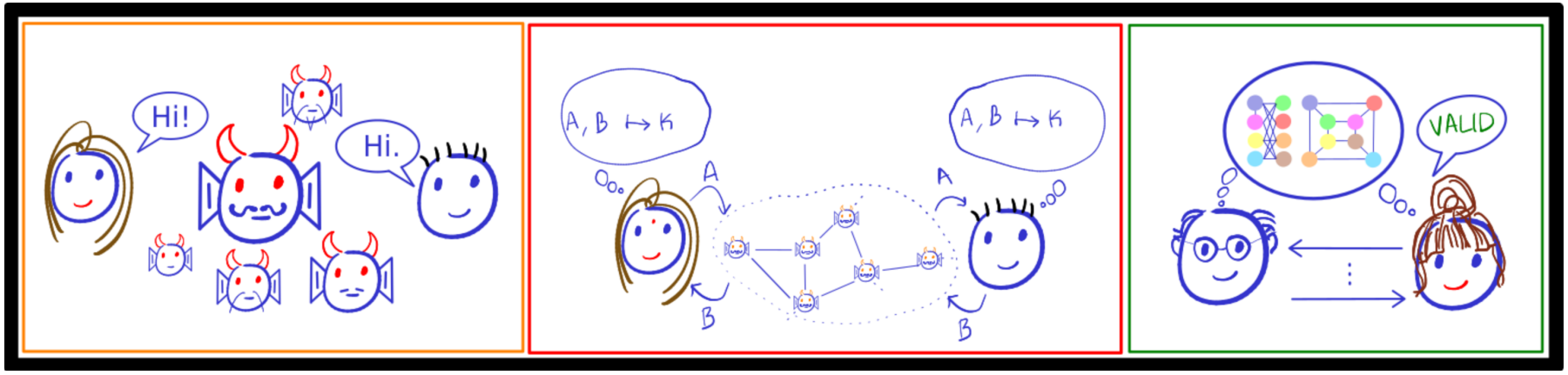

CS409m: Introduction to Cryptography

Lecture 01 (30/Jul/25)

Instructor: Chethan Kamath

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  - Six ungraded assignments to help with quizzes and exams

Weightage	Towards
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30%	Mid-sem
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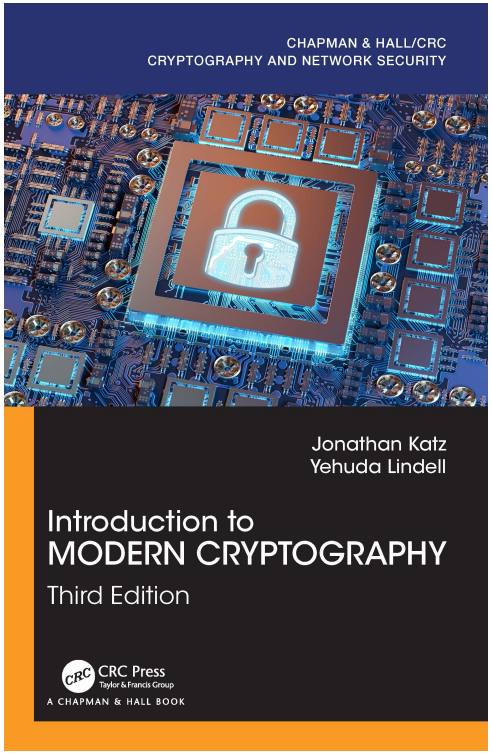
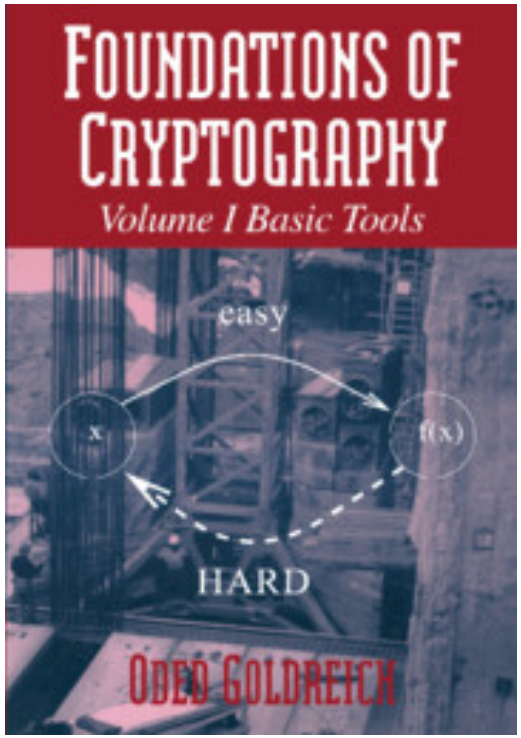
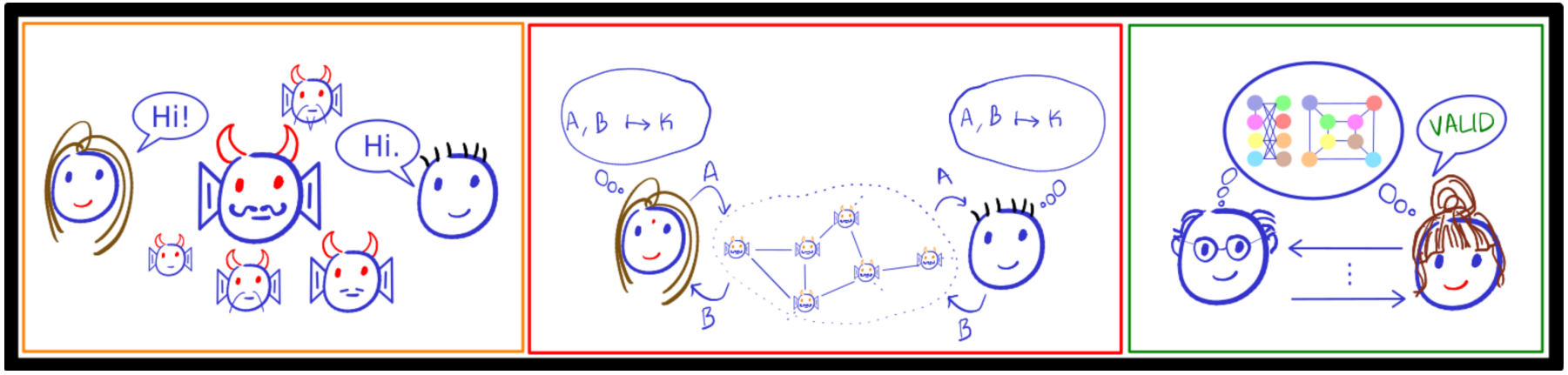
- Important dates on course website (soon)
  - Hands-on Exercise 0: today!
  - Assignment 1: 01/Aug
  - Quiz 1: 22/Aug

Administrivia...





- Resources
  - Slides and other resources will be posted on course website
    - cse.iitb.ac.in/~ckamath/courses/2025a/CS409m.html
  - Announcements/online discussion on Moodle:
    - moodle.iitb.ac.in/course/view.php?id=7460



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You Use Cryptography all the Time!

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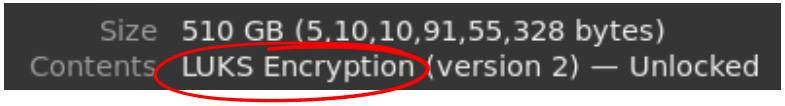
UPI
UNIFIED PAYMENTS INTERFACE

Online transactions



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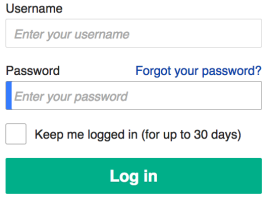

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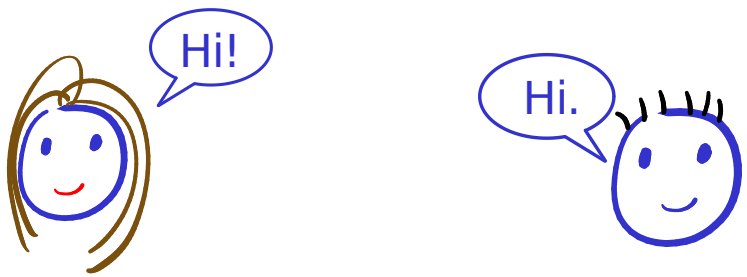
What is Cryptography?...

- Science of carrying out *tasks* securely in an adversarial setting
- A loose analogy: gossip



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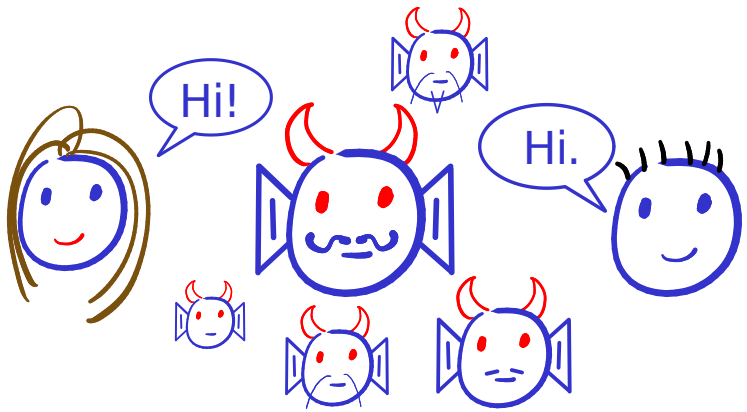

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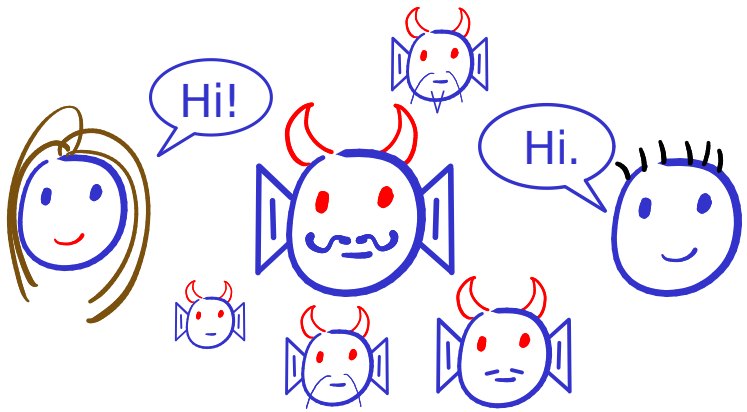

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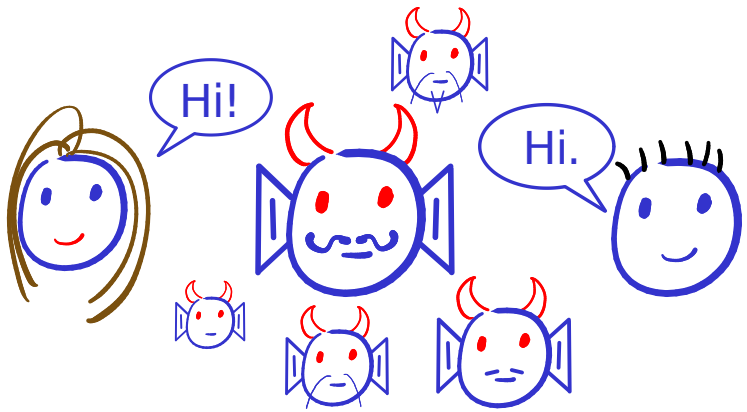

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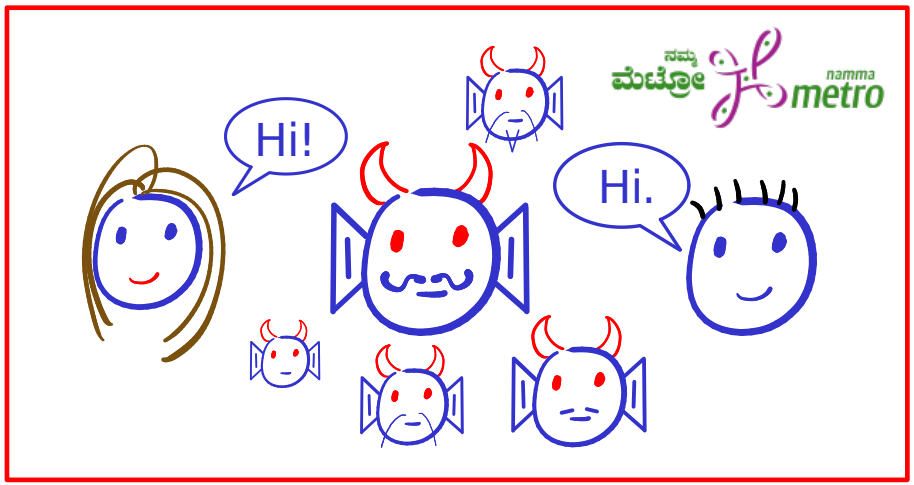

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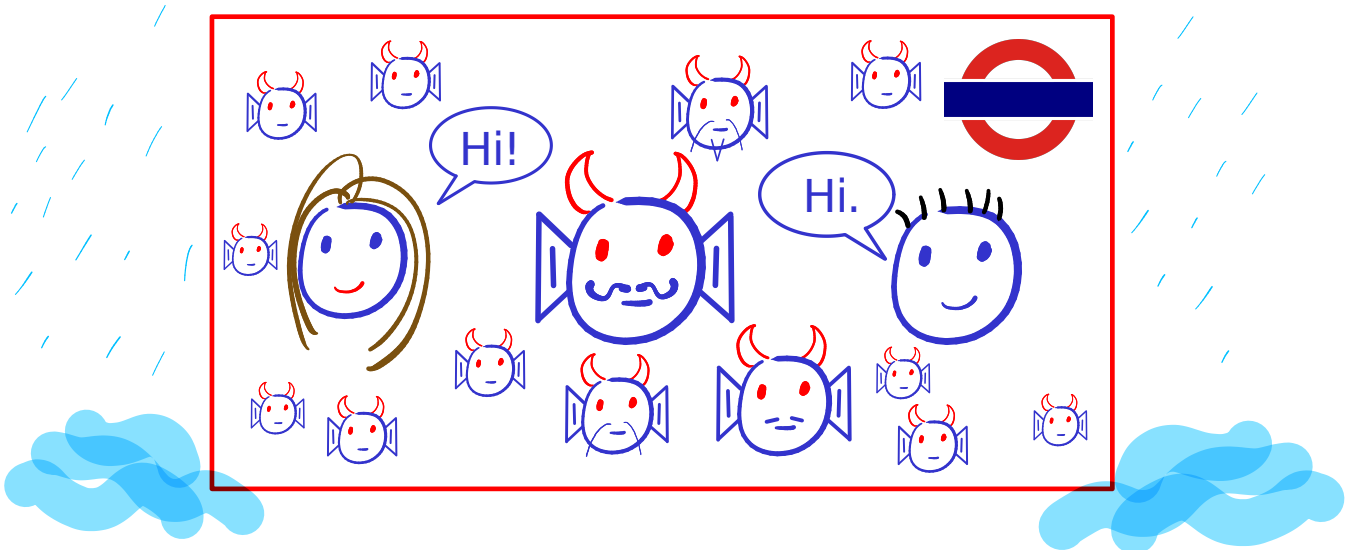

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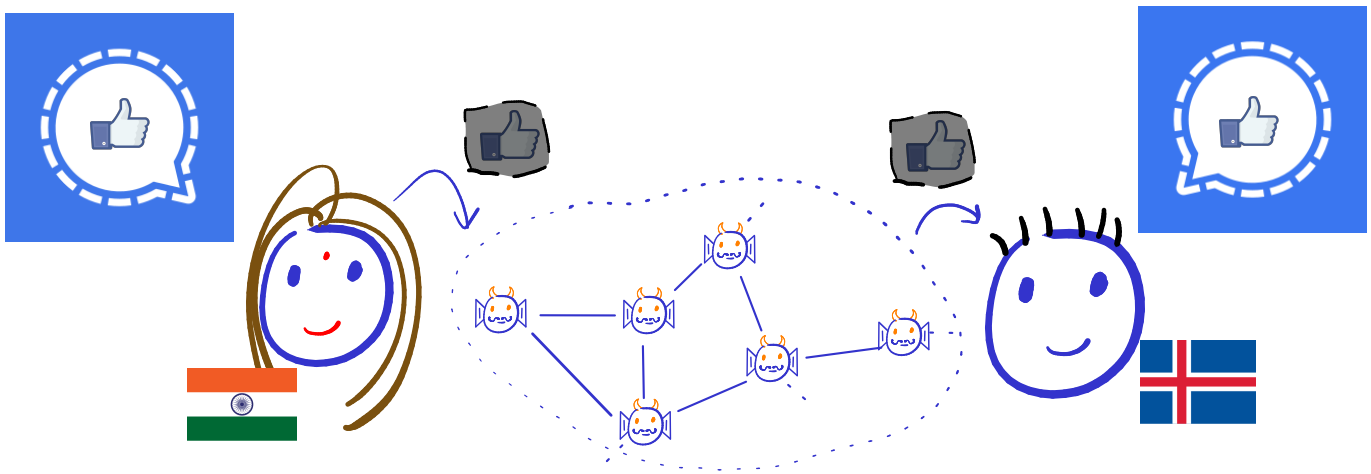

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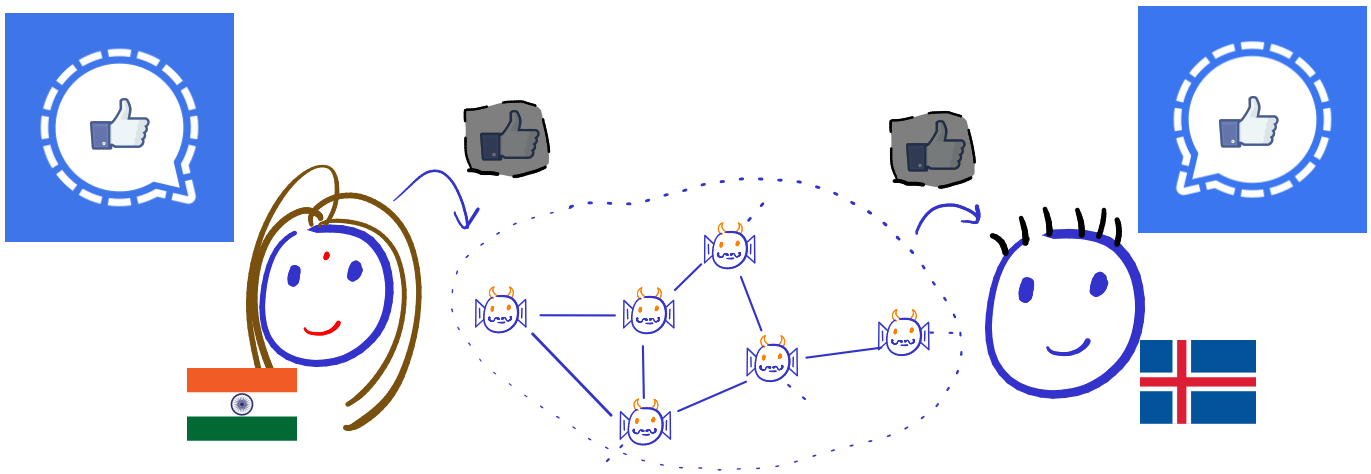

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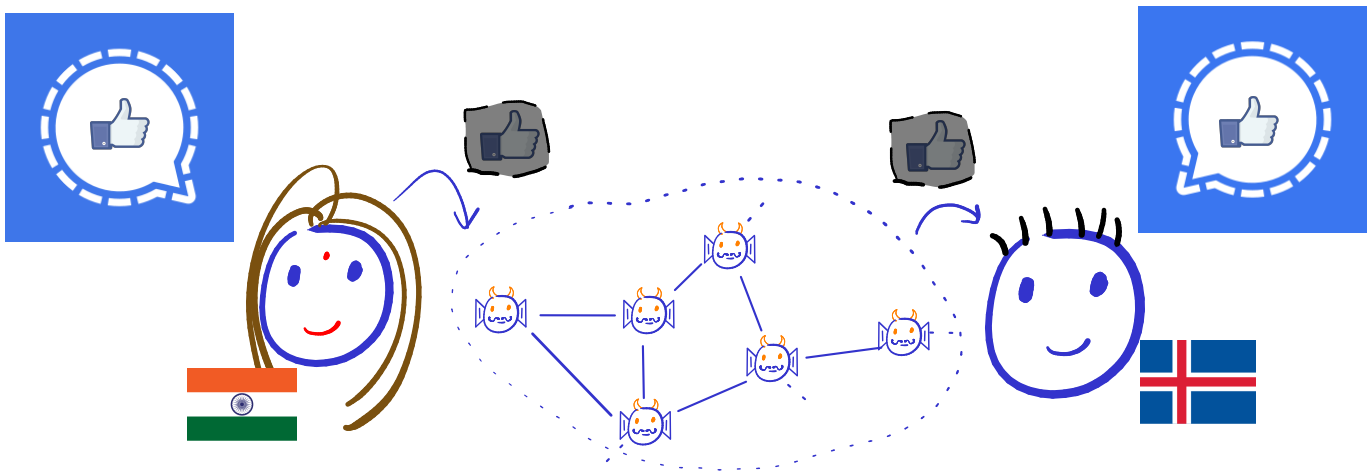

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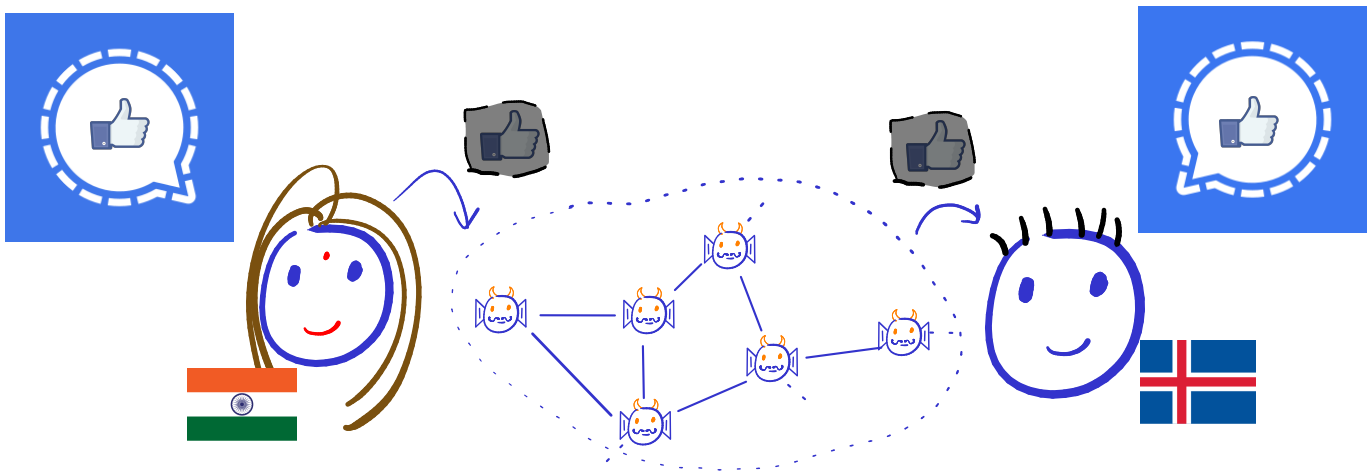

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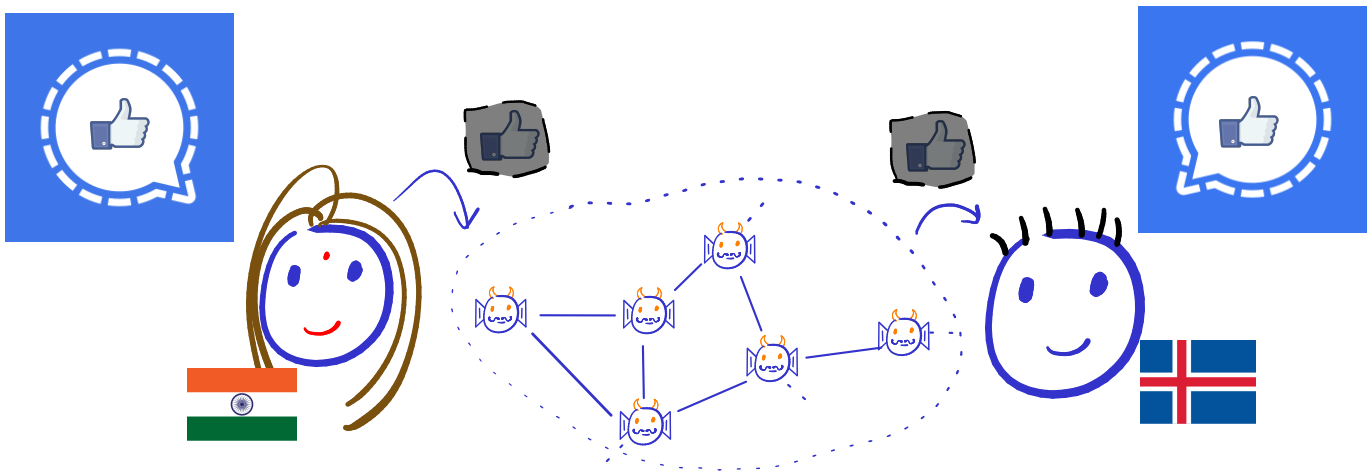

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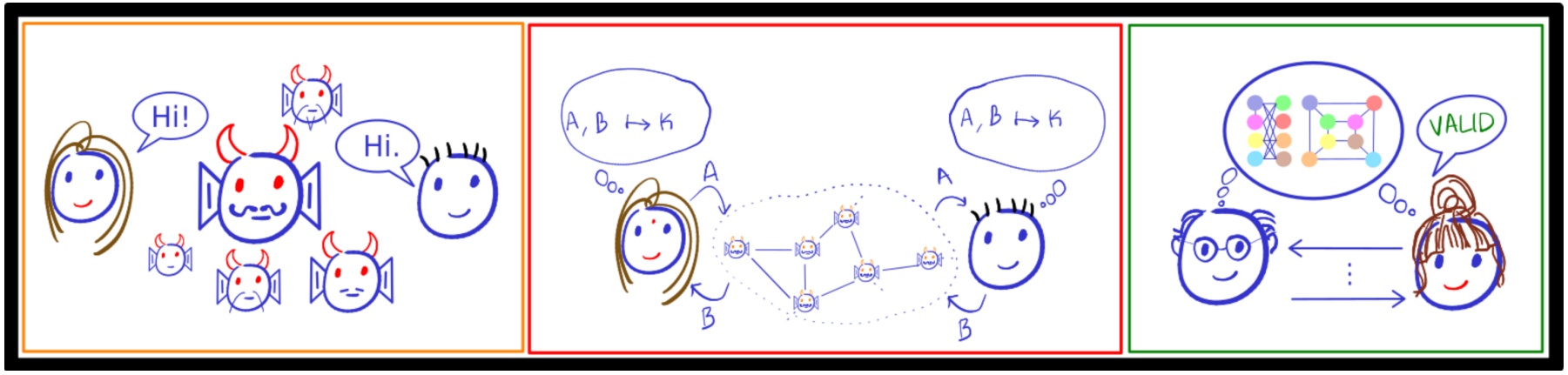
  - State actors (e.g., can tamper with phone, inject malware)



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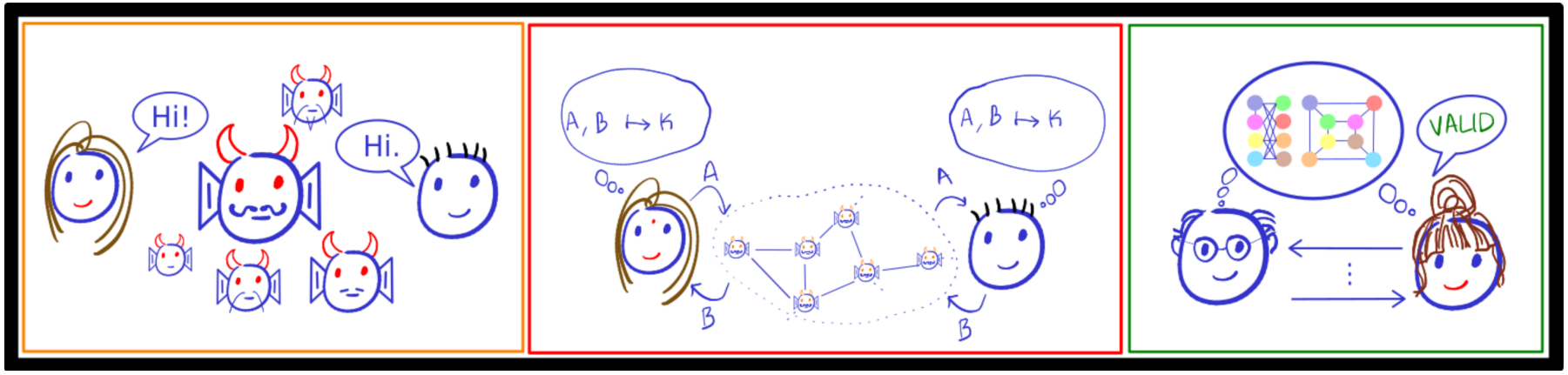

CS409m: Introduction to Modern Cryptography

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Classical *vs.* Modern Cryptography

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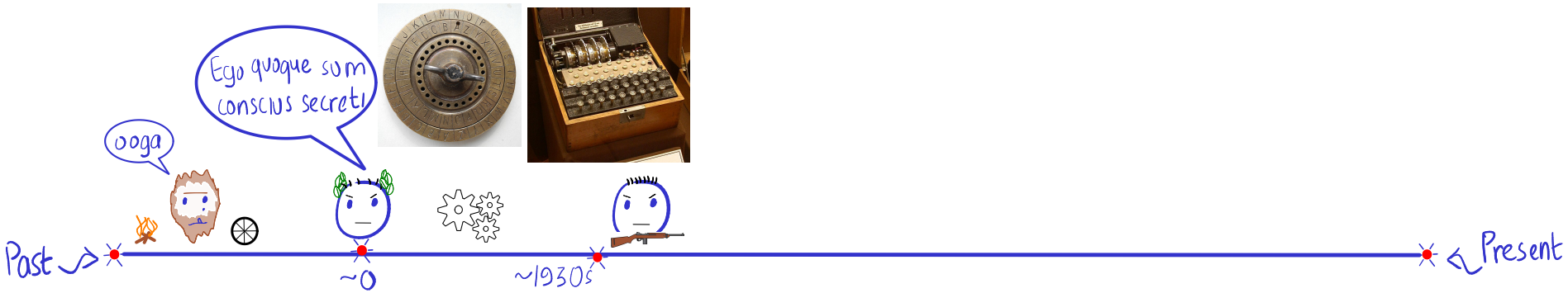

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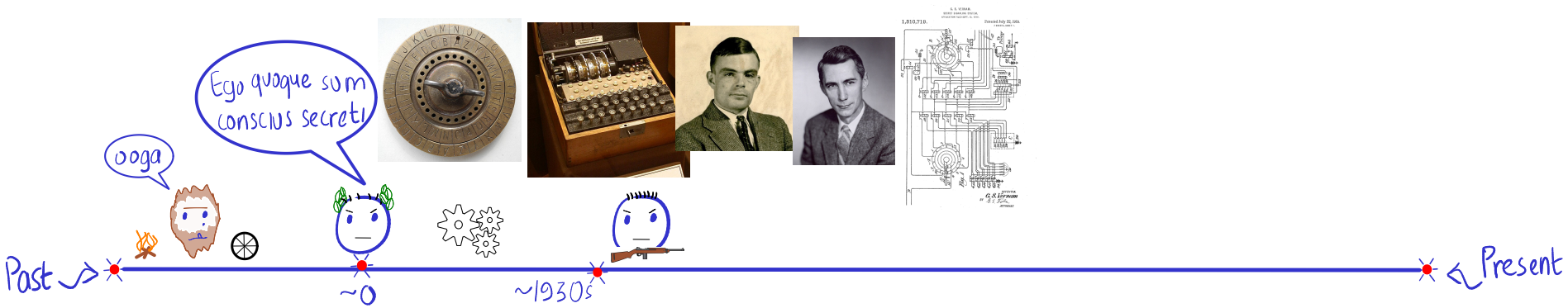

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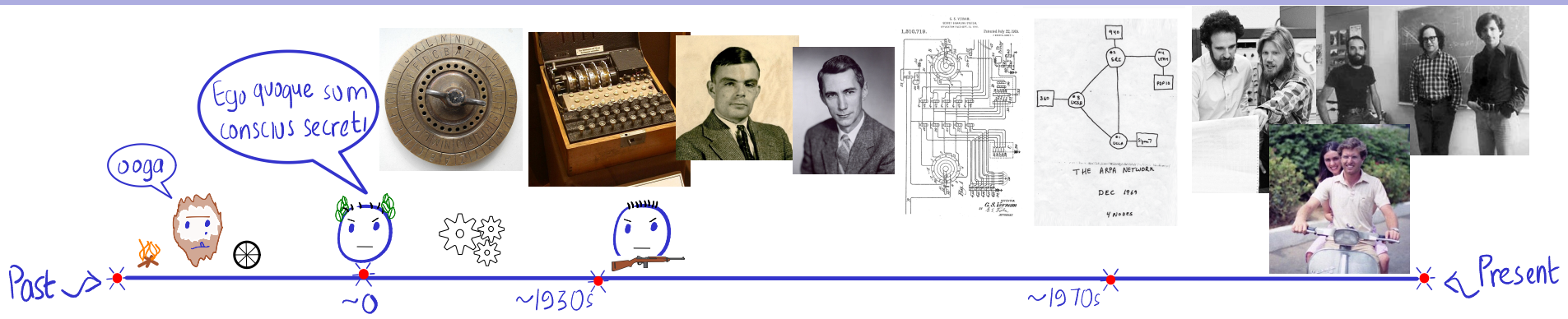

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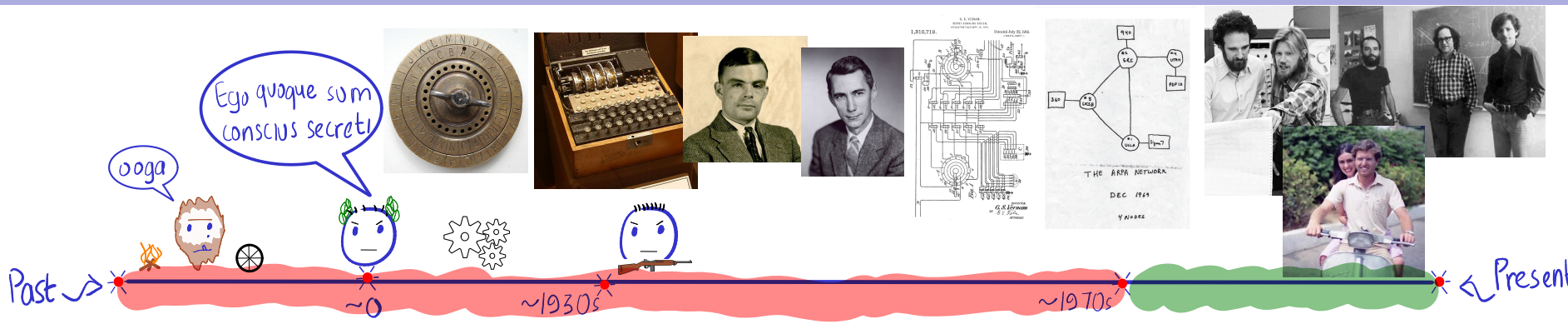

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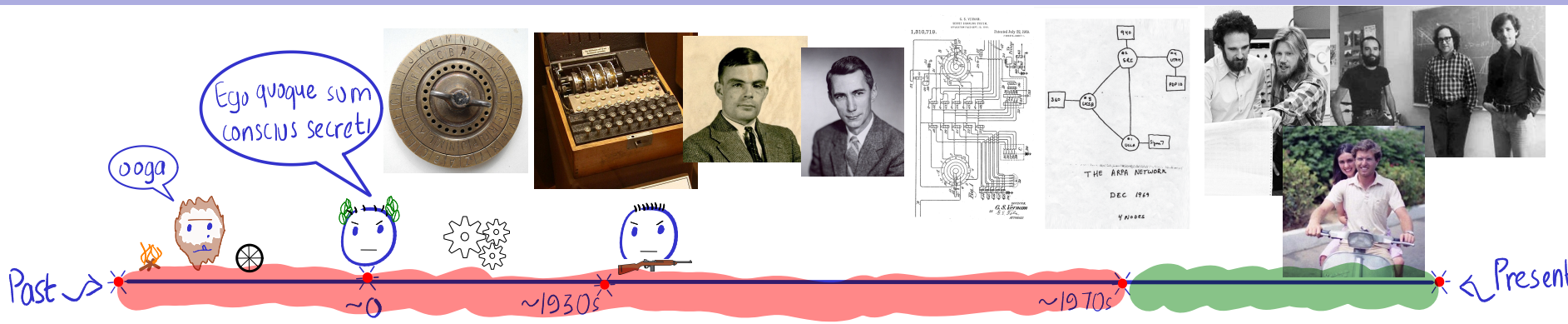

Guiding principles:

- Code design
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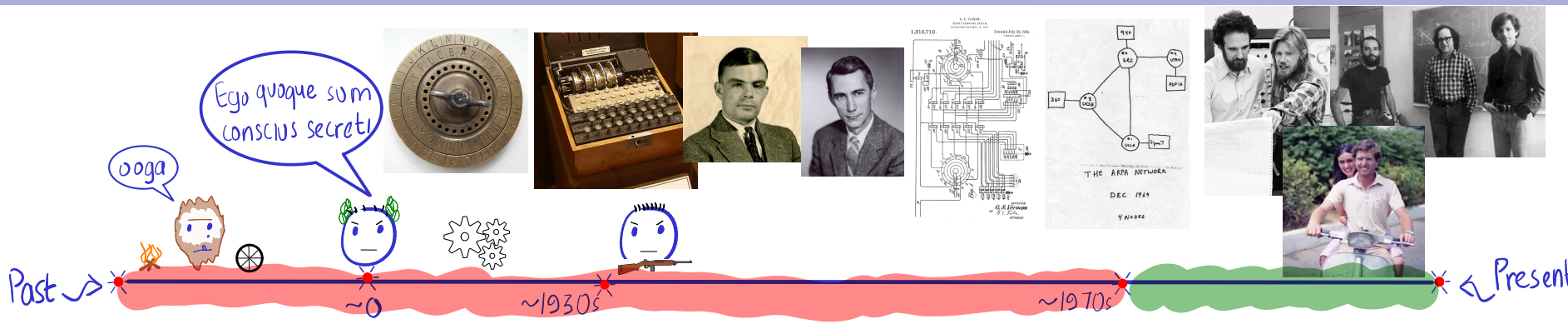

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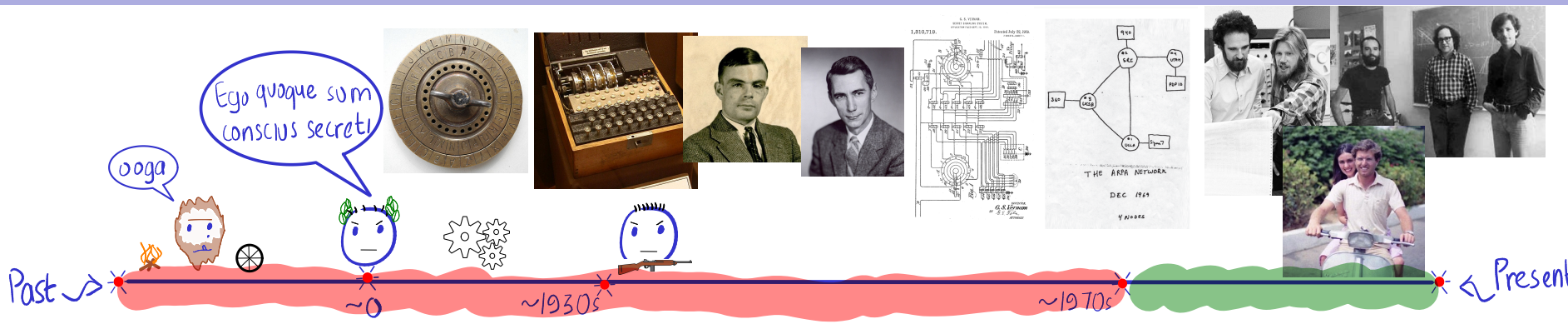

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E.g.:

- Classical ciphers
- Steganography

- Diffie-Hellman key-exchange, RSA encryption...

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  - Closely follows Sruthi Sekar's CS409m from Fall'24

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- No prerequisites, but the following is a plus

  - Basic probability, algebra and number theory
  - Knowledge of Python

This Lecture: An Overview of the Modules...

1. Module I: Secure Communication in Shared-Key Setting

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The Universal Need for Private Communication

MODULE 1
(Shared keys)

For a large part of history

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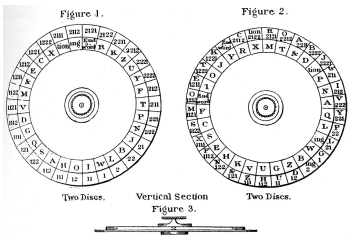

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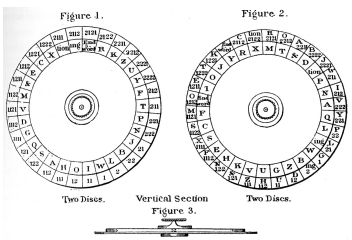

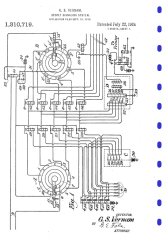

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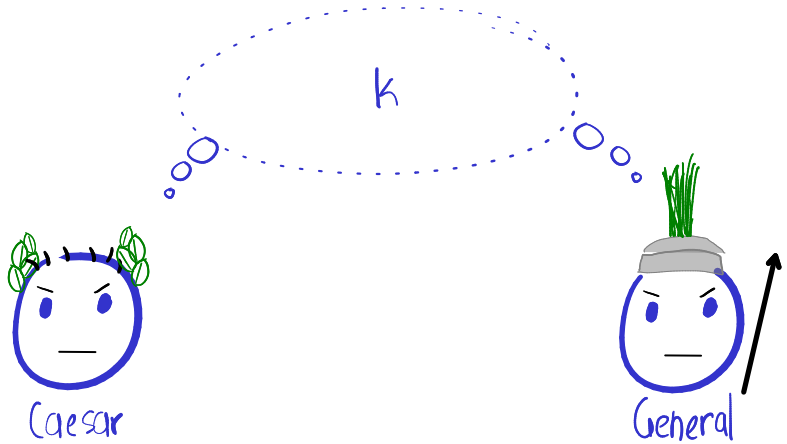

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  - k from keyspace $\mathcal{K}$

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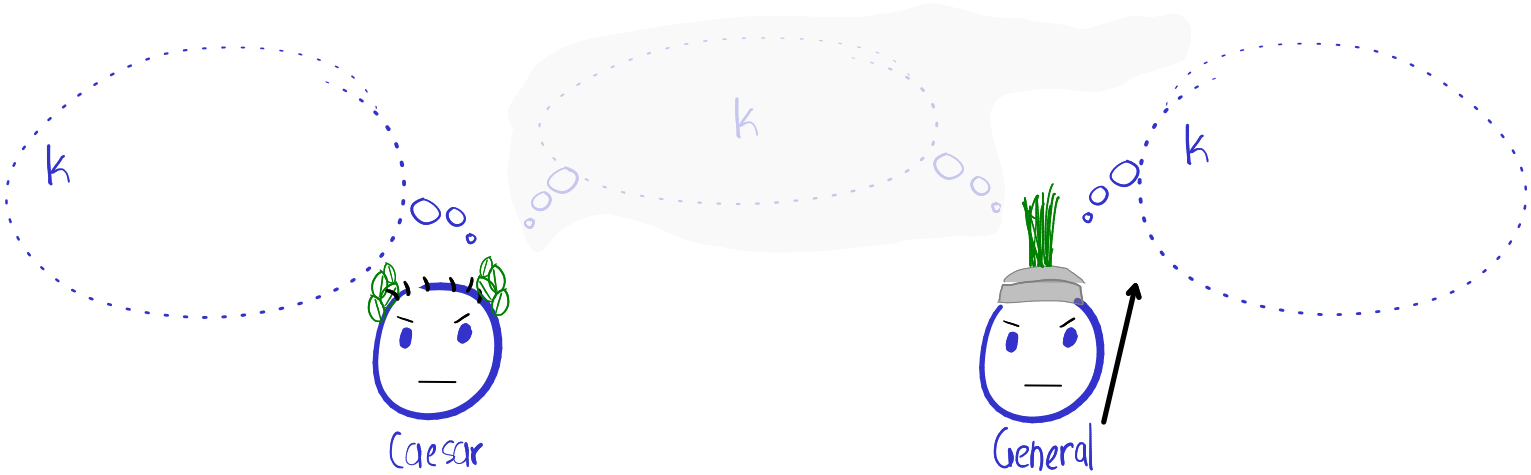

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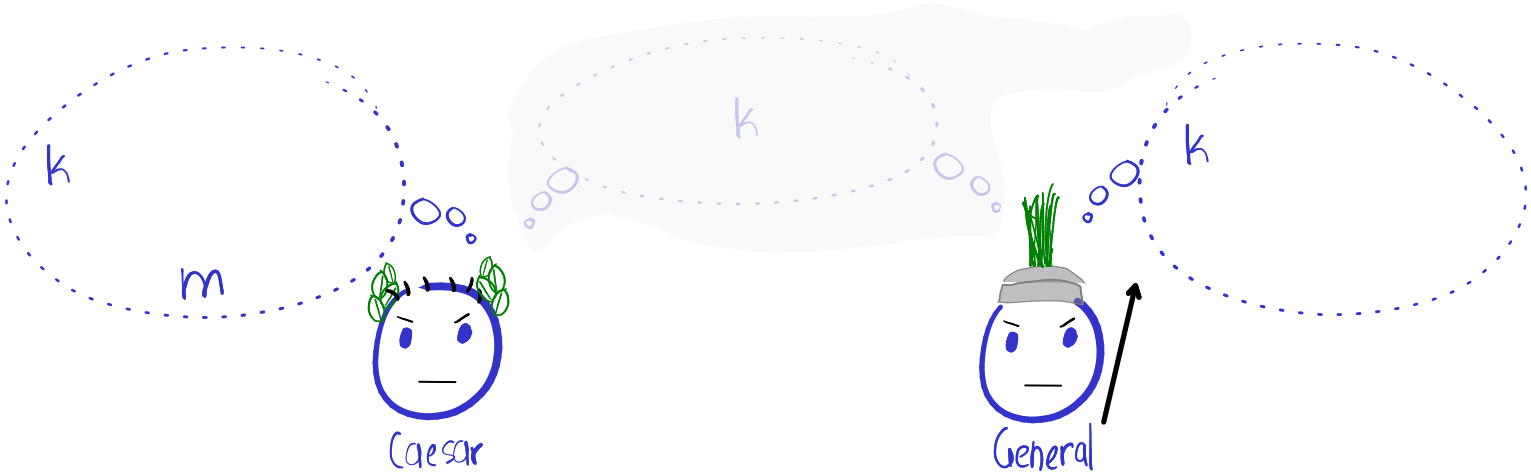

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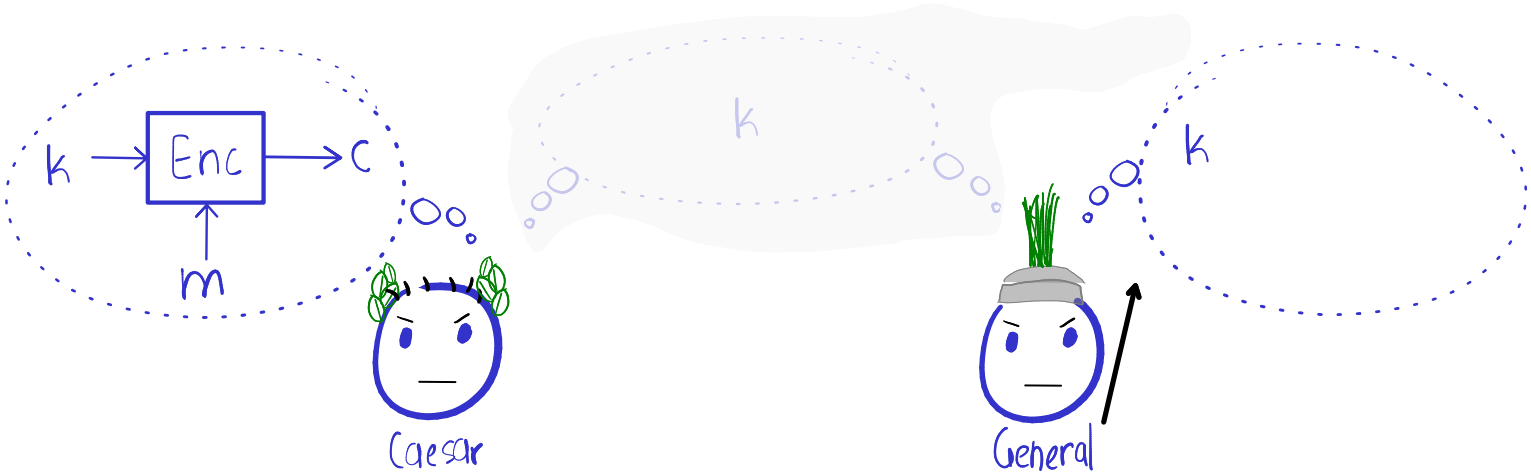

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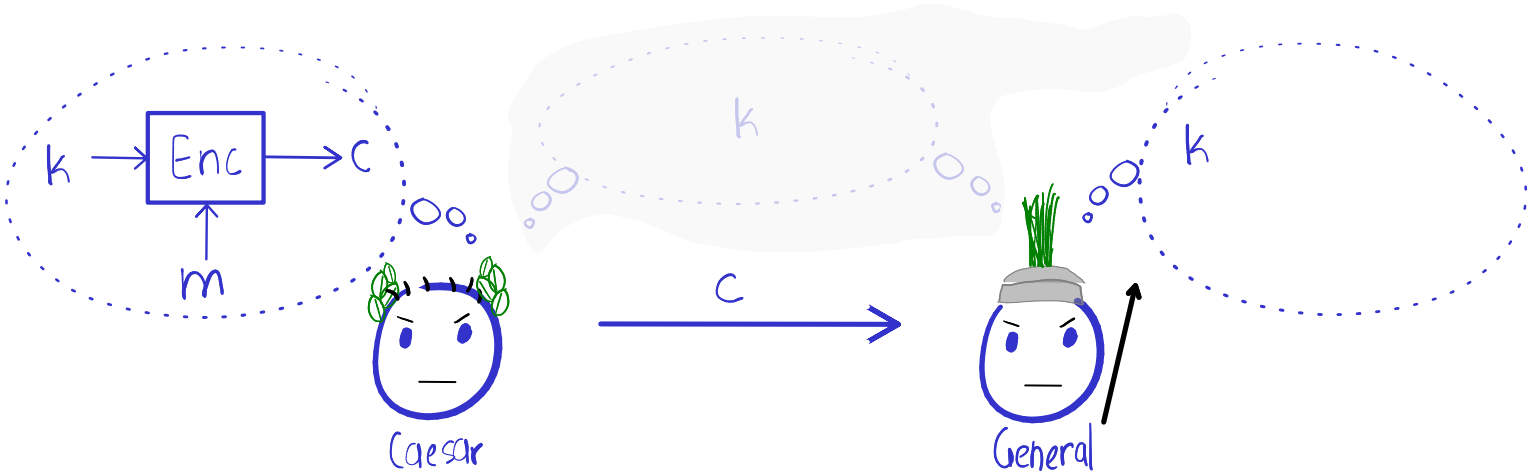

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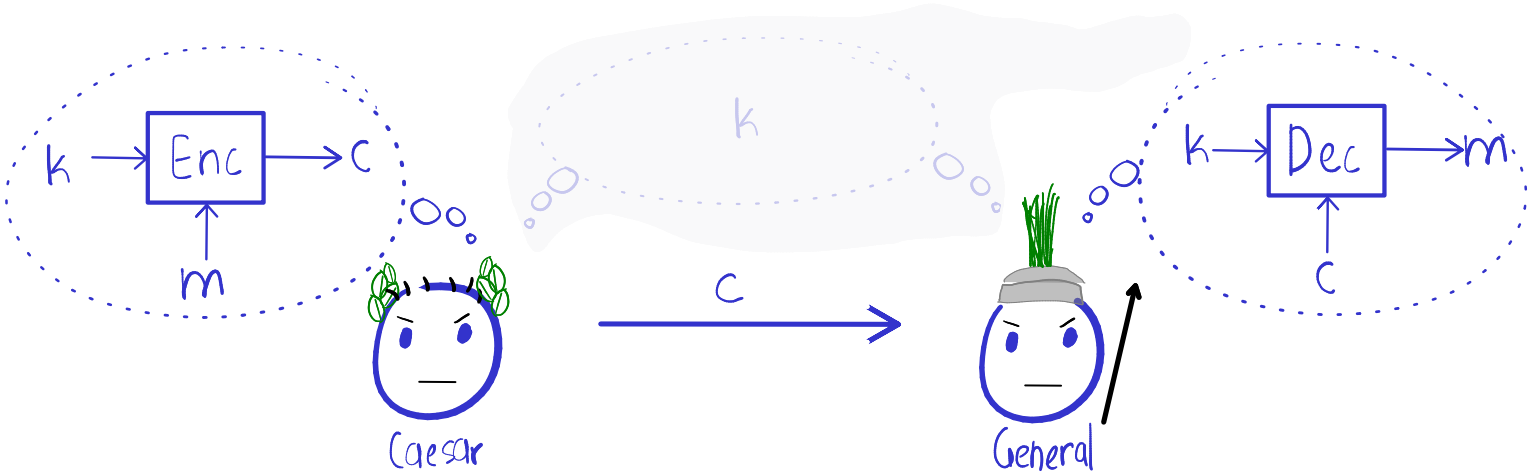

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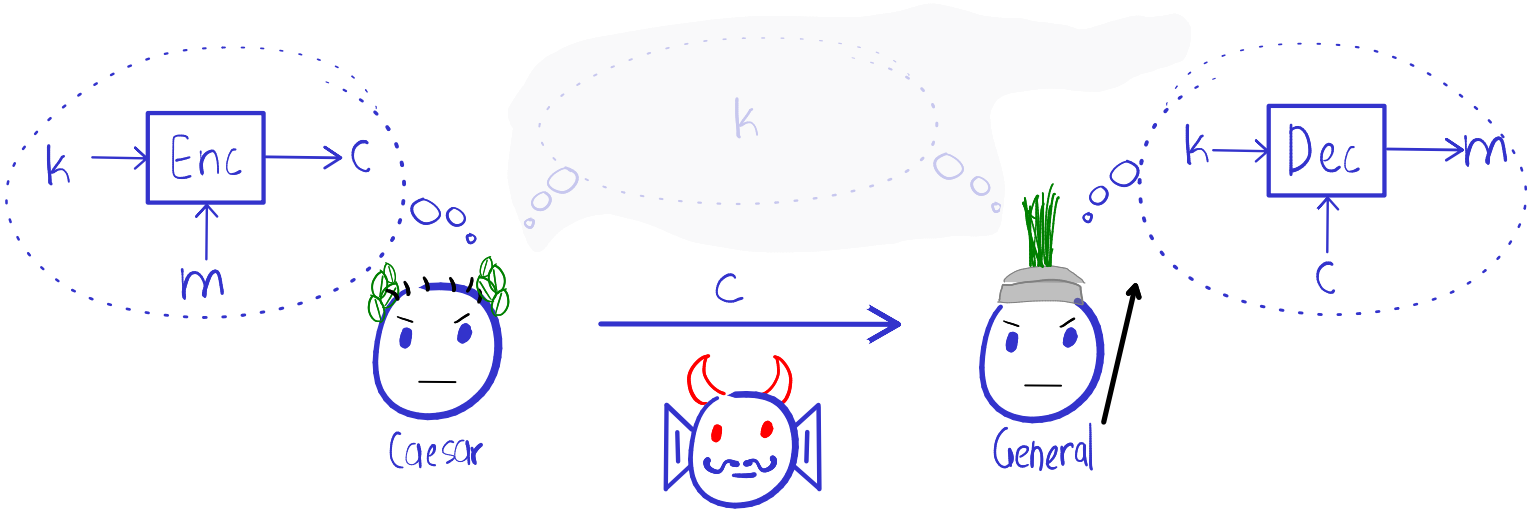
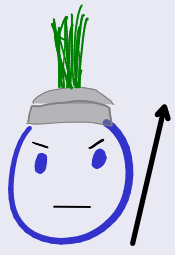
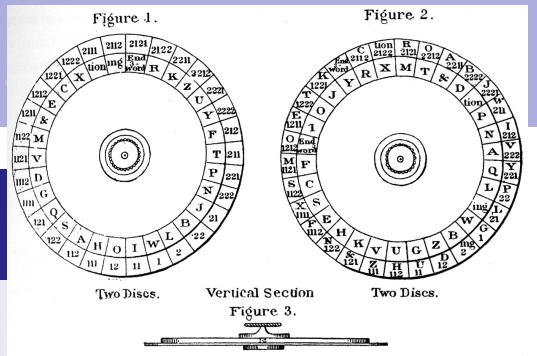


- Setting: Caeser and his General (somehow) share a key k and want to communicate m
  - k from keyspace $\mathcal{K}$
  - m: message from some message space (set) $\mathcal{M}$
  - c: ciphertext (hidden message) lies in ciphertext space $\mathcal{C}$
- *Eve* is listening!

Shift Cipher (Caeser Cipher)

Construction 1 (for message space $\{a, \cdots, z\}^\ell$)





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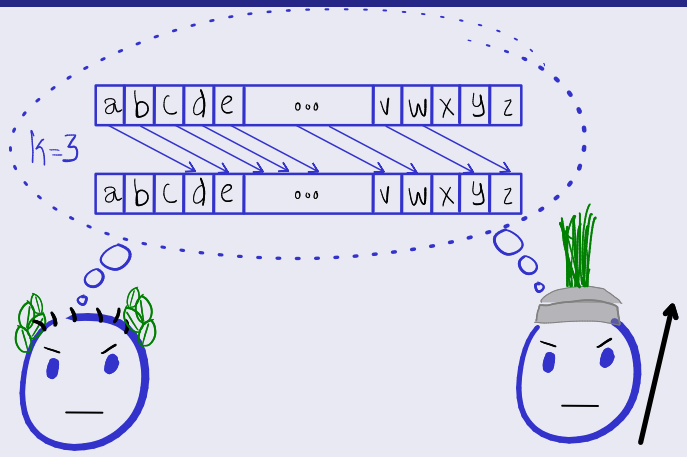

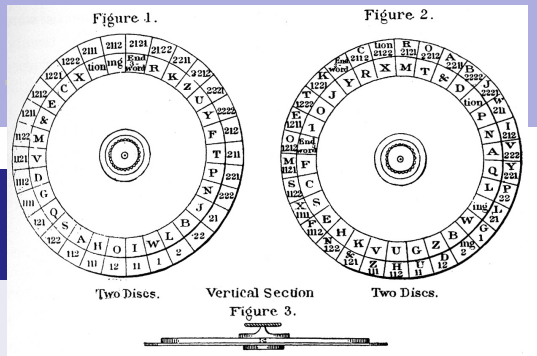

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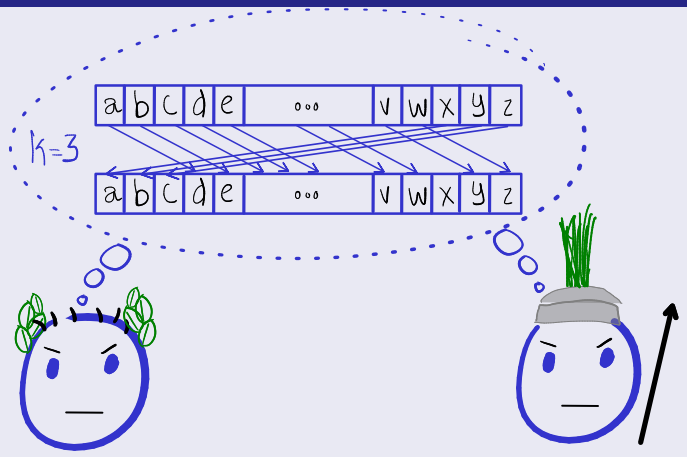

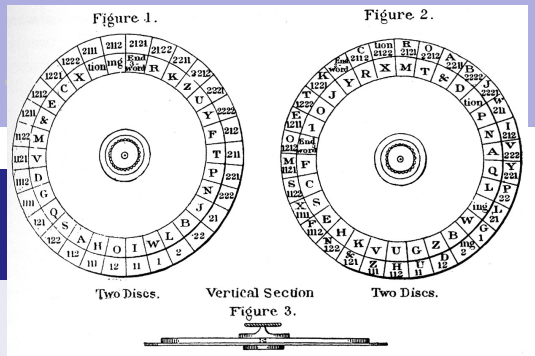

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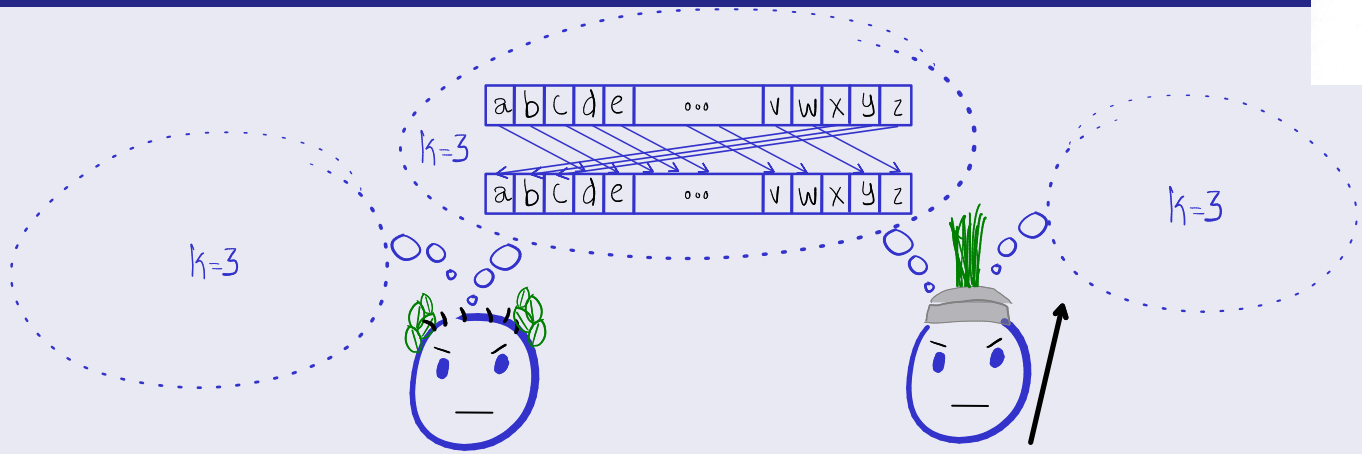

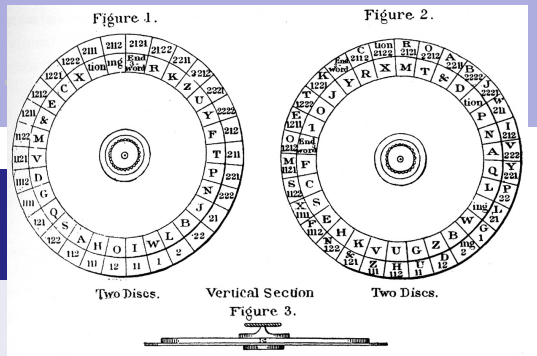

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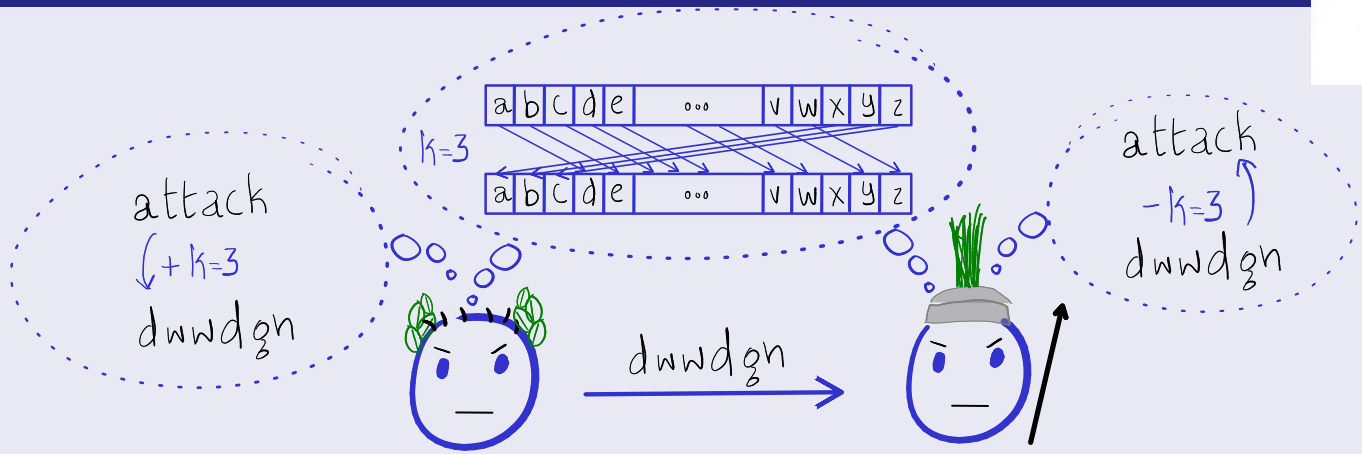

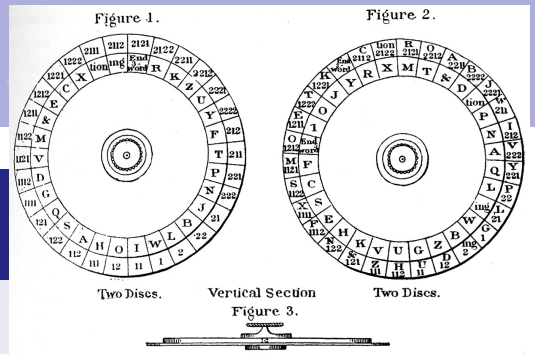

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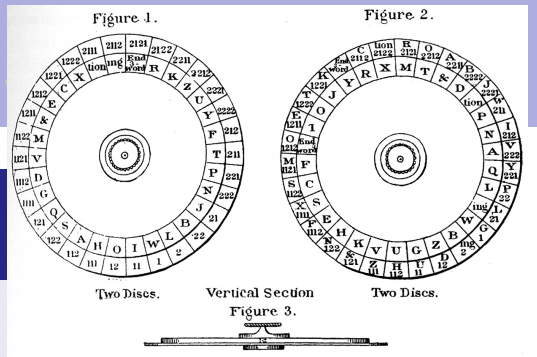

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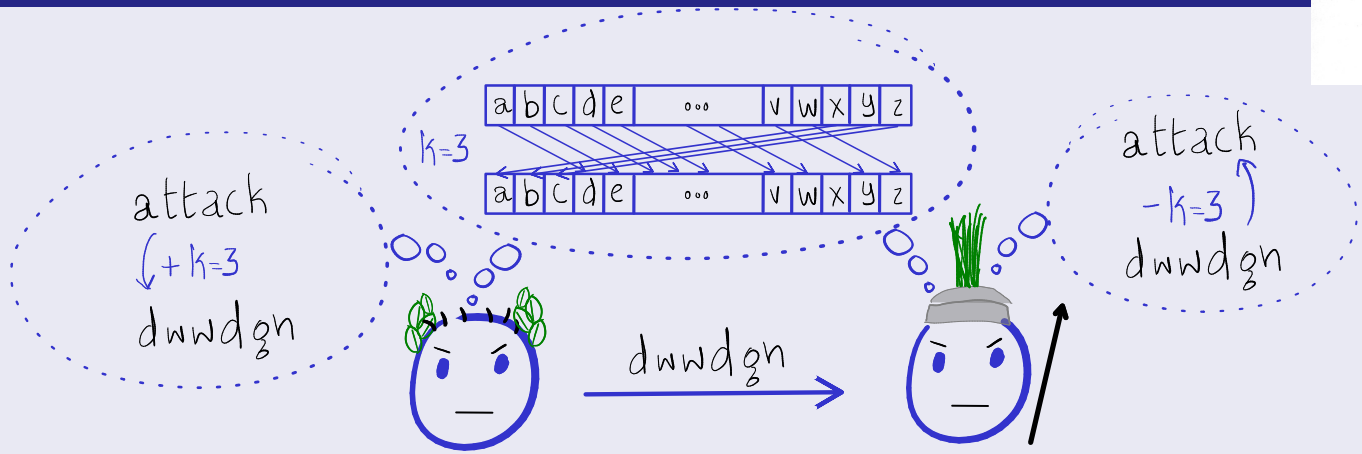

Exercise 1

1. What is the key-space? What is the ciphertext-space?
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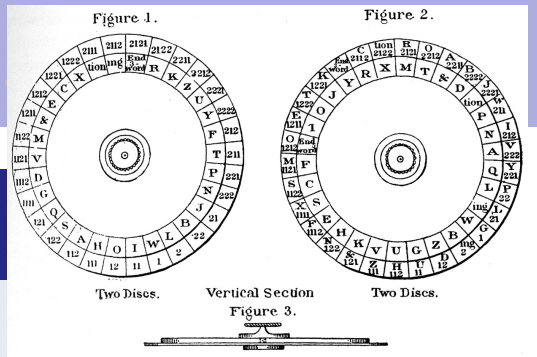

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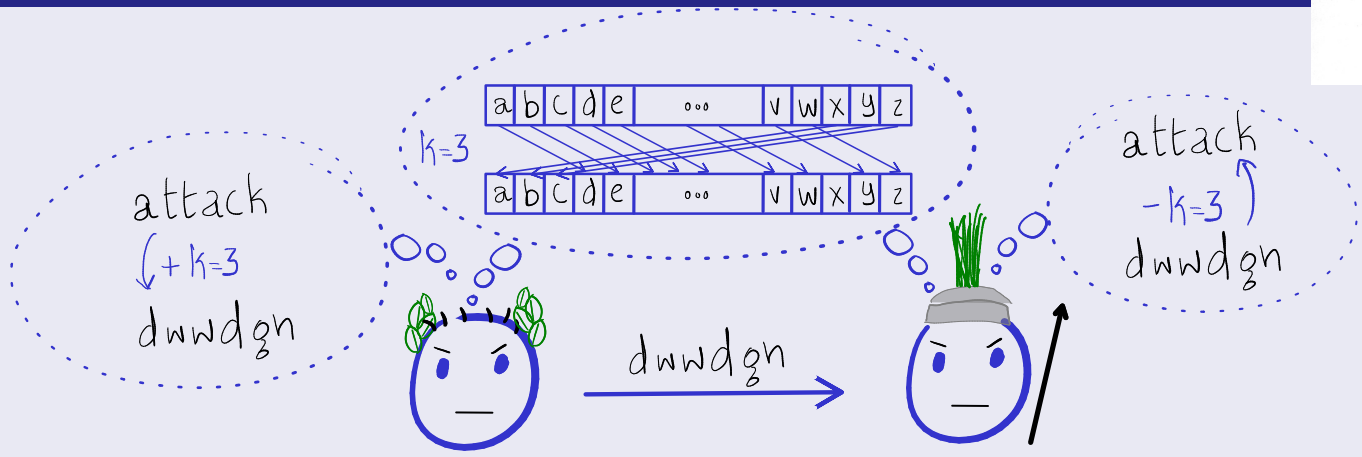
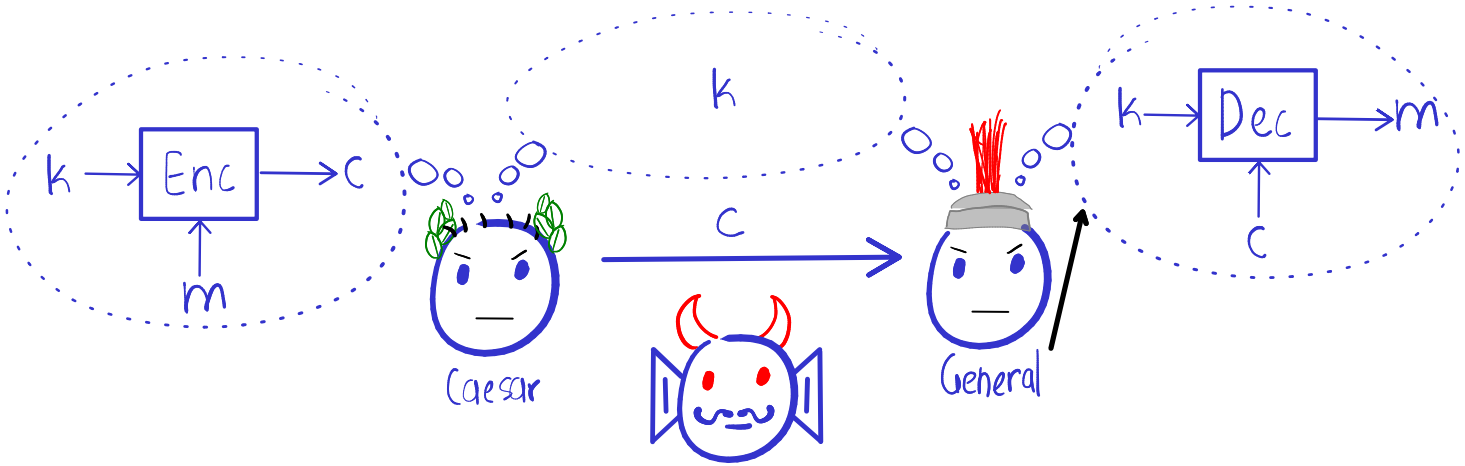


Exercise 1

1. What is the key-space? What is the ciphertext-space?
2. What is the probability that $k = 10$? What is $\mathrm{Enc}(10, \texttt{attack})$?
   Assume that Caeser only sends either `attack` or `defend`.
3. What is the probability that the ciphertext is `kddkmu`, (resp. `kddkmw`)?
4. If ciphertext is `kddkmu`, is it possible that message is `defend`?

First Let's Try to Model our Eavesdropper Eve



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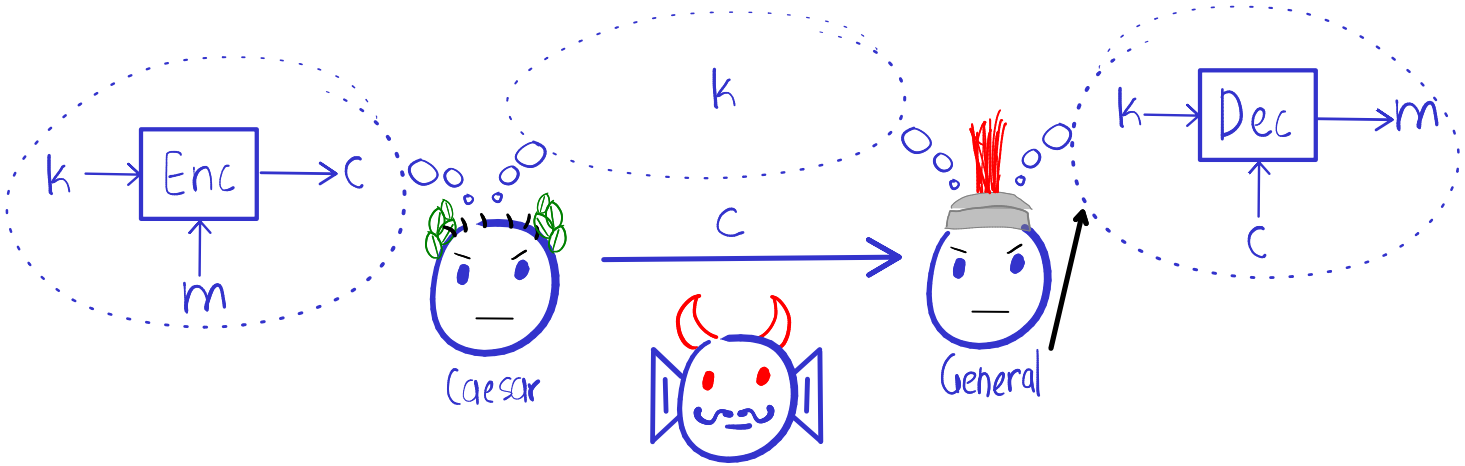

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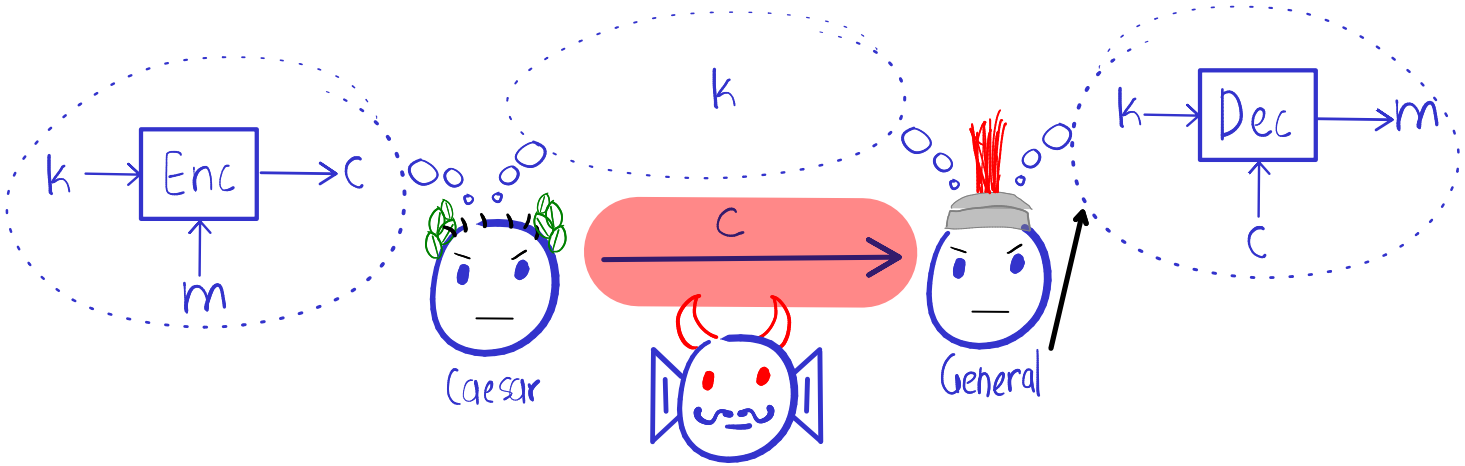

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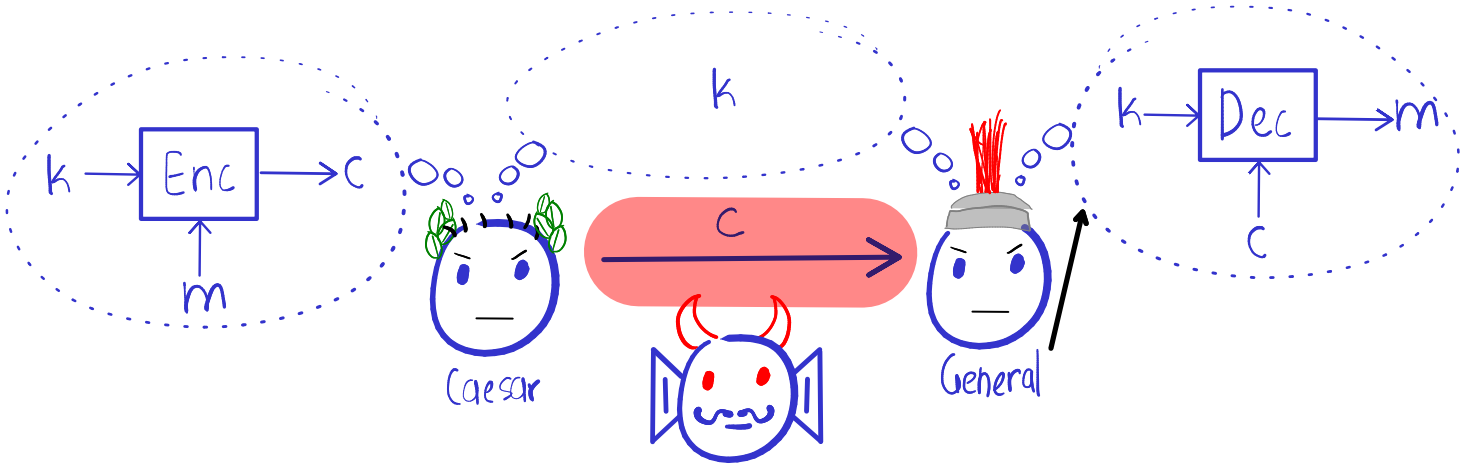

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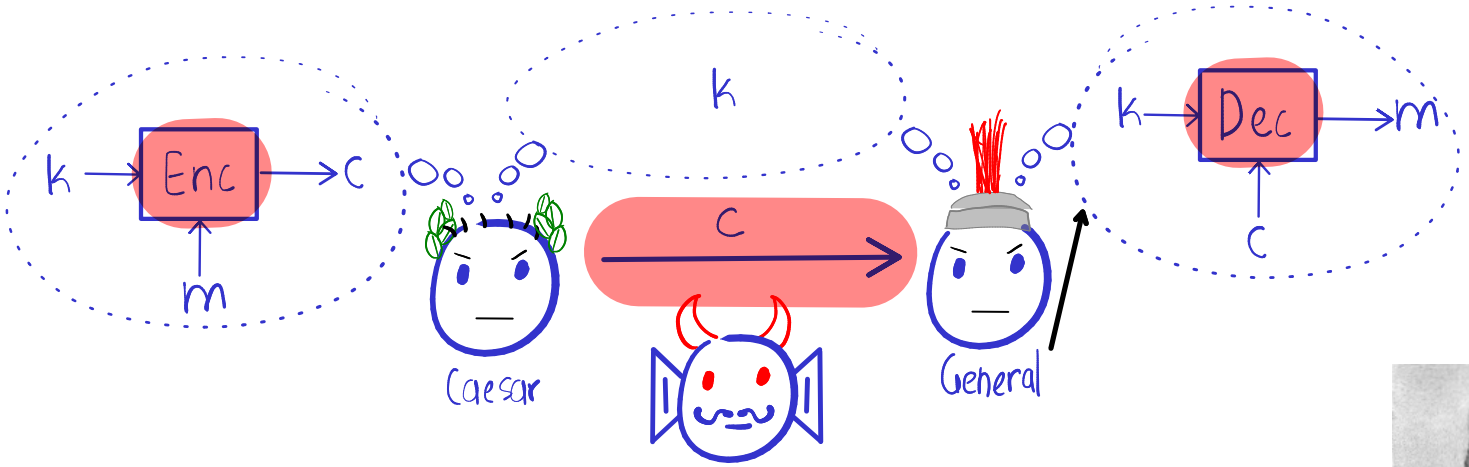

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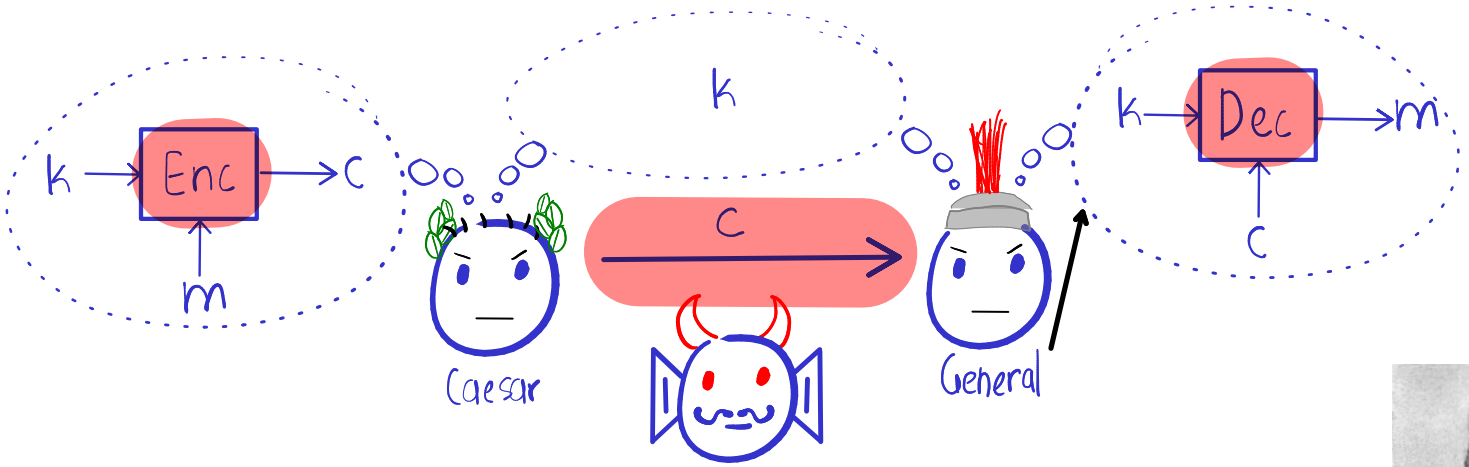

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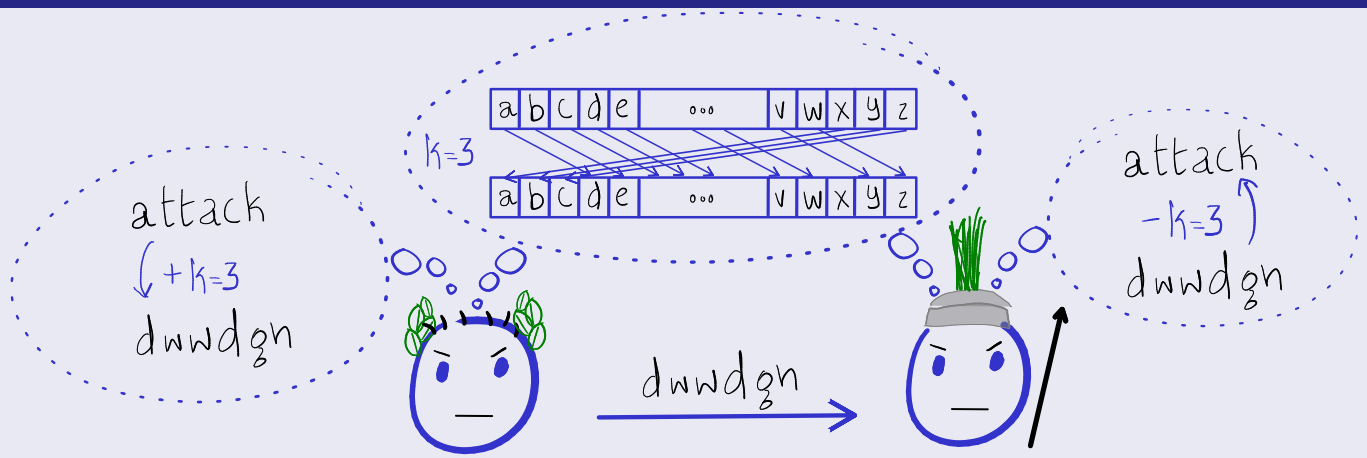
    'One ought to design systems under the assumption that the enemy will immediately gain full familiarity with them.'
  - What about the key? No, then everything is open
  - Randomness used to encrypt?

Shift Cipher (Caeser Cipher)...

Construction 1 (for message space $\{a, \cdots, z\}^\ell$)



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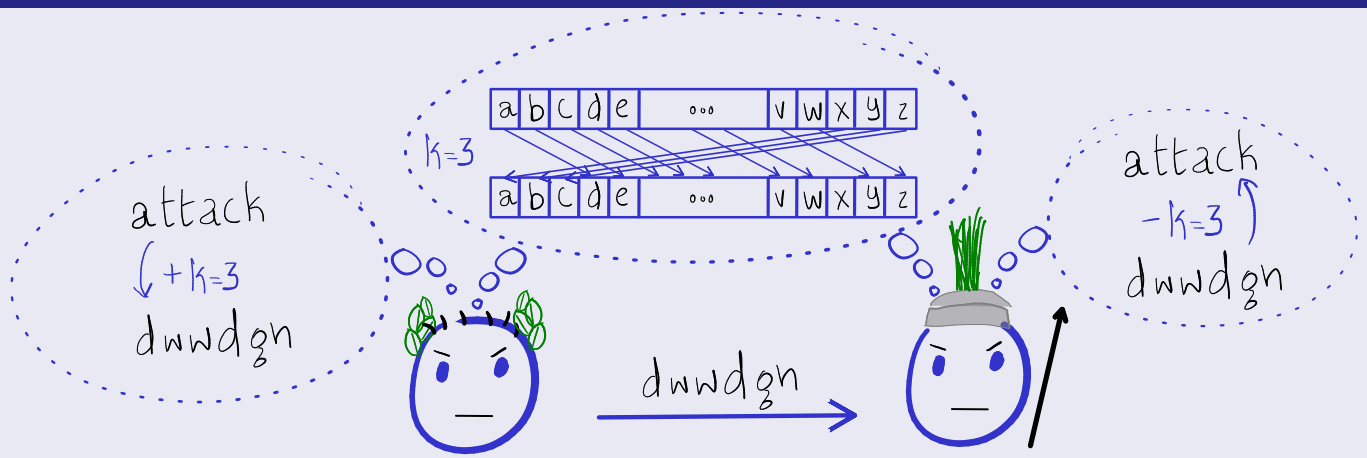

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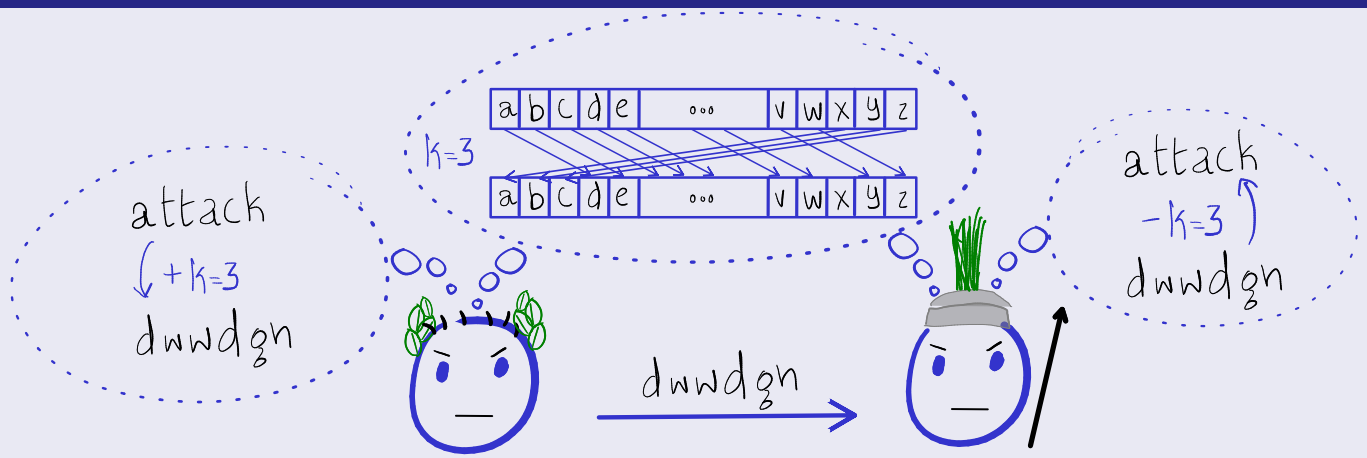


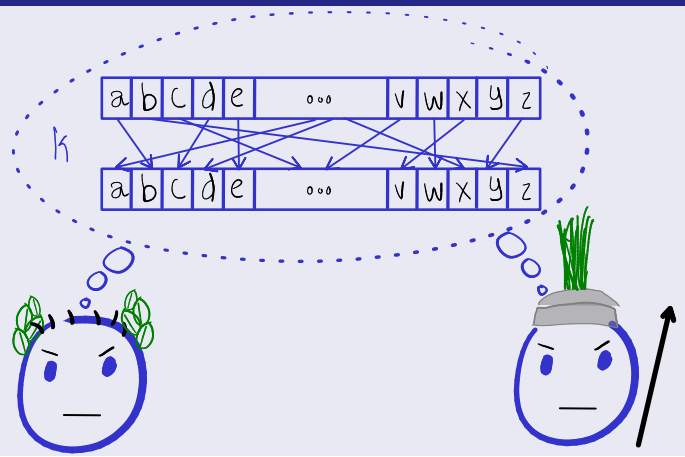
- What can Eve learn?
  - Whole message, by exhaustive key search (brute force)
- What have *we* learnt?
  - *Large-enough* key-space is necessary to thwart *brute force*

Exercise 2

That about what happens if the length of the message is $\ell = 1$

Substitution Cipher...

Construction 2 (Message space $\{a, \cdots, z\}^\ell$)



- Key is a *permutation* of $\{a, \cdots, z\}$.

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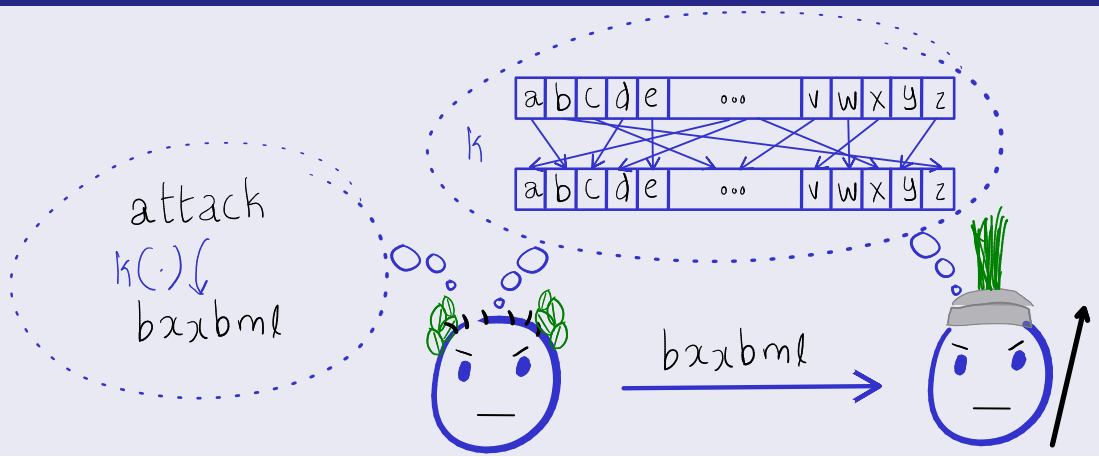

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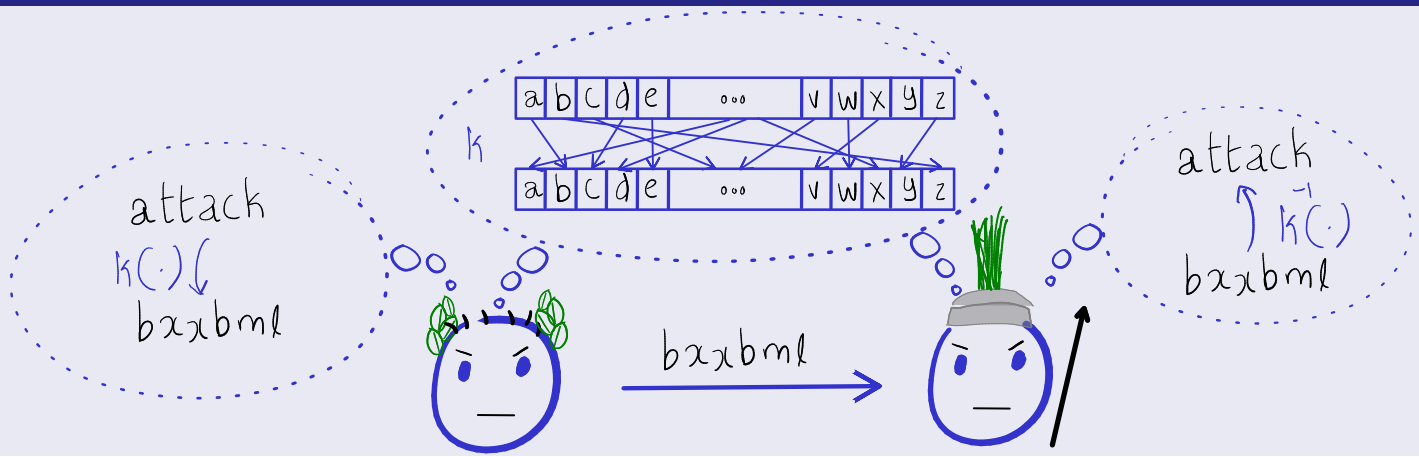

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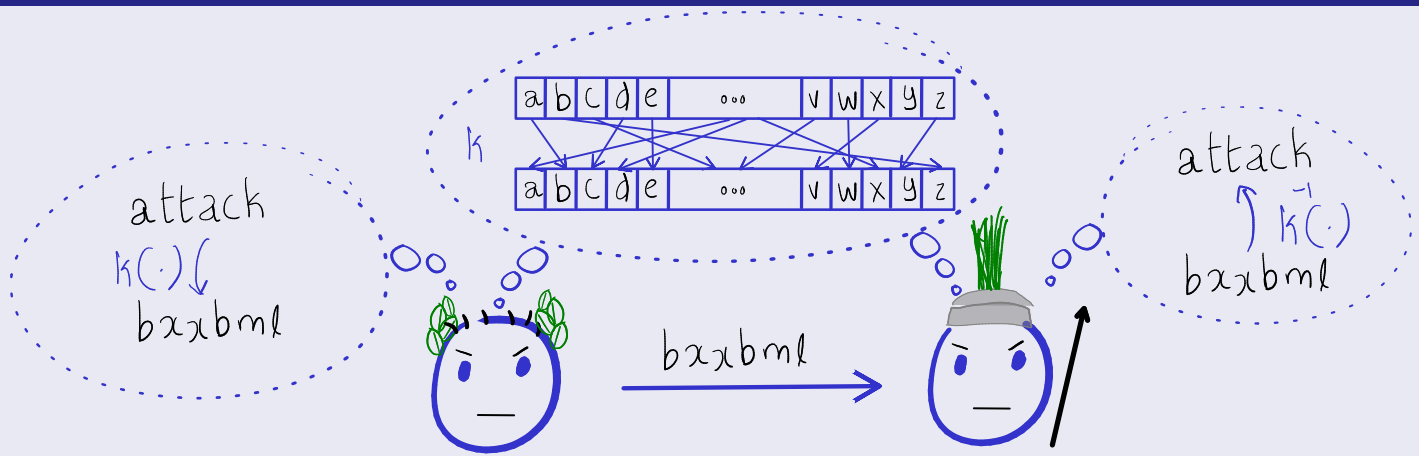

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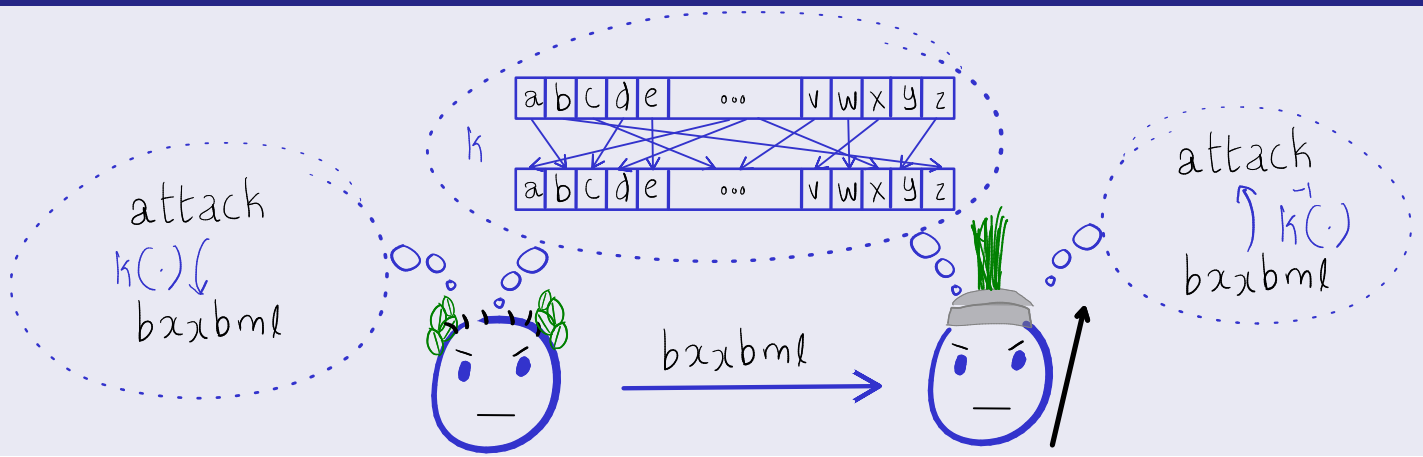

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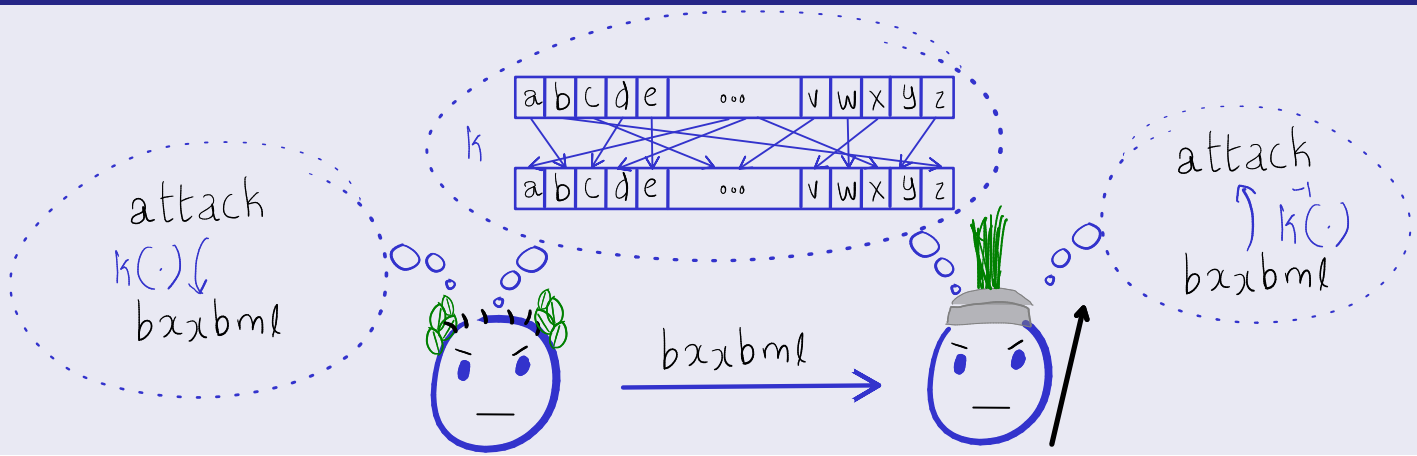
Exercise 3 (Decrypt the following)

Xibkgltizksb rh gsv hxrvmxv lu hvxfivob xziibrmt lfg gzhph (v.t., hvxivg xlnnfmrxzgrlm) rm zm zwevihzirzo hvggrmt.

Substitution Cipher...

Construction 2 (Message space $\{a, \cdots, z\}^{\ell}$)



What can Eve learn?

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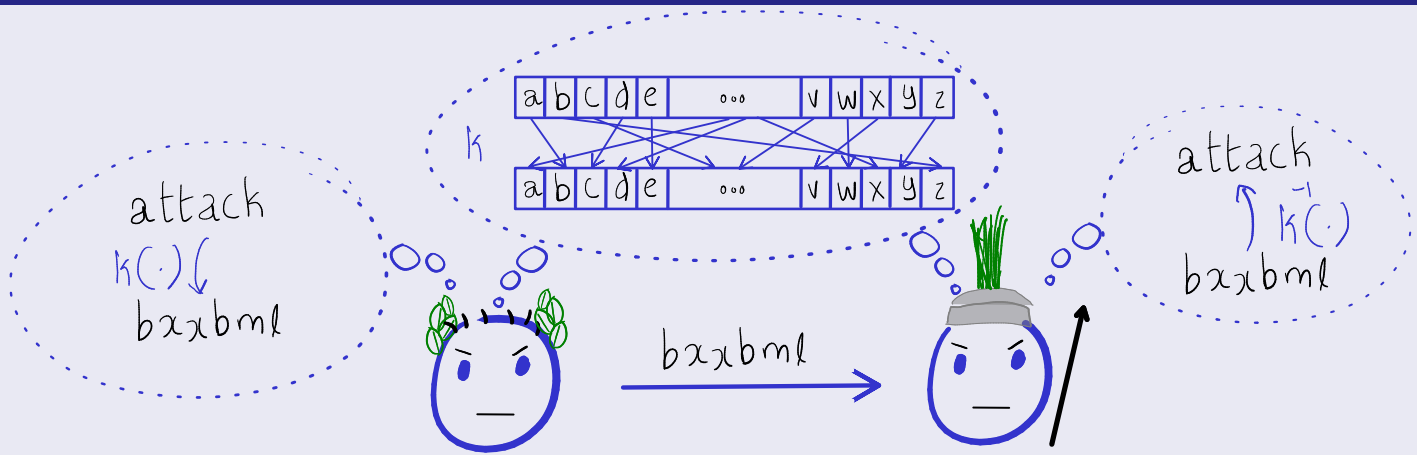

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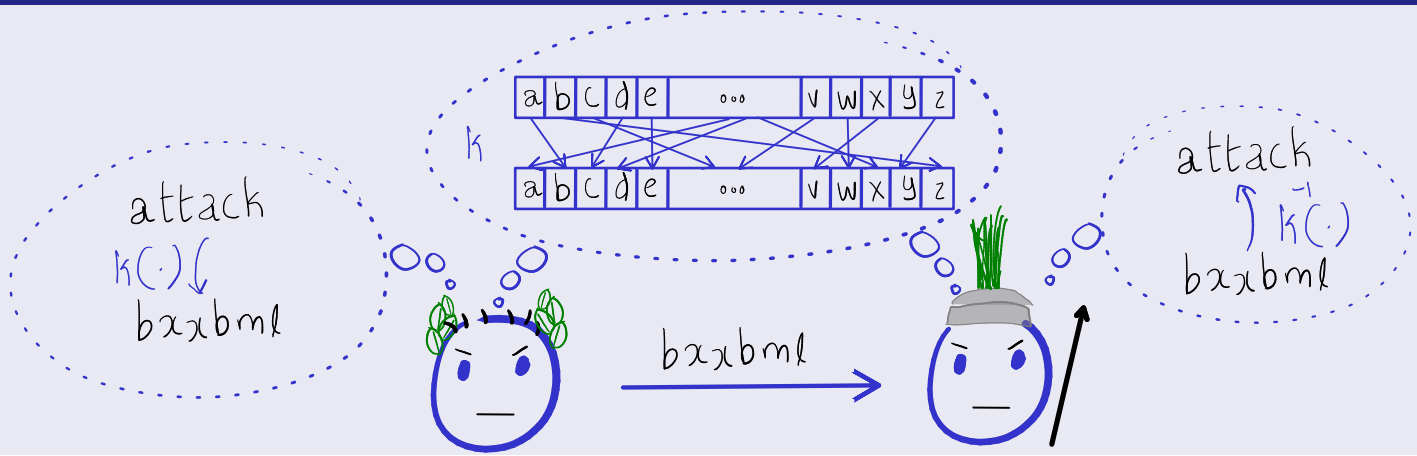

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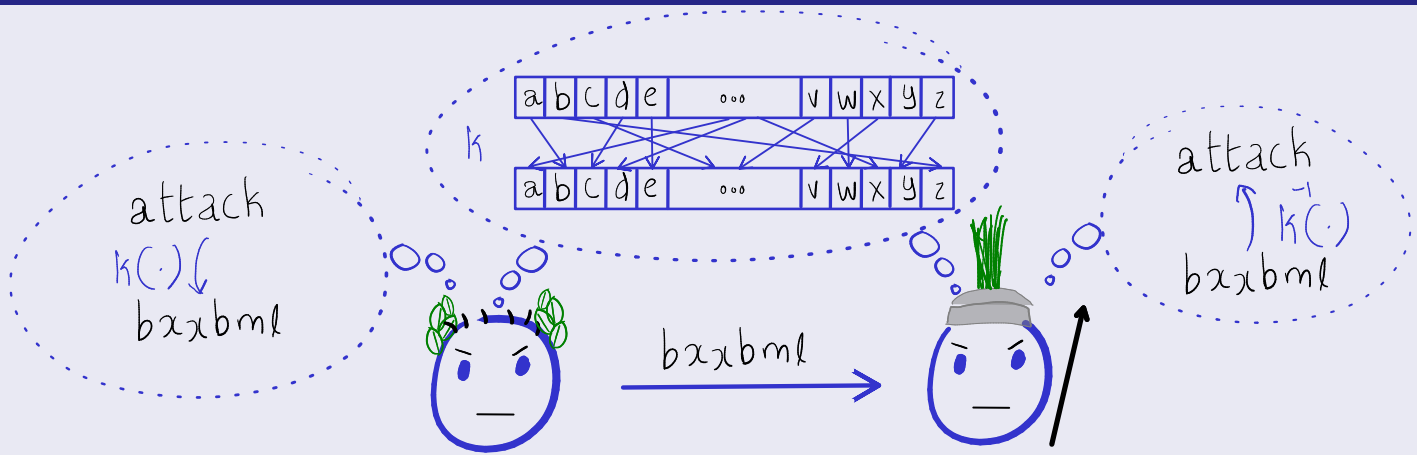

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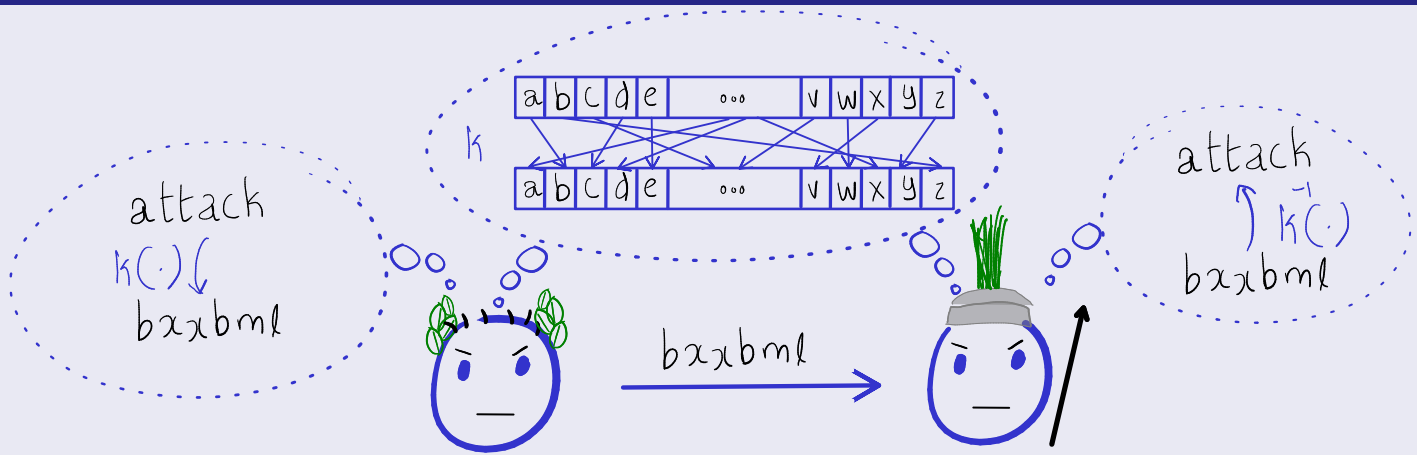

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  - Must *hide* simple *statistical properties* of the plaintext
    - Should not map a plaintext character to same ciphertext character

Polyalphabetic Ciphers...

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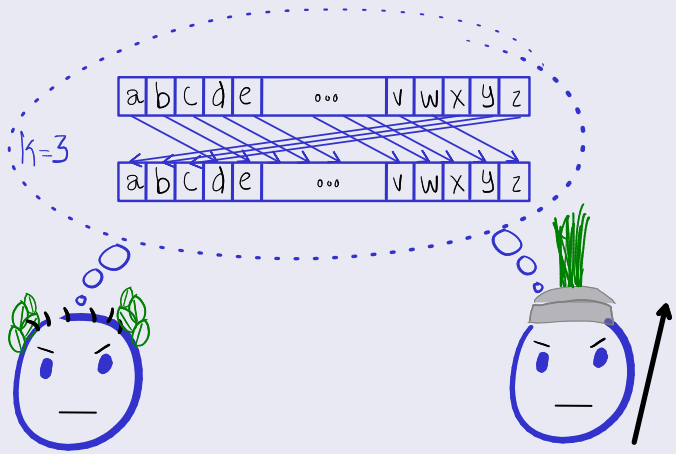

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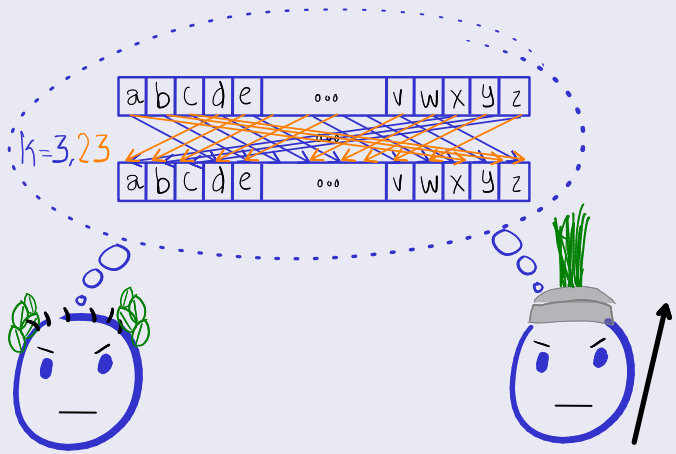

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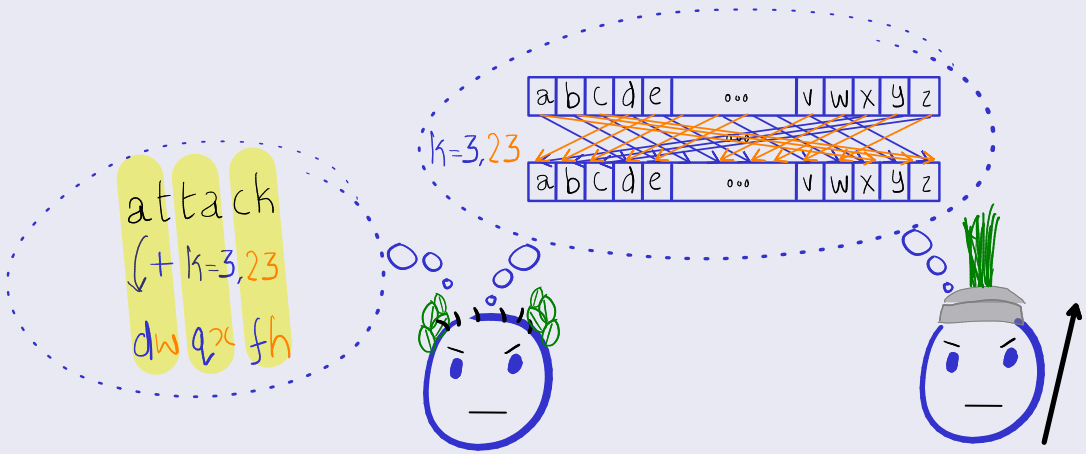

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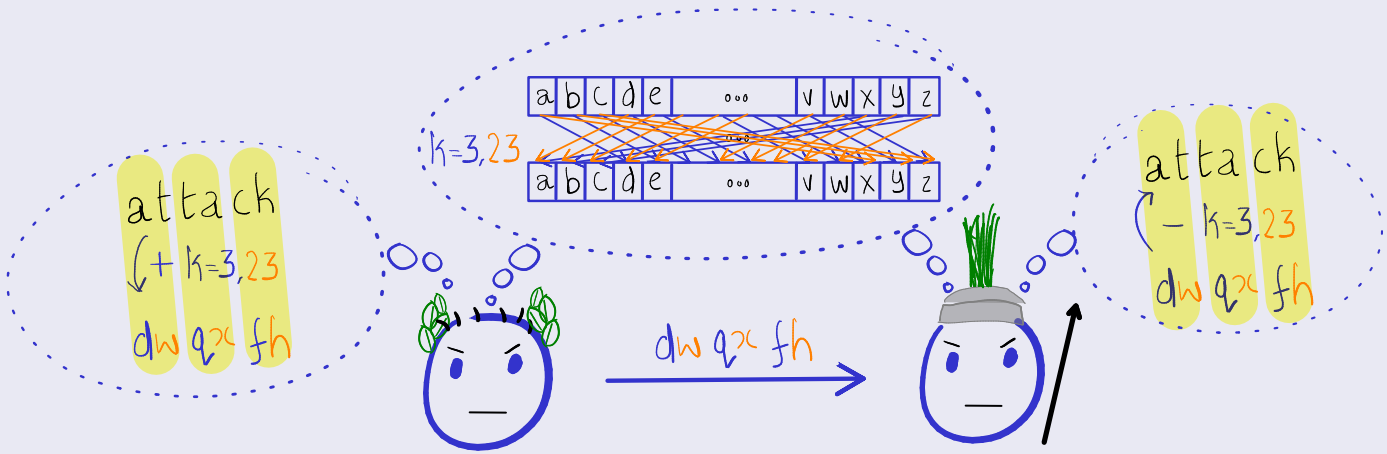

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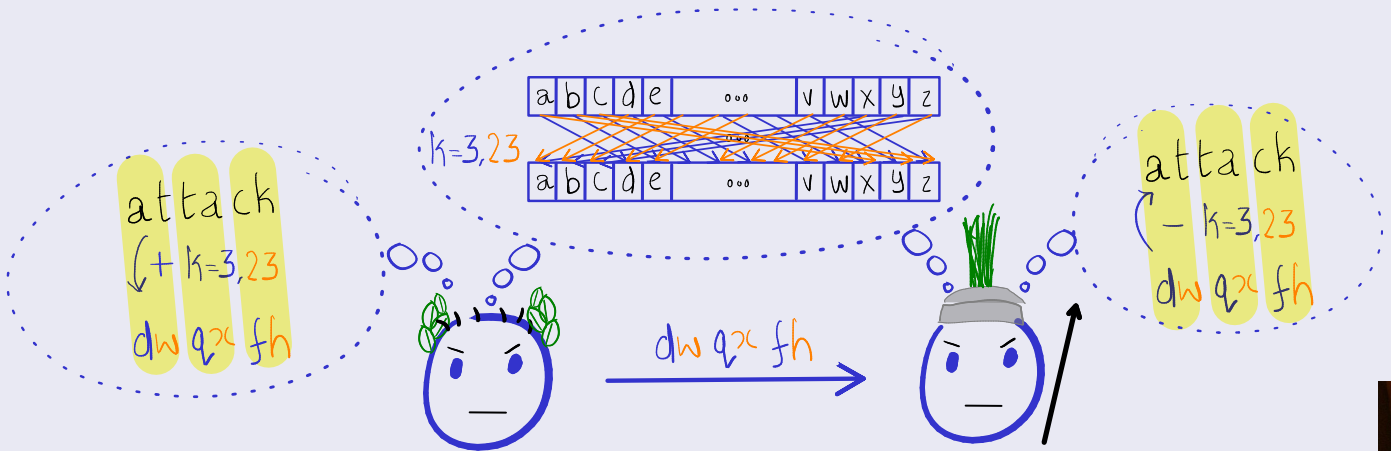

Exercise 4

1. Write down the pseudocode for polyalphabetic shift cipher.
2. Work out the details of *polyalphabetic* substitution cipher.

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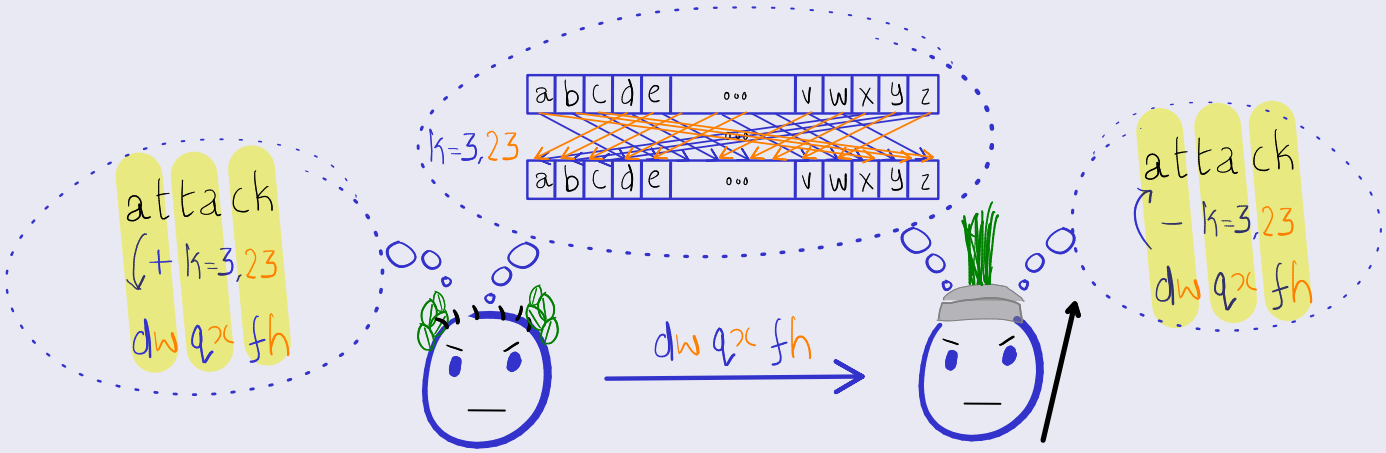

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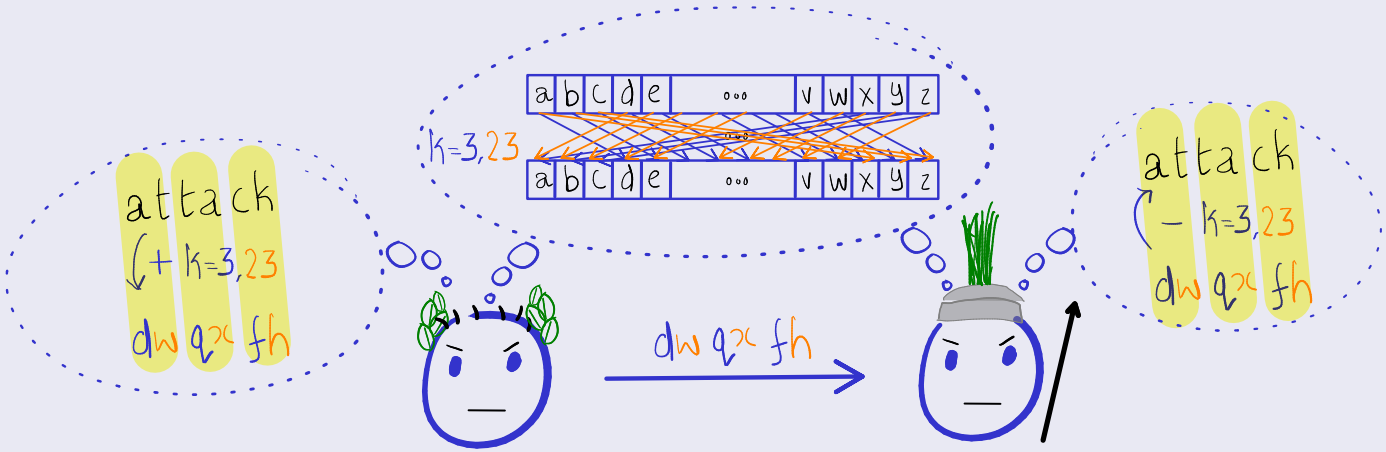

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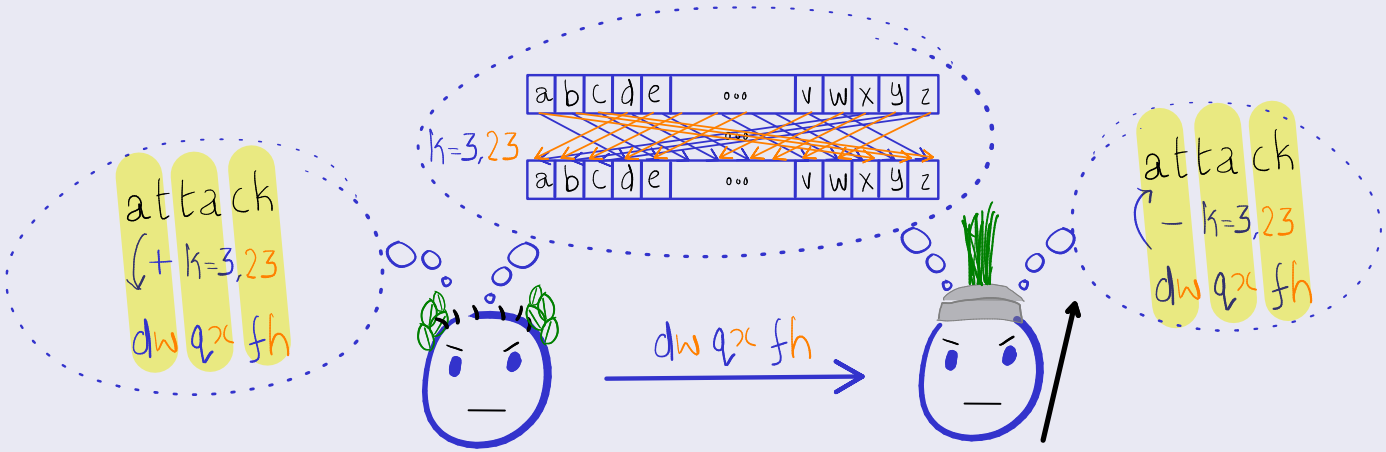

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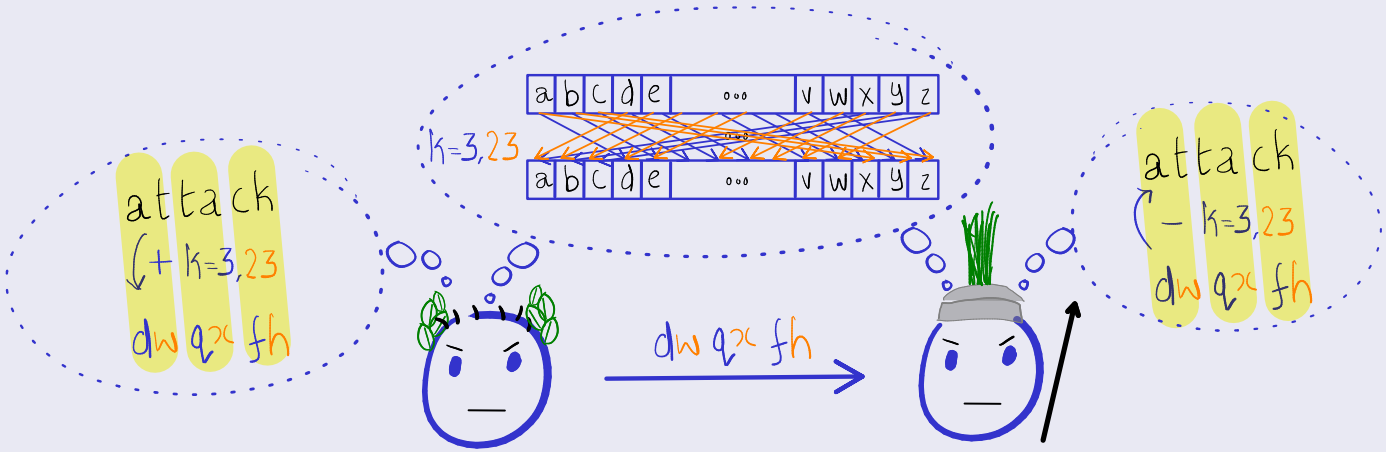

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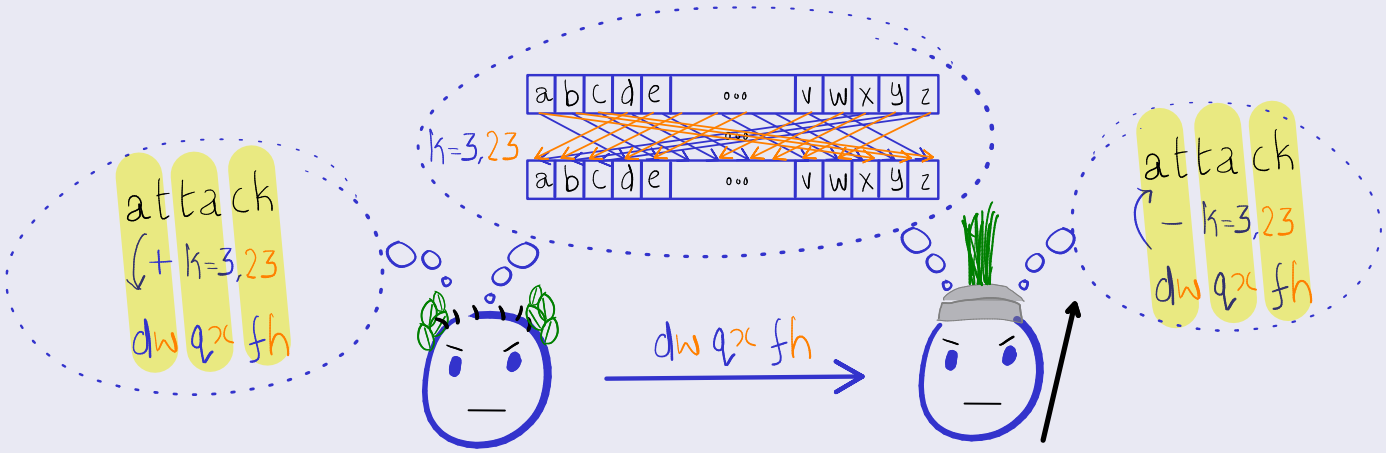

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    - Perfect secrecy!

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- What we will learn in Module I:
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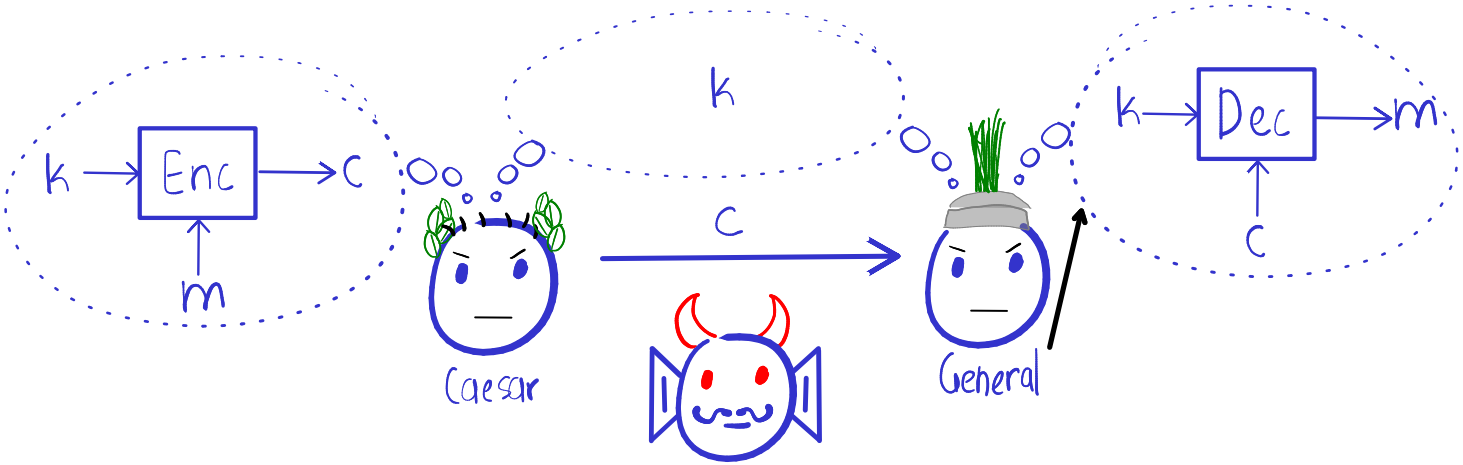
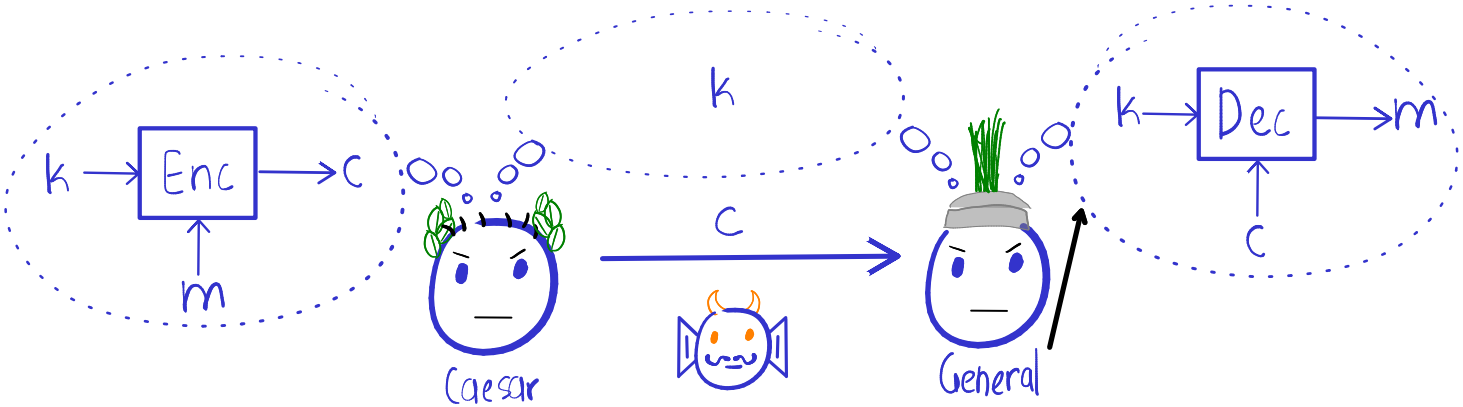


  - How to overcome Shannon's impossibility?

Task: Secret Communication with Shared Keys...

- What we will learn in Module I:
  - One-time pad (OTP), and why it is perfectly secret
  - Shannon's impossibility: for perfect secrecy, $|k| \geq |M|$



  - How to overcome Shannon's impossibility?
  - Restrict/bound the adversary's computational capabilities
    - How to model computationally-bounded adversaries?
    - Hardness assumptions: e.g., pseudo-random generator (PRG)
    - Secret communication with $|M| > |k|$ assuming PRG

What Else? Dealing with More Resourceful Adversaries

- What if Eve *also* has control over the messages?
- What we will learn: *chosen-plaintext attack* (CPA) and CPA-secure scheme from pseudo-random functions

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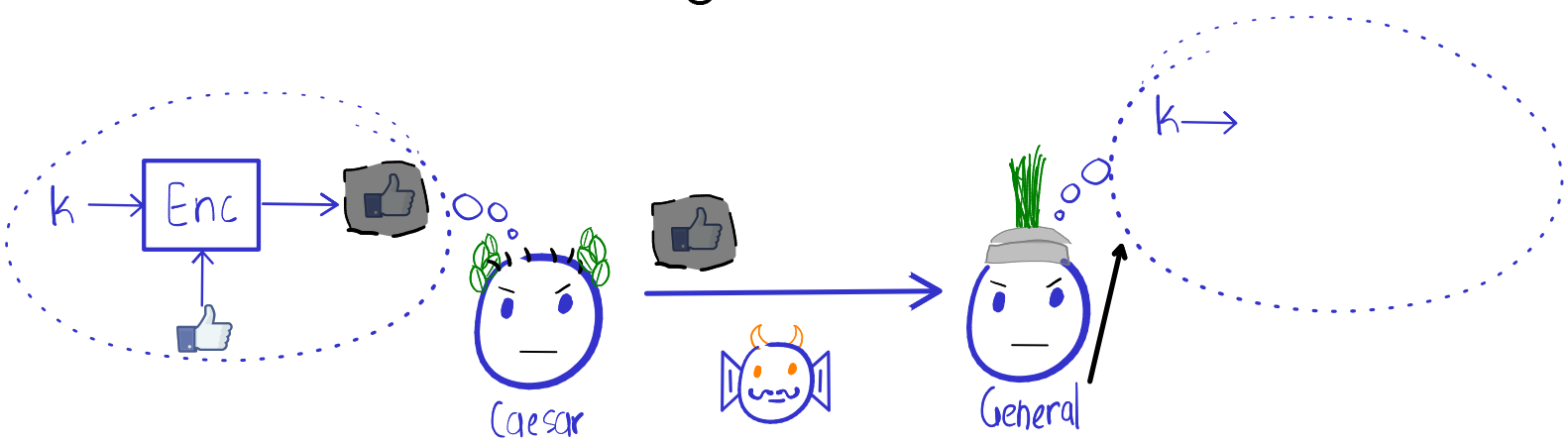

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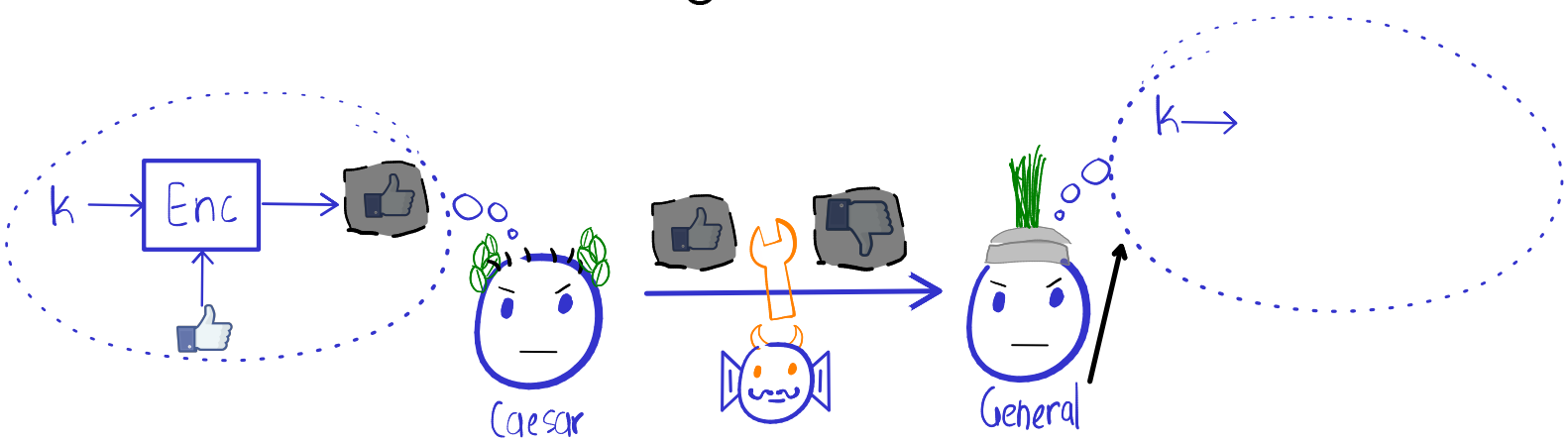

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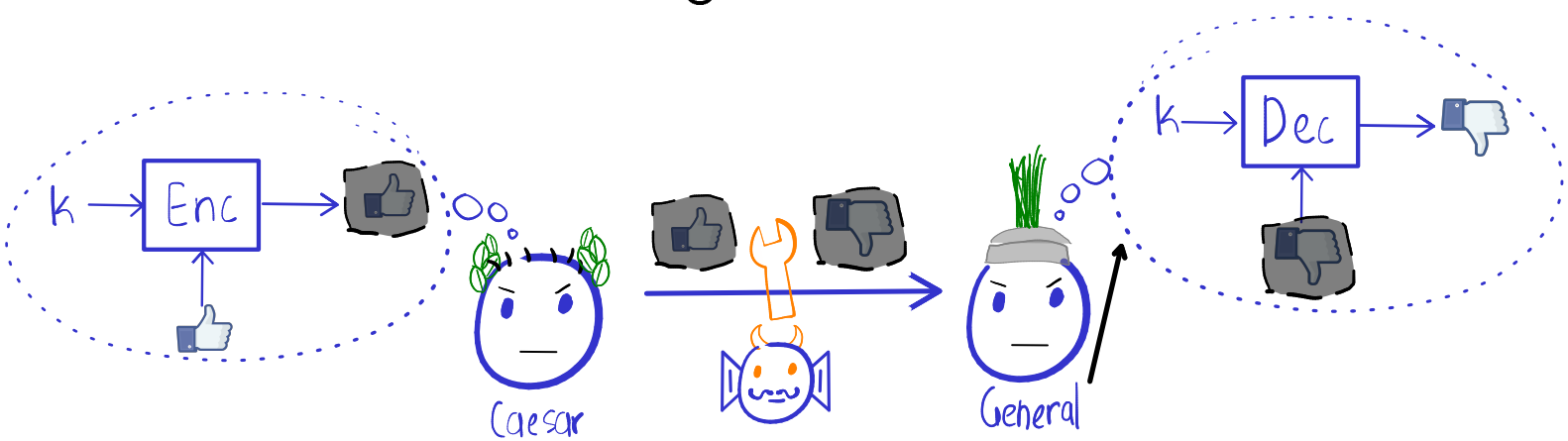
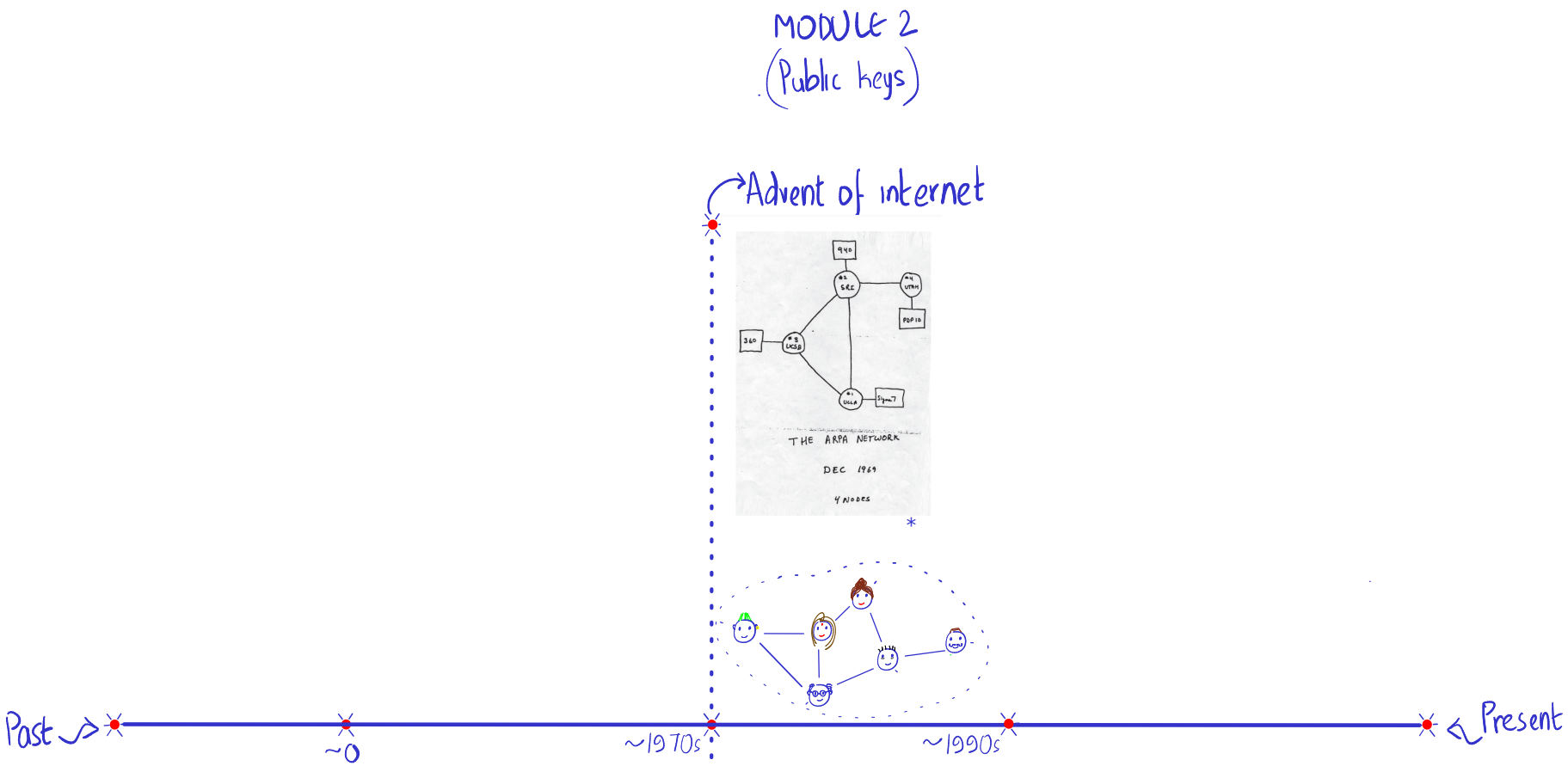


An Overview of the Course

1. Module I: Secure Communication in Shared-Key Setting
2. Module II: Secure Communication in Public-Key Setting
3. Module III: Some Advanced Topics

Advent of Internet and the Scaling Problem



- Limitation of shared-key encryption: requires prior meeting

Credit for images: (*Wikipedia User: DARPA)

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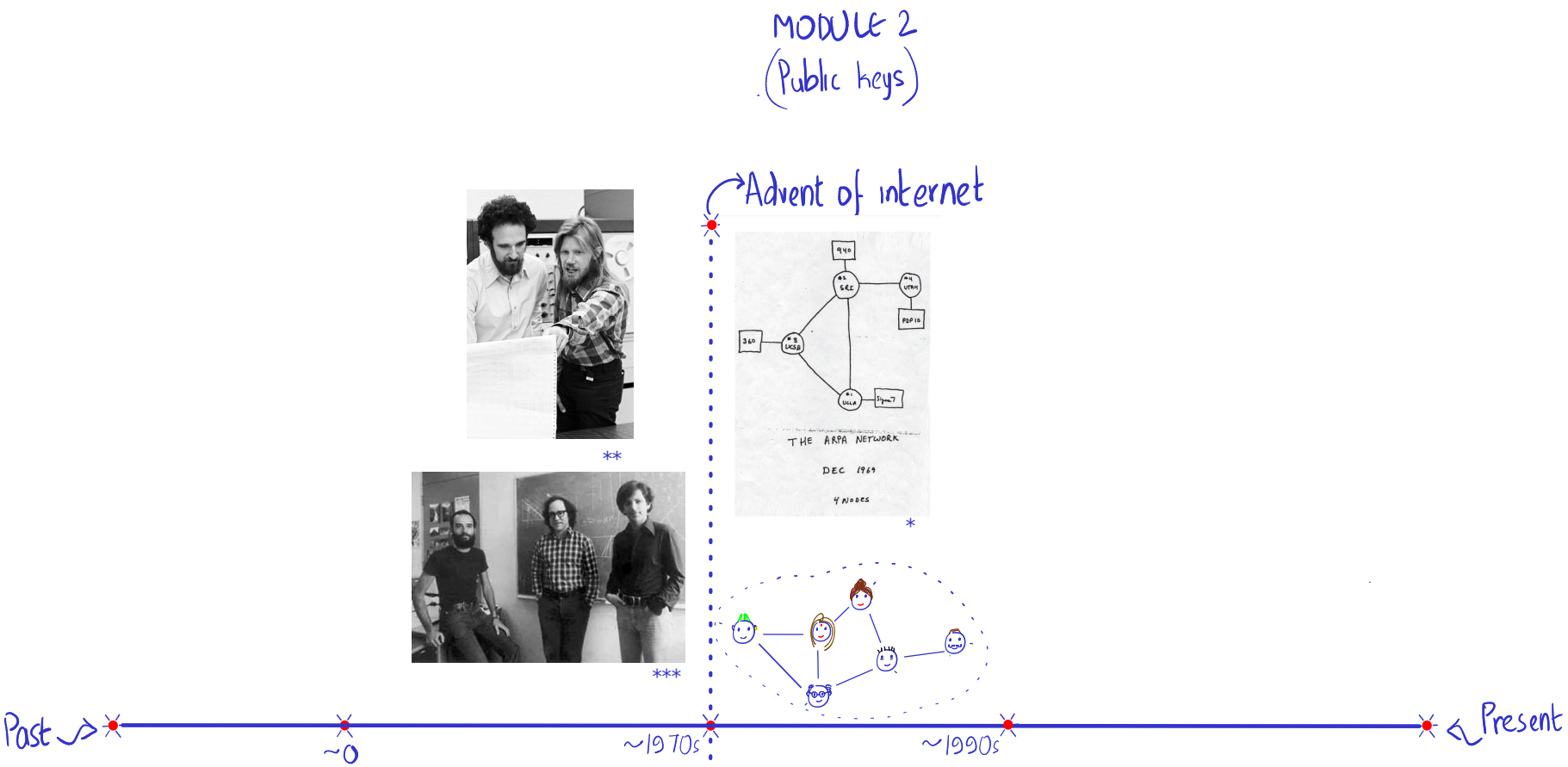

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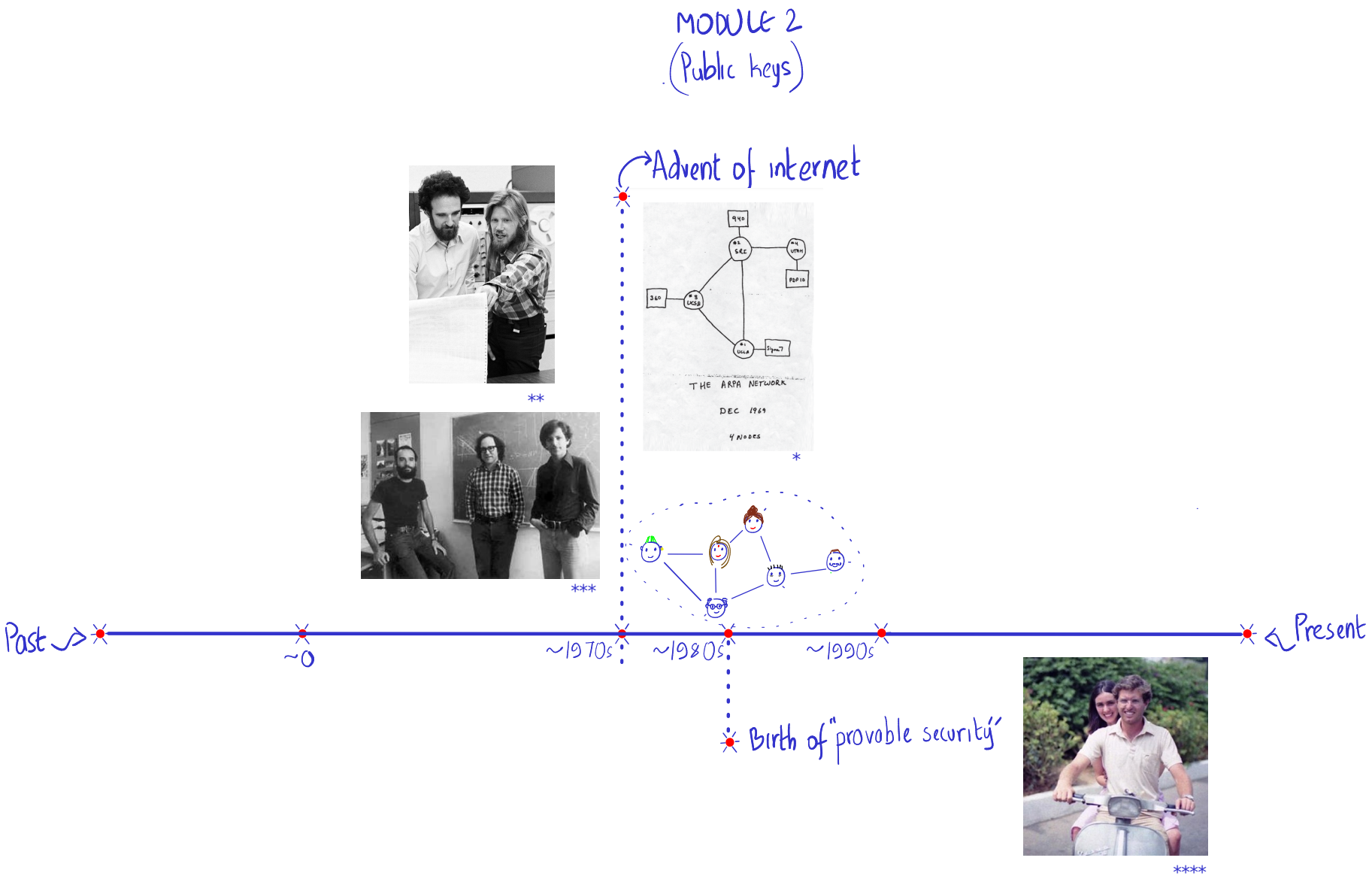

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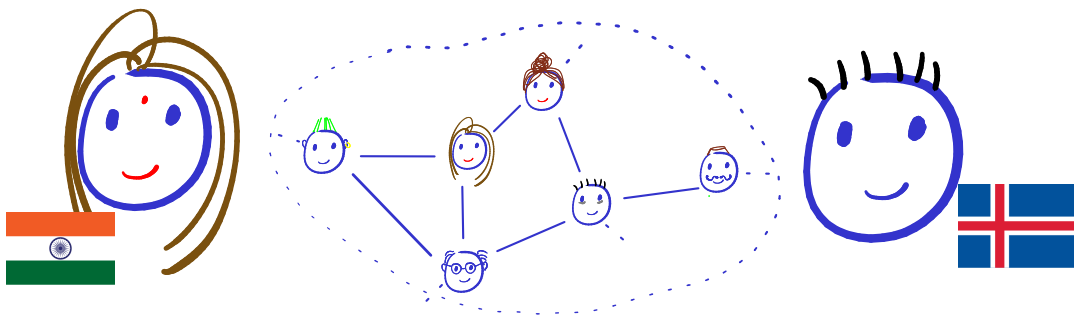

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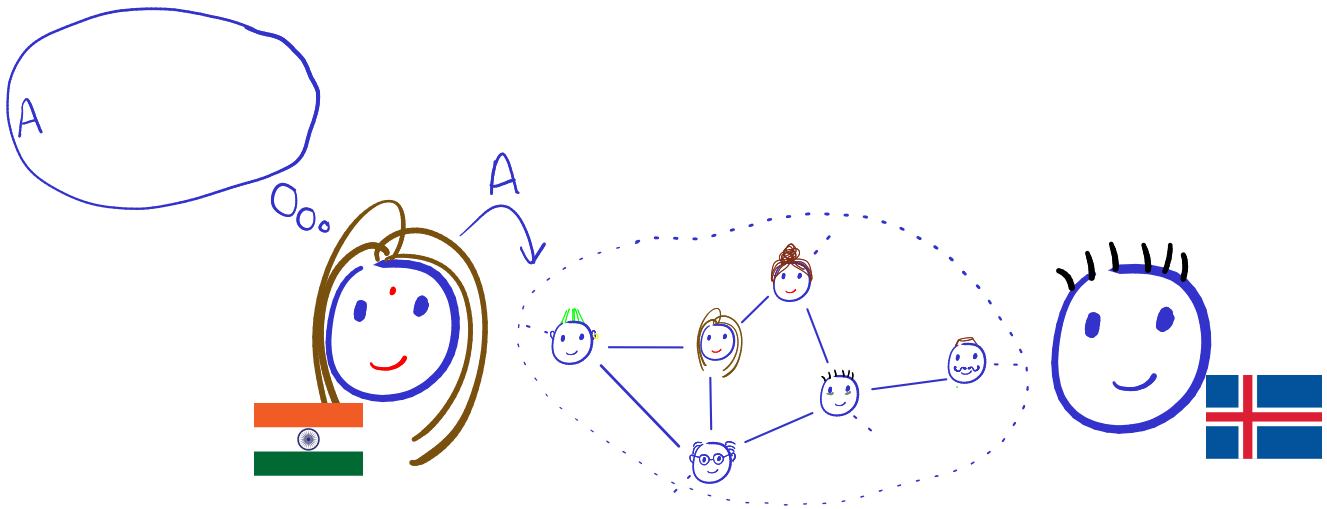

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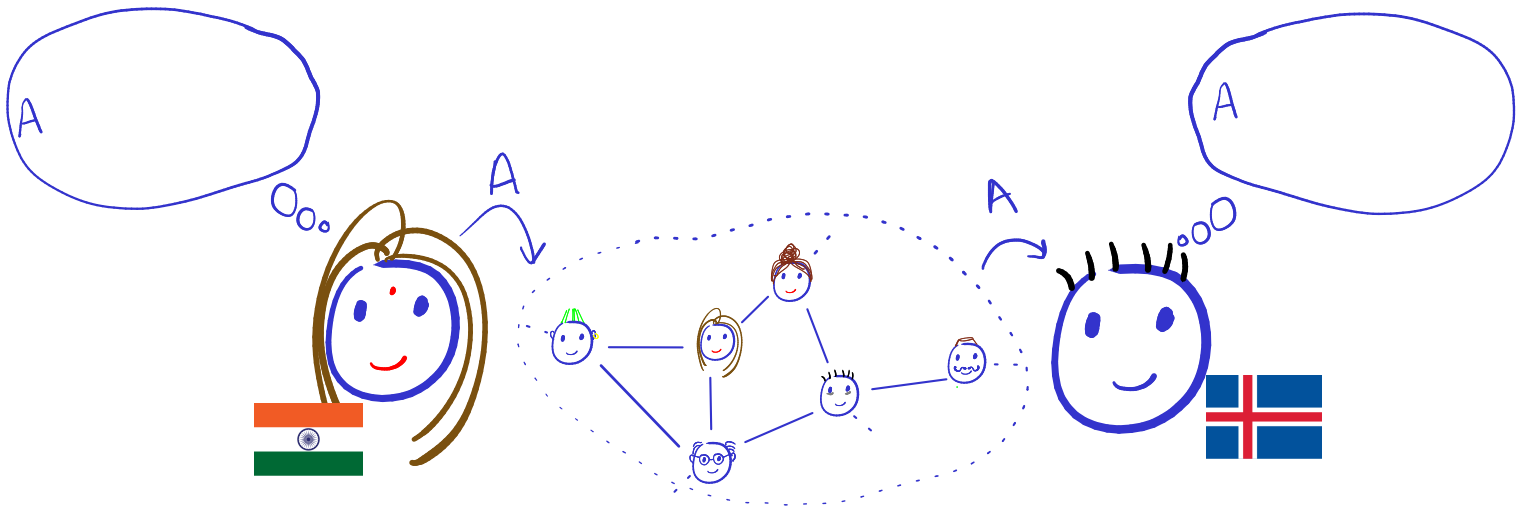

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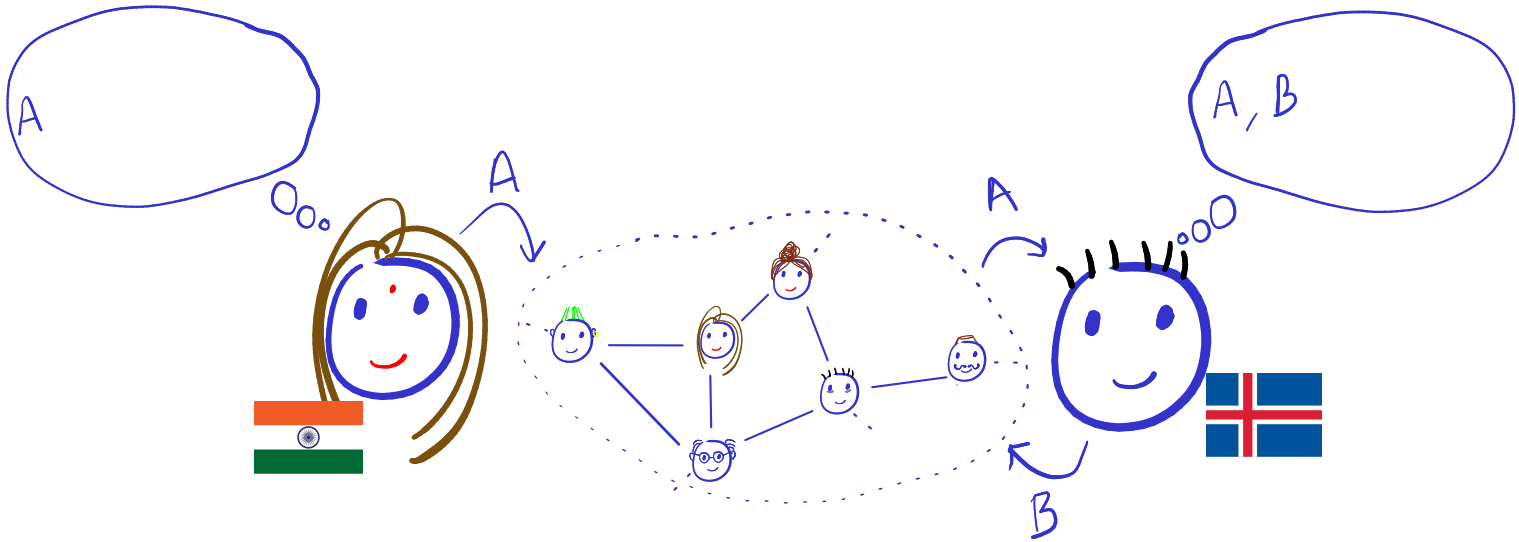

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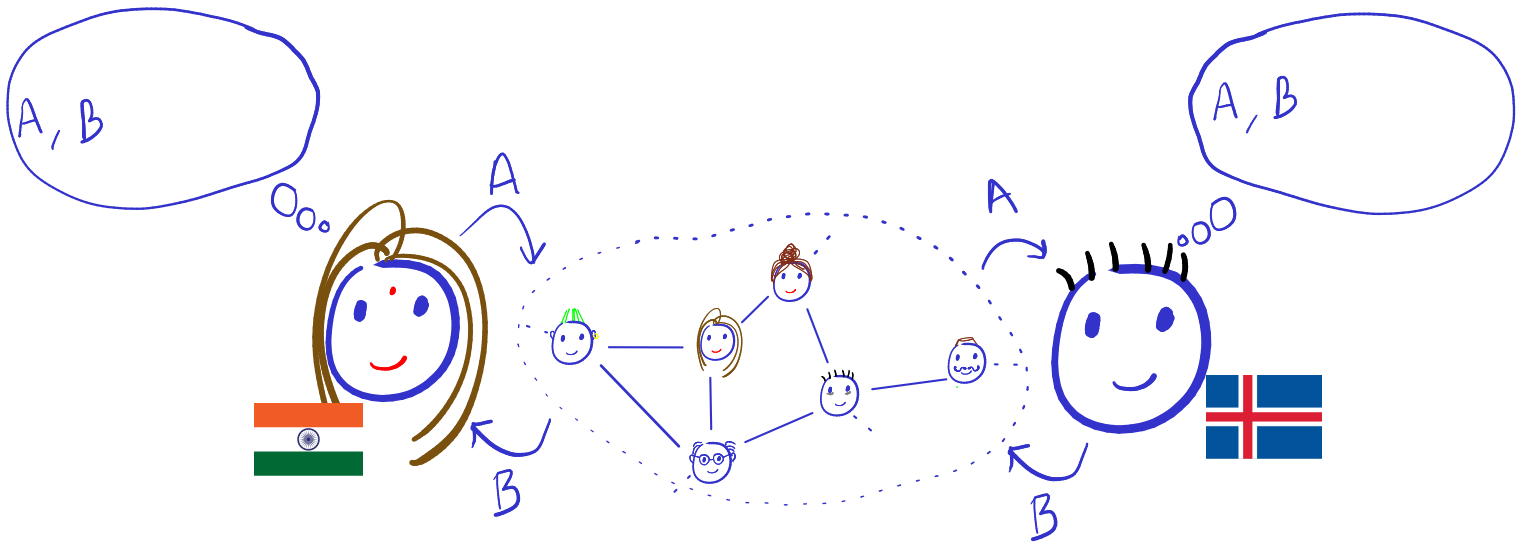

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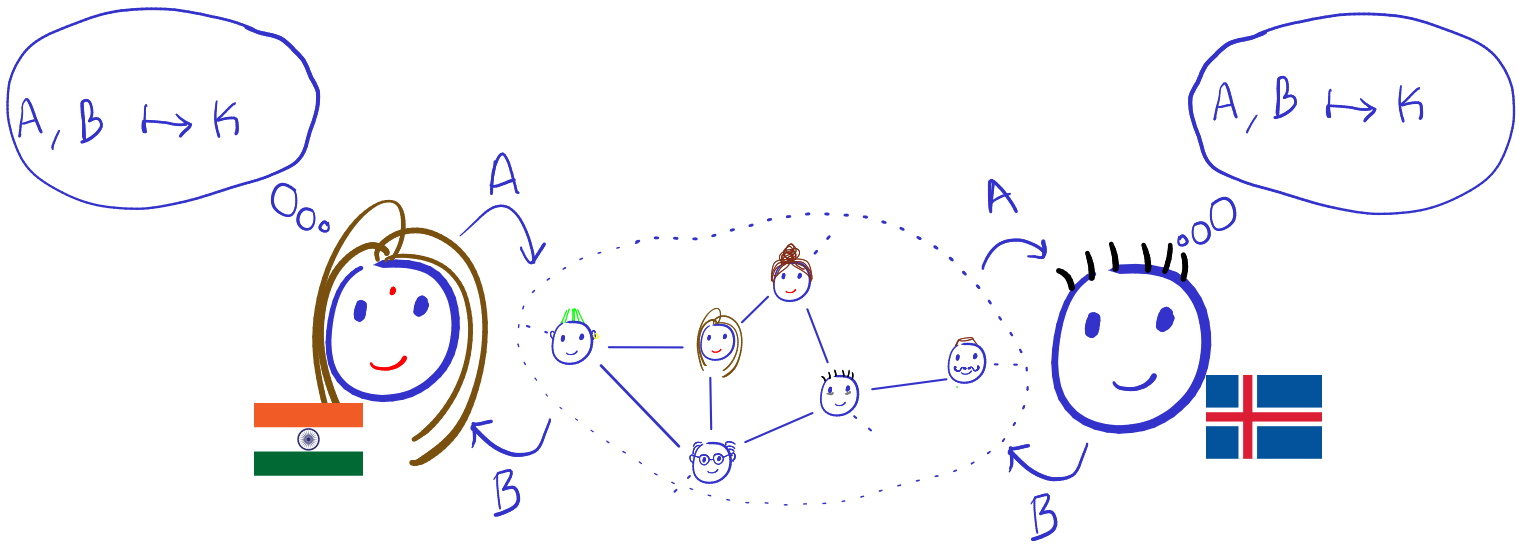

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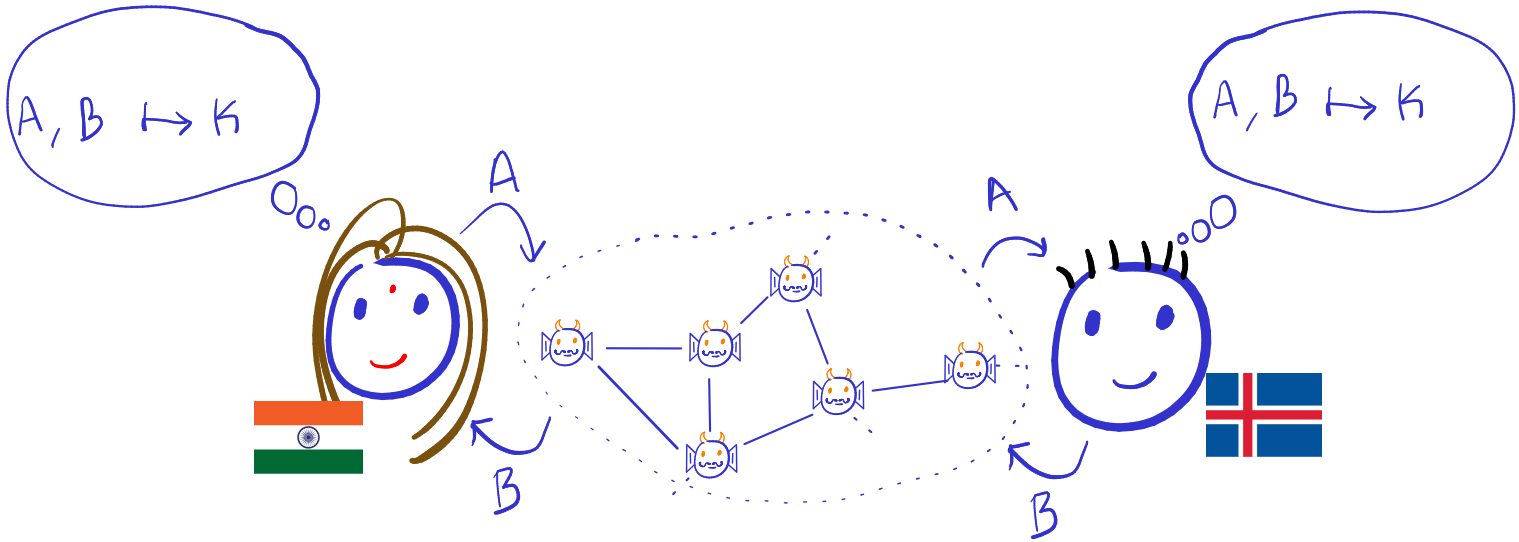

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  - Adversary: *Computationally-bounded* eavesdropper Eve
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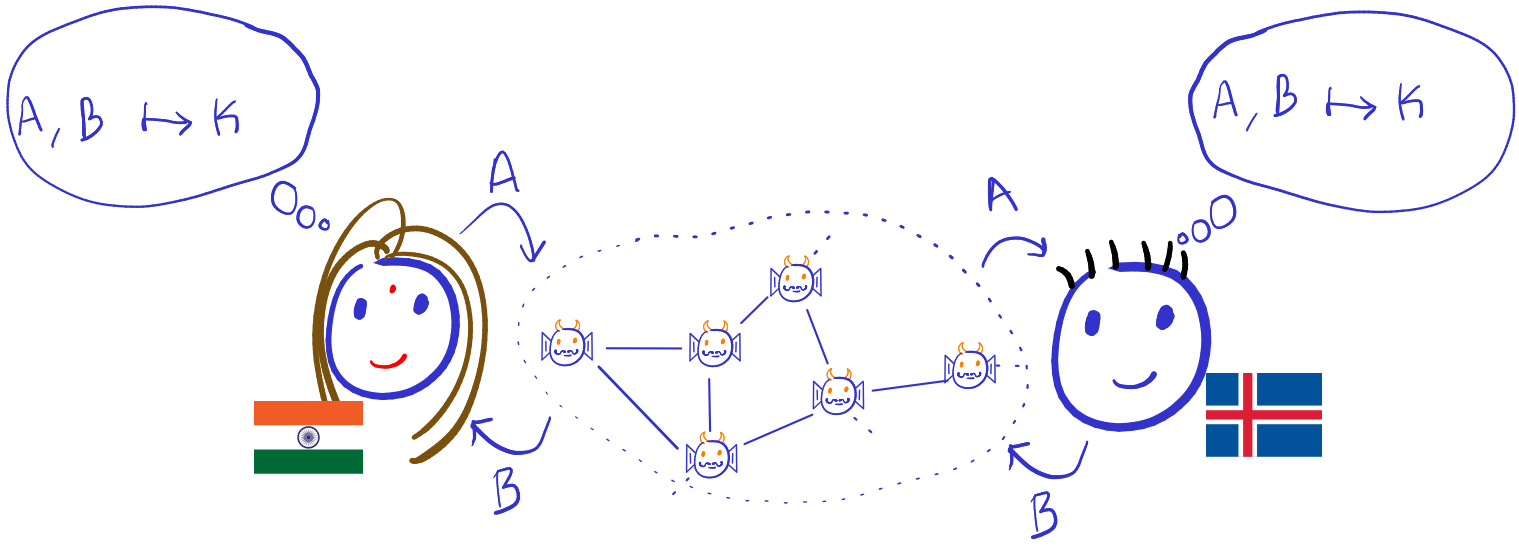

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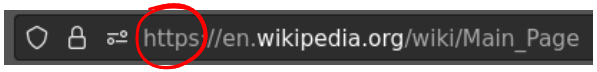
- What we will learn:
  - Some group theory and number theory
  - Diffie-Hellman key exchange



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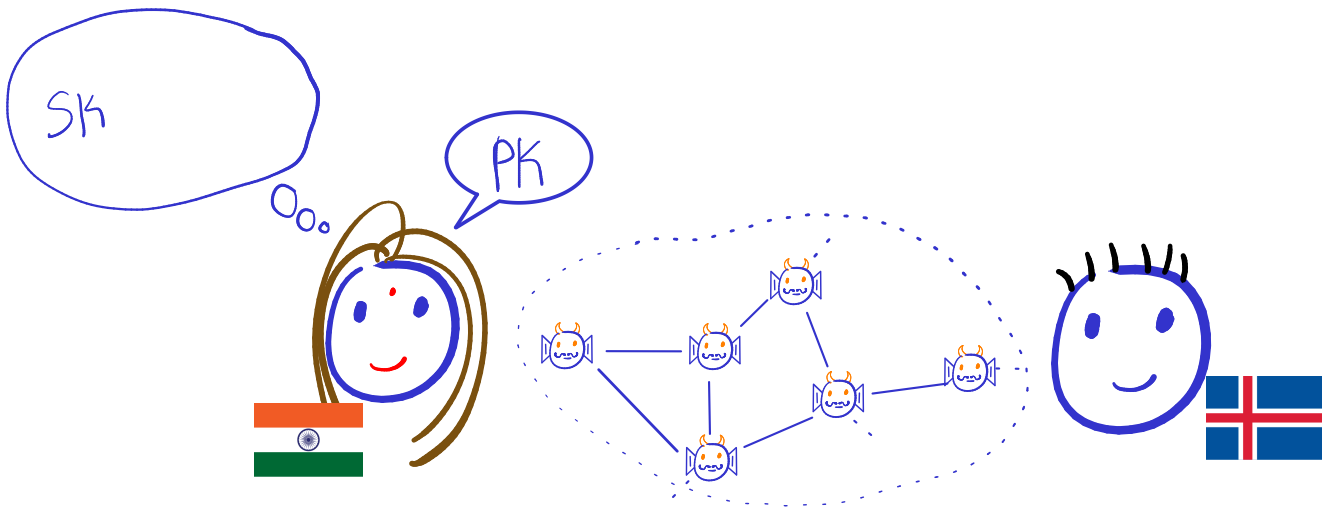
- Setting: Alice has published a public key PK, and Bob wants to send a secret message M to her



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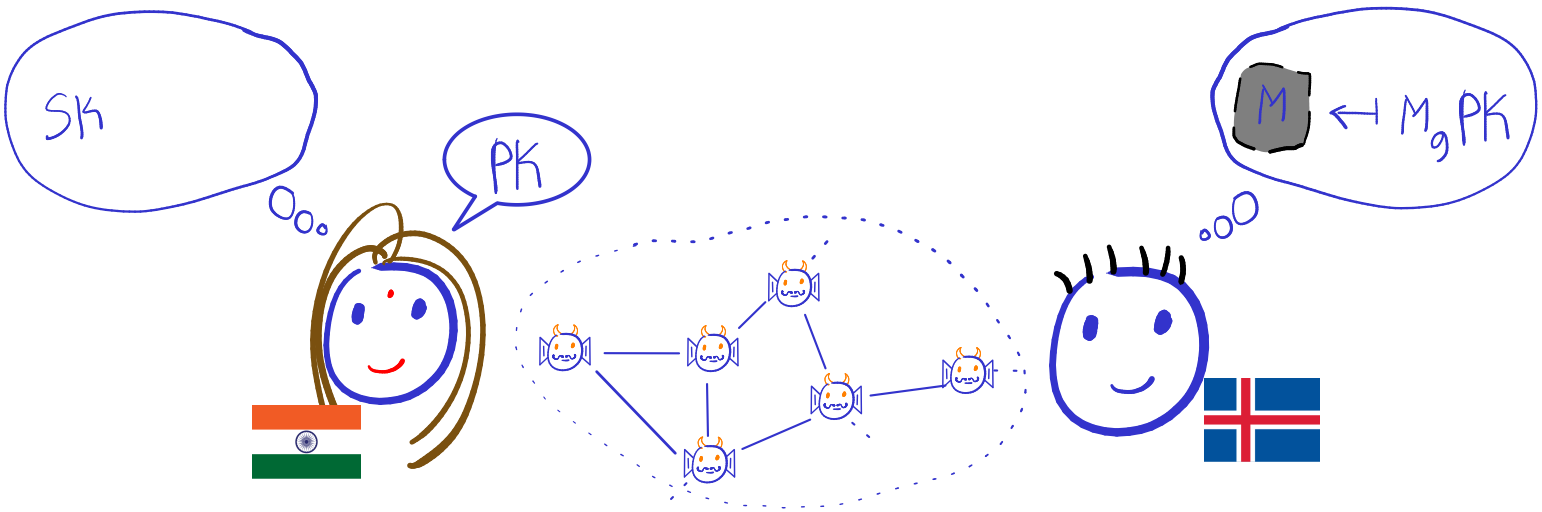

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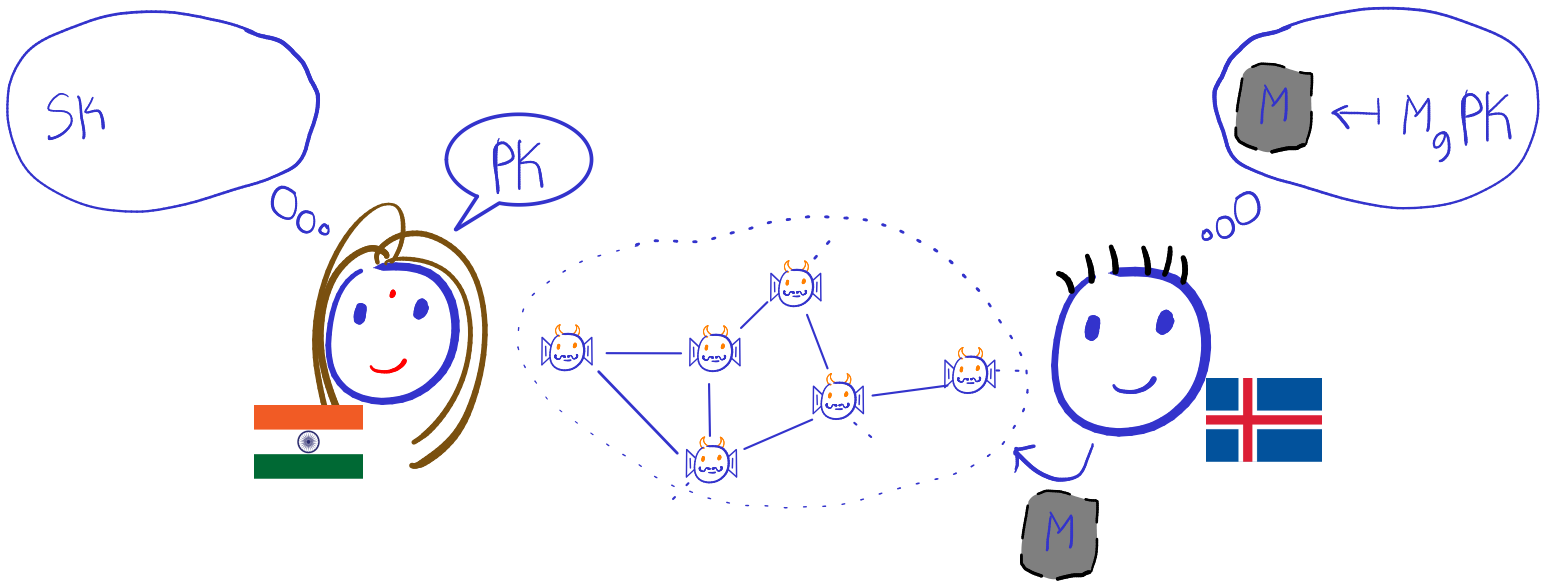

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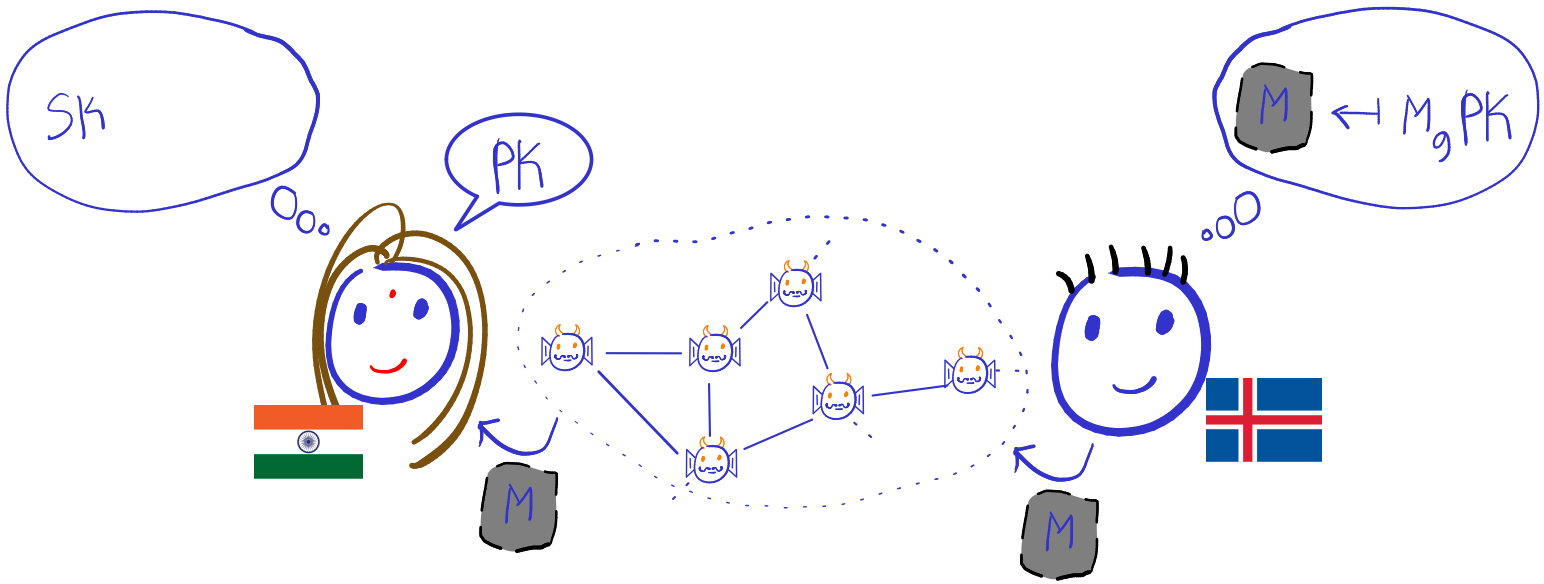

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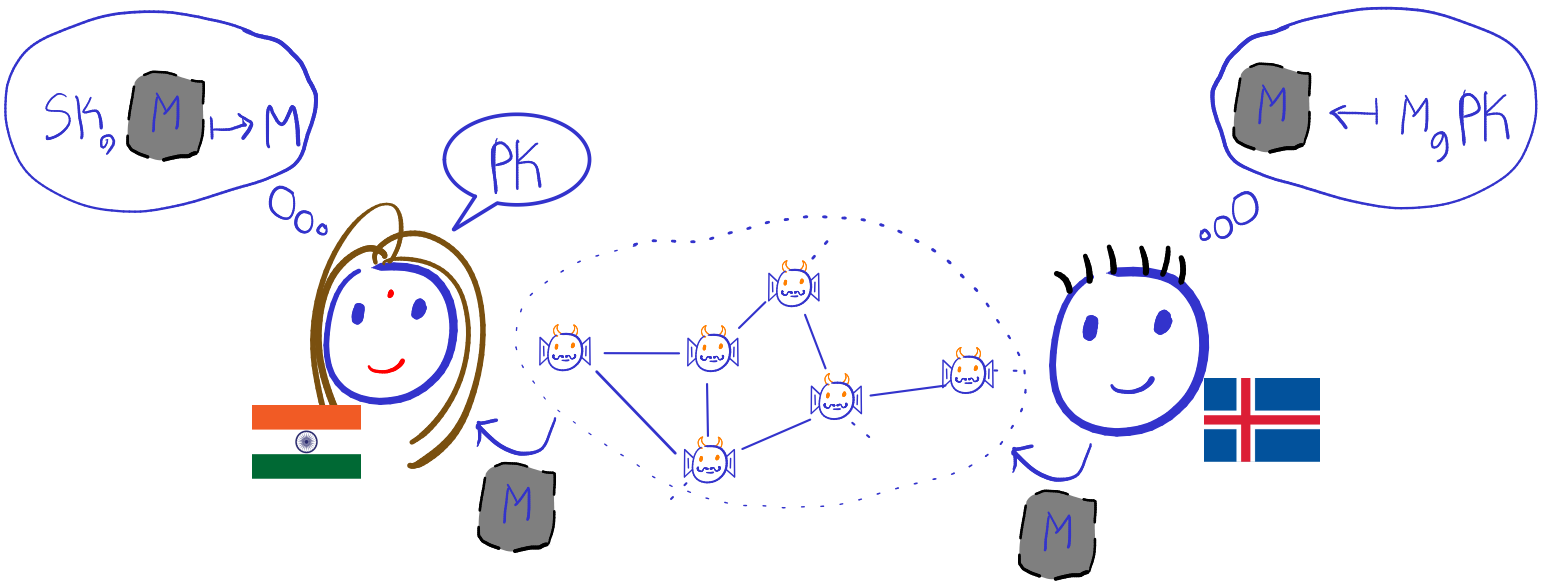

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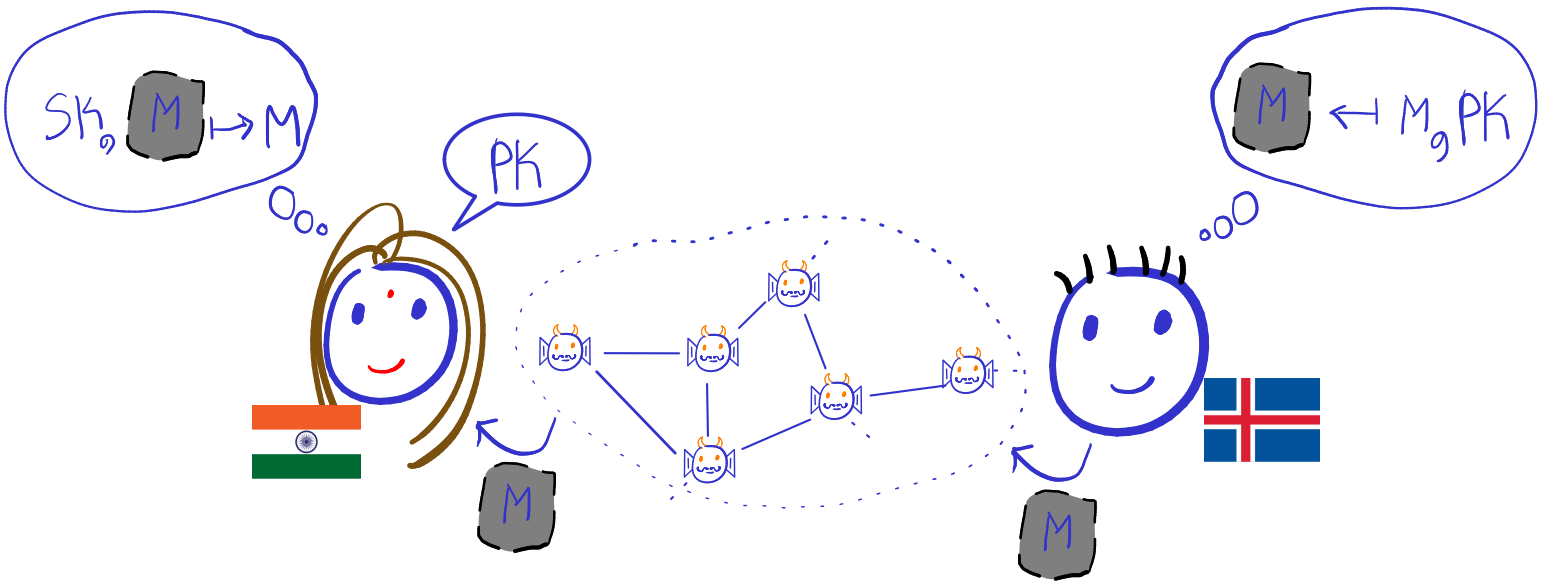

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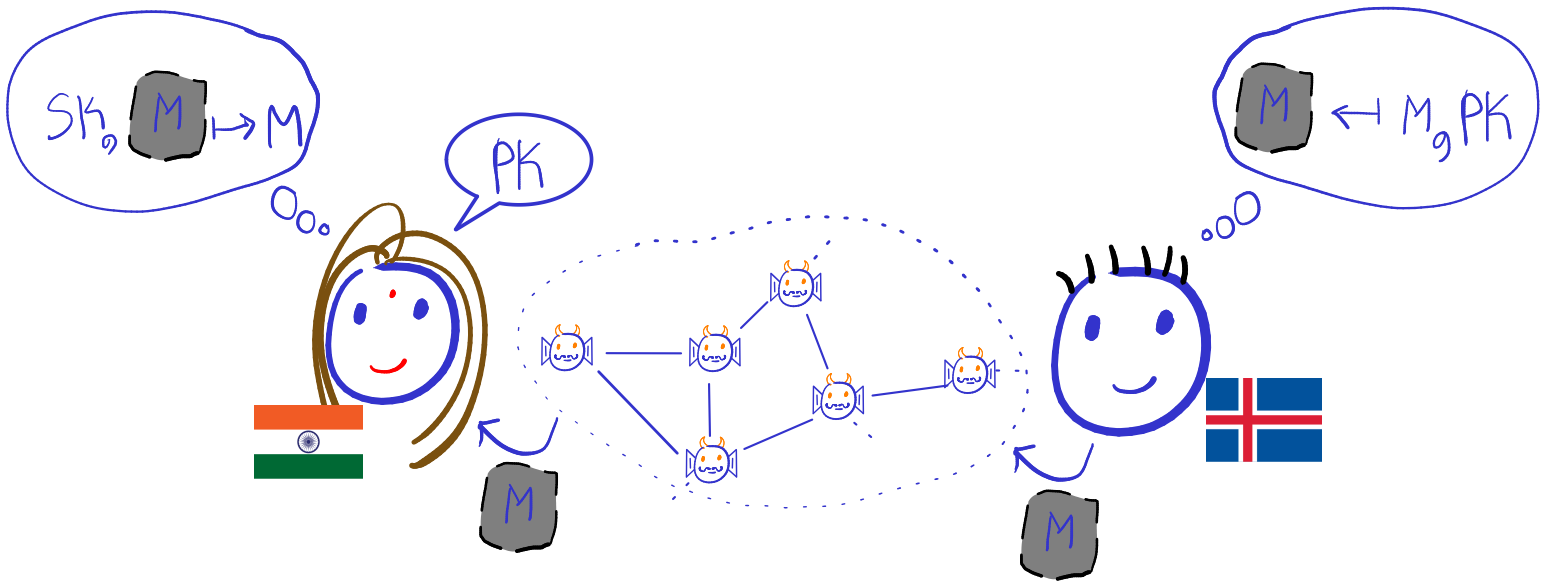

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- How to deal with tampering adversary in public-key setting?
- What we will learn: digital signatures

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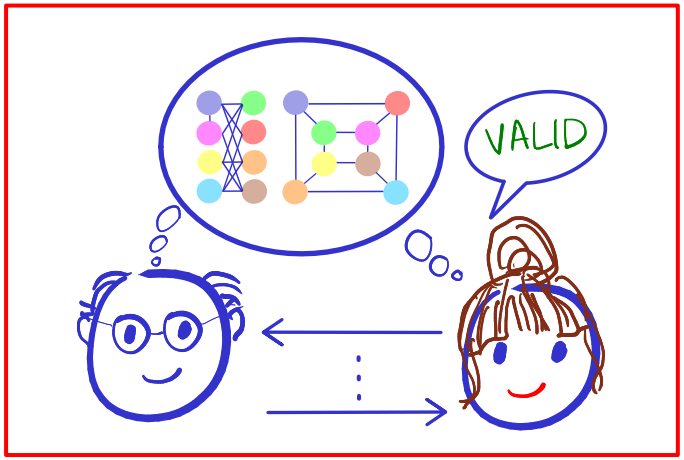
Some Advanced Topics

- Beyond communication?
  - Identification protocols
  - Zero-knowledge proofs



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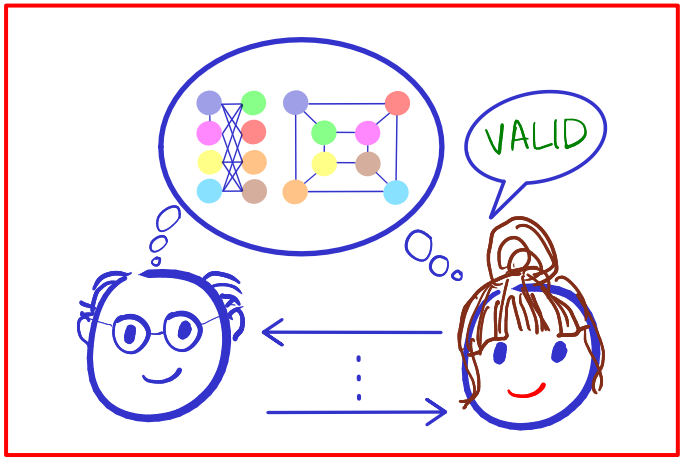

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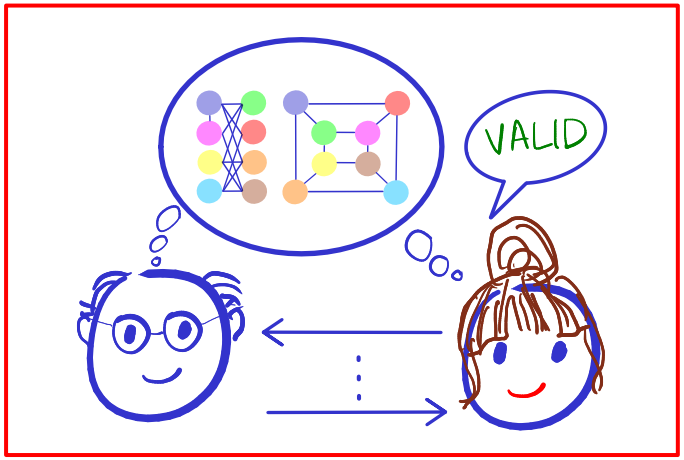

- Combine various primitives!
  - SSL/TLS
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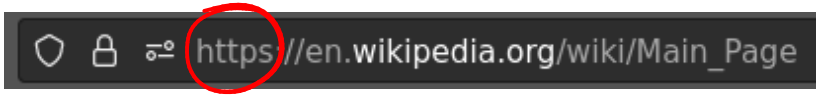

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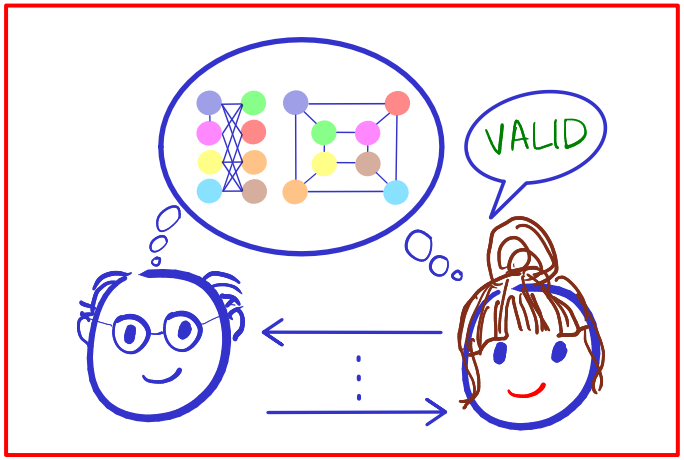

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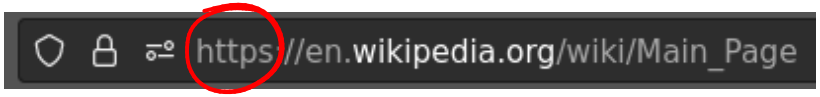

- Advanced notions of PKE? (if time permits)
  - Homomorphic encryption

Next Lecture

- Probability toolkit

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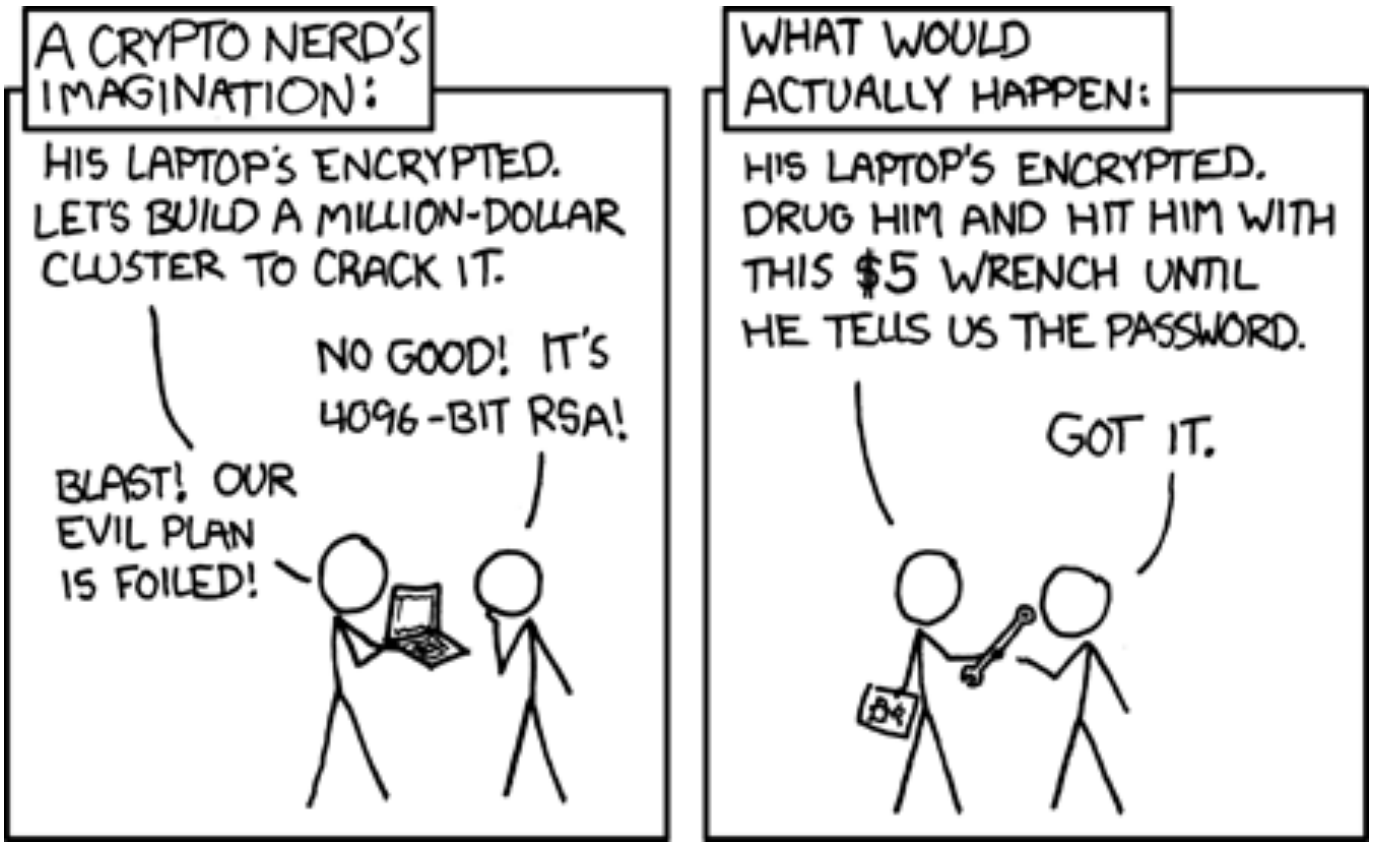

https://xkcd.com/538/

- More questions?