Introduction to Symmetric and Asymmetric Cryptography

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Objectives

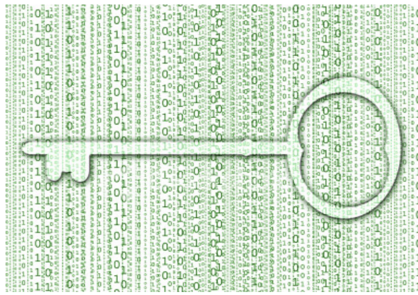
- Motivate the needs for cryptography
- Explain the role of cryptography in everyday use
- Symmetric Cryptography:
  - Describe the main concept
  - Analyse some examples
  - Discuss strength and limitations
- Asymmetric Cryptography
  - Describe the main concept
  - Analyse some examples
  - Discuss strength and limitations
- Questions.

Why Use Cryptography?

- To communicate secret information when other people (eavesdroppers) are listening.

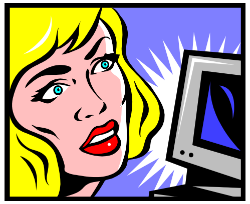
- When attacker has access to the raw bits representing the information
  - **Mitigation: Data encryption**

Cryptographic techniques →

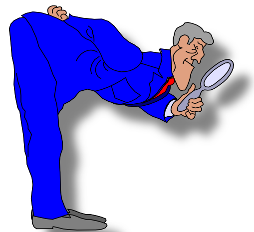


The Cast of Characters

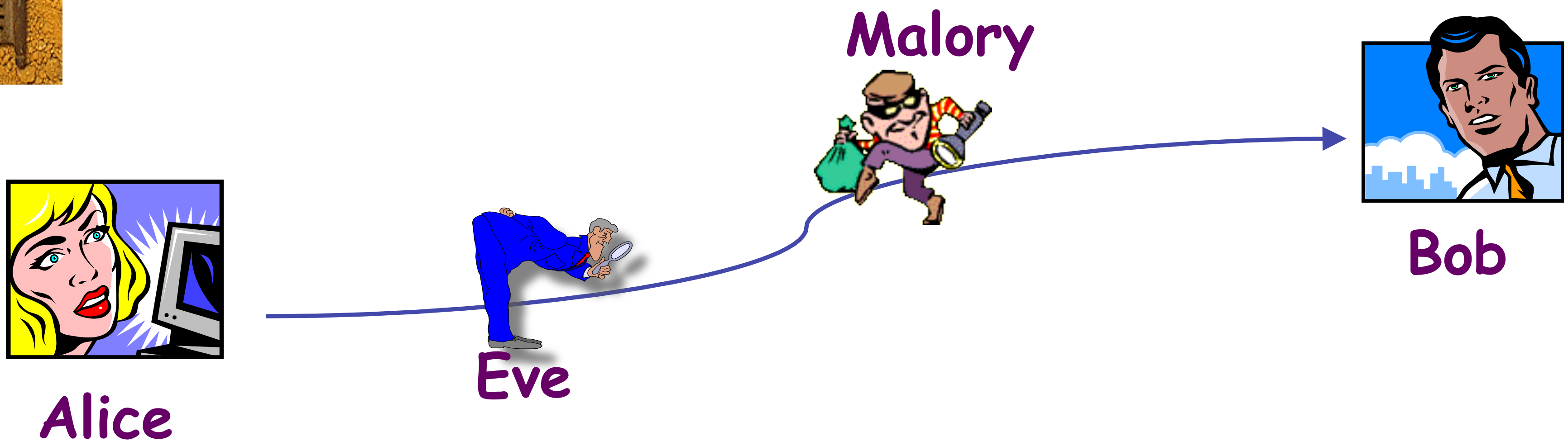
- **Alice** and **Bob** are "honest" players.



- **Eve** and **Malory** are adversaries (intruders)
- **Eve** "eavesdropper", is a passive intruder. Sniffs messages at will
- **Malory** is an active "intruder". Aims to view, alter, delete and inject messages into the network



Confidentiality

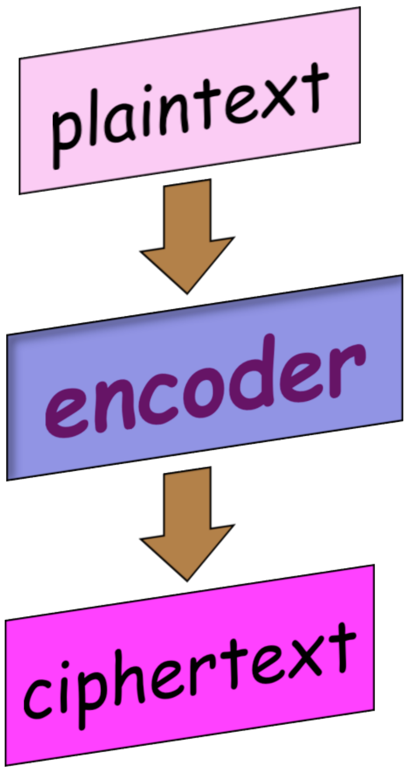


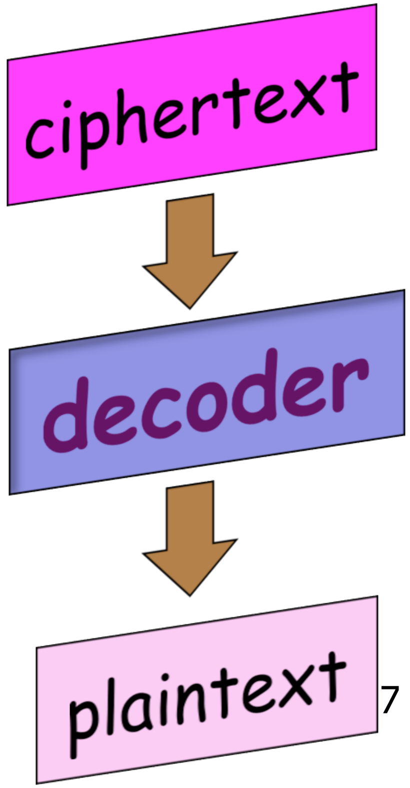
- **Problem:** **Alice** and **Bob** would like to exchange messages over a public network (such as Internet) in such a way that information contents are not revealed to anyone but the intended recipient.

- **Solution:** **Data Encryption** + clever **Cryptography**

How does it work?

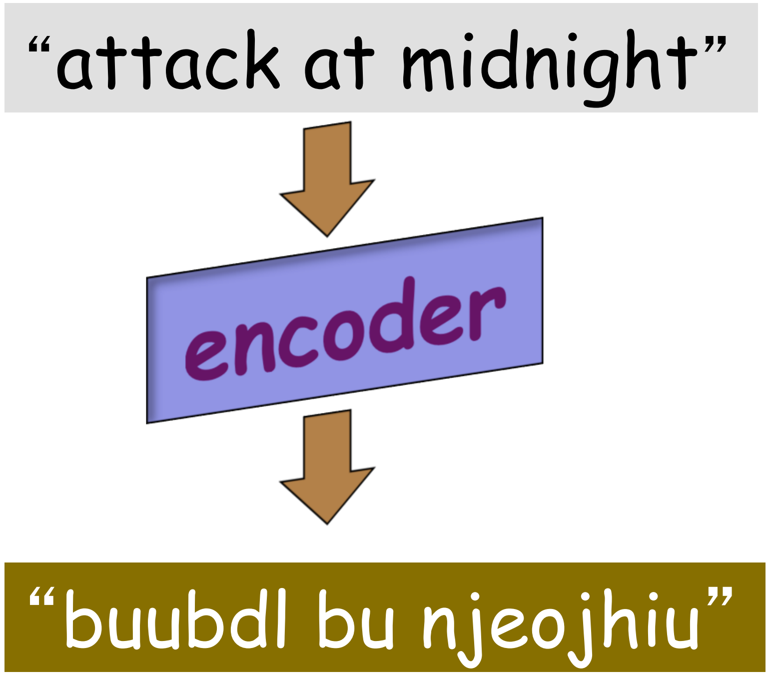
- Two functions are needed:

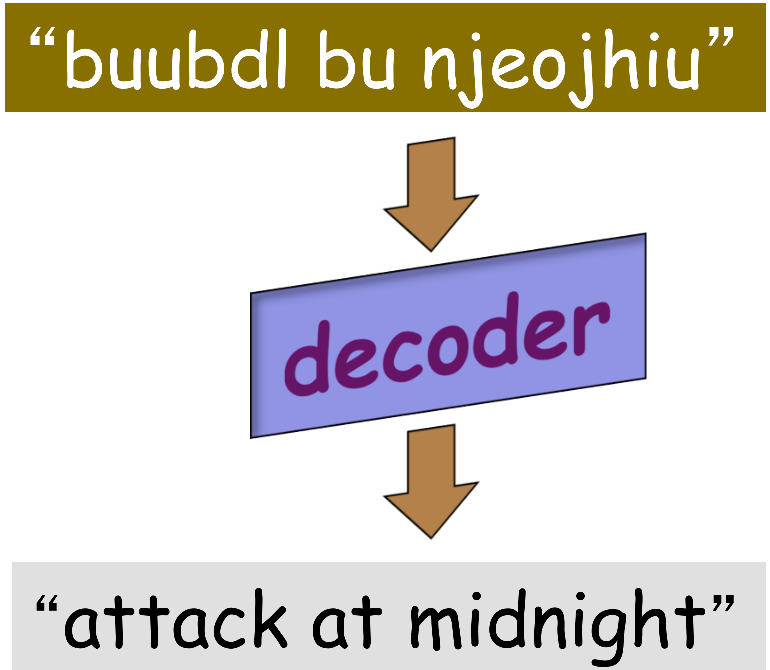




Example

- **encoder** function is next letter in the alphabet
- **decoder function** is …





Encryption and Decryption

"attack at midnight" - *plaintext*

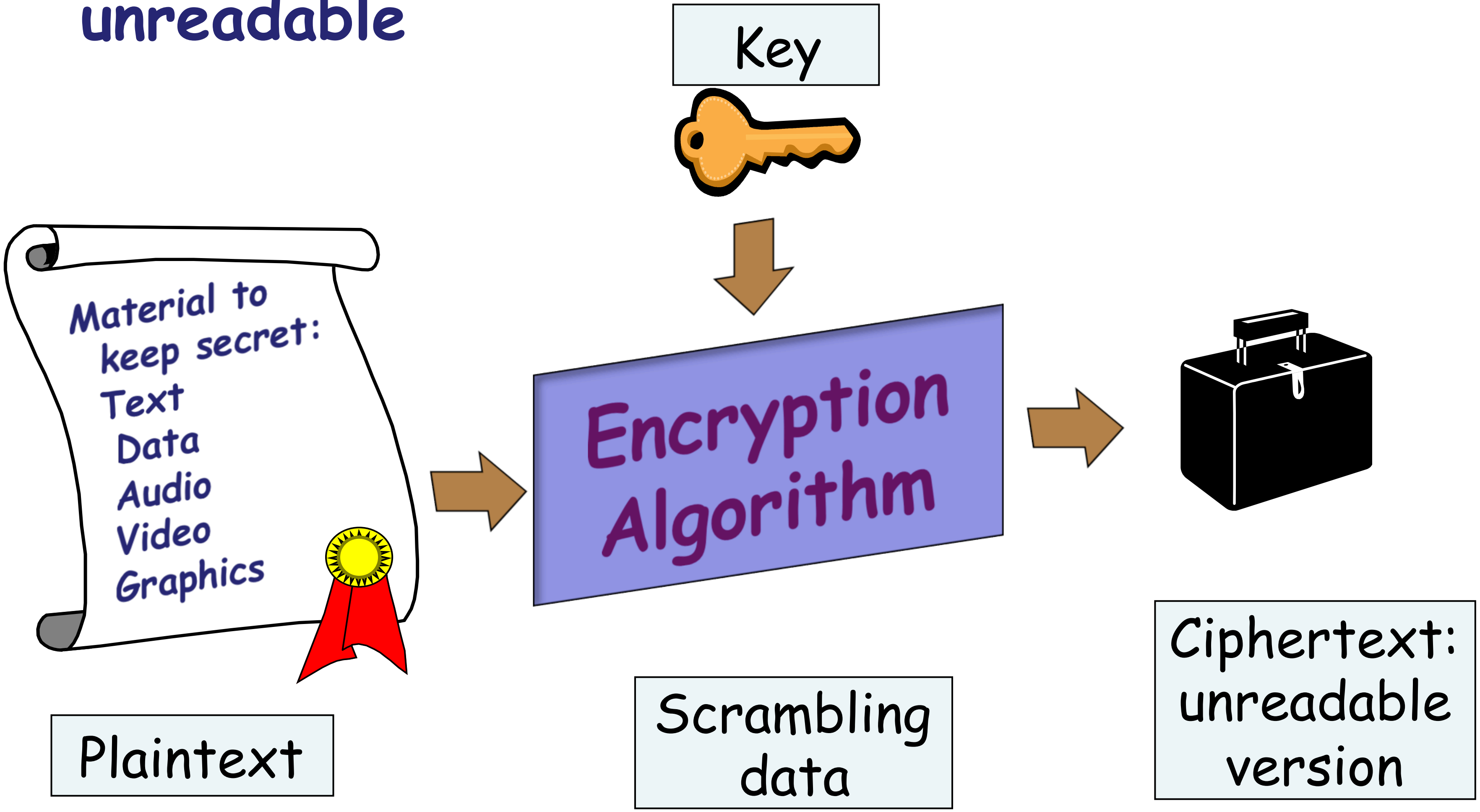
↓

"buubdl bu njeojhiu" - *ciphertext*

- **Encoding** the contents of the message (the plaintext) in such a way that hides its contents from outsiders is called **encryption**.
- The process of **retrieving** the plaintext from the *cipher-text* is called **decryption**.
- Encryption and decryption usually make use of a **key**, and the coding method is such that decryption can be performed only by knowing the proper key.

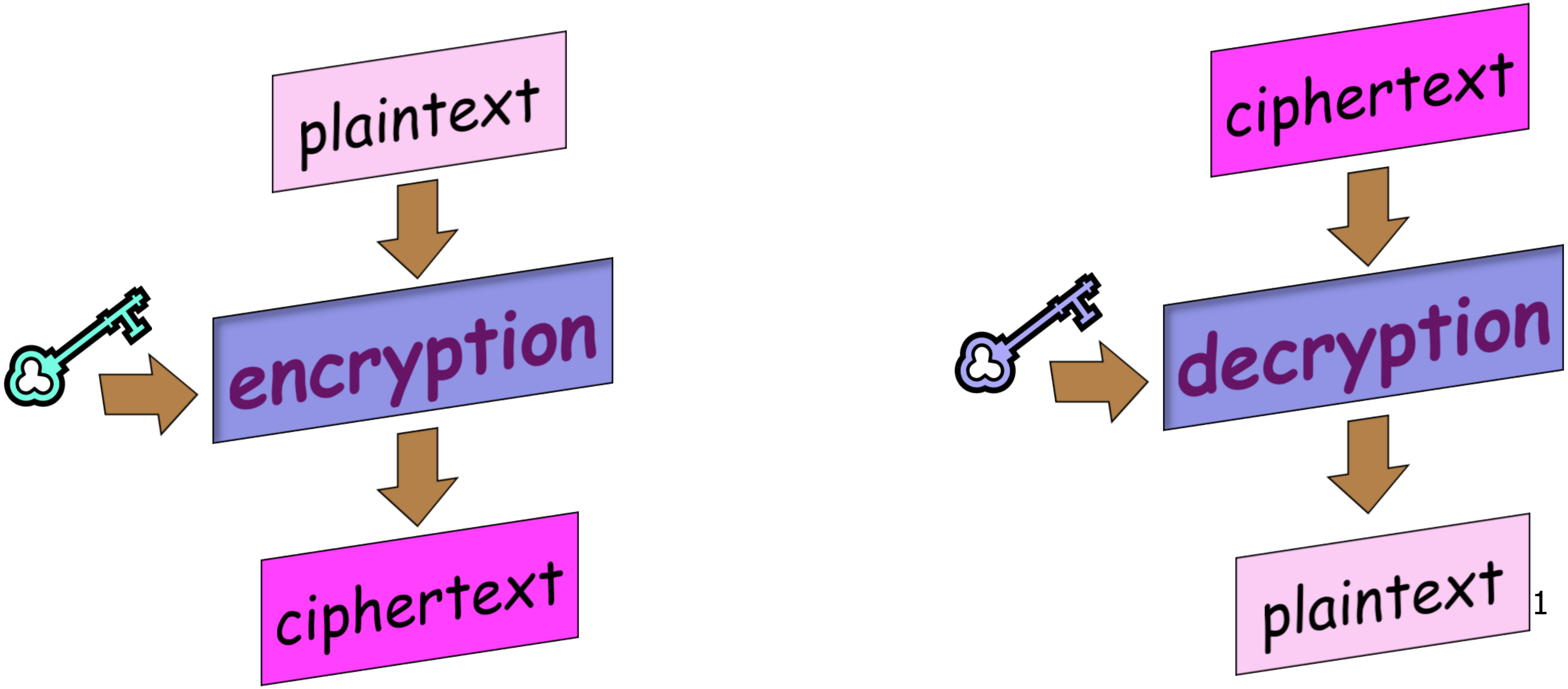
The Encryption Process

Aim: to hide a message content by making it unreadable



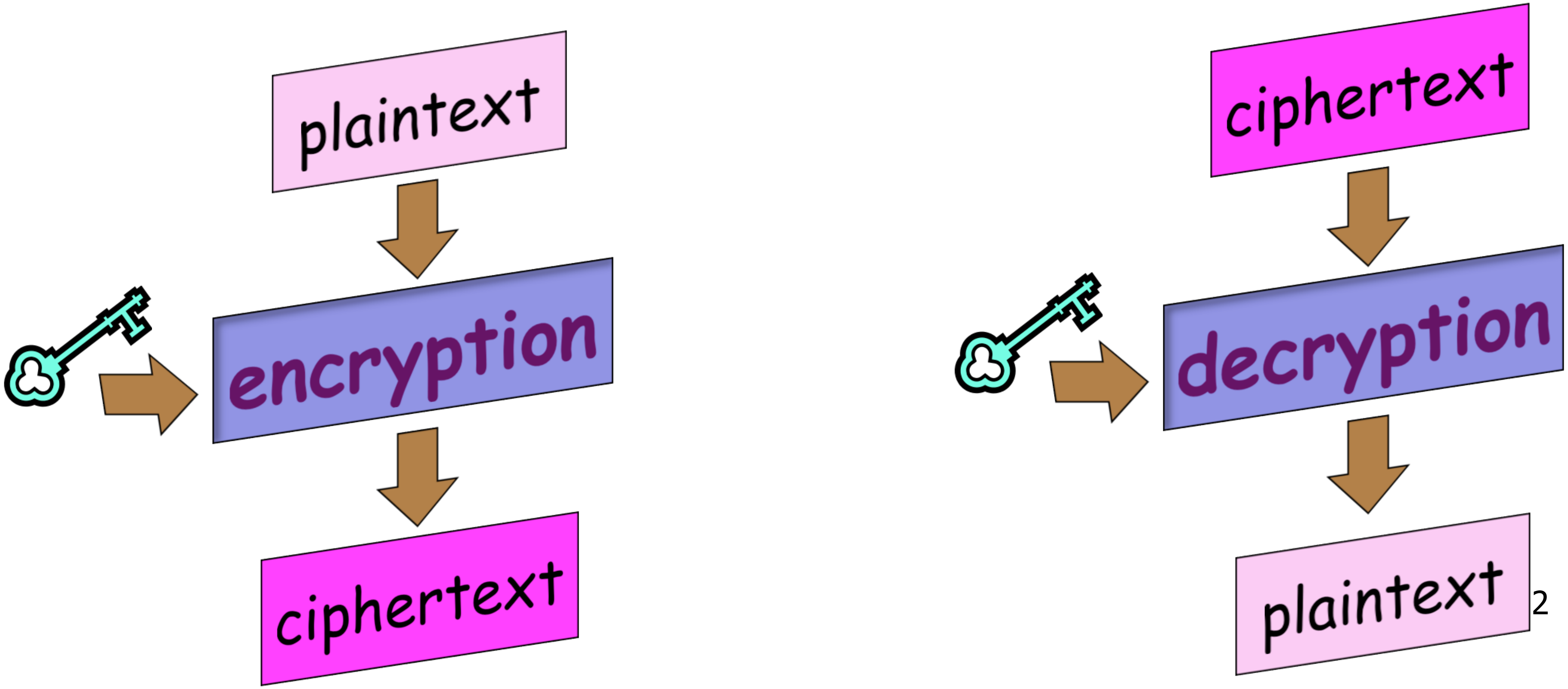
Encryption and Decryption

- The **encryption** and **decryption** functions take a **key** as an additional input.



Shared Keys

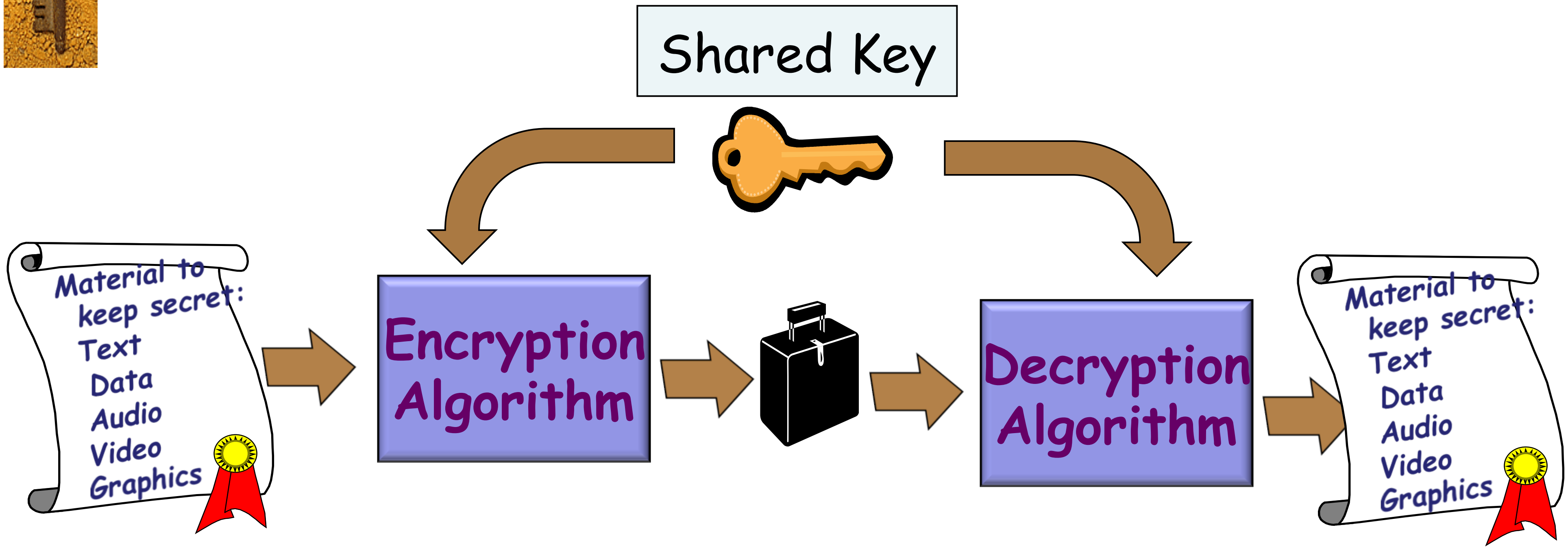
- In a symmetric cryptosystem the **encryption** key and the **decryption** key are identical.
- A longer key implies stronger encryption.

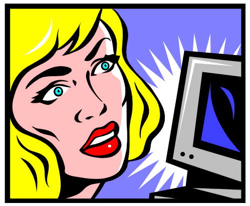


Symmetric Cryptosystems

Use the same key (the secret key) to encrypt and decrypt a message

Symmetric Encryption





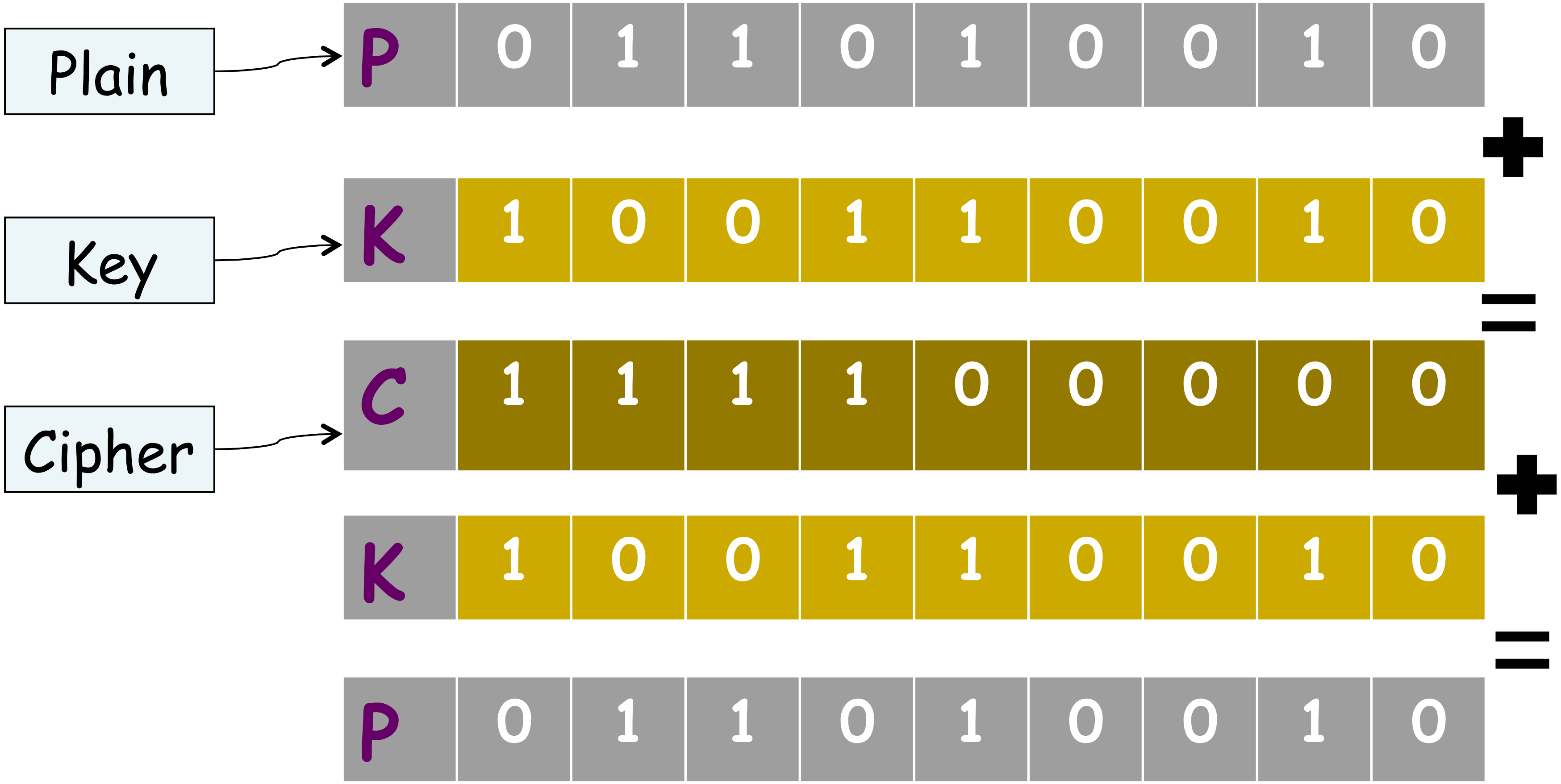
Alice

Sender and recipient
Must both know the key.
This is a weakness!

Bob

Symmetric XOR Cipher

- P encrypts to C with key K and C decrypts P to with same key K.

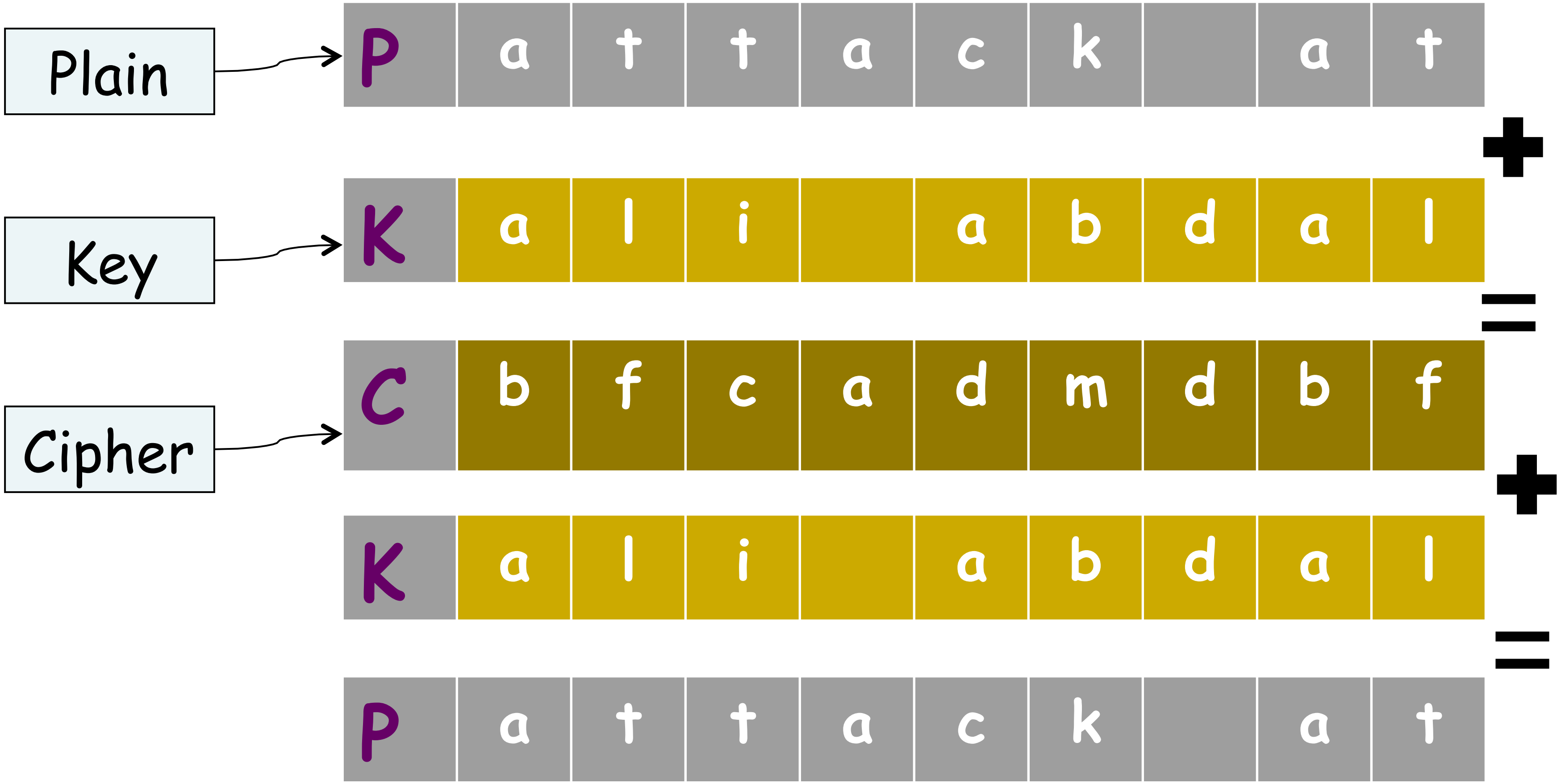


One Time Pad

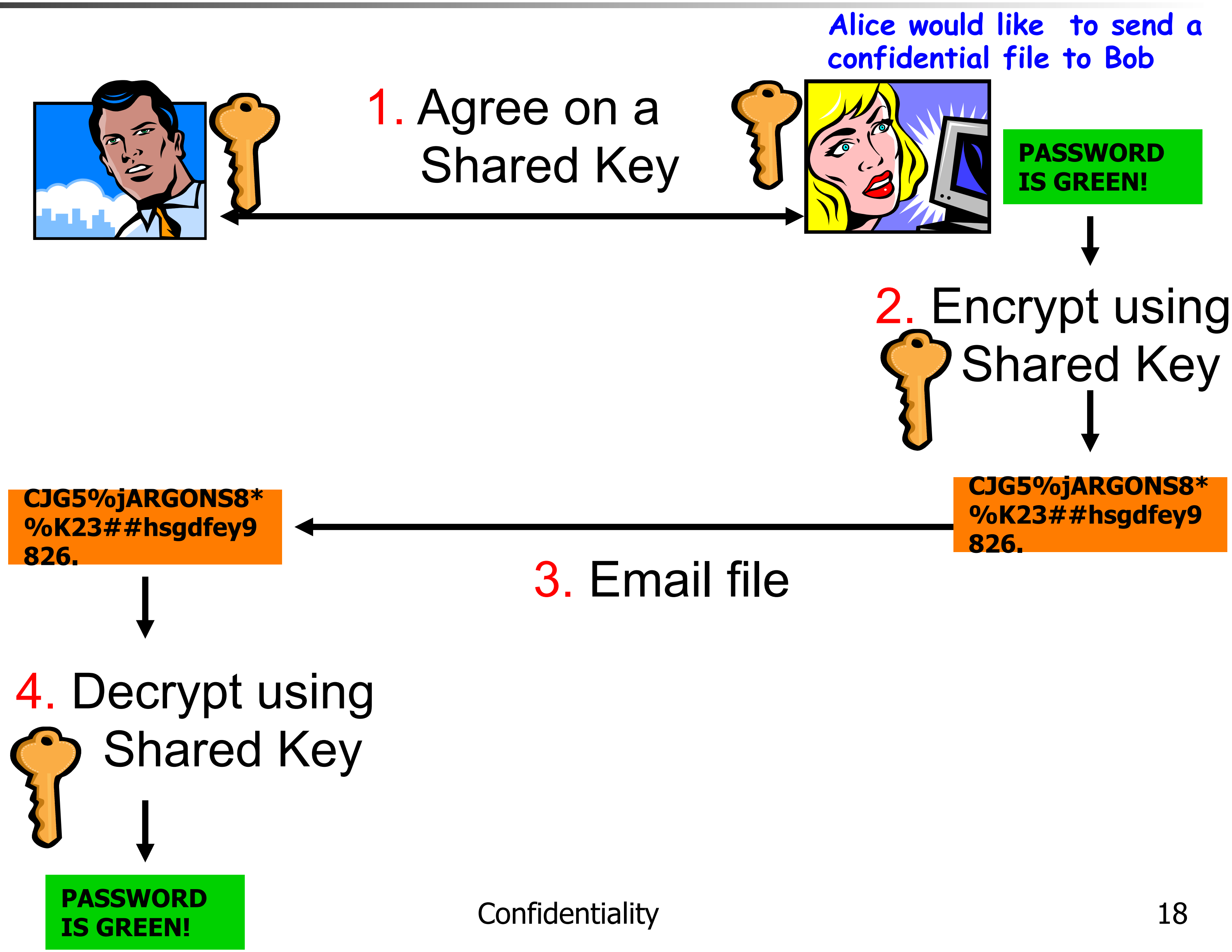
- The perfect encryption
- Pad: perfectly random list of letters
  - Use each letter exactly once to encrypt one letter of message and to decrypt the one letter of message
  - Discard each letter once used (hence, pad)
  - Method: Add the message letter and the key letter Mod 26. This is reversible like XOR.
- The message can never, ever, be found (unless you have the pad).

Example -one time pad

- P encrypts to C with key K and C decrypts P to with same key K.

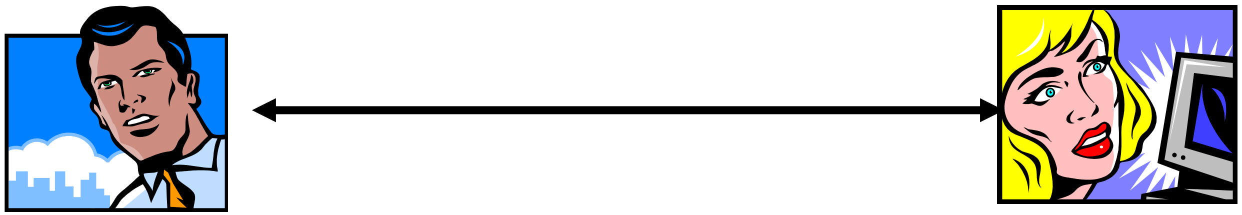


Symmetric Encryption

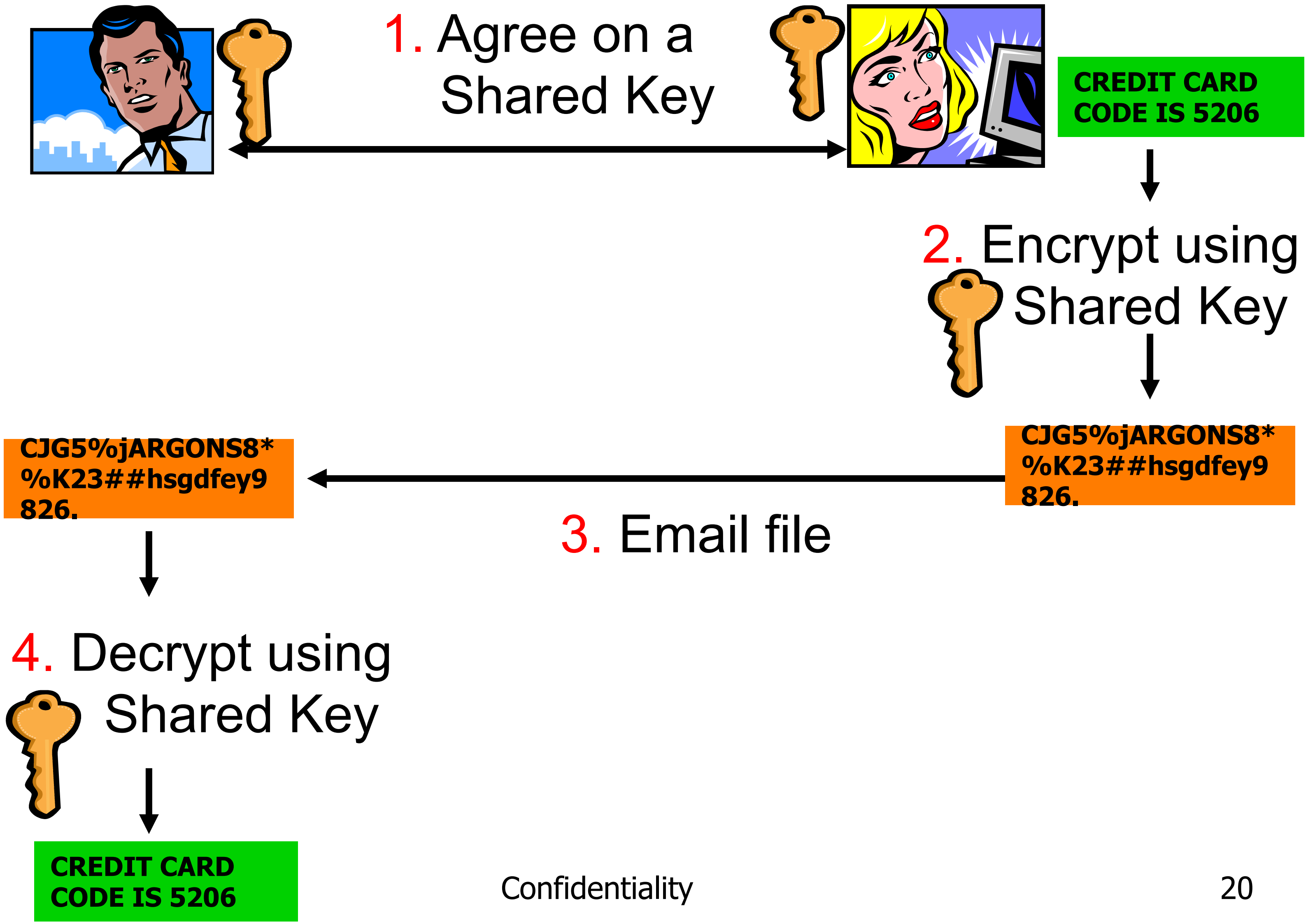


Emailing an encrypted message

Alice wants to send a confidential message CREDIT CARD CODE IS 5206 to Bob



Symmetric Encryption



Symmetric Cryptosystems

1. Data Encryption Standard (DES)

- Developed in the 1970s; made a standard by the US government, was adopted by several other governments worldwide and was widely used in the financial industry until 2004.
- Block cipher with 64-bit block size.
- Uses 56-bit keys: Strong enough to keep most random hackers and individuals out, but it is easily breakable with special hardware.
- A variant of DES, Triple-DES or **3DES** is based on using DES three times (normally in an encrypt-decrypt-encrypt sequence with three different, unrelated keys). Many people consider Triple-DES to be much safer than plain DES.

Advanced Encryption Standard (AES)

- Current standard.
- DES was perceived as breakable in mid 2000.
- AES was a stronger replacement to DES.

Symmetric Cryptosystems (2)

2. **RC2, RC4 and RC5** (RSA Data Security, Inc.)
   - Variable-length keys as long as 2048 bits
   - Algorithms using 40-bits or less are used in browsers to satisfy export constraints
   - The algorithm is very fast. Its security is unknown, but breaking it seems challenging. Because of its speed, it may have uses in certain applications.
3. **IDEA (International Data Encryption Algorithm)**
   - Developed at ETH Zurich in Switzerland.
   - Uses a 128 bit key, and it is generally considered to be very secure.
   - Patented in the United States and in most of the European countries. The patent is held by Ascom-Tech. Non-commercial use of IDEA is free. Commercial licenses can be obtained by contacting idea@ascom.ch.
   - Used in email encryption software such as PGP and RSA

Symmetric Cryptosystems (3)

4. **Blowfish**
   - Developed by Bruce Schneider.
   - Block cipher with 64-bit block size and variable length keys (up to 448 bits). It has gained a fair amount of acceptance in a number of applications. No attacks are known against it.
   - Blowfish is used in a number of popular software packages, including Nautilus and PGPfone.
5. **SAFER**
   - Developed by J. L. Massey (one of the developers of IDEA). It is claimed to provide secure encryption with fast software implementation even on 8-bit processors.
   - Two variants are available, one for 64 bit keys and the other for 128 bit keys. An implementation is in ftp://ftp.funet.fi/pub/crypt/cryptography/symmetric/safer.

Limitations

- Parties that have not previously met cannot communicate securely
- Many people need to communicate with a server (many-to-one communications)
  - cannot keep server key secret for long
- Once the secret key is compromised, the security of all subsequent messages is suspect and a new key has to be generated
- Authentication service must know private key
  - privacy implications---someone else knows your key
  - two possible points of attack
  - changing authentication service requires a new key
- Digital signatures are difficult
- Cross-realm authentication
  - accessing services outside the domain or realm of your authentication server is problematic
  - requires agreement and trust between authentication services
  - introduces another potential point of attack

Analysis

- Private or symmetric key systems rely on symmetric encryption algorithms where information encrypted with a key K can only be decrypted with K.
- Secret key is exchanged via some other secure means (hand-delivery, over secured lines, pre-established convention).
- Time to crack known symmetric encryption algorithms

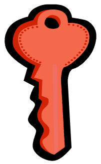
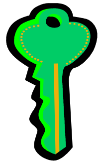
KEY LENGTH	SPEND $$THOUSANDS	SPEND $$MILLIONS	SPEND $100 MILLION
40 bits	seconds	< 1 second	< .01 second
56 bits	hours	minutes	1 second
64 bits	days	hours	minutes
80 bits	years	months	days
128 bits	> million years	> million years	> centuries

Symmetric Cryptosystems Problems

- How to transport the secret key from the sender to the recipient securely and in a tamperproof fashion?
- If you could send the secret key securely, then, in theory, you wouldn't need the symmetric cryptosystem in the first place -- because you would simply use that secure channel to send your message.
- Frequently, trusted couriers are used as a solution to this problem.

Asymmetric Cryptosystems

In asymmetric-key cryptography, users do not need to know a symmetric shared key; everyone

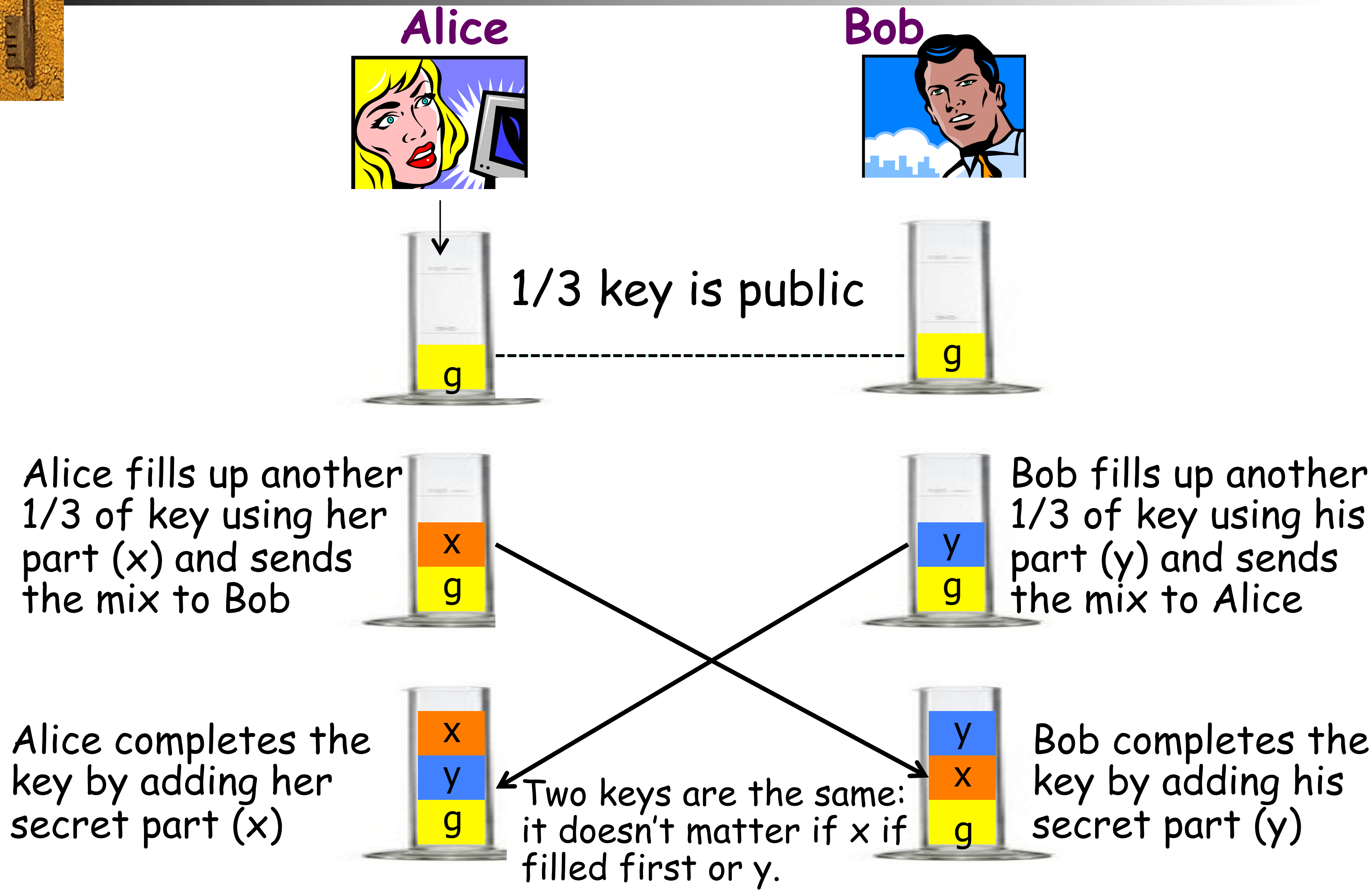
- shields a **private** key  and
- advertises a **public** key 

Key Agreement

- Alice and Bob don't already share a key and can't meet to do so. How can they make their future communications confidential?

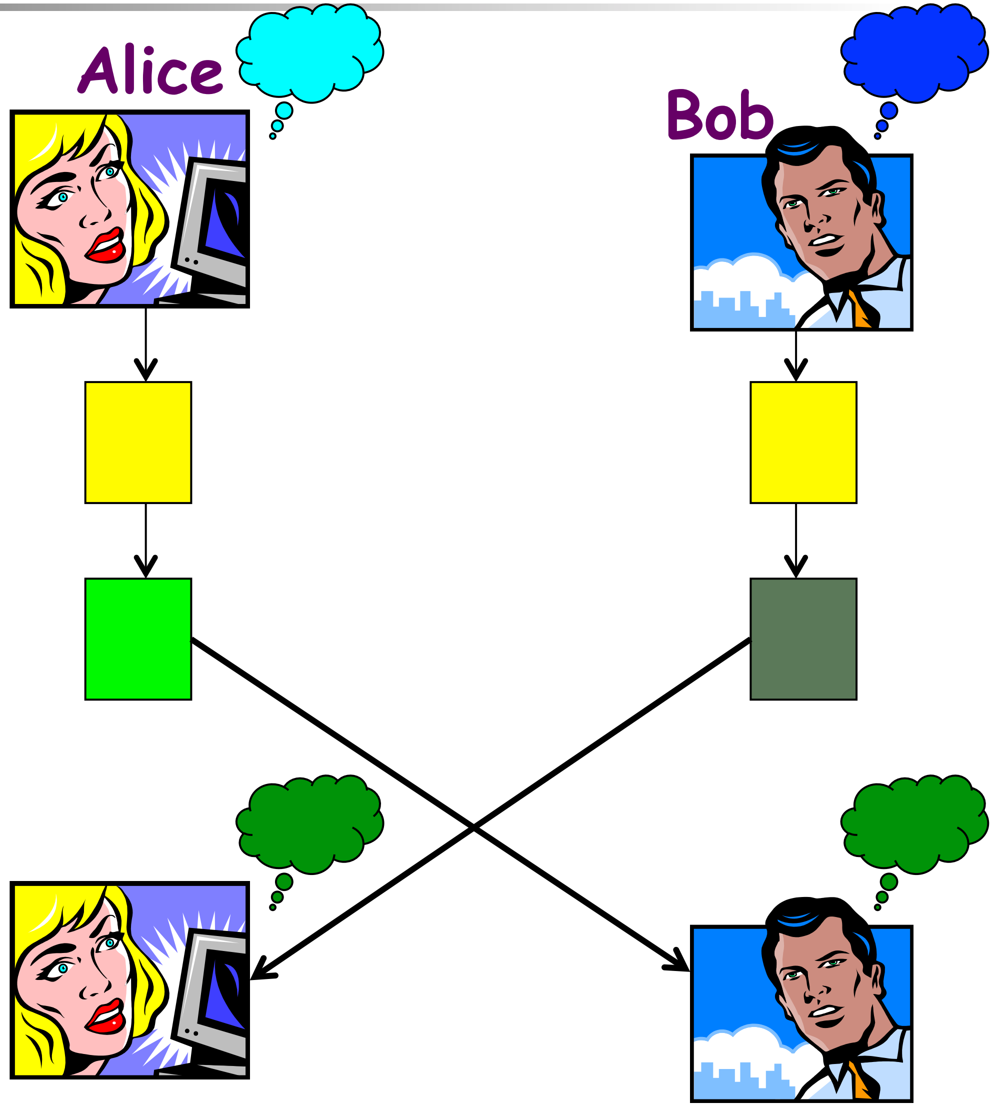
- The main protocol we study is the celebrated Diffie-Hellmann Key Exchange (DHKE) protocol.

Diffie-Hellman Key Exchange Idea

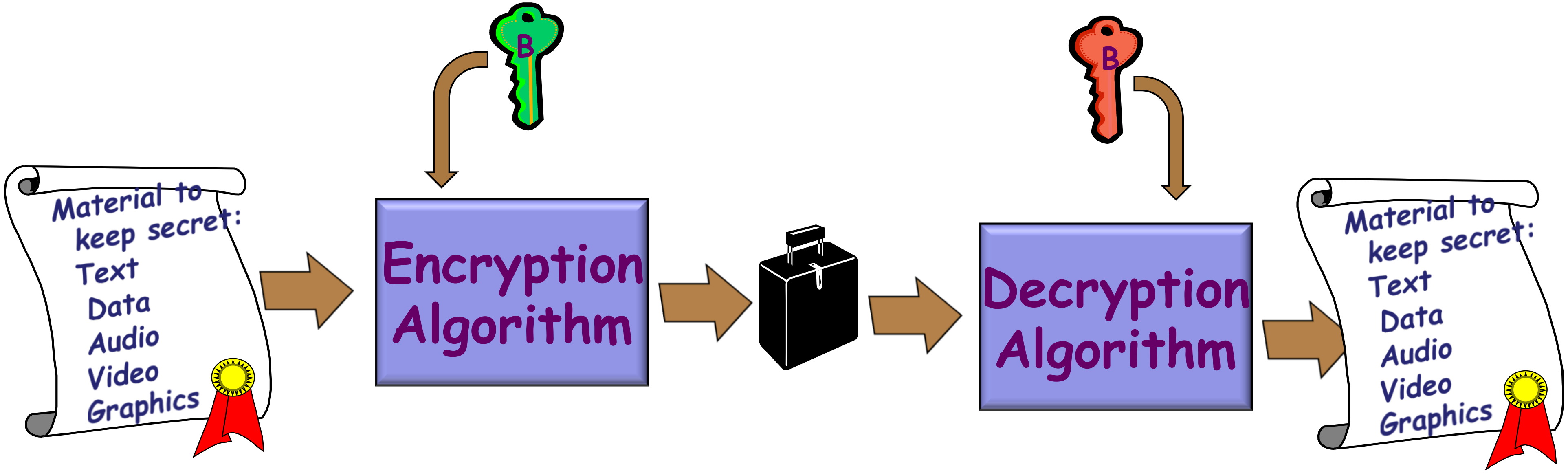


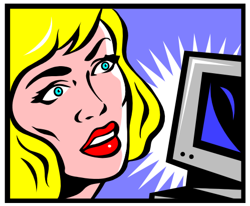
An alternative interpretation

- Alice & Bob each think of a secret color (known only to them)
- They mix their color with yellow (agreed upon openly ahead of time) and exchange.
- They mix their color with what they've received.
- Both have the same color but observer cannot duplicate.



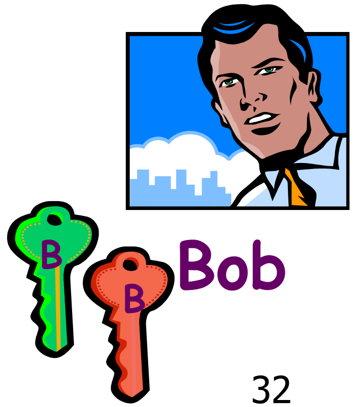
Asymmetric Encryption





Alice

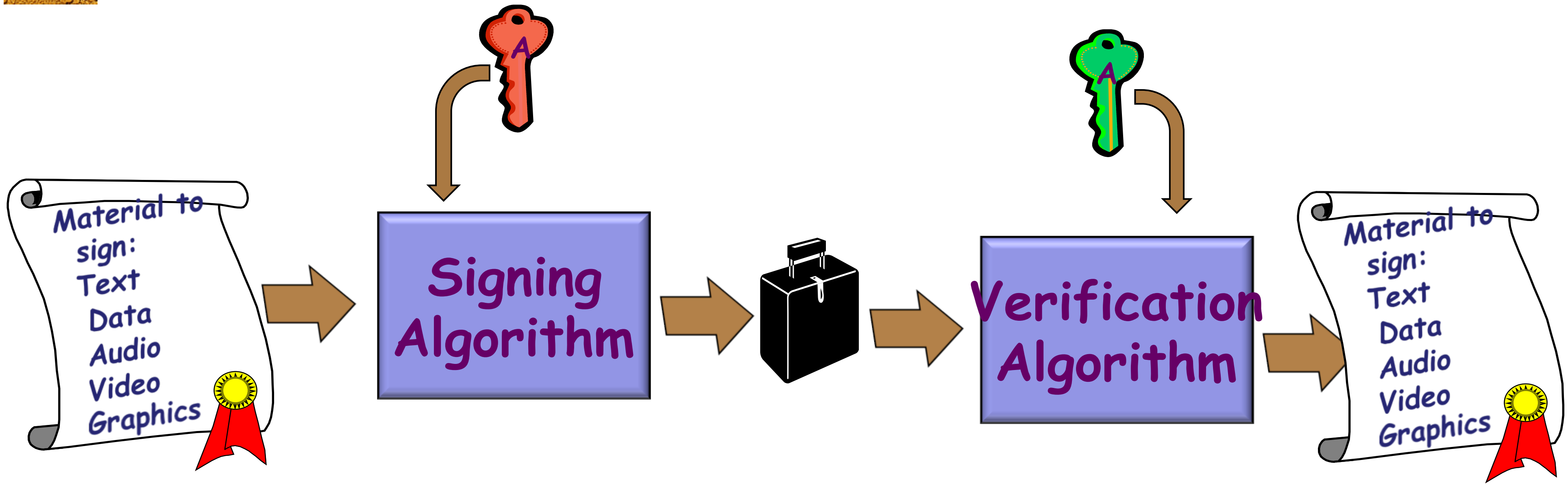
Sender knows **public** key
Recipient knows **private** key.

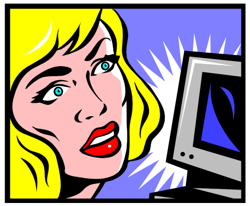


Bob

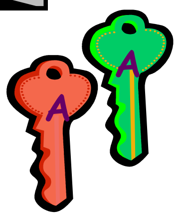
A

Signing and verification





Alice



Sender knows **private** key
Recipient knows **public** key.

Bob

Properties

- These algorithms are based on computationally intensive problems such as finding the prime factors of large numbers.
  - Longer the length of the key pair, the more time it takes to crack the private key
  - Keys used in today's internet will take millions of years to crack using today's technologies

Slow …

- Public key cryptosystems are slow, really slow!
  - three orders of magnitude (1000 times) slower than AES
  - mainly used as key exchange tool
- Scientists are supposed to be real "smart" and love to solve difficult problems
  - but even they hope to never solve factoring
  - if you can find a quick solution,
    - fame, dollars and danger lurk!

Problems

- Keys are usually very long and encryption is expensive
  - RSA encryption is a 1000 times slower than typical symmetric algorithms
  - hard to remember secret key - where do you store it?
  - typically only used for authentication, then a random key and a symmetric encryption algorithm is used for subsequent communication
- Multicast is problematic
  - Better to authenticate using public key algorithm, then use random key with symmetric algorithm
- How do you know you have the right public key for a principal?
  - Public key is usually distributed as a document ``signed'' by a well- known and trusted certification authority (e.g. Verisign). This is called a certificate. How do you determine if signature is up-to- date? What if the key has been compromised?

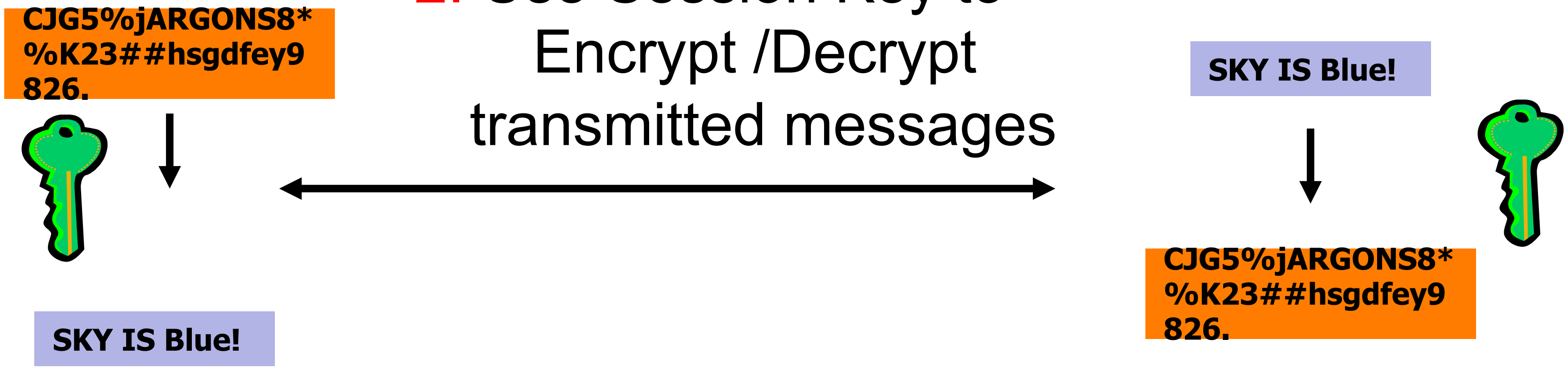
Analysis

- *Private (Symmetric) key:*
  - \+ encryption is fast
  - ➢ identity is not easily portable across authentication services
  - ➢ secret key *must* be held by server
  - \+ good for structured, organizational security
- *Public (Asymmetric) key:*
  - ➢ encryption is slow
  - \+ identity is inherently portable
  - \+ secret key need not *ever* be revealed
  - \+ provides digital signatures
  - \+ good for individuals in loosely structured networks

Digital Envelopes

1. Agree on a Session Key

2. Use Session Key to Encrypt /Decrypt transmitted messages



Digital Envelope

- Combination of public-key (asymmetric) cryptography and symmetric systems
- Sender:
  - Generate a secret key at random called the session key (which is discarded after the communication session is done)
  - Encrypt the message using the session key and the symmetric algorithm of your choice
  - Encrypt the session key with the recipient's public key. This becomes the "digital envelope"
  - Send the encrypted message and the digital envelope to the recipient

Digital Envelope

- Recipient
  - Receive the envelope, uses private key to decrypt it recovering the session key.
  - The message is secure since it is encrypted using a symmetric session key that only the sender and recipient know.
  - The session key is also secure since only the recipient can decrypt it.
  - Can even act like a one time pad

Summary

- Cryptosystems: Symmetric & Asymmetric
  - Symmetric: Use the same key (the secret key) to encrypt and decrypt a message
  - Asymmetric: Use one key (the public key) to encrypt a message and different key (the private key) to decrypt it.
- Symmetric Cryptosystems Problems
  - How to transport the secret key from the sender to the recipient securely and in a tamperproof fashion? If you could send the secret key securely, then, in theory, you wouldn't need the symmetric cryptosystem in the first place -- because you would simply use that secure channel to send your message.
  - Frequently, trusted couriers are used as a solution to this problem.
- Modern solutions combine features from both Symmetric & asymmetric cryptosystems.

Questions?

Summary

- Cryptography enables parties to communicate on open networks without fear of being eavesdropped
  - all cryptographic schemes have their limitations
- Symmetric schemes use a common key for encryption and decryption.
- Asymmetric (public key) schemes use a public-private key pair where the public key is used by senders to encrypt and only the recipient with the private key can decrypt the message.
- Trade-offs between symmetric and asymmetric schemes.
- Digest functions (Hash-functions) can be used to maintain integrity of a message and make it tamper-proof.
- Digital envelopes combine the security of asymmetric schemes with the efficiency of symmetric schemes.
- Certification authorities allow authenticated access to public keys.
- A hierarchy of certification authorities (hierarchy of trust) can be used.
- Certification Revocation Lists maintain a list of invalid certificates.

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Source: Bob Thibadeau http://dollar.ecom.cmu.edu/sec/lec02.ppt