Leakage-Resilient Key-Dependent Message Secure Encryption Schemes

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Joint work with Dhairya Gupta (IITD) and Harihar Swaminathan (IITD)

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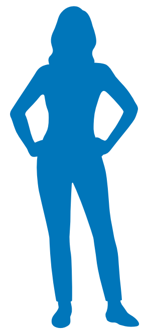
Introduction

Encryption Scheme

Encryption Scheme



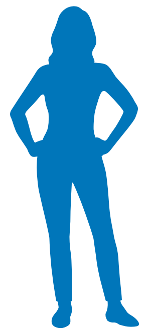
ALICE

Encryption Scheme

ALICE

BOB

Encryption Scheme



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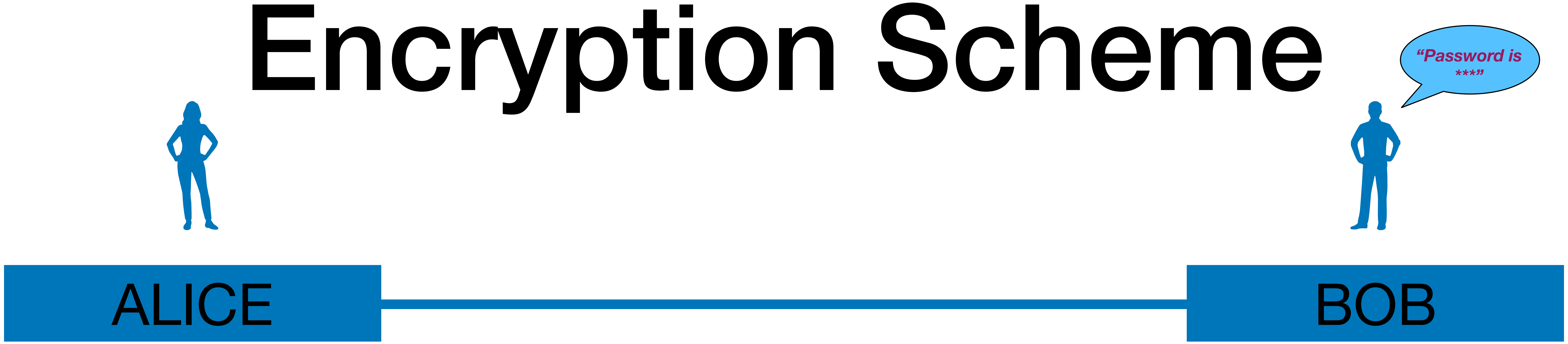

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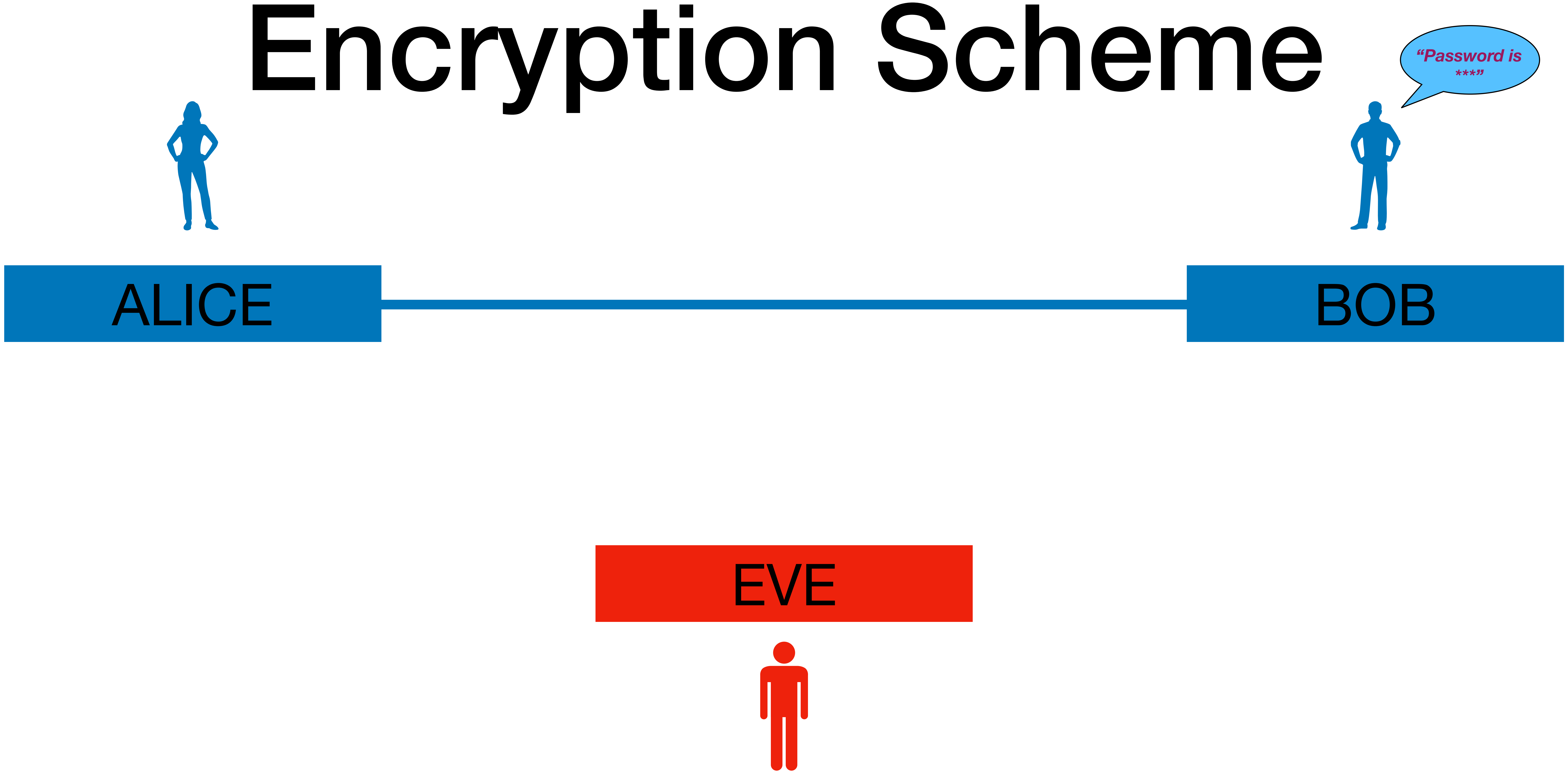
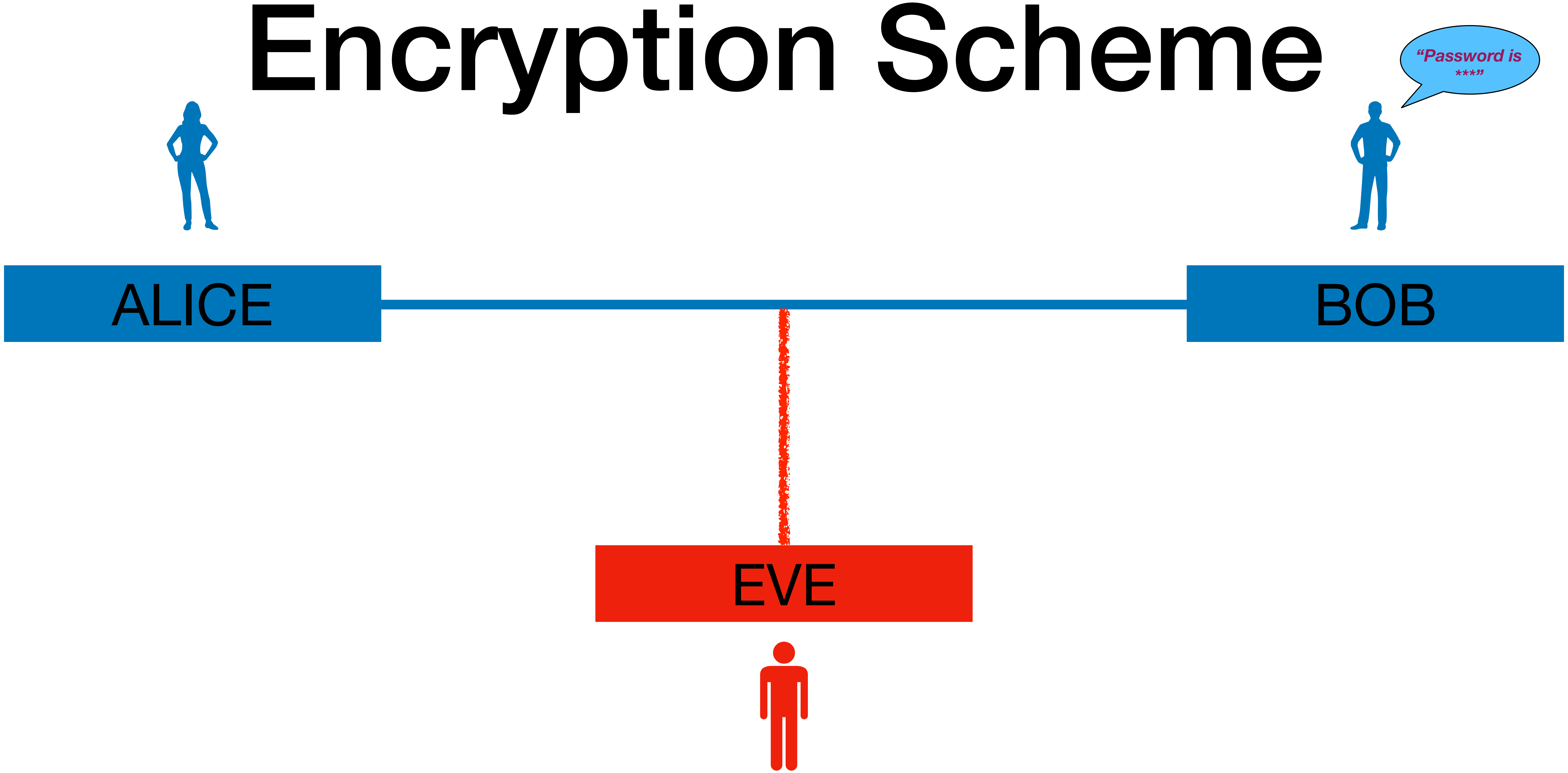


ALICE

BOB

EVE

Encryption Scheme



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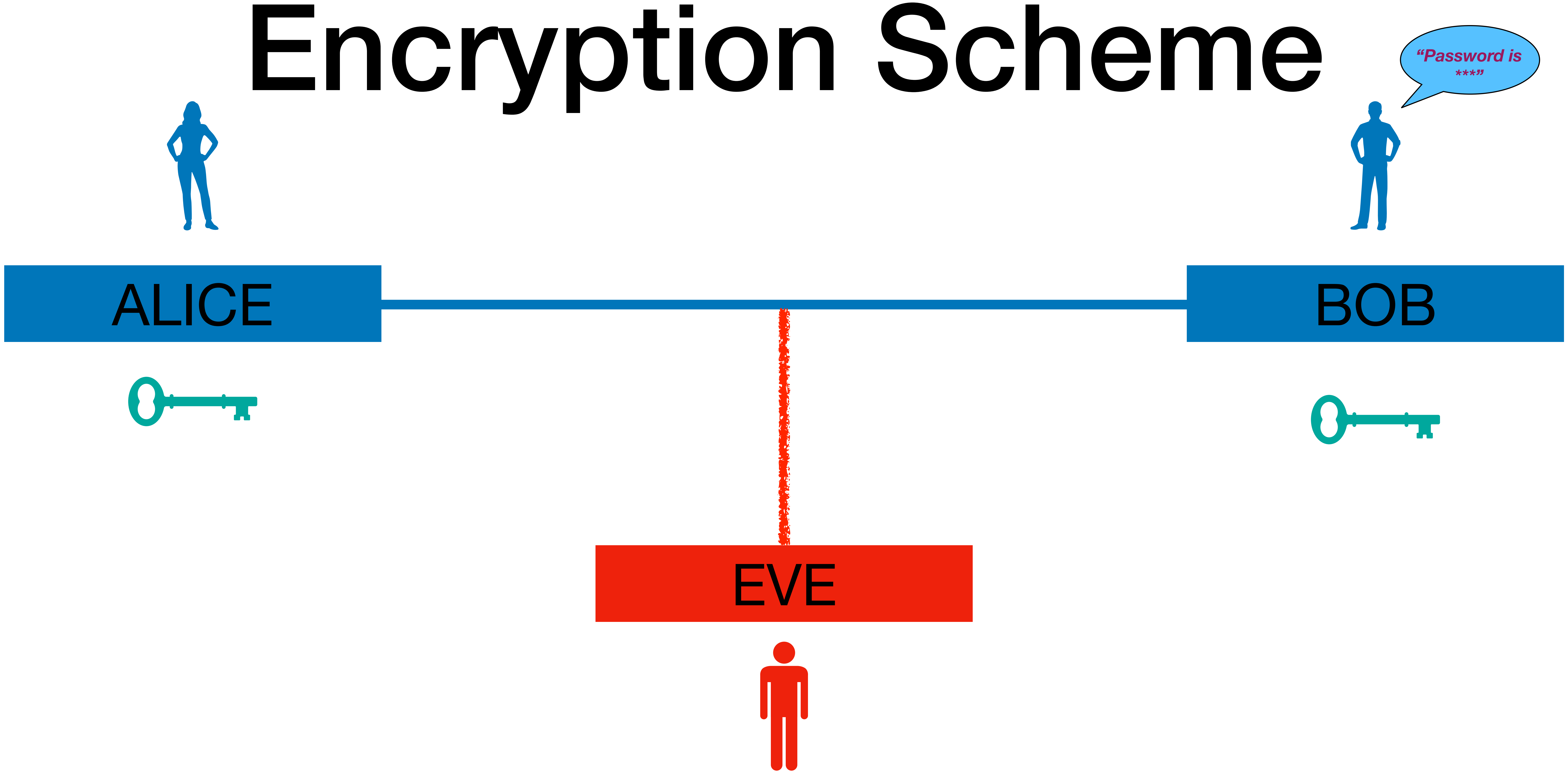

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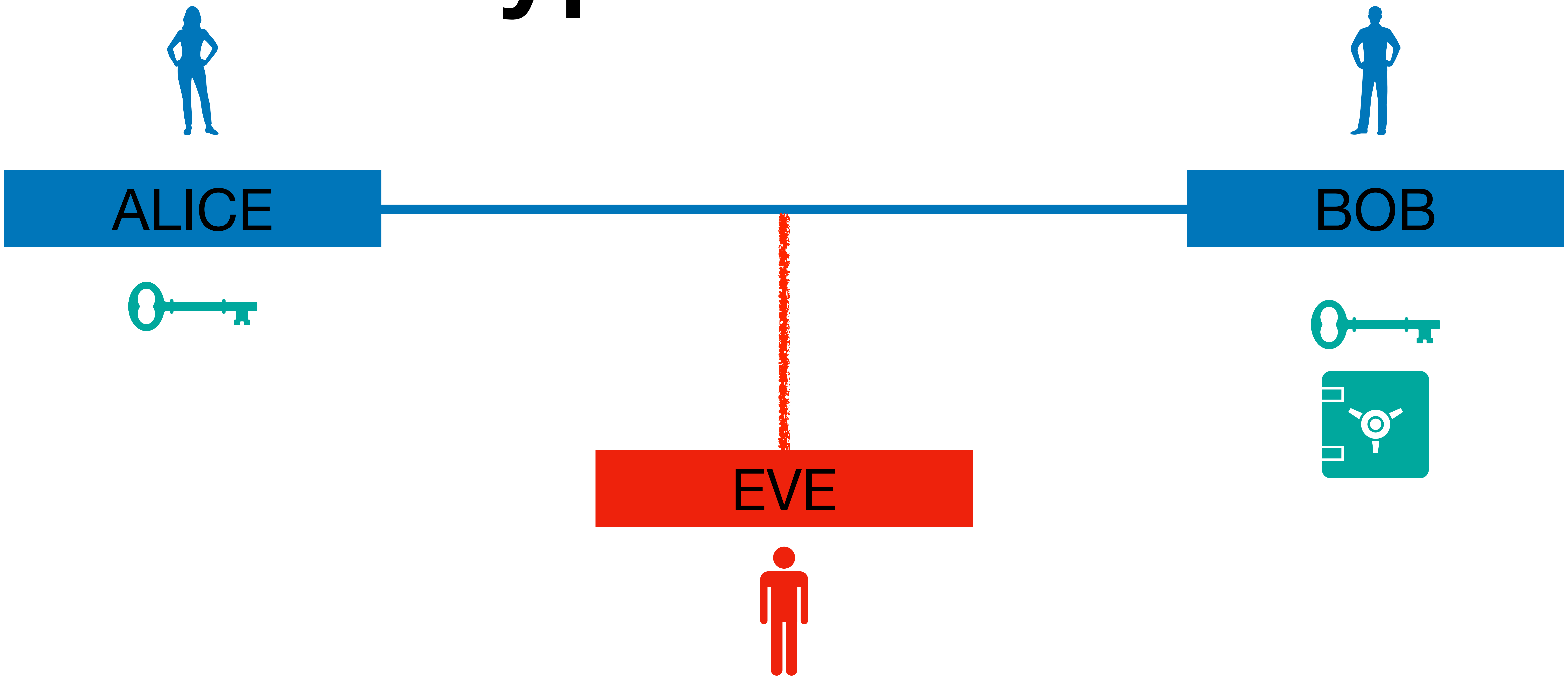

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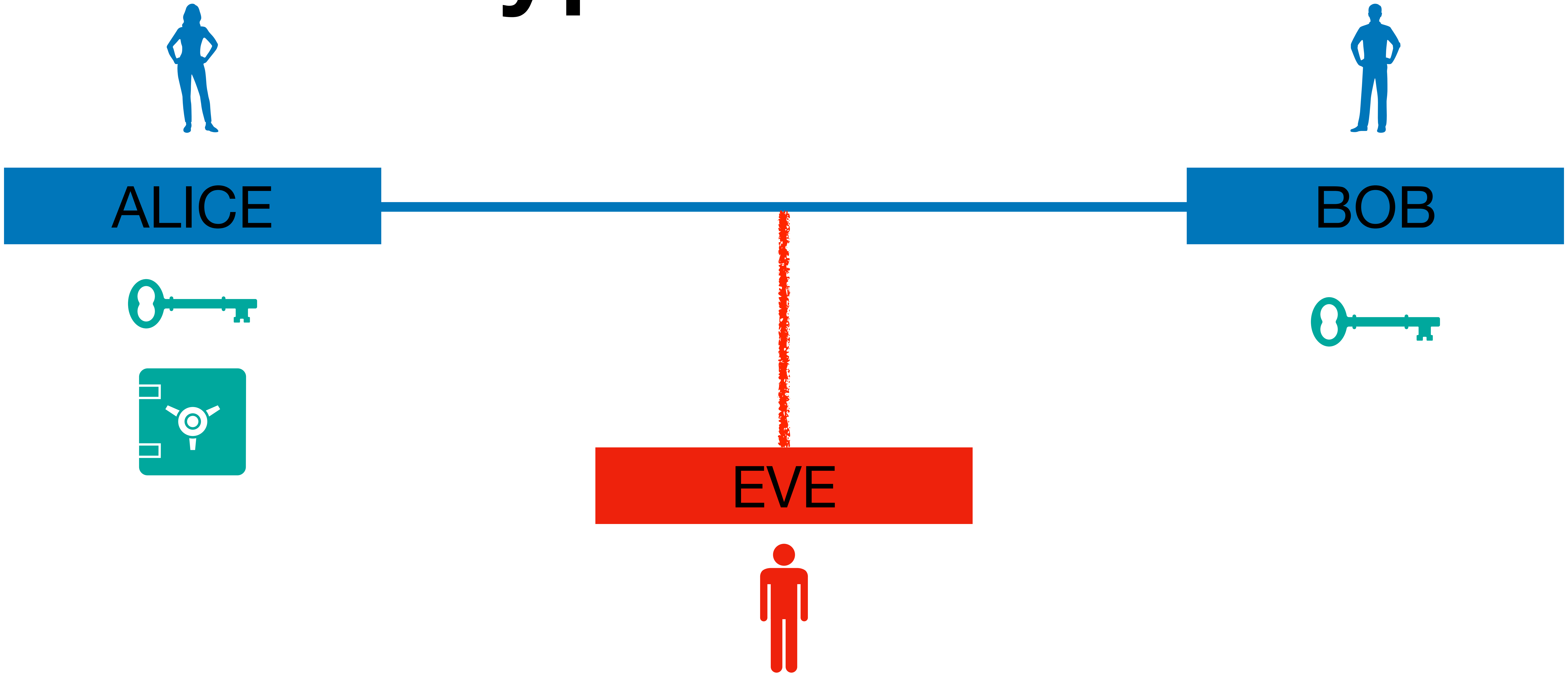

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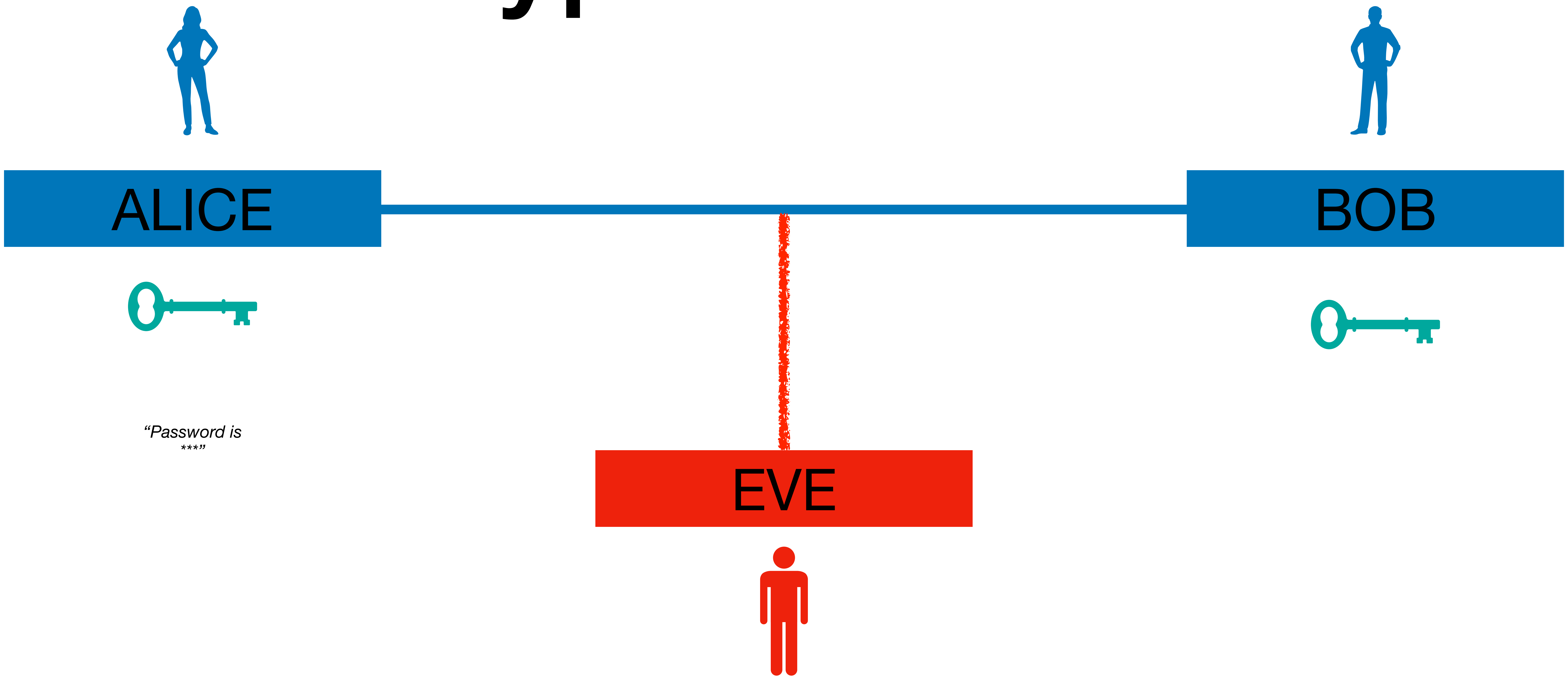


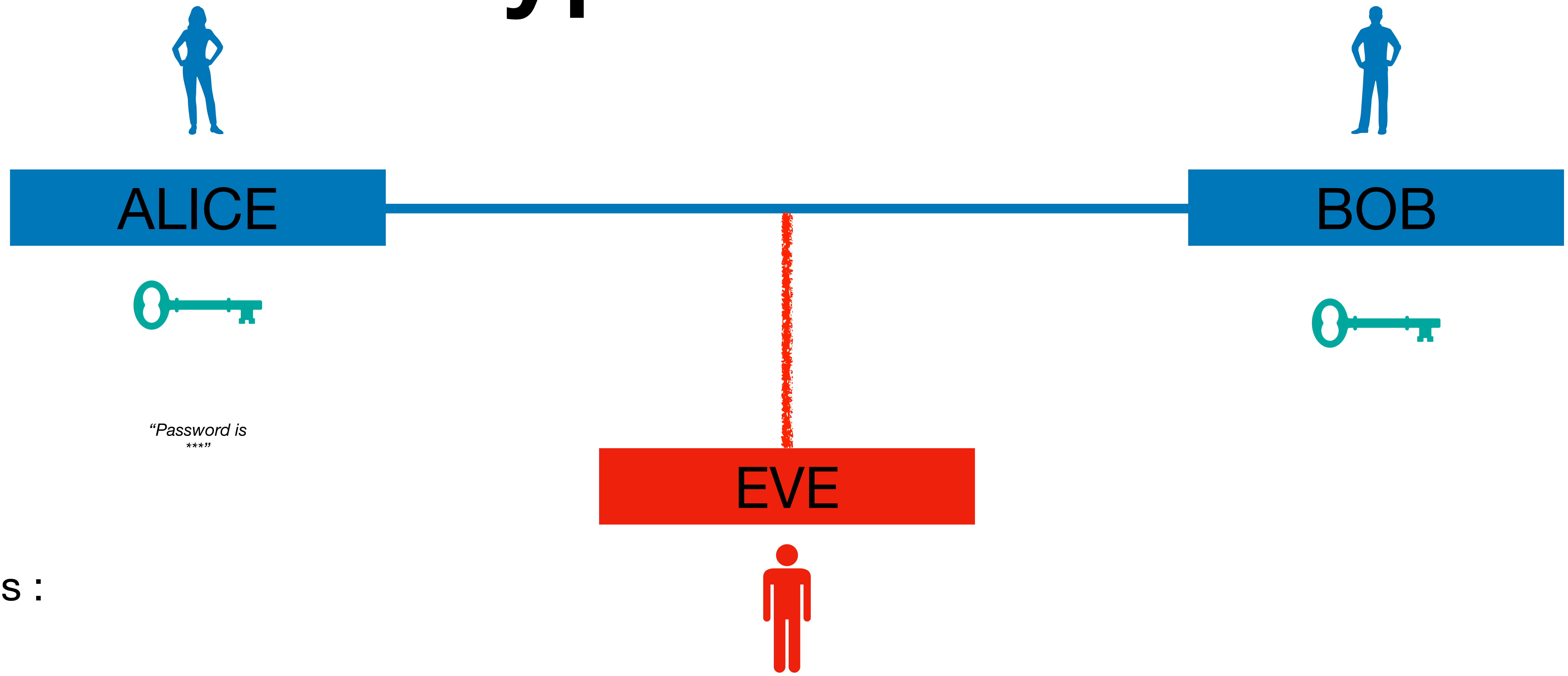
ALICE

BOB

“Password is ***”

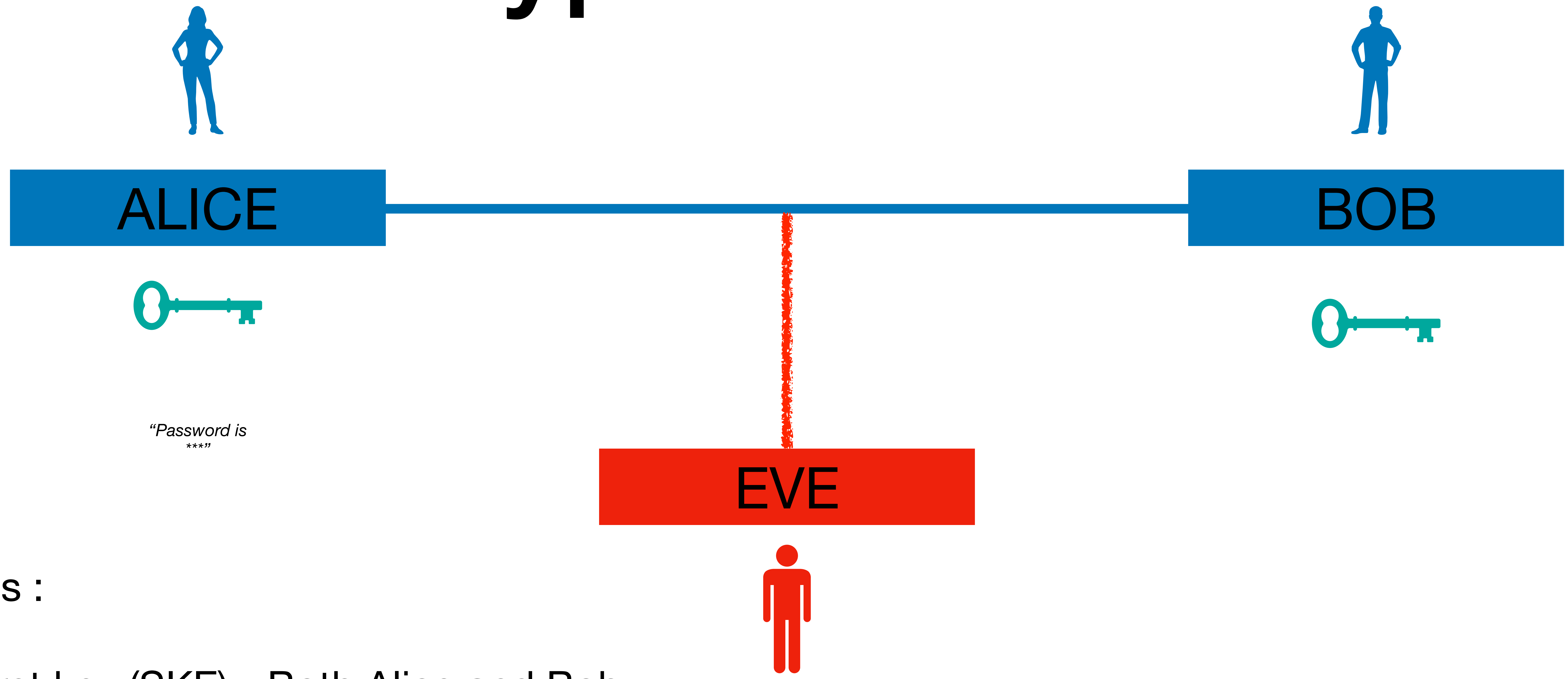
EVE

Encryption Scheme



2 types :

Encryption Scheme



2 types :

- secret key (SKE) - Both Alice and Bob have the same key.

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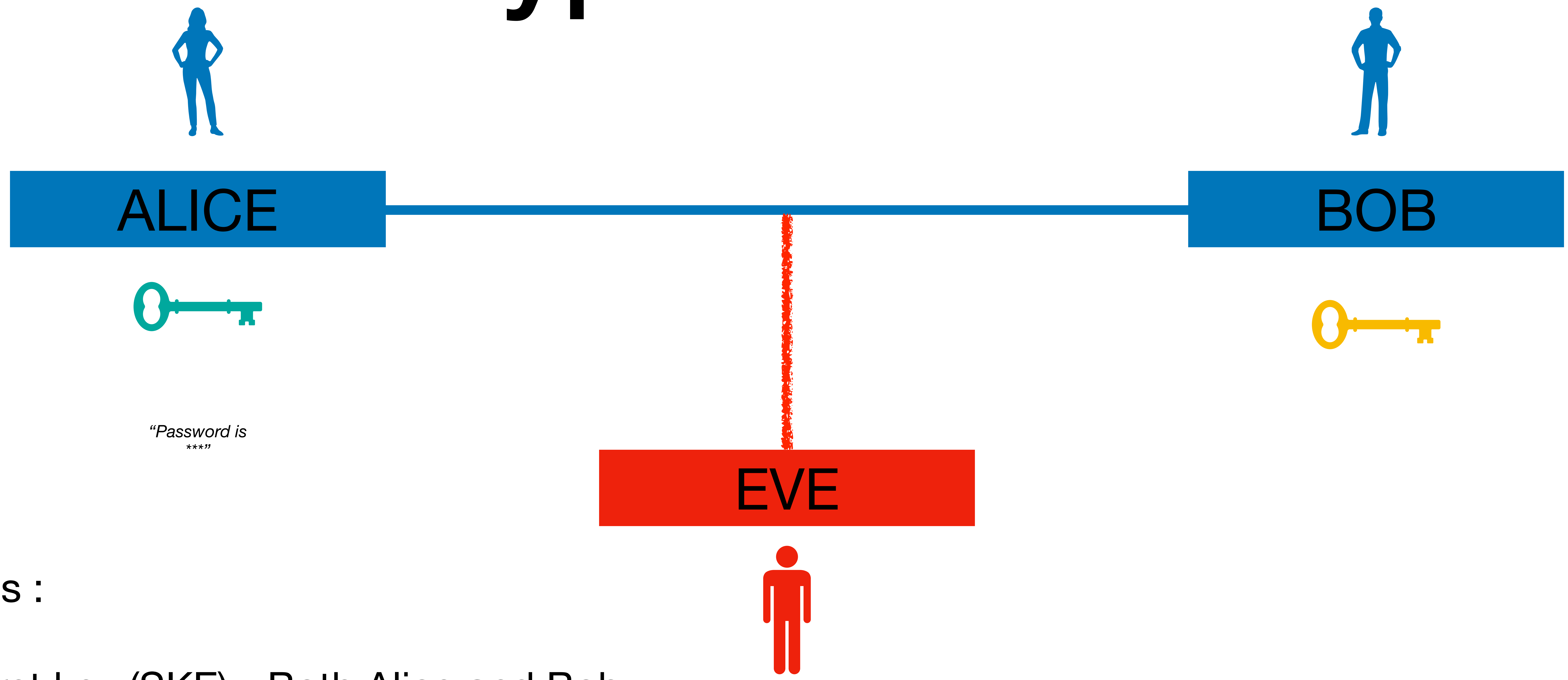

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- public key (PKE) - Encryptor has public key and decryption has secret key.

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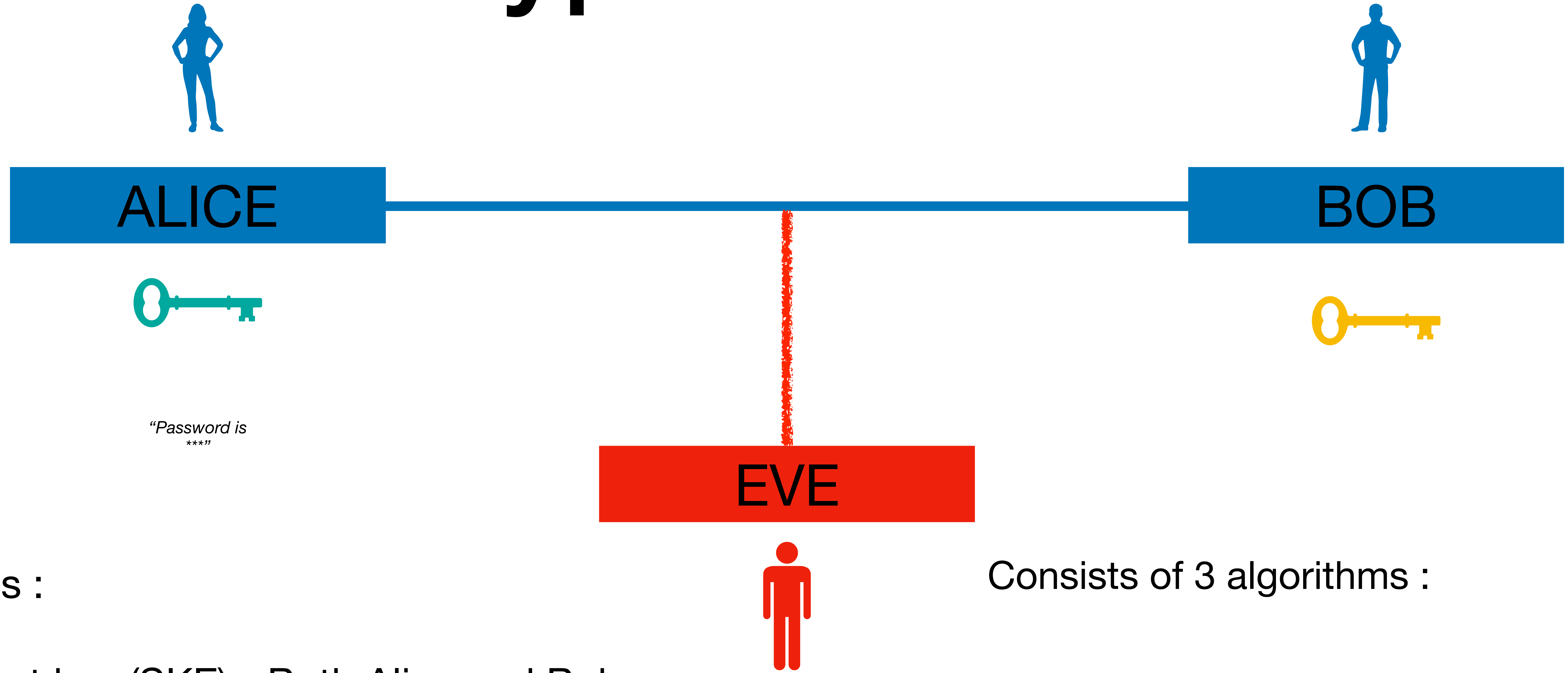

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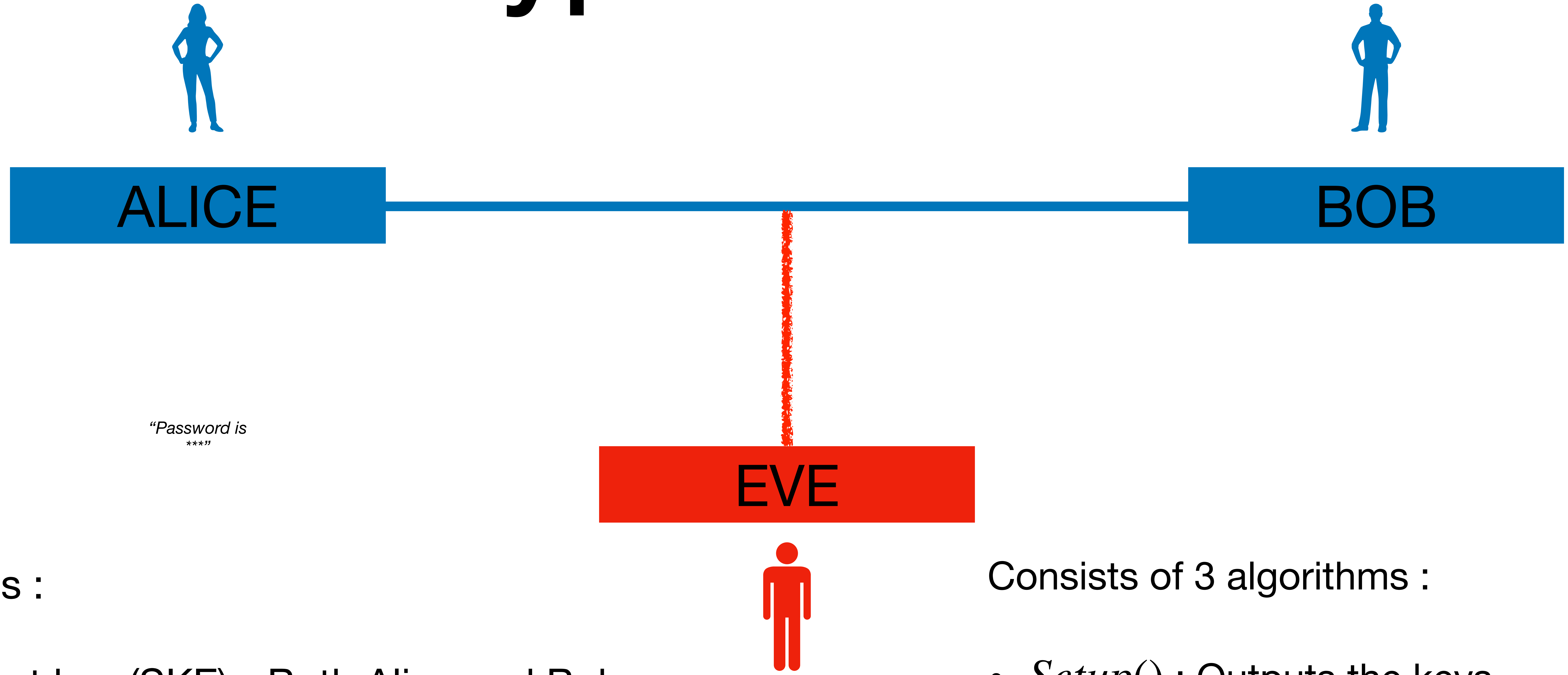
ALICE

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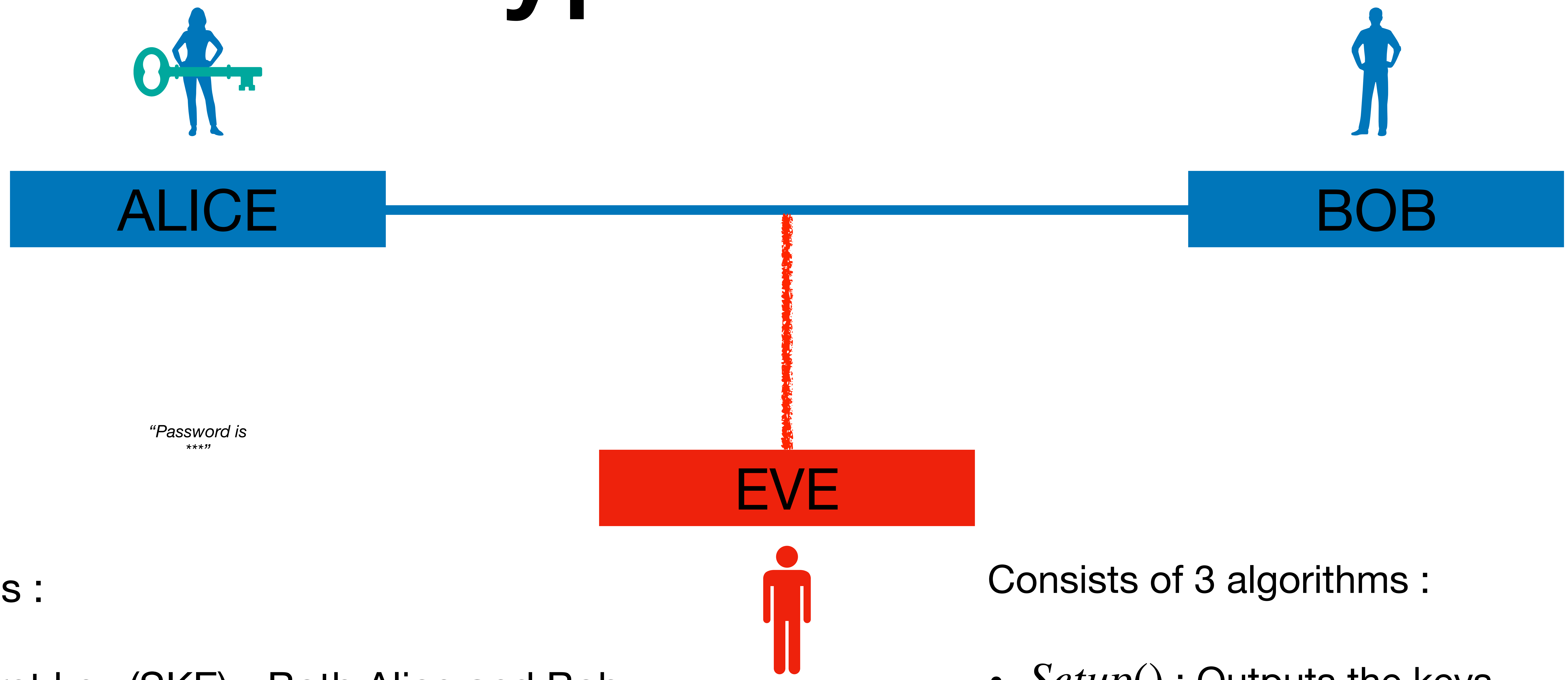

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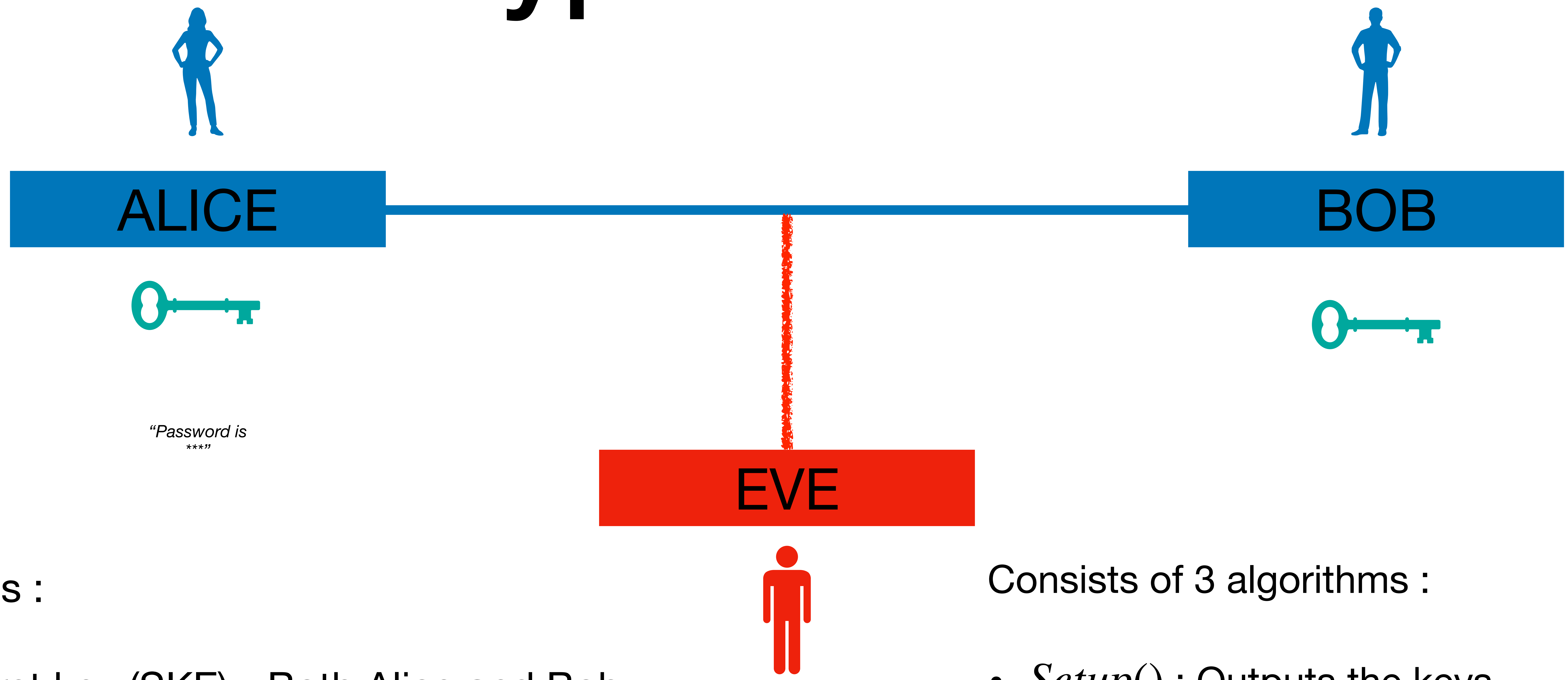

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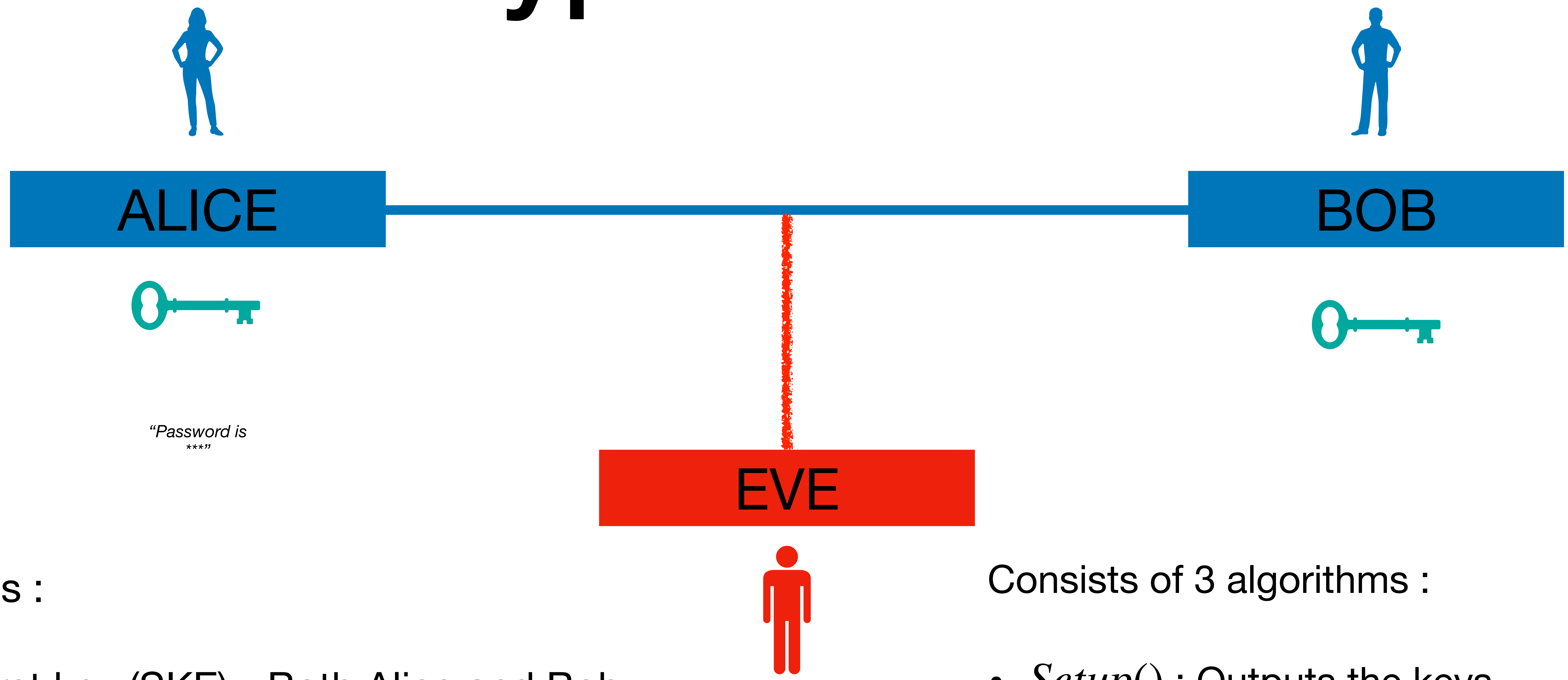

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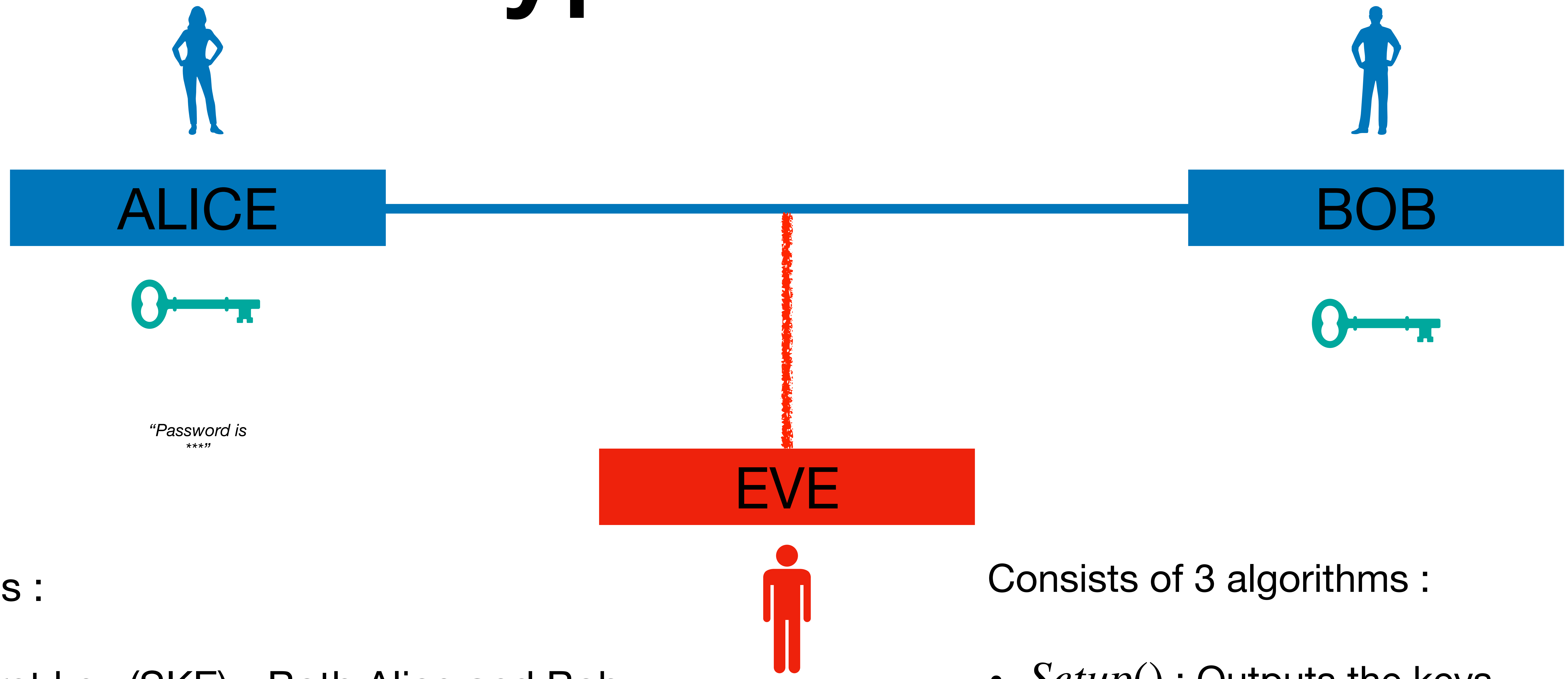

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Consists of 3 algorithms :

- $Setup()$: Outputs the keys
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- $Dec(sk, c)$: Outputs message or error

Public-Key Encryption

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- Goldwaser,Micali-84 proposed semantic security.

Security Definitions

Standard Security [Goldwaser,Micali-84]

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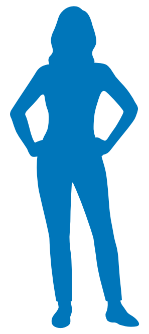

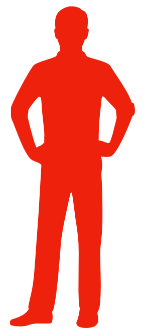

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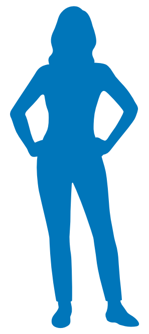
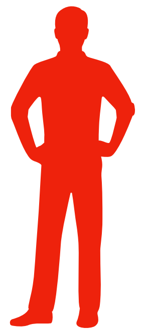


Challenger



Adversary

Standard Security [Goldwaser,Micali-84]

Challenger

Adversary

$(pk, sk) \leftarrow Setup()$

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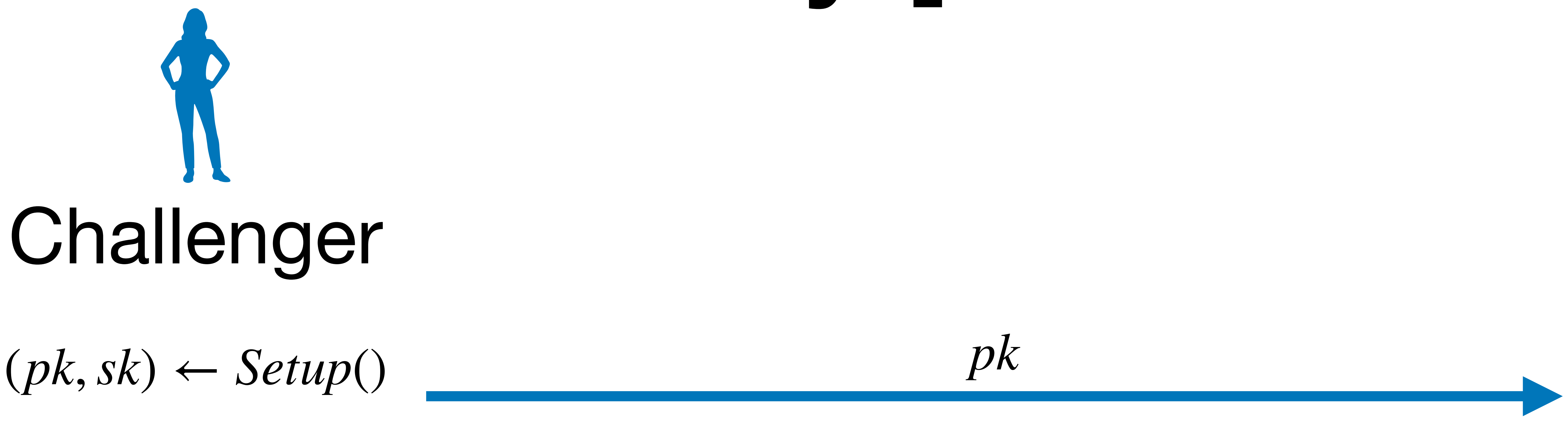

Challenger

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$\xrightarrow{pk}$

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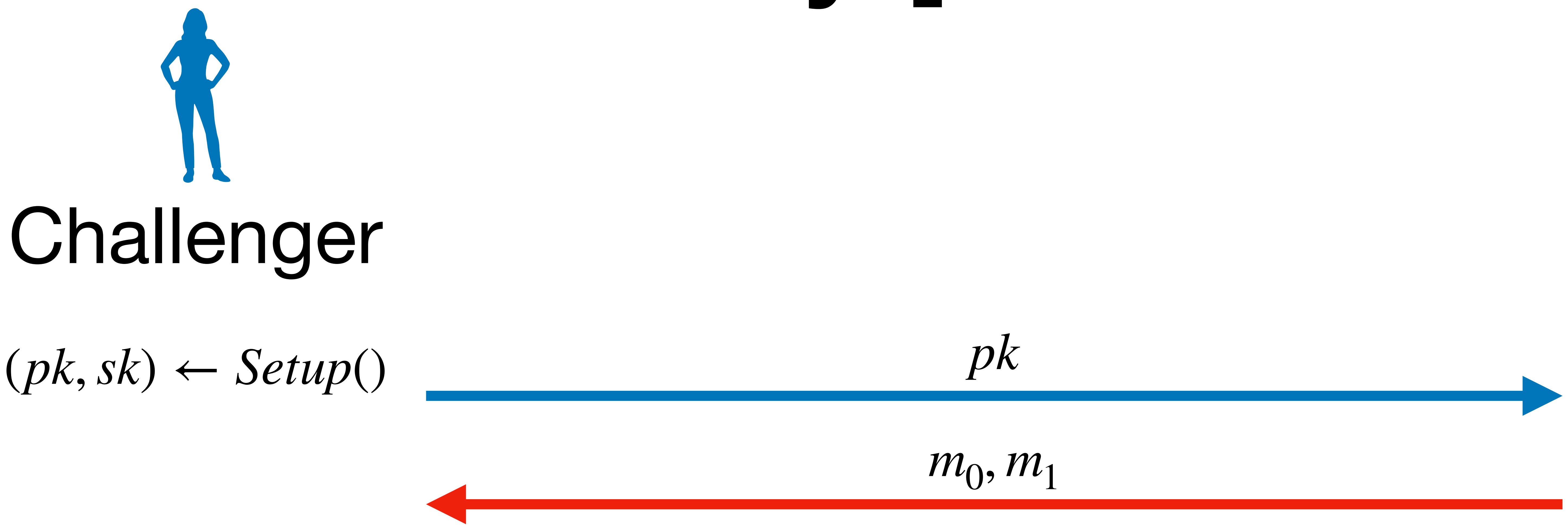

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m_0, m_1

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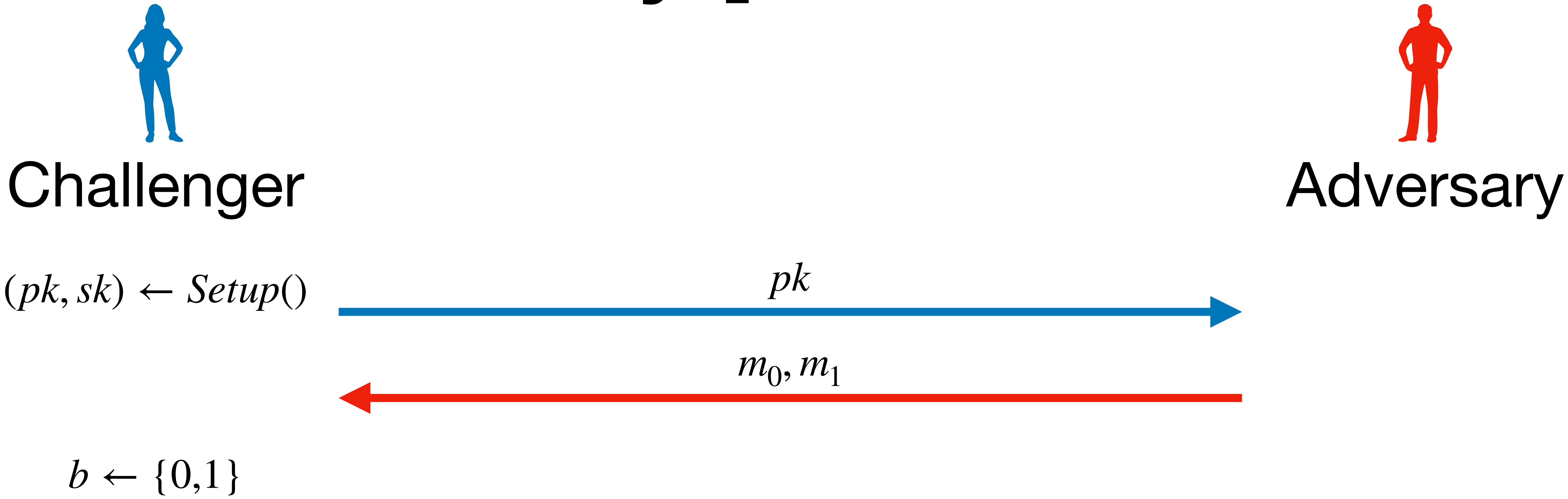

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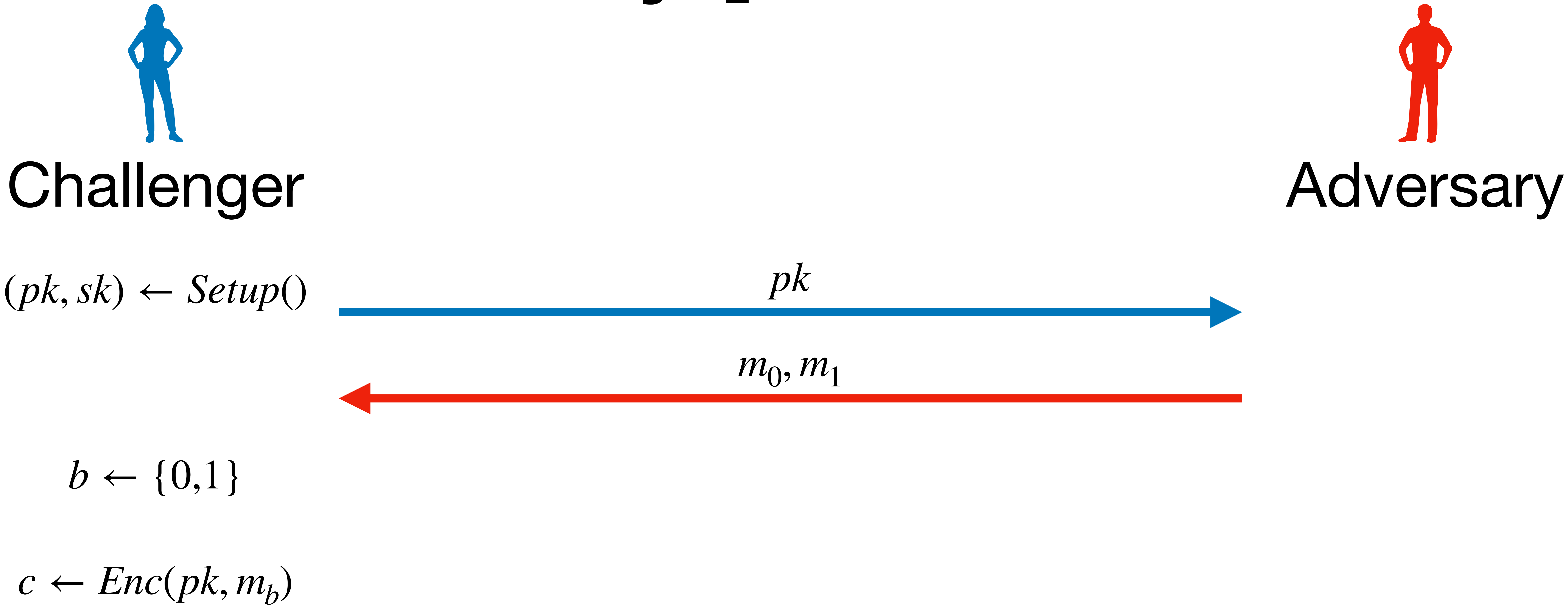

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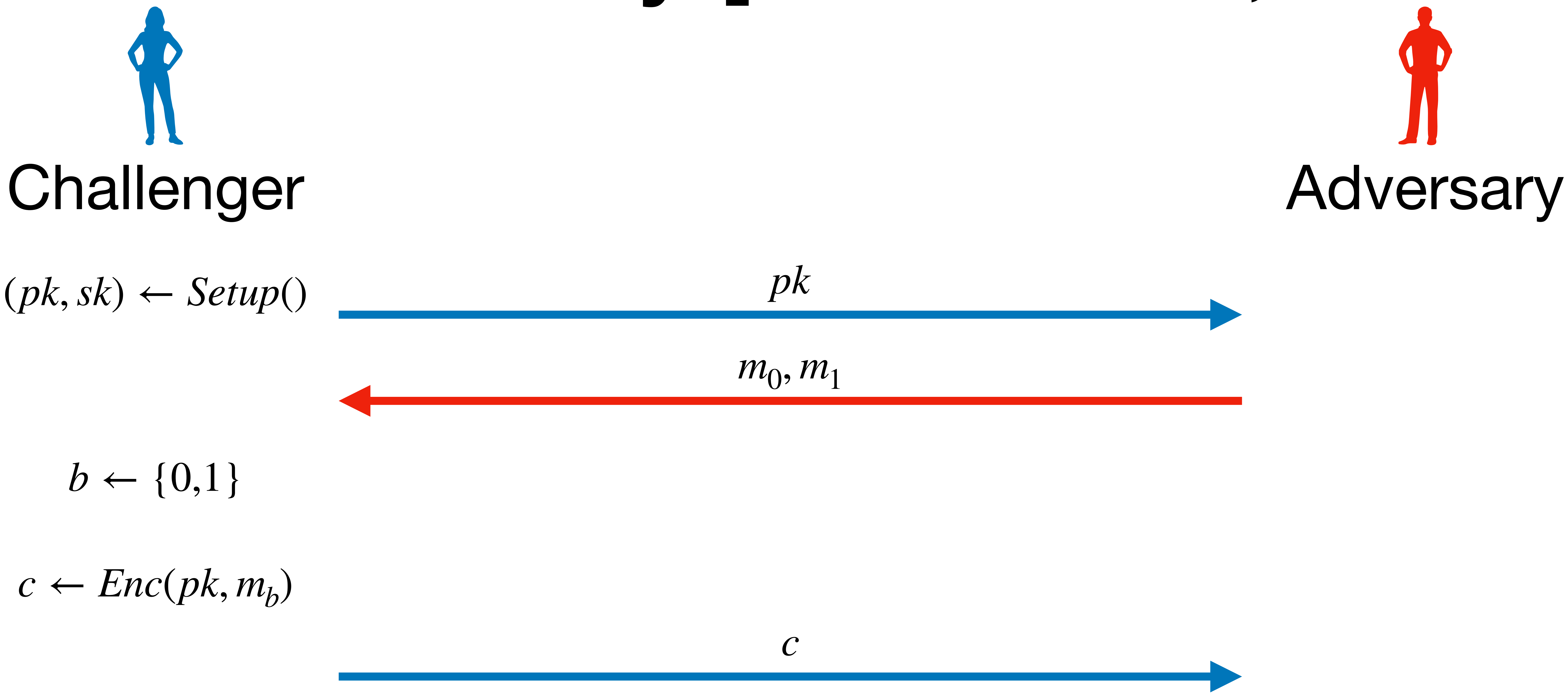

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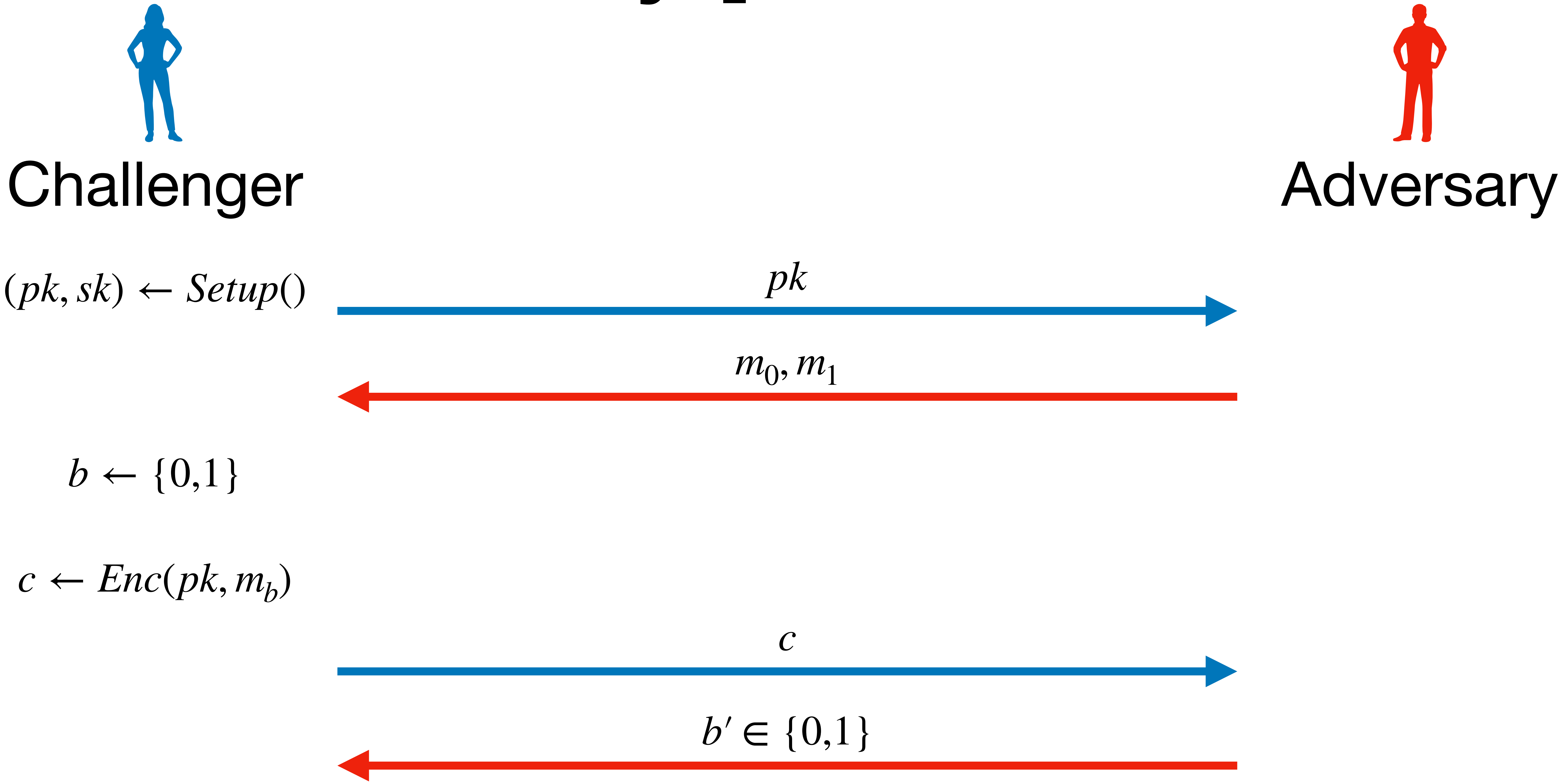

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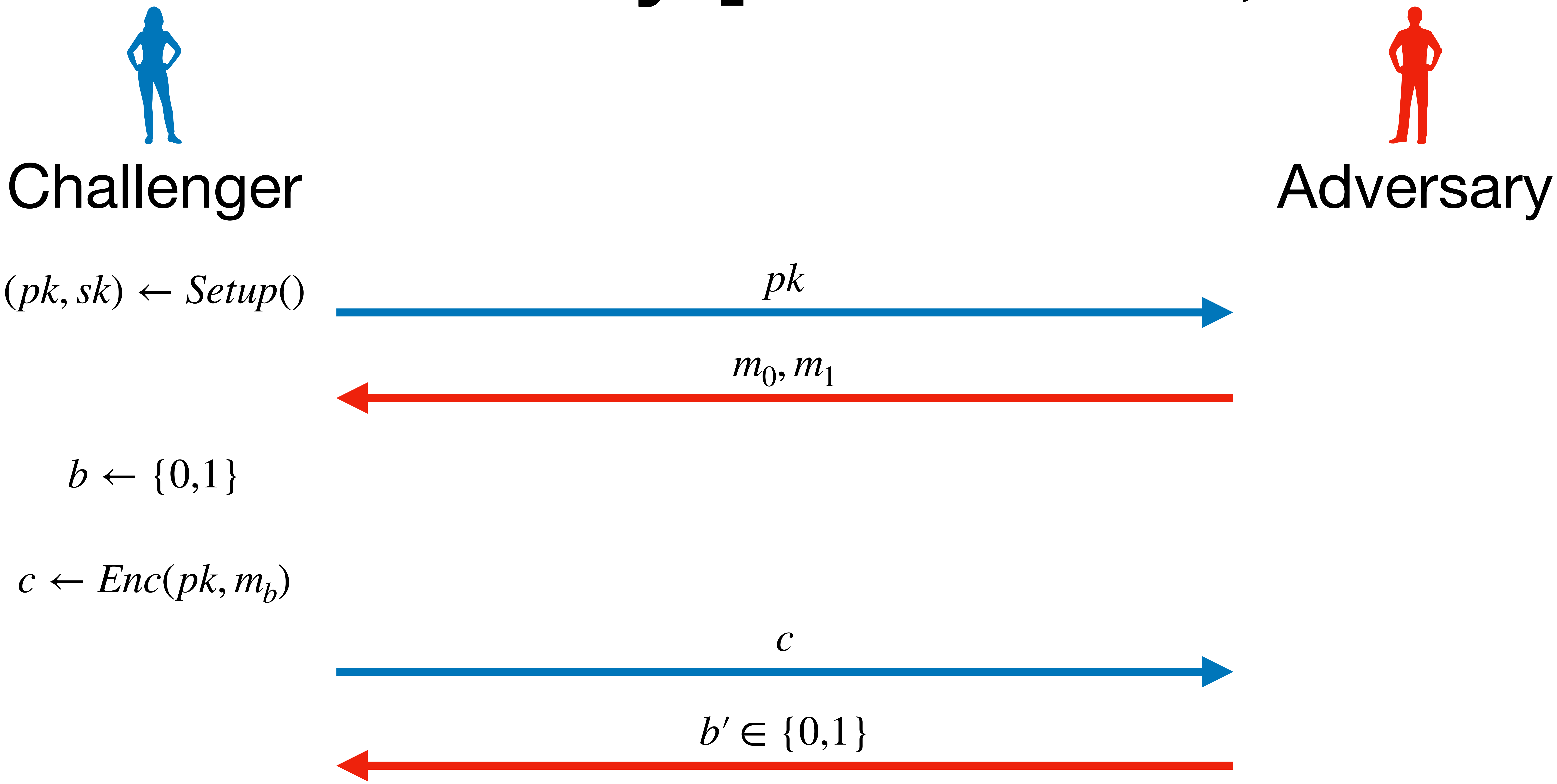

Challenger

Adversary

$(pk, sk) \leftarrow Setup()$ $\xrightarrow{pk}$

$\xleftarrow{m_0, m_1}$

$b \leftarrow \{0,1\}$

$c \leftarrow Enc(pk, m_b)$

$\xrightarrow{c}$

$\xleftarrow{b' \in \{0,1\}}$

Adversary wins if $b = b'$

More Security Notions

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- Chosen-Ciphertext Attacks

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Can Secret Key be leaked?

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- In practice, secret key can be leaked using side-channel attacks.

Leakage-Resilience

Security against Leakage

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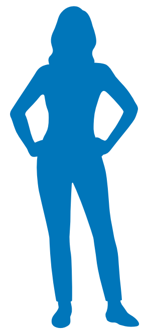

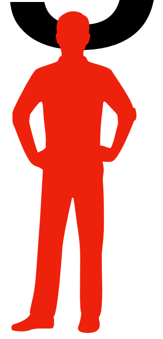

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Challenger

Adversary

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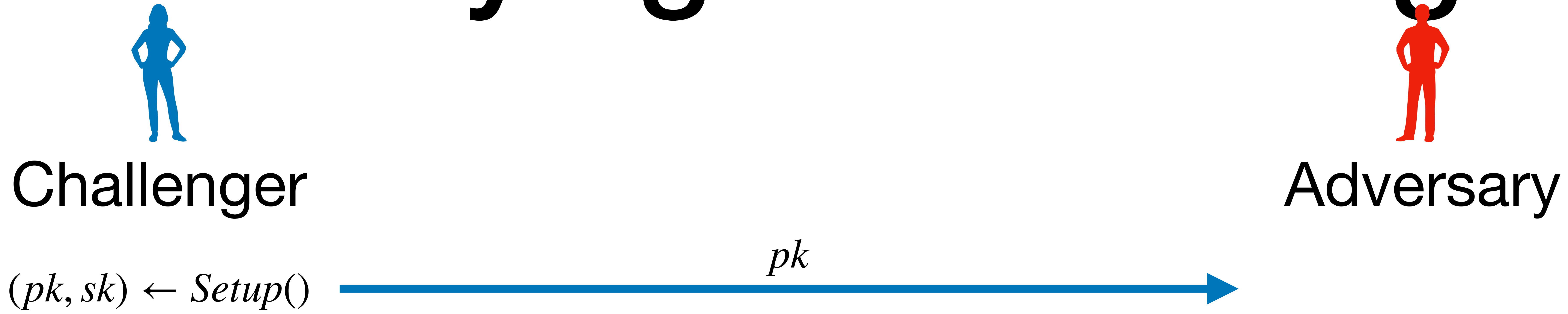

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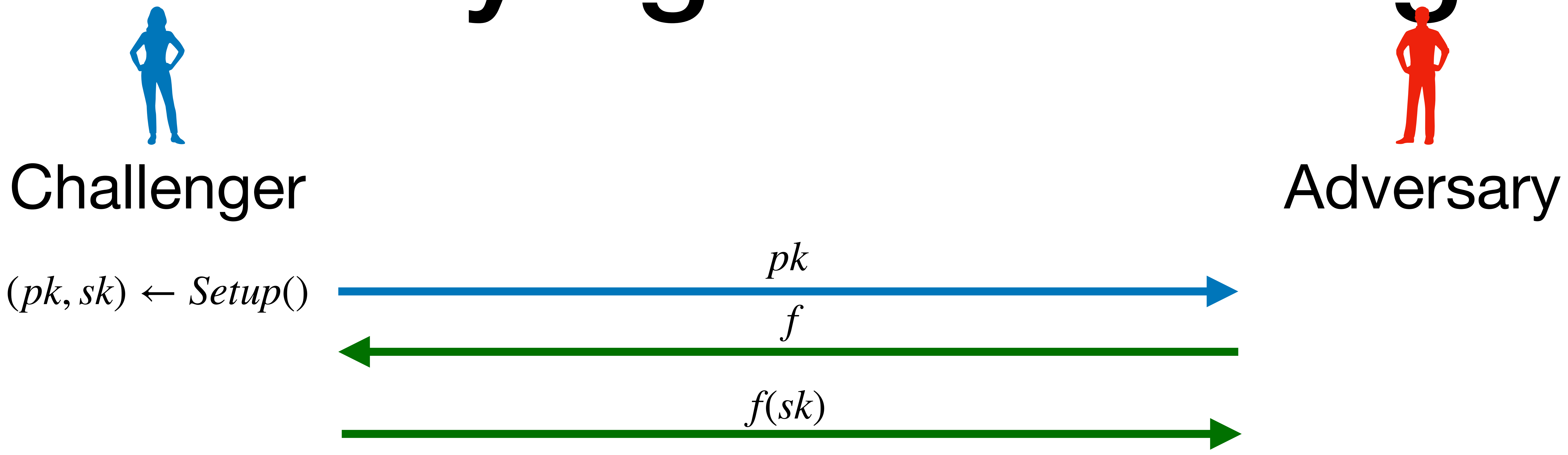


Challenger

Adversary

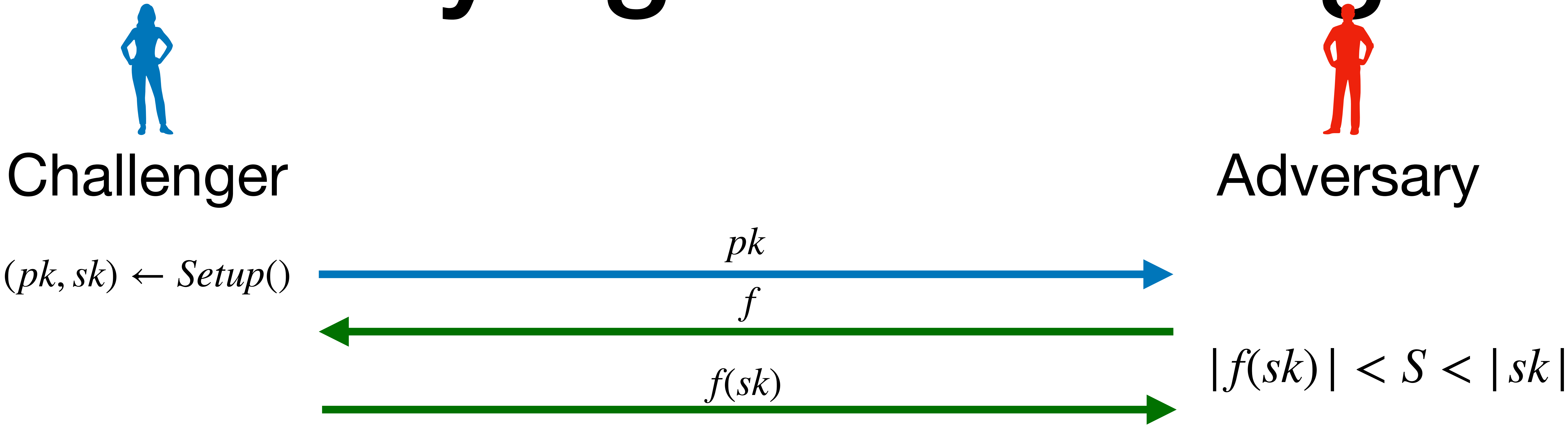
$(pk, sk) \leftarrow Setup()$

pk

f

$f(sk)$

Security against Leakage



Challenger

Adversary

$(pk, sk) \leftarrow Setup()$

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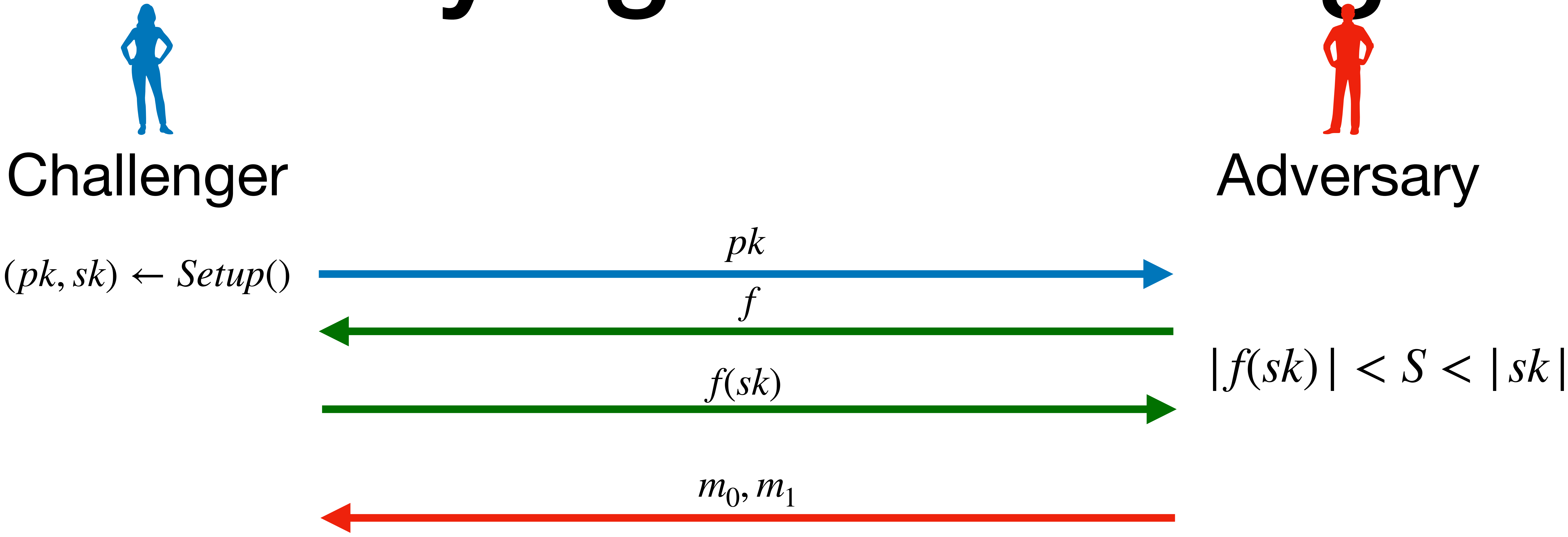
f

$f(sk)$

$|f(sk)| < S < |sk|$

Security against Leakage



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m_0, m_1

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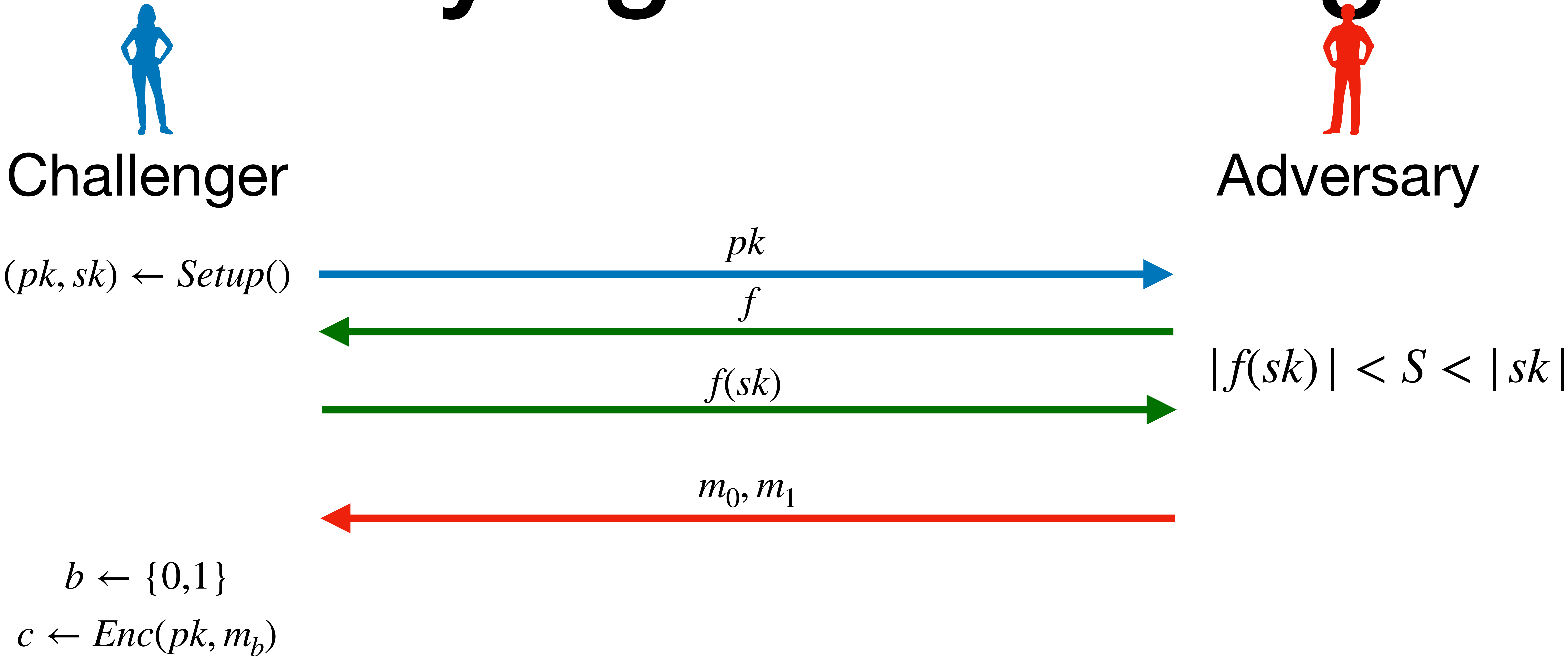

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$b \leftarrow \{0,1\}$

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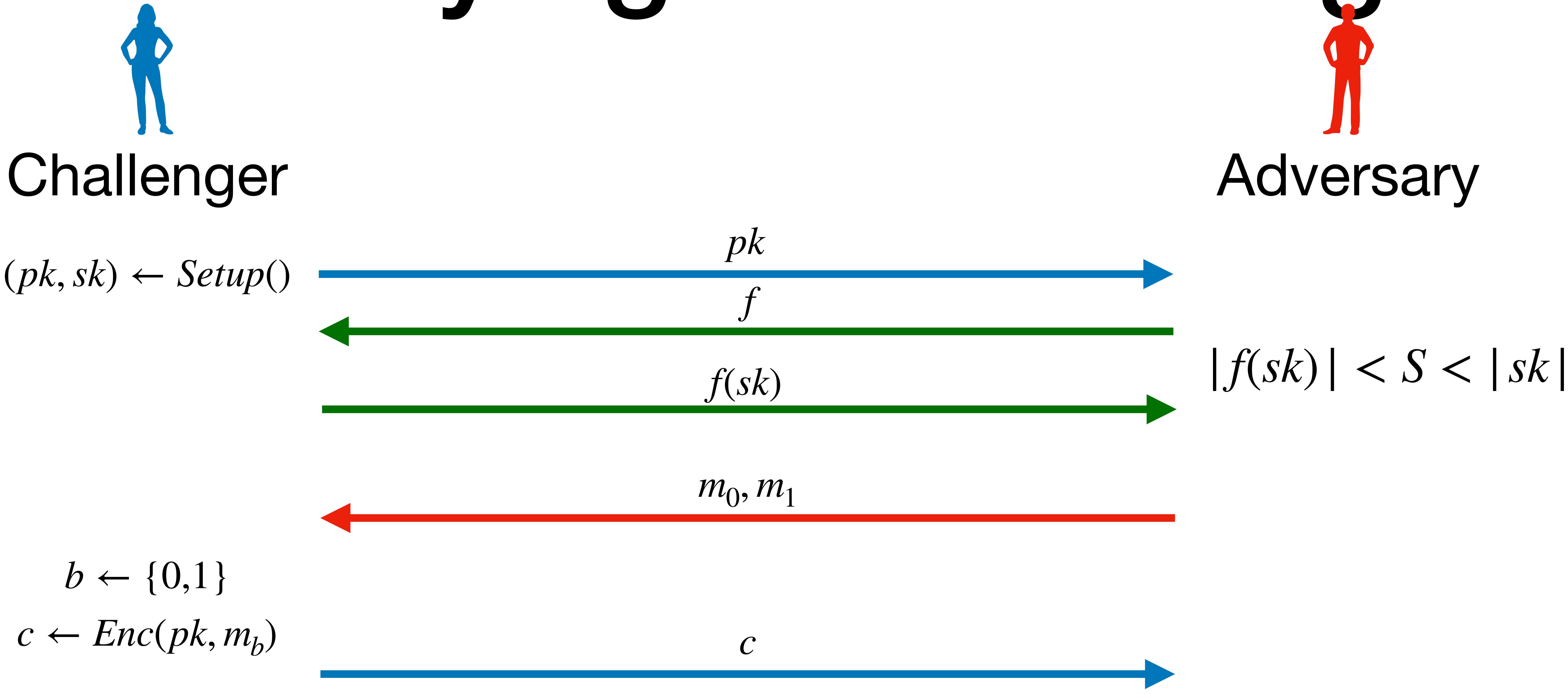
Security against Leakage



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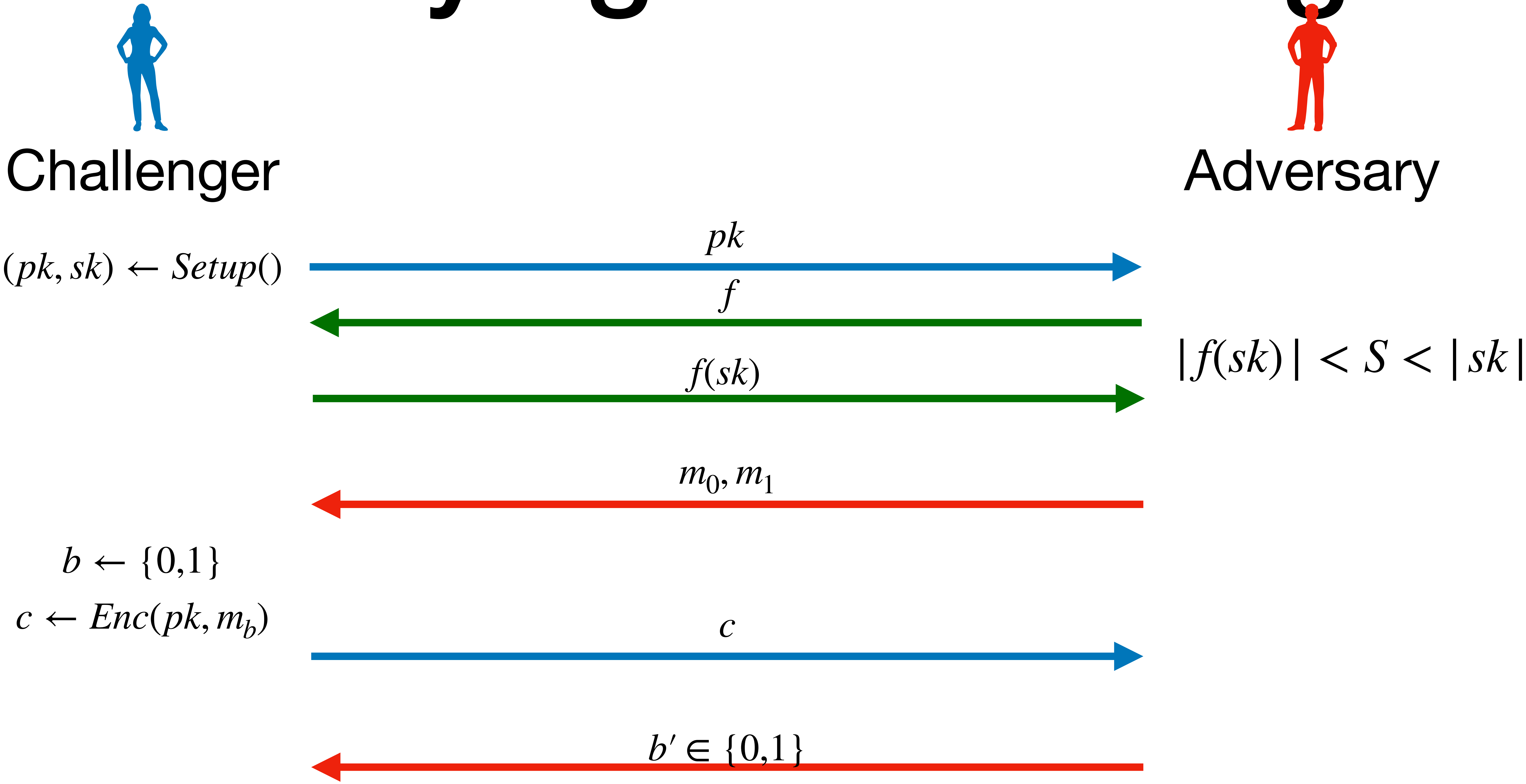

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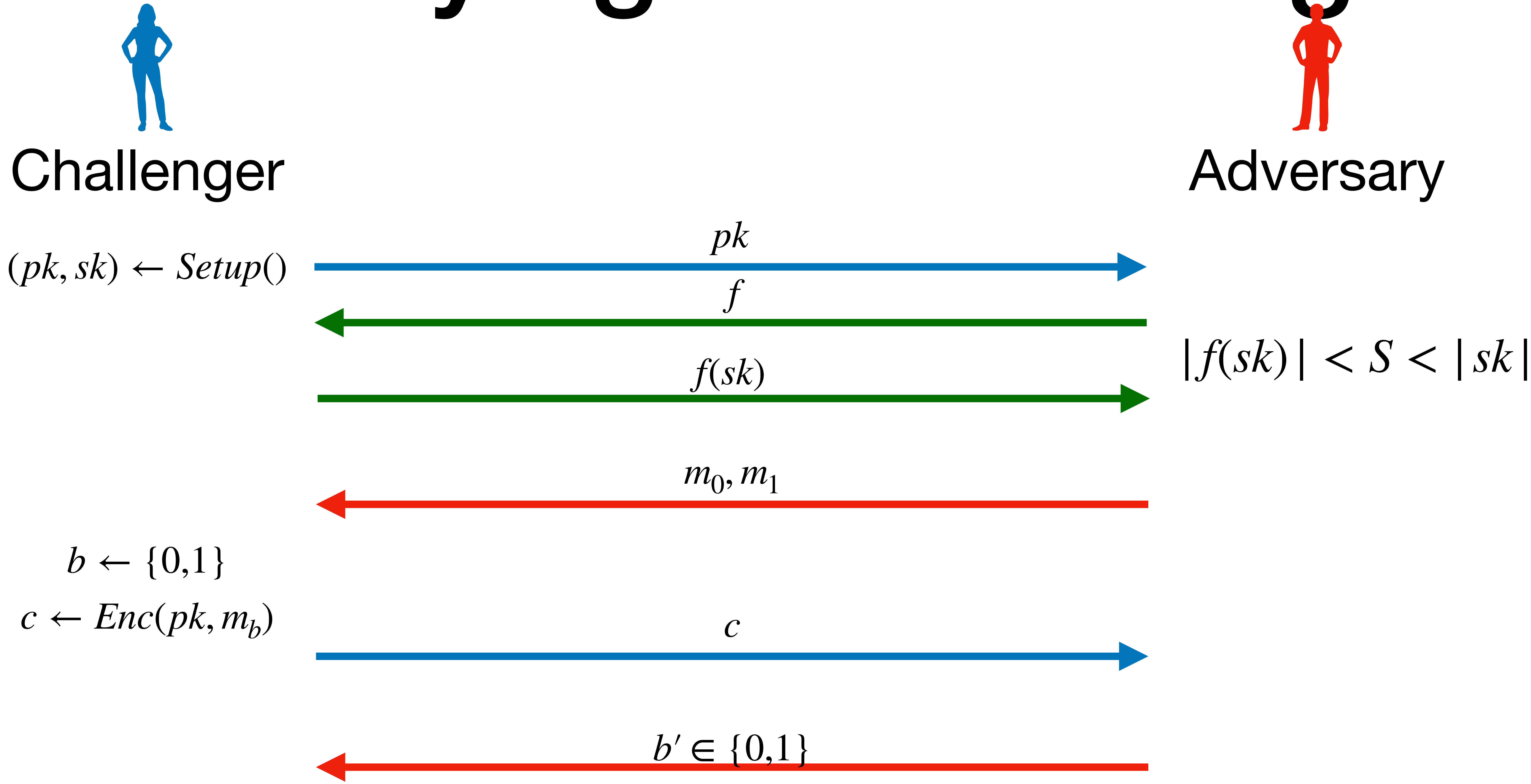

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Adversary wins if $b = b'$

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- Canetti et al.-00 and Dodis et al.-01 gave construction where f returns bits of sk.

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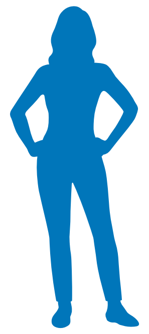
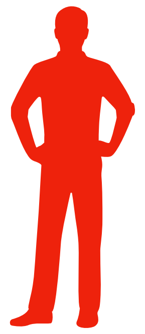
- Other works include Dodis et al.-09, Brakerski et al.-10, Dodis et al.-10, Faonio et al.-15 and many more.

Key-Dependent Message Security

KDM Security

KDM Security





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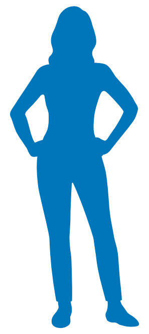

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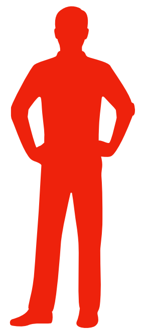


Adversary

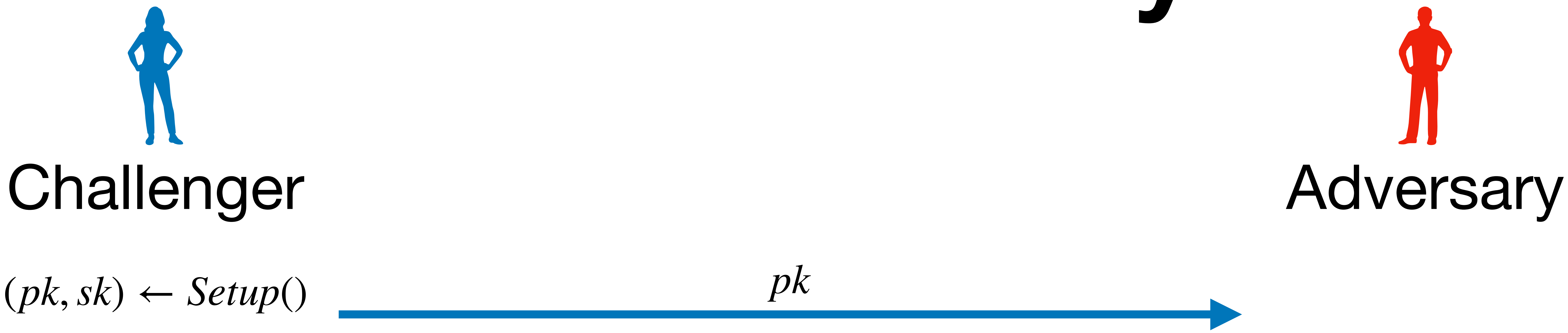
KDM Security

Challenger

Adversary

$(pk, sk) \leftarrow Setup()$

KDM Security



Challenger

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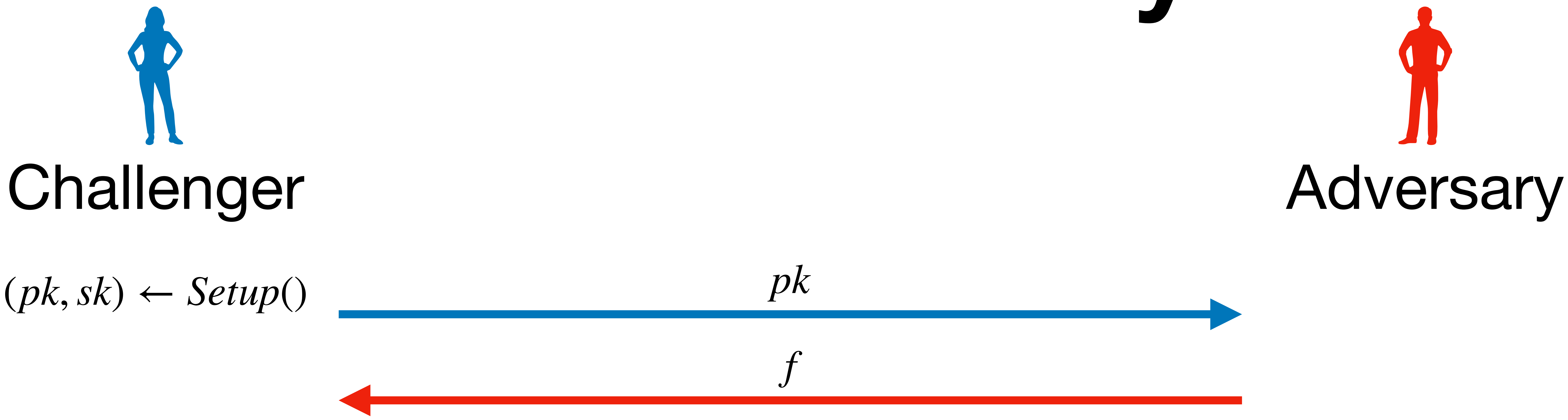
pk

KDM Security



Challenger

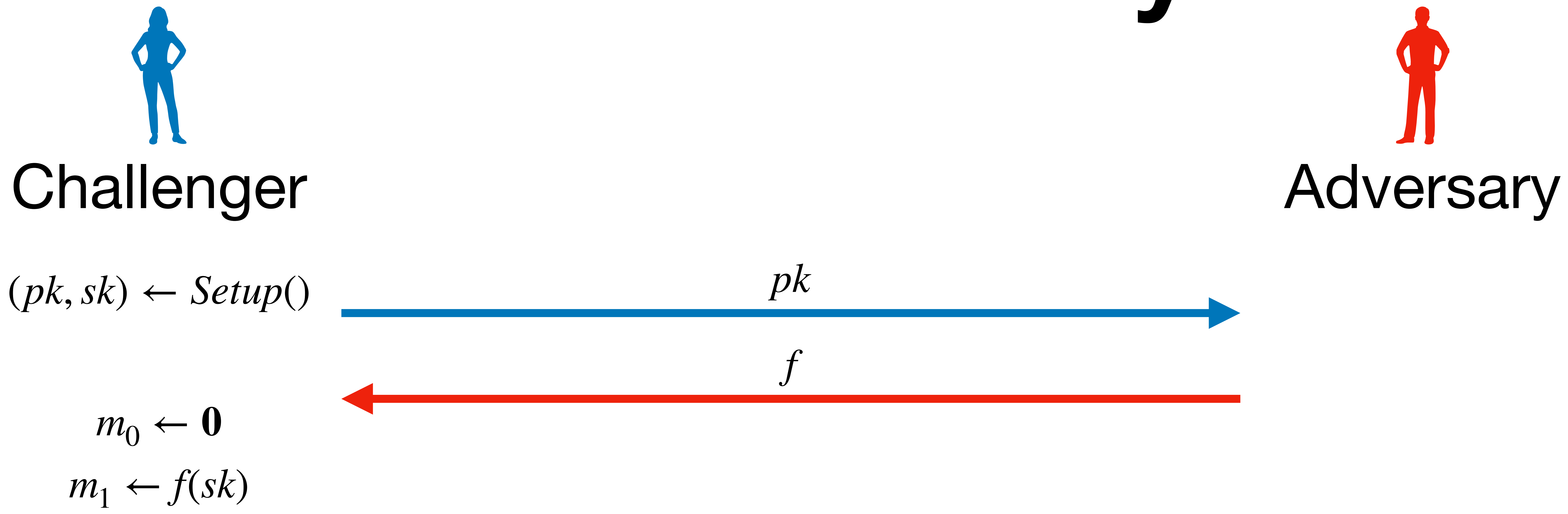
Adversary

$(pk, sk) \leftarrow Setup()$

pk

f

KDM Security



Challenger

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$(pk, sk) \leftarrow Setup()$

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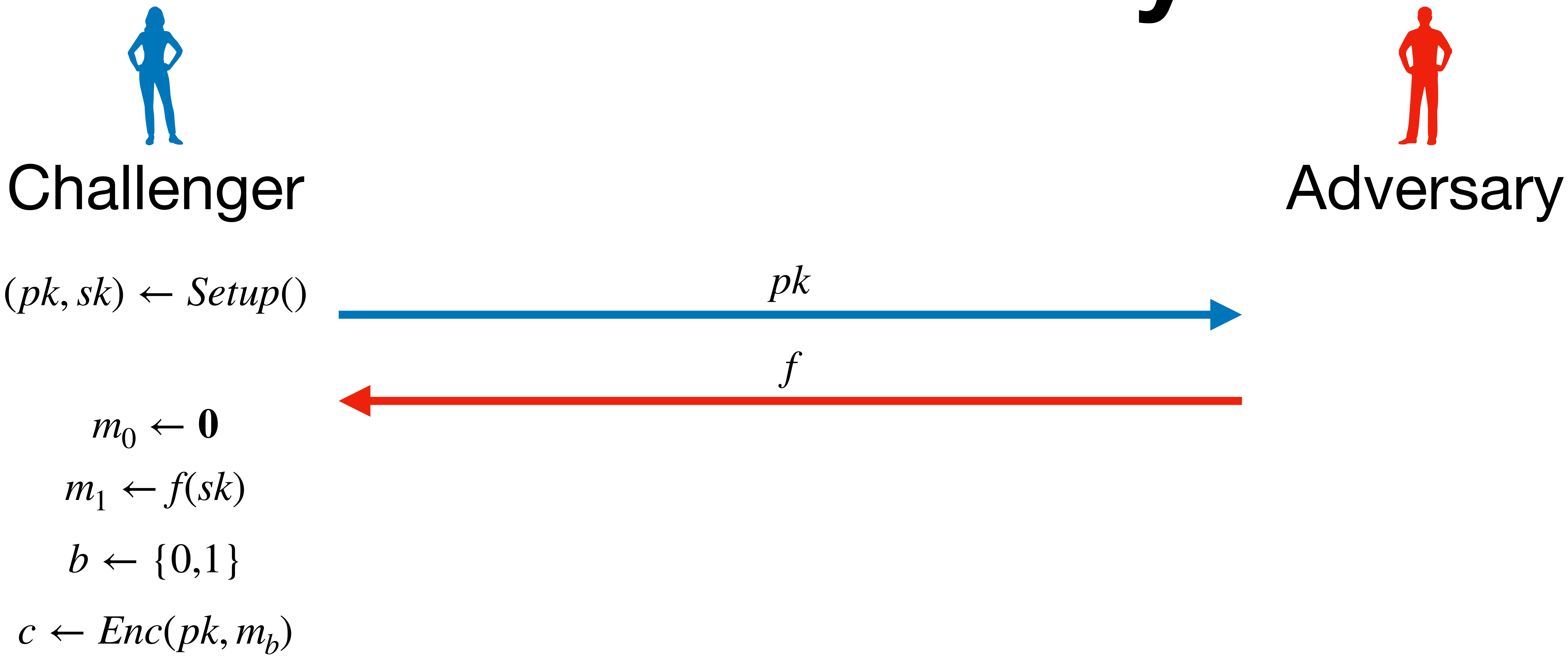
f

$m_0 \leftarrow \mathbf{0}$

$m_1 \leftarrow f(sk)$

KDM Security



Challenger

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$(pk, sk) \leftarrow Setup()$

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f

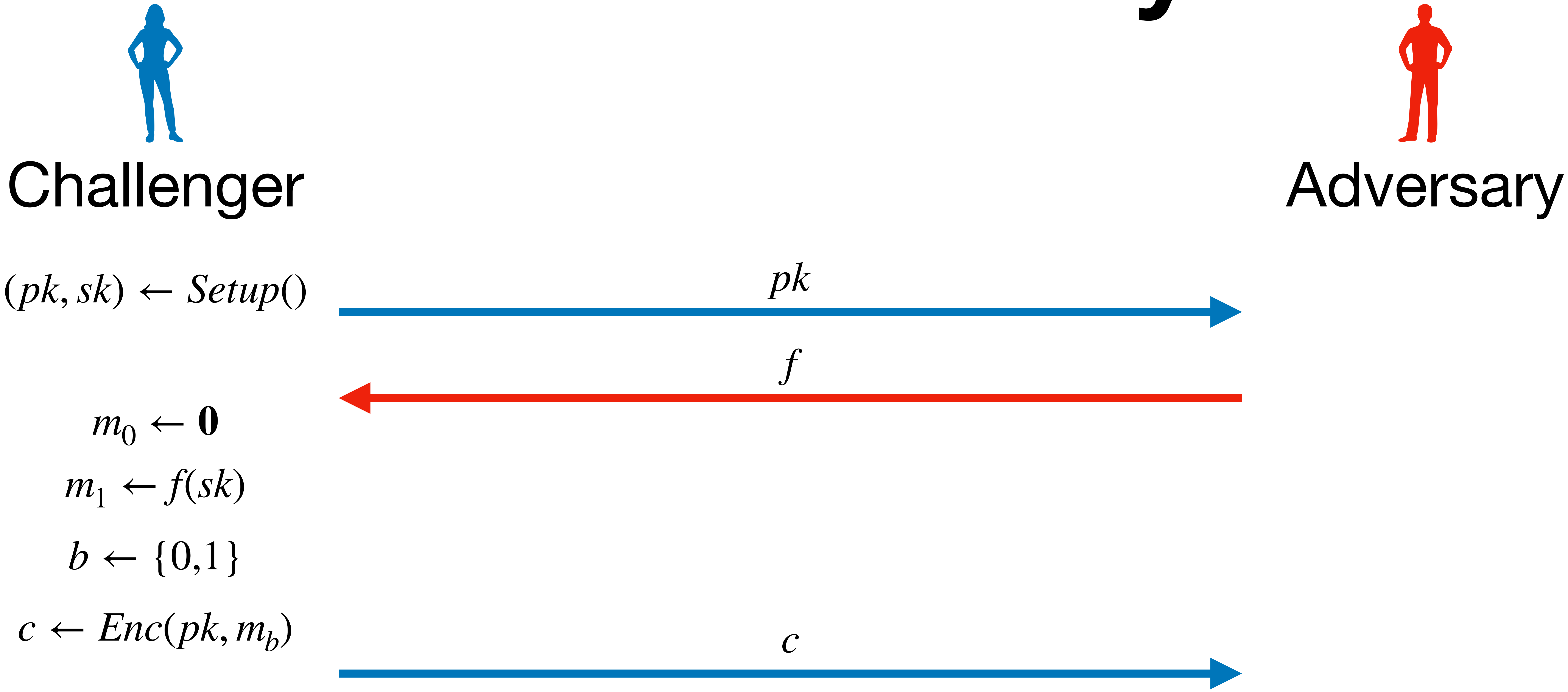
$m_0 \leftarrow \mathbf{0}$

$m_1 \leftarrow f(sk)$

$b \leftarrow \{0,1\}$

$c \leftarrow Enc(pk, m_b)$

KDM Security



Challenger

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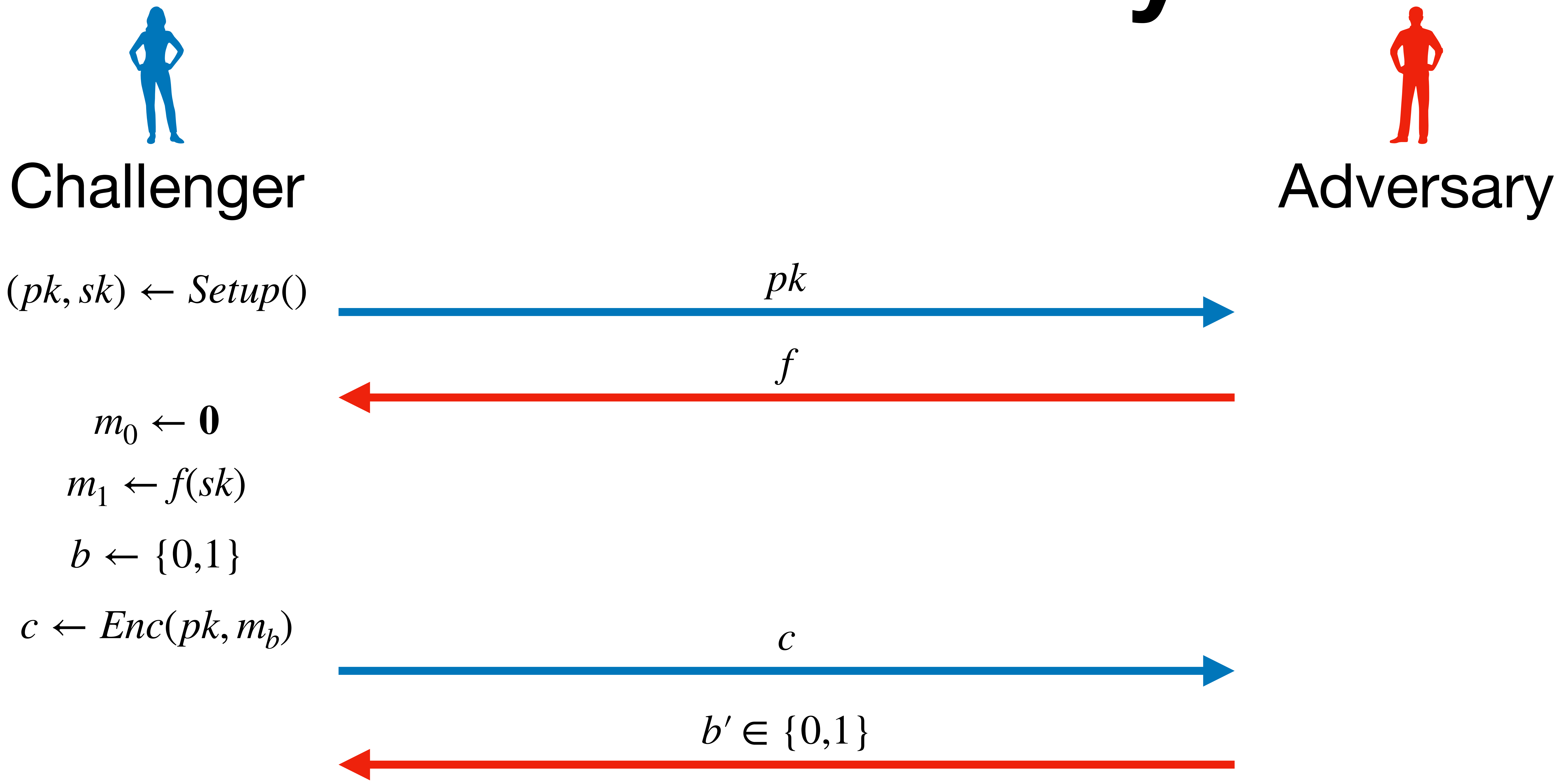

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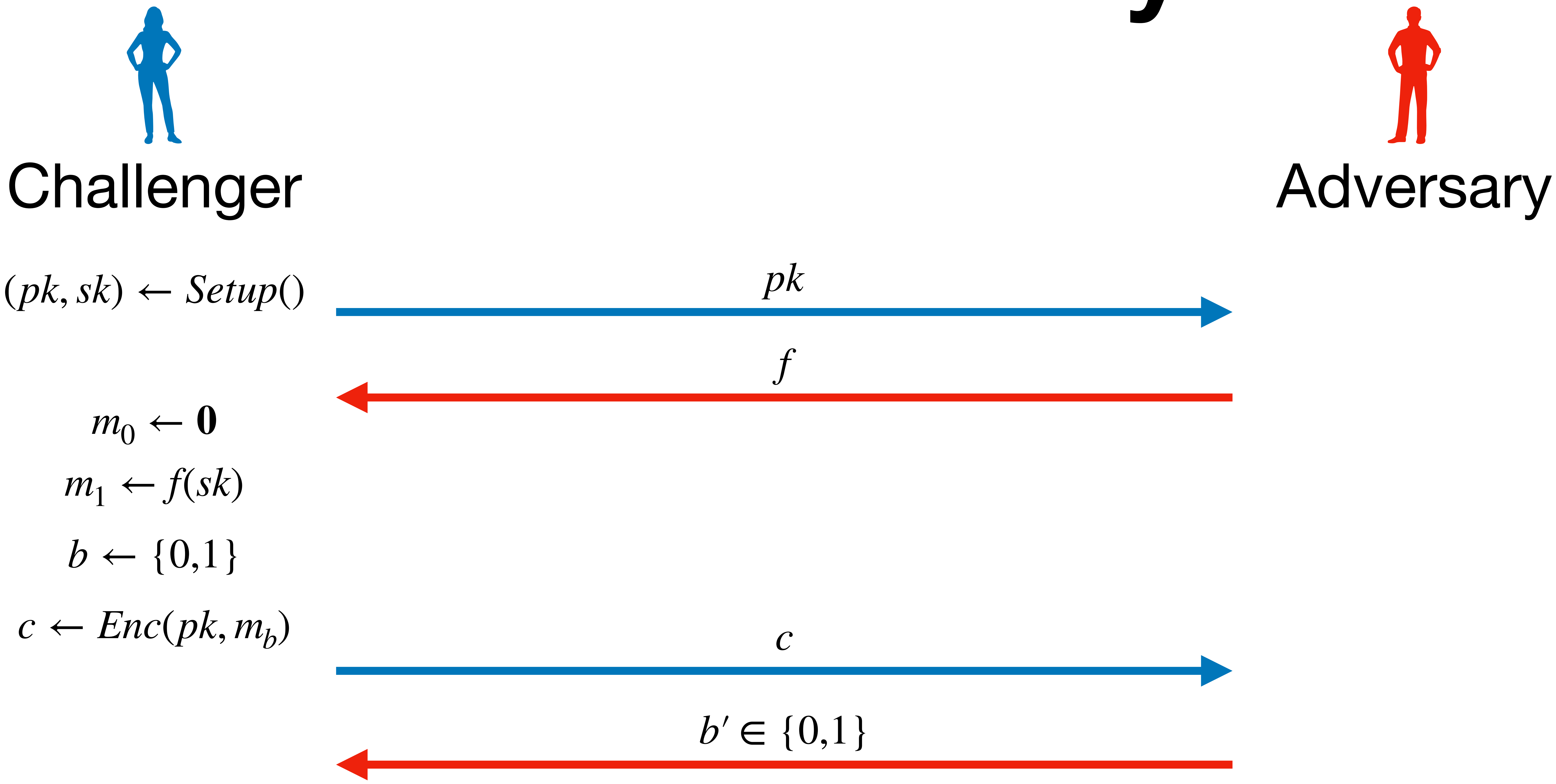

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- Applebaum, Cash, Peikert, Sahai-09 gave construction for KDM-secure PKE from LWE.

Leakage-Resilient Key Dependent Message Secuity

LR-KDM security

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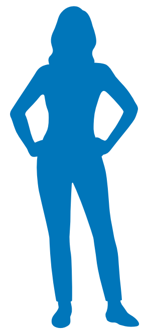

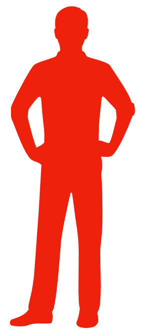

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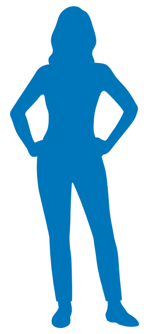

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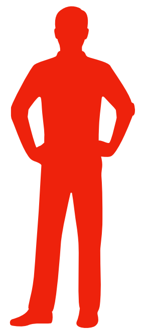

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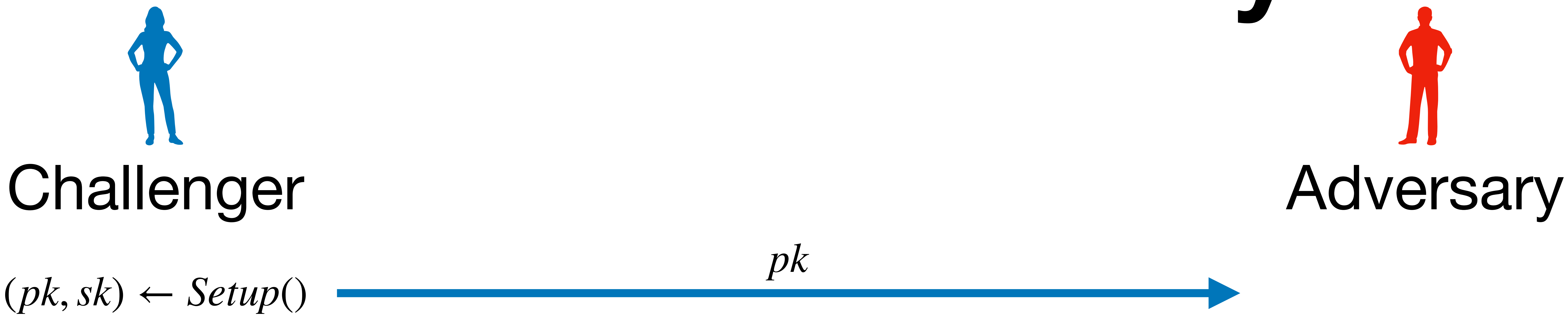

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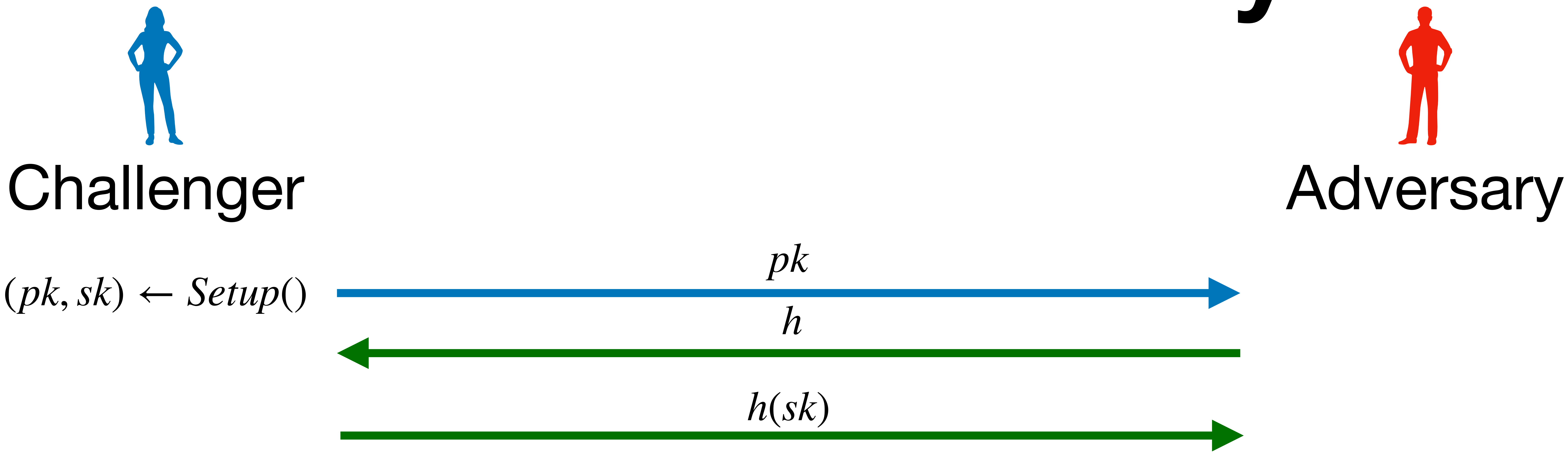

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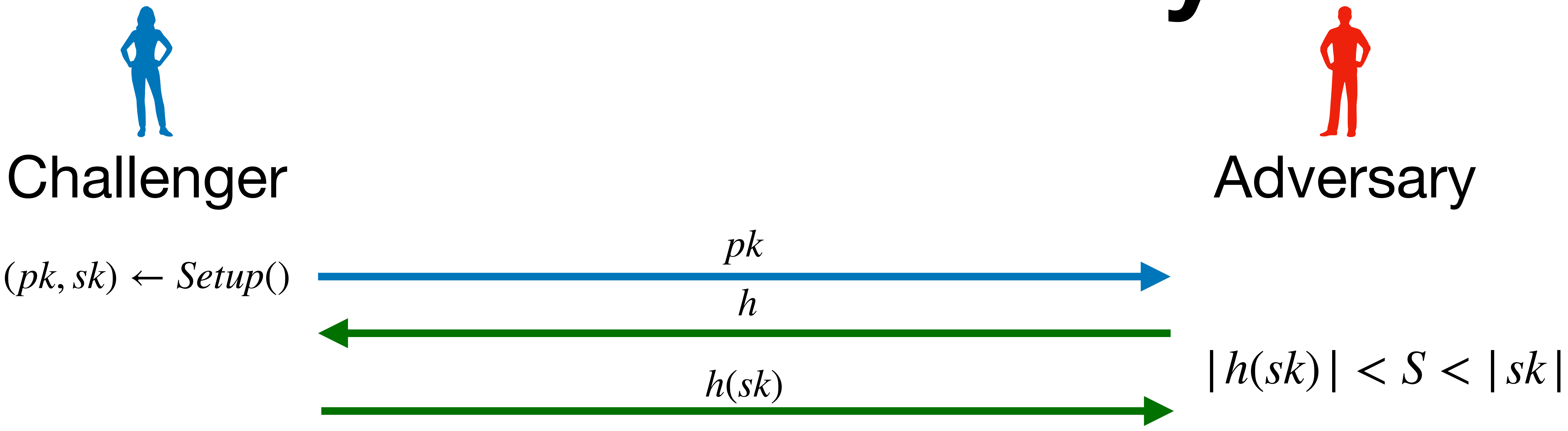

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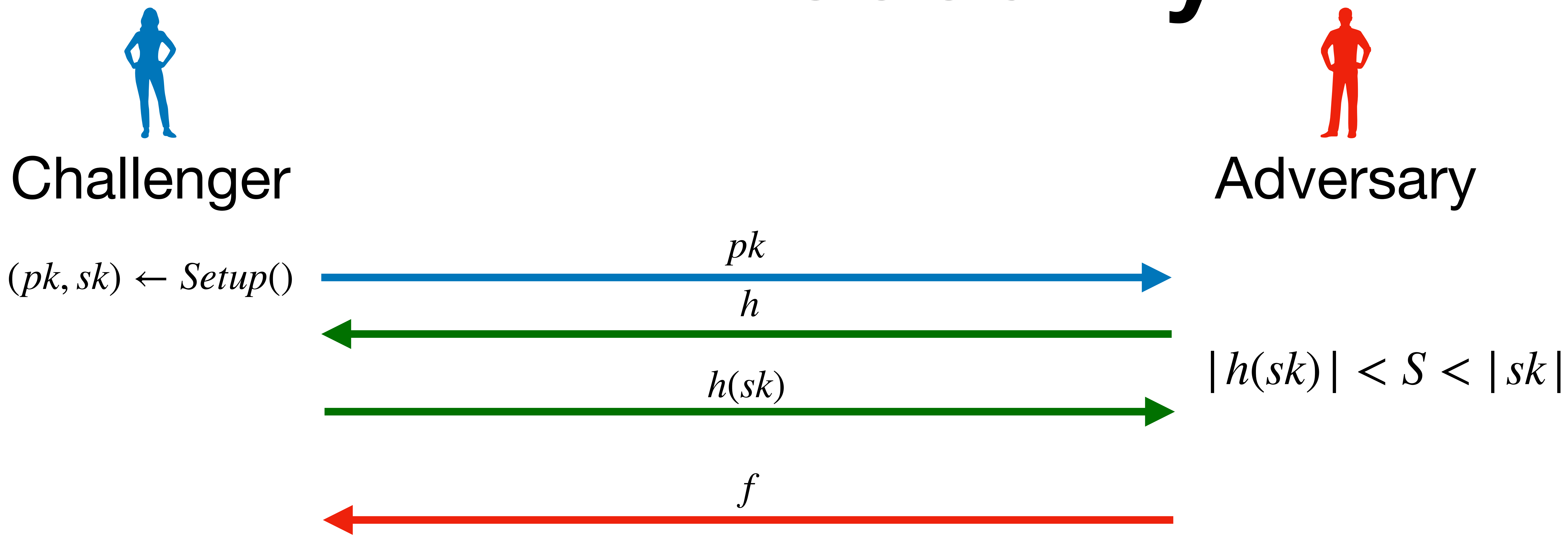

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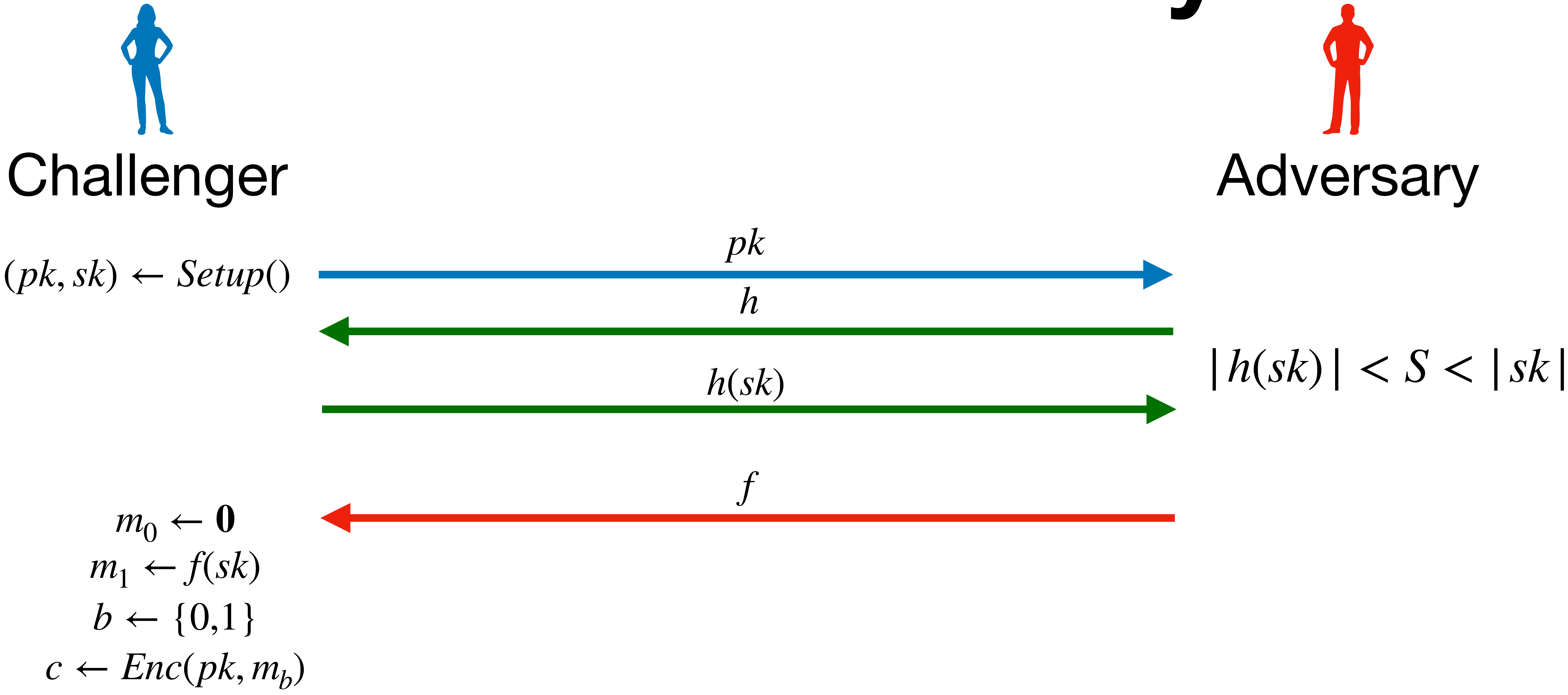

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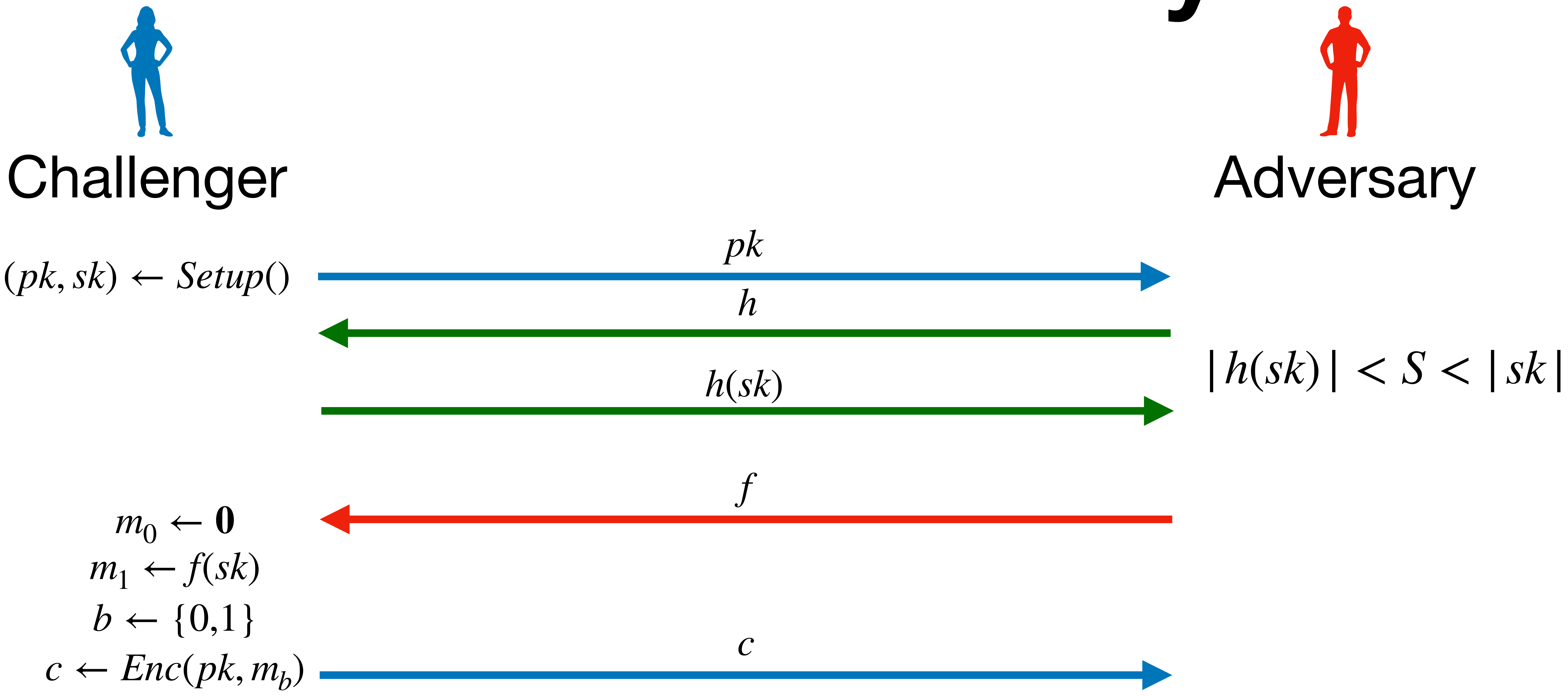

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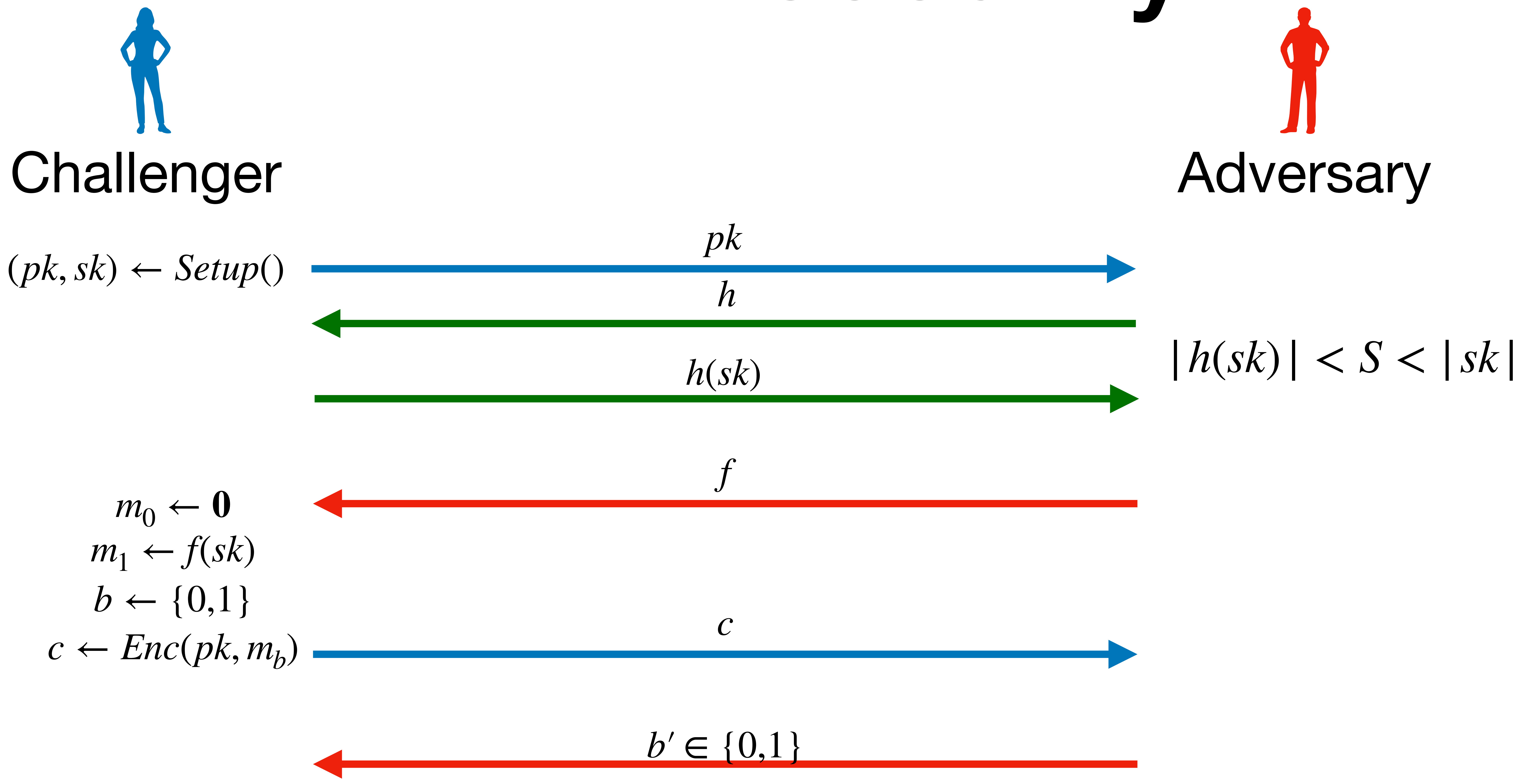

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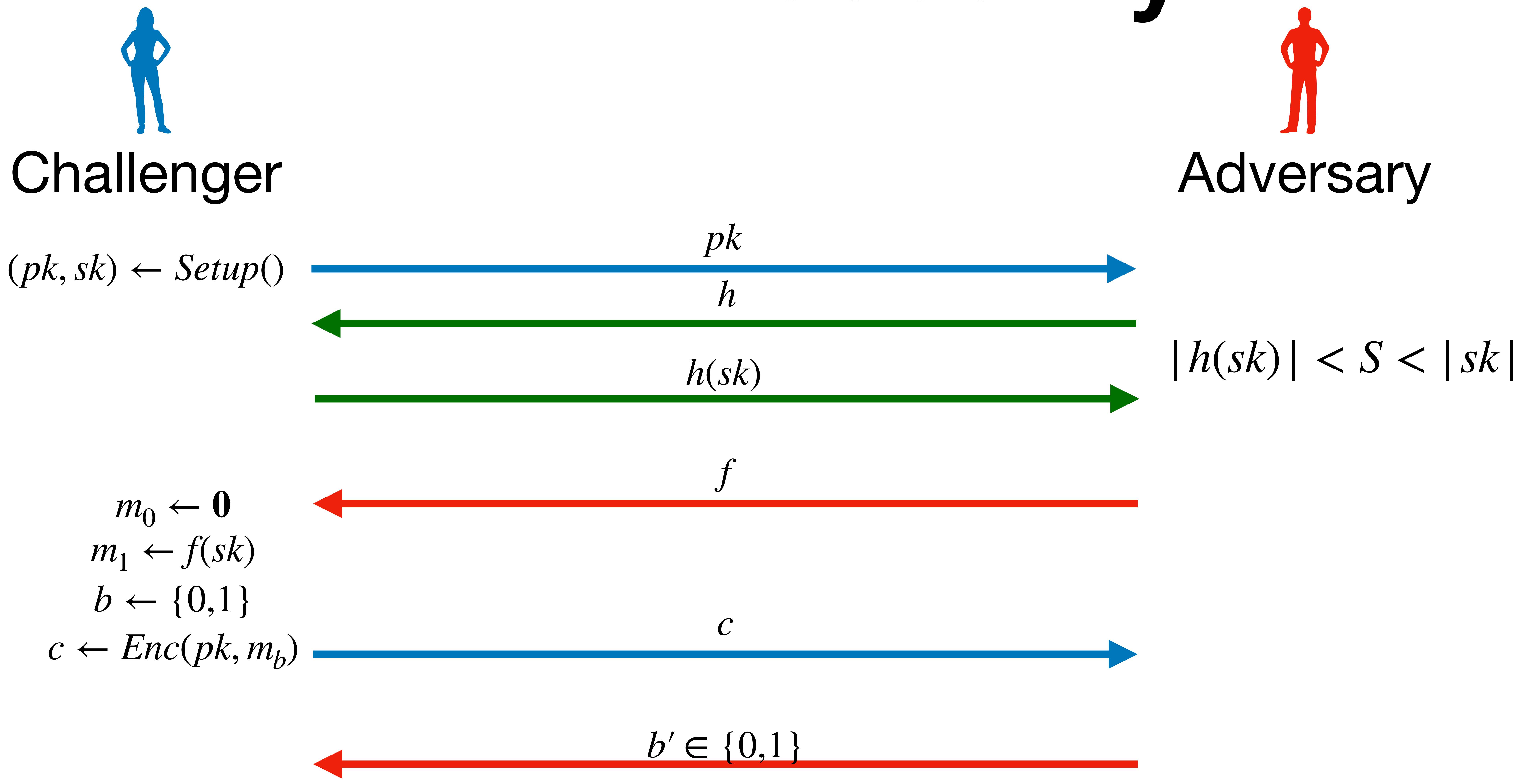

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- Dodis, Karthikeyan, Wichs-21 defined CS+LR Security which is stronger than LR-KDM and used it to construct updatable PKE schemes.

Separation Result

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There exists schemes that are LR and KDM secure,
but isn’t LR-KDM secure.

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- $Dec(sk, ct)$: Output $SKE'.Dec(ske.sk, c_1)$.

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- Using k, it checks whether $c_0 = PRF(k, 0)$ or not.

Constructions and Amplifications

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- We showed that batch encryption schemes are also LR-KDM secure.

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- We showed these can be used in the LR-KDM setting.

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- LR-KDM in advanced primitives such as IBE and ABE.

Thank You!