CSE 484 / CSE M 584: Computer Security and Privacy

Cryptography
[Symmetric Encryption]

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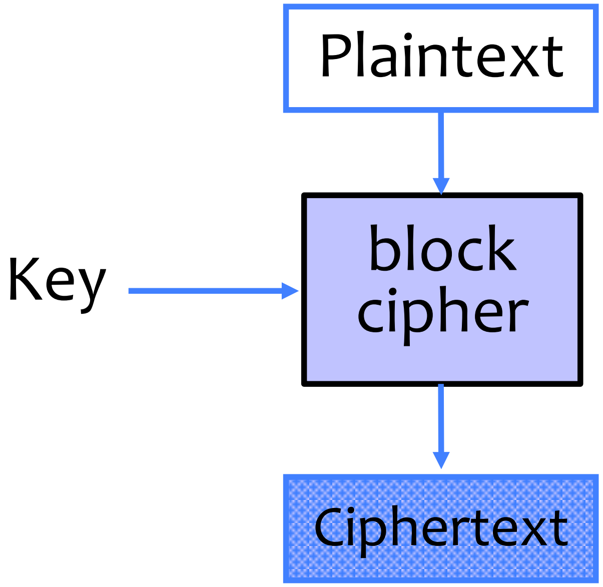
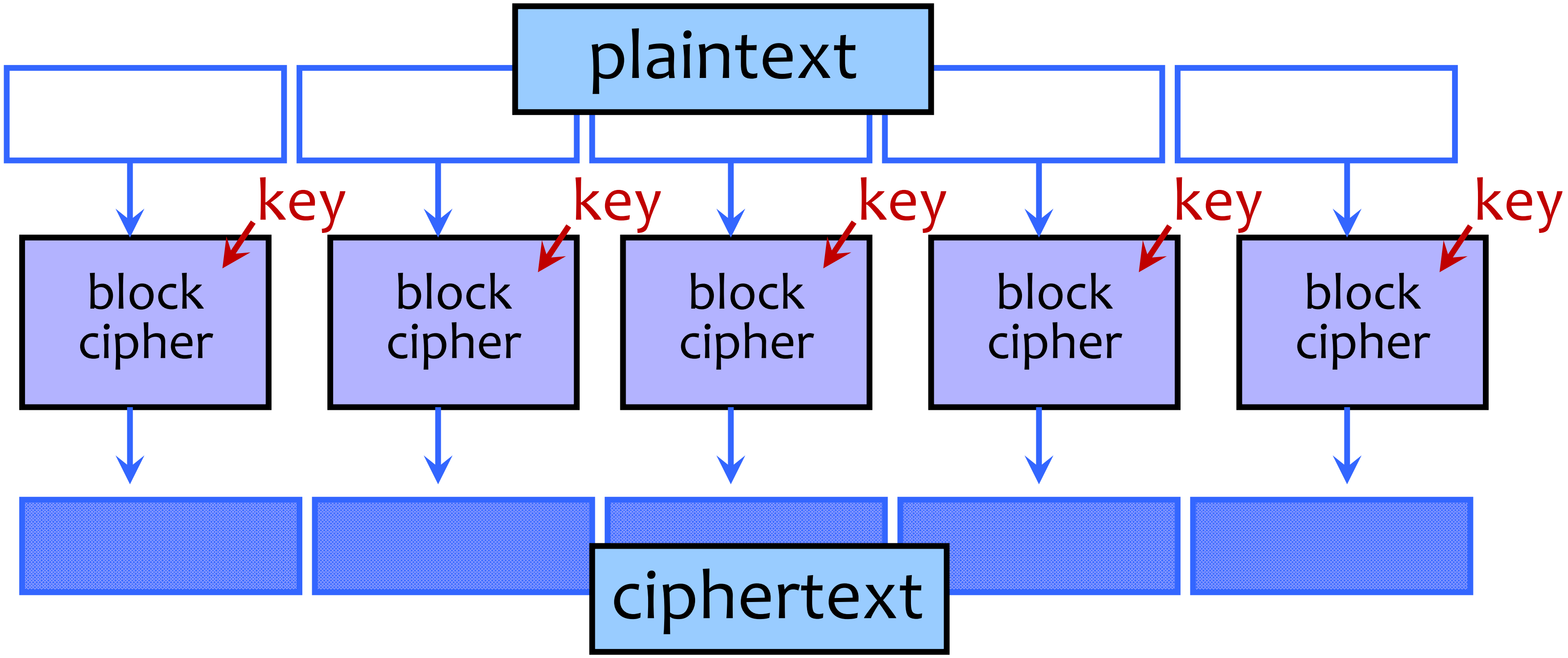
Reminder: Block Ciphers

- Operates on a single chunk ("block") of plaintext
  - For example, 64 bits for DES, 128 bits for AES
  - Each key defines a different permutation of possible outputs
  - Same key is reused for each block (can use short keys)

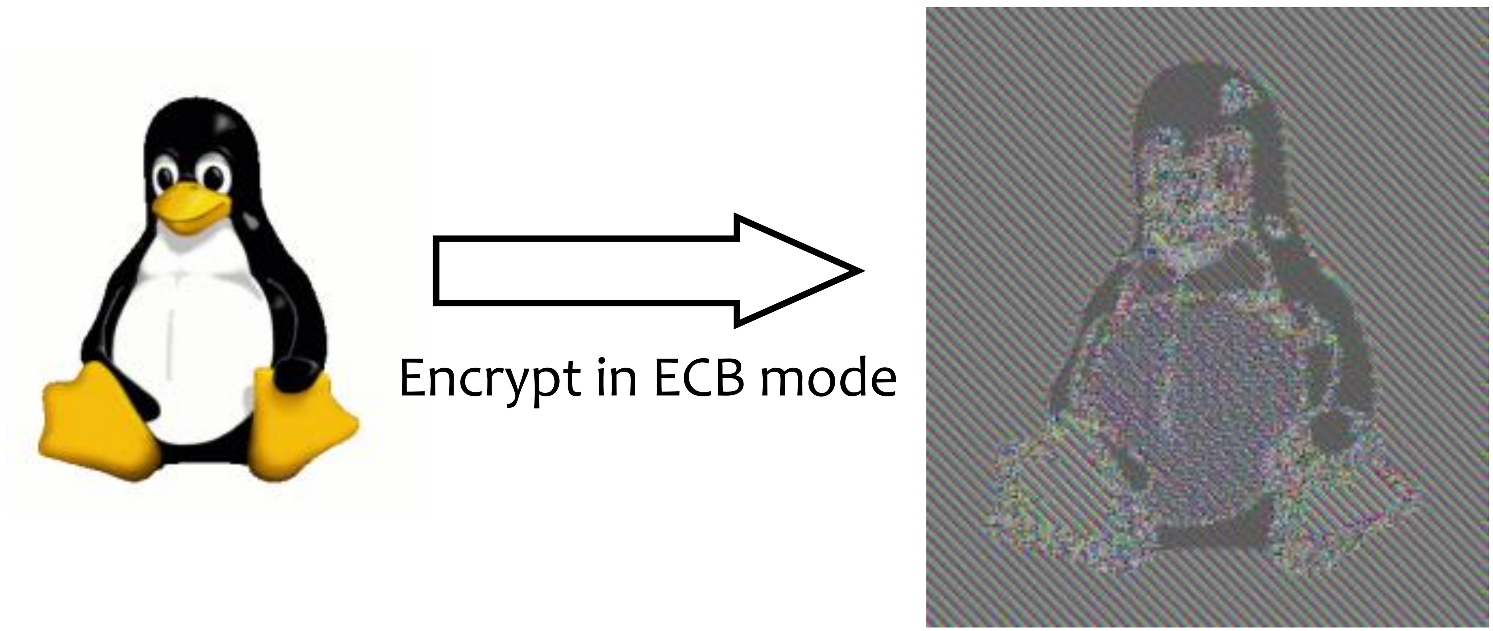


Electronic Code Book (ECB) Mode



- Identical blocks of plaintext produce identical blocks of ciphertext
- No integrity checks: can mix and match blocks

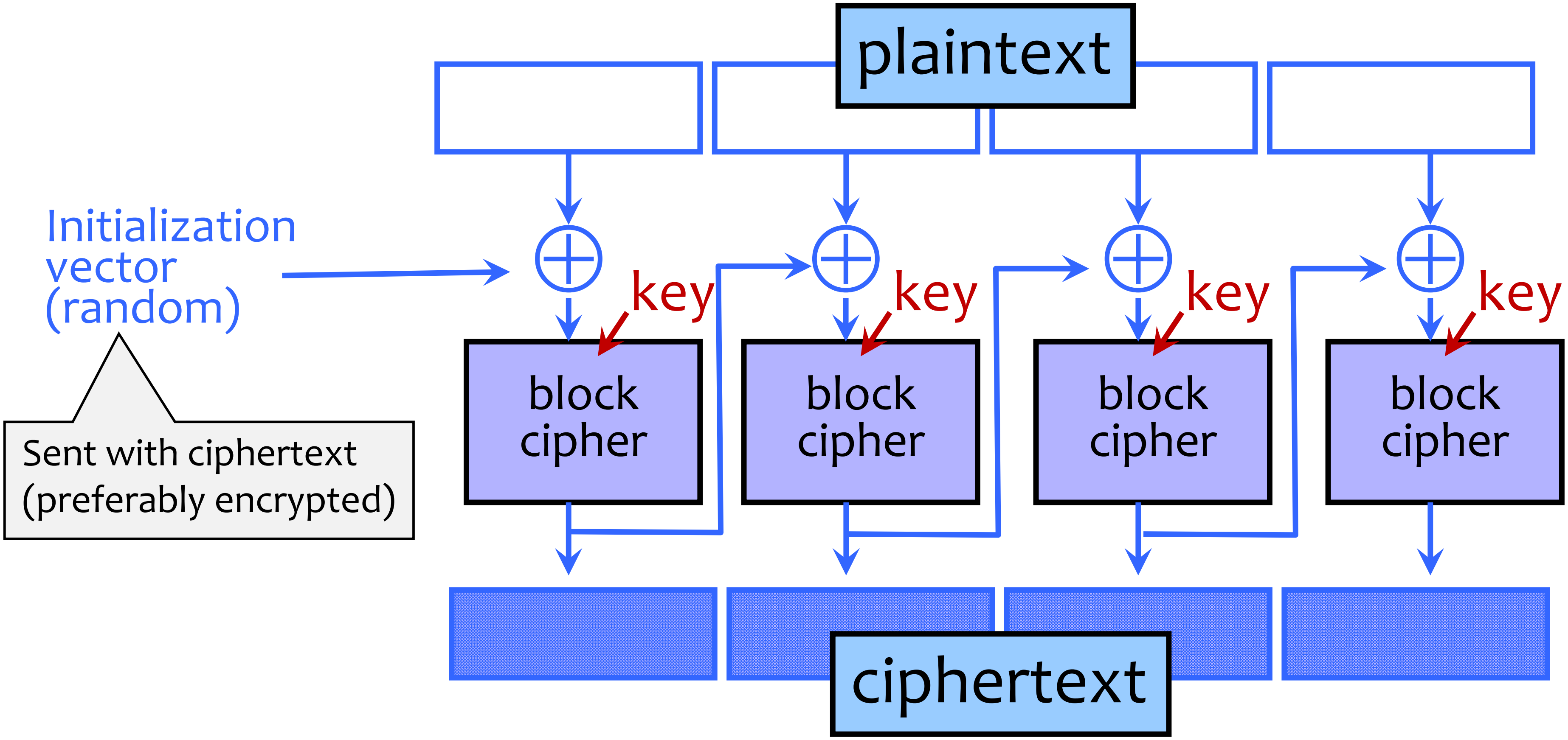
Information Leakage in ECB Mode



Encrypt in ECB mode

[Wikipedia]

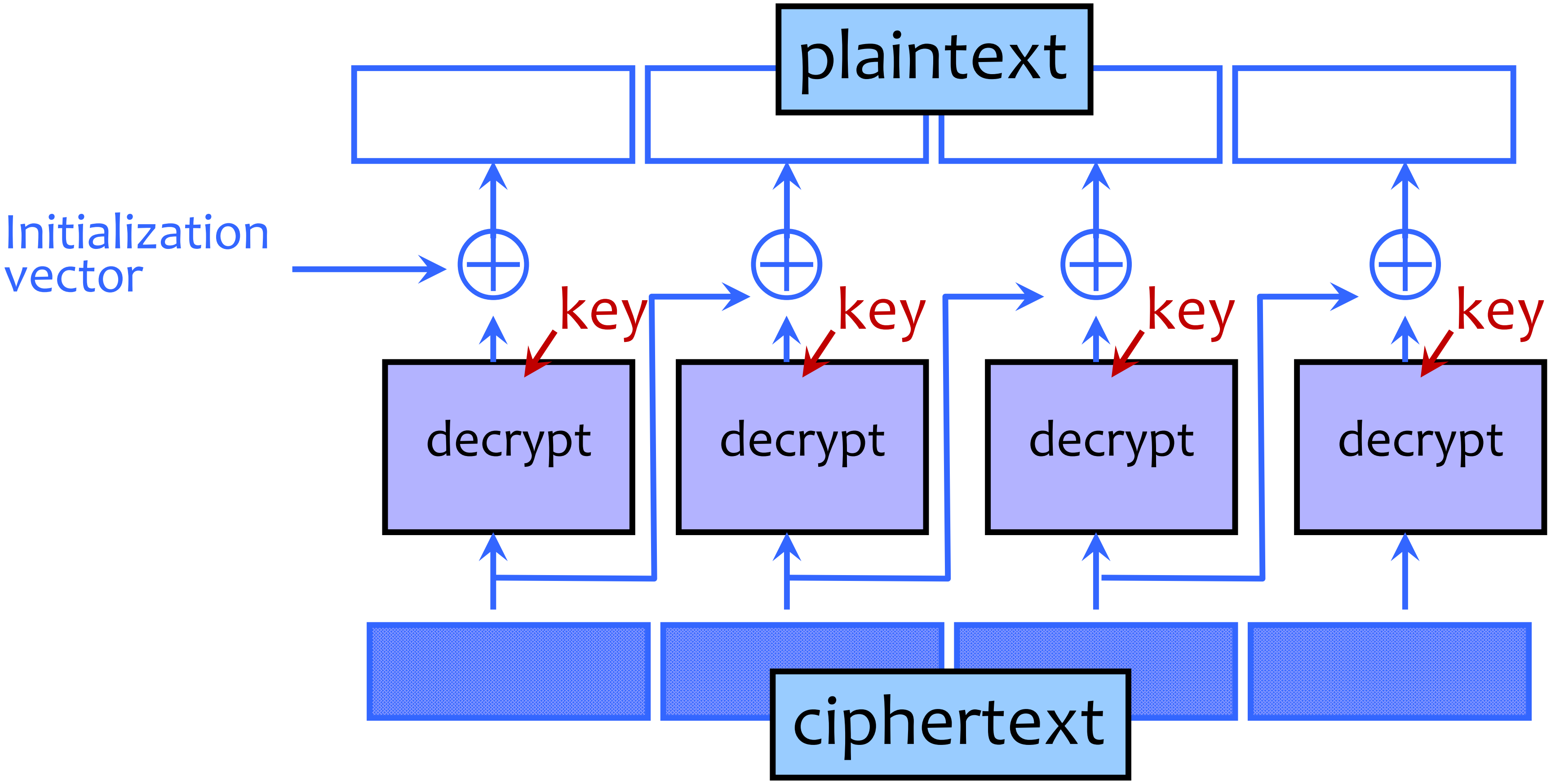
Cipher Block Chaining (CBC) Mode: Encryption



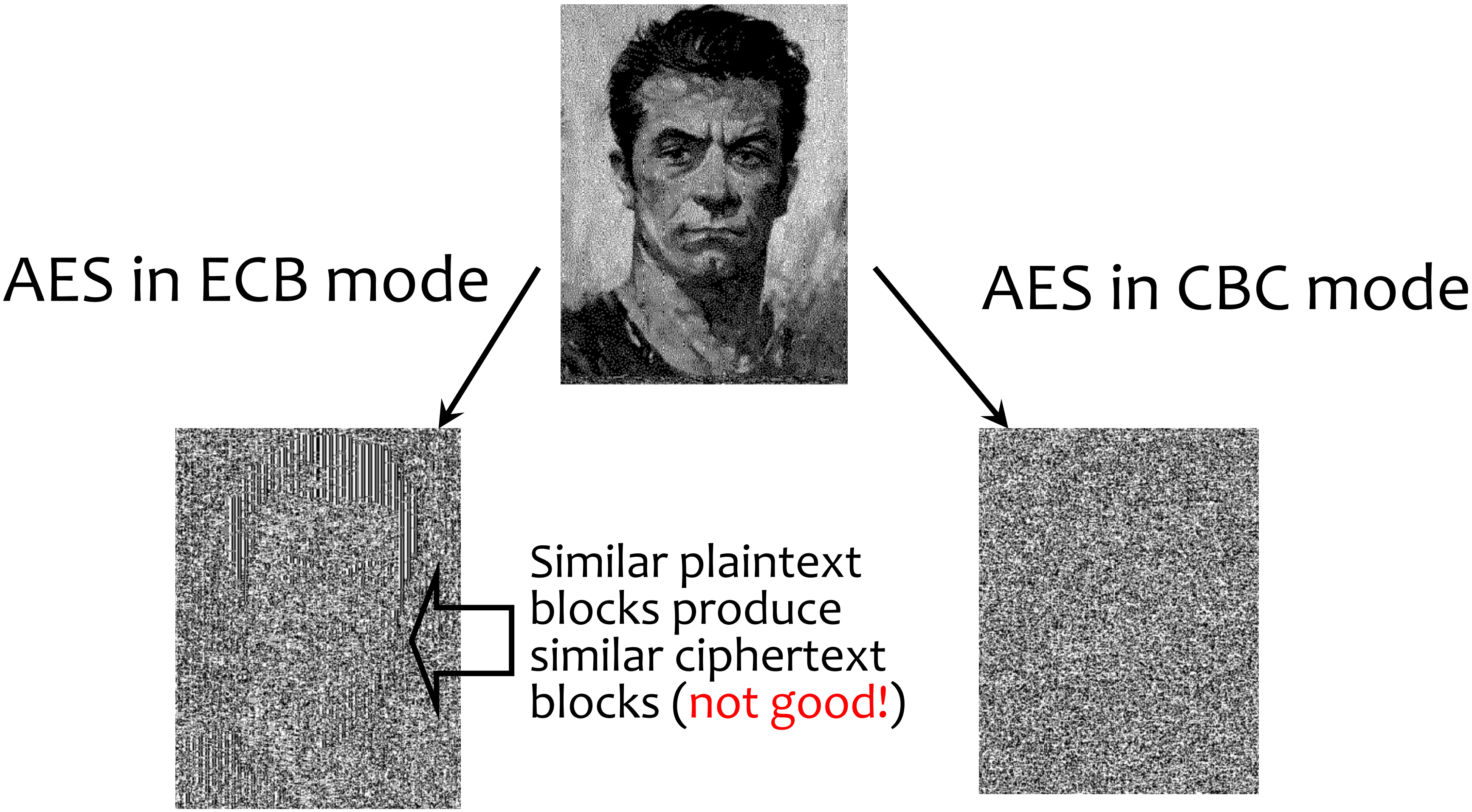
Sent with ciphertext (preferably encrypted)

- Identical blocks of plaintext encrypted differently
- Last cipherblock depends on entire plaintext
  - Still does not guarantee integrity

CBC Mode: Decryption



ECB vs. CBC



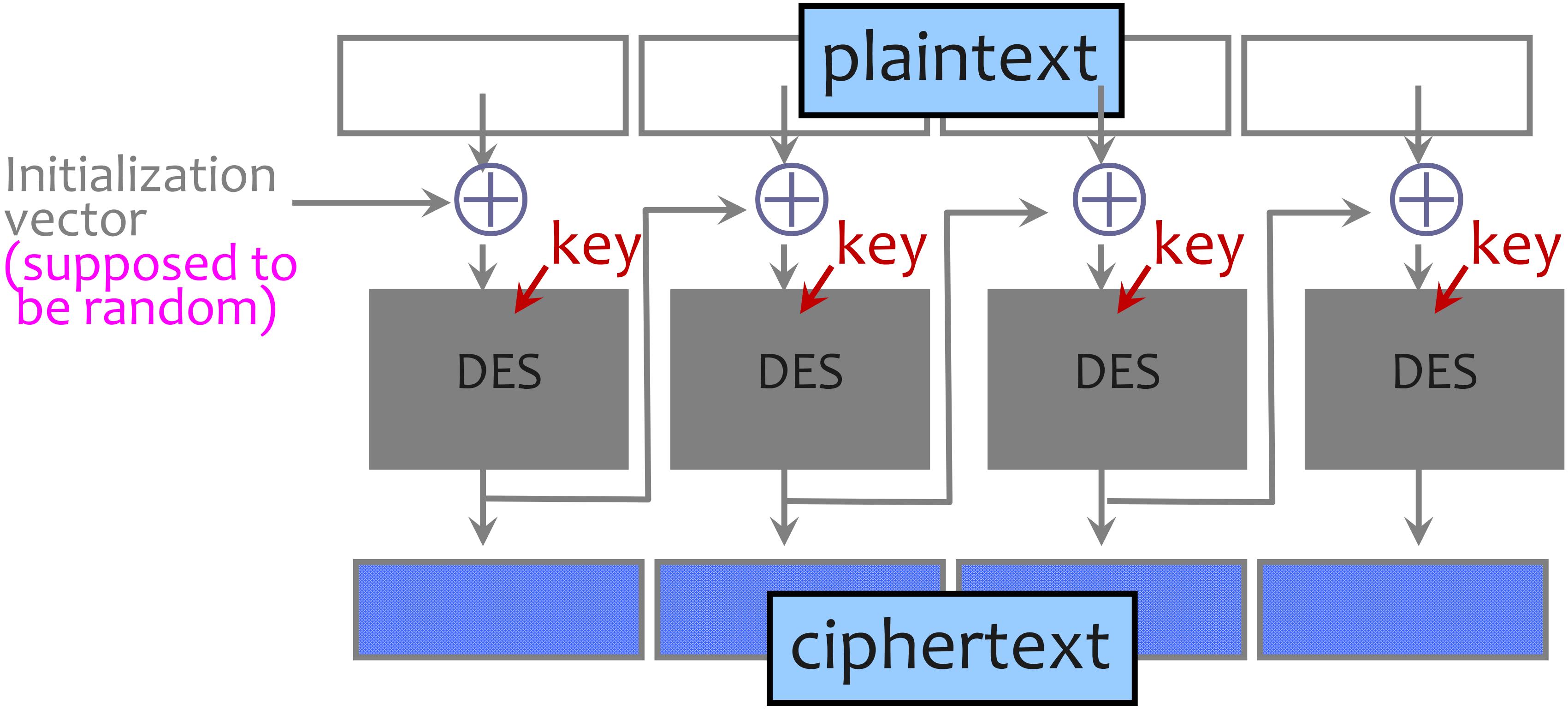
AES in ECB mode

AES in CBC mode

Similar plaintext blocks produce similar ciphertext blocks (not good!)

[Picture due to Bart Preneel]

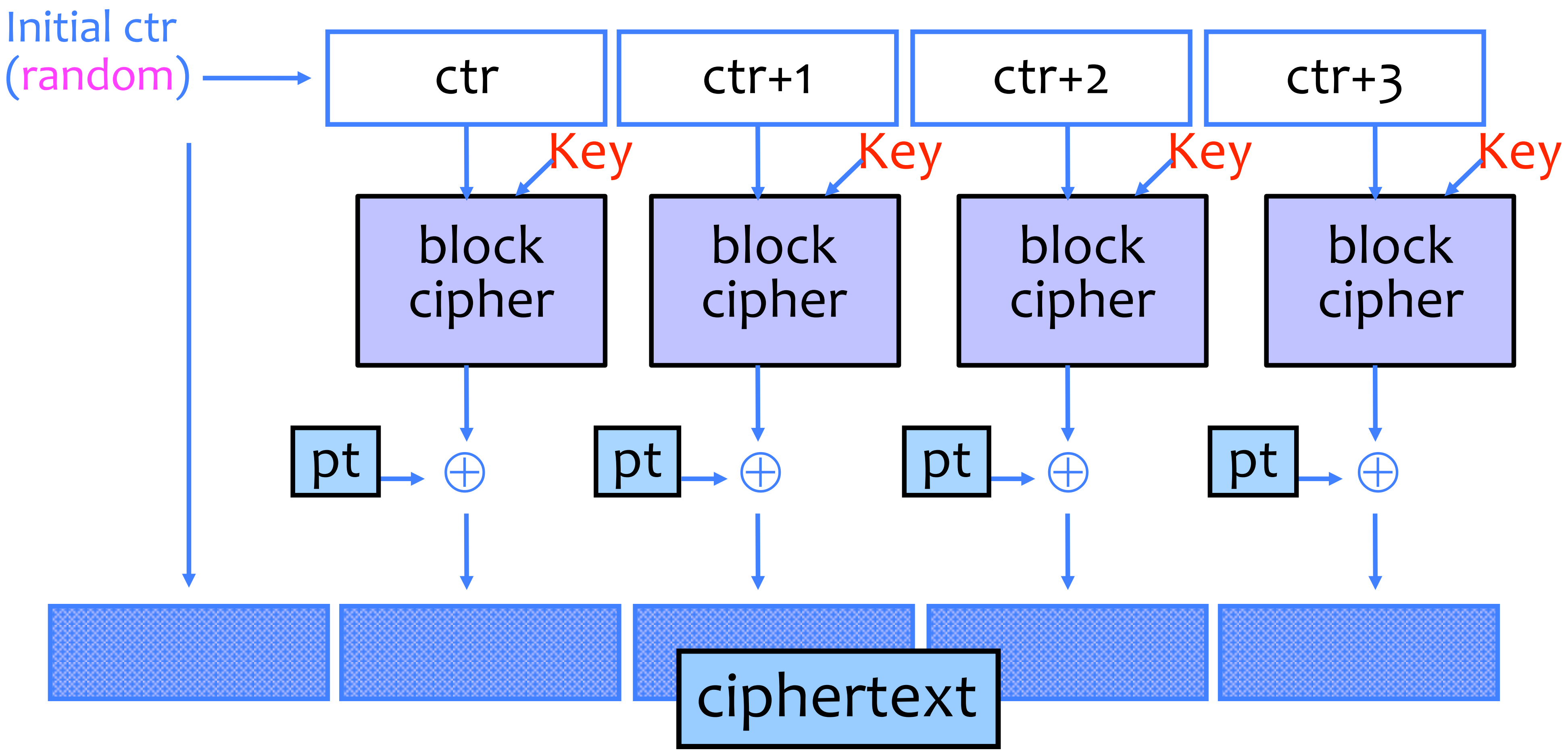
Initialization Vector Dangers



Found in the source code for Diebold voting machines:

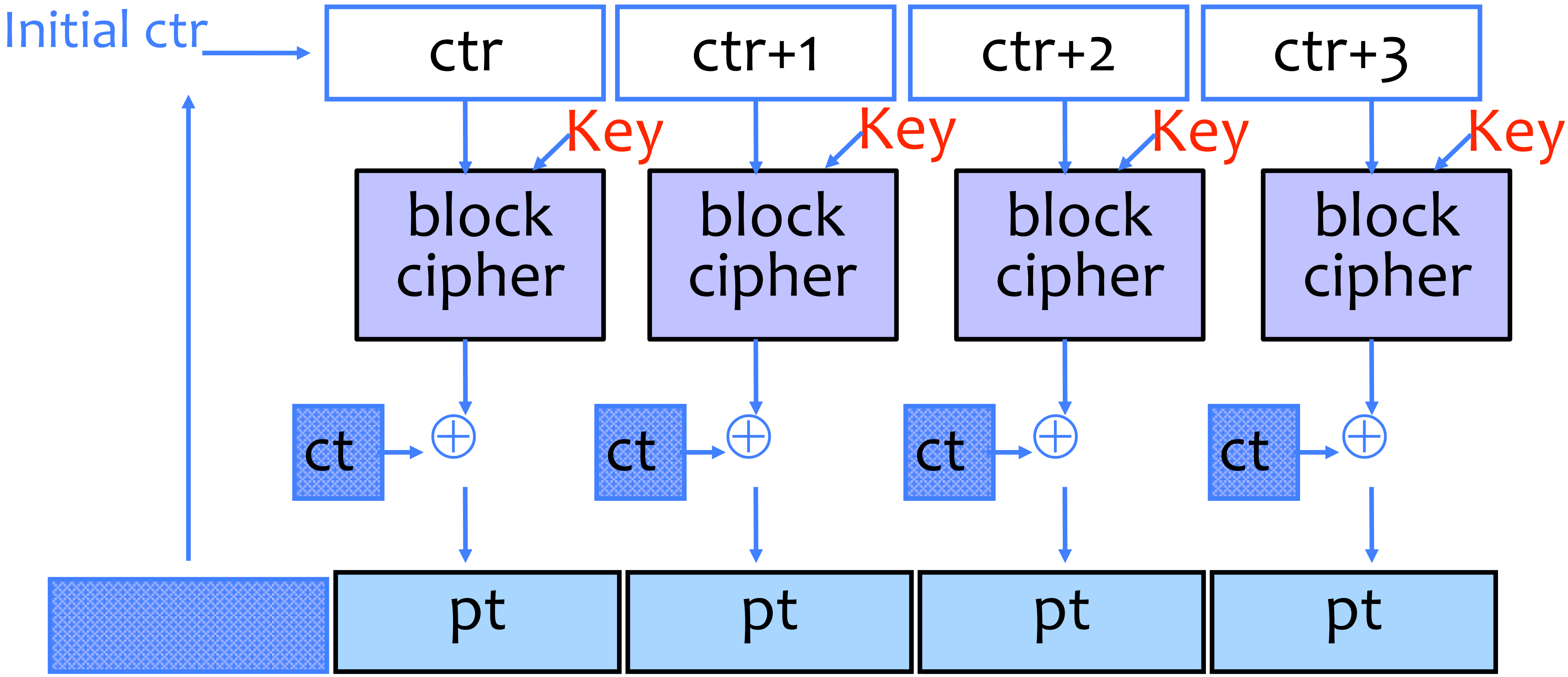
```
DesCBCEncrypt((des_c_block*)tmp, (des_c_block*)record.m_Data,
              totalSize, DESKEY, NULL, DES_ENCRYPT)
```

Counter Mode (CTR): Encryption



- Identical blocks of plaintext encrypted differently
- Still does not guarantee integrity; Fragile if ctr repeats

Counter Mode (CTR): Decryption



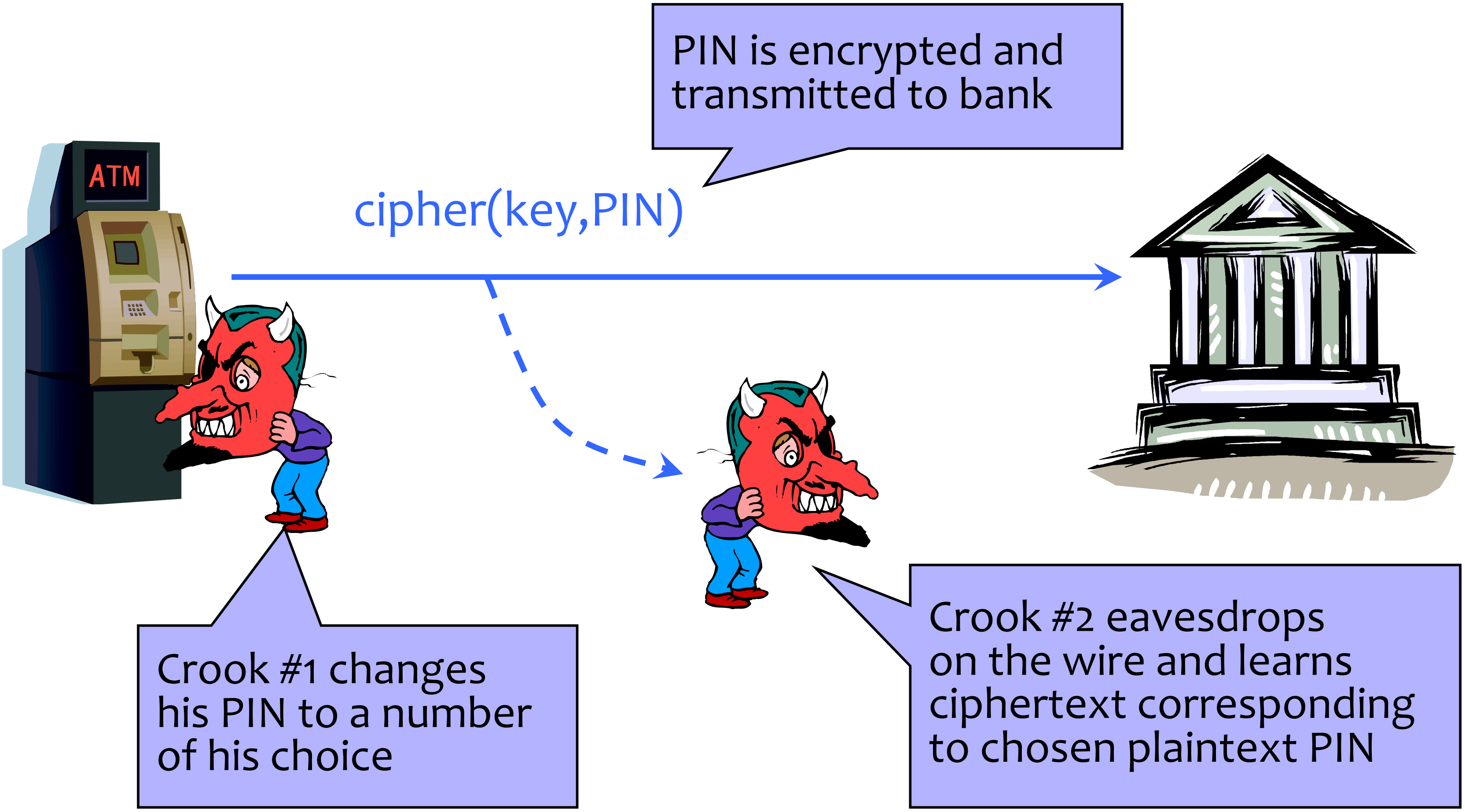
When is an Encryption Scheme "Secure"?

- Hard to recover the key?
  - What if attacker can learn plaintext without learning the key?
- Hard to recover plaintext from ciphertext?
  - What if attacker learns some bits or some function of bits?

How Can a Cipher Be Attacked?

- Attackers knows ciphertext and encryption algthm
  - What else does the attacker know? Depends on the application in which the cipher is used!
- Ciphertext-only attack
- KPA: Known-plaintext attack (stronger)
  - Knows some plaintext-ciphertext pairs
- CPA: Chosen-plaintext attack (even stronger)
  - Can obtain ciphertext for any plaintext of his choice
- CCA: Chosen-ciphertext attack (very strong)
  - Can decrypt any ciphertext except the target

Chosen Plaintext Attack



PIN is encrypted and transmitted to bank

cipher(key,PIN)

Crook #1 changes his PIN to a number of his choice

Crook #2 eavesdrops on the wire and learns ciphertext corresponding to chosen plaintext PIN

… repeat for any PIN value

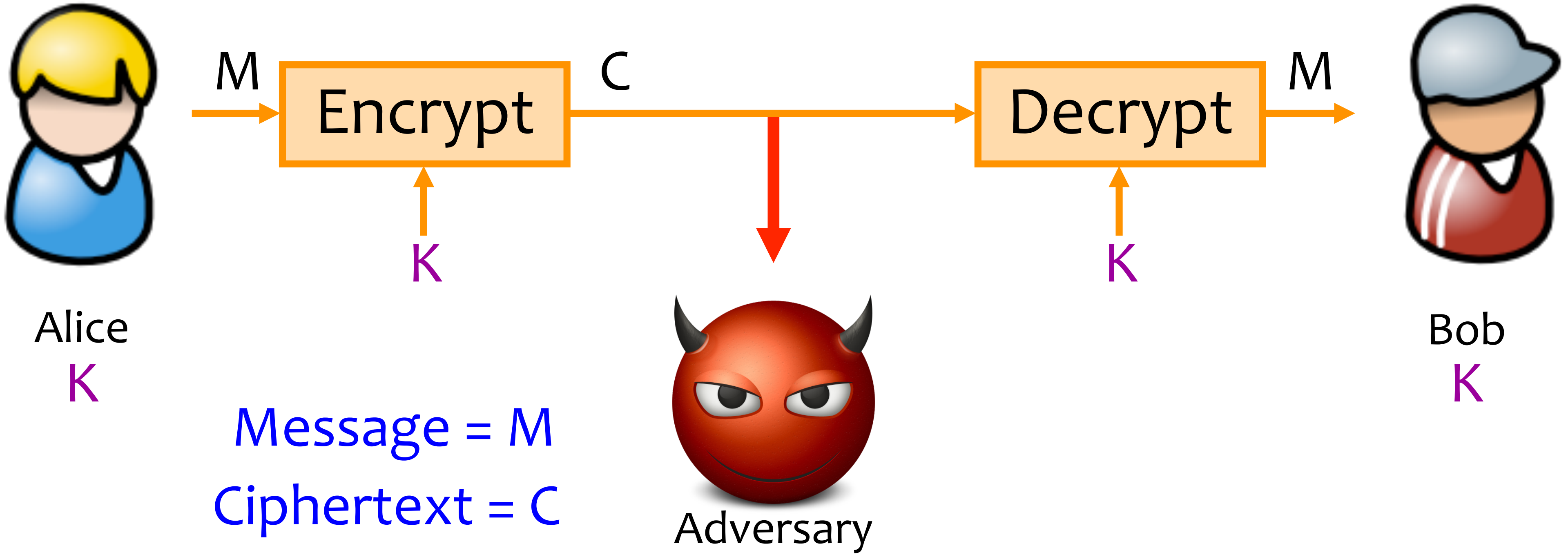
Very Informal Intuition

Minimum security requirement for a modern encryption scheme

- Security against chosen-plaintext attack (CPA)
  - Ciphertext leaks no information about the plaintext
  - Even if the attacker correctly guesses the plaintext, he cannot verify his guess
  - Every ciphertext is unique, encrypting same message twice produces completely different ciphertexts
    - Implication: encryption must be randomized or stateful
- Security against chosen-ciphertext attack (CCA)
  - Integrity protection – it is not possible to change the plaintext by modifying the ciphertext

So Far: Achieving Privacy

Encryption schemes: A tool for protecting privacy.



M

Encrypt

C

Decrypt

M

K

K

Alice

K

Bob

K

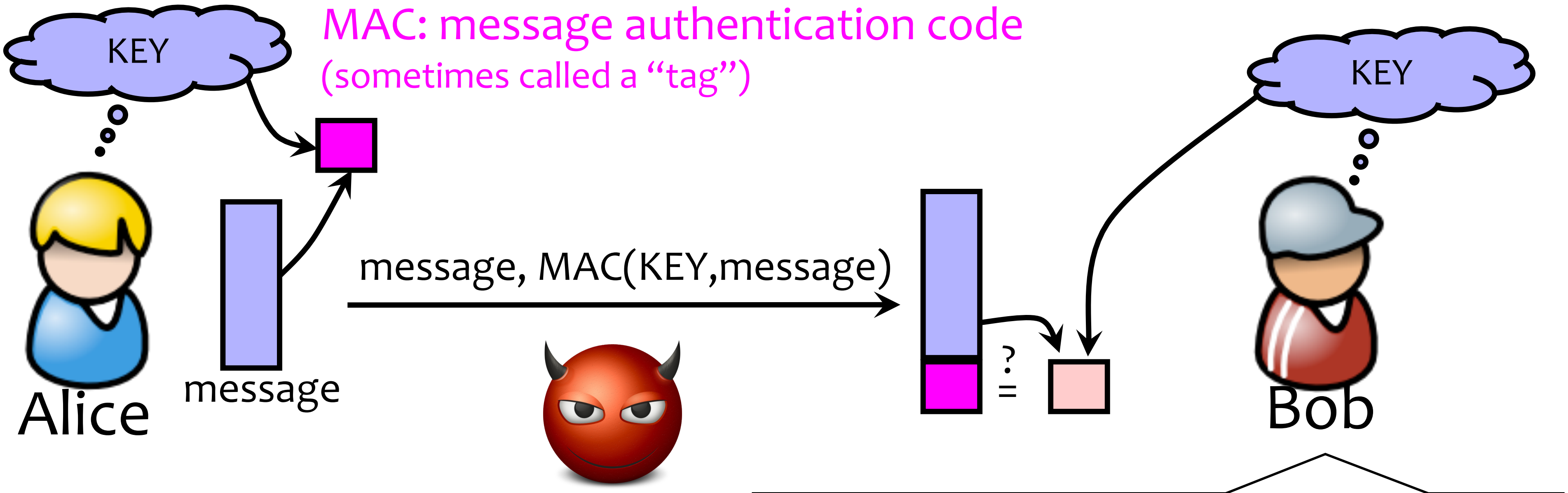
Adversary

Message = M

Ciphertext = C

Now: Achieving Integrity

Message authentication schemes: A tool for protecting integrity.



MAC: message authentication code
(sometimes called a "tag")

Recomputes MAC and verifies whether it is equal to the MAC attached to the message

Integrity and authentication: only someone who knows KEY can compute correct MAC for a given message.