CSE 484 / CSE M 584: Computer Security and Privacy

Cryptography: Symmetric Encryption [continued]

Fall 2016

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Thanks to Franzi Roesner, Dan Boneh, Dieter Gollmann, Dan Halperin, Yoshi Kohno, John Manferdelli, John Mitchell, Vitaly Shmatikov, Bennet Yee, and many others for sample slides and materials ...

Announcements

- Homework 2 (on crypto) will be out early next week.

Participatory Security Mindset Anecdote

- Cyberwarfare class gave an unfair exam on short notice:

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- "You may cheat on this exam."

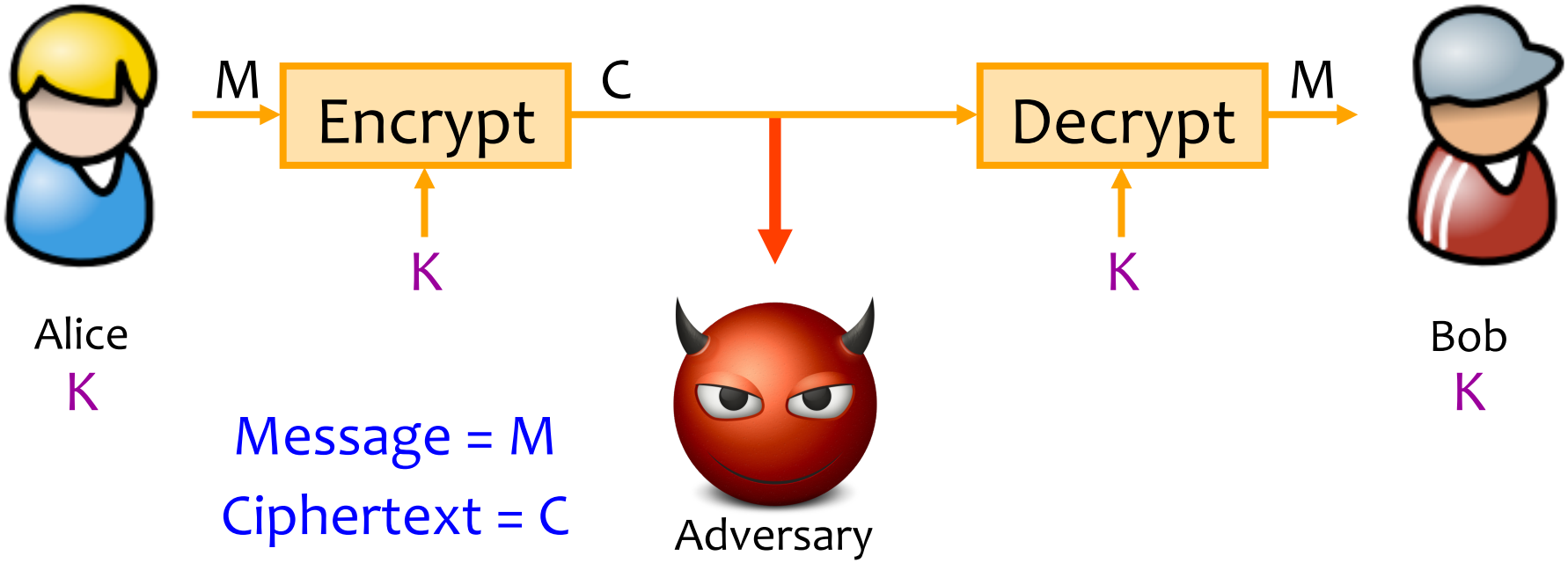
My favorites

- Write 100 digits of pi on a piece of paper *before the exam.* Turn it in.

- Write 3.1415926535 followed by 90 random digits. Turn it in, assuming graders too lazy to check past the first 10 digits

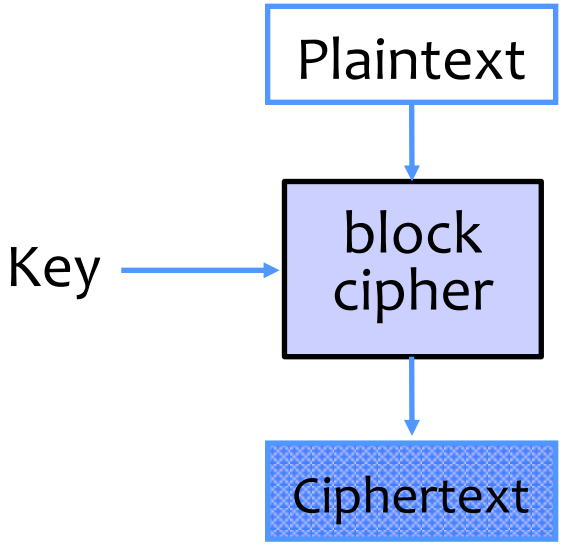
Achieving Privacy (Symmetric)

Encryption schemes: A tool for protecting privacy.

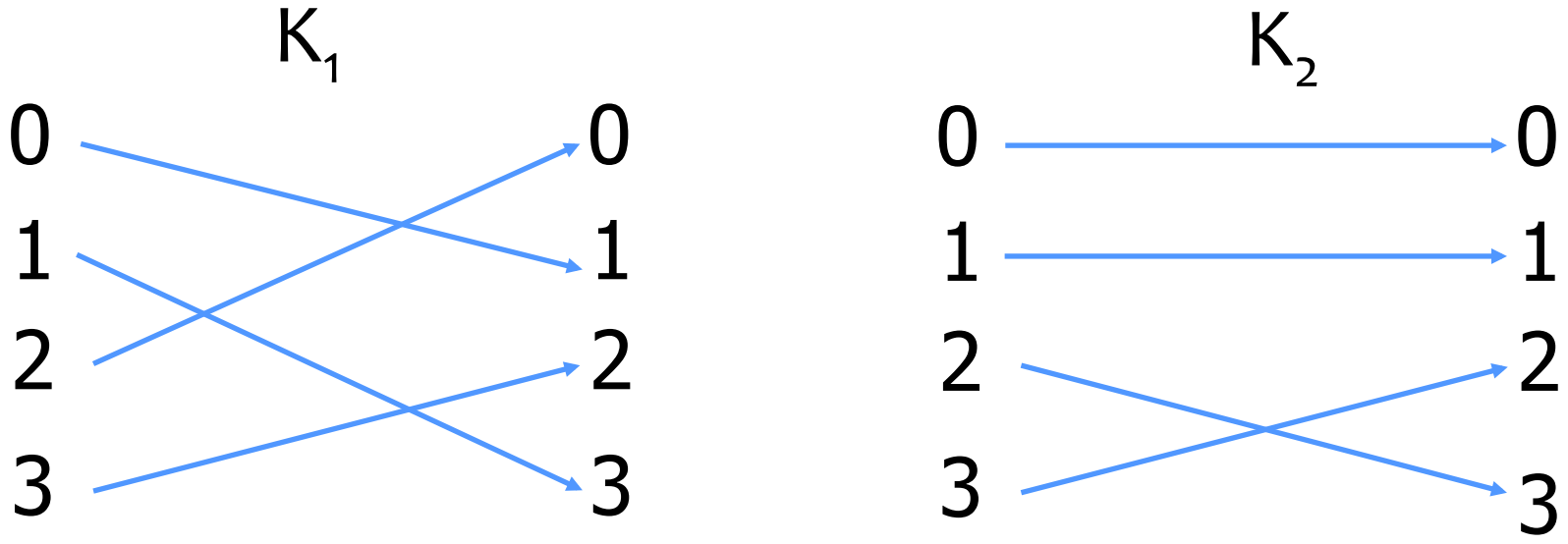


Block Ciphers

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

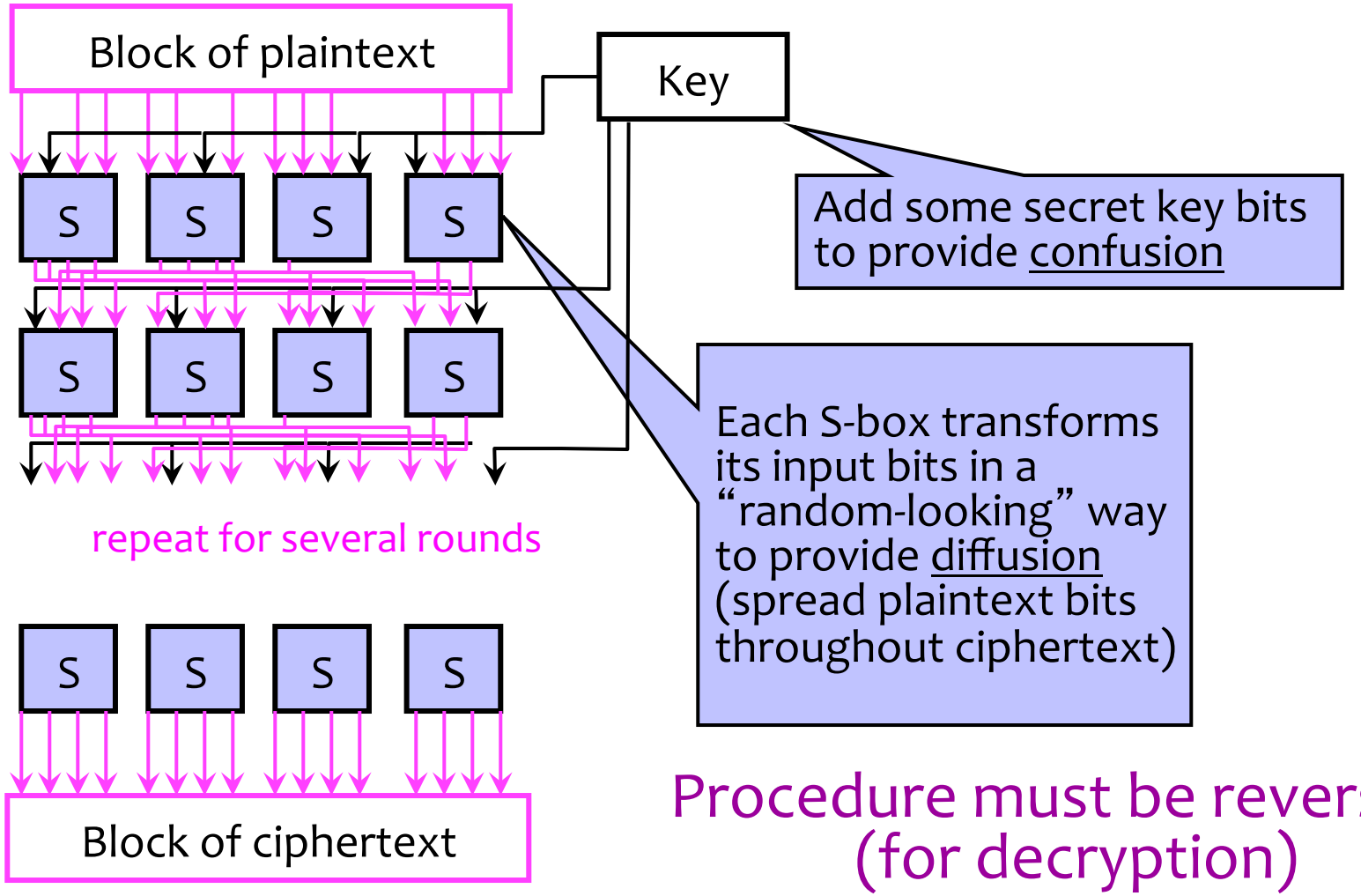


Permutations



- For N-bit input, $2^N!$ possible permutations
- Time and cost of breaking the cipher exceed the value and/or useful lifetime of protected information

Block Cipher Operation (Simplified)



Procedure must be reversible (for decryption)

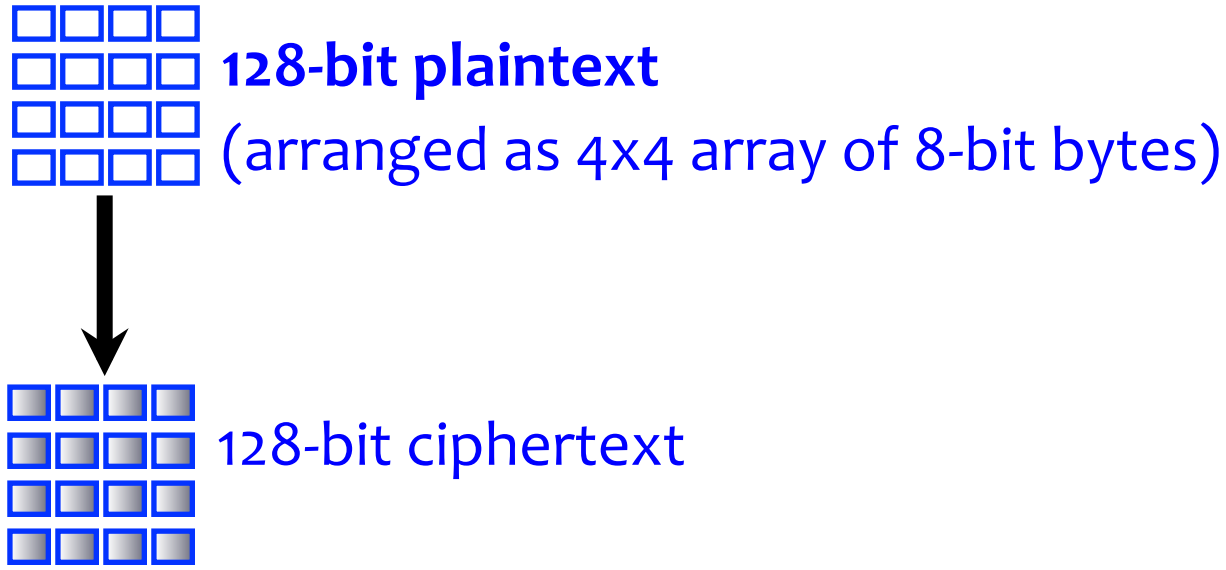
Standard Block Ciphers

- **DES: Data Encryption Standard**
  - Feistel structure: builds invertible function using non-invertible ones
  - Invented by IBM, issued as federal standard in 1977
  - 64-bit blocks, 56-bit key + 8 bits for parity

- **AES: Advanced Encryption Standard**
  - New federal standard as of 2001
    - NIST: National Institute of Standards & Technology
  - Based on the Rijndael algorithm
    - Selected via an open process
  - 128-bit blocks, keys can be 128, 192 or 256 bits

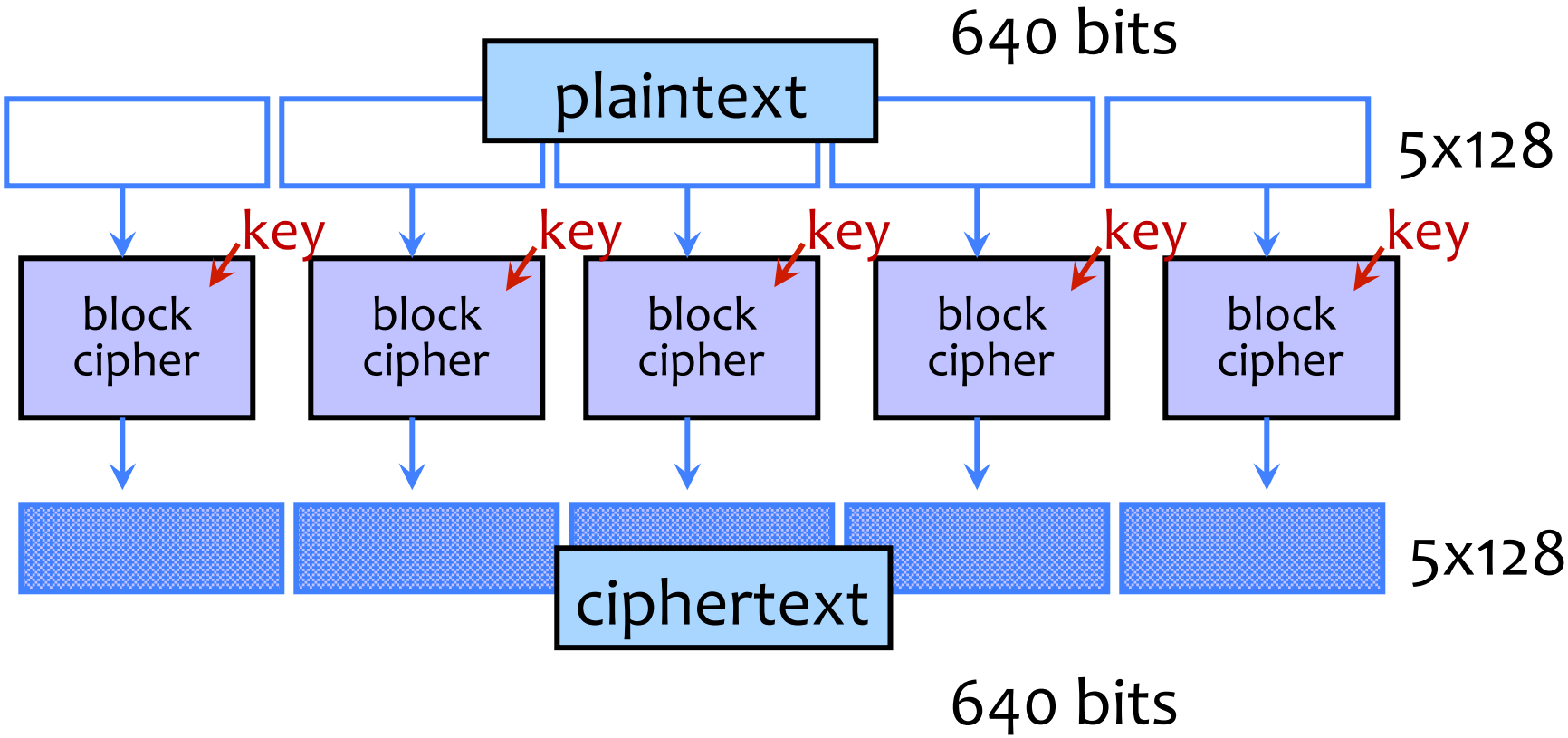
Encrypting a Large Message with AES

- 128-bit block size, but plaintext is longer.

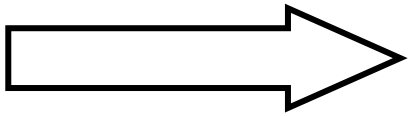


- What should we do?

Electronic Code Book (ECB) Mode



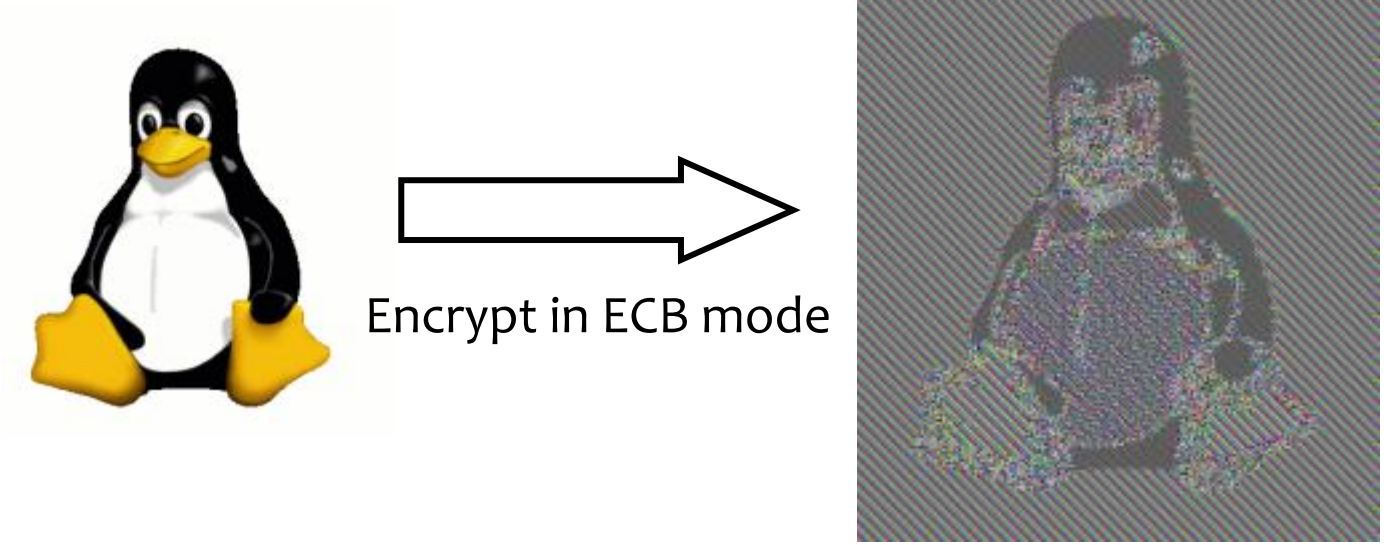
Information Leakage in ECB Mode



Encrypt in ECB mode

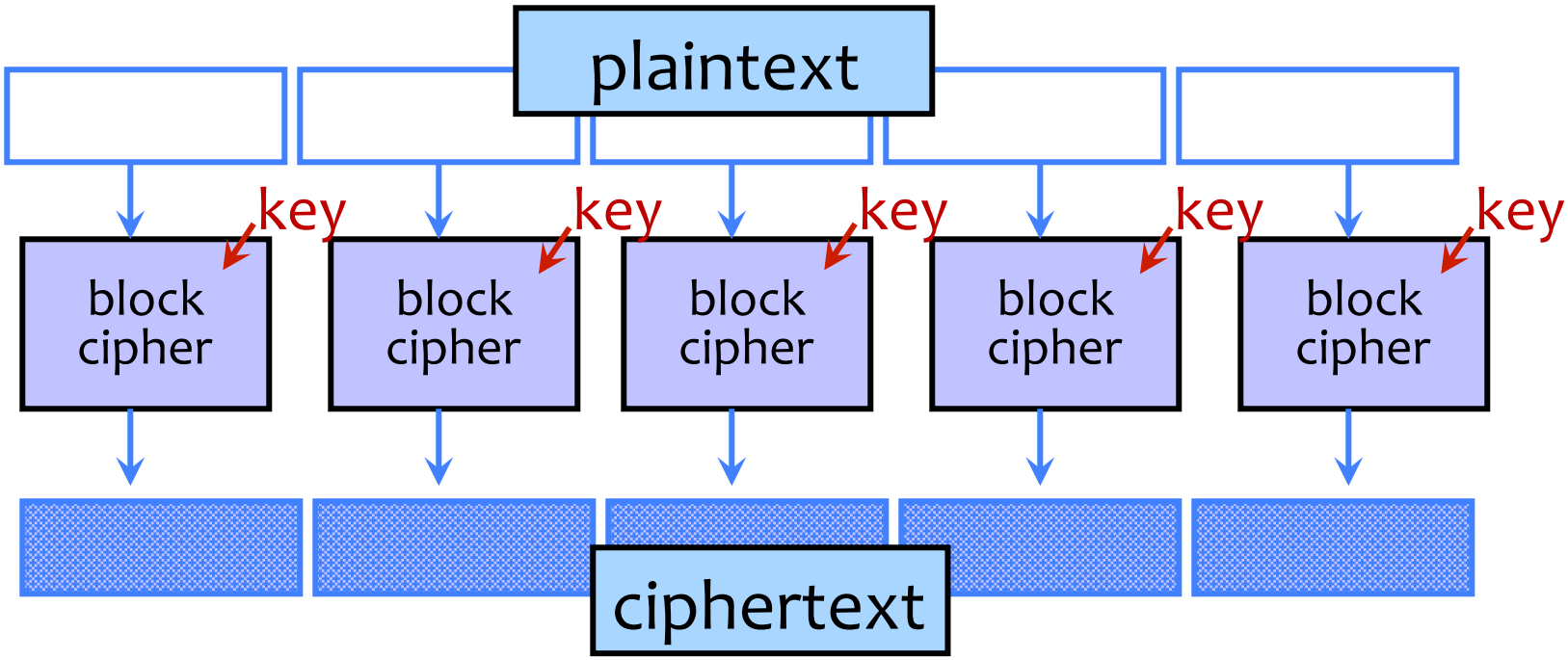
[Wikipedia]

Information Leakage in ECB Mode



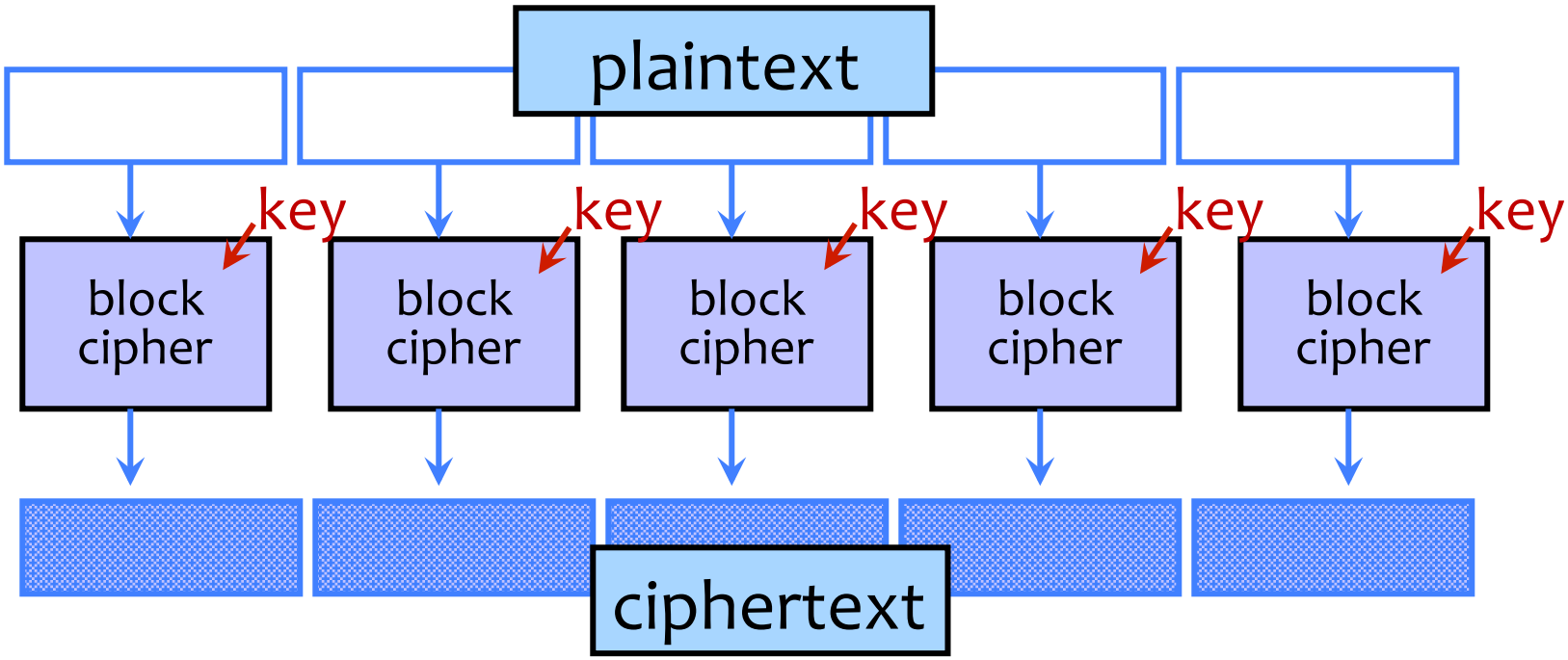
[Wikipedia]

Electronic Code Book (ECB) Mode

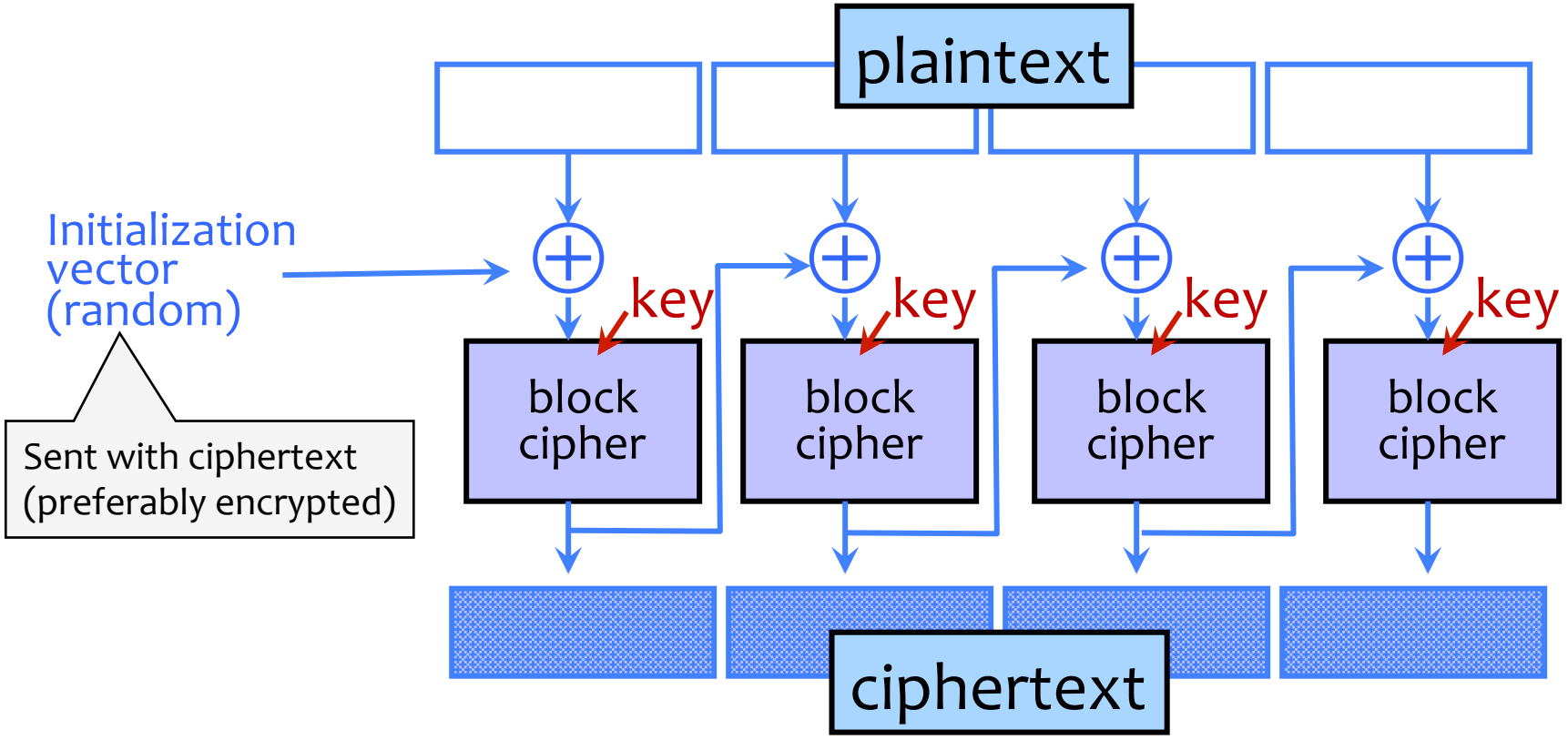


- Identical blocks of plaintext produce identical blocks of ciphertext
- No integrity checks: can mix and match blocks

Cipher Block Chaining (CBC) Mode

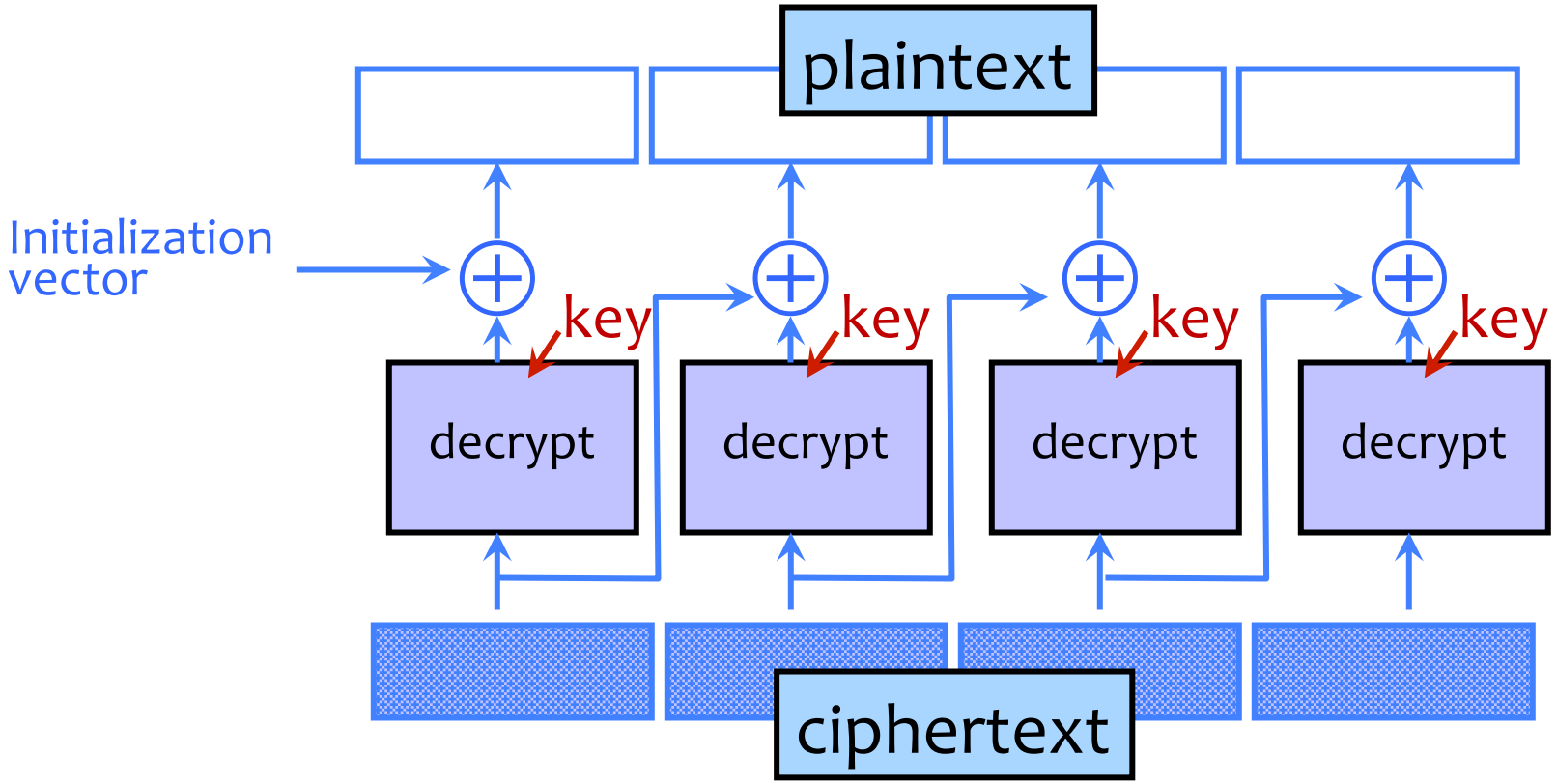


Cipher Block Chaining (CBC) Mode: Encryption

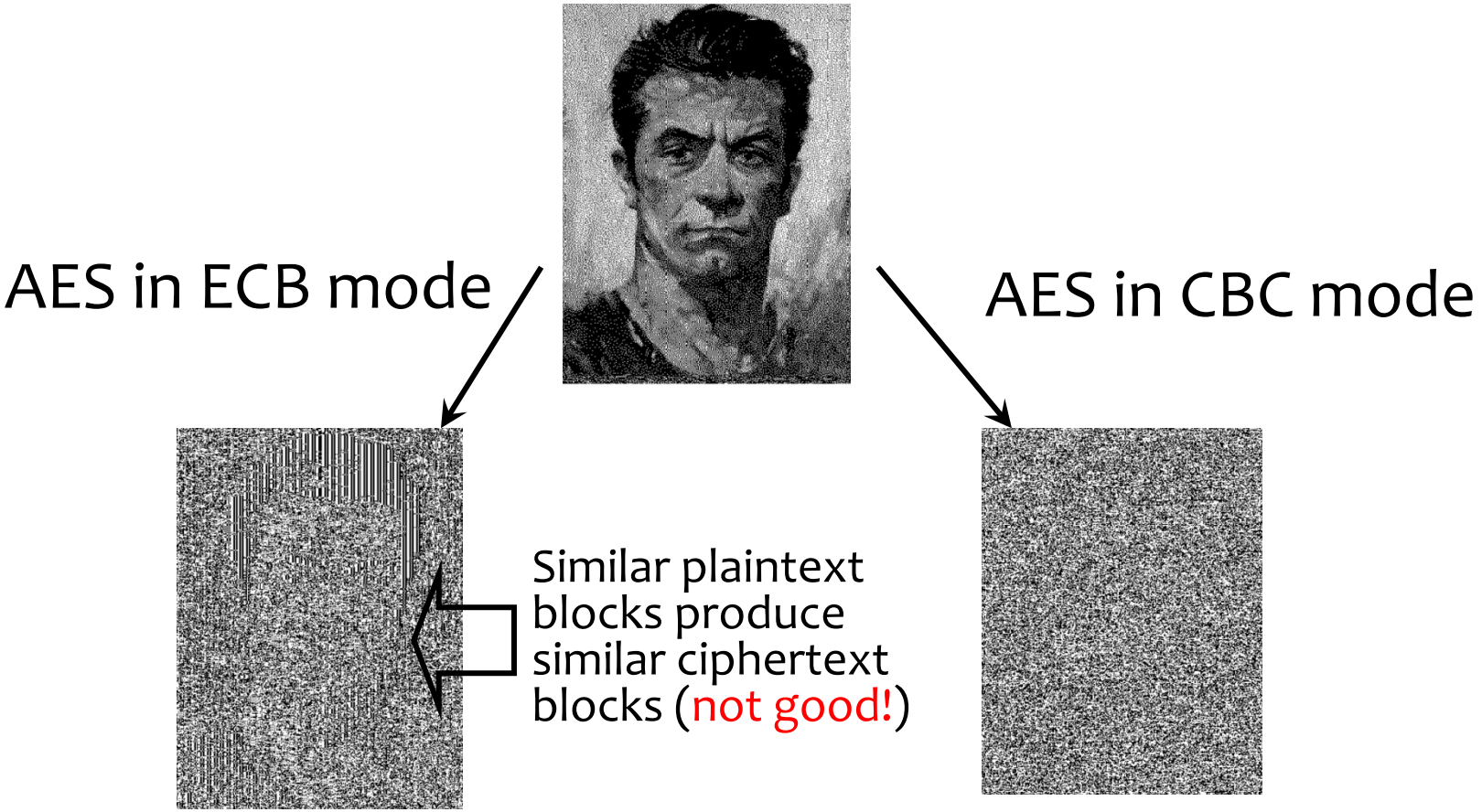


- Identical blocks of plaintext encrypted differently
- Last cipherblock depends on entire plaintext
  - Still does not guarantee integrity

CBC Mode: Decryption

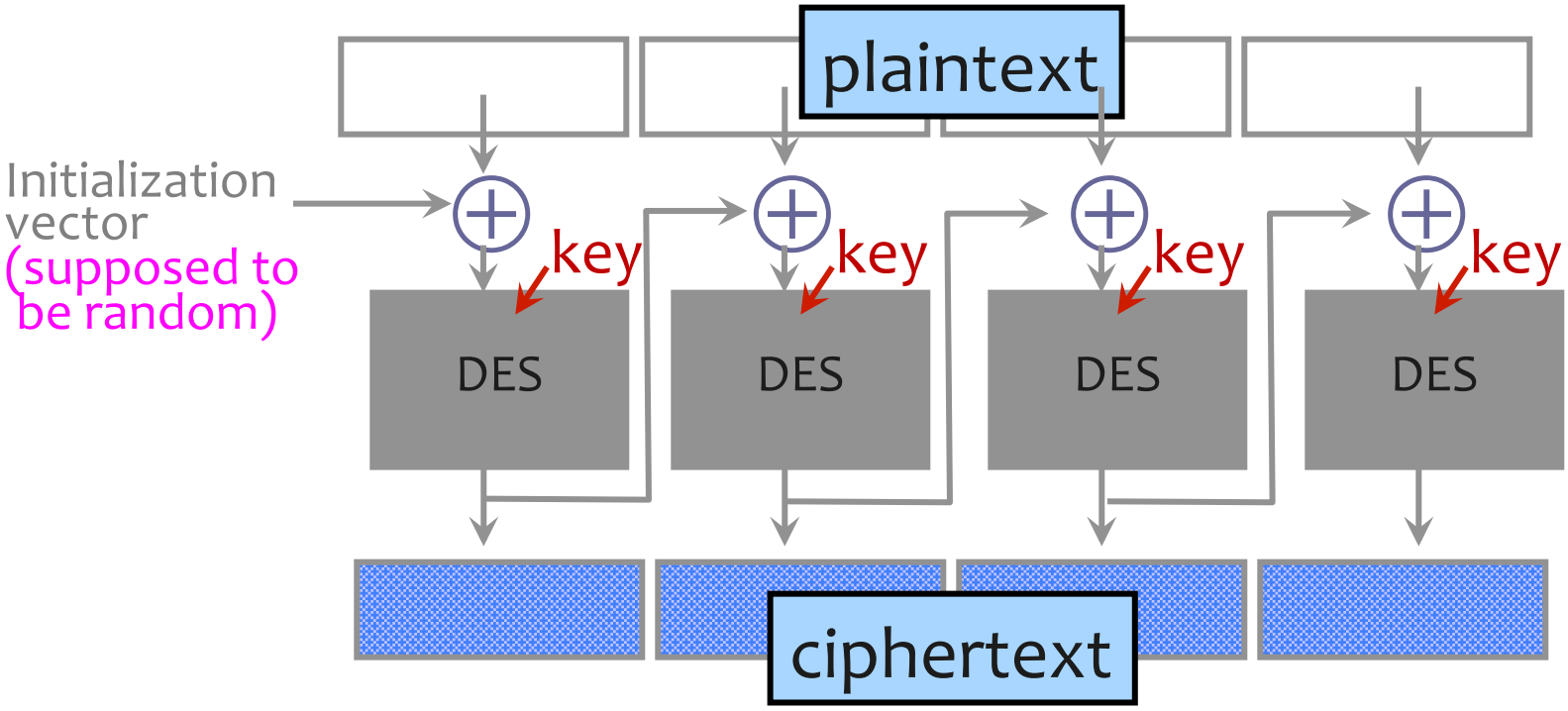


ECB vs. CBC



[Picture due to Bart Preneel]

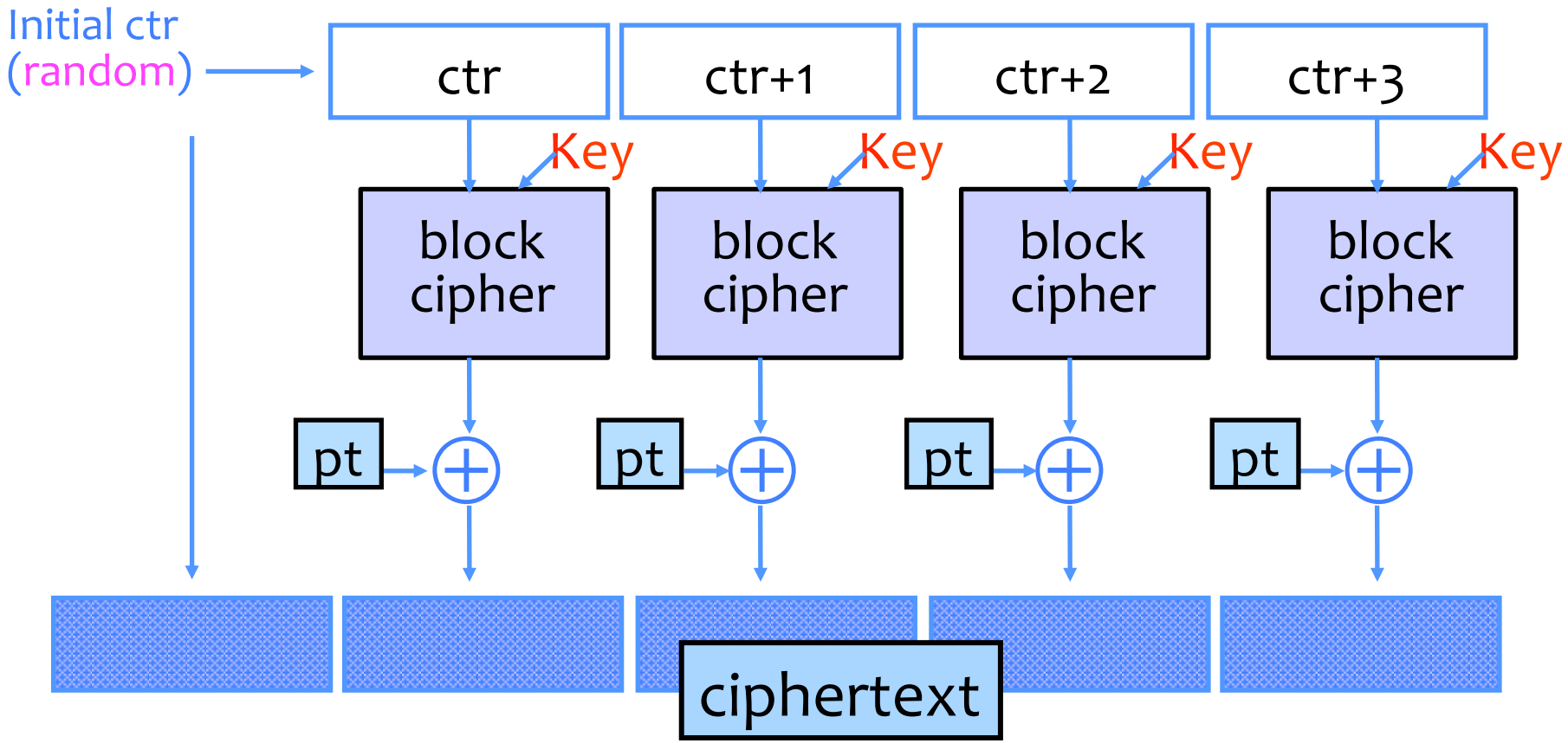
CBC and Electronic Voting



Found in the source code for Diebold voting machines:

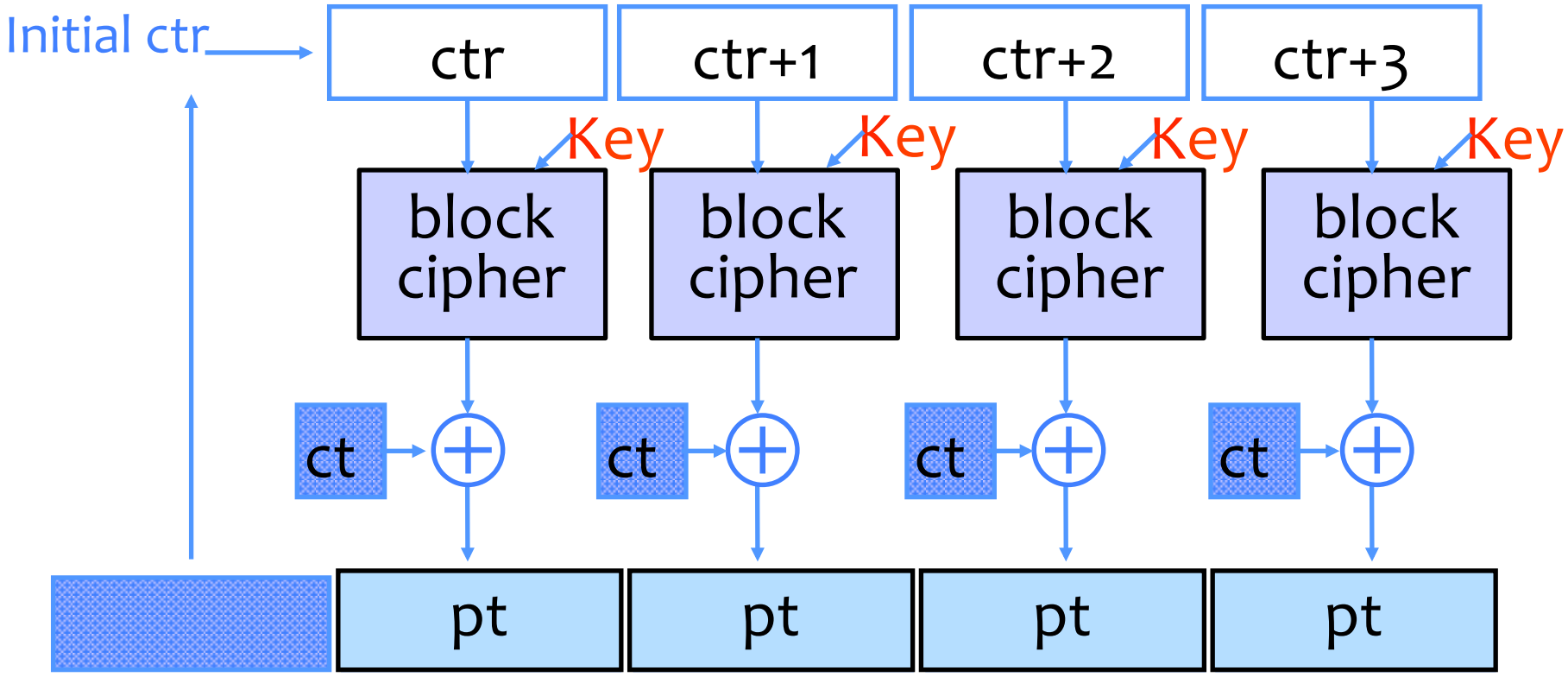
```
DesCBCEncrypt((des_c_block*)tmp, (des_c_block*)record.m_Data,
        totalSize, DESKEY, NULL, DES_ENCRYPT)
```

Counter Mode (CTR): Encryption



- Identical blocks of plaintext encrypted differently
- Can compute in parallel (unlike CBC)
- Still does not guarantee integrity; Fragile if ctr repeats

Counter Mode (CTR): Decryption



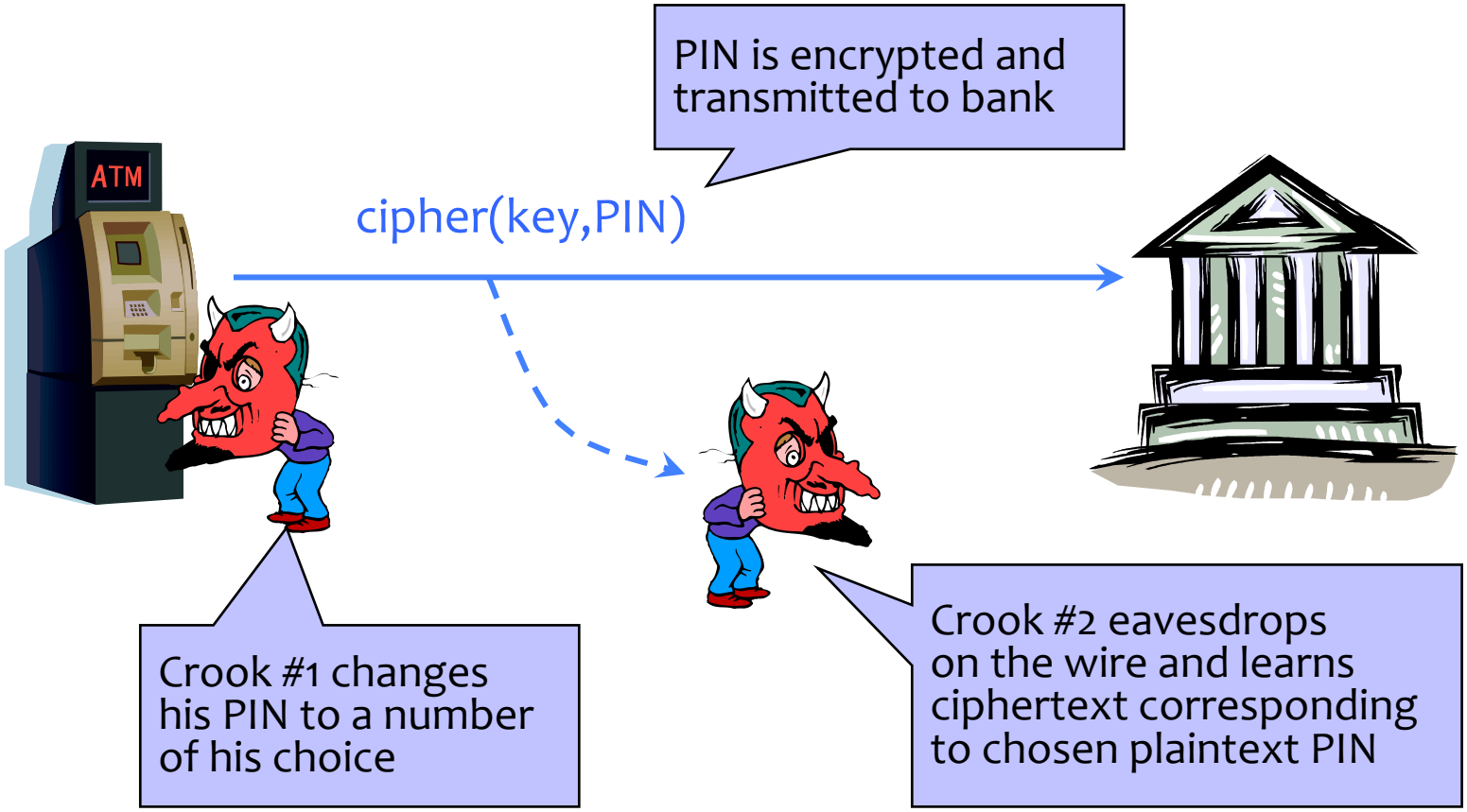
When is an Encryption Scheme "Secure"?

- 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?
- Fixed mapping from plaintexts to ciphertexts?
  - What if attacker sees two identical ciphertexts and infers that the corresponding plaintexts are identical?
  - Implication: encryption must be randomized or stateful

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



… 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
- Security against chosen-ciphertext attack (CCA)
  - Integrity protection – it is not possible to change the plaintext by modifying the ciphertext