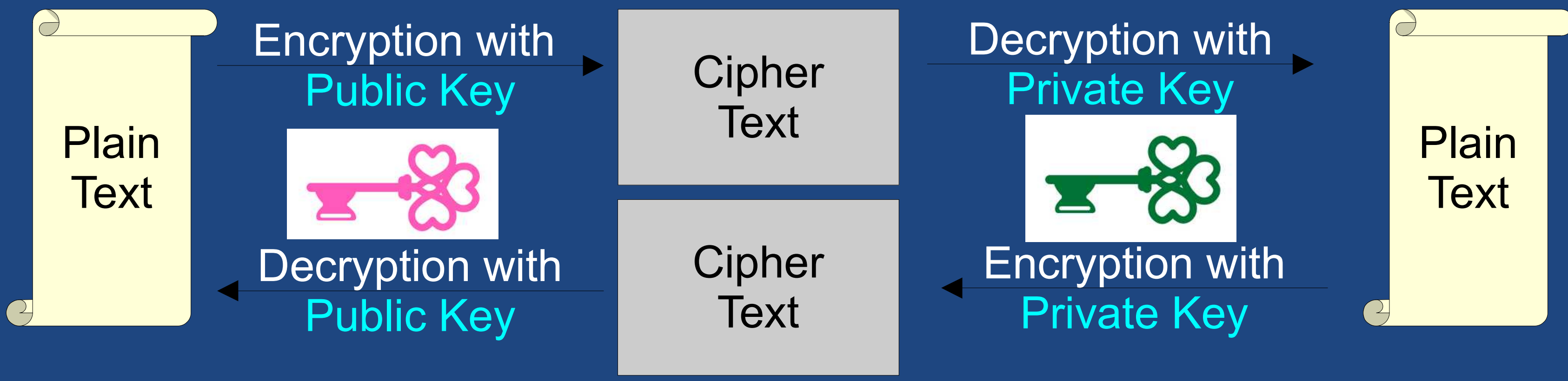
- AES is an example private key crypto algorithm
  - Need the same key to encrypt and decrypt.



https://binaryterms.com/advanced-encryption-standard-aes.html

Public Key Crypto
or
Asymmetric Crypto
(Two keys)

Public Key Crypto (Asymmetric)



- There are two keys:
  - Public key: can be known to anybody
    - Used to encrypt and verify signatures (more below).
  - Private key: ..
    - Used to decrypt and sign signatures (more below).
- Fundamental property of public key encryption:
  - ..

Toy Asymmetric Algorithm

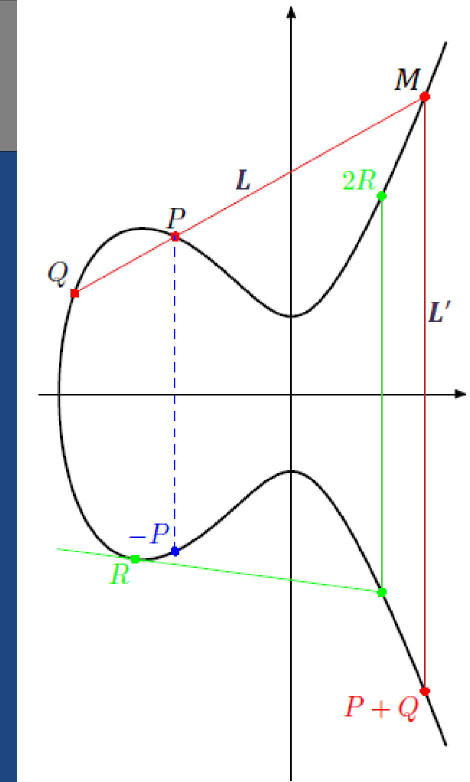
- How does asymmetric encryption actually work?
- Key 1 and Key 2 are effectively an “inverse” of each other
  - ..
- Analogy to Caesar’s Cipher
  - Key 1: Encrypt by shifting letter to right by 7
  - Key 2: Decrypt by shifting letter to right by 19
  - Example: Message is “Hi”

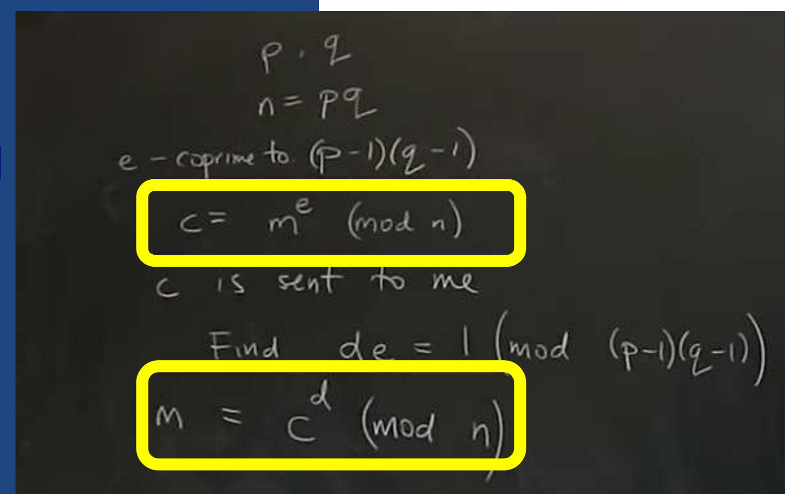
    A B C D E F G **H** I J K L M N **O** P Q R S T U V W X Y Z

    - H shifted right by 7 = O
    - O shifted right by 19 = H
  - We are always doing the same algorithm (toy is shifting right).

Generating Keys

- Generating keys
  - The public and private keys are ..
- Example approaches to generating keys
  - Factoring very large prime numbers,
  - Solving "Twisted Edwards curves" (ed25519)
- Description of RSA algorithm https://www.youtube.com/watch?v=qph77bTKJTM
  - Uses simple numbers to show how it works. 8m





Keeping Secrets

- Example: Keeping Secrets
  - Alice wants to send a secret message to Bob
  - ..
  - Bob decrypts the cipher-text using his private key
- Analysis
  - Since only Bob knows Bob's private key,
    only Bob can decrypt the cipher-text.
  - Hence Alice and Bob can securely share the message.

Verifying Sender

- Example: Verifying Sender
  - Bob wants Alice to know that he sent a messages and it has not been altered.
  - ..
  - Alice decrypts the cipher-text using Bob's public key.
- Analysis
  - Since only Bob knows Bob's private key,
    ..
  - Alice knows it was Bob who created the message.

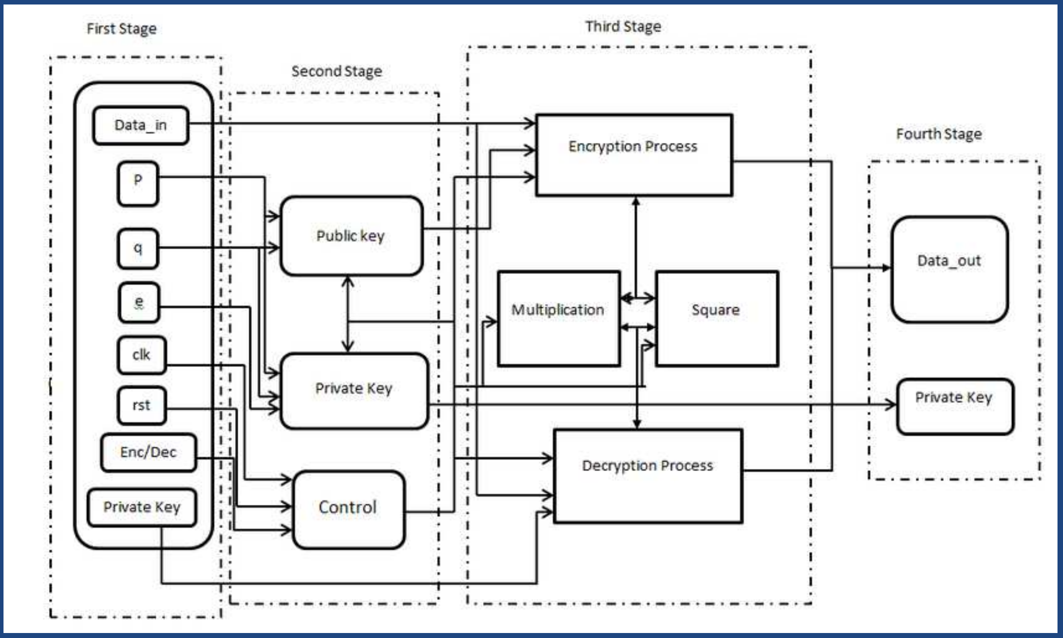
Secret and Verified

- Example: Secret and Verified

  Combine previous two examples.
  - Alice wants to send a verified, secret message.
  - ..
    - Anyone can decrypt it with her public key.
    - But only she can encypt with it; so we know she sent it!
  - ..
    - Only Bob can decrypt it with his private key.
- Analysis
  - Only Bob can decrypt the message (using his private key), and he'll know that only Alice can create it (using her private key).

Public Key

- Benefit:
  - This does not require having
    ..
  - Lots of other use cases beyond encryption / decryption
- Example algorithm: RSA.



https://www.researchgate.net/figure/RSA-Algorithm-Process_fig3_282249995

Summary

- Cryptography
  - From plain text, create cipher text that others cannot read or change.
- Types of algorithms
  - 0 Keys: Hash function
  - 1 Key: Symmetric encryption (private-key)
    - Both sides know the same secret key.
  - 2 Keys: Asymmetric encryption (public-key)
    - You share a public key with the world.
    - Anyone can encrypt messages for you using this key.
    - Only you can decrypt messages using your secret private key which matches the public key.