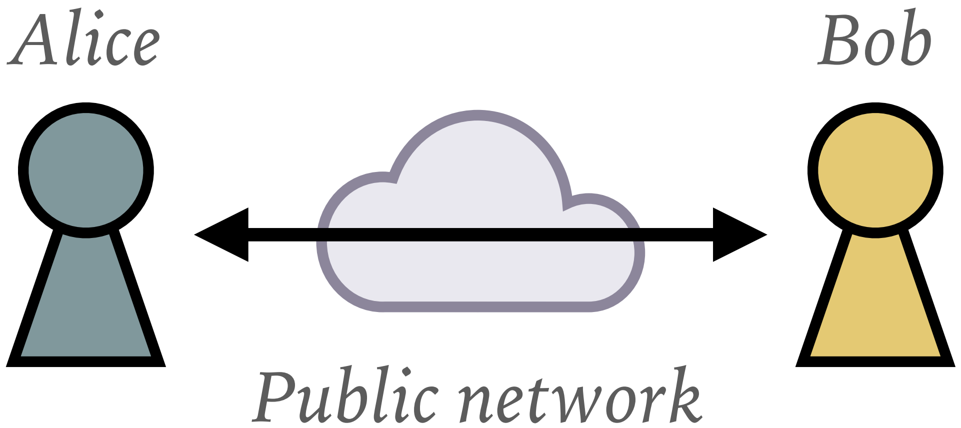
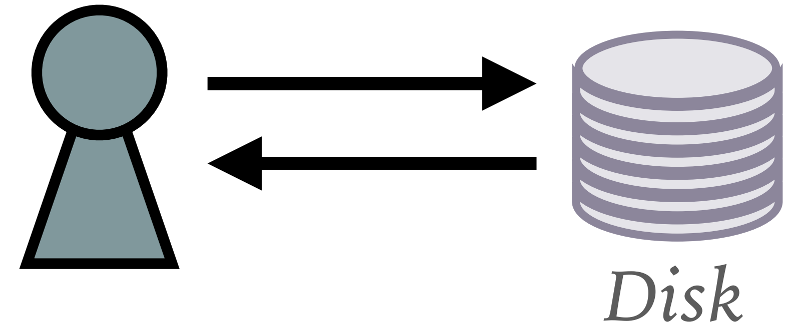
CRYPTOGRAPHY INTRO

GRAD SEC

OCT 17 2017

SCENARIOS AND GOALS





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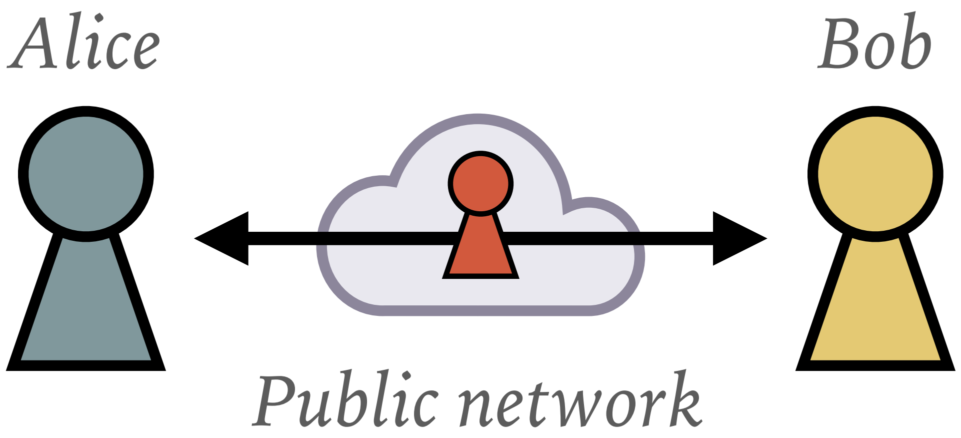

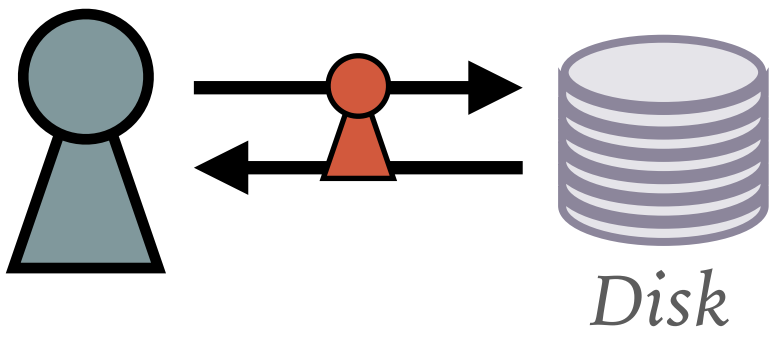

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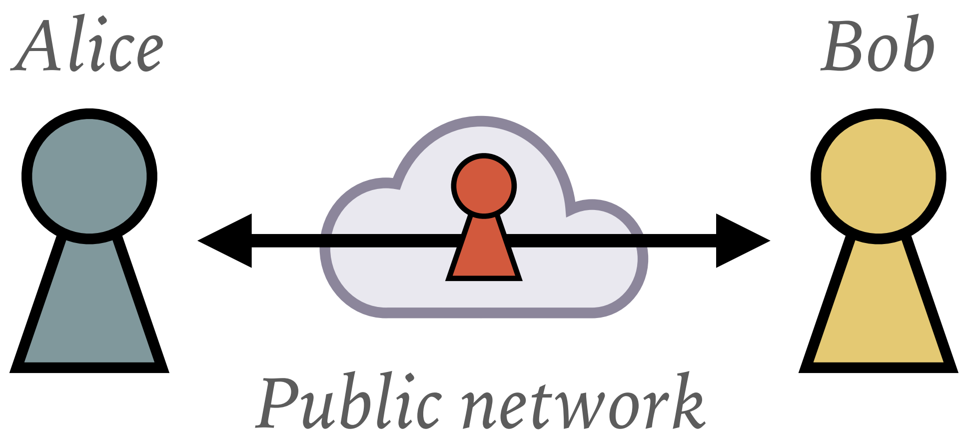
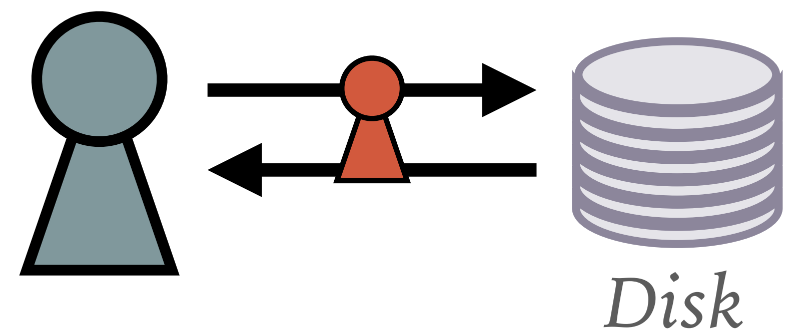


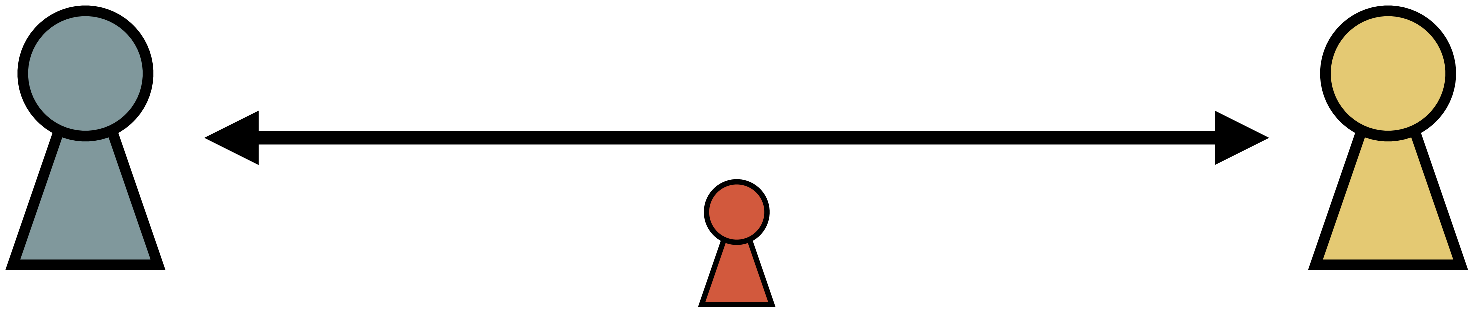


CONFIDENTIALITY Keep others from reading Alice's messages / data

INTEGRITY Keep others from undetectably tampering with Alice's messages / data

AUTHENTICITY Keep others from undetectably impersonating Alice (keep her to her word, too)

RANDOMNESS



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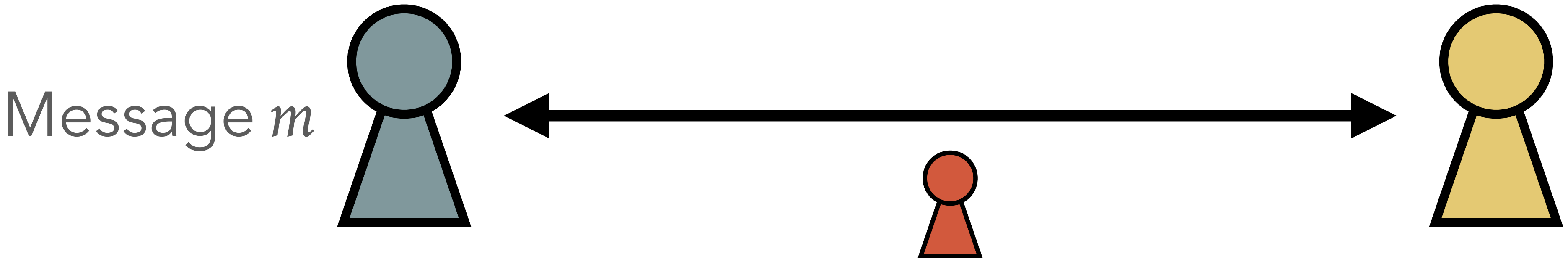

RANDOMNESS

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Message m
Something that leaks
no information about m
Original m

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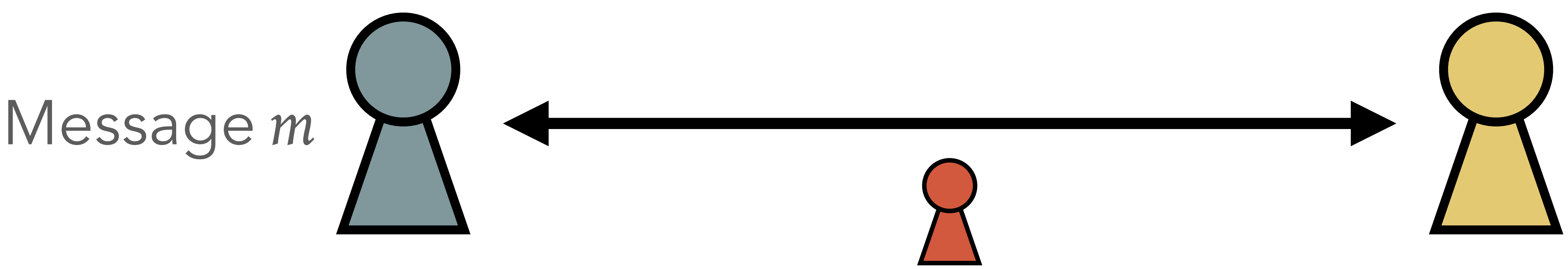
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RANDOMNESS


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Original m


<m, unpredictable 'tag'>
Message m

RANDOMNESS


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Message m
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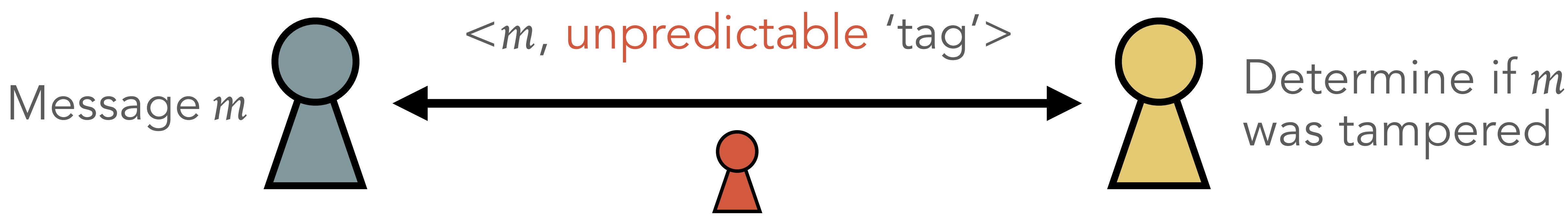
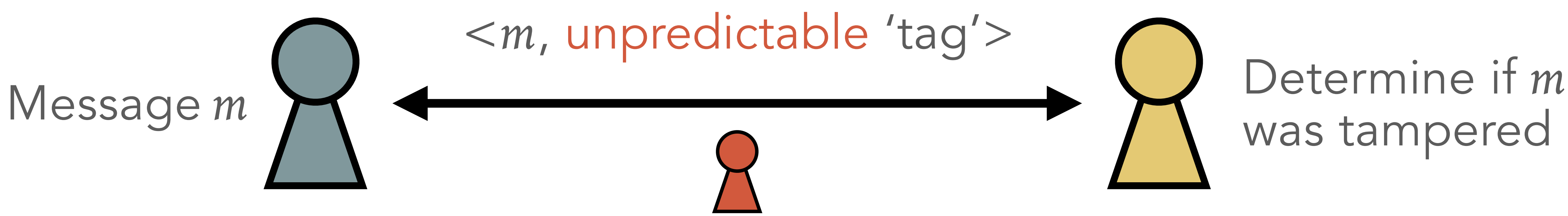

<m, unpredictable ‘tag’>
Message m
Determine if m
was tampered

RANDOMNESS



Ideally, to the attacker, it is indistinguishable from a string of bits chosen uniformly at random

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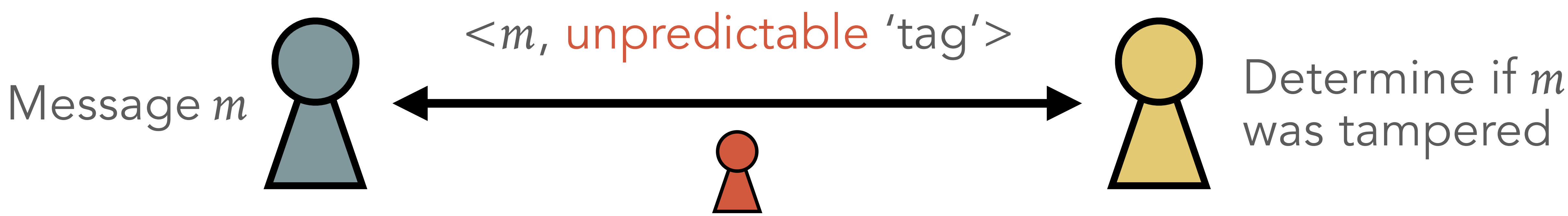

Ideally, to the attacker, it is indistinguishable from a string of bits chosen uniformly at random

This will be impossible with Alice and Bob having a shared secret

WHAT WE IDEALLY HAVE: RANDOM FUNCTIONS

Consider the set of all permutations $f_i : X \to X$

f_1	0	1	2	3	4	…
f_2	1	0	2	3	4	…
$\vdots$						
$f_{\|X\|!}$	7	9	5	1	8	…

Think of X as all
128-bit bit strings

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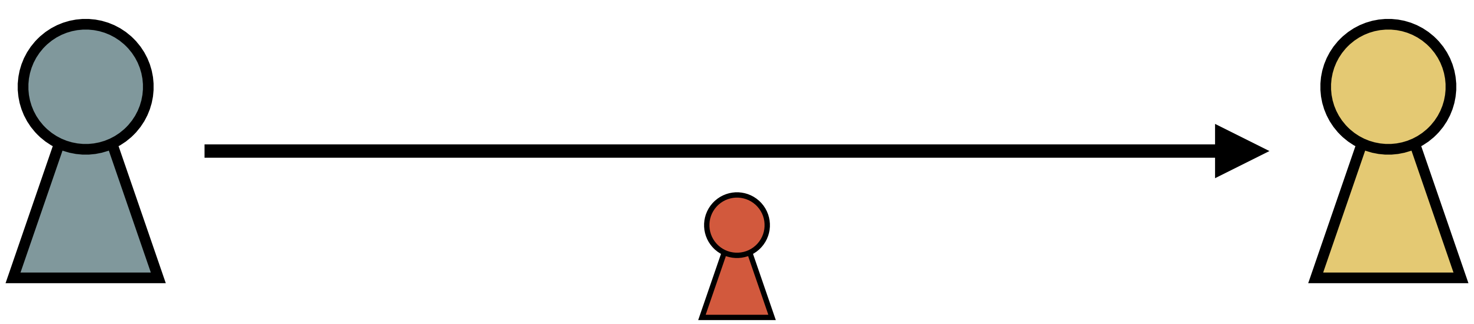

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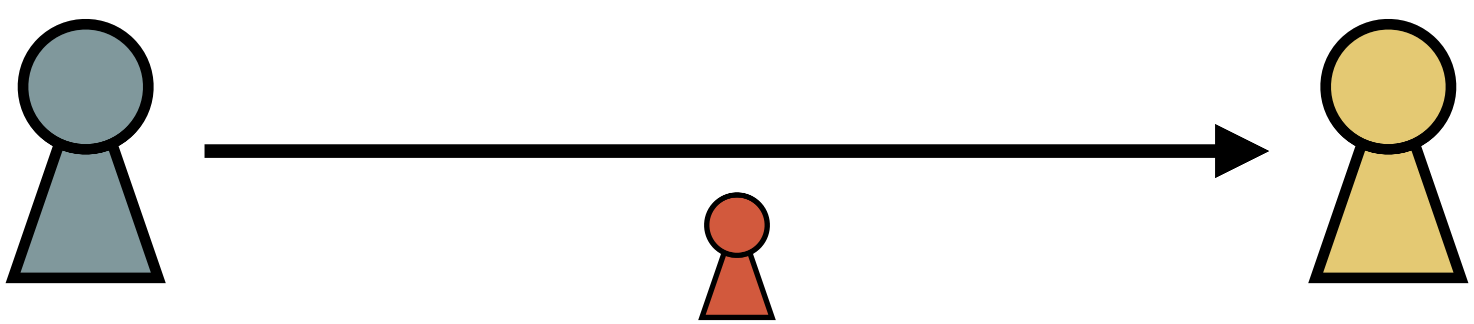
Shared secret: index i chosen u.a.r.



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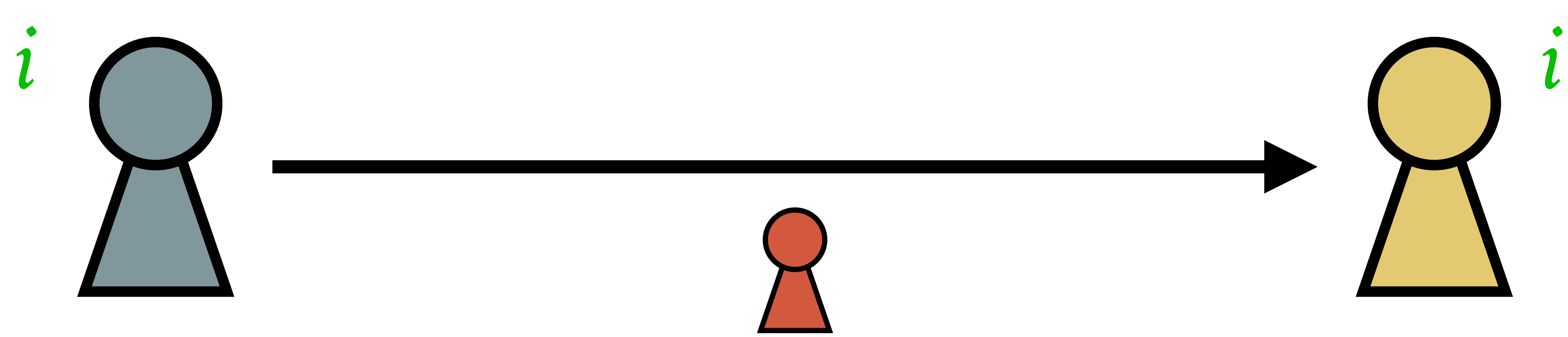

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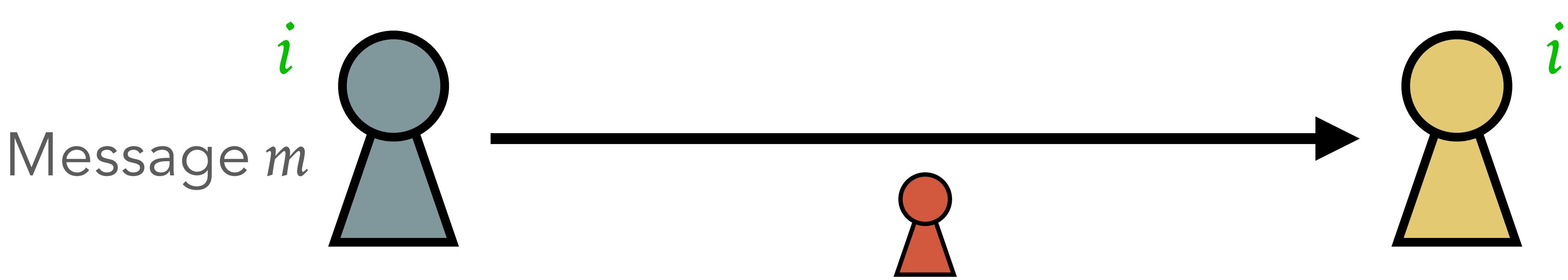

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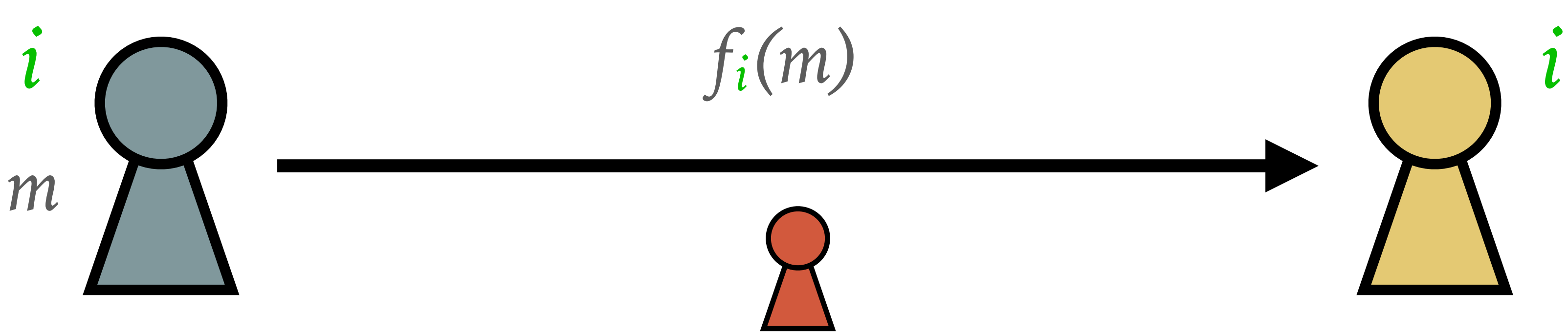
Message m



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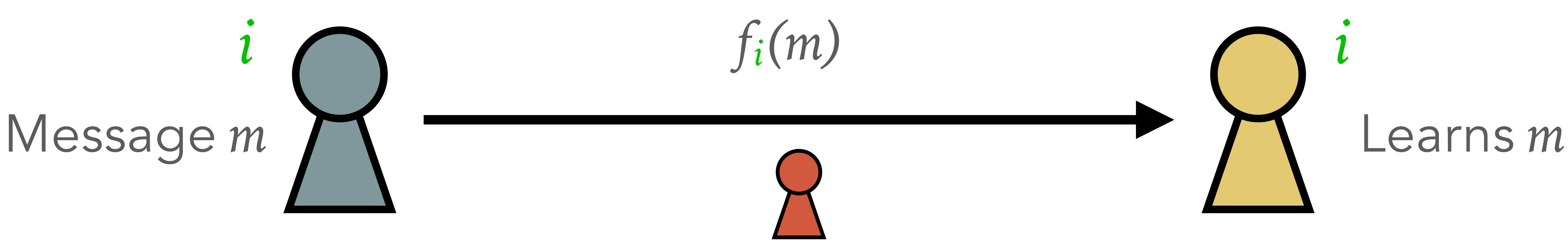

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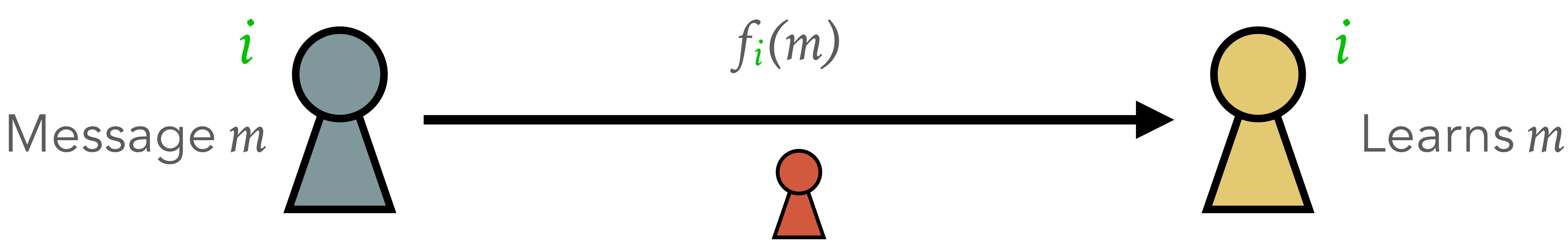

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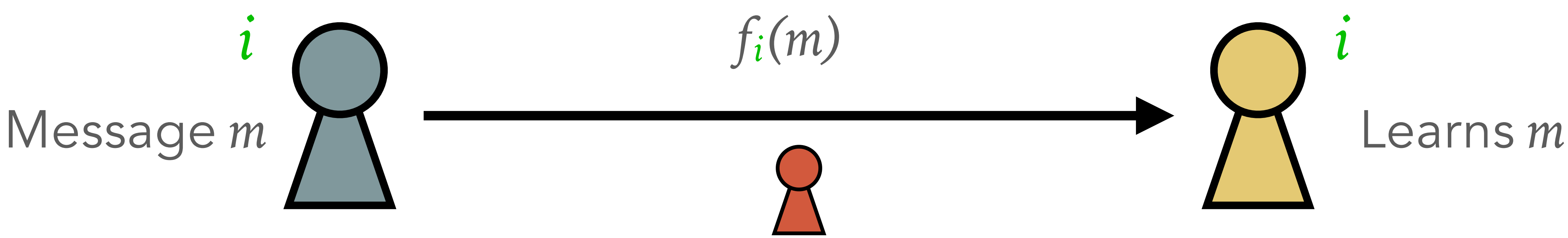

Without knowing i, learns nothing about m

i is our key

WHAT WE IDEALLY HAVE: RANDOM FUNCTIONS

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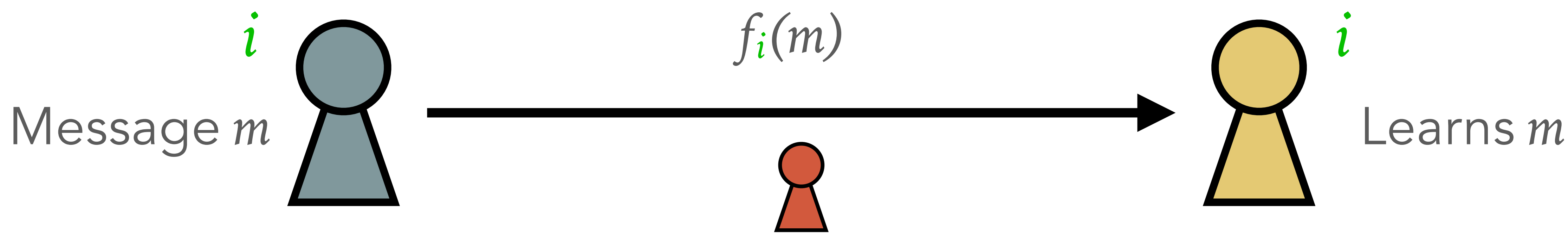

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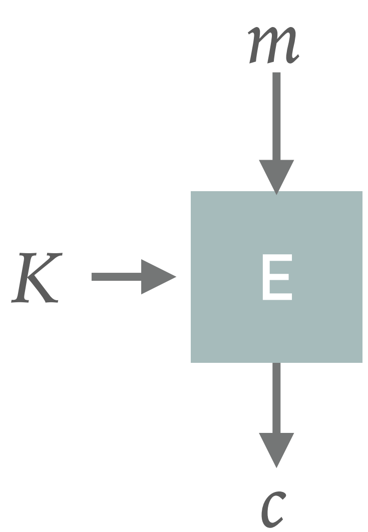
In essence, this protocol is saying "Let's use the i^{th} permutation function"

Infeasible to store all permutation functions

So instead cryptographers construct *pseudorandom functions*

BLACKBOX #1:
BLOCK CIPHERS

BLOCK CIPHERS

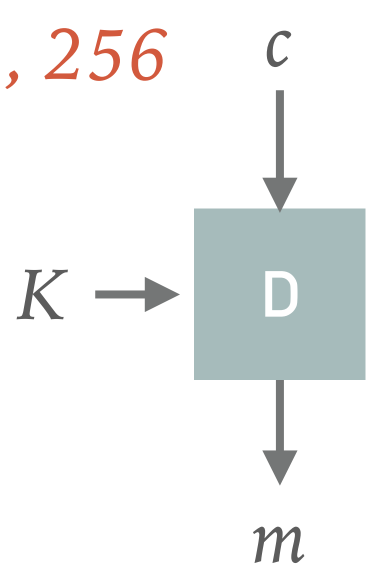


Plaintext

Same fixed block size
(AES: 128 bits)

Ciphertext

AES key sizes:
128, 192, 256



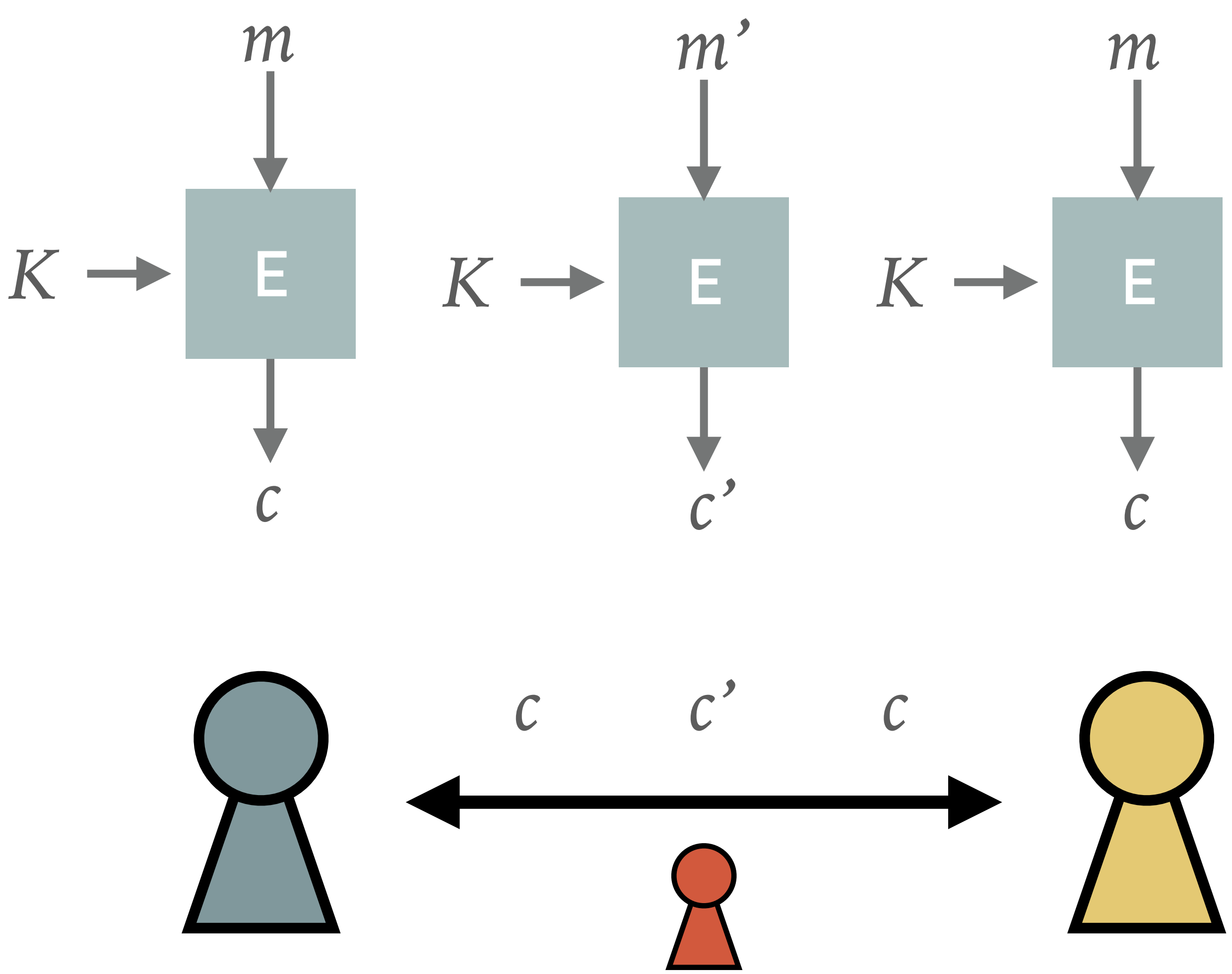
Block ciphers are deterministic

For a given m and K,
E(K,m) always returns the same c

Confusion: *Each bit of the ciphertext should depend on each bit of the key*

Diffusion: *Flipping a bit in m should flip each bit in c with Pr = 1/2*

BLOCK CIPHERS ARE DETERMINISTIC



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An eavesdropper could determine when messages are re-sent

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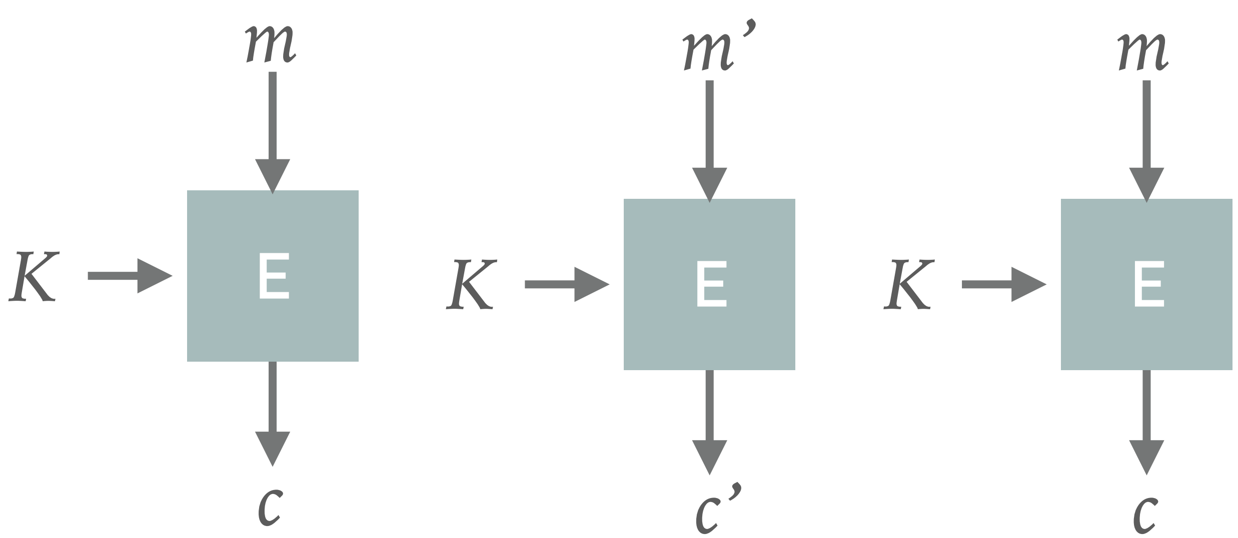

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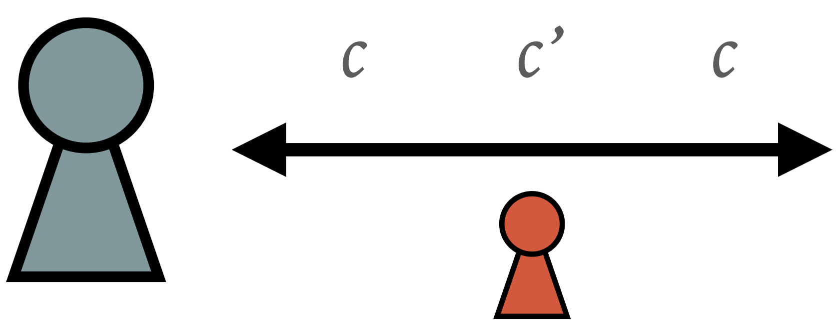
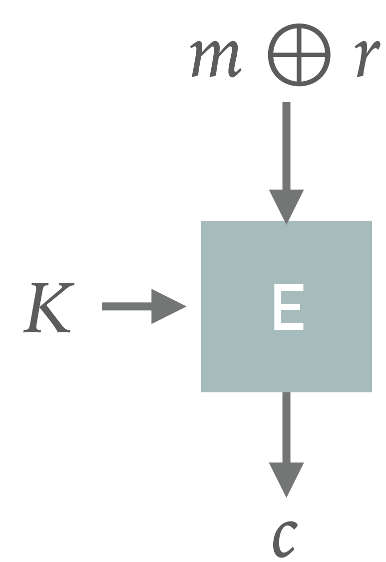


An eavesdropper could determine when messages are re-sent

Choose random r



Send c and r

INITIALIZATION VECTORS

r just needs to be different each time

Random: Must send with the message
Good if messages can be reordered

Counter: Can infer from message number
Good if messages are delivered in-order

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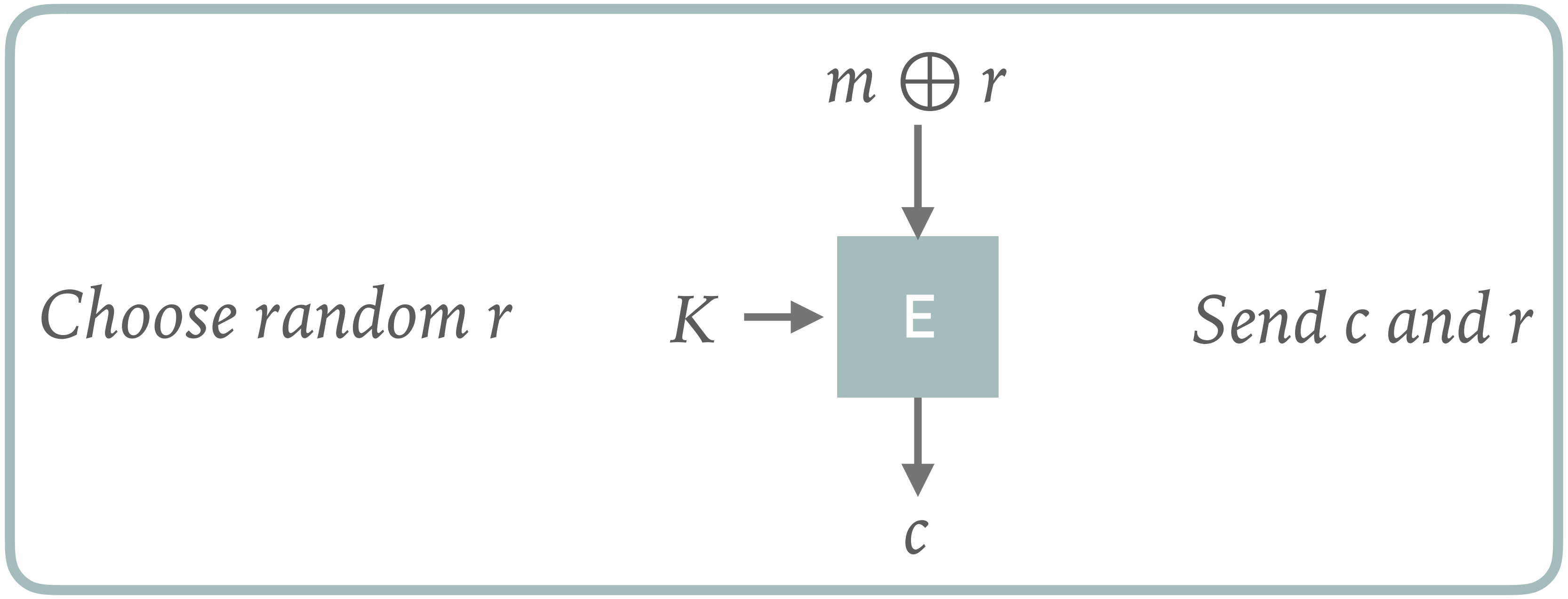

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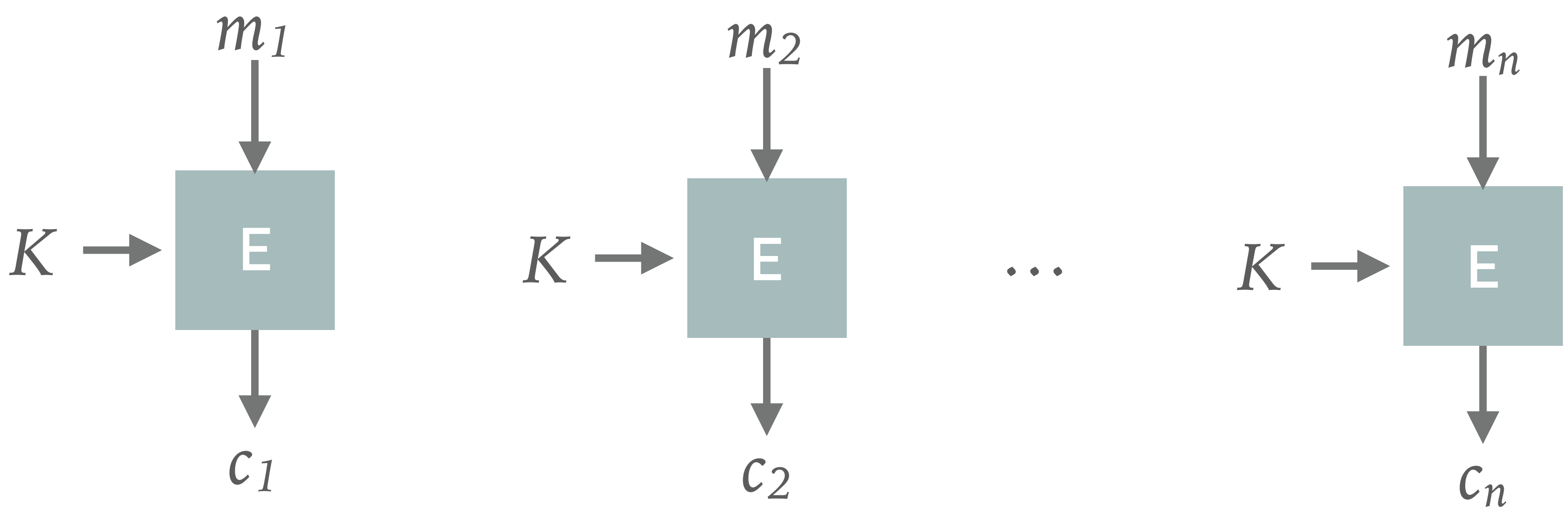
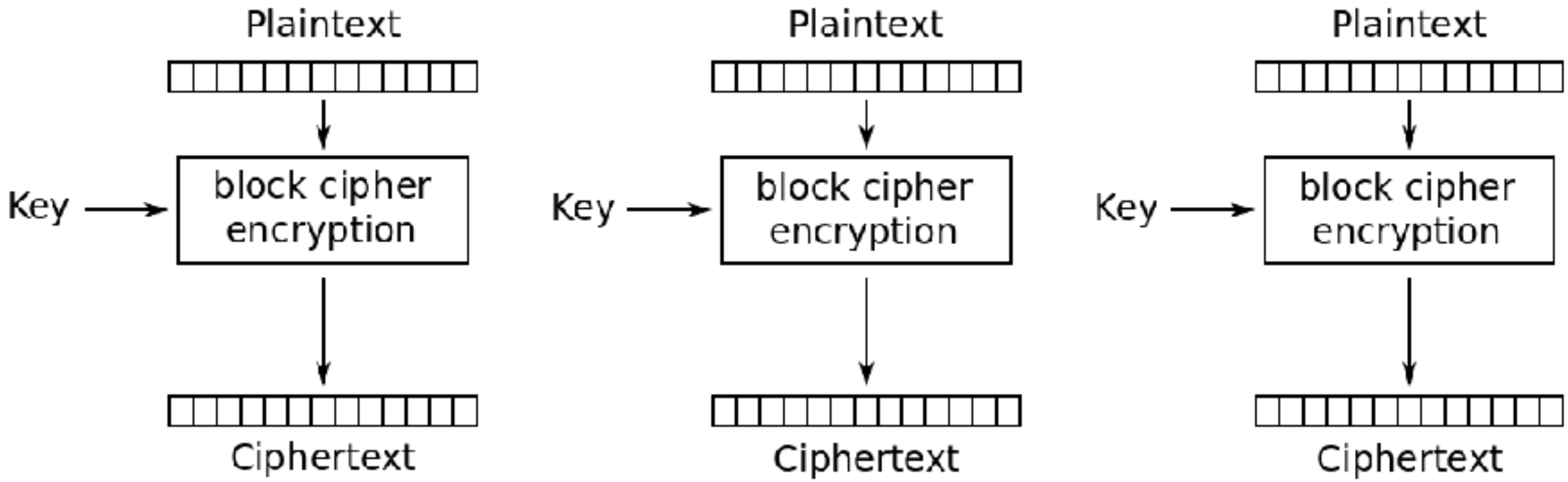
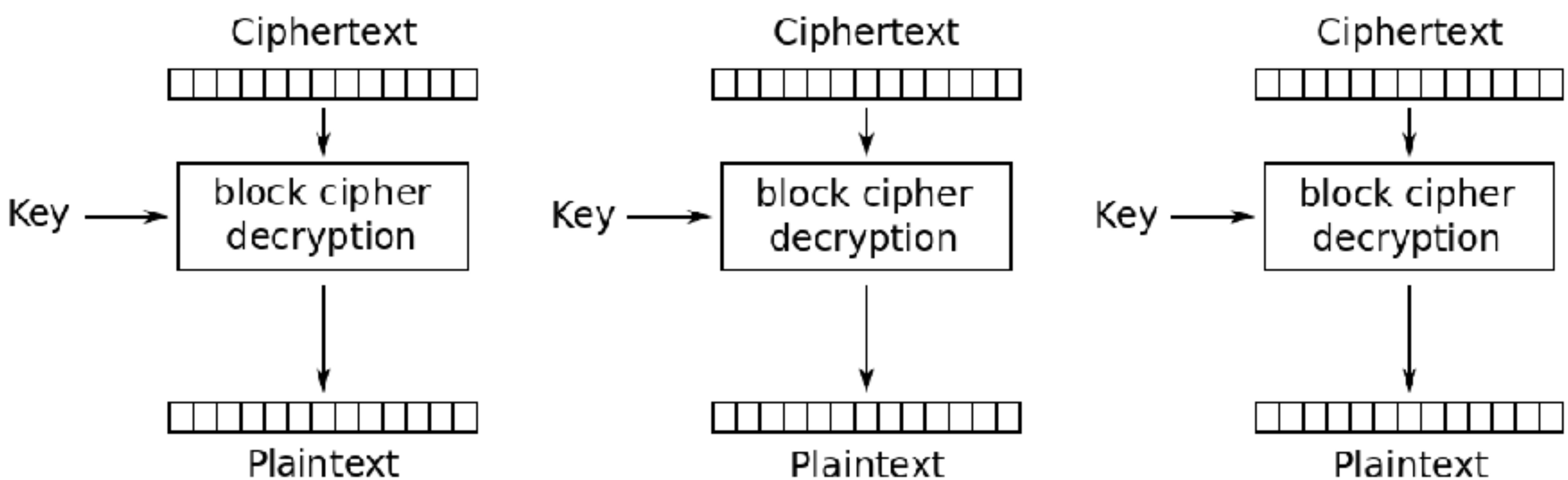
BLOCK CIPHERS HAVE FIXED SIZE



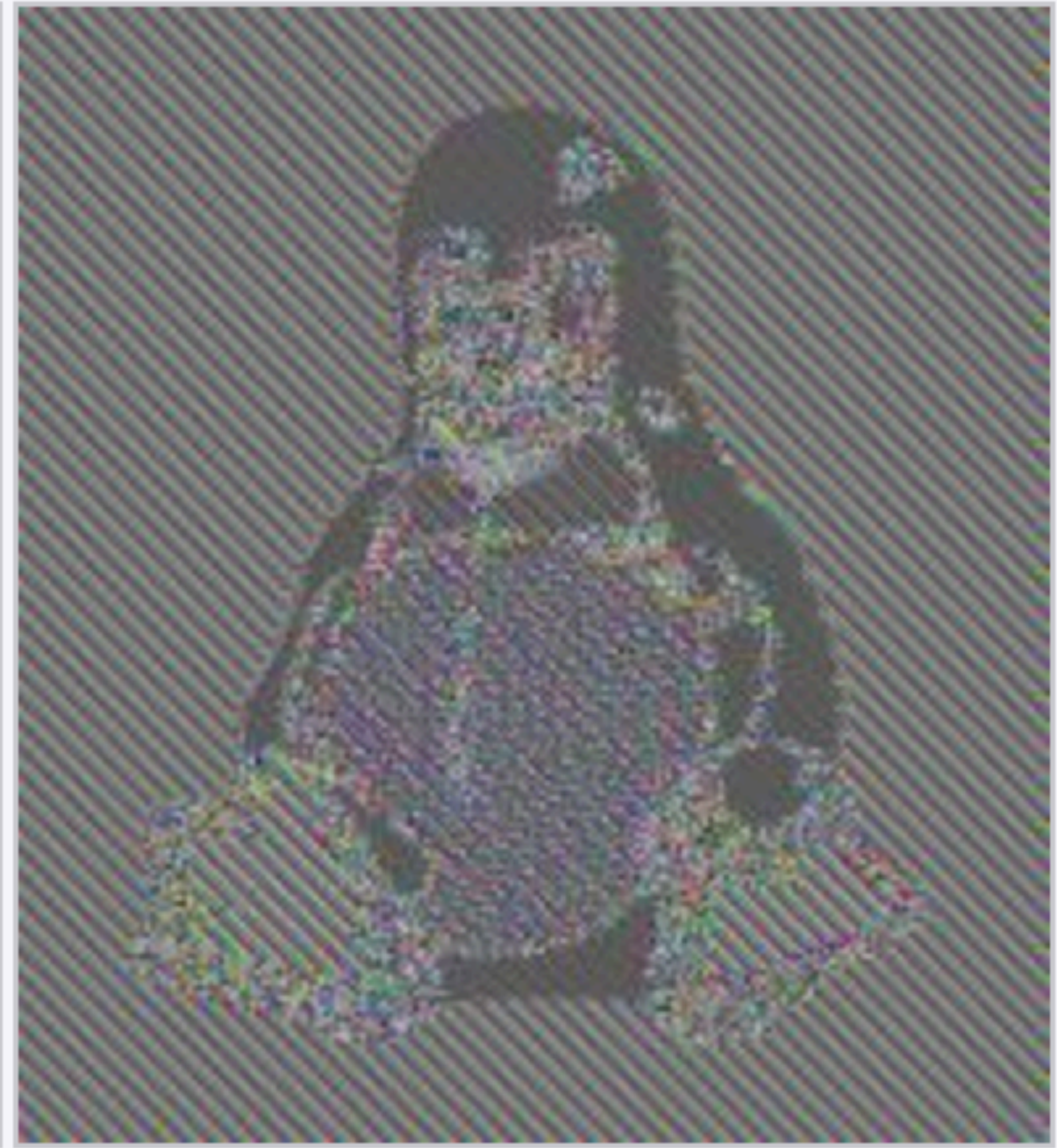


Electronic Codebook (ECB) mode encryption



Electronic Codebook (ECB) mode decryption

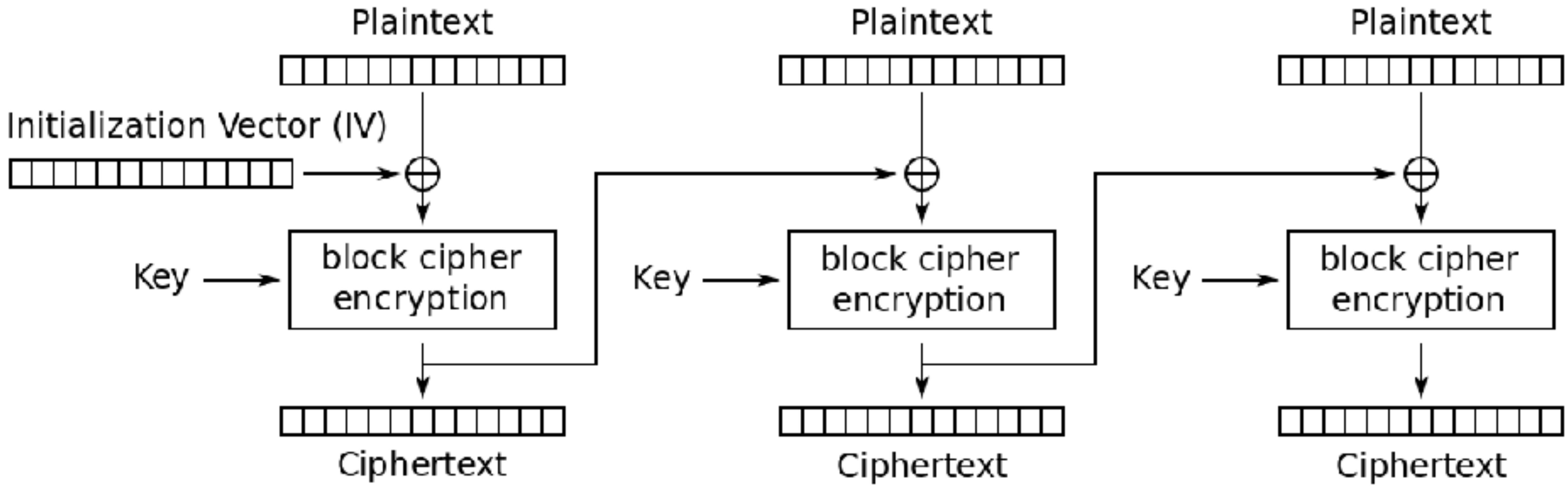
Original image



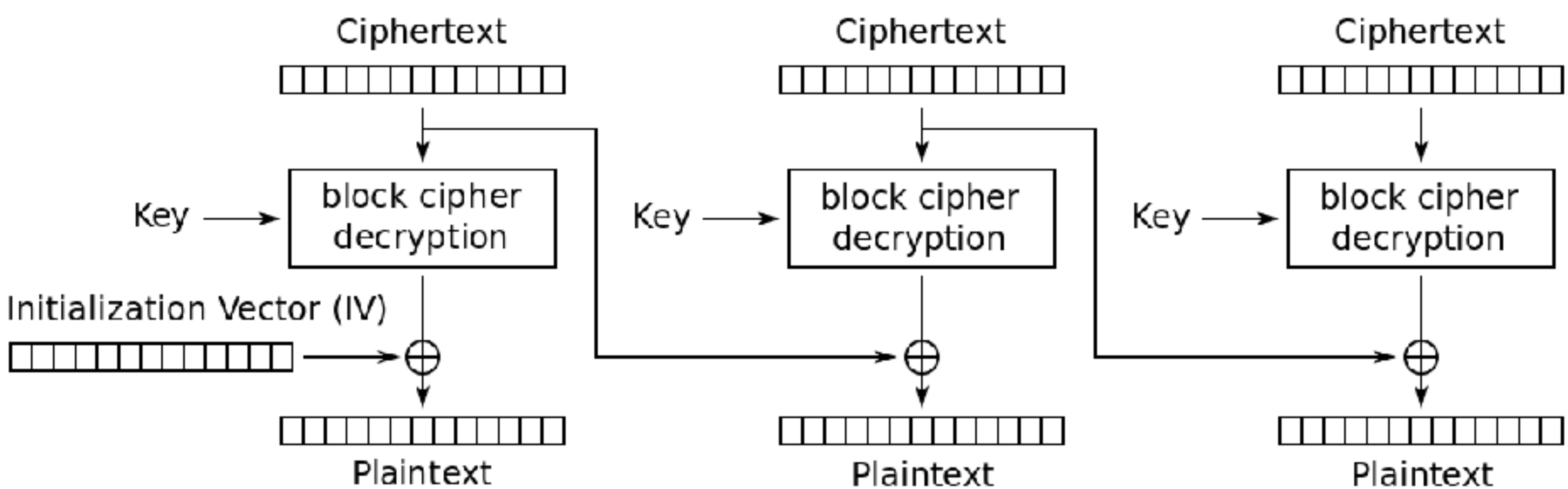
Encrypted using ECB mode

NEVER use ECB

(but over 50% of Android apps do)



Cipher Block Chaining (CBC) mode encryption



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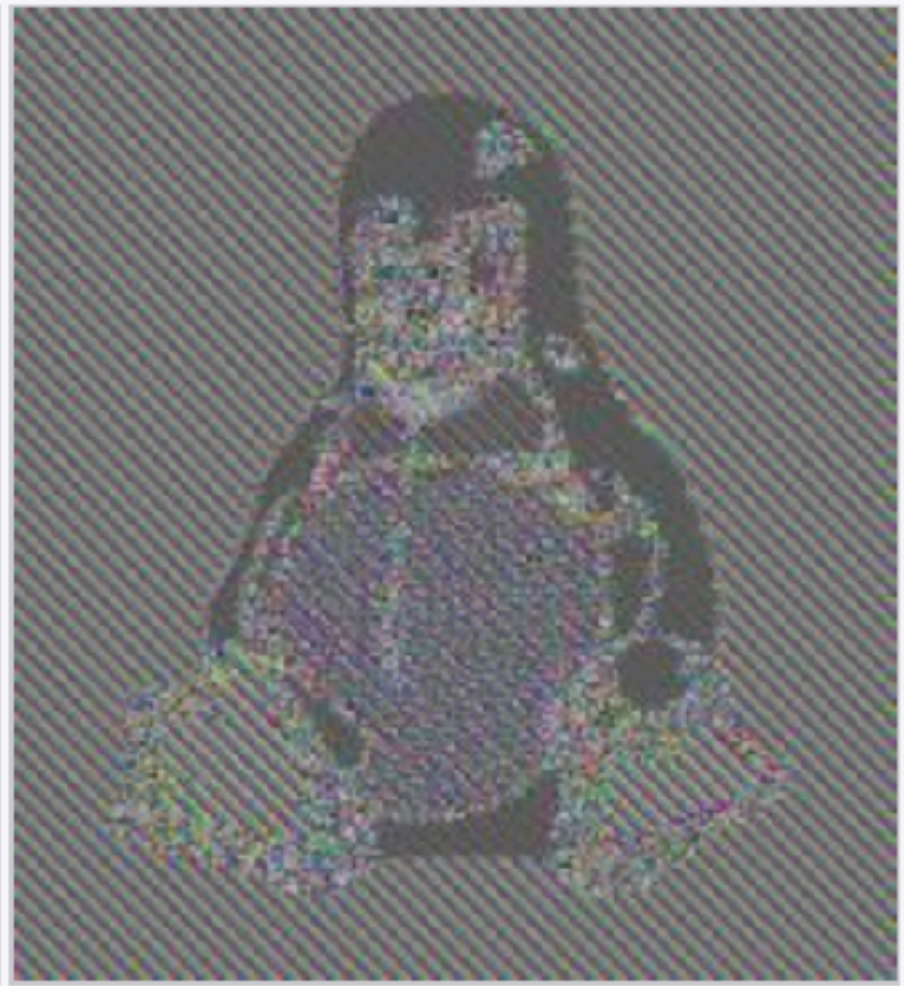

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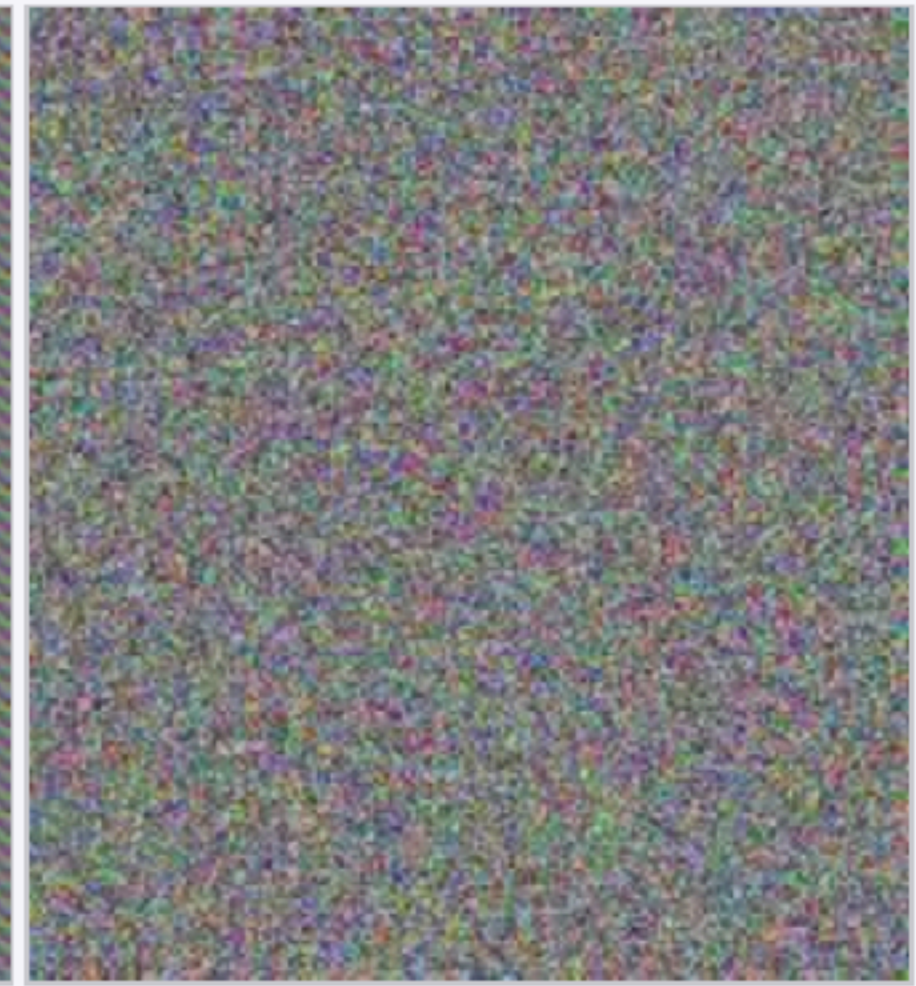
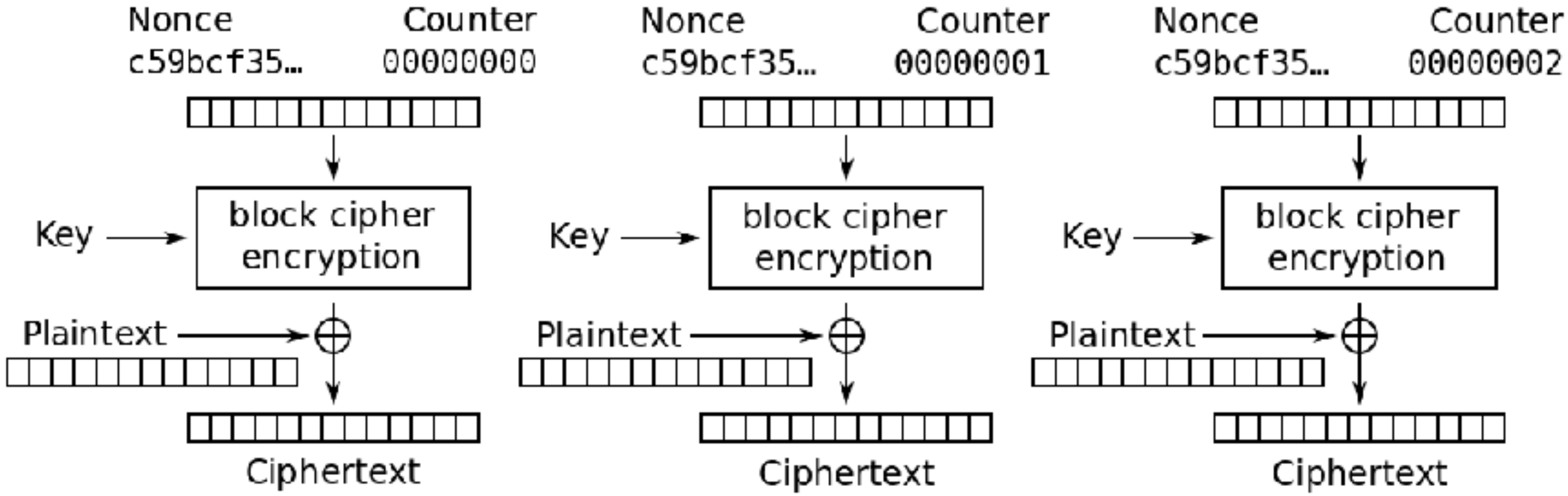
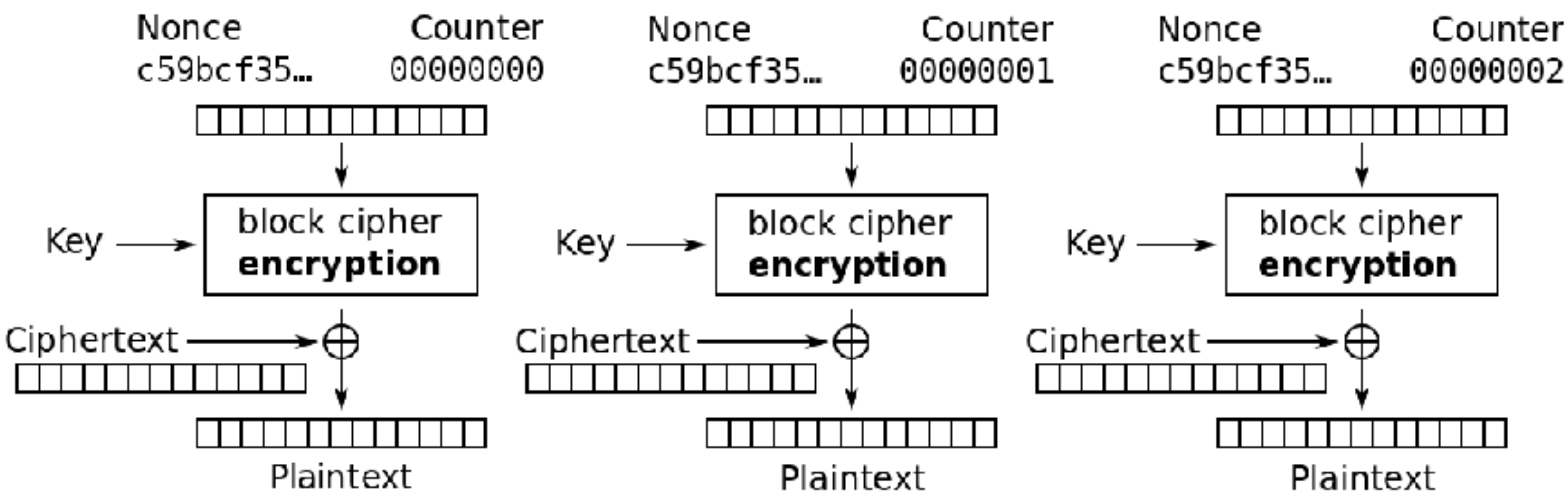


Modes other than ECB result in pseudo-randomness



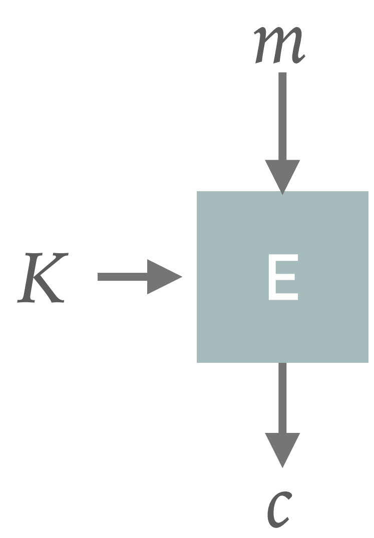
Counter (CTR) mode encryption



Counter (CTR) mode decryption

BLACKBOX #2:
MESSAGE AUTHENTICATION CODE (MAC)

MESSAGE AUTHENTICATION CODES

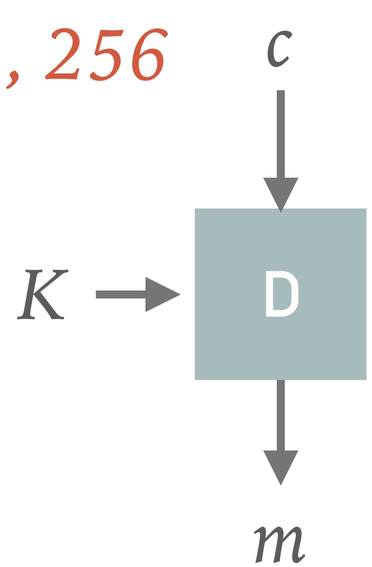


Plaintext

Same fixed ***block size***
(AES: 128 bits)

Ciphertext

AES key sizes:
128, 192, 256



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Diffusion: *Flipping a bit in m should flip each bit in c with Pr = 1/2*

MESSAGE AUTHENTICATION CODES

- Sign: takes a key and a message and outputs a "tag"
  - Sgn(k,m) = t
- Verify: takes a key, a message, and a tag, and outputs Y/N
  - Vfy(k,m,t) = {Y,N}
- Correctness:
  - Vfy(k, m, Sgn(k, m)) = Y

ATTACKER'S GOAL: EXISTENTIAL FORGERY

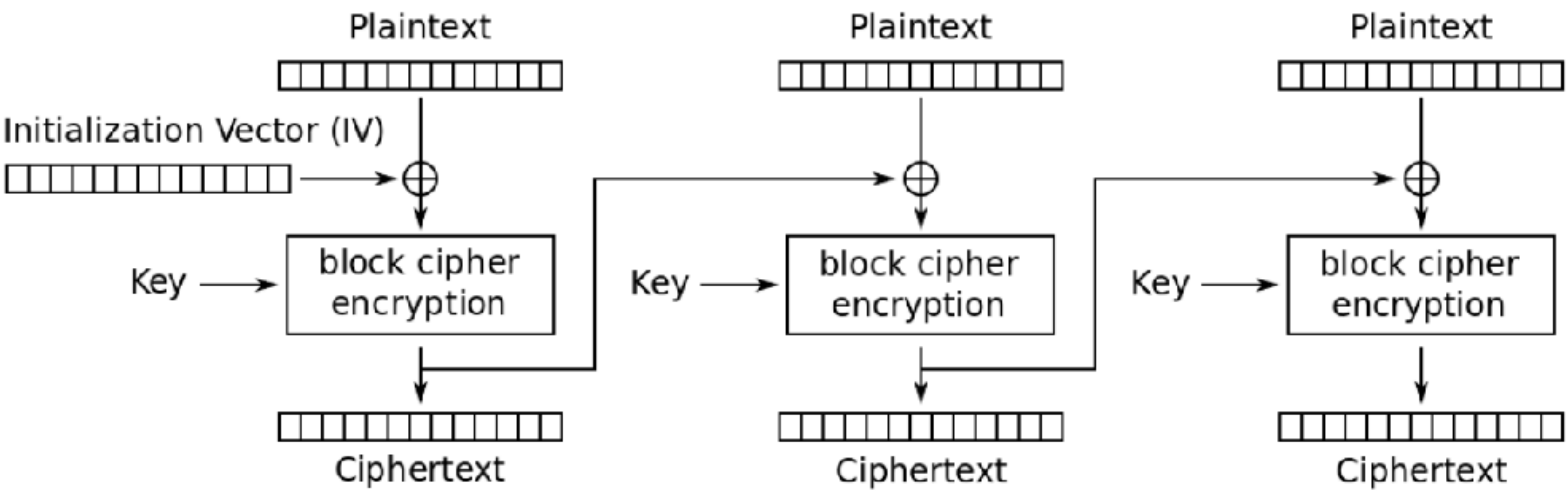
- A MAC is secure if an attacker cannot demonstrate an existential forgery despite being able to perform a chosen plaintext attack:

- Chose plaintext:
  - Attacker gets to choose m1, m2, m3, …
  - And in return gets a properly computed t1, t2, t3, …

- Existential forgery:
  - Construct a new (m,t) pair such that Vfy(k, m, t) = Y

ENCRYPTED CBC

Just take the last block in CBC *It's a trap!*



Cipher Block Chaining (CBC) mode encryption

Use a separate key and encrypt the last block

BLACKBOX #3:
HASH FUNCTIONS

HASH FUNCTION PROPERTIES

- Very fast to compute
- Takes arbitrarily-sized inputs, returns fixed-sized output
- Pre-image resistant:
  Given $H(m)$, hard to determine m
- Collision resistant
  Given m and $H(m)$, hard to find $m' \neq m$ s.t. $H(m) = H(m')$

Good hash functions: SHA family (SHA-256, SHA-512, …)

HASH MACS

- Sign(k, m):
  - opad = 0x5c5c5c…
  - ipad =0x363636…
  - $H((k \oplus opad) \| H((k \oplus ipad) \| m))$

- Verify:
  - Recompute and compare